TRUCKEE MEADOWS WATER
AUTHORITY

2016 – 2035 WATER RESOURCE PLAN

VOLUME III

APPENDICES

TRUCKEE MEADOWS WATER
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2016-2035 WATER RESOURCE PLAN

APPENDIX 2

SOURCE WATER RELIABILITY

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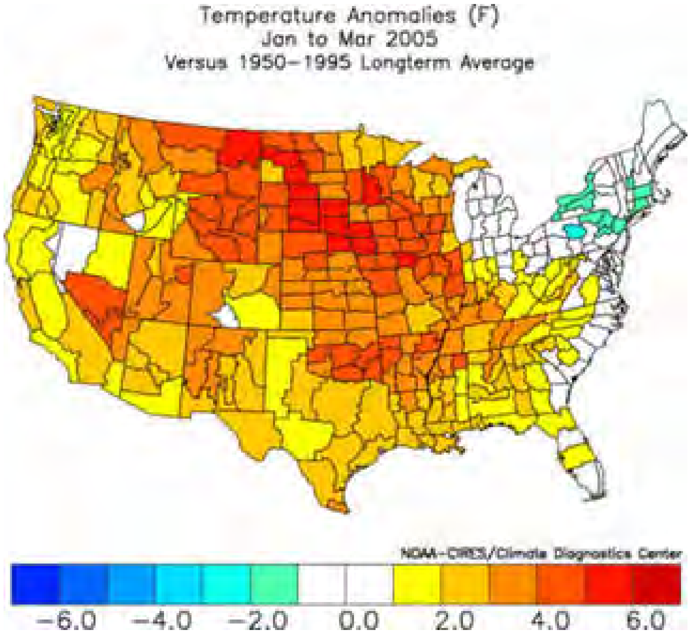
APPENDIX 2-1

NASA – WHAT’S THE DIFFERENCE BETWEEN WEATHER AND CLIMATE?

CLIMATE CHANGE: GLOBAL TEMPERATURE PROJECTIONS

Feb. 1, 2005

NASA - What's the Difference Between Weather and Climate?



Latest three month average temperature and precipitation anomalies for the United States.

Credits: NOAA

The difference between weather and climate is a measure of time. Weather is what conditions of the atmosphere are over a short period of time, and climate is how the atmosphere "behaves" over relatively long periods of time.

When we talk about climate change, we talk about changes in long-term averages of daily weather. Today, children always hear stories from their parents and grandparents about how snow was always piled up to their waists as they trudged off to school. Children today in most areas of the country haven't experienced those kinds of dreadful snow-packed winters, except for the Northeastern U.S. in January 2005. The change in recent winter snows indicate that the climate has changed since their parents were young.

If summers seem hotter lately, then the recent climate may have changed. In various parts of the world, some people have even noticed that springtime comes earlier now than it did 30 years ago. An earlier springtime is indicative of a possible change in the climate.

In addition to long-term climate change, there are shorter term climate variations. This so-called climate variability can be represented by periodic or intermittent changes related to El Niño, La Niña, volcanic eruptions, or other changes in the Earth system.

What Weather Means

Weather is basically the way the atmosphere is behaving, mainly with respect to its effects upon life and human activities. The difference between weather and climate is that weather consists of the short-term (minutes to months) changes in the atmosphere. Most people think of weather in terms of temperature, humidity, precipitation, cloudiness, brightness, visibility, wind, and atmospheric pressure, as in high and low pressure.

In most places, weather can change from minute-to-minute, hour-to-hour, day-to-day, and season-to-season. Climate, however, is the average of weather over time and space. An easy way to remember the difference is that climate is what you expect, like a very hot summer, and weather is what you get, like a hot day with pop-up thunderstorms.

Things That Make Up Our Weather

There are really a lot of components to weather. Weather includes sunshine, rain, cloud cover, winds, hail, snow, sleet, freezing rain, flooding, blizzards, ice storms, thunderstorms, steady rains from a cold front or warm front, excessive heat, heat waves and more.

In order to help people be prepared to face all of these, the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS), the lead forecasting outlet for the nation's weather, has over 25 different types of warnings, statements or watches that they issue. Some of the reports NWS issues are: Flash Flood Watches and Warnings, Severe Thunderstorm Watches and Warnings, Blizzard Warnings, Snow Advisories, Winter Storm Watches and Warnings, Dense Fog Advisory, Fire Weather Watch, Tornado Watches and Warnings, Hurricane Watches and Warnings. They also provide Special Weather Statements and Short and Long Term Forecasts.

NWS also issues a lot of notices concerning marine weather for boaters and others who dwell or are staying near shorelines. They include: Coastal Flood Watches and Warnings, Flood Watches and Warnings, High Wind Warnings, Wind Advisories, Gale Warnings, High Surf Advisories, Heavy Freezing Spray Warnings, Small Craft Advisories, Marine Weather Statements, Freezing Fog Advisories, Coastal Flood Watches, Flood Statements, Coastal Flood Statement.

Who is the National Weather Service?

According to their mission statement, "The National Weather Service provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters and ocean areas, for the protection of life and property and the enhancement of the national economy. NWS data and products form a national information database and infrastructure which can be used by other governmental agencies, the private sector, the public, and the global community."

To do their job, the NWS uses radar on the ground and images from orbiting satellites with a continual eye on Earth. They use reports from a large national network of weather reporting stations, and they launch balloons in the air to measure air temperature, air pressure, wind, and humidity. They put all this data into various computer models to give them weather forecasts. NWS also broadcasts all of their weather reports on special NOAA weather radio, and posts them immediately on their Interactive Weather Information Network website at:http://iwin.nws.noaa.gov/iwin/graphicsversion/bigmain.html.

What Climate Means

In short, climate is the description of the long-term pattern of weather in a particular area.

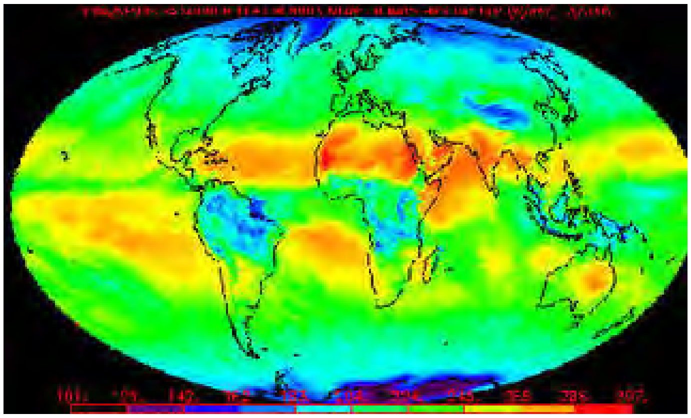
Some scientists define climate as the average weather for a particular region and time period, usually taken over 30-years. It's really an average pattern of weather for a particular region.

When scientists talk about climate, they're looking at averages of precipitation, temperature, humidity, sunshine, wind velocity, phenomena such as fog, frost, and hail storms, and other measures of the weather that occur over a long period in a particular place.

For example, after looking at rain gauge data, lake and reservoir levels, and satellite data, scientists can tell if during a summer, an area was drier than average. If it continues to be drier than normal over the course of many summers, than it would likely indicate a change in the climate.

Why Study Climate?

The reason studying climate and a changing climate is important, is that will affect people around the world. Rising global temperatures are expected to raise sea levels, and change precipitation and other local climate conditions. Changing regional climate could alter forests, crop yields, and water supplies. It could also affect human health, animals, and many types of ecosystems. Deserts may expand into existing rangelands, and features of some of our National Parks and National Forests may be permanently altered.



An example of a Monthly Mean Outgoing Longwave Radiation (OLR) product produced from NOAA polar-orbiter satellite data, which is frequently used to study global climate change.

Credits: NOAA

The National Academy of Sciences, a lead scientific body in the U.S., determined that the Earth's surface temperature has risen by about 1 degree Fahrenheit in the past century, with accelerated warming during the past two decades. There is new and stronger evidence that most of the warming over the last 50 years is attributable to human activities. Yet, there is still some debate about the role of natural cycles and processes.

Human activities have altered the chemical composition of the atmosphere through the buildup of greenhouse gases – primarily carbon dioxide, methane, and nitrous oxide. The heat-trapping property of these gases is undisputed although uncertanties exist about exactly how Earth's climate responds to them. According to the U.S. Climate Change Science Program (http://www.climatescience.gov), factors such as aerosols, land use change and others may play important roles in climate change, but their influence is highly uncertain at the present time.

Who Studies Climate Change?

Modern climate prediction started back in the late 1700s with Thomas Jefferson and continues to be studied around the world today.

At the national level, the U.S. Global Change Research Program coordinates the world's most extensive research effort on climate change. In addition, NASA, NOAA, the U.S. Environmental Protection Agency (EPA) and other federal agencies are actively engaging the private sector, states, and localities in partnerships based on a win-win philosophy and aimed at addressing the challenge of global warming while, at the same time, strengthening the economy. Many university and private scientists also study climate change.

What is the U.S. Global Change Research Program?

The United States Global Change Research Program (USGCRP) was created in 1989 as a high-priority national research program to address key uncertainties about changes in the Earth's global environmental system, both natural and human-induced; to monitor, understand, and predict global change; and to provide a sound scientific basis for national and international decision-making.

Since its inception, the USGCRP has strengthened research on global environmental change and fostered insight into the processes and interactions of the Earth system, including the atmosphere, oceans, land, frozen regions, plants and animals, and human societies. The USGCRP was codified by Congress in the Global Change Research Act of 1990. The basic rationale for establishing the program was that the issues of global change are so complex and wide-ranging that they extend beyond the mission, resources, and expertise of any single agency, requiring instead the integrated efforts of several agencies.

Some Federal Agencies Studying Climate

In the 1980s the National Weather Service established the Climate Prediction Center (CPC), known at the time as the Climate Analysis Center (CAC). The CPC is best known for its United States climate forecasts based on El Niño and La Niña conditions in the tropical Pacific.

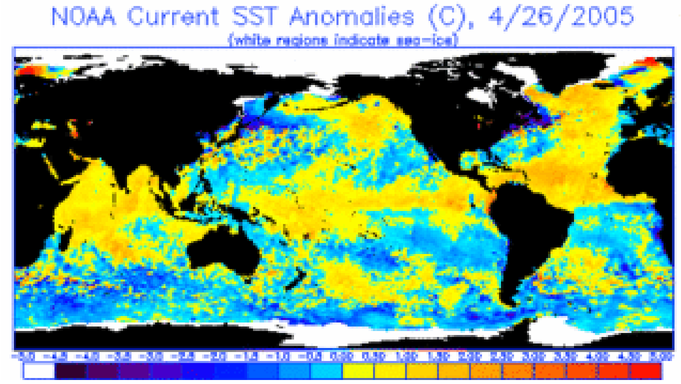


Image Above: The operational SST anomaly charts are useful in assessing ENSO (El Niño - Southern Oscillation) development, monitoring hurricane "wake" cooling, and even major shifts in coastal upwelling.
Credits: NOAA

CPC was established to give short-term climate prediction a home in NOAA. CPC's products are operational predictions or forecasts of how climate may change and includes real-time monitoring of climate. They cover the land, the ocean, and the atmosphere, extending into the upper atmosphere (stratosphere). Climate prediction is very useful in various industries, including agriculture, energy, transportation, water resources, and health.

NASA has been using satellites to study Earth's changing climate. Thanks to satellite and computer model technology, NASA has been able to calculate actual surface temperatures around the world and measure how they've been warming. To accomplish the calculations, the satellites actually measure the Sun's radiation reflected and absorbed by the land and oceans.NASA satellites keep eyes on the ozone hole, El Nino's warm waters in the eastern Pacific, volcanoes, melting ice sheets and glaciers, changes in global wind and pressure systems and much more.

At the global level, countries around the world have expressed a firm commitment to strengthening international responses to the risks of climate change. The U.S. is working to strengthen international action and broaden participation under the support of the United Nations Framework Convention on Climate Change.

Today, scientists around the world continue to try and solve the puzzle of climate change by working with satellites, other tools and computer models that simulate and predict the Earth's conditions.

For information about the U.S. Global Change Research Program, please visit:
http://www.usgcrp.gov/

For information about NASA's study of Earth's climate, please visit on the Internet:
http://www.nasa.gov/vision/earth/features/index.html

For a review of 2004's Global Temperature, please visit:
http://www.nasa.gov/vision/earth/lookingatearth/earth_warm.html

For information about NASA, please visit on the Internet:
http://www.nasa.gov

For information about the National Weather Service, please visit on the Internet:
http://www.nws.noaa.gov/

For immediate watches and warnings, visit the NWS Interactive Weather Information Network website at:
http://iwin.nws.noaa.gov/iwin/graphicsversion/bigmain.html

To find a NOAA weather radio station near you:
http://www.nws.noaa.gov/nwr/

For a glossary of weather terms, please visit the National Weather Service Weather Glossary on the Internet at:
http://www.nws.noaa.gov/glossary/

Rob Gutro
NASA's Earth-Sun Science News Team/SSAI

NASA Goddard Space Flight Center, Greenbelt, Md., and excerpts from NOAA's CPC web page, and the U.S. EPA web page. 2/2005

Edits: Dr. J. Marshall Shepherd, NASA/GSFC, Drew Shindell, NASA/GISS, Cynthia M. O'Carroll, NASA/GSFC
Last Updated: July 31, 2015
Editor: NASA Administrator

Tags: Climate

Climate.gov
science & information for a climate-smart nation

Author:

David Herring

Reviewer:

Keith Dixon, Katharaine Hayhoe, Rick Rosen

Tuesday, March 06, 2012

According to climate scientists, our world is highly likely to continue to warm over this century and beyond. This conclusion is based on scientists' understanding of how the climate system works and on computer models designed to simulate Earth's climate. Results from a wide range of climate model simulations suggest that our planet's average temperature could be between 2 and 9.7°F (1.1 to 5.4°C) warmer in 2100 than it is today.

The main reason for this temperature increase is carbon dioxide and other heat-trapping "greenhouse" gases that human activities produce. The biggest source of added carbon dioxide is from people burning coal and other fossil fuels.

The exact amount of warming that will occur in the coming century depends largely on the energy choices that we make now and in the next few decades, particularly since those choices directly influence how fast we put heat-trapping gases into the atmosphere. In addition to uncertainty about what those choices will be, there are also details we don't yet know about how the climate will respond to continued increases in heat-trapping gases, particularly over longer time scales.

Explore this interactive graph: Click and drag to display different parts of the graph. To squeeze or stretch the graph in either direction, hold you Shift key down, then click and drag. The graph shows the average of a set of temperature simulations for the 20th century (black line), followed by projected temperatures for the 21st century based on a range of emissions scenarios (colored lines). The shaded areas around each line indicate the statistical spread (one standard deviation) provided by individual model runs. (Data processing by Jay Hnilo, CICS-NC, using data courtesy the Coupled Model Intercomparison Project, or CMIP3.)

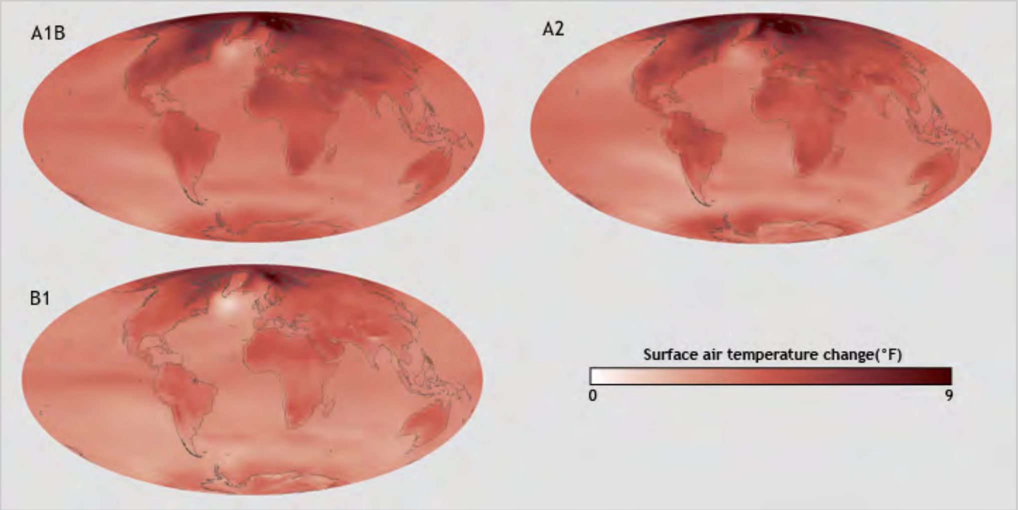
Climate scientists are continually improving their understanding of how Earth's climate system works. They can generate global temperature projections because they have been painstakingly observing and measuring the main mechanisms that influence climate for more than a century. They have developed a good understanding of the key ways that energy and water flow through the planet's climate system, and how the different parts of the climate system interact with one another. This understanding is translated into complex computer software known as "global climate models."

The graph above demonstrates that people are a big wild card in the climate system. How fast will human population grow? How much energy will we choose to use? Will our primary sources of energy continue to be fossil fuels (such as coal, oil, and natural gas)? To what extent will we continue to slash and burn foreste regions, and how fast will we reforest cleared areas? These are the types of choices that will determine our greenhouse gas emissions and ultimately drive the amount of warming Earth experiences.

The net impacts of these human actions and choices on future greenhouse gas concentrations are fed into models as different “scenarios.” For example, the scenario represented by the blue trend line above (IPCC Scenario B1) assumes that humans worldwide will make more sustainable development choices by using a greater range of, and more efficient, technologies for producing energy. In this scenario, carbon emissions are projected to increase from today’s rate of about 9 billion metric tons per year to about 12 billion tons per year in 2040, and then gradually decline again to 1990 levels—5 billion tons per year—by 2100.

The scenario represented by the red trend line (IPCC Scenario A2) assumes humans will continue to accelerate the rate at which we emit carbon dioxide. This is consistent with a global economy that continues to rely mainly on coal, oil, and natural gas to meet energy demands. In this scenario, our carbon emission increases steadily from today’s rate of about 9 billion tons per year to about 28 billion tons per year in 2100. The middle trend (green, IPCC Scenario A1b) assumes humans will roughly balance their use of fossil fuels with other, non-carbon emitting sources of energy.

Because temperature projections depend on the choices people make in the future, climate scientists can’t say which one of the scenarios is more likely to come to pass by the end of the century. These scenarios are estimates, and greenhouse gas concentrations may grow at rates that are higher or lower than the scenarios shown in the graph. If future carbon dioxide emissions follow the same trajectory as they have over the last decade, increasing at a rate of more than 3 percent per year, carbon dioxide levels in the atmosphere would exceed the scenario represented by the red line (IPCC scenario A2) by the end of this century, if not before.



These maps show the average of a set of climate model experiments projecting changes in surface temperature for the period 2050-2059, relative to the period from 1971-1999. The top left map corresponds with the green trend line above (IPCC scenario A1B); the top right map matches the red trend line above (IPCC scenario A2); and the bottom left map matches the blue trend line (IPCC scenario B1). All models project some warming for all regions, with land areas warming more than oceans. large versions: [A1B (/media-folders/media-root/file/7677)] | [A2 (/media-folders/media-root/)] | [B1 (/media-folders/media-root/file/7685)] (Maps by Ned Gardiner, Hunter Allen, and Jay Hnilo, CICS-NC, using data courtesy the Coupled Model Intercomparison Project, or CMIP3.)

While Earth's average temperature has warmed and cooled throughout our planet's history, it's extremely rare for a single life form to drive significant climate change, and never before has a single species had the power to force Earth's climate to change at the rate climate models project human activities will force our world to warm this century.

Though scientists expect Earth to be perceptibly warmer 100 years from now than it is today, there is still a wide range in how much warming Earth will experience. Our choices will make a big difference.

References

Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Avery, M. Tignor, and H.L. Miller (eds.). (2007): Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA.

Friedlingstein, P., R.A. Houghton, G. Marland, J. Hackler, T.A. Boden, T.J. Conway, J.G. Canadell, M.R. Raupach, P. Ciais, and C. Le Quere (2010): "Update on CO2 emissions." Nature Geoscience. Vol 3. Dec 2010. p811-810.

Science Reviewers: Keith Dixon, NOAA Geophysical Fluid Dynamics Laboratory; Katharine Hayhoe, Texas A&M; and Rick Rosen, NOAA Climate Program Office.

Source URL (modified on 2014-06-02 18:16): https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature-projections

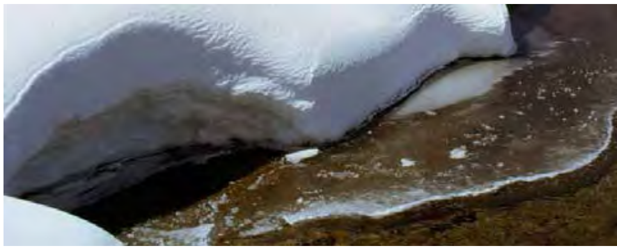
TRUCKEE MEADOWS WATER AUTHORITY

APPENDIX 2-2

CALIFORNIA CLIMATE SCIENCE & DATA

JUNE, 2015

CALIFORNIA DEPARTMENT OF WATER RESOURCES



California Climate Science and Data

FOR WATER RESOURCES MANAGEMENT

June 2015

The California Department of Water Resources

is engaged in the science and data critical for climate change adaptation and mitigation. This booklet summarizes the latest indicators, implications and strategies for water managers in California with regard to a changing climate and the water-energy nexus. The steady march toward warmer global temperatures, greater weather extremes, reduced snowpack, higher sea level, and compromised water supply reliability warrant consideration by water managers in their decision making.

Unless otherwise indicated, scientific literature references are from the California Water Plan Update 2013 http://www.waterplan.water.ca.gov/cwpu2013/final/index.cfm.

For more on DWR's Climate Change Program and contact information, please go to: http://www.water.ca.gov/climatechange/.

Elissa Lynn, Editor
Climate Change Program, June 2015.

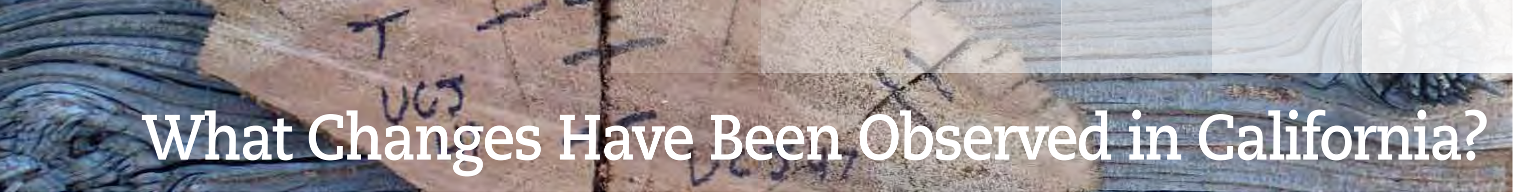
Introduction

Climate change creates critical challenges for California water resources management. The vulnerability of the water sector to climate change stems from a modified hydrology that affects the frequency, magnitude, and duration of extreme events, which, in turn, affect water quantity, quality, and infrastructure. Warmer temperatures drive the snow line higher and reduce snowpack, resulting in less water storage. Intense rainfall events will continue to affect the state, possibly leading to more frequent and/or more extensive flooding. The acceleration of sea level rise will produce higher storm surges during coastal storms. Droughts are likely to become more frequent and persistent during this century.

Because California contains multiple climate zones, each region of the state will experience a combination of impacts from climate change unique to that area. While significant uncertainties still remain for local precipitation and temperature changes, projections at the regional and statewide levels are already available. Water supply managers in California have multiple tools and institutional capabilities to limit vulnerability to changing conditions, which can also serve as response mechanisms to a wide range of climate changes.

This brochure summarizes the observations, projections, and challenges that climate change poses for water resources management in California, and highlights climate change content developed for the California Water Plan Update 2013 (http://www.waterplan.water.ca.gov/cwpu2013/final/index.cfm),

The impacts of climate change in California have been detected in temperature, precipitation and runoff records. Snowpack has historically served California as a critical reservoir, melting during the peak demand period in late spring and summer. As the climate continues to warm, flood protection, water supply infrastructure and water management practices may need to be adapted to address the impacts of California's changing hydrologic regime.

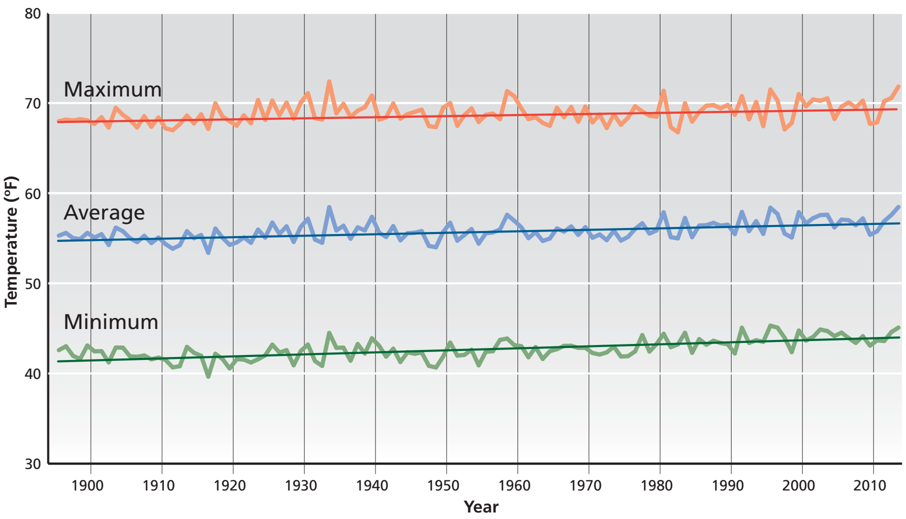


What Changes Have Been Observed in California?

TEMPERATURES

California temperatures have shown a warming trend in the past century. According to the Western Region Climate Center, the state has experienced an increase of 1.1 to 2 degrees Fahrenheit (°F) in mean temperature in the past century. Both minimum and maximum annual temperatures have increased, but the minimum temperatures (+1.6 to 2.5 °F) have increased more than maximums (+0.4 to 1.6 °F).

California's Observed Average Temperatures



Temperatures in California have undergone a slow but steady warming over the past century. These trends indicate higher wildfire potential, habitat risk, and changing hydrology. Observational air temperatures for California can be found on the California Climate Tracker at the Western Region Climate Center: http://www.wrcc.dri.edu/monitor/cal-mon/.

CoCoRaHS

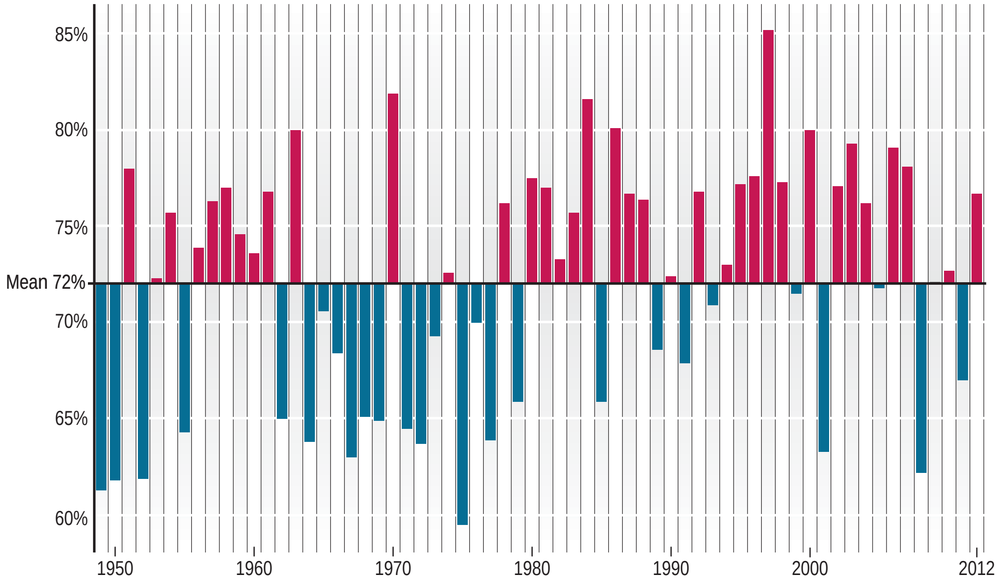
The Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) is a non-profit, community based network of volunteers that take daily local measurements of rain, hail and snow. By providing high quality, accurate measurements, the observers supplement existing automated networks and provide useful data to scientists, resource managers, and decision makers. The DWR Climate Change Program staff support CoCoRaHS through regional coordination, data management, and volunteer recruitment. Staff also promote CoCoRaHS through science and water workshops for teachers. To enroll in the program, go to: http://www.cocorahs.org

Photo courtesy of CoCoRaHS

Rain/Snow Historical Trends

Location of main analysis area in California

Rain as Percentage of Total Precipitation



Percentage of precipitation falling as rain over the 33 main water supply watersheds of the State is shown for water years ending 1949 through 2012 (Oct 1948-Sept 2012), using Western Region Climate Center historic precipitation and freezing level re-analysis (http://www.wrcc.dri.edu/).

These watersheds experience a mean of 72 percent of precipitation as rain; years with red bars have a higher percentage of rain than the mean, and years with blue bars have a lower percentage of rain than the mean. Years with a higher percentage of rain are more common in the later period of record, in agreement with expectations under a warming climate and previous studies. There is substantial annual variability due to climate signals that occur on annual and decadal scales.

http://www.water.ca.gov/climatechange/docs/Estimating%20Historical%20California%20Precipitation%20DWR%20CWP%207-7-2014%20FINAL.pdf

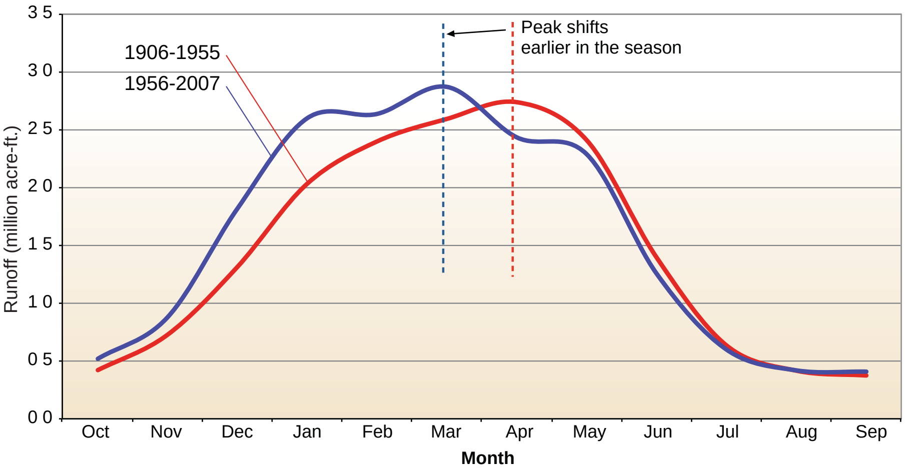
RAIN/SNOW TRENDS

In recent decades, there has been a trend toward more rain than snow in the total precipitation volume. This factor plays a role in reducing total snowpack, which represents up to one-third of the state's water supply.

RUNOFF TIMING

The timing of runoff has changed in California's largest water-supply watershed, the Sacramento River System, shifting to earlier in the season. Snowmelt provides an annual average of 15 million acre feet of water, slowly released by melting from about April to July each year. Much of the State's water infrastructure was designed to capture the slow spring runoff and deliver it during the drier summer and fall months. The water management community has invested in, and depends on, a system based on historical hydrology, but managing to historical trends will no longer work.

Monthly Average Runoff of Sacramento River System



Average monthly runoff in the Sacramento River System is a critical component of California's water supply. Flood protection and water supply infrastructure have been designed and optimized for historical conditions. However, the timing of peak monthly runoff between 1906-1955 (red line) and 1956-2007 (blue line) has shifted nearly a month earlier indicating that this key hydrology metric is no longer stationary. Timing is projected to continue to move earlier in the year, further constraining water management by reducing the ability to refill reservoirs after the flood season has passed.

PALEOCLIMATE (TREE RING) RECORDS

The value of paleoclimatic records is to document natural climate variability, including extreme events, prior to the period of instrumental records. The information is also helpful in assessing the skill of climate models in representing past conditions, such as extended periods of drought. Tree-ring data from species such as western juniper and Jeffrey pine give climate scientists a record of natural hydrologic variability extending centuries into the past. University of Arizona scientists from the Laboratory of Tree-Ring Research have developed hydrologic reconstructions for the Sacramento, San Joaquin and Klamath Rivers for the California Department of Water Resources.

The decadal scale droughts of the 1920s-30s and 1980s-90s, particularly in the Sacramento and San Joaquin River basins, remain notably severe in the centuries-to-millennium context. For the Sacramento and San Joaquin River Basins the record-low flow occurred in the year 1580, with only about half the total flow of the driest reconstructed year (1924) of the modern measured time frame.

The 12th century contains the driest 50-year period in the Sacramento basin, while late 1400s contains multi-decadal periods with flows lower than 20th and 21st century droughts of this length in the San Joaquin. In the Klamath River basin, single and multi-year periods of drought in the latter half of the 1600's were the most severe periods in this reconstruction.

California's multi-year drought that began in 2012 will certainly rank as one of the driest periods on record, but its duration and the coincident temperatures will determine final comparison with the paleoclimatic extremes.

Western juniper from Sardine Point, Sierra Nevada, California (inner ring date: 830; outer ring date: 1342). Such samples from snags and remnant wood on the landscape in the Sierra Nevada and Rocky Mountains reveal past episodes of widespread multi-decadal drought unmatched in duration and severity by droughts of recent centuries. Drought in the mid-1100s was unusual for encompassing both the Sacramento and Colorado River Basins. Collected July 2013 by the University of Arizona, Laboratory of Tree-Ring Research, Tucson, AZ. The Paleoclimate Study can be accessed at http://www.water.ca.gov/climatechange/articles.cfm

What Does the Future Hold?

TEMPERATURE PROJECTIONS

Future projections of temperatures across California by Scripps Institution of Oceanography indicate that by 2060-2069 mean temperatures will be 3.4 to 4.9 °F higher across the state than they were in the period 1985-94. Seasonal trends indicate a greater increase in the summer months (4.1 to 6.5 °F) than in winter months (2.7 to 3.6 °F) by 2060-2069.

PRECIPITATION PROJECTIONS

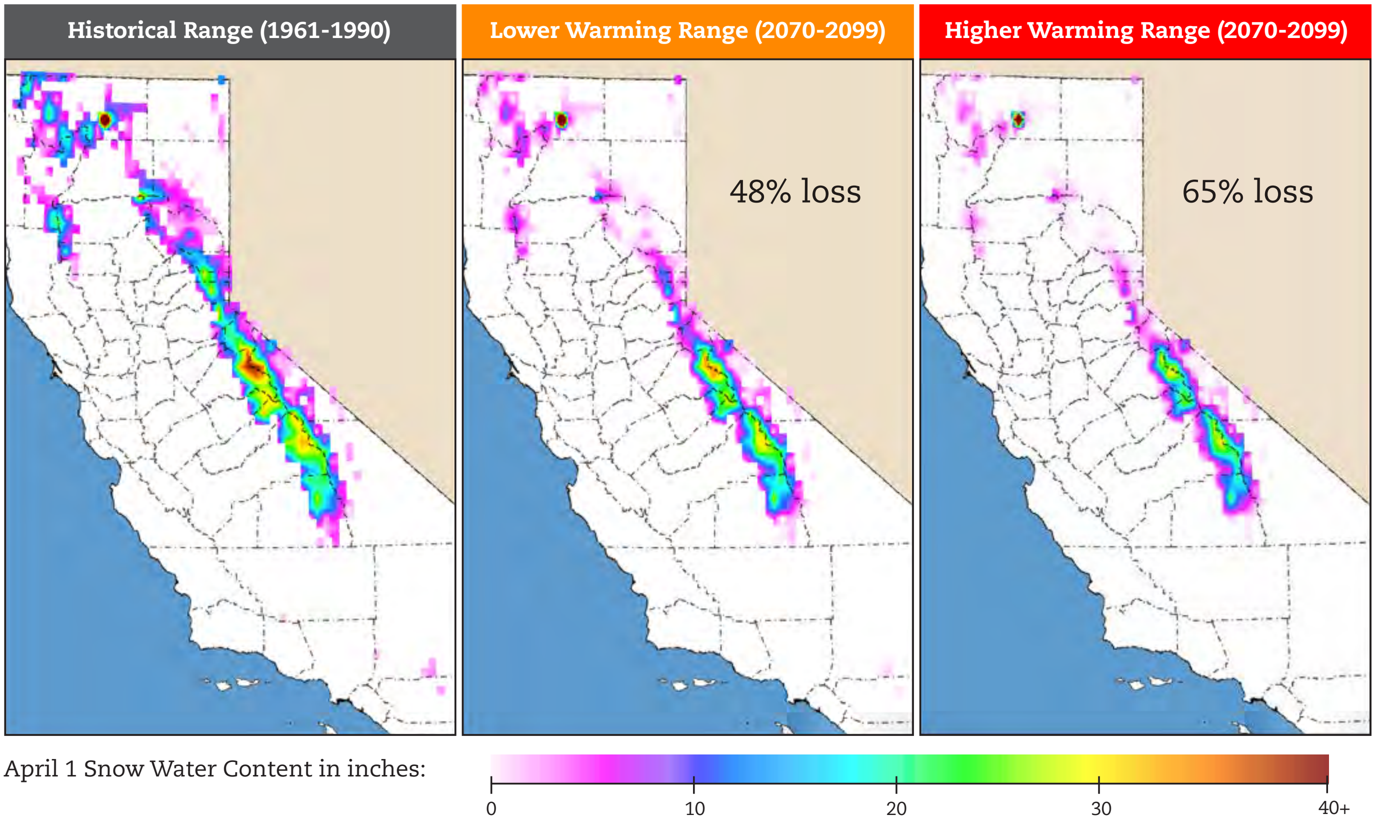
Climate change will lead to a number of hydrologic impacts for California. More intense dry periods are anticipated under warmer conditions, leading to extended, more frequent drought. Extremes on the wet end of the spectrum are also expected to increase, due to more frequent warm, wet atmospheric river events and a higher proportion of precipitation falling as rain instead of snow. These wetter extremes impact the system's ability to provide effective flood protection.

Most climate model precipitation projections for the state anticipate drier conditions in Southern California, with heavier and warmer winter precipitation in Northern California. Because there is less scientific detail on localized precipitation changes, there is a need to adapt to this uncertainty at the regional level (see pages 14-17).

SNOWPACK PROJECTIONS

While observed trends indicate California's climate is already changing, future climate change is anticipated to bring even greater water resource impacts. Based on modeling research at Scripps Institution of Oceanography, by the end of the century, the Sierra snowpack may experience a 48-65 percent loss from the 1961-1990 average. As the northern Sierra's peaks are relatively lower than the southern Sierra, a warmer climate is projected to cause greater snowpack reduction in the state's northern mountains.

Historical and Projected California Snowpack



Historical and projected April 1 Snow Water content for the Sierra for lower and higher warming scenarios depicting the effect of human generated greenhouse gases and aerosols on climate. By the end of this century, the Sierra snowpack is projected to experience a 48 to 65 percent loss from its average at the end of the previous century.

HOW DO SCIENTISTS USE CLIMATE MODELS IN CALIFORNIA?

Climate models are computer programs that use mathematical equations to represent relevant processes in the atmosphere, ocean, land and ice that make up the earth's climate system. Different global climate models (GCMs) are run on large computer systems at several international centers to explore past, present and possible future climate conditions. GCMs are "driven" by known or assumed climate forcings, including fluctuations in solar energy, volcanic activity, changing greenhouse house gas concentrations, aerosols, and land use changes. Based on these forcings, GCMs project global climate conditions and how they might change over time. A "simulation" refers to a single run of a GCM for one set of climate conditions.

Climate change simulations are not perfect forecasts; they are affected by uncertainty in assumed future emissions of aerosols and greenhouse gases, the model's representation of the real climate system, and natural variability. Because of these uncertainties, climate scientists consider ensembles (groups) of climate simulations from several GCMs to investigate different scenarios and a range of possible future variations and changes. Additionally, the climate science community is exploring a set of possible "Representative Concentration Pathways" which provide scenarios of future greenhouse gas emissions and other anthropogenic influences. The various GCMs are run to represent each of these future scenarios, resulting in hundreds of available climate simulations.

GCMs provide broad-brush representations of temperatures, precipitation amounts and timing, winds and other hydrologic processes. In a GCM, the complexity of California's topography and climate is simplified and is represented by merely a handful of data points. To determine watershed- or regional-level responses to climate and hydrologic changes, the data from a GCM must be developed to a finer scale through a process known as downscaling.

Climate model simulations do not provide strong consensus regarding precipitation trends in most locations around the globe, including California. It is possible that throughout the 21st century, the total amount of precipitation statewide will remain, on average, about the same. However, the distribution, timing and type of that precipitation may vary. What is quite certain is that future years will continue to be subjected to natural climate variability, such as El Niño and other large-time-scale oscillations.

Climate model simulations provide greater consensus in temperature trends - virtually all models show significant warming in future decades. Climate models project that by mid-century (2060-2069) temperatures in California will be 3.4 to 4.9 °F higher across the state than they were from 1985 to 1994.

Climate modeling will continue to produce more realistic and improved capability to explore future conditions, as observations accumulate and better fundamental understanding is gained by scientists. These advances will lead to a better understanding of possible scenarios, including the frequency of extremes such as drought and floods that California will face in the future.

CALIFORNIA STATE CLIMATOLOGIST

The California State Climatologist Office (SCO) is maintained in the Department of Water Resources.. The role of the SCO is to collaborate with National Oceanic and Atmospheric Administration programs to provide climate information and interpretation for California, and work with Department of Water Resources personnel, other State and federal agencies and the academic community on projects related to climate, climate change, and their intersection with water management.

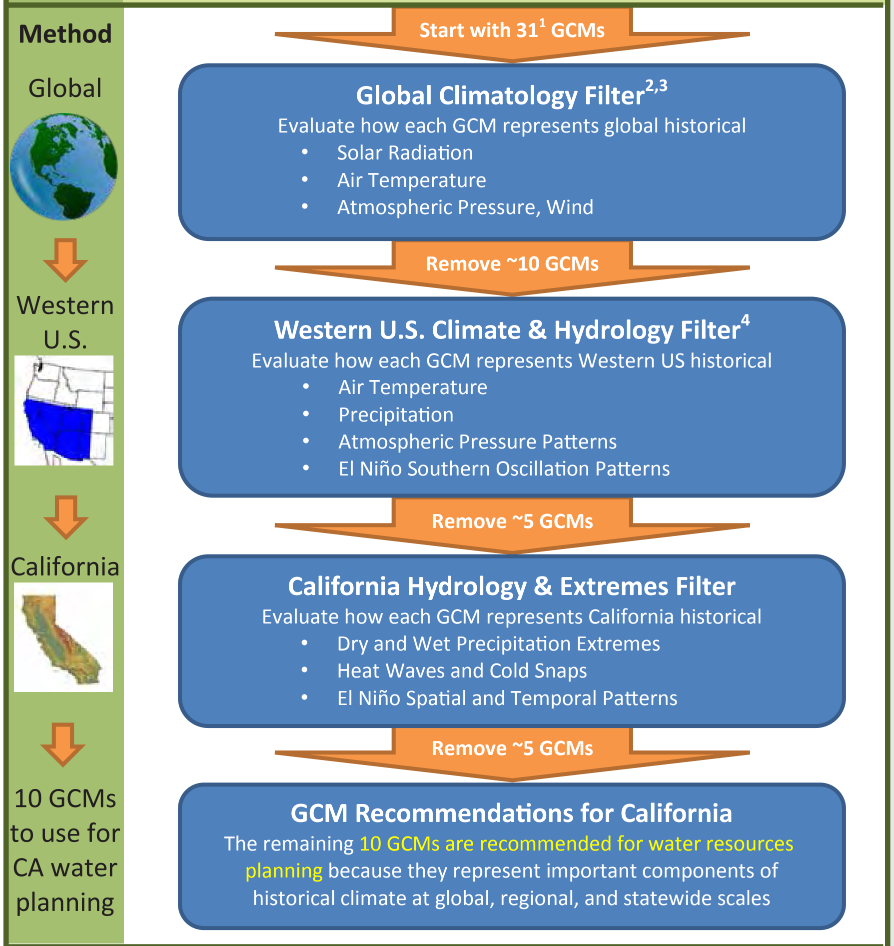
http://www.water.ca.gov/floodmgmt/hafoo/csc/

AASC
AMERICAN ASSOCIATION OF STATE CLIMATOLOGISTS

Choosing Global Climate Models to use for California Water Resources Planning

Criteria

- Scientists recommend using information from several Global Climate Models
- Using information from all available GCMs isn't practical
- Remove GCMs that fall short in representing historical climate and hydrologic processes important for California's water resources planning



Method

Global

Start with 31[1] GCMs

Global Climatology Filter[2,3]

Evaluate how each GCM represents global historical

- Solar Radiation
- Air Temperature
- Atmospheric Pressure, Wind

Remove ~10 GCMs

Western U.S.

Western U.S. Climate & Hydrology Filter[4]

Evaluate how each GCM represents Western US historical

- Air Temperature
- Precipitation
- Atmospheric Pressure Patterns
- El Niño Southern Oscillation Patterns

Remove ~5 GCMs

California

California Hydrology & Extremes Filter

Evaluate how each GCM represents California historical

- Dry and Wet Precipitation Extremes
- Heat Waves and Cold Snaps
- El Niño Spatial and Temporal Patterns

Remove ~5 GCMs

10 GCMs to use for CA water planning

GCM Recommendations for California

The remaining 10 GCMs are recommended for water resources planning because they represent important components of historical climate at global, regional, and statewide scales

References:

[1] CA-DWR Climate Change Technical Advisory Group analysis used GCMs available at the start of the investigation that met certain data requirements (2013).

[2] Gleckler, P. J., Taylor, K. E., and Doutriaux, C.: Performance metrics for climate models, J. Geophys. Res.-Atmos. (2008).

[3] IPCC, Climate Change 2013: The Physical Science Basis, Cambridge University Press, Cambridge, UK and New York (2013).

[4] Rupp, D. E., J. T. Abatzoglou, K. C. Hegewisch, P. W. Mote: Evaluation of CMIP5 20th century climate simulations for the Pacific Northwest USA, J. Geophys. Res.-Atmos. (2013).

CLIMATE MODEL SELECTION

The Department of Water Resources has engaged an external advisory panel, the Climate Change Technical Advisory Group (CCTAG), to provide guidance and perspective on climate change analysis for water resources in California (http://www.water.ca.gov/climatechange/cctag.cfm).

A large collection of model simulations is a practical challenge to many users and decision makers because of the large amount of data and number of simulations to process, analyze and evaluate. To develop a more tractable climate change ensemble, a model sampling or "culling" procedure must be undertaken. To identify this subset, first a comparison between model output and historical observations was made. After assessing how GCMs performs globally, each model was reviewed for how well it replicates the climate structure of the western United States, and then finally, for how well it characterizes key variables for managing water resources in California, such as temperature, precipitation and relative humidity. These models comprise a more appropriate subset for water resources analysis than those used in previous climate change studies by the State of California, such as the CAT-12 scenarios (Climate Action Team, 2008), although there is no guarantee that model performance has a strong influence on the credibility of projections.

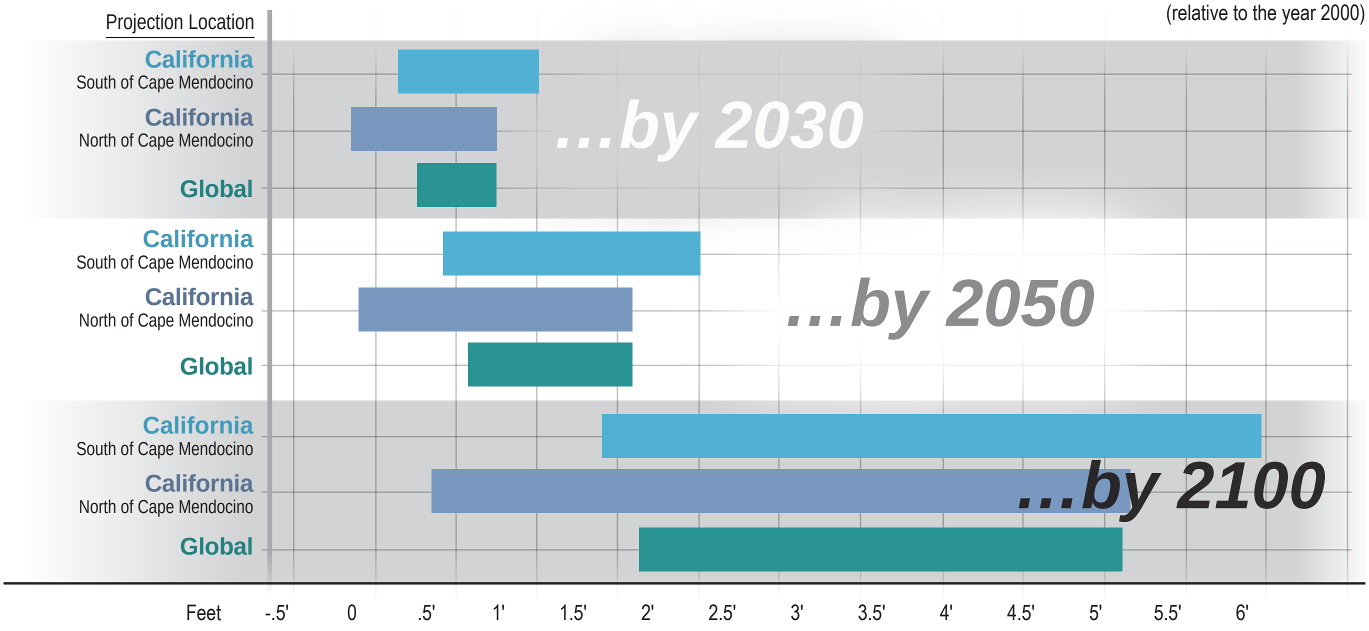
SEA LEVEL RISE

A warming climate causes sea level to rise in two ways; first, by warming the oceans which causes the water to expand, and second, by melting land ice which transfers water to the ocean. Recent satellite data shows that the rate of sea level rise is accelerating, with melting of land ice now the largest component of global sea level rise (about 65 percent), largely because ice loss rates are increasing.

During the last century, sea level at the Golden Gate in San Francisco has shown a 7-inch rise, similar to global measurements. Future sea level rise along the California coast may be uneven. Models indicate that it depends on the global mean sea level rise and regional factors, such as ocean and atmospheric circulation patterns; melting of modern and ancient ice sheets; and tectonic plate movement.

The sea-level rise implications for California include increased risk of storm surge and flooding for coastal residents and infrastructure, including many of the State's low-lying coastal wastewater and recycled water treatment plants. Most coastal damage from sea level rise is caused by the confluence of large waves, storm surges, and high astronomical tides during strong El Niño conditions. The State is vulnerable to these impacts, some of which are projected to increase under climate change. Even if storms do not become more intense and/or frequent, sea level rise itself will magnify the adverse impact of any storm surge and high waves on the California coast. Some observational studies report that the largest waves are already getting higher and winds are getting stronger, but data records do not go back far enough to confirm whether these are long term trends.

California and Global Sea Level Rise projections



Reprinted with permission from "Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future," 2012, from the National Academy of Sciences, Courtesy of the National Academies Press, Washington, D.C.

Summary of regional projections of mean sea level rise from a National Research Council of the National Academies (http://dels.nas.edu/Report/Level-Rise-Coasts/13389) study, sponsored by California, Oregon, Washington, and three federal agencies. The highest observed values of sea level rise will occur during winter storms, especially during El Niño years when warmer ocean temperatures result in temporarily increased sea levels. Observed values can be much greater than the mean values shown here. For example, observed California sea levels during winter storms in the 1982-83 El Niño event were similar in magnitude to the mean sea levels now being projected for the end of the 21st century.

Many of the Sacramento-San Joaquin Delta islands lie below sea level, as this view of one of the Delta channels shows. Sea level rise poses an additional threat to already-stressed Delta levees which protect Delta communities and farms, as well as water supplies for millions of Californians.

For the millions who rely on drinking water or agriculture irrigated by Delta water exports, the most critical impact of rising seas will be additional pressure on an already vulnerable levee and water delivery system, which protects numerous islands currently below sea level and sinking. Catastrophic levee-failure risk continues to increase, with the potential to inundate Delta communities and interrupt water supplies throughout the State. Even without levee failures, Delta water supplies and aquatic habitat may be affected at times, owing to more seawater intrusion caused by sea level rise. Without additional releases of freshwater from reservoirs to repel higher sea levels, sea water will penetrate further into the Delta and will degrade drinking and agricultural water quality and alter ecosystem conditions. Alternatively, releasing additional freshwater from reservoirs to repel the higher sea levels will have impacts on water supply.

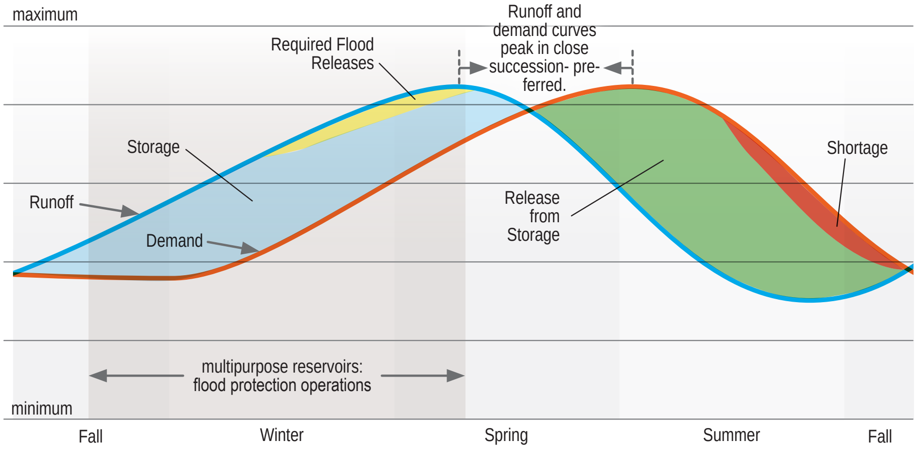
IMPACT TO WATER SUPPLY SYSTEMS

This figure shows conceptually how the hydrologic changes anticipated under a warming climate place additional stress on water supply systems. These changes increase the volume of runoff that arrives at reservoirs during the flood protection season and reduce the stored water available to meet summer peaks in water demand. At the same time, higher temperatures, resulting from climate change, increase peak summer demands beyond historical levels. Existing infrastructure will need to be adapted to the new timing of runoff, as well as accommodate higher flows from more powerful individual storm events in a warmer atmosphere. Overall flexibility needs to be incorporated into water infrastructure and operations.

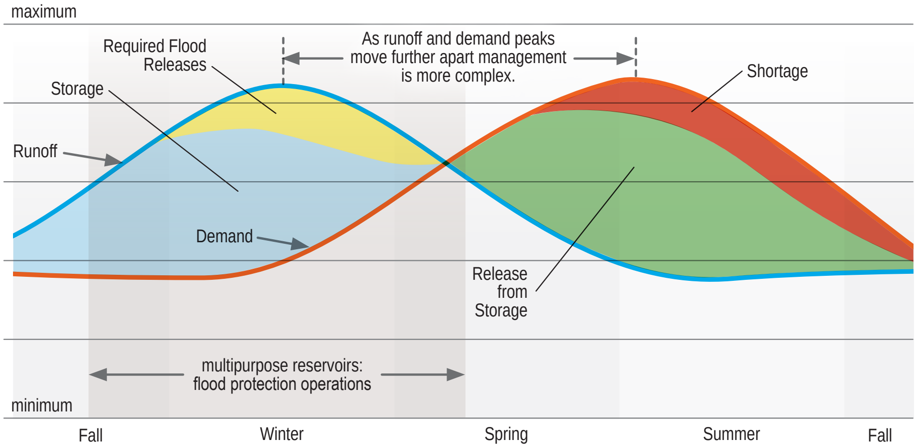
How Earlier Runoff Affects Water Availability

The impacts of earlier runoff and increased summertime water demand are shown conceptually in the two curves. The curves show the general shape and timing of runoff and demand in California (individual watersheds will each have unique characteristics). Under "Current Conditions" (top box) runoff peaks in early spring only a few months before demand peaks in early summer. Much of the difference between high runoff and low demand in fall and winter can be captured and stored in the state's existing surface and groundwater storage facilities. That storage meets most of the demands later in spring and summer and shortages are minimal. Under "Projected Conditions" (lower box) runoff peaks in mid-winter, months before demand peaks in spring and summer. Summer-time demand is higher due to higher temperatures and high demand lasts longer into early fall due to longer growing seasons. Earlier runoff is captured in storage facilities, but because the runoff arrives while reservoirs are being managed for flood protection, much of the runoff must be released to maintain flood protection storage space in reservoirs. In spring and summer demand far exceeds runoff and releases from storage, making shortages much more common.

Current Conditions:



Projected Conditions:

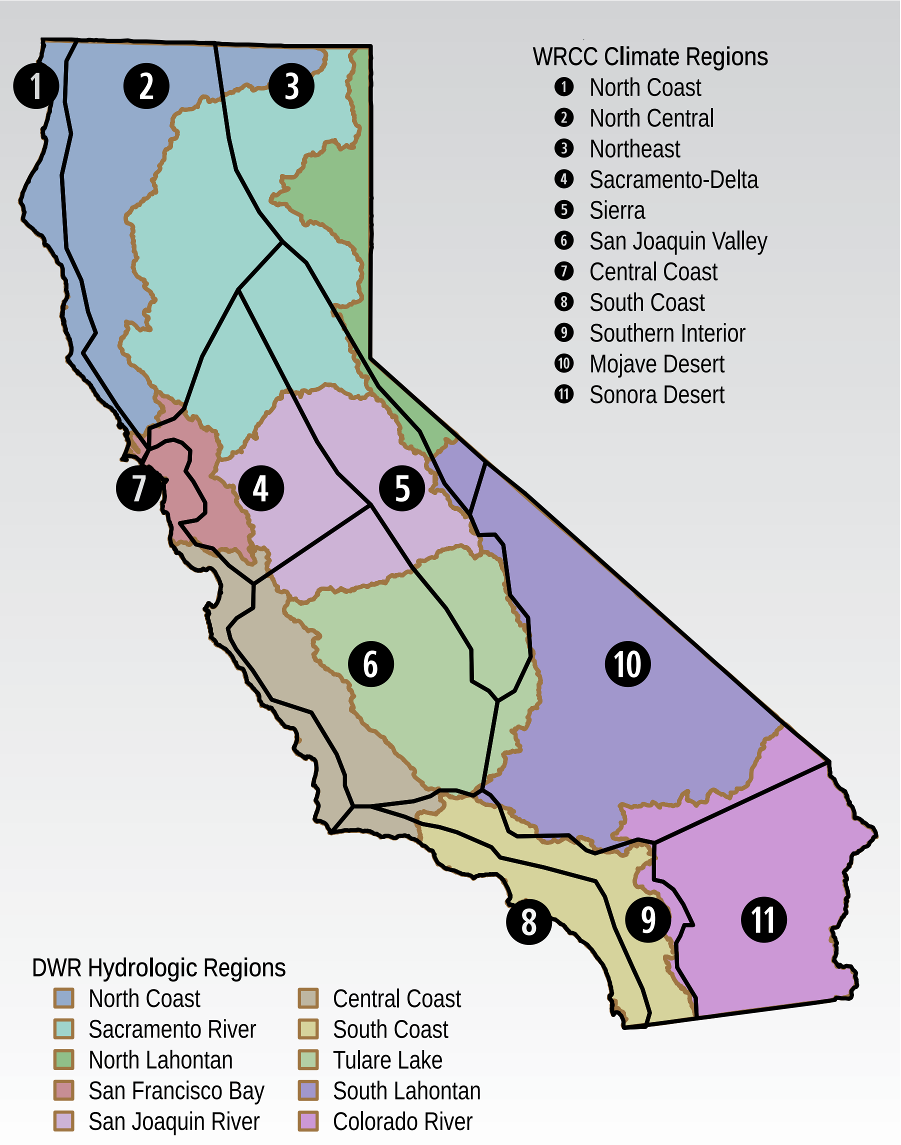


Regional Impacts and Strategies

Due to the geographical, topographic and climatic variations of California, both the impacts from and strategies for climate change are regionally dependent. This section highlights regionally specific temperature change observations, projected temperature increases, climate change vulnerabilities and Resource Management Strategies (RMSs) best suited to respond to climate change at the regional level.

The figures on pages 12 and 3 show observed temperature changes and future temperatures projections for various parts of the state. There is a great deal of variability among and within regions for both the historical and future trends. The mapping convention for the temperature figures comes from the Western Region Climate Center, explained below.

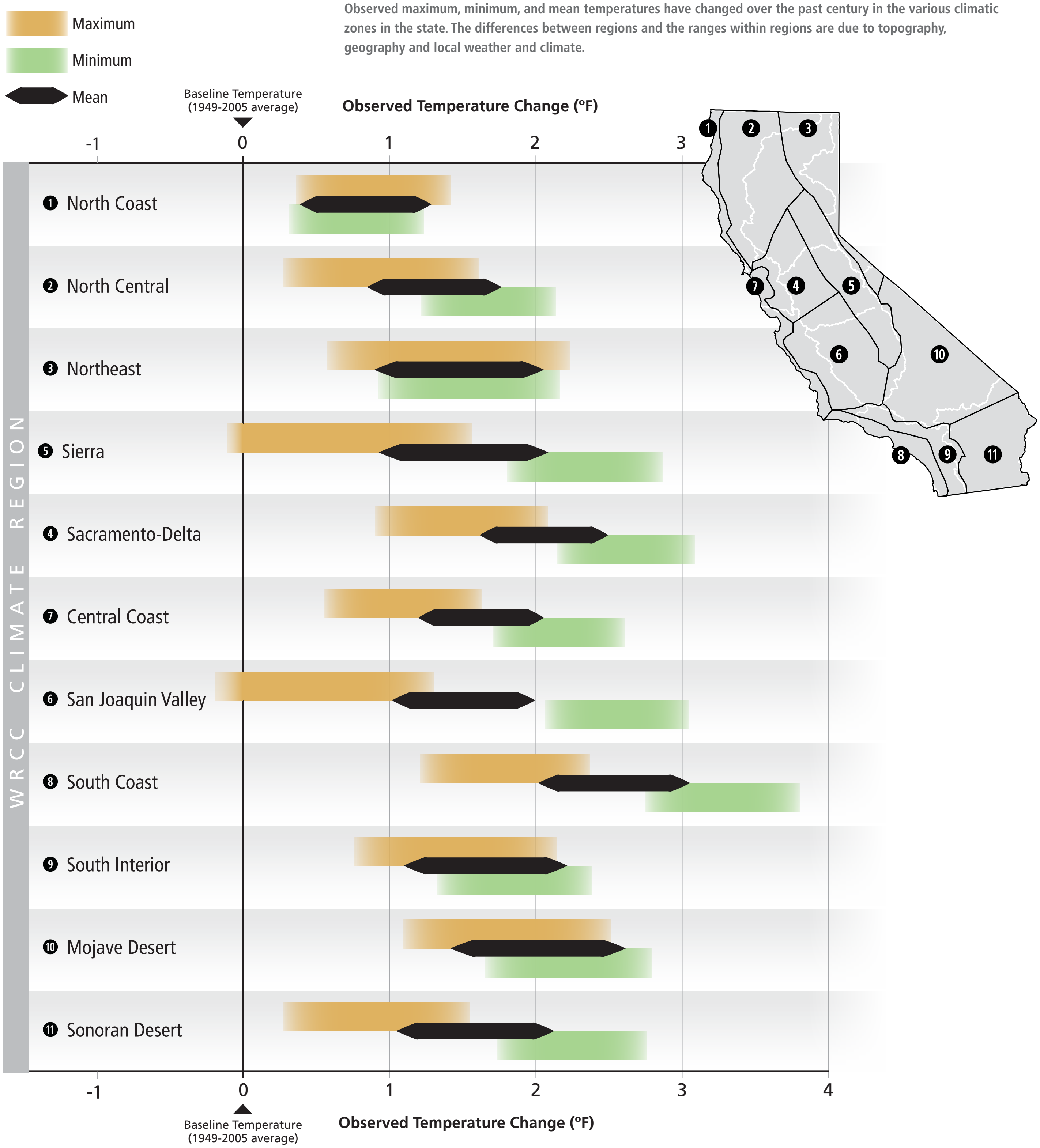
DWR Hydrologic and Western Region Climate Center Climate Regions



The Western Region Climate Center (WRCC) divides California into 11 separate climate regions, and generates historic temperature time-series and trends for these regions (http://www.wrcc.dri.edu/monitor/cal-mon/frames_version.html). DWR uses 10 Hydrologic Regions, with the Delta and Mountain Counties being overlays of other DWR Hydrologic Regions. Each DWR Hydrologic region spans one or more of the WRCC climate regions.

Observed Temperature Change 1895-Present

Observed maximum, minimum, and mean temperatures have changed over the past century in the various climatic zones in the state. The differences between regions and the ranges within regions are due to topography, geography and local weather and climate.



Projected Temperature Increase by Mid-21st Century

Future temperature change projections are based on a recent study by Scripps Institution of Oceanography using the most sophisticated methodology to date. Winter mean, annual mean, and summer mean temperatures are projected to increase by the amounts shown by 2060-69, compared to the period from 1985-1994. There is variability in the warming response between different climatic zones in California.

VULNERABILITIES

Because of the economic, geographical, and biological diversity of California, vulnerabilities and risks due to current and anticipated future changes are best assessed on a regional basis. A few of the key climate vulnerabilities for each hydrologic region are provided below to highlight how climate change vulnerabilities vary throughout California (see California Water Plan Update 2013 Hydrologic Regions map on page 15, which are slightly different than the WRCC regions used on pages 12 and 13).

South Coast

- Coastal infrastructure and near-shore ecosystems are vulnerable to increasing sea level and storm surges, while coastal aquifers could be affected by increasing salinity intrusion.
- Magnitude and frequency of extreme precipitation events may increase, resulting in greater flood risk, debris flows, and degradation of habitat for special-status species.
- Higher temperatures and longer dry seasons would increase wildfire risk and impair water quality in local streams and lakes.
- Loss of snowpack storage may reduce reliability of imported water supplies

South Lahontan

- Higher temperatures and longer dry seasons would increase wildfire risk and impair water quality in local streams and lakes.
- Loss of snowpack storage may reduce reliability of surface imported water supplies and replenishment of local supplies, and result in greater demand on groundwater resources.
- Reduced snowpack and changes in runoff timing would impact the winter-dependent economy supporting disadvantaged communities.

Colorado River

- Magnitude and frequency of extreme precipitation events may increase, resulting in greater flood risk and debris flows.
- More frequent and longer droughts would reduce imported water supply reliability and decrease local water quality and habitat.

Central Coast

- Coastal infrastructure and near-shore ecosystems are vulnerable to increasing sea level and storm surges, while coastal aquifers could be affected by increasing salinity intrusion.
- Magnitude and frequency of extreme precipitation events may increase, resulting in greater flood risk, debris flows, and degradation of habitat for special-status species.
- Higher temperatures and longer dry seasons would increase wildfire risk and impair water quality in local streams and lakes.

San Joaquin River

- Loss of snowpack storage may reduce reliability of surface water supplies and result in greater demand on groundwater resources.
- Magnitude and frequency of extreme precipitation events may increase, resulting in greater flood risk, debris flows, and degradation of habitat for special-status species.
- Increased air and water temperatures would place additional stress on sensitive ecosystems and species.
- Increasing temperatures and variable precipitation patterns would affect agricultural crops by reducing winter chill-hours, increasing extreme heat days and increasing evapotranspiration.

Tulare Lake

- Loss of snowpack storage may reduce reliability of surface imported water supplies and replenishment of local supplies, and result in greater demand on groundwater resources.
- Magnitude and frequency of extreme precipitation events may increase, resulting in greater flood risk, debris flows, and degradation of habitat for special-status species.
- Increased air and water temperatures would place additional stress on sensitive ecosystems and species.
- Increasing temperatures and variable precipitation patterns would affect agricultural crops by reducing winter chill-hours, increasing extreme heat days and increasing evapotranspiration.

San Francisco Bay

- Magnitude and frequency of extreme precipitation events may increase, resulting in greater flood risk.
- Sea level rise may increase the susceptibility of tidal wetlands to more frequent, longer and deeper flooding.
- Increases in temperature and changes in precipitation patterns may alter ecosystems and impact native species.
- Loss of snowpack storage may reduce reliability of surface water supplies and result in greater demand on other sources of supply.

Sacramento-San Joaquin Delta (overlay area)

- Increases in temperature and changes in precipitation patterns may alter ecosystems and impact native species.
- Magnitude and frequency of extreme precipitation events may increase, resulting in greater flood risk.
- Water quality may be impacted by lower summer low flows, and increased water temperatures.
- Sea level rise may increase stress on Delta levees and change water quality.

Mountain Counties (overlay area)

- Increases in temperature and changes in precipitation patterns may alter ecosystems and impact native species.
- Loss of snowpack storage may reduce reliability of surface water supplies
- Snowpack reduction may have significant impacts on the water-related tourism industry.
- Higher temperatures and longer dry seasons may increase wildfire risk.

Sacramento River

- Increased air and water temperatures would place additional stress on sensitive ecosystems and species.
- Loss of snowpack storage may reduce reliability of surface water supplies and result in greater demand on groundwater resources.
- Magnitude and frequency of extreme precipitation events may increase, resulting in greater flood risk.
- Water quality could be impacted by more intense storm events, decreased summer low flows, and increased water temperatures.

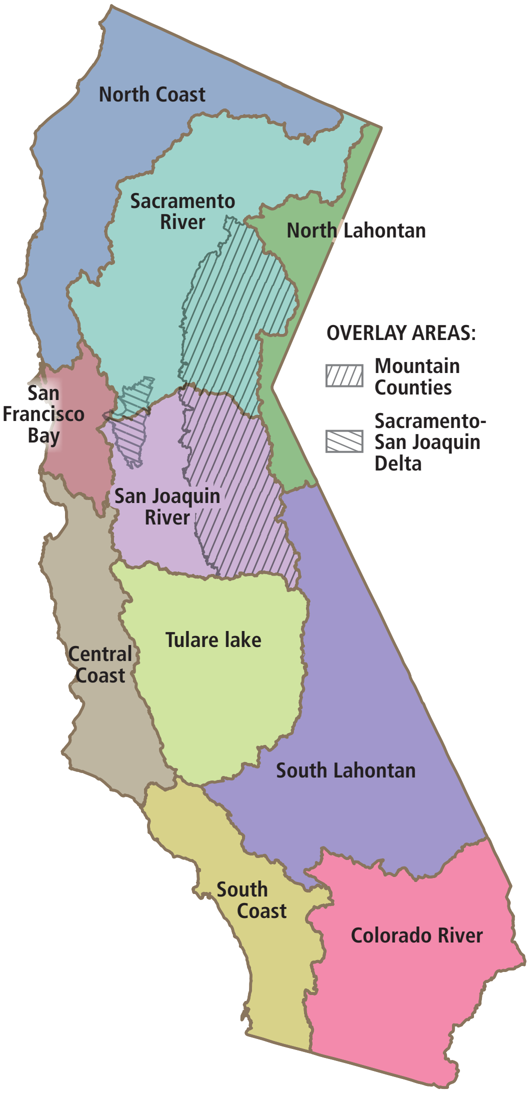
North Coast

- Loss of snowpack storage may reduce summer low flows for local rivers leading to increased stress on fish and other aquatic species.
- Impacts to fisheries are possible due to shifts in ocean chemistry which lower pH, reducing oyster and clam productivity.
- Sea level rise may make tidal marshland susceptible to more frequent, longer and deeper flooding.
- Higher temperatures and longer dry seasons would increase wildfire risk and impair water quality in local streams and lakes.

North Lahontan

- Increased air and water temperatures would place additional stress on sensitive ecosystems and species.
- Loss of snowpack storage may reduce reliability of surface water supplies and result in greater demand on groundwater resources.
- Magnitude and frequency of extreme precipitation events may increase, resulting in greater flood risk.
- Higher temperatures and longer dry seasons would increase wildfire risk.

DWR Hydrologic Regions



CLIMATE CHANGE ADAPTATION THROUGH RESOURCE MANAGEMENT

Climate Change Vulnerability

- Drought
- Flood
- Changing Hydrology
- Sea Level Rise
- Wildfire
- Rising Temperatures
- Ecosystem Services

California Water Plan Update 2013 presented a comprehensive and diverse set of Resource Management Strategies (RMSs) that can help meet the water-related resource management needs of each region and the State. An RMS is a technique, program, or policy that helps local agencies and governments manage their water and related resources. RMSs can be considered as tools in a toolkit. Just as the mix of tools in any given kit depends on the job to be accomplished, the combination of strategies will vary from region to region, depending on climate, projected growth, existing water system, environmental and social conditions, and regional goals.

Each RMS is summarized below along with its potential adaptation benefits for certain climate change vulnerabilities (see key to the left.) For a complete description of each RMS, please visit the California Water Plan Update 2013 at http://www.waterplan.water.ca.gov/cwpu2013/.

Resource Management Strategies

Reduce Water Demand

Agricultural Water Use Efficiency: Water delivery and use practices to achieve net water savings or increased production.

Urban Water Use Efficiency: Practices that maximize use of available water supplies by reducing waste and increasing efficiency.

Improve Flood Management

Flood Management: Considers land and water resources on a watershed scale, employing structural and nonstructural flood management measures to maximize the benefits of floodplains, minimize loss of life and damage to property from flooding, and recognize benefits to ecosystems from periodic flooding.

Improve Operational Efficiency and Transfers

Conveyance – Delta: New facility would help meet the coequal goals of the Delta Plan by providing for a more reliable supply of water while simultaneously maintaining sufficient bypass flows for State and federally listed species of concern.

Conveyance – Regional/Local: Improvement and maintenance of water conveyance systems to improve system reliability, protect water quality, increase available water supplies, and provide operational flexibility.

System Reoperation: Changing existing operation and management procedures for a water resources system consisting of supply and conveyance facilities and end user demands with the goal of increasing desired benefits from the system.

Water Transfers: Temporary or long-term change in the point of diversion, place of use, or purpose of use due to a transfer, sale, lease, or exchange of water or water rights.

Conjunctive Management and Groundwater Storage: Coordinated and planned use and management of surface water and groundwater resources to maximize the availability and reliability of water supplies.

Desalination (Brackish and Sea Water): Removal of salts from saline waters; desalinate sea water for coastal communities and brackish groundwater for inland water users.

Precipitation Enhancement: Commonly called “cloud seeding,” artificially stimulates clouds to produce more rainfall or snowfall than they would produce naturally.

Municipal Recycled Water: Recycling of municipal wastewater treated to a specified quality to enable it to be used again.

Surface Storage – CALFED/State: Refers to five potential surface storage reservoirs that are being investigated by the California Department of Water Resources (DWR), U.S. Bureau of Reclamation (USBR), and local water interests. See Surface Storage Regional/Local for surface storage definition.

Surface Storage – Regional/Local: Human-made, above-ground reservoirs to collect water for later release when needed. Surface storage has played a key role in California where the quantity, timing, and location of water demand frequently does not match the natural water supply availability.

Improve Water Quality

Drinking Water Treatment and Distribution: Development and maintenance of public water treatment and distribution facilities. Reliability, quality, and safety of the raw water supplies are critical to achieving this goal.

Groundwater/Aquifer Remediation: Removal of contaminants which affect beneficial use of groundwater.

Matching water quality to use: Management strategy that recognizes that not all water uses require the same water quality.

Pollution Prevention: Reducing or eliminating waste at the source by modifying production processes, promoting the use of non-toxic or less toxic substances, implementation of practices or conservation techniques that reduce generation or discharge of pollutants, and application of alternative technologies to prevent pollutants from entering the environment.

Salt and Salinity Management: Reduces salt loads that impact a region; also a key component of securing, maintaining, and recovering usable water supplies. A few of the ways salts enter surface and ground water supplies are through the natural geology, sea water intrusion and fertilizer application.

Urban Stormwater Runoff Management: Activities to manage both stormwater and dry-weather runoff. Dry-weather runoff occurs when, for example, excess landscape irrigation water flows to the storm drain.

Practice Resource Stewardship

Agricultural Land Stewardship: Agricultural lands used to produce public environmental benefits in conjunction with the food and fiber they have historically provided while keeping lands in private ownership.

Ecosystem Restoration: Improve condition of modified natural landscapes and biological communities to provide for their sustainability and for their use and enjoyment by current and future generations.

Forest Management: Management activities on public and privately-owned forest lands to improve availability and quality of water for downstream users.

Land Use Planning and Management: Collaboration between land use planners and water managers to promote more efficient and effective land-use patterns and integrated regional water management (IRWM) practices to produce safer and more resilient communities.

Sediment Management: Strategies to address excessive sediment in watersheds. Sediment is material such as sand, silt, or clay, suspended in or settled on the bottom of a water body.

Watershed Management: Process of creating and implementing plans, programs, projects, and activities to restore, sustain, and enhance watershed functions.

Recharge Area Protection: Ensuring that areas suitable for recharge continue to be capable of adequate recharge rather than being covered by urban infrastructure, such as buildings and roads, and preventing pollutants from entering groundwater to avoid expensive treatment that may be necessary prior to beneficial use.

People and Water

Economic Incentives: Financial assistance, water pricing, and water market policies intended to influence water management. Economic incentives can influence the amount and time of water use, wastewater volume, and source of water supply.

Outreach and Engagement: Use of tools and practices by water agencies to facilitate contributions by public individuals and groups toward good water management outcomes.

Water and Culture: Linking cultural considerations to water management. Increasing the awareness of how cultural values, uses, and practices are affected by water management, as well as how they affect water management, will help inform policies and decisions.

Water-Dependent Recreation: Planning for water-dependent recreation activities in water projects, water managers play a critical role in ensuring that all Californians today and into the future are able to enjoy such activities.

Other

Other Resource Management Strategies: A variety of water management strategies could potentially generate benefits that meet one or more water management objectives, however these management strategies have limited capacity to strategically address long-term regional water planning needs. Strategies include crop idling for water transfers, dewvaporation or atmospheric pressure desalination, fog collection, irrigated land retirement, rain-fed agriculture, snow fences, and waterbag transport/storage technology.

Water-Energy Nexus

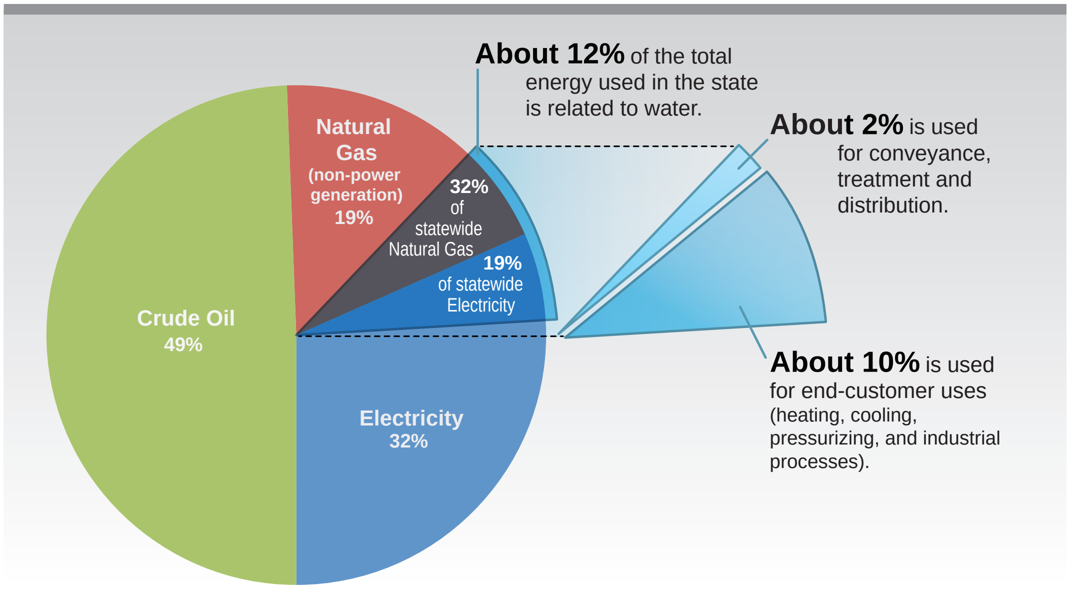
Water and energy have a complex relationship with multiple interdependencies, often called the water-energy nexus. Energy is used throughout the water sector to extract, convey, treat, distribute, and heat water. “Energy intensity” is the total amount of energy calculated on a whole system basis, required for the use of a given amount of water in a specific location.

Water-related energy use in California is depicted in the figure below, including electricity, natural gas, and crude oil consumption. The California Energy Commission’s (CEC’s) 2005 study estimated that water systems and users in California accounted for about 19 percent of statewide electricity consumption and 32 percent of statewide natural gas (non-power generation) consumption. The majority of water sector energy consumption is by water end-users, including water heating and cooling; advanced treatment by industrial users; and on-site pumping and pressurization for irrigation and other purposes. The remaining water-sector energy consumption occurs in water and wastewater system operations, including water extraction, conveyance, treatment, distribution, and wastewater collection and treatment.

Most electricity generation and energy uses result in greenhouse gas (GHG) emissions related to climate change. Reducing energy intensity and energy uses can reduce GHG emissions in the water sector and contribute to climate change mitigation.

The other side of the water-energy nexus relates to the amount of water used in producing energy, including water used in the energy sector for extraction of natural gas and other fuels, used as the working fluid for hydropower or the working fluid and cooling in thermal generation systems, and used for irrigating biofuels.

Energy Use Related to Water



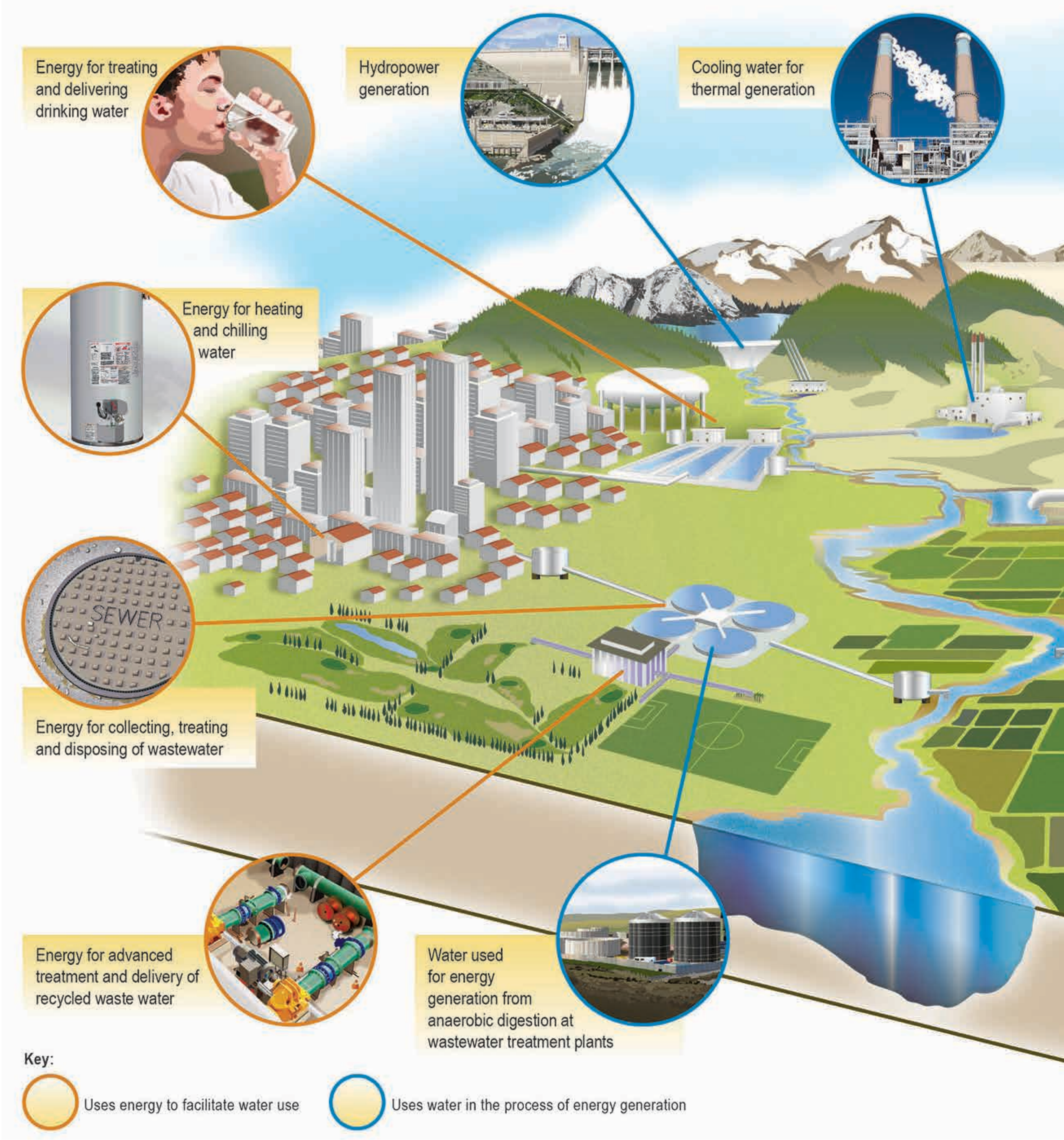
The Lodi Energy Center (shown above), a new natural gas energy plant that opened in August 2012 has enabled California's State Water Project to substantially cut greenhouse gas emissions. The Department of Water Resources (DWR) shares the 296-megawatt capacity facility with Lodi Electric Utility, City of Azusa, Bay Area Rapid Transit (BART), City of Biggs, City of Gridley, City of Healdsburg, City of Lompoc, Modesto Irrigation District, Plumas-Sierra Rural Electric Cooperative, Power and Water Resources Pooling Agency (PWRPA), Silicon Valley Power, and City of Ukiah. This new facility provides DWR cleaner energy to replace a portion of its power formerly served by coal-fired generation. The Lodi Energy Center's advanced emission control technology and fast-start capability allow it to deliver about 200 megawatts of power capacity within just 30 minutes. This feature helps grid operators integrate intermittent weather dependent sources of renewable electricity generated by the sun and wind into California's electrical system. Fast-start capability also reduces greenhouse gas emissions by 30 percent when compared to conventional units.

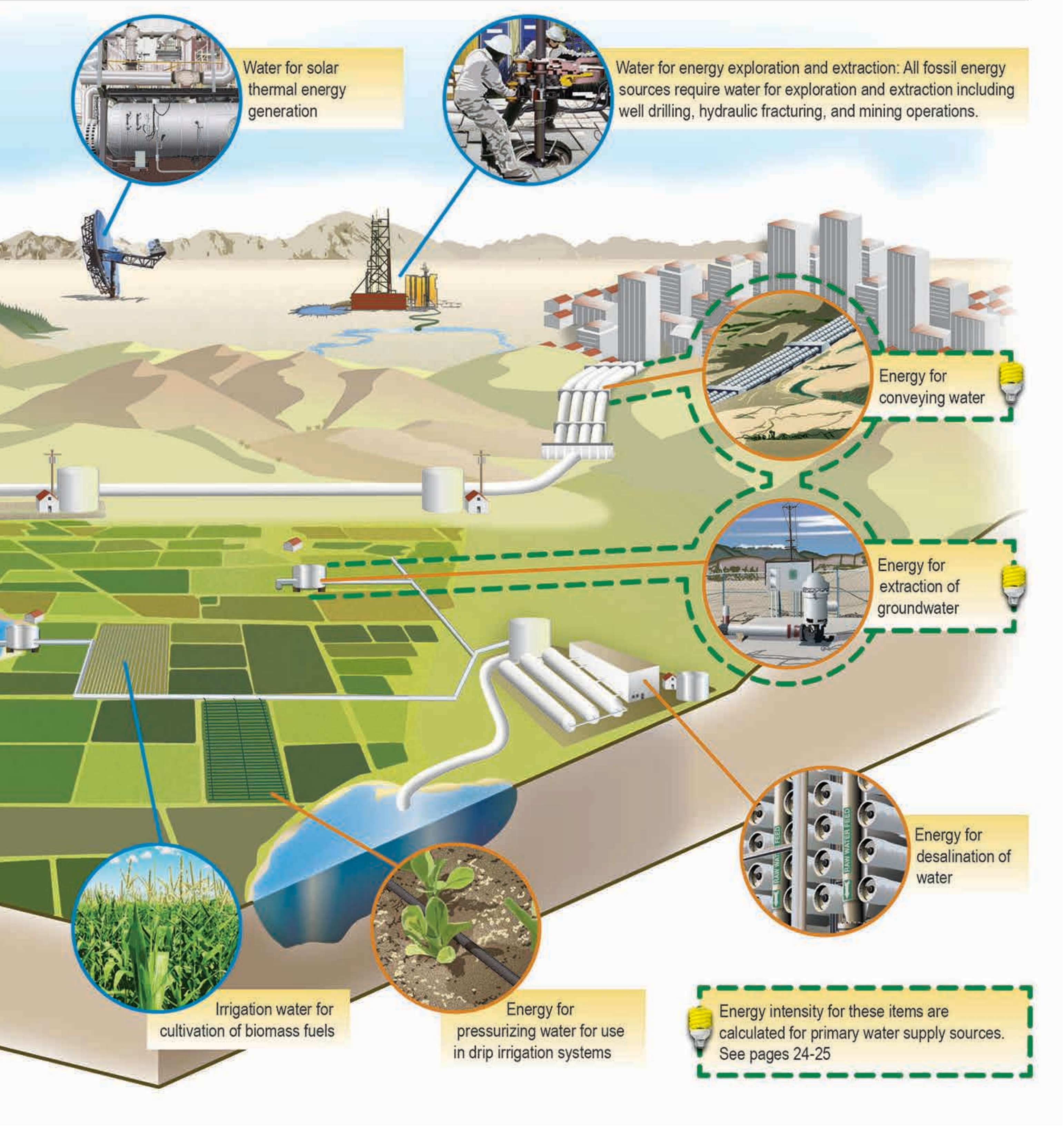
Water requirements for energy systems are highly variable and depend on many factors.

The Water Energy Connection diagram on page 20 illustrates the multiple ways that water and energy sectors are interwoven in California. Connections where water is used in the generation of energy are highlighted in blue, while connections where energy is expended in the use of water are highlighted in orange. The energy required for extraction and conveyance of water are indicated with green hatches and yellow light bulbs, which is further detailed on pages 23-25.

Understanding the relationship of water and energy is important for decision-making, with regard to using limited water and energy supplies efficiently to meet increasing future demands. The connections between these sectors should be kept in mind when making resource and planning decisions.

The Water and Energy Connection





Water for solar thermal energy generation

Water for energy exploration and extraction: All fossil energy sources require water for exploration and extraction including well drilling, hydraulic fracturing, and mining operations.

Energy for conveying water

Energy for extraction of groundwater

Energy for desalination of water

Irrigation water for cultivation of biomass fuels

Energy for pressurizing water for use in drip irrigation systems

Energy intensity for these items are calculated for primary water supply sources. See pages 24-25

California Hydrologic Regions and Major Water Projects

ENERGY INTENSITY OF REGIONAL WATER USAGE

Energy is used in the water sector to extract, convey, treat, distribute, use, condition, and dispose of water and wastewater. The California Water Plan Update 2013 provides detailed information on the water-energy connection, including energy intensity (EI) information at the regional level. EI information is designed to help inform the public and water utility managers about the relative energy requirements of the major water supplies used to meet demand. Because energy usage is closely related to GHG emissions, this information can support measures to reduce GHG emissions, as mandated by the State.

The energy intensity regional figures on pages 24-25 show the amount of energy associated with the extraction and conveyance of one acre-foot of water for each of the major water sources within ten hydrologic regions. The Delta and Mountain Counties are covered in the regional reports they overlay.

The relative quantity of each water source used within a region is also included, as a percentage. Energy required for water treatment, distribution, and end uses of the water are not included. Not all water types are available in each region. Some water types flow mostly by gravity to the delivery location and may require little or no energy to extract and convey. As a default assumption, minimum EI of at least 250 kilowatt hours per acre-foot (kWh/af) was assumed for all water types. The map on page 22 shows California's diverse set of local, State, and federal water projects superimposed over the state's hydrologic regions to provide context for the energy intensity regional figures. For additional detail on EI figures, see http://www.water.ca.gov/climatechange/water-energy.cfm.

Teerink Pumping Plant north of Los Angeles lifts water 232.5 feet. The pumping plant is one of 20 operated as part of the State Water Project (SWP). DWR implements a comprehensive program to continuously monitor, maintain, and increase the energy efficiency of pumps and turbines throughout the SWP system. By continuously evaluating and improving pumping and hydroelectric generating efficiencies, DWR minimizes energy needs and maximizes energy generated. http://www.water.ca.gov/about/swp.cfm.

Energy Intensity per Acre-Foot of Water

Energy intensity (EI) in these figures is the estimated energy required for the extraction and conveyance of one acre-foot of water. An acre-foot is the volume of water that would cover one acre to a depth of one foot; equal to 43,560 cubic feet or 325,851 gallons; it approximates the water needs of a family of four for one year. These figures reflect only the amount of energy needed to move from a supply source to a centralized delivery location (not all the way to the point of use). Small light bulbs are for EI greater than zero, and less than 250 kilowatt hours per acre foot (kWh/AF). Large light bulbs represent 251-500 kWh/AF of water (e.g., four light bulbs indicate that the water source has EI between 1,501-2,000 kWh/AF). The percent of regional water supply may not add up to 100% because not all water types are shown in this figure. EI values of desalinated and recycled water are covered in Resource Management Strategies, Volume 3 of the California Water Plan. For detailed energy intensity information see http://www.waterplan.water.ca.gov/technical/cwpu2013/index.cfm#climate

North Coast

Type of Water	Energy Intensity (• = 1-250 kWh/AF 💡 = 251-500 kWh/AF)	Percent of Regional Water Supply
Colorado (Project)	*This type of water not available*	0%
Federal (Project)	• <250 kWh/AF	21%
State (Project)	*This type of water not available*	0%
Local (Project)	• <250 kWh/AF	27%
Local Imports	• <250 kWh/AF	1%
Groundwater	• <250 kWh/AF	28%

San Francisco

Type of Water	Energy Intensity (• = 1-250 kWh/AF 💡 = 251-500 kWh/AF)	Percent of Regional Water Supply
Colorado (Project)	*This type of water not available*	0%
Federal (Project)	💡 •	12%
State (Project)	💡 💡	12%
Local (Project)	• <250 kWh/AF	15%
Local Imports	• *<250 kWh/AF	38%
Groundwater	💡	19%

* Hetch Hetchy is a net energy provider

Central Coast

Type of Water	Energy Intensity (• = 1-250 kWh/AF 💡 = 251-500 kWh/AF)	Percent of Regional Water Supply
Colorado (Project)	*This type of water not available*	0%
Federal (Project)	💡 •	7%
State (Project)	💡 💡 💡 💡 •	3%
Local (Project)	• <250 kWh/AF	3%
Local Imports	*This type of water not available*	0%
Groundwater	💡	79%

South Coast

Type of Water	Energy Intensity (• = 1-250 kWh/AF 💡 = 251-500 kWh/AF)	Percent of Regional Water Supply
Colorado (Project)	💡 💡 💡 💡 •	21%
Federal (Project)	• <250 kWh/AF	<1%
State (Project)	💡 💡 💡 💡 💡 💡 •	27%
Local (Project)	• <250 kWh/AF	4%
Local Imports	0*	5%
Groundwater	💡 •	33%

* Los Angeles Aqueduct is a net energy provider

Sacramento River

Type of Water	Energy Intensity (💡 = 1-250 kWh/AF 💡 = 251-500 kWh/AF)	Percent of Regional Water Supply
Colorado (Project)	*This type of water not available*	0%
Federal (Project)	💡 <250 kWh/AF	28%
State (Project)	💡 <250 kWh/AF	<1%
Local (Project)	💡 <250 kWh/AF	30%
Local Imports	*This type of water not available*	0%
Groundwater	💡 <250 kWh/AF	19%

San Joaquin

Type of Water	Energy Intensity (💡 = 1-250 kWh/AF 💡 = 251-500 kWh/AF)	Percent of Regional Water Supply
Colorado (Project)	*This type of water not available*	0%
Federal (Project)	💡 <250 kWh/AF	16%
State (Project)	💡	<1%
Local (Project)	💡 <250 kWh/AF	29%
Local Imports	*This type of water not available*	0%
Groundwater	💡 <250 kWh/AF	31%

Tulare Lake

Type of Water	Energy Intensity (💡 = 1-250 kWh/AF 💡 = 251-500 kWh/AF)	Percent of Regional Water Supply
Colorado (Project)	*This type of water not available*	0%
Federal (Project)	💡 <250 kWh/AF	15%
State (Project)	💡	8%
Local (Project)	💡 <250 kWh/AF	16%
Local Imports	*This type of water not available*	0%
Groundwater	💡	50%

North Lahontan

Type of Water	Energy Intensity (💡 = 1-250 kWh/AF 💡 = 251-500 kWh/AF)	Percent of Regional Water Supply
Colorado (Project)	*This type of water not available*	0%
Federal (Project)	*This type of water not available*	0%
State (Project)	*This type of water not available*	0%
Local (Project)	💡 <250 kWh/AF	44%
Local Imports	*This type of water not available*	0%
Groundwater	💡 <250 kWh/AF	22%

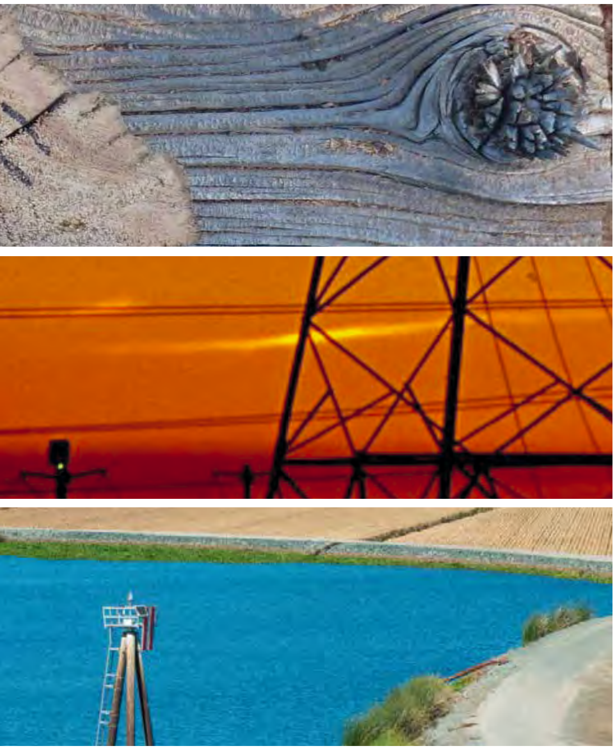
South Lahontan

Type of Water	Energy Intensity (💡 = 1-250 kWh/AF 💡 = 251-500 kWh/AF)	Percent of Regional Water Supply
Colorado (Project)	*This type of water not available*	0%
Federal (Project)	*This type of water not available*	0%
State (Project)	💡💡💡💡💡💡💡	14%
Local (Project)	💡 <250 kWh/AF	7%
Local Imports	*This type of water not available*	0%
Groundwater	💡	64%

Colorado River

Type of Water	Energy Intensity (💡 = 1-250 kWh/AF 💡 = 251-500 kWh/AF)	Percent of Regional Water Supply
Colorado (Project)	💡 <250 kWh/AF	79%
Federal (Project)	*This type of water not available*	0%
State (Project)	💡💡💡💡💡💡💡💡💡	1%
Local (Project)	💡 <250 kWh/AF	<1%
Local Imports	*This type of water not available*	0%
Groundwater	💡	9%

DEPARTMENT OF WATER RESOURCES
STATE OF CALIFORNIA



TRUCKEE MEADOWS WATER
AUTHORITY

APPENDIX 2-3

2006 CLIMATE CHANGE STUDY

Potential Climate Change and Impacts on Water Resources

prepared by

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Potential Climate Change and Impacts on Water Resources

Abstract

As a natural process of the climate system, the Earth's climate has been forever changing. Climate change in the last 100 years, however, is thought to have been influenced by human activities, in particular greenhouse gas (GHG) emissions. Early signs of this change, such as increased mean annual temperatures and thinner sea ice, have been observed in many regions of the world. According to global climate models, continued increases in greenhouse gas emissions could cause further changes in temperature, with the global mean temperature potentially rising by approximately 2.7 to 10.4º F by 2100. This potential change in climate could cause changes in atmospheric and oceanic circulation patterns, and in the hydrologic cycle, leading to altered patterns of precipitation and runoff. Warmer temperatures will potentially increase moisture availability and precipitation. However in mountainous regions, such as the Sierra Nevada, a larger fraction of the total precipitation could be in the form of rain, resulting in shorter snow accumulation periods, reduced annual snowpacks, earlier spring melting, and reduced summer flows. To plan effectively, it is important to understand how and why climate may change in the future and how that may affect water resources. The goal of this document is to summarize the current state-of-knowledge of climate change as it relates to water resources in the western United States.

Climate Change and Global Warming

As a natural process of the climate system, the Earth's climate has been forever changing. Most recently, within the past 100 years, scientists have witnessed a general warming trend in temperatures termed "global warming." Additionally, this "warming" seems to have accelerated during the past two decades. While natural processes contribute to global warming, it is also widely believed that human activities are attributing to the rapid temperature rise. A majority of scientists contend that human activities have "altered the chemical composition of the atmosphere through the buildup of greenhouse gases – primarily carbon dioxide, methane, and nitrous oxide" – and that this buildup has resulted in rising global temperatures (US EPA). However, it is important to point out that within the scientific community controversy continues regarding the extent and effects of human impacts on global climate change.

Atmospheric Greenhouse Gas and Aerosol Concentrations

The major greenhouse gasses, carbon dioxide, methane, nitrous oxide and water vapor, occur naturally in the atmosphere. These greenhouse gases trap and retain energy in the Earth's atmosphere and help keep temperatures hospitable. When there is an elevated buildup of these gases in the atmosphere, however, problems may arise. Human activities are releasing large quantities of these substances into the atmosphere. For example, according to the US Environmental Protection Agency (US EPA) since the beginning of the industrial revolution atmospheric concentrations of carbon dioxide have increased nearly 30%, methane concentrations have more than doubled, and nitrous oxide concentrations have risen by about 15%.

While concentrations of carbon dioxide (CO_2) have increased, the exact source of the recent rise in atmospheric CO_2 has not been determined with certainty. It is likely caused by an interacting combination of natural and anthropogenic forces. This appears reasonable because the magnitudes of human release and atmospheric rise are comparable, and the atmospheric rise has occurred contemporaneously with the increase in production of CO_2 from human activities following the Industrial Revolution (Soon *et al.* 1999). However, the factors that influence CO_2 concentrations are not fully understood. The current increase in CO_2 follows a 300 year warming trend following a Little Ice Age (Keigwin 1996). Some have hypothesized that the recent changes in atmospheric CO_2 can be explained by the oceans emitting gases naturally as temperatures rise following the Little Ice Age (Segalstad 1998). However, the expected associated drop in ocean CO_2 concentrations has not been observed (Sabine *et al.* 2004).

Human activities have also increased concentrations of atmospheric aerosols (microscopic, airborne particles) since pre-industrial times. Aerosols are emitted by industrial processes (fossil-fuel combustion and biomass burning) and their increased concentration offsets simultaneous warming by reducing solar radiation to the ground. Unlike greenhouse gases, which are generally long-lived, aerosols fall out of the atmosphere fairly rapidly, either dry (through sedimentation) or within rain (as condensation nuclei), and therefore are not uniformly mixed across the globe.

Atmospheric composition will continue to change throughout the 21st century. The Intergovernmental Panel on Climate Change (IPCC) Special Report on Emission Scenarios (SRES)(IPCC 2000) summarizes the results of global climate models that were used to forecast atmospheric concentrations of greenhouse gases based upon a range of emission scenarios. According to the IPCC report, emissions of CO_2 due to fossil fuel burning will strongly influence trends in atmospheric CO_2 concentration during the 21st century. By 2100, atmospheric CO_2 concentrations are projected between 540 to 970 ppm (90 to 250% above the concentration of 280 ppm in the year 1750). These projections include land and ocean climate feedbacks.

Global Temperature Records

Records show a measurable warming trend in the Earth's surface temperature over the past 100 years, with a rapid acceleration in warming over the past two decades (Figure 1). Over the past century, the global average surface temperature has increased by approximately 1º F (0.5º C). Further, 9 of the 10 warmest years on record have occurred since 1995. According to recent data released by the National Climatic Data Center (www.ncdc.noaa.gov), 2005 was likely the warmest or second warmest year in the global instrumental temperature record.

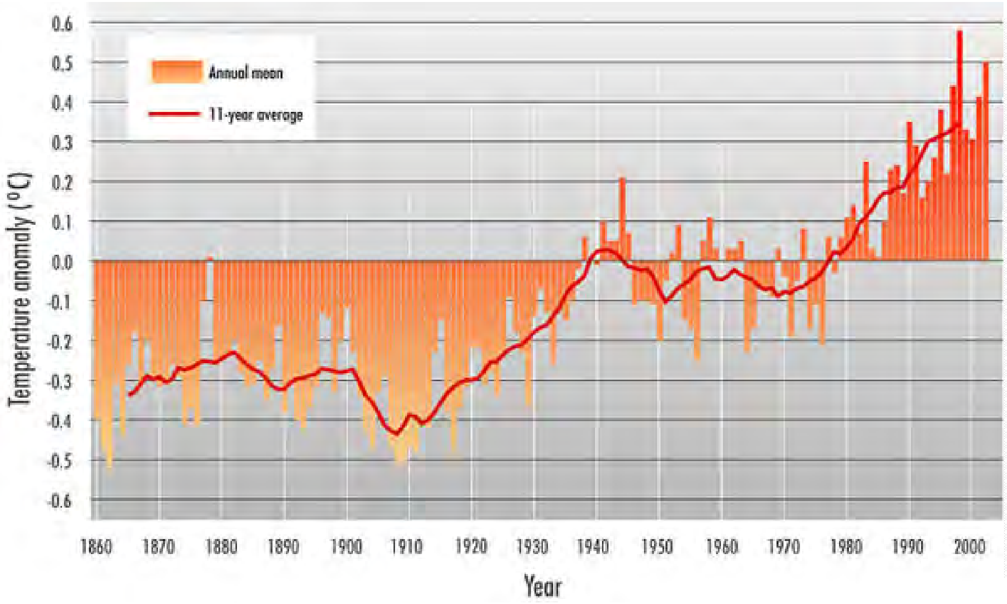

Figure1. Global mean land and sea-surface temperature anomalies for the duration of the instrumental record (Australian Bureau of Meteorology).

The Earth's surface temperature varies naturally over a wide range, but available temperature records are spatially and temporally limited. Records going back longer than 350 years are reconstructed from proxies. Reconstructed data produced from tree ring width, ice cores, and sedimentary deposits contain important limitations due to their required interpretation. For example, tree width and density have become less sensitive to changes in temperature over the last few decades (Briffa *et al.* 1998). The limited spatial extent of surface records results in only 18.4% of the Earth's surface being accurately described by direct measurement (Michaels *et al.* 2000). Further, the influence of land use change on temperature records is known to affect measurements through the urban heat island phenomenon. This systematic error has been extensively studied and debated. Peterson *et al.* (2003) found a bias in urban stations after 1990 at several stations. The researchers described the need to reassess designations of surface temperature stations as urban, suburban, or rural on a periodical basis.

Complex three-dimensional coupled ocean-atmosphere general circulation models (GCMs) can be used to predict future climate conditions under various greenhouse gas emission scenarios. Using an ensemble of GCMs and emission scenarios, the IPCC (IPCC WGI 2001) produced the range of predicted CO_2 and temperature changes shown in Figure 2. The globally averaged surface temperature is projected to increase by 2.7° to 10.4°F (1.4 to 5.8°C) over the period of 1990 to 2100. The projected rate of warming is much larger than the observed changes during the 20th century and very likely would be without precedent during at least the last 10,000 years. However, these models contain sources of uncertainty and there is a variety of debate with regards to these model predictions. An overview of the sources of uncertainty and debate is provided below.

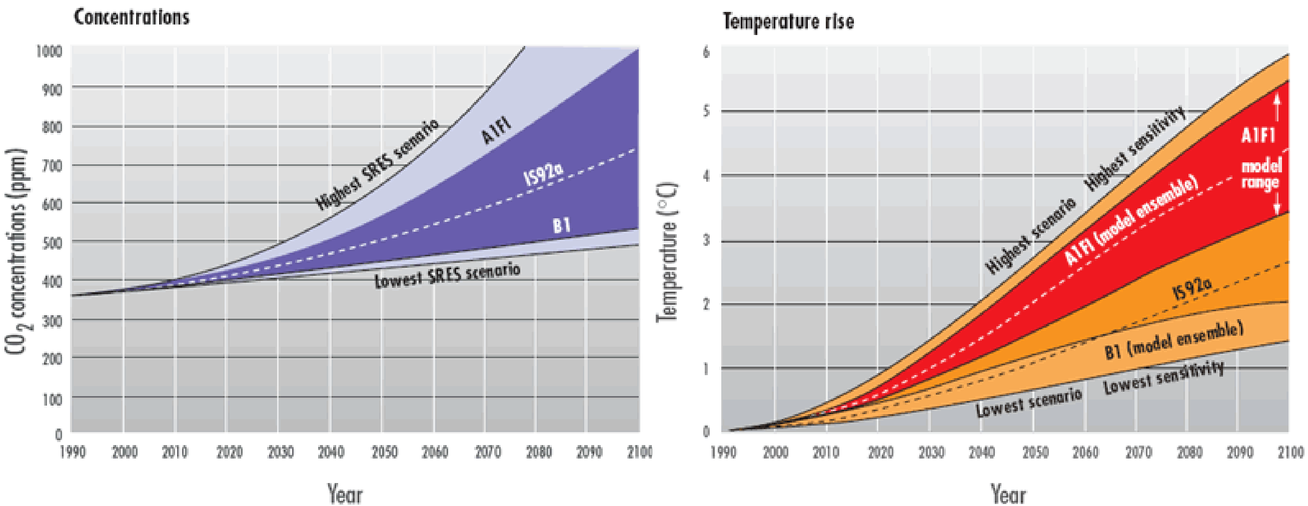

Figure 2. Atmospheric CO_2 concentrations scenarios and simulated changes in global temperature (Australian Bureau of Meteorology).

Sources of Uncertainty

As discussed above, the IPCC estimates that global average temperature will rise by between 2.7° to 10.4°F by the year 2100. Although climate models estimate that temperatures may warm, opponents of global warming theories point out that climate science cannot make definitive predictions yet because many of the physical processes modeled are only rudimentarily understood and are variously parameterized. Because the climate is a coupled, non-linear dynamic system, the climate models have many uncertainties. Without experimental validation of the models, the calculation of the climate response to increased anthropogenic atmospheric CO_2 will remain in doubt. For example, opponents of global warming theories that attribute temperature rise to human activities argue that the correlation between rising temperatures and CO_2 concentrations following the Industrial Revolution does not prove causation. The US EPA further reiterates the warning provided by all climate modelers to people considering the impacts of future climate change: *the projections of climate change in specific areas are not forecasts but are reasonable examples of how the climate might change* (US EPA).

The two primary sources of uncertainty are 1) forecasts of future greenhouse gas emissions; and 2) the nature of many feedback processes in the climate system. Future GHG emissions depend on the rate of growth of the world's economy and population, generation of energy technology, land use changes, and policies aimed at reducing emissions. Feedback processes may strongly influence global warming. For example, increased atmospheric water vapor may amplify warming, while changes in the extent of cloud cover and the characteristics of clouds may either enhance or diminish warming. Soon *et al.* (1999) discussed the following six important areas of uncertainty and error in climate modeling.

1) *Water vapor feedback* - The feedback process starts with increasing temperature that increases atmospheric water vapor concentration. Water vapor is itself a strong greenhouse agent, which in turn could amplify the warming caused by elevated CO_2. The model parameterization used to

describe this feedback mechanism is complex and has received criticism (e.g. Renno *et al.* 1994). Without adequate observations, it is difficult to determine the correct parameterization.

2) *Cloud forcing* – Climate models produce different projected temperature changes because they incorporate different estimates of the parameters that describe the behavior of cloud formation. Clouds are known to have an important influence on surface temperatures. However, current GCMs over-predict the coverage of high clouds by a factor as large as 2 to 5. The spatial distribution of clouds is also incorrect. Therefore, the parameterization of radiative, latent and convective effects of cloud forcing needs further improvements.

3) *Ocean-atmospheric interaction* – The dynamic nature of air-sea coupling is complex and requires intense *in situ* and satellite observations of heat, momentum, and freshwater fluxes. This is an active area of GCM research.

4) *Sea-ice-snow feedback* – Currently, GCM results under-predict the variance of sea-ice thickness in the Arctic on decadal to century time scales. This result emphasizes the importance of including realistic surface fluxes and modeling of convective overturning and vertical advection in both the Arctic and adjacent oceans.

5) *Biosphere-atmosphere-ocean feedbac*k – Biospheric feedback influences the global carbon budget because enhanced plant growth will sequester CO_2. Understanding this feedback holds the promise of an internally consistent description of the relationship of CO_2 to climate change.

6) *Flux errors* – Many models have substantial flux errors for which calibration adjustments are introduced into the calculations. One important consequence is the dampening of low-frequency variability in the simulation of climate state due to over stabilization.

The impacts of feedback mechanisms on predicted temperature are shown in Figure 3. Accounting for the range of uncertainty in these feedback processes results in a range of possible changes in global average temperatures for any given change in GHG concentrations. The range of temperature changes projected by the IPCC reflects the combined effects of all of these sources of uncertainty. Further, even greater uncertainty exists in regional predictions of climate change. Regional projections of impacts are most needed by decision-makers, and yet are not easily extracted from global climate model simulations. Results can sometimes even be contradictory at the regional scale, with either wetter or drier conditions predicted depending on the model used for the simulation.

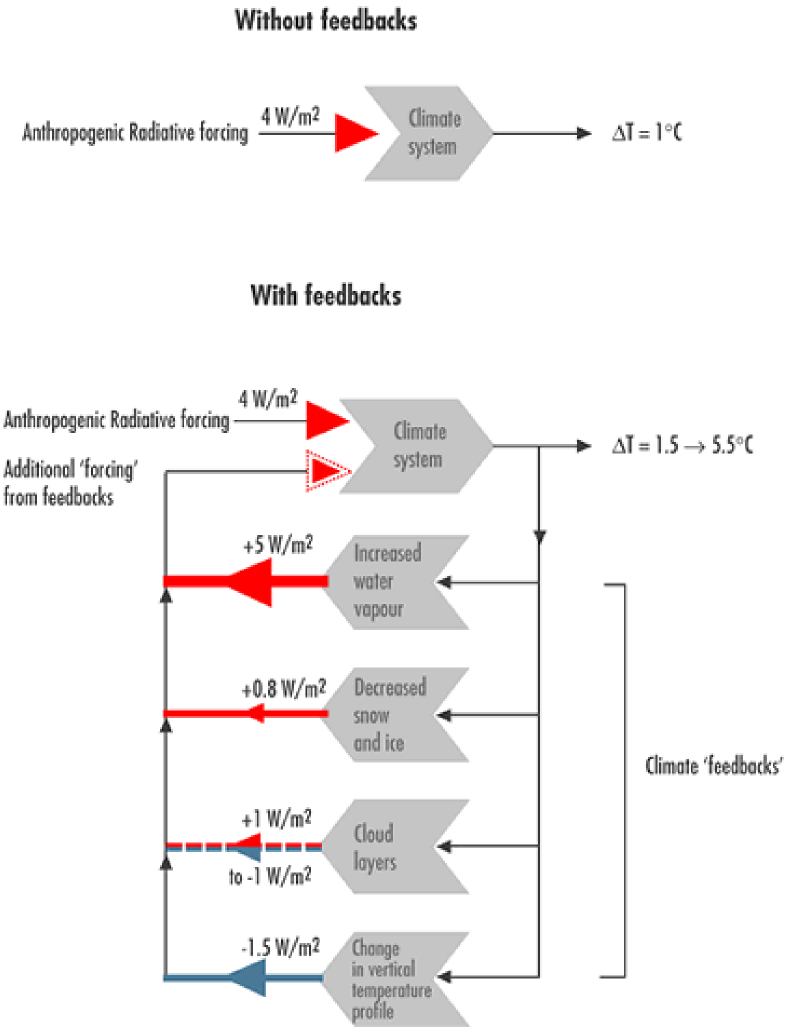

Figure 3. Schematic showing the influence of climate feedbacks on radiative forcing driving a climate model. The arrows are indicative of the magnitude and sign of individual feedbacks (Australian Bureau of Meteorology).

Potential Impacts of Climate Change on Water Resources

Although the science of climate change and predictions of future temperature and precipitation remain largely uncertain (particularly at the regional level), it is still appropriate to consider the potential impacts of such change on water resources. This information will enhance our ability to respond to change as the science advances and uncertainty is reduced. In this section, observed changes in hydrologic processes corresponding with recent warming trends in the western U.S. and potential impacts of future climate change on hydrologic processes are discussed.

Potential changes to the climate will likely alter the hydrologic cycle in ways that impact water resources. Regional climate-change projections are uncertain. However, the magnitude of projected warming combined with a strong regional reliance on mountain snowpack creates some consistency in the implication of climate change for the western U.S. The amount, intensity, and temporal distribution of precipitation could potentially change. Recent research suggests an intensification of the global hydrological cycle, leading to more intense but possibly less frequent periods of precipitation (longer periods of drought alternating with spells of heavy rainfall) (Trenberth 2003). In the west, warmer temperatures could affect the proportion of winter precipitation falling as rain or snow, accumulation of snowpack, and snowmelt timing. Evapotranspiration could change with changes in soil moisture availability, and plant responses to elevated CO_2 concentrations. In addition, changes in the quantity of water percolating to groundwater storage could result in changes in aquifer levels, in base flows entering surface streams, and in seepage losses from surface water bodies to the groundwater system.

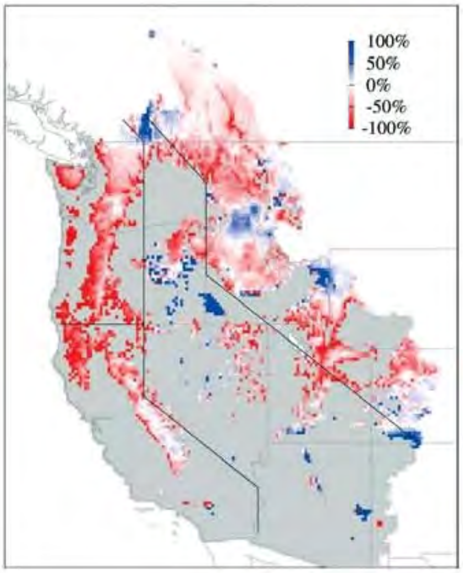

Figure 4. Linear trends in 1 Apr SWE for 1950–97 from a hydrologic simulation (Mote et al. 2003).

The overall scientific consensus is that globally the Earth will be warmer with higher globally averaged precipitation. However, current scientific understanding does not provide confident projections of the magnitude or precise nature of changed precipitation patterns. Unlike the projections of precipitation change, climate models are fairly consistent in predictions of regional surface temperature. Because temperature is central in determining the accumulation and melting of snow and ice, these scenarios are especially relevant to regions where snowpack dominates the hydrology. Even with wetter winters, a warmer climate will result in a greater portion of winter precipitation falling as rain rather than snow, an elevated winter snowline, and a decrease in the snow-covered areas and total winter snowpack (Figure 4). Some of the most sensitive areas are where winter temperatures are now only slightly below freezing. Temperature also determines the timing of melt-off, and a warmer climate will likely result in an earlier melt season. Many regions are likely to see an increase in winter or early spring stream flows and reduced summer flows.

The results of warmer temperatures have been observed across the western U.S. Winter and spring temperatures have increased in western North America during the twentieth century (Folland *et al.* 2001), and there is a large body of evidence suggesting this widespread warming has produced changes in hydrology and plants. In the western U.S and southwestern Canada, spring snowpacks have been smaller and have been melting earlier in most mountain areas. Snow extent and depth have generally decreased in the west (Mote 2003). These declines have often occurred despite increases in total winter precipitation in those locations. The timing of spring snowmelt-driven streamflow has shifted earlier in the year (Cayan *et al.* 2001; Stewart *et al.* 2005), as is expected in a warming climate (Figure 5). There has also been a century-long downward trend in late spring and early summer flow as a proportion of total annual flow (Dettinger and Cayan 1995). Earlier spring melting and reduced spring snowpacks have been especially evident in the Cascade and northern Sierra Nevada Mountains, where winter temperatures are relatively mild. Some higher elevation mountain locations in the Southern Sierra Nevada and Rocky

Mountain ranges have shown an increasing trend in April 1 snowpacks, but even there the peak in spring runoff is generally occurring earlier (Stewart *et al.* 2004).

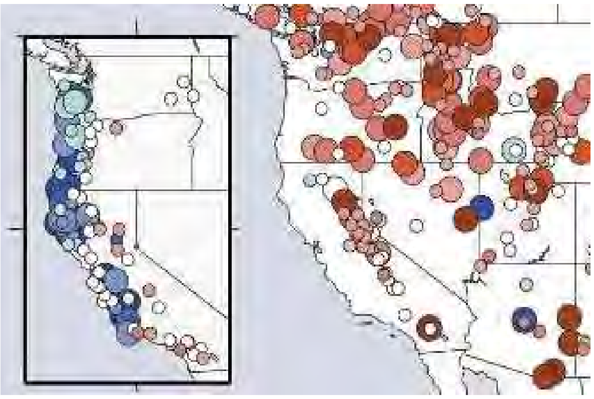

Figure 5. Trends in the date of center of mass of annual flow for snowmelt- and (inset) non-snowmelt-dominated gauges. Shading indicates magnitude of the trend expressed as the change (days) in timing over the 1948–2000 period (red negative and blue positive) (Stewart et al. 2005).

Dettinger *et al.* (2004) completed a simulation of hydrologic response to climate variation and change in three Sierra Nevada watersheds (including the Carson River watershed). The research used climate predictions from a GCM coupled with a hydrologic model to investigate future changes in streamflow. Although the climate model projections were near the lower edge of the available climate change simulations, in terms of warming and changes in precipitation, the results still showed significant and disruptive changes in the hydrology and ecosystems of the simulated basins. Predicted outcomes included large and clear trends towards earlier snowmelt runoff and reductions in summertime low flows and soil moisture. They found that snowmelt and streamflow could arrive about one month earlier by 2100 in response to an increased proportion of rain to snow and earlier snowmelt episodes.

Warming of the climate could increase total evaporation from open water, soil, shallow groundwater, and water stored on vegetation, along with transpiration through plants. The interplay between atmospheric energy, moisture, and turbulence, and plant water use efficiency under different water, energy, nutrient, and CO_2 levels is complex and not yet fully understood. In dry regions, water availability, surface temperature and wind are important determinants of actual evaporation. Increases in surface temperature and higher wind speeds promote potential evaporation, while the greatest change will likely result from an increase in the water-holding capacity of the atmosphere.

The loss of snowpack could have a greater impact on groundwater recharge than estimates based only on changes in the amount of precipitation would indicate. Because snowmelt yields more recharge per unit amount of precipitation than rain, even if total precipitation remains constant, a shift from snow to rain could cause significantly decreased recharge (Earman *et al.* 2006). While the lessened amount of snowfall would be one contributor to loss of recharge, the changed conditions could also reduce the recharge efficiency of snow compared to that observed today. Thinner snowpacks subjected to increased temperatures would melt more rapidly than at present, increasing the likelihood of the melt running off rather than infiltrating.

Future climate change could influence municipal and industrial water demands, as well as competing agricultural irrigation demands. Municipal demand depends on climate to a certain extent, especially for garden, lawn, and recreational field watering, but rates of use are highly dependent on utility regulations. Shiklomanov (1999) notes different rates of use in different climate zones, although in making comparisons between cities it is difficult to account for variation in non-climatic factors. Studies in the UK (Herrington 1996) suggest that a rise in temperature of about 1.1°C by 2025 would lead to an increase in average per capita domestic demand of approximately 5 percent – in addition to non-climatic trends – but would result in a larger percentage increase in peak demands, since demands for landscape watering may be highly concentrated.

This section highlights some of the potential changes that could occur if regional climatic shifts occur as predicted from current climate models. While it is prudent to understand these potential impacts, further analyses are needed prior to concluding that global warming is impacting the Truckee Meadows region and implementing changes to water resource management.

Appendix

Long-term records of temperature and greenhouse gases

In order to provide context for recent changes in climate, it is helpful to investigate long-term climatic patterns. There is strong evidence that the Earth has experienced long periods during which average global temperatures were much colder and much warmer than today. Changes in the Earth's climate system throughout geologic time can be linked to changes in the components of the climate system, changes in the composition of the atmosphere, and the seasonal distribution and total amount of incoming solar energy.

The composition of the atmosphere has changed as a result of biological and geophysical processes, including storage of carbon in the ocean and its subsequent release, volcanic eruptions, and the occasional sudden release of methane from ocean floor sediments.

Three long-term cycles in the Earth's orbit combine to give a complicated pattern. Eccentricity is the change in the shape of the earth's orbit around the sun. Over a 95,000 year cycle, the earth's orbit around the sun changes from a thin ellipse to a circle and back again. When the orbit around the Sun is most elliptical, there is larger difference in the distance between the Earth and Sun at perihelion (period when the Earth is closet to the Sun) and aphelion (period when the Earth is farthest from the Sun). The Earth is currently in a period of low eccentricity (nearly circular). Obliquity describes the slight change in the Earth's tilt (22.1° and 24.5°) over a cycle that lasts about 42,000 years. When the tilt is larger, seasons are stronger and less snow melts in the polar regions because of the shorter days and reduced sunlight, allowing glaciers to form and spread. The Earth's tilt is currently 23.5°. The third type of orbital change is called precession, the cyclical wobble of Earth's axis in a circle. One complete cycle for Earth takes about 26,000 years. Precession does not directly cause temperature changes, but rather it changes the portion of the orbit at which a given season occurs. The current axis results in the Earth being closest to the Sun during the North American winter, resulting in milder seasonal fluctuations. This is important because glaciers require land on which to form. Most of the land surface on Earth is now in the northern hemisphere. Therefore, when the Earth's axis is oriented for northern winters to occur on the cooler part of the orbit, glaciers will tend to grow.

Changes in the seasonal distribution of incoming solar energy may have triggered the beginning and end of previous ice ages. However, the solar impacts were greatly amplified by positive feedbacks within the climate system, including changes in the reflection of sunlight back into space by ice-covered areas, changes in ocean circulation, and dramatic changes in atmospheric concentrations of greenhouse gases, especially CO_2 and CH_4.

Ice cores from glaciers and ice sheets around the world provide some of the best records of environmental conditions and climate change. In January 1998, the collaborative ice-drilling project between Russia, the United States, and France at the Vostok station in East Antarctica yielded the deepest ice core ever recovered, reaching a depth of 3,623 m (Petit *et al.* 1999). The Vostok ice-core record extends through four climate cycles, with ice slightly older than 420,000 years (Figure 6). The

Vostok data revealed a high correlation between GHG concentrations and temperature variations through four glacial cycles (Shackleton 2000). Atmospheric carbon dioxide concentrations varied from about *180 parts per million* (ppm) at the height of each glaciation to about *310 ppm* at the peak of each warming. Similarly, methane concentrations varied from approximately *350* to *800 parts per billion (ppb)*. The current atmospheric CO_2 concentration is approximately *375 ppm* and the methane concentration is approximately *1800 ppb* (Figure 3).

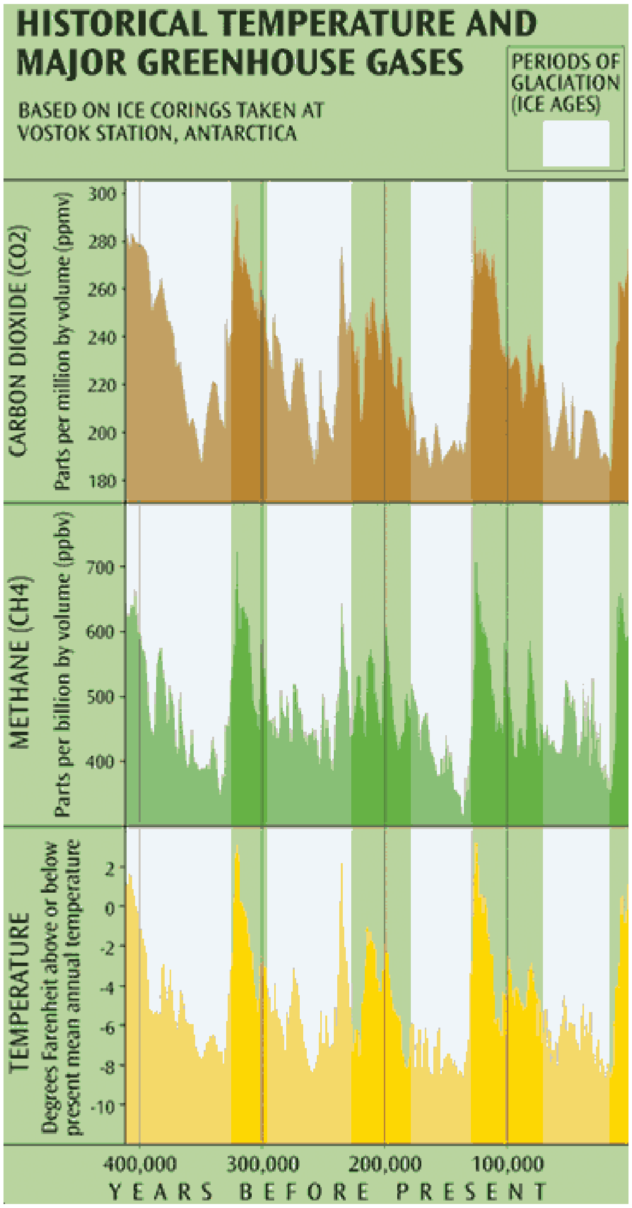

Figure 6. Temperature and GHG records from the Vostok Ice Corps (Petit et al. 1999).

Ocean Circulation Patterns

In addition to GHG concentrations, several natural processes influence the Earth's climate over various periods of time. Recent studies have shown the influence of coupled oceanic-atmospheric variability on climate of regions around the world. The most widely understood oceanic and atmospheric phenomenon is the El Niño-Southern Oscillation (ENSO). Other large-scale climate occurrences include the Pacific Decadal Oscillation (PDO), the Atlantic Multidecadal Oscillation (AMO), and the North Atlantic Oscillation (NAO).

ENSO is a major source of inter-annual climate variability in the western United States. ENSO variations are more commonly known as El Niño (the warm phase of ENSO) or La Niña (the cool phase of ENSO). An El Niño is characterized by stronger than average sea surface temperatures in the central and eastern equatorial Pacific Ocean, reduced strength of the easterly trade winds in the Tropical Pacific, and an eastward shift in the region of intense tropical rainfall (Figure 7). A La Niña is characterized by the opposite – cooler than average sea surface temperatures, stronger than normal easterly trade winds, and a westward shift in the region of intense tropical rainfall. Although ENSO is centered in the tropics, the changes associated with El Niño and La Niña events affect climate around the world. These events are typically on the order of 6 and 18 months in length (Tootle and Piechota 2004).

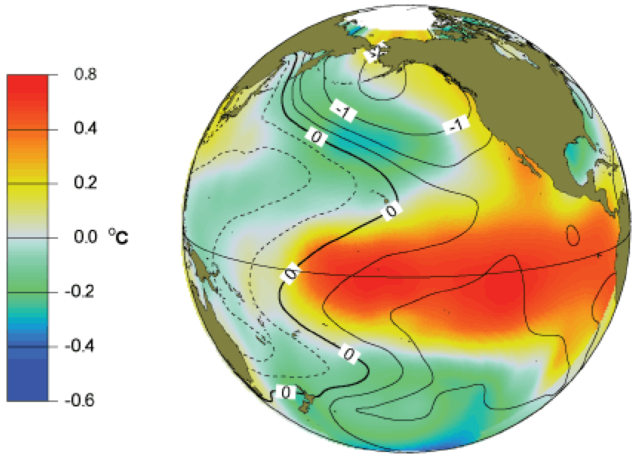

Figure 7. ENSO warm phase (http://www.cses.washington.edu/cig/).

The PDO is an oceanic-atmospheric phenomena associated with persistent, bimodal climate patterns in the northern Pacific Ocean that oscillate with a characteristic period on the order of 50 years (Mantua and Hare 2002). When the PDO is in its positive coastal warm phase, as it was for most of the period from 1977 through the mid-1990s, sea surface temperatures along the west coast of North America are unusually warm, the winter Aleutian low intensifies, and the Gulf of Alaska is unusually stormy. The slowly evolving state of the ocean, as measured by the PDO, interacts with the more rapid ENSO-related changes to influence storm tracks and, thus, the likelihood of unusually heavy or light seasonal precipitation. For example, a positive PDO appears to reinforce the effects of an El Niño, making wet winter conditions in the southwestern United States and dry conditions in the Pacific Northwest more likely than would be the case if the PDO were in the negative (coastal cool) phase.

The North Atlantic Oscillation (NAO) is associated with a meridional oscillation in atmospheric mass between Iceland and the Azores and has displayed quasi-biennial and quasi-decadal behavior since the late 1800s (Hurrell and Van Loon 1997) and its behavior is generally referred to as decadal. A positive NAO pattern drives strong, westerly winds over northern Europe, while southern Europe, the Mediterranean and Western Asia experience unusually cool and dry conditions. In the negative phase, winter conditions are unusually cold over northern Europe and milder than normal over Greenland, northeastern Canada, and the Northwest Atlantic. The Atlantic Multidecadal Oscillation (AMO) is observed through North Atlantic Ocean sea surface temperature variability with a periodicity of 65–80 years (Gray *et al.* 2004).

Thermohaline circulation in the World's oceans provides the connection between the movement of cold, salty water in the oceans' depths and the movement of warm, less saline water at the surface (Broecker 1997). Warm, low-salinity water from the tropical Pacific and Indian Oceans flows around the tip of South Africa and ultimately joins the Gulf Stream to transport heat from the Caribbean to Western Europe. As the water moves northward, evaporative heat loss cools the water and leaves it saltier and more dense. The cold, salty water sinks in the North Atlantic and flows back toward Antarctica, thus pushing the conveyor along. It is likely that increased high-latitude runoff and ice-melt caused by human-induced climate change will slow the thermohaline circulation. However, the impacts on projected temperature changes for Europe and the northern latitudes are not clear (IPCC WGI 2001).

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Hydrologic Trend Analyses for the Truckee Meadows Region

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Hydrologic Trend Analyses for the Truckee Meadows Region

Executive Summary

Environmental change can result from a wide range of human induced activities and natural processes including land use change, resource management, and potential global climate change. These changes can influence all aspects of the hydrologic cycle including the magnitude, timing, and forms of precipitation, snowfall, streamflow, and lake volumes. The objective of this project was to investigate climate and hydrologic data in the Truckee Meadows region in order to reveal potential signs of environmental change that may be consistent and coincident with global warming. The analyses included investigations of temperature, precipitation, snow water equivalent, streamflow volume and timing, and reservoir volumes for the for the Lake Tahoe and Truckee River hydrographic basins.

Linear regression analyses were used to identify the following data trends:

- Temperature data revealed a slight trend towards increased minimum and maximum temperatures at most gages. However, a few stations showed trends towards decreased temperatures and year to year variability was quite high at all stations.
- Annual precipitation showed very high variability with an overall trend towards slightly reduced winter precipitation.
- Snow water equivalent (SWE) showed very high variability with some stations reporting a trend towards increased snowpack and others showing reduced snowpack trends.
- The SWE trends were highly correlated with instrument elevation, where high elevation stations observed increased SWE and the low elevation stations observed reduced SWE.
- Mean annual streamflow data varied widely between water years.
- Long-term streamflow volume and timing trends were investigated through linear regressions of the cumulative streamflow volumes. The records revealed no consistent trends in streamflow volume or timing for the period of record.
- Cumulative volume linear regression analyses were also used to investigate trends in reservoir volumes. The reservoir volumes displayed an obvious dependence on precipitation, as periods of drought strongly influenced reservoir volumes.

In order to investigate correlations between hydrologic variables and possible modifications in hydrologic processes, the following double-mass analyses were conducted:

- Relationships between streamflow and precipitation were studied at four paired stations. The results confirmed the expected high degree of correlation between these variables. The functions between precipitation and streamflow remained consistent throughout the records, indicating no observed modifications in large scale precipitation-runoff-streamflow processes at un-dammed gages.
- Double mass analysis of precipitation and reservoir volumes further demonstrated the high degree of correlation between these variables.
- Analyses of SWE and streamflow data revealed a slight deviation from historical trends over the past four water years.
- No consistent departures from long term patterns were observed between streamflow and reservoir volumes.
- Patterns between SWE and reservoir volumes remained consistent throughout the period of record.

To summarize, no significant changes were found in the climatic and hydrologic variables over the period of record. Temporal trends in temperature, winter precipitation, and SWE were observed at some stations. However, very high year-to-year variability was observed for all stations and parameters.

Methodology

Volume and timing analyses were performed on historic gage records throughout the region. A Geographic Information Systems (GIS) based inventory was produced containing regional weather stations, snowcourses, stream gages, and reservoir levels. Details of the database components are given below. The database was then used to investigate changes in precipitation, snowpack, streamflow volume and timing, and reservoir volumes over the period of record. This investigation was conducted using mass and double-mass analyses of the climate and hydrologic variables. The analyses are summarized in Table 1. The details of the analyses for specific variables are given within the discussion of results.

Table 1. Summary of mass and double-mass analyses

Mass Analyses	**Double-Mass Analyses**
- Temperature - Precipitation - Snowpack - Streamflow - Reservoir Volumes	- Precipitation vs. Snowpack - Precipitation vs. Streamflow - Precipitation vs. Reservoir Volumes - Streamflow vs. Snowpack - Streamflow vs. Reservoir Volumes - Reservoir Volumes vs. Snowpack

Database Development

Weather Stations

A GIS database was developed to store, retrieve, and analyze climate and hydrologic data. GIS shapefiles were obtained from Truckee Meadows Water Authority (TMWA), Environmental Protection Agency (EPA), and the United States Geologic Survey (USGS). Climate data were compiled from the National Weather Service (NWS) Cooperative Observer Program (COOP). Weather station records included precipitation and minimum and maximum temperature data. All COOP gages within 50 miles of the Truckee and Carson River basins were identified. The Carson River basin was included in this study to augment the limited number of qualified gages in the Truckee River basin, particularly for the double mass analyses. This process revealed approximately 35 gages. The study gages were filtered both geographically and according to available period of record. Filtering resulted in 11 gages being considered in the study (Figure 1). The station locations were added to the GIS database and the historical data was requested from the Western Regional Climate Center. The time series data were linked to the GIS database in a hyperlink format. Details of the gage records can be found in Appendix L.

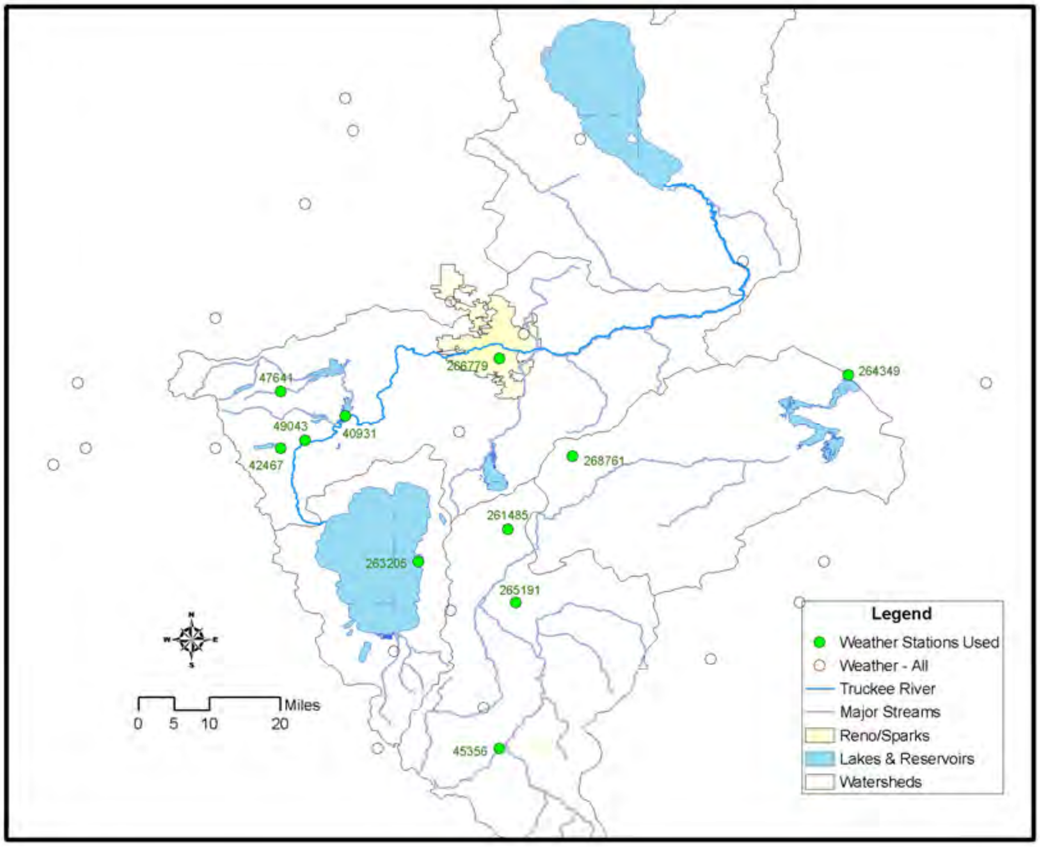

Figure 1. Truckee and Carson River basins and locations of study weather stations.

Reservoir Volume and Stream Discharge

Daily and monthly records of lake and reservoir storage volumes for all major water bodies were requested from the USGS and the data were linked to the GIS database. Daily historical streamflow records were downloaded from the USGS NWISWeb Water Data website. As with the climate data, data records and station coordinates were obtained for all stream gage stations in the region. The potential gages were then filtered to identify the gages with adequate periods of record. This resulted in 24 gages to be considered in the analysis (Figure 2). The time series data were linked to the GIS database in a hyperlink format. Details of the reservoir and stream gage records can be found in Appendix L.

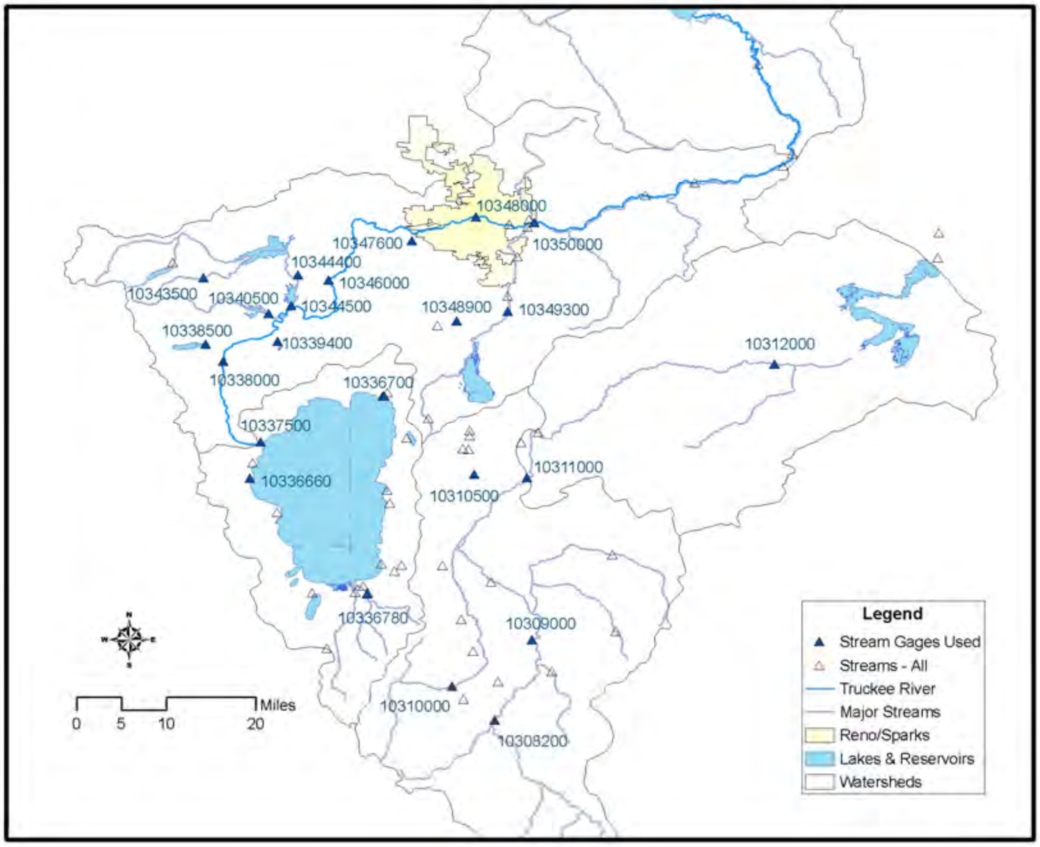

Figure 2. USGS streamgage stations for the Truckee and Carson River Basins.

SNOTEL and Snowcourse Data

Snow water equivalent data were first obtained for all regional NRCS SNOTEL stations. However, the SNOTEL data were only available from 1980 forward. To extend the period of analysis, historical snowcourse data were also obtained. Although the snowcourse data are only available at a limited temporal resolution, the periods of record extend back more than 50 years at many of the stations. The snowcourse stations used in the study are shown in Figure 3. The snowcourse data were linked to the GIS database in a hyperlink format. Details of the snowcourse records can be found in Appendix L.

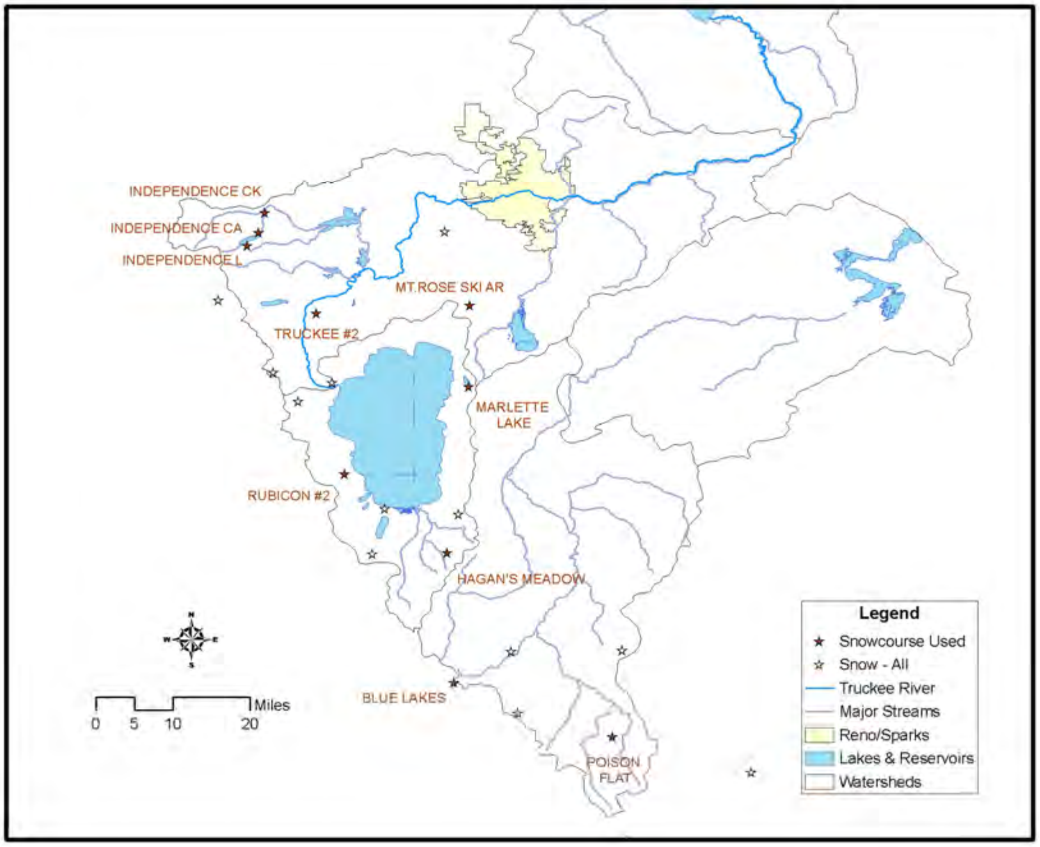

Figure 3. Snowcourse station locations in the Truckee and Carson River basins.

Results

Temperature Data

Linear regressions were used to evaluate trends in annual minimum and maximum temperature at eight weather stations. As an example of the regression results, Figure 4 shows temperature data for the Truckee Ranger Station. Results for the remaining stations can be found in Appendix A. The data revealed a slight trend towards increased minimum and maximum temperatures at five gages. However, three stations showed a trend towards decreased temperatures and year to year variability was quite high at all stations. The regional temperature trends were overall less than the observed global increase in surface temperature of approximately 1º F over the past century.

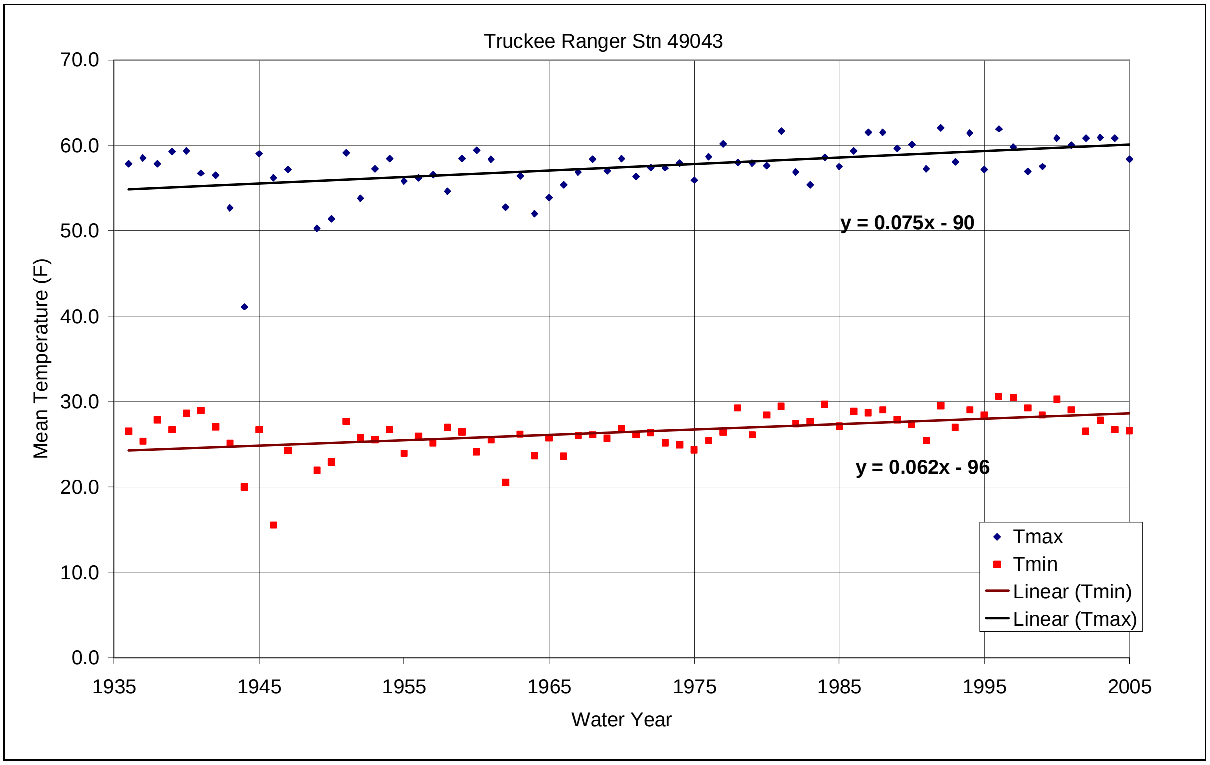

Figure 4. Mean annual maximum and minimum temperature at Truckee Ranger Station, 49043.

Precipitation

Precipitation data were examined over a range of temporal scales. Figures 5 and 6 contain seasonal precipitation trends for the Sagehen Creek and the Reno Airport, respectively. The seasons were defined as Winter (October through March) and Summer (April through September). The precipitation showed very high year-to-year variability at all stations. Winter precipitation displayed a slight decreasing trend for seven out of the nine stations. Little or no trend was observed in mean summer precipitation. Results for the remaining precipitation trends are shown in Appendix B.

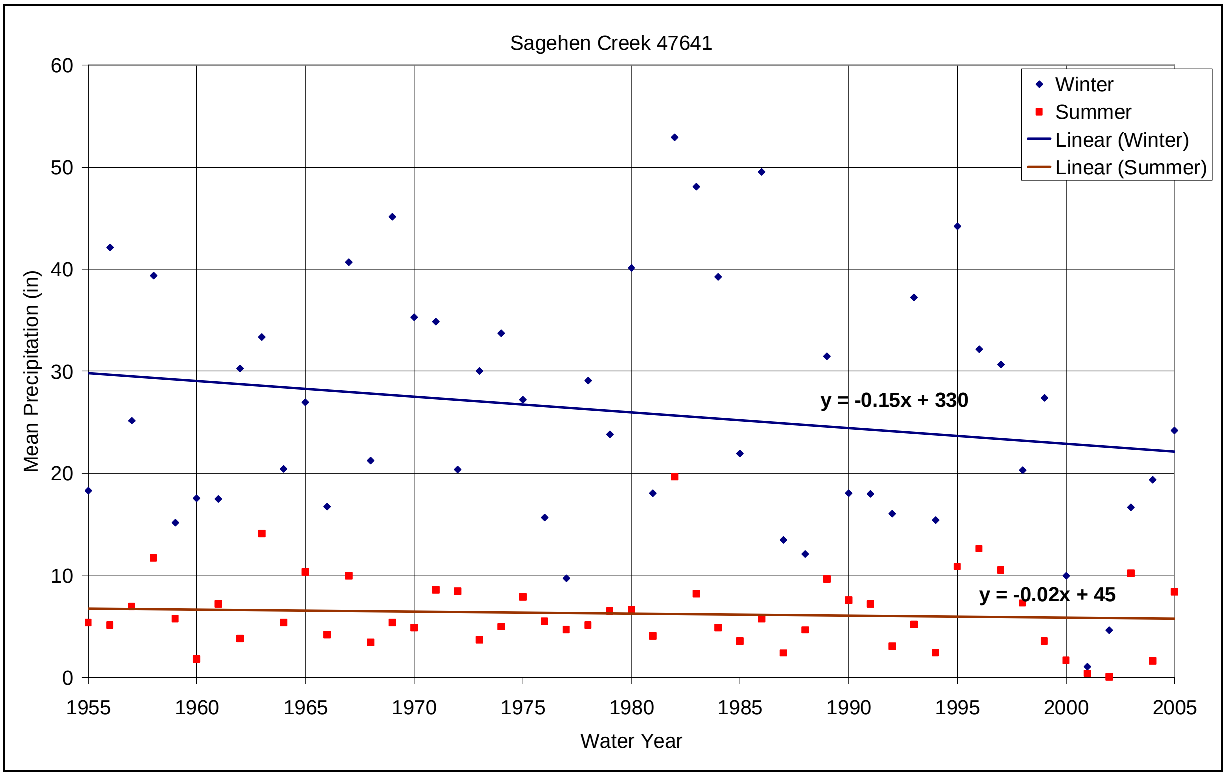

Figure 5. Mean winter and summer precipitation at Sagehen Creek 47641.

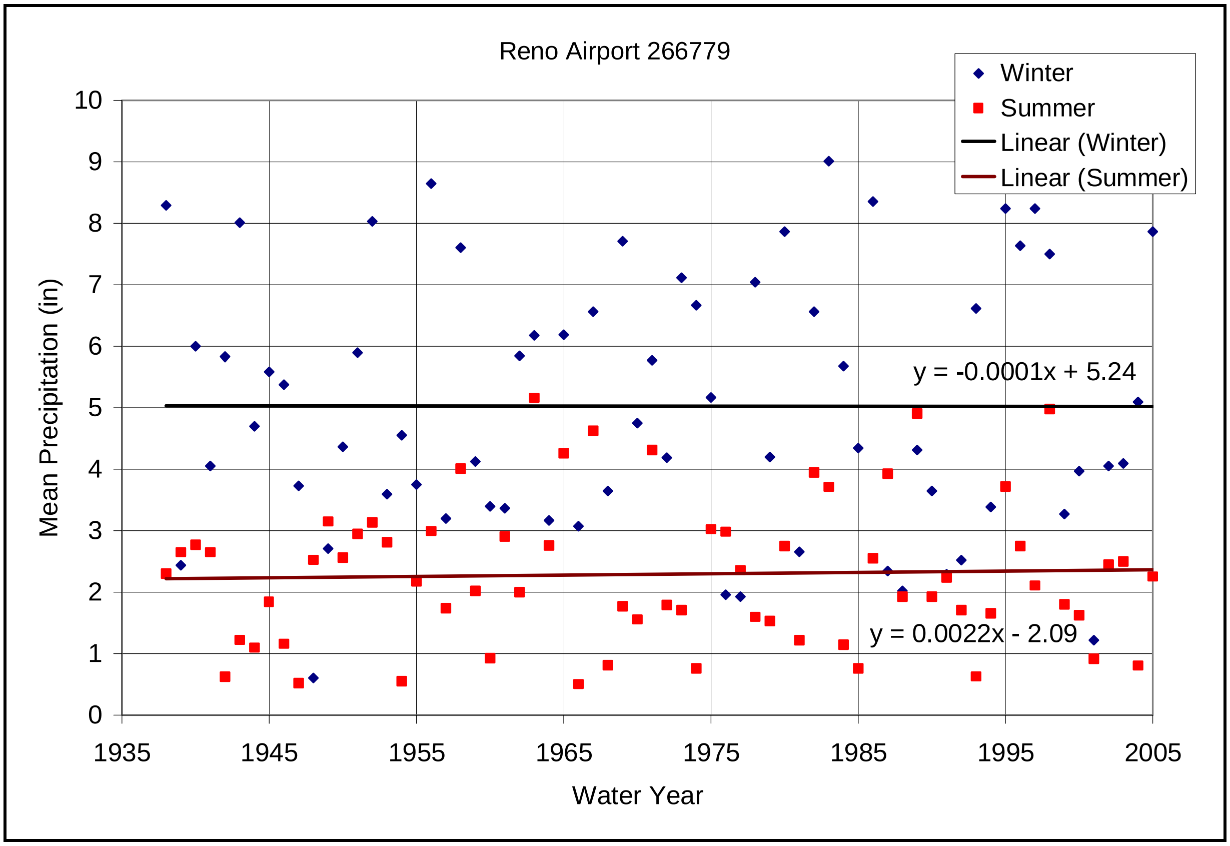

Figure 6. Mean winter and summer precipitation at the Reno Airport 2666779.

Snow Water Equivalent

Snow water equivalent (SWE) showed very high variability with some stations reporting a slight trend towards increased snowpack and others showing reduced snowpack trends. For example, SWE trends for Independence Creek and Mt. Rose Ski Area snowcourse stations are shown in Figures 7 and 8, respectively. Although SWE trends were very small, and variability was very high, the trends were highly correlated with instrument elevation. High elevation stations observed increased SWE and the low elevation stations observed reduced SWE (Figure 9). Although this observation is consistent with expectations for climate change, further investigations of precipitation and temperature trends in the Truckee Meadows (discussed above) did not corroborate this hypothesis. For example, high elevation weather stations did not observe increased precipitation and temperature changes were not correlated with elevation. The remaining SWE data can be found in Appendix C.

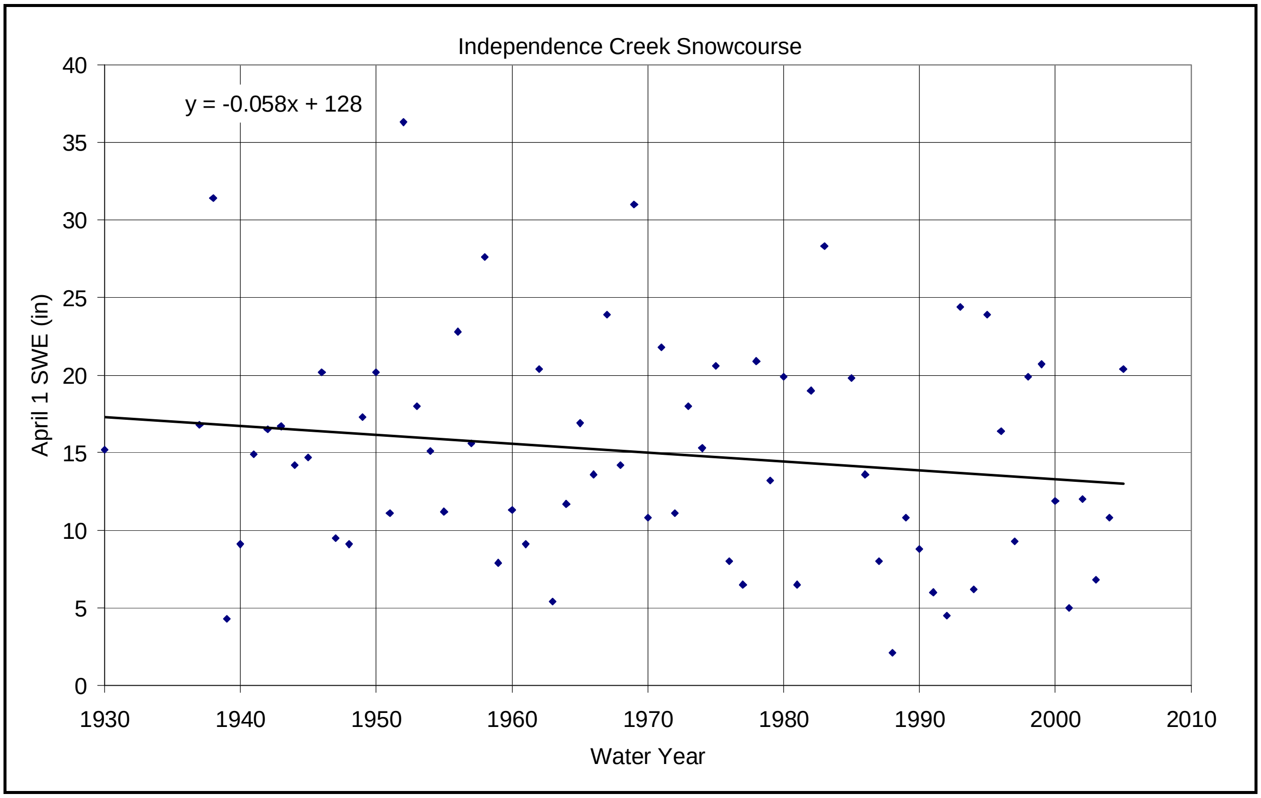

Figure 7. Annual April 1st SWE at the Independence Creek snowcourse station.

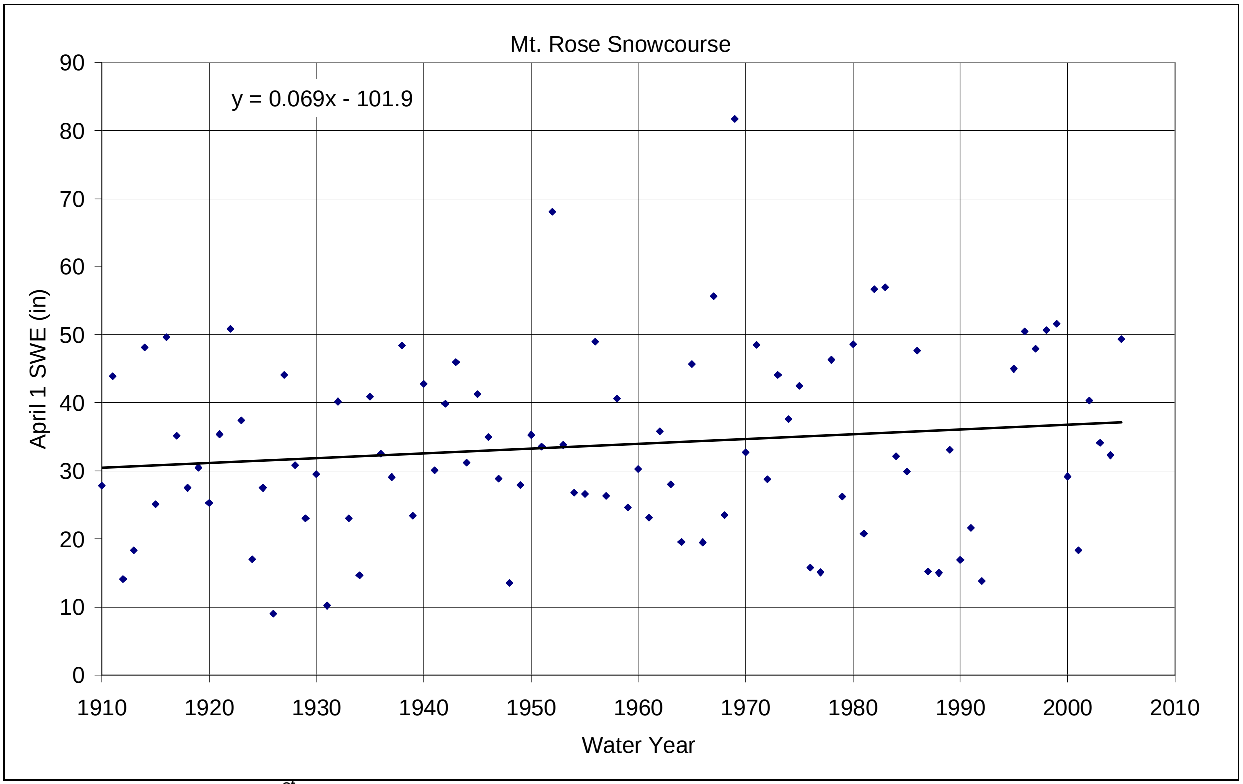

Figure 8. Annual April 1st SWE at the Mt Rose Ski Area snowcourse station.

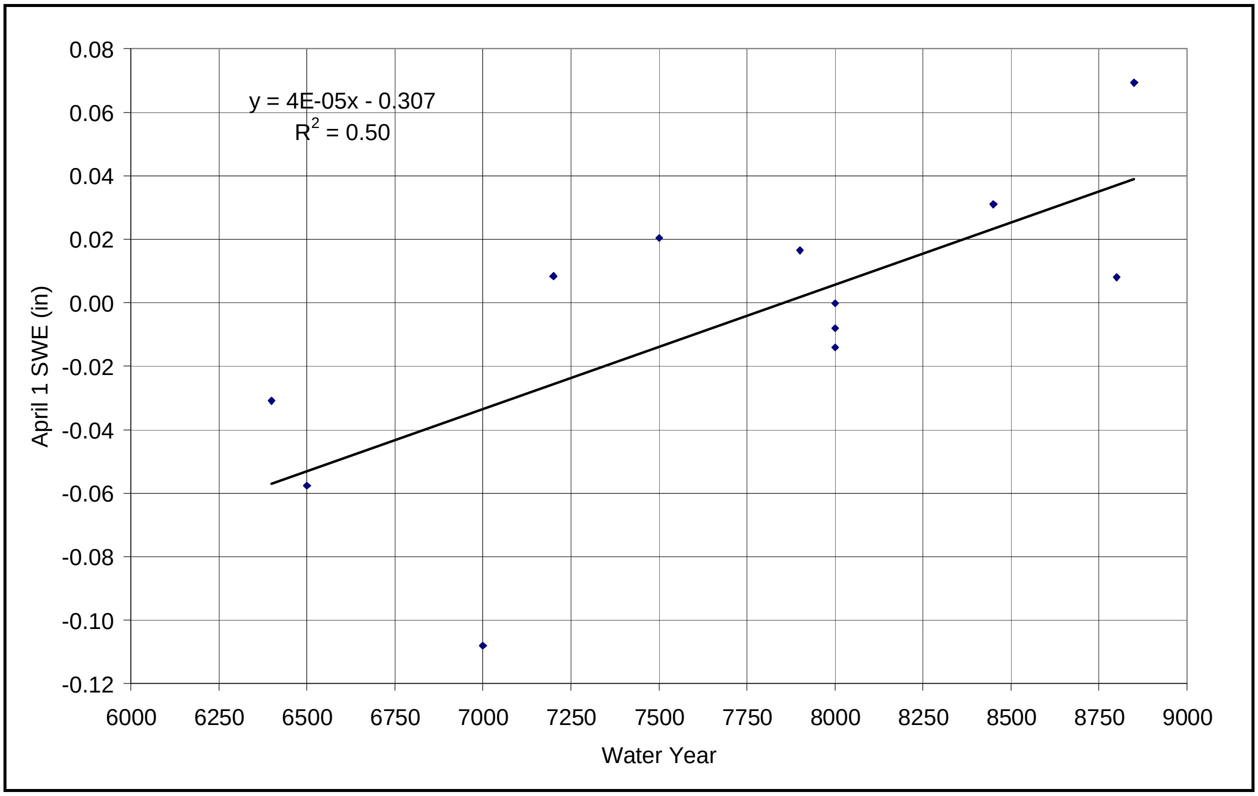

Figure 9. Trends in April 1 SWE snowcourse data as a function of station elevation.

Streamflow

Long term streamflow trends were investigated through a linear regression of the cumulative streamflow volumes. As expected, mean annual streamflow data varied widely between water years. The records revealed no observable trends over the period of record. Figure 10 contains an example of the streamflow data for the Truckee River at Reno. All other streamflow data can be found in Appendix D.

In addition to the streamflow volume analyses, streamflow timing was also studied. The timing was studied by investigating trends in the date at which the center of mass of the annual hydrograph occurred. As with the volume data, the center of mass data showed high year-to-year variability. A trend towards an earlier occurring date for the center of mass was observed for 14 out of the 21 stations. Figure 11 contains the center of mass data for the Little Truckee River above Boca Reservoir.

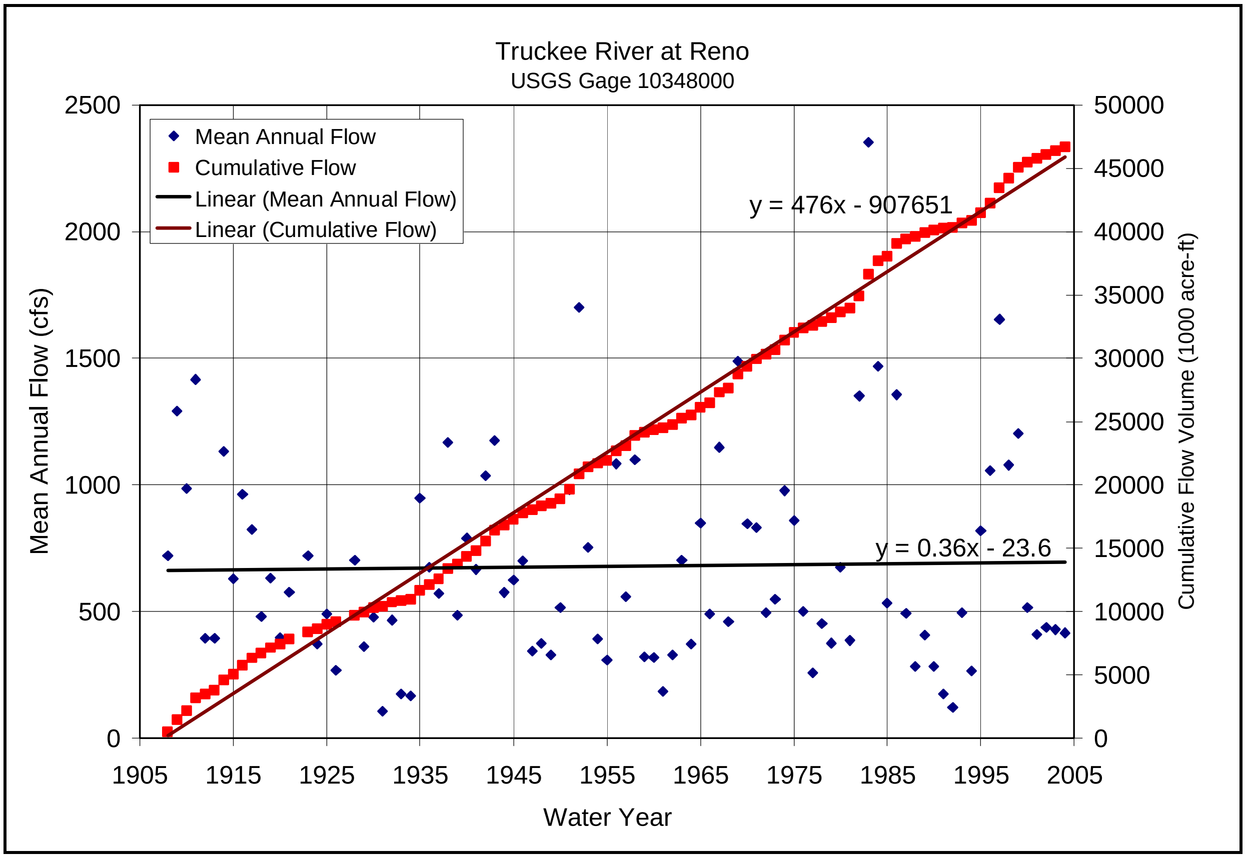

Figure 10. Mean annual streamflow and cumulative flow volumes for the Truckee River at Reno.

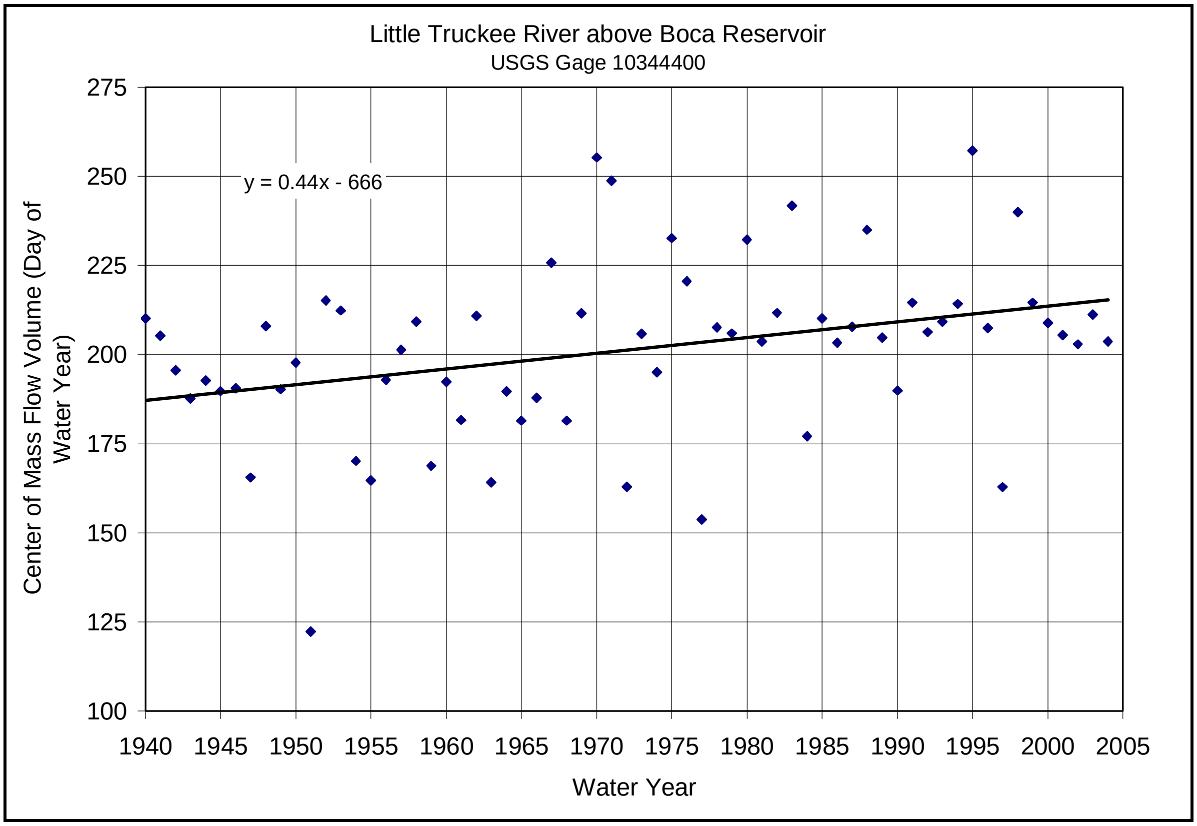

Figure 11. Little Truckee River above Boca Reservoir streamflow center of mass.

Reservoir Volumes

Mean annual reservoir storage volumes and cumulative mean annual storage were also investigated. The reservoir volumes displayed an obvious dependence on climate, as periods of drought clearly influenced reservoir volumes. This dependence is demonstrated by Figure 12, which contains data for Boca Reservoir. In periods of high precipitation and streamflow (e.g. 1972 to 1986), the reservoir volume was high and the cumulative volume climbed faster than the historical trend. However, during periods of drought (e.g. 1987 to 1995) the reservoir volumes dropped dramatically, and the cumulative storage volumes climbed slower than the historical trend. For Lake Tahoe, the storage volume became negative as the lake level fell below its natural rim. During this period, the cumulative storage volume trend was actually negative. Lake Tahoe trends, along with the other major regional reservoirs, are shown in Appendix E.

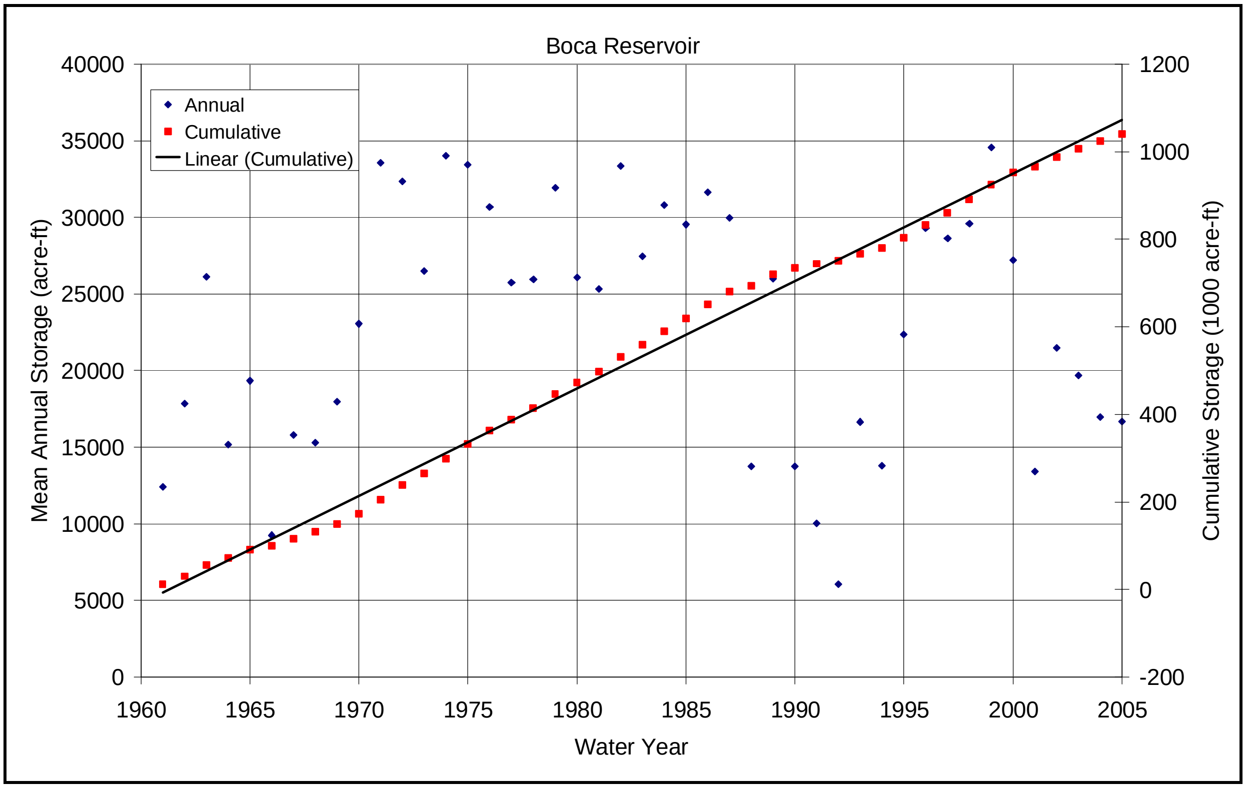

Figure 12. Mean annual storage and cumulative storage for Boca Reservoir.

Precipitation and Snowpack

Double mass analyses were conducted on precipitation and snowpack data at two sets of gages. Although snowfall and SWE is reported at the COOP stations, this data is considered less reliable than snowcourse stations. Thus, the analysis was restricted to COOP precipitation and snowcourse stations that were in close proximity. The results for the double mass analysis between annual precipitation at the Truckee Ranger Station and April 1st SWE at the Truckee #2 Snowcourse station are shown in Figure 13. The data reveals a very consistent trend between precipitation and SWE throughout the periods of record. This suggests that the form of precipitation and snowmelt patterns have not changed noticeably.

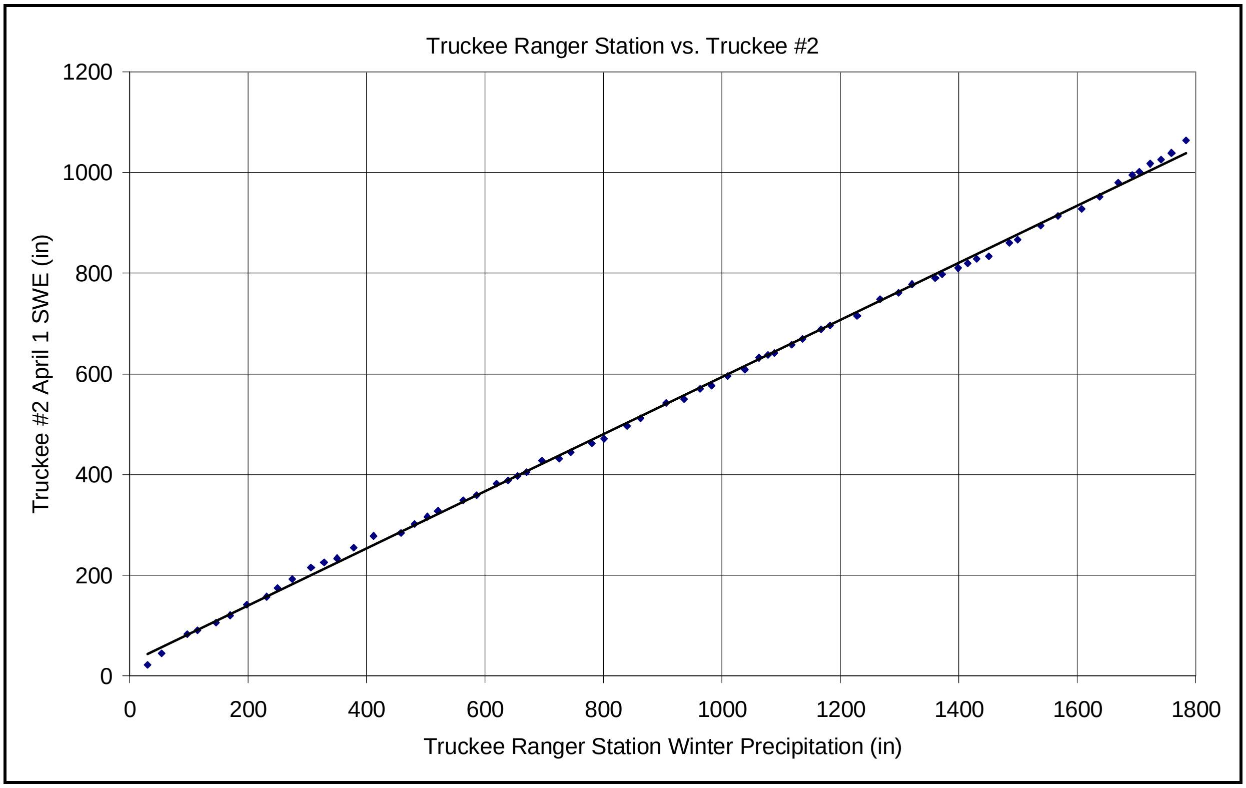

Figure 13. Double mass curve for Truckee #2 snowcourse station April 1 SWE and Truckee Ranger Station winter precipitation.

Precipitation and Streamflow

Relationships between streamflow and precipitation were studied at four paired stations. The stations were selected so that the gaged precipitation was 'representative' of the observed streamflow. Also, streamflow records that were influenced by reservoir construction and other local human activities were not considered. The results confirmed the expected high degree of correlation between precipitation and streamflow. The function between precipitation and streamflow remained consistent throughout the period of record, indicating no observed modifications in large scale precipitation-runoff-streamflow processes at un-dammed gages. Figure 14 contains the results of the double mass analysis for the Donner State Park weather station and the Donner Creek streamgage. The results of the remaining three analyses are shown in Appendix G.

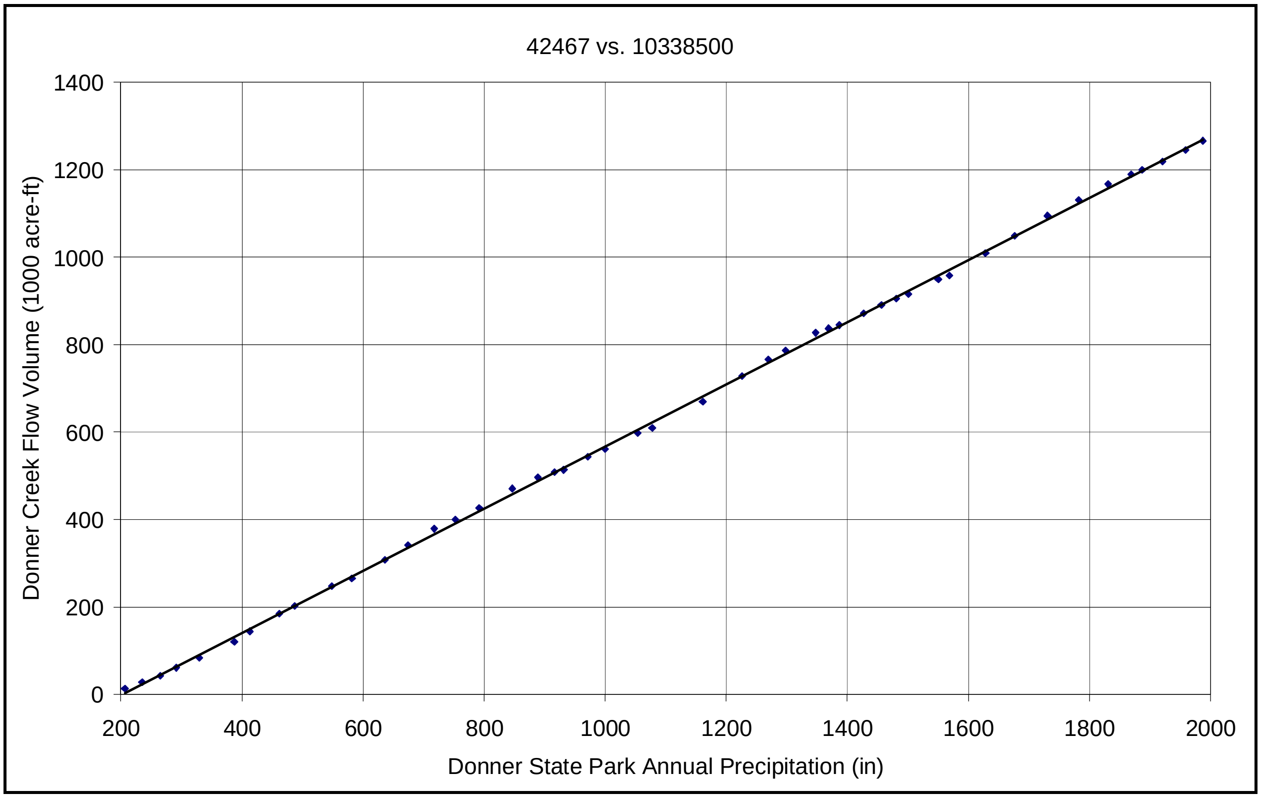

Figure 14. Double mass curve for streamflow volume for Donner Creek and annual precipitation at Donner State Park.

Precipitation and Reservoir Storage Volume

Double mass analysis of precipitation and reservoir storage volumes further demonstrated the high degree of correlation between these variables. The analyses were completed for five paired stations and the results can be found in Appendix H. An example of this data is shown in Figure 15, which contains the analyses between Boca Reservoir storage volumes and annual precipitation at the Boca weather station. The consistent linear long-term trend between these variables indicates that the underlying processes have not influenced by potential climate change.

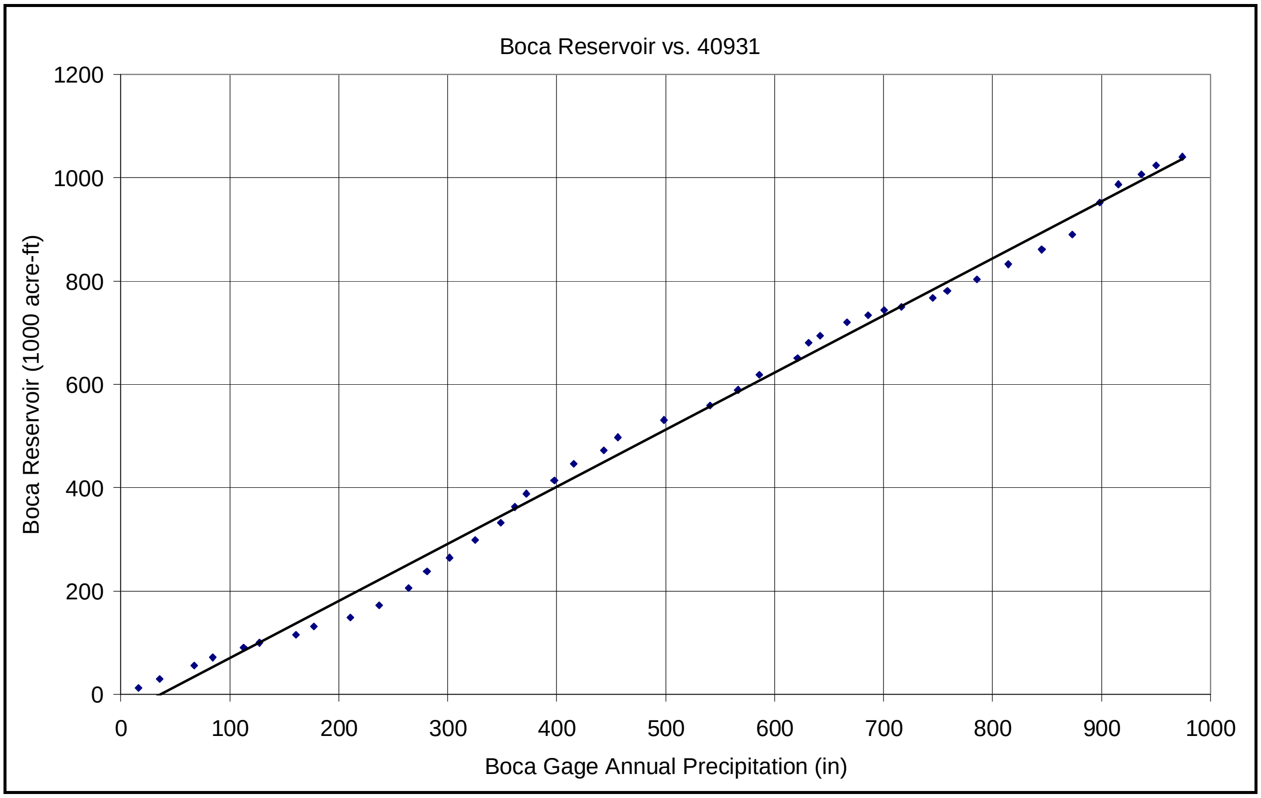

Figure 15. Double mass curve of Boca Reservoir storage and Boca annual precipitation.

Snow Water Equivalent and Streamflow

Relationships between streamflow and SWE were studied at six paired stations. The stations were selected so that the gaged SWE was representative of the observed streamflow. Figure 16 shows the results of the analysis between Independence Lake SWE and Sagehen Creek streamflow. The results for the remaining analyses can be found in Appendix I. The data showed a high degree of correlation between SWE and streamflow. Recent data showed no strong departure from long term trends. These results indicate that the processes of snowfall, snow accumulation, snowmelt, and runoff have remained relatively consistent throughout the period of record.

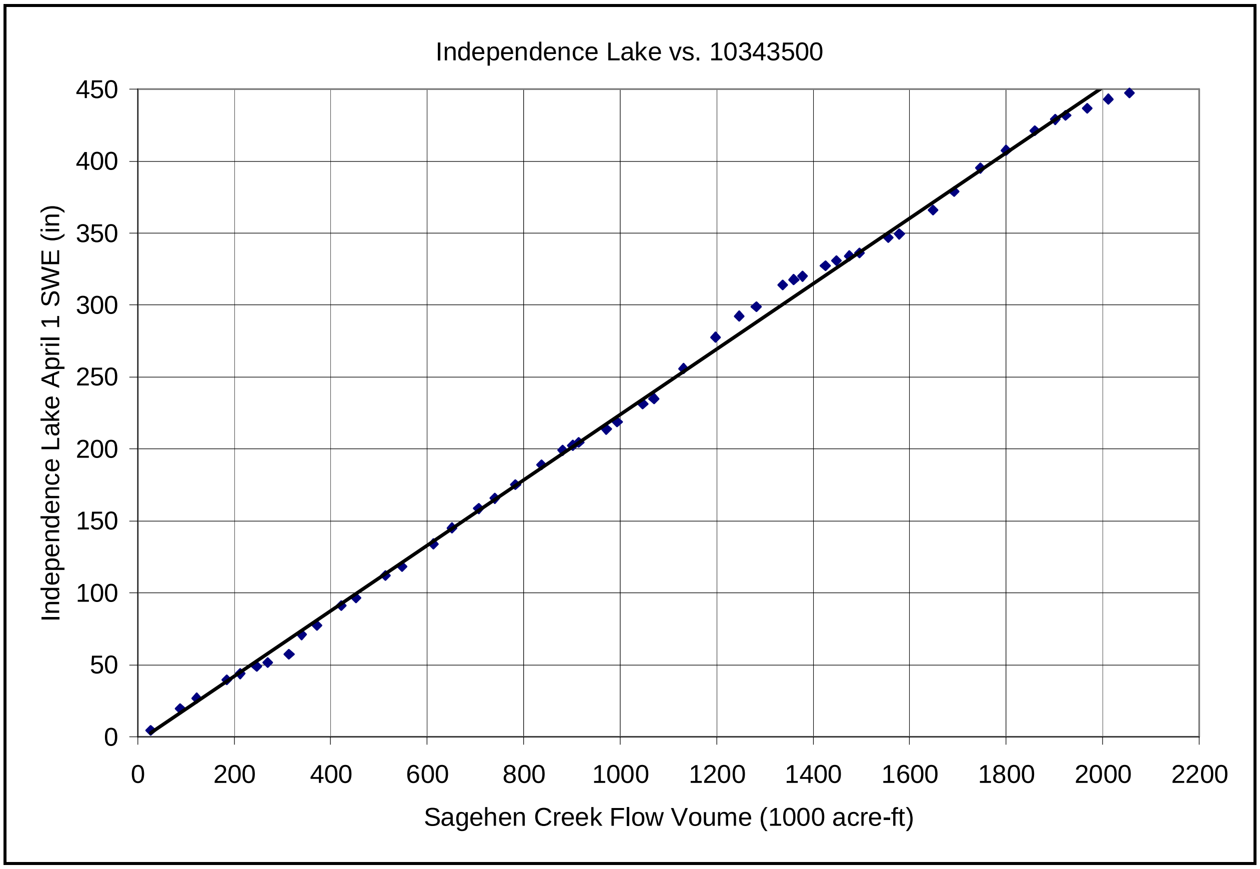

Figure 16. Independence Lake SWE and Sagehen Creek streamflow volumes.

Streamflow and Reservoir Volumes

Double mass analyses were conducted for Boca Reservoir, Donner Lake, Stampede Reservoir and Lake Tahoe. For Boca Reservoir and Lake Tahoe, inflow and outflow streams were both considered. Results of the Boca Reservoir Analysis are shown in Figure 17, and all other analyses can be found in Appendix J. No consistent departures from long term patterns were observed between streamflow and reservoir volumes. Further, consistent trends were observed between upstream and downstream streamflow records.

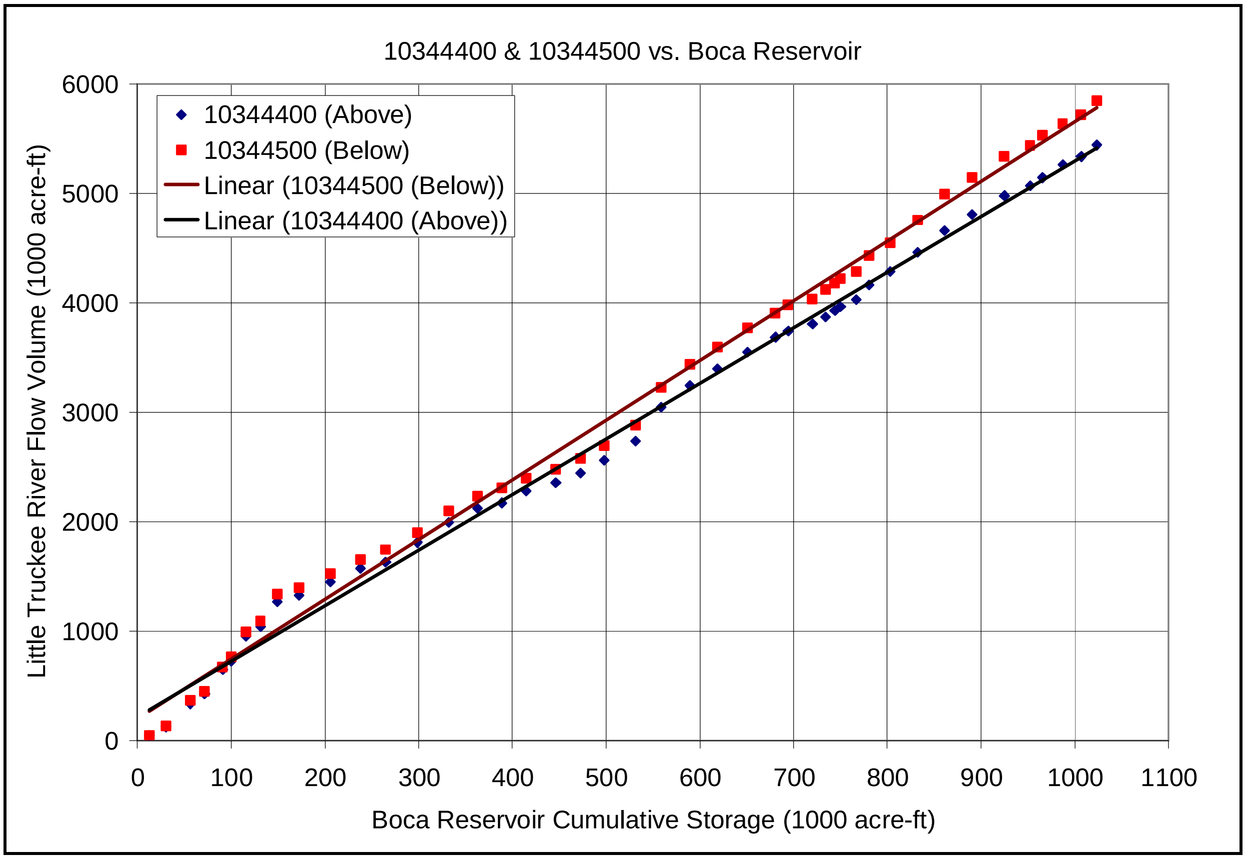

Figure 17. Little Truckee River streamflow volume and Boca Reservoir storage.

Snowpack and Reservoir Storage Volumes

Double mass analysis of April 1 SWE and reservoir storage volumes demonstrated the expected high degree of correlation between these variables. The analyses were completed for four paired stations and the results can be found in Appendix K. Figure 18 contains the double mass analysis of Lake Tahoe storage volume and Hagen's Meadow April 1 SWE. The data not only reveals the correlation between these datasets, but it also shows the impacts of major drought events that caused the Lake Tahoe volume to drop below its natural rim. After these events, SWE continues to accumulate while Lake Tahoe cumulative storage volumes actually decrease.

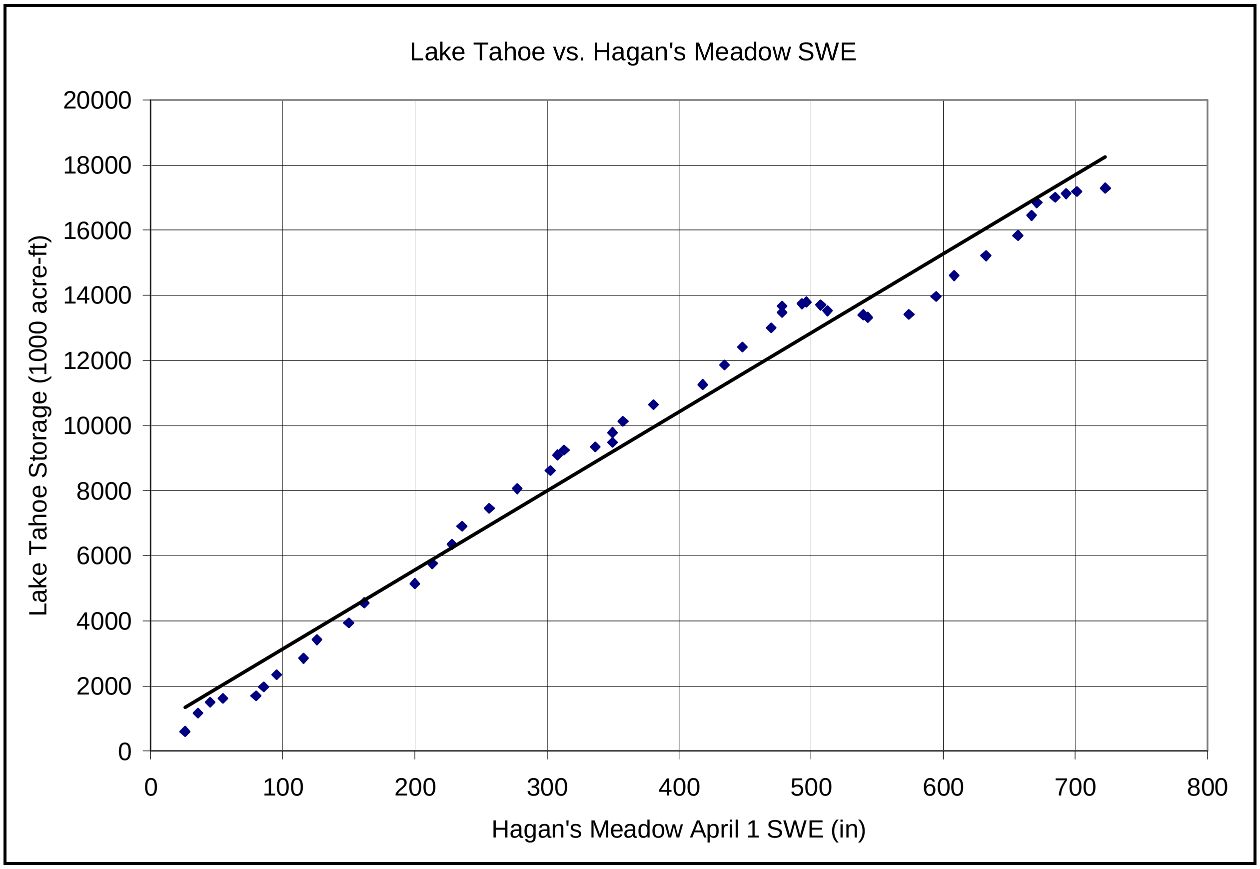

Figure 18. Lake Tahoe storage and April 1 SWE at Hagen's Meadow snowcourse station.

Summary

In order to reveal potential signs of environmental change in the Truckee Meadows region that may be consistent and coincident with global warming, historical climate and hydrologic data were evaluated. The data were compiled in a GIS database and linear regression and double mass analyses were performed. For all variables, year-to-year variability was very high; making it difficult to identify data trends. No consistent or prevalent changes in temperature, precipitation, SWE, hydrograph volume/ timing, or reservoir storage volumes were found. Further, relationships between variables appeared to remain consistent over time. No clear evidence of global warming or associated changes in volume or timing of hydrologic variables was found.

Appendix A

Temperature

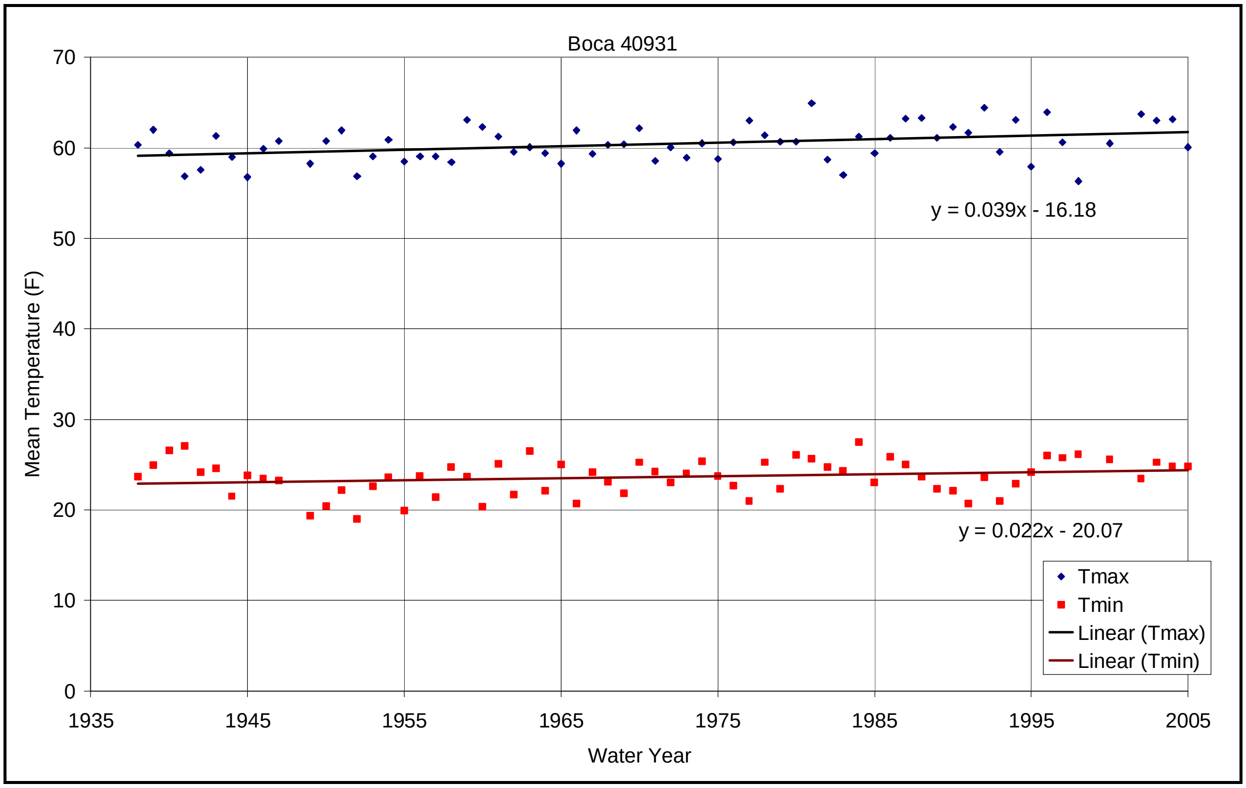

Figure A1. Mean annual maximum and minimum temperature at Boca Gage 40931.

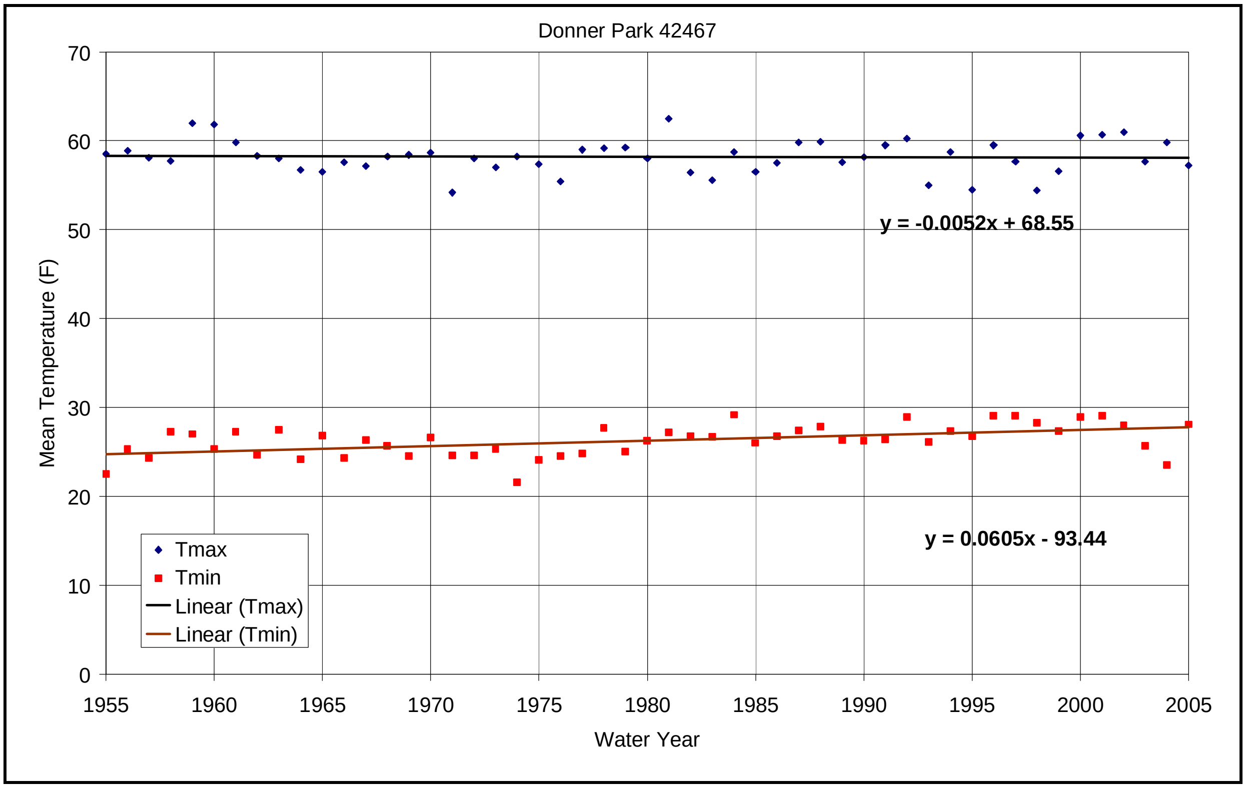

Figure A2. Mean annual maximum and minimum temperature at Donner Park 42467.

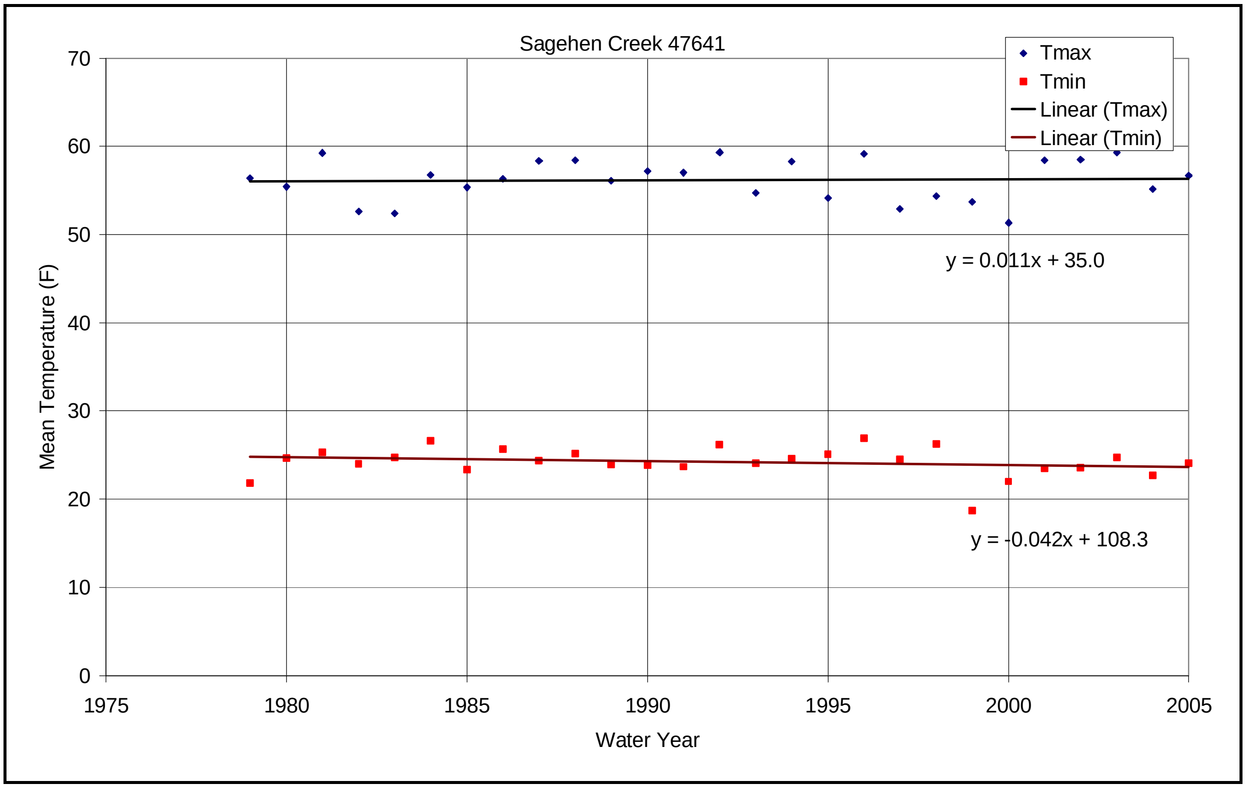

Figure A3. Mean annual maximum and minimum temperature at Sagehen Creek 47641.

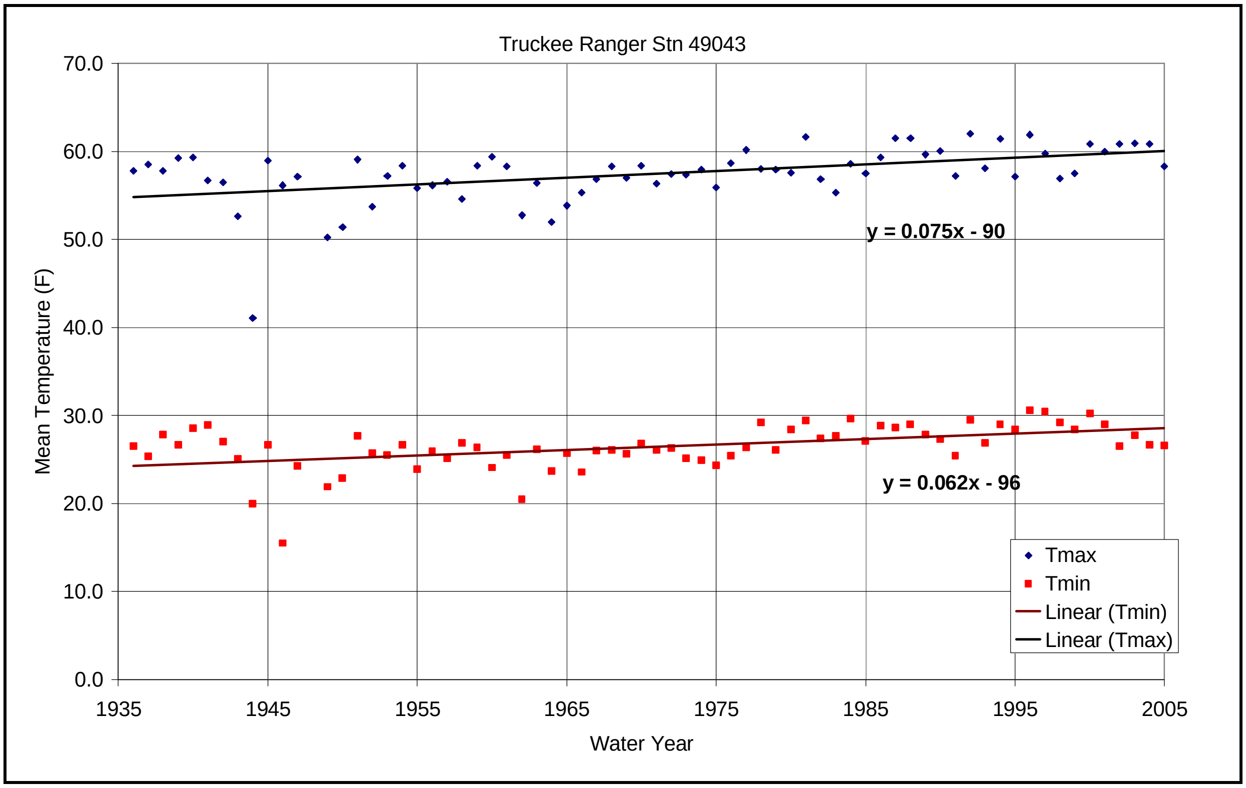

Figure A4. Mean annual maximum and minimum temperature at Truckee Ranger Station 49043.

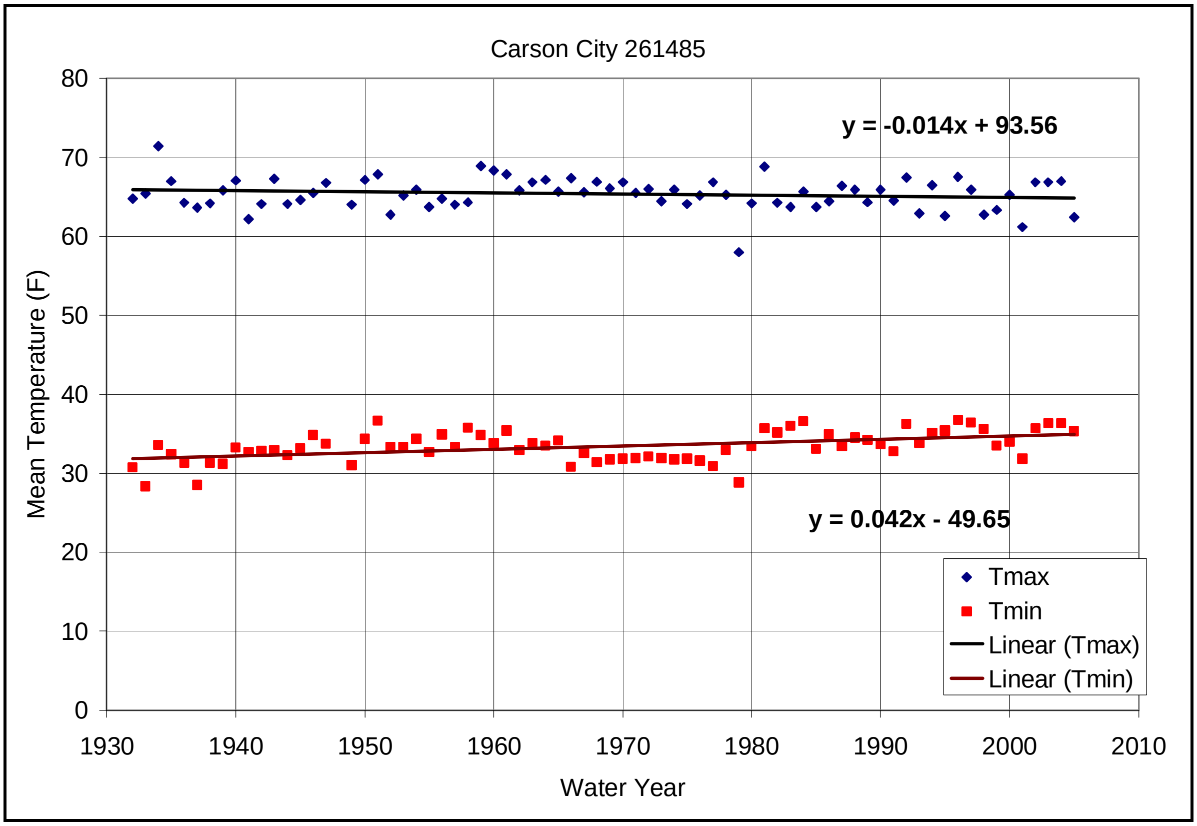

Figure A5. Mean annual maximum and minimum temperature at Carson City 261485.

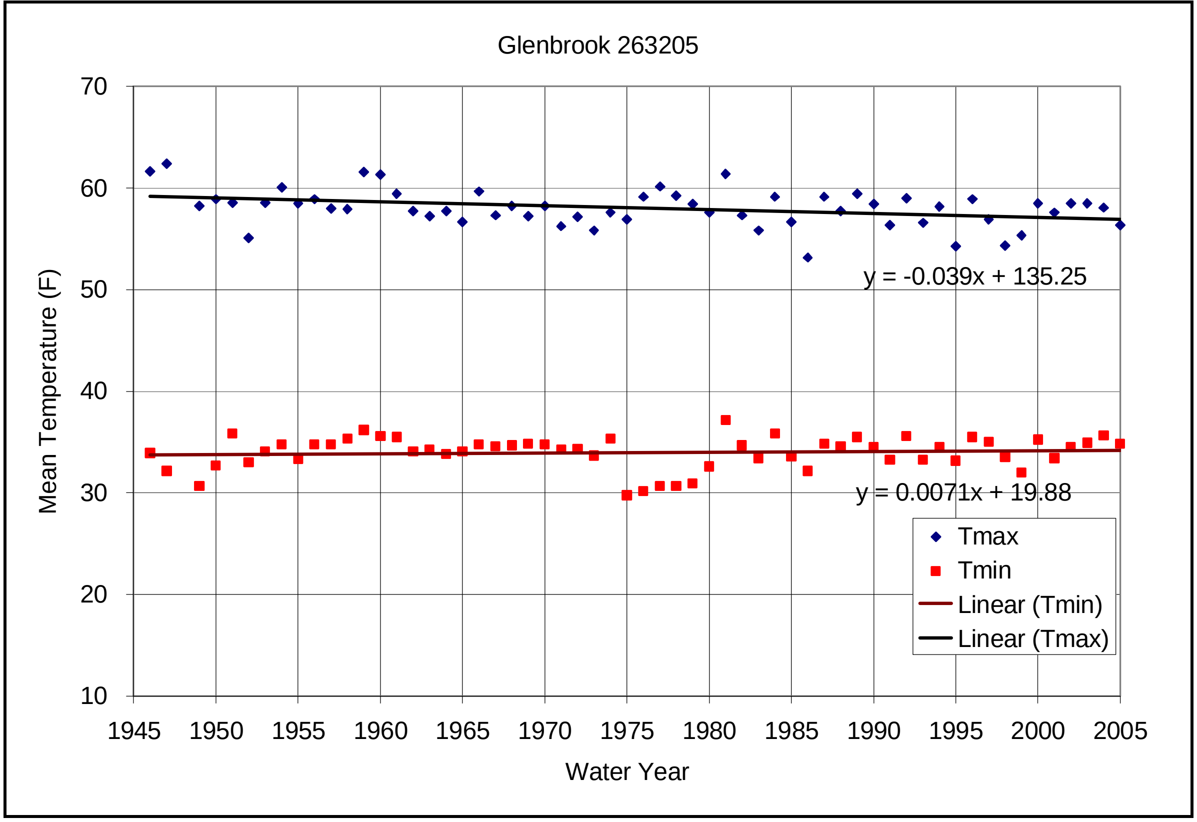

Figure A6. Mean annual maximum and minimum temperature at Glenbrook 263205.

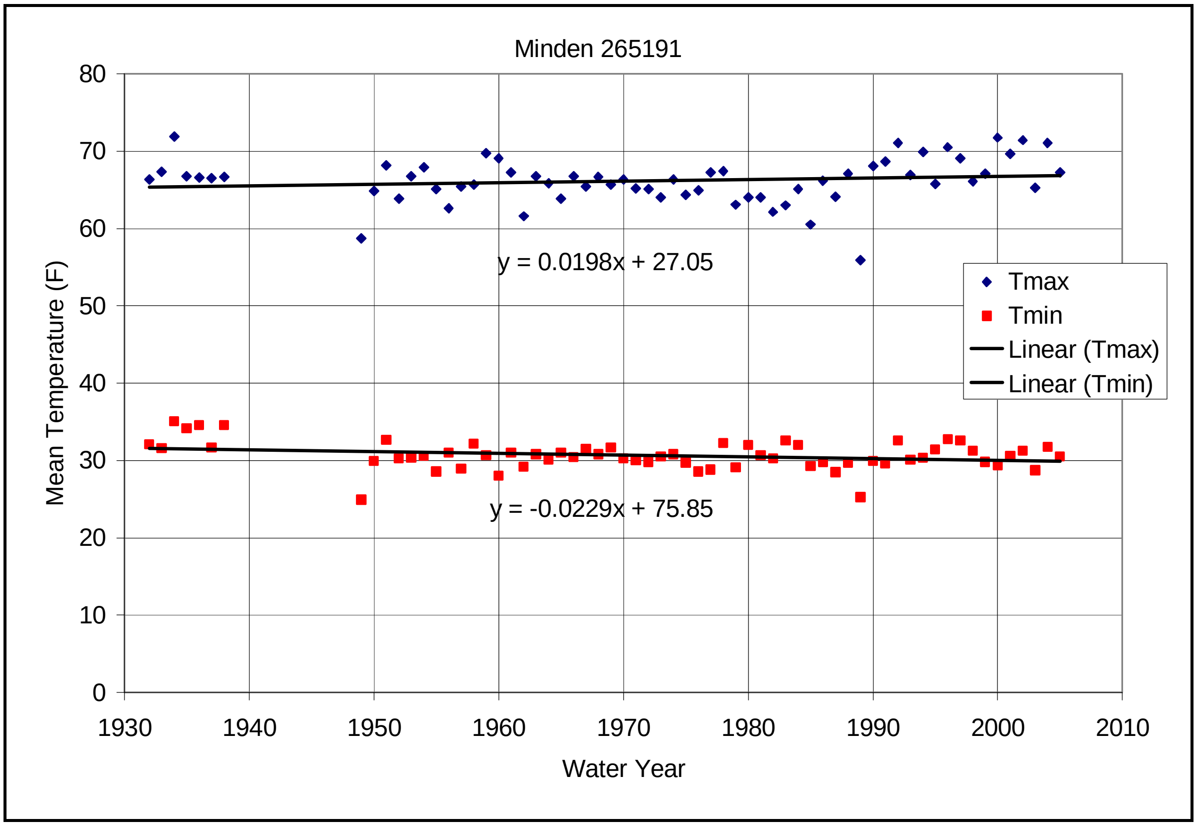

Figure A7. Mean annual maximum and minimum temperature at Minden 265191.

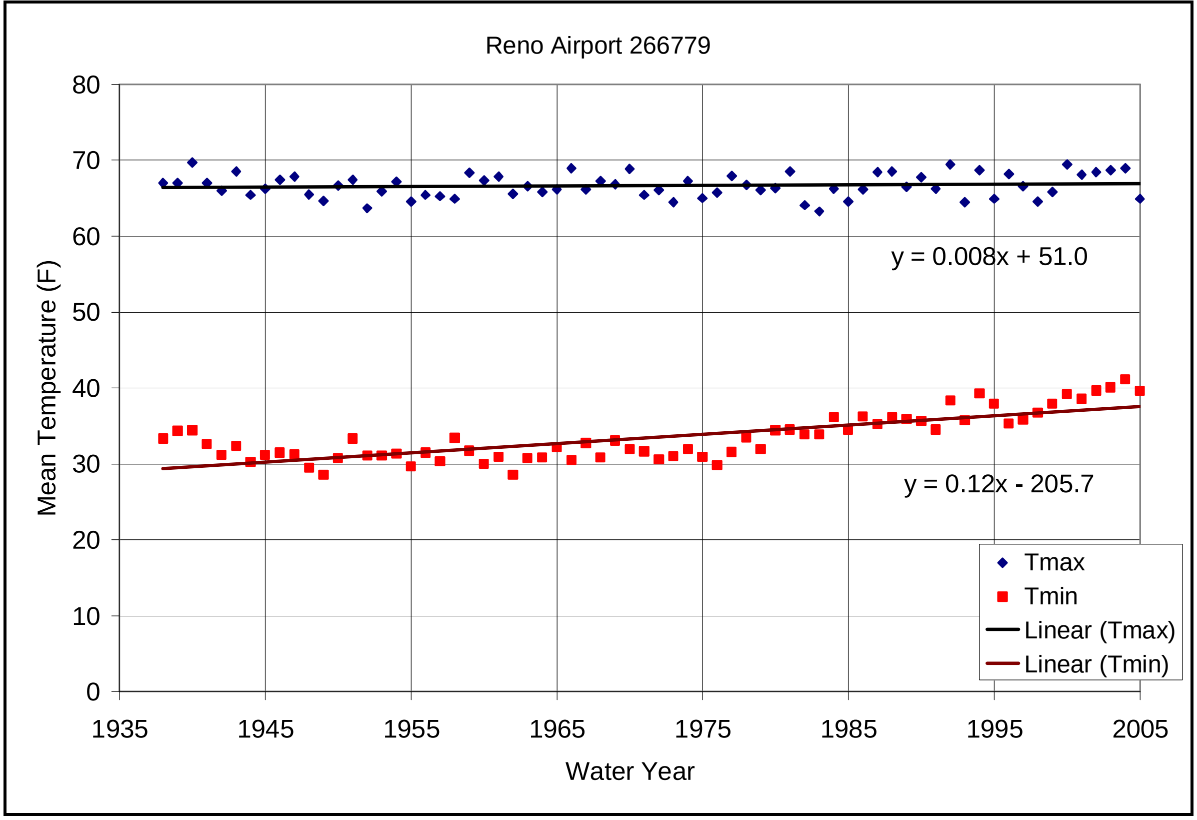

Figure A8. Mean annual maximum and minimum temperature at Reno Airport!266779.

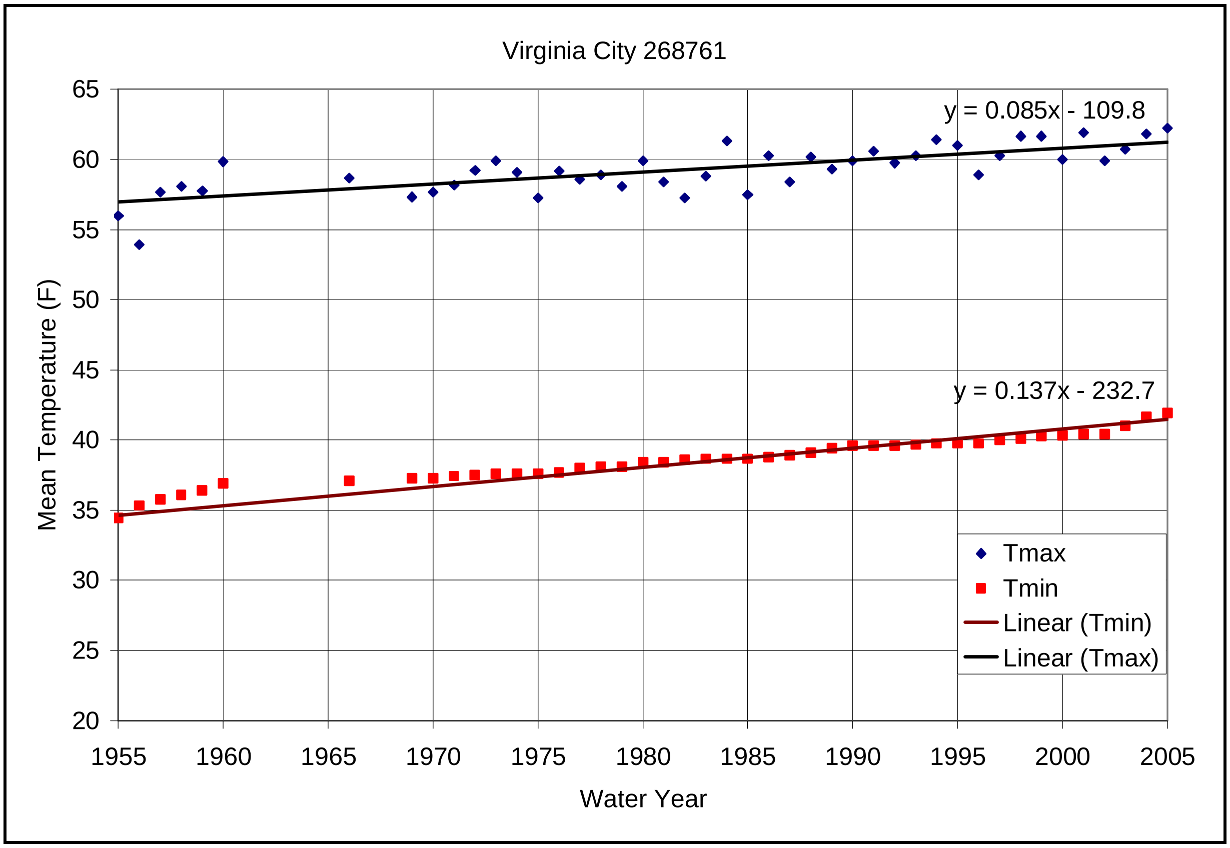

Figure A9. Mean annual maximum and minimum temperature at Virginia City 268761.

Appendix B

Precipitation

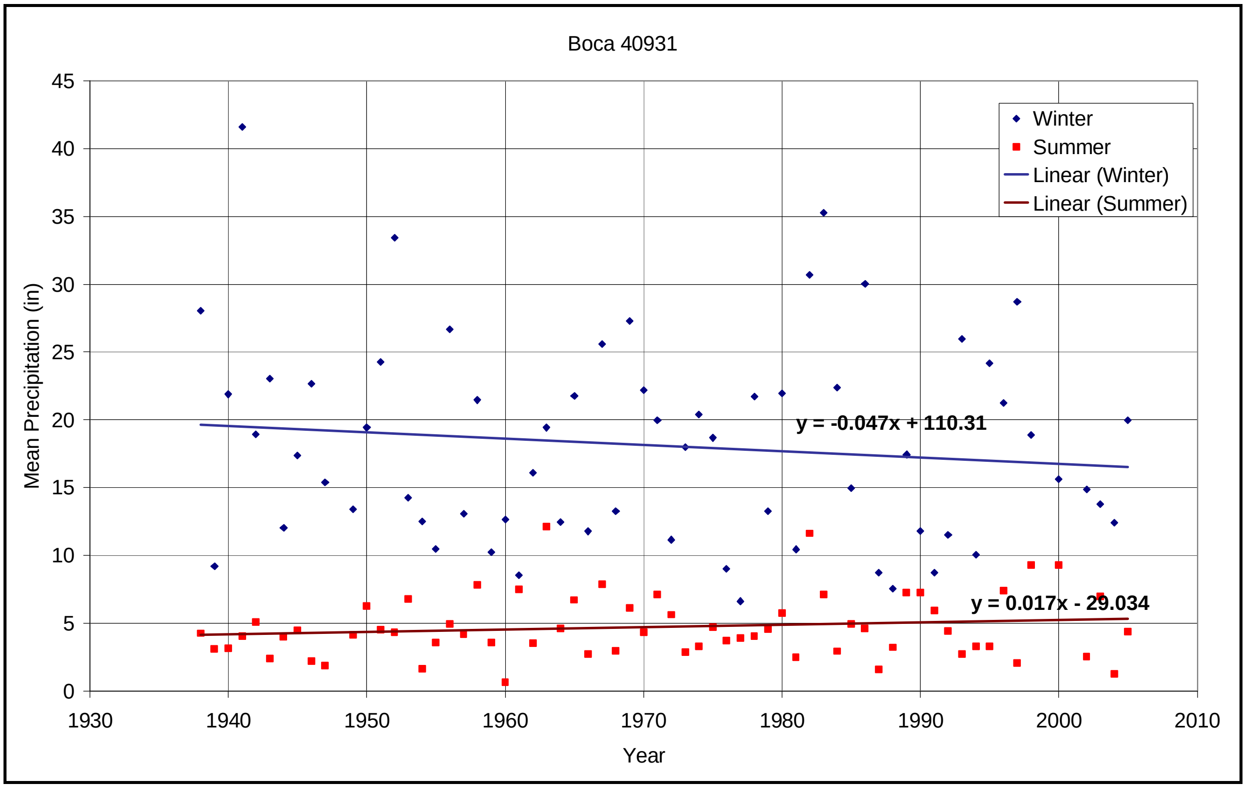

Figure B1. Mean winter (Oct-March) and summer (April-September) precipitation at Boca Gage 40931.

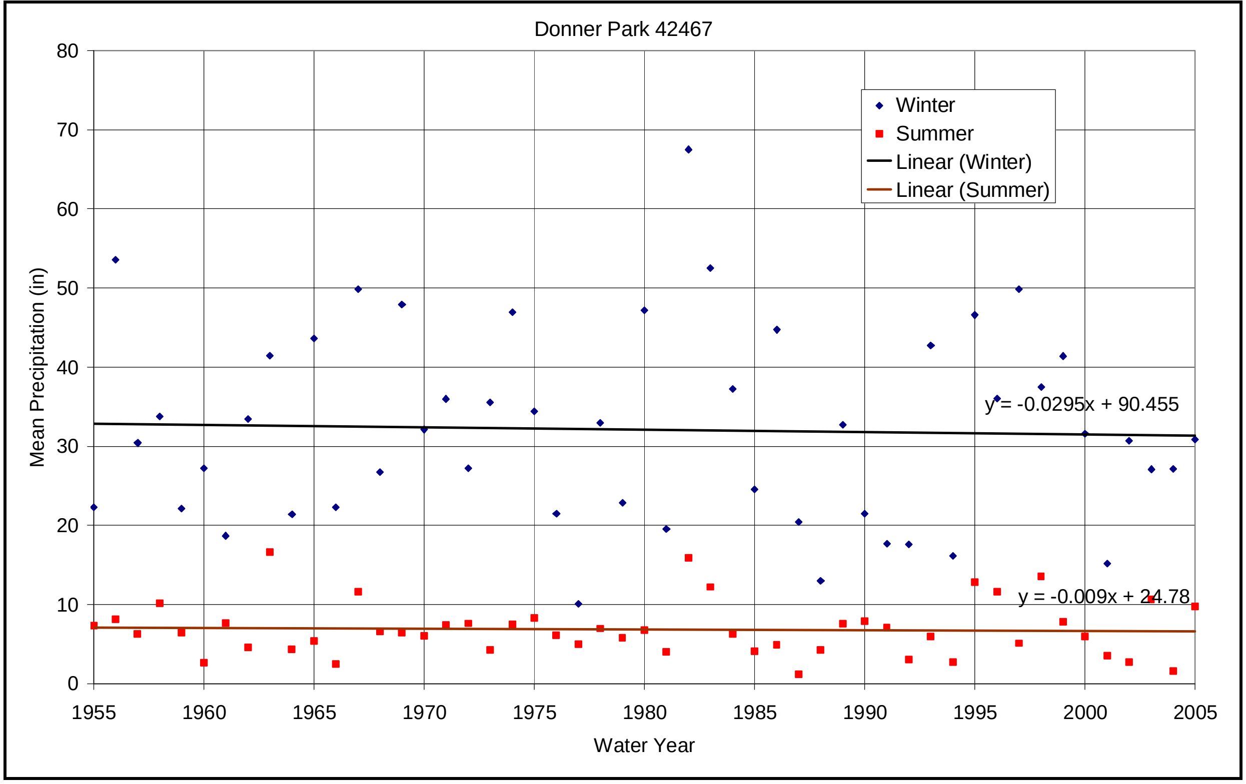

Figure B2. Mean winter and summer precipitation at Donner Park 42467.

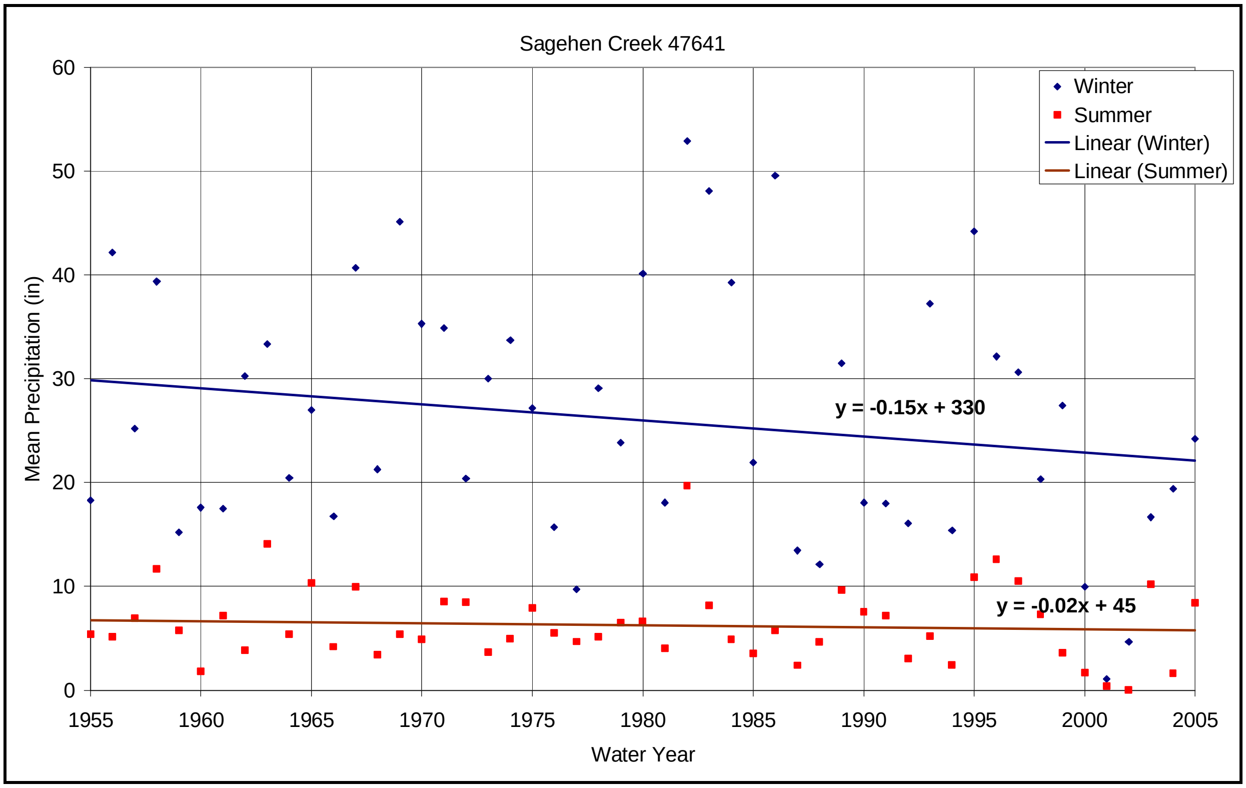

Figure B3. Mean winter and summer precipitation at Sagehen Creek 47641.

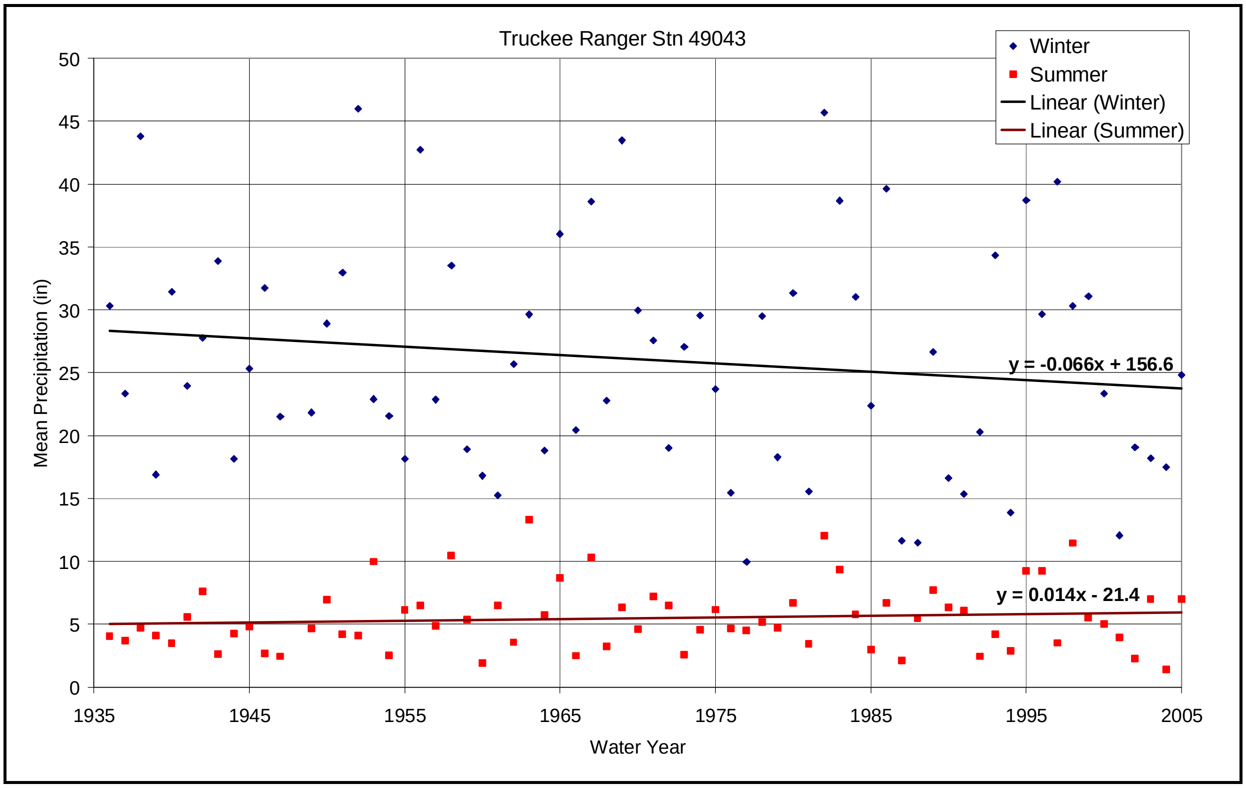

Figure B4. Mean winter and summer precipitation at Truckee Ranger Station 49043.

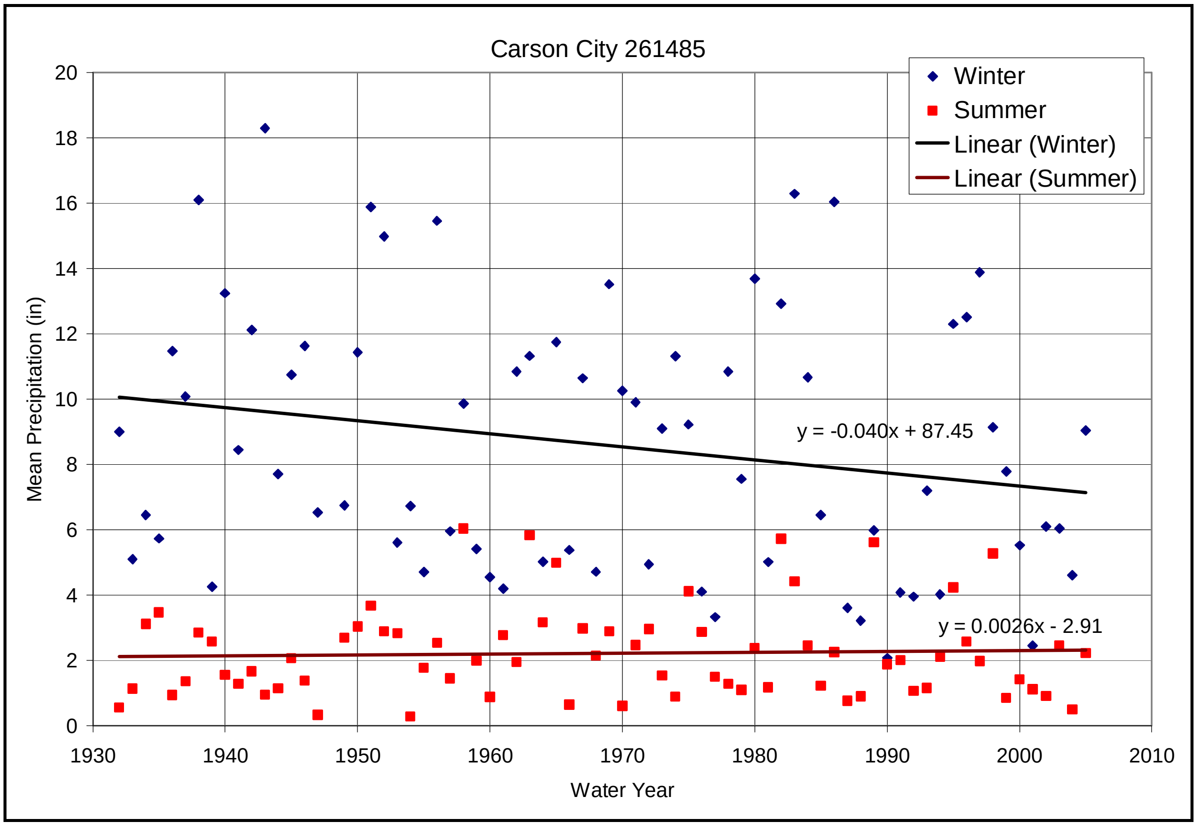

Figure B5. Mean winter and summer precipitation at Carson City 261485.

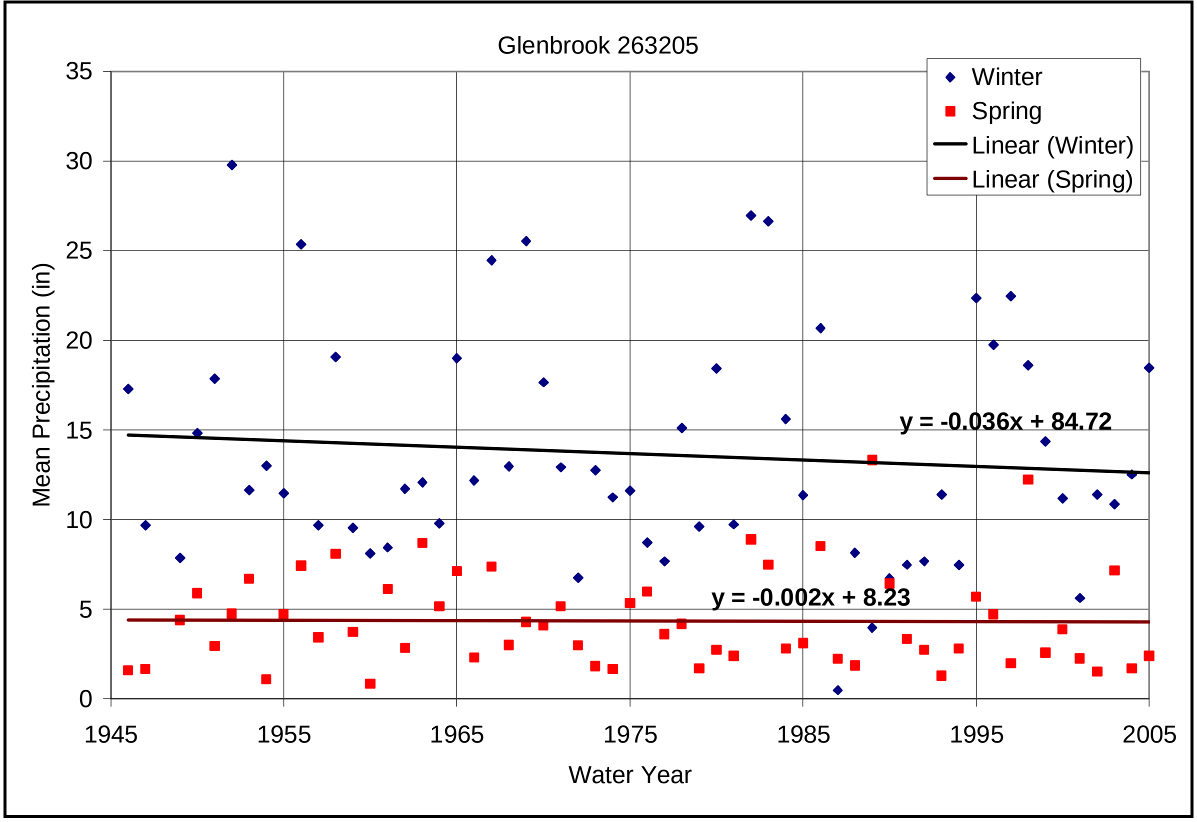

Figure B6. Mean winter and summer precipitation at Glenbrook 263205.

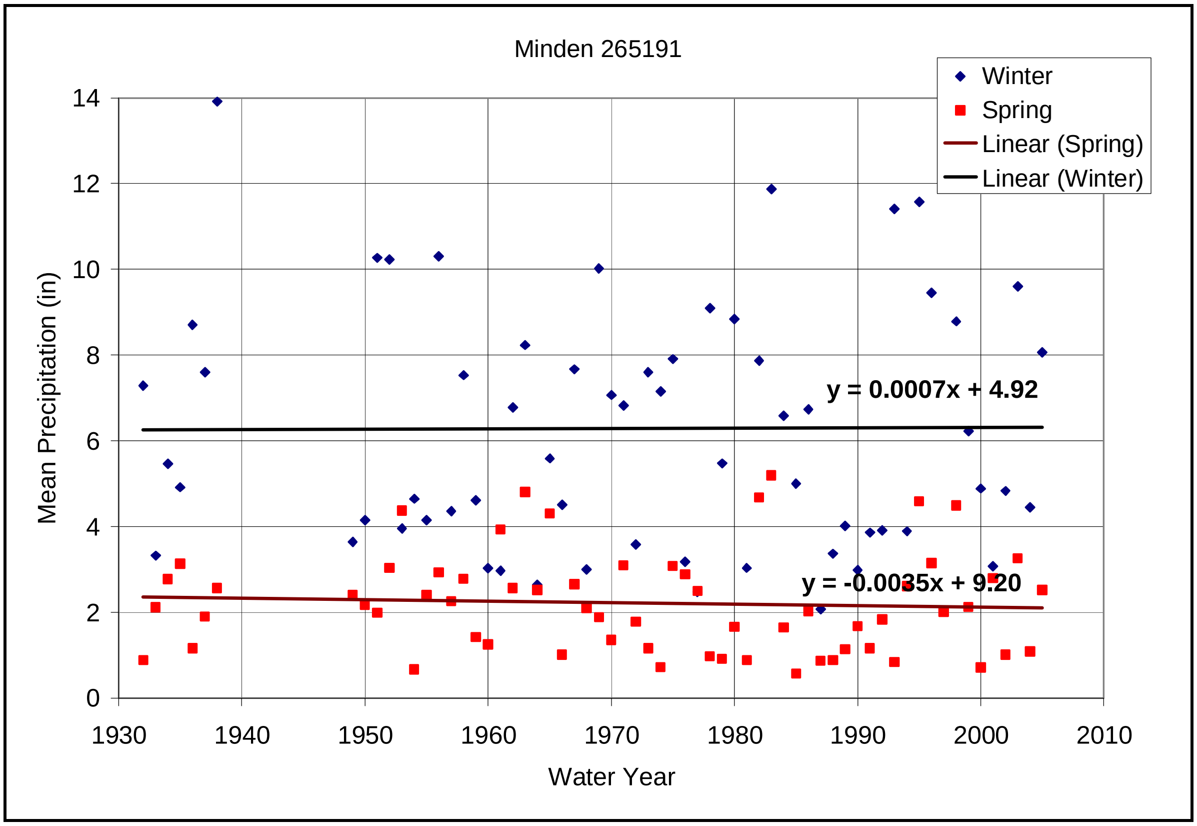

Figure B7. Mean winter and summer precipitation at Minden 265191.

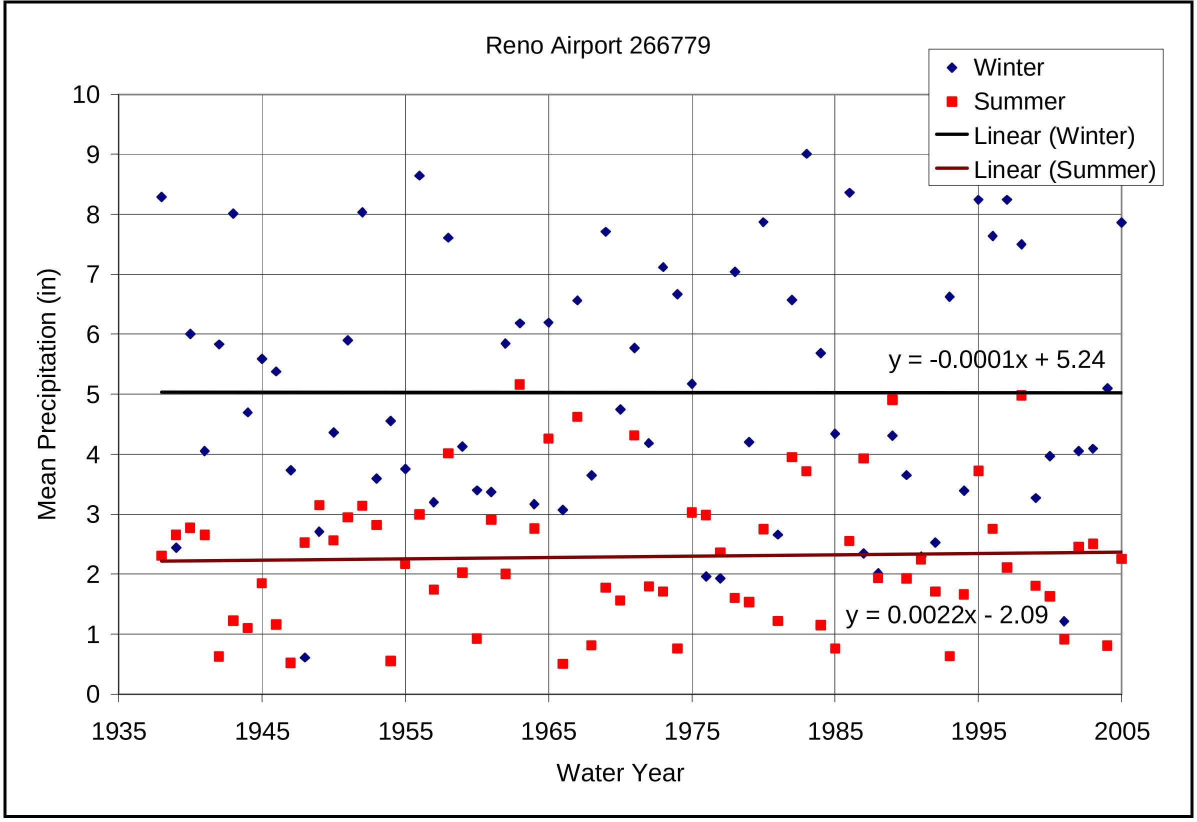

Figure B8. Mean winter and summer precipitation at the Reno Airport!2666779.

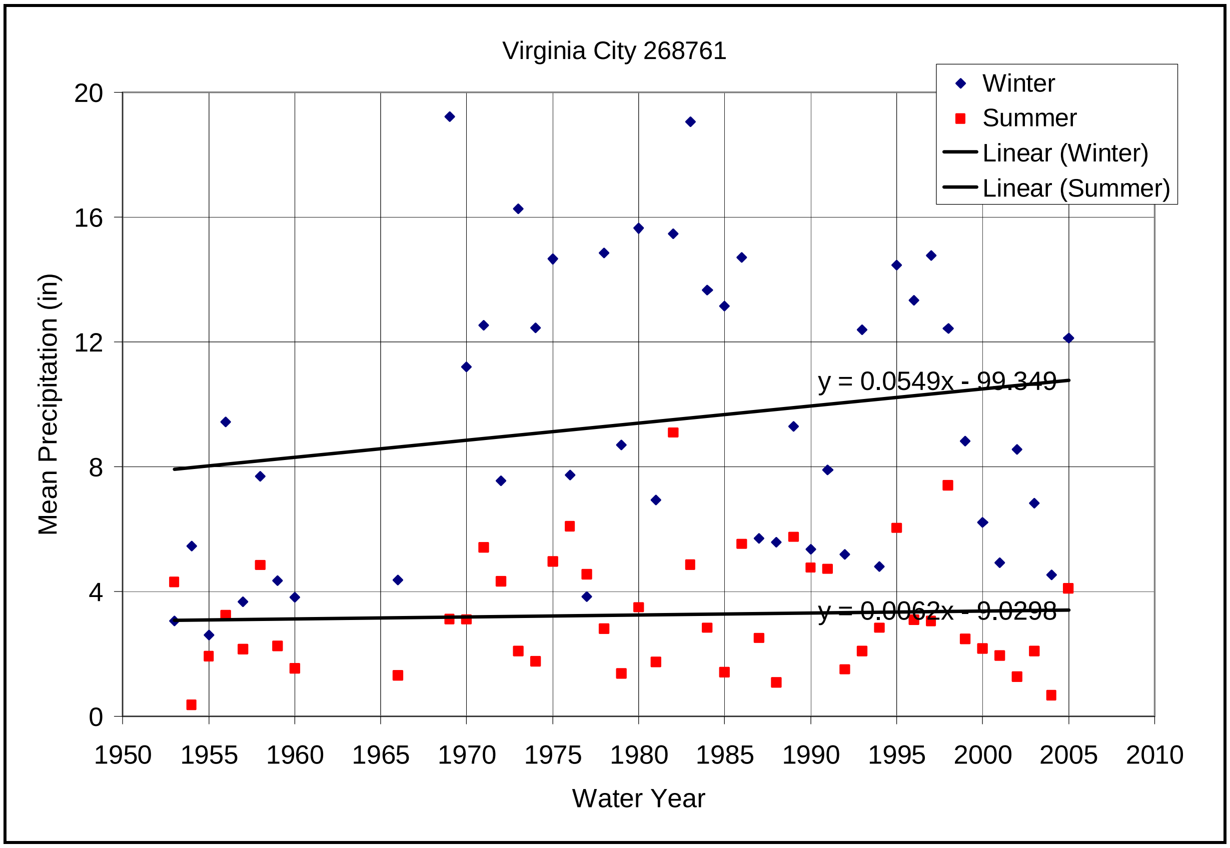

Figure B9. Mean winter and summer precipitation at Virginia City 268761.

Appendix C

Snowpack

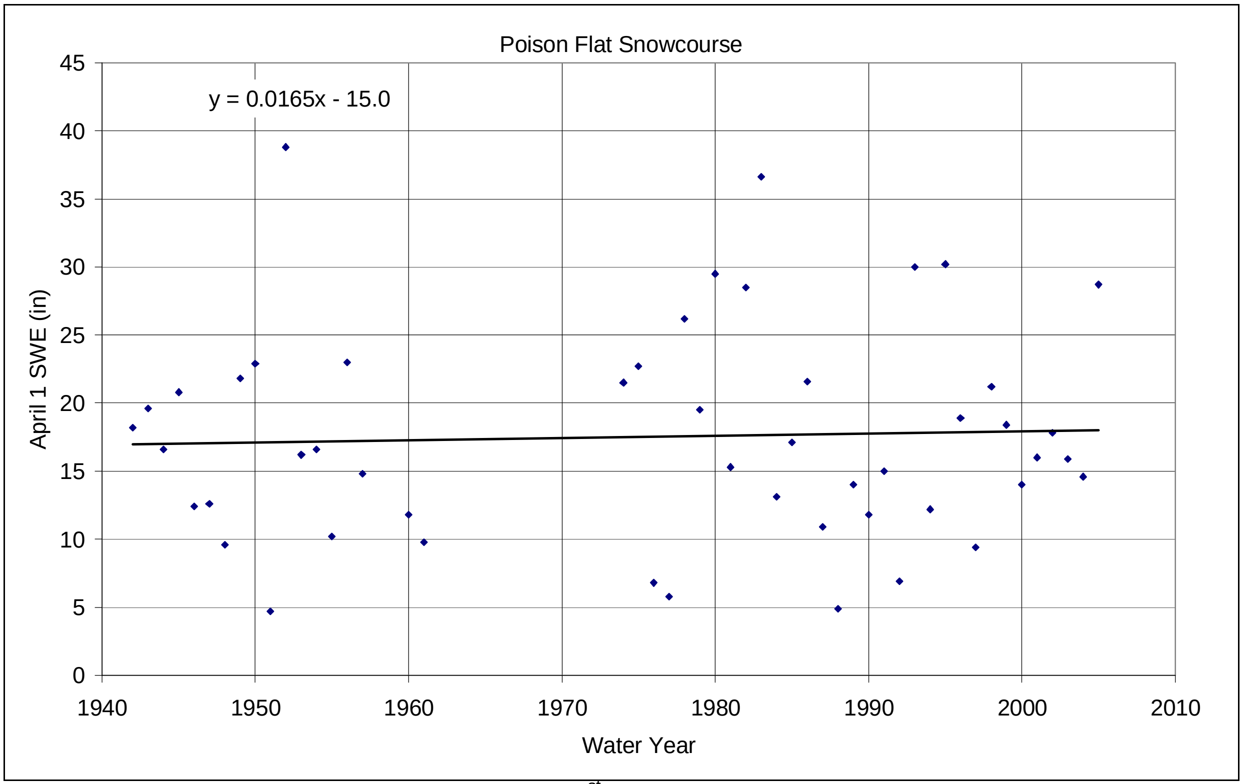

Figure C1. Poison Flat snowcourse station April 1st SWE.

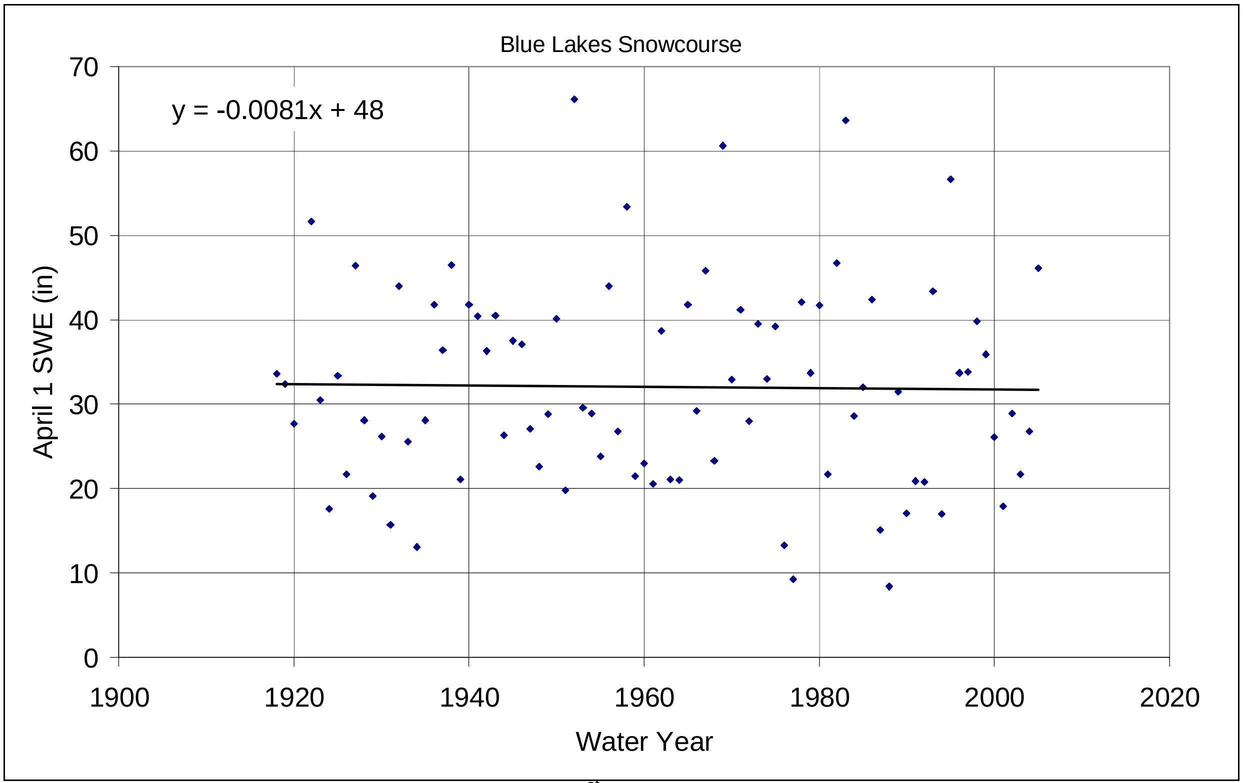

Figure C2. Blue Lakes snowcourse station April 1st SWE.

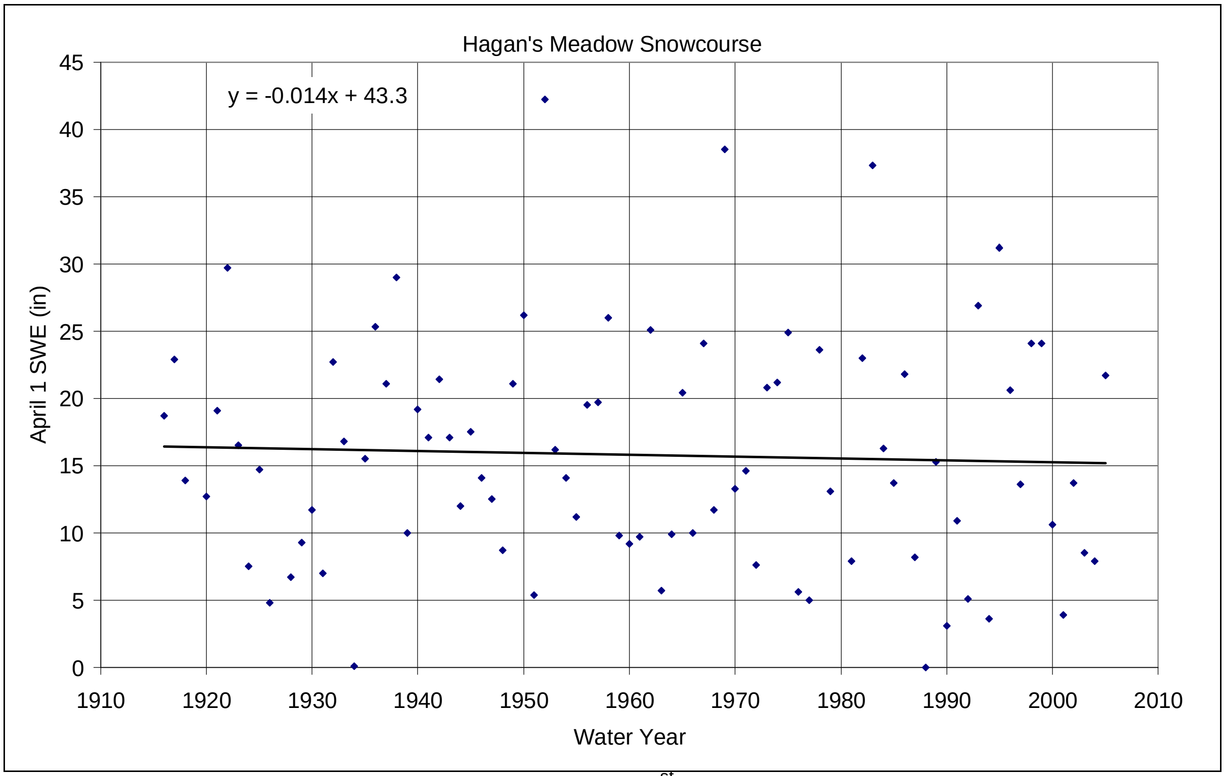

Figure C3. Hagan's Meadow snowcourse station April 1st SWE.

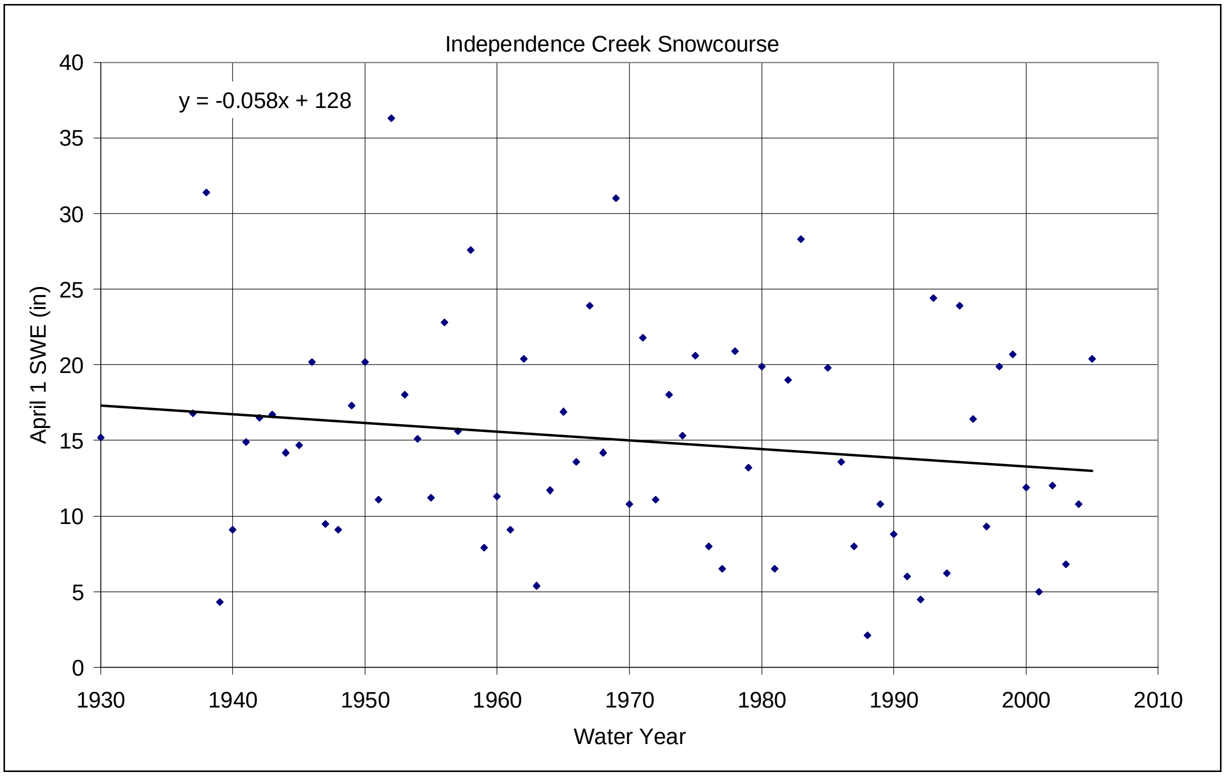

Figure C4. Independence Creek snowcourse station April 1st SWE.

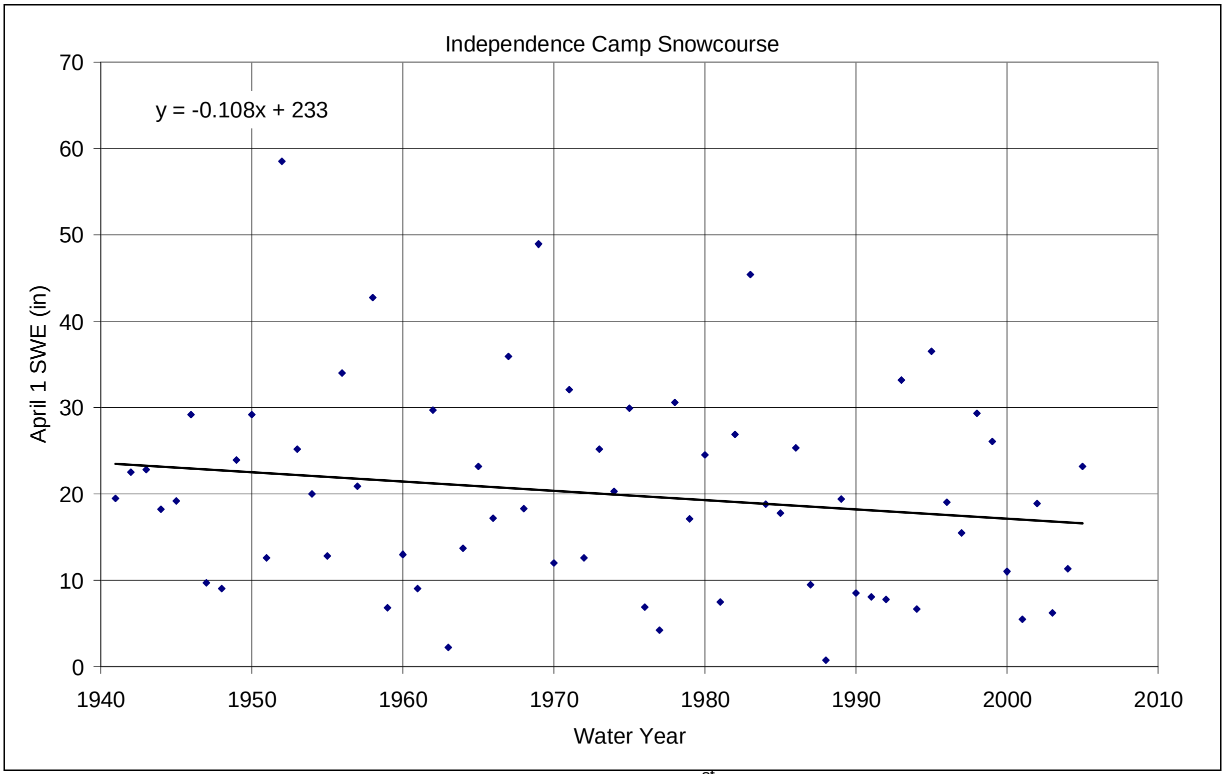

Figure C5. Independence Camp snowcourse station April 1st SWE.

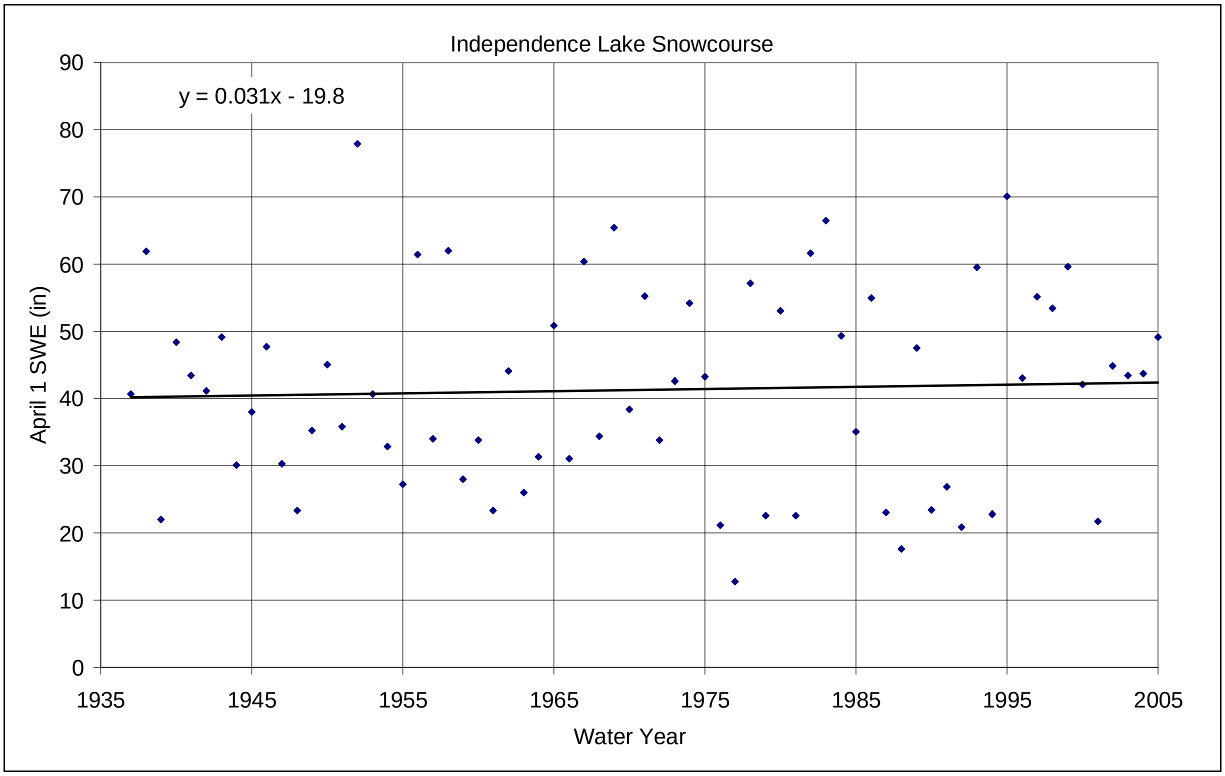

Figure C6. Independence Lake snowcourse station April 1st SWE.

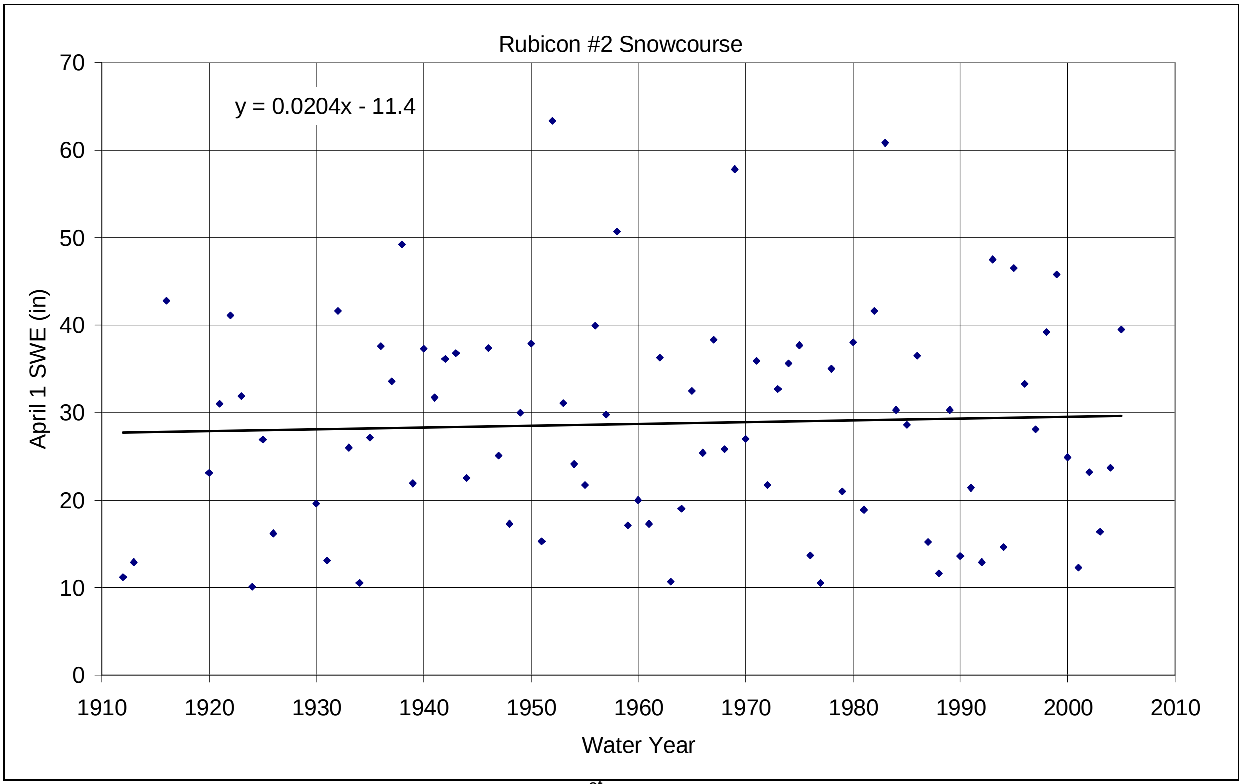

Figure C7. Rubicon #2 snowcourse station April 1st SWE.

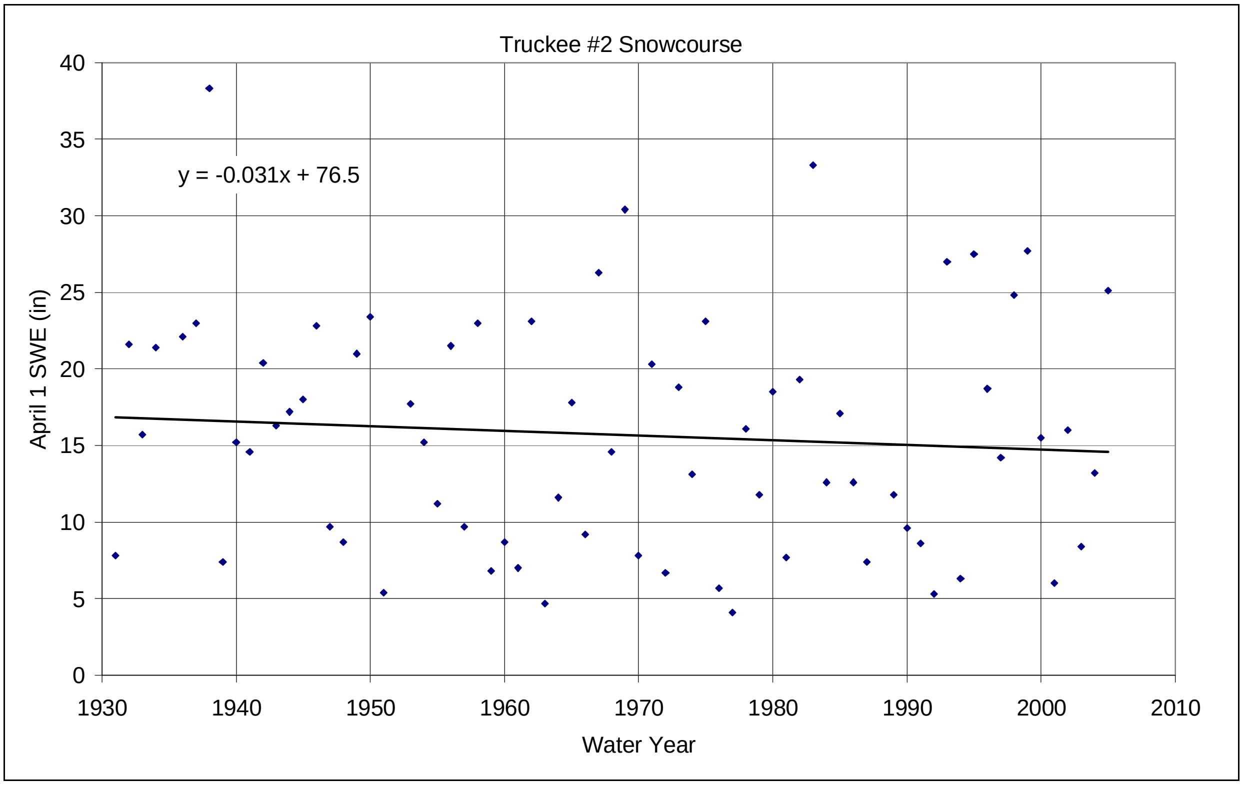

Figure C8. Truckee #2 snowcourse station April 1st SWE.

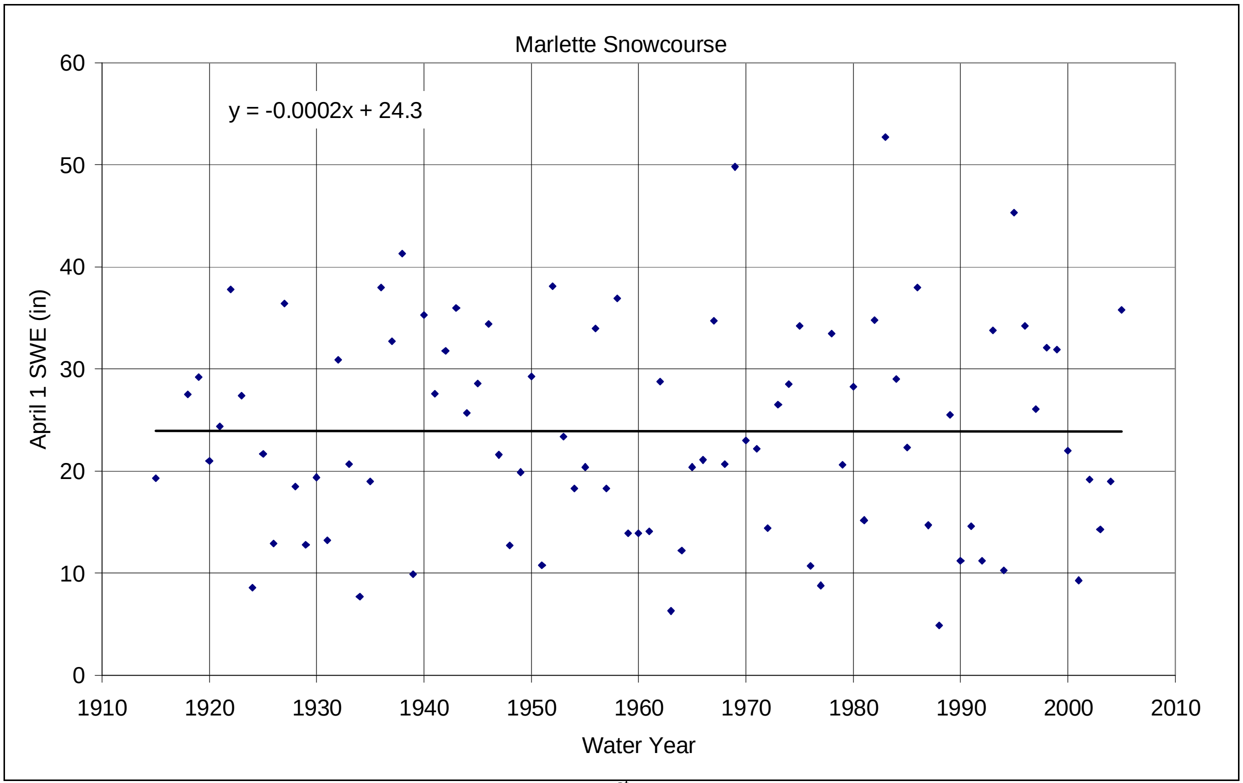

Figure C9. Marlette Lake snowcourse station April 1st SWE.

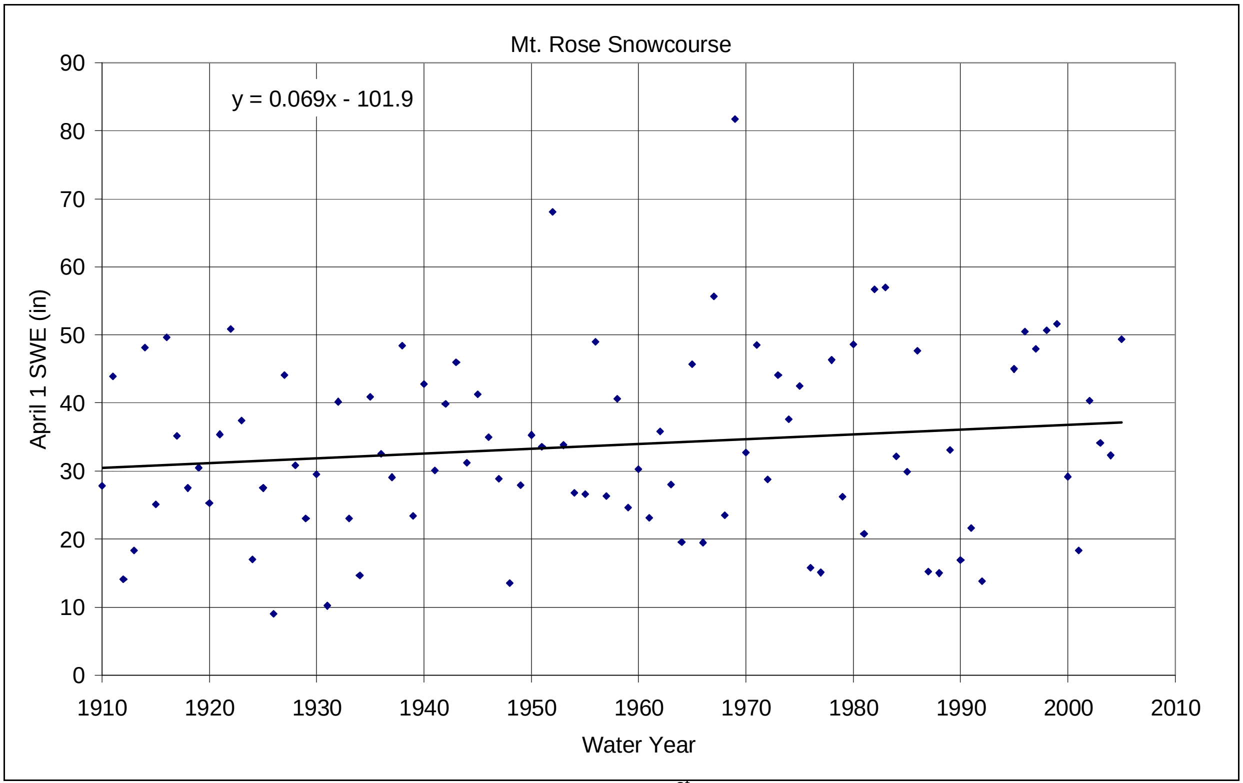

Figure C10. Mt Rose Ski Area snowcourse station April 1st SWE.

Appendix D

Streamflow

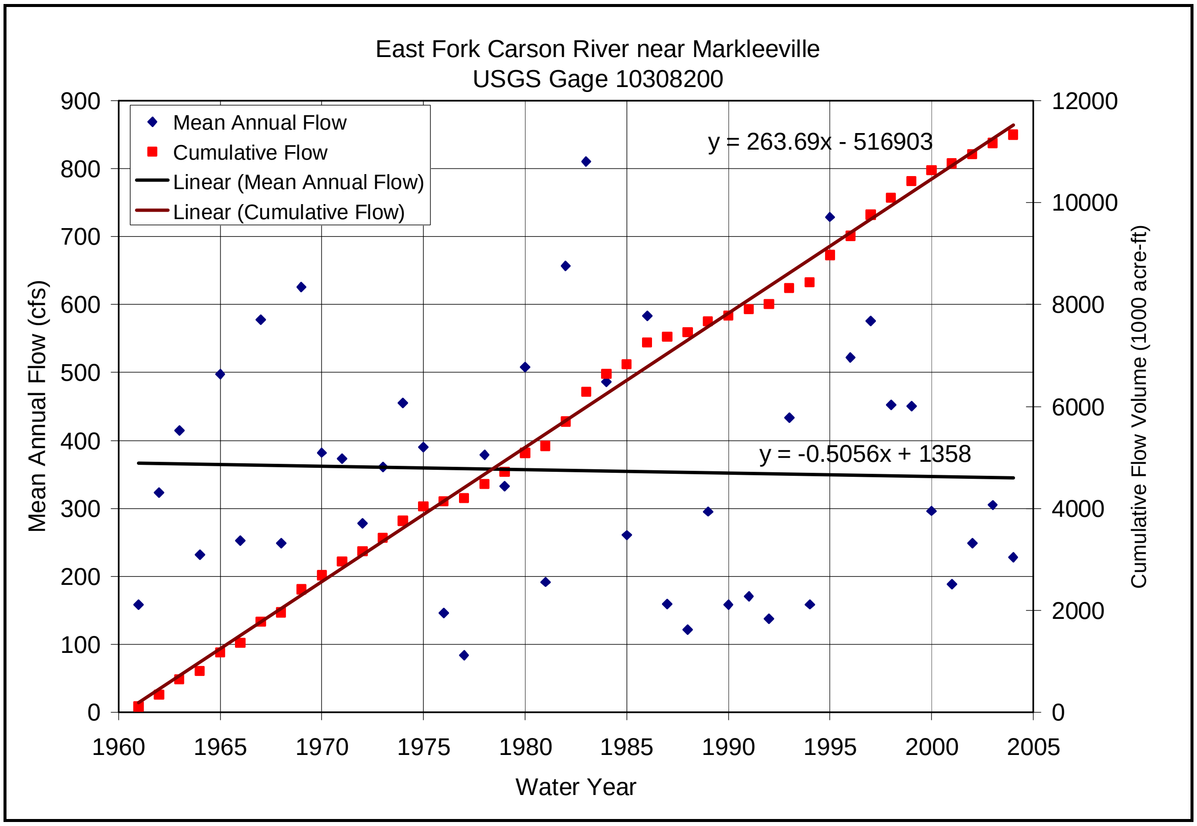

Figure D1. East Fork of the Carson River near Markleeville annual streamflow.

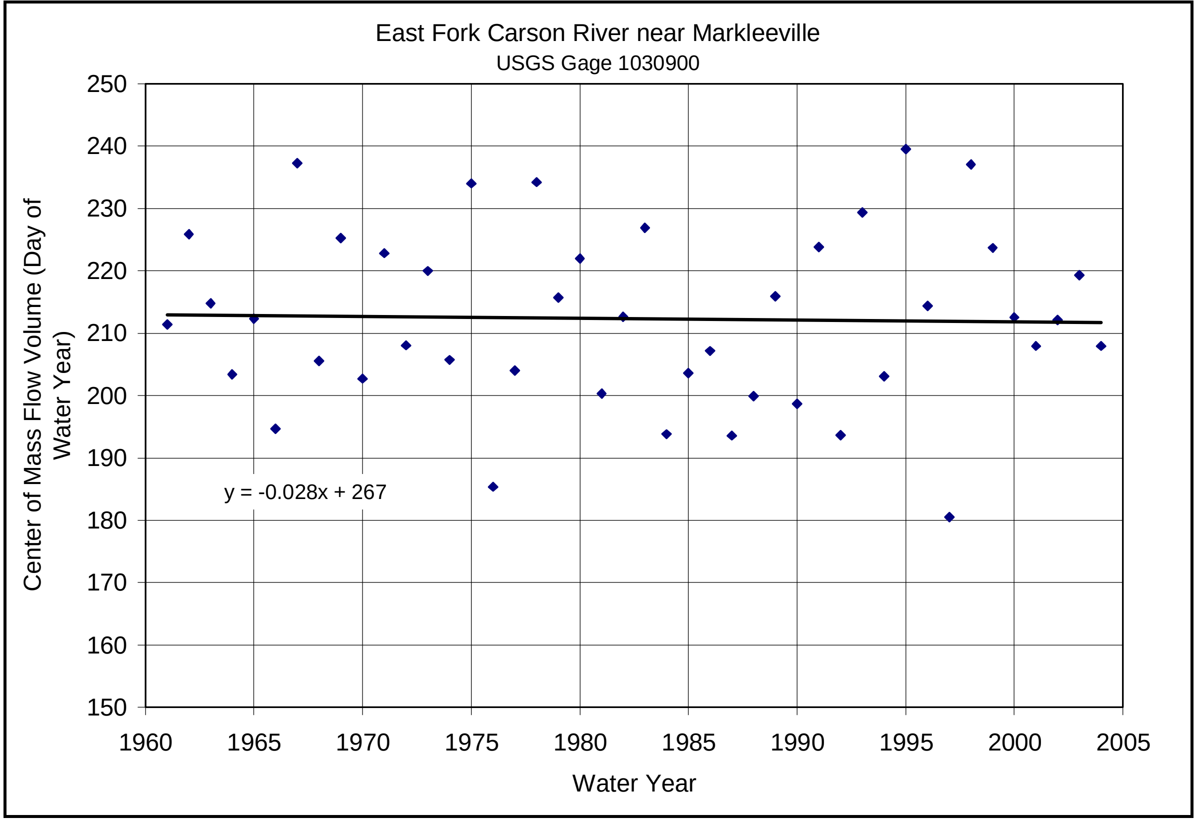

Figure D2. East Fork of the Carson River near Markleeville streamflow center of mass.

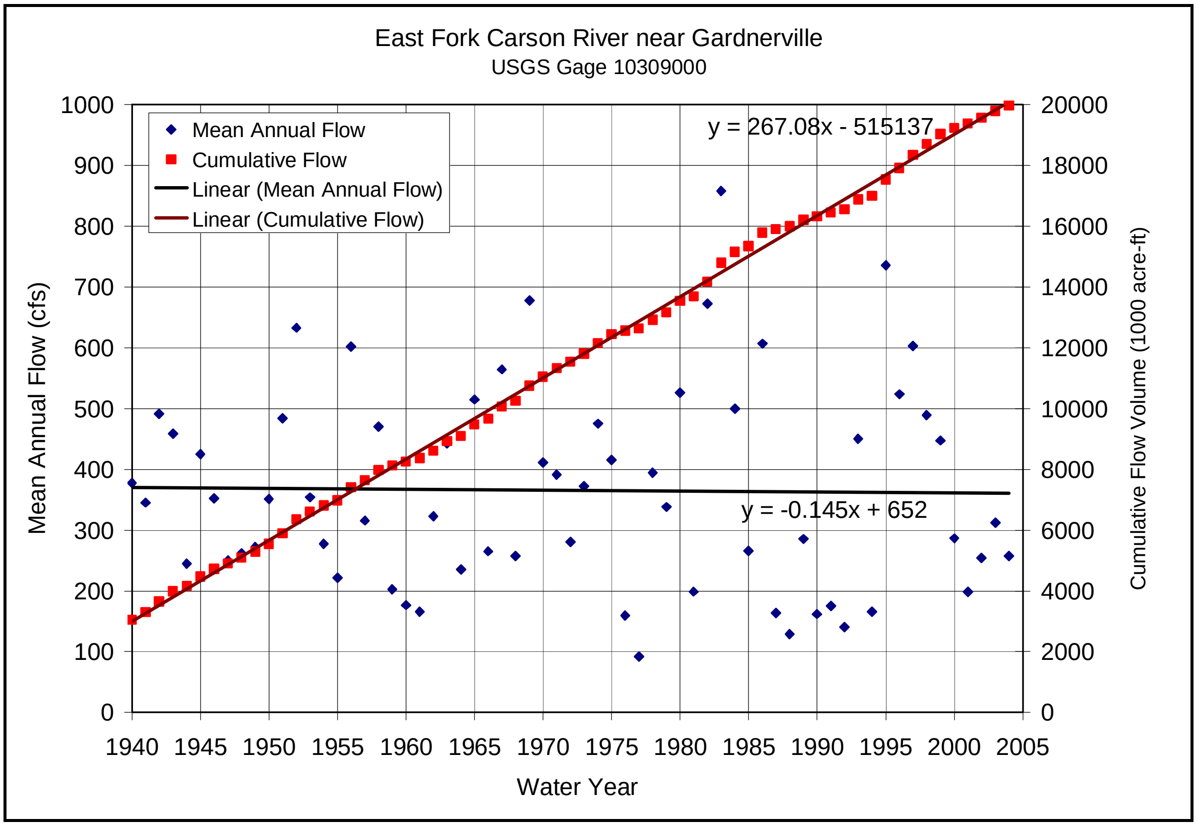

Figure D3. East Fork of the Carson River near Gardnerville annual streamflow.

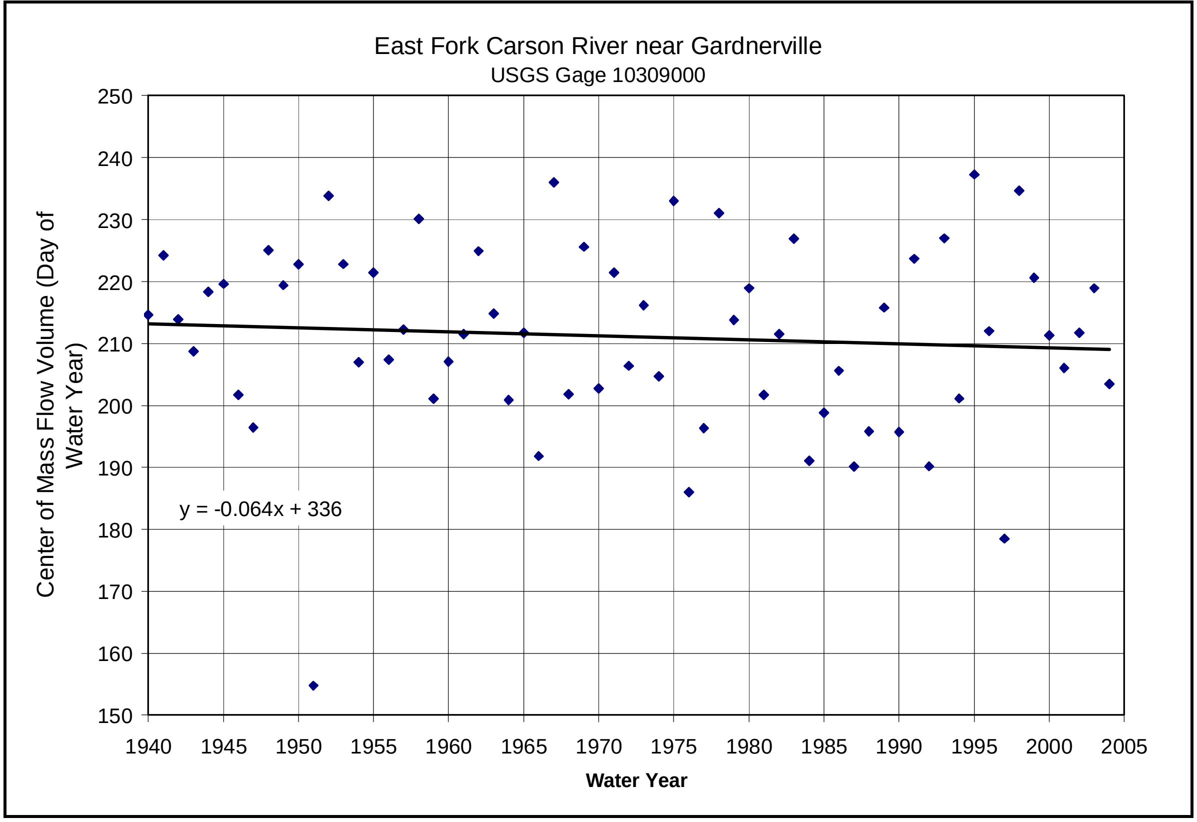

Figure D4. East Fork of the Carson River near Gardnerville streamflow center of mass.

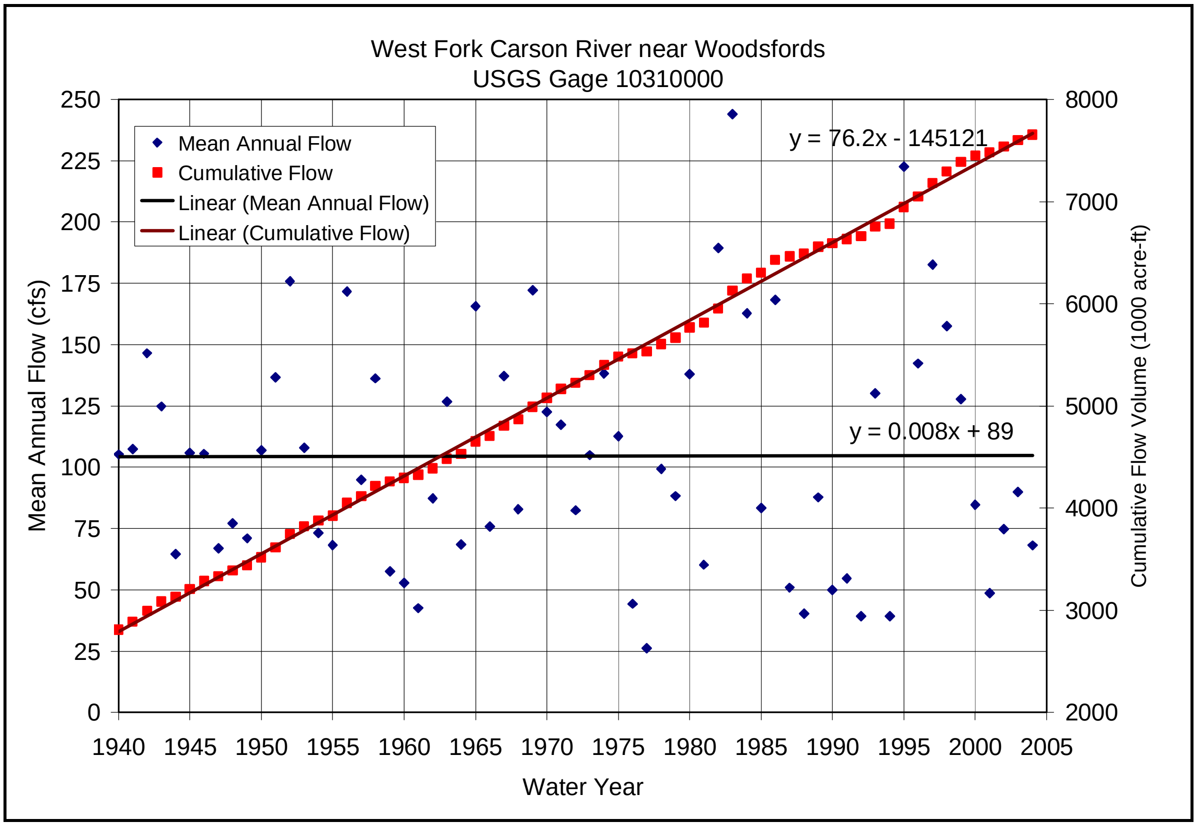

Figure D5. West Fork of the Carson River near Woodsford annual streamflow.

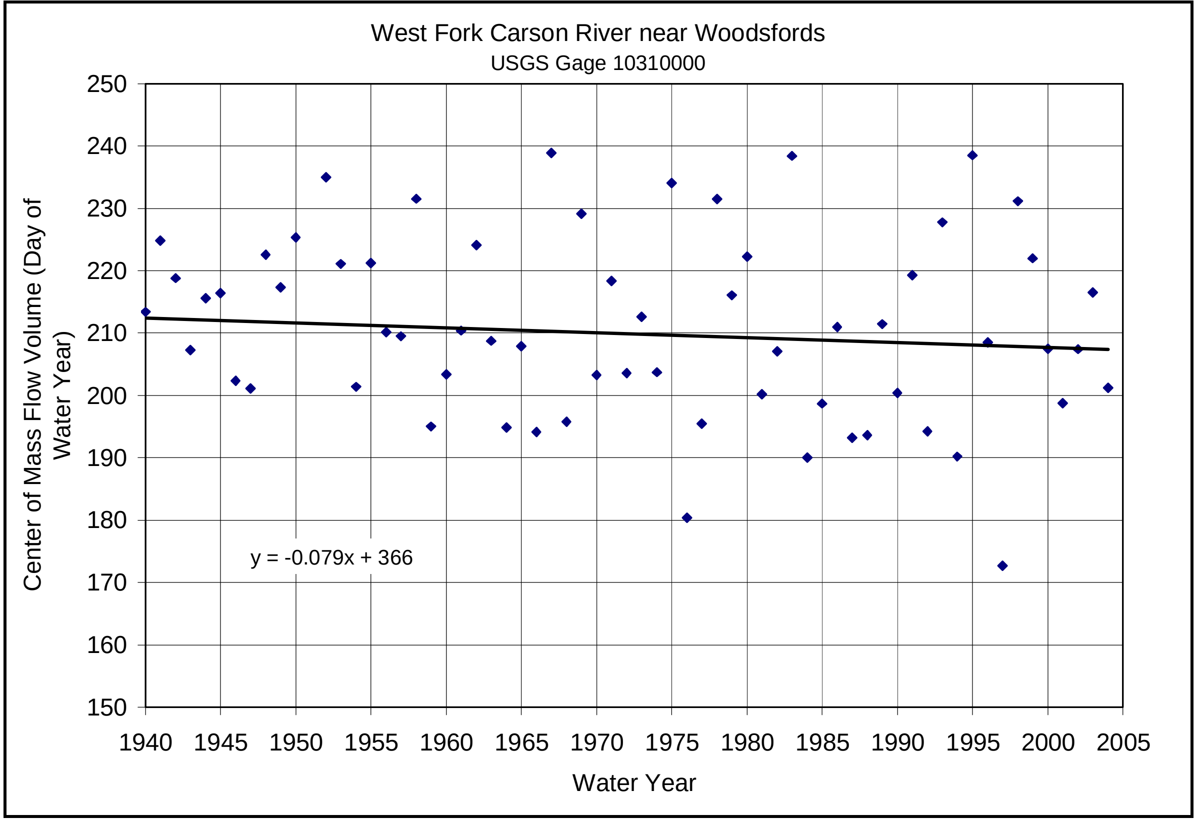

Figure D6. West Fork of the Carson River near Woodsford streamflow center of mass.

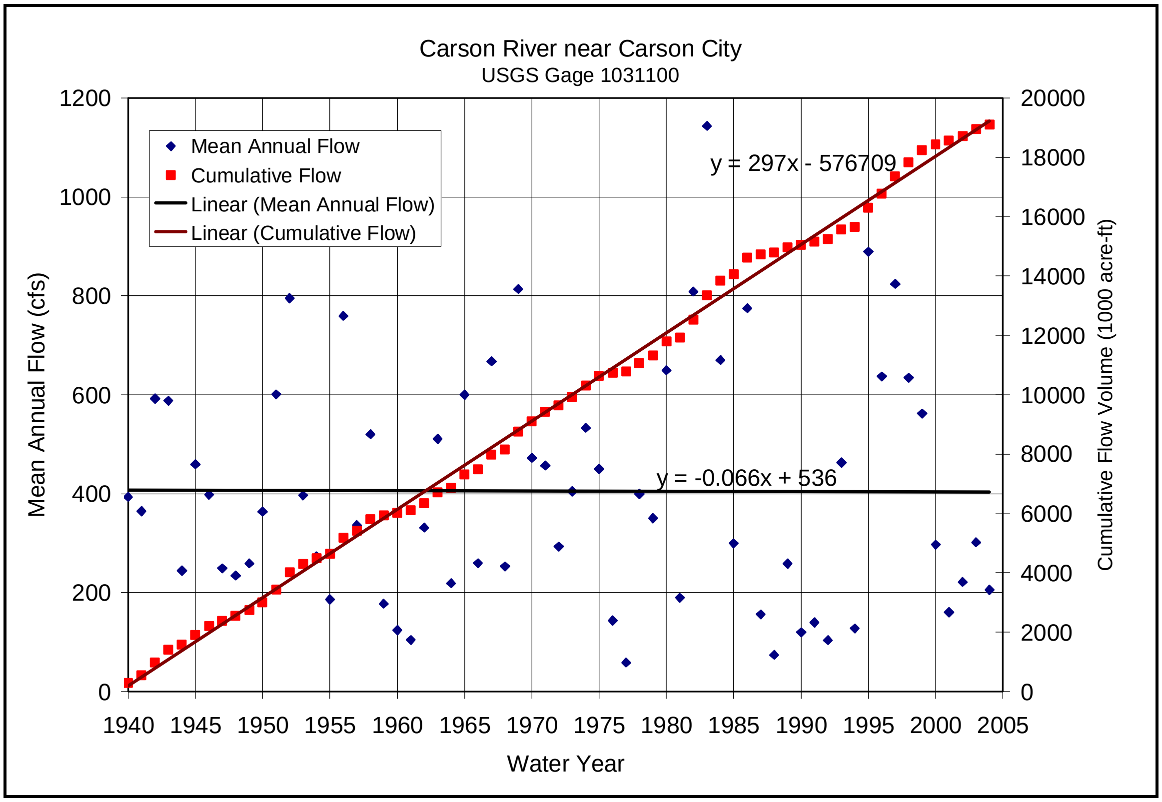

Figure D7. Carson River near Carson City annual streamflow.

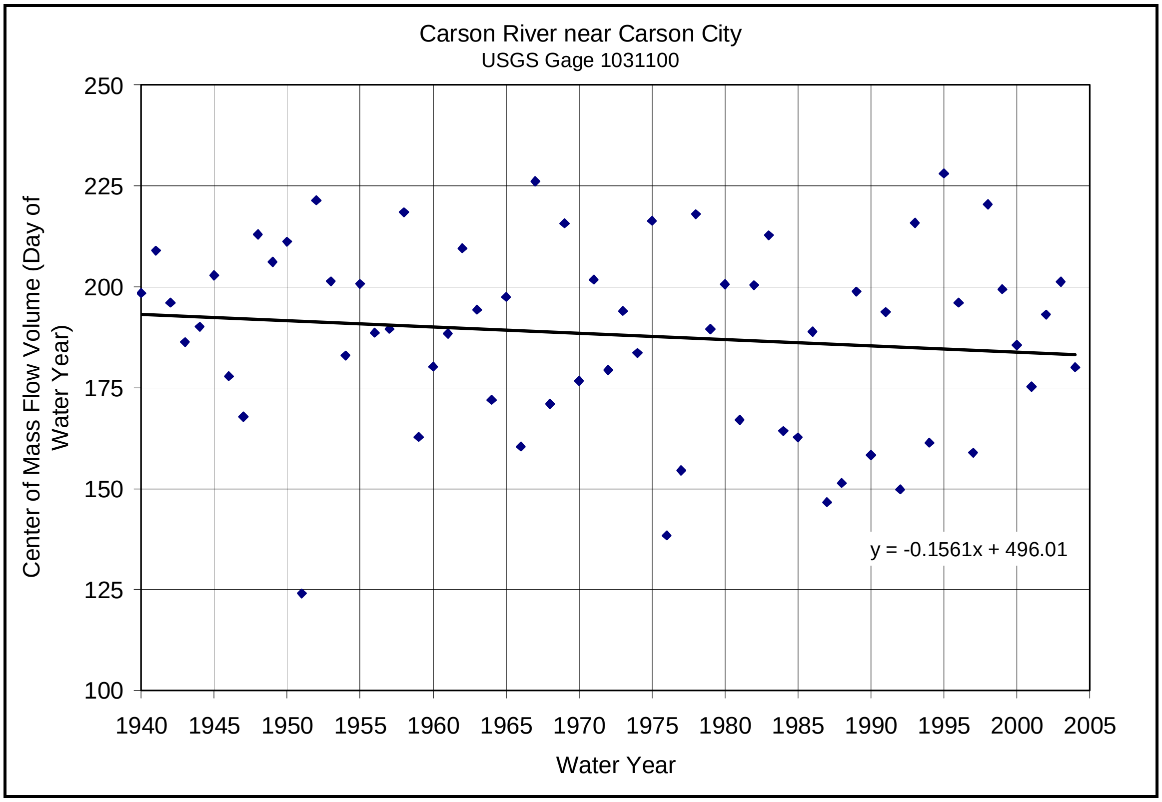

Figure D8. Carson River near Carson City streamflow center of mass.

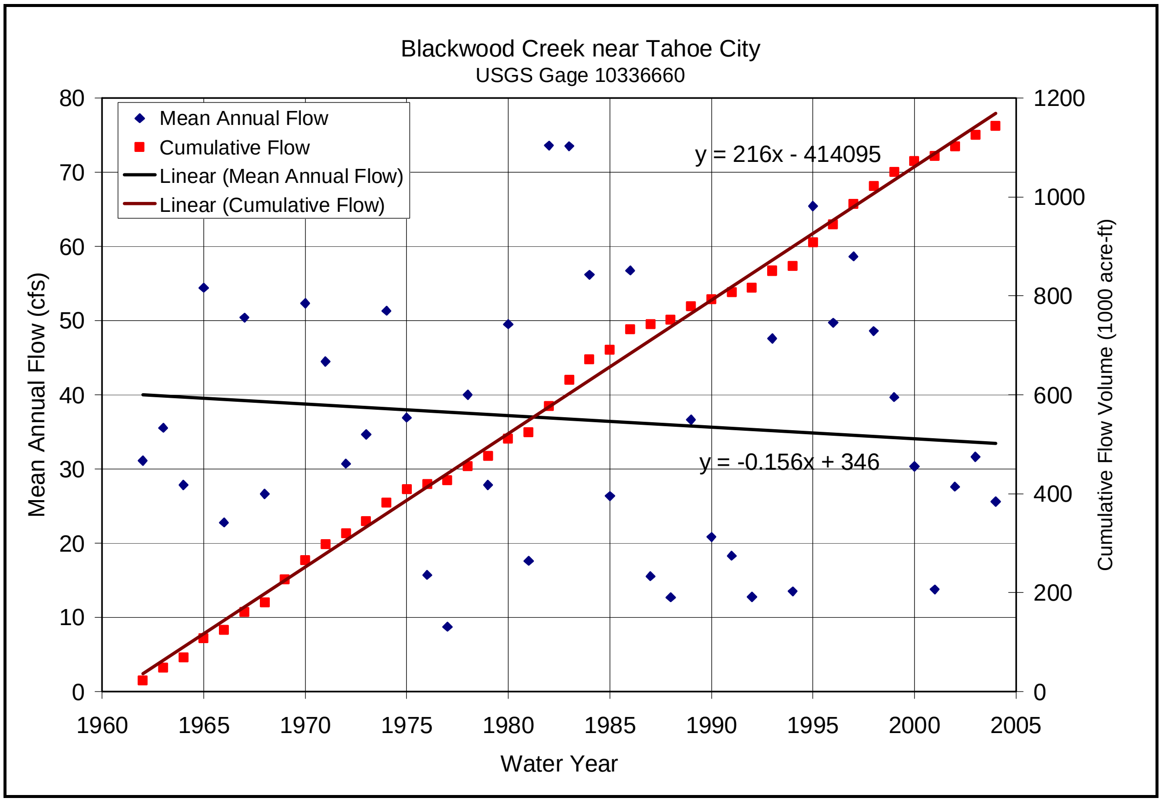

Figure D9. Blackwood Creek near Tahoe City annual streamflow.

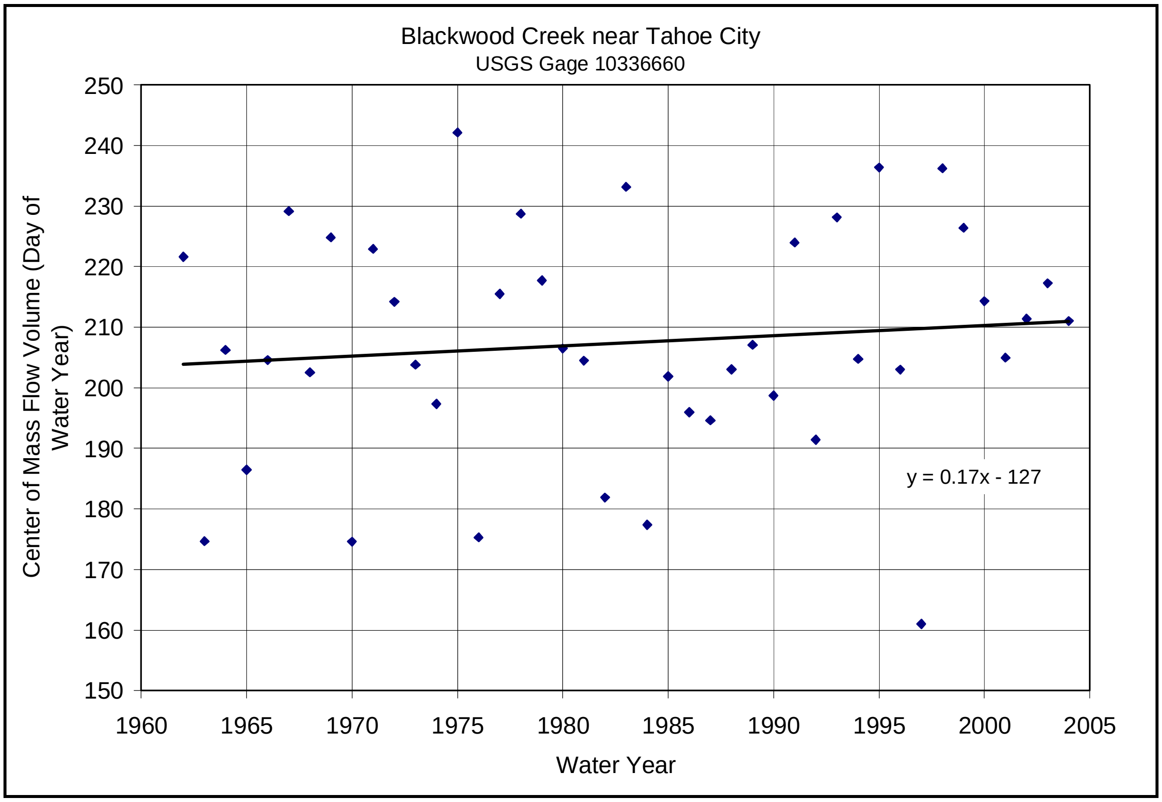

Figure D10. Blackwood Creek near Tahoe City streamflow center of mass.

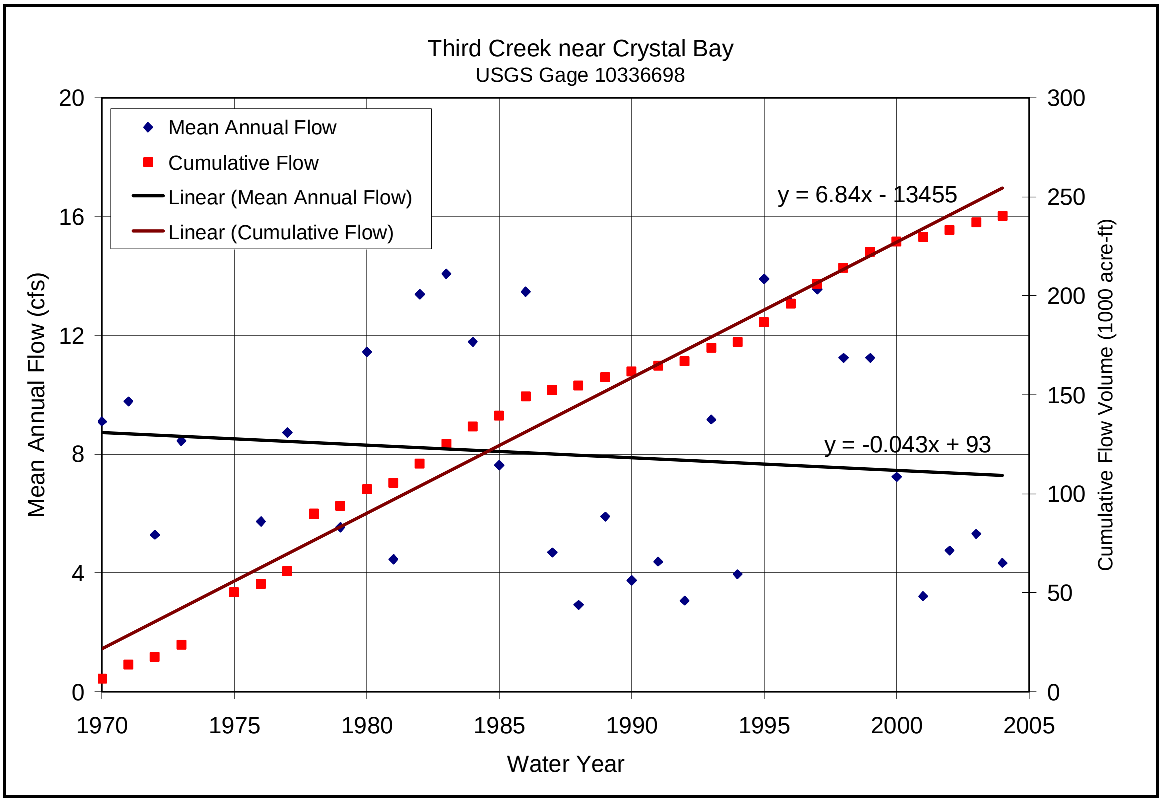

Figure D11. Third Creek near Crystal Bay annual streamflow.

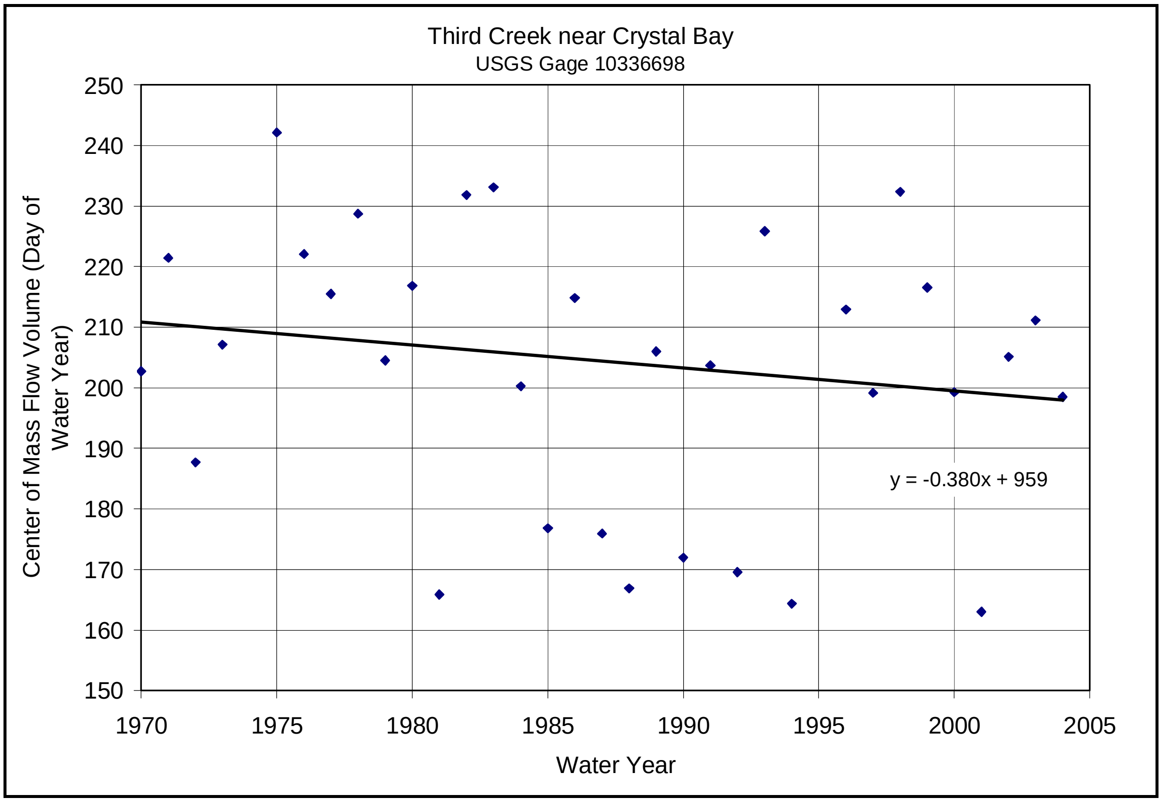

Figure D12. Third Creek near Crystal Bay streamflow center of mass.

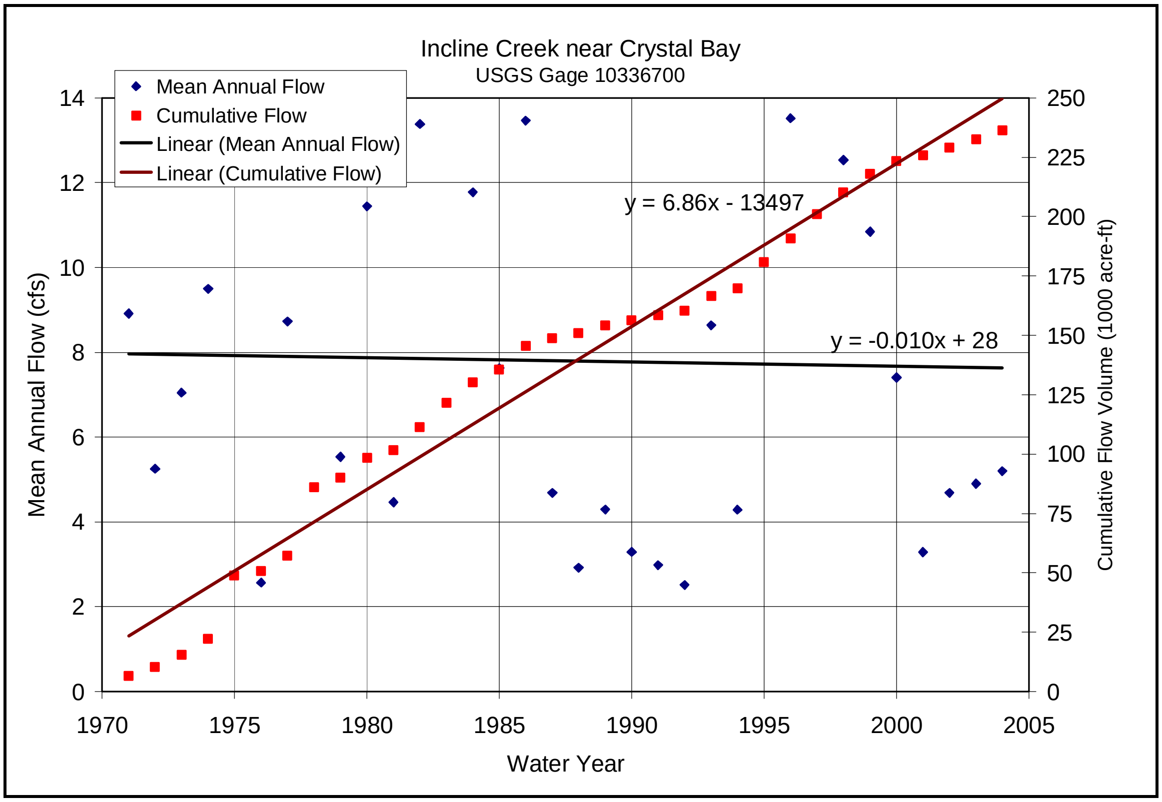

Figure D13. Incline Creek near Crystal Bay annual streamflow.

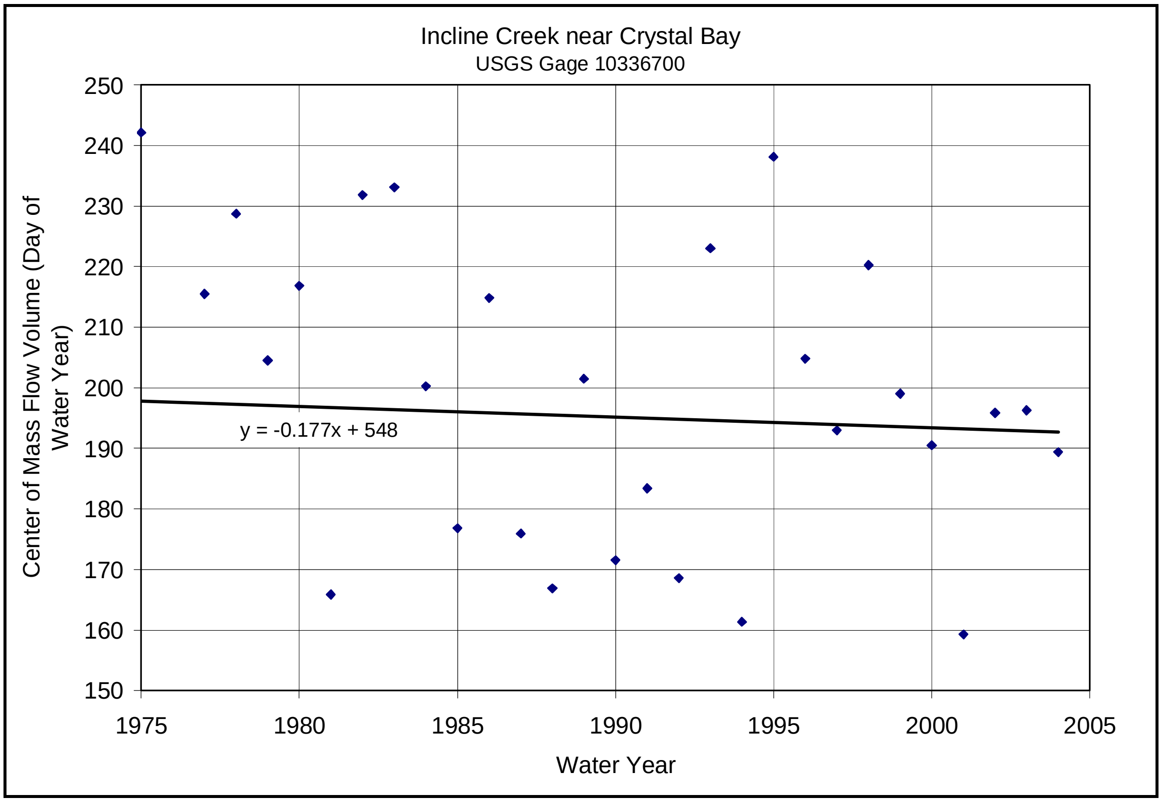

Figure D14. Incline Creek near Crystal Bay streamflow center of mass.

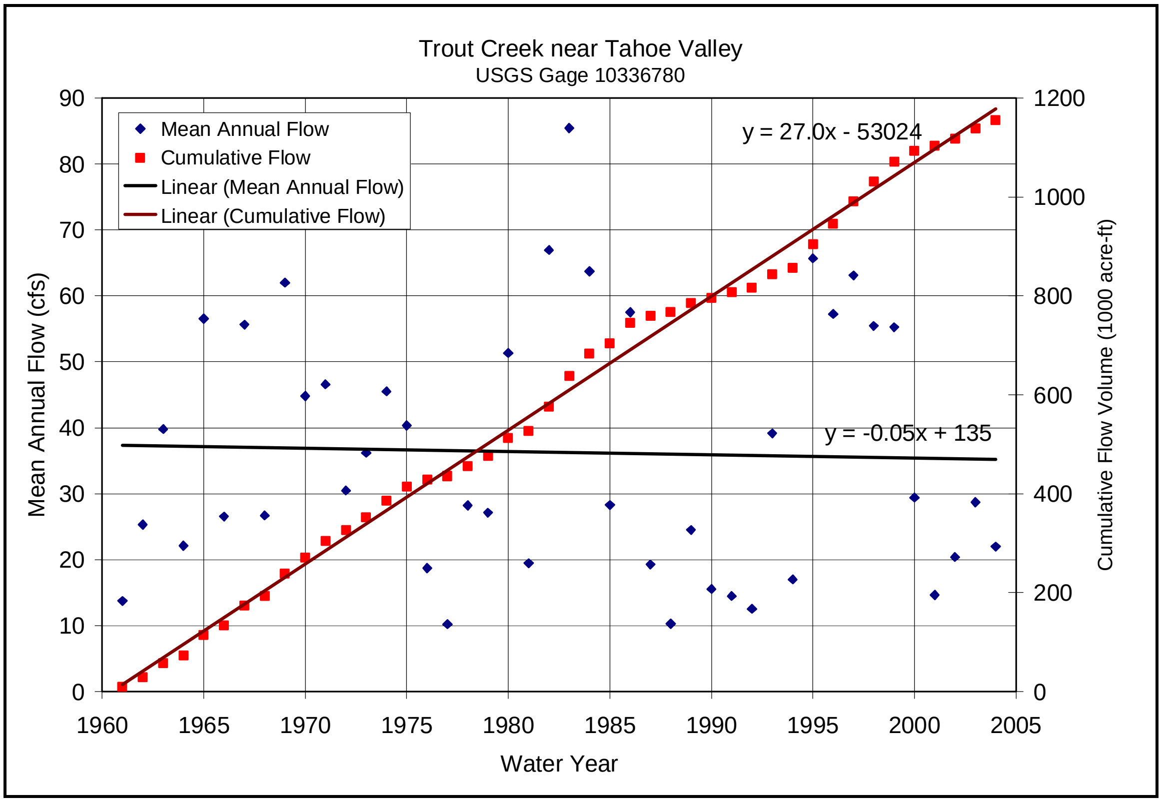

Figure D15. Trout Creek near Tahoe Valley annual streamflow.

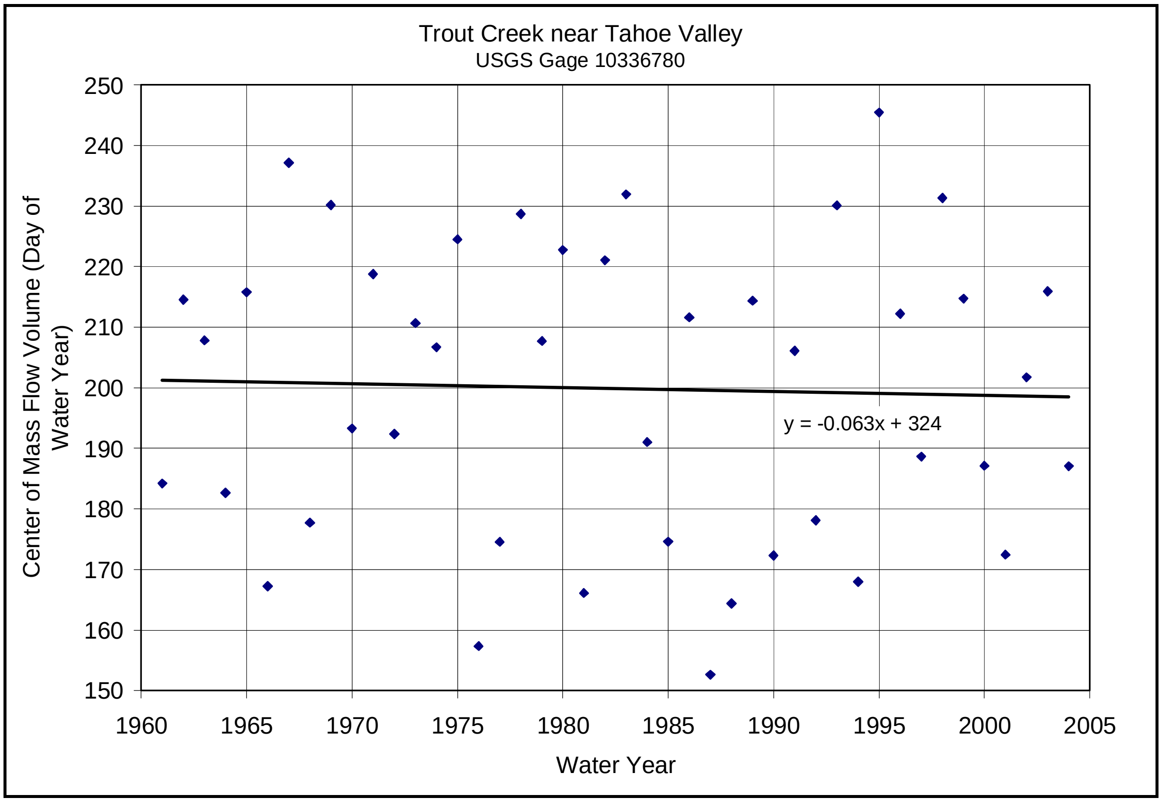

Figure D16. Trout Creek near Tahoe Valley streamflow center of mass.

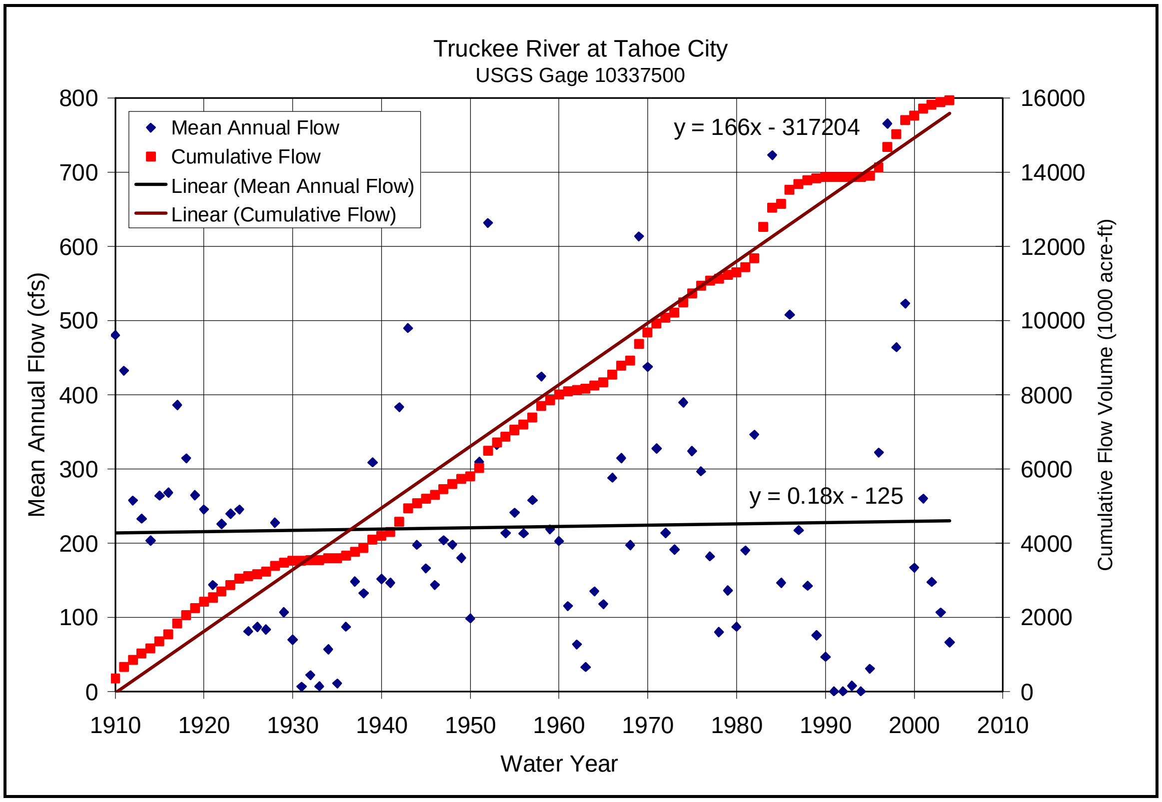

Figure D17. Truckee River at Tahoe City annual streamflow.

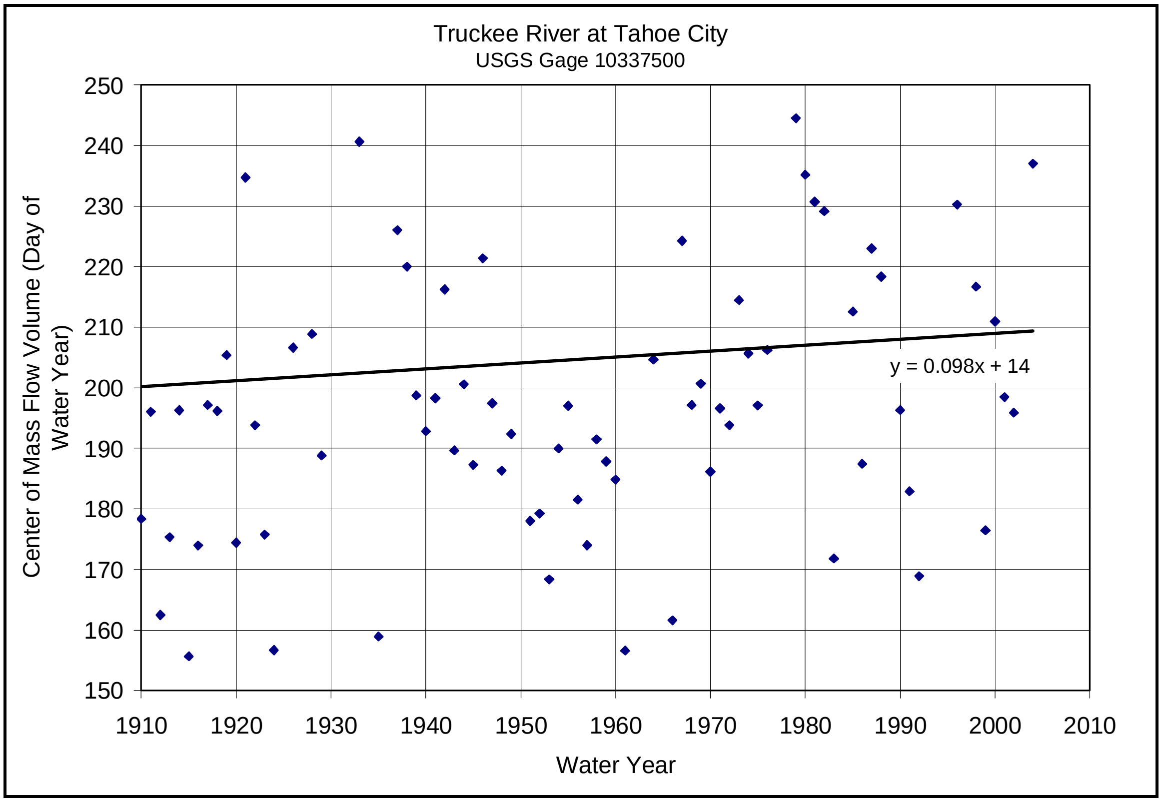

Figure D18. Truckee River at Tahoe City streamflow center of mass.

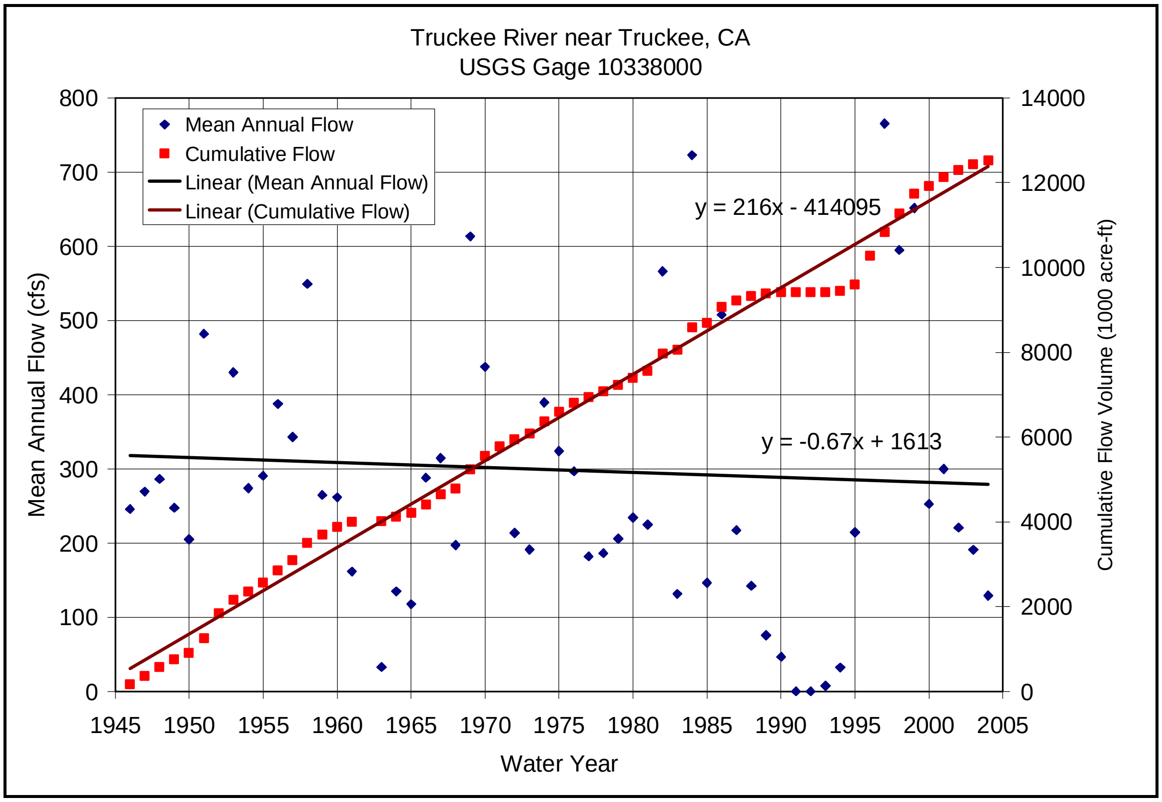

Figure D19. Truckee River near Truckee, CA annual streamflow.

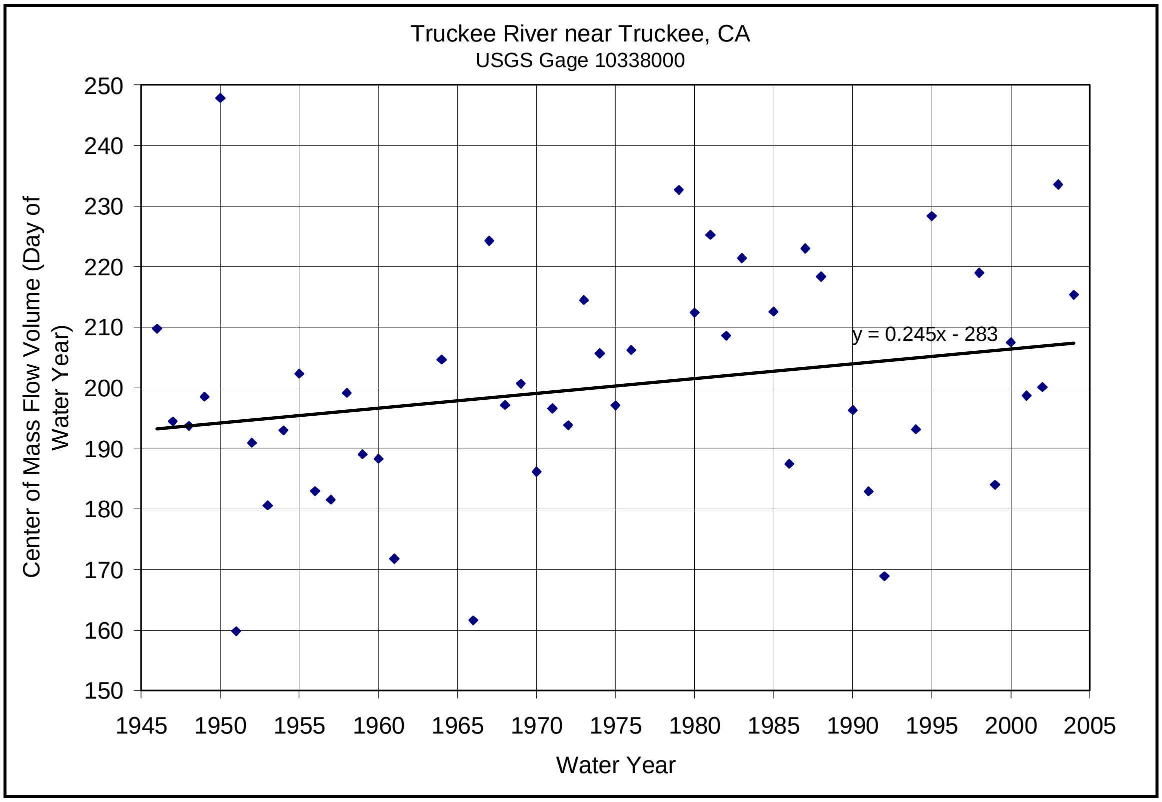

Figure D20. Truckee River near Truckee, CA streamflow center of mass.

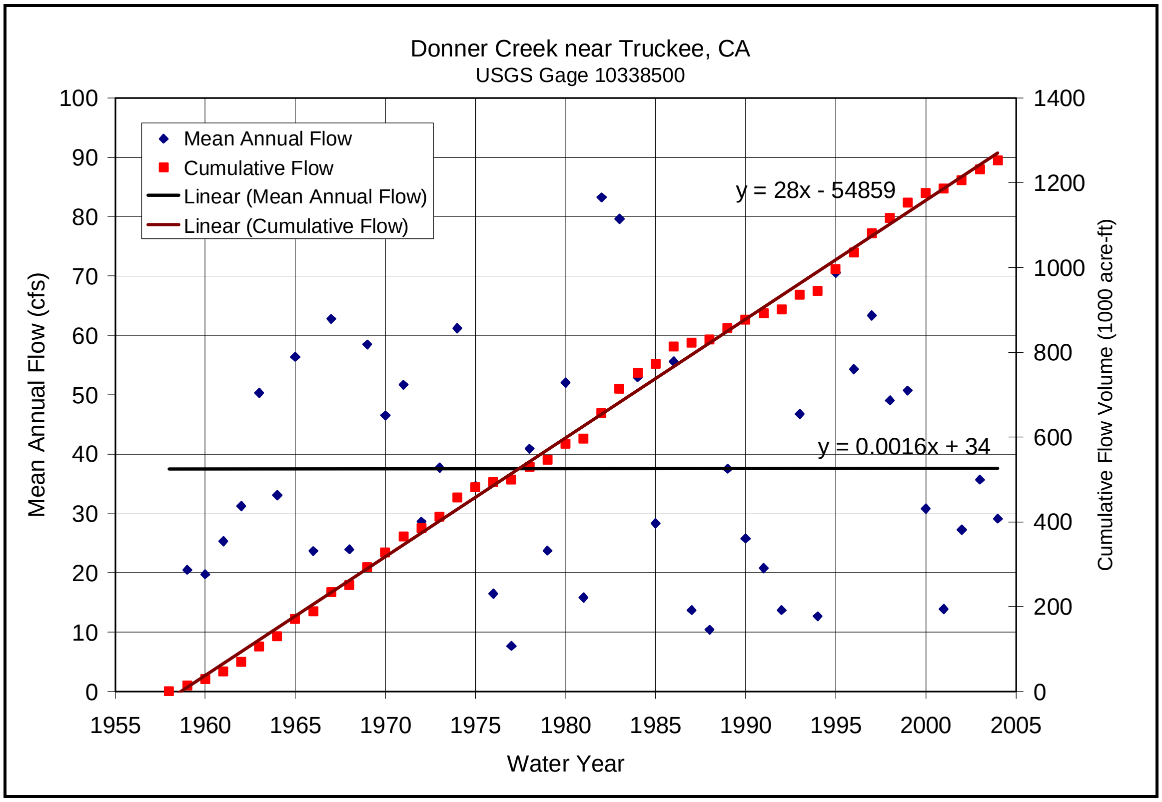

Figure D21. Donner Creek near Truckee, CA annual streamflow.

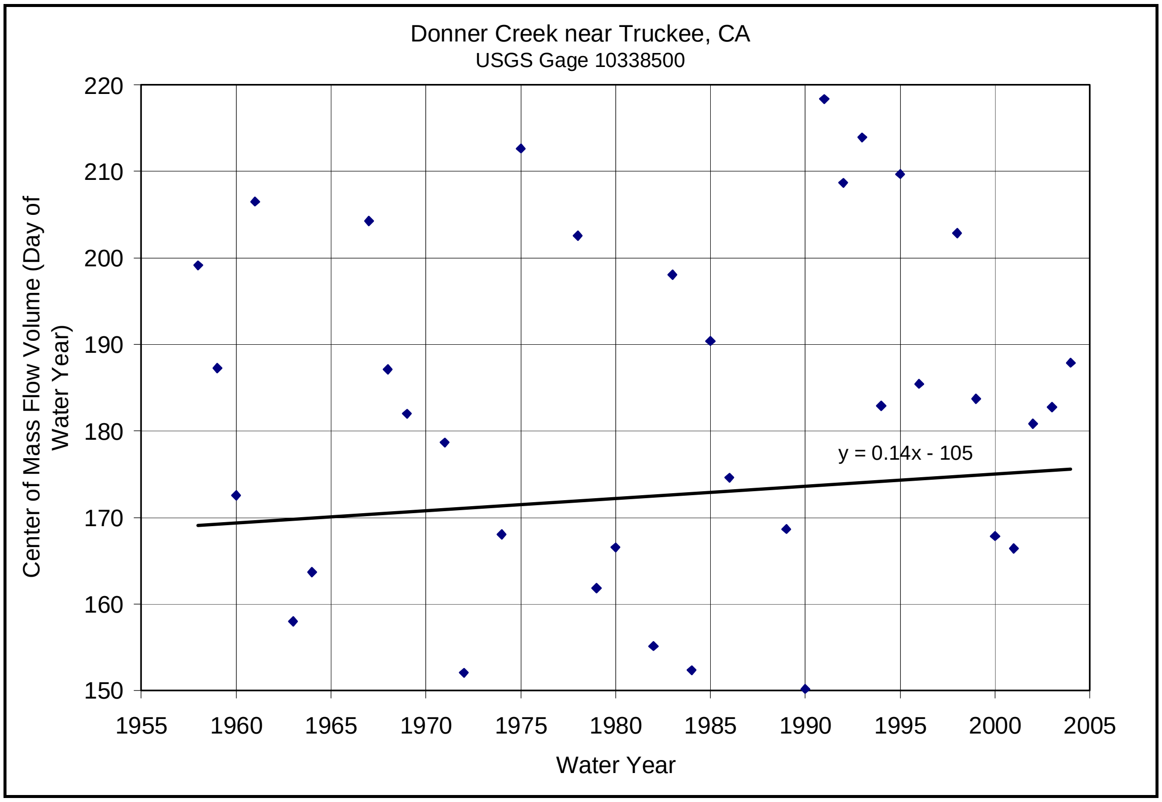

Figure D22. Donner Creek near Truckee, CA streamflow center of mass.

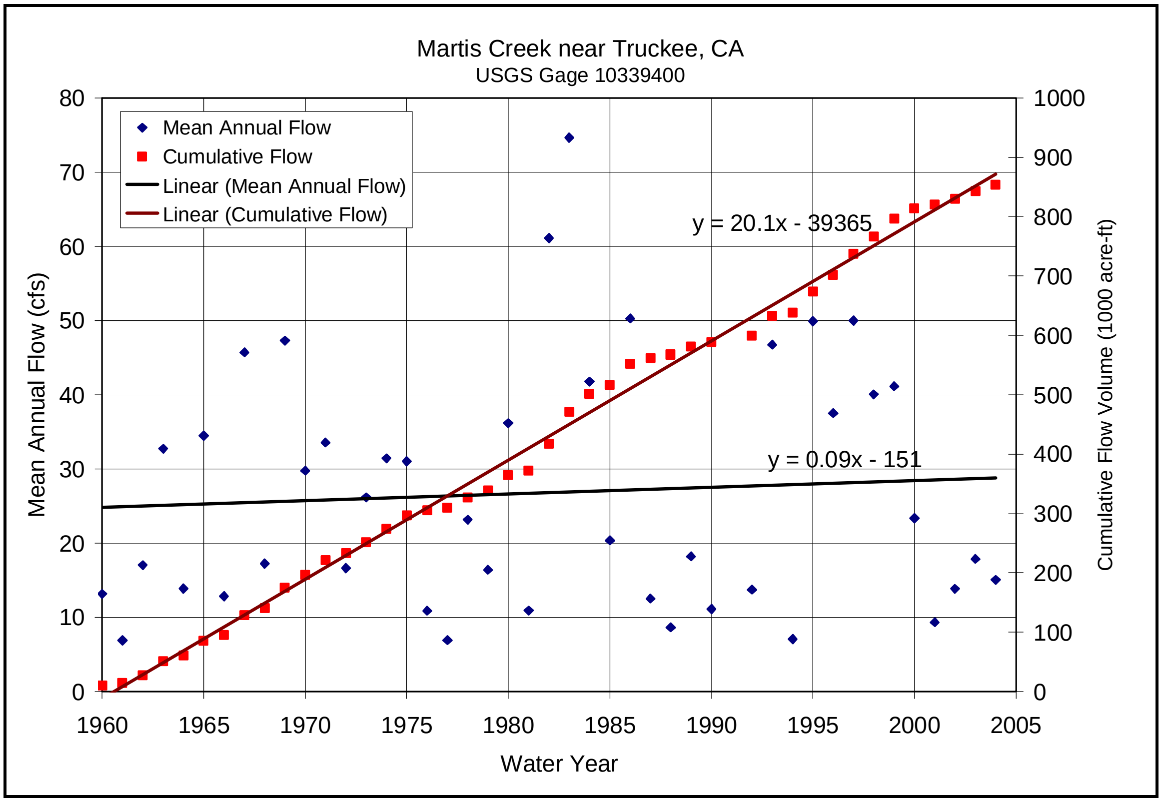

Figure D23. Martis Creek near Truckee, CA annual streamflow.

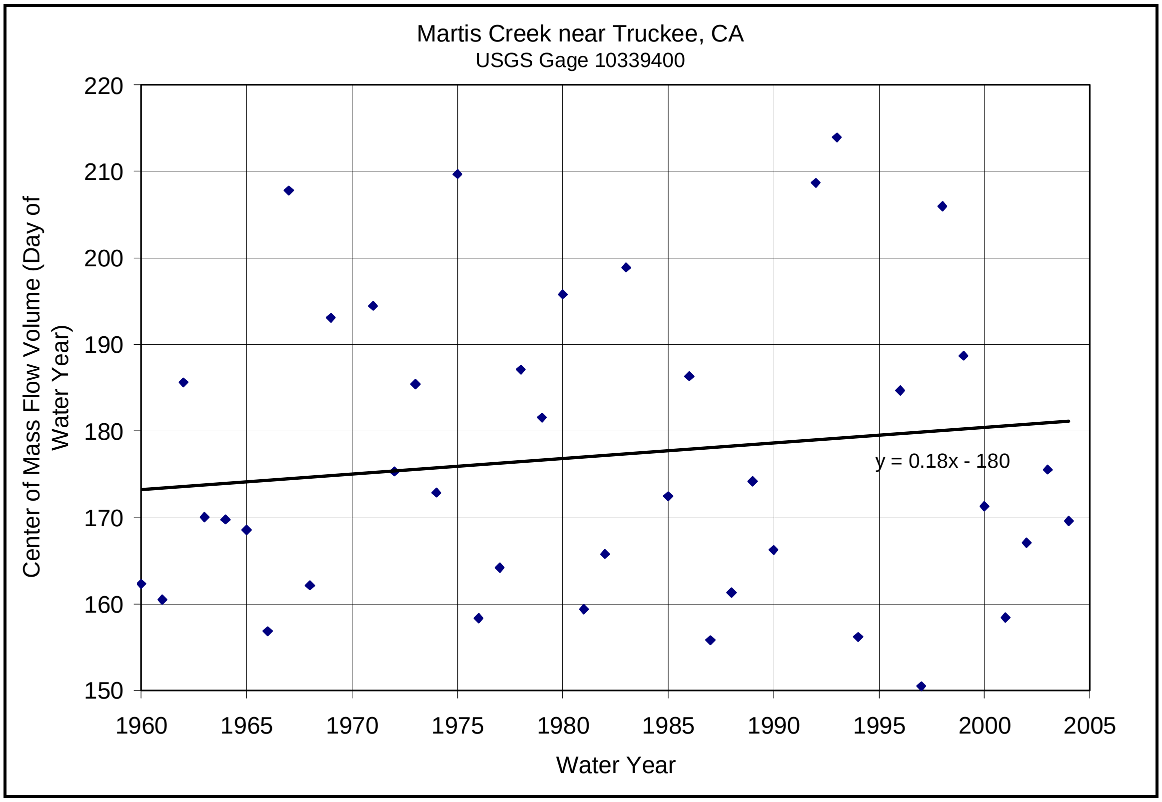

Figure D24. Martis Creek near Truckee, CA streamflow center of mass.

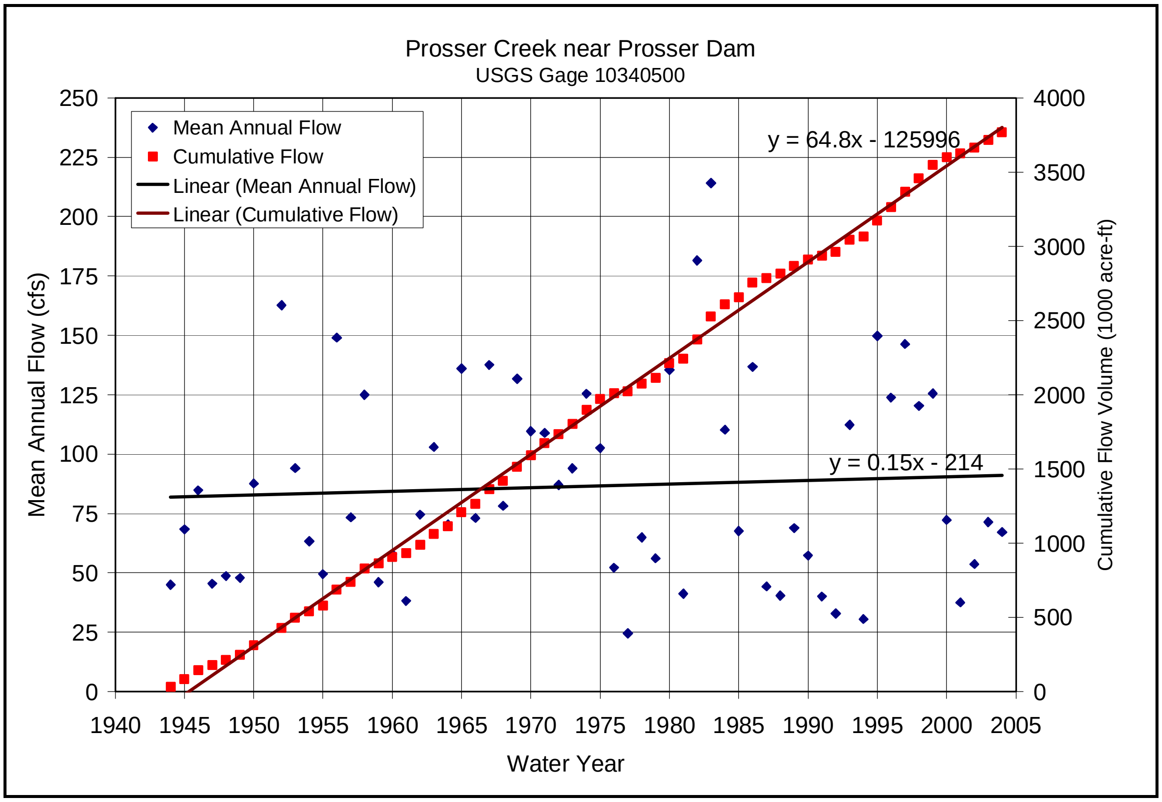

Figure D25. Prosser Creek near Prosser Dam annual streamflow.

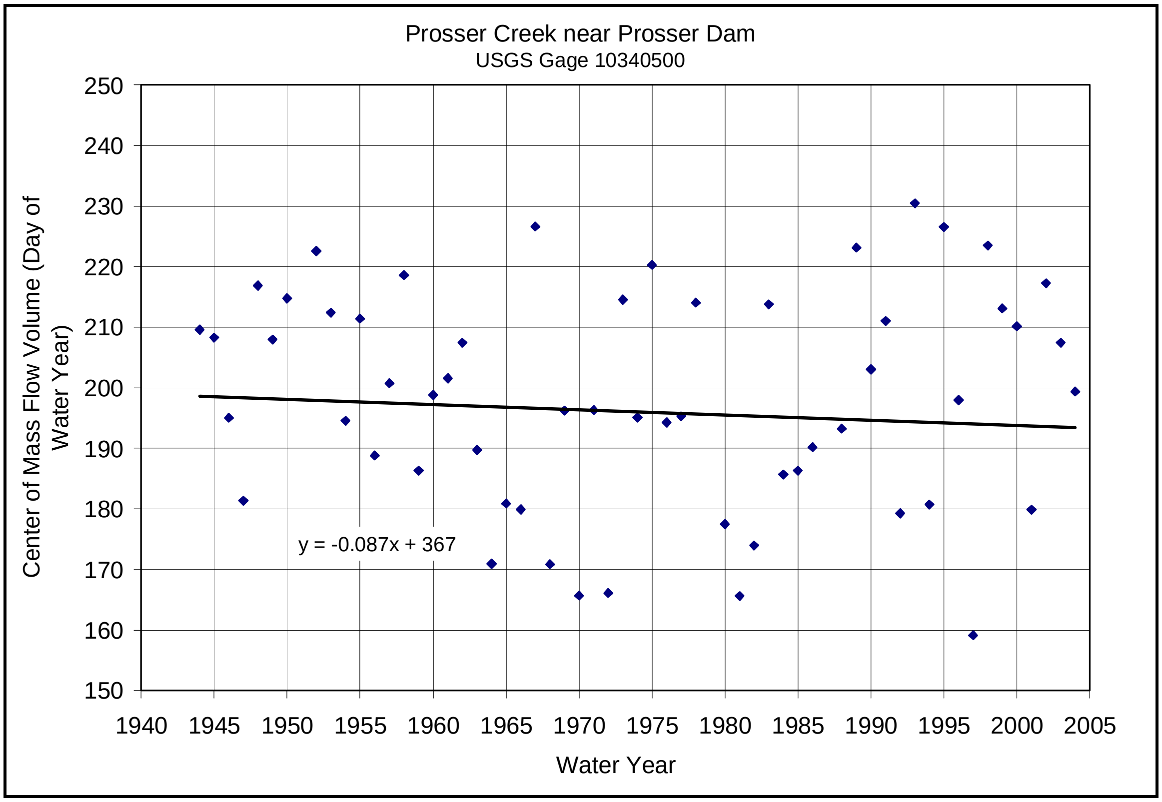

Figure D26. Prosser Creek near Prosser Dam streamflow center of mass.

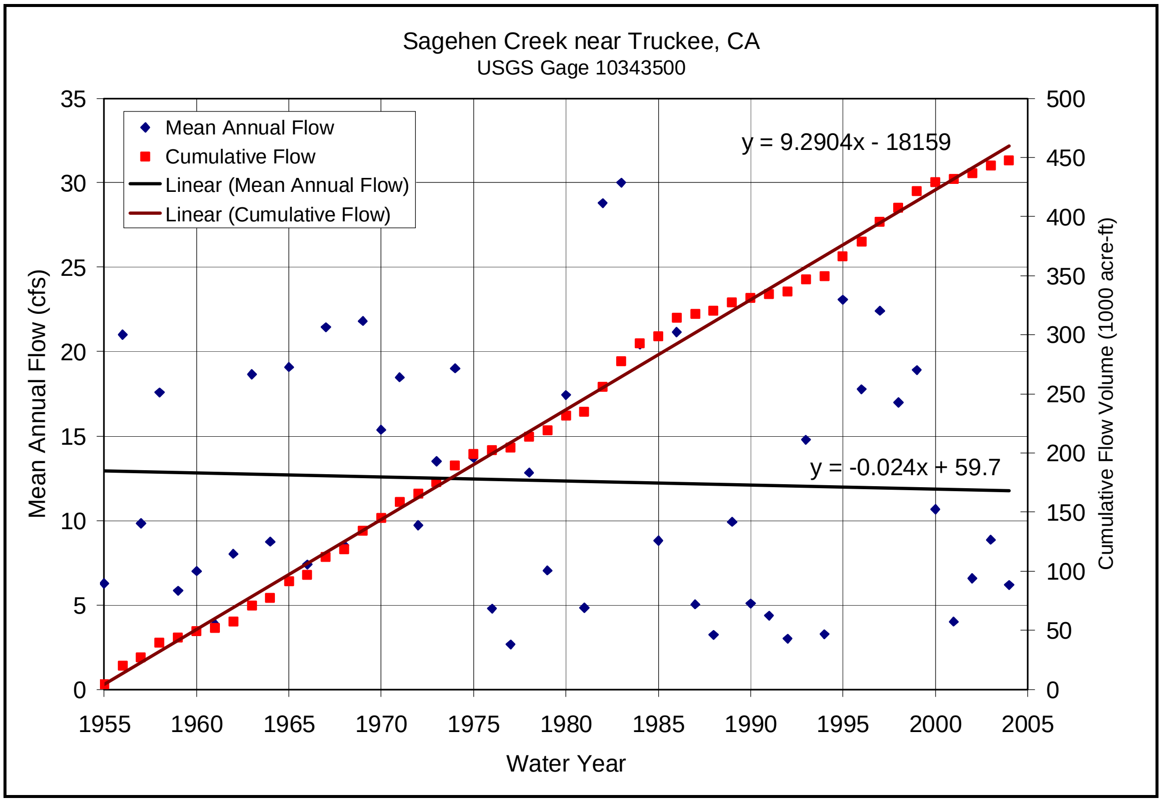

Figure D27. Sagehen Creek near Truckee, CA annual streamflow.

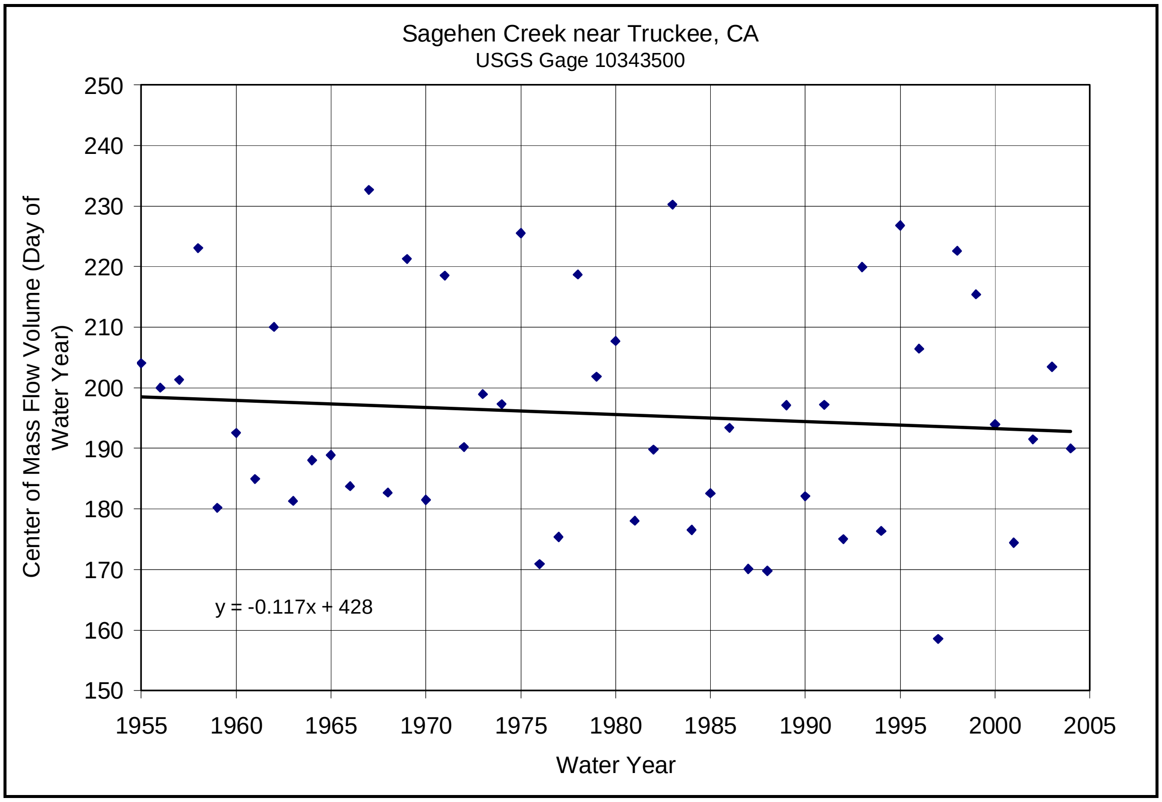

Figure D28. Sagehen Creek near Truckee, CA streamflow center of mass.

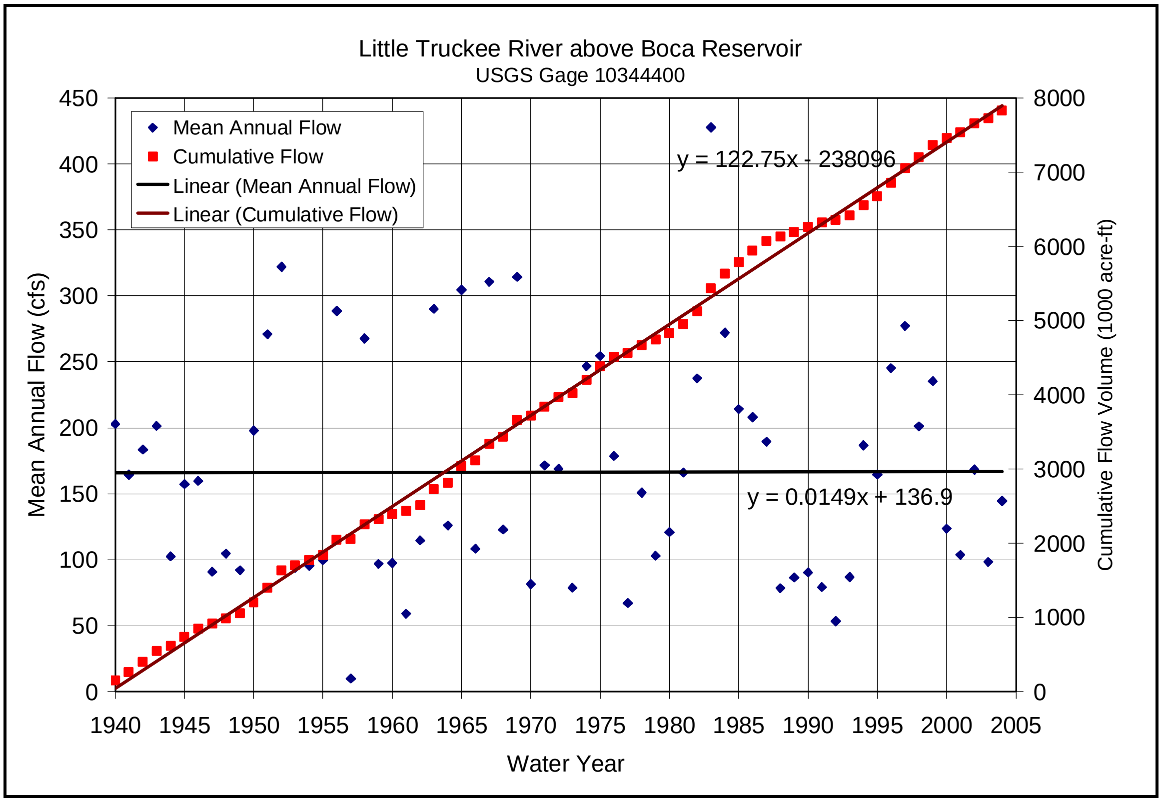

Figure D29. Little Truckee River above Boca Reservoir annual streamflow.

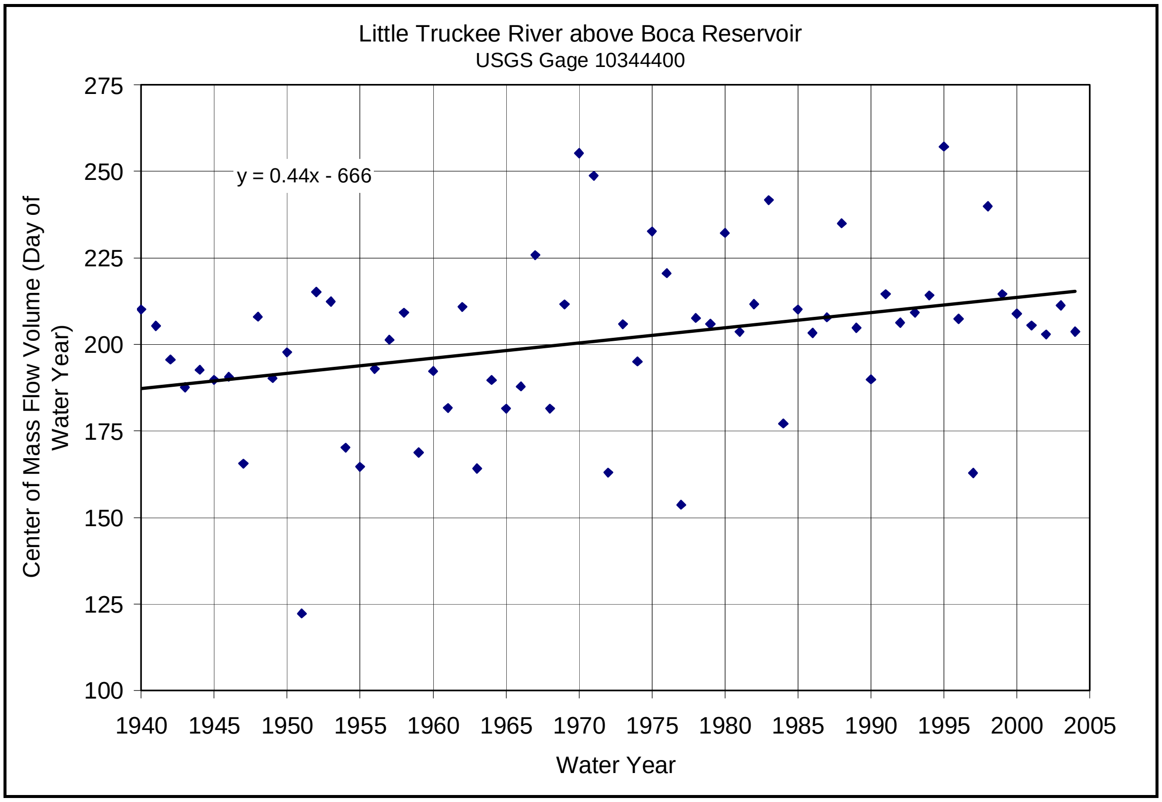

Figure D30. Little Truckee River above Boca Reservoir streamflow center of mass.

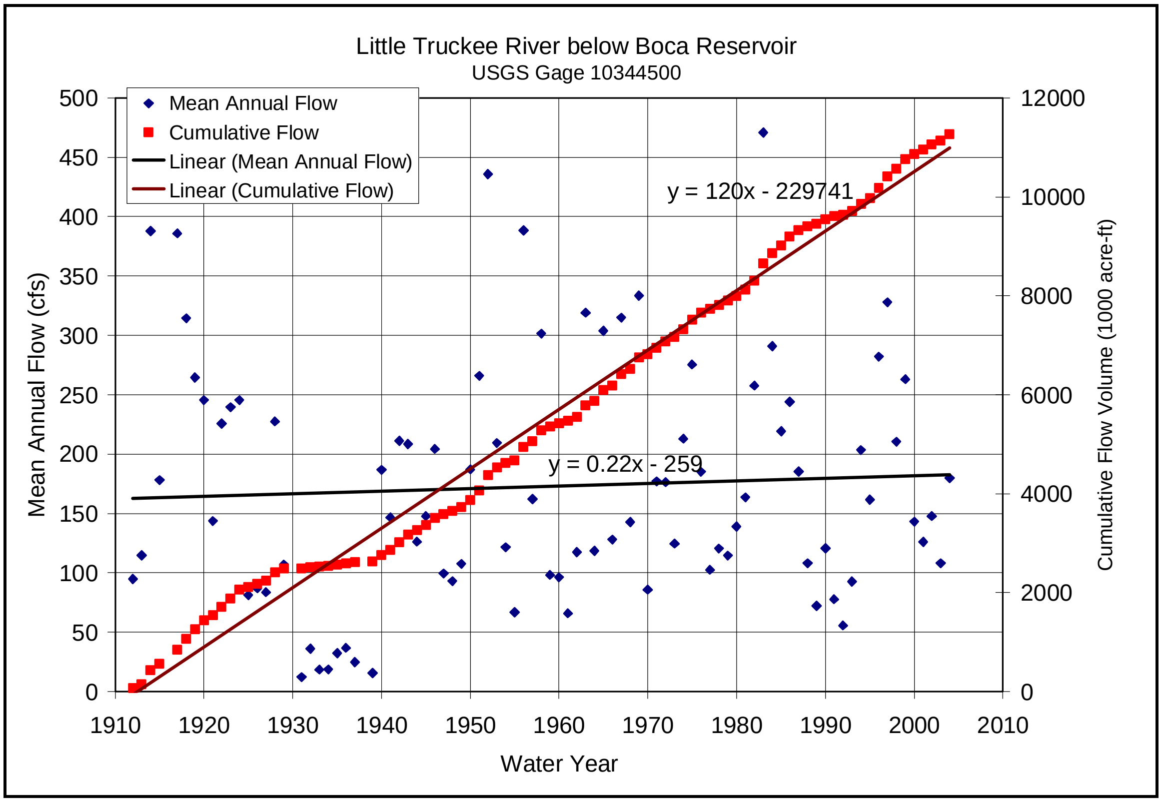

Figure D31. Little Truckee River below Boca Reservoir annual streamflow.

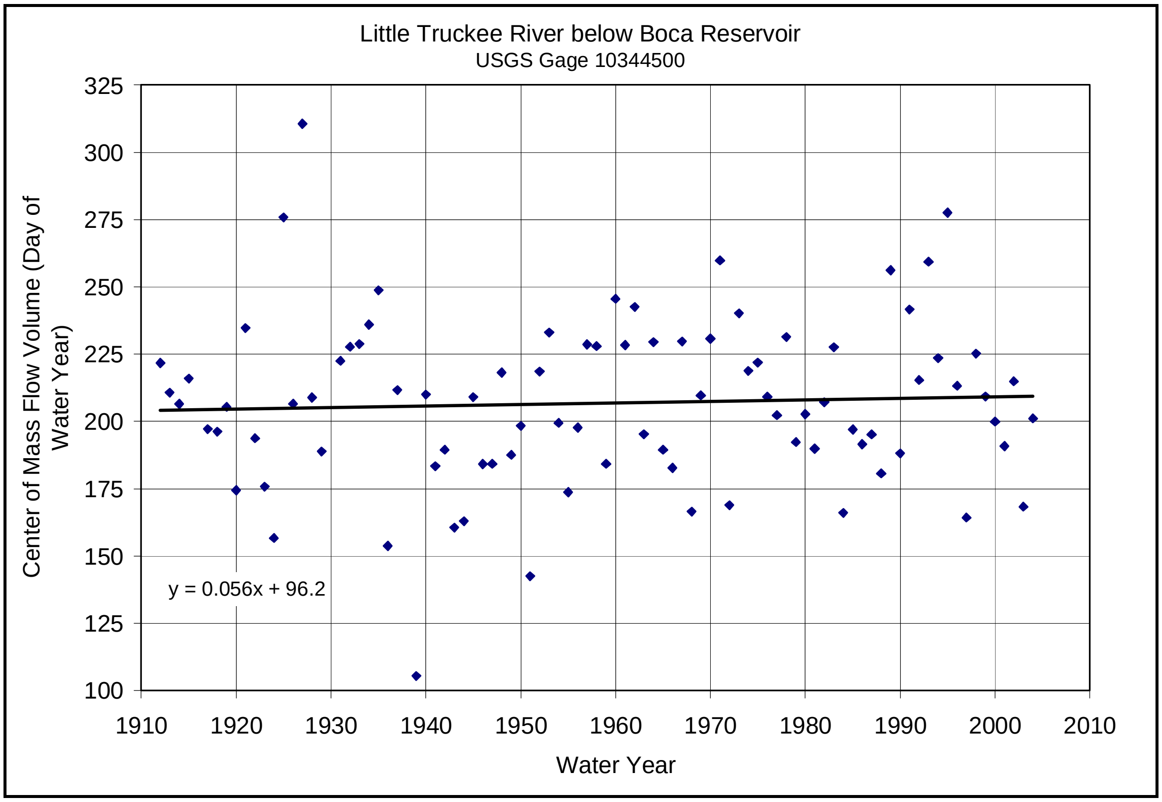

Figure D32. Little Truckee River below Boca Reservoir streamflow center of mass.

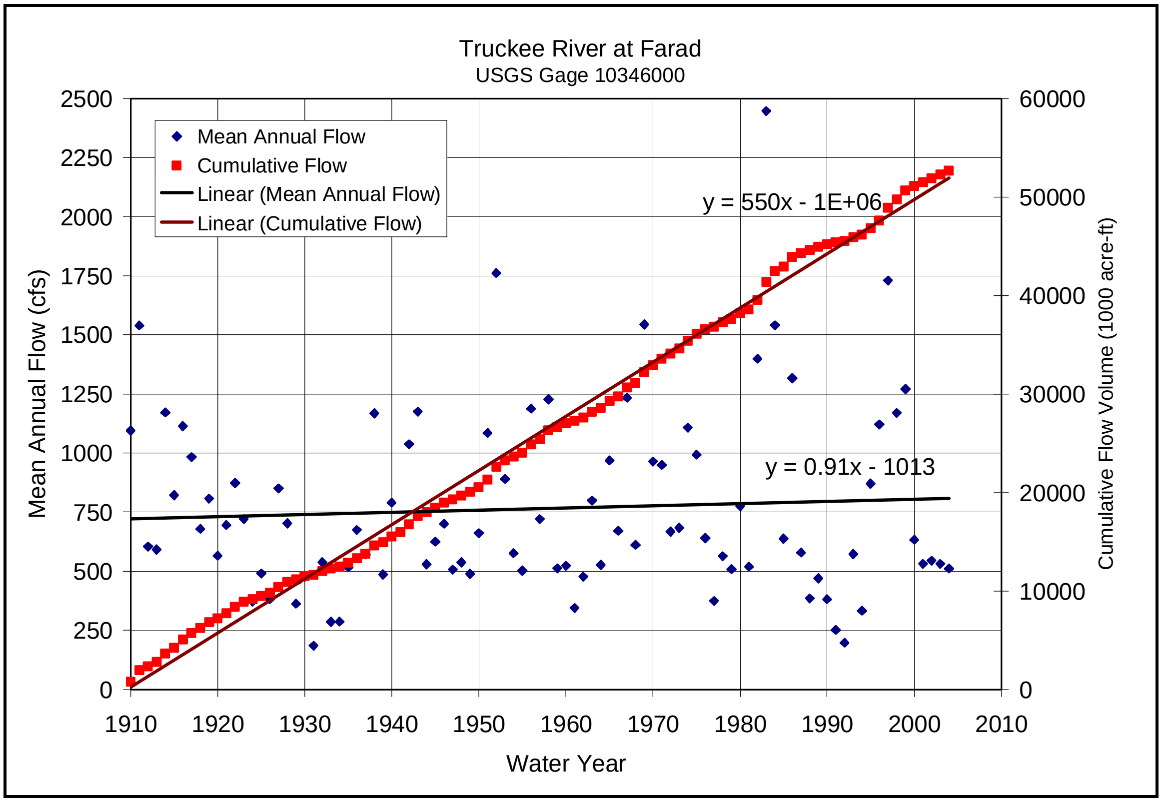

Figure D33. Truckee River at Farad annual streamflow.

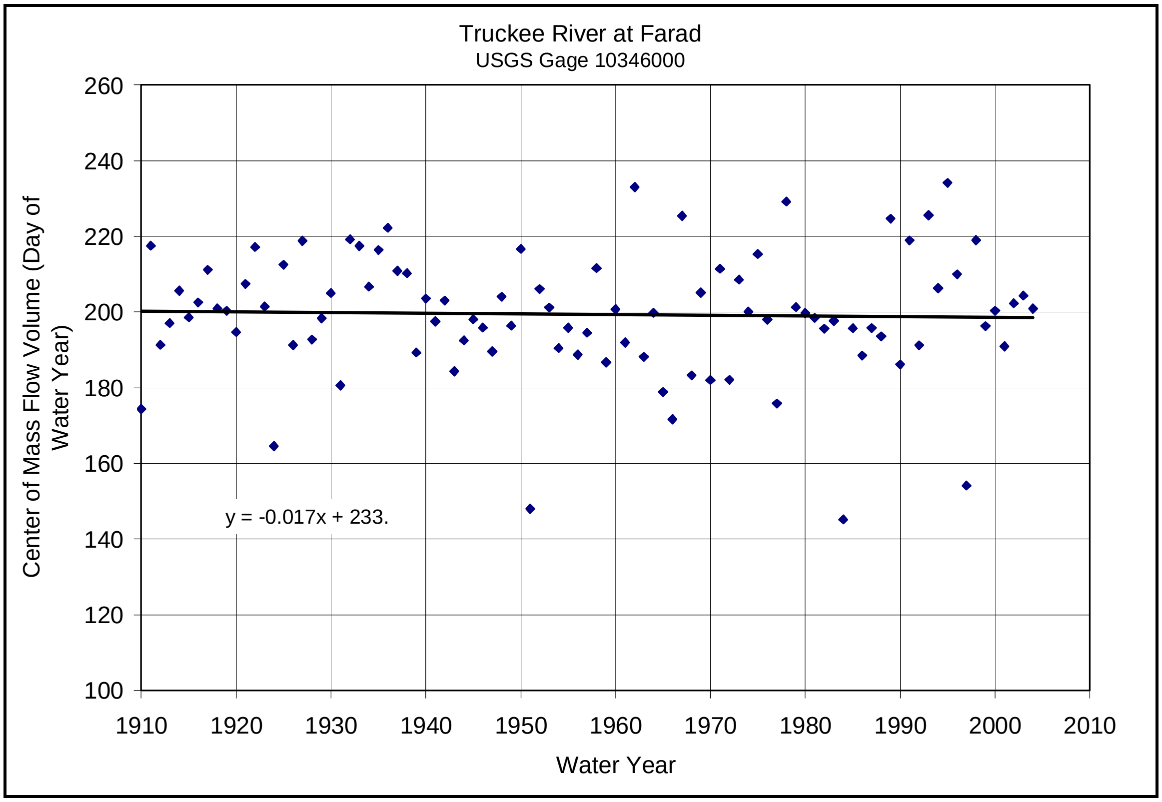

Figure D34. Truckee River at Farad streamflow center of mass.

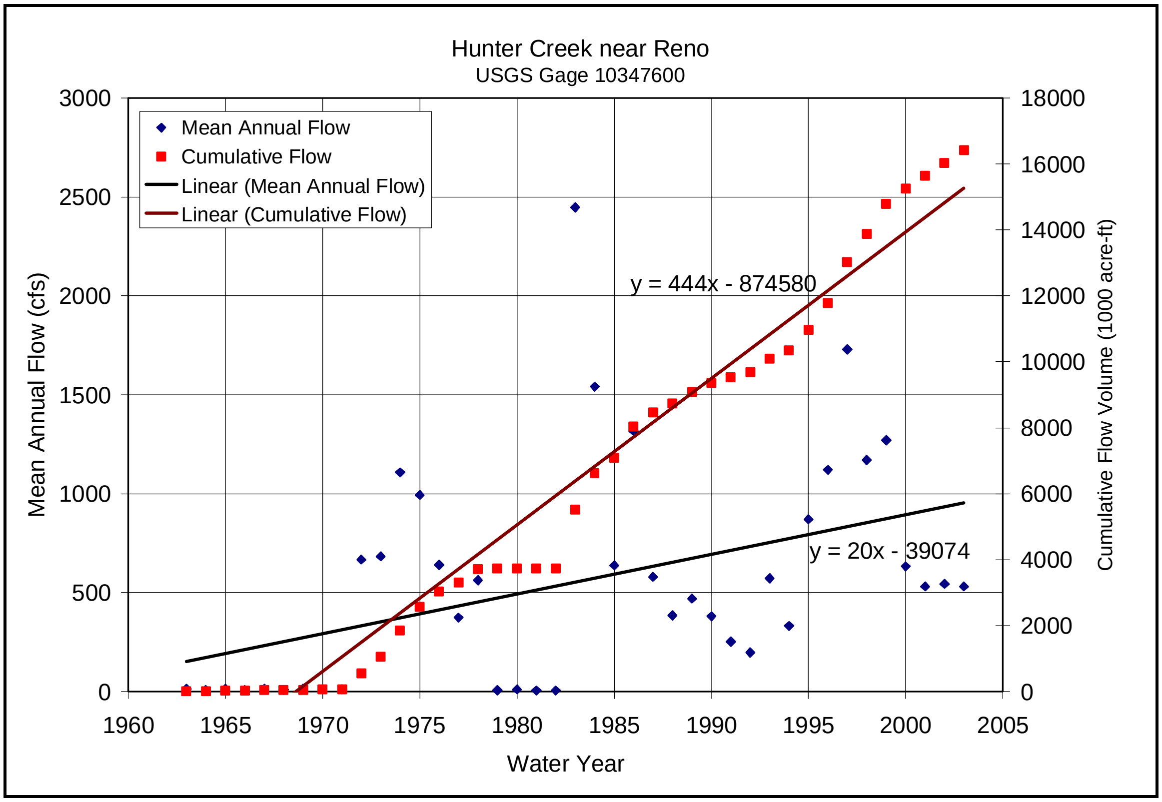

Figure D35. Hunter Creek near Reno annual streamflow.

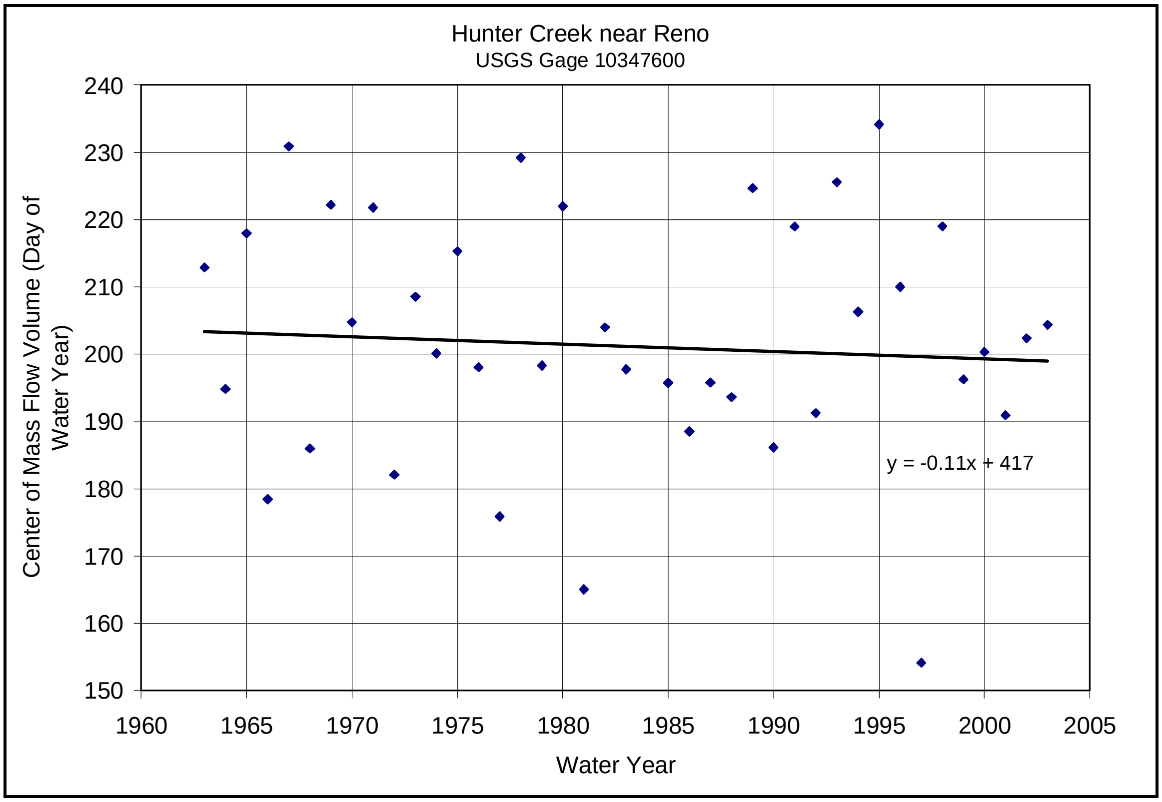

Figure D36. Hunter Creek near Reno streamflow center of mass.

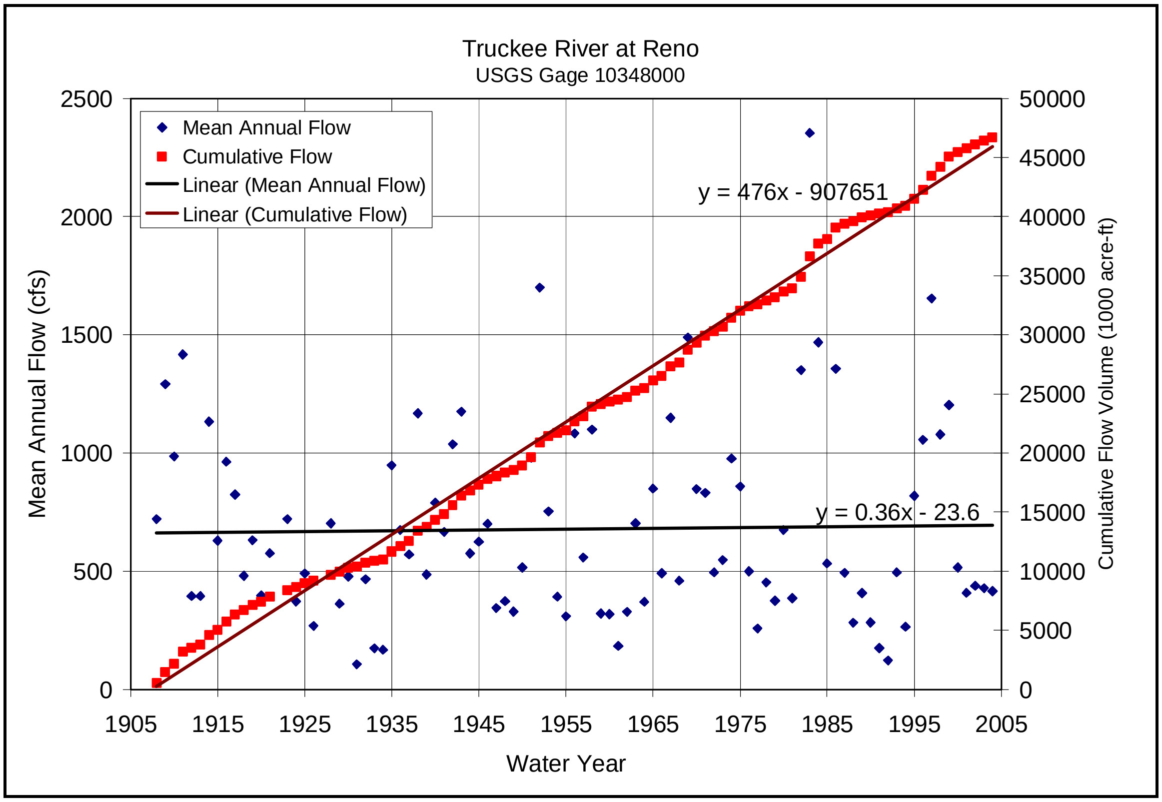

Figure D37. Truckee River at Reno annual streamflow.

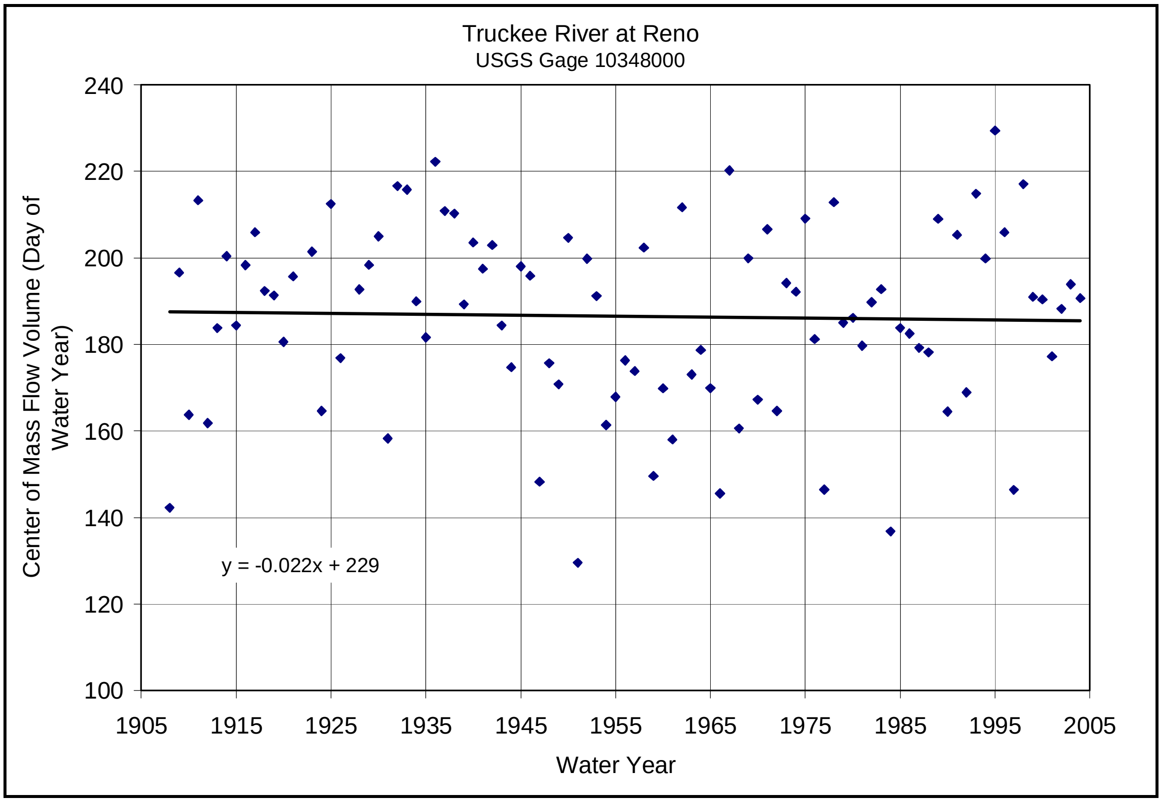

Figure D38. Truckee River at Reno streamflow center of mass.

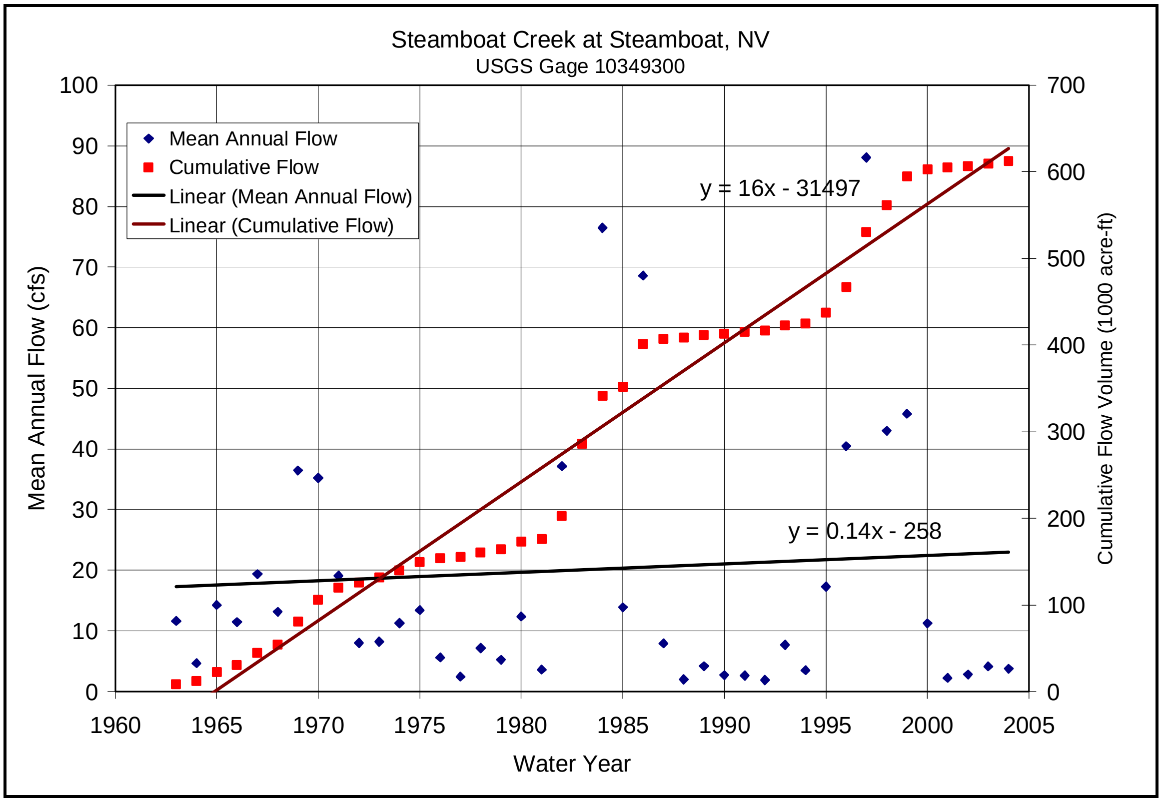

Figure D39. Steamboat Creek at Steamboat, NV annual streamflow.

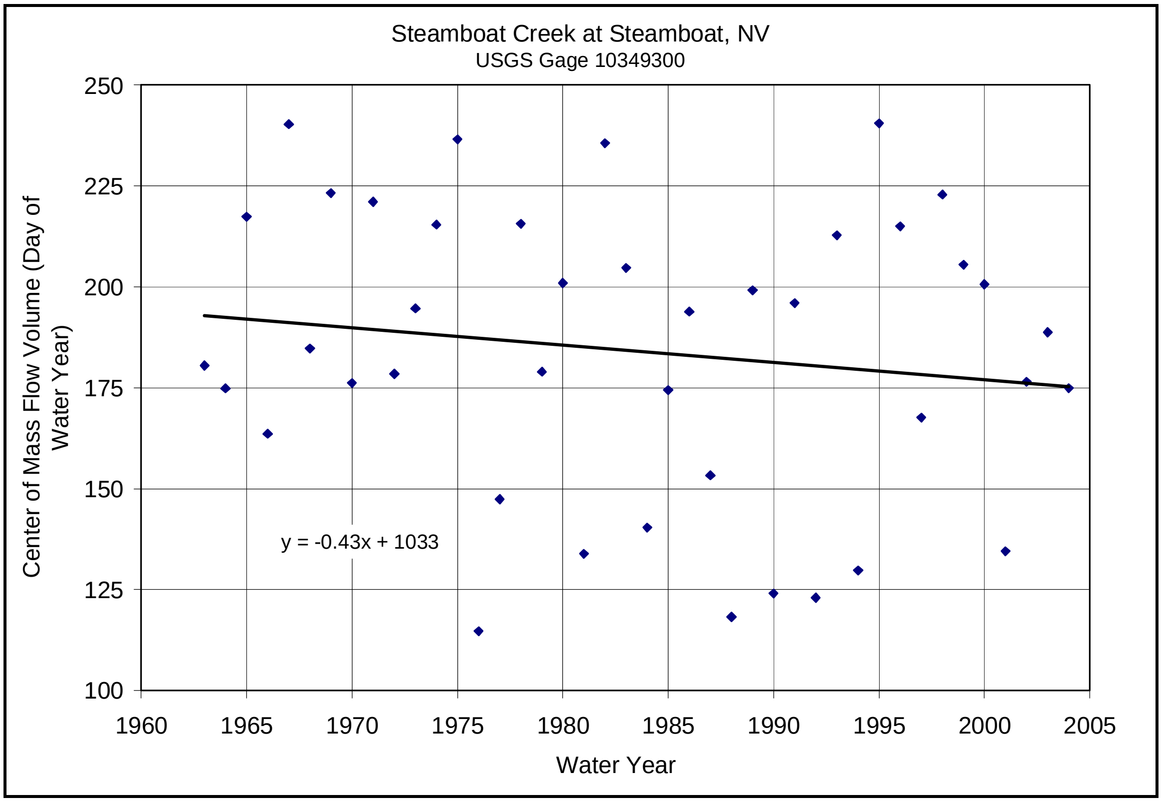

Figure D40. Steamboat Creek at Steamboat, NV streamflow center of mass.

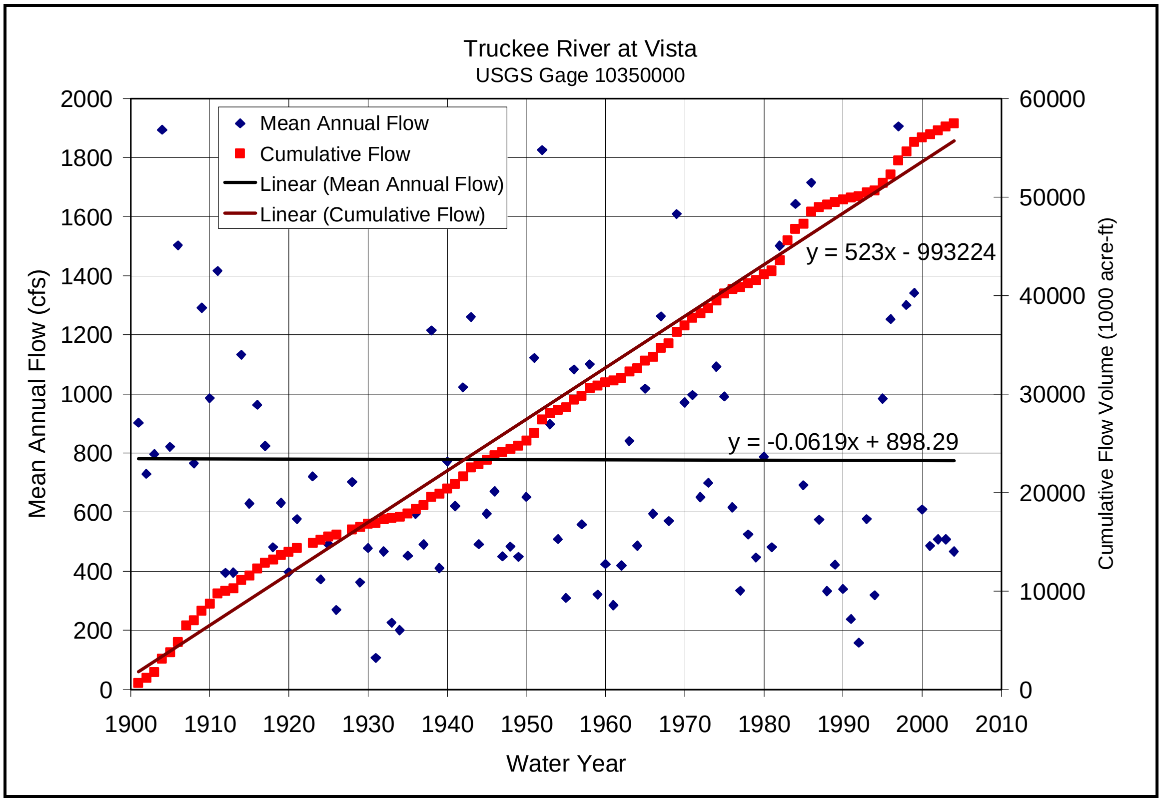

Figure D41. Truckee River at Vista annual streamflow.

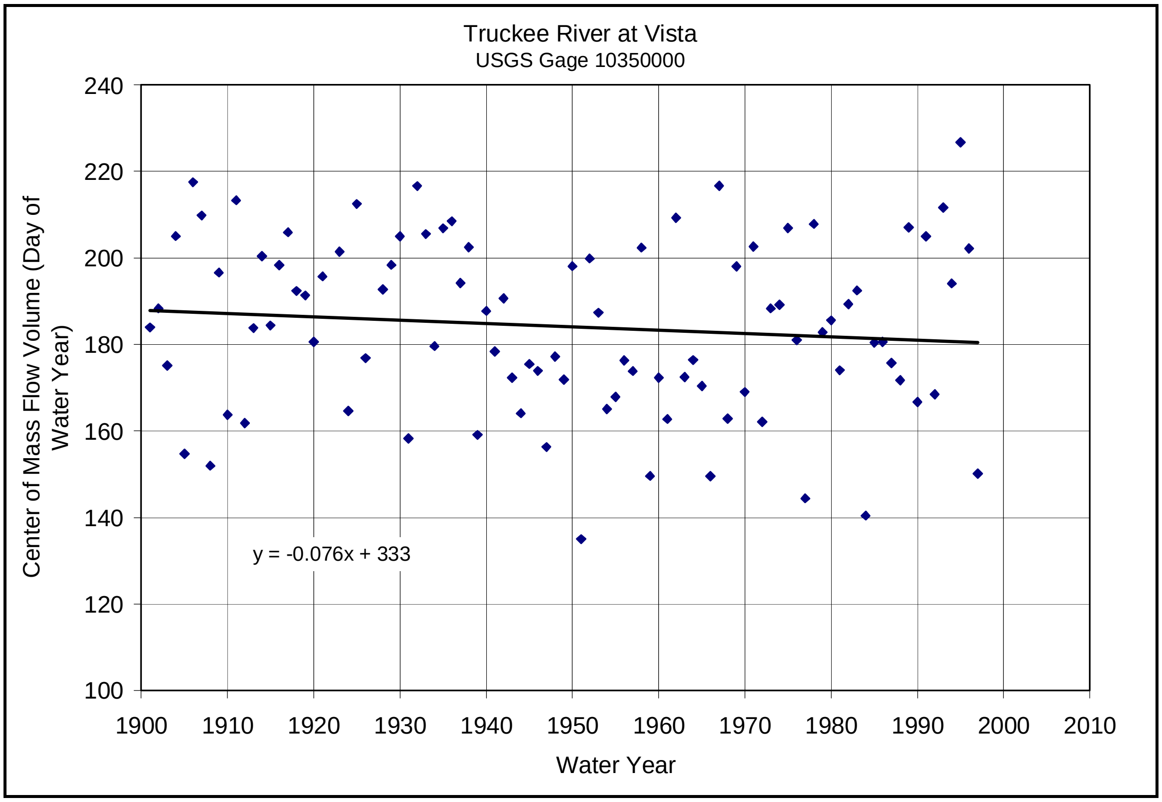

Figure D42. Truckee River at Vista streamflow center of mass.

Appendix E

Reservoir Volumes

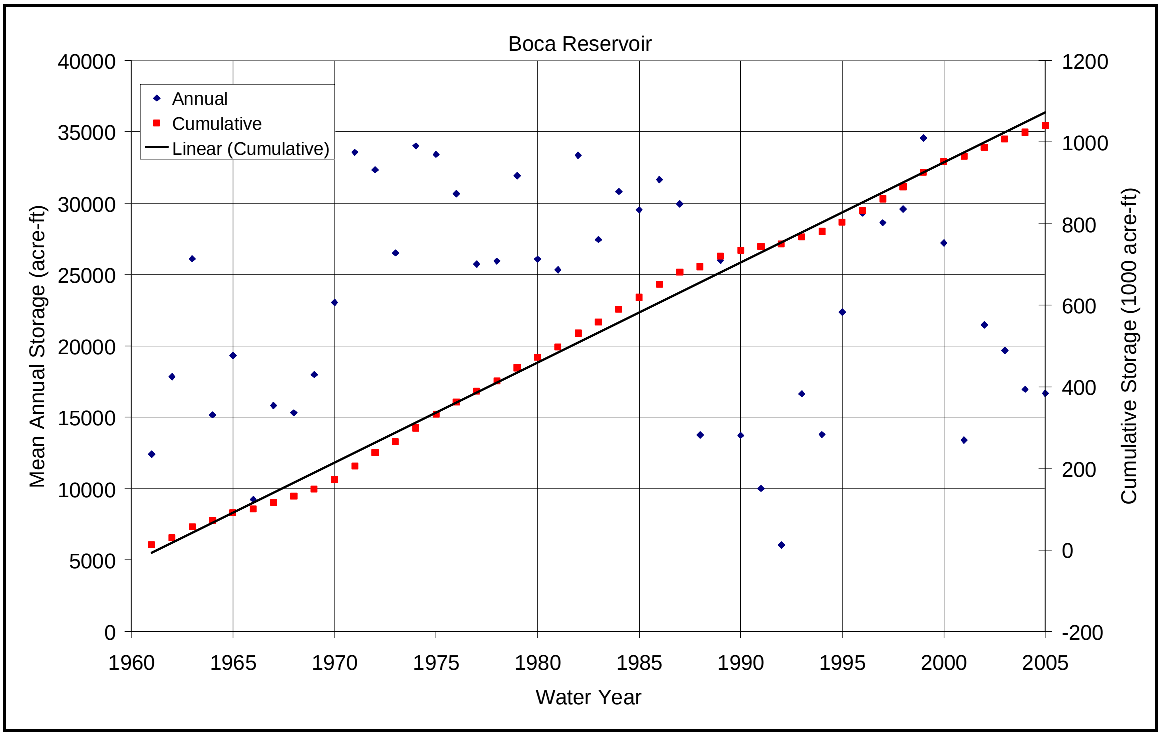

Figure E1. Mean annual storage and cumulative storage for Boca Reservoir.

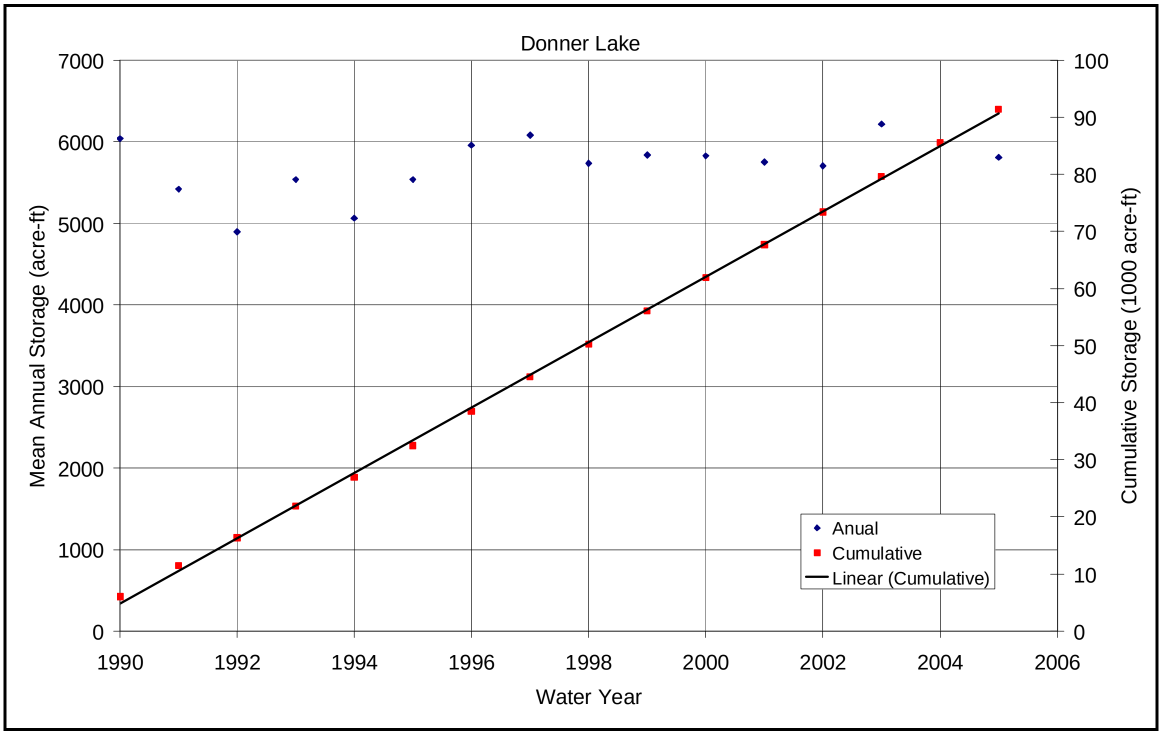

Figure E2. Mean annual storage and cumulative storage for Donner Lake.

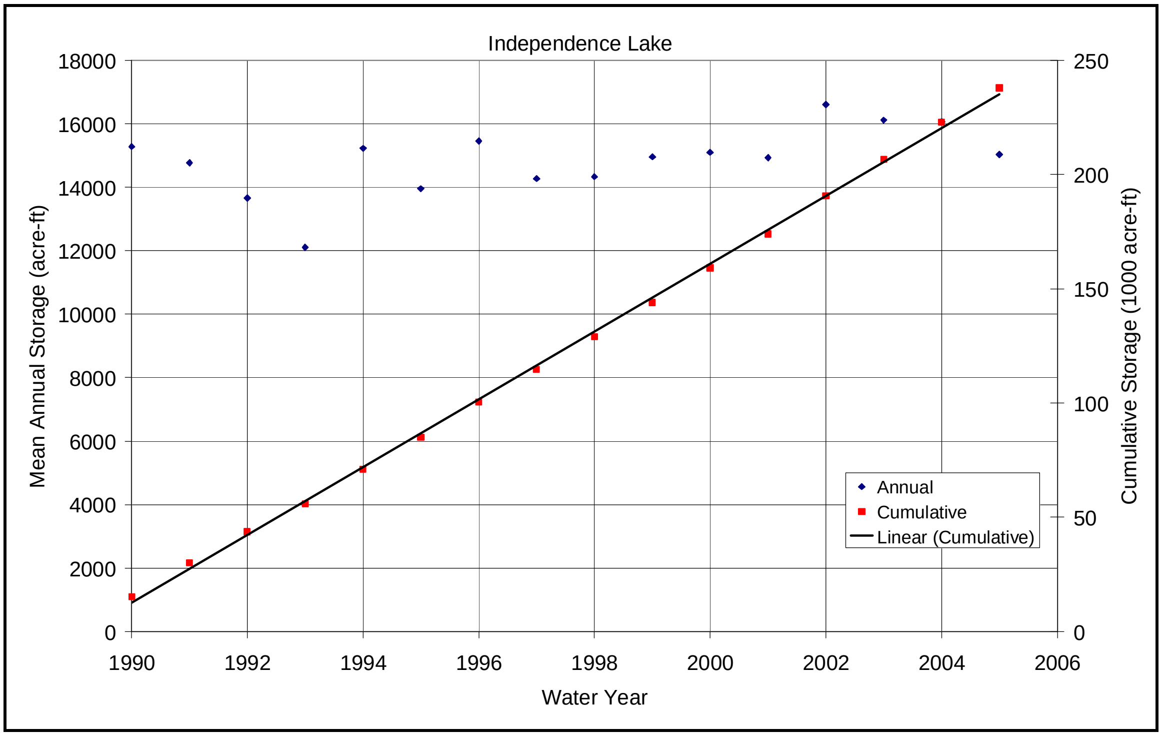

Figure E3. Mean annual storage and cumulative storage for Independence Lake.

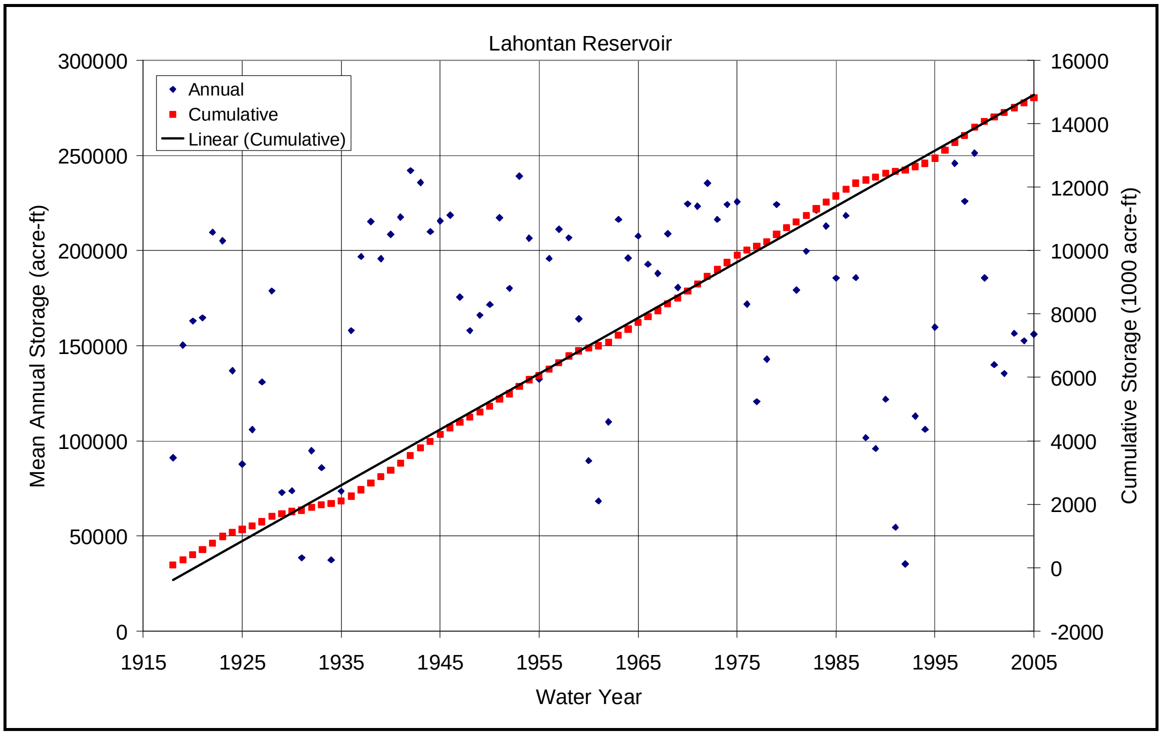

Figure E4. Mean annual storage and cumulative storage for Lahontan Reservoir.

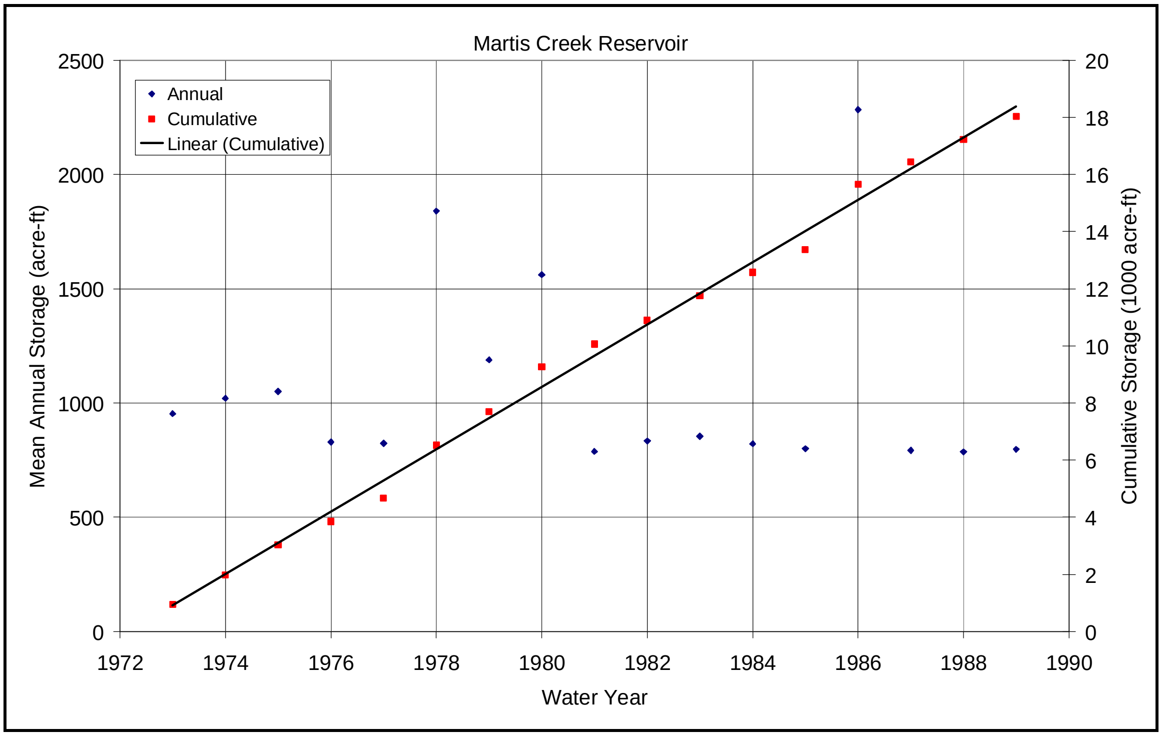

Figure E5. Mean annual storage and cumulative storage for Martis Creek Reservoir.

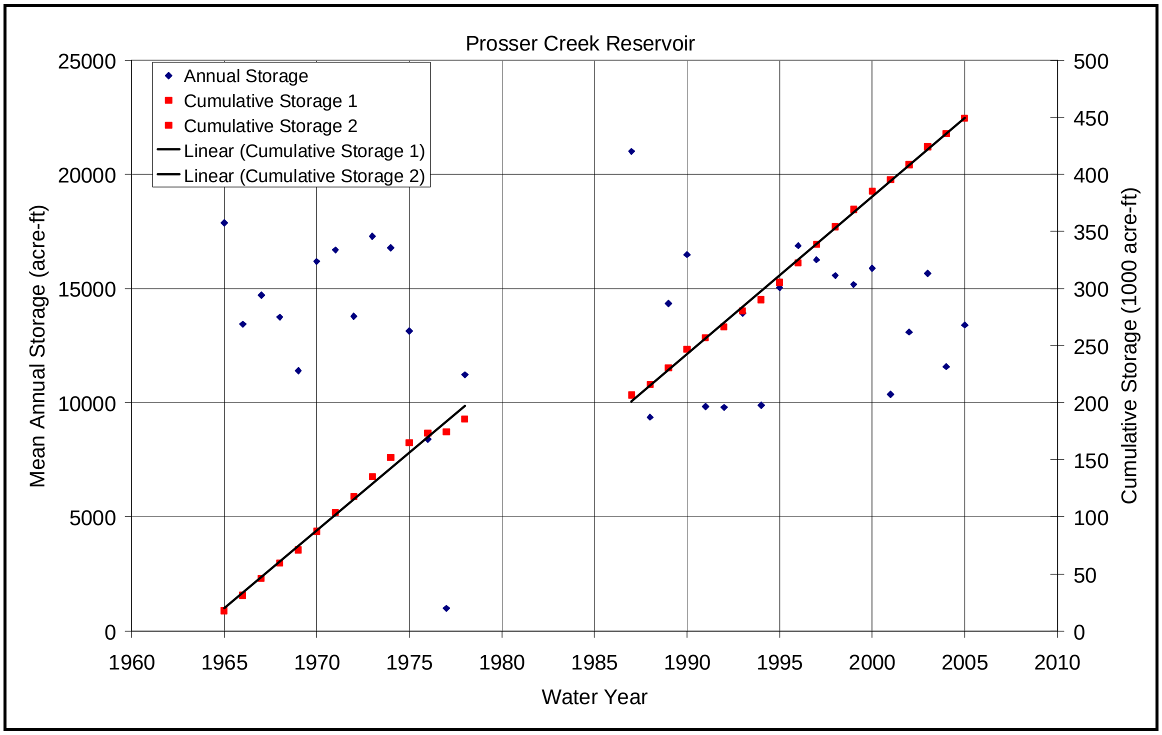

Figure E6. Mean annual storage and cumulative storage for Prosser Creek Reservoir.

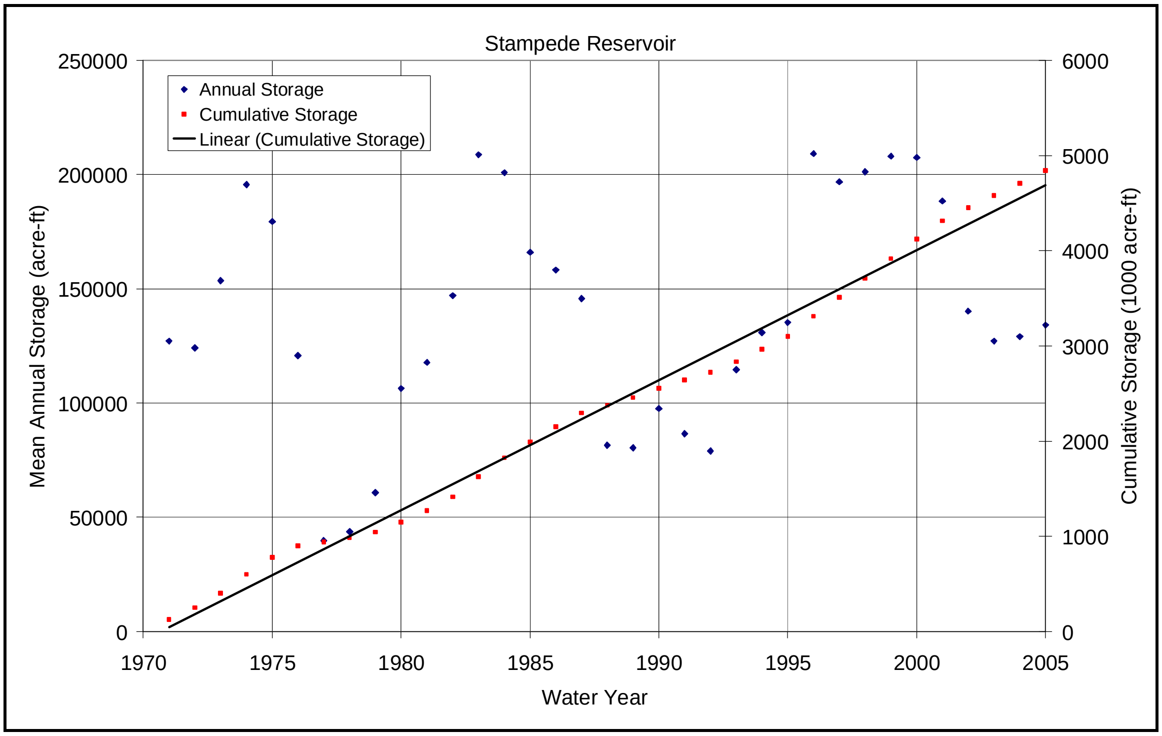

Figure E7. Mean annual storage and cumulative storage for Stampede Reservoir.

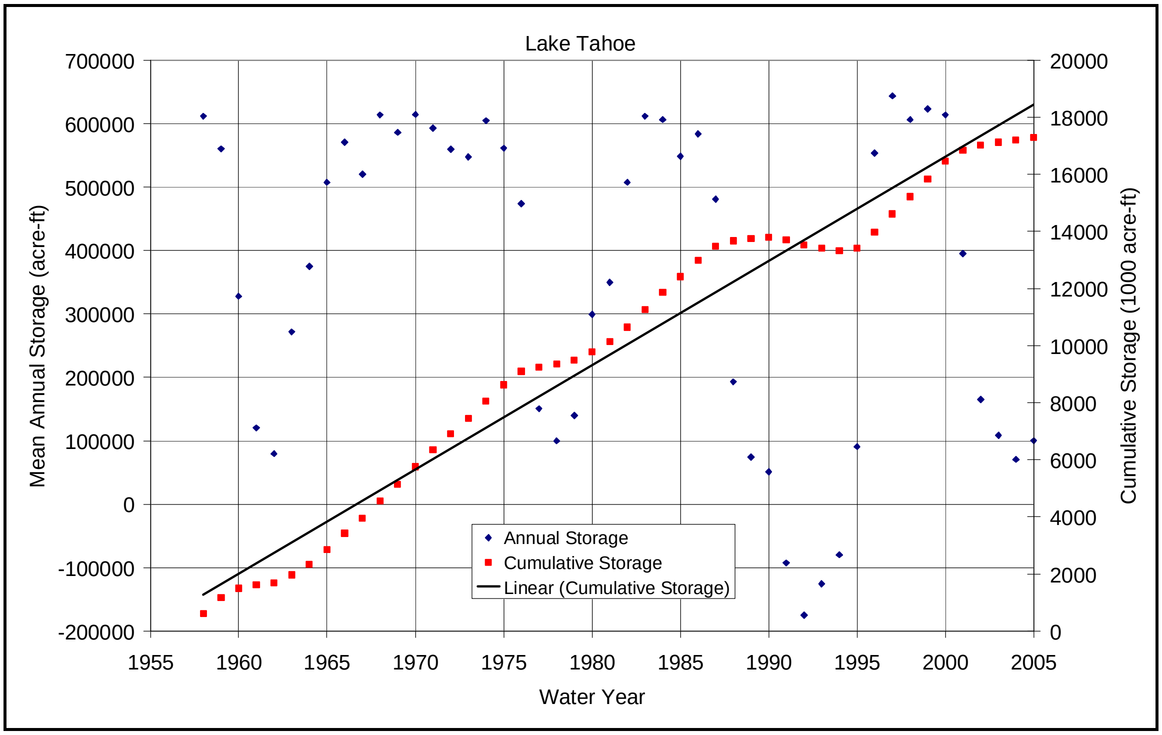

Figure E8. Mean annual storage and cumulative storage for Lake Tahoe.

Appendix F

Double Mass Curve Analysis
Precipitation and Snowpack

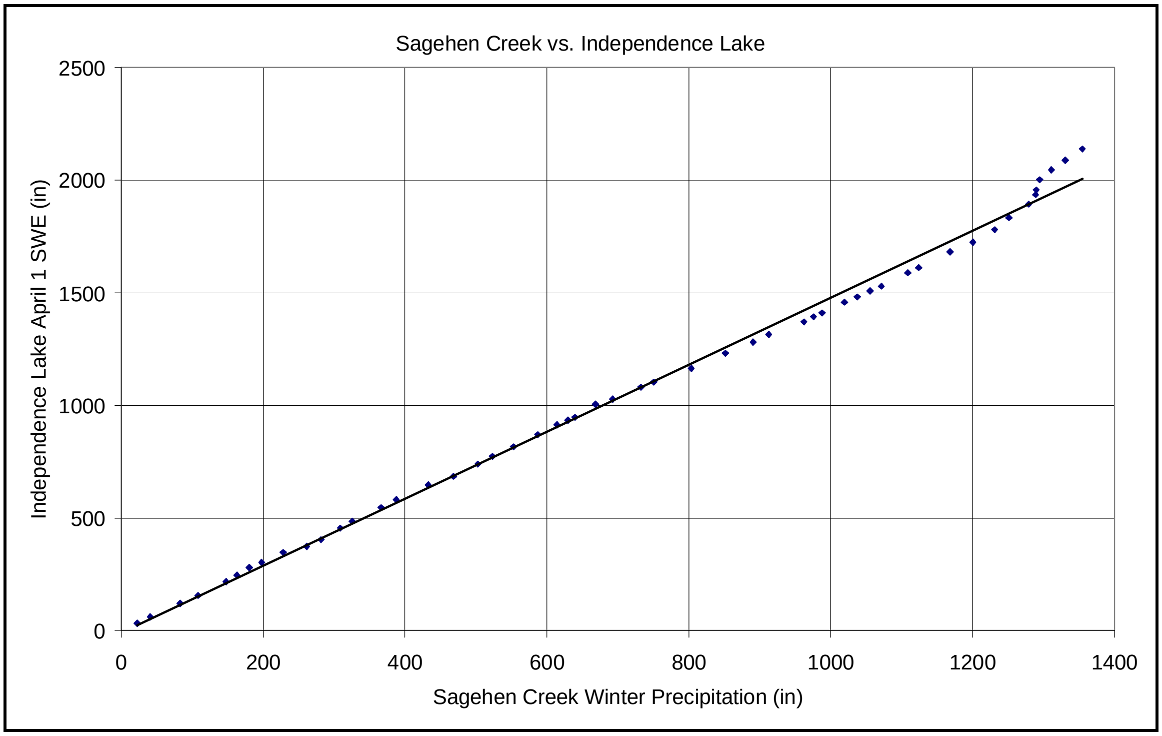

Figure F1. Double mass curve for Independence Lake snowcourse station April 1 SWE and Sagehen Creek winter precipitation.

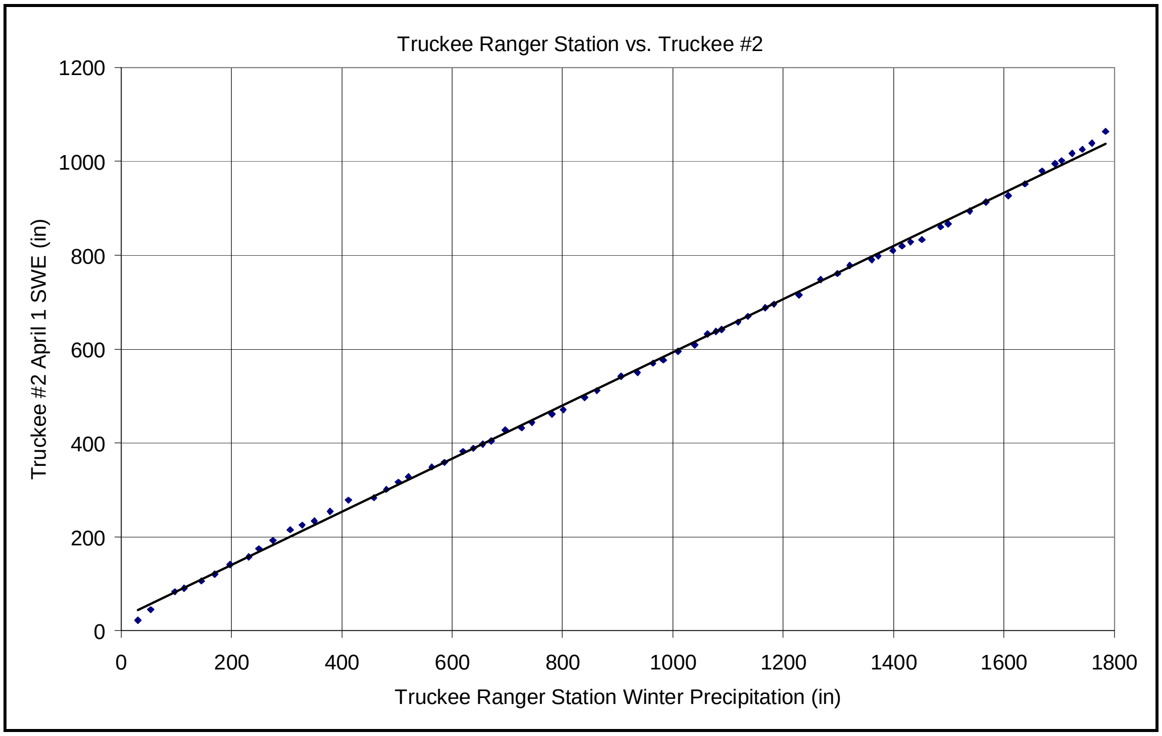

Figure F2. Double mass curve for Truckee #2 snowcourse station April 1 SWE and Truckee Ranger Station winter precipitation.

Appendix G

Double Mass Curve Analysis
Precipitation vs. Streamflow

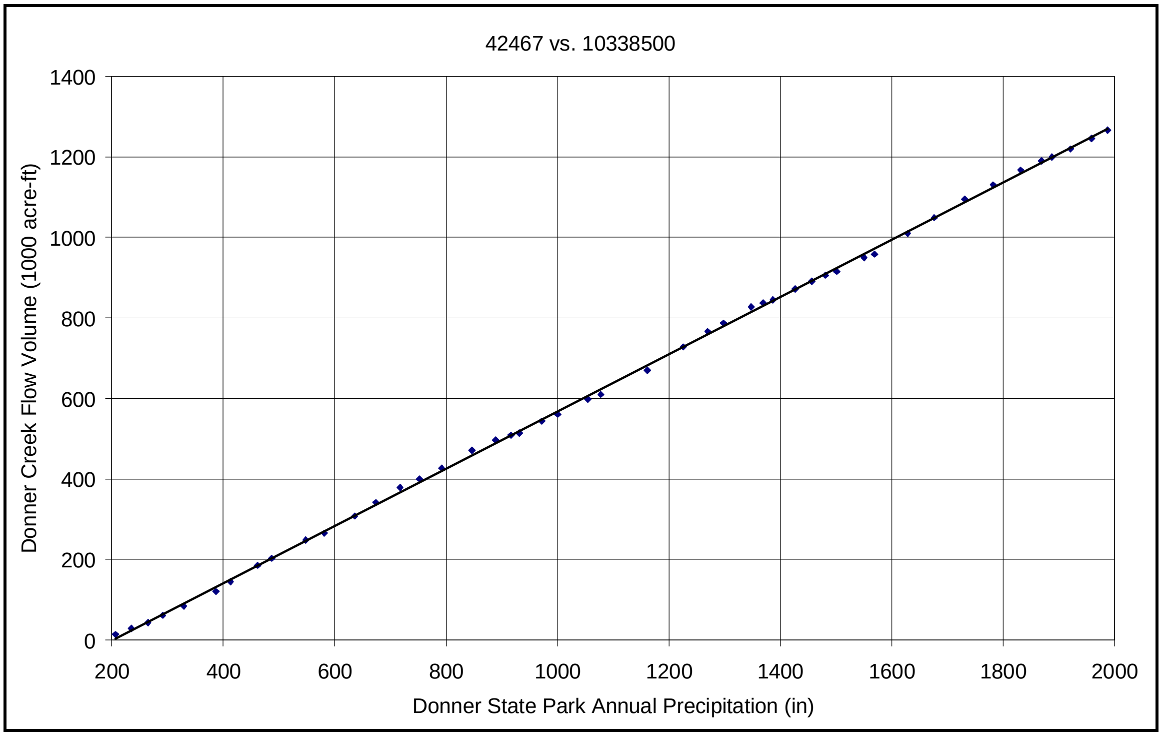

Figure G1. Double mass curve for streamflow volume for Donner Creek and annual precipitation at Donner State Park.

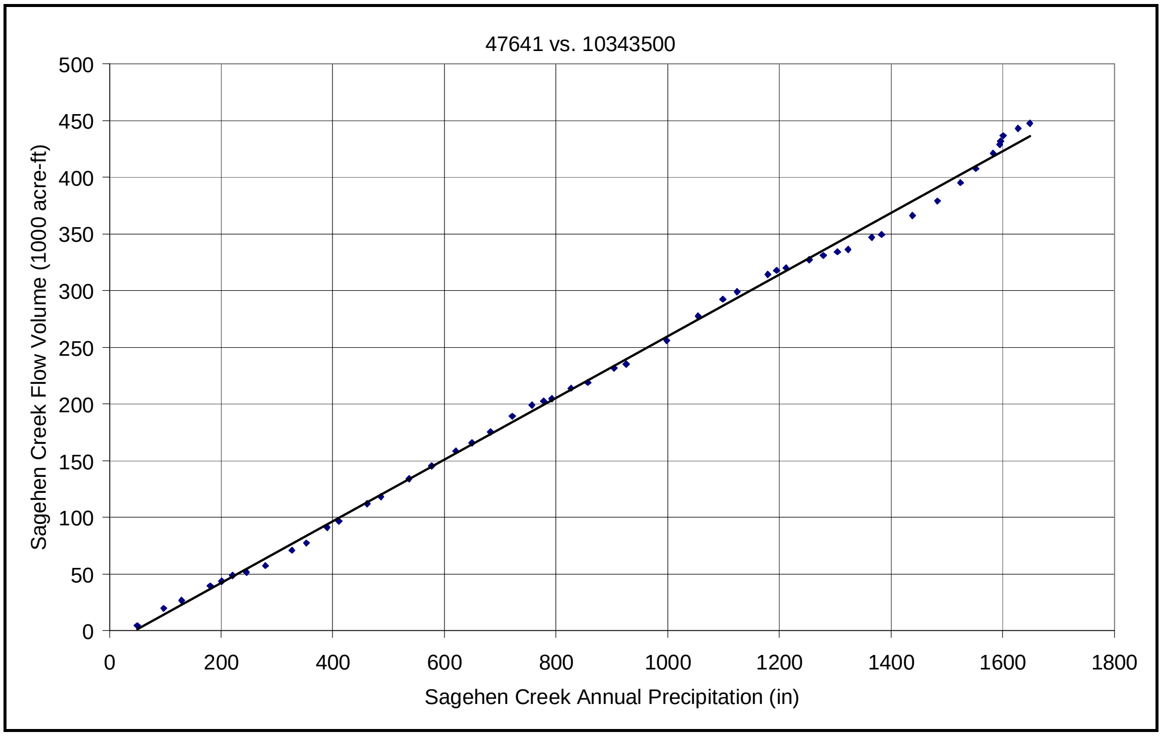

Figure G2. Double mass curve for Sagehen Creek streamflow volume and annual precipitation at the Sagehen weather station.

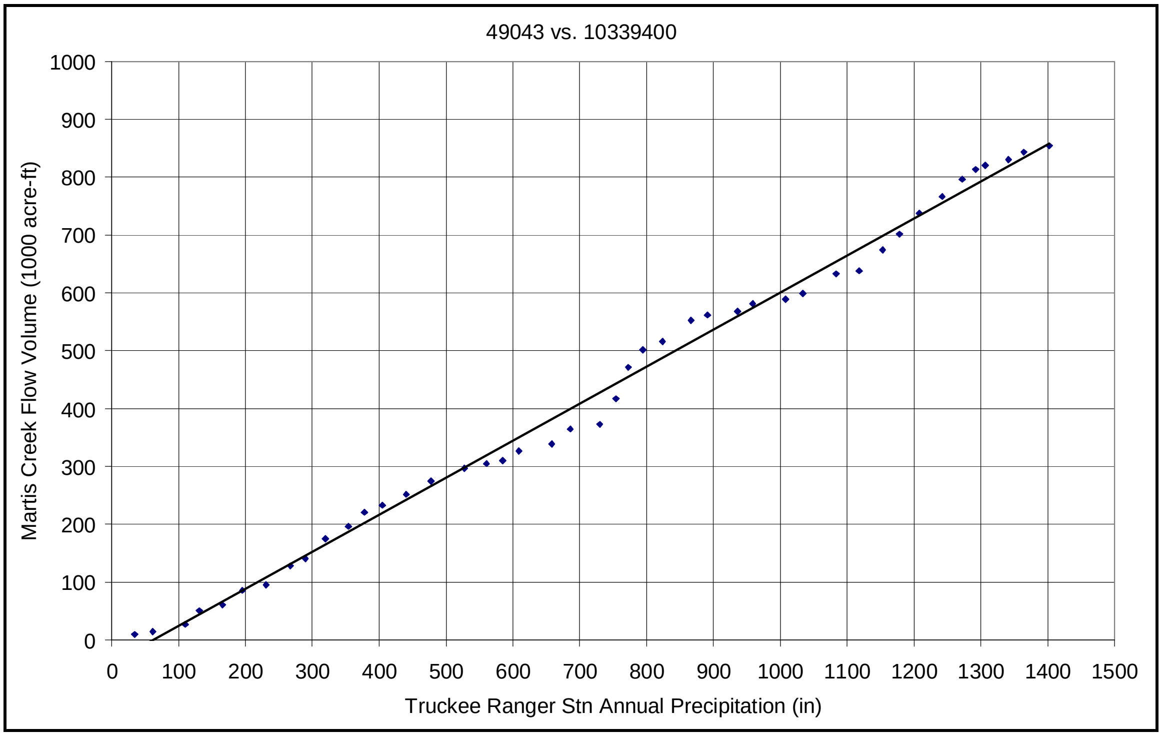

Figure G3. Double mass curve for Martis Creek streamflow volume and annual precipitation at the Truckee Ranger Station.

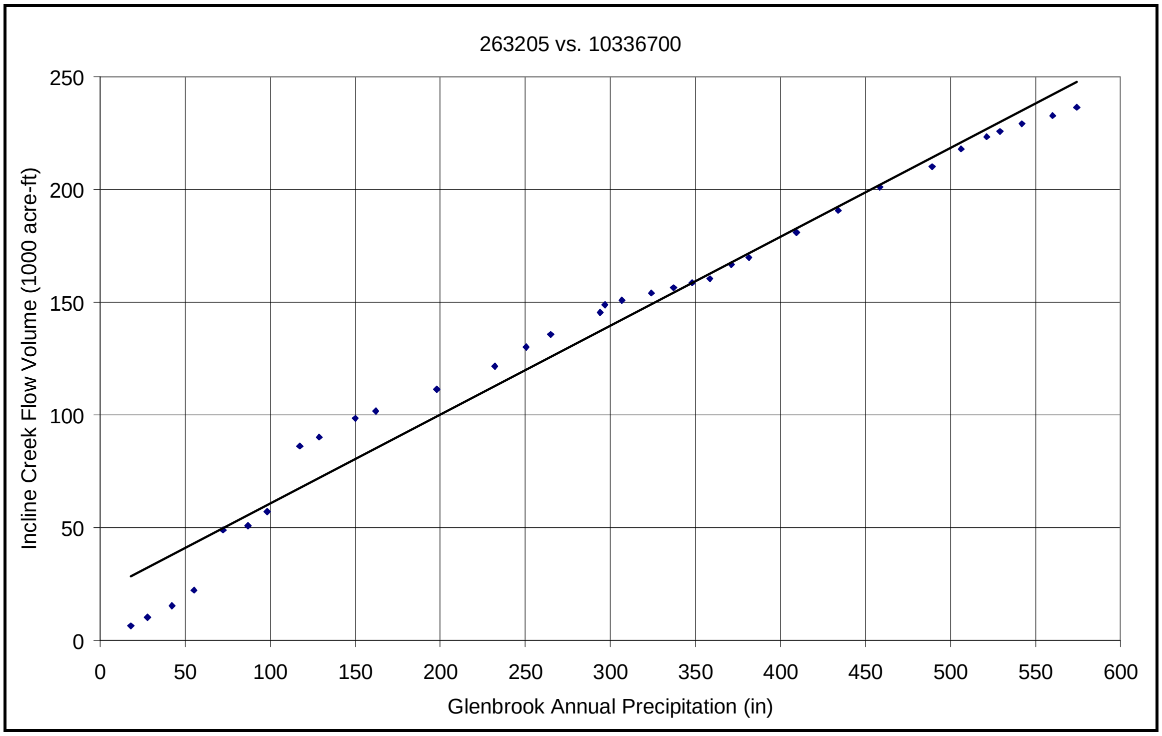

Figure G4. Double mass curve for Incline Creek streamflow volume and annual precipitation at the Glenbrook weather station.

Appendix H

Double Mass Curve Analysis
Precipitation vs. Reservoir Volumes

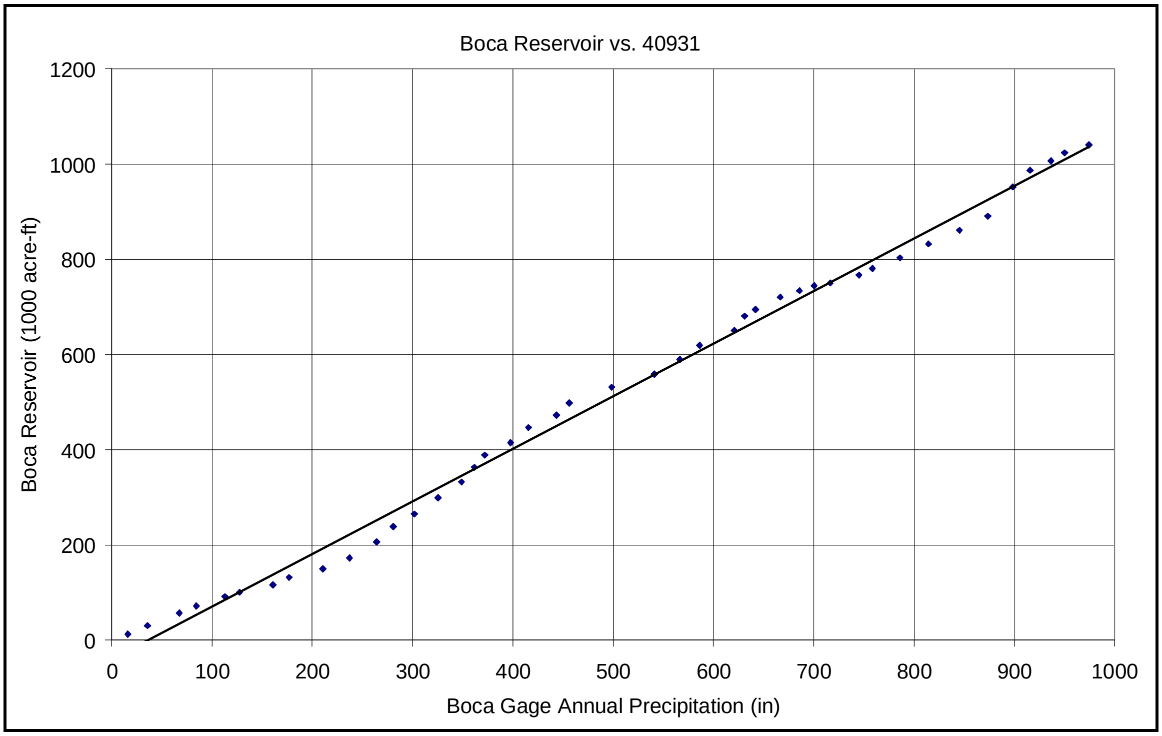

Figure H1. Double mass curve of Boca Reservoir storage and Boca annual precipitation.

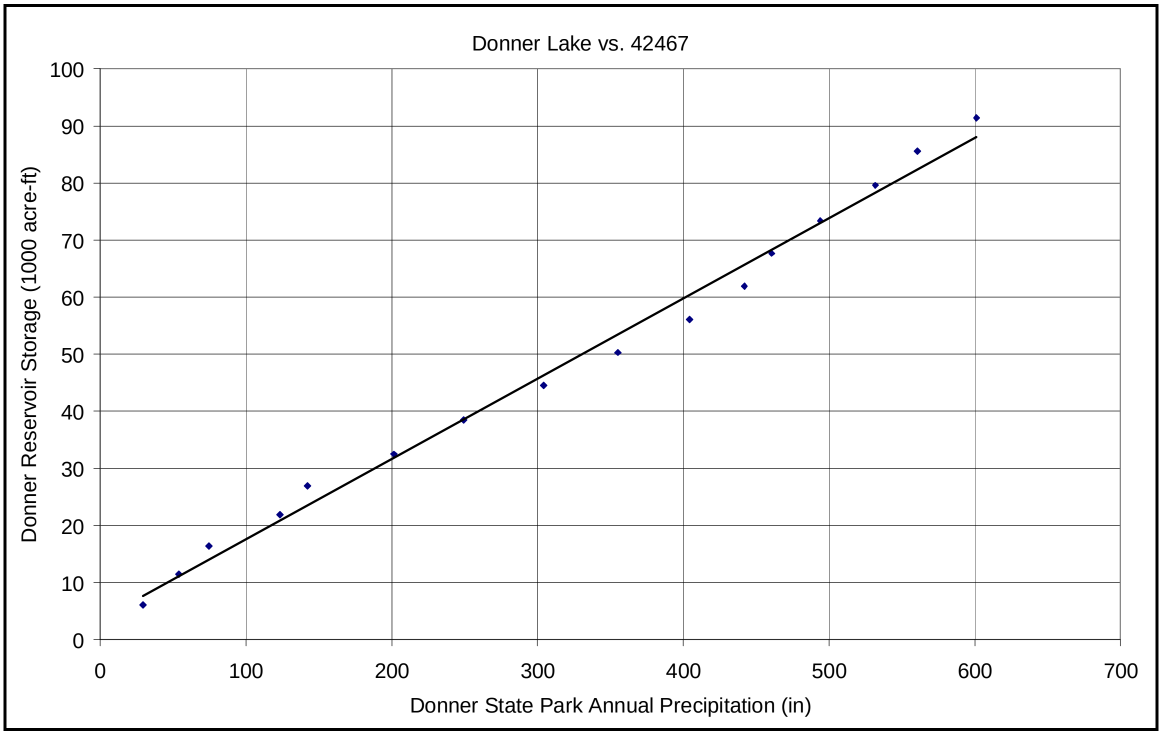

Figure H2. Double mass curve of Donner Lake storage and Donner State Park annual precipitation.

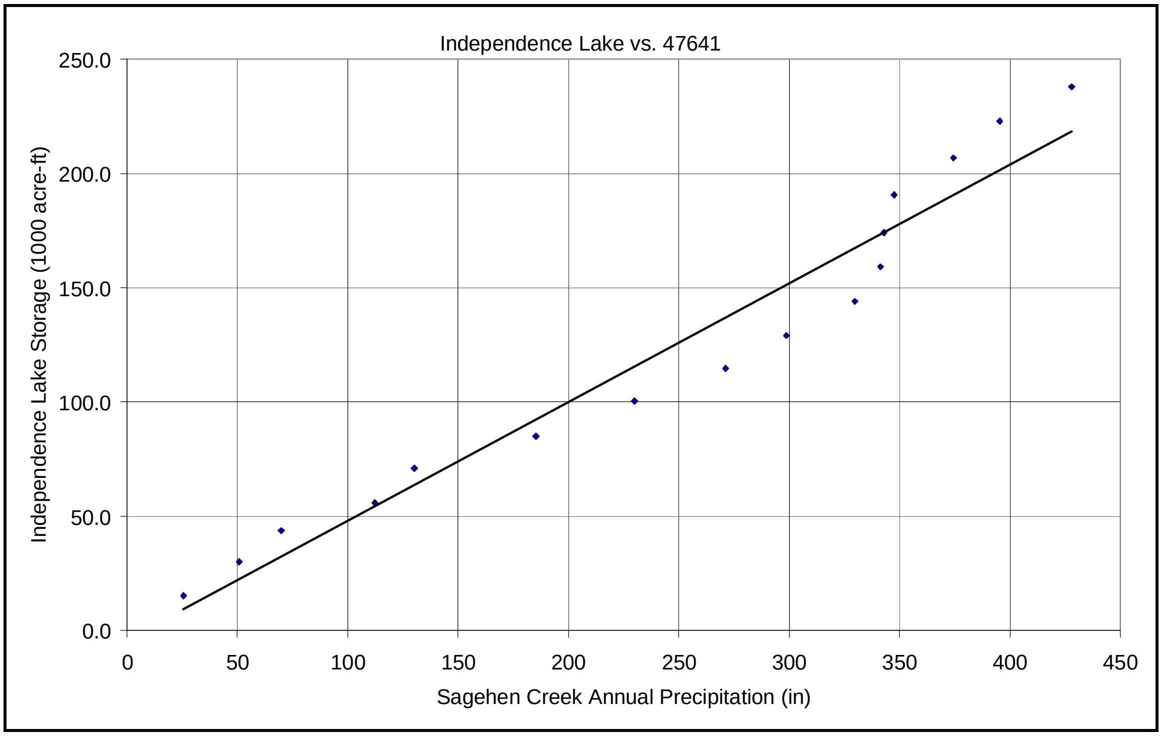

Figure H3. Double mass curve of Independence storage and Sagehen Creek annual precipitation.

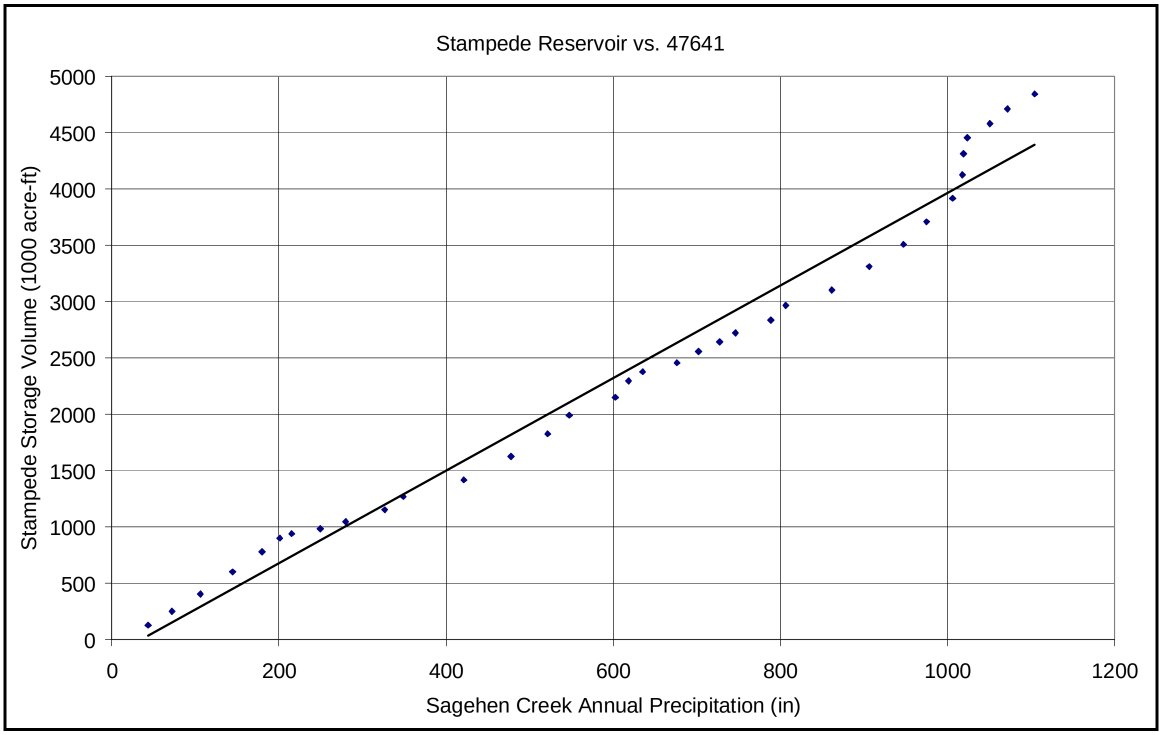

Figure H4. Double mass curve of Stampede Reservoir storage and Sagehen Creek annual precipitation.

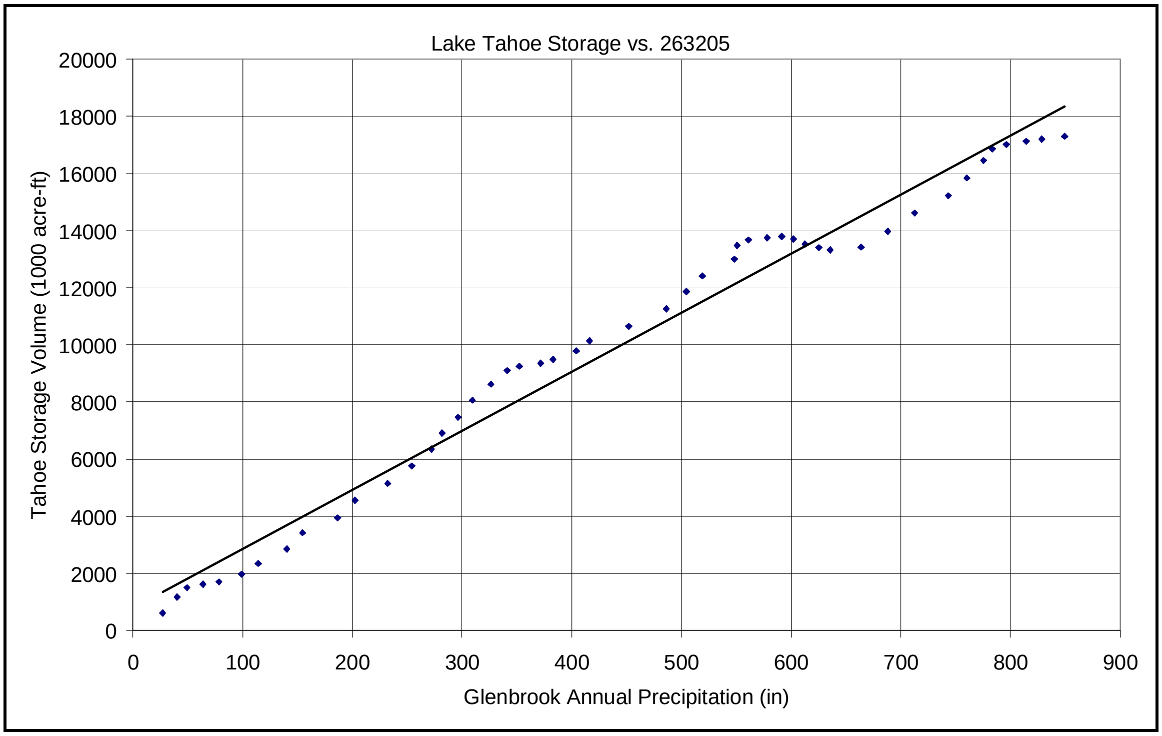

Figure H5. Double mass curve of Lake Tahoe storage and Glenbrook gage annual precipitation.

Appendix I

Double Mass Curve Analysis
Streamflow vs. Snowpack

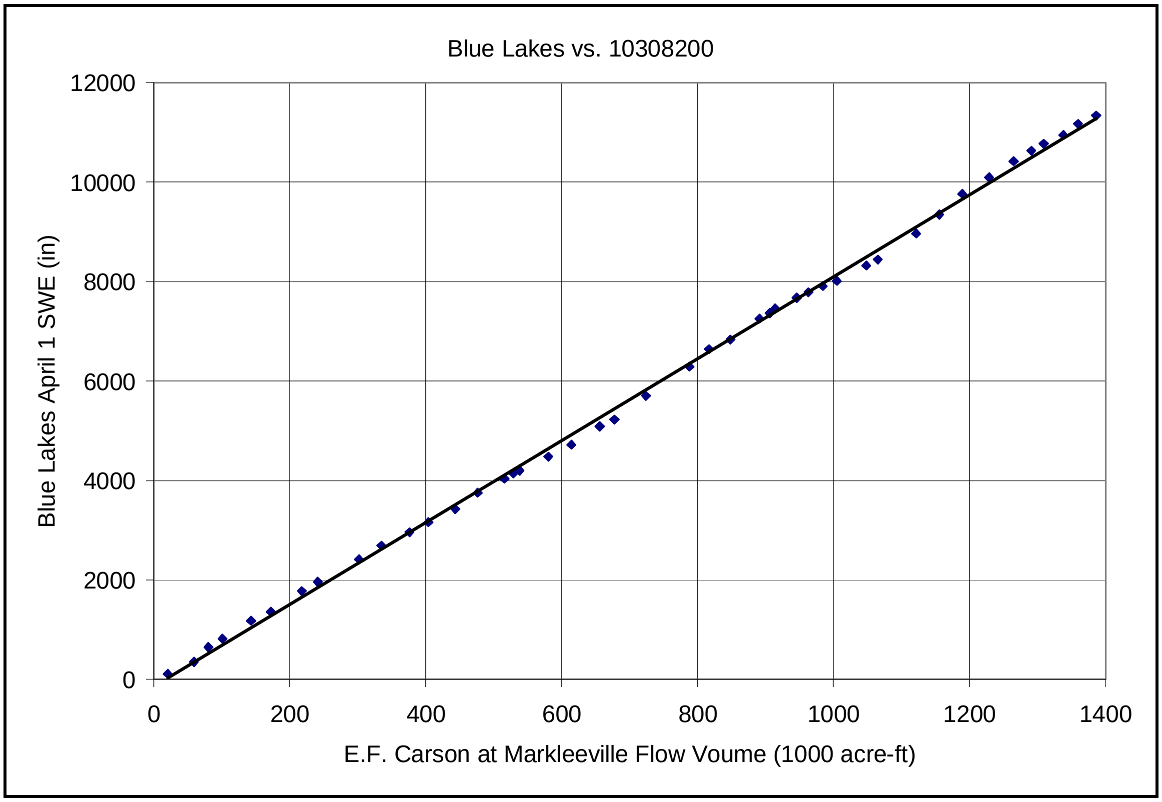

Figure I1. Blue Lakes SWE and streamflow in the E. Fork of the Carson at Markleevilles.

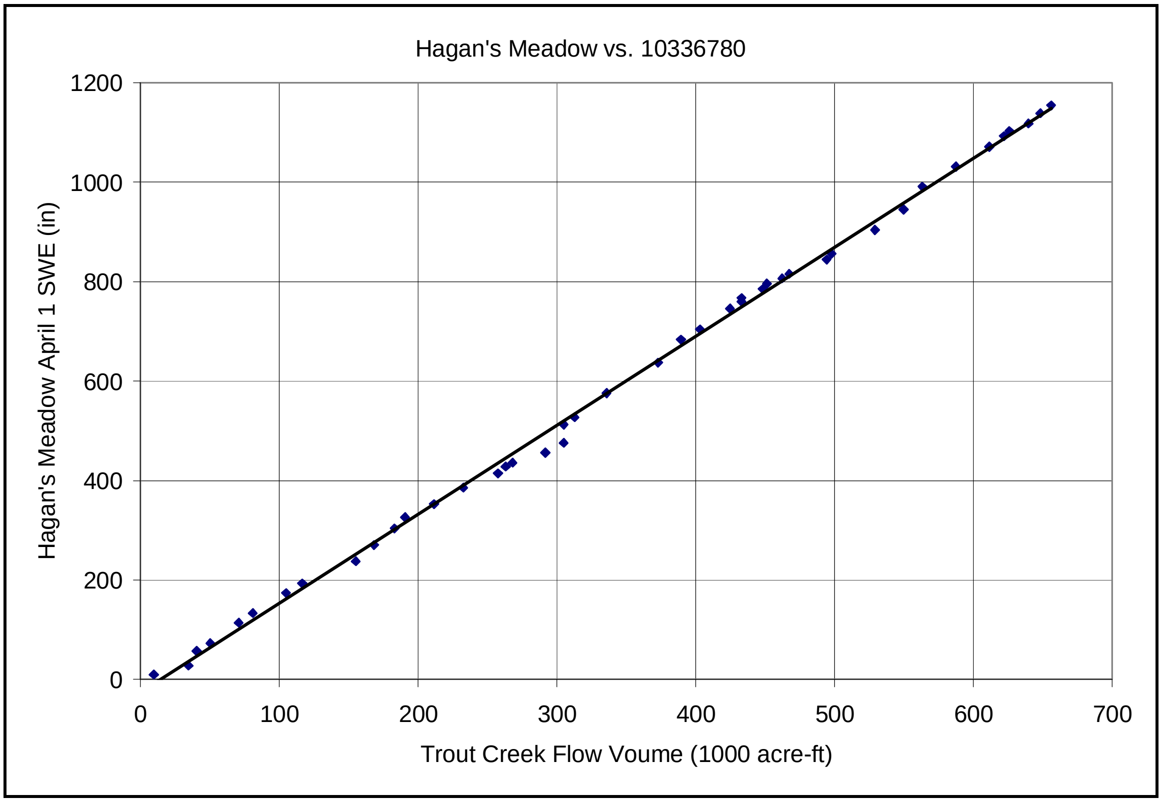

Figure I2. Hagan’s Meadow SWE and Trout Creek streamflow volumes.

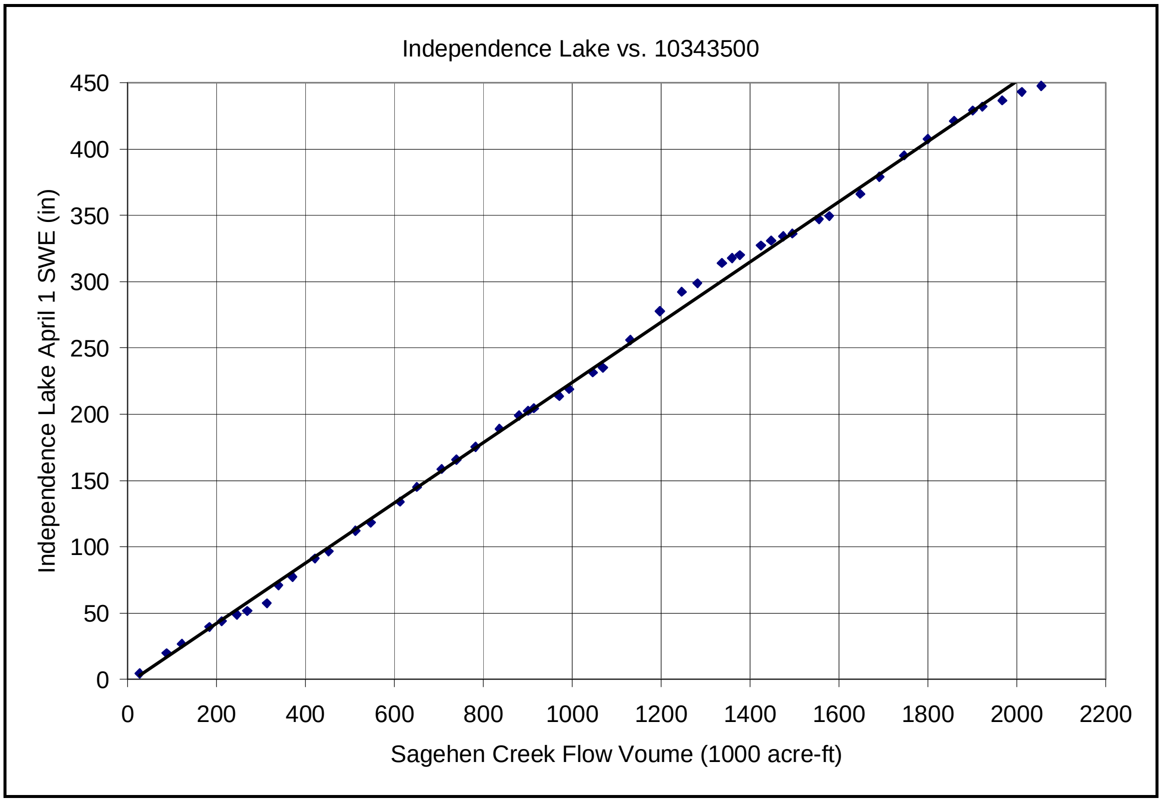

Figure I3. Independence Lake SWE and Sagehen Creek streamflow volumes.

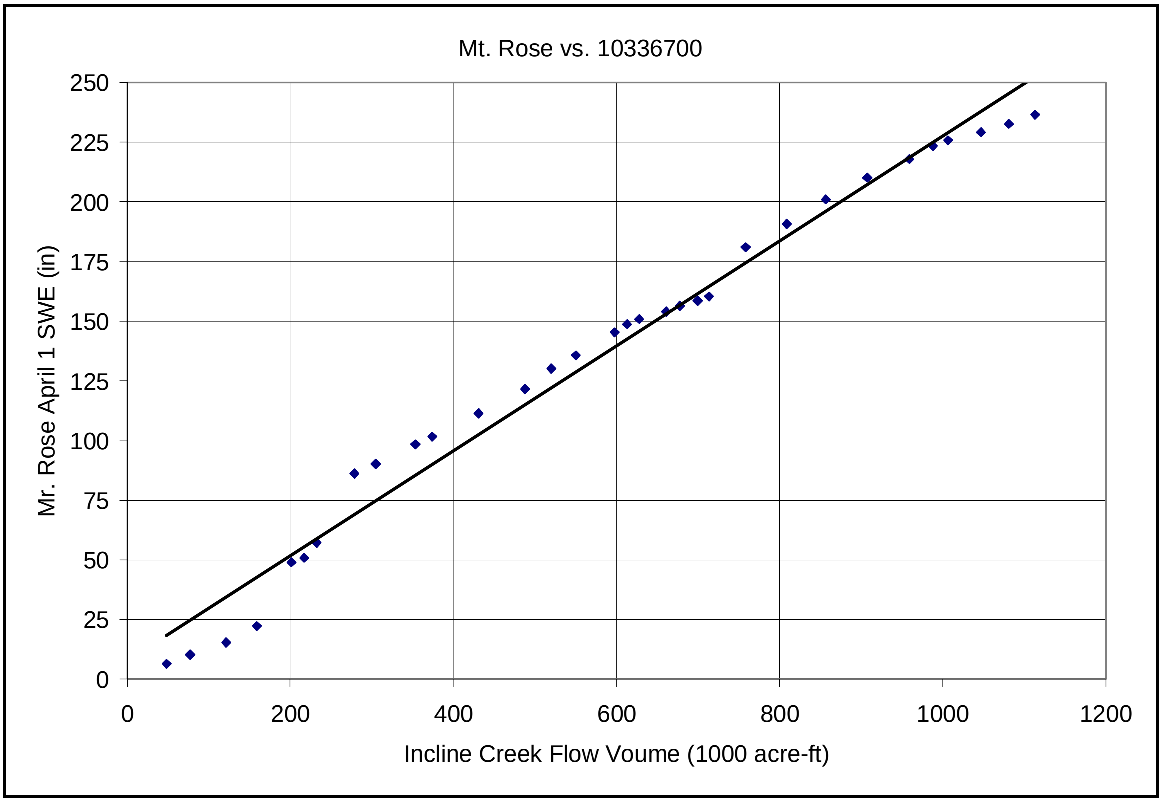

Figure I4. Mt. Rose SWE and Incline Creek streamflow volumes.

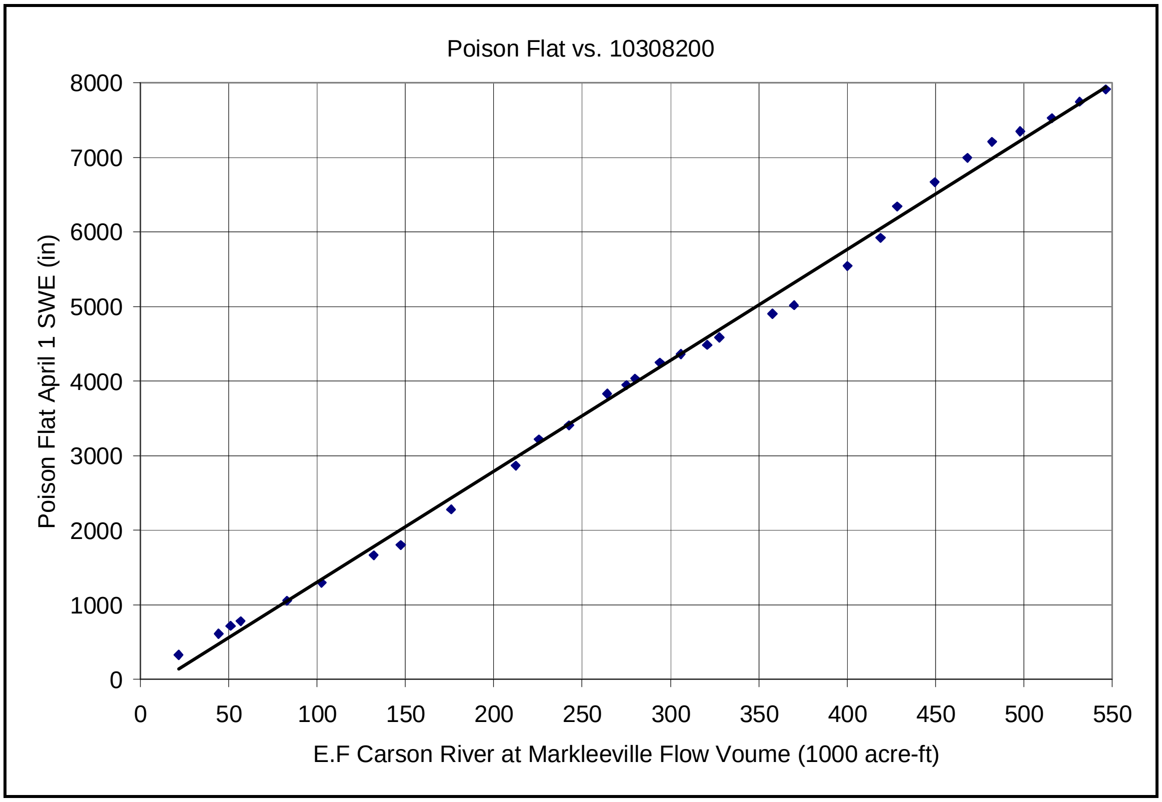

Figure I5. Poison Flat SWE and E.F Carson River at Markleeville streamflow volumes.

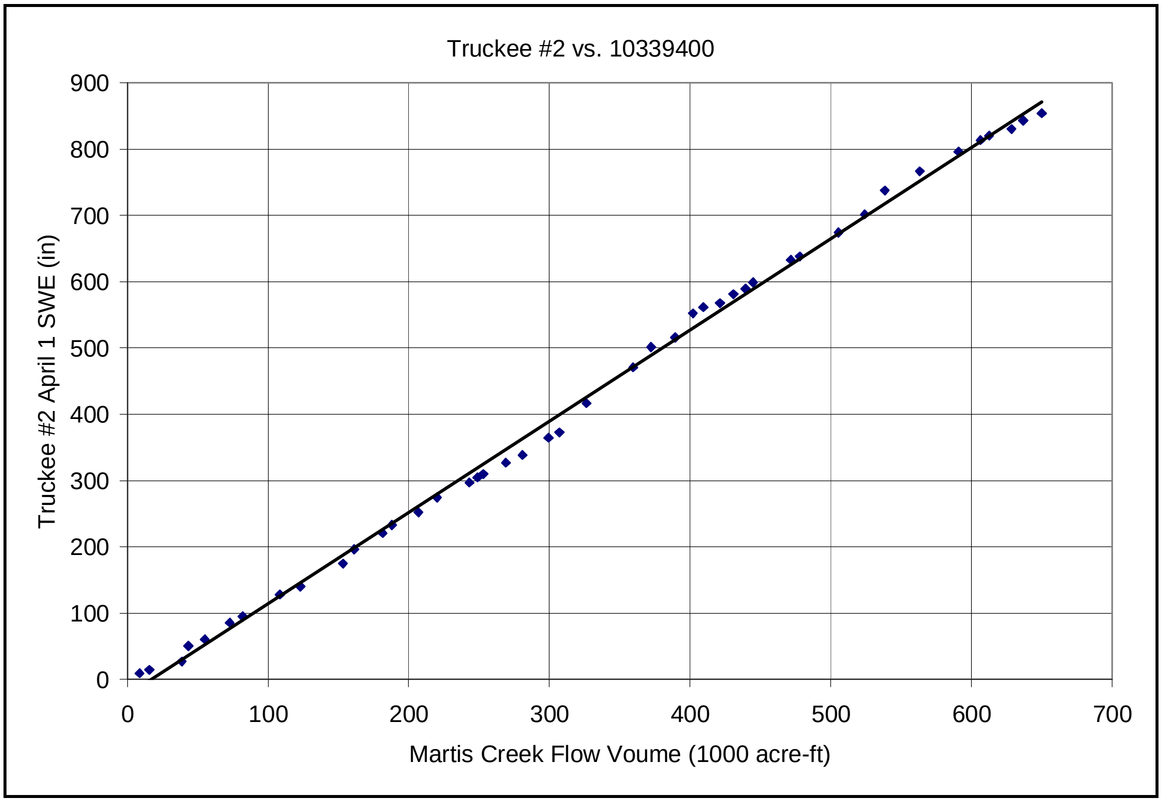

Figure I6. Truckee #2 SWE and Martis Creek streamflow volumes.

Appendix J

Double Mass Curve Analysis
Streamflow vs. Reservoir Volumes

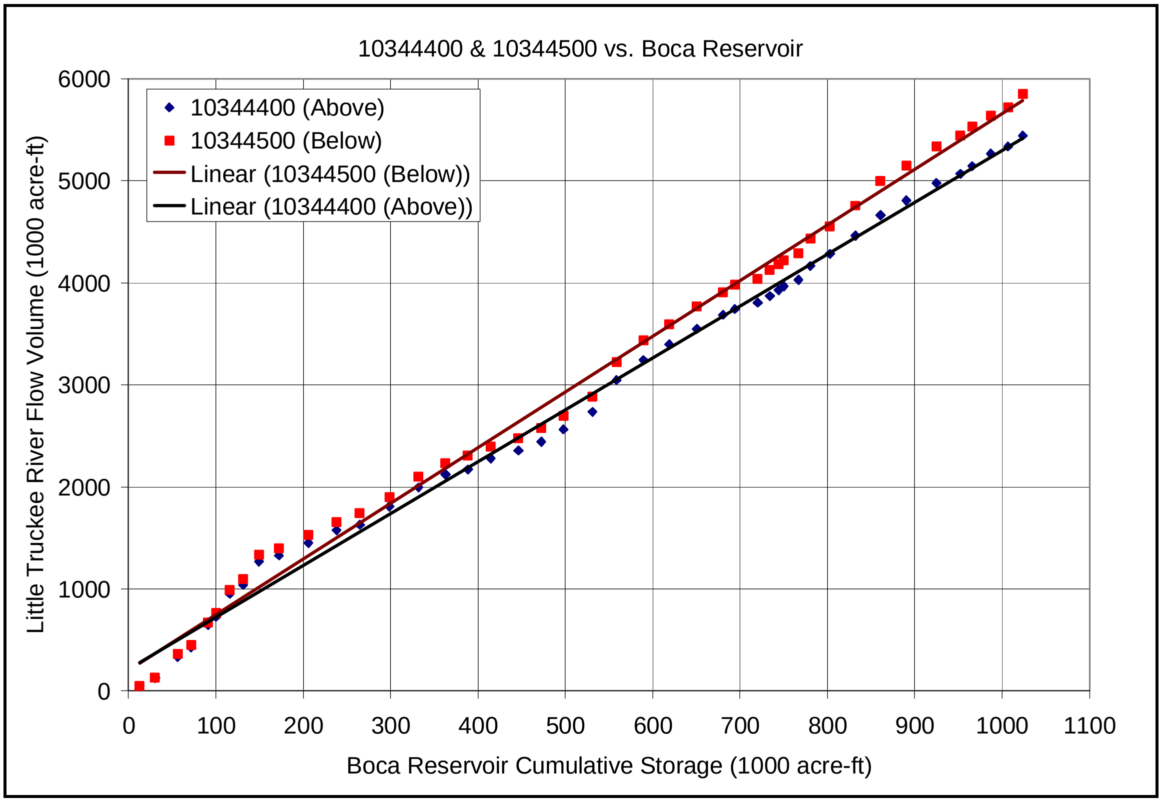

Figure J1. Little Truckee River streamflow volume and Boca Reservoir storage.

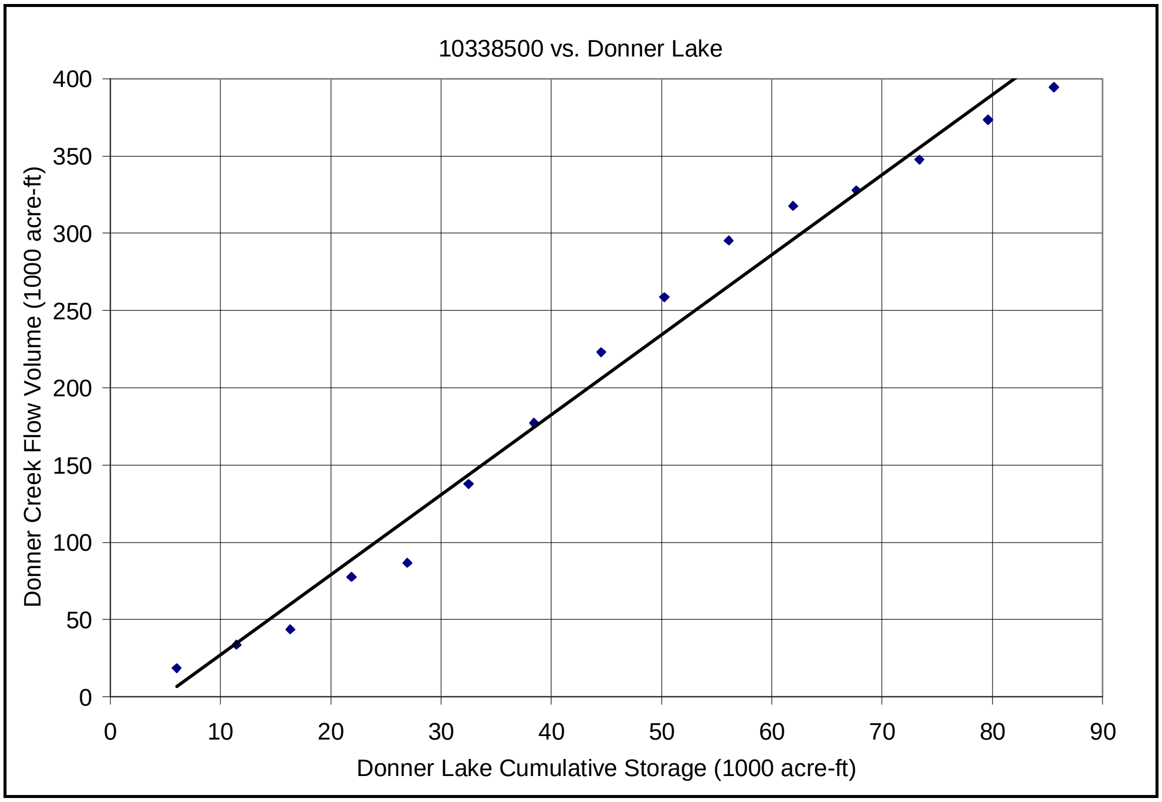

Figure J2. Donner Creek streamflow volume and Donner Lake storage.

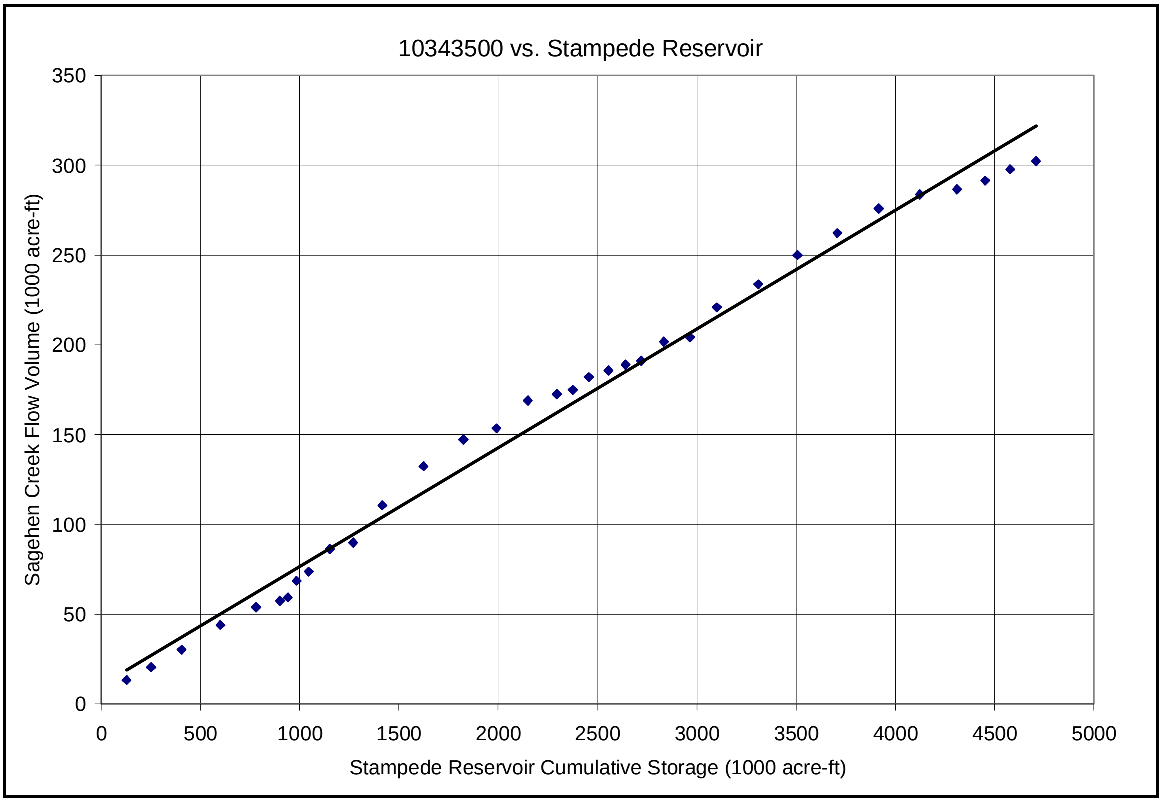

Figure J3. Sagehen Creek streamflow volume and Stampede Reservoir storage.

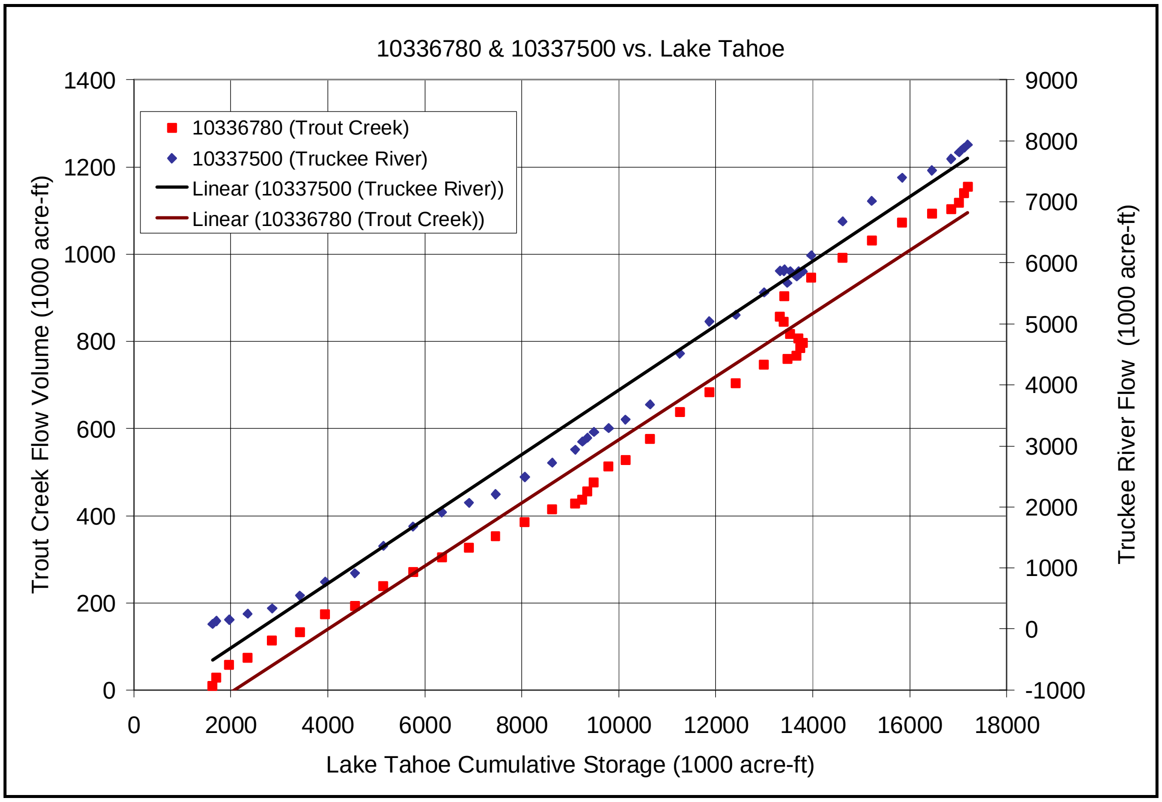

Figure J4. Trout Creek streamflow volume and Lake Tahoe storage.

Appendix K

Double Mass Analysis
Reservoir Volume vs. Snowpack

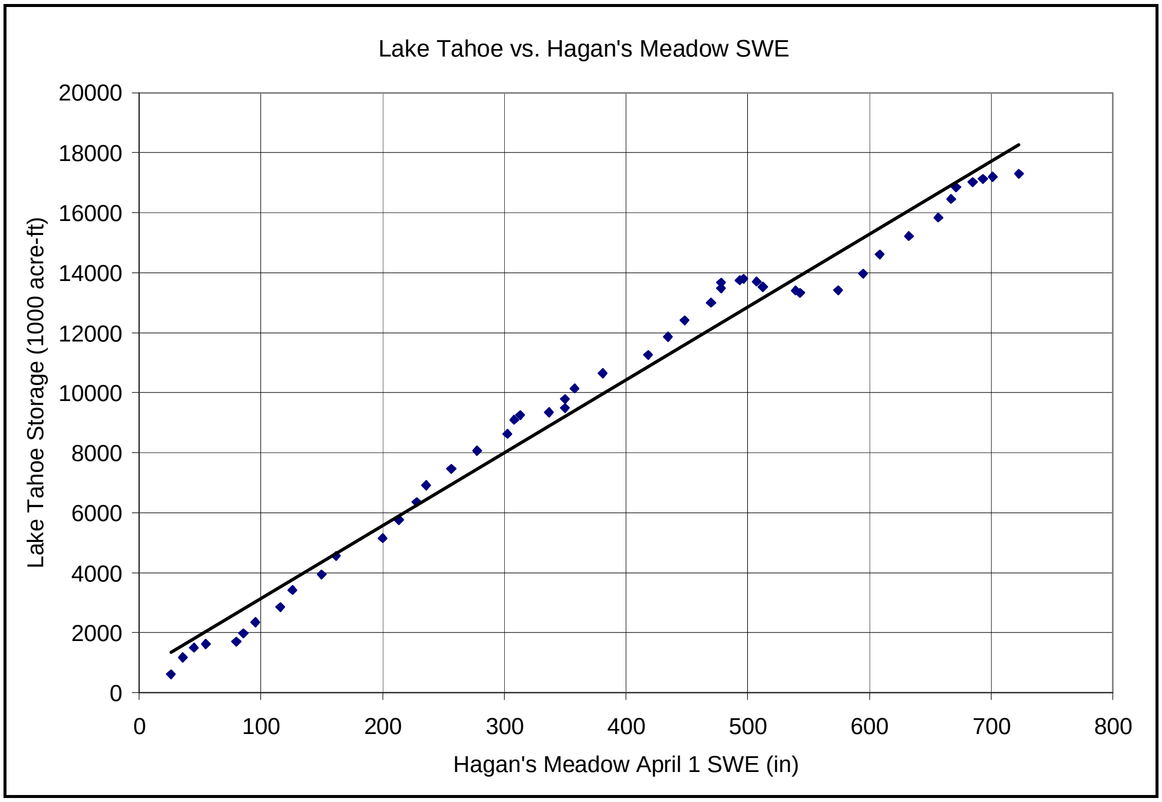

Figure K1. Lake Tahoe storage and April 1 SWE at Hagen's Meadow snowcourse station.

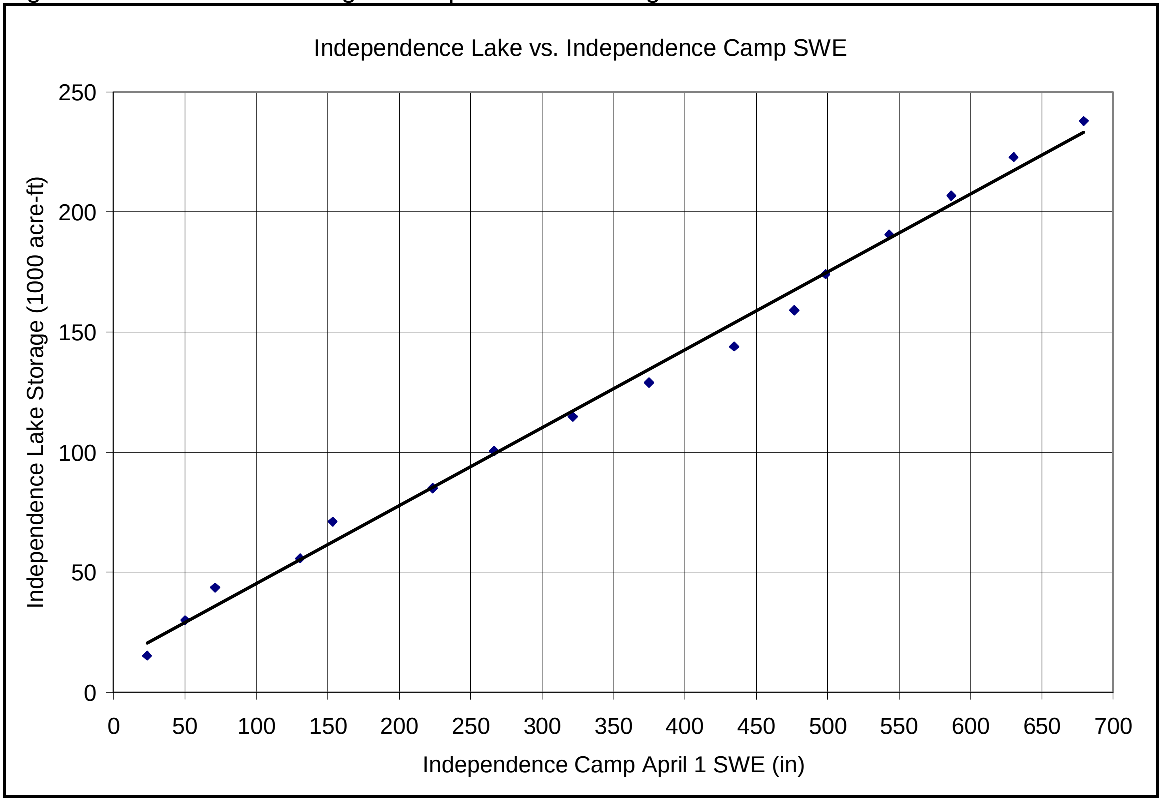

Figure K2. Independence Lake storage and April 1 SWE at Independence camp.

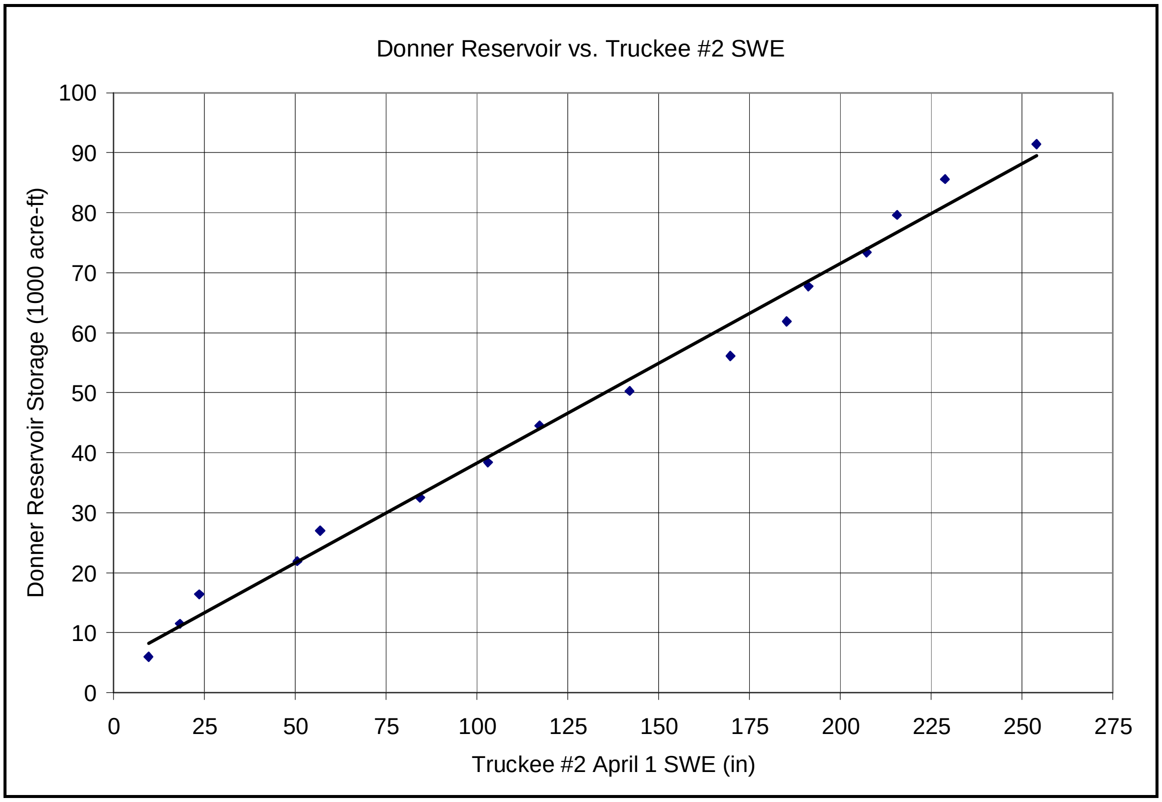

Figure K3. Donner Reservoir storage and April 1 SWE at Truckee #2 snowcourse station.

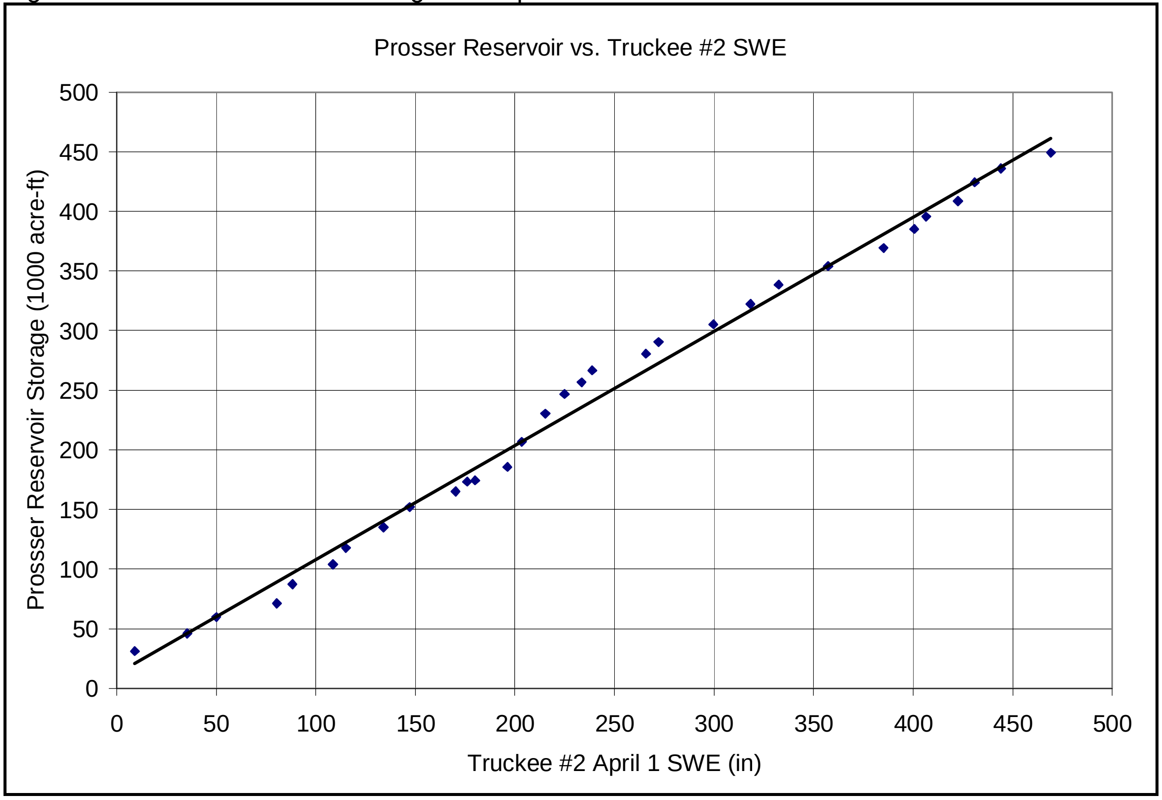

Figure K4. Prosser Reservoir storage and April 1 SWE at Truckee #2 snowcourse station.

Appendix L

Database Descriptions

Table L1. Snowcourse database information.

Name	*ID*	*Latitude*	*Longitude*	*Start*	*End*
Poison Flat	19|06s	38.5055	-119.6261	1942	2005
Blue Lakes	19|05s	38.6078	-119.9244	1918	2005
Hagen's Meadow	19|03s	38.8519	-119.9374	1916	2005
Independence Creek	20k03s	39.4902	-120.2813	1930	2005
Independence Camp	20k04s	39.4528	-120.2927	1941	2005
Independence Lake	20k05s	39.4275	-120.3134	1937	2005
Rubicon	20|02s	38.9992	-120.1303	1912	2005
Truckee	20k13s	39.3009	-120.1841	1931	2005
Marlette Lake	19k04s	39.1640	-119.8967	1915	2005
Mt. Rose Ski Area	19k07s	39.3157	-119.8947	1910	2005

Source: Natural Resources Conservation Service, National Water and Climate Center
http://www3.wcc.nrcs.usda.gov/snow/snowhist.html

Table L2. Streamgage database information.

Name	**ID**	**Latitude**	**Longitude**	**Start**	**End**
E.F. Carson R @ Markleeville	10308200	38.7146	-119.7649	1960	2005
E.F. Carson R @Gardnerville	10309000	38.8449	-119.7046	1900	2005
W.F. Carson R @Woodfords	10310000	38.7696	-119.8338	1900	2005
Clear Creek @ Carson City	10310500	39.1132	-119.7982	1948	2005
Carson R @ Cason City	10311000	39.1077	-119.7132	1939	2005
Carson R @ Fort Churchill	10312000	39.2917	-119.3111	1911	2005
Blackwood Cr. @ Tahoe City	10336660	39.1074	-120.1621	1960	2005
Third Cr. @ Crystal Bay	10336698	39.2405	-119.9466	1969	2005
Incline Cr. @ Crystal Bay	10336700	39.2402	-119.9449	1969	2005
Trout Cr. @ Tahoe Valley	10336780	38.9199	-119.9724	1960	2005
Truckee R @ Tahoe City	10337500	39.1663	-120.1444	1900	2005
Truckee R @ Truckee	10338000	39.2963	-120.2055	1944	2005
Donner Cr. @ Donner Lake	10338500	39.3235	-120.2344	1929	2005
Martis Cr. @ Truckee	10339400	39.3288	-120.1177	1958	2005
Prosser Cr. Bl. Prosser Dam	10340500	39.3732	-120.1316	1942	2005
Sagehen Cr. @ Truckee	10343500	39.4316	-120.2380	1953	2005
Little Truckee R. above Boca	10344400	39.4357	-120.0844	1939	2005
Little Truckee R. below Boca	10344500	39.3869	-120.0955	1911	2005
Truckee R. @ Farad	10346000	39.4280	-120.0341	1909	2005
Hunter Cr. @ Reno	10347600	39.4909	-119.8997	1961	2005
Truckee R. @ Reno	10348000	39.5302	-119.7955	1906	2005
Galena Cr. @ Streamboat	10348900	39.3619	-119.8267	1961	1994
Streamboat Cr. @ Steamboat	10349300	39.3771	-119.7437	1961	2005
Truckee R. @ Vista	10350000	39.5205	-119.7010	1900	2005

Source: U.S. Geological Survey, National Water Information System: Web Interface
http://water.usgs.gov

Table L3. COOP weather station database information.

Name	ID	Latitude	Longitude	Start	End
Boca	40931	39.3833	-120.1000	1936	2005
Donner Memorial St. Park	42467	39.3167	-120.2333	1953	2005
Markleeville	45356	38.7000	-119.7833	1931	2004
Sagehen Creek	47641	39.4333	-120.2333	1953	2005
Truckee Ranger Station	49043	39.3333	-120.1833	1935	2005
Carson City	261485	39.1500	-119.7667	1931	2005
Glenbrook	263205	39.0833	-119.9500	1945	2005
Lahontan Dam	264349	39.4667	-119.0667	1931	2005
Minden	265191	39.0000	-119.7500	1931	2005
Reno Airport	266779	39.5000	-119.7833	1937	2005
Virginia City	268761	39.3000	-119.6333	1951	2005

Source: National Weather Service, Cooperative Observer Program, via the Western Regional Climate Center
http://www.nws.noaa.gov/om/coop/
http://www.wrcc.dri.edu/

Table L4. Reservoir and Lake storage database information.

Name	ID	Latitude	Longitude	Start	End
Boca Reservoir	BOC	39.3830	-120.1000	1960	2005
Donner Lake	DNL	39.3240	-120.2330	1989	2005
Independence Lake	INL	39.4500	-120.2830	1988	2005
Lahontan Reservoir	10312100	39.2750	-119.0400	1917	2005
Martis Creek Reservoir	MRT	39.3270	-120.1130	1972	2005
Prosser Reservoir	PRS	39.3794	-120.1367	1964	2005
Stampede Lake	STP	39.4710	-120.1030	1970	2005
Lake Tahoe	TAH	39.1810	-120.1180	1957	2005

Source: California Department of Water Resources, Division of Flood Management, by request
http://cdec.water.ca.gov/misc/resinfo.html
Except for Lahontan Reservoir, which was from the USGS National Water Information System: Web Interface
http://waterdata.usgs.gov/nv/nwis/

PRELIMINARY EVALUATION OF CLIMATIC DATA IN TRUCKEE MEADOWS REGION

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1 INTRODUCTION

Our climate has always been in a state of change. Within the last 1000 years, the Sierra Nevada Mountains have undergone two warm, dry periods of 150 and 200 year duration during AD 900–1350, and a Little Ice Age, from AD 1400 to 1900 (Millar and Wolfenden, 1999). Any changes to the climate in the present times have the potential to severely disrupt the growth and survival of our civilization. Of all avenues which are affected by climate change, water availability is one of the most significant. The survival and growth of a number of our cities, agricultural areas, environmental reserves, natural resources, etc. will depend upon our preparedness for reacting towards changing climate and water availability.

Annual precipitation has increased for most of North America with large increases in northern Canada, but with decreases in the southwest U.S., the Canadian Prairies and the eastern Arctic (Trenberth et al., 2007; Shein, 2006). Heavy precipitation frequencies in the U.S. were at a minimum in the 1920s and 1930s, and increased to the 1990s (1895 to 2000) (Kunkel, 2003; Groisman et al., 2004). Streamflow in the eastern U.S. has increased 25% in the last 60 years (Groisman et al., 2004), but over the last century has decreased by about 2%/decade in the central Rocky Mountain region (Rood et al., 2005). Since 1950, stream discharge in both the Colorado and Columbia River basins has decreased, at the same time annual evapotranspiration (ET) from the conterminous U.S. increased by 55 mm (Walter et al., 2004). The fraction of annual precipitation falling as rain (rather than snow) increased at 74% of the weather stations studied in the western mountains of the U.S. from 1949 to 2004 (Knowles et al., 2006).

As is clear from the studies cited above, climate change has a multi-pronged effect on water resources. It not only changes the inflow of water into the water bodies, but also the outflow by changing withdrawals, evaporation from the water surface, and transpiration by plants. Several regions in the world are expected to face water shortages due to climatic changes but the situation is expected to be more severe in regions which are already arid or semi-arid. The US South West is one such region where water might be a limiting factor to further development. Several studies have been conducted to evaluate the impacts of climate change and their mitigation in river basins in the Western US (Payne et al, 2004; Hamlet and Lettenmaier, 1999; VanRheenen et al, 2004; Christensen et al, 2004).

Climate change projections for Southwestern United States remain uncertain about the magnitude of temperature and precipitation changes. Nonetheless, most climate change projections agree upon an increase in temperature and a reduction in precipitation in this region (IPCC, 2007; Seager et al., 2007). This will result in a greater portion of precipitation occurring as rainfall and an increased rate of snowmelt in the Sierra Nevada Mountains (Pupacko, 1993; Dettinger, 2005). Additionally this would cause an increase in streamflow during the spring season and drier conditions during summers, thus changing the entire hydrological cycle of the watershed by altering the flow hydrograph of streams and rivers (Knowles et al., 2006; Stewart et al., 2004; Stewart et al, 2005).

Historical records show that global runoff increases by 4% for every 1^{o}C rise in temperature (Labat et al., 2004) but the changes may vary regionally and must be studied in greater detail for effective policy making.

Climate of the Western US has experienced large changes. It is estimated that since the 1940s the temperature in the western US has risen by 1-2^{o}C with a more pronounced increase in winter and spring temperatures (Karl et al, 1993; Dettinger et al, 1995; Lettenmaier et al, 1994; Vincent et al, 1999). Spring in this region onsets earlier these days and spring snowmelt pulses in streams have shifted back (Cayan et al, 2001, Regonda et al, 2005). An analysis of certain climate change scenarios for California revealed a significant warming of the region and significant losses in snow cover in Northern and Central Sierra Nevada Mountains (Cayan et al, 2008; Pierce et al, 2008). April 1 snow water equivalent (SWE) has declined 15 to 30% since 1950 in the western mountains of North America, particularly at lower elevations and primarily due to warming rather than changes in precipitation (Mote, 2003; Mote et al., 2005; Lemke et al., 2007).

The changes in climate are expected to increase the intensity and frequency of major flood events in the river basins of Sierra Nevada Mountains (Kim 2005). Most existing modeling studies of increased atmospheric CO_2 point to increased precipitation variability (Giorgi et al., 1994; Maurer et al, 2006; Mearns et al., 1995a, b; Trenberth et al, 2003). Significant changes in patterns in streamflow through the year can be expected in the future due to climate change (Maurer 2007) with increases in winter streamflow and decreases in summer stream flows and a shift of flow towards the earlier part of the year (Maurer and Duffy, 2005). Climate change is also estimated to have major negative impacts on the reservoirs relying on the runoff from Sierra Nevada Mountains. This will severely limit the potential of such reservoirs in fulfilling their designated purposes of water supply, hydropower generation, environmental, and ecological functions (Vicuna et al, 2007).

The Truckee Meadows Water Authority (TMWA), which is the largest water purveyor in the Reno-Sparks region, in the western US, relies primarily on the snowmelt and runoff from the Sierra Nevada Mountains to provide 85% of the water it delivers to its customers via Truckee River diversions. The Truckee River which is a 140 miles long river originating at Lake Tahoe and draining into Lake Pyramid. Primary source of water for Lake Tahoe and consequently Truckee River is the snowpack on the Sierra Nevada Mountains. Therefore, it is one of those regions which can experience a significant change in the water availability in the future because of the changing climate.

One of the principal responsibilities of the Truckee Meadows Water Authority (TMWA) is to assure that the water resources are developed and managed to fulfill the present and future water needs of the greater Truckee Meadows community (Chapter 277, NRS). In order to achieve this objective, TMWA has a 20 year water resource plan that is updated every 3 to 5 years. Climate change, because of its uncertainty of magnitude, and implications on hydrology, poses a major challenge in the course of efficient planning.

Therefore, planners and decision makers must have access to the latest developments in the field of climate change science and the study of its impacts on water availability.

Another difficulty in planning for climate change arises due to a lack of spatial resolution suitable enough to be adopted for most watersheds (Giorgi and Mearns, 1991; Leung et al., 2003). Forecasts that may be applicable to a large region in general may not be applicable to smaller watersheds on a finer temporal resolution. Therefore, it is necessary to combine information from various sources to make the projections more adaptable to the Truckee Meadows region. This report compiles the knowledge from the latest studies, field data, experiments, and computer simulations and brings an integrated assessment of the climatic changes experienced by the Truckee Meadows and changes that it should prepare to expect in the future. It will be helpful to the decision makers while framing water management policies by providing them with an insight into the changes anticipated in the hydrological processes in the Truckee Meadows region due to climate change and to examine their policies so as to mitigate its potential effects.

Future climate changes have the potential to threaten the sustainability of water resources of Truckee Meadows by disturbing the hydrological processes and changing the water availability patterns. Scientific knowledge and the latest information on the developments in the field of climate change and hydrology is a very powerful tool in the hands of planners to develop well directed policies. In view of this, in 2006, Dr. Mark Stone of the Desert Research Institute prepared two reports for TMWA on climate change and its impacts on the hydrology of the region. The first document summarized the state of the science in climate change research with an emphasis on potential impacts on water resources. The second report contained an extensive analysis of the gauged weather, streamflow, and reservoir data in the Truckee River and Lake Tahoe basins to attempt to identify early signs of climate change impacts in the region. The purpose of these reports was to inform the TMWA management of how climate change could impact their ability to carry out their mission of water delivery to their customers. The present report updates those reports with current information and additional data sources which have become available over the past 3 years. This additional information is important to consider due to the recent proliferation of climate change research. Further, this report also includes the analysis of spatially explicit gridded datasets available from various sources to expand the analysis of station data carried out in previous reports.

This study will improve the understanding of the impact of potential climatic changes on the water resources of the Truckee Meadows region. The primary deliverables of the proposed research is this updated report on the state of the science of climate change impacts research and on the trends analysis which incorporates the gridded data described above.

1.1 Study Area

The study area is located in the north western part of Nevada on the Border with California. It contains the urban areas of Reno with a population of 214,853, Sparks with a population of 87,139, and Carson City with population of 54,939 (US Census Bureau). Figure 1 shows the relief of the study area. The western edge of the study area lies on the

Sierra Nevada Mountains and has an elevation of up to 3200 m above sea level. Carson Desert and Pyramid Winnemucca Lakes which are the lowest points in the study area lie on the floor of the Great Basin and have elevation of 1100 m. A significant portion of the snowcaps on the Sierra Nevada Mountains, which are the primary source of water to Lake Tahoe, Truckee River and Carson River, lie in California. However, a greater portion of the study area lies in the Great Basin in Nevada.

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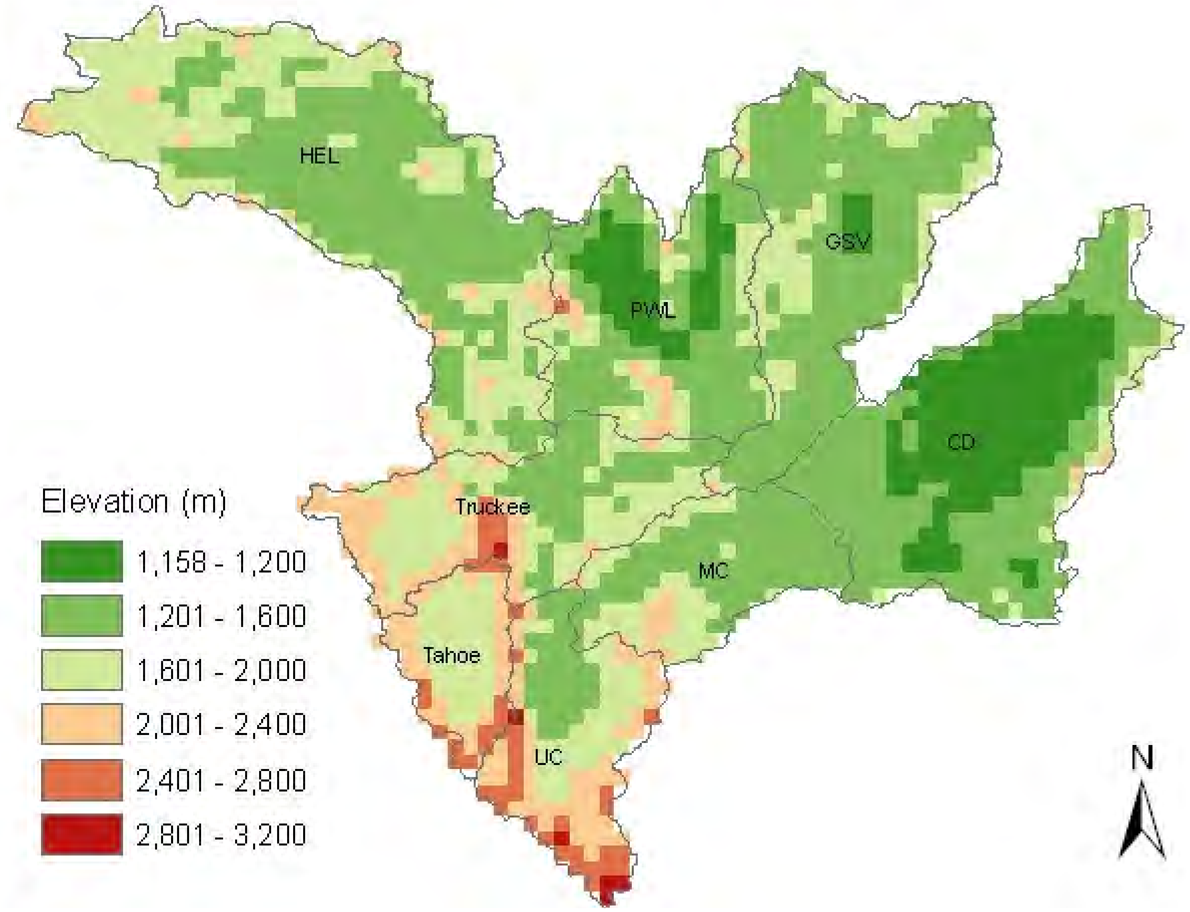

Figure 1 Elevation of the study area above MSL.

1.2 Objectives

Weather stations, stream gauges, and reservoir levels can all provide insights into long term trends in climate and hydrology. These sources include data from Natural Resources Conservation Service Snowpack Telemetry (SNOTEL), NWS Cooperative Network, Remote Automated Weather Stations, USGS High Altitude Precipitation, USGS streamflow gages, USGS groundwater monitoring wells, and Snow Course Stations. These stations were used in the 2006 report to study potential trends in the region. However, there are several limitations to gauged data which have led researchers to enhance the usefulness of the measured records by interpolating them over an extended area. Gauged data is collected at a single point and therefore has serious limitations in terms of studying spatial patterns in data. Further, inconsistencies in measuring techniques in both time and space often makes comparison studies quite complicated.

This limitation can be overcome through the use of gridded datasets which are based on a re-analysis of historical data using process based simulation models that ingest historic data. Precipitation-elevation Regressions on Independent Slopes Model (PRISM) and The Variable Infiltration Capacity (VIC) are examples of spatially gridded data that are used in this study to add to the data analysis task performed in the previous reports. Each of these is explained in brief in the following paragraphs.

PRISM, developed by the Spatial Climate Analysis Service and Oregon Climate Service, is an analytical model that uses station point data, a digital elevation model and additional spatial datasets to produce 4 km resolution grids of monthly temperature and precipitation across the continental US (Daly et al., 2002; Daly et al., 1994). As the model is also designed to incorporate high elevation data from mountainous regions and to accommodate difficult climate mapping situations in innovative ways, PRISM is well suited to capture the complex climatological conditions present in the western US (Nanus et al., 2003). PRISM is currently the primary dataset being used in WestMap, and is also implemented in the California Climate Tracker (CCT) to bolster climate information across sparsely monitored locations in the state of California. PRISM has also been adopted by NOAA's NWS for a number of products and projects. Monthly accumulated precipitation along with monthly averaged maximum and minimum temperatures will be used as inputs to derive a number of the drought indices of interest.

The VIC model (Liang et al., 1996) is a macroscale hydrologic model that is capable of distinguishing characteristics of subgrid heterogeneity in soils, vegetation, topography and precipitation. The VIC dataset is advantageous for examining hydrologic changes over the study area given its 1/8 degree or 10x12 km horizontal spatial and daily temporal resolution. VIC provides information of temperature, precipitation, snow water equivalent, soil moisture, runoff, and evapotranspiration for every pixel. One of the premier advantages of VIC is its simulation of the snow water and energy balance which is a key component of the hydrologic setting of the study area. VIC has been implemented in numerous research studies and operational products, and is well established for usage across the western US (Lettenmaier et al., 1999; VanRheenen et al., 2004; Christensen et al., 2004).

The broad objectives of this study can be summarized as follows.
Objective 1: Update the state of the science literature review, which was completed in 2006, with relevant publications and products released over the past 3 years.
Objective 2: Expand the data analysis task by evaluating spatial patterns and extended records available from the gridded datasets.
Objective 3: Perform a cursory analysis of existing climate change scenarios that have been downscaled for the Truckee basin to provide an overview of expected trends and related uncertainty.

2 PAST CLIMATE TRENDS

2.1 PRISM

It has been shown in a number of studies that topography plays a major role in the distribution of precipitation and temperature over an area especially in mountainous regions. The rate of precipitation as well as temperature varies considerably at different elevations and on the different faces of a relief. This feature, however, is not adequately represented by statistical or graphical methods of precipitation interpolation. Parameter-elevation Regressions on Independent Slopes Model (PRISM) is an analytical model that can be used to distribute point measurements of monthly, seasonal, and annual precipitation to a geographic grid. PRISM uses data from weather stations and digital elevation models to model annual, monthly and event based climate events that are gridded and GIS compatible.

The Lake Tahoe watershed primarily comprises of mountainous regions of the Sierra Nevada Mountains. In such topography, conventional interpolation methods are not sufficient to model climate parameters such as precipitation, temperature, etc. Therefore, this study utilizes the outputs from PRISM to evaluate the changes that have occurred to the climate of the region in the past decades. A collaborative effort between the Spatial Climate Analysis Service and the Oregon Climate Service has resulted in detailed, high-quality spatial climate datasets, referred to as PRISM maps (Daly et al., 2001). PRISM is an analytical model that distributes point measurements of monthly, seasonal, and annual precipitation to a geographic grid of four kilometers by four kilometers. By use of a resampling algorithm, two-kilometer by two-kilometer resolution grids can be estimated. These grids are produced in a GIS compatible latitude-longitude grid or a gridded map projection.

Digital elevation models (DEMs) are used in conjunction with observed precipitation values in the PRISM model to determine variation in precipitation as a function of elevation. DEMs contain information that describes the earth’s topography, including slope, aspect, and elevation. Because the PRISM precipitation dataset is a function of the observed data and topography, orographic precipitation and rain shadows are uniquely and accurately modeled in PRISM (Daly et al., 2001).

Three existing climate datasets are used by PRISM to create maps: the National Climatic Data Center 1961-1990 normals dataset (CLIM-81) observed by the National Weather Service Cooperative Climate Network; the NRCS SNOTEL (SNOwpack TELemetry) network dataset, and supplemental datasets submitted by the individual State Climatologists or regional climate centers (Daly et al., 2001). The PRISM Evaluation Group (PEG), composed of State and Regional Climatologists, representatives of national agencies, NRCS representatives and other state and local government users, evaluated and endorsed the PRISM model for Idaho, Nevada, Oregon, and Utah data (Daly et al., 2001). An examination of average annual PRISM precipitation values in the Willamette River basin, northern Oregon, resulted in 0.1 cm (1.0 percent of observation) cross validation bias and 17 cm (10 percent of observation) mean absolute error (Daly et al., 1994).

PRISM is designed and updated to map climate parameters in varying terrains, including high mountains, rain shadows, coastal regions, and other complex climatic regimes. PRISM accounts for topographic facet (hill slope orientation) to handle rain shadows, and for elevation, a primary driver of climate patterns (Daly et al., 2001). Two main advantages of using PRISM data are that precipitation values are available on a regular grid size of four kilometers by four kilometers, and the data are available in digital form. These two factors allow PRISM data to be easily integrated with other water budget components and calculations within a Geographic Information System (GIS) environment.

To analyze the PRISM data, the study area was segmented into eight smaller sub basins. The sub basins used for this purpose were derived from the hydrologic units shapefile obtained from the National Atlas website last downloaded on August 7, 2009 (http://www.nationalatlas.gov/atlasftp.html#hucs00m). Table 1 shows the details of the watersheds studied using PRISM data.

Table 1 Division of the study area.

Sub-watershed	**Denomination**	**Pixels**	**Area (Km^2)**
Carson Desert	CD	335	5360
Granite Springs Valley	GSV	263	4208
Honey Eagle Lakes	HEL	437	6992
Middle Carson	MC	139	2224
Pyramid Winnemucca Lakes	PWL	215	3440
Lake Tahoe	Tahoe	79	1264
Truckee River	Truckee	191	3056
Upper Carson	UC	147	2352
Entire Watershed	Entire	1806	28896

Monthly precipitation, average monthly minimum and maximum temperature data were downloaded from the PRISM Group's ftp site for the years 1895 to 2008. These files stretch on a four kilometer by four kilometer grid scale covering the entire continental United States. Because a very small window of the entire United States dataset was needed, clipping of the data to the study area was completed as an initial step using the eight smaller subdivisions of the region. These clipped data were then used for determining the temperature and precipitation values over the watershed for the above mentioned time period on a monthly time scale. The end product of data processing resulted in precipitation data in millimeters, and monthly average maximum and minimum temperatures in ^{o}C. The monthly temperature and precipitation values were then tabulated and trends were generated. A detail of the data processing procedure is provided in the Appendix 6.1.

Figure 2 and Figure 3 show the average maximum and minimum monthly temperatures for the study area in 2007. Temperature variation within the study area shows an expected increase from west to east because of lowering of elevation. Similarly, Figure 4 shows the precipitation distribution over the study area. The south western edge of the study area, which has the maximum elevation, also receives the highest amount of precipitation. It decreases from west to east because of the rain shadow effect produced by the Sierra Nevada Mountains on the west portion of the study area.

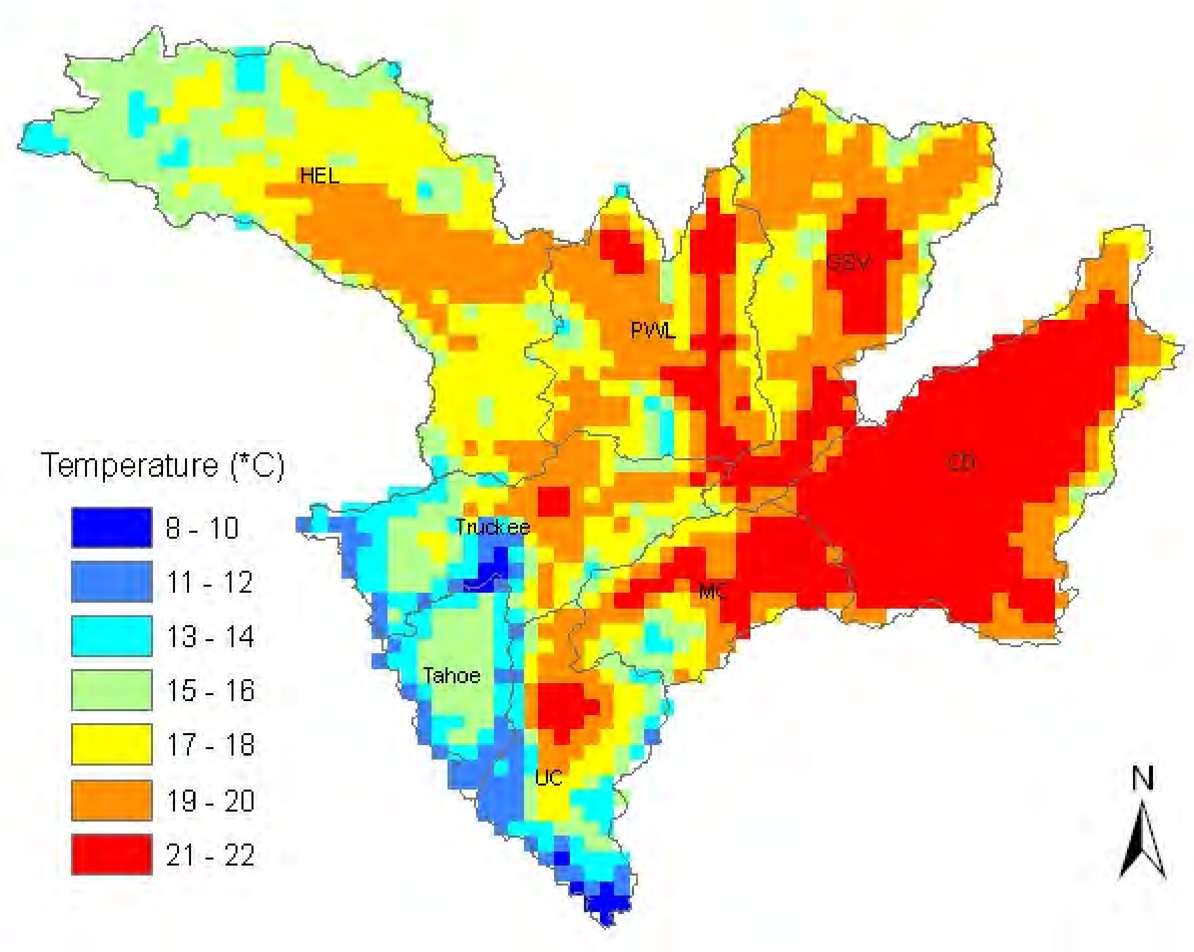

Figure 2 Average maximum monthly temperature for 2007.

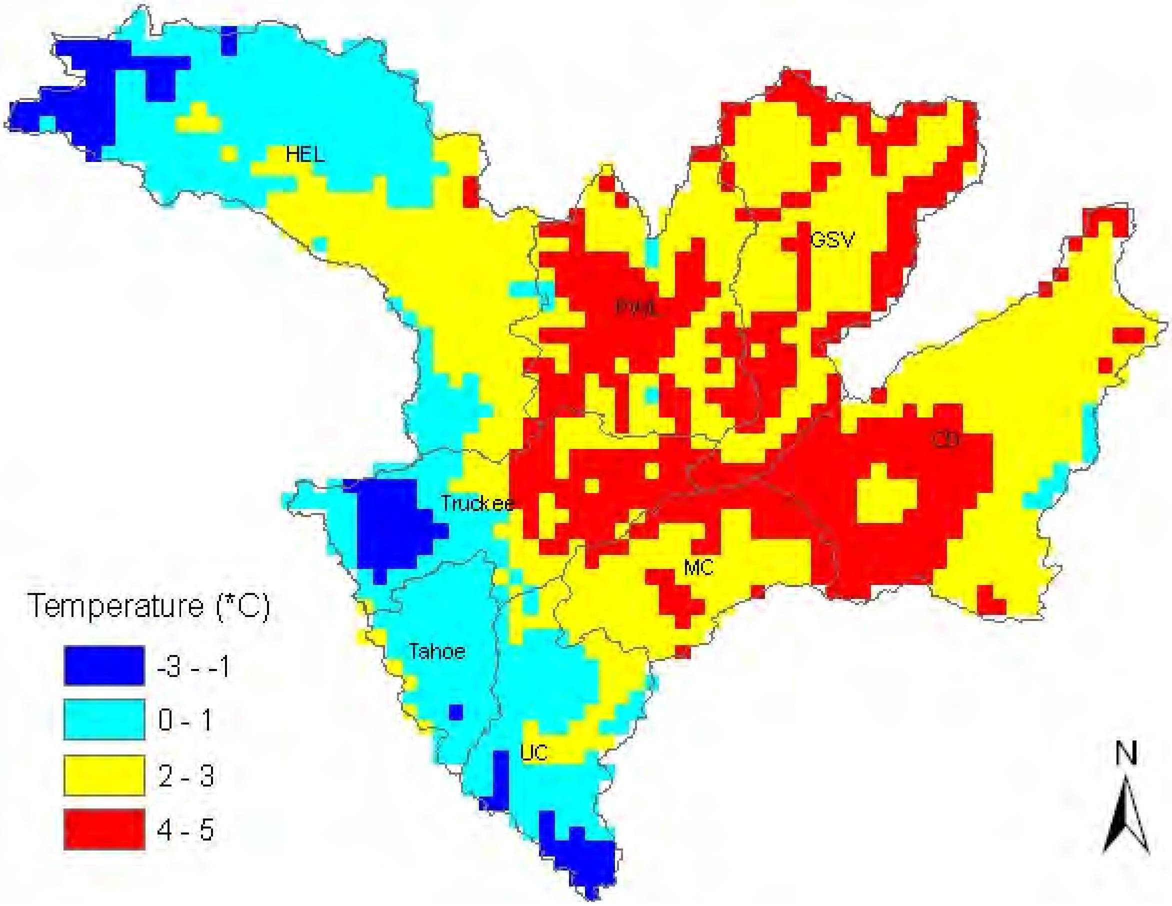

Figure 3 Average minimum monthly temperature for 2007.

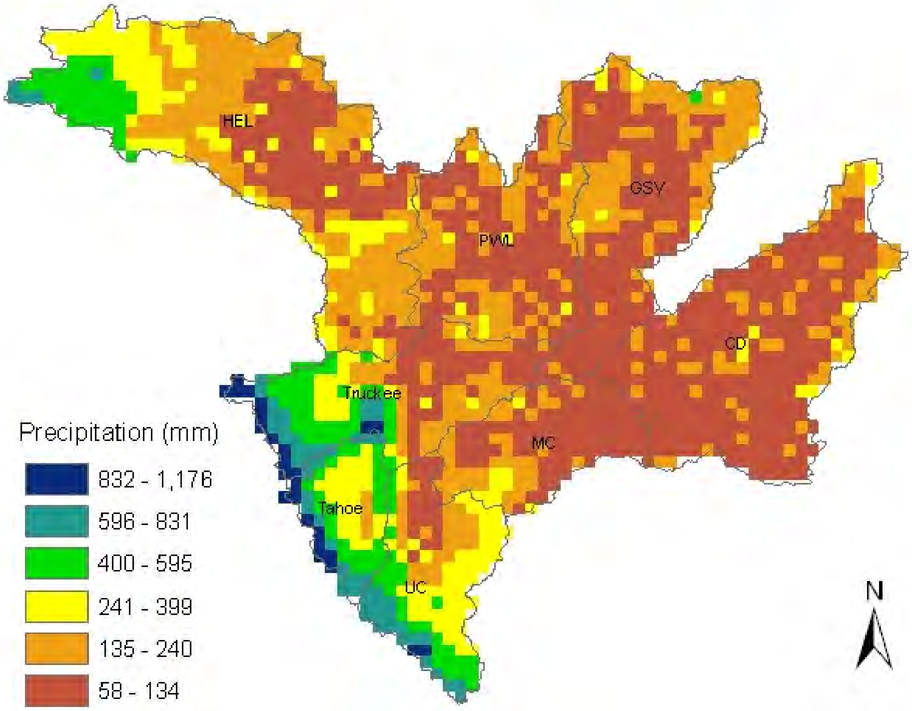

Figure 4 Total precipitation for 2007.

Analysis of precipitation data for the eight sub regions shows that annual precipitation has experienced an increasing trend in six of the sub regions excluding Honey Eagle Lakes and Upper Carson (Table 2). Figure 5 shows the variation in annual precipitation in the Lake Tahoe Basin. Breaking down the annual precipitation trends into the four seasons reveal that the increase is not uniform throughout the year. All but GSV show a decrease in winter precipitation with UC experiencing the largest rate of decrease. In case of spring season, all regions at lower altitudes experienced an increasing trend in precipitation during the study period and all the high altitude regions show a decline in spring precipitation. However, for the summer months, all regions show similar increasing trends. The high altitude regions which show a decreasing trend for spring precipitation show the greatest rates of increase in fall precipitation thus more than compensating for the decline experienced in winter and spring seasons. The lower regions also experience an increase in fall precipitation but at a smaller rate.

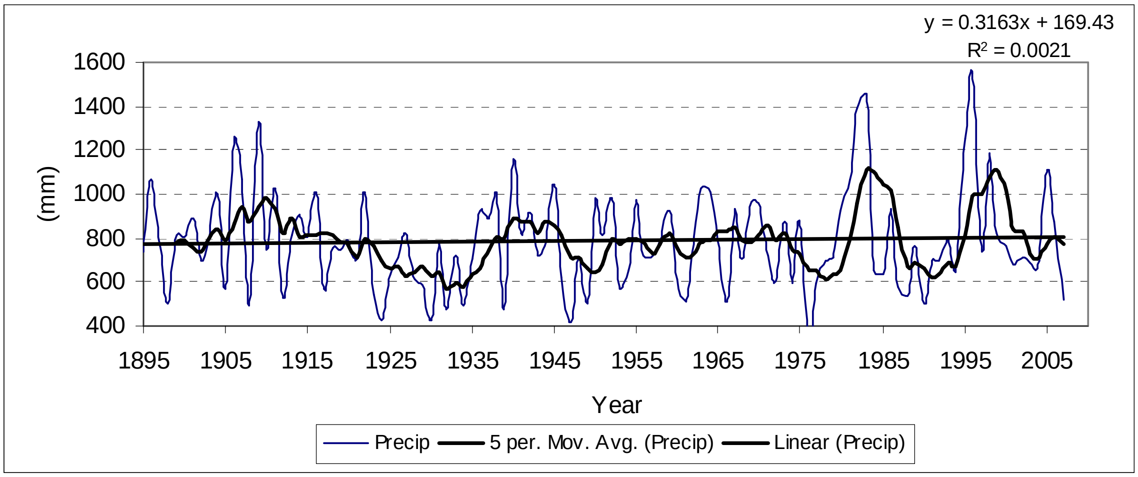

Figure 5 Annual precipitation for Lake Tahoe Basin.

Table 2 Annual average rate of change in precipitation.

Precipitation Trends		**Winter**	**Spring**	**Summer**	**Fall**	**Annual**
Carson Desert	CD	-0.0068	0.1335	0.1216	0.1006	0.3423
Granite Springs Valley	GSV	0.0007	0.1594	0.1471	0.1192	0.4283
Honey Eagle Lakes	HEL	-0.0432	-0.0679	0.114	-0.0022	-0.0198
Middle Carson	MC	-0.1408	0.0157	0.114	0.1052	0.0756
Pyramid Winnemucca Lakes	PWL	-0.1414	0.0165	0.1051	0.0579	0.0343
Lake Tahoe	Tahoe	-0.0797	-0.2516	0.1663	0.5514	0.3163
Truckee River	Truckee	-0.0086	-0.2608	0.1221	0.4065	0.214
Upper Carson	UC	-0.3452	-0.2393	0.1526	0.3977	-0.0823
Entire Study Area	Entire	-0.0718	-0.0233	0.1255	0.1500	0.1607

The monthly maximum and minimum temperatures for the Lake Tahoe basin have been rising as seen in Figure 6 and Figure 7. Temperature trends for all sub regions in the study area show consistent rising trends over the period of study (Table 3 & Table 4).

The analyses of average monthly minimum and maximum temperatures show that the rate of change was not uniform for the four seasons.

Maximum temperatures increased all over the study area for all seasons but average maximum temperature for winters displayed the highest rate of increase. Minimum temperatures on the other hand show a reversed trend for the winter season with the lowest rate of increase of all seasons.

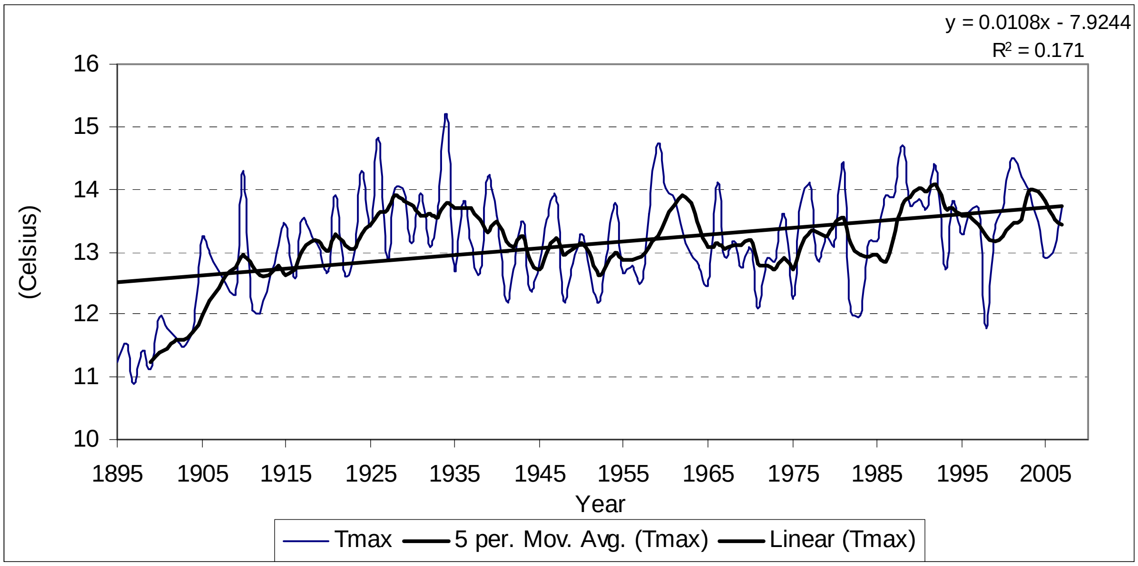

Figure 6 Annual average monthly maximum temperatures for Lake Tahoe Basin.

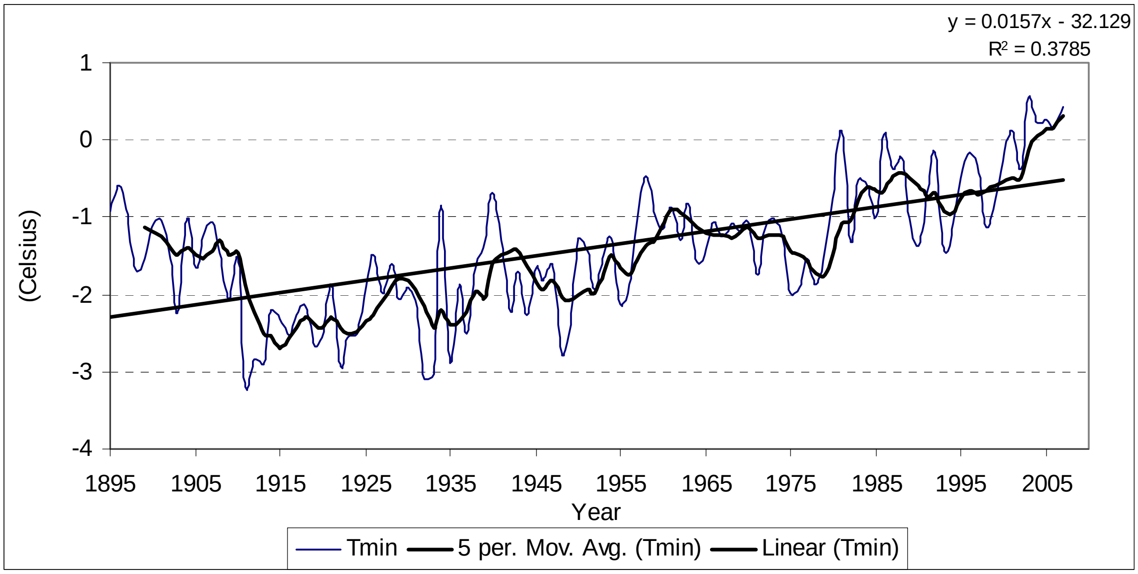

Figure 7 Annual average monthly minimum temperatures for Lake Tahoe Basin.

Table 3 Annual average rate of change in maximum temperatures.

Maximum Temperature		**Winter**	**Spring**	**Summer**	**Fall**	**Annual**
Carson Desert	CD	0.0234	0.0121	0.0109	0.0107	0.0143
Granite Springs Valley	GSV	0.017	0.0101	0.0102	0.0006	0.0095

Honey Eagle Lakes	HEL	0.0202	0.0103	0.0091	0.0004	0.01
Middle Carson	MC	0.015	0.0093	0.0108	0.0064	0.0104
Pyramid Winnemucca Lakes	PWL	0.0214	0.0123	0.0139	0.0032	0.0127
Lake Tahoe	Tahoe	0.0144	0.011	0.0101	0.0077	0.0108
Truckee River	Truckee	0.0172	0.0122	0.0201	0.0088	0.0146
Upper Carson	UC	0.0131	0.011	0.0088	0.009	0.0105
Entire Watershed	Entire	0.0189	0.011	0.0115	0.005	0.0116

Table 4 Annual average rate of change in minimum temperatures.

Minimum Temperature		**Winter**	**Spring**	**Summer**	**Fall**	**Annual**
Carson Desert	CD	0.0122	0.0142	0.0101	0.0093	0.0153
Granite Springs Valley	GSV	0.0095	0.0072	0.0133	0.0098	0.001
Honey Eagle Lakes	HEL	0.0064	0.0095	0.0164	0.0143	0.0117
Middle Carson	MC	0.012	0.0155	0.0171	0.0179	0.0155
Pyramid Winnemucca Lakes	PWL	0.0101	0.0119	0.0198	0.0166	0.0147
Lake Tahoe	Tahoe	0.0145	0.0144	0.017	0.0169	0.0157
Truckee River	Truckee	0.0067	0.01	0.0122	0.0136	0.011
Upper Carson	UC	0.0118	0.0116	0.0214	0.0167	0.0154
Entire Watershed	Entire	0.0096	0.0104	0.0153	0.0146	0.0125

2.2 VIC Hydrological Model

This study also uses the outputs of the Variable Infiltration Capacity (VIC) hydrological model to analyze the changes occurring to the snow water equivalent (SWE) in the region between 1915 and 2005. Daily gridded meteorological data obtained from the Surface Water Modeling group at the University of Washington from their web site at http://www.hydro.washington.edu/Lettenmaier/Data/gridded/, the development of which is described by Hamlet and Lettenmaier (2005) and Maurer et al., (2002). VIC is a macroscale hydrologic model that balances both surface energy and water over a grid mesh, typically at resolutions ranging from a fraction of a degree to several degrees latitude by longitude. The primary sources of meteorological data used in the data-processing sequence include NCDC Co-op data, monthly time step HCN and HCCD data, and PRISM data (Hamlet and Lettenmaier, 2005).

Most of the grid cells selected for the analysis lie along the periphery of Lake Tahoe. Figure 8 displays the grid cells from VIC model outputs which are used for the analysis of SWE changes. Each grid cell covers 1/8th of a degree grid cell (i.e. 13.8 km along the longitudes and approximately 10.1 km along the latitudes). To determine the changes in SWE over the time horizon afforded by VIC data, average SWE for January was calculated for each year. Figure 9 shows that the mean SWE for January has increased by almost 1mm per year. SWE calculations for April 1 were also carried out which showed a decline for all the grid cells. Therefore, to understand this inconsistency, March 1 and February 1 SWE were calculated for all the cells. The results show a rise in the SWE for January 1 and February 1 for all the grid cells whereas all the grid cells evaluated display a decline in April 1 SWE (Table 5). The average change in SWE per year ranges from 0.22 mm/yr to 1.07 mm/yr.

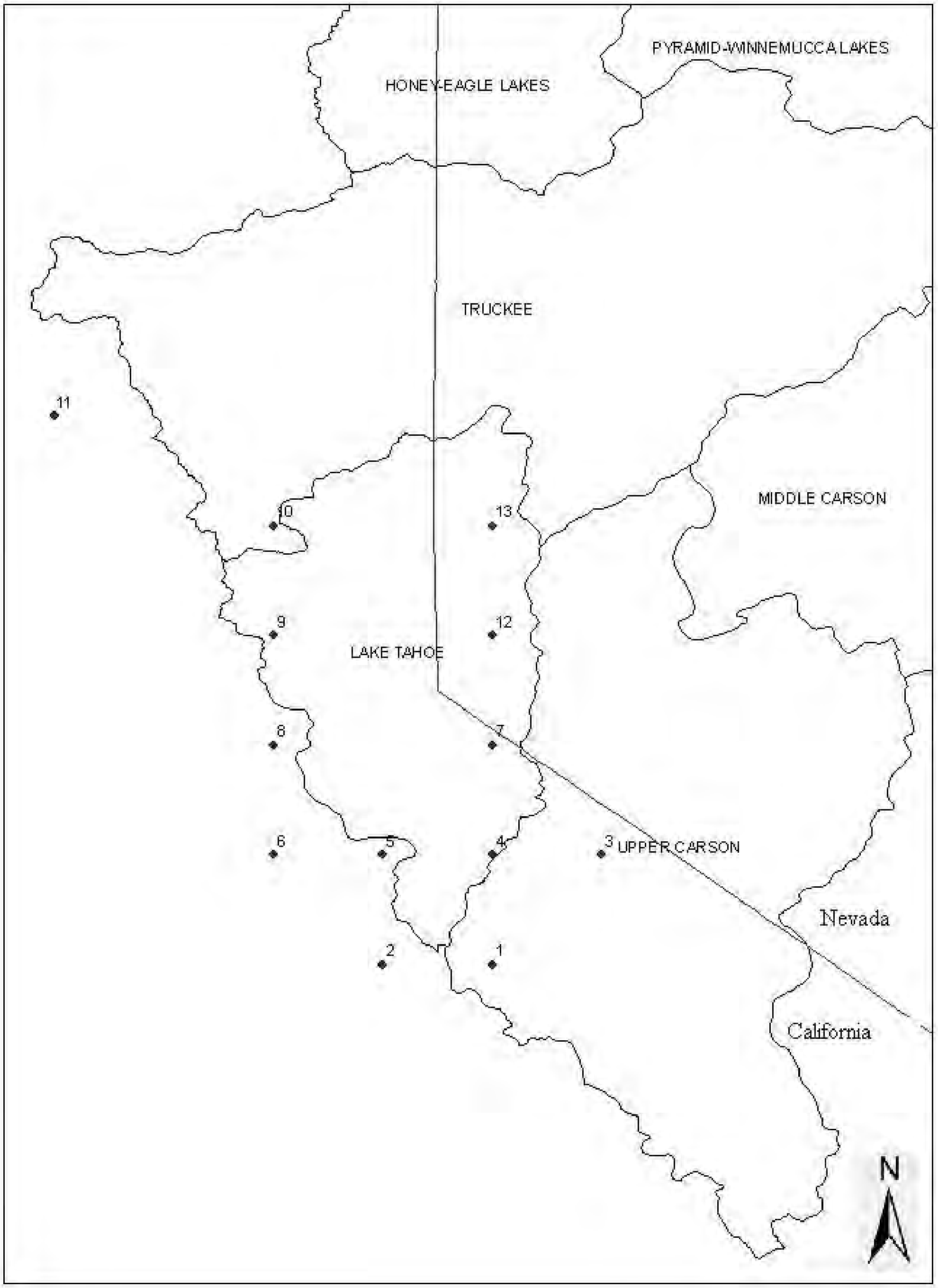

Figure 8 Location of VIC grid cells used for estimating SWE variations.

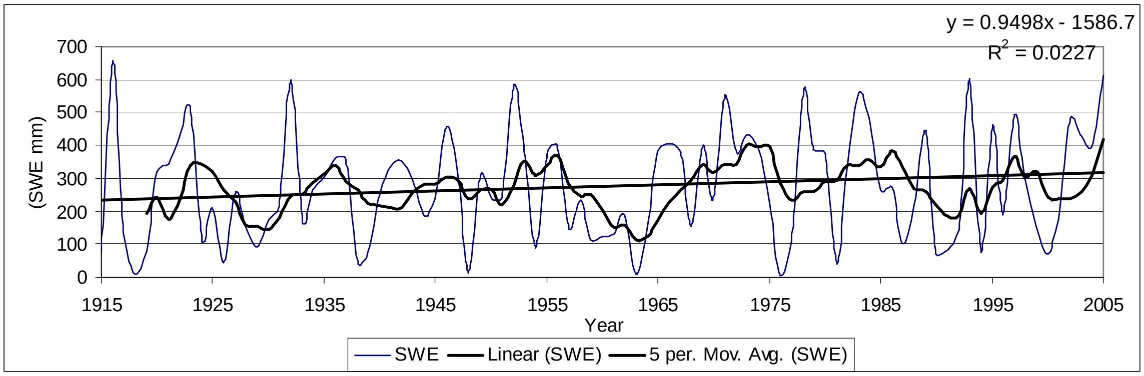

Figure 9 Mean January SWE variation for grid cell #1.

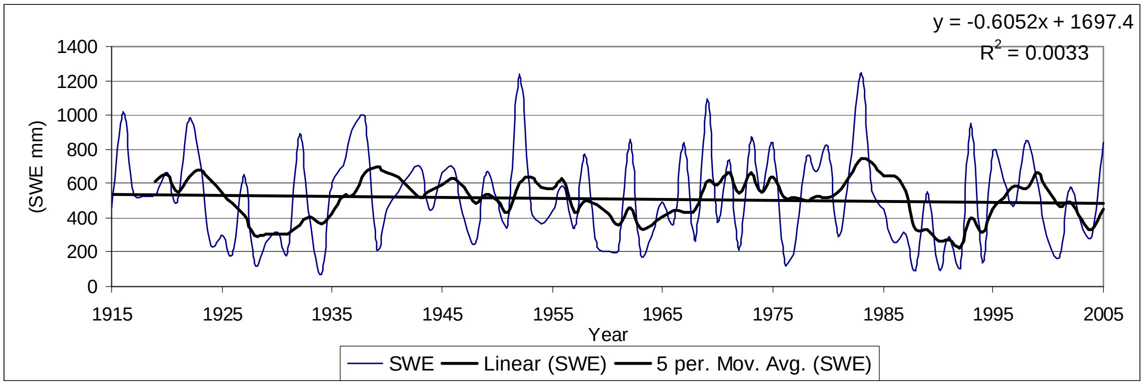

Figure 10 April 1 SWE for grid cell #2.

Table 5 VIC results for SWE variations.

Grid Cell	Latitude	Longitude	Average Change/Year (mm)				
			Mean Jan	**1-Apr**	**1-Mar**	**1-Feb**	**1-Jan**
1	38.6875	-119.938	1.079	-0.0413	0.3831	0.9179	1.1618
2	38.6875	-120.063	0.9498	-0.6052	0.0154	0.7107	1.1386
3	38.8125	-119.813	0.2191	-0.1405	-0.1725	0.0609	0.3279
4	38.8125	-119.938	1.0508	-0.0709	0.2505	0.8597	1.1997
5	38.8125	-120.063	1.0261	-0.3269	0.2751	0.8396	1.1811
6	38.8125	-120.188	0.4951	-0.5896	-0.2314	0.2683	0.7333
7	38.9375	-119.938	0.5468	-0.3521	-0.1536	0.363	0.7069
8	38.9375	-120.188	1.0262	-0.5268	0.1914	0.8565	1.1877
9	39.0625	-120.188	0.4471	-1.072	-0.4237	0.22	0.6665
10	39.1875	-120.188	0.7225	-0.101	0.1599	0.5842	0.8456
11	39.3125	-120.438	0.9876	-0.4272	0.1807	0.6736	1.1597
12	39.0625	-119.938	0.2212	-0.4176	-0.1687	0.0821	0.4019
13	39.1875	-119.938	0.3266	-0.5255	-0.2924	0.1996	0.5101

3 FUTURE CLIMATE CHANGE

3.1 Emission Scenarios

Green House Gas (GHG) emissions are dependent on a large number of factors which are interrelated in very complex and dynamic system. The emissions are driven by factors such as demographic development, socio-economic development, and technological change. Predicting the evolution of these factors is extremely difficult but a number of possible alternative paths, along which the future might unfold, can be postulated. These scenarios assist in analyzing the effects of changing climate on available resources and comparing available measures to mitigate its effects. Emission scenarios provide us with several alternative paths along which the world may progress and thus how GHG emissions might change over time. A number of such scenarios based on a wide array of driving forces have been developed by researchers all around the world.

Four different narrative storylines describing a range of possible alternative paths, excluding “surprise” or “disaster” scenarios have been generated by the IPCC based on literature. These were developed to describe consistently the relationships between emission driving forces and their evolution and add context for the scenario quantification. Each storyline represents different combination of demographic, social, economic, technological, and environmental developments. All scenarios based on the same storyline constitute a scenario “family”. Each scenario represents a specific quantitative interpretation of one of four storylines described below.

Four qualitative storylines yield four sets of scenarios called “families”: A1, A2, B1, and B2. All are equally valid with no assigned probabilities of occurrence. The set of scenarios consists of six scenario groups drawn from the four families described in Table 6: one group each in A2, B1, B2, and three groups within the A1 family, characterizing alternative developments of energy technologies: A1FI (fossil fuel intensive), A1B (balanced), and A1T (predominantly non-fossil fuel). Within each family and group of scenarios, some share “harmonized” assumptions on global population, gross world product, and final energy. These are marked as “HS” for harmonized scenarios. “OS” denotes scenarios that explore uncertainties in driving forces beyond those of the harmonized scenarios.

The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B).

The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological changes are more fragmented and slower than in other storylines.

The B1 storyline and scenario family describes a convergent world with the same global population that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.

The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

Table 6 Summary of four SRES storylines

	A1	**A2**
World	Market Oriented	Differentiated
Economy	Fastest Per Capita	Regionally oriented, lowest per capita growth
Population	2050 peak, then decline	Continuously increasing
Governance	Strong regional	Self reliance with preservation of local identities
Technology	Three groups: A1F1 (Fossil fuel), A1T (Non-fossil), & A1B Balanced)	Slowest and the most fragmented growth
	B1	**B2**
World	Convergent	Local solutions
Economy	Service and information based, lower growth than A1	Intermediate growth
Population	Same as A1	Continuously increasing at a rate lower than A2
Governance	Global solutions to economic, social and environmental sustainability	Regional solutions to environmental protection and social equity
Technology	Clean and resource efficient	More rapid than A2; less rapid and more diverse than A1/B1

The shortwave impact of changes in boundary-layer clouds, and to a lesser extent midlevel clouds, constitutes the largest contributor to inter-model differences in global cloud feedbacks.

3.2 Climate Models

Eighteen modeling groups performed a set of coordinated, standard experiments, and the resulting model output, analyzed by hundreds of researchers worldwide, forms the basis for much of the current IPCC assessment of model results. A total of 23 models by 18 groups are currently used by IPCC to generate the future climate change scenarios. (Randall et al., 2007). The modeling groups and models used for this purpose are mentioned in Table 7.

Table 7 AOGCMs featured in IPCC Reports.

Model	**Sponsors/Country**	**References**
CSIRO-MK3	Commonwealth Scientific and Industrial Research Organisation (CSIRO) Atmospheric Research, Australia	Gordon et al., 2002; O'Farrell, 1998.
MIROC3.2 (medres)	Center for Climate System Research (University of Tokyo), National Institute for Environmental Studies , and Frontier Research Center for Global Change (JAMSTEC), Japan	K-1 Developers, 2004; Oki and Sud, 1998.
UKMO-HadCM3	Hadley Centre for Climate Prediction and Research/Met Office, UK	Pope et al., 2000; Gordon et al., 2000; Cattle and Crossley,1995; Cox et al., 1999.

Figure 11 shows the continuation of the 20th-century simulations for warming trends. Lines show the multi-model means, shading denotes the ±1 standard deviation range of individual model annual means. Discontinuities between different periods have no physical meaning and are caused by the fact that the number of models that have run a given scenario is different for each period and scenario, as indicated by the coloured numbers given for each period and scenario at the bottom of the panel. For the same reason, uncertainty across scenarios should not be interpreted from this figure (see Section 10.5.4.6 for uncertainty estimates).

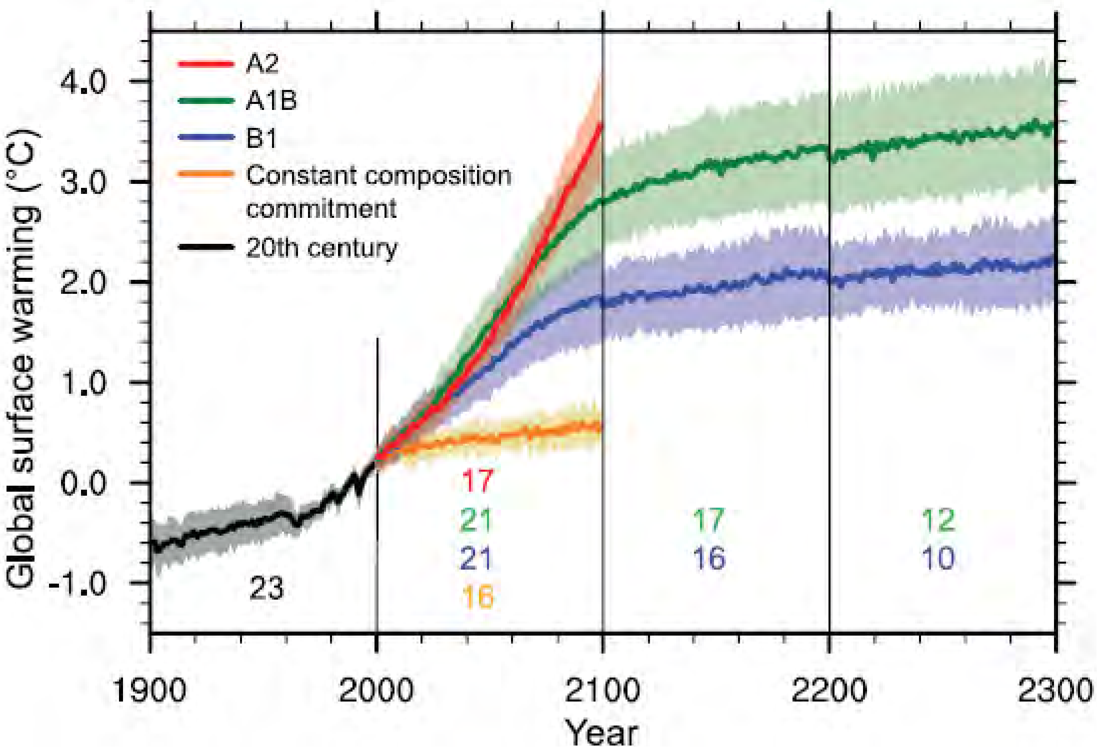

Figure 11: Multi-model means of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1. (Source: IPCC FAR)

3.3 Climate Change Projections

Accurate climate projections play a crucial role in determining the success of water management plans by providing an estimate of changes occurring to temperature and precipitation patterns which govern water availability. This section of the report compiles the climate change projections up to the end century obtained from three major coupled atmosphere-ocean general circulation models MIROC-M3, UKMO-HadCM3, and CSIRO-Mk3.0 for three emission scenarios namely A2, A1B, and B1.

Figure 12 shows the time series of globally averaged (left) surface warming (surface air temperature change, °C) and (right) precipitation change (%) from the various global coupled models for the scenarios A2 (top), A1B (middle) and B1 (bottom). Numbers in parentheses following the scenario name represent the number of simulations shown. Values are annual means, relative to the 1980 to 1999 average from the corresponding 20th-century simulations, with any linear trends in the corresponding control run simulations removed. A three-point smoothing was applied. Multi-model (ensemble) mean series are marked with black dots.

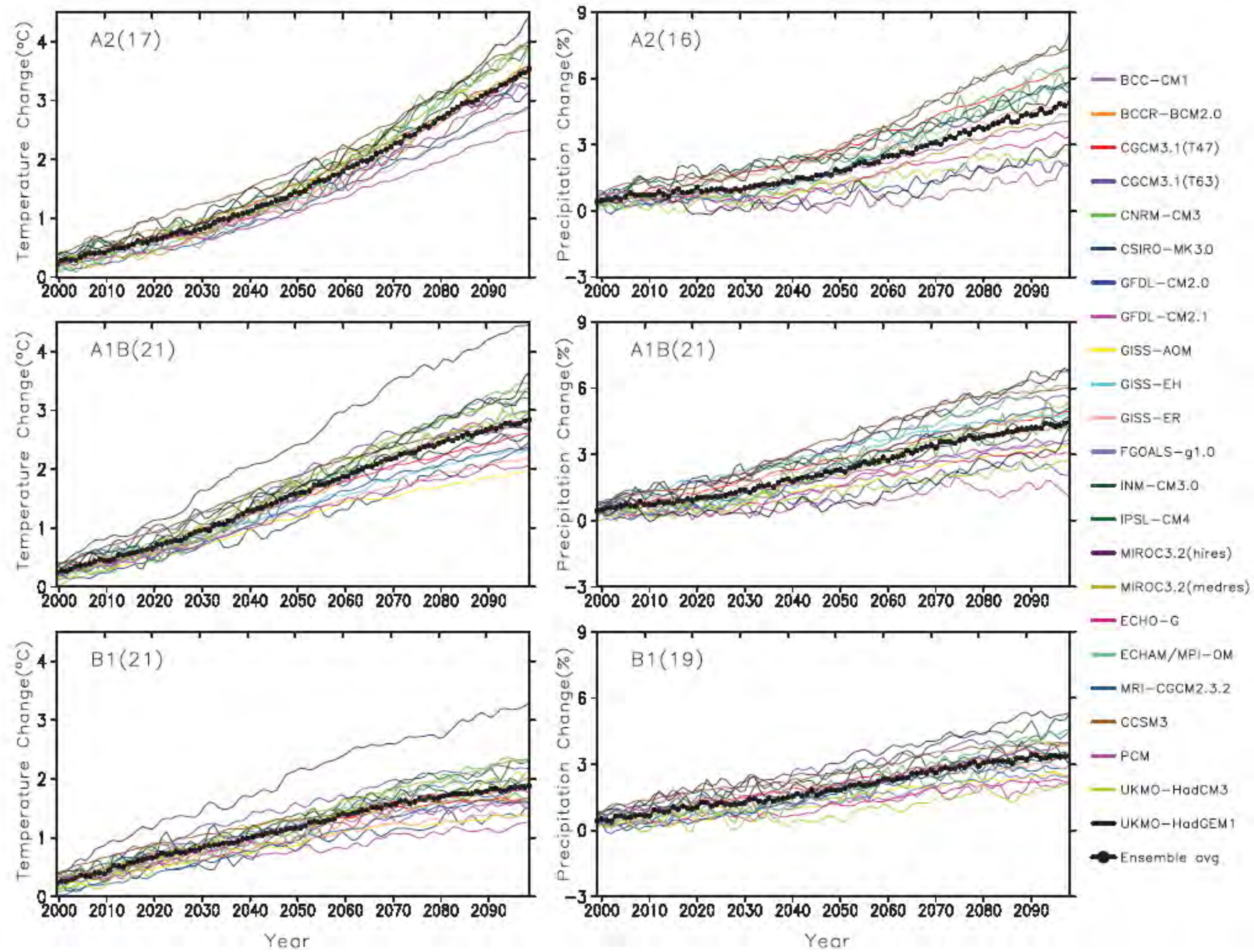

Figure 12: Time series of globally averaged surface air temperature and precipitation changes. (Source: IPCC FAR)

Confidence in climate models comes from the physical science behind their creation, and their skill at reproducing observed climate and past climate changes. Models have proven to be extremely important tools for simulating and understanding climate, and there is considerable confidence that they are able to provide credible quantitative estimates of future climate change, particularly at larger scales. Nonetheless, most models still suffer from a number of drawbacks which impose significant limitations on their results. Some of these drawbacks include their ability in representing clouds and man made aerosols etc which lead to uncertainties in the magnitude, timing, and spatial detail of predicted climate change. Nevertheless, over several decades of model development, they have consistently provided a robust and unambiguous picture of significant climate warming in response to increasing greenhouse gases at a global scale. However, since confidence in the changes projected by global models decreases at smaller scales, other techniques, such as the use of regional climate models, or downscaling methods, should be preferred for the study of regional and local scale climate change.

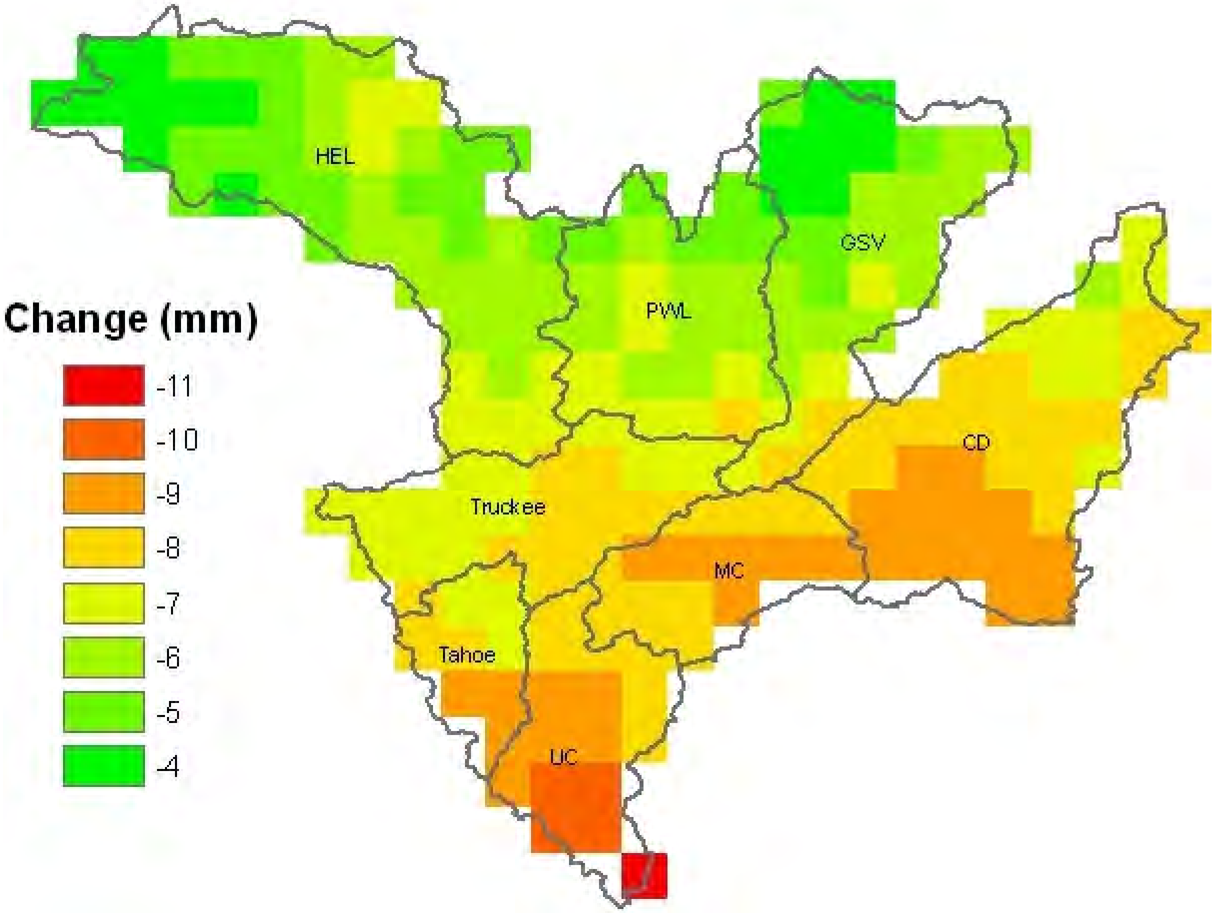

Figure 13 Precipitation change by mid 21st century as suggested by ensemble results from the three model outputs used in this study.

Figure 13 shows the anticipated mean precipitation departure by mid 21st century. The figure shows the estimated change in annual precipitation averaged over a period between 2040 and 2060. The change is compared to the mean historic data from 1961 to 1990. Figure 14 shows the reduction in precipitation by the end of 21st century. Both figures show significant decreases in annual precipitation in the high altitude regions of the study area. This region corresponds to the watershed of Lake Tahoe, Truckee River, and the Carson River and hence a decrease in precipitation in this area can significantly reduce the flow into these water bodies.

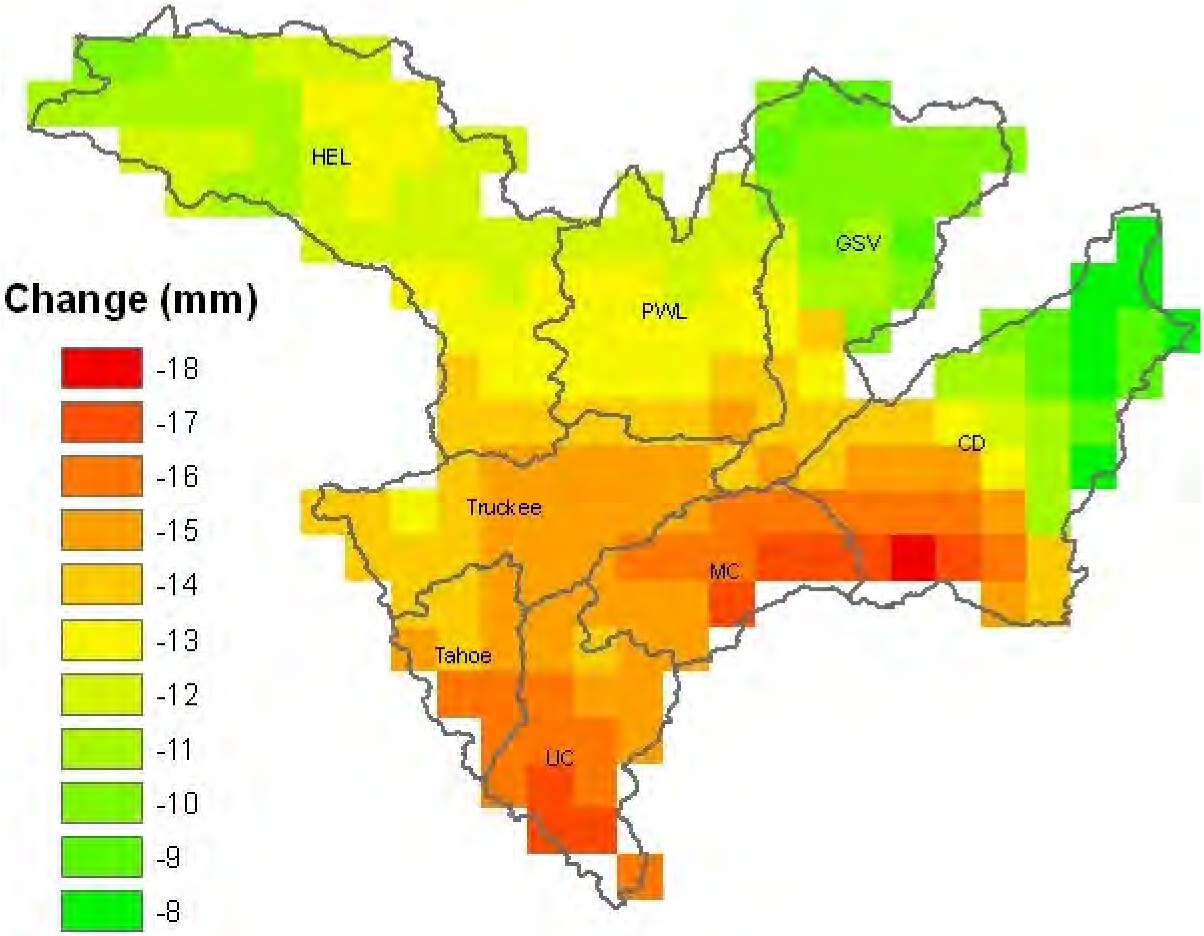

Figure 14 Precipitation change by the end of 21st century.

Table 8 and Table 9 provide a summary of the changes in precipitation and temperatures anticipated over the study area during the span of the 21st century. For all scenarios, an increase in average temperature and a decrease in annual precipitation are observed. The models predict an increase of 2.5 to 5.5 °F by 2050 and 4 to 11°F by 2100. The increase is expected to be more pronounced in the summer and fall as compared to winters and spring.

Table 8 (a-c) Ensemble average from MIROC-M3, UKMO-HadCM3, and CSIRO-Mk3.0 models Summary of anticipated changes in precipitation and temperature by mid 21st century under emission scenarios (a) A2, (b) A1B, and (c) B1.

Table 8(a)

Period	Variable	Change	Units
Dec-Feb	Temp	4.00	F
Mar-May		4.50	F
Jun-Aug		5.00	F
Sep-Nov		5.00	F
Annual		5.50	F
Dec-Feb	Precip	7.50	%
Mar-May		-18.50	%
Jun-Aug		-15.91	%
Sep-Nov		-7.00	%
Annual		-11.00	%

Table 8(b)

Period	Variable	Change	Units
Dec-Feb	Temp	4.50	F
Mar-May		3.50	F
Jun-Aug		5.50	F
Sep-Nov		5.50	F
Annual		5.50	F
Dec-Feb	Precip	-6.00	%
Mar-May		-15.00	%
Jun-Aug		-21.84	%
Sep-Nov		-14.92	%
Annual		-7.50	%

Table 8(c)

Period	Variable	Change	Units
Dec-Feb	Temp	3.50	F
Mar-May		2.50	F
Jun-Aug		4.50	F
Sep-Nov		4.00	F
Annual		4.00	F
Dec-Feb	Precip	-3.00	%
Mar-May		-7.00	%
Jun-Aug		-6.00	%
Sep-Nov		1.50	%
Annual		-4.50	%

Table 9 (a-c) Ensemble average from MIROC-M3, UKMO-HadCM3, and CSIRO-Mk3.0 models Summary of anticipated changes in precipitation and temperature by the end of 21st century under emission scenarios (a) A2, (b) A1B, and (c) B1.

Table 9(b)

Period	Variable	Change	Units
Dec-Feb	Temp	6.50	F
Mar-May		5.50	F
Jun-Aug		9.50	F
Sep-Nov		7.50	F
Annual		7.50	F
Dec-Feb	Precip	-11.00	%
Mar-May		-17.00	%
Jun-Aug		-16.50	%
Sep-Nov		-8.18	%
Annual		-13.00	%

Table 9 (a)

Period	Variable	Change	Units
Dec-Feb	Temp	6.50	F
Mar-May		6.50	F
Jun-Aug		11.00	F
Sep-Nov		8.50	F
Annual		8.50	F
Dec-Feb	Precip	-4.50	%
Mar-May		-29.33	%
Jun-Aug		-9.44	%
Sep-Nov		9.50	%
Annual		-7.00	%

Table 9(c)

Period	Variable	Change	Units
Dec-Feb	Temp	4.50	F
Mar-May		4.00	F
Jun-Aug		6.50	F
Sep-Nov		5.50	F
Annual		6.00	F
Dec-Feb	Precip	-12.50	%
Mar-May		-17.00	%
Jun-Aug		-17.00	%
Sep-Nov		-1.17	%
Annual		-10.50	%

4 CONCLUSIONS

Analysis of precipitation data shows that annual precipitation has increased during the last century. On dividing the trends into the four seasons, it was observed that the increase was not consistent for all the seasons. Winter precipitation has decreased over the last century whereas summer and fall precipitation has increased. Furthermore, the largest decrease in winter precipitation was experienced by the regions located at a high altitude in the Sierra Nevada Mountains. These regions are responsible for feeding Lake Tahoe, the Truckee River and the Carson River. Therefore, a decrease in winter precipitation in these regions means lesser snowpack and consequently lower inflows into the water bodies.

The results from VIC outputs show a rise in the SWE for January 1 and February 1 for all the grid cells whereas all the grid cells evaluated display a decline in April 1 SWE. These results obtained from VIC outputs are in agreement with the findings from PRISM data which suggest that precipitation during the fall season (Oct to Dec) has increased during the same period. The lowered SWE in the later half of winter months also corroborates the finding from PRISM data which shows that precipitation during the winter months has decreased.

Temperature trends for all sub regions in the study area show consistent rising trends over the last century. Increased temperatures in combination with changing precipitation patterns can change the hydrology of the study area. The results from this study cannot conclusively estimate the individual effects of temperature and precipitation changes on SWE but this combination is likely to be a major factor causing the shifting of SWE bulk towards the first half of the winters.

Future estimates from the climate models used in this study show decreases in annual precipitation throughout the study area. In addition the projections suggest a decrease in precipitation for all seasons throughout the watershed for all emission scenarios. The decreases are greater in magnitude in the high altitude regions of the study area. This region corresponds to the watershed of Lake Tahoe, the Truckee River, and the Carson River and hence a decrease in precipitation in this area can significantly reduce the flow into these water bodies. This finding however is inconsistent with the results obtained from PRISM and VIC outputs which show an increase in summer and fall precipitation in the study area over the last century. This inconsistency could be a result of the topography of the study area and the inability of climate models to generate accurate future trends for relatively small regions with abrupt changes in topography.

(notes: I have a general concern about the significance of the trend lines created in the Excel charts. The very low R^2 points one to conclude that the trend might not be statistically significant. If possible have Dinesh add 95% confidence interval to some of key statistics. I am going to try to do some time series test on some of the data to see if the trend lines are significant.

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6 APPENDICES

6.1 Processing steps for PRISM Dataset

Step 1.Downloading Data: PRISM data can either be downloaded interactively from (http://mole.nacse.org/prism/nn/index.phtml?vartype=ppt&year0=2003&year1=2003) or from the PRISM Group's ftp site (ftp://prism.oregonstate.edu/pub/prism/us/grids/)

Step 2.Unzipping: The files downloaded from the sources mentioned in Step 1 were unzipped and converted to ascii files by changing the extension to <*.asc>. Due to a large number of files, individual unzipping would have been impractical. Therefore, "7-zip" freeware was used for this process.

Step 3.Processing in ArcGIS: Resulting files from Step 2 were imported into ArcGIS and converted into raster format. "Modelbuilder" feature in ArcMap was used to automate the processing of files for this step and all other subsequent steps due to the large number of files.

Step 4.Raster files obtained from Step 3 were then clipped using the watershed shapefiles.

Step 5.Attributes tables were created for all the clipped raster files.

Step 6.Additional field ("precip" for precipitation files and "temp" for temperature files) was created in the attributes tables for the clipped raster files to hold the product of the fields "Value" and "Count".

Step 7."Summary Statistics" tool in ArcMap was used to obtain the mean of the field "precip/temp" and sum of the field "count". In addition,

Step 8.Summary statistics obtained as *.dbf files, for each corresponding raster file, were converted into *.xls files for processing in Matlab.

Step 9.A Matlab program was used to read the statistics of "precip/temp" and "Count" from the .xls files created in Step 8.

Step 10.The average temperature or depth of precipitation over the watershed were calculated using

$$\mathrm{X} = \mathrm{Y} \times C / P$$

Where
X =
Y = precip or temp read in Step 9
C = Count read in Step 9
P = Number of pixels the raster file for the corresponding watershed.

6.2 Notes:

ArcMap was unable to process all the files simultaneously using Modelbuilder. Therefore, files were processed one watershed at a time.

Due to naming protocols in ArcMap, files obtained after processing had complicated names. Renaming was found to be useful to prevent mixing up of files.

Theoretically it is possible to combine Steps 3 to 8 in one model but difficulties were encountered while running these processes in a single model. Modelbuilder failed to execute certain steps when multiple processes were combined in a single model.

The following Matlab code was used to execute the process described in Step 9.

```
xlsFiles = dir(‘Path\*.xls')
Matrix = zeros (length(xlsFiles),1)
for k = 1:length(xlsFiles);
  filename = xlsFiles(k).name
  data = xlsread(filename, 'a2:a2')
  Matrix(k) = data
end
xlswrite ('Path’\output_filename.xls', Matrix, 'Sheet1')
```

TRUCKEE MEADOWS WATER AUTHORITY

APPENDIX 2-4

2015 CLIMATE CHANGE STUDY

Climate dynamics and their potential impact on water resources in the Tahoe/Truckee River basins

Final Report

Prepared by

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For the use of

Truckee Meadows Water Authority
Reno, Nevada, USA

October 15, 2015

Summary of Findings and Recommendations

1. **Suggestions on how TMWA might use climate data/models in conducting risk assessments or continue to monitor the changes and applicability of climate sciences.**

Debate is raging on the connections between recent climatic changes, greenhouse warming, and extreme drought, with diverging views appearing constantly, even in the peer-reviewed literature. While the reliability of global climate model (GCM) simulations continues to improve, there are still uncertainties that suggest downscaling exercises should be viewed with some caution, especially for long-term water resource management. Instrumental data, however, show increased variability of Lake Tahoe water levels in the current millennium, with as many (three) extended (i.e., two years or longer) droughts in the last fifteen years as there have been in the previous half-century. A commonly used drought index, the Palmer Drought Severity Index (PDSI), points to drought episodes in the last fifteen years with average duration of about 40 months, which is about four times longer than in its entire 120-year record (average of about 10 months). Extreme caution, and continued monitoring of multiple hydroclimatic variables, are therefore recommended to conduct, and constantly update, risk assessments.

2. **Recommendation on which historic drought episodes to use in water supply planning/modeling.**

Based on various sources of instrumental data from the start of the 20th Century to present, drought periods in the Tahoe/Truckee River Basin can vary from one to as many as eight years in duration. TMWA's current water planning is based on the hydrology of 1987-1994, the worst drought presently on record. Our analysis has not revealed other historic drought episodes that would offer more information, since the "Dust Bowl" drought (1928-1935) was of about the same duration, but the amount of instrumental data available for that period is less, or less reliable, than what is available for the 1987-1994 period.

3. **Recommendation on collecting tree-ring data directly located in the Truckee River and Carson River watersheds.**

Recently published tree-ring studies aimed at placing the current California drought in a longer perspective have spliced instrumental records on top of reconstructed ones, because the actual reconstructions end about a decade earlier than the instrumental record. Because of variance compression in the extended record, plus the relatively high uncertainty associated with methods used to pad proxy records with instrumental ones, it is difficult to evaluate how the current drought compares to those in the reconstructions. Updating old, and developing new, tree-ring records from sites located in or near the Truckee and Carson River watersheds, in combination with recent advances in producing km-level gridded reconstructions and in task-specific water-balance modeling, is expected to improve the quality of hydroclimatic reconstructions for the target region, so that the current drought can be most effectively compared to those that occurred in previous centuries.

Introduction

This report is provided to the Truckee Meadows Water Authority in support of the 2016-2025 Water Resource Plan (“WRP”). This WRP is being written while the region is in the fourth year of an exceptional drought. The questions being asked during this planning cycle include “Is this drought a new worst drought?”, “Are droughts becoming more frequent?”, “How rare is the current drought?”, and of course “How long could this drought last?”. This report addresses some of these questions by considering research that is on-going at University of Nevada, Reno (“UNR”), selected published studies on climate models and projections, tree-ring data, and locally available instrumental records relevant to the Truckee Meadows region.

Current Drought Context

The Truckee Meadows depend on the annual flow of water from the Truckee River to supply municipal water to the communities of Reno and Sparks, irrigation water for agricultural producers, and various environmental needs. The Truckee River system is dependent on the amount or size of accumulated snowpack, which can be highly variable from year to year. Simply stated, the larger the snowpack, the greater the Truckee River flows; conversely, the smaller the snowpack, the smaller the Truckee River flows. Comparing annual snowpack accumulations for the Truckee River Basin, it is possible to see that, beginning in 2012, snowpack accumulations have been well below the long-term average [*Tahoe Environmental Research Center*, 2015; p.7.8]. This report is written as the region experiences its fourth consecutive year of exceptionally low-precipitation. Drought Situations[1] exist when there is inadequate natural flow in the Truckee River and there is not enough stored water in Lake Tahoe and/or Boca Reservoir to maintain required rates of flow to meet Floriston Rates, or the elevation of Lake Tahoe is projected to be less than half-a-foot above its natural rim on or before November 15 each year.

During relatively minor droughts, TMWA’s supplies might not be impacted; thus there is no need to use drought reserves to meet customer demand. It is during exceptional and longer droughts, and then only during the more critical dry years within the drought period, that reserves are required. Based on past history it is not until at least the third drought year in a row that upstream reserves may have to be used. In the 1987 through 1994 drought of record, only in the summer of 1991 and 1992 were drought reserves required to meet customer demands. It is important to also note that in the past, the use of reserves has only occurred between the months of June and October, primarily during the irrigation season. In those years when Floriston Rates were not met through the irrigation season, flows in the Truckee River by November were once again sufficient to meet wintertime needs. TMWA’s current water planning is based on the hydrology of 1987-1994, the worst drought currently on record. In the current drought period,

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[1] Pursuant to TROA: “**Drought Situation** means a situation under which it is determined by April 15, based on procedures set forth in Section 3.D, either there will not be sufficient **Floriston Rate Water** to maintain **Floriston Rates** through October 31, or the projected amount of **Lake Tahoe Floriston Rate Water** in Lake Tahoe, and including **Lake Tahoe Floriston Rate Water** in other **Truckee River Reservoirs** as if it were in Lake Tahoe, on or before the following November 15 will be equivalent to an elevation less than 6,223.5 feet Lake Tahoe Datum.”

drought reserves were required to meet TMWA customer demands in both 2014 and more so in 2015. Although water year 2015 had the lowest snowpack in recorded history [*Tahoe Environmental Research Center*, 2015; p.7.8], it cannot be stated with any certainty as to what the duration or direction the current drought period will take. This report considers the instrumental record, recent tree-ring studies, and local instrumental data for comparable historic events to place current events into a longer and larger context.

Regional Context

Water supply shortages are capable of producing some of the worst environmental disasters, ranging from widespread crop failures to land degradation, with consequences that include human migration and permanent transformations in socio-ecological systems [*Cook et al.*, 2014]. At the time of this writing, California and western Nevada are enduring an extremely severe drought while having to cope with ever-increasing water demands for agricultural, urban, and environmental systems [*Howitt et al.*, 2014]. The Governor of California has mandated across the board 25% reduction in water use, while the Governor of Nevada has convened a State Drought Forum to craft drought response policies. Debate is raging on the connections between recent climatic changes, greenhouse warming, and extreme drought, with diverging views appearing constantly, even in the peer-reviewed literature [e.g., *Diffenbaugh et al.*, 2015; *Mao et al.*, 2015]. In order to fully comprehend the severity of such events, and design policies that reduce vulnerability of water resources to projected impacts of global warming [*Stakhiv*, 2011], a long-term perspective is required. This appears particularly important given the recent divergence between air temperature trends simulated by climate models and actual observations, both globally [*Fyfe et al.*, 2013] and for the conterminous US [*Privalsky and Yushkov*, 2015].

Overview of Instrumental Records and Climate Projections

Instrumental records over the past century or so have shown that the seasonal discharge regime of rivers and streams in the western US varies substantially from year to year in response to the varied impact of large-scale ocean and atmospheric oscillations [*Cayan et al.*, 1999; *McCabe et al.*, 2008]. Modes of interannual and interdecadal climate, such as the El Niño-Southern Oscillation [ENSO; *Trenberth*, 1997] and the Pacific Decadal Oscillation [PDO; *Mantua and Hare*, 2002], have been found to affect the US west coast climate [*McCabe and Dettinger*, 1999; *Johnstone and Mantua*, 2014]. At the same time, climate model simulations based on greenhouse warming and used by the Intergovernmental Panel on Climate Change (IPCC) show that in the western US moisture stress is likely to increase [*Seager et al.*, 2007; *Garfin et al.*, 2013]. Future scenarios even include drastic transformations of ecosystems and landscapes in the next decades as a consequence of severe heat waves and their effects on forests [*Allen et al.*, 2010; *Williams et al.*, 2013]. Properly evaluating modern changes and the likelihood of future ones benefits from a historical perspective that goes beyond the instrumental record to capture underlying long-term dynamics that would otherwise be impossible to detect [*National Research Council*, 2006]. In particular, tree-ring records have been used as proxy indices of spatial and temporal climate variability [*Cook et al.*, 2004; *Woodhouse et al.*, 2010; *Biondi*, 2014], and hold the potential to elucidate long-term drought variability in relation to global biogeochemical changes [*Anderegg et al.*, 2015].

Reasons for Including the Carson River Watershed

Increasing human pressure on western water resources requires an understanding of climatic impacts at the regional and local level, which are required for water resource management. The focus of this report is on the Tahoe/Truckee River basin, which straddles the boundary between California and Nevada, and that can be compared with the adjacent Carson River basin (**Figure 1**). The Carson River [*Hess*, 1999] is characterized by relatively natural flows compared to the more regulated Truckee River [*Berris et al.*, 2001]. In fact, it can be shown that the variability of stream discharge in these two basins is remarkably similar at interannual to interdecadal time scales, making the Carson River a useful analog for examining long-term hydroclimatic variability in the Tahoe/Truckee River basin. Besides the Lake Tahoe water level, which is typically used as the main indicator of water resources status in the target region, other century-long instrumental records used in this report include monthly Climate Division data, such as drought indices [*Guttman and Quayle*, 1996], which go back to January 1895 and have been recently updated [*Vose et al.*, 2014]. Numerical and graphical tools were applied to examine the likelihood of extended drought episodes, which represents one of the main issues facing Truckee Meadows Water Authority in terms of water resource planning.

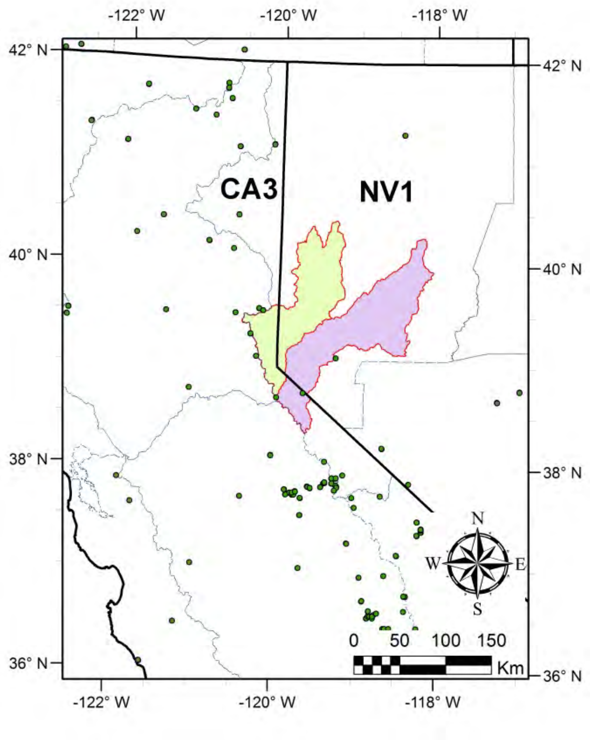

Figure 1. Map of Truckee (lime fill color) and Carson (purple fill color) River Basins considered in this report (red boundaries). The location of tree-ring chronologies (green circles) [*Contributors of the International Tree-Ring Data Bank*, 2014], state boundaries (dark black lines), and Climate Divisions (light blue lines) [*Guttman and Quayle*, 1996] are also shown. The two watersheds are included in the area covered by Nevada Climate Division 1 (NV1) and California Climate Division 3 (CA3) (graphics by F. Biondi and S. Strachan).

Century-long Instrumental Time Series

Among the time series of interest for water resource planning in the Tahoe/Truckee River basins, the level of Lake Tahoe occupies a prominent position. Daily gage heights are available from the US Geological Survey for over a hundred years (**Figure 2**), and they clearly show the recent drought. Although the lake level dropped even further than in 2015 during the 1930s 'Dust Bowl' period, and reached its absolute minima in the early 1990s, the interval between highs and lows appears shorter in recent decades. Graphically, this is shown by three distinct low-level periods since the start of the new millennium, as opposed to three distinct low-level periods over the previous half-century (**Figure 2**). While the period of record is likely too short for a rigorous statistical analysis, the possibility that alternating wet and dry periods may become more variable, thus making droughts more frequent, may deserve additional consideration. On the other hand, the lake level record is not entirely natural, because of the Lake Tahoe Dam, which was constructed in the 1870s and controls the upper 6.1 ft of the lake, creating up to 732,000 acre-feet of highly regulated and carefully managed storage capacity [*Anonymous*, 1994].

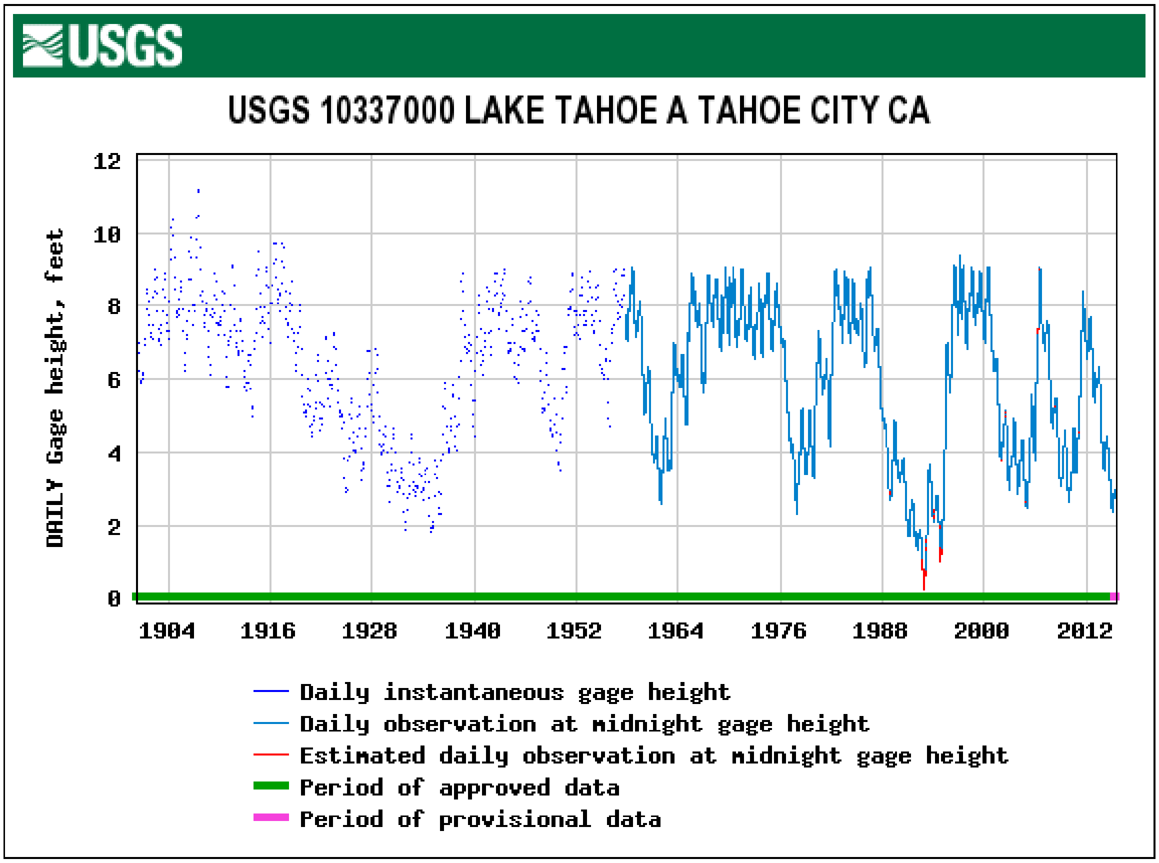

Figure 2. Time series of daily Lake Tahoe levels at Tahoe City until mid-July 2015 (USGS station 10337000; graph generated from http://waterdata.usgs.gov/nwis/dv?cb_00065=on&format=gif_default&site_no=10337000&referred_module=sw&period=&begin_date=1900-04-30&end_date=2015-08-10).

Streamflow data for the Truckee River also span a century-plus time interval. To compare the Truckee and Carson River basins, monthly total discharge was obtained for six stations along the Truckee (Tahoe City, CA; Donner, CA; Farad, CA; Vista, NV; Reno, NV; and Wadsworth, NV), and for three stations along the Carson (Woodfords, CA; Gardnerville, NV; and Fort Churchill, NV). Total streamflow was computed for each gage by water year (October-September), then normalized (i.e., converted to standard deviation units, or sdu) and averaged together by river basin. The period of analysis was 1900-2014, which had no missing values for the Truckee six-station average (**Figure 3**), and only 1911 for the Carson three-station average (**Figure 4**). By using normalized values, it was possible to directly overlay the Truckee and Carson average streamflows (**Figure 5**). The 2015 water year, albeit part of the ongoing drought, was not yet finished at the time of this analysis.

The variability of Carson streamflow remains essentially the same at all stations (**Figure 4**), whereas the Truckee streamflow presents some differences in variability between gauging stations (**Figure 3**). When plotted on the same graph, the water-year streamflows are overall quite similar, and with less pronounced low flows in the Truckee (**Figure 5**), most likely because of regulated flows rather than natural ones. The close connection between stream discharge in both basins and regional climatic patterns that control water-year precipitation is further revealed by correlation maps between average streamflow (shown in **Figure 5**) and water-year total precipitation from all Climate Divisions in the conterminous US (**Figure 6**).

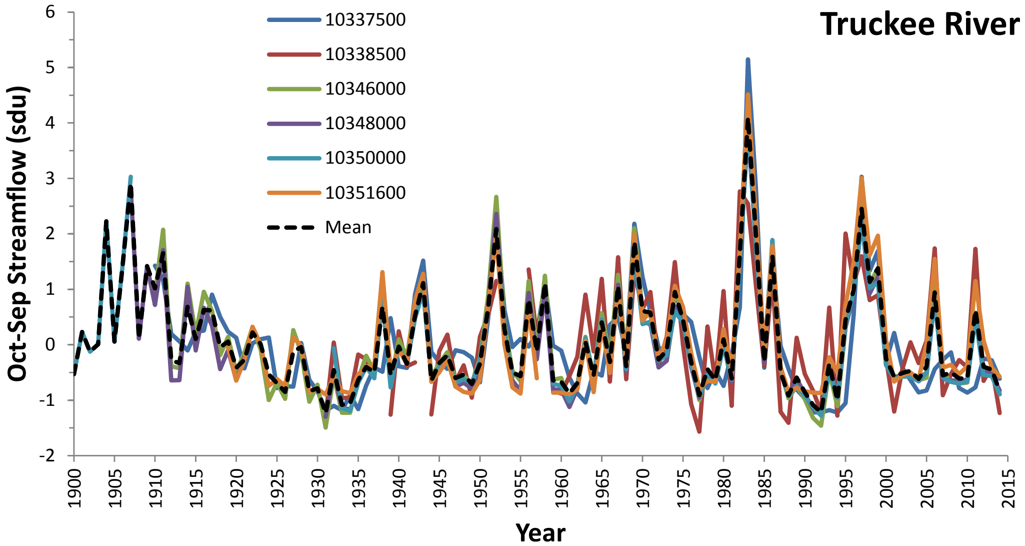

Figure 3. Total monthly river discharge (in standard deviation units, sdu) for the water year (October through September) computed from 1900 to 2014 using six gauging stations in the Truckee basin (USGS gauge station numbers: 10337500 = Tahoe City, CA; 10338500 = Donner, CA; 10346000 = Farad, CA; 10348000 = Reno, NV; 10350000 = Vista, NV; and 10351600 = Wadsworth, NV) (graphics by F. Biondi).

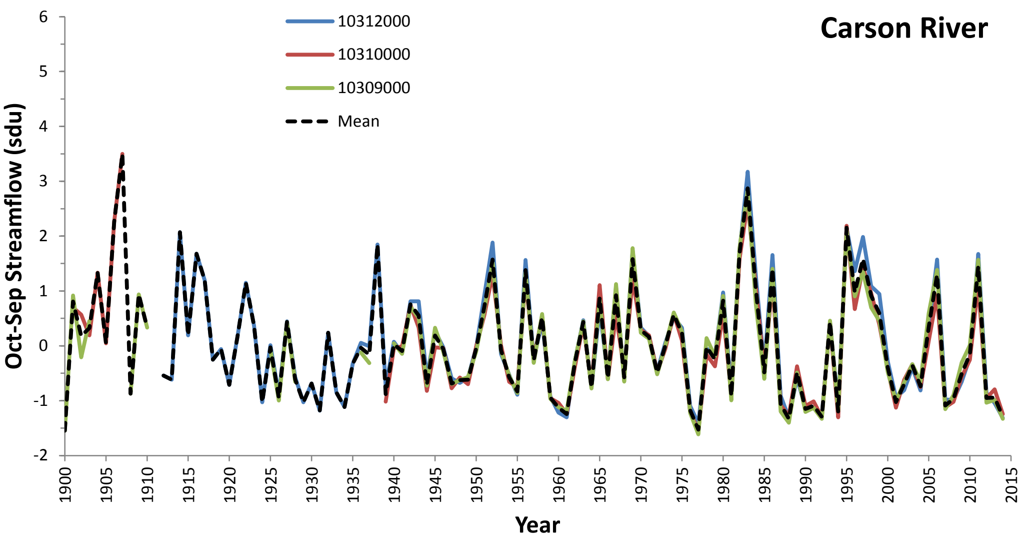

Figure 4. Total monthly river discharge (in standard deviation units, sdu) for the water year (October through September) computed from 1900 to 2014 using three gauging stations in the Carson basin (USGS gauge station numbers: 10310000 = Woodfords, CA; 10309000 = Gardnerville, NV; and 10312000 = Fort Churchill, NV) (graphics by F. Biondi).

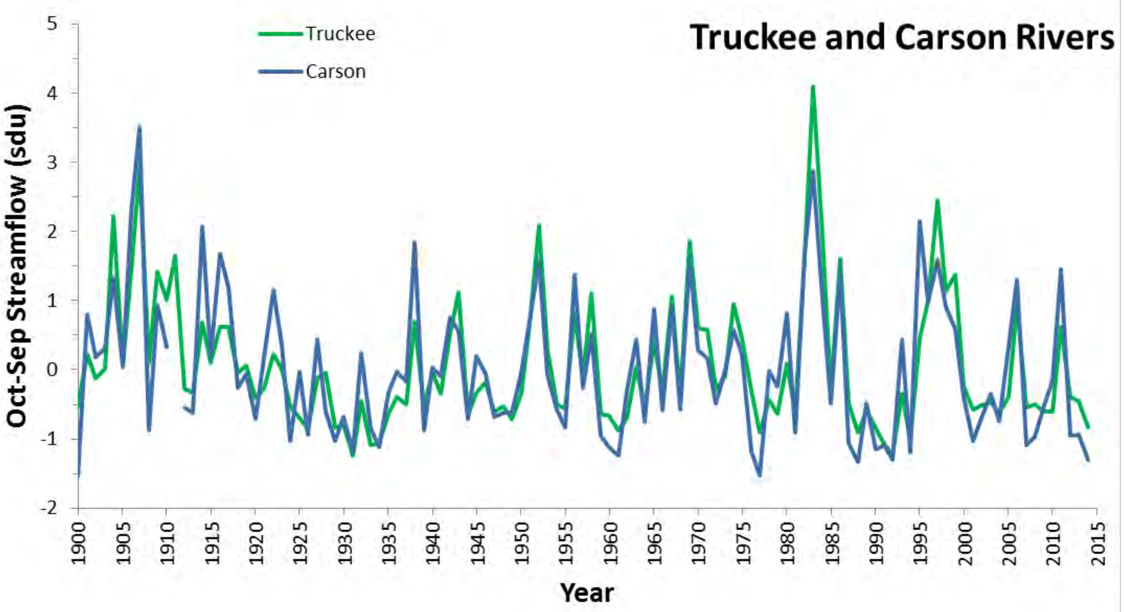

Figure 5. Average river discharge (in standard deviation units, sdu) for the water year (October through September) computed from 1900 to 2014 using 6 gauging stations in the Truckee basin, and 3 in the Carson basin. Streamflows co-vary at interannual and interdecadal time scales, and show high values corresponding to the two strong El Niño episodes of 1982-83 and 1997-98 (graphics by F. Biondi).

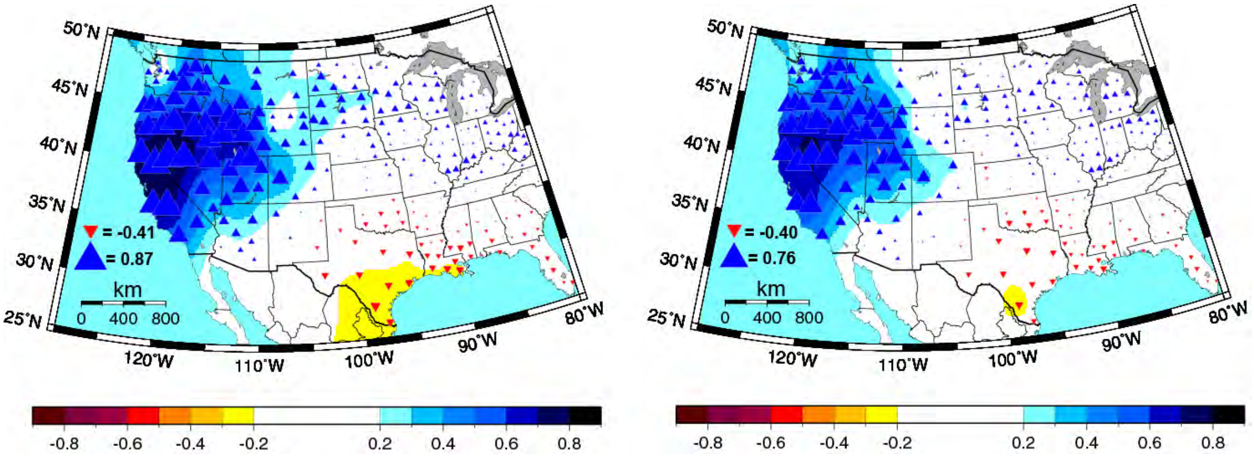

Figure 6. Map of linear correlations between total water-year precipitation in US Climate Divisions and total water-year streamflow for the Carson (left) and Truckee (right) River Basin during 1900-2014. Point values, plotted at the barycenter of the climate divisions, are shown by blue upright triangles when positive, and by red inverted triangles when negative, with symbol size proportional to the correlation value. Interpolated surfaces are plotted using blue shades for positive values, and red shades for negative ones. Geographical pattern of positive correlations indicate that river discharge is linked to large-scale climatic patterns that also determine the variability of precipitation in the western US, especially in the Sierra Nevada and nearby regions. Moving into areas where ENSO effects on climate regime are typically stronger, i.e. the American Southwest and Pacific Northwest [*Brown and Comrie*, 2004], correlations decline rapidly towards zero, although very strong El Niño years, such as the 1982-'83 and 1997-'98 events [*An and Jin*, 2004], corresponded to very high streamflows in the Truckee-Carson River Basins (**Figure 5**) (graphics by F. Biondi).

It should be mentioned that climate division data have been recently revised to improve their quality [*Vose et al.*, 2014], and the new version was used in this report. The new Climate Division records incorporate data from the high-elevation Snowpack Telemetry (SNOTEL) network, which are particularly relevant for the topographically complex landscape of the western US. In a study published this year, SNOTEL data were found to be affected by warming artifacts and sensor biases that, when propagated into climate datasets that incorporate them, including the well-known PRISM products [*Daly et al.*, 2008], have most likely amplified the "1981–2012 western U.S. elevation-dependent warming by +217 to +562%" [*Oyler et al.*, 2015]. PRISM, the Parameter-elevation Regressions on Independent Slopes Model, is a topographically-driven interpolation algorithm, and in its original version [*Daly et al.*, 1994] climatic data used as input for the model did not undergo any time-discontinuity screening, either for urban heat island effects or for changes in station location or instrumentation. Because of this, PRISM output, albeit extremely useful in the spatial domain, is typically unreliable for time-series analysis or temporal trend detection (Chris Daly, *pers. comm.* to F. Biondi). Both Climate Division and PRISM time series are routinely used for climate change assessments [e.g., *Garfin et al.*, 2013], normally without mention of such caveats.

Climatic Division data were analyzed in more detail for the two divisions that include the Tahoe/Truckee and Carson River watersheds (**Figure 1**), i.e. Nevada Division 1 (Northwest) and

California Division 3 (Northeast Interior Basins). Annual summaries of mean temperature (**Figure 7**) and total precipitation (**Figure 8**) were computed in order to remove the annual cycle and uncover time-series trends. The monthly values of two drought indices [*Heim Jr.*, 2002], PDSI (Palmer Drought Severity Index, **Figure 9**) and SPI-24 (Standardized Precipitation Index for a 24-month window, **Figure 10**) were also downloaded and plotted.

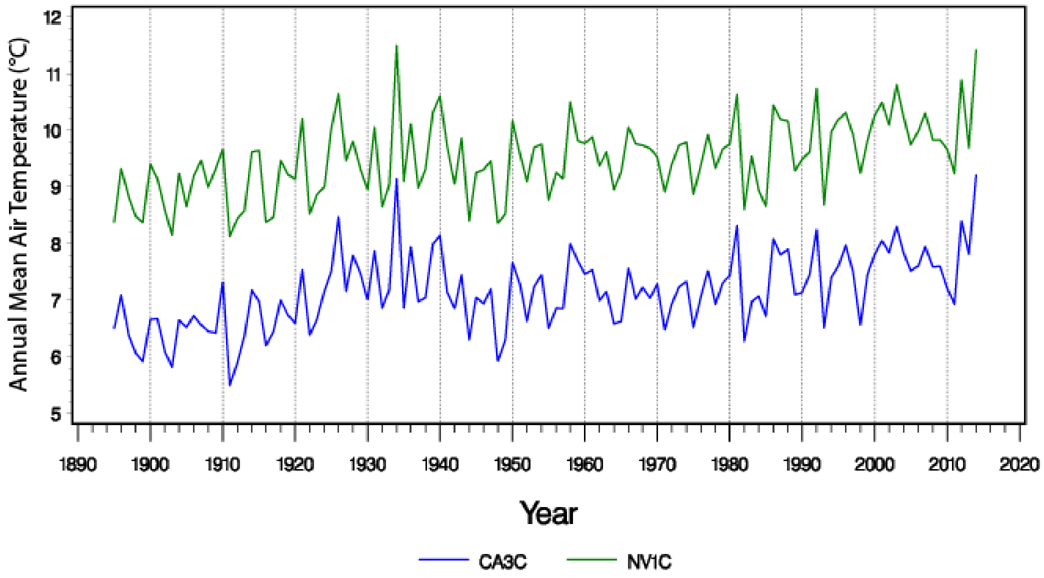

Figure 7. Time series of average annual air temperature for the two climate divisions (CA3 and NV1) that include the Truckee and Carson watersheds. The series spans 1895-2014, since the last months of 2015 were not available at the time of this analysis (graphics by F. Biondi).

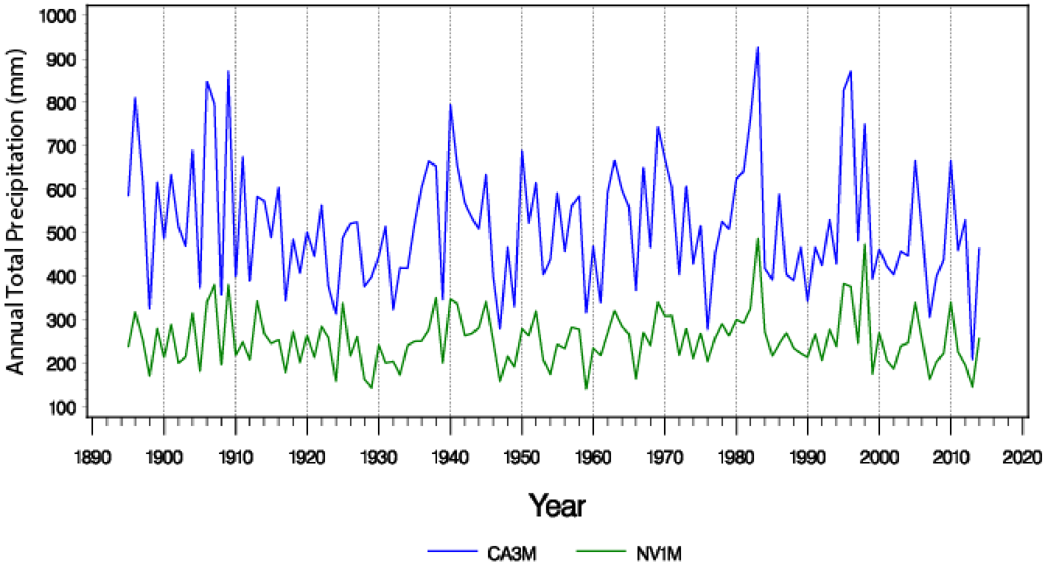

Figure 8. Time series plot of total annual precipitation for the two climate divisions (CA3 and NV1) that include the Truckee and Carson watersheds. The series spans 1895-2014, since the last months of 2015

were not available at the time of this analysis (graphics by F. Biondi).

The two divisional time series co-vary at interannual and interdecadal time scales, with the California division being cooler (**Figure 7**) and wetter (**Figure 8**) than the Nevada one, as expected. The warmest years were 1934 and 2014, with the former being slightly higher in Nevada, and the latter being slightly higher in California. Drought indices, which are standardized to remove differences in average climatic regime [*Keyantash and Dracup*, 2002], are also in excellent time-series agreement, with the PDSI series (**Figure 9**) showing a tendency for longer drought durations in the second millennium. To more quantitatively investigate this possibility, which would have important consequences for water resource planning, the PDSI and SPI-24 time series were analyzed in terms of wet and dry episodes. Episodes above (or below) a reference level (in this case, the zero value) are called positive (or negative), and each episode is characterized by its duration, magnitude, and peak. Duration is the number of time intervals the process remains continuously above (or below) a reference level. Magnitude is the sum of all series values for a given duration, hence it is equivalent to the area above (or below) the reference level. Peak is the absolute maximum among all series values for a given duration. This approach typically identifies about an equal amount of episodes above and below the reference level. Analysis of episode parameters allows a less subjective identification of the "strongest, "greatest", or "most remarkable" periods, and although this approach is normally used for drought analysis, it can be applied to any cumulated deviations [*Biondi et al.*, 2008].

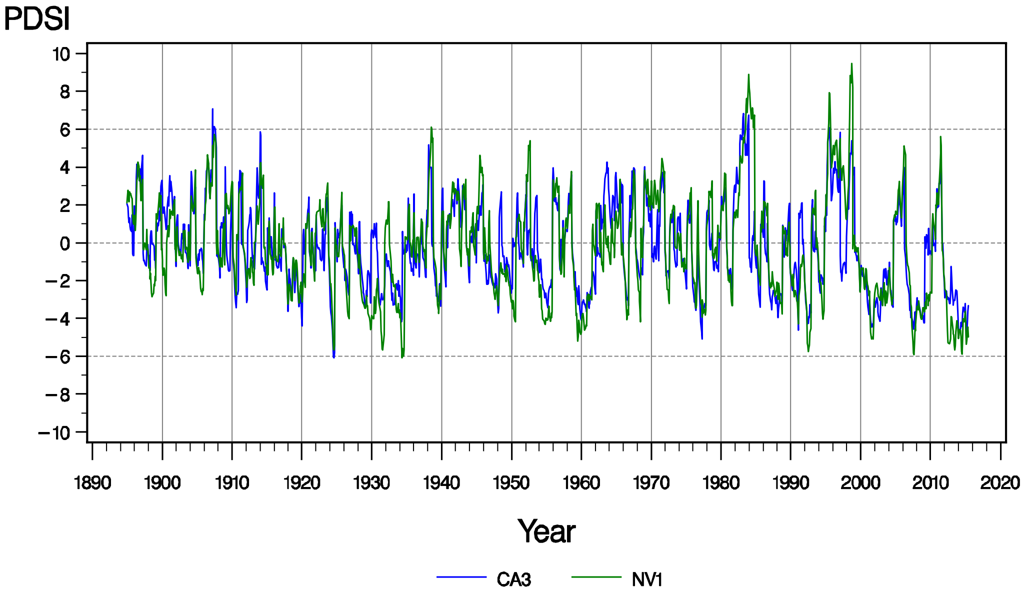

Figure 9. Time series of monthly Palmer Drought Severity Index (PDSI) for the two climate divisions (CA3 and NV1) that include the Truckee and Carson watersheds. Records begin in January 1895, and were available until June 2015 (graphics by F. Biondi).

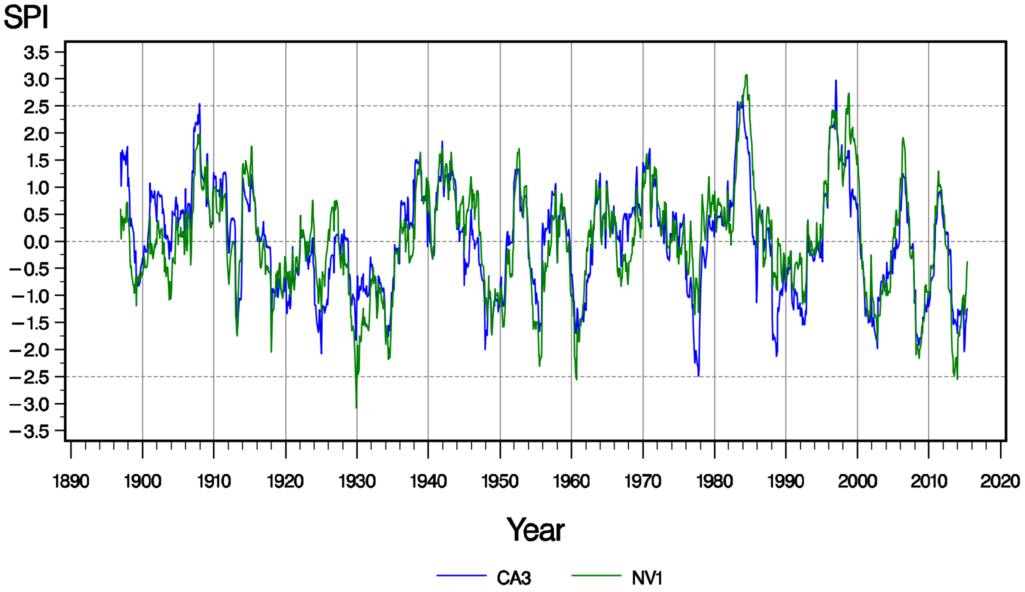

Figure 10. Time series of monthly Standardized Precipitation Index (SPI) over a 24-month window for the two climate divisions (CA3 and NV1) that include the Truckee and Carson watersheds. Records begin in January 1895, and were available until June 2015 (graphics by F. Biondi).

After averaging the two climate divisions (CA3 and NA1), the higher variability of the PDSI time series compared to the SPI-24 values (**Figure 11**) is reflected in their standard deviations (2.41 for PDSI, 0.96 for SPI-24). As a way to test if the two drought indices differed with respect to overall patterns from 1895 to present, or in terms of temporal changes they may have undergone in the new millennium, dry and wet episodes were quantified based on periods above and below the zero reference value. Given that the most important features of a drought, especially for long-term planning purposes, are its duration and magnitude, only these two parameters were considered [*Biondi et al.*, 2005]. Each episode parameter was ranked separately, and the two ranks were added to obtain the final episode score; the higher the score, the stronger the episode (**Table 1**). It should be pointed out that other ranking schemes and/or ways to score time series episodes could have provided somewhat different results, but the approach followed in this report, albeit relatively simple, is well supported by advanced statistical theory [*Kozubowski and Panorska*, 2005; 2008].

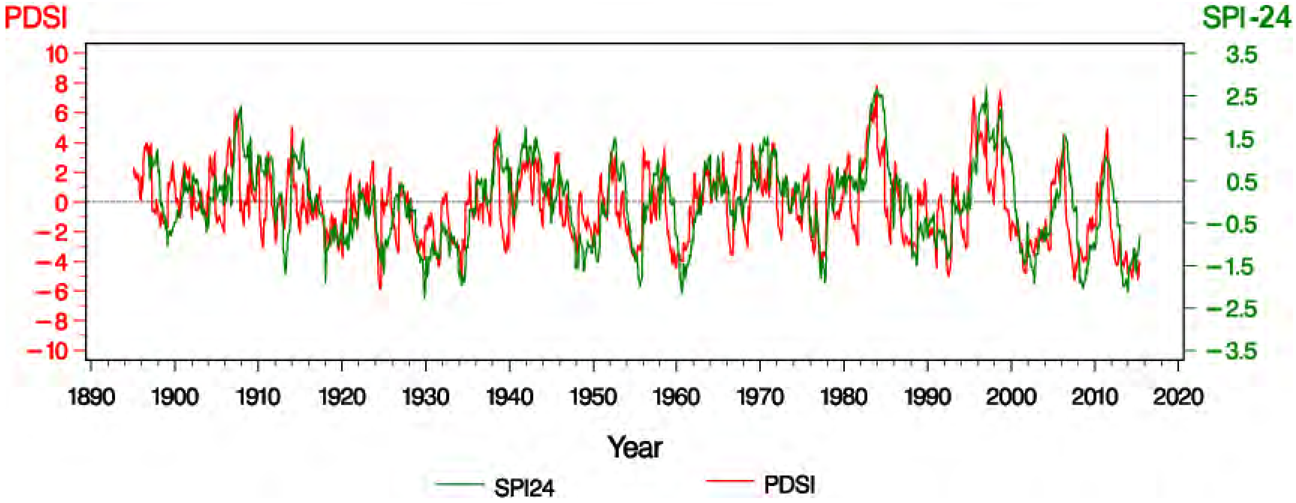

Figure 11. Time-series plot of monthly Palmer Drought Severity Index (PDSI) and Standardized Precipitation Index for a 24-month window (SPI-24). Each drought index represents the average of two Climate Divisions, CA3 and NV1, and was used for episode analysis (**Table 1**) (graphics by F. Biondi).

The overall slower-varying behavior of SPI-24 compared to PDSI is reflected in the number of episodes, which were 94 for SPI-24, with average duration of about 15 months, and almost twice as many (162) for PDSI, with average duration of about 9 months. However, the opposite pattern has emerged in the new millennium, with fewer dry and wet spells recorded by PDSI (7 episodes, with average duration of 28 months, considering both positive and negative ones) than by SPI-24 (9 episodes, with average duration of 20 months, considering both positive and negative ones). The longest drought according to PDSI was in the early 2000s, from March 1999 to September 2004, for a total of 67 months. Using SPI-24, the longest drought was the 'Dust Bowl' one, from April 1928 to December 1935, for a total of 93 months. In terms of magnitude, the largest drought according to PDSI is the current one (from September 2011 to June 2015), closely followed by the early 2000s dry spell. Using SPI-24, the greatest drought magnitude is again assigned to the 'Dust Bowl' episode.

When both duration and magnitude are considered since January 1895 (**Table 1**), the three strongest PDSI episodes are all negative (i.e, droughts), and all in the new millennium. These three droughts are, in descending order, the current episode (Sep 2011-Jun 2015), the early 2000s one (Mar 1999-Sep 2004), and the one sandwiched between the 2005 and 2011 wet years (a drought of 45 months, from July 2006 to March 2010). Using SPI-24, the three strongest episodes consist of one extremely dry period, the 'Dust Bowl' one, followed by two wet spells, both characterized by strong El Niño episodes: these two wet spells range from December 1978 to November 1985, and from March 1995 to May 2000. In conclusion, a commonly used drought metric, i.e. PDSI, has shown drought episodes in the last 15 years with average duration of about 40 months, which is about four times longer than in its entire 120-year record (average drought duration of about 10 months). Extreme caution, and continued monitoring of hydroclimatic variables, are therefore recommended to conduct, and constantly update, risk assessments.

Table 1. The 10 strongest episodes identified in the 1446-month (January 1895 – June 2015) drought record using either PDSI or SPI-24 (see **Figure 11** for a time series plot). Positive (Pos) episodes indicate wet periods; Negative (Neg) episodes indicate dry periods. Ranking was done for the 162 PDSI episodes and for the 94 SPI-24 episodes. The two episode parameters (duration and absolute magnitude) were separately ranked (with increasing ranks for increasing values), and the two ranks (DurScore and MagScore) were added to obtain the final Score (the higher its value, the stronger the episode).

PDSI

Start (yr)	Start (mo)	End (yr)	End (mo)	Dur (mo)	Episode	Abs Mag	DurScore	MagScore	Score
2011	9	2015	6	46	Neg	168.6	161	162	323
1999	3	2004	9	67	Neg	163.6	162	161	323
2006	7	2010	3	45	Neg	130.1	160	159	319
1981	10	1984	11	38	Pos	152.5	155	160	315
1958	9	1961	13	41	Neg	114.3	158	157	315
1928	5	1931	12	44	Neg	110.1	159	156	315
1994	11	1997	11	37	Pos	122.3	154	158	312
1968	11	1971	12	38	Pos	79.1	155	154	309
1917	6	1920	7	38	Neg	71.6	155	151	306
1953	9	1955	11	27	Neg	74.2	151	153	304

SPI-24

1928	4	1935	12	93	Neg	96.0	94	94	188
1978	12	1985	11	84	Pos	90.0	93	92	185
1995	3	2000	5	63	Pos	95.3	91	93	184
1906	11	1911	11	61	Pos	64.9	90	91	181
2000	6	2005	2	57	Neg	53.4	87	90	177
1988	2	1992	12	59	Neg	48.9	88	89	177
1968	2	1973	5	64	Pos	43.5	92	84	176
1947	2	1950	13	48	Neg	46.4	85	88	173
1940	12	1944	12	49	Pos	46.3	86	87	173
1917	2	1921	13	60	Neg	42.2	89	83	172

Justification for Using Proxy Time Series

Because the length of instrumental records is relatively short for climate change analysis, an extension is often used to improve estimates of average, extremes, and overall probability distributions of hydroclimatic parameters [*Salas et al.*, 2008]. Proxy records derived from growth layers of long-lived tree species have been used to augment time series of streamflow [*Meko et al.*, 2001], precipitation [*Gray et al.*, 2004], soil moisture [*Yin et al.*, 2008], snow water equivalent [*Woodhouse*, 2003], Palmer Drought Severity Index [*Cook et al.*, 2004], standardized precipitation index [*Touchan et al.*, 2005], flood events [*St. George and Nielsen*, 2003], and lake levels [*Bégin*, 2001]. Pioneer dendrohydrological work was indeed conducted in the Truckee River basin of the Sierra Nevada, where *Hardman and Reil* [1936] produced one of the first ever tree-ring extensions of precipitation and streamflow. Over the years, additional reconstructions have been produced using essentially the same approach, namely a statistical regression between a single hydrological parameter as predictand and a number of tree-ring chronologies as predictors, with the most advanced models allowing for both temporal persistence and noise terms [*Meko and Woodhouse*, 2011; *Salas et al.*, 2015].

Information on climatic changes and drought episodes can be gathered using other proxy records derived from sedimentary columns in lakes and wetlands, their geochemistry and the pollen types they contain, remaining evidence of lake level fluctuations, and others [*Bradley*, 2014]. A number of such proxy records have suggested extended droughts in the Great Basin of western North America during the Common Era [*Stine*, 1994; *Mensing et al.*, 2008; *McCabe-Glynn et al.*, 2013]. The extent of hydroclimatic episodes lasting several decades that have affected the Sierra Nevada was recently underscored by the analysis of submerged trees in Fallen Leaf Lake that persisted for about two centuries in the twelfth and thirteenth centuries [*Kleppe et al.*, 2011]. This extreme episode partially overlapped extended droughts during the mid-11th and mid-12th century reconstructed for the Colorado River Basin [*Meko et al.*, 2007] as well as the Sacramento River Basin and Southern California region [*MacDonald et al.*, 2008].

While all proxy records are subject to limitations, their value becomes more evident when one considers the information that can be obtained from downscaling global climate model (GCM) simulations. Such downscaling, which allows for watershed-level climate change predictions, can be dynamical or statistical. The former is based on regional climate models with finer horizontal grid resolution and/or surface features; the latter uses statistical regressions to represent relationships between large-scale atmospheric variables and local ones such as daily precipitation or air temperature [*Lim et al.*, 2007]. Downscaling exercises, no matter how they are performed, rely on the fundamental assumption that GCMs are able to skillfully simulate climate forcings and feedbacks, as well as multi-year climate modes (ENSO, PDO, etc.) and monsoonal circulation [*Pielke Sr. and Wilby*, 2012]. Reliance on GCMs is increasingly being questioned, even with regard to basic processes such as radiative forcing [*Chung and Soden*, 2015], because of the recent divergence between model simulations and instrumental observations (**Figure 12)**, possibly in connection with Pacific Ocean climate variability [*England et al.*, 2014].

Adding to potential sources of uncertainty, oceanic data with adequate spatial coverage are relatively short [*Hirahara et al.*, 2013], which is the reason why great emphasis has been placed on improving oceanic records using the ARGO network of floating buoys [*von Schuckmann et al.*, 2014]. A recent article widely reported in the media [*Karl et al.*, 2015] has suggested that global surface air temperature kept increasing during recent decades, and was therefore in better agreement with model simulations than previously reported. Among the adjustments to temperature datasets included in *Karl et al.* [2015], there was no consideration given to ARGO oceanic temperature data. Another article [*Nieves et al.*, 2015], published shortly thereafter in the same scientific journal, came to a somewhat different conclusion but did not receive equal coverage by major media outlets. In their analysis, *Nieves et al.* [2015] included

ARGO data in order to examine the slowdown in surface temperature warming observed over the past two decades. Overall, the debate on the reliability of GCM simulations continues, so that downscaling exercises should be viewed with some caution, especially for long-term water resource management.

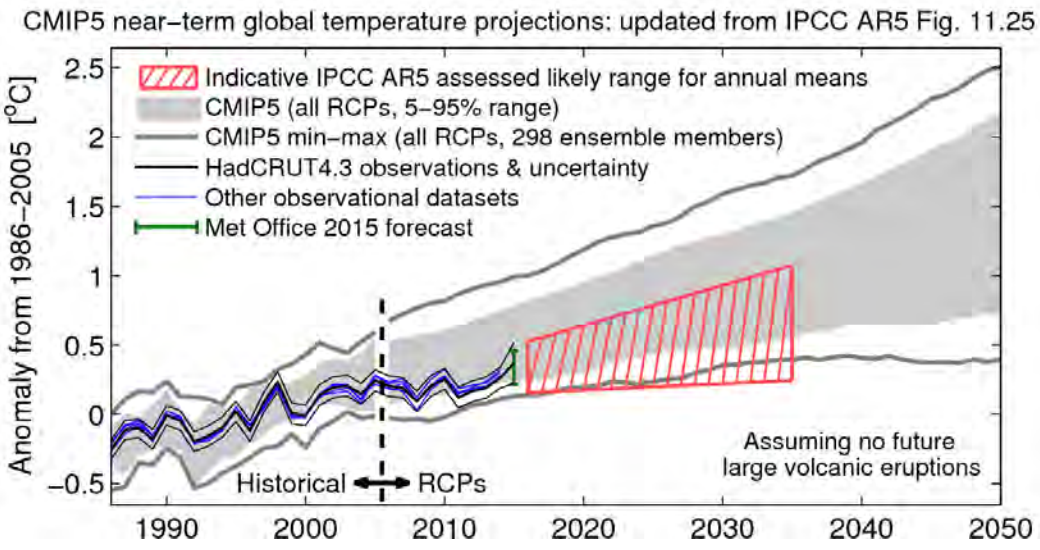

Figure 12. Comparison between observed and simulated global temperature trends up to July 2015. HadCRUT is a collaborative product of the U.K. Met Office Hadley Centre and the Climatic Research Unit at the University of East Anglia. It consists of global historical surface temperature anomalies relative to a 1961-1990 reference period. Monthly data are available on a 5° geographical grid. CMIP5 is the Coupled Model Intercomparison Project Phase 5, which provides simulations for IPCC assessment reports. RCPs are Representative Concentration Pathways for greenhouse gas and aerosol concentrations, together with land use changes, that are used by the climate modelling community, and which are themselves subject to a number of assumptions and their associated uncertainty (graphics by http://www.climate-lab-book.ac.uk/comparing-cmip5-observations/).

Recent Dendroclimatic Studies of California Drought

In previous paragraphs, it was suggested that the instrumental time series of some hydroclimatic variables in the Truckee/Tahoe basin have shown different patterns in the new millennium compared to the entire length of the record, which covers the previous century or so. In particular, it was noted that:

- Lake Tahoe water levels show increased variability in the new millennium, with as many (three) extended (i.e., two years or longer) droughts in the last fifteen years as there have been in the previous half-century (**Figure 2**);
- PDSI, averaged from two Climate Divisions, has fluctuated less, showing drought episodes in the last fifteen years with average duration of about 40 months, which is about four times longer than in its entire 120-year record (average drought duration of

about 10 months); in addition, the three strongest episodes are all second-millennium droughts (**Table 1**).

The main value of proxy records is that they provide much longer time series than those available from instrumented sites. Therefore, numerous other dry and wet episodes become available to evaluate if the second millennium, and particularly the current drought, have been unusual compared to the past few centuries.

The extremely high interest, and demand, for a longer perspective on the ongoing drought is highlighted by recent dendroclimatic studies. Last year, *Griffin and Anchukaitis* [2014] used four blue oak (*Quercus douglasii*) tree-ring chronologies from central and southern California to reconstruct October through June normalized mean precipitation from CA Climate Divisions 4–7. Calibration with the instrumental records was in reality based on only two sites during 2004-2014, since the other two chronologies ended in 2003 [*Stahle et al.*, 2013]. They also spliced an average of instrumental PDSI values from the same climate divisions onto an average of existing PDSI reconstructions for central and southern California[2]. Their statement "that 2014 is the worst single drought year of at least the last ~1200 years in California" was therefore based on mixing instrumental records, typically with higher variance, and reconstructed ones. Similarly, the "cumulative severity" of the 2012-2014 episode, which "is the worst drought on record (−14.55 cumulative PDSI)", was calculated after padding reconstructed values with instrumental ones. The practice of grafting the instrumental record onto a proxy reconstruction is not recommended because of variance compression in the proxy, together with the difficulty in evaluating the appropriateness of numerical adjustments used to account for this difference in variability. To avoid this problem, the comparison should be based on reconstructed values for the entire period, including the instrumental one [*Biondi et al.*, 2002]. *Griffin and Anchukaitis* [2014] also "estimate that ~44% of 3 year droughts go on to last 4 years or longer" and that "approximately 50% of 3 year periods with below-average precipitation continue on to last for 4 years or longer." Their most intriguing result lies in how higher air temperatures, rather than precipitation deficits alone, may be responsible for this extremely dry episode, although temperature data used in their study only cover the instrumental period.

Another climate reconstruction based on blue oak (*Quercus douglasii*) tree-ring chronologies was published this year [*Belmecheri et al.*, 2015]. This study used a regional proxy record that extended until 2005, and was then compared to a regional instrumental snow water equivalent (SWE) record that extended until 2015. The proxy record was summarized by the first principal component scores of 33 tree-ring chronologies, and the instrumental record was summarized by the first principal component scores of 108 SWE stations. The instrumental record was again grafted onto the reconstruction, making comparisons between present and past values difficult to evaluate, as previously mentioned for the *Griffin and Anchukaitis* [2014] study. Because accurate analyses require updating the proxy records, which is not an easily accomplished task, the importance of resampling and/or expanding the tree-ring network available for the Tahoe/Truckee region is very clear.

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[2] The reconstruction data are available online from the NOAA Paleoclimate website, http://www.ncdc.noaa.gov/paleo/study/17556.

Preliminary Tree-ring Reconstruction of Water-year Streamflow Episodes

For this report, we analyzed drought episodes reconstructed using publicly-available tree-ring records, both as a comparison with recently published studies and because new proxy records are not yet available to us. Our dendrochronological reconstruction of water-year streamflow was performed using as predictors the western US tree-ring chronologies available from the public-domain ITRDB dataset [*Contributors of the International Tree-Ring Data Bank*, 2014]. The initial screening was performed by computing linear correlations between the Carson or the Truckee River water-year streamflows (**Figure 5**) and ITRDB chronologies that (a) end on or after 1950; (b) are at least longer than 100 years; (c) are located between 100-125°W and 30-50°N.

A total of 923 ITRDB chronologies met the selection criteria, and these correlations were mapped to show geographical patterns (**Figure 13**). Correlations were slightly higher with Carson River streamflow, as shown by its $r \geq 0.5$ with 37 ITRDB sites, compared to $r \geq 0.5$ with 24 ITRDB sites for Truckee River streamflow. Final tree-ring predictors of Carson River streamflow, the more natural one, were selected according to these criteria: (a) start date in year 1500 or earlier; (b) end date in year 2000 or later; (c) location west of 114°; (d) correlation with water-year streamflow greater than 0.4 over at least the 1900-2000 period (because of a and b).

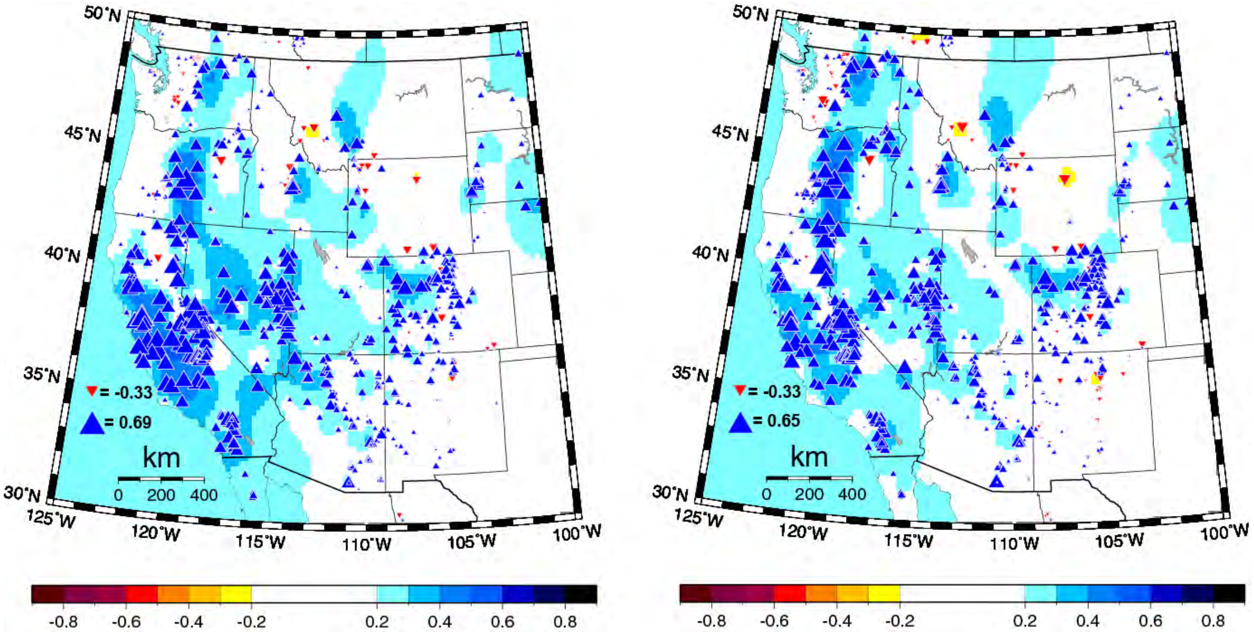

Figure 13. Map of linear correlations between ITRDB tree-ring chronologies and total water-year streamflow for the Carson (left panel) and Truckee (right panel) River Basin during the period of overlap. Point values, plotted at the location of ITRDB sites, are shown by blue upright triangles when positive, and by red inverted triangles when negative, with symbol size proportional to the correlation value. Interpolated surfaces are plotted using a pseudo-color scale that uses blue shades for positive values, and red shades for negative ones. Based on the geographical pattern of positive correlations, the maps indicate that river discharge is well correlated with tree-ring records from California, Oregon, and Nevada, with slightly higher values for the Carson than the Truckee River (graphics by F. Biondi).

The initial selection criteria, which guaranteed a record extension of about 400 years, i.e. a four-fold increase of the instrumental length, identified 33 chronologies (**Figure 14**). Among these predictors, there was a predominance of pine species (15 *Pinus monophylla*, 3 *Pinus ponderosa*, 2 *Pinus jeffreyi*, 1 *Pinus flexilis*), followed by blue oak (7 *Quercus douglasii*) and western juniper (5 *Juniperus occidentalis*). Record extension was attained using a simple linear regression with the mean of all 33 predictors from 1500 to 2001, which explained 55% of the streamflow variance during the period of overlap with the instrumental data (1900-2001). Analysis of residuals indicated no significant autocorrelation (Durbin-Watson value of 2.053), and the reconstructed time series (**Figure 15**) was analyzed in terms of episode duration and magnitude using the same scoring scheme as for PDSI and SPI-24 (**Table 2**).

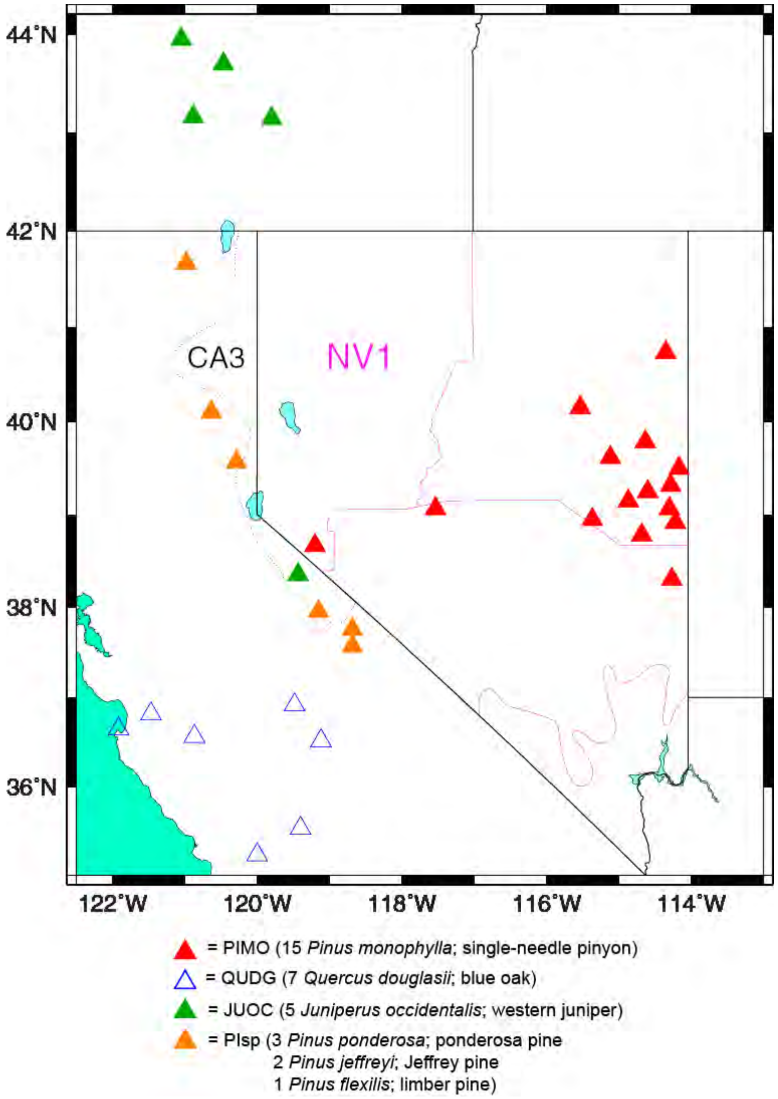

Figure 14. Location of 33 tree-ring chronologies that had correlations higher than 0.4 with the Carson River streamflow, began in 1500 or earlier, ended in 2000 or later, and are located west of 114° longitude. Symbols identify the tree species (solid for conifers, empty for hardwoods), which are mostly pines (15 *Pinus monophylla*, 3 *Pinus ponderosa*, 2 *Pinus jeffreyi*, 1 *Pinus flexilis*), followed by blue oak (7 *Quercus douglasii*) and western juniper (5 *Juniperus occidentalis*). These records were used for a preliminary tree-ring extension of water-year streamflow (graphics by F. Biondi).

On average, the 211 wet and dry spells had a 2.4-year duration, with the longest episodes being a 9-year wet period in the early 1980s (1978-1986), and two 8-year droughts in 1841-1848 and 1924-1931. These were also the three strongest episodes in the entire reconstruction (**Table 2**). While this information points to the value of proxy records, for instance in terms of defining the longest drought over a period five times longer than the instrumental one, it should be emphasized that up-to-date, and more local, tree-ring chronologies would be needed to strengthen this preliminary analysis. In other words, updating old, and developing new, tree-ring records from sites located in the Truckee and Carson River watersheds, in combination with recent advances in producing km-level gridded reconstructions [*Biondi*, 2014] and in task-specific water-balance modeling [*McCabe and Wolock*, 2011; *Saito et al.*, 2015], is expected to improve the quality of hydroclimatic reconstructions for the Tahoe/Truckee region.

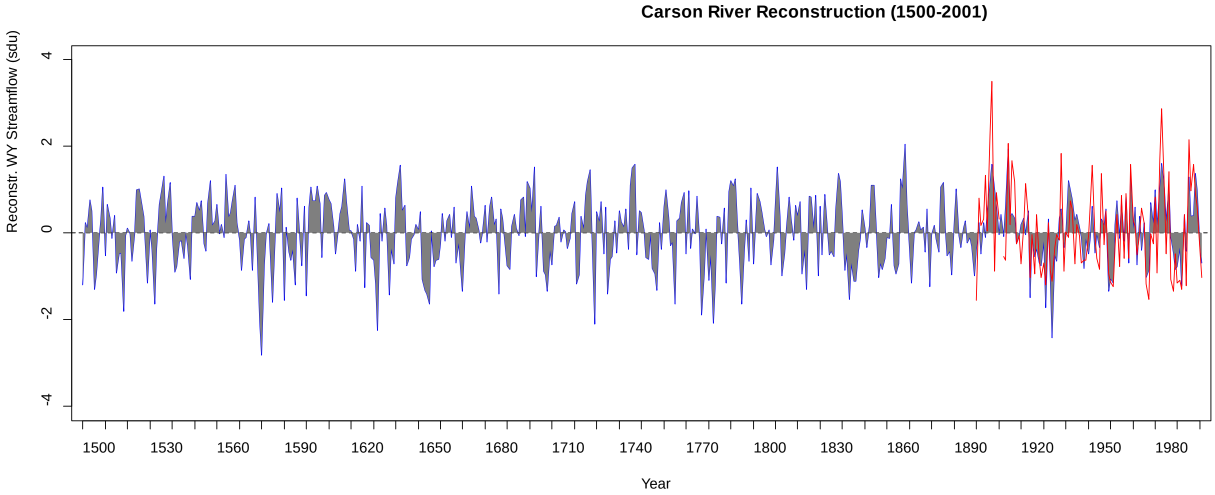

Figure 15. Time-series plot of normalized water-year streamflow (sdu = standard deviation units) reconstructed from a simple linear regression with the average of 33 tree-ring chronologies from the western US (see **Figure 14**). Instrumental records (red curve) used for calibration covered the 1900-2001 period. Visual inspection shows that the reconstruction is more effective at capturing droughts than very wet periods, such as the early 1900s pluvial and the El Niño events of the early 1980s and late 1990s. Episodes (gray shading) above or below the zero reference level were analyzed in terms of their duration and magnitude (**Table 2**). Even though not included in the three strongest episodes, the driest years in the reconstruction were 1580 and 1934, both well-known widespread droughts in the western US [*Cook et al.*, 2010; *Woodhouse et al.*, 2010; *Cook et al.*, 2014] (graphics by F. Biondi).

Table 2. The 10 strongest episodes identified in the 502-year (1500-2001) reconstructed streamflow (see **Figure 15** for a time series plot). Positive (Pos) episodes indicate wet periods; Negative (Neg) episodes indicate dry periods. Ranking was done for the 211 episodes in the same way as for **Table 1**. This reconstruction, and the episodes identified in it, is preliminary, since up-to-date tree-ring chronologies are required to provide the most reliable assessment of the current drought.

Start (year)	End (year)	Episode	Dur (yrs)	Abs Mag	DurScore	MagScore	Score
1978	1986	Pos	9	7.0	211	211	422
1841	1848	Neg	8	6.2	209	210	419
1924	1931	Neg	8	5.7	209	208	417
1534	1540	Pos	7	5.0	208	206	414
1601	1606	Pos	6	4.9	201	204	405
1564	1569	Pos	6	4.3	201	195	396
1941	1946	Pos	6	3.8	201	191	392
1578	1582	Neg	5	5.9	183	209	392
1987	1992	Neg	6	3.7	201	188	389
1905	1909	Pos	5	4.9	183	203	386

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TRUCKEE MEADOWS WATER
AUTHORITY

APPENDIX 2-5

CLOUD SEEDING REPORT

2014

Annual Report

Cloud Seeding Project for Tahoe and Truckee Basins for WY2015: Status Update for Oct 2014 -June 2015

Submitted to

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By

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1. Introduction

The goals of the DRI cloud seeding efforts in the Tahoe/Truckee Basin remain essentially the same from previous years: to enhance snowfall from winter storms and to increase the snowpack of the Tahoe and Truckee Basins through the application of wintertime cloud seeding technology. This report constitutes an update on project status for the first three quarters of the TMWA/WRWC grant period, covering 1 Oct 2014 -30 June 2015.

1.1. Brief Project Description

The project design and method of operation are the same as those used for the previous few seasons. Seeding is conducted from a line of five ground-based cloud seeding generators (CSGs) positioned on, or a few miles upwind of, the main Sierra Nevada crest to the west of Lake Tahoe (Fig. 1). The generators are positioned to take advantage of the generally westerly to southwesterly wind directions in winter storms in the Tahoe area, and are remotely activated by DRI staff when the proper weather and cloud conditions for seeding were verified. Forecasting for potential cloud seeding events during WY2015 began on November 1, 2014 and continued until May 28, 2015.

2. Summary of Phase 1 Activity

Activity under Phase 1 of the project was concluded during the first quarter and included preparation of the five seeding generators at the locations shown in Fig. 1. This work required several weeks, and included re-installation of the Barker generator as required by USFS permits for use of the site. Additional Phase 1 tasks included refilling the seeding solution tanks, refilling propane tanks, and testing all generator components and communications links.

3. Summary of Phase 2 Activity

Phase 2 of the project includes the actual cloud seeding operations and supporting work such as forecasting and real time monitoring of weather over the Tahoe target area. The project meteorologists monitor the weather and make forecasts for seeding events that are expected within one to five days. Throughout Phase 2 the cloud seeding field technicians and project meteorologists made at least weekly checks of cloud seeding equipment by logging into the data loggers, briefly activating the units and monitoring key operating parameters such as flame temperature and solution flow.

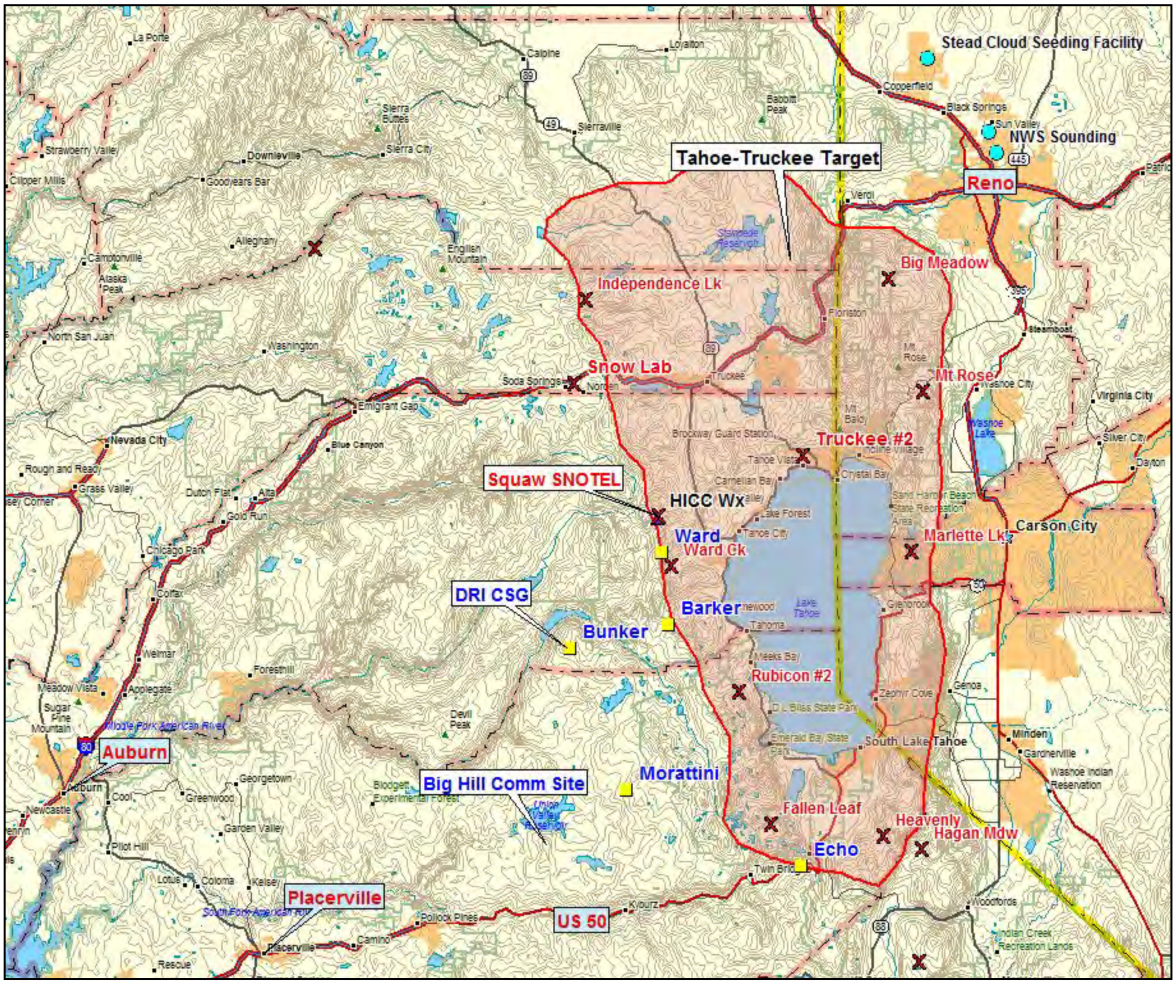

Figure 1. Map showing the Tahoe-Truckee cloud seeding target area (red shading) and instrument sites in and around the target area. NRCS SNOTEL sites, which measure precipitation and snow water equivalent (SWE) are indicated by red Xs. Ground seeding sites are shown as yellow squares. Reno facilities are shown in the upper right as cyan-colored circles. Weather data shown in Section 4 of this report were collected near the sites labeled Snow Lab, Squaw SNOTEL, and NWS Sounding.

3.1. Summary of Tahoe-Truckee Cloud Seeding Operations

The cloud seeding activity during Phase 2 that occurred through the winter season are presented in this report. By the end of May a total of 20 seeding operations had been conducted, with the final seeding operation of Phase 2 on 24-25 April 2015. Figure 2 shows the monthly totals for seeding hours and seeding events for all of WY2015. For the season there were a total of 681 seeding hours conducted over 20 separate events. The details of all operations are given in Appendix A. The record warm and dry winter led to lower total seeding hours than the previous seasons that the project has been funded by TMWA and WRWC. An analysis of generator operating efficiency (*ratio of actual seeding hours to total hours possible if all CSGs had operated correctly throughout all events*) for the season produced a value of 90%, which is significantly improved from last season. Poor communication to the Bunker Hill site caused the biggest loss of seeding hours. A few other problems, such as ignition failures, low flow, and depleted solution were also encountered, but were typically dealt with quickly and lead to fewer lost hours compared to the communication problem.

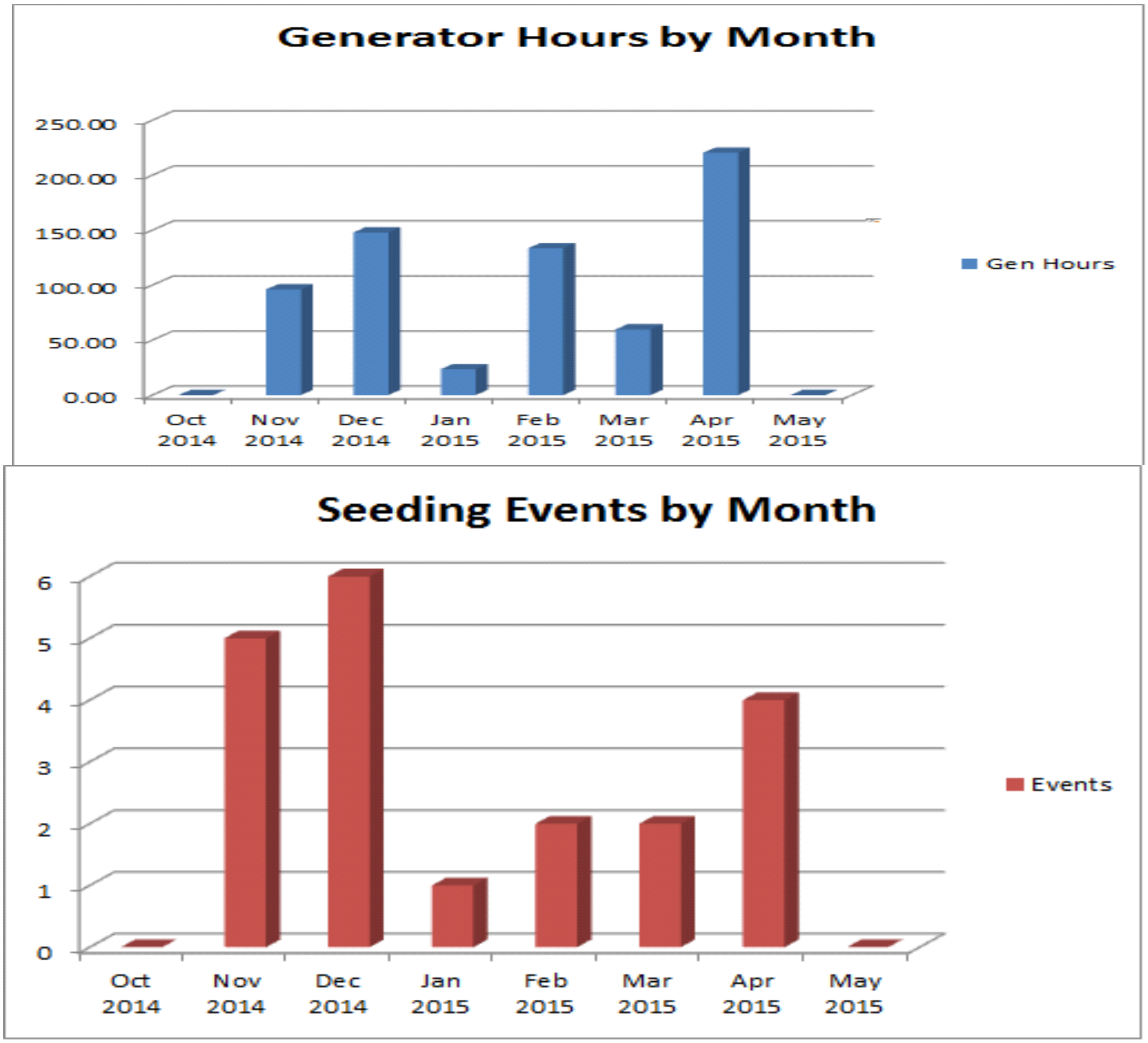

Figure 2. Monthly summaries for Tahoe-Truckee area cloud seeding operations in WY2015. Top panel shows CSG seeding hours by month and bottom panel shows the number of seeding events by month.

3.2. Water Year Summary

Figure 3 documents the history of snowwater liquid equivalent (SWE) accumulations (relative to 30-year median values) in the Tahoe and Lower Truckee Basins for WY2015. The winter season was again dry, with the snowpack's SWE only briefly reaching 50% of the median in late December.

Snowfall was minimal through much of the late fall. A set of warm storms in early December increased the snowpack somewhat, but SWE in both the Tahoe and the lower Truckee basins were at about 30% of the median values by the end of a very dry January. SWE remained exceptionally low as a set of very and wet warm rainstorms moved through area in early February. Storms in early February only increased the SWE in the highest elevations of the Tahoe Basin and lower Truckee Basin. Only a few additional storms occurred though the second half of the calendar winter and a very warm early spring in March allowed the low SWE values to go to near zero. A few spring storms added a bit of snow in April but only minimally added to the SWE.

The winter snowfall history at specific SNOTEL sites in the Truckee Basin is documented in Fig. 4. The sites shown vary in location (see Fig. 1) and altitude. The Central Sierra Snow Lab (CSSC) is the lowest site (6255 ft.) located upwind (west) of the main Sierra Nevada crest. Squaw is just above 8000 ft. and located slightly downwind (east) of the Sierra crest, and Big Meadow the highest site at 8250 ft. is in the Carson Range on the east side of Lake Tahoe. The warm early December storm seemed to only impact the Sierra Crest (Big Meadow showed no increase in SWE) is shown in Fig. 4, as is the extended dry period that encompassed most of January 2015. The second big warm storm occurred in early February, with Squaw SWE increasing by 5 inches. A storm in late February added slightly to the SWE at all three sites. By the end of March the snow was gone from both CSSL and Big Meadow, and less than 2-inches at Squaw. The 30-year median SWE at Squaw on March 31 is just under 50-inches. A late April storms briefly increased the snowpack at all three sites.

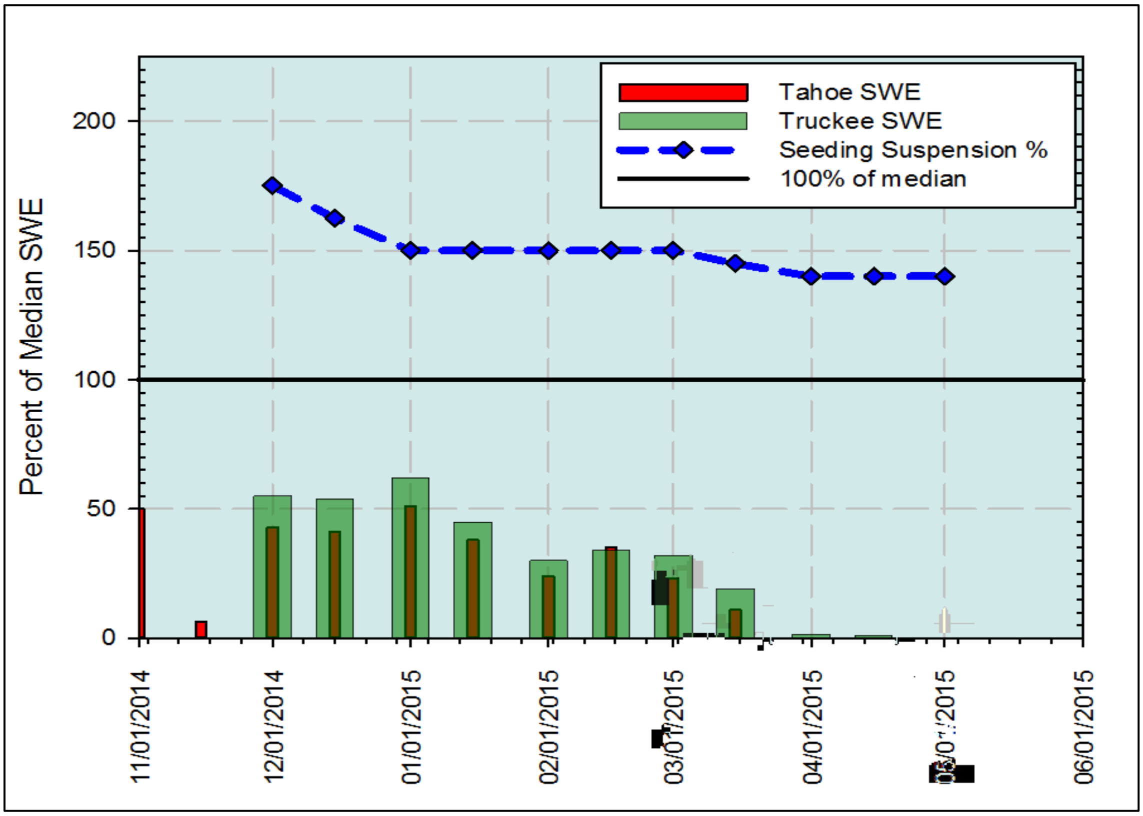

Figure 3. Snow water equivalent (SWE) percentages relative to 30-year median values for the Lower Truckee and Tahoe Basin for WY2015. Black line highlights 100% of the median. Blue dashed line shows SWE percentage thresholds at which cloud seeding is suspended due to above normal snowpack. Wide green bars show Truckee Basin SWE and thin red bars show Tahoe Basin

4. Summary of Phase 3 Activity

The phase 3 work typically begins in late May after the end of all seeding operations and includes the analysis of weather data during cloud seeding periods, an estimate of snow water augmentation from the season's seeding, and final postseason maintenance work on the CSG network. Maintenance includes removal of the Barker CSG because of its accessibility to the public during the summer. This was done in June this year. The ordering of expendable supplies for future operations also generally occurs as part of Phase 3, and this will be done during the final quarter of the contract period.

All of the significant storm systems in WY 2015 were warmer than normal and thus seeding conditions were not always optimal. In addition, some of these storms were characterized by relatively low atmospheric stability, such that the associated clouds were often more of a convective nature than the stratiform clouds observed in many wintertime storms in the Sierra Nevada range. With such convective clouds, updrafts of up to 10 m/s are possible, allowing seeding material to reach greater altitudes and colder temperature than is possible with stratiform cloud systems. Thus, it is quite possible that even when temperatures are warmer than -5°C at 700 mb (10,000'), the seeding material can be taken to somewhat higher altitudes within the clouds where supercooled liquid water at temperatures less than -5°C are present. Because of this, seeding strategies were modified somewhat for this period. The strategy allows seeding to commence for 700 mb. temperatures between 0°C and -5°C if it was determined that either convective clouds were already present over generator sites or that sufficient atmospheric instability (as determined from observed and model forecast temperature and moisture profiles) was present to promote convective cloud development.

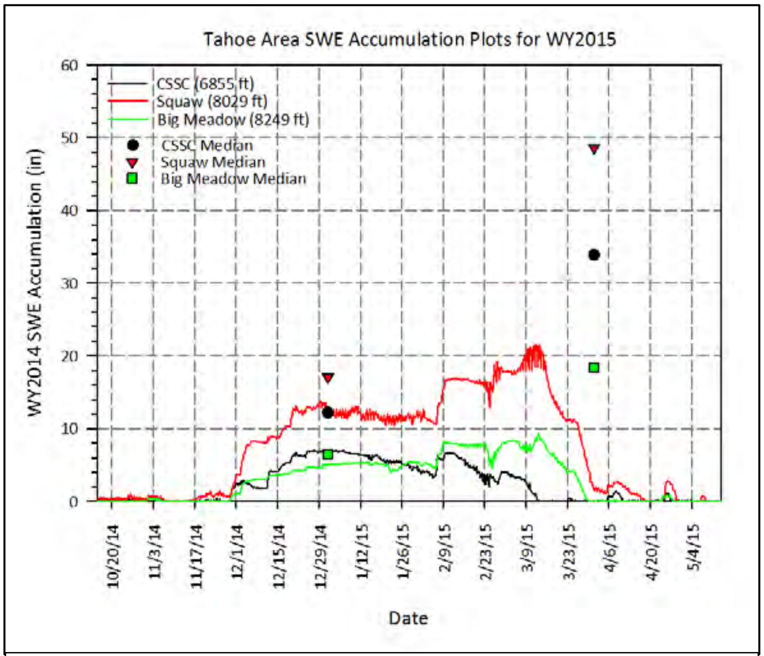

Figure 4. SWE accumulation plots for three SNOTEL sites in the Tahoe-Truckee River Basin. Note the locations in Fig. 1.

A complete assessment of weather conditions during seeding events is part of the Phase 3 analyses. The weather data and seeding periods for November 2014 are shown in Fig. 5. The season started quickly with a seeding event on November 1st. The next 3 weeks were too warm for operations. A complex set of storms moved through the area late in the month. These storms were not that cold, but the periods with 10,000' MSL temperatures colder than -5°C and the more unstable periods were seeded.

In early December (Fig. 6) a very wet but warm storm ('Pineapple Express') moved across the Sierra under southwesterly flow. This system was much to warm to seed. By December 12 at 10,000' MSL temperatures cooled below -5°C and several seeding events were conducted though the middle of the month. A cold storm ('Inside Slider') moved just east of the area on December 24-25 but winds were from the east throughout this event. January 2015 was quite dry and much warmer than the climatological normal (Fig. 7). There was only one seeding event in an unstable atmosphere at the end of the month with light precipitation.

At the end of first week of February 2015 (Fig. 8) a pair of warm and very wet 'Pineapple Express' storms moved across the area under southwesterly flow aloft. Most of the precipitation fell as rain, even across the highest elevations of the Sierra Crest. The end of the second event was seeded as the temperatures cooled and winds became more westerly. At the end of the month a colder Gulf of Alaska storm moved across the area. This entire event was seeded. March 2015 (Fig. 9) was also quite warm and dry. A brief event was seeded on March 2 and second stronger event on March 22. April 2015 (Fig. 10) was somewhat more active than earlier in the season with 4 events in the month. The first two storms of the month were cold with winds from the northwest and ideal cloud seeding conditions. A short event occurred as a cold front crossed the Sierra on April 14. Late in the month a cold front again crossed the area, which allowed an extended period of cloud seeding with 10,000' MSL temperatures colder than -5°C, low clouds, and winds generally from the northwest.

The WY2015 seeding events are summarized in Fig. 11 where several weather variables are averaged or totaled over each seeding period. An hour was added to the end of each analysis period to account for any continued effects from seeding after CSGs were shut down. The data from the Tahoe City Snotel has replaced the Squaw Valley base data set, since that data set has been shown to be unavailable for extended periods of time in previous seasons. These two sites are close to each other and at about the same elevation. Figure 11 indicates that the 20 seeding events generally met all project seeding criteria. Exceptions were Events 4, 12 and 13, which had 700 mb. temperatures slightly higher than the -5° C seeding threshold. The events 12 and 13 both were under unstable conditions where the seeding material would be expected to mix higher than the normal threshold and to colder levels of the clouds. Seventeen of the 20 events had measureable precipitation, although four events had less than 0.2 in. The differences in precipitation amounts between the observation stations were significant this winter. CSSL or the Squaw SNOTEL in the main Sierra Nevada range typically record the most precipitation, although Mt Rose in the Carson Range recorded more than Squaw during four events. The most precipitation (2.2 in) during any single seeding event was recorded at Squaw in late April.

There were several different 700 mb. wind direction regimes during seeding events in WY2015. Seven events had a more west to northwesterly flow pattern. All but one (event 12) of these 7 events had temperatures below the 5° C seeding threshold. The remainder of the events had more typical south to southwesterly flow including all of the unseeded Pineapple Express storms.

In estimating the effect of seeding on snow water equivalent in the following section, the data in Figs. 11 and the data plots like Fig. 5 were first used to determine a seedability factor (SF) for each seeding period. The SF semi-quantitatively estimates how well the project seeding criteria were satisfied for each event. If cloud cover, wind and temperature criteria are all satisfied, then SF is one. If the wind criterion is only satisfied during half of an event then SF drops to 0.5. For the temperature criterion SF is reduced if the 700mb temperature is above -5° C; from 0.9 for the first degree above -5°, down to 0.2 at -1°, and 0 at or above freezing. This reduction in SF was applied to stratiform atmospheric cloud structures. For convective cloud structures the temperature threshold (SF = .95) was increased to -3.5°C with the SF linearly decreasing and set to 0 at the freezing level. To estimate snow water augmentation for the season an event duration-weighted value of SF was computed and found to be 0.92.

The 2 new TMWA/WRWC high-resolution snow gauges (one in Hope Valley and one above Incline Village) will help reassess the weather and resulting impacts from cloud seeding.

WY2015 Snow Water Augmentation Estimate

The analysis of weather events and seeding criteria in the previous section and from other analysis indicated that the project seeding criteria were identified in realtime a high percentage of the time during the winter of 2014-15. As noted in the previous section the estimate of snow water increase from seeding is factored according to the percent of time that criteria are met. As indicated above the seedability factor (SF) was computed to be 0.92. Our original proposal indicates that the expected benefit from cloud seeding is an increase in the precipitation rate of 0.25 mm per hour (~0.01 inch per hour). Past studies of seeding plume dispersion over mountainous target areas, and documentation of the fallout area (of snow) within a seeding plume, have shown that the area affected by one seeding generator is approximately 35 square miles. This area of effect will vary as cloud conditions and wind speed vary, and can also change as the dimension of the mountain barrier along the wind direction changes. For simplicity (and because all the parameters affecting area cannot be precisely evaluated) the area is taken as a constant.

Following previous years, the estimate of the amount of snow water produced by seeding (W_s) is provided by multiplying the total time of generator operation (T_s = 681.35 hours) by the precipitation rate increase (P_s = 0.25 mm per hour). This product is then multiplied by the area of effect (A_s = 35 sq. miles), and then by SF (0.92). To obtain the estimate in units of acre-feet the following conversions are also needed:

0.25 mm = 0.00328 ft.
1 sq. mile = 640 acres.

So, for the 2014-15 winter season the estimated snow water increase from seeding is:

W_s = 681.35 h x 0.25 mm/h x 0.00328 ft/mm x 35 sq mi x 640 acres/sq mi x 0.92

W_s ≈ 11,513 acre-feet.

A comparison of seeding operations in the current water year with those from 18 prior years is shown in Fig. 12. The comparison includes Nevada state-funded program water years 1998 to 2009, and the years of TRF and TMWA/WRWC sponsorship. The top panel also shows the number of seeding generators used in each season. Snow water augmentation estimates were computed using the same method for all seasons except the first three shown, when the seedability factor was not used. Seeding hours tend to reflect the frequency of storms in a given year, thus the lower number of hours during the drier years from 2007 through 2009. However, lower seeding hours can also occur in very wet years like 2000 when seeding was suspended during flooding events. WY2011 is also something of an anomaly since seeding hours were about 72% of the 16-year average (due to the snowpack suspension in April and May), but the storm frequency was well above average. The WY2015 snow water augmentation estimate was about 78% of the 16-year average of 14,643 acre-feet.

5. Budget and Expenditures

The project has gone as planned and is on budget. A final expenditures spreadsheet will be submitted to the sponsor in the fourth quarter of WY2015.

Reference

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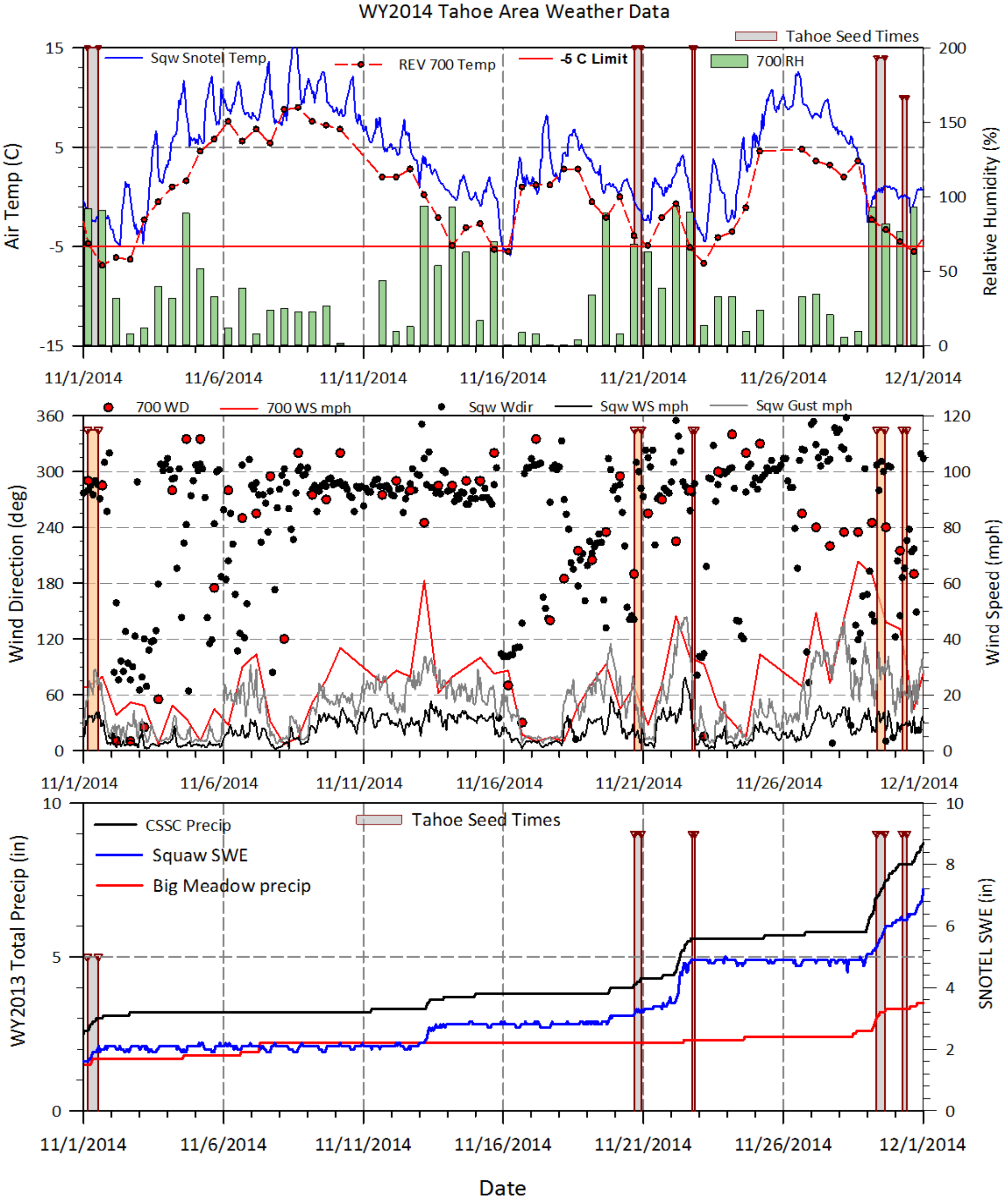


Figure 5. Tahoe area weather data and cloud seeding periods (shaded regions) for November 2014. Top panel shows 700 mb. temperature and relative humidity, and Squaw SNOTEL temperature. Middle panel shows wind data at 700 mb. and Squaw, and bottom panel presents precipitation or SWE accumulation at CSSL, and Squaw and Big Meadow SNOTEL sites.

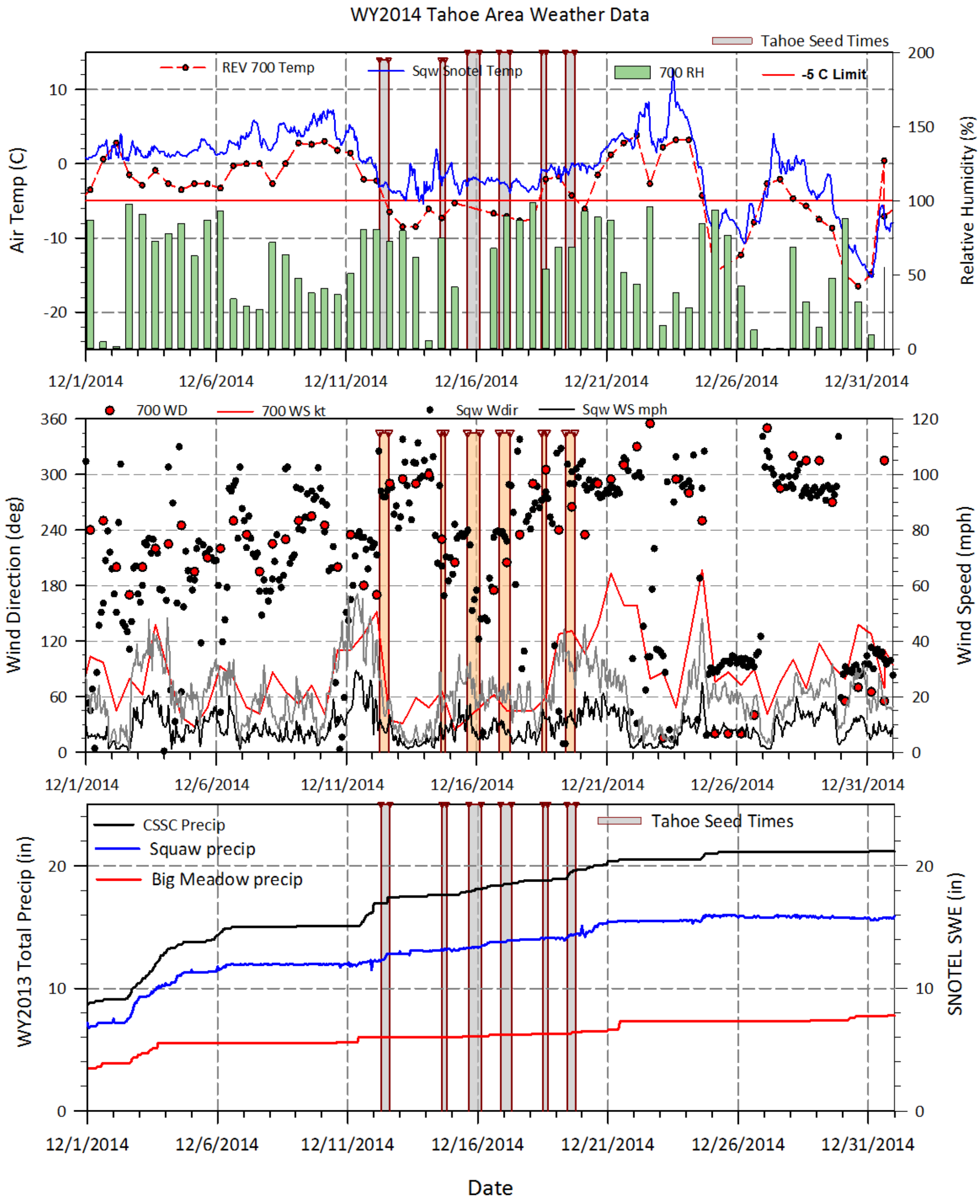


Figure 6. As in figure 5 but for the month of December 2014.

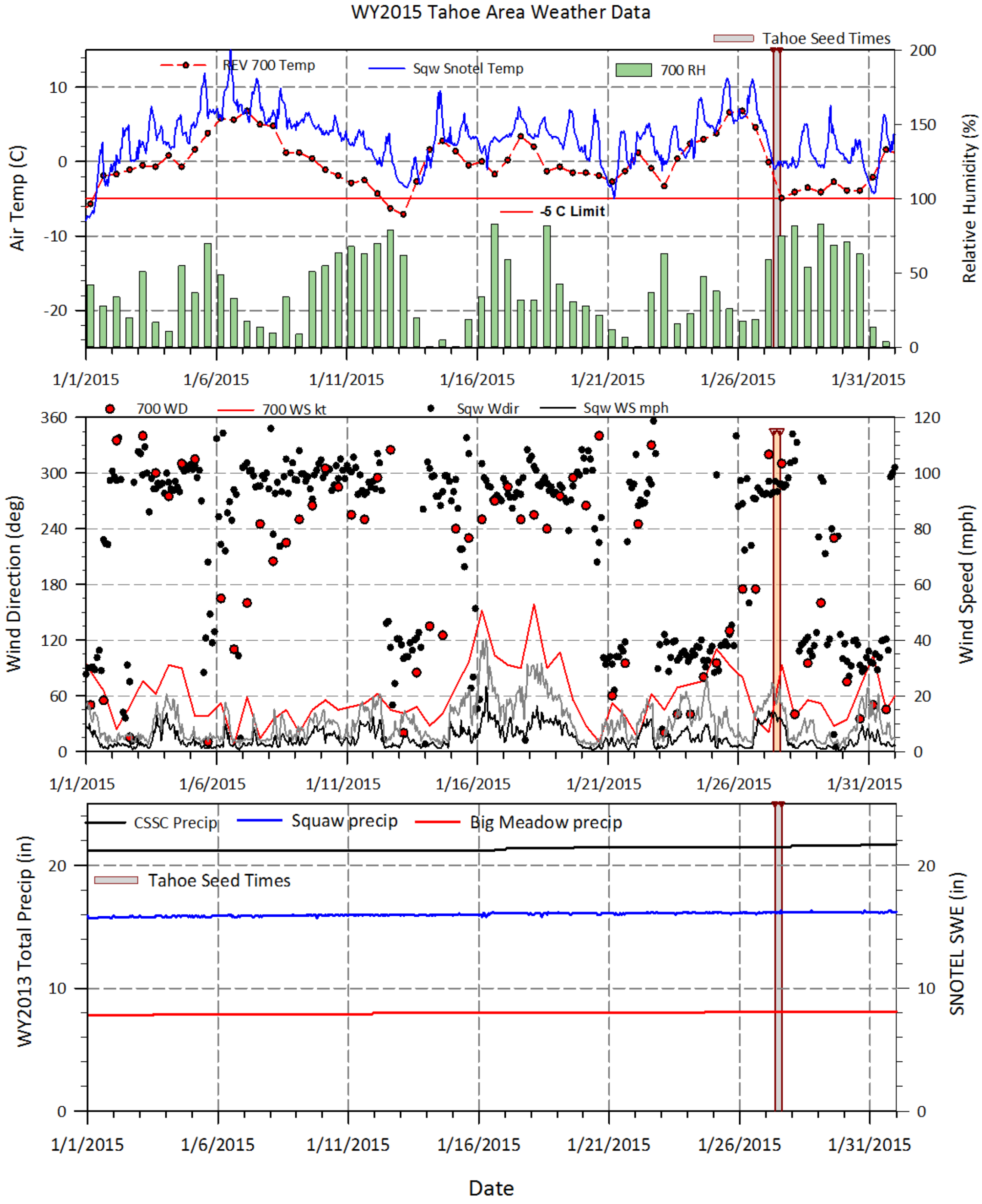


Figure 7. As in figure 5 but for the month of January 2015.

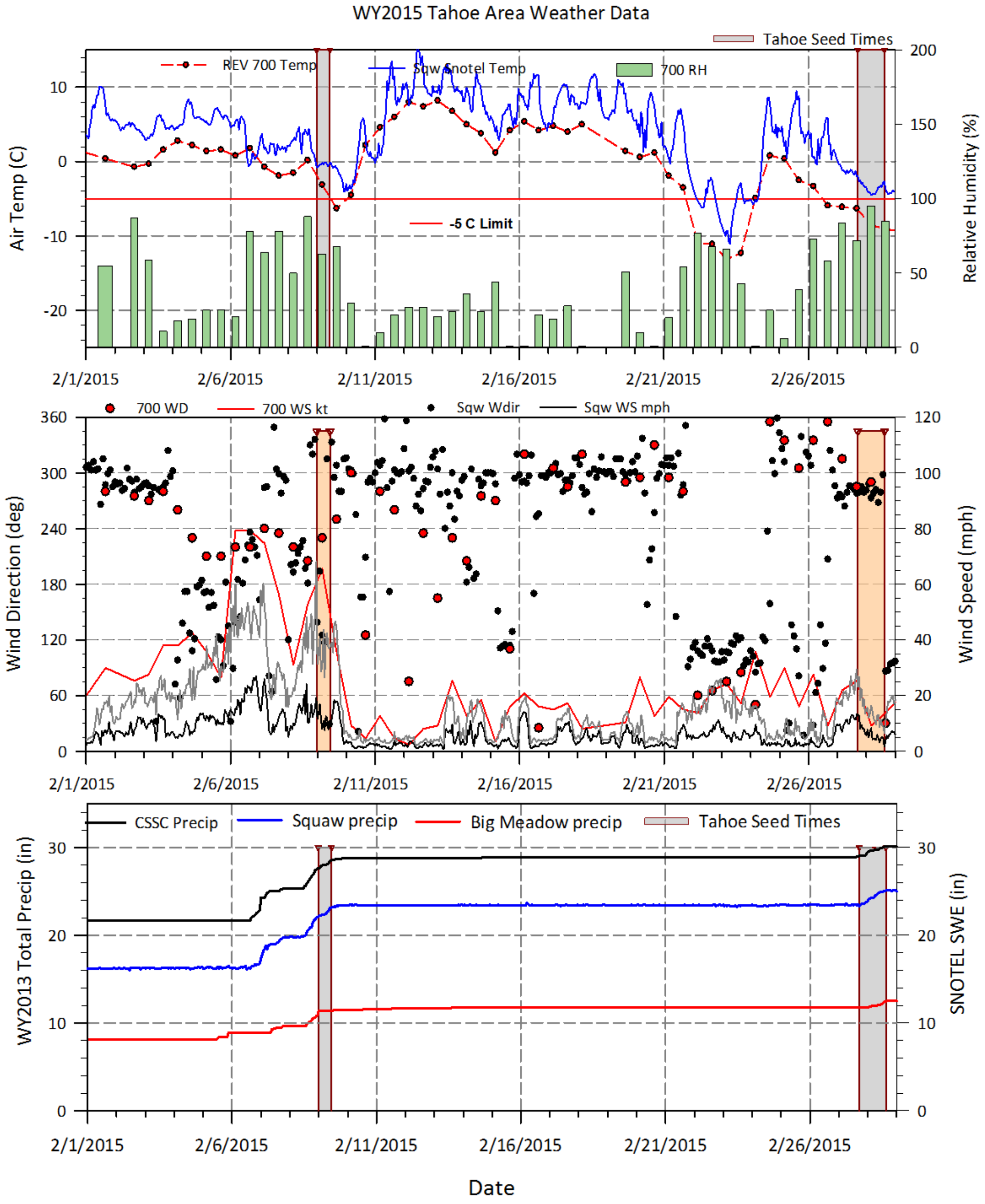


Figure 8. As in figure 5 but for the month of February 2015.

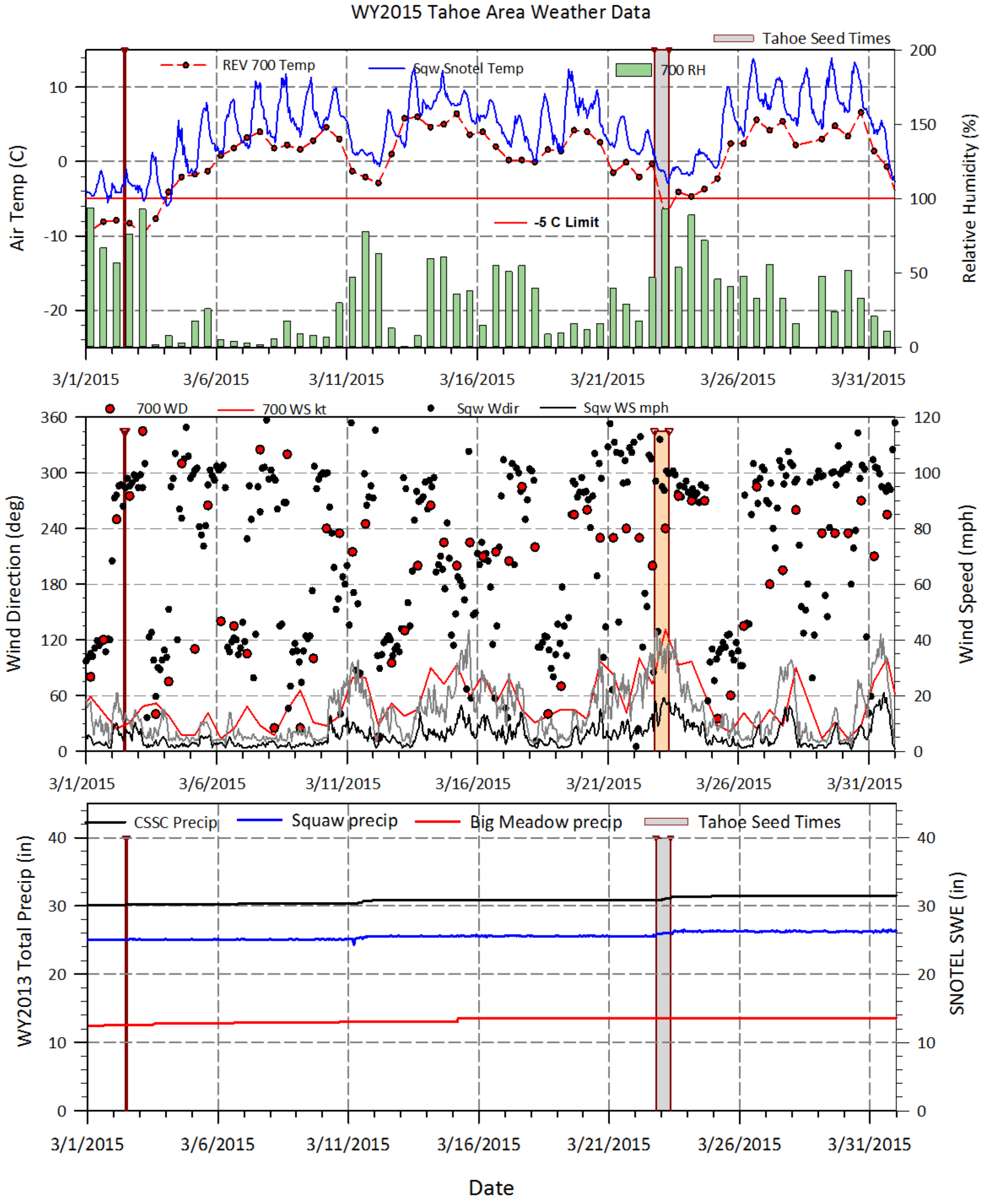


Figure 9. As in figure 5 but for the month of March 2015.

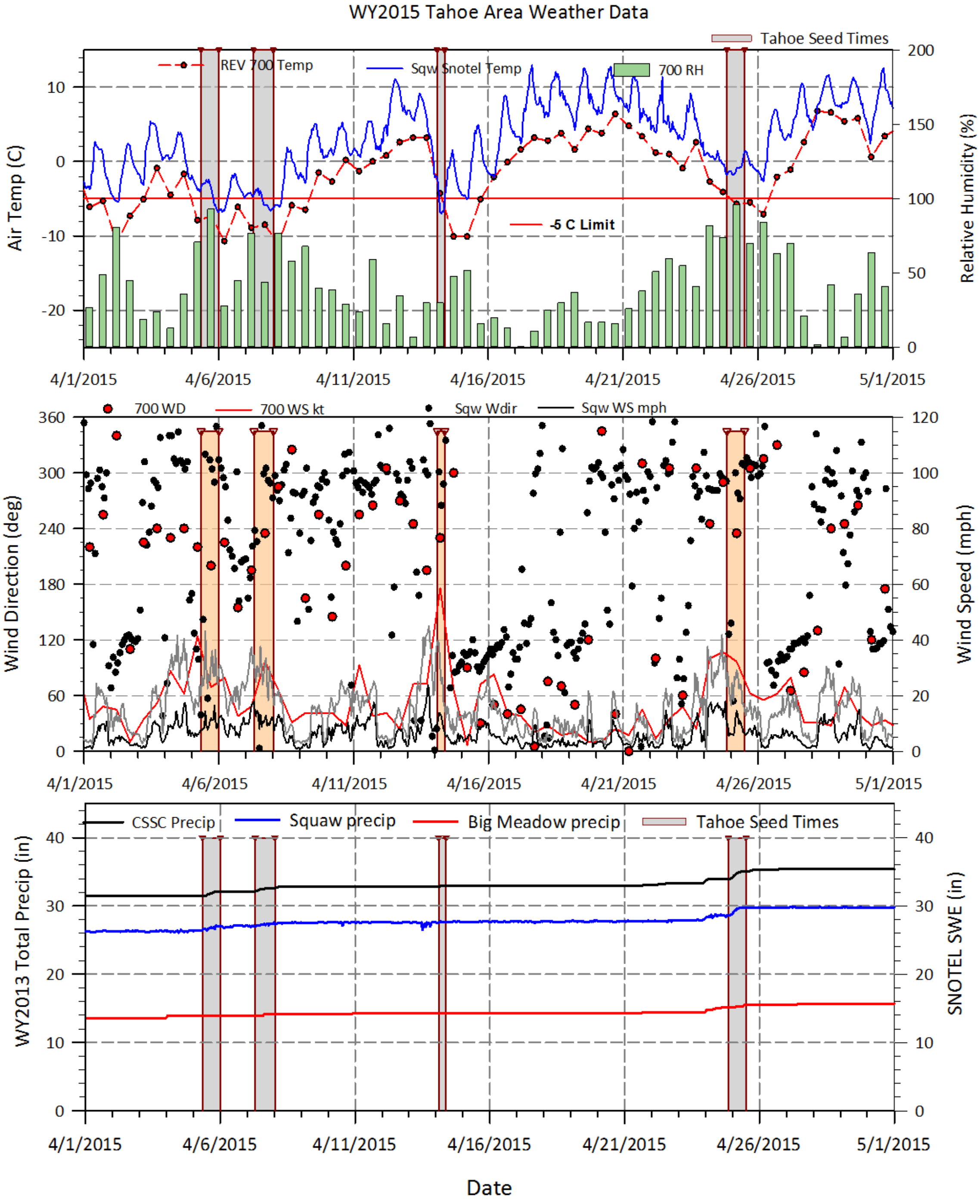


Figure 10. As in figure 5 but for the month of April 2015.

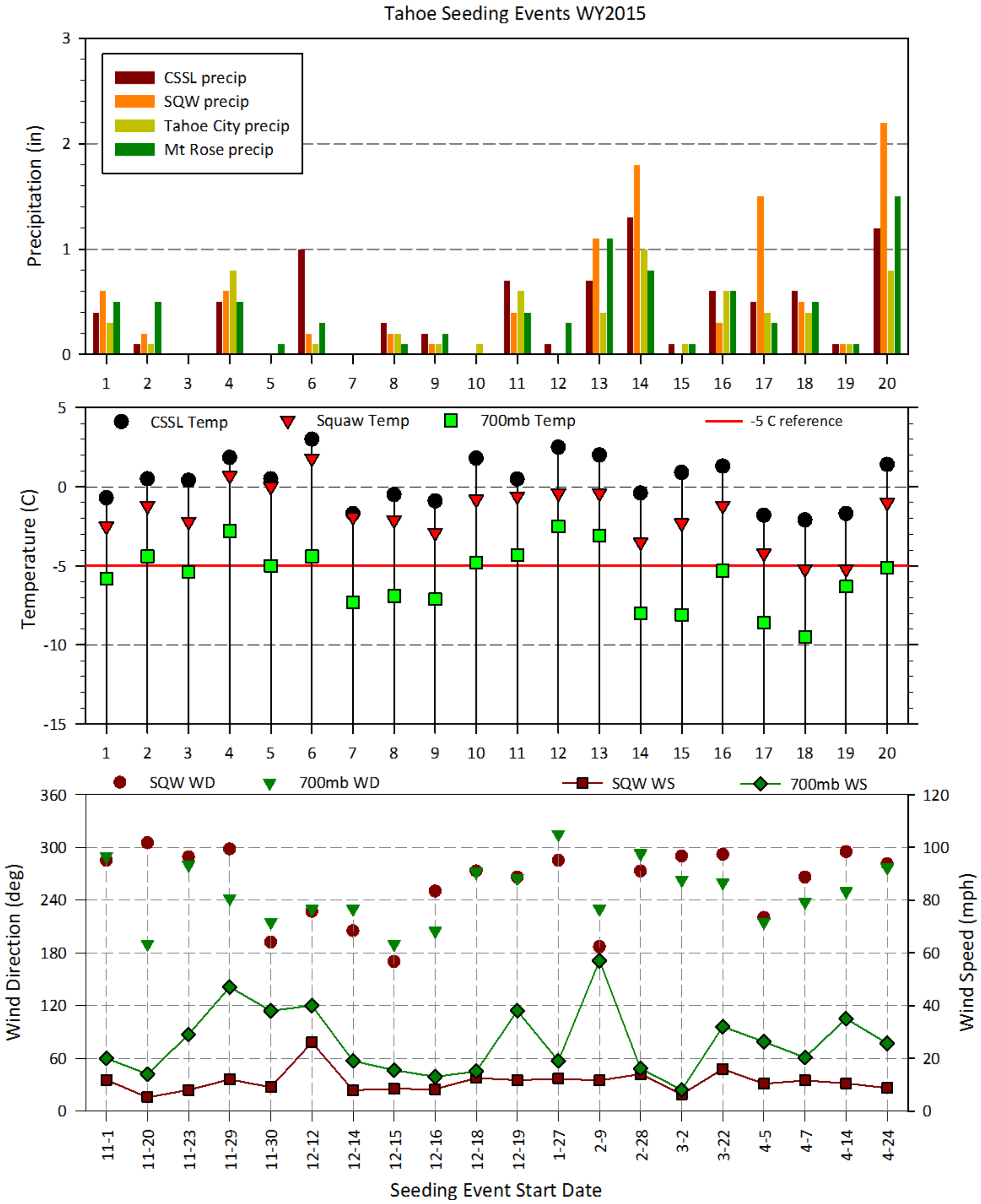


Figure 11. Weather variables for cloud seeding periods in the Tahoe area during November 2014 through May 2015. Top panel shows precipitation accumulation at the Central Sierra Snow Lab (CSSL), Squaw Valley (SQW), Tahoe City, and Mt. Rose SNOTEL sites. Middle panel presents the average temperature at CSSL and the Squaw SNOTEL, and the 700 mb. temperature interpolated to the midpoint of each seeding period. Bottom panel shows the average wind direction and speed at the Squaw SNOTEL, and the midpoint values at 700 mb. The bottom panel scale is annotated with the start date of each seeding period.

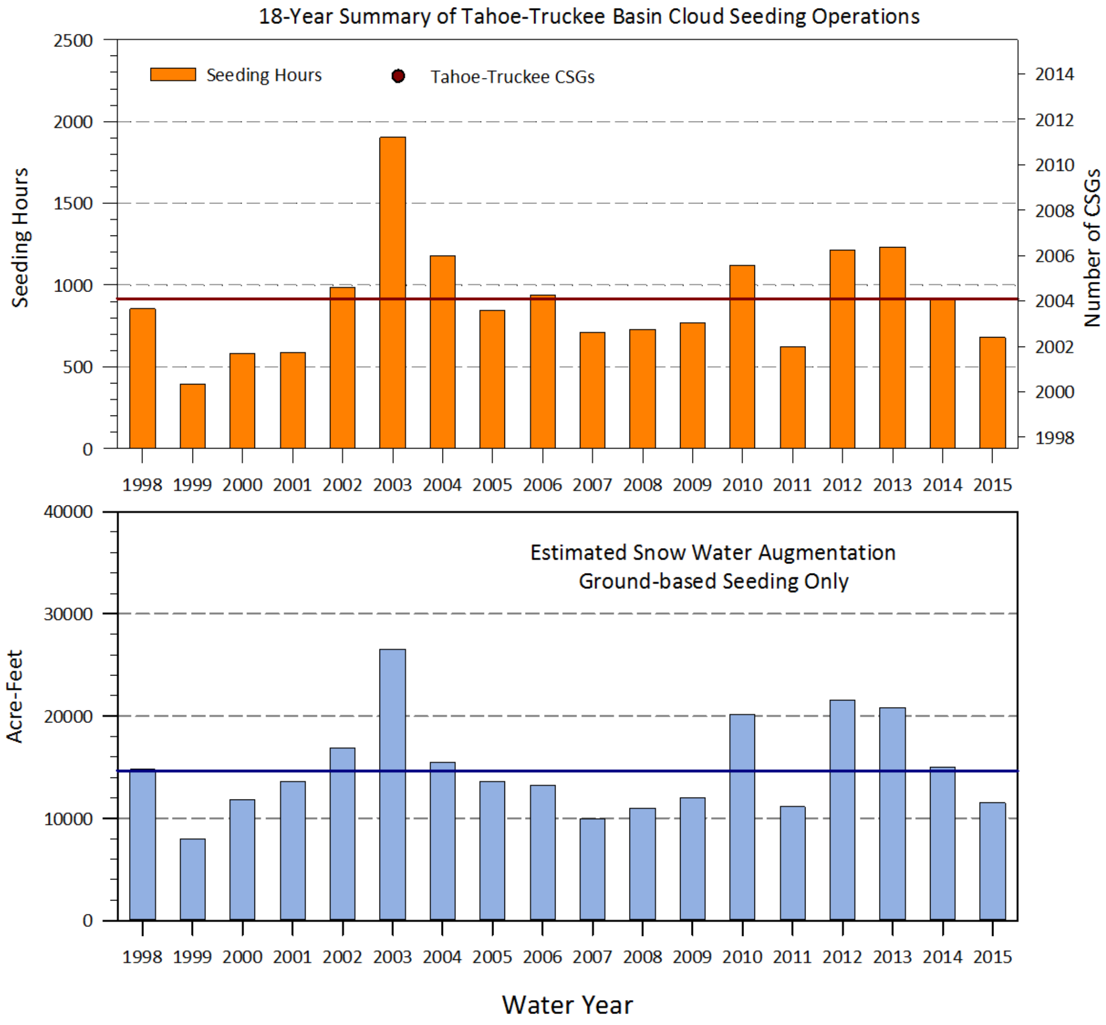
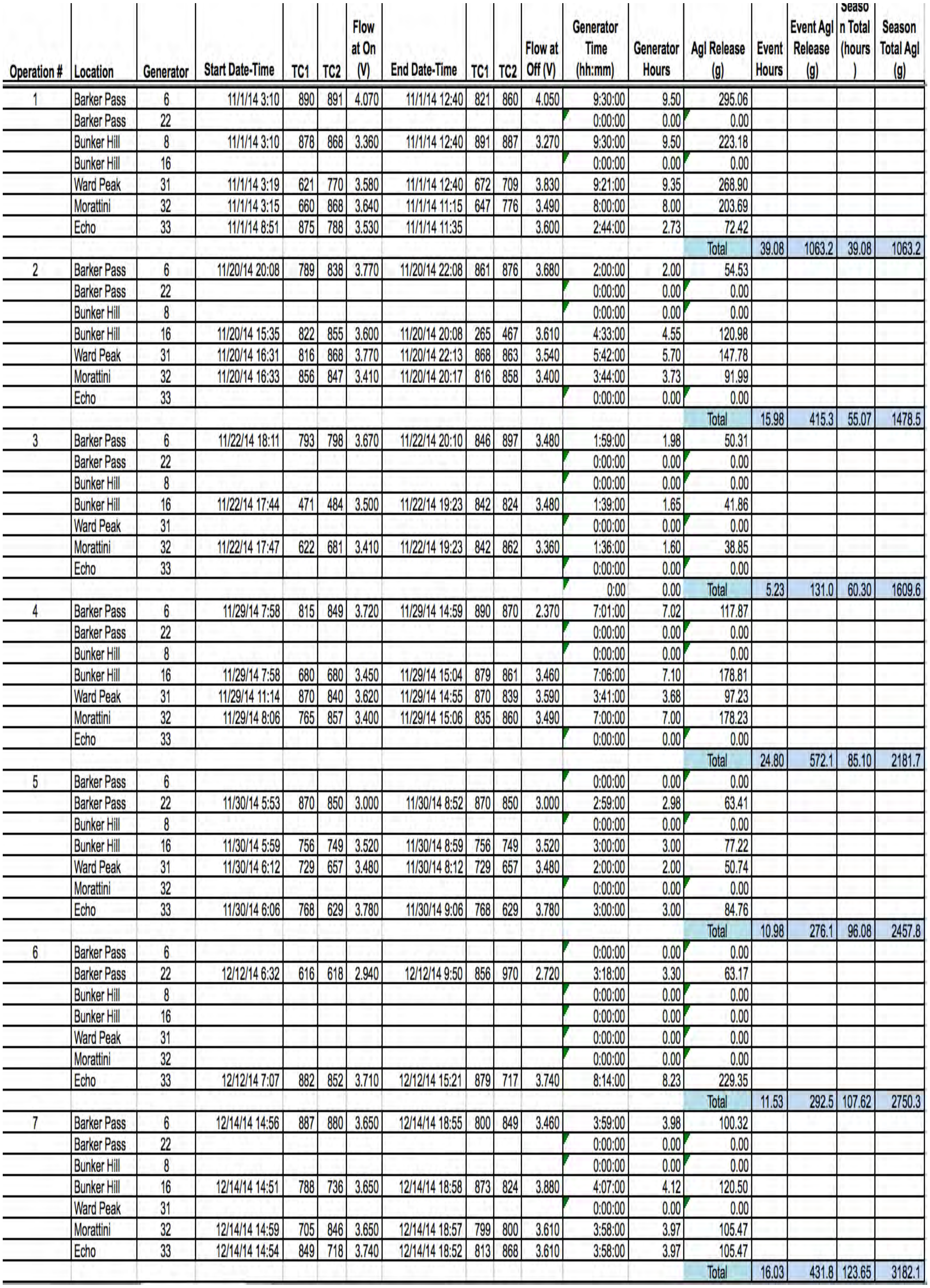


Figure 12. History of cloud seeding hours and snow water augmentation estimates in the Tahoe-Truckee Basin for Water Years 1998 to 2015. The Nevada state-funded project ran from 1998 to 2009. Solid line on each graph represents the 16-year average.

Appendix A. Tahoe Seeding Operations: 1 November 2014 to 14 December 2014

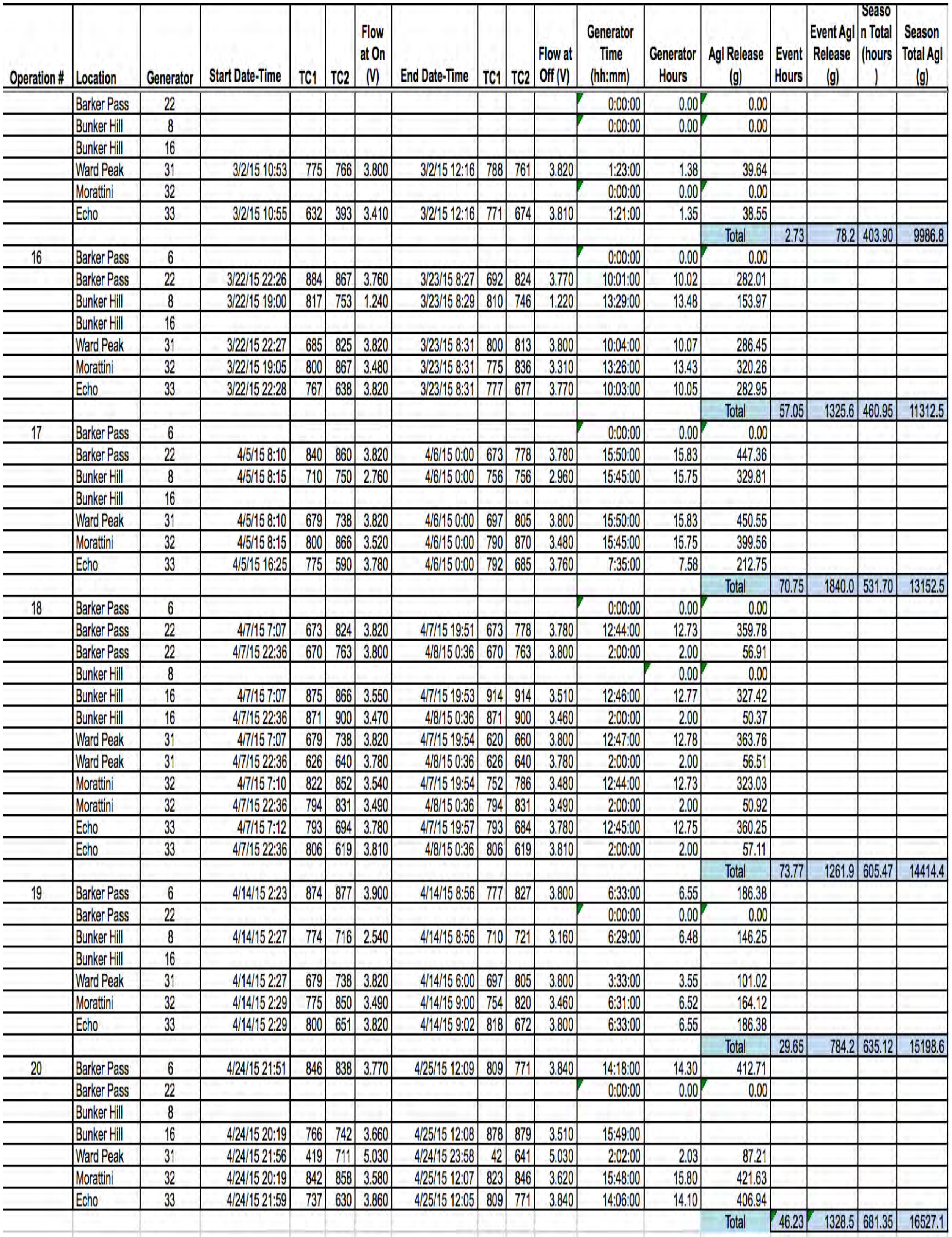


Operation #	Location	Generator	Start Date-Time	TC1	TC2	Flow at On (V)	End Date-Time	TC1	TC2	Flow at Off (V)	Generator Time (hh:mm)	Generator Hours	AgI Release (g)	Event Hours	Event AgI Release (g)	Season Total (hours)	Season Total AgI (g)
1	Barker Pass	6	11/1/14 3:10	890	891	4.070	11/1/14 12:40	821	860	4.050	9:30:00	9.50	295.06				
	Barker Pass	22									0:00:00	0.00	0.00				
	Bunker Hill	8	11/1/14 3:10	878	868	3.360	11/1/14 12:40	891	887	3.270	9:30:00	9.50	223.18				
	Bunker Hill	16									0:00:00	0.00	0.00				
	Ward Peak	31	11/1/14 3:19	621	770	3.580	11/1/14 12:40	672	709	3.830	9:21:00	9.35	268.90				
	Morattini	32	11/1/14 3:15	660	868	3.640	11/1/14 11:15	647	776	3.490	8:00:00	8.00	203.69				
	Echo	33	11/1/14 8:51	875	788	3.530	11/1/14 11:35			3.600	2:44:00	2.73	72.42				
													Total	39.08	1063.2	39.08	1063.2
2	Barker Pass	6	11/20/14 20:08	789	838	3.770	11/20/14 22:08	861	876	3.680	2:00:00	2.00	54.53				
	Barker Pass	22									0:00:00	0.00	0.00				
	Bunker Hill	8									0:00:00	0.00	0.00				
	Bunker Hill	16	11/20/14 15:35	822	855	3.600	11/20/14 20:08	265	467	3.610	4:33:00	4.55	120.98				
	Ward Peak	31	11/20/14 16:31	816	868	3.770	11/20/14 22:13	868	863	3.540	5:42:00	5.70	147.78				
	Morattini	32	11/20/14 16:33	856	847	3.410	11/20/14 20:17	816	858	3.400	3:44:00	3.73	91.99				
	Echo	33									0:00:00	0.00	0.00				
													Total	15.98	415.3	55.07	1478.5
3	Barker Pass	6	11/22/14 18:11	793	798	3.670	11/22/14 20:10	846	897	3.480	1:59:00	1.98	50.31				
	Barker Pass	22									0:00:00	0.00	0.00				
	Bunker Hill	8									0:00:00	0.00	0.00				
	Bunker Hill	16	11/22/14 17:44	471	484	3.500	11/22/14 19:23	842	824	3.480	1:39:00	1.65	41.86				
	Ward Peak	31									0:00:00	0.00	0.00				
	Morattini	32	11/22/14 17:47	622	681	3.410	11/22/14 19:23	842	862	3.360	1:36:00	1.60	38.85				
	Echo	33									0:00:00	0.00	0.00				
											0:00	0.00	Total	5.23	131.0	60.30	1609.6
4	Barker Pass	6	11/29/14 7:58	815	849	3.720	11/29/14 14:59	890	870	2.370	7:01:00	7.02	117.87				
	Barker Pass	22									0:00:00	0.00	0.00				
	Bunker Hill	8									0:00:00	0.00	0.00				
	Bunker Hill	16	11/29/14 7:58	680	680	3.450	11/29/14 15:04	879	861	3.460	7:06:00	7.10	178.81				
	Ward Peak	31	11/29/14 11:14	870	840	3.620	11/29/14 14:55	870	839	3.590	3:41:00	3.68	97.23				
	Morattini	32	11/29/14 8:06	765	857	3.400	11/29/14 15:06	835	860	3.490	7:00:00	7.00	178.23				
	Echo	33									0:00:00	0.00	0.00				
													Total	24.80	572.1	85.10	2181.7
5	Barker Pass	6									0:00:00	0.00	0.00				
	Barker Pass	22	11/30/14 5:53	870	850	3.000	11/30/14 8:52	870	850	3.000	2:59:00	2.98	63.41				
	Bunker Hill	8									0:00:00	0.00	0.00				
	Bunker Hill	16	11/30/14 5:59	756	749	3.520	11/30/14 8:59	756	749	3.520	3:00:00	3.00	77.22				
	Ward Peak	31	11/30/14 6:12	729	657	3.480	11/30/14 8:12	729	657	3.480	2:00:00	2.00	50.74				
	Morattini	32									0:00:00	0.00	0.00				
	Echo	33	11/30/14 6:06	768	629	3.780	11/30/14 9:06	768	629	3.780	3:00:00	3.00	84.76				
													Total	10.98	276.1	96.08	2457.8
6	Barker Pass	6									0:00:00	0.00	0.00				
	Barker Pass	22	12/12/14 6:32	616	618	2.940	12/12/14 9:50	856	970	2.720	3:18:00	3.30	63.17				
	Bunker Hill	8									0:00:00	0.00	0.00				
	Bunker Hill	16									0:00:00	0.00	0.00				
	Ward Peak	31									0:00:00	0.00	0.00				
	Morattini	32									0:00:00	0.00	0.00				
	Echo	33	12/12/14 7:07	882	852	3.710	12/12/14 15:21	879	717	3.740	8:14:00	8.23	229.35				
													Total	11.53	292.5	107.62	2750.3
7	Barker Pass	6	12/14/14 14:56	887	880	3.650	12/14/14 18:55	800	849	3.460	3:59:00	3.98	100.32				
	Barker Pass	22									0:00:00	0.00	0.00				
	Bunker Hill	8									0:00:00	0.00	0.00				
	Bunker Hill	16	12/14/14 14:51	788	736	3.650	12/14/14 18:58	873	824	3.880	4:07:00	4.12	120.50				
	Ward Peak	31									0:00:00	0.00	0.00				
	Morattini	32	12/14/14 14:59	705	846	3.650	12/14/14 18:57	799	800	3.610	3:58:00	3.97	105.47				
	Echo	33	12/14/14 14:54	849	718	3.740	12/14/14 18:52	813	868	3.610	3:58:00	3.97	105.47				
													Total	16.03	431.8	123.65	3182.1

Appendix A. Tahoe Seeding Operations: 15 December 2014 to 28 February 2015

Operation #	Location	Generator	Start Date-Time	TC1	TC2	Flow at On (V)	End Date-Time	TC1	TC2	Flow at Off (V)	Generator Time (hh:mm)	Generator Hours	Agl Release (g)	Event Hours	Event Agl Release (g)	Season Total (hours)	Season Total Agl (g)
8	Barker Pass	6	12/15/14 6:20	880	883	2.710	12/15/14 11:00	911	880	3.570	4:40:00	4.67	122.31				
	Barker Pass	6	12/15/14 15:35	900	907	2.870	12/16/14 3:00	899	889	2.760	11:25:00	11.42	221.84				
	Ward Peak	31	12/15/14 6:13	634	624	3.650	12/15/14 11:00	748	732	3.530	4:47:00	4.78	123.57				
	Ward Peak	31	12/15/14 15:30	769	787	3.510	12/16/14 3:00	737	699	3.440	11:30:00	11.50	287.52				
	Morattini	32									0:00:00	0.00	0.00				
	Echo	33	12/15/14 4:18	846	709	3.530	12/15/14 11:00	911	880	2.840	6:42:00	6.70	134.15				
	Echo	33	12/15/14 15:35	863	720	3.530	12/16/14 1:00	858	816	3.530	9:25:00	9.42	243.26				
													Total	48.48	1132.6	172.13	4314.7
9	Barker Pass	6	12/16/14 21:43	878	859	2.790	12/17/14 7:17	891	874	2.530	9:34:00	9.57	170.56				
	Barker Pass	22									0:00:00	0.00	0.00				
	Bunker Hill	8									0:00:00	0.00	0.00				
	Bunker Hill	16									0:00:00	0.00	0.00				
	Ward Peak	31	12/16/14 21:41	732	757	3.590	12/17/14 7:17	783	601	3.450	9:36:00	9.60	240.90				
	Morattini	32									0:00:00	0.00	0.00				
	Echo	33	12/16/14 21:43	871	786	3.530	12/17/14 7:18	879	744	3.530	9:35:00	9.58	247.56				
													Total	28.75	659.0	200.88	4973.8
10	Barker Pass	6	12/18/14 12:10	843	868	2.600	12/18/14 16:31	870	868	2.730	4:21:00	4.35	83.58				
	Barker Pass	22									0:00:00	0.00	0.00				
	Bunker Hill	8									0:00:00	0.00	0.00				
	Bunker Hill	16	12/18/14 12:08	814	822	3.780	12/18/14 15:08	814	822	3.780	3:00:00	3.00	84.76				
	Ward Peak	31	12/18/14 12:04	693	513	3.600	12/18/14 16:27	889	874	3.600	4:23:00	4.38	116.13				
	Morattini	32	12/18/14 12:06	607	813	3.470	12/18/14 15:06	607	813	3.470	3:00:00	3.00	75.83				
	Echo	33	12/18/14 12:02	780	561	3.360	12/18/14 15:06	780	561	3.360	3:04:00	3.07	74.46				
													Total	17.80	434.8	218.68	5408.53
11	Barker Pass	6	12/19/14 10:19	813	822	3.750	12/19/14 18:39	880	902	2.530	8:20:00	8.33	148.57				
	Barker Pass	22									0:00:00	0.00	0.00				
	Bunker Hill	8									0:00:00	0.00	0.00				
	Bunker Hill	16									0:00:00	0.00	0.00				
	Ward Peak	31	12/19/14 10:13	761	733	3.660	12/19/14 18:43	813	662	3.630	8:30:00	8.50	227.64				
	Morattini	32									0:00:00	0.00	0.00				
	Echo	33	12/19/14 10:15	772	682	3.580	12/19/14 18:42	871	715	3.680	8:27:00	8.45	230.39				
													Total	25.28	606.6	243.97	6015.1
12	Barker Pass	6	1/27/15 10:40	841	900	2.540	1/27/15 14:27	858	878	3.660	3:47:00	3.78	102.42				
	Barker Pass	22									0:00:00	0.00	0.00				
	Bunker Hill	8	1/27/15 8:20	840	839	3.400	1/27/15 14:28	791	870	2.290	6:08:00	6.13	100.03				
	Bunker Hill	16									0:00:00	0.00	0.00				
	Ward Peak	31	1/27/15 10:40	794	818	3.720	1/27/15 14:25	829	846	3.820	3:45:00	3.75	107.47				
	Morattini	32	1/27/15 8:20	843	883	3.580	1/27/15 14:26	898	887	3.850	6:06:00	6.10	176.67				
	Echo	33	1/27/15 10:40	768	689	3.100	1/27/15 14:29	799	689	3.100	3:49:00	3.82	84.20				
													Total	23.58	570.8	267.55	6585.9
13	Barker Pass	6	2/8/15 23:56				2/8/15 23:56				0:00:00	0.00					
	Barker Pass	22	2/8/15 23:56	865	835	3.800	2/9/15 5:34	811	821	3.600	5:38:00	5.63	149.25				
	Bunker Hill	8															
	Bunker Hill	16	2/8/15 23:37	741	778	3.680	2/9/15 5:30	786	827	3.670	5:53:00	5.88	159.84				
	Ward Peak	31	2/8/15 23:58	850	790	3.810	2/9/15 5:30	823	841	3.820	5:32:00	5.53	158.57				
	Morattini	32	2/8/15 23:30	730	856	3.500	2/9/15 5:30	710	872	3.500	6:00:00	6.00	153.32				
	Echo	33															
													Total	23.05	621.0	290.60	7206.9
14	Barker Pass	6	2/27/15 22:40	902	895	1.510	2/28/15 15:05	875	884	1.590	16:25:00	16.42	209.49				
	Barker Pass	22	2/27/15 16:56	893	890	3.390	2/27/15 22:36	893	890	3.390	5:40:00	5.67	139.12				
	Bunker Hill	8	2/27/15 16:59	805	778	2.950	2/28/15 15:05	847	840	3.160	22:06:00	22.10	498.52				
	Bunker Hill	16															
	Ward Peak	31	2/27/15 16:58	814	803	3.800	2/28/15 15:05	818	768	3.820	22:07:00	22.12	633.81				
	Morattini	32	2/27/15 16:52	833	849	3.580	2/28/15 15:05	824	848	3.580	22:13:00	22.22	584.38				
	Echo	33	2/27/15 17:02	833	849	3.510	2/28/15 15:05	779	691	3.840	22:03:00	22.05	636.38				
													Total	110.57	2701.7	401.17	9908.6

Appendix A. Tahoe Seeding Operations: 1 March to 25 May 2015



Operation #	Location	Generator	Start Date-Time	TC1	TC2	Flow at On (V)	End Date-Time	TC1	TC2	Flow at Off (V)	Generator Time (hh:mm)	Generator Hours	AgI Release (g)	Event Hours	Event AgI Release (g)	Season Total (hours)	Season Total AgI (g)
	Barker Pass	22									0:00:00	0.00	0.00				
	Bunker Hill	8									0:00:00	0.00	0.00				
	Bunker Hill	16															
	Ward Peak	31	3/2/15 10:53	775	766	3.800	3/2/15 12:16	788	761	3.820	1:23:00	1.38	39.64				
	Morattini	32									0:00:00	0.00	0.00				
	Echo	33	3/2/15 10:55	632	393	3.410	3/2/15 12:16	771	674	3.810	1:21:00	1.35	38.55				
													Total	2.73	78.2	403.90	9986.8
16	Barker Pass	6									0:00:00	0.00	0.00				
	Barker Pass	22	3/22/15 22:26	884	867	3.760	3/23/15 8:27	692	824	3.770	10:01:00	10.02	282.01				
	Bunker Hill	8	3/22/15 19:00	817	753	1.240	3/23/15 8:29	810	746	1.220	13:29:00	13.48	153.97				
	Bunker Hill	16															
	Ward Peak	31	3/22/15 22:27	685	825	3.820	3/23/15 8:31	800	813	3.800	10:04:00	10.07	286.45				
	Morattini	32	3/22/15 19:05	800	867	3.480	3/23/15 8:31	775	836	3.310	13:26:00	13.43	320.26				
	Echo	33	3/22/15 22:28	767	638	3.820	3/23/15 8:31	777	677	3.770	10:03:00	10.05	282.95				
													Total	57.05	1325.6	460.95	11312.5
17	Barker Pass	6									0:00:00	0.00	0.00				
	Barker Pass	22	4/5/15 8:10	840	860	3.820	4/6/15 0:00	673	778	3.780	15:50:00	15.83	447.36				
	Bunker Hill	8	4/5/15 8:15	710	750	2.760	4/6/15 0:00	756	756	2.960	15:45:00	15.75	329.81				
	Bunker Hill	16															
	Ward Peak	31	4/5/15 8:10	679	738	3.820	4/6/15 0:00	697	805	3.800	15:50:00	15.83	450.55				
	Morattini	32	4/5/15 8:15	800	866	3.520	4/6/15 0:00	790	870	3.480	15:45:00	15.75	399.56				
	Echo	33	4/5/15 16:25	775	590	3.780	4/6/15 0:00	792	685	3.760	7:35:00	7.58	212.75				
													Total	70.75	1840.0	531.70	13152.5
18	Barker Pass	6									0:00:00	0.00	0.00				
	Barker Pass	22	4/7/15 7:07	673	824	3.820	4/7/15 19:51	673	778	3.780	12:44:00	12.73	359.78				
	Barker Pass	22	4/7/15 22:36	670	763	3.800	4/8/15 0:36	670	763	3.800	2:00:00	2.00	56.91				
	Bunker Hill	8										0.00	0.00				
	Bunker Hill	16	4/7/15 7:07	875	866	3.550	4/7/15 19:53	914	914	3.510	12:46:00	12.77	327.42				
	Bunker Hill	16	4/7/15 22:36	871	900	3.470	4/8/15 0:36	871	900	3.460	2:00:00	2.00	50.37				
	Ward Peak	31	4/7/15 7:07	679	738	3.820	4/7/15 19:54	620	660	3.800	12:47:00	12.78	363.76				
	Ward Peak	31	4/7/15 22:36	626	640	3.780	4/8/15 0:36	626	640	3.780	2:00:00	2.00	56.51				
	Morattini	32	4/7/15 7:10	822	852	3.540	4/7/15 19:54	752	786	3.480	12:44:00	12.73	323.03				
	Morattini	32	4/7/15 22:36	794	831	3.490	4/8/15 0:36	794	831	3.490	2:00:00	2.00	50.92				
	Echo	33	4/7/15 7:12	793	694	3.780	4/7/15 19:57	793	684	3.780	12:45:00	12.75	360.25				
	Echo	33	4/7/15 22:36	806	619	3.810	4/8/15 0:36	806	619	3.810	2:00:00	2.00	57.11				
													Total	73.77	1261.9	605.47	14414.4
19	Barker Pass	6	4/14/15 2:23	874	877	3.900	4/14/15 8:56	777	827	3.800	6:33:00	6.55	186.38				
	Barker Pass	22									0:00:00	0.00	0.00				
	Bunker Hill	8	4/14/15 2:27	774	716	2.540	4/14/15 8:56	710	721	3.160	6:29:00	6.48	146.25				
	Bunker Hill	16															
	Ward Peak	31	4/14/15 2:27	679	738	3.820	4/14/15 6:00	697	805	3.800	3:33:00	3.55	101.02				
	Morattini	32	4/14/15 2:29	775	850	3.490	4/14/15 9:00	754	820	3.460	6:31:00	6.52	164.12				
	Echo	33	4/14/15 2:29	800	651	3.820	4/14/15 9:02	818	672	3.800	6:33:00	6.55	186.38				
													Total	29.65	784.2	635.12	15198.6
20	Barker Pass	6	4/24/15 21:51	846	838	3.770	4/25/15 12:09	809	771	3.840	14:18:00	14.30	412.71				
	Barker Pass	22									0:00:00	0.00	0.00				
	Bunker Hill	8															
	Bunker Hill	16	4/24/15 20:19	766	742	3.660	4/25/15 12:08	878	879	3.510	15:49:00						
	Ward Peak	31	4/24/15 21:56	419	711	5.030	4/24/15 23:58	42	641	5.030	2:02:00	2.03	87.21				
	Morattini	32	4/24/15 20:19	842	858	3.580	4/25/15 12:07	823	846	3.620	15:48:00	15.80	421.63				
	Echo	33	4/24/15 21:59	737	630	3.860	4/25/15 12:05	809	771	3.840	14:06:00	14.10	406.94				
													Total	46.23	1328.5	681.35	16527.1

TRUCKEE MEADOWS WATER AUTHORITY

APPENDIX 2-6

2012 STATE OF NEVADA DROUGHT PLAN

STATE OF NEVADA
DROUGHT PLAN

Revised March 2012

Executive Summary

This State Drought Plan establishes an administrative coordinating and reporting system between agencies to appropriately respond and provide assistance to address drought and mitigate drought impacts. After outlining the significance of drought and types of drought encountered, this Plan identifies a system used in monitoring the magnitude, severity and extent of drought within the state on a county-by-county basis. It establishes a framework of actions based on three stages of drought response: Drought Watch (Stage #1), Drought Alert (Stage #2) and Drought Emergency (Stage #3).

The Drought Response Committee, comprised of representatives from the State Climate Office, Division of Water Resources and Division of Emergency Management, is involved throughout each of these stages and is responsible for monitoring drought conditions, collecting data associated with drought, overseeing intergovernmental coordination, disseminating information, reporting to the Governor and working with the State Emergency Operation Center on drought response (if applicable). The Drought Response Committee may establish *ad hoc* Task Force(s). Members of Task Force(s) will serve as experts in the drought affected region, serve as liaisons to local or federal government and collect needed information about the actual and/or projected impacts of the drought. If a drought reaches Stage #3 Drought Emergency, upon the decision of the Governor, the Division of Emergency Management may activate the State Emergency Operations Center. This Center will be advised by the Drought Response Committee, making drought response policy recommendations as needed, supporting local drought emergency response efforts and carrying out the Governor's policies.

Jason King, P.E. State Engineer	Christopher B. Smith, Chief	Kate A. Berry, Director
Division of Water Resources	Division of Emergency Management	State Climate Office

1. Drought

Drought is a complex physical and social phenomenon of widespread significance. Drought is not usually a statewide phenomenon; differing situations in the state make drought local or regional in focus. Despite all the problems droughts have caused, drought has proven difficult to define. There is no universally accepted definition because drought, unlike flood, is not a distinct event and drought is often the result of many complex factors acting on and interacting within the environment. Complicating the problem of a drought definition is the fact that drought often has neither a distinct beginning nor end. It is recognizable only after a period of time and, because a drought may be interrupted by short spells of one or more wet months, its termination is difficult to recognize. The most commonly used drought definitions are based on: 1) meteorological and/or climatological conditions, 2) agricultural problems, 3) hydrological conditions, 4) economic considerations and 5) induced drought problems. Each type of drought will vary in severity, but all are closely related and caused by lack of precipitation.

1.1 Meteorological Drought

Meteorological drought is often defined by a period of well-below-normal precipitation. The commonly used definition of meteorological drought is an interval of time, generally of the order of months or years, during which the actual moisture supply at a given place consistently falls short of climatically appropriate moisture supply.

1.2 Agricultural Drought

Agricultural drought is typically defined as a period when soil moisture is inadequate to meet evapotranspirative demands so as to initiate and sustain crop growth. Another facet of agricultural drought is deficiency of water for livestock or other farming activities.

1.3 Hydrologic Drought

Hydrologic drought refers to periods of below-normal streamflow and/or depleted reservoir storage.

1.4 Economic Drought

Economic drought is a result of physical processes but concerns the areas of human activity affected by drought (e.g., municipal water supply shortages). The human effects, including the losses and benefits in the local and regional economy, are often a part of this definition.

1.5 Induced Drought

Induced drought is a condition of shortage which results from over-drafting of the normal water supply. The condition is aggravated by negative precipitation experience and below normal streamflow or aquifer recharge. An induced drought is brought about by introducing agricultural, recreational, industrial or residential consumptions into an area which cannot naturally support them.

2. Drought Monitoring System

While lower than normal precipitation is usually the cause of specific problems creating a drought situation, a drought condition is not simply a lack of rainfall or snow accumulation but can also be related to deficiencies in soil moisture and ground-water; lack of surface water in streams and rivers; and/or reduction of surface water stored in lakes and reservoirs. A number of factors are involved in determining if a drought exists and its severity for a given region: precipitation, snowpack, soil moisture, streamflow, surface water storage, and groundwater levels.

The US Drought Monitor is an independent and scientific approach that synthesizes multiple indices and impacts and is updated weekly. It integrates varies types of drought, with a particular emphasis on meteorological, agricultural, and hydrological drought. The US Drought Monitor is coordinated through the National Drought Mitigation Center at the University of Nebraska, Lincoln, with input and support from a number of federal, state, and local partners nationwide. To identify the initial stages of drought, the US Drought Monitor will be applied to counties in the State of Nevada. There are five drought intensity categories identified in the US Drought Monitor:

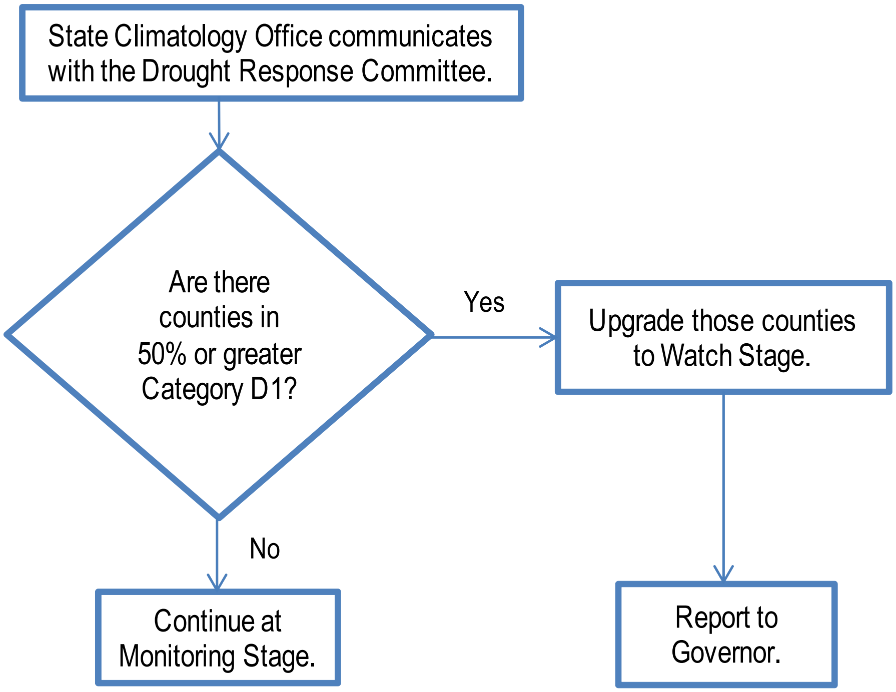
D0	Abnormally Dry
D1	Drought – Moderate
D2	Drought – Severe
D3	Drought – Extreme
D4	Drought – Exceptional

Issues posed by economic drought and induced drought will also be taken into account when moving into the third drought stage outlined in the following sections.

3. Measures Initiating Action

The Drought Response Committee is comprised of a representative from the Office of the State Climatologist, the Division of Water Resources, and the Division of Emergency Management. Drought Response Committee members remain in contact and, if it is determined that a Watch Stage exists for any counties, then the Nevada State Climatologist will call a meeting of the Drought Response Committee. Reports to the Governor are generated by the Drought Response Committee whenever there is a change in drought stage and throughout Drought Alert and Drought Emergencies stages.

Ongoing Monitoring

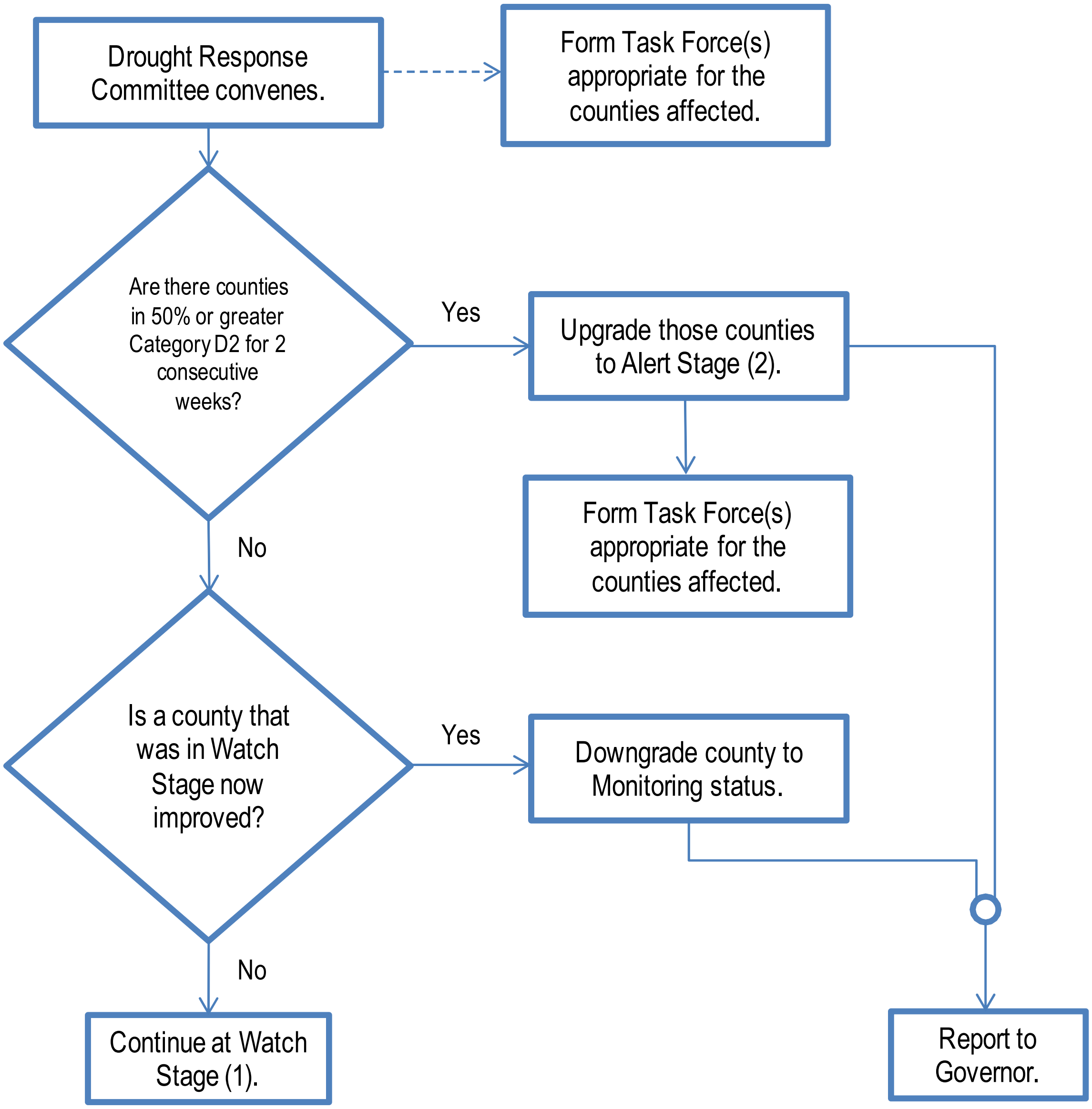


3.1 Drought Watch Stage

The Drought Watch Stage (Stage #1) begins when 50% or more of a county is classified as D1 (drought – moderate) in the Drought Monitor. During the Drought Watch Stage, the Drought Response Committee will assemble to monitor conditions within the area. The Drought Response Committee will monitor trends and serve as sources of technical information for state and local decision-makers, as well as for the public and media. The Drought Response Committee is composed of the directors (or their designees) of the State Climate Office, the Division of Water Resources, and the Division of Emergency Management. The chair of the Drought Response Committee will be the director of the State Climate Office.

Drought Impact Task Forces are *ad hoc* groups formed by the Drought Response Committee to act as experts in the drought affected region, serve as liaisons to local or federal government, and provide information needed for dissemination to decision-makers and stakeholders. Task Forces may be expanded or restricted as needed to suit the needs of the situation. Multiple small Task Forces (coordinated through the Drought Response Committee) may be more effective than a single large Task Force. This formation is optional at the Drought Watch stage, but is likely to be necessary at the Drought Alert Stage.

1. Drought Watch Stage

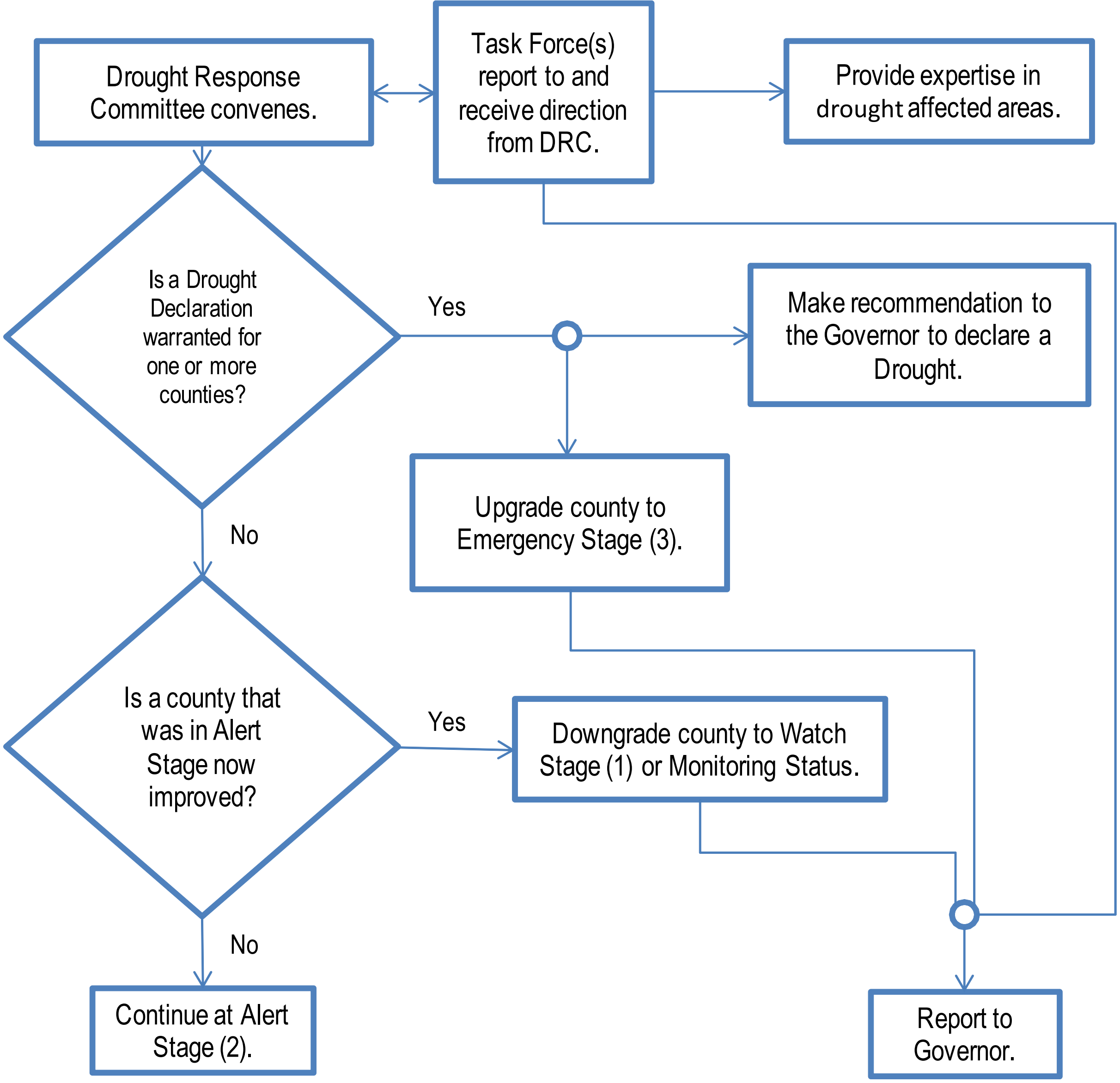


3.2 Drought Alert Stage

The Drought Alert Stage (Stage #2) occurs when 50% or more of a county is classified as D2 (drought – severe) or higher in the Drought Monitor for a minimum of two weeks. The Drought Response Committee will appoint the appropriate task force(s), on an *ad hoc* basis, in this stage. Task force members must be able to speak for their agencies or organizations and have authority to make reasonable commitments toward effective cooperation and coordination. A Task Force(s) may assess actual and projected impacts on the state's economy, agriculture, and/or fish and wildlife resources in the area impacted by the drought. The chair of a Task Force will report regularly to the Drought Response Committee with details concerning the drought extent, magnitude, and impacts and will provide information about drought mitigation measures being taken by public agencies or private individuals or organizations.

The Drought Response Committee will monitor the progress of Task Forces, and evaluate the adequacy of data collection, procedures, and reports. Further, the Drought Response Committee will collate information from individual Task Forces in order to develop its own assessments, projections, and trends. The Drought Response Committee will oversee intergovernmental coordination, including federal agency actions, and make timely reports on the status of the drought and response activities to the Governor, other state leaders, the media, and the public.

2. Drought Alert Stage



3.3 Drought Emergency Stage

The Drought Emergency Stage (Stage #3) begins after the Drought Alert Stage. This stage begins when the Drought Response Committee makes a recommendation, based on information from the Tasks Force(s) and other sources, that a drought should be formally declared for affected counties. The Drought Response Committee determines whether a critical situation exists or when it becomes obvious that existing state resources and strategies are insufficient to deal with the growing problems and needs. Upon making the recommendation, the Drought Response Committee alerts the Governor that identified portions of the state are experiencing a Drought Emergency.

The issue of whether to formally declare a drought is both controversial and important. The State of Nevada will approach formal declaration with caution. Formal designation may not substantially reduce economic impacts and may cause serious economic impacts on tourism, agriculture, finance, and other industries. Unless a drought situation is expected to be of extreme magnitude, the safest approach is to aid county and local governments in determining their own situations. In many cases existing networks and processes of public agencies, water system managers, and experts are available to assess and address particular needs. The criteria for such a recommendation is not as rigidly defined as it is for earlier stages, since the need is dictated by local and specific conditions and based on reporting and recommendations of the Drought Response Committee and Task Force(s). The declaration of a Drought Emergency signifies that conditions are present that may produce negative impacts in certain counties or regions. The Drought declaration may be a trigger point for federal resources. If the drought conditions persist to an extraordinary level, it may negatively impact a county to the point that it exhausts local resources available to respond to the emergency, the affected county may elect to execute a disaster declaration.

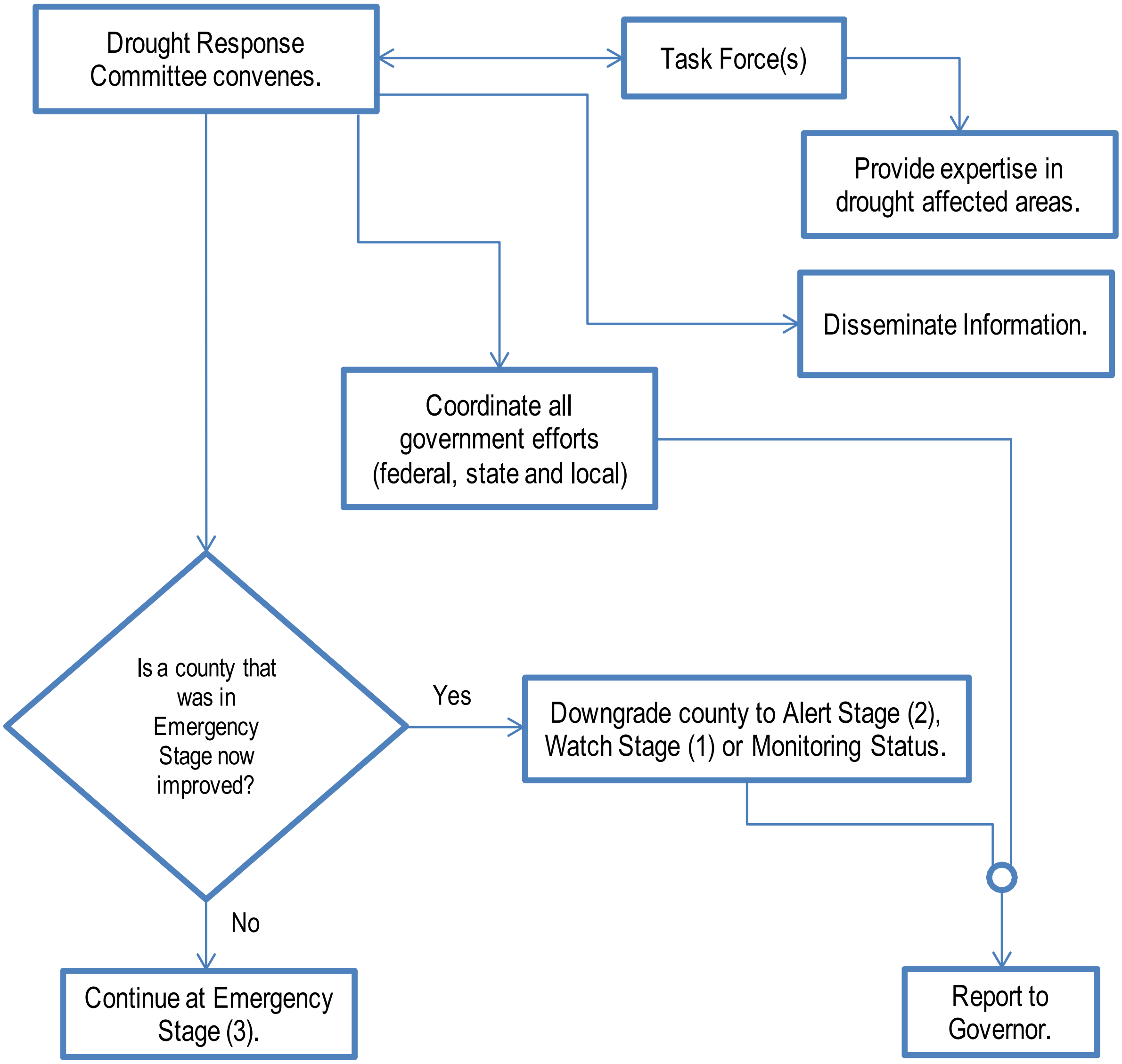
In the Drought Emergency Stage, the Drought Response Committee prepares a press release for the Governor. The Governor then may activate the State Emergency Operations Center (SEOC). The SEOC will be overseen by the director of the Division of Emergency Management (or designee) and will coordinate with directors (or their designees) of the Nevada State Climate Office and the Nevada Division of Water Resources as lead responsible agencies, so that continuity of response efforts is maintained.

Under a Drought Emergency declaration the Division of Emergency Management, acting in its authority in accordance with Nevada Revised Statute (NRS) 414 and the State Comprehensive Emergency Management Plan (SCEMP), will coordinate state response efforts and make mitigation, response and recovery recommendations to affected counties. The Division of Emergency Management coordinates the state's resources through the State Emergency Operations Center (SEOC) to support local drought emergency response efforts and to carry out the Governor's policies. The Division of Emergency Management may also request support and resources from federal agencies such as the U.S. Department of Agriculture, Bureau of Reclamation and Federal Emergency Management Agency and from non-governmental organizations such as the American Red Cross as needed based on the drought conditions and needs of the local jurisdictions.

Upon activation, the SEOC assumes a number of drought related responsibilities, including interagency and intergovernmental coordination and media relations. The SEOC reviews recommendations to address unmet needs from the Drought Response Committee and Task Forces and develops strategies to coordinate the delivery of resources through state mutual aid, state agencies, federal agencies, and non-governmental organizations. During the Drought Emergency stage, the SEOC directs the initiatives of the Drought Response Committee and Task Force(s). The Drought Response Committee will continue assessment activities and will provide advice and support to the SEOC, making drought response policy recommendations as needed through the duration of the drought. During the Drought Emergency stage, Tasks Force(s) will provide recommendations on possible mitigation solutions along with their assessments of the situation both to the Drought Response Committee and to the SEOC. Drought Response Committee duties take priority over the normal duties assigned to the Division of Water Resources.

The SEOC provides general policy direction and, as appropriate, makes policy recommendations to the Governor for his disposition (such as emergency funding requests and suggested legislative action). The SEOC may advise the Governor on the use of his emergency powers, including any requested data to support the Governor's request, if necessary, for a Secretarial or Presidential Disaster Declaration. The Governor will set the state's priorities, drought mitigation, response and recovery policy and resource allocation direction based on information and recommendations given to the Governor by the Drought Response Committee and the needs of the affected local jurisdiction, county or tribe. The Governor engages with the state legislature when new authority and funding are necessary. If needs exceed the resources of the State, the Governor may request Federal Disaster Assistance. Federal assistance that does not need state action should be implemented when necessary without going through the Center.

3. Drought Emergency Stage



3.4 End of Drought

As the drought subsides and the emergency passes, if continuing assistance requirements can be met within normal state administrative channels, the Center prepares a press release for the Governor to declare the end to the drought emergency. Prior to disbanding, the Center will prepare and issue a final report on its activities to the Governor. When the Center disbands, the Drought Response Committee again assumes primary responsibility for response activities and for interagency and intergovernmental coordination until all counties of the state are out of the drought alert and drought watch stages. Before disbanding, the Drought Response Committee will prepare and issue a final report to the Governor and appropriate agencies.

TRUCKEE MEADOWS WATER AUTHORITY

APPENDIX 2-7

SPILL RISK ASSESSMENT

Probabilistic Hazardous Materials Contamination Model for a Municipal Water Source

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In 1997 conditional probability was used to assess the frequency of contamination of the Truckee River by hazardous material (hazmat) released during a rail or highway accident. A Great Basin stream originating at Lake Tahoe, Calif., and terminating at Pyramid Lake, Nev., the Truckee River is the principal water source for the Reno–Sparks (Nev.) metropolitan region. The 1997 probabilistic assessment was based on sparse to nonexistent data for accident frequency and other factors. Assumptions made during the 1997 study were reassessed in 2007 using a significantly more comprehensive database for rail and highway accidents and hazmat incidents. The 2007 assessment confirmed that estimates of hazmat contamination probability (likelihood) were reasonable and even low. Consequently, the operational plan to be implemented, should a hazmat contamination occur, relies on estimates of arrival times coupled with the ability to shut down water treatment plants and rely on groundwater resources during such an emergency.

Keywords: *hazmat, hazardous material, probability, risk, safety*

This article serves two purposes: first, to describe the development of a model for evaluating the contamination risk to a river by the release of a hazardous material (hazmat) during a rail or highway accident and second, to detail the application of this model in an actual case study conducted over a decade-long period. The particular river on which the study is based is the Truckee River, a perennial stream that originates at Tahoe City, Lake Tahoe, Calif., flows northeastward through the communities of Reno and Sparks, Nev., and terminates at Pyramid Lake in northwestern Nevada (Figure 1).

BACKGROUND

Truckee River environs. The Truckee River is the principal source of raw surface water to be treated and delivered to the communities of Reno and Sparks. Additionally, 31 wells provide 16% of municipal water needs; moreover, should the Truckee River become contaminated, these wells can provide all of the indoor water demand during an emergency for an extended period of days or weeks. Upstream of the Reno–Sparks metropolitan region, the Truckee River flows through narrow, steep-sided canyons. Central Pacific Railroad Co. of California constructed the Transcontinental Railroad in 1869, following the river as it courses through these canyons. Since 2002, this rail route has been used and maintained by the Union Pacific Railroad. Additionally, a major interstate highway, Interstate 80 (I-80), was constructed through the same canyons between Truckee and Reno. As shown in the photograph on this page, the river, rail line, and highway are in close spatial proximity at several locations.

Risk model development. An accident during highway or rail transport of hazmat could potentially result in catastrophic contamination of the Truckee River, depending on the location of the accident. The motivation for risk-model development with application to the Truckee River was to aid in decision-making in

This screen capture from Google Earth (with elevation and distance added) shows the close spatial proximity of Interstate 80 (I-80), the rail route, and the Truckee River at 12 km upstream from the first Truckee Meadows Water Authority water treatment plant. Elevation (shown in white) drops by 21 m from the right edge of the I-80 pavement to the left edge of the rail line ballast. The total distance (shown in yellow) from the right edge of the I-80 pavement to the bank of the Truckee River is approximately 86 m.

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planning for the response to such an occurrence (Høj & Kröger, 2002). The key question to be answered centered on the level of response planning warranted to plan for possible river contamination. How catastrophic the contamination would be depends on multiple factors, including the type of hazmat released, the time of year (which influences water demand), and the location where the contamination occurs (the distance upstream of treatment plant water intakes). Planning for a catastrophic contamination involves assessing the likely hazmat substances that may be released, the reaction time of emergency crews, the water demand, and the likelihood of such a contamination happening. The type of risk assessment that is used for decision-making depends on need. Route-selection optimization considers population density and all types of hazmat: gas, liquid, solid, explosive, and radioactive (Battelle, 2011; Erkut & Verter, 1998).

In the case of the current study, population density was not explicitly modeled. Only liquid and solid, nonradioactive hazmat was considered. Although explosiveness was not explicitly considered, explosive materials are taken into account as part of the solid hazmat volume transported via rail and highway. Of concern are the possible contamination of the major water source for a metropolitan area of moderate size and the resources, if any, that should be stockpiled at the water treatment plant in the event of water contamination. With these considerations in mind, a risk model was first developed in 1997 at a time when relatively few literature resources existed to provide examples of transportation risk analysis. One exception was a study that examined hazmat transportation risk based on accident frequency and release frequency (Harwood et al, 1993). These two fundamental components—accident frequency and release frequency—along with hazmat volume were included in the 1997 model. A conditional probability formulation enabled the quantification of risk based on individual event probabilities defined by actual data (although these data were limited at the time).

Increased availability of data and literature resources. A decade later, the database for accidents, hazmat volume, and release frequency was far more extensive, especially with respect to rail transport. Moreover, many more literature resources were available for both conceptual model development and database development. One study conceptualized risk theoretically, using expected values defined by selected data distributions (Fabiano et al, 2002). In this particular study, distributions of parameters important to the risk assessment (such as accident frequency) were modeled using known functions such as Gaussian (normal) and Poisson. Values of parameters used as input to the risk assessment calculation were selected using these models. This parametric approach was cross-validated using discrete distributions of actual accidents and traffic volume. The distribution function that yielded the best accuracy as determined through cross-validation was selected for further modeling. Another study (Gheorghea et al, 2005) focused on rail transport and describes the construction of a highly detailed risk-assessment model based on every factor that might contribute to derailing accidents. The four most likely factors causing derailing accidents are broken rails or welds, buckled track, train handling (excluding use of brakes), and broken wheels (Barkan et al, 2003). Derailing is the most likely rail accident to result in a container breach.

FIGURE 1 The Truckee River from its head at Lake Tahoe to its base at Pyramid Lake

The approximate location of the Chalk Bluff municipal water intake treatment plant is shown. This Chalk Bluff plant would be affected by any hazmat release into the river upstream (west). Map courtesy of the United States Geological Survey, www.usgs.gov.

Objective. What follows is a review of the 1997 model development when literature and data resources were limited to nonexistent. That presentation is followed by an assessment of the 1997 model conducted in 2007 with considerably improved databases for rail and highway transportation of hazmat. Data for this assessment were collected for the California counties of Nevada, Placer, and Sierra and the Nevada county of Washoe. One objective of this article is to demonstrate that a low data approach such as the 1997 model is nonetheless worth performing and can compare well with a model using a more detailed database.

RISK-ASSESSMENT MODEL

A quantitative risk assessment of Truckee River contamination was conducted in 1997 for the Sierra Pacific Power Co., a public utility that delivered electricity, natural gas, and water. At the time, the database on accidents was not accessible via the Internet. Some data for rail accident frequency were available for rail traffic between Truckee and Sparks. These data were supplied separately by the Federal Railroad Administration (FRA) for Nevada rail accident frequencies and the California Department of Transportation (Caltrans). The data consisted only of accident numbers with no other information available on such details as accident severity, the type (if any) of hazmat involved in the accident, the release (if any) of this hazmat, the weather conditions during the accident, and the time of year in which the accident occurred. The database for highway accident frequency was available for I-80 from the California–Nevada border eastward to Wadsworth, Nev. The data consisted of accident type, contributing factor, frequency of property damage accidents, frequency of injury accidents, and frequency of fatal accidents. Additionally, average vehicle miles traveled (AVMT) data were available for hazmat transport for 1994. These data were supplied by the Nevada Department of Transportation (NDOT).

An approach to risk assessment was developed that provided some bounds on actual risk because narrowly defining risk was not possible, given the limitations of the database circa 1997. Model development was approached as a conditional probability calculation. For example, if an event, A, happens, then the probability of an event, B, happening given that event A has already occurred is written as

$$P(B|A) \tag{1}$$

This probability is explicitly computed as P(A) × P(B), the product of the probabilities for each event. For example, with a fair coin toss, the probability of heads, given that heads occurred on the previous toss, is 1 in 4. The probability of each outcome is ½; therefore, the conditional probability of obtaining two heads in a row, P(heads|heads), is P(heads) × P(heads) = ½ × ½ = ¼.

A similar calculation was used to determine the risk of a river contamination by hazmat released during a transportation accident. Many events were thought to have an influence on this contamination scenario, including accident frequency, hazmat type and volume, proximity of an accident to the river, and severity of the accident. Conditional probability provided a framework for characterizing risk. In the most general of terms, the model was written as

$$\text{Risk} = P(A|B|C \ldots) = P(A) \times P(B) \times P(C) \times \ldots \tag{2}$$

This model is intentionally written as open-ended to show that any number of contributing events can be considered. Moreover, events A, B, C, and so on are presumed to be independent. If an accident occurs, a container of hazmat may or may not be involved. If the container itself did not cause the accident, then the two events—accident and hazmat involvement—are independent. In the case in which the hazmat is the cause of an accident, then the two events cannot be presumed independent events; a different model would be needed to assess the likelihood of this circumstance. In the current study, such a scenario was deemed too unlikely to warrant the development of a model just for this circumstance. Other events—such as accident severity, weather conditions, and time of year—are also independent of all other events unless weather conditions, for example, caused the accident. In general, most often the events used in the model are independent.

The initial focus was to define probabilities of individual events on the basis of actual data. Alternatively, probabilities could have been computed using theoretical probability functions. This alternative approach was rejected for two reasons. First, there was no way to justify a particular probability function for a particular event. Second, a realistic risk assessment based on actual data was sought in opposition to a theoretical characterization.

Because of the database limitations, however, a realistic risk assessment was at best an approximation. In light of this realization, several calculation scenarios were used that considered a differing number of events in the model to determine bounds (and an upper bound in particular) on risk. An upper bound on risk was thought to be provided by the model

$$\text{Risk, upper bound} = P(\text{hazmat}|\text{accident}) = P(\text{hazmat}) \times P(\text{accident}) \tag{3}$$

in which the probability of an accident is based on data for any and all accidents, regardless of severity. For this reason, this form of the model is considered to overestimate actual risk.

More realistic assessments of risk were envisioned by adding components to the upper-bound calculation. Accident severity was considered to be a significant additional component. Just because an accident occurs involving one or more railcars or vehicles carrying hazmat does not mean that the hazmat is released. An accident severe enough to breach the container of hazmat is necessary for release to occur. Other components to be considered for additions to the model include weather conditions, time of the year, proximity to the river, and type of hazmat (solid or liquid). Weather conditions and time of the year are considered to be separate components of the model because extreme weather conditions can result in accidents at any time of the year, and contamination of a river is more serious during the time of year when water demand is high. For northwestern Nevada, higher water demand exists from late spring to early fall. Applications of the risk model in the next section demonstrate that addition of just one more component—accident severity—to the upper-bound model significantly reduces the computed risk.

APPLICATION OF THE MODEL

Data supplied by FRA, Caltrans, and NDOT enabled the following calculations of probability of accident resulting in property damage:

$$P(\text{accident, rail}) = 0.0106 \text{ accidents per day} \tag{4}$$

$$P(\text{accident, highway, I-80}) = 1.14 \text{ accidents per day} \tag{5}$$

These values of probability characterized accident frequency in 1997 along sections of rail and highway that are in close proximity to the Truckee River, especially reaches upstream (west) of Reno to the city of Truckee.

Accidents within rail yards were excluded in computing the probability of rail accidents even though rail yards are associated with a relative high rate of hazmat incidents (Cozzani et al, 2007; Anderson & Barkan, 2004). The three rail yards closest to Reno and Sparks are located in Sparks and the California municipalities of Portola and Roseville and do not pose any

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threat to the Truckee River upstream of intakes for municipal water. Although the Sparks rail yard is in close proximity to the Truckee River, it is downstream of intakes for the municipal water supply. The rail yards in Portola and Roseville are not within the Truckee River watershed. For this reason, hazmat release incidents during loading and unloading, although noted as likely activities for hazmat release (Clark & Besterfield-Sacre, 2009), were excluded here.

In determining P(hazmat), highway hazmat transportation frequency was provided by AVMT data. For rail transport, the frequency and types of hazmat were obtained through the Reno Fire Department. At the time, the rail company that supplied this information to the city of Reno was the Southern Pacific Railroad. On the basis of the information supplied, the frequency of hazmat transport by rail was determined to be 0.10; in other words, data available in 1997 indicated that 10% of railcars traveling alongside the Truckee River were transporting hazmat. For highway transport, the probability of a vehicle carrying hazmat was computed from the AVMT data to be 0.0056 for I-80.

Maximum risk (upper-bound) of contaminating the Truckee River was computed on the basis of these values of probability with the following results:

$$\text{Rail: } P(\text{hazmat}|\text{accident}) = P(\text{hazmat}) \times P(\text{accident}) = 0.10 \times 0.0106 = 0.0011 \quad (6)$$

$$\text{Highway: } P(\text{hazmat}|\text{accident}) = P(\text{hazmat}) \times P(\text{accident}) = 0.0056 \times 1.14 = 0.0064 \quad (7)$$

These resulting probabilities represent frequency of contamination per day. For rail, 0.0011 contaminations per day translate to one contamination every 910 days (2.5 years), and for highway, 0.0064 contaminations per day translates to one contamination every 156.25 days (0.43 years). By this characterization, accidents on I-80 were approximately six times more likely to involve hazmat in 1997 compared with accidents on rail. This outcome demonstrates that even with a limited database, an assessment of relative risk is possible—in this case, a realization that highway transport is more likely to be associated with an accident that involves a vehicle carrying hazmat. Local history of the area indicates that contaminations on the order of one every 2.5 years (rail) or one every five months (highway) have not been experienced. In fact, no contamination of the Truckee River has occurred in recent memory. This historic knowledge suggests that the values of risk computed in the previous paragraph are conservative.

Incorporating an additional component in the risk model—in this case, the severity of an accident—yields a more realistic risk assessment. In 1997, however, the database was too limited to enable a direct count of accidents severe enough to have resulted in the release of hazmat. Therefore, accident severity had to be estimated. Because of the limited database for rail, the estimated severity was determined as the number of accidents (of total accidents) that involved two or more railcars. This estimated severity was 0.032; that is, 3.2% of the accidents in the database involved two or more railcars. For highway, the estimated severity was determined as the number of accidents out of total accidents that resulted in one or more fatalities. This estimated severity was 0.014, or 1.4% of accidents on the highway. Incorporating these values of probability into the foregoing maximum risk model yields the following:

$$\text{Rail: } P(\text{hazmat}) \times P(\text{accident}) \times P(\text{severity}) = 0.10 \times 0.0106 \times 0.032 = 0.000034 \quad (8)$$

$$\text{Highway: } P(\text{hazmat}) \times P(\text{accident}) \times P(\text{severity}) = 0.0056 \times 1.14 \times 0.014 = 0.000089 \quad (9)$$

These values of risk are in terms of contaminations per day and translate to one contamination every 29,412 days (80.5 years) for rail and one contamination every 11,236 days (30.75 years) for highway. As noted previously, water demand in northwestern Nevada is higher for about half of the year. Defining P(time of year) as 0.5 and incorporating this component into the risk model assesses the risk of hazmat contamination during higher water demand as one contamination every 161 years for rail and one contamination every 61.5 years for highway.

These estimates were also thought to be conservative, which emphasizes the imprecision of the database used in these computations. Equating the severity of rail accidents to the number of railcars involved is nonsensical in the presence of the high-quality data available today that include a description of each accident; however, such an estimate of severity was all that the 1997 database permitted. Similarly, the 1997 highway data did include frequency of fatalities, but fatal accidents are not necessarily severe enough to cause containers within vehicles to rupture. For these reasons, the 1997 estimates of hazmat contamination frequency of the Truckee River—one contamination every 80.5 years for rail transport and one contamination every 30.75 years for highway transport—were considered to be overestimates.

If the question, "What is the combined risk for contaminating the Truckee River by hazmat released during an accident on rail *or* highway?" is asked, then the risk values (probabilities) are summed. The word "or" is important and represents the union of the two events, an event on rail or an event on highway. The probability of the union of two events, A and B, is computed as

$$P(A) + P(B) - (\text{the probability of the intersection of these two events}) \quad (10)$$

The intersection of two events is written as P(A *and* B), with the word "and" being important. The intersection of two events is a situation in which the two events occur simultaneously. In the current study, the probability of accidents occurring simultaneously on rail and highway in which hazmat was released was deemed so small as to be neglected in the calculation of the union of the two events. The combined risk is consequently 0.000034 + 0.000089 = 0.000123 contaminations per day, or one contamination every 8,130 days (22.25 years; 44.5 years if the time of year is considered). Such an outcome must still be considered to be conservative (i.e., an overestimate), given that local history

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TABLE 1 Rail accident data, 1975–2004

Accident Parameters	Number of Rail Hazmat Incidents per Year, 1975–1989														
	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
California Counties of Nevada, Placer, and Sierra															
Accidents (total)	19	21	23	29	26	30	19	11	32	7	13	1	7	6	7
Haz 1	0	1	4	3	0	3	1	0	0	0	1	0	1	1	2
Haz 2	0	0	1	2	0	2	1	0	0	0	1	0	1	1	1
Haz 3	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
Haz 4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Nevada, Washoe County															
Accidents (total)	4	4	8	12	8	0	4	4	1	6	1	2	2	0	1
Haz 1	0	0	1	1	0	0	1	0	0	0	0	0	1	0	0
Haz 2	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
Haz 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haz 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Accident Parameters	Number of Rail Hazmat Incidents per Year, 1990–2004														
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
California Counties of Nevada, Placer, and Sierra															
Accidents (total)	9	10	2	5	14	15	8	3	8	5	4	11	12	18	9
Haz 1	0	3	1	1	3	1	1	0	2	2	0	4	3	0	2
Haz 2	0	3	1	0	1	1	0	0	1	2	0	0	0	0	1
Haz 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haz 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nevada, Washoe County															
Accidents (total)	1	0	6	1	3	0	0	1	1	1	0	2	0	4	1
Haz 1	0	0	1	0	2	0	0	1	1	0	0	0	0	0	0
Haz 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haz 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haz 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

hazmat—hazardous material, haz 1—accidents in which hazmat was involved, haz 2—accidents in which railcars carrying hazmat were damaged, haz 3—accidents in which hazmat was released, haz 4—accidents that resulted in the evacuation of people

indicates that in 1997, contaminations of the Truckee River had not occurred with this frequency.

1997 MODEL VALIDATION USING 2007 DATA

In 2002, the Truckee Meadows Water Authority (TMWA) purchased the water distribution and water treatment system from Sierra Pacific Power Co. Because the database available for risk assessment in 1997 was limited, TMWA funded a study in 2006–2007 to reassess the risk of Truckee River hazmat contamination, this time making use of the vastly improved database that was readily accessible via the Internet.

Rail accident data are complete, comprehensive, and available through the FRA website (FRA, 2014), where users can conduct a detailed search for rail accidents in any portion of the United States. A search for accidents in which railcars carrying hazmat were involved yielded the data in Table 1.

Although highway accident data are still not as easily accessible as rail accident data, there is a comprehensive database for hazmat incidents. The Bureau of Transportation Statistics, a division of the US Department of Transportation (USDOT), maintains a website of incident data that can be searched via the Hazardous Materials Information Resource System (HMIRS), the central repository for Material Safety Data Sheets for US military services and civil agencies (USDOT, 2014). A hazmat incident is defined by USDOT as the leakage (release) of a hazardous substance from a container. An incident does not necessarily involve

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an accident; for example, an incident can, and often does, occur during loading and unloading of containers. However, any accident during hazmat transport that is so severe as to cause a leakage of hazmat from a container certainly constitutes an incident that would be documented in the incident database.

Hazmat incident reports are available for all 50 states but only within the period from 1995 to 2002. Nonetheless, these eight years of data are sufficient for the risk characterization necessary to the current study to reassess the risk of hazmat contamination to the Truckee River. Hazmat incident data are available for all modes of transportation. Because highway is one mode of transportation included in this database, the frequency of highway accidents that result in a hazmat leakage can be easily determined. Although this determination is less direct in comparison with what is possible using the rail safety data provided by the FRA, it is no less accurate. Search results for hazmat incidents are summarized in Table 2.

Table 3 is presented to enable the assessment of rail accident data during two equal time intervals: 1975–1989 and 1990–2004. A statistically significant decrease in the average total rail accident rate was identified for the three California counties for 1990–2004 compared with 1975–1989, which suggests improved rail operational safety. This result may indicate a decrease in future contamination risk for the Truckee River. The California result is based on 95% confidence (Table t, two-tailed test, is 2.05). For the more recent period, 1990–2004, a statistically significant decrease in accidents was seen in Washoe County, Nev., but the confidence is 90% (Table t, two-tailed test, is 1.70). Rail safety

TABLE 2 Hazmat incidents, 1995–2002

	Number of Hazmat Incidents per Year (All Modes of Transportation)							
Accident Parameters	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
California Counties of Nevada, Placer, and Sierra								
Incidents	8	3	7	7	5	11	10	4
Environmental damage	0	0	0	0	0	0	0	0
Nevada, Washoe County								
Incidents	25	12	23	18	19	19	49	20
Environmental damage	0	0	0	0	0	0	0	0

hazmat—hazardous material

TABLE 3 Summary table of California and Nevada rail hazmat incidents comparing 1975–1989 and 1990–2004

	Number of Hazmat Incidents									
	CA* Total	**NV† Total**	**CA, Haz 1**	**NV, Haz 1**	**CA, Haz 2**	**NV, Haz 2**	**CA, Haz 3**	**NV, Haz 3**	**CA, Haz 4**	**NV, Haz 4**
Totals, Table 1	384	78	40	10	20	2	2	0	1	0
Mean, 1975–2004	12.80	2.60	1.33	0.31	0.62	0.06	0.06	0	0.03	0
Mean, 1975–1989	16.25	3.62	1.06	0.25	0.62	0.12	0.12	0	0.06	0
Mean, 1990–2004	8.81	1.69	1.50	0.37	0.62	0.062	0	0	0	0
Variance, 1975–2004	71.163	8.555	1.628	0.286	0.629	0.087	0.060	0	0.03	0
Variance, 1975–1989	97.533	11.583	1.662	0.2	0.517	0.117	0.117	0	0.062	0
Variance, 1990–2004	20.029	4.094	1.600	0.383	0.783	0.062	0	0	0	0
t statistic	2.65	1.89	–0.94	–0.61	0	0.53	1.36	0	0.93	0
Table t (95% confidence)	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05
Reject null hypothesis	Yes	No	No	No	No	No	No	No	No	No

hazmat—hazardous material, haz 1—accidents in which hazmat was involved, haz 2—accidents in which railcars carrying hazmat were damaged, haz 3—accidents in which hazmat was released, haz 4—accidents that resulted in the evacuation of people

*CA indicates California counties of Nevada, Placer, and Sierra.
†NV indicates Washoe County, Nev.

Null hypothesis: H_0: $Mean_{75-89} = Mean_{90-04}$ and the alternative hypothesis, H_a, holds that the two means are not equal should the null hypothesis be rejected.

Computation of the *t* statistic: (Mean, A – Mean, B) / ($\sqrt{(Var(A)/NA) + (Var(B)/NB)}$, in which *NA* is the number of data values in group A and *NB* is the number of data values in group B. For example, comparing the mean total accidents for California for group A, 1975–1989, and group B, 1990–2004, the *t* statistic is equal to $(16.25 - 8.81)/((97.53/15) + (20.029/15))^{1/2} = 2.65$. In this case, the value of the *t* statistic is greater than the table value of 2.05, so the null hypothesis is rejected, and the alternative hypothesis is accepted, identifying a statistically significant decrease in total California accidents for the more recent period of 1990–2004.

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also has improved within Washoe County since 1990, but this statement is not quite as certain as it is for the California counties.

Several additional conclusions can be drawn from Tables 1 through 3. For one, no accident on rail (Table 1) or, in fact, by any mode of transportation (Table 2), has resulted in a release of hazmat (identified by the columns headed "Haz 3" in Table 3) within the Truckee River watershed from 1975 to 2004. Within the same time frame, two accidents resulted in release of hazmat (haz 3) in Placer County, one of which was severe and forced the evacuation of citizens (identified by the columns headed "Haz 4" in Table 3) from Newcastle, Calif., in 1988. Both Placer County incidents occurred within the Sacramento River watershed. An additional conclusion that may be drawn from Table 3 is that rail accidents occurring in California are potentially more severe than those occurring in Nevada, with more hazmat substances likely to be involved and railcars carrying hazmat substances likely to be damaged severely enough to cause a hazmat release. No rail accident in California, however, has resulted in a release of a hazmat substance within the Truckee River watershed during the period of this study.

Table 3 mean values for the entire period from 1975 to 2004 suggest that the frequency of railcars carrying hazmat is approximately 10%. This is the value that was used in the first risk assessment study conducted in 1997. When mean values for the period from 1990 to 2004 are studied, however, the frequency appears to be closer to 20% (i.e., double the value used in the original 1997 risk assessment). This frequency is inferred from the notion that P(total accident) × P(hazmat) = P(hazmat is involved in an accident). In the total period from 1975 to 2004, P(total accidents, Calif.) is 12.53, and P(total accidents, Nev.) is 2.65. P(hazmat involved in accident, Calif.) is 1.28, and P(hazmat involved in accident, Nev.) is 0.31. Dividing P(hazmat involved in accident) by P(total accident) for each state yields P(hazmat, Calif.) = 1.28/12.53 = 0.10 (10%) and P(hazmat, Nev.) = 0.31/2.65 = 0.12 (12%).

For the period from 1990 to 2004, P(hazmat involved in accident) is 1.5 for California (mean haz 1) and 0.37 for Nevada. Total mean accidents within this time frame are 8.81 for California and 1.69 for Nevada. With the use of these values, P(hazmat, Calif.) = 1.5/8.81 = 0.17 (17%) and P(hazmat, Nev.) = 0.37/1.69 = 0.22 (22%). For the period from 1975 to 1989, these frequency values are 6.5% for California, obtained by dividing mean haz 1 for California with this timeframe, 1.06, by the mean total accidents, 16.25; frequency values are 6.9% for Nevada, found by dividing mean haz 1 for Nevada within this timeframe, 0.25, by the mean total accidents, 3.62. This outcome reveals a substantial increase in rail transport of hazmat.

Even though the frequency of hazmat transport by rail has increased significantly since 1990, no statistically significant difference was seen in the frequency of accidents involving hazmat, accidents severe enough to cause damage to railcars carrying hazmat, and accidents causing a release of hazmat between the two time intervals of 1975–1989 and 1990–2004. The null hypothesis used for this assessment (Table 3) is H_0: $\text{Mean}_{75-89} = \text{Mean}_{90-04}$; the alternative hypothesis, H_a, holds that the two means are not equal should the null hypothesis be rejected. With respect to the transport of hazmat, the fact that the null hypothesis was not rejected shows that despite the increase in hazmat transport since 1990, the average number of accidents, the average number of accidents involving railcars carrying hazmat, the average number of accidents causing damage to railcars carrying hazmat, and the average number of accidents severe enough to cause a release of hazmat are statistically indistinguishable from pre-1990 averages (Table 4).

Actual transportation statistics were used to test the probability-based risk calculations that developed in the 1997 study. The 1997 study relied heavily on conceptual calculations of risk, in large part because of the lack of accessible transportation data available.

As shown in Table 5, P(hazmat|accident) for rail transport of hazmat in California in actuality is three to four times higher than the incidence computed in the 1997 study (1.28 events per year versus 0.38 events per year). For Washoe County, Nev., the two values are more similar, with actual incidence at 0.31 per year and computed level of incidence at 0.29 per year. With respect to the portion of the Truckee River that flows through California, if Placer County rail accident data are discounted, then the actual P(hazmat|accident) risk changes from 1.28 incidents per year to one incident in 32 years, which took place in 1977 near Norden, Calif., within the Sacramento River watershed. Placer County includes only a small portion of the rail line within the Truckee River watershed; similarly, Sierra County includes only a small portion of the rail line near the Truckee River. Therefore, a rail accident severe enough to release hazmat into the river is most likely to occur in Nevada County, Calif. The rate of one accident in 32 years (0.03 per year) is more realistic for the California risk. Accordingly, risk of hazmat contamination to the Truckee River originating from a rail accident is considered negligible. This statement is bolstered by the fact that no accident on rail has caused a hazmat incident within the Truckee River watershed during the available database period beginning in 1975.

Highway data remain difficult to obtain for anything more detailed than a summary by state, a limitation that also affected the 1997 study. With the very detailed HMIRS database, however, hazmat incidents are accessible for individual counties for each state (USDOT, 2014). A hazmat incident is defined as a spill of a

TABLE 4 Frequency of rail accidents in general and involving hazmat for any given year

Annual Frequency					
Region	**Rail Accidents**	**Haz 1**	**Haz 2**	**Haz 3**	**Haz 4**
California[*]	12.53	1.28	0.63	0.06	0.03[†]
Nevada[‡]	2.65	0.31	0.09	§	§

hazmat—hazardous material, haz 1—accidents in which hazmat was involved, haz 2—accidents in which railcars carrying hazmat were damaged, haz 3—accidents in which hazmat was released, haz 4—accidents that resulted in the evacuation of people

[*] California counties of Nevada, Placer, and Sierra

[†] The period 1975–2004 shows one incident, which occurred in 1988 in Newcastle, Calif., in the Sacramento River watershed.

[‡] Washoe County, Nev.

§No incidents occurred in the time frame 1975–2004, so frequency is not yet defined or known.

TABLE 5 Comparison of risk calculations from 1997 versus actual data through 2004

	Time Frame and Region			
Risk Calculation	**CA, 1997**	**NV, 1997**	**CA, 2004**	**NV, 2004**
P(accident), rail	3.9 per year	0.9 per year	12.53 per year	2.66 per year
P(accident), highway	1.14 per day, I-80	1.14 per day, I-80	27.6 per day, entire state	1.65 per day, entire state
P(hazmat), rail	10% (0.1)	10% (0.1)	20% (0.20)	20% (0.20)
P(hazmat), highway	0.0056, I-80	0.0056, I-80	1.6% (0.016)	1.6% (0.016)
P(hazmat|accident), rail, computed	0.38 per year	0.29 per year		
P(hazmat|accident), rail, actual (haz 1)	No data	No data	1.28 per year	0.31 per year
P(hazmat|accident), highway, computed	0.0064 per day, I-80	0.0064 per day, I-80		
P(hazmat|accident), highway, actual	No data	No data	0.36 per day (131 per year) entire state	0.031 per day (11.3 per year), entire state
P(damage|hazmat|accident), rail, actual*	Not computed (no data)	Not computed (no data)	No event in TRW, 1975–2004	2 events in Washoe County, 1975–2004, both in Sparks rail yard
P(spill|hazmat|accident), rail, computed	0.0125 per year	0.0065 per year		
P(spill|hazmat|accident), rail, actual	No data	No data	2 events, 1975–2004, both in Sacramento River watershed	No event, 1975–2004; P is undefined
P(spill|hazmat|accident), highway, computed	0.71 per year	0.35 per year		
P(spill|hazmat|accident), highway, actual	No data	No data	No event, 1995–2002; P is undefined	No event, 1995–2002 P is undefined
P(TRW|spill|hazmat|accident), rail, actual	No data	No data	No event, 1975–2004; P is undefined	No event, 1975–2004; P is undefined
P(TRW|spill|hazmat|accident), rail, actual	No data	No data	No event, 1995–2002; P is undefined for Placer, Nevada, and Sierra Counties	No event, 1995–2002; P is undefined for Washoe County

CA—California, hazmat—hazardous material, I-80—Interstate 80, NV—Nevada, TRW—Truckee River watershed

*Damage includes derailment but does not include spillage.

Except where otherwise indicated, CA data pertain only to the California counties Nevada, Placer, and Sierra, and NV data pertain only to Washoe County, Nev.; I-80 data refer to those portions of the interstate passing through the California counties of Nevada, Placer, and Sierra and Washoe County, Nev.
P(accident), rail data were obtained from the Federal Railway Administration website (FRA, 2014).
P(accident), highway data were obtained from the Bureau of Transportation Statistics website (USDOT, 2014).
P(hazmat), rail and highway data for 1975–2004 were back-calculated as P(hazmat|accident) per P(accident).
P(hazmat|accident), rail data exclude accidents within rail yards.
P(spill|hazmat|accident), computed = P(spill) P(hazmat|accident); P(spill), rail, 1975–2004, CA & NV = [P(spill hazmat|accident), rail, actual, CA] which is equal to one event in 31 years (0.032); P(spill), highway = 0.125 per year
No accident on rail has resulted in a hazmat spill within the Truckee River watershed, 1975–2004.
No accident on the highway has resulted in a hazmat spill within the Truckee River watershed, 1995–2002.

hazardous material, regardless of the cause of the spill. Because incidents include a release of hazmat during an accident, the HMIRS database is valuable for inferring P(spill|hazmat|accident) for any mode of transportation. The values reported in Table 5 for highway are inferences based on the HMIRS database. On the basis of the HMIRS database, P(spill|hazmat|accident) for highway is no greater than 0.11 per year, given the fact that no hazmat incident is associated with a highway accident within the Truckee River watershed during the period 1995–2002. The HMIRS database, although comprehensive for individual counties, comprises only data within the timeframe 1995–2002.

DISCUSSION

Results of this hazard/risk assessment are not adequate for use in complying with the Public Health Security and Bioterrorism Preparedness and Response Act of 2002, better known as the Bioterrorism Act (US Public Law 107–188, 2002). This act requires community drinking water systems serving populations of more than 3,300 to conduct assessments of their vulnerabilities to terrorist attacks or other intentional acts and to defend against adversarial actions that might substantially disrupt the ability of the system to provide a safe and reliable supply of drinking water. The assessment necessary for compliance with this act does not involve the collection of data for characterizing accident frequency or severity. Terrorist acts are deliberate, not accidental. Moreover, design details of the water treatment system are important input to this assessment process; such details were not relevant to, and therefore not included in, the assessment of hazmat contamination risk.

Source water–protection goals and a source water–protection action plan are two of the six primary elements of the ANSI/AWWA G300 Water Protection Standard (ANSI/AWWA, 2007). Source water requires protection from contamination by hazmat release. In November 2009, the Preparedness, Emergency

Response, and Recovery Critical Infrastructure Partnership Advisory Council Working Group issued the report *All-Hazard Consequence Management Planning for Water Sector* (CIPAC, 2009). According to Section II of this report, "When thinking about emergency preparedness, response, and recovery, it is important that utilities consider high probability hazards that they may face and all the potential consequences that flow from them." The key phrase here is "high probability hazards."

Given the assessment that risk of Truckee River contamination by hazmat released during an accident is small, TMWA decided not to stockpile chemicals or institute any other operational changes at or to water treatment plants. Given that TMWA has an alternate water supply (i.e., wells), it was decided to focus on response times and creation of a plan to adjust operations. To this end, TMWA developed a contaminant spill model (Rivord et al, 2014) to provide estimates of how long it would take for a spill to reach one of the treatment plant inlets and how long the plants might have to remain offline. If such an incident were to occur in summer, TMWA could limit outdoor watering and switch production over to the 31 production wells. If the incident were to occur during winter, the production wells could replace surface water, and the plants could be taken offline until the spill had been cleaned up or had passed the plants.

SUMMARY

As shown in this study, when a database is limited, working with conditional probability estimates to develop upper and lower bounds for risk yields a reasonable characterization of actual risk. Given a comprehensive database, the conditional probability model is more precise. This study found that the 2007 calculations represented better estimates of risk, yet the 1997 estimates were reasonable when compared with the 2007 calculations.

A cost analysis (Verma, 2009) was not part of this study. The cost of a hazmat contamination of the Truckee River is difficult or impossible to estimate. The cost could in fact be zero, depending on the location of the accident and the type of hazmat involved. At the opposite extreme, the cost could be in the millions of dollars if an accident were to occur in the summer, disrupting water delivery for irrigation.

Since the conclusion of the 2007 study, additional work (Qiao et al, 2009) has been devoted to estimating accident frequency for the transport of hazmat by highway. This accident frequency remains difficult to calculate with confidence. As shown in this article, data for rail accidents are highly detailed, and calculations of accident frequency have a high confidence. Access to highway transport incidents, on the other hand, is more difficult. Qiao and colleagues (2009) proposed methods that included fuzzy logic for estimating highway hazmat accident frequency for which error is quantifiable. Still, the estimates of highway hazmat-transportation risk reported here are intentionally conservative, given the lower confidence in the database.

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PEER REVIEW

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TRUCKEE MEADOWS WATER AUTHORITY

APPENDIX 2-8

MODELING CONTAINMENT SPILLS IN THE TRUCKEE RIVER

Modeling Contaminant Spills in the Truckee River in the Western United States

Jeremy Rivord[1]; Laurel Saito, P.E., M.ASCE[2]; Glenn Miller[3]; and Shawn S. Stoddard[4]

Abstract: Originating at Lake Tahoe, the Truckee River provides 85% of drinking water for the Reno/Sparks metropolitan area. Major highways and a railroad run adjacent to the river, which increases risk of a contaminant spill into the river that could have detrimental effects on drinking water supplies. A one-dimensional solute transport model (OTIS) was applied to the Truckee River. Data from dye studies on the river were used to determine a relationship to estimate dispersion coefficients for the Truckee River and calibrate the model. Two sizes of hypothetical contaminant spills from 9 locations under 13 flow scenarios were simulated. Travel times to the first water intake for a train spill of 130,000 L ranged from 3 to 46 h and maximum simulated concentrations of a conservative water soluble contaminant at the intake ranged from 340 to 4,800 mg/L. Model output was influenced by uncertainties in the equation for longitudinal dispersion, so model runs were executed with estimated dispersion values that were a factor of 1.5 greater and less than the equation-estimated value of dispersion.
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Author keywords: Modeling; Transport and fate; Rivers/streams; OTIS.

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Introduction

Large contaminant spills from transportation accidents have impacted aquatic ecosystems and water quality of municipal drinking waters [Government Accountability Office (GAO) 2006]. On August 5, 2005, nine Canadian National rail cars fell off a bridge into the Cheakamus River north of Vancouver, British Columbia, releasing 41,000 L of sodium hydroxide that killed more than 500,000 fish in an 18-km section of the river (Canadian Broadcasting Corporation 2006). Similarly in 1991, 70,000 L of metam sodium, a commonly used agricultural fumigant, was spilled into the Sacramento River when several rail cars overturned near Dunsmuir, California. The spill degraded into several products toxic to humans and aquatic life. Metam sodium-derived analytes were detected in sites downstream from the spill 23 days after the spill (del Rosario et al. 1994) and the spill impacted the aquatic ecosystem at monitoring sites up to 55 km downstream for 26 days (Brett et al. 1995). However, the quick response in monitoring solute concentrations assisted officials in managing the accident and verifying when water was safe to drink (del Rosario et al. 1994).

Solute transport models that can predict travel times and contaminant concentrations due to spills are useful for municipalities that rely on nearby rivers for drinking water supplies. This paper describes the application of the one-dimensional transport with inflow and storage (OTIS) model (Runkel 1998) to the Truckee River in California and Nevada. OTIS has been used to model in-channel solute mixing and transport, nutrient uptake, and trace metal chemical reactions for both steady and unsteady state scenarios for streams and rivers (Runkel 2000).

The Truckee River and its tributaries provide approximately 85% of total water supplies to the cities of Reno and Sparks, Nevada (TMWA 2012). Originating at Lake Tahoe at Tahoe City, California, the river flows in close proximity to California Highway 89, U.S. Interstate 80 (I-80), and the Union Pacific Railroad (UPRR) into the Reno-Sparks area (Fig. 1). Regular traffic on the highway and rail line and harsh winter conditions present the potential for a contaminant spill. While there is an emergency response plan for spills in the Truckee River corridor [Truckee River Area Committee (TRAC) 2005], it does not address spill travel times. Truckee Meadows Water Authority (TMWA), the area's drinking water purveyor, has a need for predicting the timing, duration, and concentration of spills that might occur on the Truckee River and contaminate drinking water of the Reno-Sparks area. The objective of this paper is to present methods for modeling this highly regulated river, including development of new dispersion equations for the Truckee River based on dye study data from 1999, 2006, and 2007.

Methods

Study Area

From its origins in California, the Truckee River flows 190 km through the Tahoe National Forest, past the town of Truckee, California, into the Truckee Meadows with the cities of Reno and Sparks, Nevada, and to its terminus at Pyramid Lake (Fig. 1). The Truckee River watershed drains approximately 8,000 km^2 and contains five major reservoirs with headwater altitudes in excess of 3,000 m around Lake Tahoe. The elevation of the river from its outlet to its terminus decreases more than 700 m. Higher altitudes around Lake Tahoe experience an average annual precipitation of 81 cm, mostly in the form of winter snow and occasional summer thunderstorms, whereas Truckee Meadows

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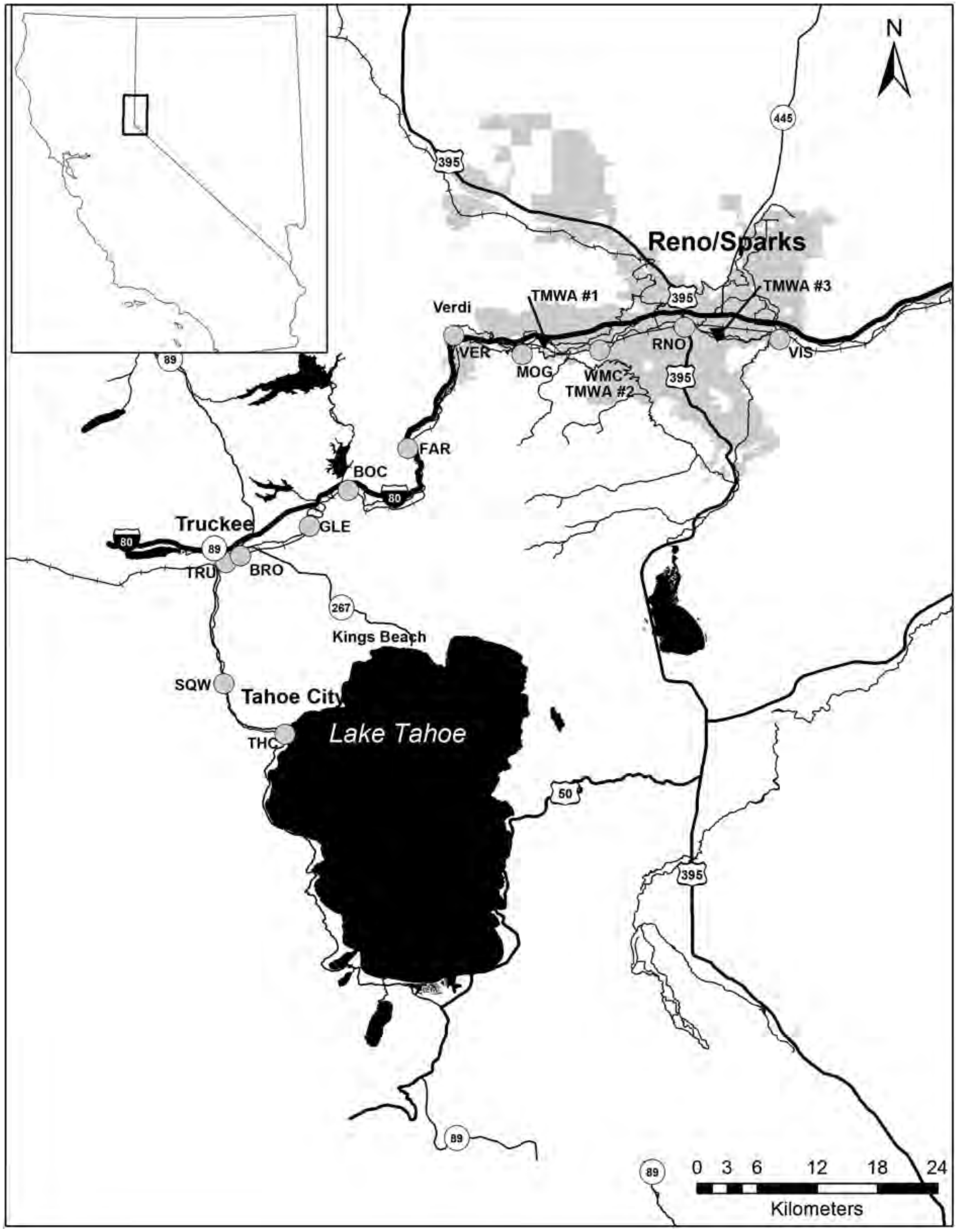

Fig. 1. Site map showing sites used in the study (see Table 1 for definitions of the site abbreviations)

and Pyramid Lake average only about 18 cm of precipitation each year. Spring snowmelt in the Sierra Nevada creates the highest river flows of the year with lower discharges typically occurring in late July and August.

Only 103 km of the river [from Lake Tahoe to U.S. Geological Survey's (USGS) Vista gauge just east of Sparks, Nevada] was included in this study. The river was divided into three portions as defined by dye studies conducted by the USGS in 1999, 2006, and 2007 (Crompton 2008; Crompton and Bohman 2000). The upper portion of the river begins at the California State Route 89 Bridge in Tahoe City, California (THC, USGS Station No. 10337500, Table 1) and is composed of five downstream sites over 32 river km (Fig. 1, Table 1). From THC, the Truckee River flows north alongside California State Route 89, passing

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Table 1. Site Abbreviations, Site Descriptions, and Distances of Sites from Lake Tahoe that were Included in Dye Studies, Surveying, and OTIS Model

Site abbreviation	Site description	Distance from Lake Tahoe (km)	Included in dye studies?	Cross-section survey?	Included in OTIS?
Upper portion					
THC	Truckee River below Tahoe City Dam	0.03	Y	Y	Y
SQW	Truckee River below confluence with Squaw Creek	10	Y	Y	Y
DEE	Deep Creek off of Hwy 89	—	N	Y	N
TRU	Truckee River near Truckee	20	Y	Y	Y
DC	Donner Creek tributary	—	N	N	Y
BRO	Truckee River at Brockway Bridge	25	Y	Y	Y
MC	Martis Creek tributary	—	N	N	Y
GLE	Truckee River at Glenshire Drive Bridge	32	Y	Y	Y
Middle portion					
GLE	Truckee River at Glenshire Drive Bridge	32	Y	Y	Y
PC	Prosser Creek tributary	—	N	N	Y
LTR	Little Truckee River tributary	—	N	N	Y
BOC	Truckee River at Boca Bridge	40	Y	Y	Y
FAR	Truckee River near Farad	55	Y	Y	Y
VER	Truckee River at Bridge Street Bridge (site not included in model domain)	69	Y	Y	N
TMWA#1	Highland Ditch (TMWA diversion)	73	Y	Y	Y
MOG	Truckee River near Mogul	77	Y	Y	Y
Lower portion					
MOG	Truckee River near Mogul	77	Y	Y	Y
WMC	Truckee River at West McCarran Bridge	84	Y	Y	Y
TMWA#2	Orr Ditch (TMWA diversion)	84	Y	N	Y
REN	Truckee River near Reno	92	Y	Y	Y
TMWA#3	Glendale Intake (TMWA diversion)	92	Y	Y	Y
VIS	Truckee River at Vista (site not included in model extent)	103	Y	Y	N

confluences with Squaw Creek (SQW) and Donner Creek. East of the town of Truckee, the river, I-80, and the Union Pacific Railroad descend into the Truckee Meadows. Tributaries Martis Creek, Prosser Creek, and the Little Truckee River join the river, all of which are controlled by reservoirs. The portion of the Truckee River from the Boca Bridge (BOC, USGS Station No. 10344505) to the Glenshire Bridge (GLE) has unconsolidated sedimentary rocks that lead to accretion from groundwater (Fox 1982; McKenna 1990).

The middle portion of the spill model covered 44 river km with four downstream dye study sample locations (Crompton 2008; Crompton and Bohman 2000). The last sample site in the upper portion (GLE) was the middle portion injection site for dye studies in 1999 and 2006. From GLE, the Truckee River enters a steep canyon (average slope of 0.0066) with I-80 adjacent to the river for the next 35 km. Between Farad, California (FAR, USGS Station No. 10346000), and Verdi, Nevada (VER, USGS Station No. 10347320), there are three hydropower diversions and returns that regularly divert 10–13 m^3/s along this section of river (David Wathen, personal communication, 2008). East of VER, the river exits the mountains and enters the flatter alluvial valley of the Truckee Meadows. The first of three TMWA municipal diversions—the Highland ditch diversion (TMWA#1), which feeds the Chalk Bluff Treatment Plant, occurs about 1 km upstream of the Mogul site (MOG, USGS Station No. 10347460), which was also the final dye study sample location of the middle portion.

The lower portion of the spill model began at MOG with two downstream sample locations and 25 km of river. Three separate dye studies on this reach occurred on May 4, 1999; August 25, 1999; and June 27, 2006. The gradient is relatively flat (about 0.0003) and there are numerous agricultural diversions throughout this reach that divert water on a seasonal basis at flows less than 0.5 m^3/s (David Wathen, personal communication, 2008). It is also in this reach where the final two TMWA treatment diversions are located. A diversion at Orr Ditch (TMWA#2) occurs about 6 km downstream of MOG and routes water to the Chalk Bluff Treatment Plant. The river passes the West McCarran Bridge (WMC) and then encounters the Glendale Treatment Plant diversion (TMWA#3), which is less than 1 km downstream from the dye study sample location at the USGS Reno gauge (REN, USGS Station No. 10348000). The final sampling location for the dye studies was at Vista (VIS, USGS Station No. 10350000).

Dye Studies

Field procedures for conducting travel time dye studies as described in Kilpatrick and Wilson (1989) were followed for both the 1999 and 2006–2007 studies (Crompton 2008; Crompton and Bohman 2000). An instantaneous slug injection of Rhodamine WT (RWT) dye was made near the center of active flow at each injection site. The amount of dye, time and location of injection, and observed streamflow were recorded for each injection. Peak concentrations did not exceed 10 $\mu g/L$ at sampling sites. Background readings were determined on-site using a Turner Designs Model 10 fluorometer (Turner Designs, Sunnyvale, California). When readings at the sample site increased from background levels, samples were collected at approximately 5-min intervals until concentrations returned to background levels. Samples were stored in a cooler and transported to the USGS Laboratory in Carson City, Nevada, for analysis with the same fluorometer at a controlled temperature. Concentrations determined in the USGS Lab were used in model calibration.

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Cross-Sectional Surveys and Sediment Sampling

In October 2006, 15 cross sections along the Truckee River were surveyed (Table 1). These measured cross sections provided physical characteristics such as channel geometry, water elevation, and average slope of the sampling sites that were used in calibrating the model. Sediment samples were also collected from 13 sites and analyzed for organic matter and particle size distribution. Results of the sediment samples provided sorption and porosity information and indicated the RWT dye was unlikely to sorb. According to USDA soil classification, 10 of the 13 sites had a very gravelly and sand substrate, and the other sites had loamy sand substrates. With the exception of five sites (THC, FAR, VER, MOG, and TMWA#1), organic matter in sediment samples was less than 1%, which would limit sorption of organic compounds.

Modeling Approach

To develop predictive plans that address accidental or intentional spills in rivers, it is important to understand the movement and transport of contaminants in a particular water body. Tracer studies have commonly been used to determine mixing characteristics of stream systems for solute transport (Stream Solute Workshop 1990). RWT dye is a commonly used tracer measured with a fluorometer, but other tracers such as chloride and dissolved iron from mine tailings have been successfully used as conservative and nonconservative tracers (Broshears et al. 1993; Kilpatrick and Wilson 1989; Knust and Warwick 2009; Stream Solute Workshop 1990).

Tracer studies provide valuable data for development of water quality and hydraulic models that can be used to model potential contaminant spills. The one-dimensional advection-dispersion equation (ADE) (Fischer et al. 1979) has been extensively used in solute transport and hydraulic studies of streams and rivers. However, response curves from the one-dimensional ADE model have been inconsistent with response curves in numerous tracer studies, especially in predicting the tail of the response (Bencala and Walters 1983; Knust and Warwick 2009). It has been hypothesized that this phenomenon was due to a temporary storage mechanism referred to as *dead zones* or transient storage (Bencala and Walters 1983; Fischer et al. 1979) that occur as eddies, pools, or subsurface flows paths, and lengthen the duration of a spilled contaminant's presence in the channel.

The transient storage model uses the one-dimensional ADE modified to account for transport delays from dead zones by simulating storage zones that exhibit a first-order mass transfer relationship with the main channel (Bencala and Walters 1983). The equations are defined as (Bencala and Walters 1983; Runkel 1998)

$$\frac{\partial C}{\partial t} = -\frac{Q}{A}\frac{\partial C}{\partial x} + \frac{1}{A}\frac{\partial}{\partial x}\left(AK\frac{\partial C}{\partial x}\right) + \frac{q_L}{A}(C_L - C) + \alpha(C_S - C) - \lambda C \tag{1}$$

$$\frac{dC_s}{dt} = -\alpha\frac{A}{A_S}(C_S - C) - \lambda_S C_S \tag{2}$$

where α = stream storage zone coefficient [1/T]; A = stream cross-sectional area [L^2]; A_S = cross-sectional area of the storage zone [L^2]; C = solute concentration in control volume [M/L^3]; C_L = solute concentration in lateral inflow [M/L^3]; C_S = solute concentration in the storage zone [M/L^3]; K = dispersion coefficient [L^2/T]; λ = main channel first-order decay coefficient [/T]; λ_S = storage zone first-order decay coefficient [/T]; Q = volumetric flow rate [L^3/T]; q_L = lateral volumetric flow rate [L^3/T]; t = time [T]; and x = downstream distance [L].

OTIS is a FORTRAN-based computer model developed by the USGS with Eqs. (1) and (2) as the governing equations for simulation of one-dimensional surface water transport. Within OTIS is a parameter estimation algorithm called OTIS-P. OTIS-P uses the adaptive nonlinear least squares technique (residual sum of squares) for instream concentrations as described by Dennis et al. (1981).

For the Truckee River OTIS model, reaches were bounded both upstream and downstream by locations where tracer samples were collected. Reaches had many 30-m segments (or control volumes), but it was assumed that cross-sectional areas of the main channel (A) and the storage zone (A_s), dispersion (K), storage zone exchange coefficient (α), and first-order decay coefficients of the main channel (λ) and the storage zone (λ_s) were constant for an entire reach.

Model Setup and Calibration

Data from the seven tracer tests conducted on the Truckee River in 1999 and 2006/2007 were used to calibrate dispersion and decay coefficients and cross-sectional areas for the Truckee River spill model. One tracer study from 1999 for the lower portion and the 2006 tracer studies for the middle and lower portions were used in model calibration for high flows (flows between 36 and 75 m^3/s). All other tracer studies were used in model calibration for moderate flows (flows between 4 and 18 m^3/s). Reach lengths and output locations were calculated using river distances from the Lake Tahoe Dam in Tahoe City, California, as documented by Crompton and Bohman (2000) and Crompton (2008). Additional river locations such as tributaries, diversions, and TMWA intakes are obtained from TMWA's River Recreation map [Truckee Meadows Water Authority (TMWA) 2007].

Two different types of upstream boundary conditions were needed for model calibration. A continuous concentration boundary condition was used for reaches that had an observation time series at the upstream boundary. For the three reaches that had a tracer injection as an upstream boundary, a step concentration was used as the boundary condition. In this case, the volume of dye injected was converted into a constant concentration sustained over one integration time step. The modeled flow regime was assumed to be steady, nonuniform flow, with steady uniform flow within a reach, but nonuniform flow for the model extent.

A water balance for each reach was set up using streamflows from the tracer studies along with tributary or diversion data. There are four large tributaries to the Truckee River as well as three run-of-river hydropower diversions and returns that divert up to 80% of instream flow. If a tributary had a considerable year-round contribution to the Truckee River, then the change in streamflow due to that tributary was simulated to occur over a distance of one 30-m segment. Tributaries modeled in this way were Donner Creek, Martis Creek, Prosser Creek, and the Little Truckee River. Change in flow for smaller tributaries like Squaw Creek and Bronco Creek was averaged over the entire reach rather than a 30-m segment.

The integration time step (Δt) used in the Truckee River spill model was set to 0.02 h (1.2 min) to account for variability in sample frequencies. When an injection served as a step concentration boundary condition, the time step was set at 0.001 h (3.6 s) to simulate the brevity and magnitude of injected tracer.

Tracer data from each dye study was analyzed using the method of moments to provide initial estimates of main channel cross-sectional area and longitudinal dispersion for OTIS-P calibration. After OTIS-P was calibrated for area, dispersion, and decay, the model was again calibrated with OTIS-P with transient storage. For each reach, initial values of the storage zone exchange coefficient were defined to be 1.0×10^{-6} L/s (Fernald et al. 2001). Initial values of A_s were set such that the ratio of storage zone

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cross-sectional area to main channel cross-sectional area (A_s/A) was 0.2, which was the mean ratio found for rivers in the Willamette Basin, Oregon (Laenen and Bencala 2001). Statistics for model fits with OTIS-P were calculated using r^2, root mean squared error (RMSE) and percent bias between modeled and observed concentrations.

Spill Scenario Simulations

Because of the Truckee River emergency response plan (TRAC 2005), a major spill on the river has a good chance of being attended to in an expeditious manner. It was therefore assumed that a train tanker spill would occur over the course of 90 min, and a semitruck spill occurred over 60 min. It was also assumed that both would be best simulated by a simple step function (i.e., concentration was constant over spill duration). The volume of a rail car spill was simulated at 130,000 L and the volume of a dual tanker rig spill from a semitruck was simulated at 75,000 L, which are maximum allowable volumes described in the Code of Federal Regulations (49CFR179.13) (Holtzman 1997). It was assumed that the contaminant spilled was a conservative constituent that did not decay or degrade, and that the density of the spilled contaminant was similar to that of water (i.e., 1,000 $\mathrm{kg/m^3}$), which allowed for the fastest transport downstream. The assumed density and spill duration were used to estimate the injection rate. The mass per unit time was then divided by the simulated streamflow in liters to define the upstream boundary condition for a spill.

Thirteen streamflow scenarios were developed at 8 sites along the Truckee River using 10 years of USGS streamflow data from October 1, 1996 through September 30, 2007. The FAR site was designated as an index site for setting model flow scenarios due to its historical significance in Truckee River operations (Horton 1997). Streamflow scenarios were defined at 2.83 $\mathrm{m^3/s}$ (100 cfs) flow increments as observed at FAR from 2.83 to 28.3 $\mathrm{m^3/s}$ (100 to 1,000 cfs) and at 42.5, 56.6, and 70.8 $\mathrm{m^3/s}$ (1,500; 2,000; and 2,500 cfs). Flows at other sites were determined by analyzing historical records for flows at each site that corresponded with each incremental flow at FAR.

To prepare for spill scenario simulations, calibrated cross-sectional areas were used with surveyed cross-sectional geometry and the Chezy-Manning equation to estimate Manning's n coefficients for each model reach (Table 2). Cross-sectional area A for each spill scenario was calculated with the calibrated Manning's n coefficients. This approach assumed that a constant Manning's n (and hence, constant cross-sectional area and slope) applied throughout each section.

Table 2. Cross-Sectional Areas Calculated by OTIS-P, Corresponding Cross-Sectional Areas Calculated with Manning's Equation for Calibration Flows Using Survey Data, and Fitted Manning's n Values for Each Cross-Section (Calibration Flows are the Flows Measured during Respective Dye Studies)

Model site	Calibration flow ($\mathrm{m^3/s}$)	OTIS-P area ($\mathrm{m^2}$)	Survey calculated area ($\mathrm{m^2}$)	Manning's n
Upper portion calibration runs for 1999 tracer data at moderate (36% exceedance) flow				
THC	7.6	16.5	28.4	0.279
SQW	8.0	11.1	13.2	0.076
TRU	8.1	13.9	14.8	0.083
BRO	9.1	14.9	14.5	0.086
GLE	9.8	17.5	18.0	0.095
Middle portion calibration runs for 1999 tracer data at moderate (35% exceedance) flow				
GLE	11.2	19.7	19.5	0.095
BOC	17.8	23.2	23.6	0.088
FAR	17.8	26.7	25.0	0.091
Lower portion calibration runs for 1999 tracer data at moderate (45% exceedance) flow				
MOG	15.4	21.9	22.5	0.090
WMC	12.2	16.3	12.3	0.035
REN	11.8	21.4	15.2	0.031
Lower portion calibration runs for 1999 tracer data at high (7% exceedance) flow				
MOG	64	46.4	48.6	0.068
WMC	65	42.1	42.1	0.046
REN	60	43.1	42.1	0.031
Upper portion calibration runs for 2006 tracer data at moderate (50% exceedance) flow				
THC	1.9	12.0	11.1	0.279
SQW	4.0	8.7	8.6	0.076
TRU	5.5	11.6	11.7	0.083
BRO	7.5	14.0	13.0	0.086
GLE	7.6	16.0	15.3	0.095
Middle portion calibration for 2006 tracer data at high (5% exceedance) flow				
GLE	60.3	42.0	61.7	0.105
BOC	64.0	43.4	43.0	0.062
FAR	75.0	56.4	57.1	0.078
Lower portion calibration for 2006 tracer data at high (13% exceedance) flow				
MOG	39.4	34.0	35.0	0.068
WMC	38.2	30.0	30.1	0.046

Note: See Table 1 for site abbreviations.

In addition, dispersion values needed to be estimated for each spill scenario. Although OTIS-P could be used to estimate observed dispersion coefficients (K_m) that fit the dye study data, it was necessary to estimate K for spill simulations at flows that were not observed during dye studies. Estimation of the dispersion coefficient was especially important because it affects the amount of time a contaminant may be present at a particular site. Longitudinal dispersion is primarily the result of velocity profiles created from shearing processes around the wetted perimeter. Using data obtained from tracer studies, longitudinal dispersion can be estimated by matching observed concentrations to simulated concentrations modeled with the ADE (Stream Solute Workshop 1990; Graf 1995). There are also numerous theoretical equations for estimating longitudinal dispersion that have been derived from bulk flow parameters using channel geometry. For an average cross-sectional area, Fischer et al. (1979) defined the "longitudinal dispersion coefficient" in the form of a triple integral that accounted for shearing throughout the main channel. With recognition that rivers are generally much wider than they are deep, Fischer et al. (1979) simplified the triple integral equation through a series of laboratory experiments and dimensional analysis to propose a bulk flow parameter equation for longitudinal dispersion

$$K = \frac{0.011U^2w^2}{hU_*} \tag{3}$$

in which U = centroid velocity [L/T]; w = full channel width [L]; h = channel depth [L]; and U_* is shear velocity over the cross section [L/T], commonly estimated as

$$U_* = \sqrt{gr_hS} \tag{4}$$

where g = gravitational acceleration [$\mathrm{L^2/T}$]; r_h = hydraulic radius [L]; and S = hydraulic gradient. Variables in Eq. (3) are measurable river characteristics using tracer studies and channel geometry. Fischer et al. (1979) found that Eq. (3) was able to predict

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dispersion coefficients within a factor of 4 of observed dispersion coefficients.

Numerous studies have built upon Eq. (3) (Liu 1977; Seo and Cheong 1998; Deng et al. 2002; Kashefipour and Falconer 2002). Seo and Cheong (1998) used dimensional analysis with a nonlinear, one-step Huber regression to derive an equation for dispersion (K_{SC}) based on 35 measured dispersion values. The relationship is defined as

$$\frac{K_{SC}}{hU_*} = 5.915\left(\frac{w}{h}\right)^{0.620}\left(\frac{U}{U_*}\right)^{1.428} \tag{5}$$

The equation was validated to 24 independent dispersion values and assessed using discrepancy ratios for predicted (K_p) and measured (K_m) dispersion values

$$\text{Discrepancy ratio} = \log\frac{K_p}{K_m} \tag{6}$$

A discrepancy ratio of zero indicates the predicted dispersion value exactly matches the measured dispersion value, whereas the prediction is overestimated for a ratio greater than zero and underestimated for a ratio less than zero (Seo and Cheong 1998). Seo and Cheong (1998) found that Eq. (5) estimated dispersion values with a range of discrepancy values from −0.6 to 1 and estimated 79% of dispersion ratios within a range of −0.3 to 0.3.

For the current study, a dispersion equation was developed for the Truckee River using data from the seven Truckee River tracer studies in 1999 and 2006/2007. First, the parameter estimation algorithm in OTIS-P was used to estimate the observed dispersion coefficient K_m for the dye study data for runs that included transient storage and runs that did not. Regression relationships between the OTIS-P K_m values and flow, reach slope (S), and OTIS-P estimated A values were examined, and the following equation was derived

$$K_{TR} = 10^{0.237102}S^{-0.60167}\left(\frac{Q}{A}\right)^{0.542335} \tag{7}$$

where K_{TR} = dispersion for the Truckee River. Eq. (7) was derived using OTIS-P estimated K_m values with transient storage ($r^2 = 0.35$; $n = 24$). Discrepancy ratios for Eq. (7) ranged from −0.6 to 0.3, and 70.8% of the discrepancy ratios were between −0.25 and 0.25. All K_{TR} values estimated with Eq. (7) were within a factor of 4 of the 24 observed dispersion values, and 79.2% were within a factor of 1.5. Fits from Eq. (7) were compared to fits using Eq. (5) to determine which equation was best to use for spill scenario simulations. Because of uncertainty associated with dispersion calculations, two additional simulations were made for each spill scenario using K_{TR} values that bracketed estimated values by $1.5K_{TR}$ (discrepancy ratio $= +0.18$) and $K_{TR}/1.5$ (discrepancy ratio $= -0.18$) to provide upper and lower bounds of travel times.

Storage was not simulated in spill model scenarios because the storage zone is a conceptual zone that is not measurable with survey data and there are no theoretical equations to estimate storage parameters. Also, initial simulations showed that the least conservative spill in terms of time of arrival and peak concentration was simulated when OTIS-P storage parameters were included. Because the simulated contaminant was assumed to be conservative, the decay coefficient for simulations was set to zero.

A MATLAB routine processed output to obtain time of arrival and departure as well as peak concentration at each TMWA diversion. Arrival and departure times were defined as the times at which simulated concentration for each spill reached a concentration of 5 μg/L (Shawn Stoddard, personal communication, 2008). Time series for each spill at each site were also output.

Results

Calibration Results

The performance of OTIS-P with and without transient storage varied between studies performed in 1999 and 2006/2007 (Figs. 2 and 3; Table 3). For the majority of model executions, OTIS-P simulations without storage tended to have the largest peak concentrations. OTIS-P models with and without storage were able to recreate arrival and departure of dye well, with model statistics generally better for calibration runs for moderate flows as compared to runs for high flows (Table 3). The difference between results with and without storage for OTIS-P was minimal. Therefore, because of the difficulty in estimating transient storage area for further runs, simulation scenarios were run without the transient storage component.

For most runs using calculated K_{SC} and K_{TR} values for calibration, model timing of peak concentrations were close to the time of observed peaks, which indicated that the cross-sectional areas used in those runs were appropriate. However, in most cases, K_{SC} values were overestimated, resulting in peak concentrations that were too low, as well as an overestimation of the duration over which tracer was present. In contrast, K_{TR} values were lower than K_{SC} values, which overall resulted in better estimates of peak concentrations, especially for high-flow dye studies. Model r^2 values for results with calculated K_{TR} values tended to be better for moderate flow, whereas high-flow conditions tended to have better percent bias results. Overall, calibration statistics for runs using K_{TR} values calculated with Eq. (7) were better than those for runs using K_{SC} values from Eq. (5), so Eq. (7) was used to estimate K values for spill scenarios. Although model runs with calculated K_{SC} and K_{TR} values did not model dispersion of observations as well as OTIS-P runs that used calibrated K values, runs with theoretically calculated K values usually had the most conservative estimates of arrival time. Thus, additional runs that used K_{TR} values calculated using Eq. (7) were expected to provide conservative estimates of arrival time as desired by TMWA.

Simulation Results

Figs. 4(a and b) show the change in estimated arrival time to the first TMWA intake at the Highland Diversion for train spills occurring at the SQW and FAR sites along the Truckee River. Upper and lower estimates using dispersion values set at $1.5K_{TR}$ and $K_{TR}/1.5$ as calculated using Eq. (7) are also shown. Results for spills at other sites were similar. Expected arrival times ranged from 3 h to almost 4 days, depending on location of spill, flow, and dispersion value used. The model parameter in OTIS [Eqs. (1) and (2)] with the strongest influence on simulated travel times was the main channel cross-sectional area, A, because it defines advective transport downstream. At lower flows, A is small, velocity is low, and the spill has a longer time to mix in the channel, resulting in a larger spread of travel times. This effect was also seen in examination of duration of impact at the Highland Diversion for train spills at different locations under different flows [Figs. 4(c and d)], with lower flows having longer durations of impacts. Simulated peak concentrations using calculated K_{TR} values for train spills at SQW and FAR ranged from 300 to 5,400 mg/L [Figs. 4(e and f)]. There were larger differences in peak concentrations between runs using $K_{TR}/1.5$ and $1.5K_{TR}$ values at low-flow scenarios, but differences decreased from being on the order of thousands of mg/L at low flows to about 200 mg/L at high flows. Results for spills from

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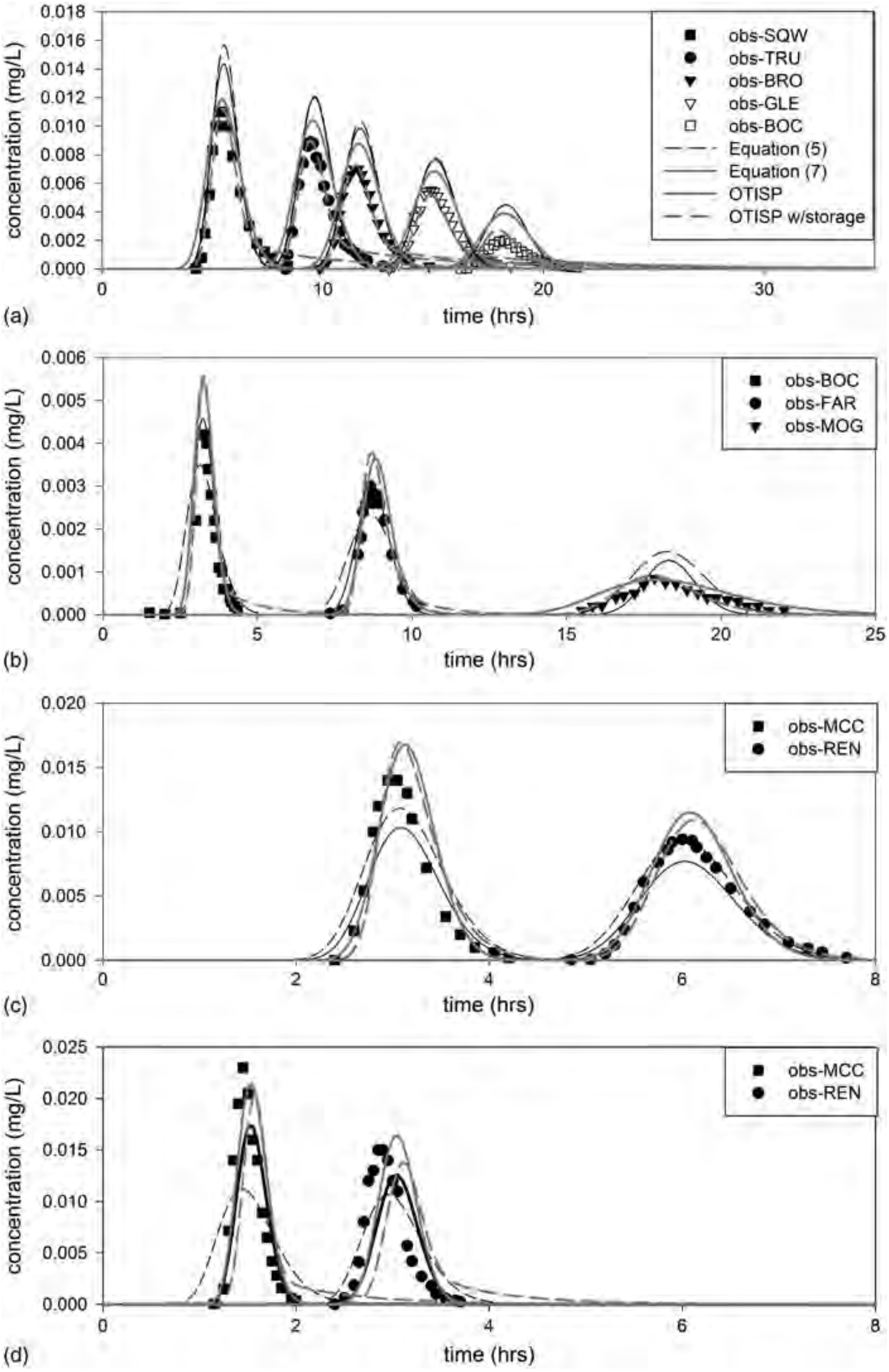

Fig. 2. 1999 tracer data and model output for (a) upper portion at moderate (36% exceedance) flow; (b) middle portion at moderate (35% exceedance) flow; (c) lower portion at moderate (45% exceedance) flow; (d) lower portion at high (7% exceedance) flow (model runs are for OTIS runs with and without storage using calibrated dispersion (K) coefficients, and for OTIS runs without storage using K_{SC} values calculated using Eq. (5) and K_{TR} values calculated using Eq. (7); site abbreviations are given in Table 1)

semitrucks showed the same patterns but were lower in magnitude and duration.

Discussion

Longitudinal Dispersion

Jobson (2001) questioned the appropriateness of certain simulation models as well as the application of theoretical estimates of dispersion due to their inability to adequately model longitudinal mixing processes. Prior to developing Eq. (7), several theoretically based longitudinal dispersion equations were investigated to be used in model simulation under flows that did not have tracer data (Fischer et al. 1979; Seo and Cheong 1998; Deng et al. 2002; Kashefipour and Falconer 2002). It was concluded that, of the prior developed equations, the Seo and Cheong (1998) equation [Eq. (5)] performed best with the Truckee River tracer data. Wallis and Manson (2004) noted that Eq. (5) had a tendency to overestimate dispersion values, which was observed in the current study (Fig. 5).

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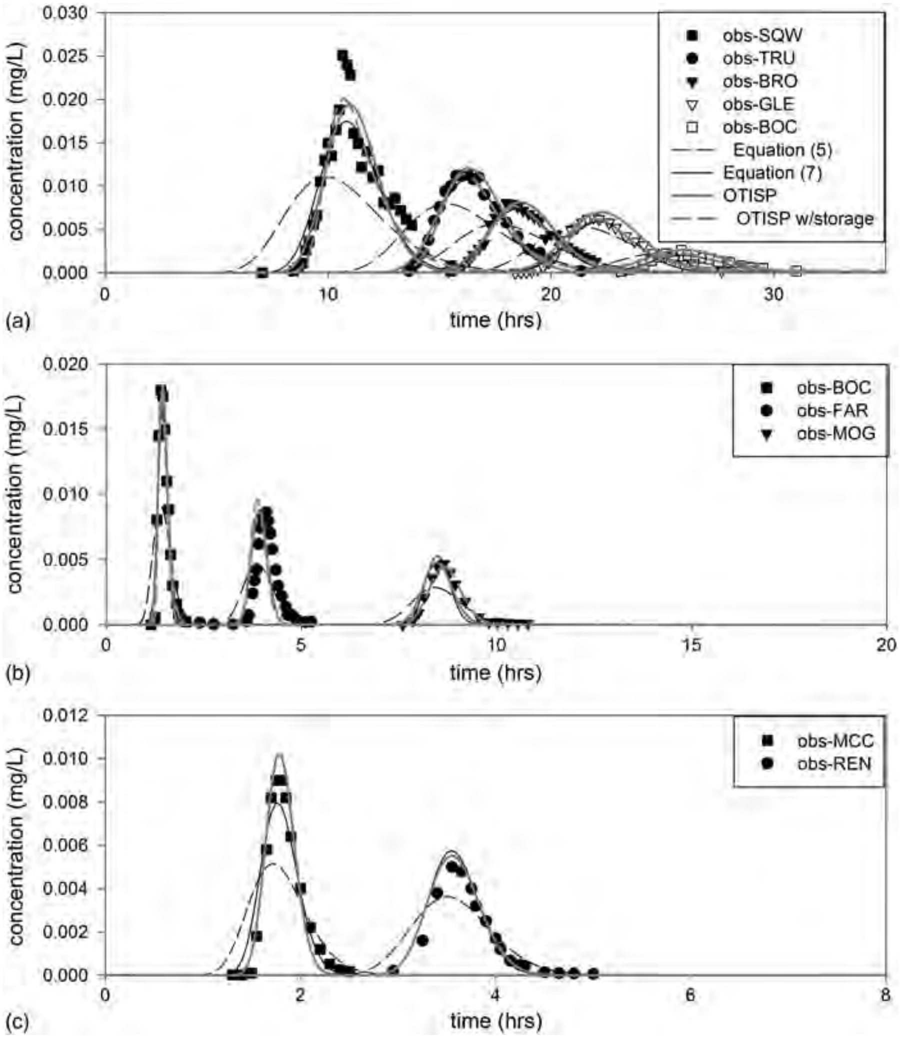

Fig. 3. 2006/2007 tracer data and model output for (a) upper portion at moderate (50% exceedance) flow; (b) middle portion at high (5% exceedance) flow; (c) lower portion at high (13% exceedance) flow (model runs are for OTIS runs with and without storage using calibrated dispersion (K) coefficients, and for OTIS runs without storage using K_{SC} values calculated using Eq. (5) and K_{TR} values calculated using Eq. (7); the model did not run under the with storage option for the lower portion; site abbreviations are given in Table 1)

Although Eq. (7) also tended to overestimate dispersion values, the overestimation was not as great as for Eq. (5) and the majority of discrepancy ratios were between −0.5 and 0.5. For the purposes of this project, overestimation of the dispersion coefficient was preferred to underestimation because overestimation produced conservative results in the Truckee River spill model in terms of arrival time. To account for uncertainty in the coefficient, dispersion coefficients were applied that were a factor of 1.5 greater or less than that estimated by Eq. (7). This ensured conservative estimates of dispersion for estimated arrival times and peak concentrations.

The magnitude of calibrated dispersion parameters determined using OTIS-P ranged from 14 to 109 m^2/s, which were similar to values found in previous studies. For rivers that have similar geometric parameters to the Truckee River, reported longitudinal dispersion values range from 8 to 38 m^2/s (Chapra 1997). Knust and Warwick (2009) estimated dispersion coefficients on the Truckee River below the VIS site to be about 20 m^2/s for a flow of 15 m^3/s. Given the highly variable results from applying dispersion equations developed using data from other rivers, we do not recommend using Eq. (7) on rivers besides the Truckee River without rigorously checking its applicability to such rivers. In addition, we did not estimate the numerical dispersion present in OTIS and thus the estimated dispersion is in addition to any inherent longitudinal dispersion.

Spill scenario results (Fig. 4) show that spill characteristics for the Truckee River are much more sensitive to flow than to dispersion. The use of dispersion values 50% greater and 50% smaller than that estimated with Eq. (7) resulted in much smaller changes in estimates of time of arrival, duration of impact, and peak concentration as compared to changes in flow, especially at low flows. In addition, it is noted that this study only modeled dispersion of a conservative constituent, and the response of actual pollutants to the dispersion term may be quite different.

Model Performance and Uncertainty

In addition to uncertainties about longitudinal dispersion, there were other uncertainties in the modeling process. For example, main channel cross sections were measured at 15 Truckee River locations over 90 km, and it was assumed that 1 measured cross-section characterized channel geometry for several km of a river segment that was in reality more heterogeneous. Errors in estimated channel geometry could affect estimated cross-sectional area and in turn the time of arrival. Measured cross sections were

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Table 3. Calibration Statistics for OTIS-P Runs without and with Transient Storage and for Calibrated Scenarios with K Values Calculated with Eqs. (5) and (7)

		OTIS-P no storage			OTIS-P with storage			OTIS with Eq. (5) K_{SC}			OTIS with Eq. (7) K_{TR}		
Site	n	r^2	RMSE (mg/l)	Bias (%)	r^2	RMSE (mg/l)	Bias (%)	r^2	RMSE (mg/l)	Bias (%)	r^2	RMSE (mg/l)	Bias (%)
Upper portion calibration runs for 1999 tracer data at moderate (36% exceedance) flows													
SQW	16	0.91	1.9×10^{-3}	28.6	0.99	5.0×10^{-4}	2.0	0.97	2.6×10^{-3}	33.7	**0.97**	**2.1×10^{-3}**	**29.3**
TRU	21	0.94	1.7×10^{-3}	32.5	0.99	3.6×10^{-4}	1.7	0.95	2.3×10^{-3}	39.9	**0.95**	**2.2×10^{-3}**	**36.8**
BRO	21	0.95	1.6×10^{-3}	39.6	0.99	2.8×10^{-4}	1.3	0.93	2.1×10^{-3}	45.0	**0.94**	**1.9×10^{-3}**	**40.1**
GLE	26	0.96	1.2×10^{-3}	41.9	0.99	3.4×10^{-4}	−4.0	0.96	1.5×10^{-3}	45.5	**0.96**	**1.4×10^{-3}**	**41.4**
BOC	22	0.94	1.3×10^{-3}	136.6	0.92	4.6×10^{-5}	45.5	0.96	1.5×10^{-3}	140.2	**0.97**	**1.4×10^{-3}**	**133.8**
Middle portion calibration runs for 1999 tracer data at moderate (35% exceedance) flows													
BOC	19	0.97	8.1×10^{-4}	35.3	0.99	6.9×10^{-4}	31.9	0.88	6.0×10^{-4}	**13.4**	**0.97**	**4.5×10^{-4}**	18.4
FAR	16	0.95	5.1×10^{-4}	21.5	0.98	5.2×10^{-4}	23.7	0.90	4.4×10^{-4}	**0.01**	**0.97**	**2.4×10^{-4}**	8.0
MOG	20	0.88	1.9×10^{-4}	42.2	0.88	1.2×10^{-4}	6.8	**0.94**	3.8×10^{-4}	60.2	0.86	**2.5×10^{-4}**	**−3.3**
Lower portion calibration runs for 1999 tracer data at moderate (45% exceedance) flows													
WMC	15	0.86	2.5×10^{-3}	15.4	0.85	2.5×10^{-3}	13.6	0.92	**2.0×10^{-3}**	**8.4**	**0.93**	2.2×10^{-3}	−12.0
REN	22	0.98	1.2×10^{-3}	14.6	0.94	1.2×10^{-3}	9.7	0.97	**7.9×10^{-4}**	**10.5**	**0.98**	9.8×10^{-4}	−12.0
Lower portion calibration runs for 1999 tracer data at high (7% exceedance) flows													
WMC	16	0.77	3.9×10^{-3}	13.4	0.42	6.2×10^{-3}	−5.2	0.75	5.6×10^{-3}	−7.9	**0.79**	**3.7×10^{-3}**	**−7.8**
REN	20	0.53	4.2×10^{-3}	4.9	0.12	5.9×10^{-3}	−18.5	**0.84**	**2.8×10^{-3}**	**1.6**	0.57	3.8×10^{-3}	−14.7
Upper portion calibration runs for 2006 tracer data at moderate (50% exceedance) flow													
SQW	30	0.87	2.5×10^{-3}	−2.9	0.92	2.1×10^{-3}	−6.8	0.22	6.5×10^{-3}	−20.1	**0.85**	**2.8×10^{-3}**	**−3.5**
TRU	22	0.97	7.9×10^{-4}	5.7	0.99	5.3×10^{-4}	−5.5	0.39	3.2×10^{-3}	**−4.0**	**0.97**	**7.7×10^{-4}**	−4.3
BRO	28	0.94	6.9×10^{-4}	6.0	0.98	4.4×10^{-4}	−5.4	0.46	1.9×10^{-3}	**−3.9**	**0.95**	**5.7×10^{-4}**	−4.8
GLE	27	0.96	6.9×10^{-4}	17.8	0.99	2.8×10^{-4}	−5.9	0.54	1.6×10^{-3}	20.9	**0.97**	**4.4×10^{-4}**	**−7.4**
BOC	19	0.92	4.5×10^{-4}	30.5	0.97	1.4×10^{-4}	−5.3	0.46	6.3×10^{-4}	25.9	**0.94**	**2.3×10^{-4}**	**−10.8**
Middle portion calibration for 2006 tracer data at high (5% exceedance) flow													
BOC	16	0.97	1.2×10^{-3}	−2.0	0.99	5.8×10^{-4}	−1.8	0.71	4.3×10^{-3}	−21.8	**0.96**	**1.4×10^{-3}**	**−4.9**
FAR	26	0.56	2.3×10^{-3}	−6.0	0.43	2.8×10^{-3}	−4.7	0.53	**2.3×10^{-3}**	−25.8	**0.54**	2.3×10^{-3}	**−6.7**
MOG	16	0.86	6.5×10^{-4}	−0.2	0.99	1.9×10^{-4}	−3.2	0.70	9.7×10^{-4}	−16.0	**0.85**	**7.3×10^{-4}**	**−4.7**
Lower portion calibration for 2006 tracer data at high (13% exceedance) flow													
WMC	16	0.98	7.5×10^{-4}	7.1	—[a]	—[a]	—[a]	0.70	2.3×10^{-3}	−11.6	**0.94**	**9.4×10^{-4}**	**0.6**
REN	17	0.97	4.0×10^{-4}	8.8	—[a]	—[a]	—[a]	0.87	7.1×10^{-4}	**−1.6**	**0.97**	**4.7×10^{-4}**	8.8

Note: RMSE = root mean squared error; n = number of observations compared. See Table 1 for site abbreviations. Bold font indicates best statistical results between Eqs. (5) and (7).

[a] OTIS-P did not run for lower portion with storage for 2006 calibration.

therefore assumed to apply to directly downstream reaches to increase the likelihood that errors in estimated main channel areas would be underestimations, which would result in prediction of faster downstream transport, providing conservative estimates of arrival time.

Uncertainty in streamflow scenarios also had the potential to alter simulated travel times. Truckee River streamflows vary daily due to reservoir operations and run-of-river diversions, and the 13 streamflow scenarios did not account for such variability of streamflow. To simulate lateral inflow from a tributary over a 30-m segment, each major tributary in the spill model had a flow value from which lateral inflow was calculated. These tributaries can exhibit variations in flow on a daily and seasonal basis that was not accounted for in the spill model. The OTIS model has been shown to be sensitive to the lateral inflow parameter, and the inability of the Truckee River spill model to account for different tributary contributions (and lateral inflow as a result) represents uncertainty in travel time estimates (Scott et al. 2003).

In the end, assumptions made to address these uncertainties in the Truckee River spill model were chosen to provide the most conservative estimate of time of arrival for TMWA operators. In the event of a spill, model estimates would primarily be used to determine the time available to mobilize for treatment options or plant shutdowns. In accordance with their emergency plan, TMWA operators would begin monitoring the river upstream of their intakes to provide actual data on the progression of the spill downstream, and model predictions of peak concentrations or duration of impact would not be as critical for making decisions about how to address the situation.

Recommendations for Further Work

To address several of the mentioned uncertainties, recommendations for further work are suggested. As is the case in much of science, more data are needed. High-flow tracer data were not available for the upper portion, which would provide data for the worst case scenario of a spill occurring on the Truckee River in terms of arrival time. It is also recommended that an additional tracer study take place for the entire model extent under low-flow conditions. The results of this study show that the largest range of uncertainty in arrival time occurs at low flows. Therefore, calibrating the OTIS model to data collected under low-flow conditions would increase the robustness of the Truckee River spill model.

Also, with any subsequent tracer studies, streamflow measurements are needed at diversions and tributaries as well as at sample sites. Streamflow and main channel cross-sectional area were the two most influential parameters of the spill model, but several of the 1999 and 2006–2007 streamflows were not actually measured; instead they were estimated using nearby stream gauge data. Similarly, none of the diversions were quantified

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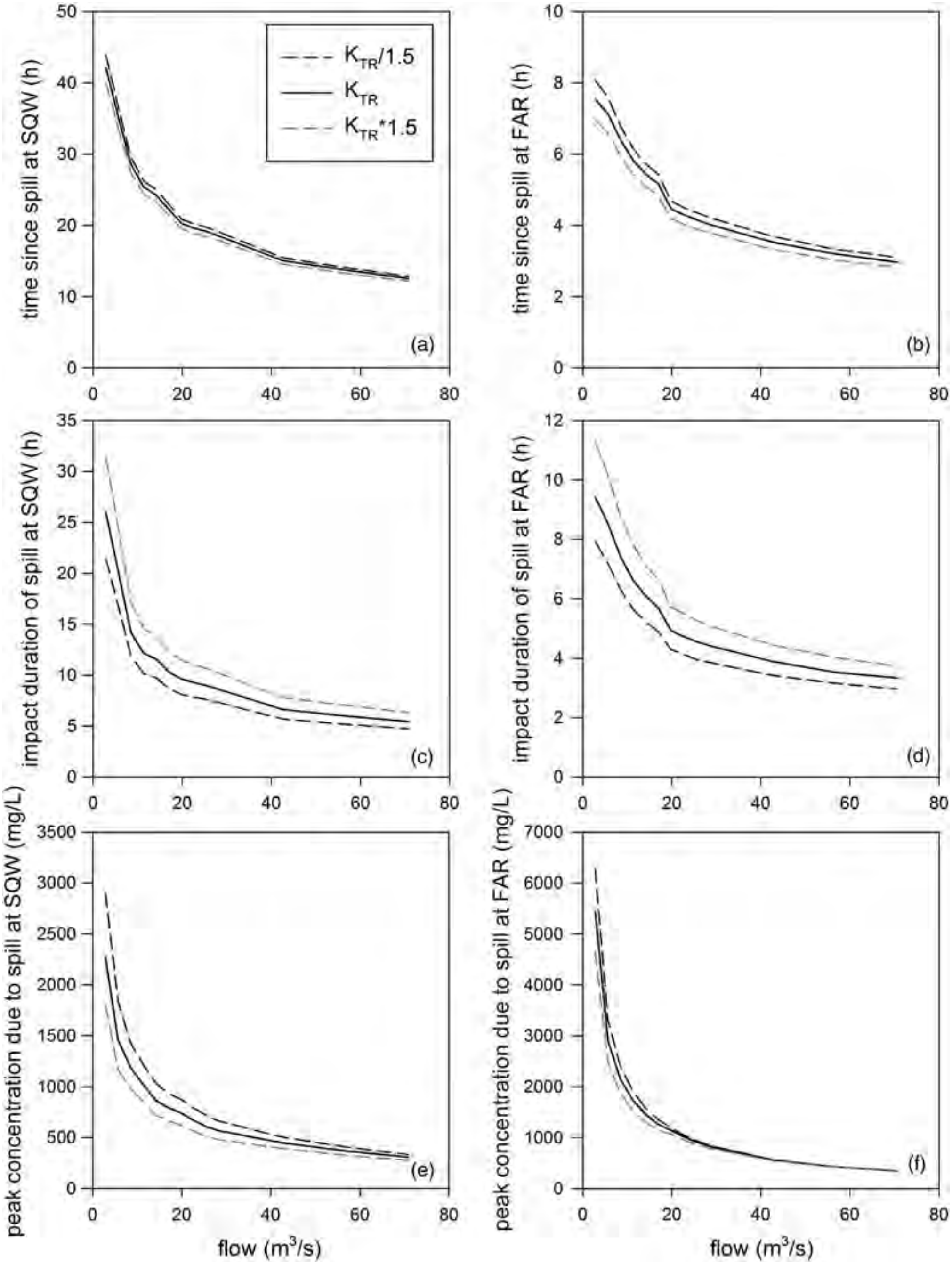

Fig. 4. Results of model simulations under different flow conditions for train spills occurring at SQW and FAR (see Table 1 for site abbreviations); simulated arrival times at TMWA Highland Diversion are shown for train spills occurring at (a) SQW and (b) FAR; simulated duration of impact at TMWA Highland Diversion are shown for (c) SQW and (d) FAR; simulated peak concentrations at TMWA Highland Diversion are shown for: (e) SQW and (f) FAR; results for runs with calculated K_{TR} values using Eq. (7) are shown, as well as results for runs with dispersion set at $K_{TR}/1.5$ and $1.5K_{TR}$)

during the two tracer studies. Calibrating the model with streamflows that are measured during tracer studies would benefit overall calibration.

To improve estimates with the existing model, the measurement of additional cross sections of the Truckee River would be beneficial for calibration of the spill model. With additional cross sections measured with corresponding streamflows, a hydrodynamic model of the Truckee River could be used to estimate better spill scenarios of streamflows along the river and corresponding cross-sectional areas. Several studies have linked unsteady hydrodynamic flow models with solute transport models to investigate the transport of hypothetical spills into a river (Wiley 1993; Nishikawa et al. 1999).

Continued research on estimation of longitudinal dispersion in rivers under different flow conditions would reduce uncertainty in model predictions. Theoretical estimates of longitudinal dispersion have evolved from early stages with an increase in estimation performance, but still are not able to make very precise predictions. Deng et al. (2002) developed an equation that accounted for the effects of river sinuosity on dispersion that performed within

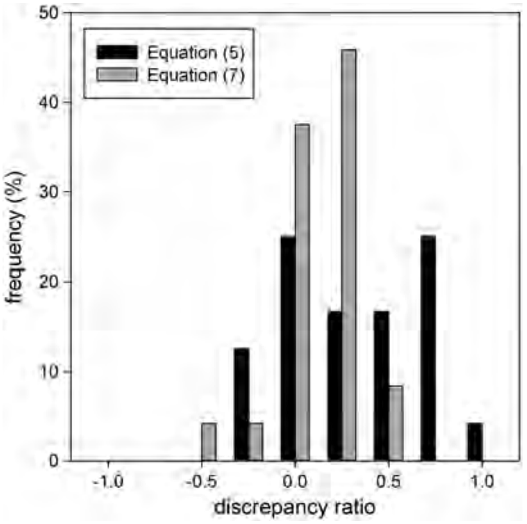

Fig. 5. Frequency plot of discrepancy ratios for dispersion values using Eq. (5) ($n = 24$) and Eq. (7) ($n = 24$)

a factor of 2 to observed values of dispersion, but the equations incorporate hydraulic parameters that are not easily measured. Further development of longitudinal dispersion equations should investigate the effects of river sinuosity on dispersion, as well as incorporating the effects of transient storage on dispersion.

Acknowledgments

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TRUCKEE MEADOWS WATER AUTHORITY

APPENDIX 2-9

BASIN SUMMARIES

A. TRUCKEE RESOURCE AREA HYDROGRAPHIC BASINS

SPANISH SPRINGS VALLEY – HYDROGRAPHIC BASIN 85

Introduction

Spanish Springs Valley (”SSV”), Hydrographic Basin 85, is a topographically closed basin bounded on the east by the Pah Rah range and on the west by the Hungry Ridge range covering an area of approximately 80 square miles. Figure 1 depicts the Spanish Springs Hydrographic Basin and location of TMWA production wells. The basin can be divided into two aquifer systems from which water is pumped into public water systems: (1) a volcanic rock aquifer located on the east side of the basin and (2) an alluvial aquifer in the western and central portion of SSV. A third portion of the basin, a granitic aquifer on the northeast basin slopes of the Pah Rah Range, is a meager aquifer that barely supports approximately 380 domestic wells.

Prior to development in the valley, which began in earnest in 1979, SSV supported various small-scale ranching and farming operations. The area has grown considerably since then from a population of 410 residents in 1979, to 2,974 in 1989, to 18,699 in 1999, 40,503 in 2010, and almost 44,000 in 2015. Water supply for SSV was from wells on the west side of SSV from the early 1960’s through the early 2000’s. Since that time, the majority of water to service the growth areas originated from the Truckee River and new wells on the east side of SSV.

Public Water Systems

TMWA currently operates eight active production wells in two distinct well fields serving almost 16,000 residential customers in SSV. The Desert Springs system is located on the west side of SSV and consists of four active production wells constructed between 1963 and 1990. One additional well, Desert Springs 4 (“DS4), currently operates as a recharge well only. The west side wells are completed in alluvial material and have production capacities ranging from 350 to 750 gallons per minute (“gpm”). The Spring Creek system is located primarily on the east side of SSV and consists of four newer wells constructed between 1997 and 2005. The east side wells are completed in fractured volcanic material and have production capacities ranging from 1,000 to 3,000 gpm.

Besides TMWA, Utilities, Inc. has facilities and customers in the Spanish Springs basin. Utilities, Inc., a Public Utilities Commission of Nevada (“PUCN”) regulated utility, has a service area north of La Posada Drive and east of Pyramid Highway and serves about 580 connections in the area previously referred to as “Sky Ranch”.

Domestic Wells

There are 410 domestic wells in SSV, most of which occur in the northeast portion of the valley. The State of Nevada allows each domestic well owner to pump up to 2 acre feet/year (“AF/yr”); 410 domestic wells have the potential to extract up to 820 AF/yr (see Figure 2).

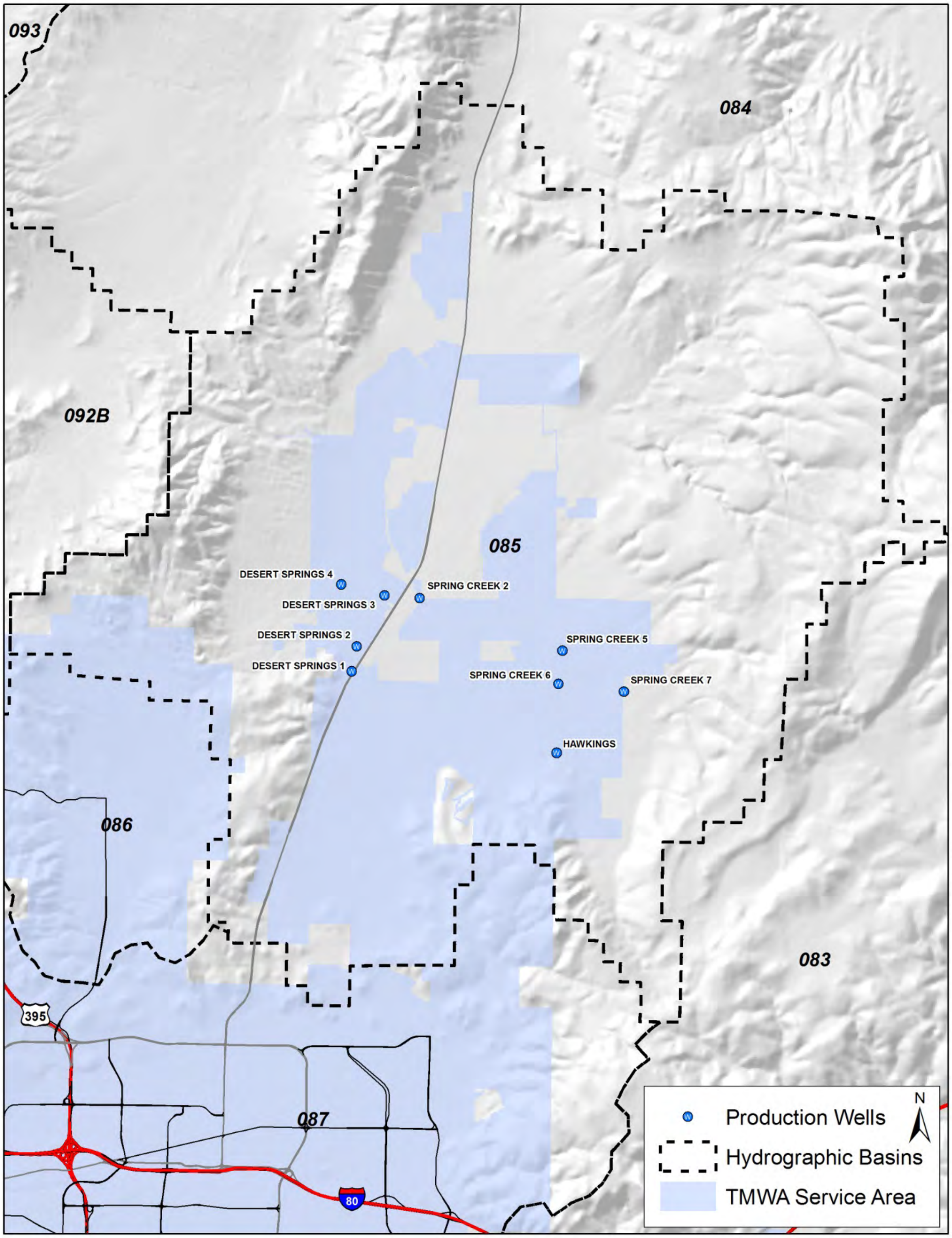

Figure 1. Spanish Springs Valley Hydrographic Basin 85 Location Map

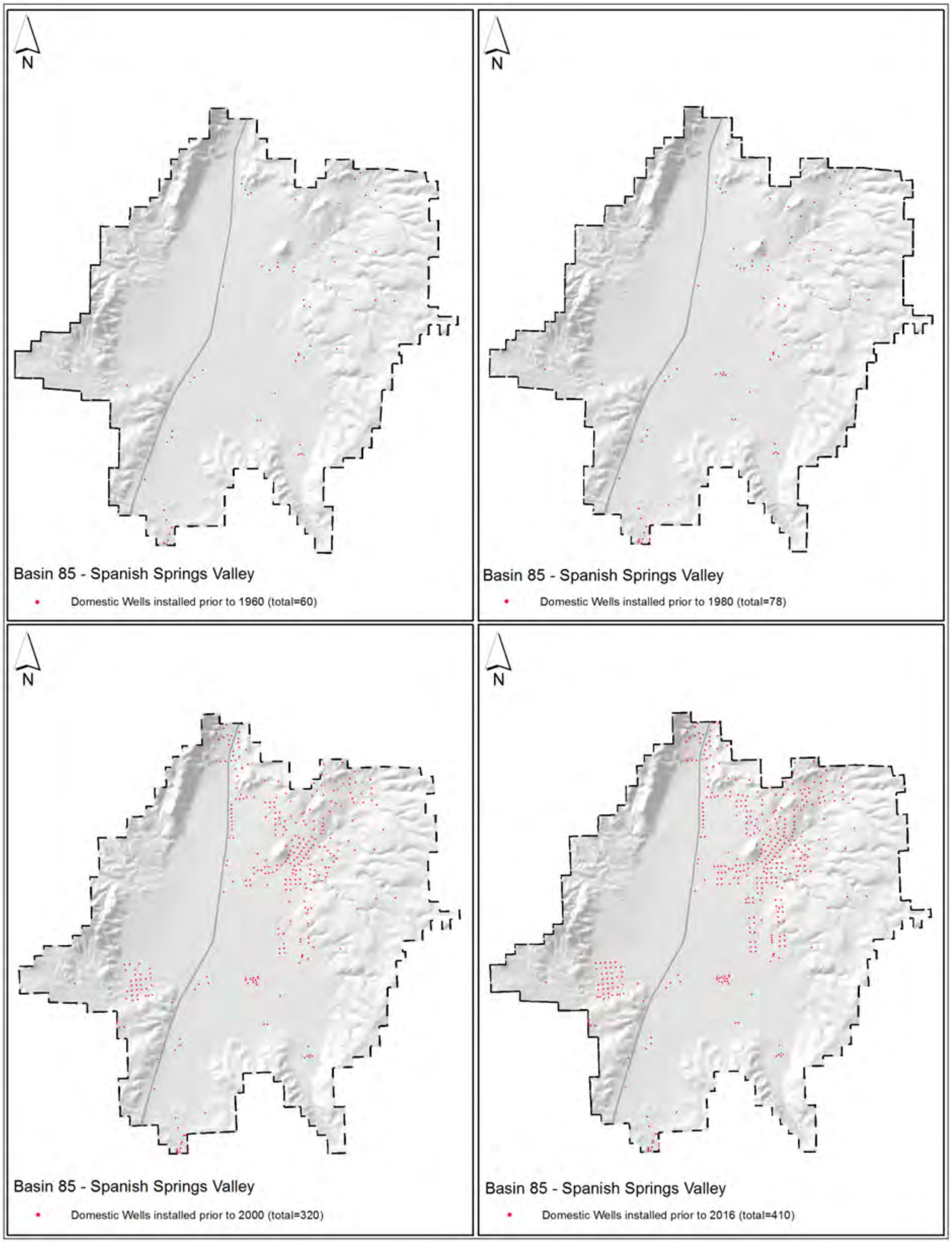

Figure 2. Change in the Number of Domestic Wells in Hydrographic Basin 85

Current Resource Management Practices

TMWA's primary source of water committed to the Spanish Springs basin is daily delivery of treated surface water from TMWA's Chalk Bluff and Glendale treatment plant. TMWA has eight wells in Spanish Springs with rights committed to serve customers in the area. The wells are used 2 to 6 months a year to augment summer peak demand or during emergency conditions. TMWA began groundwater recharge activities at its Hawkins Court well in 2009 and anticipates increasing recharge significantly over the next 5 years in several of the former Washoe County Department of Water Resources ("WDWR") wells.

Winter demands are met with treated Truckee River water. Surface water is also used in the summer irrigation season to meet base flow demand and increase water quality from water delivered from west side wells. Peak day demands during the summer are met by eight groundwater wells. Facilities were completed in 2009 that allows TMWA to increase the deliveries of Truckee River water so that reliance on wells for winter supplies can be reduced.

Water Resources

Natural Groundwater Recharge

About 67% of the annual 8 inches/year precipitation in SSV falls as snow and rain from November through April. Most of the precipitation on the valley floor is lost through evaporation and has an insignificant impact on groundwater recharge (Berger et al., 1997). Natural ephemeral streams are generated from intense rainstorms or large snow melt episodes and drains towards the center of SSV.

The Orr Ditch imports irrigation water from the Truckee River and the North Truckee Drain was constructed to return irrigation runoff to the Truckee Meadows. Natural groundwater recharge from mountain snowmelt and runoff to the basin is estimated at 1,300 AF/yr (Pohll, 2015). Recharge from the Orr Ditch is estimated at 140 AF/yr (Pohll, 2015). Water transported via the Orr Ditch has declined significantly over the past ten years due to conversion of irrigable lands and their water rights to residential housing and overall reductions of flow in the Orr Ditch.

Besides precipitation and Orr Ditch recharge, the main water inputs to the groundwater system are septic effluent, municipal well recharge, turf irrigation from domestic, public, and recreational parcels.

Groundwater Pumping

Over the past fifteen years, the majority of pumping has moved from the west side of SSV to the east side of SSV. Municipal groundwater withdrawals peaked in 2007, with over 3,100 AF withdrawn from the aquifer. Since that time there has been a significant decline in pumping, with withdrawals continuing to decrease from over 3,100 AF in 2007 to less than 2,000 AF in 2015. As shown in Figure 3, pumping has decreased on the west side by almost 1,700 AF/yr and has increased on the east side by approximately 1,300 AF/yr, with an overall decrease in pumping of approximately 400 AF/yr.

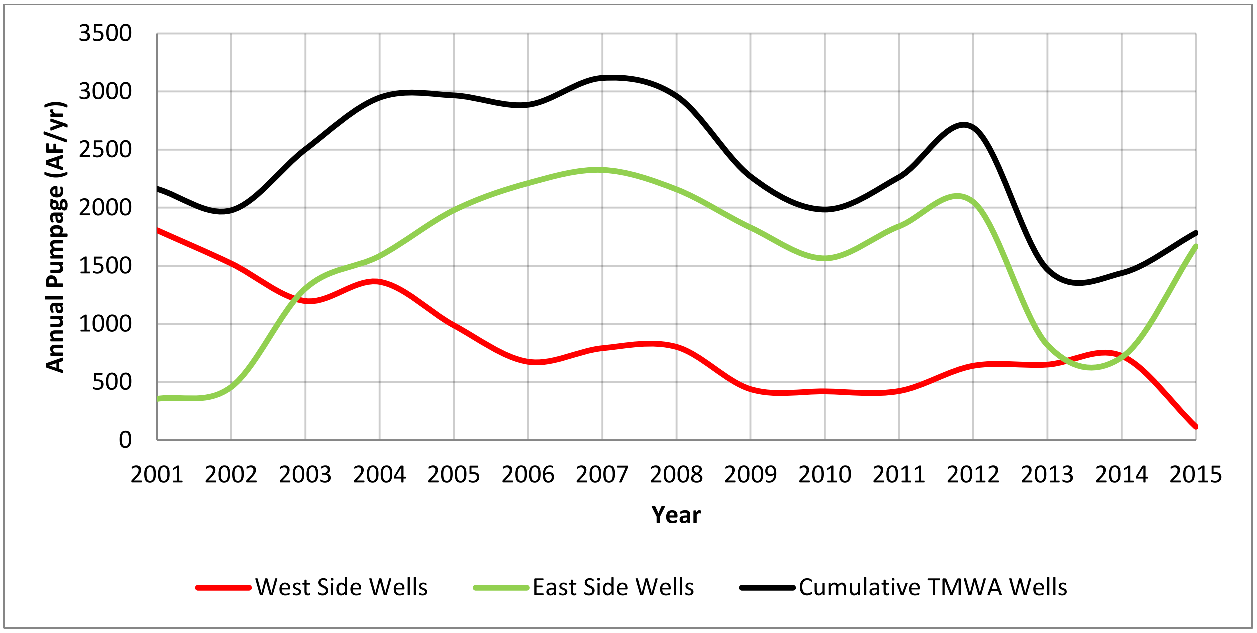

Figure 3. Cumulative Groundwater Pumping in Hydrographic Basin 85

Groundwater Levels

As depicted in Figure 4, regional groundwater elevations indicate flow towards the center of SSV off of mountain ranges from the east and west, and then north or south towards subsurface flow connections to neighboring basins.

Hydrographs from 2001 to 2015 represent changes in water levels resulting from the variation in precipitation, pumping, natural recharge, municipal recharge, evapotranspiration, and aquifer properties. The graphs indicate that water levels fluctuate seasonally with rises during non-pumping, natural recharge, and municipal recharge periods (winter months) and declines during pumping periods (summer months). Figures 5 and 6 depict water level changes over time in selected wells throughout SSV.

Groundwater levels have declined in the eastern part of SSV, while water levels have risen on the west side of SSV. This can be attributed to a transition over the last fifteen years to reduced pumping on the west side to avoid water quality issues associated with septic effluent, and increased pumping on the east side where water quality is unaffected. Municipal well recharge on the west side of SSV also contributed to the water level recovery. Surface water delivered to SSV over the past eight years has also reduced the need for pumping; which helps groundwater levels to rebound.

Figure 7 depicts water level declines of approximately six feet on the east side near the Spring Creek production wells, while increasing over five feet on the west side 2001 and 2005. Water levels on the west side have been recovering for almost 10 years due to reduced pumping on the west side and recharge at DS4.

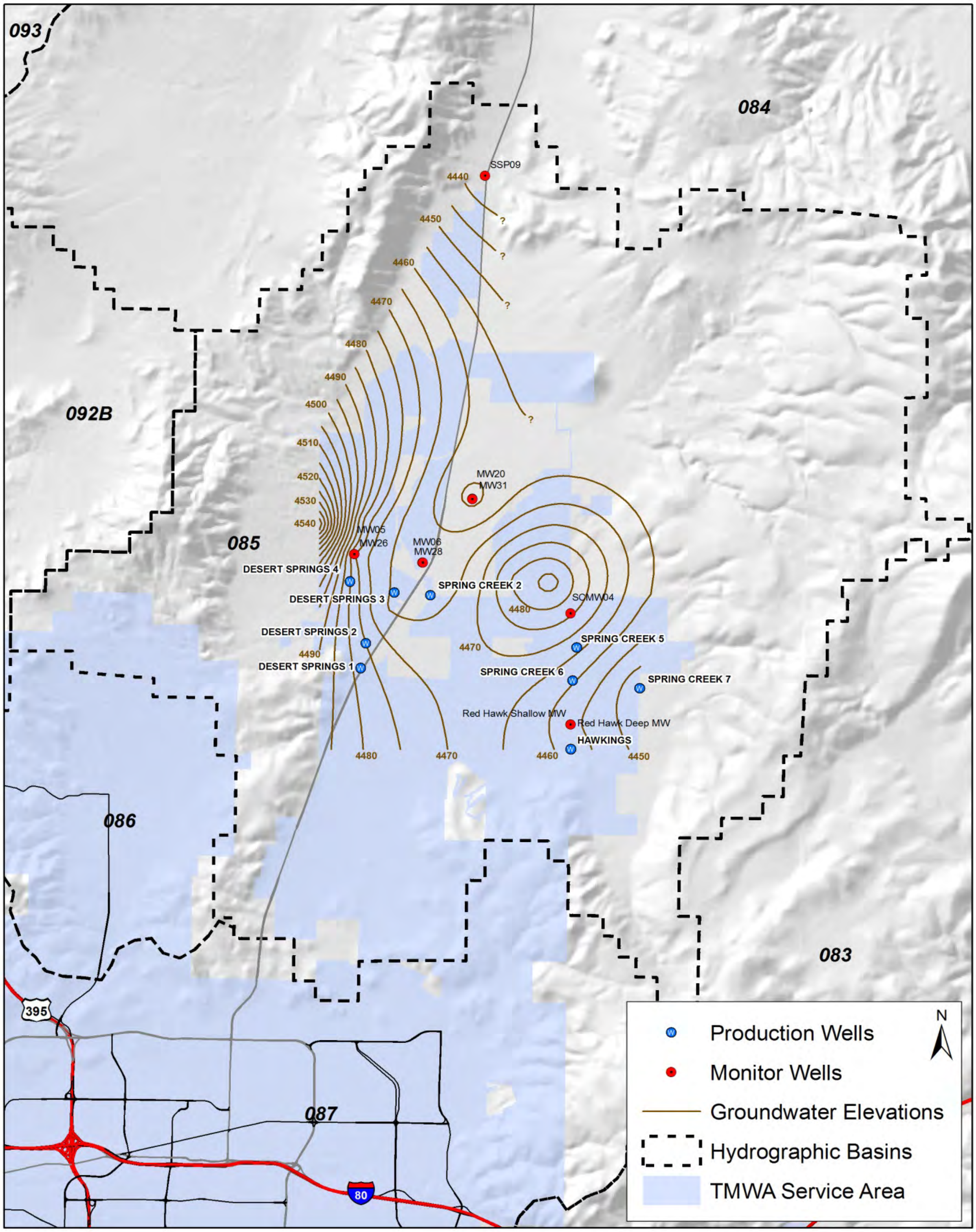

Figure 4. 2015 Groundwater Elevations Contour Map for Hydrographic Basin 85

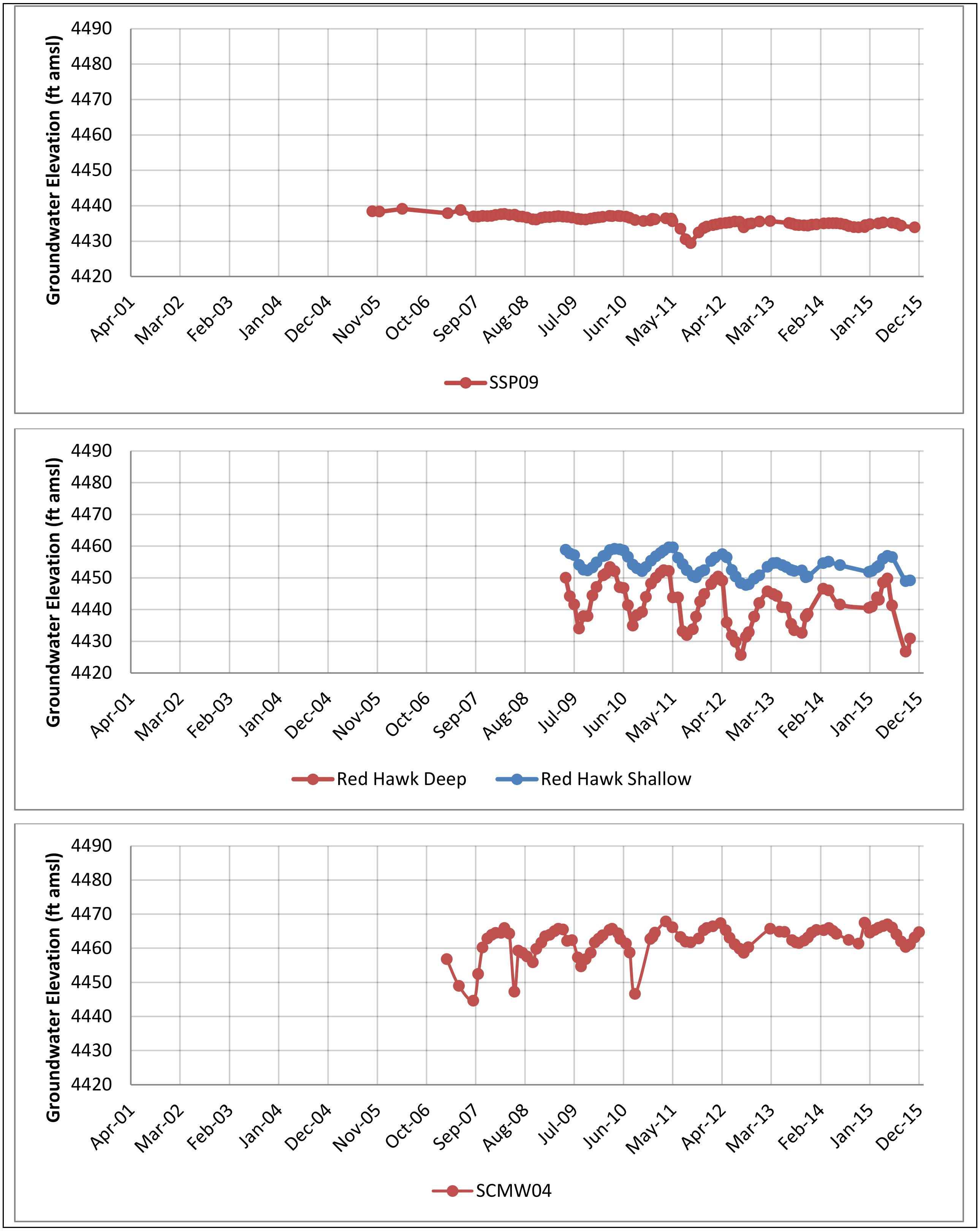

Figure 5. Change in Water Level in Selected Monitoring Wells

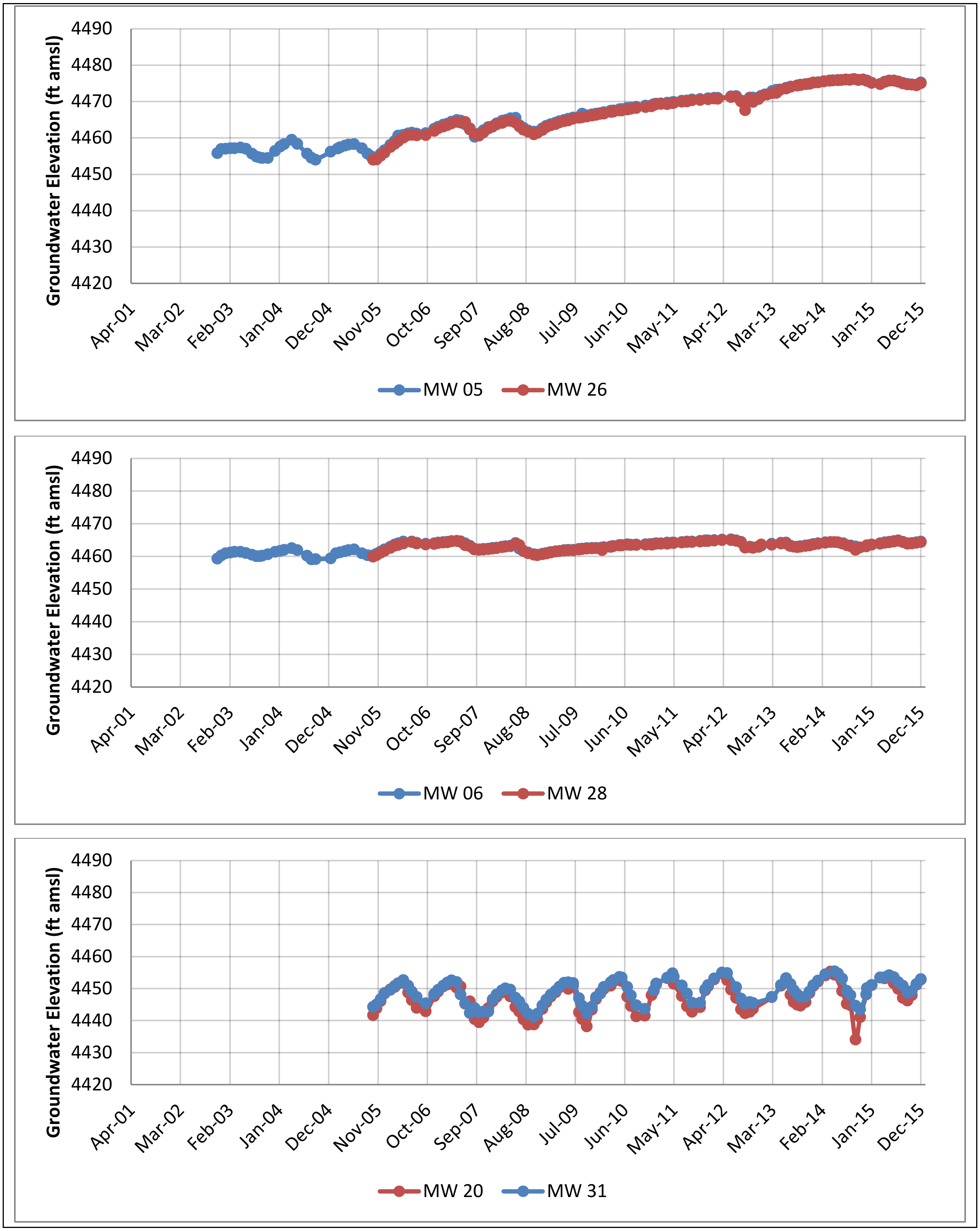

Figure 6. Change in Water Levels in Selected Monitoring Wells

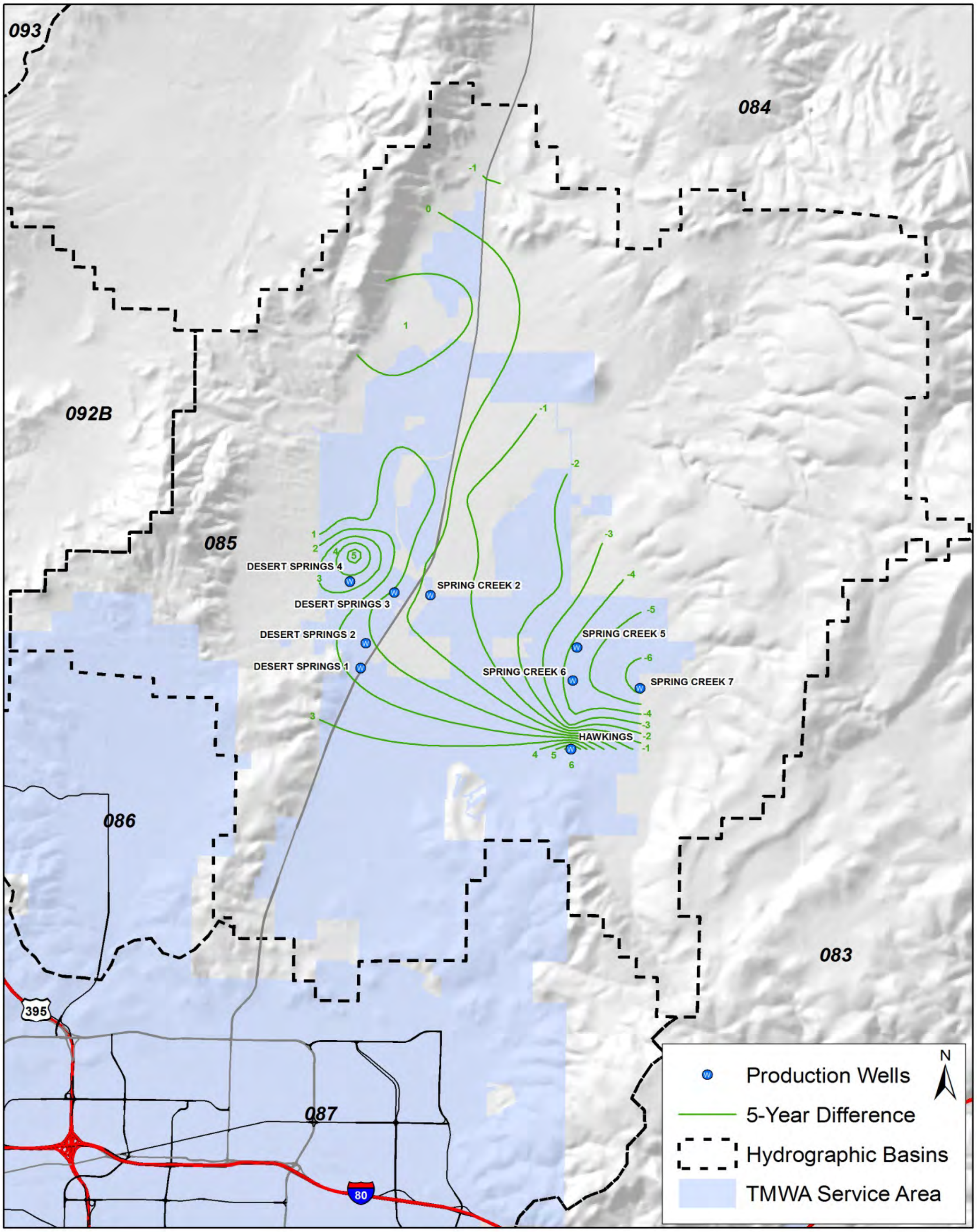

Figure 7. Difference in Groundwater Elevations 2010-2015 Hydrographic Basin 85

Groundwater Quality and Quantity

As depicted in Figure 8, poor groundwater *quality* exists in the central and southwest part of SSV whereas low water *quantity* dominates the northeast part of SSV. Poor groundwater quality is found in the southwest of SSV due to hydrothermally altered volcanic rock with high concentrations of arsenic and sulfate. In the center of SSV, septic tank effluent has polluted shallow groundwater with nitrate. Nitrate contamination has persisted over the past twenty years, rendering five production wells (Desert Springs 1, 2, 3, and 4 and Spring Creek 2) at risk. WDWR thoroughly investigated nitrate contamination and prepared full report that details sources, extent, and migration of nitrate titled, "Final Report: Spanish Springs Nitrate Remediation Pilot Project, Phase II: Nitrate Source, Extent, Magnitude, Migration, and Management Options" (Kropf and Dragan, 2010). Blending with Truckee River water and other well water is the current groundwater treatment practice for nitrate and arsenic. In addition to converting homes on septic to sewer, increasing the amount of artificial recharge ("ASR") in west side wells is a future alternative to help mitigate water quality issues.

All TMWA wells in SSV have been evaluated for future potential contamination through a Wellhead Protection Plan ("WHPP") updated in 2015. The plan includes the 2, 5, 10, and 20-year capture zones for each production well along with the locations of potential contamination sites. Additional information on groundwater contamination concerns in SSV is contained in TMWA's WHPP.

Aquifer Storage and Recovery

Recharge operations began in the east, southeast side of SSV in 2009. From 2009 through 2015, TMWA has successfully injected approximately 3,331 acre feet ("AF") of water to the groundwater system at the Hawkings Well. Water levels respond favorably and show a seasonal increase of approximately 7 feet in the Hawkings Well area. Information on the Hawkings Well ASR Program is contained in the 2015 semi-annual report titled, "Report on Aquifer Storage and Recovery, Spanish Springs Valley Hydrographic Basin; January 1 through June 30, 2015" filed with Nevada Divisions of Environmental Protection ("NDEP") and Nevada Division of Water Resources ("NDWR").

Pilot project recharge activities have been ongoing on the west side of SSV since 2012. In 2015, TMWA successfully recharged approximately 72 AF of water to the groundwater system at DS4. Water levels respond favorably and show a seasonal increase of over 30 feet in the DS4 area. In response to recharge of treated surface water, water quality in the area has shown improvement. Concentrations of nitrate-N have decreased by as much as 70 mg/L in nearby shallow groundwater since pilot recharge activities began in 2012. Information on the DS4 Pilot Recharge Program is contained in the 2015 semi-annual report titled, "Recharge Pilot Project, Spanish Springs Valley, Washoe County, Nevada; Semi-Annual Report, January through June 2015" filed with NDEP.

In 2015, TMWA recharged 1,055 AF in SSV and plans to increase ASR considerably. As improvements are made over the next five years, there is the potential to recharge upwards of 5,000 AF in the east and west side wells on an annual basis.

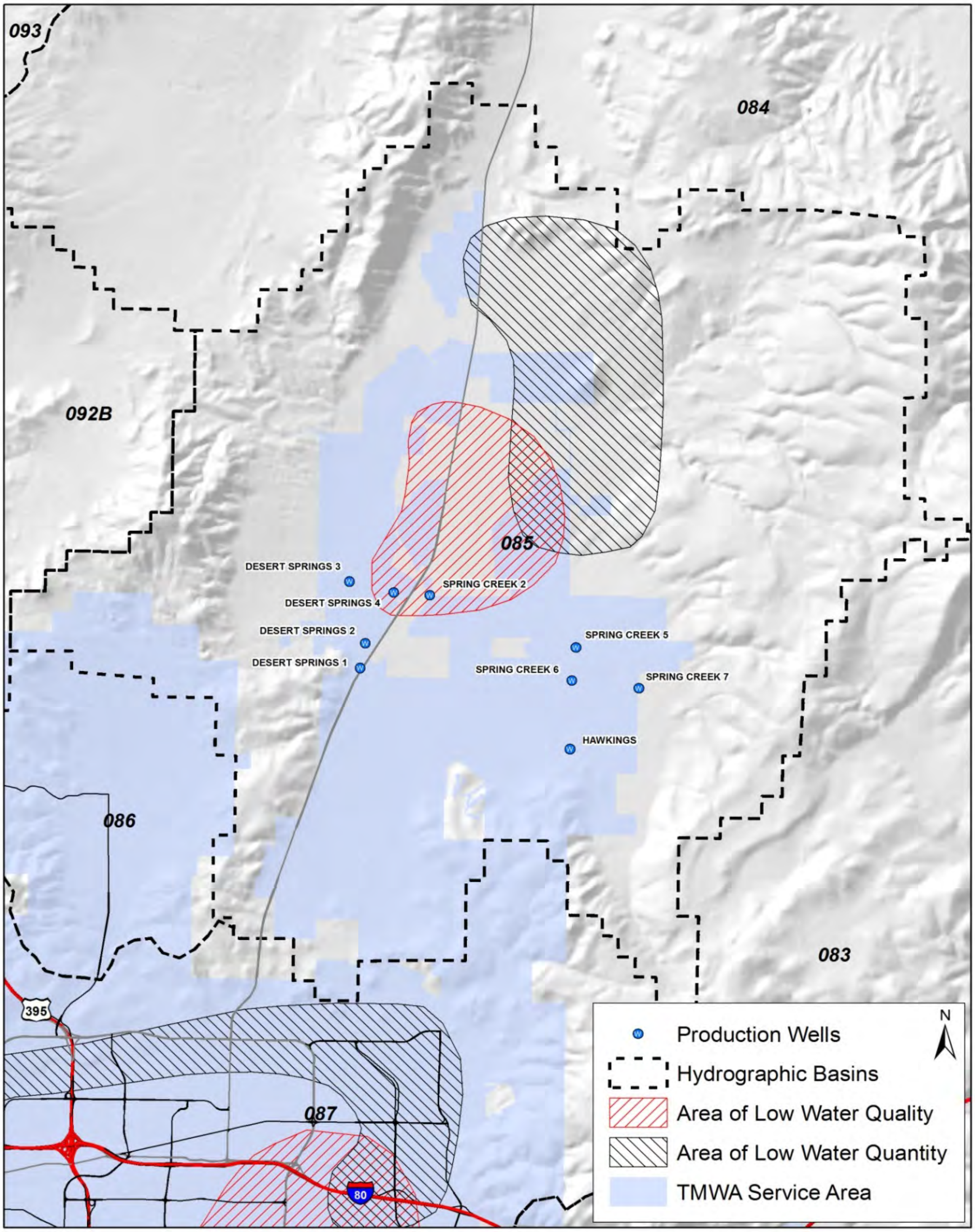

Figure 8. Areas of Poor Water Quality and Low Water Quantity in Hydrographic Basin 85

Groundwater Modeling

Several groundwater models have been completed for SSV over the years. The most recent version is an update to the 2009 Pohll et. al. model and is titled "Update to the Spanish Springs Valley Groundwater Model" (Pohll, 2015). Significant revisions in 2015 included:

- Updating the simulation period to include stresses from 2007 through 2014.
- Including injection at DS4 and Hawkings wells.
- Improving geologic model and spatial variability of hydraulic conductivity fields.
- Revising the spatial distribution of groundwater recharge including mountain-block recharge and transmission losses from the Orr Ditch and excess irrigation.
- Including water level measurements from domestic wells in the North-Northeast (Spring Creek East wells) in the calibration.
- Incorporating groundwater recharge from numerous turf irrigators.

The results of the updated model created the graphics and findings incorporated into this Basin Summary; are the basis of the capture zone analyses for TMWA's production wells; and are the basis of analysis for TMWA's WHPP.

Basin Challenges and Possible Solutions

The primary challenge is bringing groundwater back into balance given water demand and water quality concerns.

Water Demand

Well production constraints on the east side are limited by permitted duties at each well and sensitivity to domestic well owners to the north. Well production constraints on the west side are mostly limited to nitrate and arsenic contamination. Current base flow demands are being met with existing resources and facilities. However, additional and/or alternate sources of supply are needed to mitigate the effects of over pumping that has occurred in the basin and to meet future demands. Possible solutions include:

- *Increase Truckee River Use.* Increased use of Truckee River water to meet base flow demands and using wells for peaking is the current operational strategy and will increase into the future. This strategy has reduced the overall amount of pumping and has allowed water levels in areas to rebound. Increased surface water deliveries should have a cumulative positive effect.
- *Artificial Recharge*. Recharge (Desert Springs wells 1, 2, 3 and 4 and Spring Creek wells 4, 5, 6 and 7) with Truckee River water in winter months. This option could also help to improve the water quality issues at the Desert Springs water systems, particularly at Desert Springs 3. TMWA is completing permitting through the State Engineer's Office and the Nevada Division of Environmental Protection ("NDEP") to recharge treated surface water.

- *Indirect Potable Reuse (IPR)***.** An IPR program could be implemented to inject highly-treated-recovery water at the north end of the basin to offset over pumping and augment groundwater supplies.
- *Import Vidler Supplies***.** Redirect a portion of Vidler supplies to the basin to meet demands and/or for recharge. Other inter-basin sources could be considered as well.

Water Quality

Water quality issues in the basin are limited to arsenic (naturally-occurring) and nitrate (natural and septic) contamination in west side wells. Even if the high density septic systems are hooked-up to sewer, nitrate plumes are expected to persist. Over pumping on the west side may cause poor water quality to migrate from the shallow aquifer to municipal wells. Possible solutions include:

- *Convert Septics to Sewer*. Continued recharge of septic effluent to groundwater over time has a cumulative negative effect on groundwater quality. Converting homes on septic to sewer stops the flow of contamination and allows natural groundwater cycling and pumping to help dilute and remove nitrate from the groundwater system over time.
- *Increase Truckee River Use*. Increased use of Truckee River water to meet base flow demands and using wells for peaking is the current operational strategy and will increase into the future. Increased use of Truckee River water provides blending of surface with groundwater which also alleviates water quality issues associated with nitrate and arsenic in the short term. Increased surface water use may allow wells on the west side to relax and reduce the load of nitrate in the system.
- *Artificial Recharge*. Recharge (Desert Springs wells 1, 2, 3 and 4 and Spring Creek wells 4, 5, 6 and 7) with Truckee River water in winter months. This option could also help to improve the water quality issues at the Desert Springs water systems, particularly at Desert Springs 3. TMWA has received approved permits from the NDEP and is completing permitting through the State Engineer's Office to recharge treated surface water.

TRUCKEE MEADOWS – HYDROGRAPHIC BASIN 87

Introduction

The Truckee Meadows lies within a topographic basin that covers about 195 square miles and is bounded on the west by the Carson Range, on the east by the Virginia Range, on the north by lower mountains and on the south by the Steamboat Hills. The cities of Reno and Sparks are the major communities in the area.

Development began in Basin 87 in the 1850's as agricultural diversion of the Truckee River dominated the Truckee Meadows. Since that time, irrigated lands have given way to residential and commercial developments that service a population for the greater Reno/Sparks area.

The basin can be described as having two geographically and hydrogeologically distinct regions from which water is pumped into public water systems: (1) an alluvial fan and fractured volcanic rock aquifer located in the southwest part of the basin referred to as the southwest alluvial fan aquifer ("Alluvial Fan") and (2) a basin-fill aquifer in the central and northern part of the Truckee Meadows referred to generally as the basin-fill aquifer ("Basin-Fill").

Figure 1 depicts Hydrographic Basin 87 with the Alluvial Fan and Basin-Fill regions, and the location of Truckee Meadows Water Authority ("TMWA") production wells.

When compared to other basins in the Great Basin Province of Nevada, the uniqueness of the Truckee Meadows hydrographic basin is the presence of the Truckee River which flows west to east through the north Truckee Meadows ("NTM") portion of the Truckee Meadows basin. The Sierra Nevada Mountains on the west side of the basin and geologic units underlying the valley are complexly faulted. Regional faulting gave the mountains their large-scale size, shape, and relief. The present topography of the basin is the result of erosion and smaller scale fault structures. The resulting valley is a structural depression filled with unconsolidated basin-fill material comprised of weathered material from the surrounding mountain ridges including layers of clay, silt, fine- to coarse-grained sand, and gravel. Generally, basin-fill is coarser near the mountain ridges and becomes finer-grained in the center of the basin. The Basin-Fill is conceptualized as a complex aquifer system comprised of: 1) alluvium, 2) partly confined alluvium, 3) fractured volcanic sequences, and 4) granitic, volcanic, or metavolcanic basement rock. Alluvial sediments (1 & 2) are estimated at 500-1,000 feet thick in this area. The Truckee River deposited large quantities of coarse-grained alluvial materials along the river corridor and dominates the lithologies encountered by the majority TMWA production wells in the northern part of the basin. The southwest Alluvial Fan is conceptualized as a complex aquifer system comprised of: 1) thin alluvial fan deposits, 2) consolidated sedimentary deposits, 3) interbedded fractured volcanic sequences, and 4) granitic, volcanic, or metavolcanic basement rock. Alluvial sediments (1 & 2) are estimated at 300-500 feet thick in this area.

TMWA currently operates 44 active production wells in Basin 87. Active wells were completed from 1960 to 2011 and have production capacities range from a low of 200 to a high of 2,500 gallons per minute ("gpm"). Seven additional wells: I Street, Dilworth, Sparks High, Reed High, Innovation, Huffaker Place, and Double Diamond 3 are currently unequipped and projected to be brought online over the next 10 years. Two other wells, Peckham and Stanford, are unsuitable for drinking purposes but are used for non-potable applications such as construction water. Twelve of the active wells are located in the Alluvial Fan and the remaining 32 wells are located in the Basin-Fill on the valley floor of the Truckee Meadows basin.[1]

Approximately 1,480 domestic wells are located in Basin 87. The majority of these wells are located in the southwest part of Basin 87 on the southwest fan. The State of Nevada allows each domestic well owner to divert up to 2 AF/yr; with a total potential extraction by all domestic wells of over 2,950 AF/yr. Figure 2 depicts the increase in domestic wells constructed in Basin 87. Over time, an increasing number of residential well owners have experienced well failures. These failures are generally attributed to the shared aquifer responding to drought conditions; shallow initial well construction; high domestic well density; the increased number of domestic wells; and municipal well production volumes.

Demands in Hidden Valley and Heron's Landing service areas are met with a combination of surface water and groundwater that is treated at the Longley Lane Treatment Plant. The well field to serve this area consists of four production wells. Treatment consists of manganese and arsenic filtration and chlorination. This treated water can also be pumped via pipeline to the south Truckee Meadows.

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[1] As a result of the merger with Washoe County, the various groundwater resources and wells that were incorporated into TMWA are further categorized whether the well is part of the original TROA agreement or are an addition to non-TROA groundwater resources. Under this categorization, TMWA's 27 pre-merger wells are considered part of TROA groundwater resources and TMWA's addition of the former Washoe County Department of Water Resources ("WDWR") 17 wells in the Truckee Meadows basin are part of the non-TROA groundwater resources. The majority of TROA wells occur in the Basin-Fill whereas non-TROA wells, with a few exceptions (Hidden Valley and Double Diamond wells), generally occur in the Alluvial Fan.

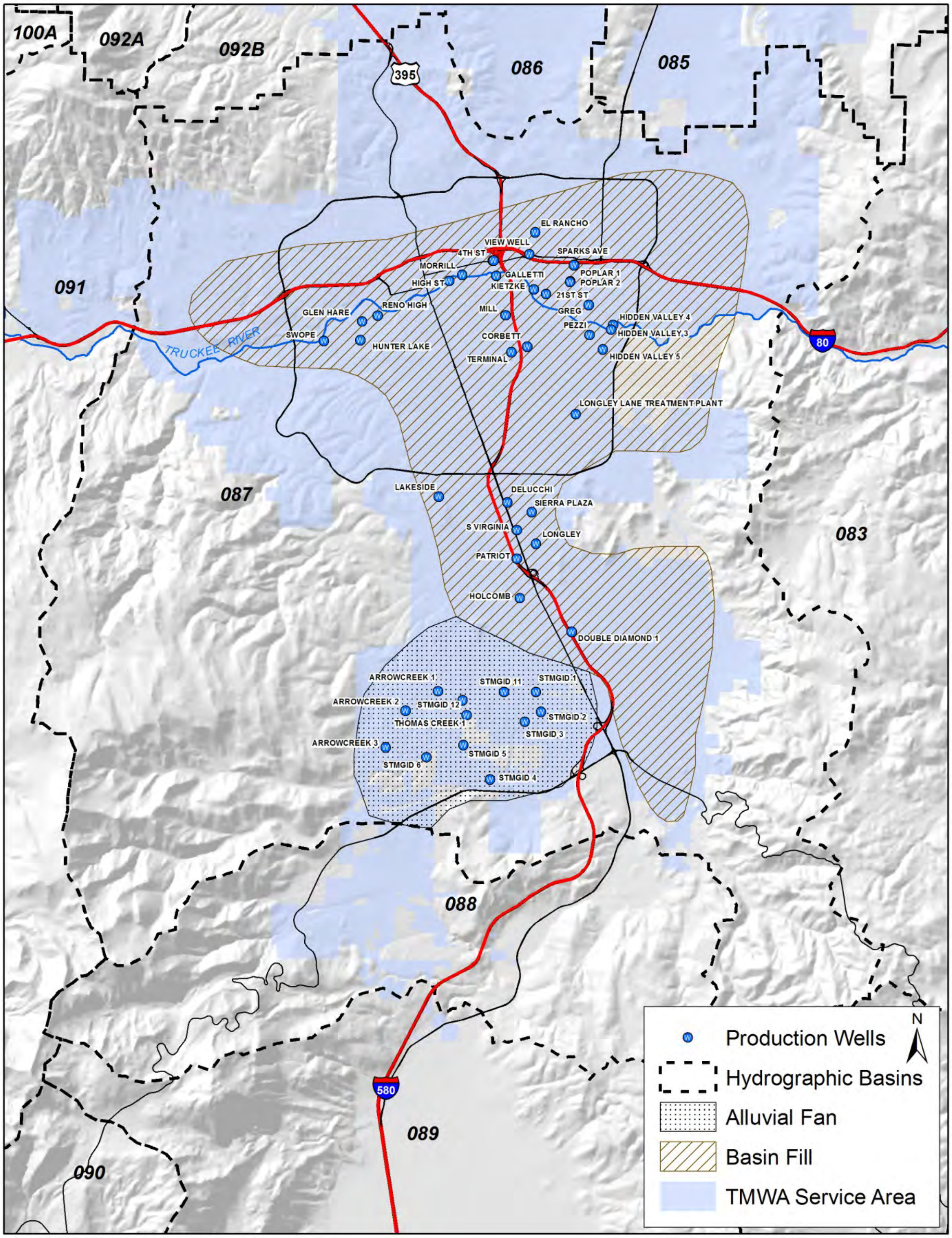

Figure 1. Truckee Meadows Hydrographic Basin 87 Location Map

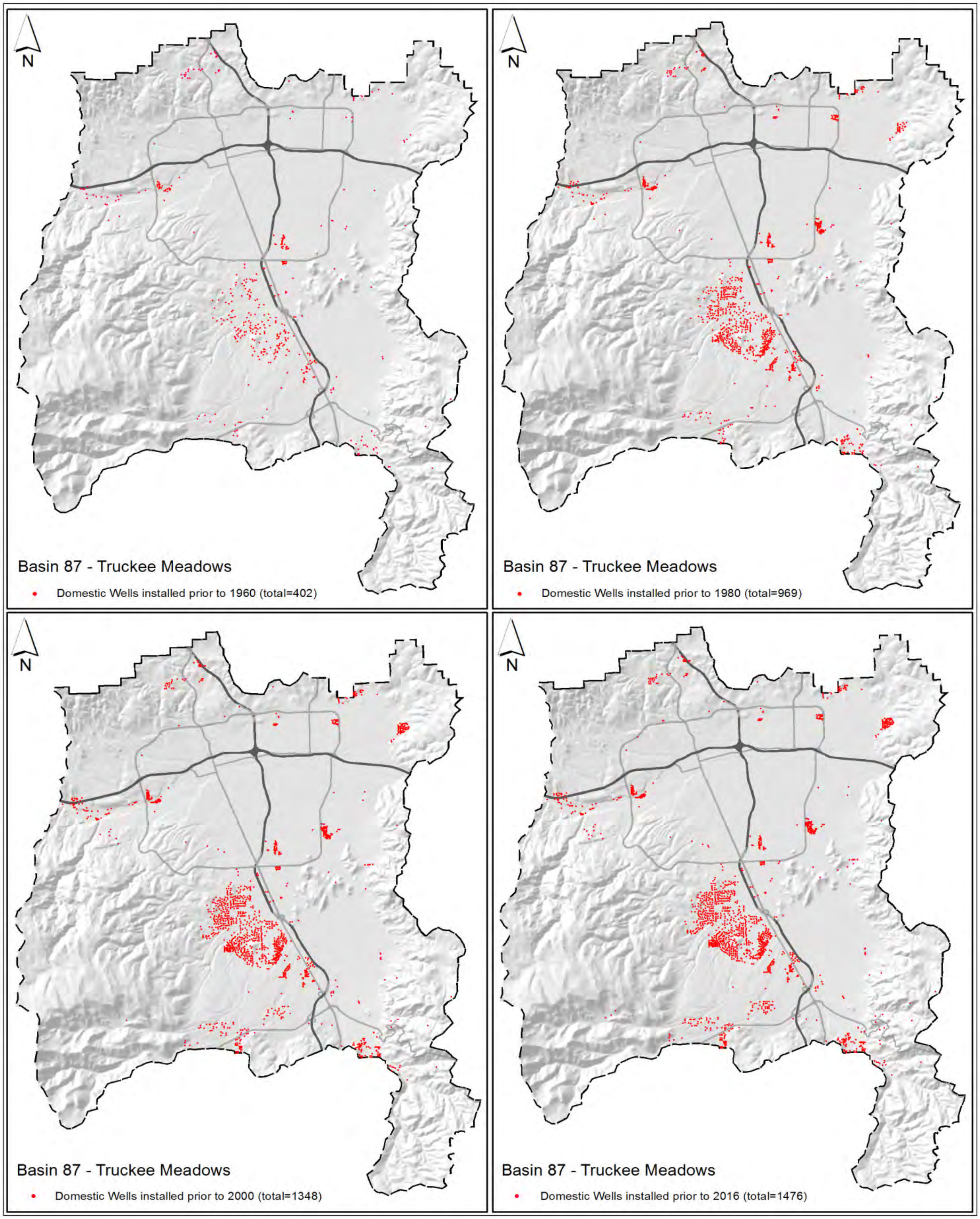

Figure 2. Changes in Number of Domestic Well in Hydrographic Basin 87

Water Resources

The Truckee River is the principal surface water source in the Truckee Meadows. The river's headwaters originate in the Sierra Nevada around Lake Tahoe where small streams feed the lake around its margins, and then discharges from the lake on the northwest side. The Truckee River enters the Truckee Meadows from the Carson Range on the west at an elevation of about 4,630 feet, meanders through the Truckee Meadows and leaves through a canyon in the Virginia Range at an elevation of about 4,370 feet. The Truckee River's principal tributary, Steamboat Creek and its tributaries Whites Creek, Thomas Creek and Dry Creek, drains to the south and southwest parts of the meadows. Steamboat Creek enters the area from the south through a bedrock constriction at an elevation of about 4,600 feet. Whites and Thomas Creeks enter at an elevation of about 5,900 feet and contribute flow to Steamboat Creek. The drainage basins of Whites and Thomas Creeks extend to near the crest of the Carson Range at an elevation of about 9,000 feet. Other streams that provide flow to the Truckee River are Alum, Hunter and Evans Creeks that drain the northwest part of the Carson Range.

A network of irrigation ditches supplies water to farms and ranches in the Truckee Meadows. Principal ditches that divert water from the Truckee River include Steamboat, Last Chance, Lake, Cochran and Pioneer ditches on the western side of the area and the Highland and Orr ditches on the northern side of the area. The Orr ditch delivers water to Spanish Springs Valley to the north of the Truckee Meadows and returns excess water to the Truckee River through the North Truckee Drain. Excess irrigation water from the ditches along the western side of the area is returned to the Truckee River by the Boynton Slough and Steamboat Creek.

Natural Groundwater Recharge

The climate in the Truckee Meadows is arid to semiarid because the area is in the rain shadow of the Sierra Nevada Mountains. Precipitation in Basin 87 falls as snow and rain typically from November through April. Precipitation for much of the Truckee Meadows ranges from about 6 to 10 inches a year on the valley floor and foothill areas, but the mountains to the west receive as much as 40 inches a year and provide the majority of the natural recharge for the basin. The natural groundwater discharge supports vegetation principally in the valley lowlands of the Truckee Meadows and provides water directly to drains and creeks passing through the Meadows.

The water-bearing materials in the Truckee Meadows are recharged from infiltration of precipitation, seepage from streams and portions of the Truckee River entering or crossing the Meadows, underflow from tributary valleys, seepage from irrigation ditches, deep percolation of water applied for irrigation of pasture, row crops, lawns and other greenscape areas, and from waste water discharged from septic tanks, and from the injection of treated surface water into public supply wells used for artificial recharge. A significant amount of recharge to the water-bearing materials in Truckee Meadows is due to seepage from irrigation canals and deep percolation of water applied for irrigation. In the past, it has been estimated that approximately 25% of water applied for irrigation percolates into the groundwater reservoir. It has been assumed that as land is converted from irrigated pasture or row crops to lawns or other types of water consumptive landscaping, the recharge from the land would be reduced.

The natural groundwater recharge estimate from upland precipitation and snow melt is about 27,000 acre feet/year ("AF/yr") for the entire basin (Van Denburgh, 1973). The southwest fan area alone is estimated to receive between 9,000 and 15,000 AF/yr as groundwater recharge from upland precipitation and snow melt.

Groundwater Pumping

Groundwater beneath the Truckee Meadows has been pumped from the aquifer system for over fifty years. Large quantities of groundwater are available from that part of the aquifer containing unconsolidated rocks of alluvial origin. Groundwater is also available from consolidated rocks, generally in the foothills surrounding Basin 87.

Twelve of TMWA's 44 wells, located in the southwest Alluvial Fan, are used up to 12 months a year; the remaining 32 wells are located in the Basin-Fill and are primarily used to augment summer peak demand or during emergency conditions. Facilities are being constructed over the next two years to allow TMWA to increase the deliveries of surface water to the higher elevations of the southwest alluvial fan so that reliance on wells for winter supplies can be reduced.

At the basin scale, the annual groundwater yield that can be withdrawn without depleting the aquifers on a sustainable basis is less than the annual recharge. Over the past five years, the average municipal groundwater withdrawals are about half of the average annual natural recharge to the basin.

Groundwater withdrawals from production wells in Basin 87 assigned to Truckee River Operating Agreement ("TROA") water supplies ranged between 5,480 and 16,580 AF/yr since 2001 (Figure 3). Pumping at non-TROA wells has decreased significantly since 2001. Groundwater withdrawals from all non-TROA production wells in Basin 87 ranged between 4,630 and 7,000 AF/yr since 2001 (Figure 4). Increased non-TROA well pumping is due to three new production wells installed in 2006, 2008, and 2012 to meet demands.

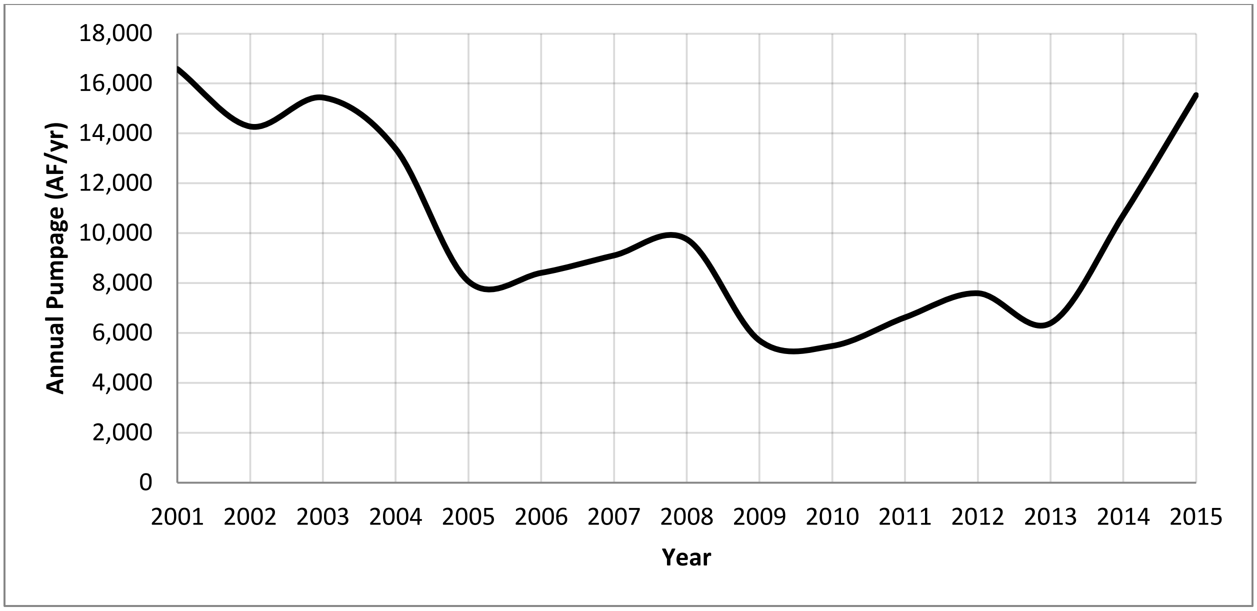

Figure 3. Groundwater Withdrawals from TROA Assigned Wells in Basin 87

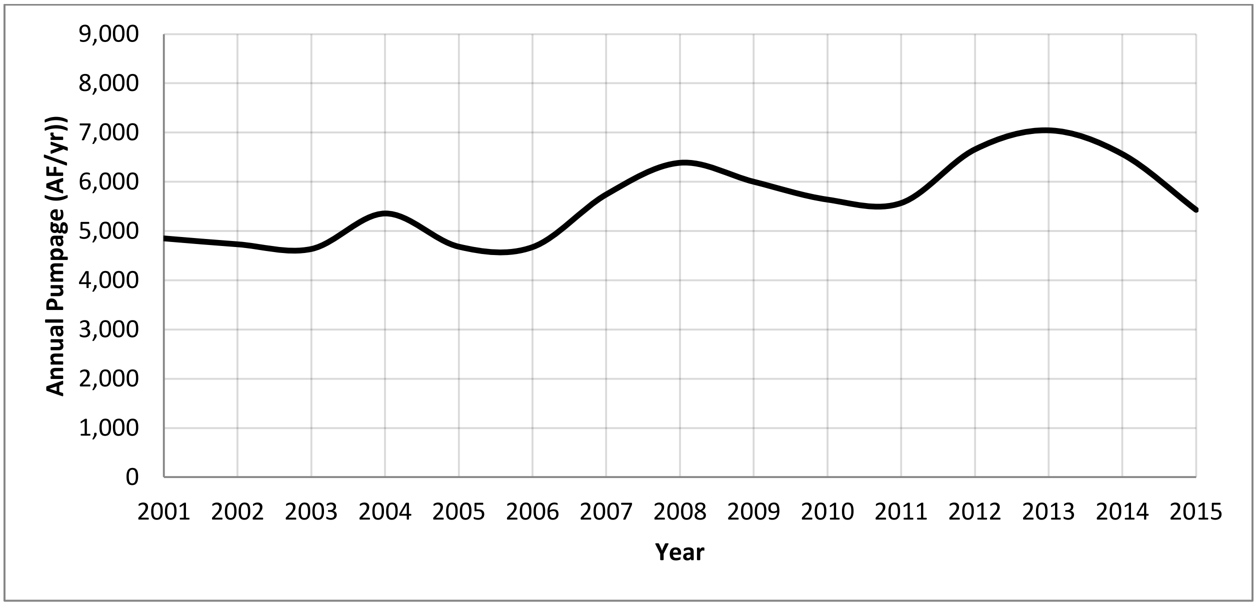

Figure 4. Groundwater Withdrawals in non-TROA Wells in Basin 87

Groundwater Levels

Groundwater elevations vary significantly throughout the basin, with groundwater at shallower depths in the Basin-Fill than groundwater in the Alluvial Fan aquifer system. Hydrographs from 2001 through 2015 represent changes in water levels resulting from the variation in precipitation, pumping, artificial recharge, evapotranspiration, and aquifer properties. The graphs indicate that water levels fluctuate seasonally with rises during non-pumping and recharge periods (winter months) and declines during pumping periods (summer months).

Figures 5 through 9 depict groundwater hydrographs for several wells within the Basin-Fill in Basin 87. Water levels are relatively stable in the Basin-Fill wells. Seasonal recharge activities allow groundwater levels to mound up, while short-duration seasonal pumping drops water levels for a brief time. As shown in the plots, water levels generally rebound immediately after pumping and especially so after recharge activities commence.

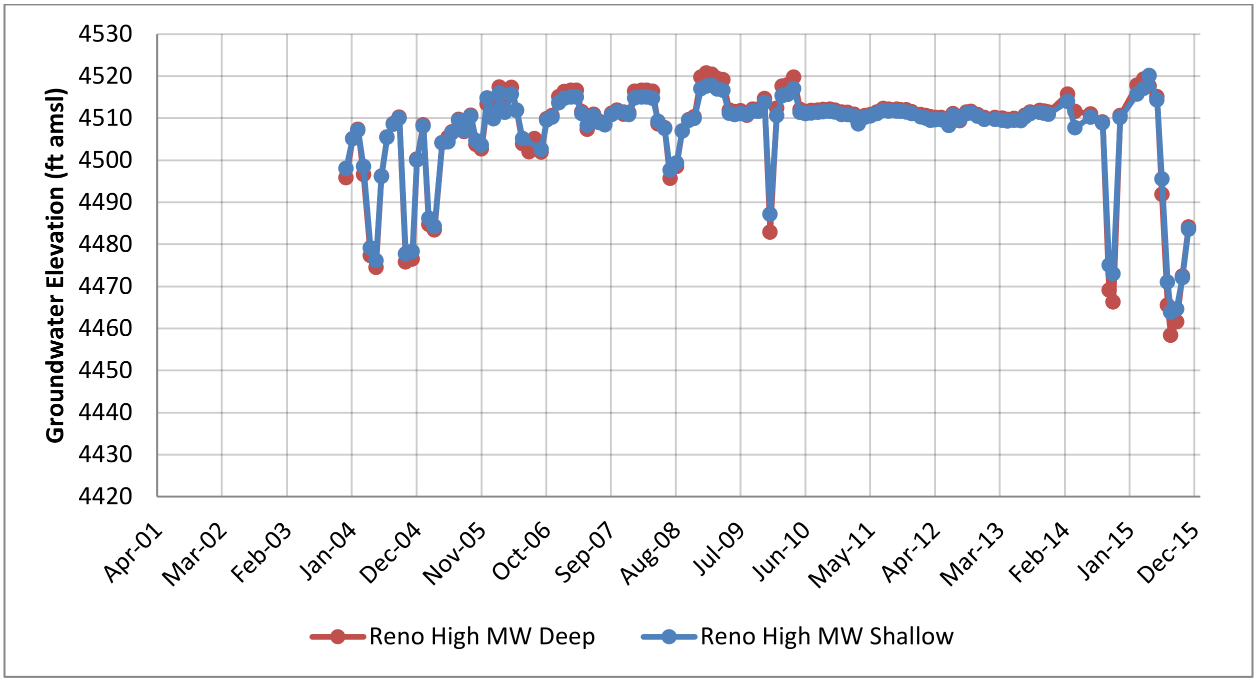

Figure 5. Basin-Fill Groundwater Hydrograph (northwest area) Basin 87

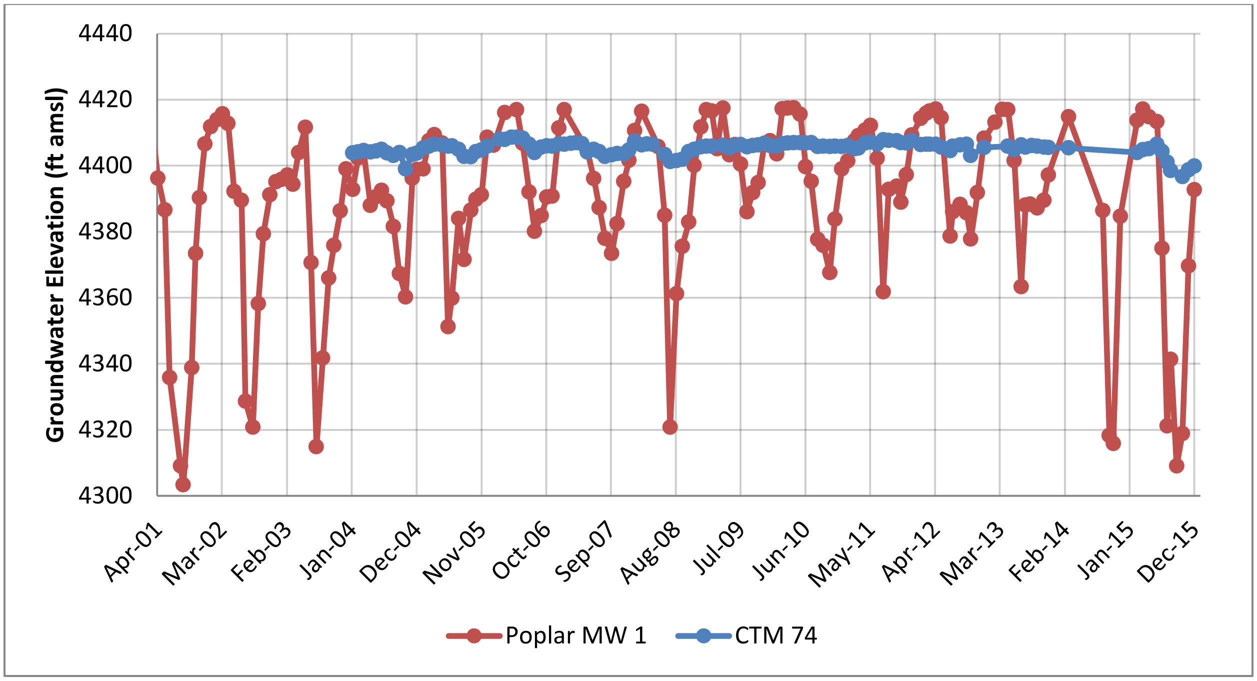

Figure 6. Basin-Fill Groundwater Hydrograph (east-central area) Basin 87

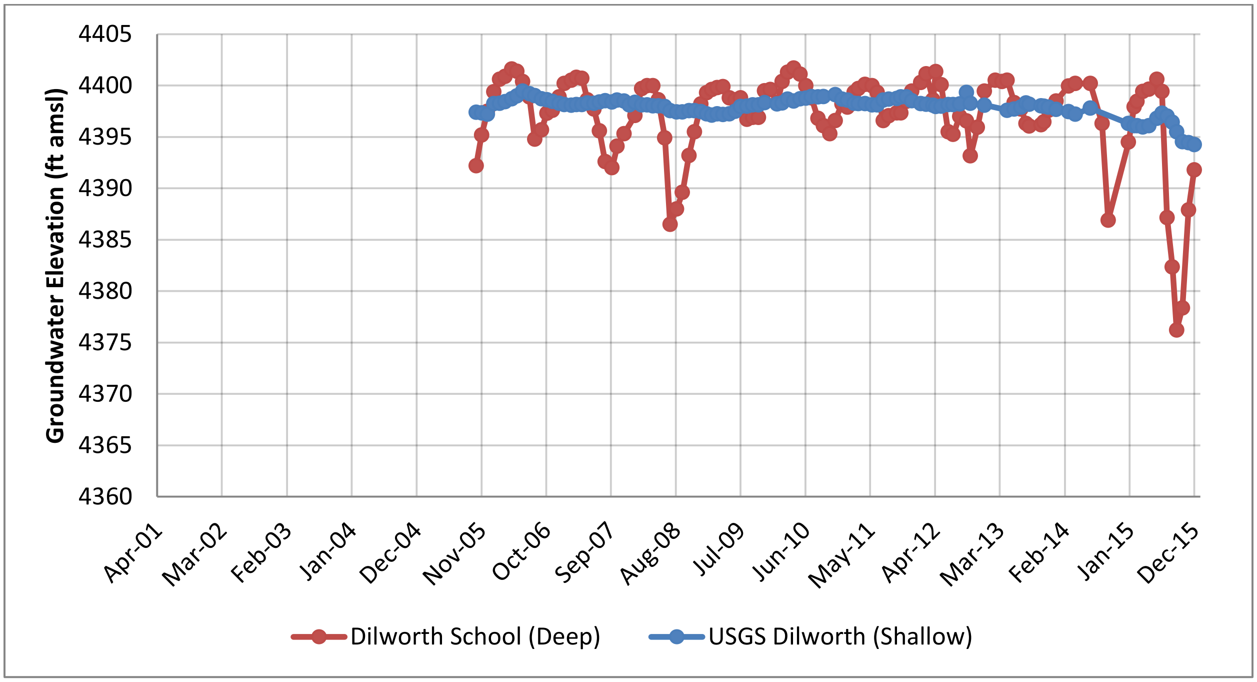

Figure 7. Basin-Fill Groundwater Hydrograph (northeast area) Basin 87

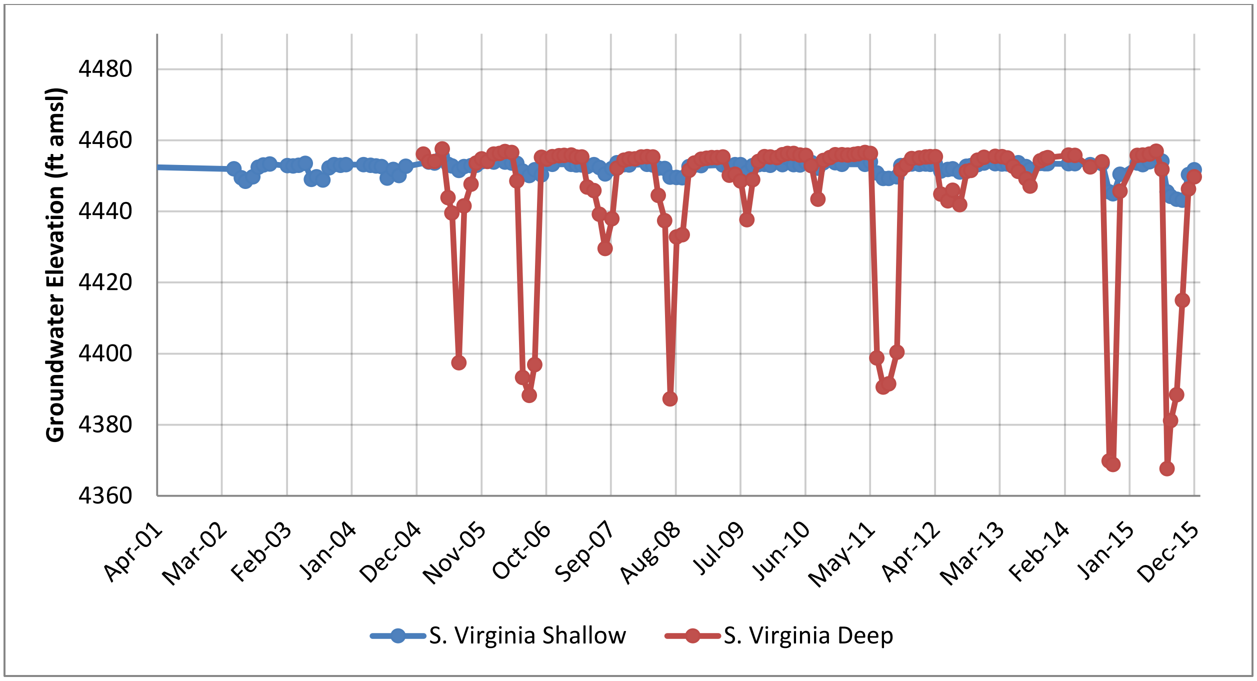

Figure 8. Basin-Fill Groundwater Hydrograph (central area) Basin 87

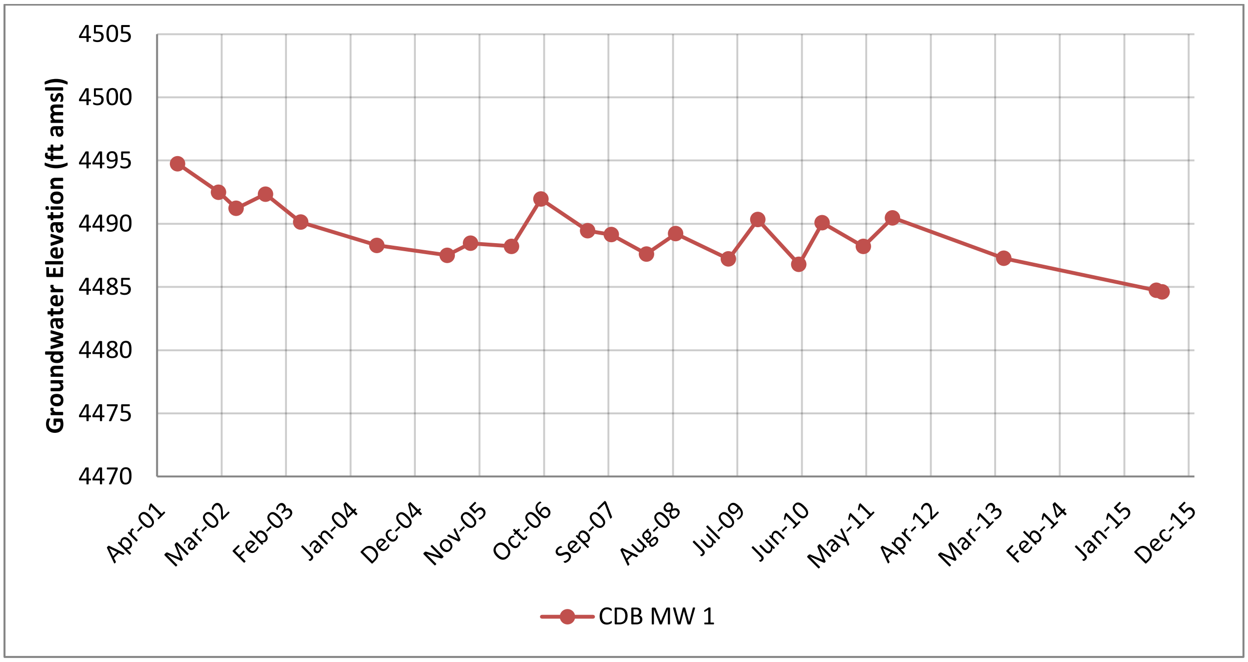

Figure 9. Basin-Fill Groundwater Hydrograph (southeast area) Basin 87

Figures 10 through 15 depict groundwater hydrographs for several wells within the southwest alluvial fan area in Basin 87. Water levels are depicted for wells on the upper elevations of the fan (Figure 10) and decrease with elevation (Figure 12) from southwest to northeast. Figures 12 through 14 depict water levels from west to east along the top of the fan (Figure 13) to the east side of the valley floor (Figure 15).

Water levels have been in decline on the southwest alluvial fan for a number of years. Municipal pumping and the high density of domestic wells in the area compound water level declines over time. The compartmentalization of aquifer materials due to numerous faults on the southwest alluvial fan may impede groundwater recharge and amplify the effects of groundwater withdrawals at wells adjacent to these faults.

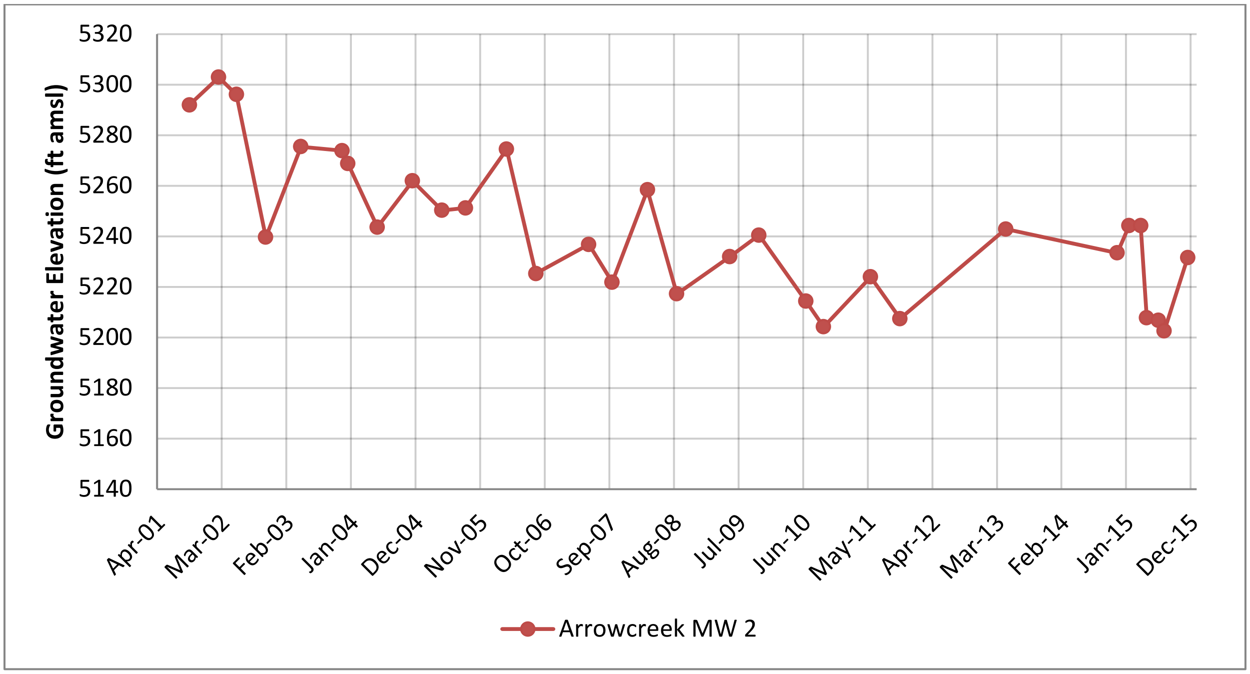

Figure 10. Southwest Alluvial Fan Groundwater Hydrograph (top of fan) Basin 87

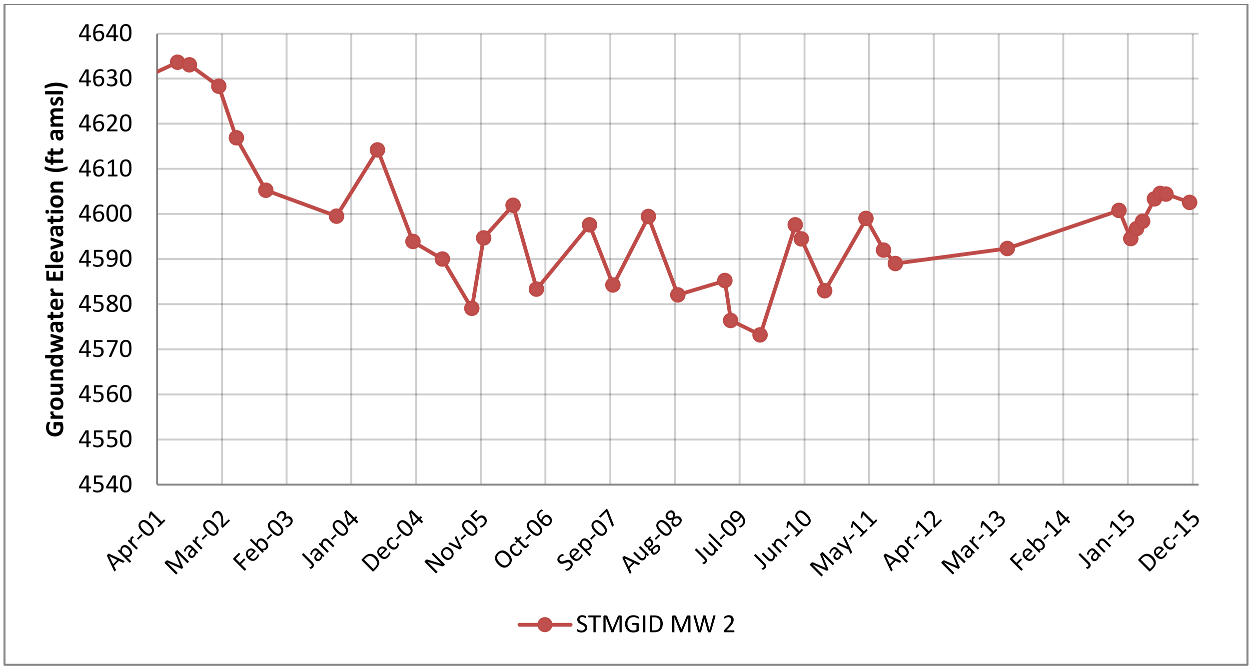

Figure 11. Southwest Alluvial Fan Groundwater Hydrograph (middle of fan) Basin 87

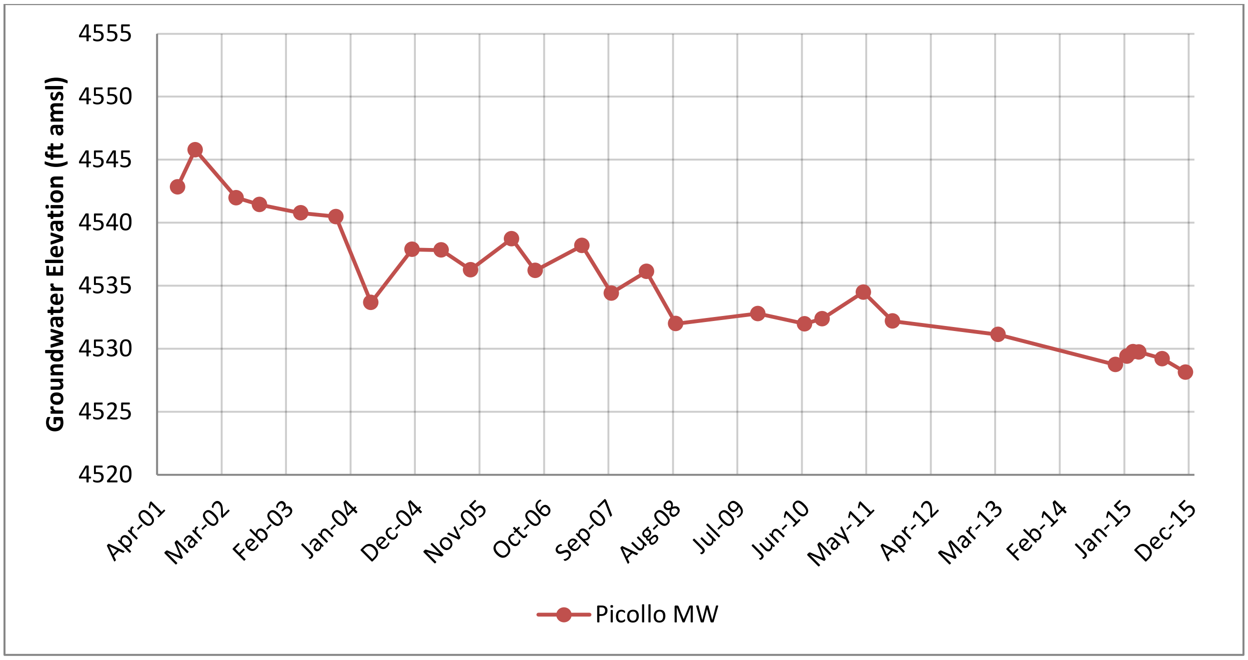

Figure 12. Southwest Alluvial Fan Groundwater Hydrograph (lower fan) Basin 87

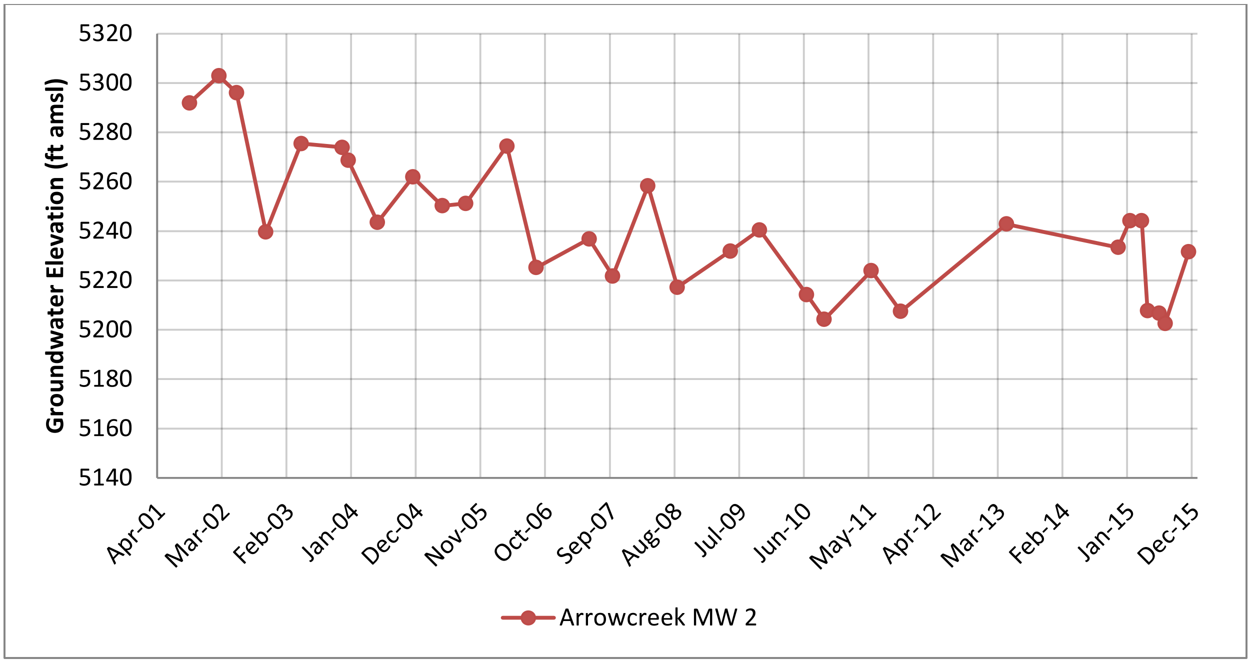

Figure 13. Southwest Alluvial Fan Groundwater Hydrograph (top of fan) Basin 87

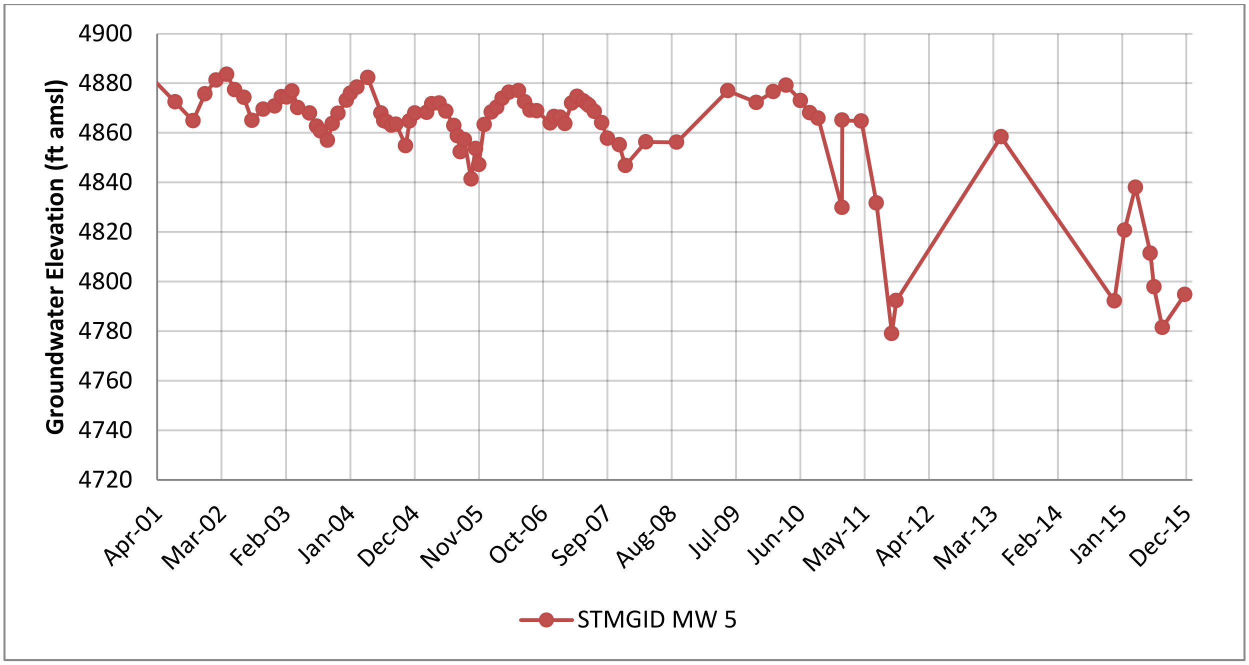

Figure 14. Southwest Alluvial Fan Groundwater Hydrograph (middle of fan) Basin 87

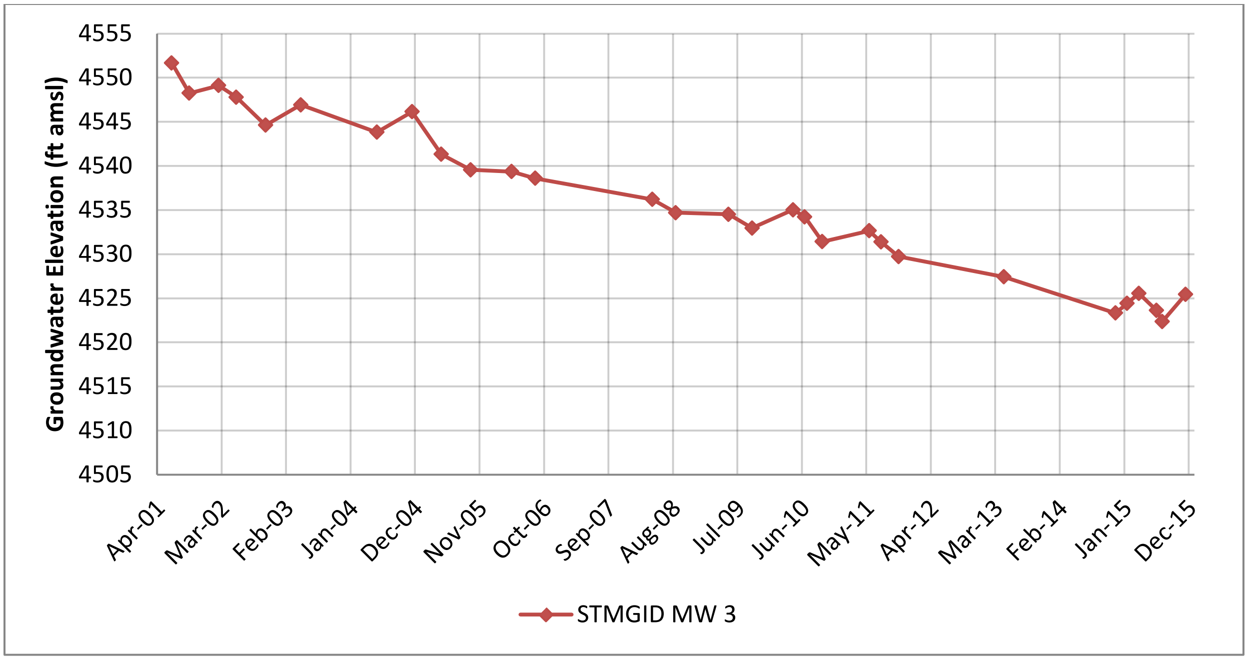

Figure 15. Southwest Alluvial Fan Groundwater Hydrograph (bottom of fan) Basin 87

Figure 16 shows how groundwater flow in Basin 87 can be generalized as flowing northeasterly from the southwest fan to the valley floor, north from the valley floor in the southern Truckee Meadows to the northern Truckee Meadows where it combines with groundwater that flows generally from west to east along the path of the Truckee River and exits the basin at the east Truckee Canyon.

Figure 17 depicts the change in water levels over time between 2010 and 2015. On a localized basis, groundwater levels rose up to 16 feet in basin-fill areas where TMWA is actively injecting water. In the southwest fan area, where injection has yet to occur, groundwater levels declined as much as 16 feet in the upper reaches of the fan on a localized basis.

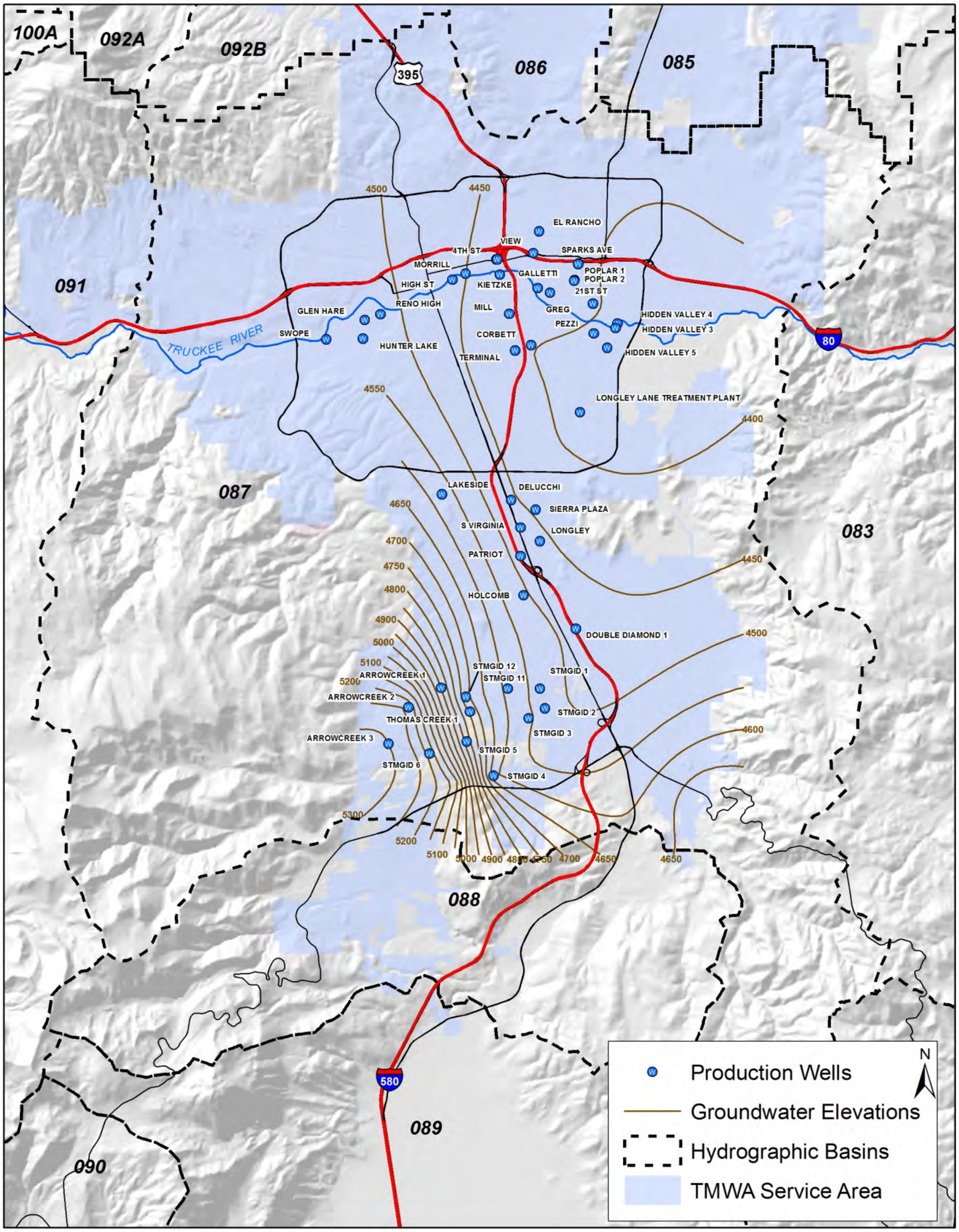

Figure 16. 2015 Groundwater Elevations Contour Map for Hydrographic Basin 87

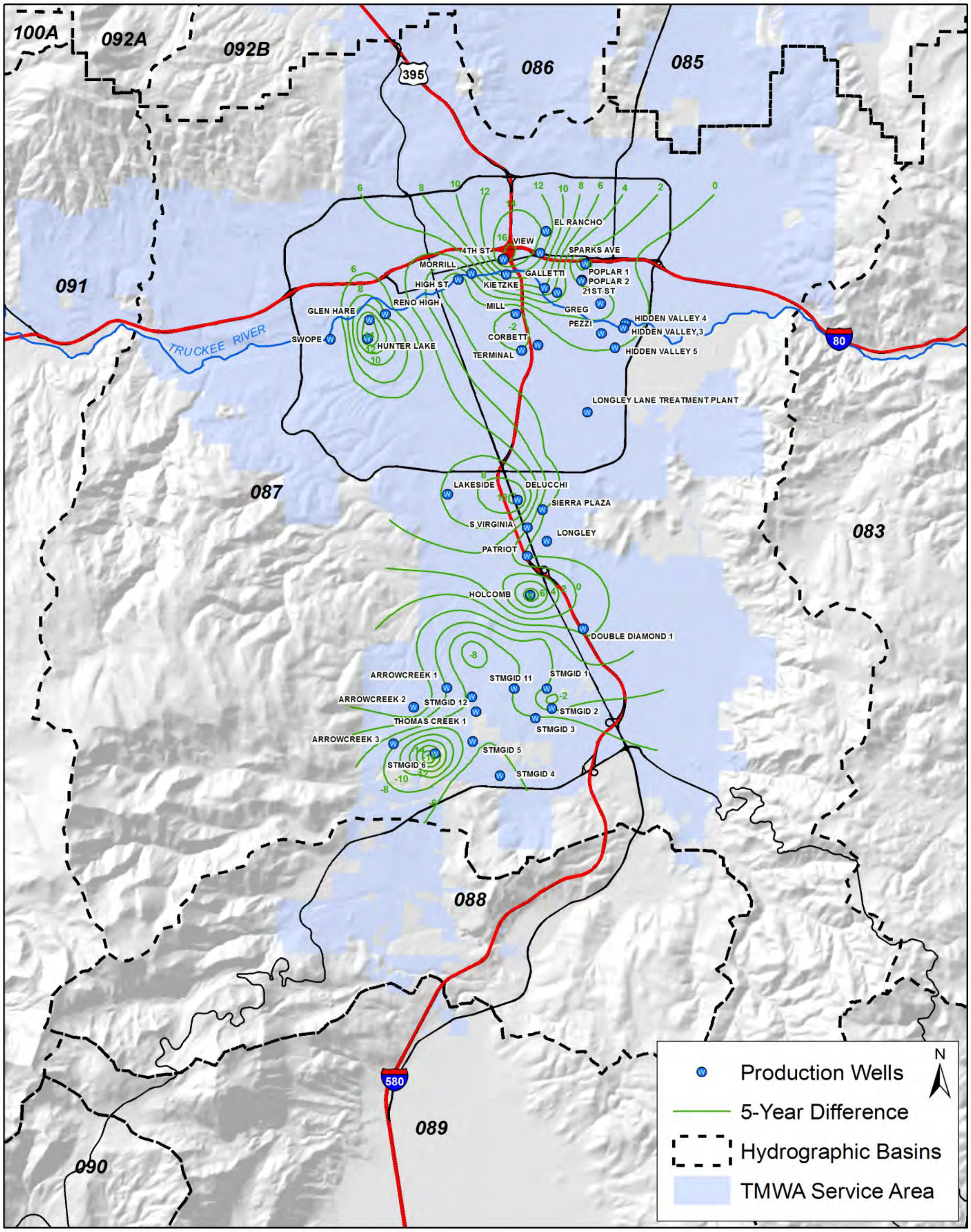

Figure 17. Difference in Groundwater Elevations 2010-2015 Hydrographic Basin 87

Groundwater Quality and Quantity

Groundwater *quality* and *quantity* varies throughout the Truckee Meadows hydrographic basin. Figure 18 depicts the areas generally characterized as having poor water *quality* or low water *quantity*.

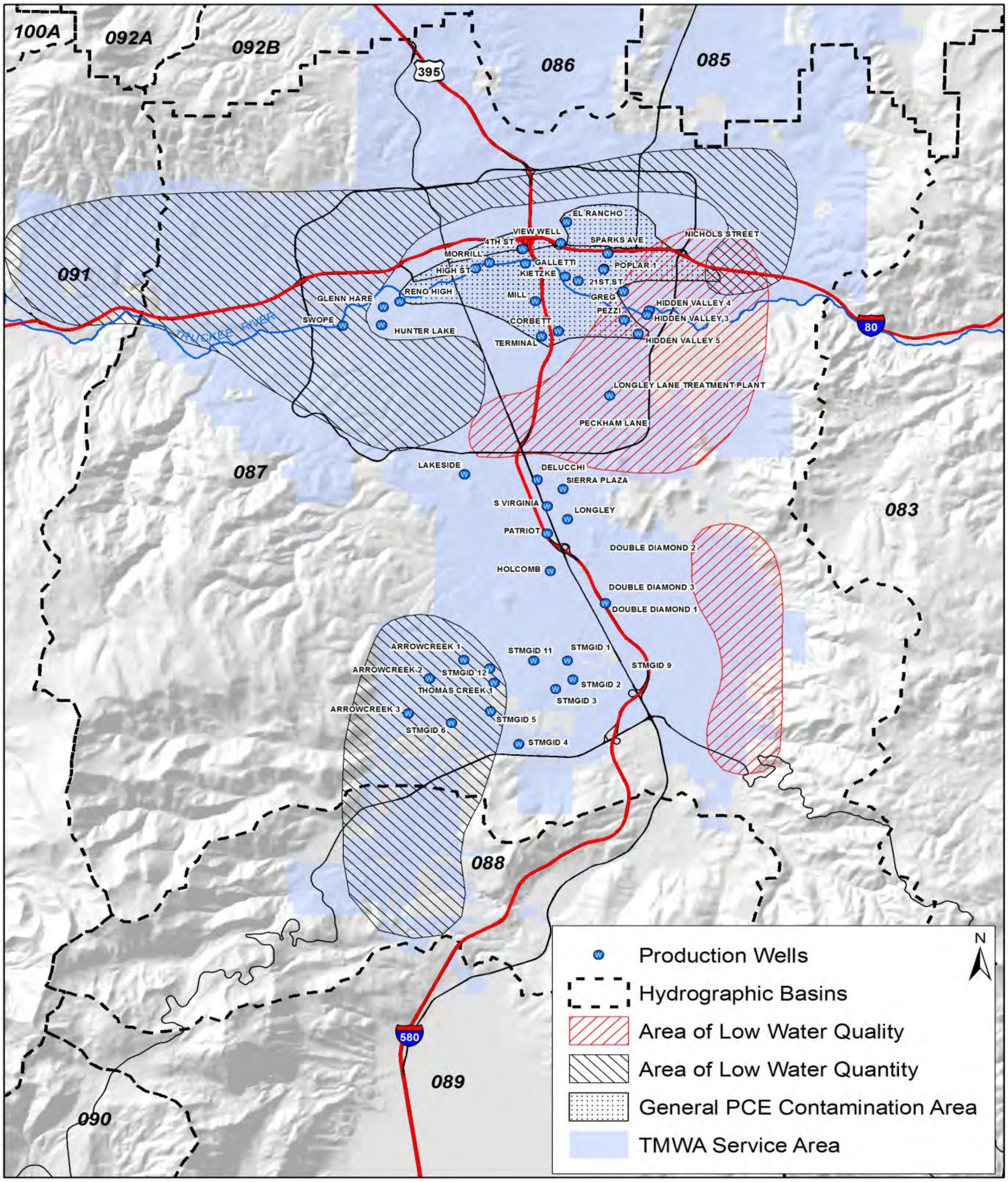

Figure 18. Areas of Poor Water Quality and Low Water Quantity in Hydrographic Basin 87

In the southern part of the Basin 87, low total-dissolved solids ("TDS") groundwater is found within the southwest alluvial fan at the base of the Sierra. The water quality deteriorates at the valley floor where it mixes with highly mineralized geothermal waters discharged from the Steamboat Springs Geothermal Area at the far south end of the basin, the Steamboat Hills area.

In the northern part of Basin 87, poor water *quality*, due to highly mineralized groundwater, is found generally in the Hidden Valley and Huffaker Hills regions. Geothermal areas are present in the west and southwest near the Moana Hills region. Groundwater with high arsenic levels is also treated by TMWA.

In 1987, testing of TMWA wells identified the presence of an organic solvent known as tetrachloroethylene ("PCE"). Mitigation of legacy (the responsible party is unknown) PCE contamination is addressed through the Washoe County Central Truckee Meadows Remediation District ("CTMRD") program. Management practices include using five TMWA wells to pump and treat groundwater at three air stripping-treatment facilities that remove PCE. The five TMWA wells are: Kietzke, Mill, High, Morrill, and Corbett. The CTMRD has identified 8 PCE contamination plumes in Basin 87. This solvent has been used since the 1930's in a variety of commercial/industrial operations such as commercial dry cleaning, paint manufacturing, and auto repair. The CTMRD program has achieved success in plume capture and containment resulting from the implementation of a prescriptive pumping schedule of the 5 TMWA wells fitted with PCE treatment equipment. According to the CTMRD, the PCE plumes do not appear to be moving or growing. TMWA is an active participant with the CTMRD program in planning for and implementing mitigation of PCE. Additional CTMRD information can be found at:

https://www.washoecounty.us/csd/utility/ctmrd/downloads.php

Attaining allowable arsenic levels (the maximum contaminant level ("MCL") of 10 parts per billion ("ppb")) from groundwater sources is an issue for TMWA's well operations. Table 1 shows the number of TMWA's wells in Basin 87 affected by arsenic. Four of the wells that exceed the 10 ppb MCL (Greg, Pezzi, Poplar #1, and Terminal) are piped to Glendale Treatment Plant ("GTP") for treatment and/or blending with treated surface water and two of the five PCE wells (Mill and Corbett) are also piped to GTP for treatment. Because of TMWA's ability to maximize Truckee River water and minimize groundwater use to the summer months, the United States Environmental Protection Agency recognizes annual running average of TMWA's water supplies to attain drinking water standards.

Other groundwater contamination sites, with potentially responsible parties, include the Sparks Solvent Fuel Site, leaky underground storage tanks sites, and additional solvent corrective action sites overseen by the Nevada Division of Environmental Protection ("NDEP"). Maps of the contamination sites are included in the TMWA Wellhead Protection Plan ("WHPP").

Relatively low water *quantity* areas run east-to-west to the north of the Truckee River. The NTM aquifer has lower transmissivity in several areas which results in lower water yield. Areas with lower water yield mostly occur where the aquifer is in bedrock or finer-grained sediments.

Table 1. Basin 87 Wells with Arsenic and Treatment

	Well Name		Average Arsenic Value (ppb)	Treat at Glendale	Sample at EPTDS*	RAA** (ppb)
1	Terminal Way	1	88	X		1.84
2	Poplar No. 1	1	85	X		1.84
3	Pezzi	1	72	X		1.84
4	Mill Street	1	37	X		1.84
5	Greg Street	1	19	X		1.84
6	Corbett	1	17	X		1.84
7	Morrill Avenue		12		X	4.42
8	Silver Lake		10		X	4.61
9	High Street		9		X	4.42
10	Kietzke Lane		9		X	4.71
11	Sparks Avenue		9		X	4.87
12	Poplar No. 2		7		X	3.97
13	View Street	2	5		X	2.38

1. Well output blended and treated with surface water at Glendale Treatment Plant

2. The historical arsenic concentration has been as high as 13 ppb; however extensive artificial recharge activities (underground blending) result in a current wellhead concentration of approximately 5 ppb

* EPTDS - Entry Point To Distribution System

** RAA - Running Annual Average, average of four quarterly As testing results

Aquifer Storage and Recovery – Existing and Potential

The Nevada Division of Water Resources ("NDWR") permit allows TMWA to recharge up to 7,000 AF/yr through 23 wells in the Basin-Fill. During 2015, TMWA recharged over approximately 2,400 AF using 14 of the permitted wells. Since recharge began in 1993, TMWA has recharged more than 30,000 AF in Basin 87 through 2015. As shown in the water level hydrographs, water levels have been relatively stable in areas where TMWA's recharge operations are on-going. Information on the NTM ASR Program is contained in the 2015 semi-annual report titled, "Report on Aquifer Storage and Recovery, Truckee Meadows Hydrographic Basin; January 1 through June 30, 2015" filed with NDEP and NDWR.

Groundwater Modeling

Groundwater models for the Truckee Meadows have been completed and updated several times over the years. In 2015, the larger Truckee Meadows Basin 87 model was converted into two separate models: the North Truckee Meadows model and the South Truckee Meadows model.

The 2015 model updates for both models included:

1. Developing a revised geologic model for both areas.
2. Reducing the model grid spacing to 300 by 300 feet.
3. Updating groundwater levels, pumping, and recharge through 2014.
4. Revising the model to include current estimates of recharge from irrigation and irrigation ditches.
5. Updating the distribution of aquifer properties using newly acquired data from aquifer tests.
6. Re-calibrating the model in the transient state.
7. Refining the model time steps to monthly.
8. Developing well capture zones for 2, 5, 10, and 20 year time periods.

The results of the updated model created the graphics and findings incorporated into this Basin Summary; are the basis of the capture zone analyses for TMWA's production wells; and are the basis of analysis for TMWA's WHPP.

Basin Challenges and Possible Solutions

The primary challenge in the basin is bringing groundwater levels on the southwest alluvial fan back into balance and continuing to provide safe drinking water despite water quality affected by PCE and arsenic in the northern part of the basin.

Water Demand

Availability of Truckee River water, TWMA's primary water supply, is challenged during periods of drought. TMWA manages its reservoir and groundwater supplies to meet the worst 8-year-drought cycle (1987-1994) of record, and is capable of meeting 9 to 10-years. Another challenge is to drill and construct additional water wells, or increase diversion capacities from the Truckee River to meet future demands as they occur. Current demands can be met with existing resources and facilities. However, additional and/or alternate sources of peaking supply are needed to meet future demands. Possible solutions include:

- *Increase Truckee River Use.* As the TROA is implemented, managing droughts should be less of a burden on resources. Increased use of Truckee River water in this basin would require more water rights to augment use of ground water and increase blending of surface with ground water to improve water quality issues. Facilities are in place to implement this option.
- *Artificial Recharge*. Continue artificial recharge at the 23 permitted wells in Basin 87, and possibly increase the rate of recharge, duration of recharge, or both. TMWA is completing permitting through the State Engineer's Office and the NDEP to inject treated surface water in former WDWR wells in the southwest fan area.
- *Extend System Reach.* Extend distribution system facilities to the upper elevations of the southwest fan to support demand in that area.

Water Quality

PCE and arsenic mitigation is another challenge at several wells in the northern part of Basin 87. TMWA, through the CTMRD program, currently uses air-stripping technology to remove PCE from well water. Possibly additional water quality solutions include:

- *Contaminant Source Control.* The CTMRD is working toward implementing source mitigation technologies throughout the NTM. Source mitigation will reduce long-term treatment costs which will be a benefit to TMWA customers. The CTMRD is also working with local and state agencies to reduce and possibly eliminate PCE discharges at their various source locations such as dry cleaners.
- *Artificial Recharge*. Continue artificial recharge at the 23 permitted wells in Basin 87, and possibly increase the rate of recharge, duration of recharge, or both. Including wells contaminated by PCE should help push contaminated water away from the wells and may dilute contamination within the aquifer.

Groundwater Levels

Water levels have been declining in the Alluvial Fan area over the years. There is a significant challenge to meet customer demands from production wells while taking care not to adversely impact water levels in the area. TMWA is constructing service lines to help meet winter time demands to allow groundwater wells in the area to rebound over a six to eight month period. Since the merger, TMWA has already tested and developed a plan to recharge a number of former WDWR wells and is aggressively pursuing groundwater recharge opportunities in the southwest fan area to enhance the recovery of groundwater levels in this region.

- *Extend System Reach.* Extend distribution system facilities to the upper elevations of the southwest fan to support demand in that area. Meeting non-pumping season demands with surface water will allow municipal wells in the upper fan area to rest, and support the recovery of groundwater levels in the area.
- *Artificial Recharge*. TMWA has received approved permits from the NDEP and is completing permitting through the State Engineer’s Office to recharge treated surface water in former WCWD wells in the southwest fan area. This option will boost the recovery of groundwater levels in the non-pumping season.

PLEASANT VALLEY - HYDROGRAPHIC BASIN 88

Introduction

The Pleasant Valley area, Hydrographic Basin 88, encompasses 39 square miles and is bound to the north by the Steamboat Hills, to the east by the Virginia Range, and to the west by the Carson Range. Pleasant Valley is separated from Washoe Valley to the south by a topographic and hydrologic divide created by low hills of granitic, volcanic, and metavolcanic rocks.

The basin can be described as having two geographically and hydrogeologically distinct regions from which water is pumped into public water systems: (1) an alluvial fan and fractured volcanic rock aquifer located in the western, higher elevation part of the basin referred to as West Pleasant Valley ("WPV") and (2) a basin-fill aquifer in the lower, eastern part of the basin referred to as East Pleasant Valley ("EPV"). Figure 1 depicts Hydrographic Basin 88, the West and East Pleasant Valley regions, and the location of TMWA production wells.

From west to east, the alluvial fan and basin-fill aquifers are similar to those described in Basin 87. In West Pleasant Valley, the alluvial fan aquifer is conceptualized as a complex aquifer system comprised of: 1) thin alluvial fan deposits, 2) consolidated sedimentary deposits, 3) thick interbedded fractured volcanic sequences, and 4) granitic, volcanic, or metavolcanic basement rock. The basin-fill aquifer system is conceptualized as a complex aquifer system comprised of: 1) alluvium, 2) partly confined alluvium, 3) fractured volcanic sequences, and 4) granitic, volcanic, or metavolcanic basement rock.

Public Water Systems

TMWA currently operates nine active production wells in Basin 88, serving approximately 54 services in EPV and 1,221 services in WPV. Three additional wells, Sunrise Estates 3, Mt. Rose 2, and STMGID 8, operate infrequently as back-up wells. Two more wells, Callamont 1 and Callamont 2, are currently unequipped and projected to be brought online over the next 10 years. All but one of the nine active wells (Sunrise Estates 1) are located in the West Pleasant Valley. Active wells were completed from 1974 to 2000 with production capacities ranging from a low of 150 to a high of 800 gallons per minutes ("gpm").

Domestic Wells

Approximately 820 domestic wells are located in Basin 88. The majority of these wells (509) are located in West Pleasant Valley on the alluvial fan. The State of Nevada allows each domestic well owner to pump up to 2 acre feet/year ("AF/yr"); 820 domestic wells have the potential to extract an estimated 1,640 AF/yr. Figure 2 depicts the increase in domestic wells constructed in Basin 88. As development continued in West Pleasant Valley, there was an increase in the number of domestic well owners who experienced well failures. These failures are generally attributed to: the shared aquifer experiencing persistent drought conditions; shallow initial well construction; high domestic well density; increasing numbers of domestic wells; and municipal well production.

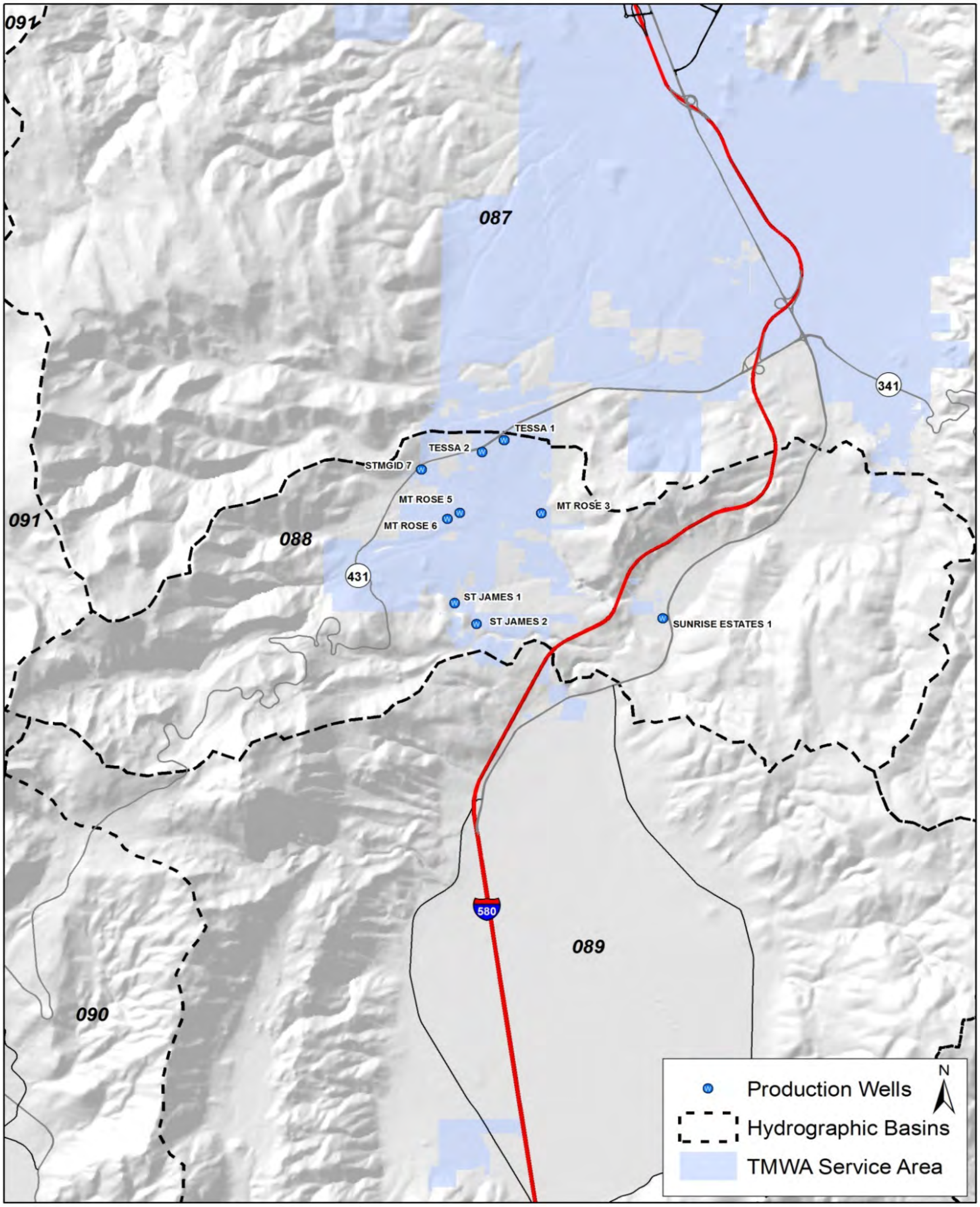

Figure 1. Pleasant Valley Hydrographic Basin 88 Location Map

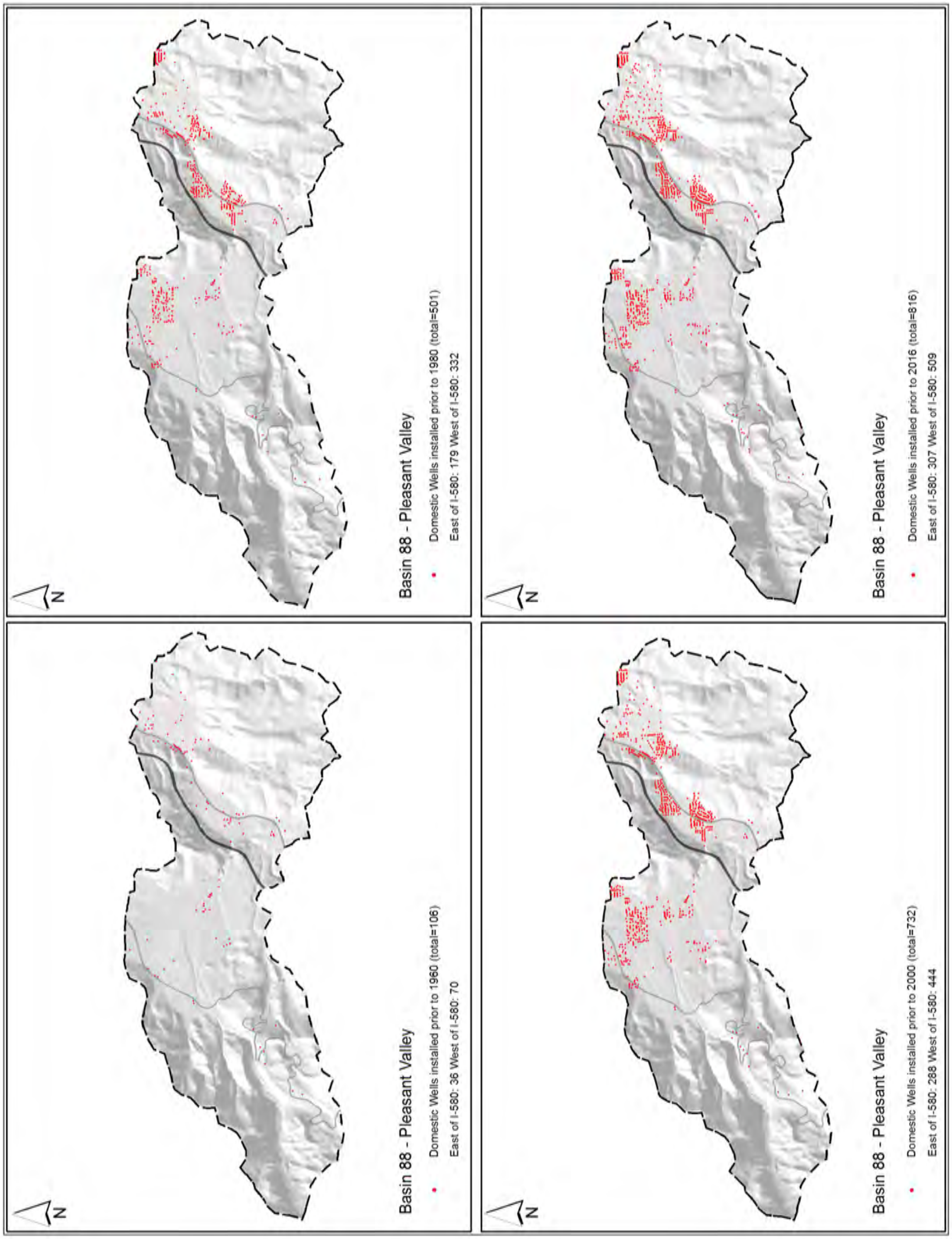

Figure 2. Change in the Number of Domestic Wells in Hydrographic Basin 88

Current Resource Management Practices

TMWA has nine wells in Pleasant Valley with water rights committed to serve customers in the area. The wells are used all year to meet demands. Although there are no recharge wells in the basin, TMWA has prepared select wells for groundwater recharge permitting and testing activities in West Pleasant Valley in 2016. TMWA anticipates implementing significant recharge operations over the next five years in several of the former WDWR production wells.

Water Resources

Surface Water

Galena and Browns Creeks enter at an elevation of about 6,400 and 6,000 feet above mean sea level ("amsl"), respectively, contribute flow to Steamboat Creek. The drainage basins of Galena and Browns Creeks extend to near the crest of the Carson Range at an elevation of about 9,000 feet.

Natural Groundwater Recharge

The climate in Pleasant Valley is arid to semiarid because the area lies in the rain shadow of the Sierra Nevada Mountains. Annual precipitation for the area ranges from about 6 to 10 inches, but the mountains to the west receive as much as 40 inches a year. The normally abundant precipitation in the mountains results in plentiful surface water in the area.

Precipitation in Basin 88 falls as snow and rain typically from November through April. The natural groundwater recharge estimate from precipitation and snow melt in the Carson Range is about 10,000 AF/yr for the entire basin (Van Denburgh, 1973).

Groundwater generally flows east from the Carson Range through the alluvial fan highlands to the basin fill lowland areas and Steamboat Creek to the east. From here it follows Steamboat Creek north into Basin 87.

Groundwater Pumping

Groundwater in Pleasant Valley has been pumped from the aquifer system for over forty years. Large quantities of groundwater are available from that part of the aquifer containing unconsolidated rocks of alluvial origin. Groundwater also is available from consolidated sediments and fractured volcanic sequences, generally in the foothills surrounding Basin 88.

The annual groundwater yield that can be withdrawn without depleting the aquifers on a sustainable basis is less than the annual recharge. Over the past five years, the average municipal groundwater withdrawals were about 20% of the average annual natural recharge to the basin.

It should be noted that each time groundwater extraction is increased or new wells are installed, groundwater surface elevations will lower as the aquifer adjusts to a new equilibrium in response to the additional pumping. This lowering of the water table can be significant in the immediate vicinity of a municipal production well.

Groundwater withdrawals from all production wells in Basin 88 ranged between 630 AF/yr and 1,950 AF/yr since 2001 (Figure 3). When plotted by east and west basin, it's easy to see the difference in pumpage and trends in each area. Groundwater pumping from east-side-basin-fill wells averages about 60 AF/yr and has decreased since 2004. Groundwater pumping from west side alluvial fan wells averages about 1,360 AF/yr and increased from 2001 through 2007, but has decreased over the last 7 years.

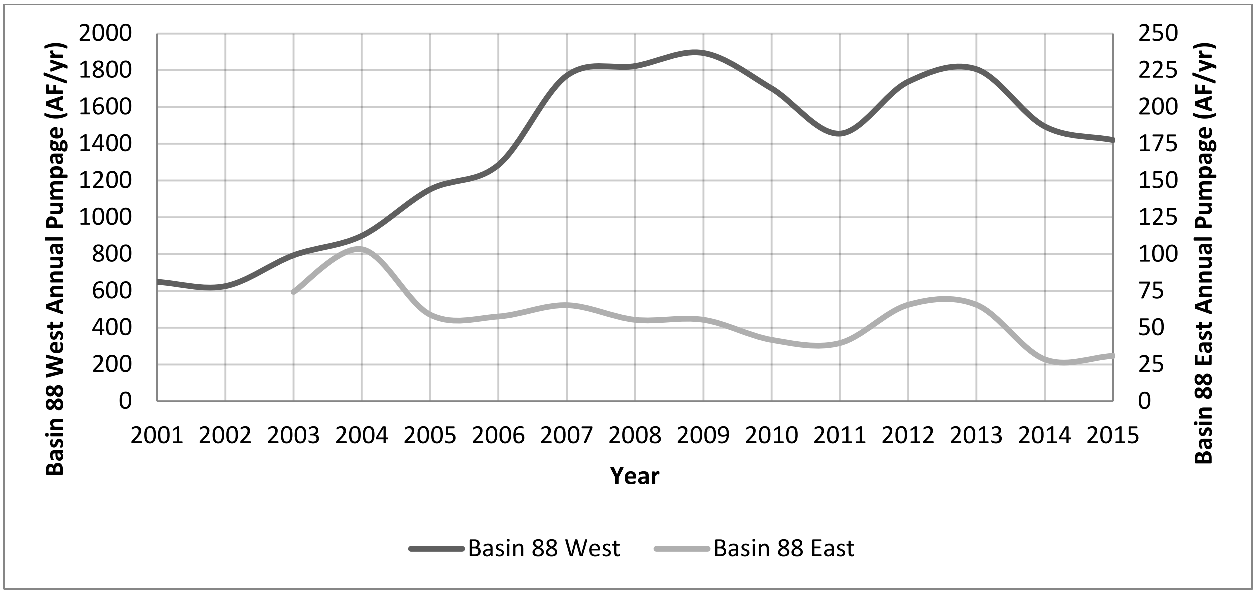

Figure 3. Groundwater Pumping East and West Basin 88

Groundwater Levels

Groundwater elevations vary significantly throughout the basin, with groundwater occurring in the West Pleasant Valley alluvial fan system at greater depths than the basin-fill aquifer in East Pleasant Valley. Hydrographs from 2001 through 2015 represent changes in water levels resulting from the variation in precipitation, pumping, natural recharge, evapotranspiration, and aquifer properties. The graphs indicate that water levels fluctuate seasonally with rises during non-pumping and natural recharge periods (winter months) and declines during pumping periods (summer months).

Figures 4 through 6 depict groundwater hydrographs for several wells within the alluvial fan aquifer on the western side of Basin 88. Water levels are steadily declining in this region. Municipal pumping and the high density of domestic wells in the area compound water level declines over time. The compartmentalization of aquifer materials due to numerous faults on the southwest alluvial fan may impede groundwater recharge and amplify the effects of groundwater withdrawals at wells adjacent to these faults.

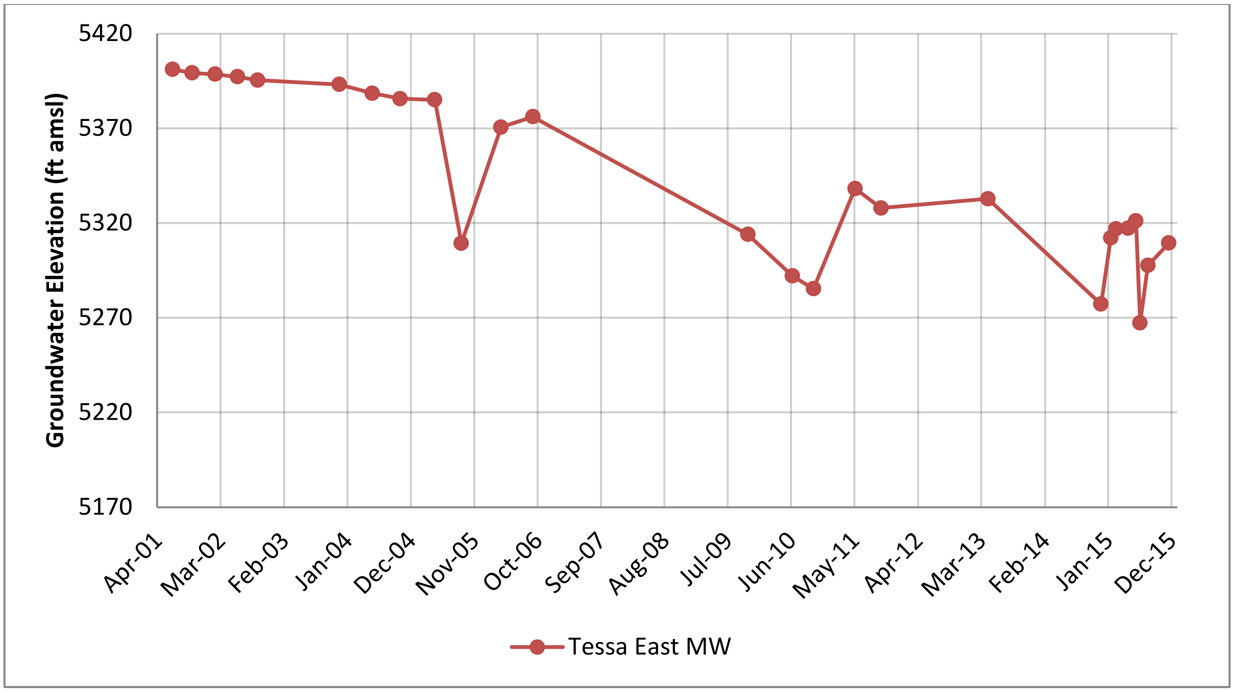

Figure 4. West Alluvial Fan Groundwater Hydrograph (northwest area) Basin 88

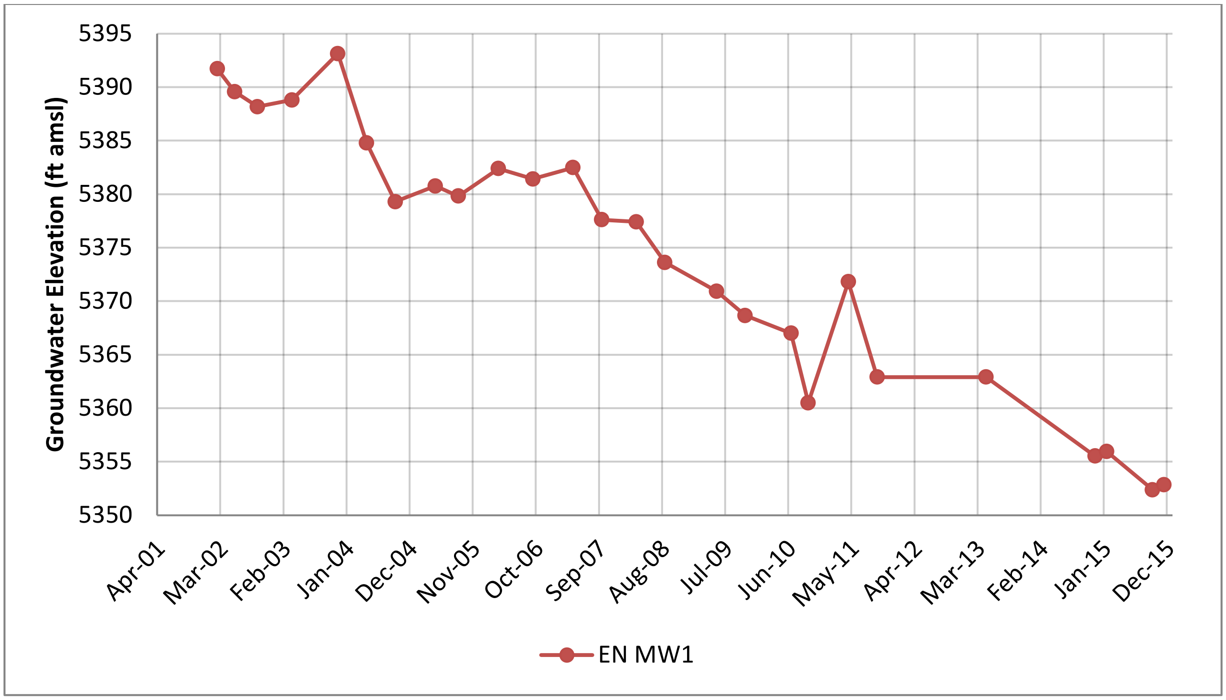

Figure 5. West Alluvial Fan Groundwater Hydrograph (west-central area) Basin 88

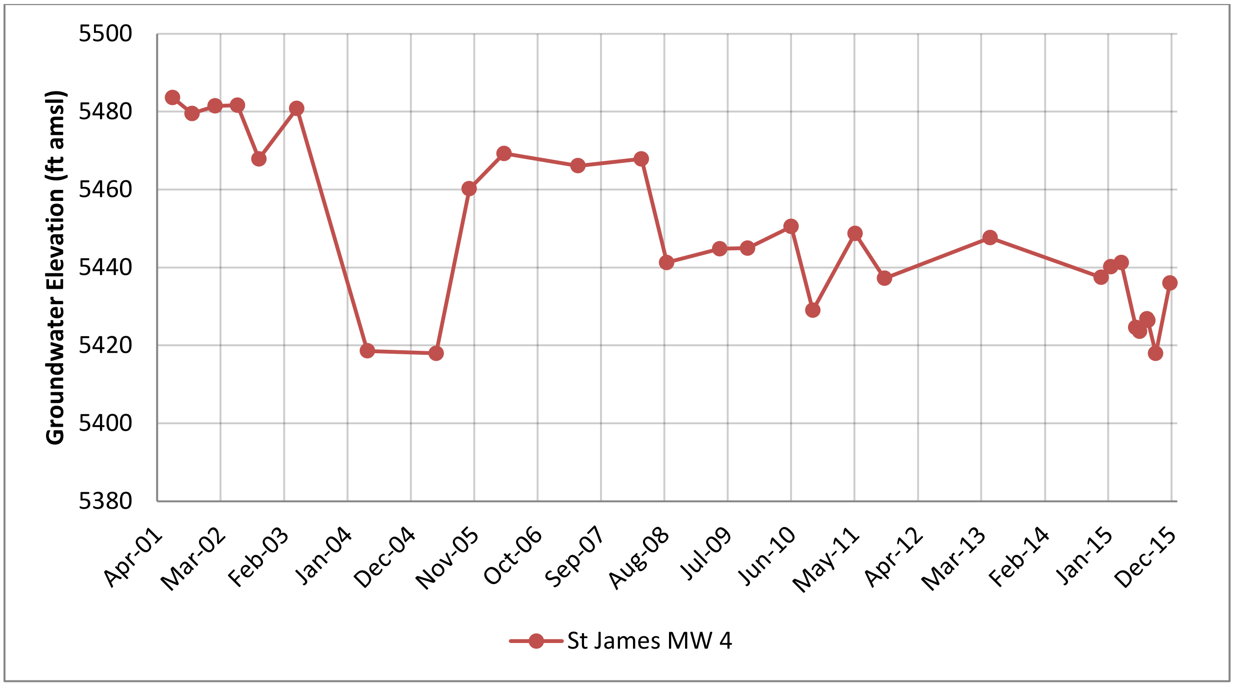

Figure 6. West Basin-Fill Groundwater Hydrograph (northeast area) Basin 88

Figures 7 and 8 depict groundwater hydrographs for two wells within the basin-fill aquifer on the east side of Basin 88. Water levels are relatively stable in the basin-fill wells. Natural seasonal recharge allows groundwater levels to recover, while short-duration seasonal pumping drops water levels for a brief time. As shown in the plots, water levels generally rebound immediately after pumping.

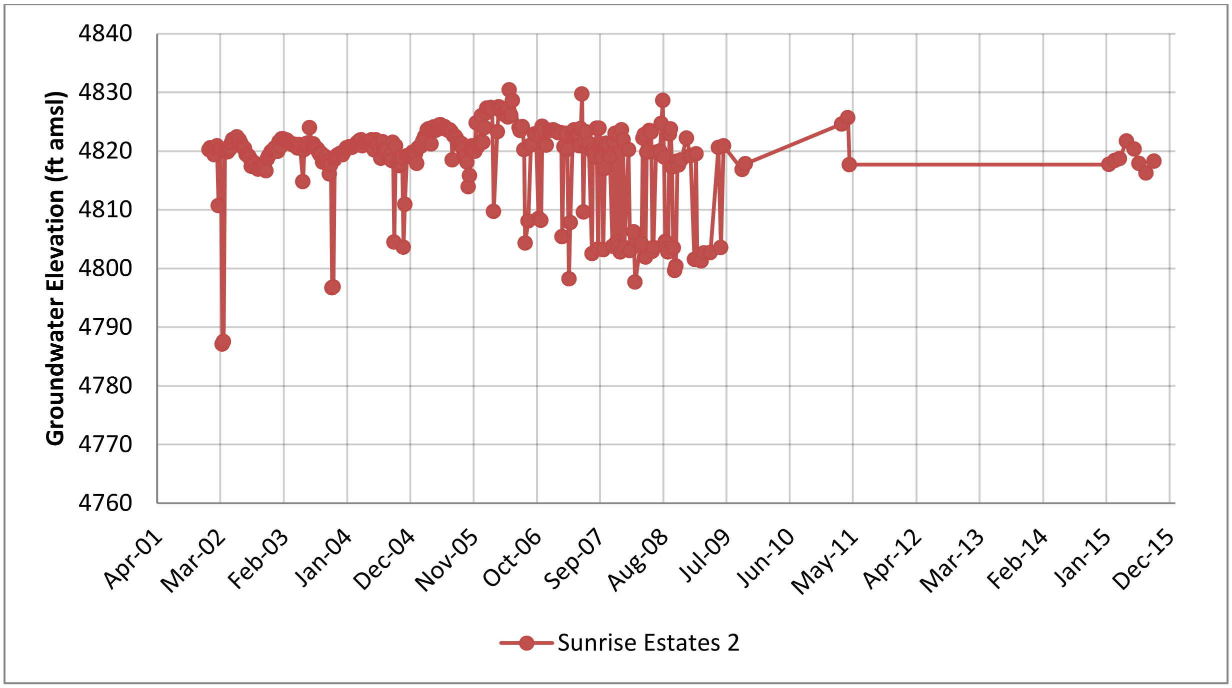

Figure 7. East Basin-Fill Groundwater Hydrograph (central area) Basin 88

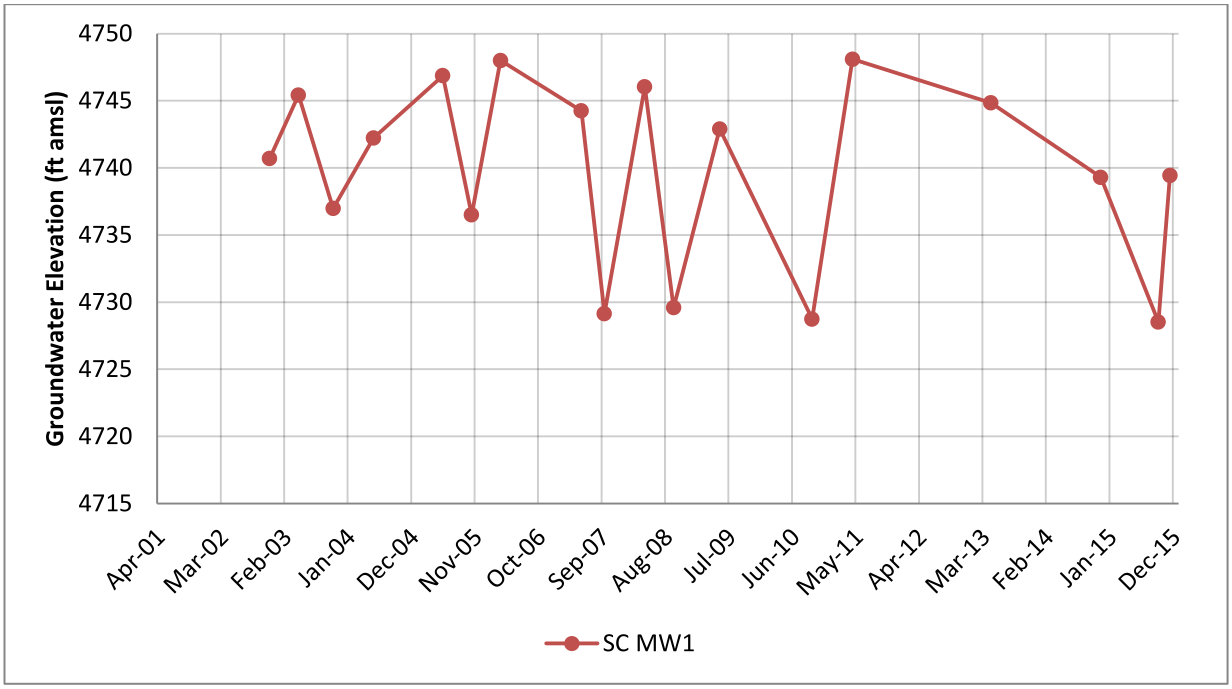

Figure 8. East Basin-Fill Groundwater Hydrograph (eastern area) Basin 88

As depicted in Figure 9, groundwater generally flows east from the Carson Range through the alluvial fan highlands to the basin fill lowland areas and Steamboat Creek to the east. From here it follows Steamboat Creek north into Basin 87.

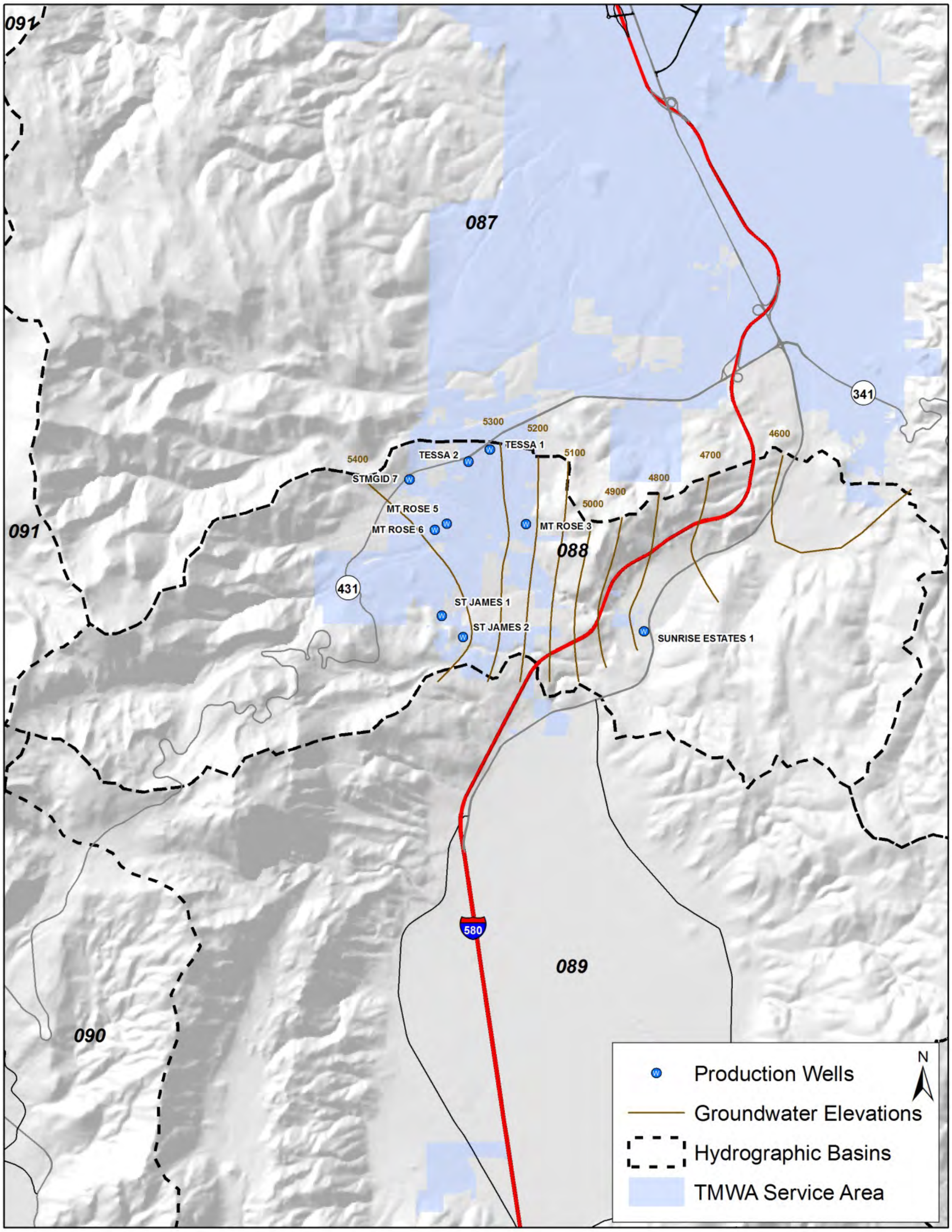

Figure 9. 2015 Groundwater Elevations Contour Map for Hydrographic Basin 88

Figure 10 depicts the change in water levels over time between 2010 and 2015. Groundwater levels declined over seven feet near production wells in Basin 88 West and over five feet in Basin 88 East.

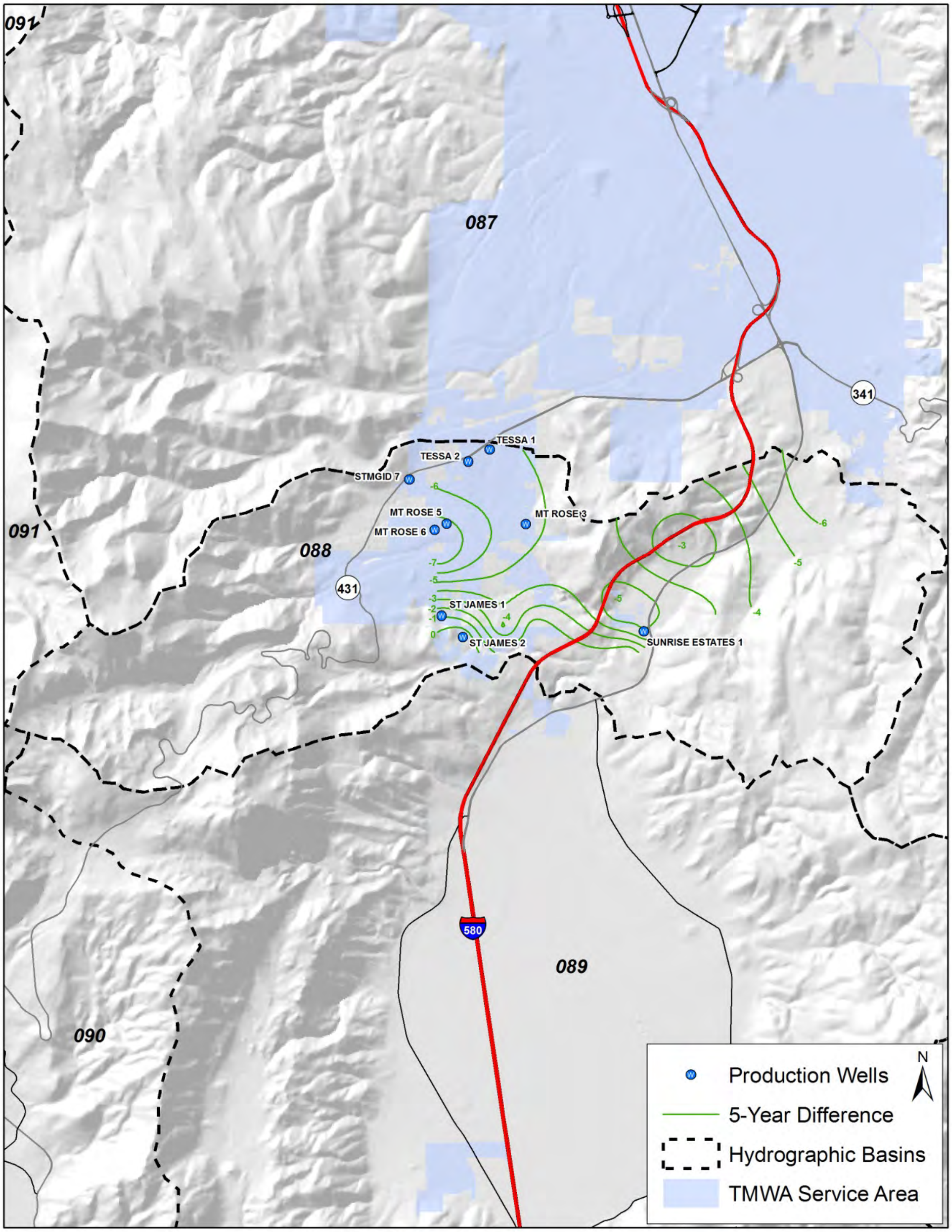

Figure 10. Difference in Groundwater Elevations 2010-2015 Hydrographic Basin 88

Groundwater Quality and Quantity

Groundwater *quality* and *quantity* varies throughout Basin 88. Figure 11 depicts the areas generally characterized as having poor water *quality* or low water *quantity*.

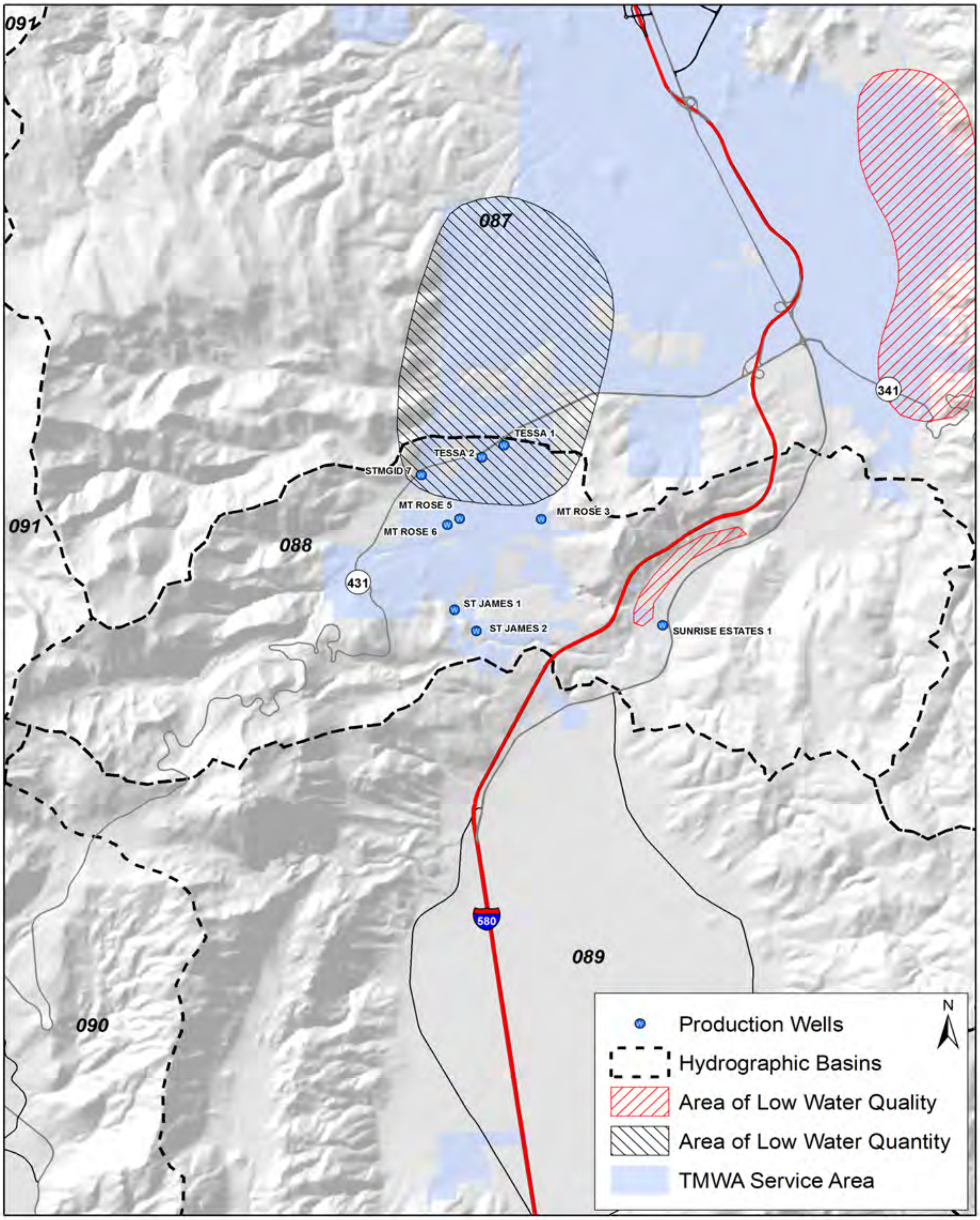

Figure 11. Areas of Poor Water Quality and Low Water Quantity in Hydrographic Basin 88

Poor water *quality,* due to highly mineralized groundwater, is found generally in the eastern portion of the basin near the eastern flank of the Steamboat Hills where geothermal influences are most pronounced.

Relatively low water *quantity* areas run south-to-north from STMGID 7 and the Tessa wells to the north out of Basin 88 and into Basin 87. The alluvial fan aquifer has lower transmissivity in several areas due to relatively thin alluvial materials and low transmissivities in fractured volcanics which results in lower water yield. Areas with lower water yield mostly occur where the aquifer is in consolidated rock and/or finer-grained alluvial sediments.

TMWA's Wellhead Protection Plan ("WHPP") has not identified obvious threats to groundwater in Basin 88, however septic effluent may impact groundwater in areas of high septic system density and shallow groundwater occurrence.

Aquifer Storage and Recovery – Existing and Potential

TMWA does not currently inject treated surface water into production wells in Basin 88 for aquifer storage and recovery ("ASR"). TMWA has received a permit through the Nevada Department of Environmental Protection ("NDEP") to begin recharge activities in select wells (Tessa 1, Tessa 2, and Mt. Rose 3) in 2016. TMWA is also extending service to the top of the alluvial fan areas in Basin 87 and 88 to supply demand during winter months, allowing production wells to rest and groundwater levels to rebound. Excess water not used for supply will be available for groundwater recharge.

Groundwater Modeling

Groundwater models for the Truckee Meadows have been completed and updated several times over the years. In 2015, the larger Truckee Meadows Basin 87 model was converted into two separate models: the North Truckee Meadows model and the South Truckee Meadows model. The South Truckee Meadows model included Basin 88.

The 2015 model updates for the Basin 88 section of the model included:

1. Developing a revised geologic model for both areas.
2. Reducing the model grid spacing to 300 feet by 300 feet.
3. Updating groundwater levels, pumping, and recharge through 2014.
4. Revising the model to include current estimates of recharge from irrigation and irrigation ditches.
5. Updating the distribution of aquifer properties using newly acquired data from aquifer tests.
6. Re-calibrating the model in the transient state.
7. Refining the model time steps to monthly.
8. Developing well capture zones for 2, 5, 10, and 20 year time periods.

The results of the updated model created the graphics and findings incorporated into this Basin Summary; are the basis of the capture zone analyses for TMWA's production wells; and are the basis of analysis for TMWA's WHPP.

Basin Challenges

Water levels have been declining in the alluvial fan area over the years. There is a significant challenge to meet customer demands from production wells while taking care not to adversely impact water levels in the area. TMWA is constructing service lines to help meet winter time demands to allow groundwater wells in the area to rebound over a six to eight month period. Since the merger, TMWA has already tested and developed a plan to recharge a number of newly-acquired wells and is aggressively pursuing groundwater recharge opportunities in the alluvial fan area to enhance the recovery of groundwater levels in this region.

Another challenge is to drill and construct additional water wells, or increase diversion capacities from the Truckee River to meet future demands as they occur. Current demands can be met with existing resources and facilities. However, additional and/or alternate sources of peaking supply are needed to meet future demands. Increased use of Truckee River water in this basin would require more water rights to augment use of groundwater and increase blending of surface with groundwater to improve water quality issues.

LEMMON VALLEY – HYDROGRAPHIC BASIN 92A and 92B

Introduction

Lemmon Valley ("LV"), Hydrographic Basins 92A and 92B, are topographically closed basins encompassing about 97 square miles. LV is designated by the State Engineer as Basin 92, and is subdivided into the east and west subbasins by the Airport Fault that runs down the middle of the basin: West Lemmon Valley is identified as Basin 92A ("WLV") and East Lemmon Valley is Basin 92B ("ELV").

The mountains surrounding and bedrock underlying the valley are complexly faulted. The mountains are comprised of igneous, volcanic, and metavolcanic rocks. Regional faulting gave the mountains their large-scale size, shape, and relief. The change in elevation ranges from approximately 4,914 feet above mean sea level ("amsl") at the eastern sub-area playa to 8,266 feet amsl at highest peak on Peavine Mountain at the south end of the basin. The present topography of the basin is the result of erosion and smaller scale fault structures. Figure 1 depicts the Lemmon Valley hydrographic basin and the locations of Truckee Meadows Water Authority ("TMWA") production wells.

The valley is a structural depression filled with unconsolidated basin-fill. Features other than mountain ridges and basin-fill deposits include two playa lakes. The basin-fill is comprised of weathered material from the surrounding mountain ridges including layers of clay, silt, fine- to coarse-grained sand, and gravel. Generally, basin-fill is coarser near the base of the mountain ridges and becomes finer-grained in the center of the valley near the playas. Playa lake deposits are mostly clay, silt, and fine-grained sand. The aquifer system is conceptualized as three hydrostratigraphic units (from top to bottom): 1) playa deposits; 2) alluvium; and 3) fractured bedrock. These units are identified as distinct units based on differences in geologic, hydraulic, and water yield characteristics.

WLV contains the Silver Lake playa in the center with TMWA servicing large commercial/ industrial properties and residential properties to the east, and additional residential properties to the southeast. North of Silver Lake is the Silver Knolls subdivision with about 500 residences that utilize domestic wells and septic tanks, and west of the Silver Knolls subdivision is the Silver Knolls Water Mutual system serving about 60 residential lots.

ELV includes the Swan Lake playa located in the central portion of the basin. TMWA serves customers located to the north, east, and south of the playa. Golden Valley is a hydrographic subarea in the southeast corner of Basin 92B which includes both residential and commercial properties in the Golden Valley area. There are over 550 properties on domestic wells and septic tanks in this subarea.

LV development began in 1948 when the United States constructed the Stead Air Force Base and surrounding military residences. Residential development using domestic wells occurred in the northeast portion of the basin in the 1960's and more so in the 1970's. Utility-supplied developments also began in the 1970's in Silver Lake, Horizon Hills, and ELV.

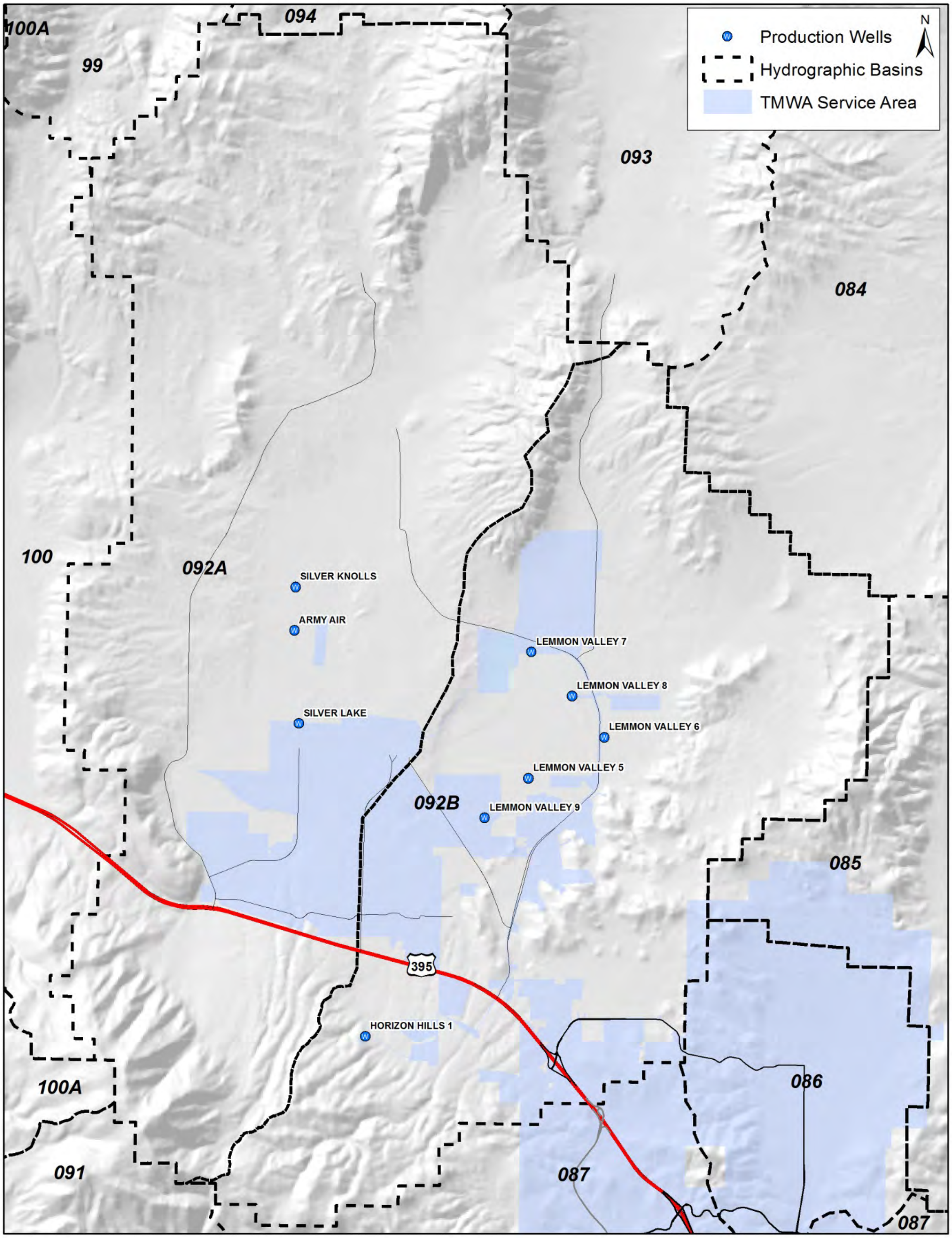

Figure 1. Lemmon Valley Hydrographic Basins 92A and 92B Location Map

By the 1980's, with the full commitment of existing ground water resources in the basin, little to no development occurred in the basin until additional Truckee River rights were dedicated to the valley. With the completion of the Vidler Importation Project in 2007 and its subsequent dedication to Washoe County, now owned and operated by TMWA as a result of the 2014 Merger, TMWA can deliver up to 8,000 acre feet/year ("AF/yr") of ground water from the Fish Spring Ranch project ("FSR") located in Honey Lake Valley Basin 97, a distance of 35 miles to the north of LV. Subject to certain permitting conditions, an additional 5,000 AF/yr from FSR may be available for future demand.

Public Water Systems

TMWA operates a wellfield in WLV and another in ELV. The WLV wellfield consists of three active wells and one unequipped well. These wells are completed in alluvium and have production capacities ranging from 800 to 2,500 gallons per minute ("gpm"). The ELV production wellfield consists of five wells completed in alluvium that have production capacities ranging from approximately 200 to 1,000 gpm.

Domestic Wells

Approximately 730 domestic wells are located in WLV with approximately 1,370 located in ELV. Areas with higher densities of domestic wells include the Silver Knolls area west of the Stead Airport, the Heppner subdivision located north and east of the Swan Lake playa in ELV, and Golden Valley in the southeast corner of ELV. These domestic well owners also utilize septic tanks. The State of Nevada allows each domestic well owner to pump up to 2 AF/yr. The 2,100 domestic wells in LV have the potential to extract up to 4,200 AF/yr. Figure 2 depicts the increase in domestic wells constructed over the years in LV. As development continued in LV, there was an increase in the number of domestic well owners who experienced well failures. These failures are generally attributed to: the shared aquifer experiencing persistent drought conditions; shallow initial well construction; high domestic well density; increasing numbers of domestic wells; and municipal well production.

Current Resource Management Practices

TMWA has three active production wells in WLV and five active wells in ELV with water rights committed to serve customers in the area. In WLV, groundwater from the three production wells is used to augment peak treated surface water demand during four to six months of the year, or during emergency conditions. The treated surface water originates at TMWA's Chalk Bluff Water Treatment Plant. During the winter months, TMWA injects treated surface water into the aquifer using two of the production wells. Over 4,500 acre feet ("AF") of surface water has been injected since 2000.

In ELV, most demand is met with groundwater extracted by the five production wells. An exception occurs in Horizon Hills and along the U. S. 395 corridor in the southern part of valley where treated surface water is delivered.

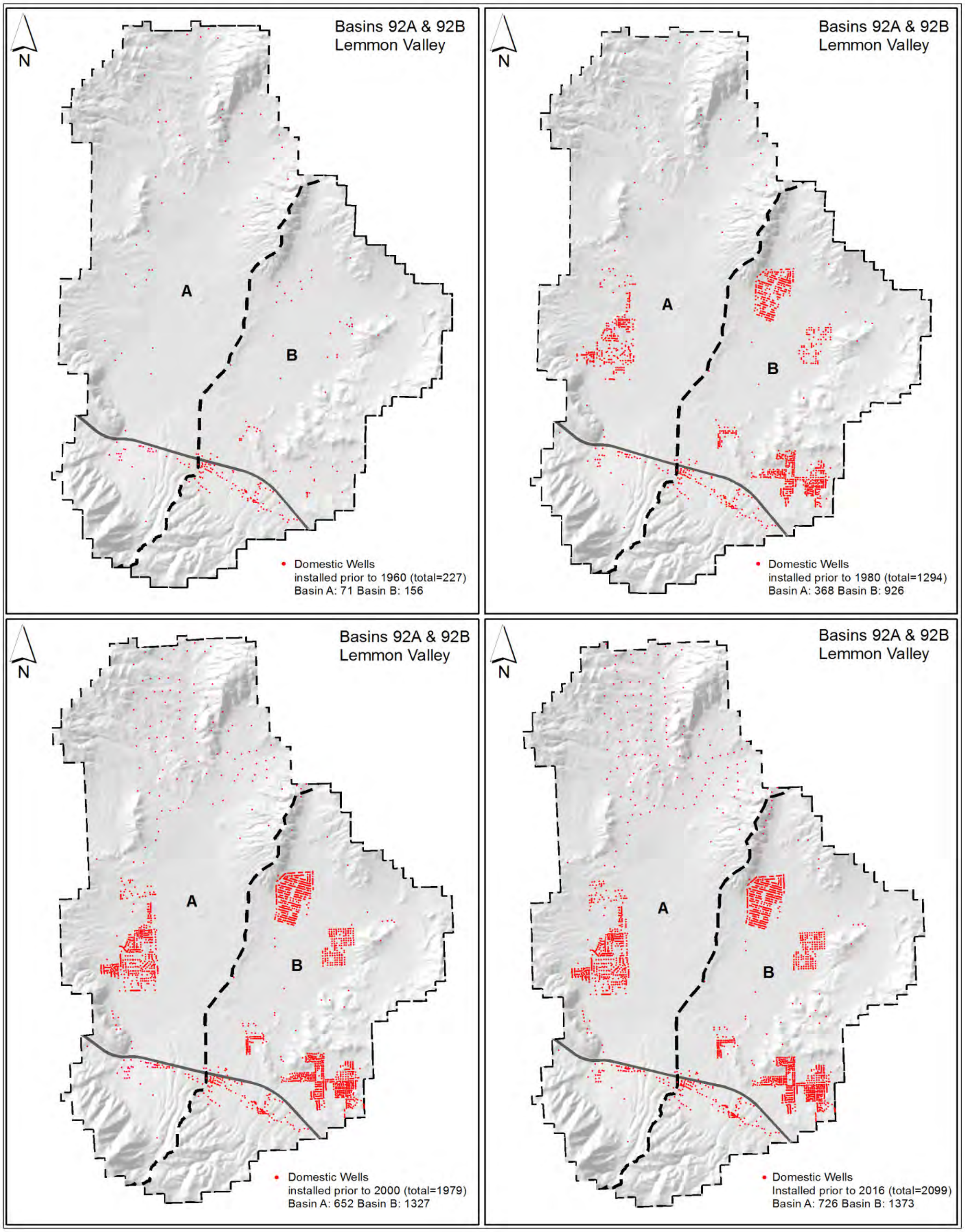

Figure 2. Change in the Number of Domestic Wells in Hydrographic Basins 92A and 92B

Since 2005, domestic well owners in Golden Valley have funded an artificial recharge program. The recharge program, managed by Washoe County, includes the purchase of approximately 120AF/yr of treated surface water from TMWA to offset declining groundwater levels in the Golden Valley subarea.

Water Resources

Surface Water

There are no perennial streams in LV. Ephemeral streams can exist during storm events or spring runoff if precipitation is sufficient. Runoff can reach the playa areas in the center of WLV and ELV but is dependent on the amount of precipitation that falls during winter months.

Natural Groundwater Recharge

The climate in LV is arid to semiarid because the area lies in the rain shadow of the Sierra Nevada Mountains. Annual precipitation for the area ranges from about 6 to 10 inches, but Peavine Mountain, the highest area of the valley, can receive more than 20 inches a year.

Precipitation in Lemmon Valley falls as snow and rain typically from November through April. Most precipitation that falls on the valley floor is lost through evaporation and has an insignificant impact on groundwater recharge. The natural recharge estimate is about 1,300 AF/yr for all of Lemmon Valley, with each subbasin getting approximately half of this amount.

Groundwater flows from the mountain ridges toward the lower-lying playa areas. Most groundwater originates from precipitation falling in the southwest part of the valley at the higher elevations of Peavine Mountain. The highest point of Peavine Mountain is 8,266 feet amsl.

Groundwater Pumping

Groundwater withdrawal from production wells in WLV has ranged between approximately 50 and 1,000 AF/yr over the past 15 years (Figure 3). Similarly, groundwater withdrawal from production wells in ELV has ranged between approximately 100 and 1,300 AF/yr over the past 15 years (Figure 4). As indicated by Figure 4, groundwater withdrawal has been significantly declining for the previous 15 years. Domestic wells also withdraw groundwater in both subbasins. Approximately 1,800 AF/yr would be withdrawn if approximately 1,800 domestic wells pumped 1 AF/yr (domestic wells are allowed to pump approximately two AF/yr). In the past, groundwater pumping exceeded groundwater recharge which resulted in water level declines in most areas of Lemmon Valley. Recharge at production wells in WLV has been successful at increasing groundwater levels, and is discussed further below.

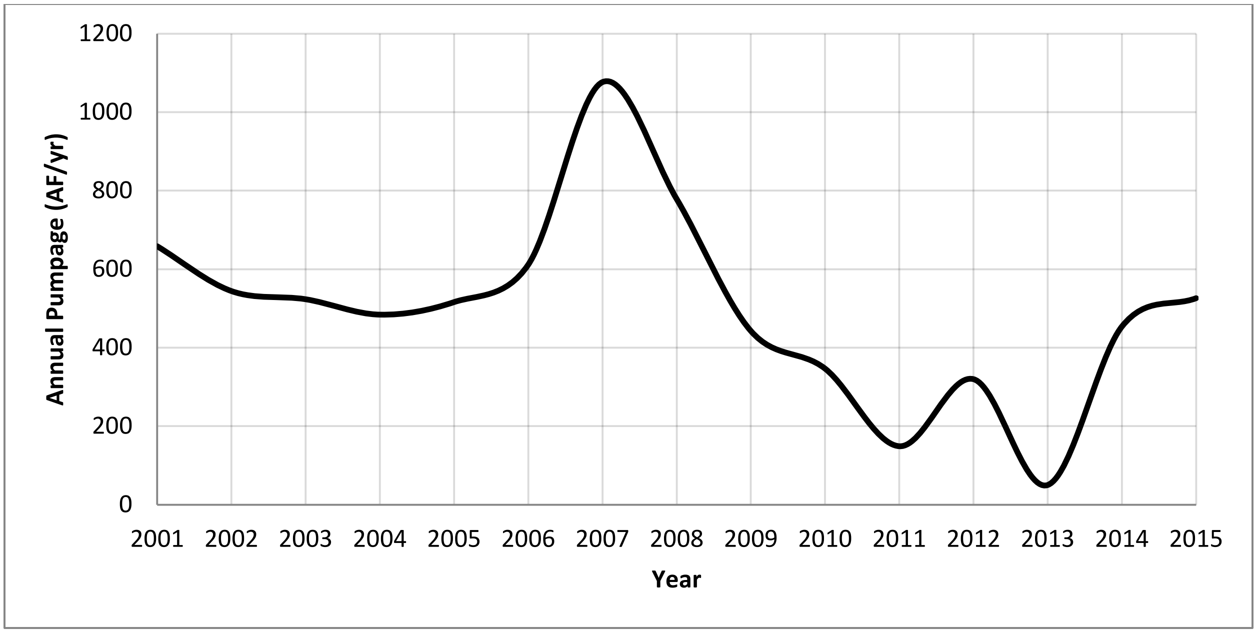

Figure 3. Groundwater Pumping West Lemmon Valley Basin 92

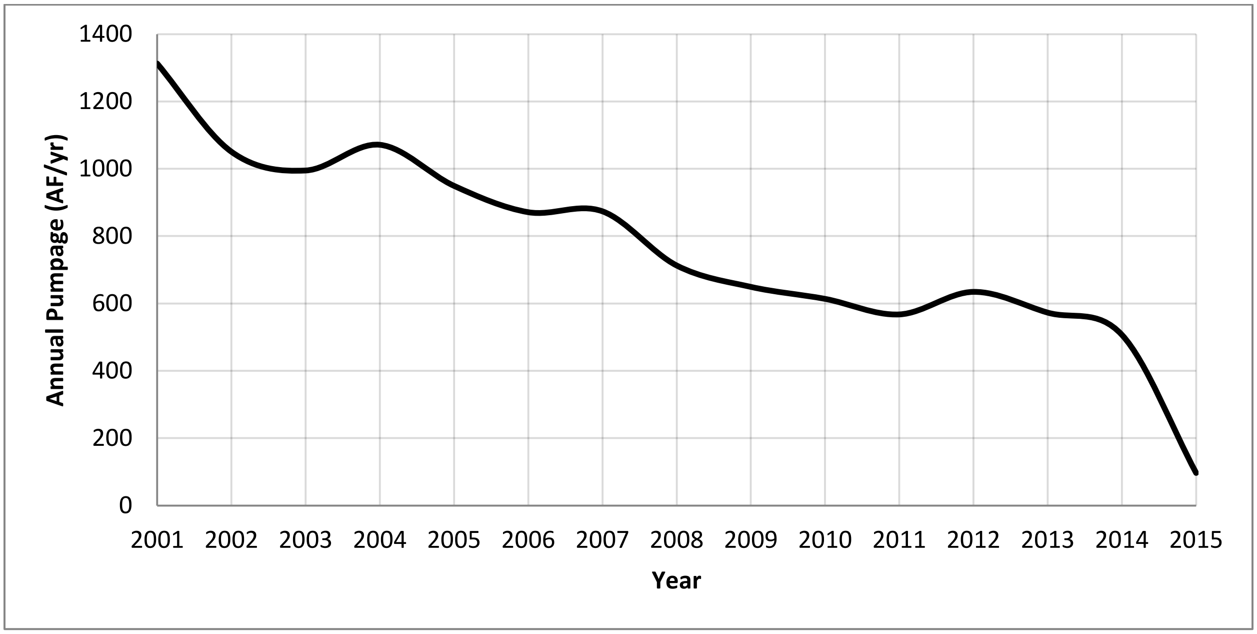

Figure 4. Groundwater Pumping East Lemmon Valley Basin 92

Groundwater Levels

Figures 5 and 6 depict groundwater hydrographs for several wells in WLV. The hydrographs represent the changes in water levels from 2001 through 2015. The water level changes are the result of the variation in precipitation, pumping, recharge, evapotranspiration, and aquifer properties. The graphs indicate that water levels in WLV fluctuate annually with rises during non-pumping and recharge periods (winter months) and declines during pumping periods (summer months). Figures 7 and 8 show the groundwater contours for April 2015 and the difference in water levels between April 2010 and April 2015. Overall, recharge at TMWA production wells has kept water levels relatively stable in WLV.

Figures 9 and 10 are groundwater hydrographs for several wells in ELV. The hydrographs represent the changes in water levels from 2001 through 2015. As in WLV, the water level changes are the result of the variation in precipitation, pumping, recharge, evapotranspiration, and aquifer properties. The graphs indicate that water levels fluctuate annually with rises during non-pumping periods (winter months) and declines during pumping periods (summer months).

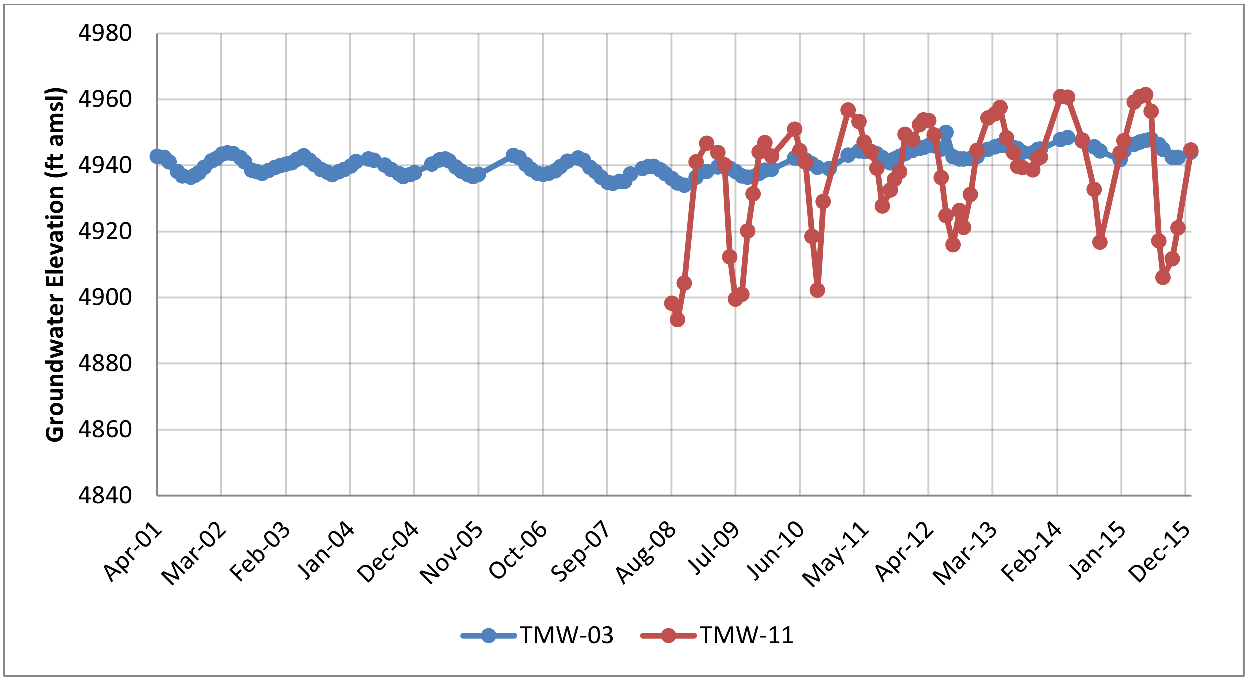

Figure 5. Water Level Changes West Lemmon Valley Basin 92

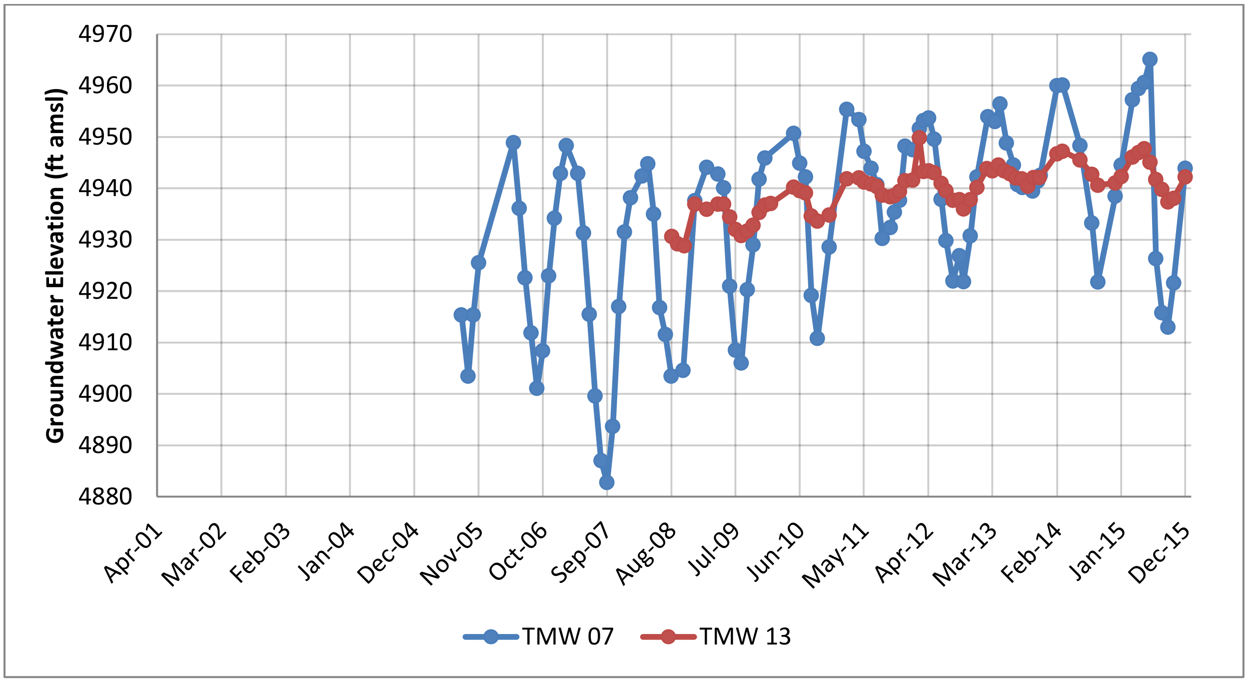

Figure 6. Water Level Changes West Lemmon Valley Basin 92

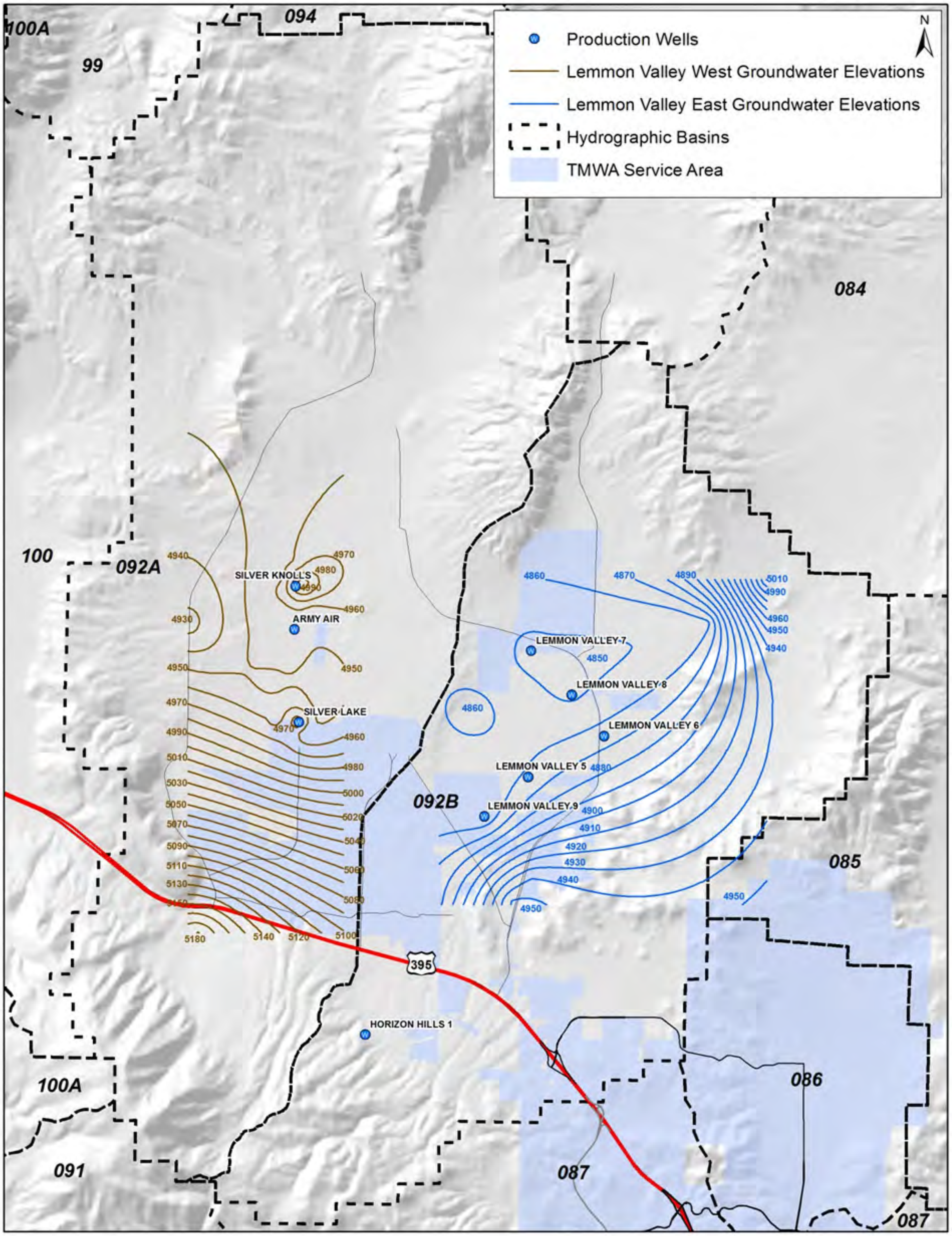

Figure 7. 2015 Groundwater Elevations Contour Map for Hydrographic Basin 92

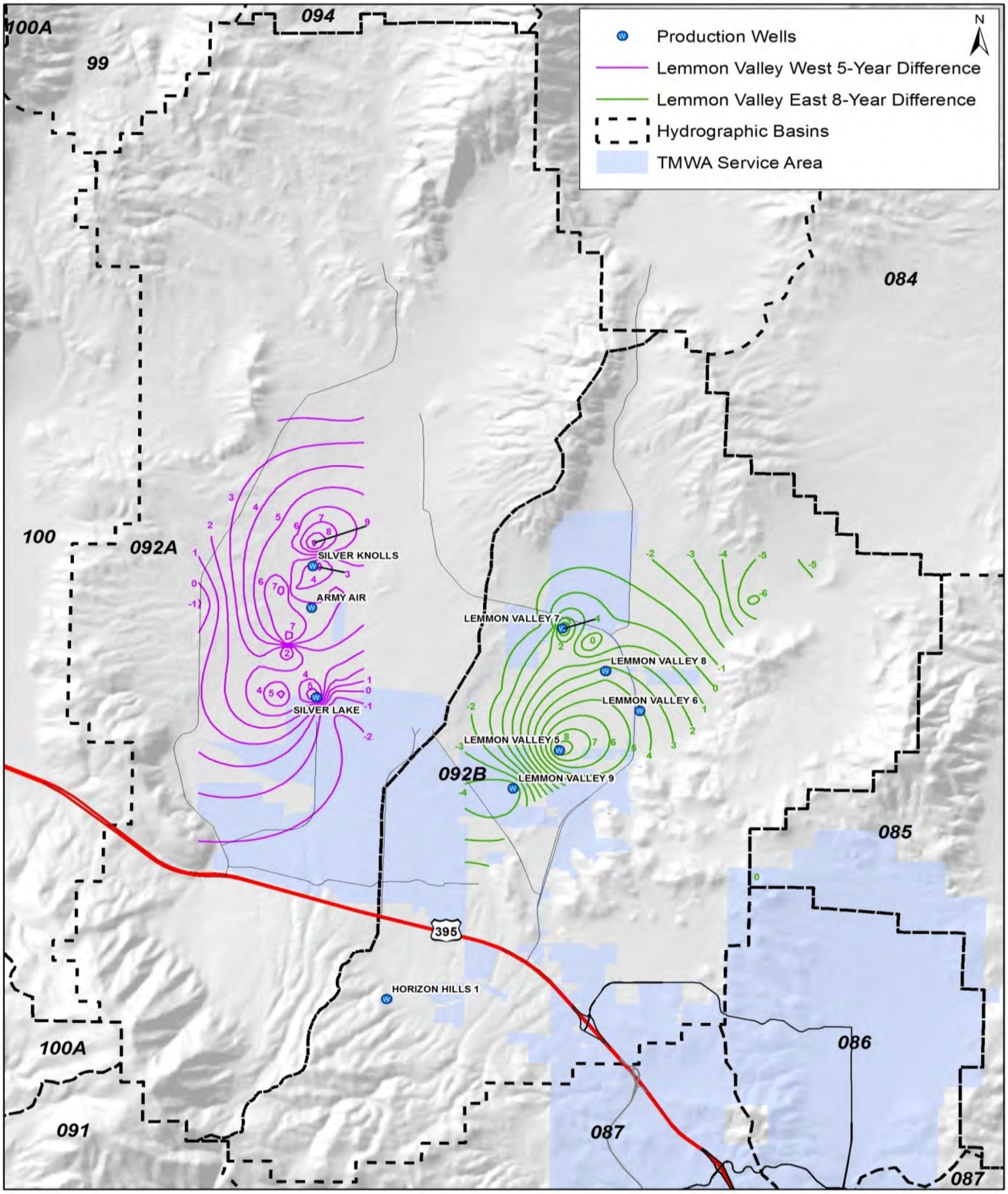

Figure 8. Difference in Groundwater Elevations 2010-2015 Hydrographic Basin 92

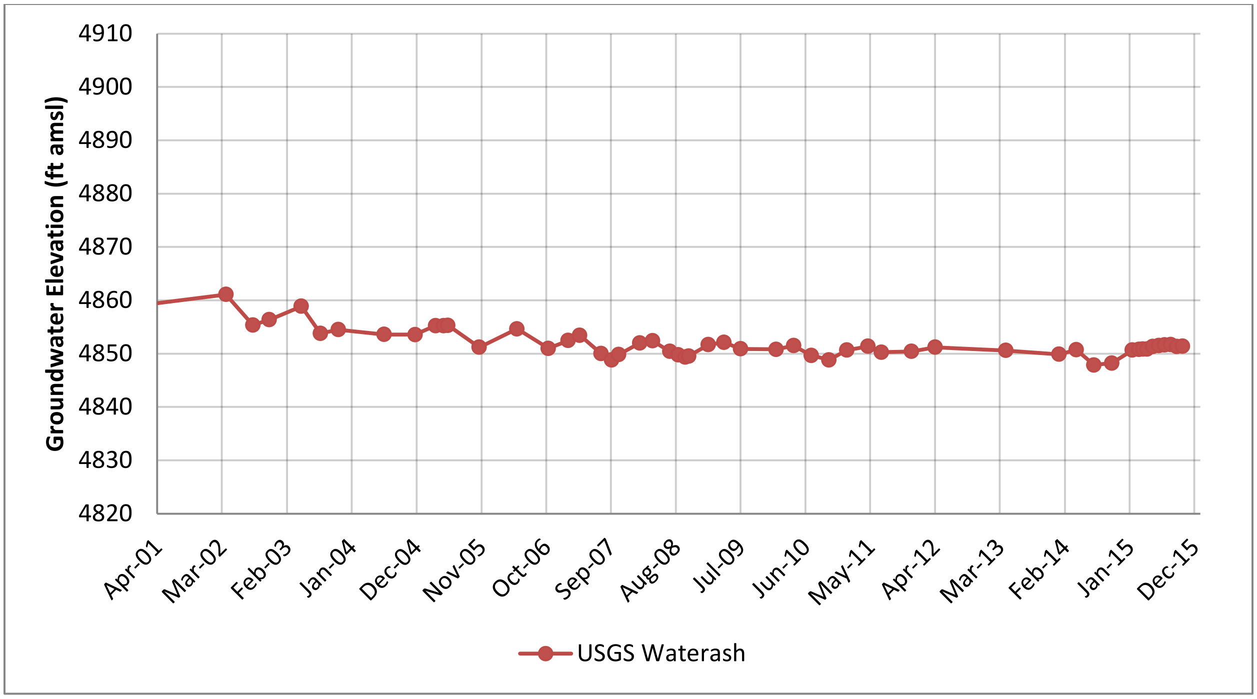

Figure 9. Change in Water Level East Lemmon Valley Basin 92

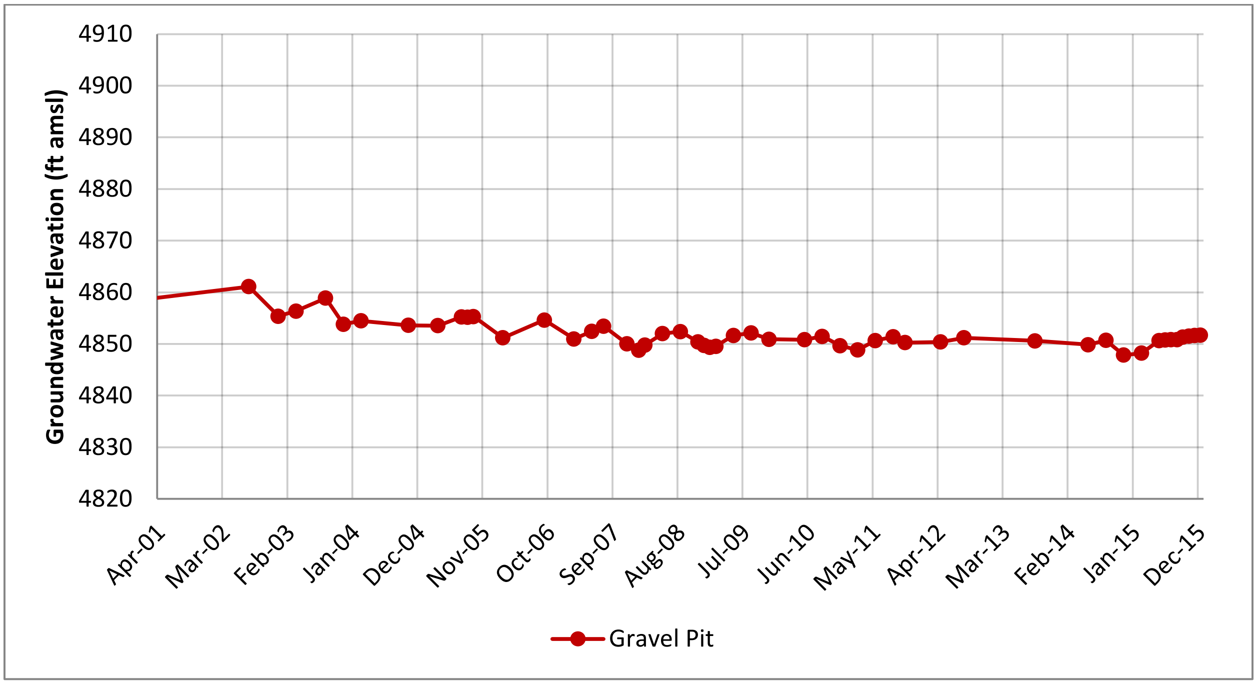

Figure 10. Change in Water Level East Lemmon Valley Basin 92

Currently, production wells in ELV are not utilized for recharge. Water levels have risen since 2010, potentially the result of reduced pumping in production wells and possibly at domestic wells.

Groundwater Quality and Quantity

Groundwater *quality* and *quantity* varies throughout LV. Highly mineralized, poor groundwater quality exists in shallow groundwater near the playa areas in both basins (Figure 11).

Locally, higher nitrate levels are associated with a higher density of septic tanks. The nitrate level found in wells are well-specific and depends on depth to groundwater, flow direction, well screen depth, and the soil types between the septic tanks and well screen.

Remediation of solvent-related contamination at the Stead Solvent Site near the southern boundary of the Stead Airport in Basin 92A began in the late 1990s. The clean-up activities have successfully reduced the migration of the contaminant plume. More information on this remediation site can be found at the Nevada Division of Environmental Protection ("NDEP") website: http://ndep.nv.gov/admin/new.htm.

All TMWA wells in Lemmon Valley have been evaluated for future potential contamination through a Wellhead Protection Plan ("WHPP") updated in 2015. The plan includes the 2, 5, 10, and 20-year capture zones for each production well along with the locations of potential contamination sites. Additional information on groundwater contamination concerns in Lemmon Valley is contained in TMWA's WHPP.

Areas with generally low water quantity are also depicted in Figure 11. Generally, lower water quantity exists in the low transmissivity zones of the fractured rock and in areas where the aquifer is predominantly finer-grained material. Fractured rock wells are located closer to the mountain ridges and away from the center of both West and East Lemmon Valleys. Areas where wells have had water quantity issues include the northern and southern parts of ELV.

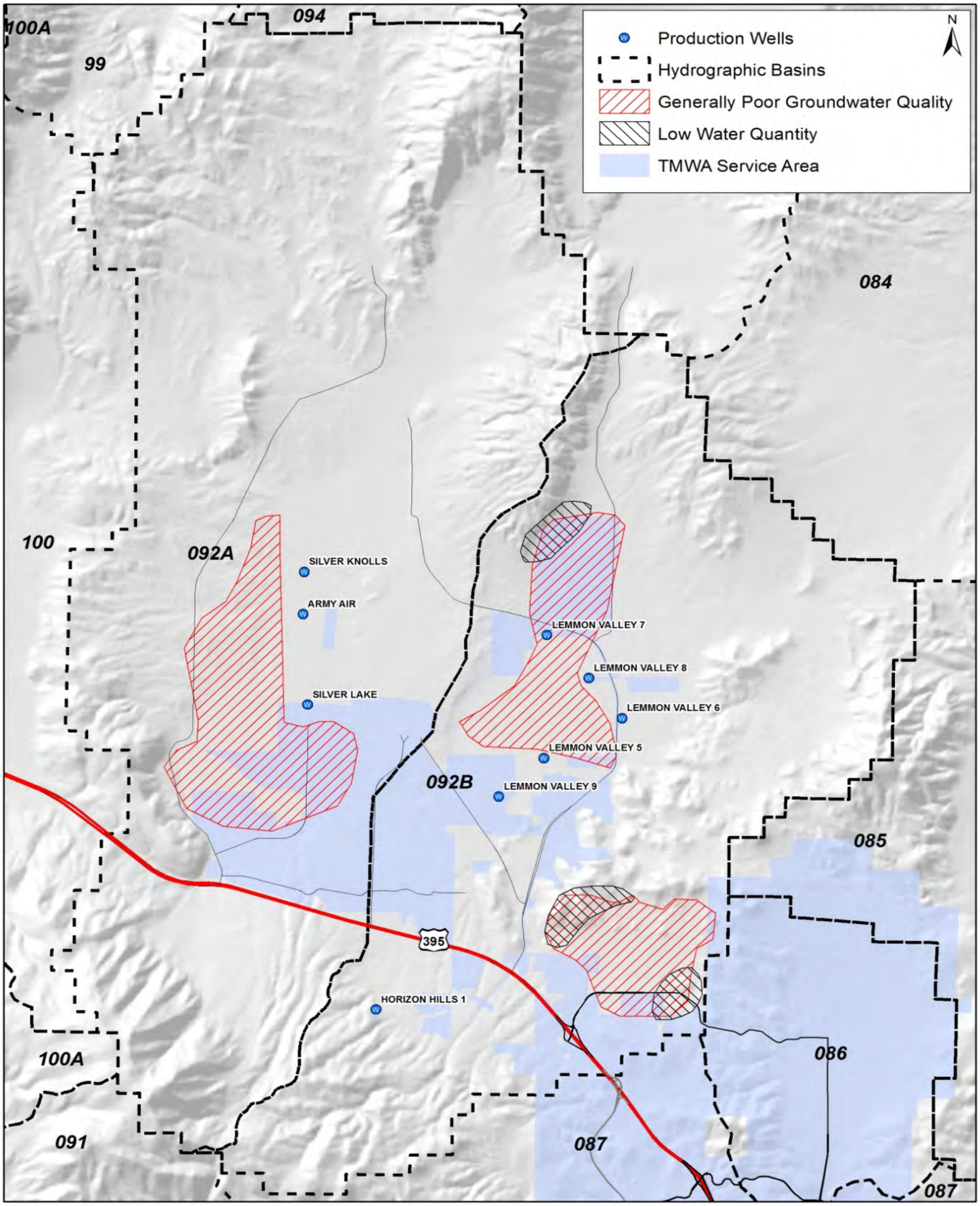

Figure 11. Areas of Poor Water Quality and Low Water Quantity in Hydrographic Basin 92

Aquifer Storage and Recovery – Existing and Potential

Recharge has occurred at the three production wells in WLV since 2000. During 2015, TMWA recharged approximately 400 AF using the three production wells in WLV. TMWA has recharged over 4,700 AF total using three production wells. As shown in the WLV hydrographs, recharge has successfully contributed to water level increases in both deeper and shallow screened wells on an annual basis between 2001 and 2015. Information on the WLV aquifer storage and recovery ("ASR") Program is contained in the 2015 semi-annual report titled, "Report on Aquifer Storage and Recovery, West Lemmon Valley Hydrographic Basin; January 1 through June 30, 2015" filed with NDEP and NDWR.

Currently, recharge does not occur at production wells in ELV.

Groundwater Modeling

Groundwater models have been completed and updated for all of LV several times over the years. In 2015, the WLV model was updated while a separate model was created for ELV. Developing two models is appropriate because the low-permeability Airport Faults minimizes groundwater east-west subsurface flow between the two subbasins.

The 2015 model update for the WLV model included:

9. Updating groundwater levels, pumping, and recharge through 2014.
10. Updating the distribution of aquifer properties using newly acquired data from aquifer tests.
11. Re-calibrating the model in the transient state.
12. Refining the model time steps to daily.
13. Develop well capture zones for 2, 5, 10, and 20 year time periods.

The 2015 model development for ELV included:

1. Updating groundwater levels, and pumping through 2014.
2. Revisiting the Airport Fault and determining that developing the stand-alone ELV model was appropriate.
3. Developing a separate model for the Golden Valley subarea.
4. Updating the distribution of aquifer properties using newly acquired data from aquifer tests.
5. Calibrating the ELV model in the steady-state and transient conditions.
6. Develop well capture zones for 2, 5, 10, and 20 year time periods.

The results of the updated model created the graphics and findings incorporated into this Basin Summary; are the basis of the capture zone analyses for TMWA's production wells; and are the basis of analysis for TMWA's WHPP.

Basin Challenges and Possible Solutions

In LV, groundwater pumping exceeded natural groundwater recharge in the past. This resulted in declining water levels which had negative impacts on wells that were not screened in deeper parts of the aquifer. Addressing water quality issues in areas where wells are impacted by elevated nitrate levels is another challenge in LV. Pumping has decreased since TMWA began the ASR program in WLV. The ASR program in Golden Valley, managed by Washoe County, has also lessened the negative impacts of over-pumping by domestic wells and poor water quality in some parts of that subarea of ELV.

Current demands can be met with existing resources and facilities. However, additional and/or alternate sources of supply are needed to mitigate the effects of over-pumping that has occurred in the basin and to meet future demands. Possible solutions include:

- *Increase Truckee River Use.* Increased use of Truckee River water in this basin would require an additional 0.5 to 1.0 AF of water rights be dedicated for Truckee River return flows for every acre foot of demand, whether that demand is for new development or to offset the use of groundwater. Increased use of Truckee River water provides blending of surface with groundwater which also solves water quality issues.
- *Artificial Recharge*. TMWA currently injects approximately 300 AF/yr in 3 wells in Basin 92A. Implementing additional recharge with FSR water is an option for LV. This option could also help to improve the water quality issues in the basin. Increase use of FSR supplies to meet demands and/or for recharge. Other interbasin sources could be considered as well.
- *Groundwater Replenishment Systems.* Groundwater Replenishment Systems ("GWRS") could inject highly-treated-recovery water at the north end of the basin to offset the over pumping and provide supply augmentation. Washoe County operates a 0.3 million gallons/day ("MGD") wastewater treatment plant in Basin 92B and the City of Reno operates a 2.25 MGD wastewater treatment in Basin 92B. An investigation is underway to determine the feasibility associated with a combined plant and GWRS.

B. NON-TRUCKEE RESOURCE AREA HYDROGRAPHIC BASINS

WASHOE VALLEY – HYDROGRAPHIC BASIN 89 (LIGHTNING W SYSTEM)

Introduction

The Lightning W water system is located in southwest Washoe Valley, west of Highway 395 and along Franktown Road. The relatively small water system is near the south–central boundary of Hydrographic Basin 89. Lightning W is on the east side of the Carson Range. The service area covers roughly one square mile.

Public Water Systems

Three production wells are included in the Lightning W system, serving 98 services. Through 2008, Lightning W Wells 1 and 2 were the water supply wells. From 2003 through 2008 these two wells produced almost equal amounts of water. Lightning W Well 3 was constructed in 2008 and became the primary groundwater source. Lightning W Wells 1 and 2 are completed in fractured rock. Well 3 is completed mostly in alluvial material with the bottom five feet being positioned in weathered granite.

Lightning W Well 1 was constructed in 1994 to a depth of 400 feet with 8-inch casing. The recommended pumping rate for this well is 90 gallons per minute (“gpm”).

Lightning W Well 2 (previously identified as the Ag Well or Upper Well) was constructed in 1963 to a depth of 622 feet with 10-inch casing. The recommended pumping rate for this well is 110 gpm.

Lightning W Well 3 was constructed in 2008 to a depth of 225 feet with 12-¾ inch casing. The recommended pumping rate for this well is 225 gpm.

Groundwater Pumping

Figure 1 depicts the groundwater pumping for the Lightning W system since 2001. Overall, annual pumping has increased over time but remains relatively low at approximately 115 acre feet/year (“AF/yr”).

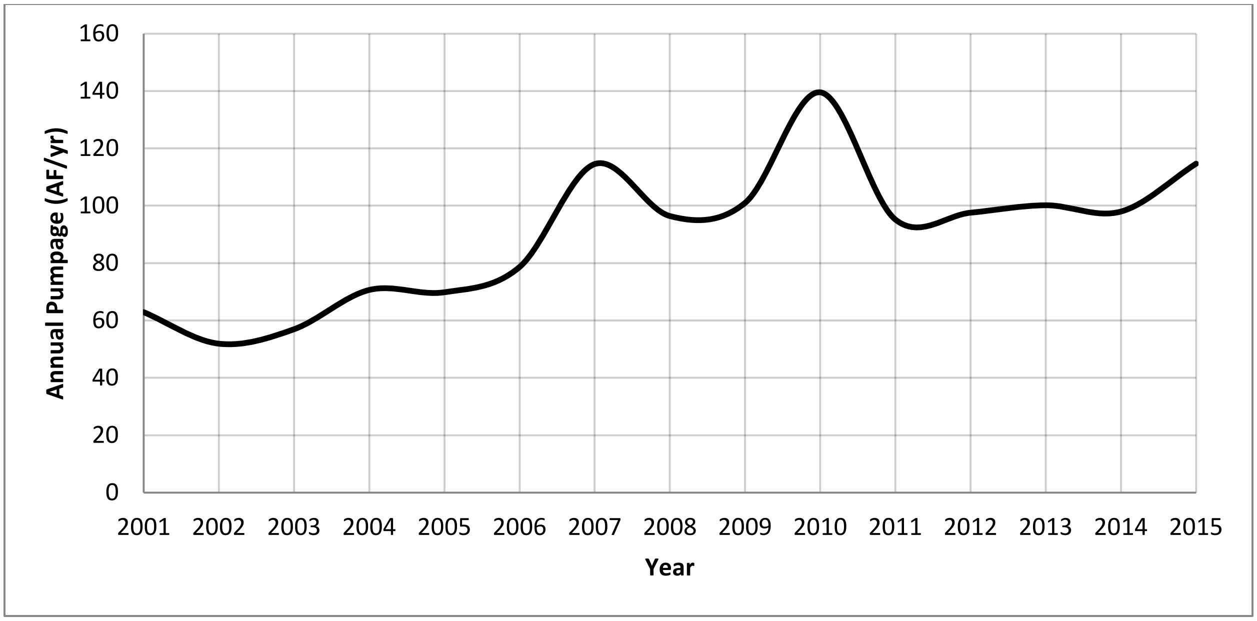

Figure 1. Groundwater Pumping Hydrographic Basin 89 - Lightning W Production Wells

Groundwater Levels

Groundwater level data for Lightning W Well 1 are shown in Figure 2. The data indicate that water levels were declining until 2009. Lightning W Well 3 began pumping in 2008 which allowed for less pumping at Lightning W Well 1. The decreased pumping at Well 1 is the likely reason for the water level trend to reverse and begin rising at this well in 2009. Historic water level data are not available for Lightning W Well 2 or Lightning W Well 3.

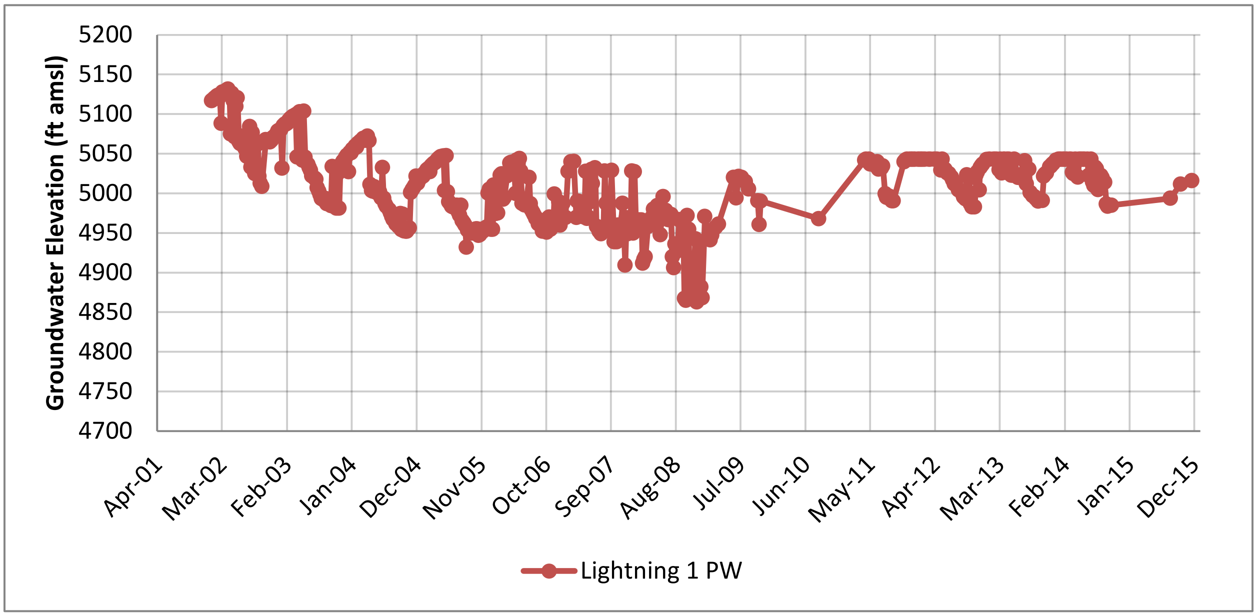

Figure 2. Water Level Changes at Lightning W Well 1

Groundwater Quality and Quantity

In the past, water quality constituents impacting the Lightning W system include uranium, gross alpha, and iron. Lightning W Well 2 is run in a back-up mode due to its low production rate. Lightning W Wells 2 and 3 are run through a treatment system to remove uranium.

The wells are able to produce sufficient groundwater quantity to serve the current customer base.

Basin Challenges

Water quality and quantity are issues for the Lightning W water system. Water quality constituents that may need to be addressed in the future include uranium, gross alpha, iron, and possibly radon if the drinking water standard is lowered for this groundwater constituent.

Groundwater quantity could also be an issue in the future. The addition of Lightning W Well 3 did provide relief for Lightning W Well 1 which allowed water levels to stabilize at this well.

WASHOE VALLEY – HYDROGRAPHIC BASIN 89 (OLD WASHOE ESTATES)

Introduction

The Old Washoe Estates water system, serving 53 services, is located at the north end of Washoe Valley in Washoe City. The production well and water system are east of Highway I-580. The relatively small water system is near the north boundary of Hydrographic Basin 89 and just south of Basin 88. The service area covers roughly one square mile.

Public Water Systems

The water system consists of one production well, Old Washoe Estates Well 3, and one unequipped backup well, Old Washoe Estates Well 4. Approximately 53 lots are included in the service area. Both production wells are completed in fractured rock.

Old Washoe Estates Well 3 was constructed to a depth of 300 feet and has 8-inch casing and screen. Its recommended pumping capacity is 150 gpm.

Old Washoe Estates Well 4 was constructed to a depth of 470 feet and has 8-inch casing and screen. Its recommended pumping capacity is 100 gpm.

Groundwater Pumping

Figure 1 depicts the groundwater pumping for the Old Washoe Estates water system since 2001. Overall, annual pumping has been stable over time at approximately 50 AF/yr.

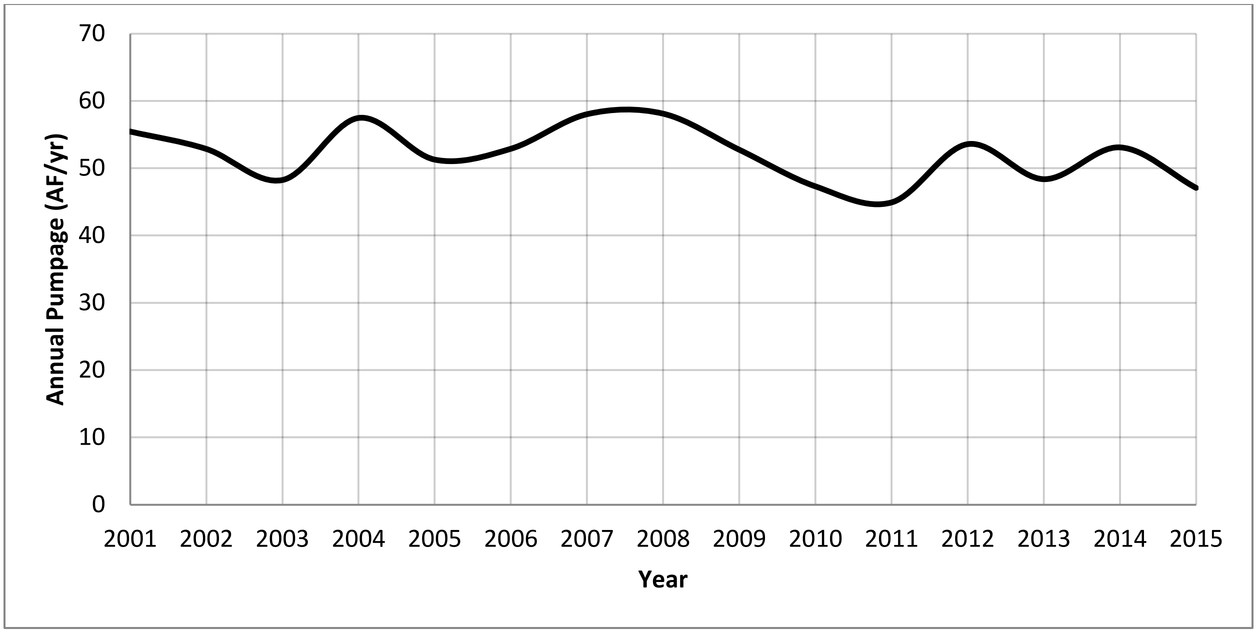

Figure 1. Groundwater Pumping Hydrographic Basin 89 - Old Washoe Estates Production Wells

Groundwater Levels

Groundwater level data for Old Washoe Estates Well 3 are shown in Figure 2. The data indicate that there has been a relatively small decline in water levels since 2006, approximately 5 feet.

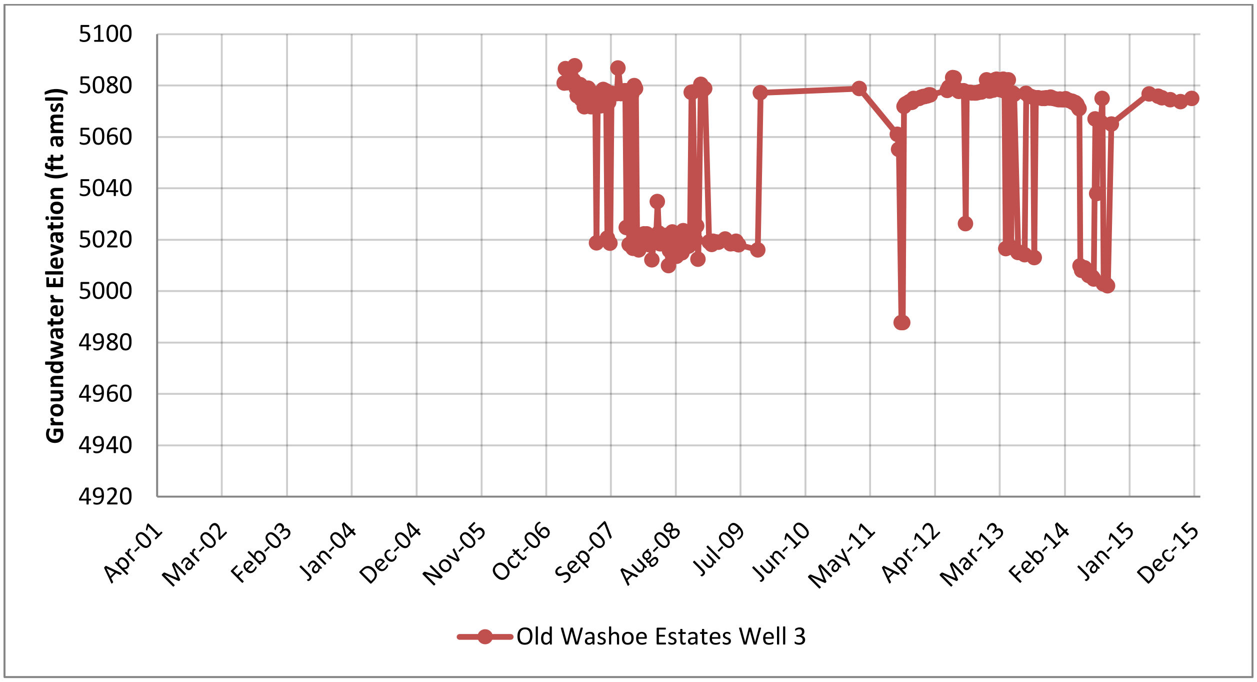

Figure 2. Groundwater Level Changes Old Washoe Estates Well 3

Groundwater Quality and Quantity

There are no water quality issues with Old Washoe Estates Well 3. Old Washoe Estates 4 also produces good quality water.

Old Washoe Estates 3 is able to produce sufficient groundwater quantity to serve the customer base. Equipping the backup well will increase the reliability of the system capacity.

Basin Challenges

Groundwater quantity could be an issue in the future. Additional wells may be required if the customer base expands.

TRACY SEGMENT HYDROGRAPHIC BASIN 83 – TRUCKEE CANYON SYSTEM

Introduction

The Truckee Canyon Water Supply System, serving 13 services, is located east of Sparks and south of I-80 near the Mustang exit. The water system is near the western boundary of Hydrographic Basin 83 and approximately 1,400 feet northwest of the Truckee River. The small water system serves an industrial park.

Public Water Systems

The water system consists of one active well and one unequipped backup well. The active well Truckee Canyon Well 1, was constructed in 1978 and is completed in volcanic rock. The unequipped backup well, Truckee Canyon 3, was completed in 2009 and is also completed in volcanic rock.

Truckee Canyon Well 1 was completed to a depth of 530 feet with 8 5/8-inch casing to 490 feet. The recommended pumping rate is approximately 100 gpm.

Truckee Canyon Well 3 was completed to a depth of 310 feet with 8 5/8-inch casing. The recommended pumping capacity has not been determined at this well.

Groundwater Pumping

Figure 1 depicts the groundwater pumping for the Truckee Canyon system since 2001. Overall, annual pumping has increased over time but remains relatively low at approximately 17 AF/yr.

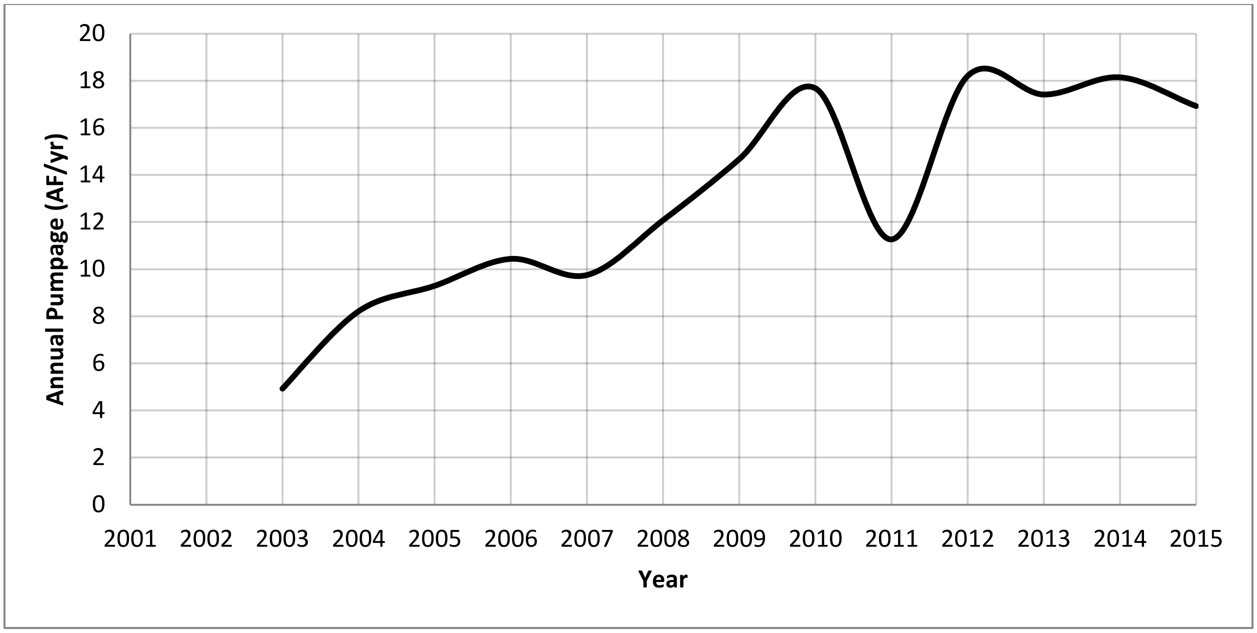

Figure 1. Groundwater Pumping Hydrographic Basin 83 - Truckee Canyon Well 1

Groundwater Levels

No water level data are available.

Groundwater Quality and Quantity

Water quality constituents impacting the Truckee Canyon system include arsenic, iron, and manganese. The groundwater is treated to meet drinking water standards.

The one-well system is able to produce sufficient groundwater quantity to serve the customer base. The unequipped well is scheduled to be online in 2016, which will increase the reliability of the system capacity.

Basin Challenges

Water quality and quantity are issues for the Truckee Canyon water system. Water quality issues are addressed with a treatment system. The treatment system will be upgraded as appropriate when the unequipped well is connected to the system.

Groundwater quantity could also be a challenge in the future. Additional wells may be required if the customer base expands.

TRACY SEGMENT HYDROGRAPHIC BASIN 83 – STAMPMILL WATER SYSTEM

The Stampmill system is located north of I-80 and Wadsworth exit. The system serves 45 customers in the Stampmill Community. The system is on the eastern edge of Hydrographic Basin 83. The service area covers less than 1 square mile.

Public Water Systems

The water system consists of two production wells, Stampmill 1 and Stampmill 2. Both production wells were constructed in 1979 and are completed in alluvial materials.

Stampmill 1 was constructed to a depth of 202 feet and has10¾-inch casing and screen. Its recommended pumping rate is 200 gpm.

Stampmill 2 was constructed to a depth of 230 feet and has inch 8$_{5/8}$–inch casing and screen. Its recommended pumping rate is 400 gpm

Groundwater Pumping

Figure 1 depicts the groundwater pumping for the Stampmill water system since 2001. Overall, annual pumping has been stable over time at 20 AF/yr.

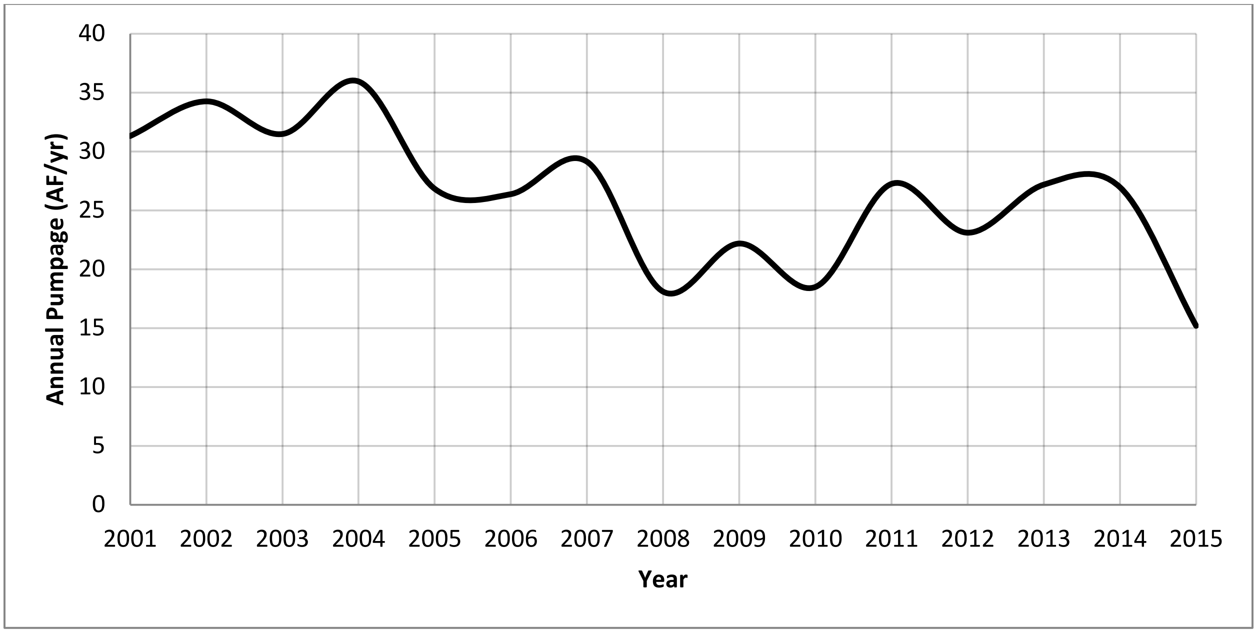

Figure 1. Groundwater Pumping Hydrographic Basin 83 - Stampmill Production Wells

Groundwater Levels

No water level data are available.

Groundwater Quality and Quantity

Iron has been a water quality issue at Stampmill 2 in the past while Stampmill 1 produces good water quality. Septic tanks are in the area which could result in nitrate issues in the future.

The wells are able to produce sufficient groundwater quantity to serve the customer base so water quantity is not a concern.

Basin Challenges

Groundwater quality could be an issue in the future. Septic tanks in the area could contribute nitrate to groundwater and degrade the water quality.

TRUCKEE MEADOWS WATER
AUTHORITY

APPENDIX 2-10

DRAFT TMWA'S WELLHEAD PROTECTION PROGRAM

SEPTEMBER 24, 2015

TRUCKEE MEADOWS WATER AUTHORITY

WELLHEAD PROTECTION PROGRAM

September 24, 2015

DRAFT

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1.0 Introduction

In 1986, amendments to the Safe Drinking Water Act (SDWA) mandated that each state develop a Wellhead Protection Program (WHPP) for the purpose of protecting groundwater that serves as a source for public drinking water supplies. The driving philosophy behind these efforts is that the cost of *cleaning up* contamination far exceeds that of *preventing* contamination.

The Wellhead Protection Program is an active tool, to be used by the Truckee Meadows Water Authority (TMWA) for the coordinated protection of public drinking water resources. Operated voluntarily, under local jurisdiction and control, the program utilizes both Environmental Protection Agency (EPA) and Nevada Division of Environmental Protection (NDEP) guidance and criteria to provide for State endorsement.

Both the EPA and NDEP suggest the inclusion of the following seven elements:

1. A team of local participants.
2. Delineation of the wellhead protection area (WHPA) around drinking water wells where contaminants may find their way into the community's drinking water system.
3. The identification of potential contaminant sources (PCS) that may affect the groundwater.
4. Management strategies for the identified and potential contaminant sources.
5. Plans for locating new wells.
6. Contingency plans to address potential contamination events.
7. Activities for public participation.

In 1996, the first WHPP was completed for the Hidden Valley wells and endorsed by the NDEP. Additional WHPPs were completed in 1998 (STMGID wells), 2000 (Lemmon Valley wells), 2005 (Mt. Rose wells), and 2008 (Spanish Springs wells) and all were endorsed by the NDEP. The first WHPP for TMWA wells was completed in 2005 and was also endorsed by NDEP.

Groundwater protection has received even more attention with the 2014 consolidation of Washoe County Department of Water Resources (WCDWR) and South Truckee Meadows General Improvement District (STMGID) with TMWA. This WHPP update integrates previous wellhead protection planning efforts of all three entities under the planning and direction of one unified water utility (TMWA). This update also incorporates significant improvements including: all production wells for the three consolidated utilities, new wellhead protection areas, an updated PCS inventory, an updated wellhead protection team, and revised management strategies.

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1.1 Purpose and Goals

The ultimate objective of a Wellhead Protection Program is summarized in the following statement:

"The goal of wellhead protection is to provide protection from contaminant releases, so that drinking water standards can be maintained at the well. It must be emphasized that it requires much less effort and money to protect an aquifer than to clean up a contaminated one."

The following summarizes the goals of the WHPP:

- Inform concerned individuals in the community about local drinking water resources and their management
- Identify and evaluate threats to drinking water resources
- Provide management tools to address potential sources of contamination
- Provide ongoing protection for current and future drinking water resources
- Involve the community through public activities, and provide information and education regarding resource protection
- Update the program regularly and monitor significant events over time

1.2 Wellhead Protection Team

A successful WHPP requires the participation and support of the appropriate TMWA staff, as well as jurisdictional authorities that affect water use and land use practices in or around the program's designated wellhead protection areas. The project team serves to notify land use planning, health, the development community and fire protection representatives of the program and associated concerns. The efforts of the team will have bearing on groundwater protection for present and future development.

Because the program is active and ongoing, the membership of the team is expected to change over time. As one member leaves, other people from the community should be asked to join. These members may include representatives of any group that may be affected by, or interested in, wellhead protection activities.

Table 1 lists the current members of the WHPP Team. Included in the table are the names, titles, contact information, and corresponding roles and responsibilities of each team member.

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Table 1
Wellhead Protection Team

Name & Agency	Title	Contact Info
Christian Kropf TMWA	Senior Hydrogeologist	1355 Capital Blvd, Reno, Nevada 89502 775-834-8016 ckropf@tmwa.com
Paul Miller TMWA	Manager, Water Operations & Water Quality	PO Box 30013, Reno, Nevada 89520-3013 775-834-8106 pmiller@tmwa.com
Wes Rubio Washoe County Health District	Senior Environmental Health Specialist	1001 E. Ninth St. Reno, Nevada 89512 775-328-2635 wrubio@washoecounty.us
Chris Anderson Washoe County Health District	Licensed Engineer	1001 E. Ninth St., Reno, Nevada 89512 775-328-2632 CAnderson@washoecounty.us
Ryan Bird City of Reno	Environmental Services Supervisor	PO Box 1900, Reno, Nevada 89505 775-334-2167 birdr@reno.gov
Toby Ebens City of Sparks	Environmental Control Supervisor	PO Box 857, Sparks, Nevada 89432-0857 775-861-4152 tebens@cityofsparks.us

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2.0 Background

2.1 Introduction and Background

TMWA is a not-for-profit, community-owned water utility, overseen by elected officials and citizen appointees from Reno, Sparks and Washoe County. TMWA began operations in June 2001 through a Joint Powers Agreement between the City of Reno, City of Sparks and Washoe County. TMWA provides high-quality drinking water to approximately 400,000 residents of the Truckee Meadows.

TMWA obtains its water supply from surface water and groundwater sources. Surface water from the Truckee River system, including water released from Lake Tahoe, Boca and Stampede Reservoirs, Independence Lake and Donner Lake, provide most of TMWA's water supply. The Chalk Bluff and Glendale plants treat the water from the Truckee River prior to it being delivered to customers through a complex distribution system. Groundwater is pumped from wells throughout the service territory and depending on the location, either supplements surface water during the summer months or provides water supply year-round.

Groundwater sources are a critical component of the TMWA water supply. TMWA currently owns and operates almost 90 active production wells which are used both as a primary source and to supplement the water supply from the treatment plants in the peak summer months and provide backup reliability throughout the year. In winter months, selected wells are recharged with treated surface water to enhance drought supplies and water quality.

The TMWA retail area covers 155 square miles with a distribution system comprised of more than 2,500 miles of underground mains and pipelines, over 110 booster pump stations, 331 pressure regulator stations, 93 storage tanks, three water treatment plants, and two treated water reservoirs. This WHPP covers almost 90 wells in eight different hydrographic basins (Nevada State Engineer's designated basin numbers 83, 85, 87, 88, 89, 92A, 92B, and 97) in northwestern Nevada. Most of the wells are located in basins 87, 88, 85, 92A, and 92B; basin characteristics are discussed in more detail below.

2.2 Basin 87 – North Truckee Meadows

Physical Setting

The Truckee Meadows can be thought of as two regions: North Truckee Meadows (NTM) and South Truckee Meadows (STM). The NTM region extends as far south as the South McCarran Blvd. area and includes Hidden Valley. The STM region starts at South McCarran Blvd. and extends south including Double Diamond, the Mt. Rose fan and foothill areas, and the Virginia Foothills. Together, NTM and STM make up the State Engineer's designated Basin 87. The geologic and hydrogeologic characteristics of STM differ from NTM in that the NTM is dominated by deep basin-fill and Truckee River deposits and the STM is dominated by a large alluvial fan complex consisting of thin alluvial fan deposits overlaying fractured volcanic sequences. Appendix B contains figures showing Hydrographic Basin 87, the NTM and STM areas, and location of TMWA production wells.

When compared to other basins in the Great Basin Province of Nevada, the uniqueness of the Truckee Meadows hydrographic basin is the presence of the Truckee River which flows west to east through NTM. The Sierra Nevada mountain range on the west side of the basin and underlying the valley are complexly faulted. Regional faulting gave the mountains their large-scale size, shape, and relief. The change in elevation ranges from approximately 4,380 feet above mean sea level at the eastern edge of the basin along the Truckee River to 8,269 feet above mean sea level at Peavine Peak in the northwest quadrant of the basin. The present topography of the basin is the result of erosion and smaller scale fault structures.

Along the east side of the basin, the Virginia Range and Pah Rah Mountains are comprised of igneous, volcanic, and metavolcanic rocks. The resulting valley is a structural depression filled with unconsolidated valley-fill material comprised of weathered material from the surrounding mountain ridges including layers of clay, silt, fine- to coarse-grained sand, and gravel. The Truckee River deposited large quantities of coarse-grained alluvial materials along the river corridor and dominates the lithologies encountered by TMWA production wells in the NTM.

Public Water Systems

TMWA currently operates 24 active or back-up production wells in NTM. Four additional wells, I Street, Dilworth, Sparks High, and Reed High are currently unequipped and projected to be brought online over the next 10 years. Two other wells, Peckham and Stanford, are unsuitable for drinking purposes but are used for non-potable applications such as construction water. All of the 24 active wells are screened in alluvium with production capacities ranging from approximately 300 to 2,500 gpm.

Groundwater Quality

Groundwater quality varies throughout the Truckee Meadows hydrographic basin.

Poor water quality, due to highly mineralized groundwater, is found generally in the southeast portion of the basin. Geothermal areas are present in the west and southwest areas of NTM. Groundwater with high arsenic levels is also treated by TMWA. The Central Truckee Meadows Remediation District (CTMRD) has identified 8 PCE contamination plumes in NTM. This solvent has been used since the 1930's in a variety of commercial/industrial operations such as commercial dry cleaning, paint manufacturing, and auto repair. The CTMRD program has achieved success in plume capture and containment resulting from the implementation of a prescriptive pumping schedule of the 5 TMWA wells fitted with PCE treatment equipment. According to the CTMRD, the PCE plumes do not appear to be moving or growing. TMWA is an active participant with the CTMRD program in planning for and implementing mitigation of PCE. Additional CTMRD information can be found at:

https://www.washoecounty.us/csd/utility/ctmrd/downloads.php

Other groundwater contamination sites, with potentially responsible parties, include the Sparks Solvent Fuel Site, leaky underground storage tanks sites, and additional solvent corrective action sites overseen by NDEP.

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2.3 Basin 87 – South Truckee Meadows

Physical Setting

The STM region starts at South McCarran Blvd. and extends south including Double Diamond, the southwest alluvial fan and foothill areas, and the Virginia Foothills. Together, NTM and STM make up the State Engineer's designated Basin 87. Appendix B contains figures that depict Hydrographic Basin 87, the NTM and STM areas, and the location of TMWA production wells.
South Truckee Meadows (STM) is identified as the southern extent of Basin 87 from South McCarran Blvd. to the topographic high along Mt. Rose Highway separating Basin 87 from Basin 88. The STM area is dominated by a large alluvial fanon the southwest with its perennial streams originating in the Sierra Nevada Mountains to the west and the central valley lowland groundwater discharge areas to the east near Double Diamond.

Regional faulting gave the mountains their large-scale size, shape, and relief. The change in elevation in the STM ranges from approximately 4,400 feet above mean sea level at the northeastern lowland discharge area along Steamboat Creek to 10,620 feet above mean sea level at the highest peak on Mt. Rose at the southwest quadrant of the basin. The west side of the basin is comprised primarily of granodiorite overlain by fractured volcanic andesitic and basaltic rock sequences. Along the east side of the basin, the Virginia Range is comprised of igneous, volcanic, and metavolcanic rocks. The resulting valley is a structural depression filled with unconsolidated valley-fill material comprised of weathered material from the surrounding mountain ridges including layers of clay, silt, fine- to coarse-grained sand, and gravel. Generally, valley fill is coarser near the mountain ridges and becomes fine-grained in the center of the valley.

The basin can be divided into two aquifer systems from which water is pumped into public water systems: (1) alluvial fan and fractured volcanic rock aquifer located on the southwest side of the basin and (2) a basin-fill aquifer in the central and northern portion of the STM.

Public Water Systems

TMWA currently operates two distinct well fields penetrating two distinct aquifer types and can be referenced as alluvial fan wells and basin-fill wells in the South Truckee Meadows area.

Mt. Rose Fan wells are completed in the alluvial fan and fractured rock aquifer on the southwest alluvial fan and are bounded on the east by S. Virginia St., on the south by the Mount Rose Hwy. and on the west by Timberline Dr. and the Carson Range. The alluvial fan well field consists of 12 active or back-up production wells constructed between 1978 and 2011 with production capacities ranging from 200 to 1,500 gpm.

Wells to the north of the Mt. Rose Fan wells are completed in the basin-fill aquifer and are located between South McCarran Blvd. and Damonte Ranch Pkwy. This well field consists of 12 active or back-up production wells constructed between 1968 and 2015 with production capacities ranging from 550 to 1,800 gpm.

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Groundwater Quality

Groundwater quality varies throughout the STM basin. Low TDS groundwater is found within the alluvial fans at the base of the Sierra. The water quality deteriorates at the valley floor where it mixes with highly mineralized geothermal waters discharged from the Steamboat Springs Geothermal Area at the south end of the valley (Steamboat Hills). Localized areas of high density septic tanks may contribute to high nitrate in shallow groundwater.

2.4 Basin 88 – Pleasant Valley

Physical Setting

The Pleasant Valley area, Hydrographic Basin 88, encompasses 39 square miles and is bound to the north by the Steamboat Hills, to the east by the Virginia Range, and to the west by the Carson Range. Pleasant Valley is separated from Washoe Valley to the south by a topographic and hydrologic divide created by low hills of granitic, volcanic, and metavolcanic rocks.

The basin can be described as having two geographically and hydrogeologically distinct regions from which water is pumped into public water systems: (1) an alluvial fan and fractured volcanic rock aquifer located in the western higher elevation part of the basin referred to as West Pleasant Valley and (2) a basin-fill aquifer in the lower, eastern part of the basin referred to as East Pleasant Valley.

Appendix B contains figures that depict Hydrographic Basin 88, the West and East Pleasant Valley regions, and the location of TMWA production wells.

From west to east, the alluvial fan and basin-fill aquifers are similar to those described in Basin 87. In West Pleasant Valley, the alluvial fan aquifer is conceptualized as a complex aquifer system comprised of: 1) thin alluvial fan deposits, 2) consolidated sedimentary deposits, 3) thick interbedded fractured volcanic sequences, and 4) granitic, volcanic, or metavolcanic basement rock. The basin-fill aquifer system is conceptualized as a complex aquifer system comprised of: 1) alluvium, 2) partly confined alluvium, 3) fractured volcanic sequences, and 4) granitic, volcanic, or metavolcanic basement rock.

Public Water Systems

TMWA currently operates 9 active production wells in Basin 88, serving approximately 30 lots. Three additional wells, Sunrise Estates 3, Mt. Rose 2, and STMGID 8, operate infrequently as back-up wells. Two more wells, Callamont 1 and Callamont 2, are currently unequipped and projected to be brought online over the next 10 years. All but two of the active wells (Sunrise Estates 1 and 3) are located in the West Pleasant Valley. Active wells were completed from 1974 to 2000 with production capacities ranging from a low of 150 to a high of 800 gpm.

Groundwater Quality

Groundwater quality varies throughout the Pleasant Valley basin. Poor water quality, due to highly mineralized groundwater, is found generally in the eastern portion of the basin near the eastern flank of the Steamboat Hills where geothermal influences are most pronounced.

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2.5 Basin 85 – Spanish Springs Valley

Physical Setting

Spanish Springs Valley (SSV) is a topographically closed basin bounded on the east by the Pah Rah range and on the west by the Hungry Ridge range covering an area of approximately 80 square miles. The basin can be divided into two aquifer systems from which water is pumped into public water systems: (1) a volcanic rock aquifer located on the east side of the basin and (2) an alluvial aquifer in the western and central portion of SSV. A third portion of the basin, a granitic aquifer on the northeast basin slopes of the Pah Rah Range, is a meager aquifer that barely supports approximately 380 domestic wells. Appendix B contains figures depicting the Spanish Springs Hydrographic Basin and location of TMWA production wells.

Public Water Systems

TMWA currently operates two distinct well fields in SSV. The Desert Springs system is located on the west side of SSV and consists of five active or back-up production wells constructed between 1963 and 1990. The west side wells are completed in alluvial material and have production capacities ranging from 350 to 750 gpm. The Spring Creek system is located primarily on the east side of SSV and consists of four newer wells constructed between 1997 and 2005. The east side wells are completed in fractured volcanic material and have production capacities ranging from 1,000 to 3,000 gpm.

Besides TMWA, Utilities, Inc. has facilities and customers in the Spanish Springs basin. Utilities, Inc., a PUCN regulated utility has a service area north of La Posada Drive and east of Pyramid Highway and serves about 580 connections in the area previously referred to as “Sky Ranch.”

Groundwater Quality

Poor groundwater quality exists in the central and southwest part of SSV. Poor groundwater quality is found in the southwest of SSV due to hydrothermally altered volcanic rock with high concentrations of arsenic and sulfate. In the center of SSV, septic tank effluent has polluted shallow groundwater with nitrate. Nitrate contamination has persisted over the past twenty years, rendering five production wells (Desert Springs 1, 2, 3, and 4 and Spring Creek 2) at risk.

WCDWR thoroughly investigated nitrate contamination and prepared full report that details sources, extent, and migration of nitrate titled, “Final Report: Spanish Springs Nitrate Remediation Pilot Project, Phase II: Nitrate Source, Extent, Magnitude, Migration, and Management Options” (Kropf and Dragan, 2010). There are two figures included in Appendix E that depict the extent of nitrate contamination in SSV. Blending with Truckee River water and other well water is the current groundwater treatment practice for nitrate and arsenic. In addition to converting homes on septic to sewer, increasing the amount of artificial recharge (ASR) in west side wells is a future alternative to help mitigate water quality issues.

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2.6 Basin 92A & 92B – Lemmon Valley

Physical Setting

Lemmon Valley (LV) is a topographically closed basin typical of those in the Basin and Range region (Harrill, 1973). The mountains surrounding and bedrock underlying the valley are complexly faulted. The mountains are comprised of igneous, volcanic, and metavolcanic rocks. Regional faulting gave the mountains their large-scale size, shape, and relief. The change in elevation ranges from approximately 4914 feet above mean sea level at the eastern sub-area playa to 8266 feet above mean sea level at highest peak on Peavine Mountain at the south end of the basin. The present topography of the basin is the result of erosion and smaller scale fault structures. Appendix B contains figures depicting the Lemmon Valley hydrographic basin and the locations TMWA production wells.

The valley is a structural depression filled with unconsolidated valley-fill. Features other than mountain ridges include valley-fill deposits and playa lakes. The valley-fill is comprised of weathered material from the surrounding mountain ridges including layers of clay, silt, fine- to coarse-grained sand, and gravel. Generally, valley-fill is coarser near the base of the mountain ridges and becomes finer-grained in the center of the valley near the playas. Playa lake deposits are mostly clay, silt, and fine-grained sand. The aquifer system is conceptualized as three hydrostratigraphic units, from top to bottom: 1) playa deposits; 2) alluvium; and 3) fractured bedrock. These units are identified as distinct units based on differences in geologic, hydraulic, and water yield characteristics.

Lemmon Valley is designated by the State Engineer as basin number 92, and is subdivided into the east and west subbasins by the Airport Fault which runs down the middle of the basin: West Lemmon Valley is identified as Basin 92A (WLV) and East Lemmon Valley is Basin 92B (ELV).

WLV contains the Silver Lake playa in the center of the subbasin with large commercial/ industrial properties and residential properties to the east, and additional residential properties to the southeast. North of Silver Lake is the Silver Knolls subdivision with about 500 residences that utilize domestic wells and septic tanks, and west of the Silver Knolls subdivision is the Silver Knolls Water Mutual system serving 64 residential lots.

ELV includes the Swan Lake playa located in the central portion of the basin. Golden Valley is a hydrographic subarea in the southeast corner of Basin 92B which includes both residential and commercial properties in the Golden Valley area. There are over 550 properties on domestic wells and septic tanks in this subarea.

Public Water Systems

TMWA operates two distinct wellfields in West and East Lemmon Valleys. The WLV wellfield consists of three equipped wells and one unequipped well. These wells are completed in alluvium and have production capacities ranging from 800 to 2,500 gpm. The ELV production wellfield consists of 5 wells completed in alluvium that have production capacities ranging from approximately 200 to 1,000 gpm.

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Besides TMWA, there is a minor utility in the Silver Knolls area, Silver Knolls Mutual Water, which serves about 64 connections. TMWA provides service in the Silver Lake development, the Stead area, and in northwest and the east side of Basin 92B.

Groundwater Quality

Highly mineralized, poor ground water quality exists in shallow groundwater near the playa areas in both basins. Locally, higher nitrate levels are associated with a higher density of septic tanks. The nitrate level found in wells are well-specific and depends on depth to groundwater, flow direction, well screen depth, and the soil types between the septic tanks and well screen.

Remediation of solvent-related contamination at the Stead Solvent Site near the southern boundary of the Stead Airport in Basin 92A began in the late 1990s. The clean-up activities have successfully reduced the migration of the contaminant plume. More information on this remediation site can be found at the Nevada Division of Environmental Protection website: http://ndep.nv.gov/admin/new.htm.

2.7 Inventory of TMWA Wells

Appendix A includes a table of active TMWA production wells, which provides pertinent information for each of TMWA's wells.

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3.0 Delineation of Wellhead Protection Areas

Sections 3.1 and 3.2 generalize the approach used to create capture zones for TMWA production wells within the various basins modeled. Text was assimilated from groundwater modeling reports provided by LBG Guyton and Dr. Greg Pohll.

3.1 Introduction

Six groundwater flow models were updated to reflect actual pumping from TMWA (and others) through the year 2014. Updated models included:

- West Lemmon Valley (Basin 92A)
- East Lemmon Valley (Basin 92B)
- Spanish Springs Valley (Basin 85)
- North Truckee Meadows (Basin 87)
- South Truckee Meadows (Basin 87)
- Pleasant Valley (Basin 88)

Future scenarios were constructed to simulate groundwater flow over a 20-year period (2014-2034) for each of the modeled areas. Projected pumping rates were based on the past 7 years of production well pumping and were simulated for 20 years through the year 2034. The models were then used to simulate water levels and groundwater velocity throughout the valley. This information was then used to estimate capture zone areas around production wells.

3.2 Methodology

Capture zones around TMWA production wells were estimated by using the results of each of the MODFLOW groundwater models (heads and groundwater velocity estimates) as input into the program MODPATH. MODPATH is a particle tracking post-processing package that was developed to compute three-dimensional flow paths using output from steady-state or transient groundwater flow simulations by MODFLOW, the U. S. Geological Survey finite-difference groundwater flow model. MODPATH uses a semi-analytical particle-tracking scheme that allows an analytical expression of the particle’s flow path to be obtained within each finite-difference grid cell. Particle paths are computed by tracking particles from one cell to the next until the particle reaches a boundary, an internal sink/source, or satisfies some other termination criterion.

Capture zones are estimated by reverse-tracking multiple particles from the well. In reverse tracking, the particles move away from the well instead of toward the well as they normally do in the aquifer under pumping conditions. Therefore, the reverse-tracked particles placed around the well typically diverge away from the well in a fashion that indicates the location of the groundwater particle at a particular point in time. By carefully defining the starting locations of particles, it is possible to perform a wide range of analyses, such as delineating capture areas. Capture zones can be estimated from these particle locations by connecting the locations of particles that have been reverse tracked from a production well for the same amount of time.

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3.3 Results

The finalized wellhead protection areas are shown on a series of figures in Appendix B. Capture zones representing time frames of 2, 5, 10 and 20 years are shown for most production wells. Some wells are located in areas where groundwater modeling has not been completed. The capture zones for those wells are represented by the area within a ½ mile radius of the well.

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4.0 Potential Contaminant Source Inventory

4.1 Background

The identification of potential contamination sources in the vicinity of existing wells is a critical component of this program. An accurate knowledge of the potential threats to groundwater quality will allow TMWA to create the best plan to protect local water resources.

To begin the process of identifying PCSs, searches from EPA's Envirofacts database and NDEP's underground storage tank databases were conducted. From Envirofacts, the RCRAInfo (Resource Conservation and Recovery Act Information) search engine was utilized to conduct searches for four categories of PCSs: large quantity hazardous waste generators (LQGs), small quantity hazardous waste generators (SQGs), conditionally exempt small quantity hazardous waste generators (CEGs) and other PCSs not classified as hazardous waste generators. Through RCRAInfo, all generators, transporters, treaters, storers, and disposers of hazardous waste are required to provide information about their activities to state environmental agencies.

NDEP maintains databases for federally regulated underground storage tanks, active underground storage tank cases undergoing investigation for leaks or remediation, and closed underground storage tank sites that have been successfully remediated. All active underground storage tanks and all tank sites closed within the last five years, have been included in the PCS database.

4.2 Methodology

4.2.1 Framework

Six tables have been created providing TMWA with a fairly comprehensive list of PCSs. These tables, located in Appendix C, depict the PCSs broken into LQGs, SQGs, CEGs, other potential sources, active underground storage tanks and closed underground storage tanks.

4.2.2 Compilation of Data

Using ArcGIS software and information from the sources described above, a database containing PCSs within TMWA service territory was developed. The database includes information from the following sources:

- Envirofacts Data Warehouse. This source of data is available on the EPA website. This website provides access to several EPA databases that provide information about environmental activities that may affect air, water, and land anywhere in the United States. Envirofacts provides many different databases for contaminants such as hazardous wastes, toxins and radiation. Depending on which search engine is utilized (RCRAInfo, TRI, etc.), it is possible to conduct searches for the generation, management, minimization, investigation or handling of different contaminants.
- RCRAInfo Search. Hazardous waste information is contained in the Resource Conservation and Recovery Act Information (RCRAInfo) database, a national program management and inventory system about hazardous waste handlers. In general, all generators, transporters, treaters, storers, and disposers of hazardous waste are required to

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provide information about their activities to state environmental agencies. This search engine was the primary search engine utilized.

- NDEP Bureau of Correction Actions. NDEP maintains databases for corrective actions/leaking underground storage tanks and federally regulated underground storage tanks. These databases provide information regarding active cases and closed cases.
- Washoe County Community Services Department, Central Truckee Meadows Remediation District (CTMRD). The CTMRD Program provided access to a database that contained historical and current PCE users, wells that are being used to monitor the PCE plumes, and PCE plume contour information.

4.3 Summary of Results

The PCS database was used to create a series of highly detailed figures showing the locations of PCSs in proximity to TMWA wells and capture zones. These figures are included in Appendix B. The WHPAs managed by TMWA contain numerous PCSs. PCSs fall into six broad categories: LQGs, SQGs, CEGs, Other PCSs, Active UST Sites and Closed UST Sites. Typical examples of each of these PCS categories are provided below.

1. Large Quantity Generators (LQGs)

Large quantity generators generate 1,000 kilograms per month or more of hazardous waste, or more than one kilogram per month of acutely hazardous waste. Many of the LQGs are industrial facilities.

Examples:
- RR Donnelley – Commercial printing
- Renown Regional Medical Center – General medical and surgical hospitals

2. Small Quantity Generators (SQGs)

Small quantity generators generate more than 100 kilograms, but less than 1,000 kilograms, of hazardous waste per month.

Examples:
- Bill Pearce Body Shop – Equipment repair and maintenance
- Bobby Page’s Dry Cleaners – Dry cleaning and laundry services

3. Conditionally Exempt Generators (CQGs)

Conditionally exempt generators generate 100 kilograms or less per month of hazardous waste or one kilogram or less per month of acutely hazardous waste.

Examples:
- 7 Eleven – Gasoline Stations with Convenience stores
- Lindells Painting Service – Painting and wall covering contractors

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4. Other Potential Contaminant Sources

These facilities are not classified as hazardous waste generators; however, they are classified as facilities containing potential contaminants. These facilities are a compilation of gas stations, auto body shops, paint shops, laundromats, and many other facilities that pose threats.

Examples:

- A1 Body Shop – Automotive Body, Paint, and Interior Repair and Maintenance
- Quickie Mart – Pharmacies and Drug Stores

5. Underground Storage Tanks

These are underground storage tanks that are federally regulated and active. These tanks have either leaked or are being investigated for leaks. There are many active tank sites in the TMWA service area. Some of the sites are being managed, but others are not.

6. Closed Storage Tanks

These are underground storage tanks that have either leaked or required remediation in the past and are now closed. The cases used in this study have been closed within the last five years.

4.4 Updating the PCS Database

The PCS inventory should be updated regularly, at least every 5 years.

4.5 PCS Observations

TMWA has responded to groundwater quality issues for a number of years, and TMWA has historically located and constructed wells which avoid aquifer intervals having inferior water quality. A few wells have been abandoned as potable sources or have been converted to non-potable uses over the years, most notably the Stanford Way Well in Sparks and the Peckham Lane Well in Reno. Both of these wells had high levels of arsenic, iron and manganese exceeding drinking water standards.

Even so, a number of important TMWA wells have experienced water quality problems prompting TMWA to take action. Six wells (Greg, Pezzi, Poplar #1, Terminal, Mill and Corbett) are piped to Glendale Treatment Plant (GTP) for treatment and/or blending with treated surface water.

Other wells near the urban center of Reno have been impacted with the contamination from a volatile organic chemical called tetrachloroethylene (PCE). PCE is a solvent that is used in dry cleaning and metallurgical operations. For many years the disposal of PCE was not regulated, it has only been recently that PCE has been regulated in drinking water. Wells that have been impacted by PCE have been equipped with treatment technologies to effectively remove the PCE prior to the distribution system. PCE has also been found at locations that threaten other production wells. The treatment and operation of these wells has been coordinated with a Washoe County organized "Remediation District" which helps to offset the cost of treatment. A map showing the extent of PCE contamination and other useful information is included in Appendix D.

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There have been other instances where groundwater contamination has threatened TMWA wells. TMWA wells on South Virginia Street have been threatened by leaking underground gasoline tanks (benzene). In addition, solvent based contamination has been found in the shallow aquifer near TMWA wells in the Stead (North Valleys) area. Even though many leaking tanks have been replaced or removed, the threat of contamination remains and TMWA continues to closely monitor groundwater quality in the affected area.

High nitrate levels exist in the groundwater in several areas of the TMWA service territory, which can usually be attributed to residential septic tanks. WCDWR and TMWA have been actively addressing this issue for many years.

In outlying, sparsely populated and predominantly residential areas, there are few PCSs. However, in commercial and industrial areas, there are a number of PCSs that should be monitored.

4.6 Using the Figures and Data Tables

A list of all the wells included in this report are included in Appendix A. The wells are listed in the order that they appear in Appendix B, which includes individual figures for each well, their respective capture zones and all identified PCSs. PCSs are shown on the figures using symbols that indicate the PCS category (LQG, SQG, Active Release Site, etc.) and are assigned an ID number. The ID numbers correspond with the data tables that are included in Appendix C.

4.7 Significant Findings

Review of the PCS data and capture zone overlays indicate the following significant concerns:

Basin No.	Well Potentially Impacted	Capture Zone (year)	PCS No.	PCS of Concern
87	Hidden Valley 3 & 5	N/A	51	Groundwater impacted Solvents: PCE, Trichloroethene, cis-1,2-Dichloroethene
87	Hidden Valley3	2	46, 47	Brownfields, Unknown Contaminants
87	High	10	62	Petroleum product in soil
87	Reno High	10	71	Gasoline in soil and groundwater
87	Delucchi	2	106	Solvents in soils and groundwater
92A	Silver Lake	20	55	Transformer oil in soil

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5.0 Contaminant Source Management Plan

5.1 Purpose

A contaminant source management plan is a plan that contains specific strategies for controlling or eliminating the known threats to local drinking water sources. The State of Nevada Bureau of Water Pollution Control provides the following direction regarding management strategies (NDEP, 2004):

"*Following the delineation of wellhead protection areas and the identification of actual and potential sources of contamination within them, an approach to managing those sources must be developed and implemented. The Bureau of Water Pollution Control recommends that a management plan be developed for all public water systems. However, because the degrees of need, financial resources, and control over land use activities vary by community, there is no model plan that can be followed uniformly. It is the responsibility of the WHPP Team and the implementing agencies to assess the level of risk to the aquifer and the level of threat posed by various contaminant sources. Based on this evaluation, each community must balance the issues of potential threats, acceptable risk, and degree of management the community is willing to support. The WHPP Team will then define the levels of management that are deemed appropriate for the community's wellhead protection areas.*"

5.2 TMWA Management Plan

The wellhead protection areas managed by TMWA contain numerous potential sources of contamination. In addition, areas and features adjacent to, and in some cases up-gradient of these WHPAs also contain potential sources of contamination. Therefore, the identification of the appropriate management strategies is helpful.

Two types of management strategies were developed to address the variety of potential contaminant sources of concern to TMWA. Management strategies for specific PCS categories were developed. In addition, a few general management tools are also proposed to address area-wide concerns, and engender cooperation between local agencies and citizens' groups.

5.2.1 Management Strategies for Specific PCS Categories.

This section addresses management strategies for specific PCS categories, such as underground storage tanks. Management strategies are summarized in Table 2 and explained in detail following the table. Potential contaminant sources located in or near WHPAs are of the highest priority.

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Table 2
Management Strategies for Specific PCS Categories

PCS Category	Management Strategy
PCE Sites	TMWA, CTMRD
Leaking Underground Storage Tanks	Identification and Reduction Plan Regulatory Enforcement WHPP Team Involvement
Abandoned or Private Wells	Well Survey Contact Owners and Drillers
Monitoring Wells	Management and Reduction Plan WHPP Team Involvement
Septic Systems	Septic Survey Contact Owners and Installers
Auto Repair, Gas Stations, Fueling Facilities, Manufacturing, Businesses	Regulatory Enforcement Contact Owners
Recreation Facilities	Interagency Cooperation WHPP Team Involvement
Government Installations	Interagency Cooperation WHPP Team Involvement

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PCE Sites

In 1995, at the direction of the Nevada Department of Environmental Protection and the Washoe County Board of Health, the Nevada State Legislature and Board of County Commissioners created the Central Truckee Meadows Remediation District (CTMRD) to address the tetrachloroethylene (PCE) contamination of the Central Truckee Meadows aquifer.

TMWA is fortunate that this District, which targets the PCS with the highest relative risk ranking, is already in place. Coordination between CTMRD and TMWA is essential. TMWA should continue to obtain updated information from CTMRD, such as contaminant plume areas to add to the PCS maps.

Leaking Underground Storage Tanks

The Nevada Division of Environmental Protection, Bureau of Corrective Actions (BCA) is responsible for remedial activities within the State. The Washoe County Health District may also play a role coordinating remedial activities. Coordination between BCA, the Health District and TMWA is essential.

It is recommended that a LUST Identification and Reduction Plan be developed by TMWA, with the cooperation of the BCA. This Plan should address tank sites with the highest potential for impacting local groundwater quality near TMWA's drinking water wells first. The integration of information compiled for the WHPP, and BCA data on remedial activities, will result in a data set that clearly highlights areas requiring immediate action.

The best way to ensure the proper organization of relevant data is for the WHPP Team to identify a member (possibly a TMWA employee) to act as a point of contact with BCA, to supervise the exchange of information, and coordinate the warranted action.

Abandoned or Private Wells

Any well without a surface seal, or unplugged, abandoned, or unused wells in the area could provide a route for contaminants to reach the aquifer used by the utility. The following recommendations are applicable to wells that might be located near the WHPAs established herein:

- Collect information from private well owners using a form letter, and incorporate this information into the WHPP. Information collected via form letter can be used to plan a survey of private wells within WHPAs managed by TMWA.
- Conduct a survey of private wells that exist within the wellhead protection areas using information collected via form letter and PCS Maps.
- Educate private well owners in the protection area about protecting wells from contamination, and proper well plugging and abandonment procedures.
- Water wells should be properly sealed and cased to prevent inundation from surface runoff.
- Ensure that all abandoned wells are properly plugged by the owner. Proper decommissioning of abandoned wells is required by State law.
- Elimination of unused private wells or septic systems as a condition of the transfer of ownership of real properties within the service area; provided that municipal water and sewer services are readily available.

Monitoring Wells

It is recommended that a Monitoring Well Management and Reduction Plan be developed by TMWA, with the cooperation of CTMRD. This Plan should address monitoring wells with the highest potential for impacting local groundwater quality near production wells first. The integration of information compiled for the WHPP, and CTMRD data on remedial activities will result in a data set that clearly highlights areas requiring immediate action.

In addition, it is recommended that every effort be made to minimize the visibility of monitoring wells. TMWA should endeavor to strictly control information regarding the locations of monitoring wells.

The potential benefit of each monitoring well must be judged against the potential harmful impact of each monitoring well. Areas with a high density of monitoring wells are particularly vulnerable. These areas may be adequately served by fewer monitoring wells. This measure would decrease area-wide risk without severely limiting the data available to planners and engineers.

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Septic Systems
Septic systems within WHPAs are already being addressed by TMWA and the WCHD. In general, TMWA's approach to this issue includes the following:

- Educate septic system owners in the area. Contact owners directly and provide helpful information while opening a channel for future communication on the subject.
- Incorporate information about the environmental impacts of septic system operation into broader public education efforts.
- Educate residents about alternatives for products considered to be household hazardous waste and the proper disposal of household hazardous waste.
- Ensure that existing septic systems are properly constructed, maintained, and removed from service.
- Use existing monitoring wells to track nitrate levels within and near WHPAs.
- Ensure closure of unused septic systems in all instances where homes or businesses have reasonable access to municipal sewer service.

Auto Repair, Gas Stations, Commercial Fueling Facilities, Manufacturing, Businesses
Fabrication and auto painters and repair shops should be made aware that disposal of hazardous wastes onto the ground or into a well of any kind is illegal.

- If identified, all activity should cease, and the NDEP's Underground Injection Control Program should be contacted. Disposal of hazardous wastes into wells constitutes one of the most serious threats to groundwater. Distribution of the NDEP Fact Sheet on Underground Injection Control to all local businesses is recommended.
- Ensure that automotive fluids are collected, contained and disposed of or recycled. Recycling should be actively encouraged as part of the Public Education portion of the program.
- Educate small business owners and managers on groundwater protection and best management practices.
- Recommend the closure of shop floor drains to business owners. Explain the increased risk of groundwater contamination associated with these drains.
- Work with local building departments to prohibit the construction of floor drains in new facilities.

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Public education and outreach is the key strategy for these PCS categories. Owners of potentially problematic businesses located within WHPAs should be contacted and provided with information regarding wellhead protection (best management practices). The operators should be informed that their business is located within a WHPA.

Many local businesses are served by Underground Storage Tanks (USTs) containing heating oil. Heating oil tanks are installed according to local building code. However, older tanks may be in use beyond their design life, leading to failure. Failures in older tanks are particularly hard to detect.

- Educate any business owners with heating oil tanks about proper maintenance and decommissioning.
- Careful monitoring of utility bill may reveal problems.

Another way TMWA may work with local businesses is by coordinating with the Environmental Control Officers of Reno and Sparks. These individuals make routine visits to regulated facilities. They perform inspections and hand out useful information, such as best management practices. With a little coordination, TMWA could integrate wellhead protection issues into this program. TMWA could investigate funding opportunities through the Small Business Development Center.

Recreation Facilities and Government Installations

Government agencies in charge of operating recreation facilities and government installations that have the potential to impact local groundwater quality should be contacted and provided with information regarding wellhead protection. Maintenance facilities associated with parks and golf courses are examples of potential contaminant sources managed by local agencies. The cooperation of local agencies, such as Parks and Recreations Departments, should be sought whenever possible.

The best way to foster cooperation between TMWA and local agencies is for the WHPP Team to identify a member (possibly a TMWA employee) to act as a point of contact with the various agencies, to supervise the exchange of information, and coordinate any warranted actions. Alternatively, key representatives of local government agencies not already involved with the Well Head Protection Program should be invited to join the WHPP Team.

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5.2.2 General Management Tools

The following list details management ideas that can be used to address general threats that are dispersed throughout the community.

1. Zoning Ordinances: Zoning ordinances are typically comprehensive land-use requirements designed to direct the development of an area, where certain land uses may be restricted or regulated in WHPAs. The support of Washoe County, City of Reno and City of Sparks are critical to the long-term success of the Wellhead Protection Program. The ultimate objective is to have the WHPP included in development master plans and to have ordinances or other acceptable controls that address land use issues (zoning) in specified WHPAs. Zoning ordinances should be established to direct the development of the wellhead protection areas, to minimize incompatible land use.

2. Subdivision Ordinances: Subdivision ordinances are applied to land that is divided into four or more sub-units for sale or development. This tool may be used for WHPAs in which ongoing development is a potential or current source of contamination, or in areas where there is inadequate well recharge. Future development projects should be evaluated by Washoe County, Reno and Sparks to ensure compatibility with the WHPP.

3. Site Plan Review: Regulations requiring developers to submit, for approval, plans for development occurring within a given area, can ensure compliance with regulations or other requirements made within a WHPA.

4. Design Standards: Design standards are typically regulations that apply to the design and construction of buildings or structures. This tool can be used to ensure that new buildings or structures placed within a WHPA are designed to minimize the potential for contaminant releases.

5. Operating Standards: Operating standards are regulations that apply to ongoing land-use activities, put in place to promote safety or environmental protection. Such standards can minimize the threat to the WHPA from ongoing activities such as the application of agricultural pesticides or the storage of hazardous substances.

6. Source Prohibitions: Source prohibitions are regulations that prohibit the presence or use of chemicals or hazardous activities within a given area. Local governments have used restrictions on the storage or handling or large quantities of hazardous material within a WHPA to reduce the threat of contamination.

7. Purchase of Property or Development Rights: This tool may be used to ensure complete control of land uses in or surrounding a WHPA. This method may be preferred if regulatory restrictions on land use are not politically feasible, and the land purchase is affordable.

8. Public Education: Section 8.0 of this report addresses Public Education. Public education often consists of brochures, pamphlets, or seminars designed to present wellhead issues and protection efforts to the public in an understandable fashion. This tool promotes the use of

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voluntary protection efforts and builds public support for a community's wellhead protection program. This is an ongoing process that will certainly pay dividends well into the future. The residents of the Truckee Meadows must become aware of the importance of protecting their drinking water resources. An awareness of where the water comes from, and what can be done to keep the water pure, empowers the entire community.

9. Groundwater Monitoring: Groundwater monitoring generally consists of sinking a series of wells and developing an ongoing water quality testing program. However, through the CTMRD, data from hundreds of monitoring wells throughout the area is already available. A water quality testing program could consist of the review of data, as it is generated through other efforts.

   This tool allows the WHPP Team to monitor the quality of the ground water supply or the movement of contaminant plumes.

10. Household Hazardous Waste Collection: Residential hazardous waste management programs can reduce the quantity of household hazardous waste being disposed of improperly. These programs have been used in localities where disposal of wastes in municipal landfills potentially threatens groundwater.

11. Visual Inspection. Visually inspect the wellhead protection areas for surface spills at least every six months.

12. Integration of the WHPP into the Washoe County 208 Water Quality Management Plan. Non-point source contamination is an important factor in the plan.

13. Coordination with the Truckee Meadows Interlocal Stormwater Committee and the Washoe County Watershed Protection Planning Group. These groups have developed great programs that address issues that are similar to those of the WHPP. They have also developed effective public education programs.

5.2.3 Implementation

TMWA will evaluate and prioritize the management strategies identified in this report. After the strategies are prioritized, TMWA will make assignments to carry out the management plan. Implementation progress will be tracked and evaluated and the management plan will be refined over time.

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6.0 Locating New Wells

In the event that TMWA develops or acquires a new public water supply well, the proposed well(s) will be subject to evaluation by the WHPP Team with respect to the guidelines for all the WHPP elements, followed by incorporation into the plan. The well's WHPA will be delineated and assessed for potential contaminant sources. The WHPA will also be managed in accordance with current WHPP goals. In addition, the contingency plan will be modified to include new wells. Management practices being implemented at existing wells may be utilized for new wells or modified where appropriate.

All new water wells and related drilling are regulated by the Nevada Division of Water Resources (NDWR) as specified in the Nevada Administrative Code (NAC) 534.010-534.500. A notice of intent to drill must be filed with the NDWR prior to drilling. In addition, a permit must be obtained to drill or replace a water well within a water basin designated by the State Engineer.

The Bureau of Safe Drinking Water mandates that the horizontal distance between a supply of water and any source of pollution must be as great as practical, but no less than one hundred feet. However, this distance is generally inadequate for wellhead protection. WHPAs should be delineated for all proposed or new wells in the same manner as for existing wells. The only difference being that the delineations and potential contaminant source inventories will be completed prior to the construction of the wells.

7.0 Contingency Plan

7.1 Introduction

Contingency planning within the context of the WHPP means being prepared to take action in response to a threat to the quality or quantity of the drinking water supply. TMWA's response plans for emergencies that threaten the quality of drinking water are covered in other agency documents, such as operation and maintenance manuals and emergency response plans.

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8.0 Public Education and Participation

The primary goal regarding public education and participation is to raise the awareness of local citizens to wellhead protection issues and enlist their support and involvement. The following are suggestions that may be used in an effort to encourage public participation:

- Develop wellhead protection flyers to be included in water billings. Flyers may be sent to customers providing information on various topics, such as how to properly dispose of household hazardous wastes and septic system management.
- Develop a public education program for local schools.
- Consult with Citizen Advisory Boards and Neighborhood Advisory Boards. TMWA may consider working with these Boards to disseminate information about wellhead protection.

- Coordinate with the Truckee Meadows Stormwater Permit Coordinating Committee (SWPCC) This group has developed great programs that address issues that are similar to those of the WHPP. They have also developed effective public education programs.

- Work with the Environmental Control Officers of Reno and Sparks. These officers can be provided with information pertaining to wellhead protection that can be provided to owners and managers of regulated facilities.

- Target specific businesses identified in this report, such as gas stations and auto repair shops. These businesses can be sent specific information that tells them that they are located in a wellhead protection area, along with some suggested management practices.

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9.0 References

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State of Nevada Division of Environmental Protection, Bureau of Water Pollution Control (January, 2002) *State of Nevada Wellhead Protection Program Guide.*

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UNR (2003) *A Source Water Assessment for the Truckee River and Lake Tahoe in Northern Nevada*

Harrill, J.R., 1973, *Evaluation of the water resources of Lemmon Valley*, Washoe County, Nevada, with emphasis on effects of ground-water development to 1971: Nevada Division of Water Resources Bulletin 42, 130 p

Washoe County Department of Water Resources (March, 2010), *Final Report, Spanish Springs Valley Nitrate Remediation Pilot Project, Phase II: Nitrate Source, Extent, Magnitude, Migration and Management Options.*

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APPENDIX A

INVENTORY OF TMWA PRODUCTION WELLS

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Inventory of TMWA Wells

Well Name	In-Service Year	Rated Capacity [MGD]	Figure No. In Appendix B
Honey Lake Valley (Basin 97)			
Fish Spring Ranch Well 1 (A)	2006	4.3	Figure 1
Fish Spring Ranch Well 2 (B)	2006	2.9	Figure 2
Fish Spring Ranch Well 2 (C)	2006	2.2	Figure 2
Fish Spring Ranch Well 4 (D)	2006	2.2	Figure 4
Fish Spring Ranch Well 5 (E)	2006	3.2	Figure 5
Fish Spring Ranch Well 6 (F)	2017*	2.9	Figure 6
Lemmon Valley East (Basin 92B)			
Lemmon Valley 5	1970	1.2	Figure 1
Lemmon Valley 6	1998	0.3	Figure 2
Lemmon Valley 7	1970	0.6	Figure 3
Lemmon Valley 8	1974	0.9	Figure 4
Lemmon Valley 9	1997	0.8	Figure 5
Lemmon Valley West (Basin 92A)			
Army Air Guard	1968	1.6	Figure 1
Silver Knolls	2006	1.7	Figure 2
Silver Lake	2005	3.2	Figure 3
Pleasant Valley (Basin 88)			
Mt Rose 3	1990	0.4	Figure 1
Mt Rose 5	1990	1.0	Figure 2
Mt Rose 6	2000	0.8	Figure 3
St James 1	1995	0.5	Figure 4
St James 2	1995	0.6	Figure 5
STMGID 7	1983	0.2	Figure 6
Sunrise Estates 1	1983	0.4	Figure 7
TESSA 1 (East)	2000	1.2	Figure 8
TESSA 2 (West)	1999	0.9	Figure 9
Spanish Springs Basin 85			
Desert Springs 1	1990	0.6	Figure 1
Desert Springs 2	1963	0.6	Figure 2
Desert Springs 3	1979	1.1	Figure 3
Hawkings	2008	4.3	Figure 4

Spring Creek 2	1988	0.7	Figure 5
Spring Creek 5	2000	1.4	Figure 6
Spring Creek 6	1997	2.5	Figure 7
Spring Creek 7	2000	2.9	Figure 8
Tracy Segment Basin 83			
Stampmill 1	1979	0.6	Figure 1
Stampmill 2	1979	0.3	Figure 2
Truckee Canyon 1	1997	0.1	Figure 3
Truckee Canyon 3	2016*	0.1	Figure 4
Truckee Meadows Basin 87(Central Wells)			
Delucchi	1972	0.8	Figure 1
Holcomb	1988	1.0	Figure 2
Huffaker Place	2016*	1.2	Figure 3
Innovation	2016*	1.0	Figure 4
Lakeside	1985	0.9	Figure 5
Longley	2000	2.2	Figure 6
Patriot	1990	1.8	Figure 7
South Virginia	1969	1.5	Figure 8
Sierra Plaza	2002	2.0	Figure 9
Truckee Meadows Basin 87(North Wells)			
21st St.	1991	2.0	Figure 1
4th St.	1971	2.2	Figure 2
Corbett	1993	2.1	Figure 3
El Rancho	1992	1.2	Figure 4
Galletti	2000	2.3	Figure 5
Glen Hare	1999	1.7	Figure 6
Greg	1967	2.0	Figure 7
Hidden Valley 3	1984	1.4	Figure 8
Hidden Valley 5	1992	0.6	Figure 9
High	1961	2.2	Figure 10
Hunter Lake	1995	3.3	Figure 11
Kietzke	1972	3.3	Figure 12
Longley Water Treatment Plant	2005	3.6	Figure 13
Mill	1960	2.6	Figure 14
Morrill	1963	2.0	Figure 15
Pezzi	1974	1.3	Figure 16
Poplar #1	1963	2.3	Figure 17
Poplar #2	1967	2.2	Figure 18
Reno High	1991	3.3	Figure 19

Sparks	1967	0.9	Figure 20
Swope	1993	0.9	Figure 21
Terminal	1961	1.7	Figure 22
View	1969	2.4	Figure 23
Truckee Meadows Basin 87(South Wells)			
ArrowCreek 1	1995	0.5	Figure 1
ArrowCreek 2	1995	1.1	Figure 2
ArrowCreek 3	1998	0.7	Figure 3
Double Diamond 1	1981	0.8	Figure 4
Double Diamond 3	2016*	2.6	Figure 5
STMGID 1	1984	1.1	Figure 6
STMGID 2	1984	0.4	Figure 7
STMGID 3	1984	0.7	Figure 8
STMGID 4	1981	0.3	Figure 9
STMGID 5	1988	1.1	Figure 10
STMGID 6	1988	2.1	Figure 11
STMGID 11	2000	0.7	Figure 12
STMGID 12	2011	1.0	Figure 13
Thomas Creek	1978	0.6	Figure 14
Washoe Valley (Basin 89)			
Lightning W 1	1994	0.1	Figure 1
Lightning W 2	1963	0.2	Figure 2
Lightning W 3	2008	0.3	Figure 3
Old Washoe Estates 3	1994	0.2	Figure 4
Old Washoe Estates 4	2016*	0.1	Figure 5

* = TMWA production wells that are unequipped or currently being drilled

** = Privately owned unequipped well

APPENDIX B

FIGURES SHOWING WELLS, CAPTURE ZONES, AND PCS’s

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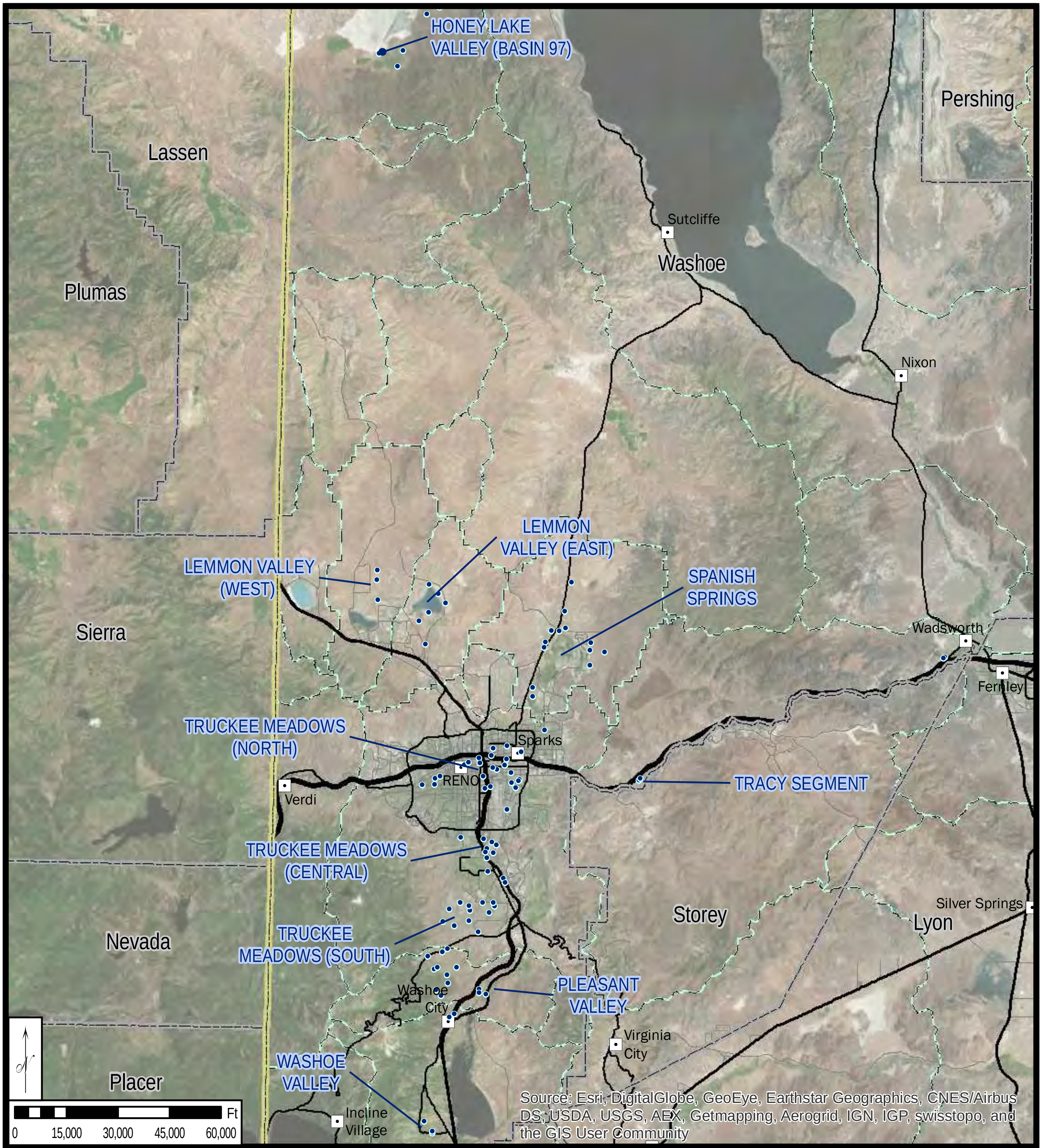

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WELLHEAD PROTECTION PROGRAM

OVERALL AREA INDEX MAP

● Water Supply Well
⊡ Cities and Towns
▢ USA States
▢ USA Counties
▢ Nevada Hydrobasins
━ Interstate Route
━ US Highway
─ State Route
─ Local Streets

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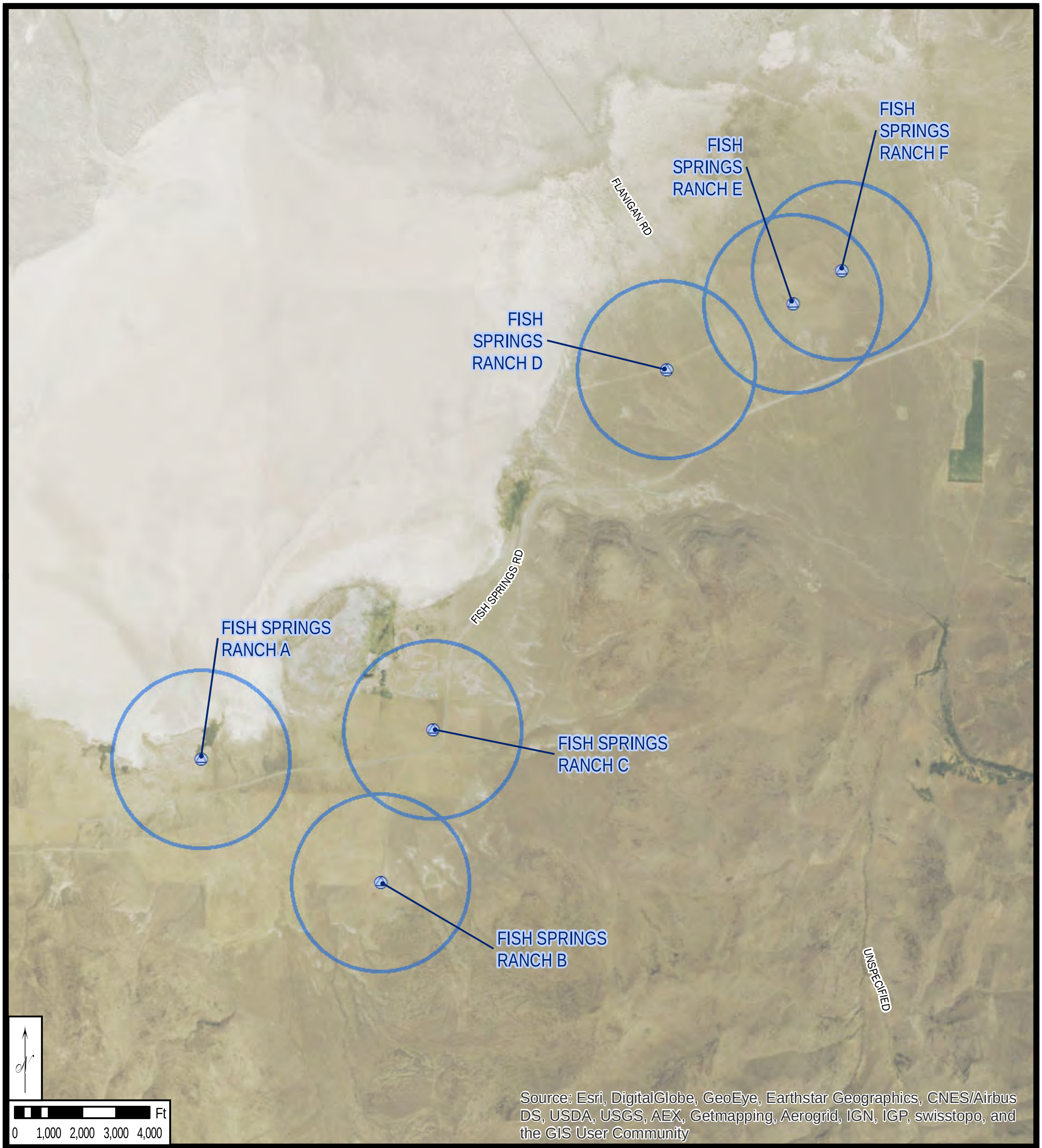

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WELLHEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

HONEY LAKE VALLEY (BASIN 97) AREA INDEX

△ WATER SUPPLY WELL
▢ 1/2 MILE CAPTURE ZONE
▢ NEVADA HYDROBASIN BOUNDARY

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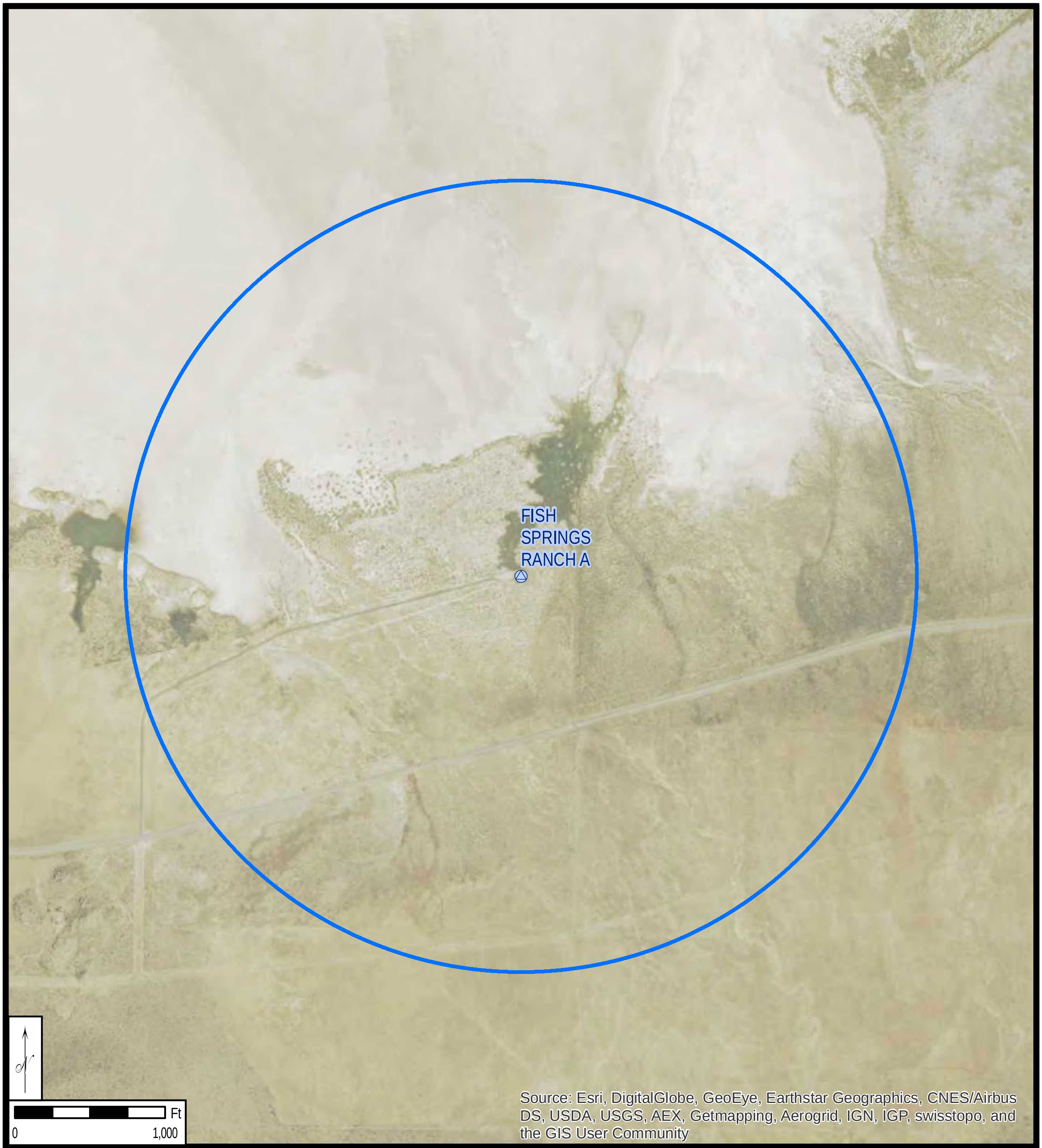

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WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

HONEY LAKE VALLEY (BASIN 97) -- FIGURE: 1

FISH SPRINGS RANCH A WELL SITE

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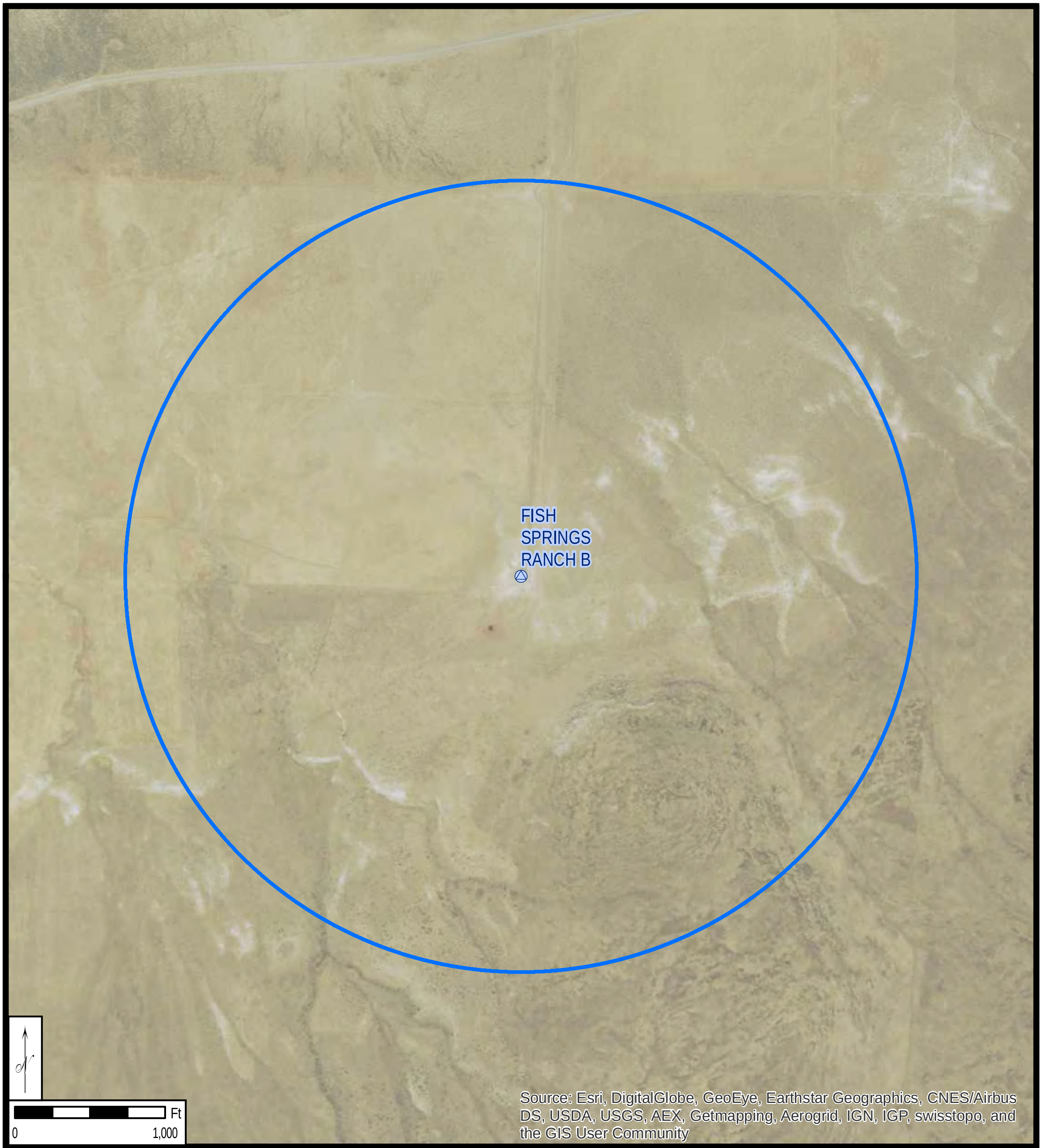
△ WATER SUPPLY WELL ◯ 1/2 MILE CAPTURE ZONE



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WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

HONEY LAKE VALLEY (BASIN 97) -- FIGURE: 2

FISH SPRINGS RANCH B WELL SITE

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△ WATER SUPPLY WELL ▢ 1/2 MILE CAPTURE ZONE

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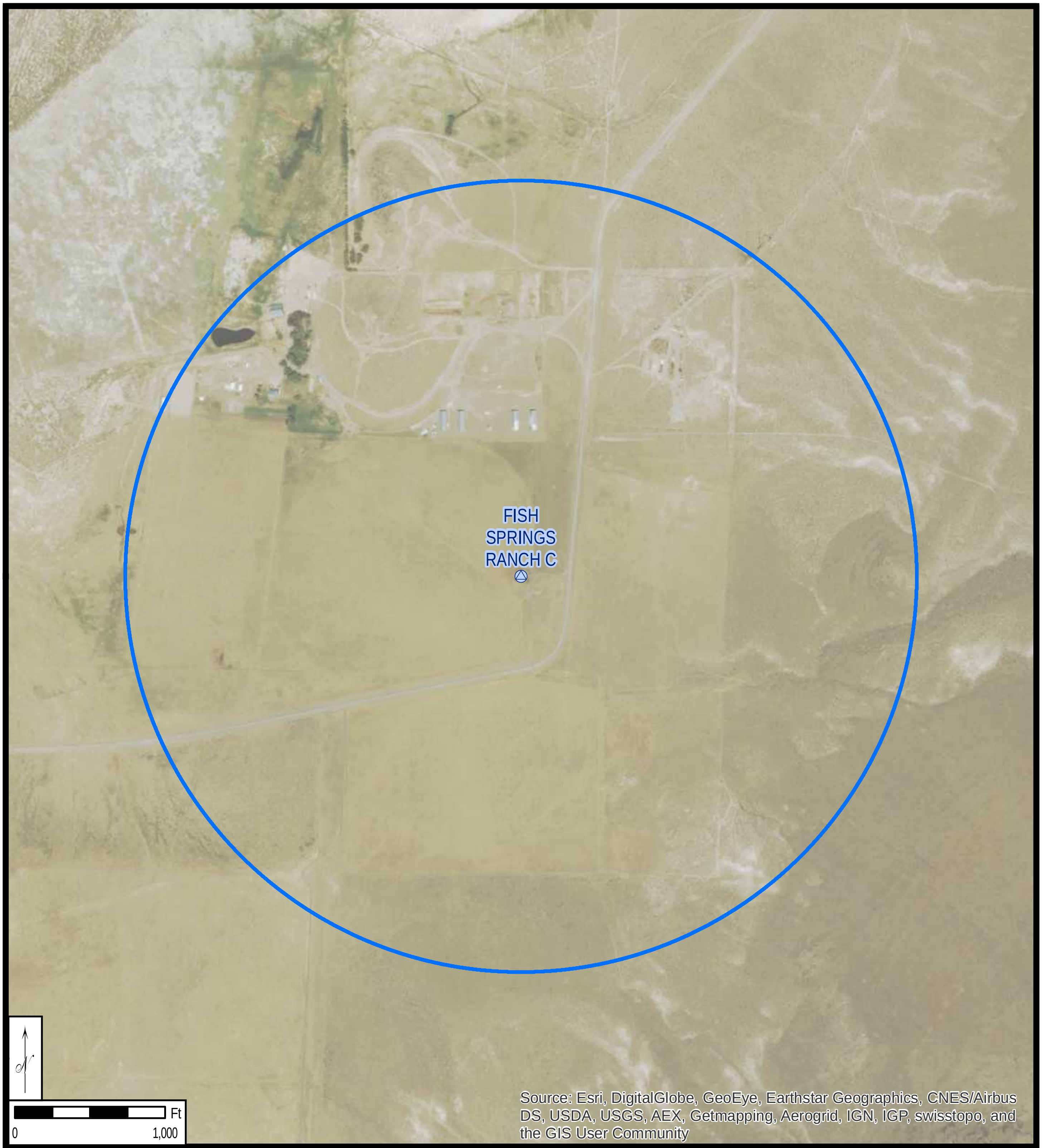

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WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

HONEY LAKE VALLEY (BASIN 97) -- FIGURE: 3

FISH SPRINGS RANCH C WELL SITE

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△ WATER SUPPLY WELL ▢ 1/2 MILE CAPTURE ZONE

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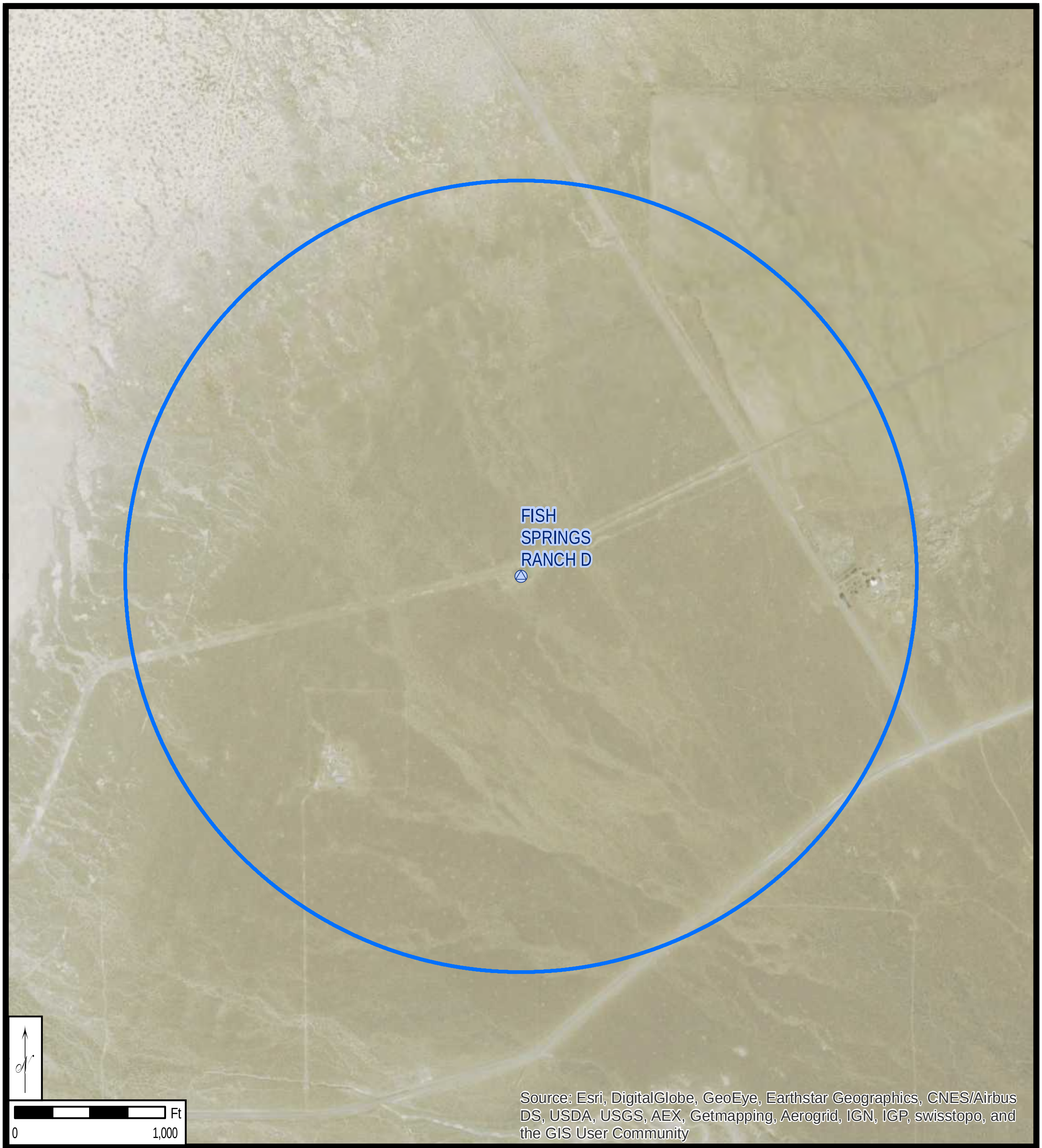

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WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

HONEY LAKE VALLEY (BASIN 97) -- FIGURE: 4

FISH SPRINGS RANCH D WELL SITE

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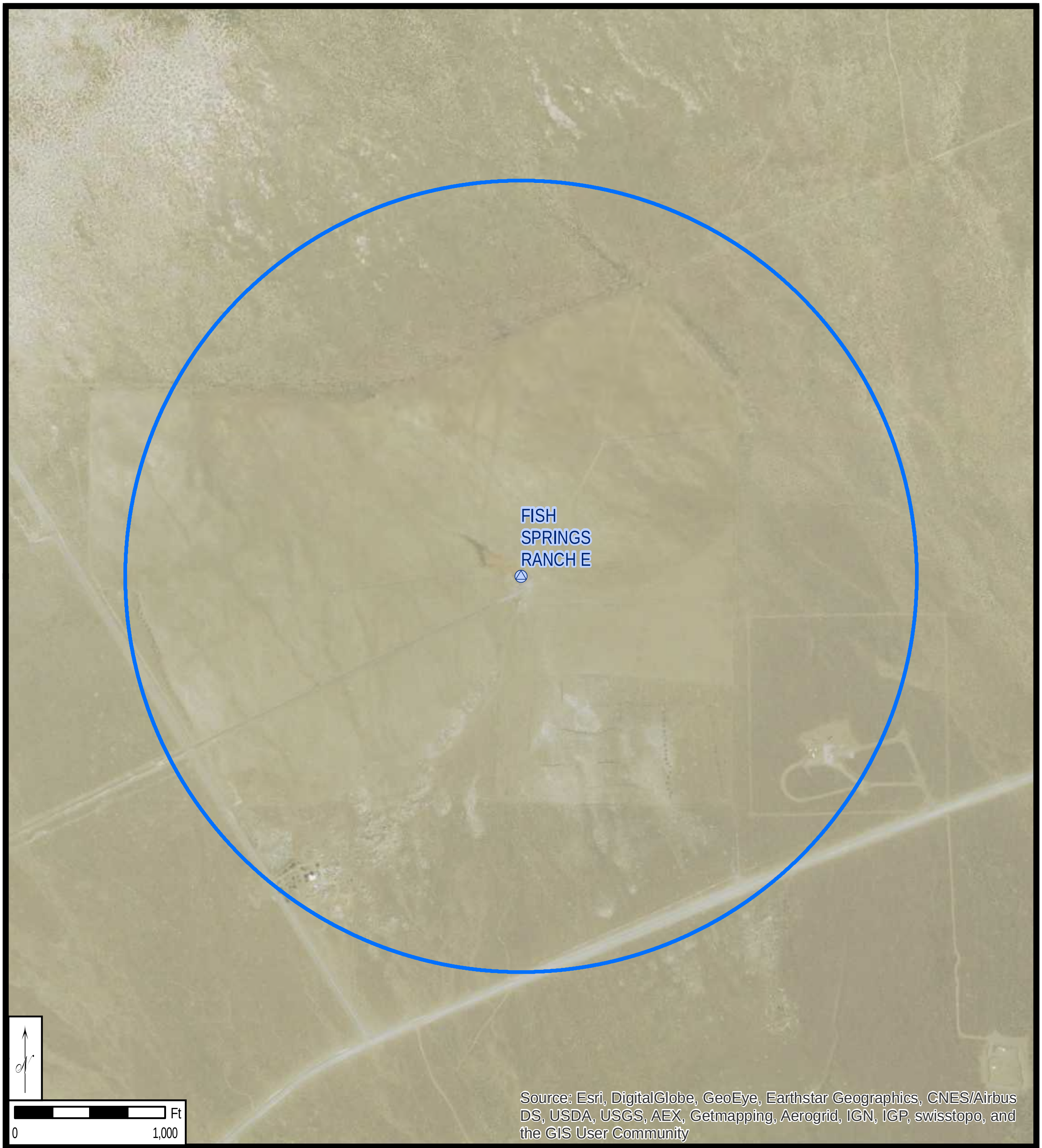
△	WATER SUPPLY WELL
▢	1/2 MILE CAPTURE ZONE



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WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

HONEY LAKE VALLEY (BASIN 97) -- FIGURE: 5

FISH SPRINGS RANCH E WELL SITE

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△ WATER SUPPLY WELL ▢ 1/2 MILE CAPTURE ZONE

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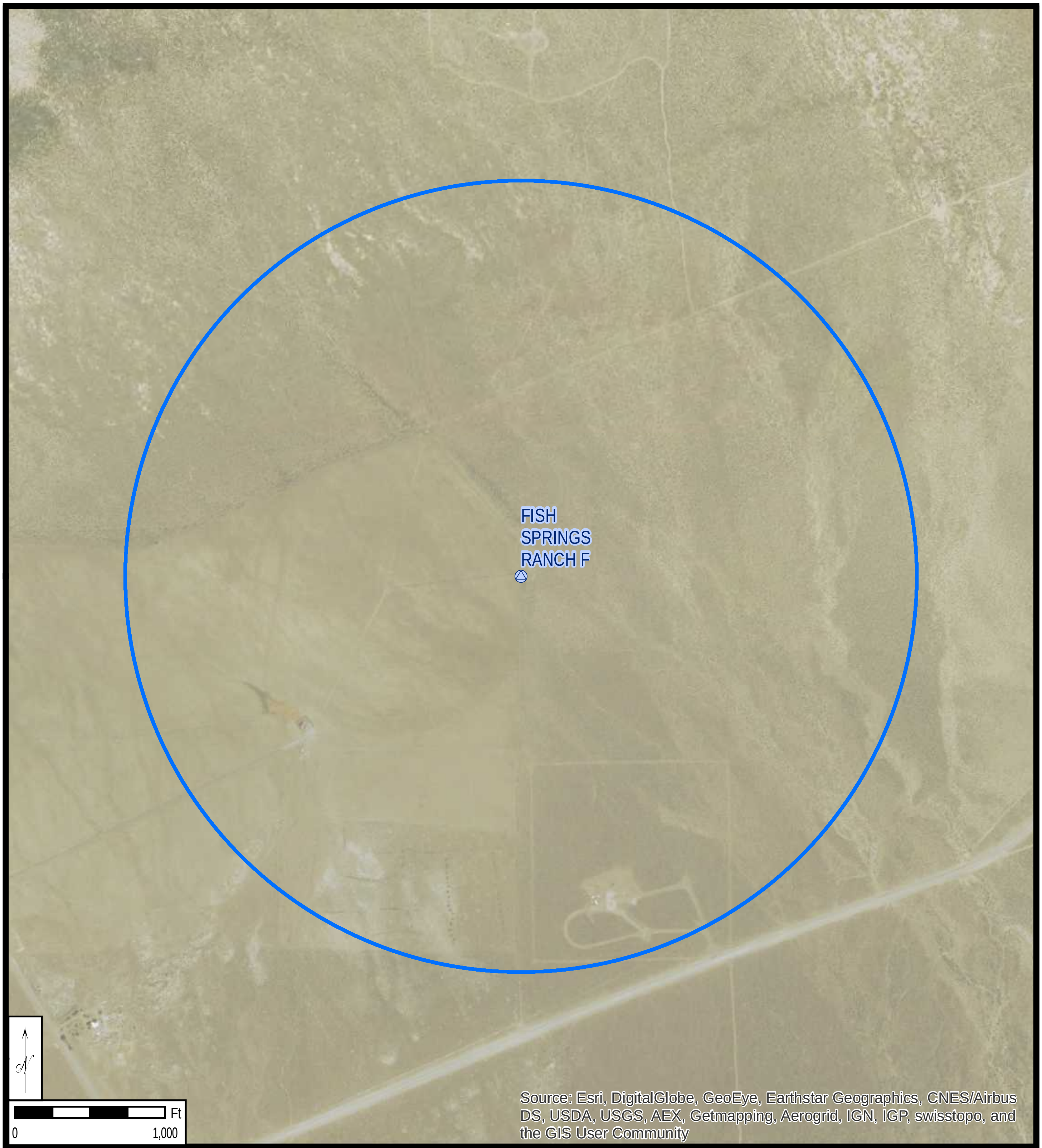

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WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

HONEY LAKE VALLEY (BASIN 97) -- FIGURE: 6

FISH SPRINGS RANCH F WELL SITE

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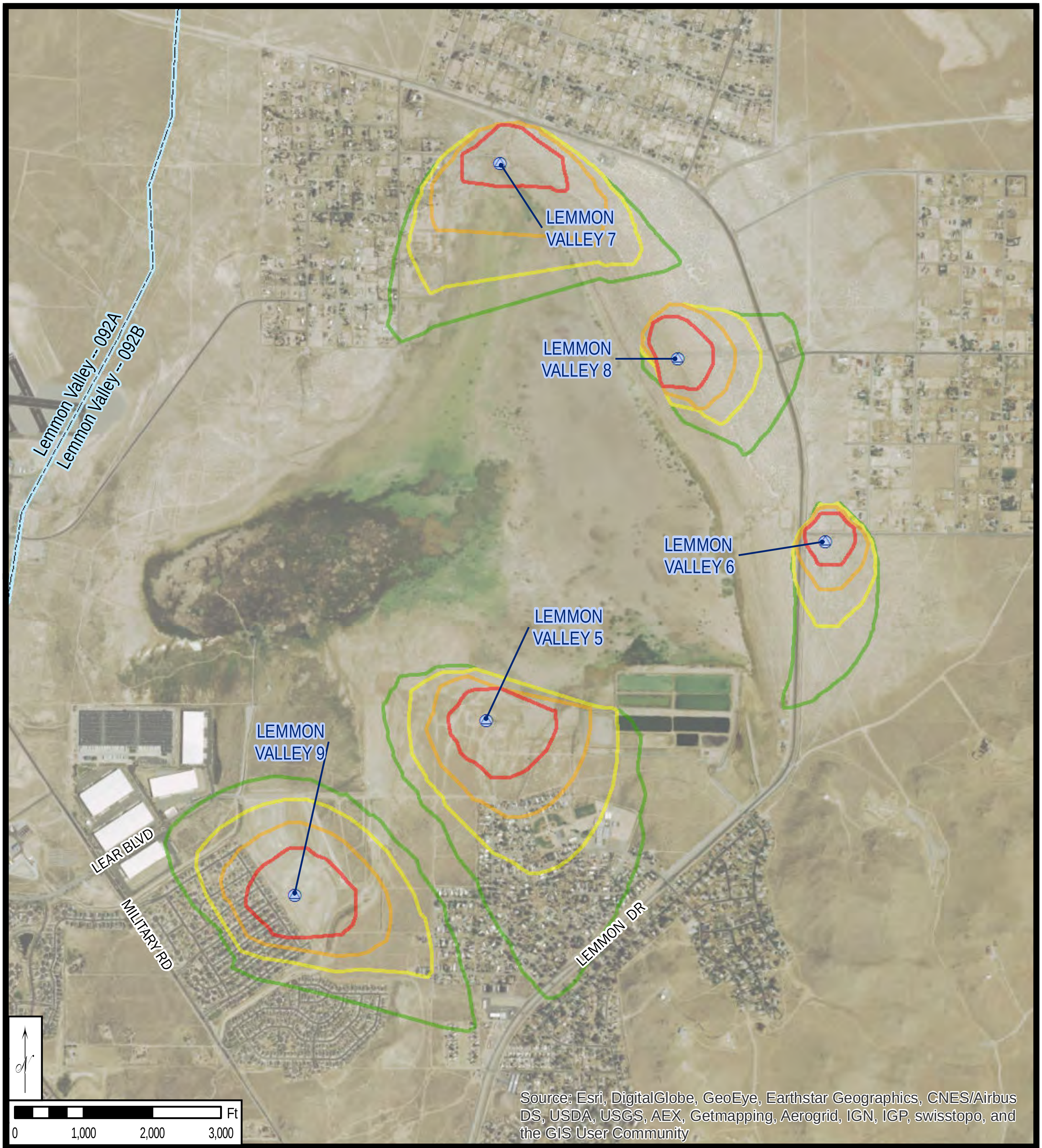
△ WATER SUPPLY WELL ▢ 1/2 MILE CAPTURE ZONE



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WELLHEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

LEMMON VALLEY (EAST) (BASIN 92B) AREA INDEX

TMWA

WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE
🟧 5 YEAR CAPTURE ZONE
🟨 10 YEAR CAPTURE ZONE
🟩 20 YEAR CAPTURE ZONE
▭ NEVADA HYDROBASIN BOUNDARY

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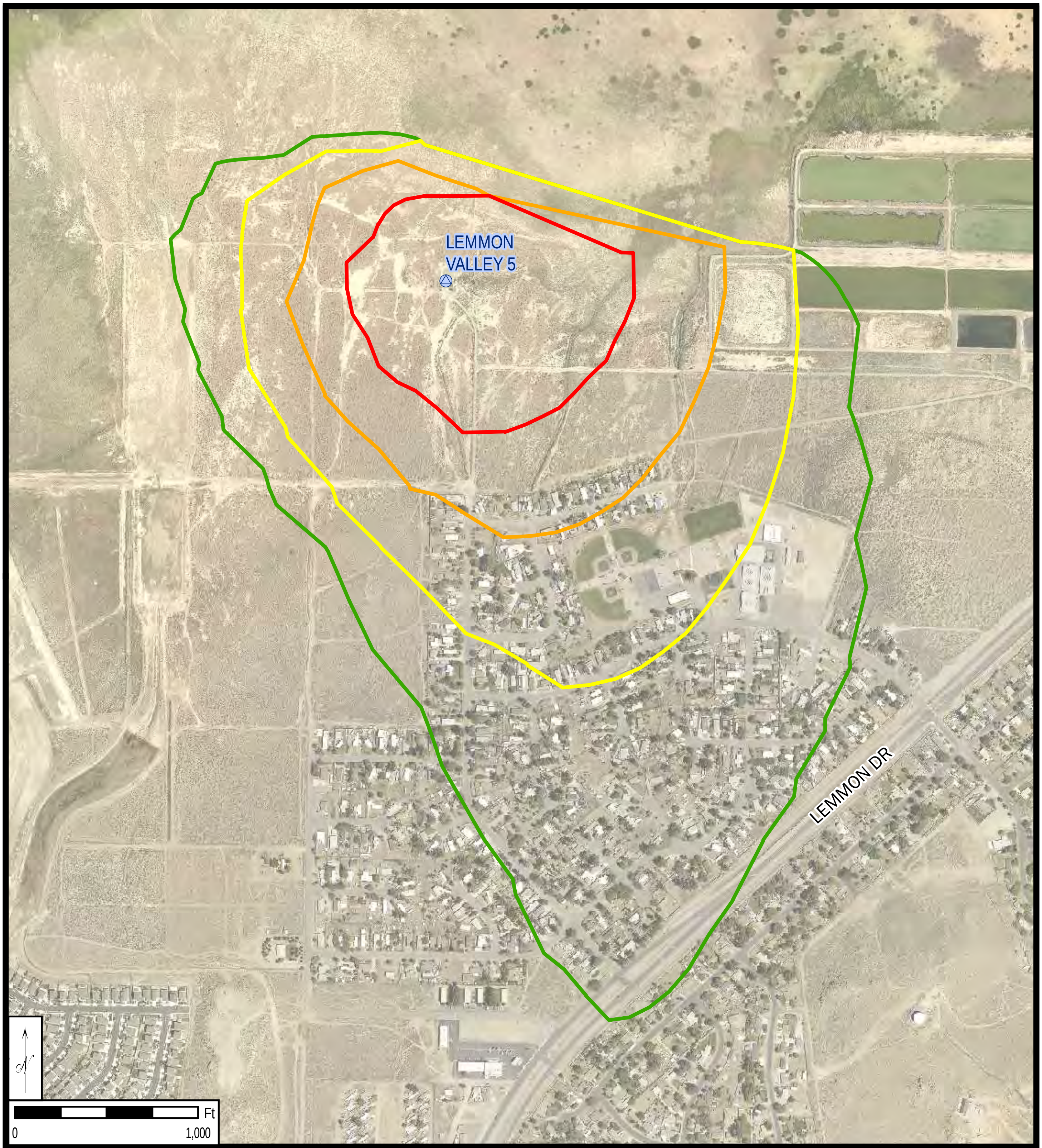

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

LEMMON VALLEY (EAST) (BASIN 92B) -- FIGURE: 1

LEMMON VALLEY 5 WELL SITE

TMWA

△ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE

🟧 5 YEAR CAPTURE ZONE

🟨 10 YEAR CAPTURE ZONE

🟩 20 YEAR CAPTURE ZONE

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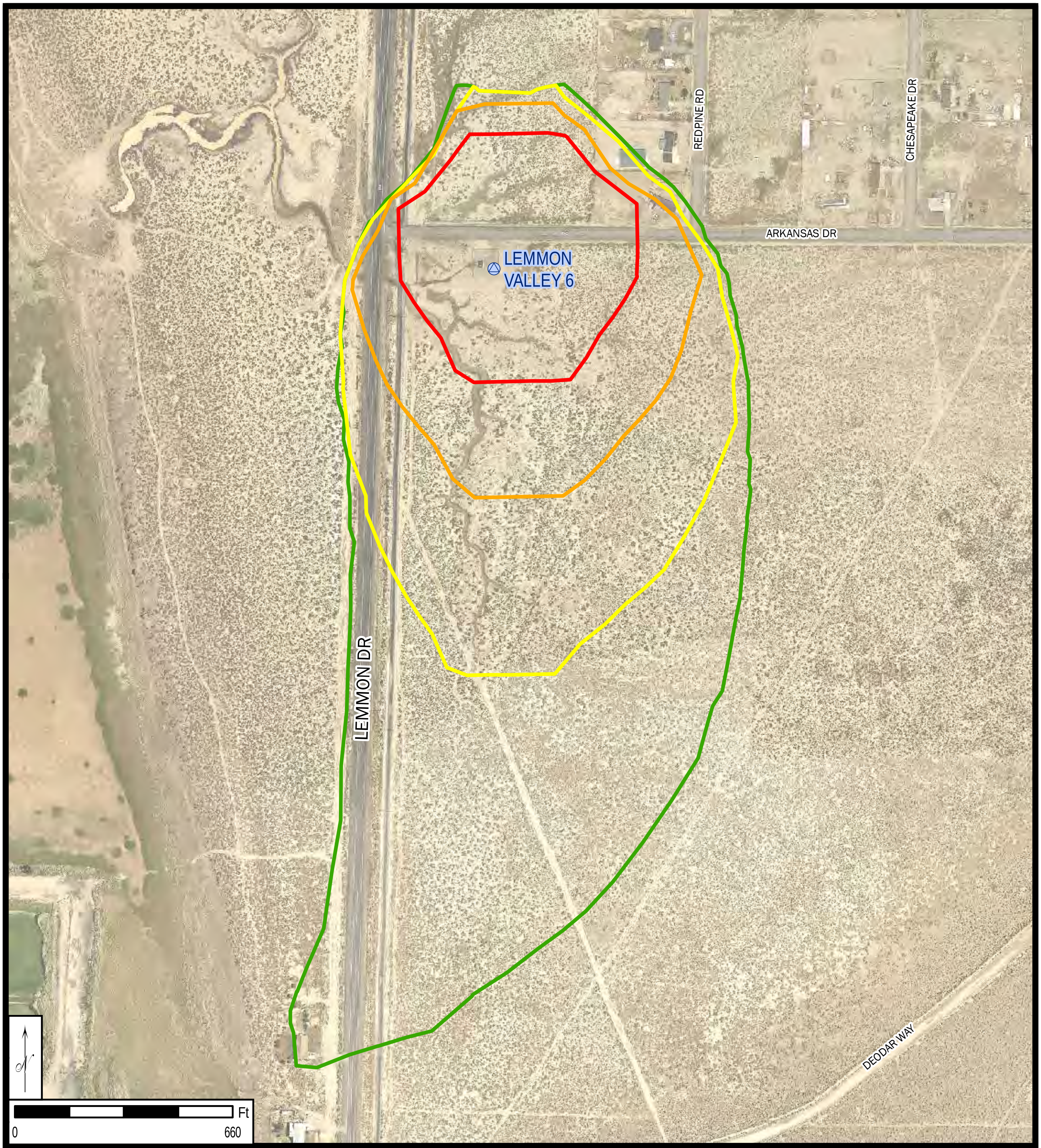

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

LEMMON VALLEY (EAST) (BASIN 92B) -- FIGURE: 2

LEMMON VALLEY 6 WELL SITE

△ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE
🟧 5 YEAR CAPTURE ZONE
🟨 10 YEAR CAPTURE ZONE
🟩 20 YEAR CAPTURE ZONE

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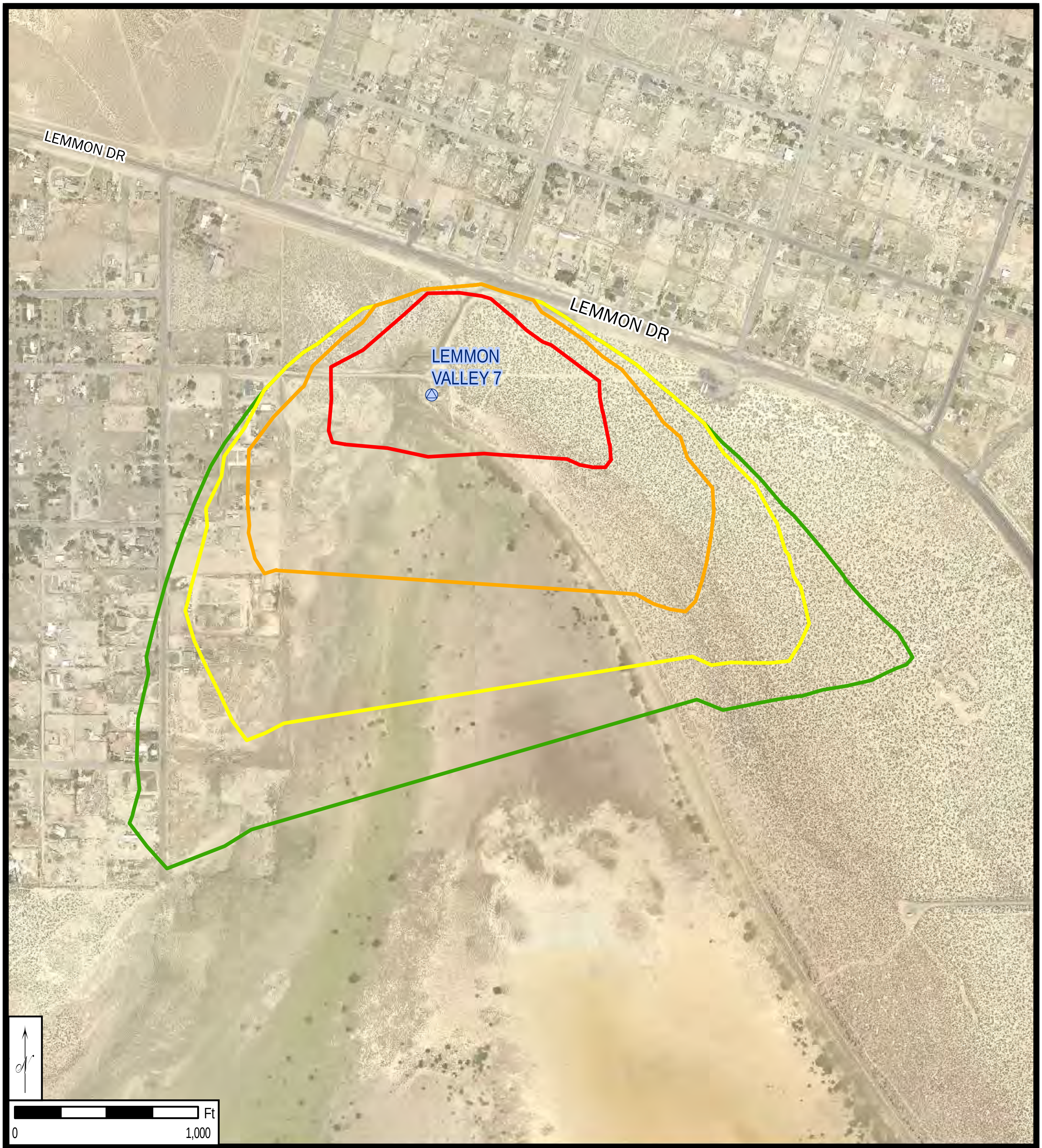

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

LEMMON VALLEY (EAST) (BASIN 92B) -- FIGURE: 3

LEMMON VALLEY 7 WELL SITE

TMWA

◬ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE

🟧 5 YEAR CAPTURE ZONE

🟨 10 YEAR CAPTURE ZONE

🟩 20 YEAR CAPTURE ZONE

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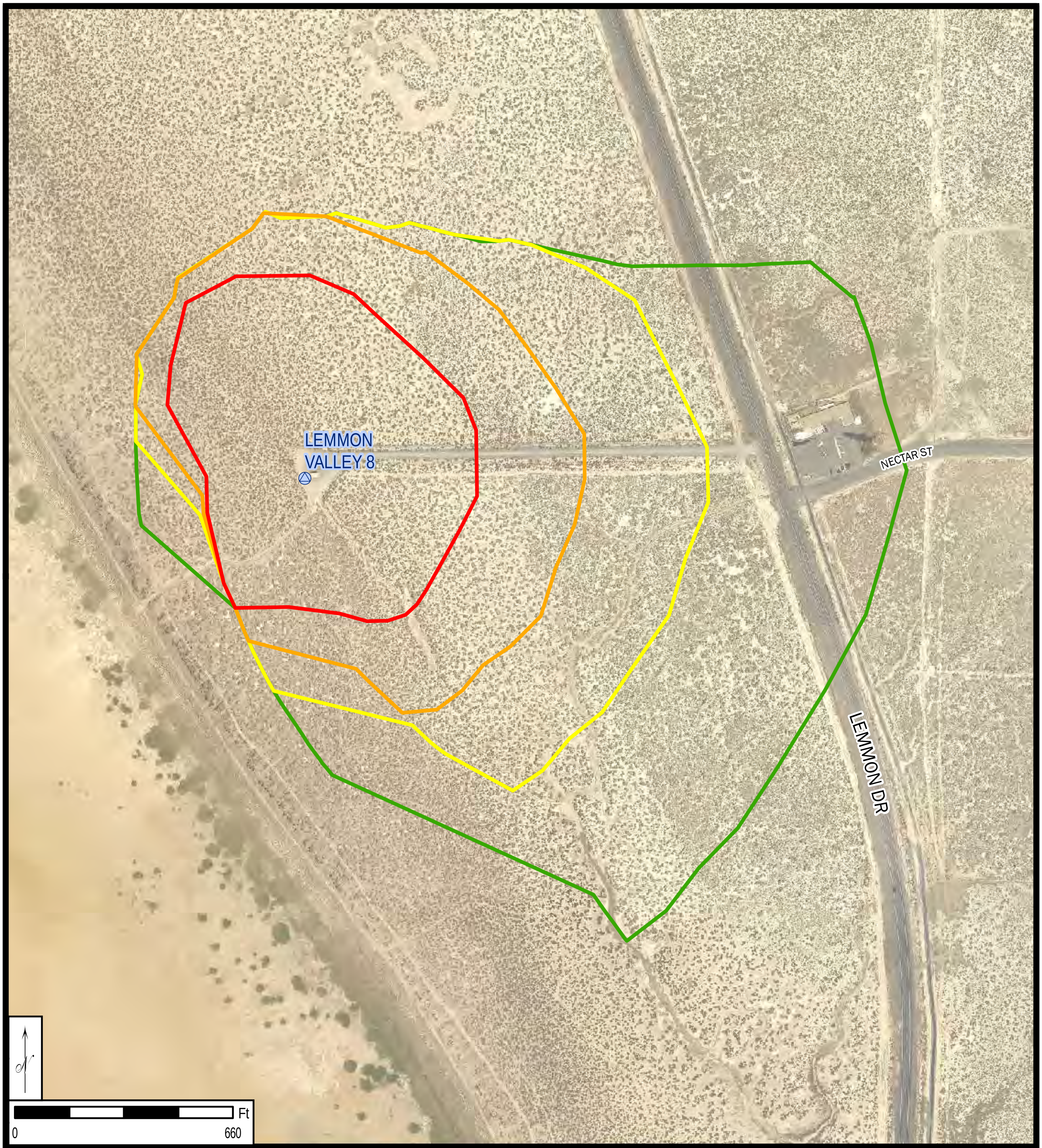

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

LEMMON VALLEY (EAST) (BASIN 92B) -- FIGURE: 4

LEMMON VALLEY 8 WELL SITE

TMWA

△ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE

🟧 5 YEAR CAPTURE ZONE

🟨 10 YEAR CAPTURE ZONE

🟩 20 YEAR CAPTURE ZONE

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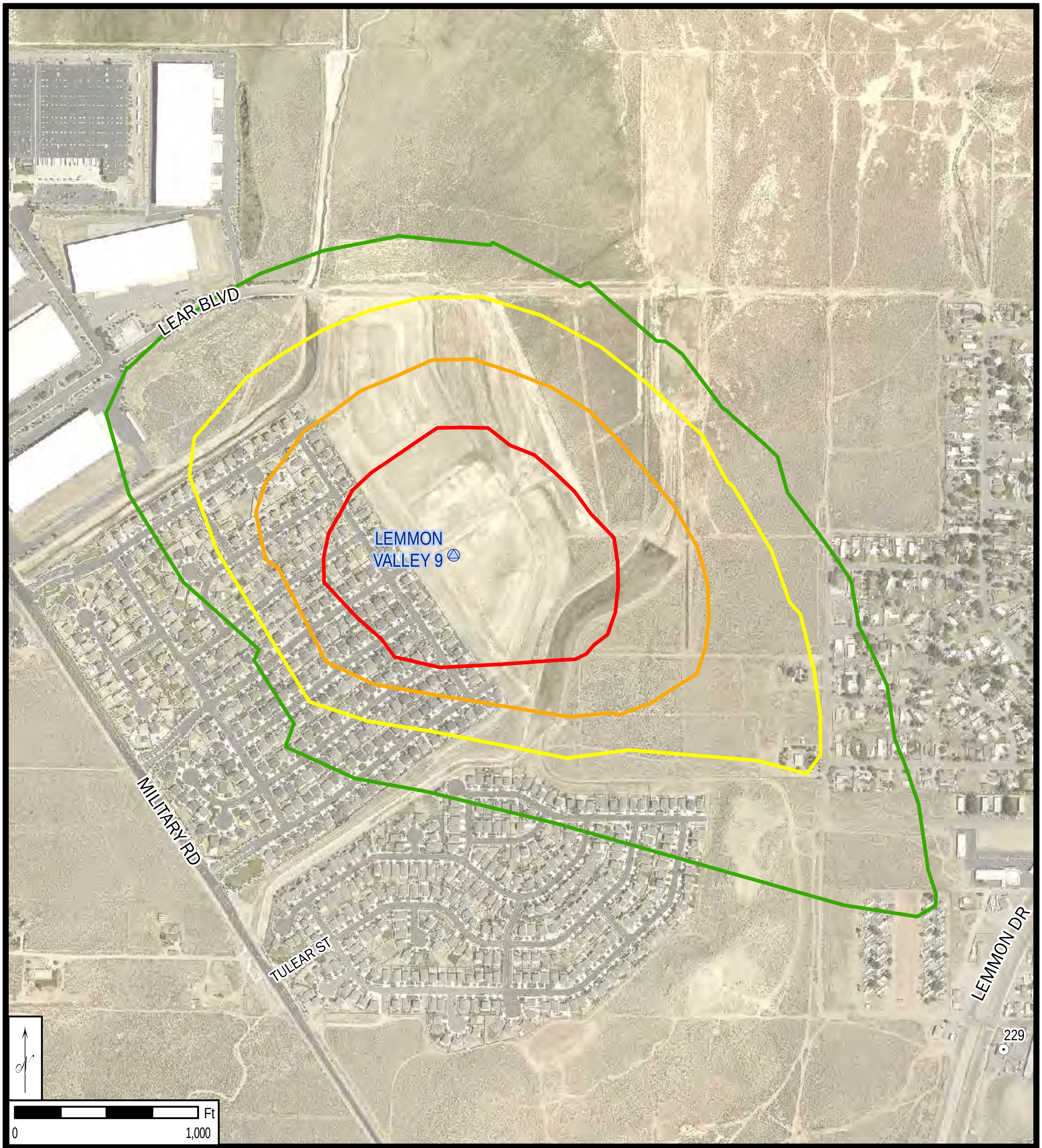

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

LEMMON VALLEY (EAST) (BASIN 92B) -- FIGURE: 5

LEMMON VALLEY 9 WELL SITE

TMWA

⊙	POTENTIAL CONTAMINANT SOURCE -- (EPA)
△	WATER SUPPLY WELL
🟥	2 YEAR CAPTURE ZONE
🟧	5 YEAR CAPTURE ZONE
🟨	10 YEAR CAPTURE ZONE
🟩	20 YEAR CAPTURE ZONE

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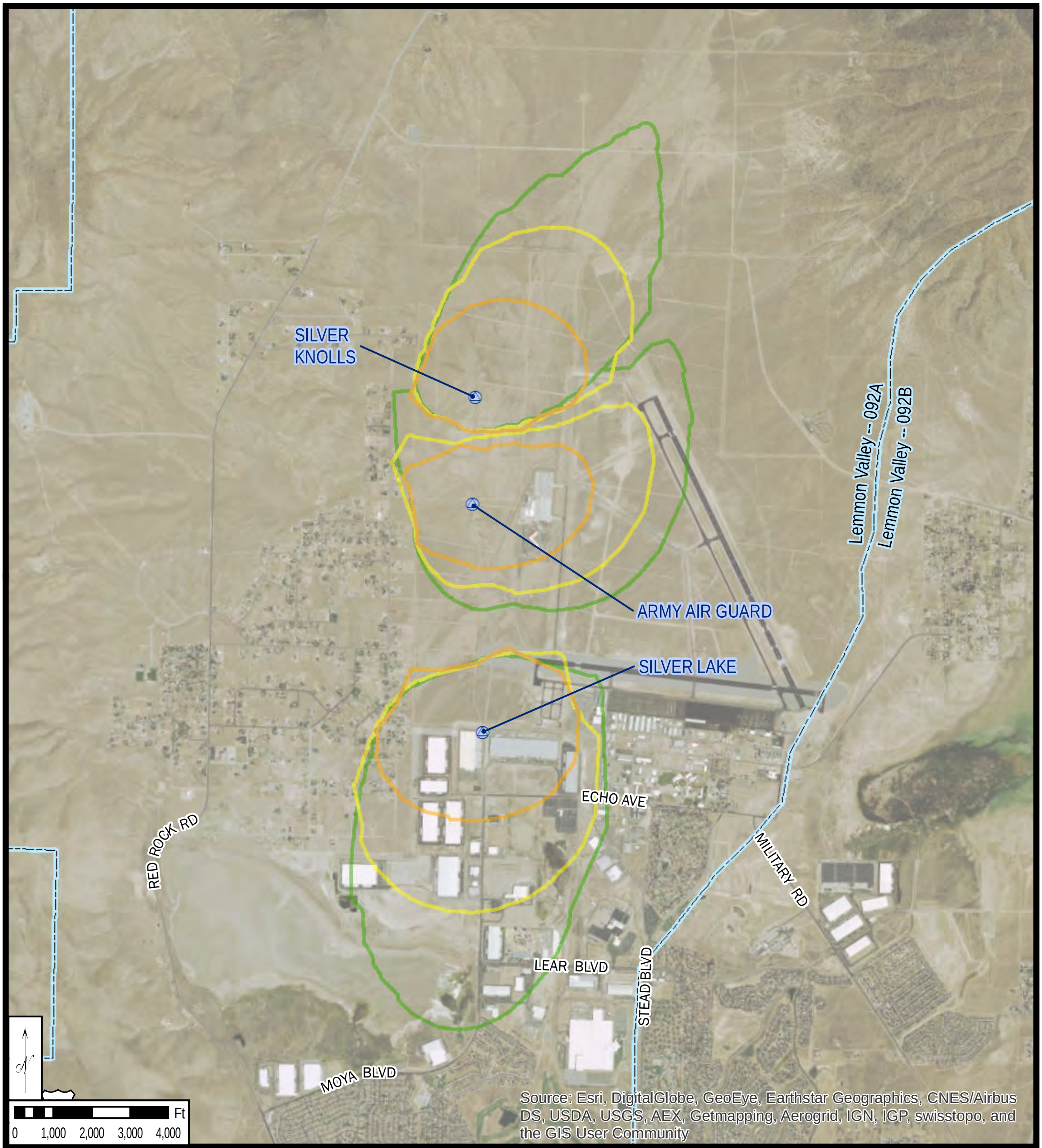

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WELLHEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

LEMMON VALLEY (WEST) (BASIN 92A) AREA INDEX

TMWA

- ▲ WATER SUPPLY WELL
- 🟧 5 YEAR CAPTURE ZONE
- 🟨 10 YEAR CAPTURE ZONE
- 🟩 20 YEAR CAPTURE ZONE
- ▭ NEVADA HYDROBASIN BOUNDARY

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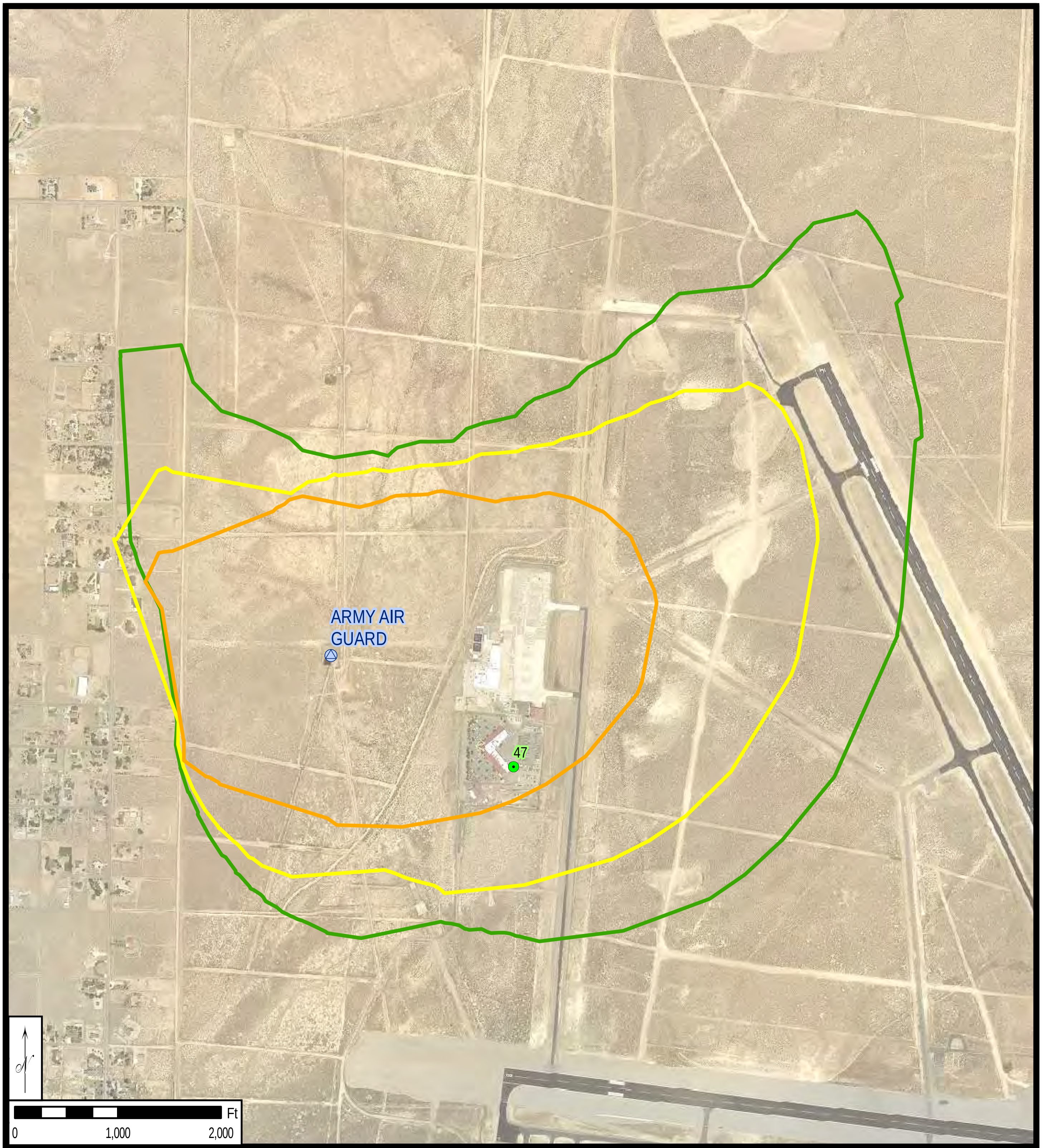

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

LEMMON VALLEY (WEST) (BASIN 92A) -- FIGURE: 1

ARMY AIR GUARD WELL SITE

TMWA

● POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)

△ WATER SUPPLY WELL

🟧 5 YEAR CAPTURE ZONE

🟨 10 YEAR CAPTURE ZONE

🟩 20 YEAR CAPTURE ZONE

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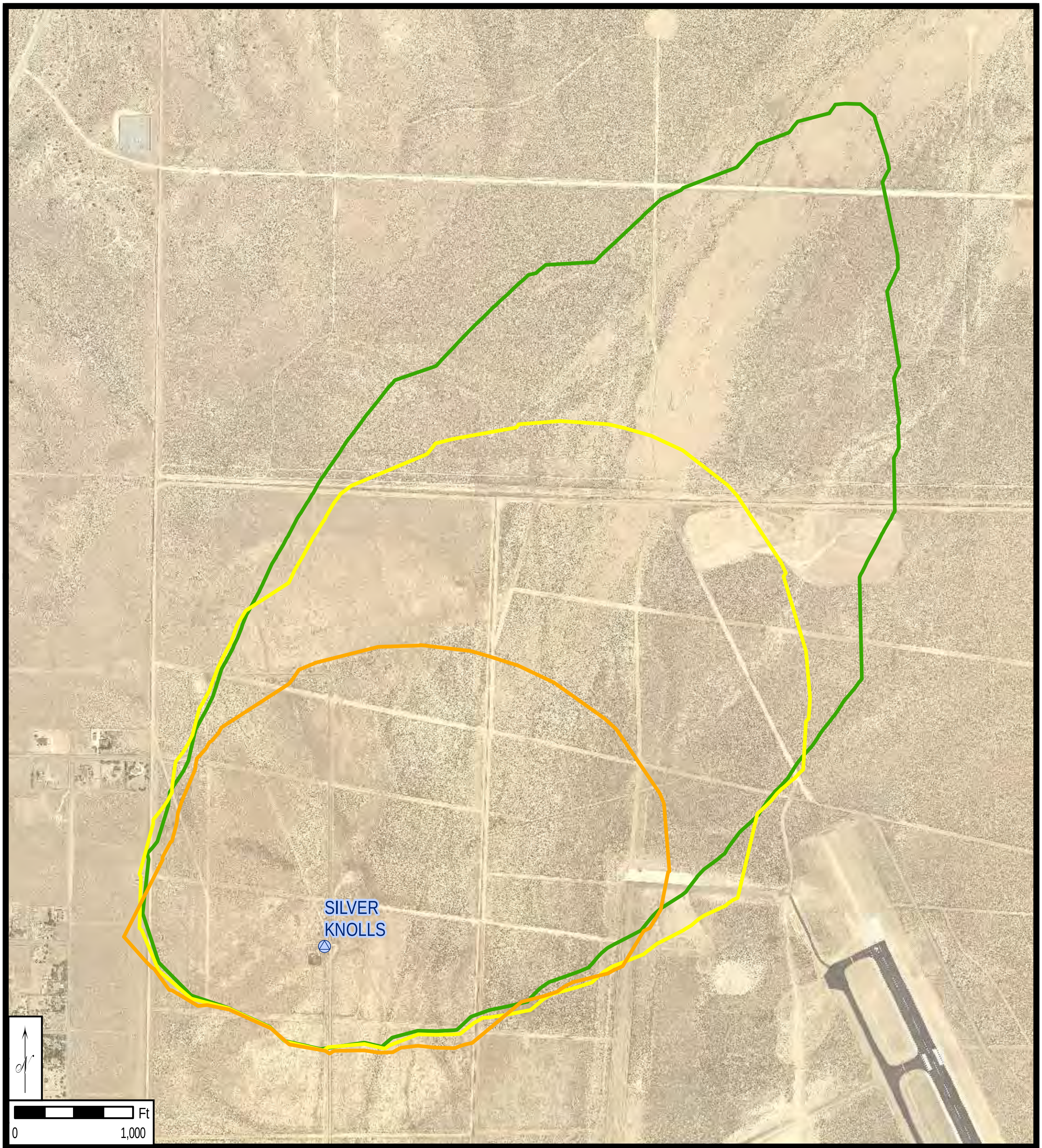

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

LEMMON VALLEY (WEST) (BASIN 92A) -- FIGURE: 2

SILVER KNOLLS WELL SITE

TMWA

- ◬ WATER SUPPLY WELL
- 🟧 5 YEAR CAPTURE ZONE
- 🟨 10 YEAR CAPTURE ZONE
- 🟩 20 YEAR CAPTURE ZONE

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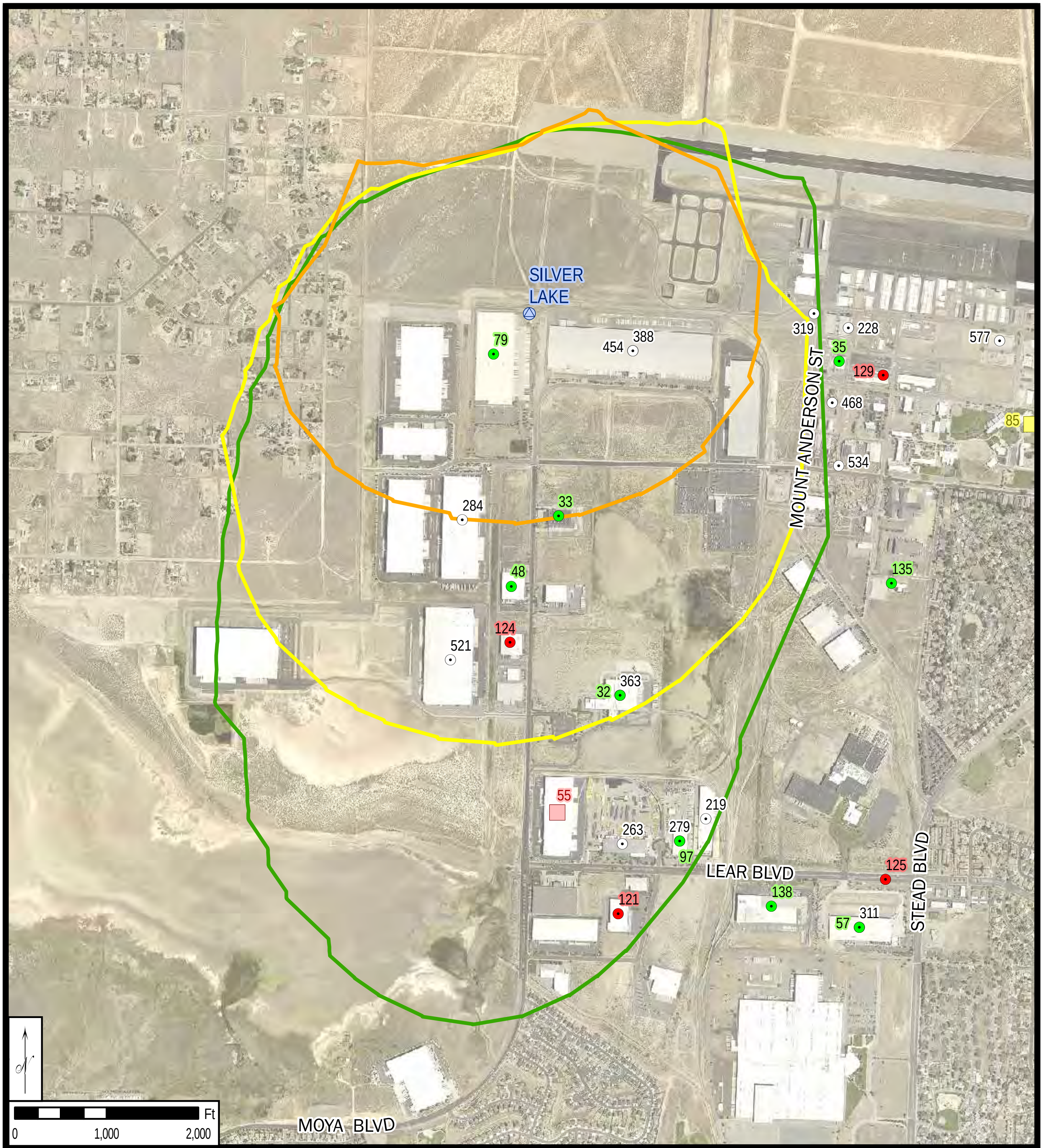

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

LEMMON VALLEY (WEST) (BASIN 92A) -- FIGURE: 3

SILVER LAKE WELL SITE

● POTENTIAL CONTAMINANT SOURCE -- LQG (EPA)
● POTENTIAL CONTAMINANT SOURCE -- SQG (EPA)
● POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)
⊙ POTENTIAL CONTAMINANT SOURCE -- (EPA)
△ WATER SUPPLY WELL
🟥 CONTAMINANT RELEASE SITE - ACTIVE (NDEP)

□ 5 YEAR CAPTURE ZONE
□ 10 YEAR CAPTURE ZONE
□ 20 YEAR CAPTURE ZONE
🟨 CONTAMINANT RELEASE SITE - INACTIVE (NDEP)

TMWA

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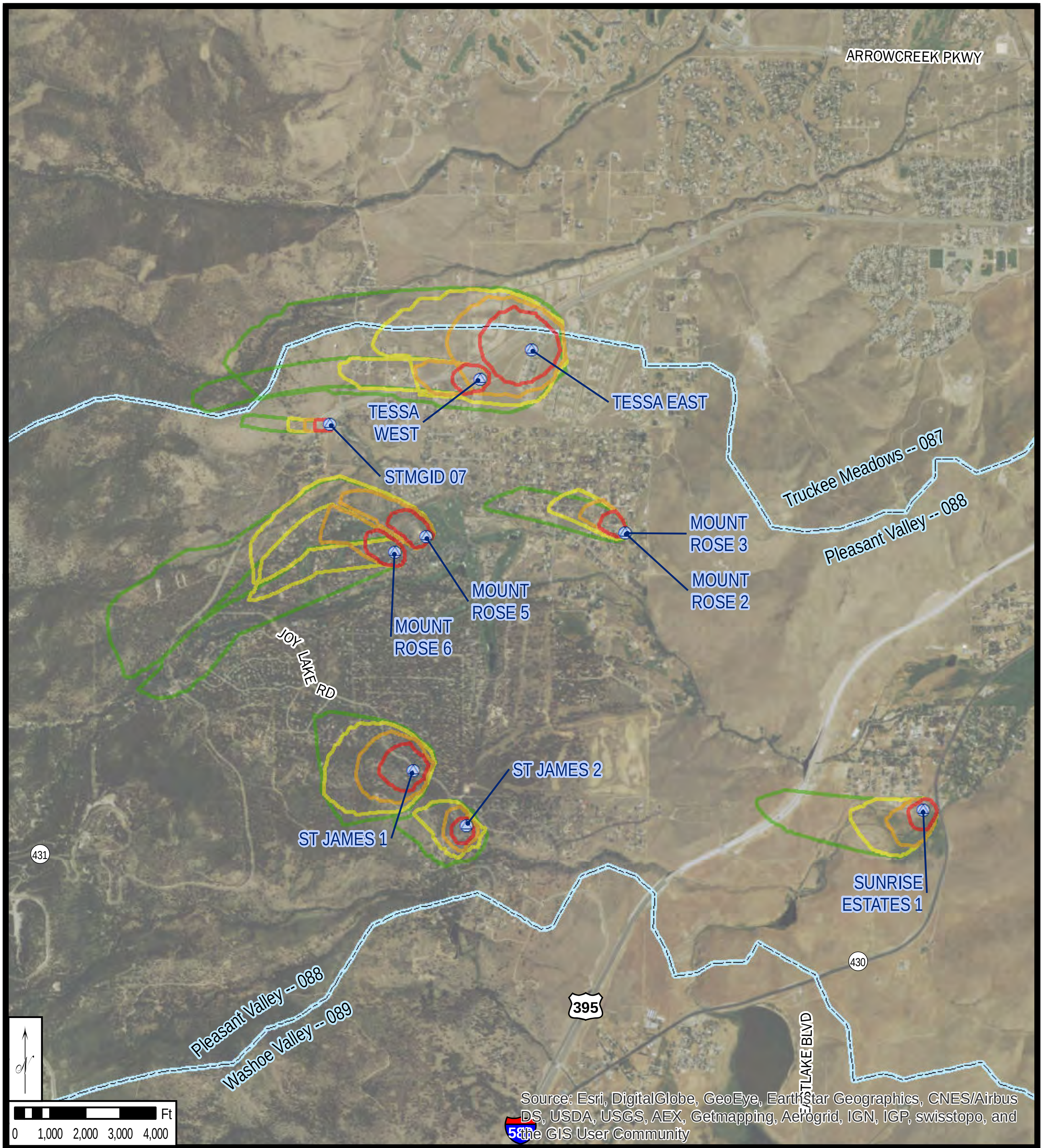

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WELLHEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

PLEASANT VALLEY (BASIN 88) AREA INDEX

- △ WATER SUPPLY WELL
- 🟥 2 YEAR CAPTURE ZONE
- 🟧 5 YEAR CAPTURE ZONE
- 🟨 10 YEAR CAPTURE ZONE
- 🟩 20 YEAR CAPTURE ZONE
- ▭ NEVADA HYDROBASIN BOUNDARY

TMWA

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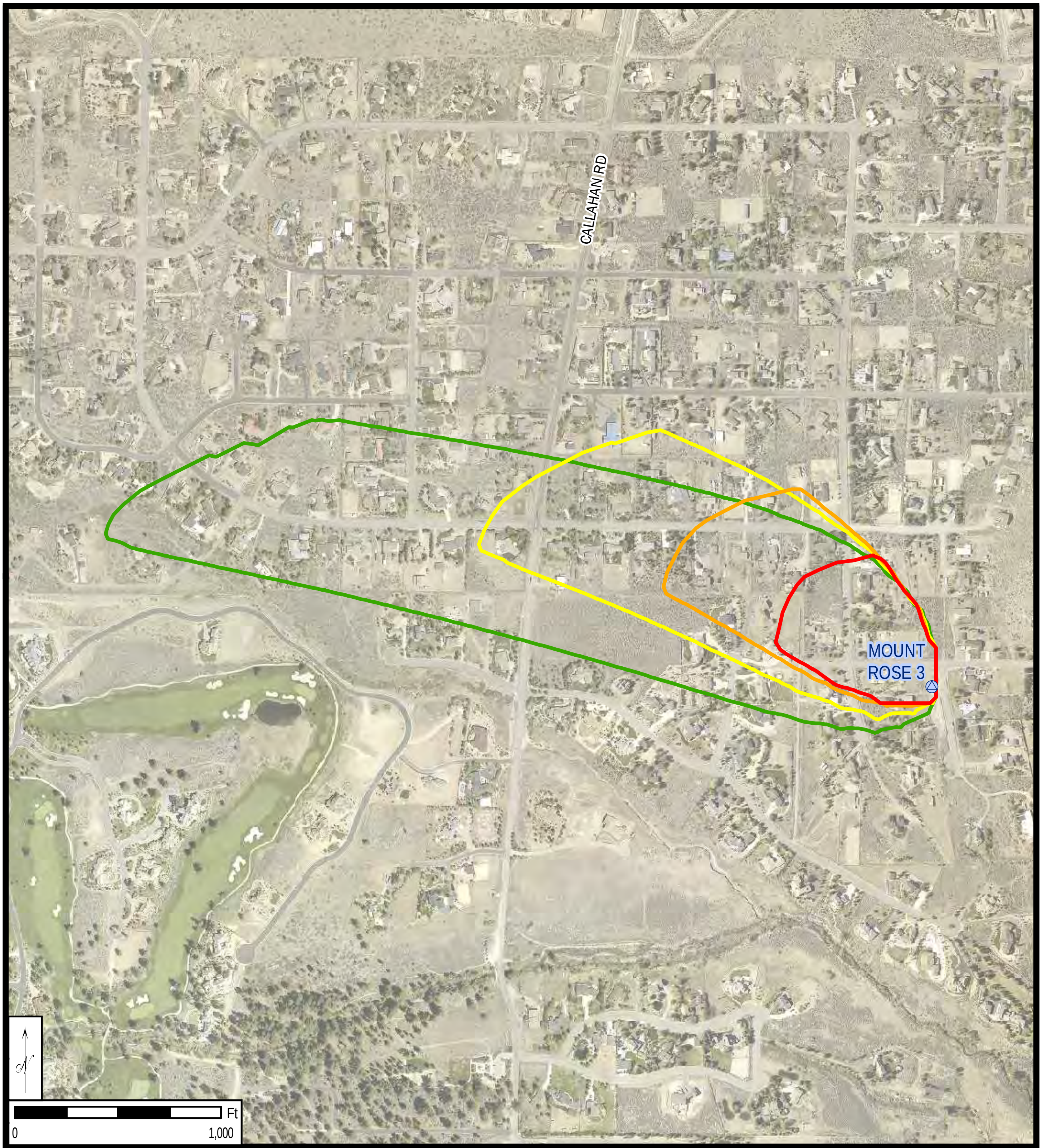

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

PLEASANT VALLEY (BASIN 88) -- FIGURE: 1

MOUNT ROSE 3 WELL SITE

TMWA

- ◬ WATER SUPPLY WELL
- 🟥 2 YEAR CAPTURE ZONE
- 🟧 5 YEAR CAPTURE ZONE
- 🟨 10 YEAR CAPTURE ZONE
- 🟩 20 YEAR CAPTURE ZONE

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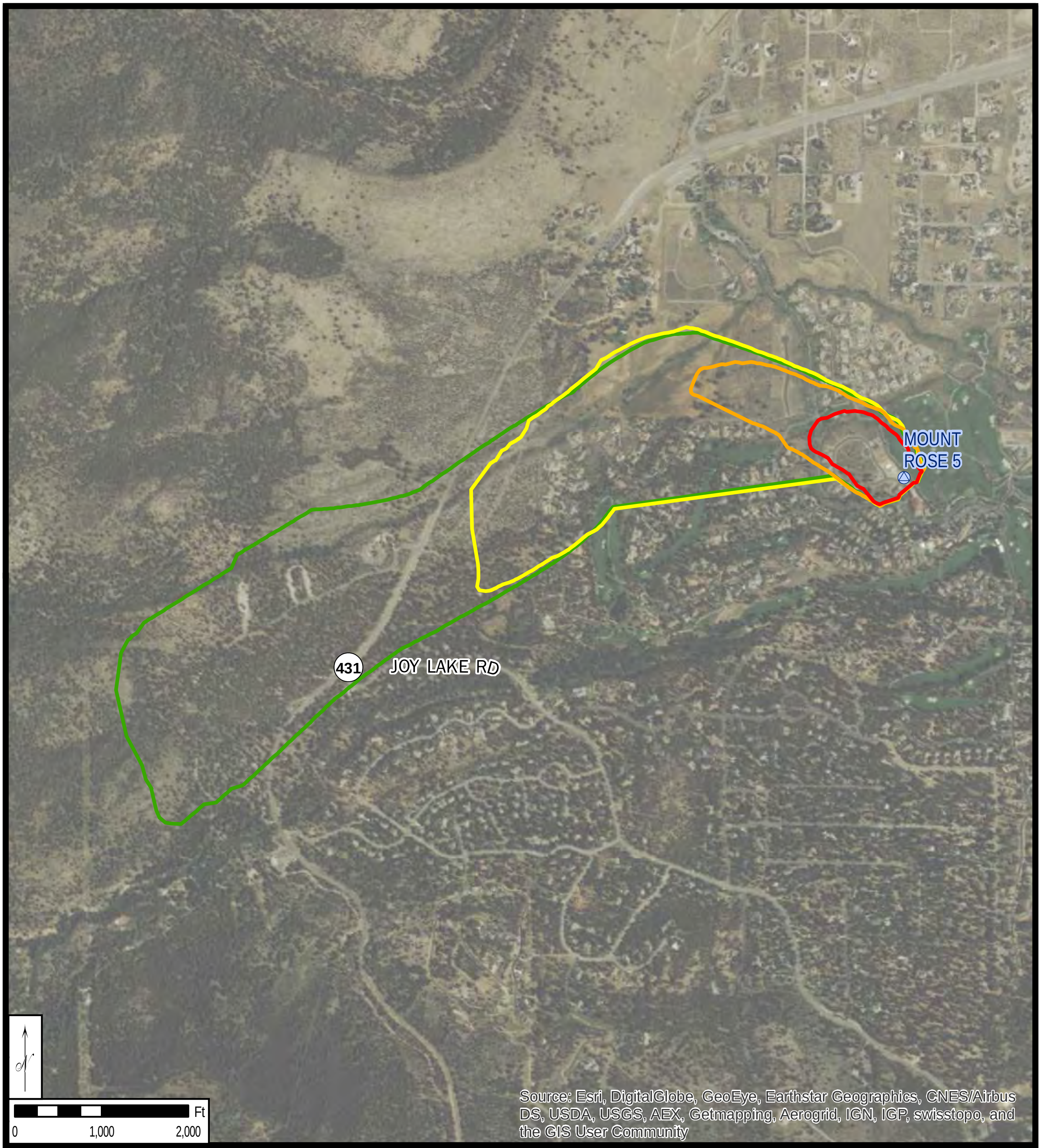

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WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

PLEASANT VALLEY (BASIN 88) -- FIGURE: 2

MOUNT ROSE 5 WELL SITE

TMWA

△ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE
🟧 5 YEAR CAPTURE ZONE
🟨 10 YEAR CAPTURE ZONE
🟩 20 YEAR CAPTURE ZONE

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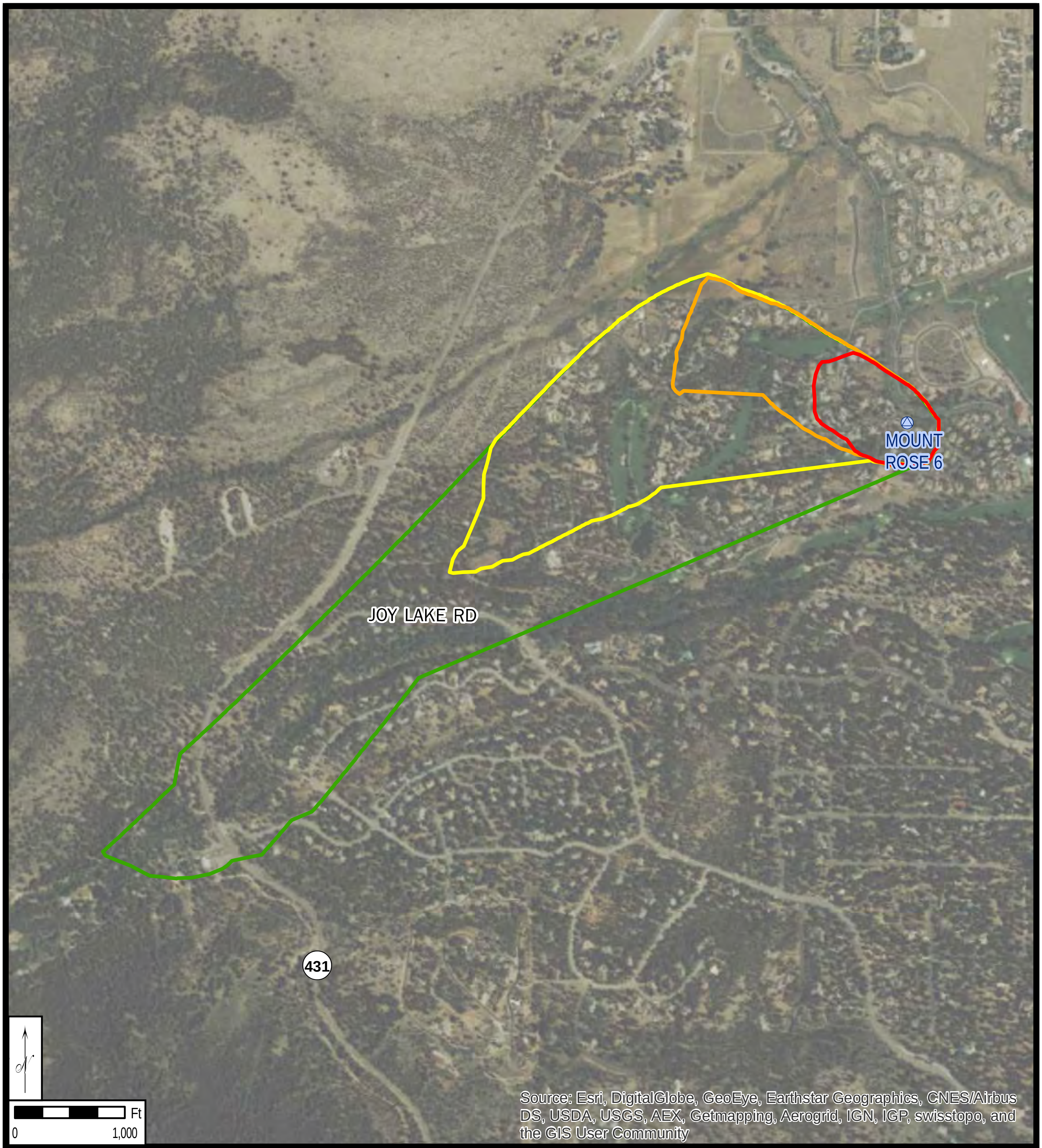

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WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

PLEASANT VALLEY (BASIN 88) -- FIGURE: 3

MOUNT ROSE 6 WELL SITE

TMWA

△ WATER SUPPLY WELL
🟥 2 YEAR CAPTURE ZONE
🟧 5 YEAR CAPTURE ZONE
🟨 10 YEAR CAPTURE ZONE
🟩 20 YEAR CAPTURE ZONE

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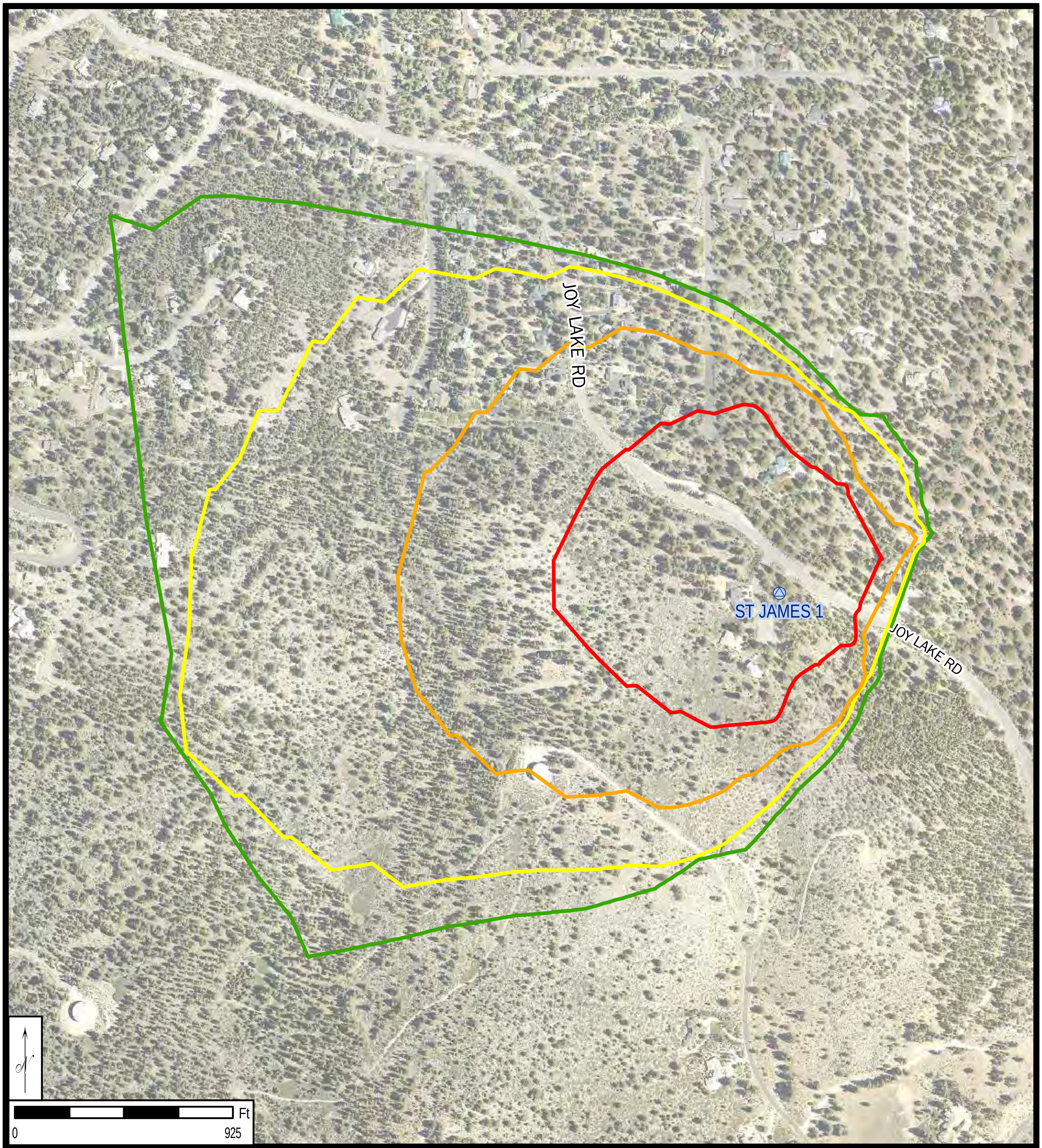

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

PLEASANT VALLEY (BASIN 88) -- FIGURE: 4

ST JAMES 1 WELL SITE

△ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE
🟧 5 YEAR CAPTURE ZONE
🟨 10 YEAR CAPTURE ZONE
🟩 20 YEAR CAPTURE ZONE

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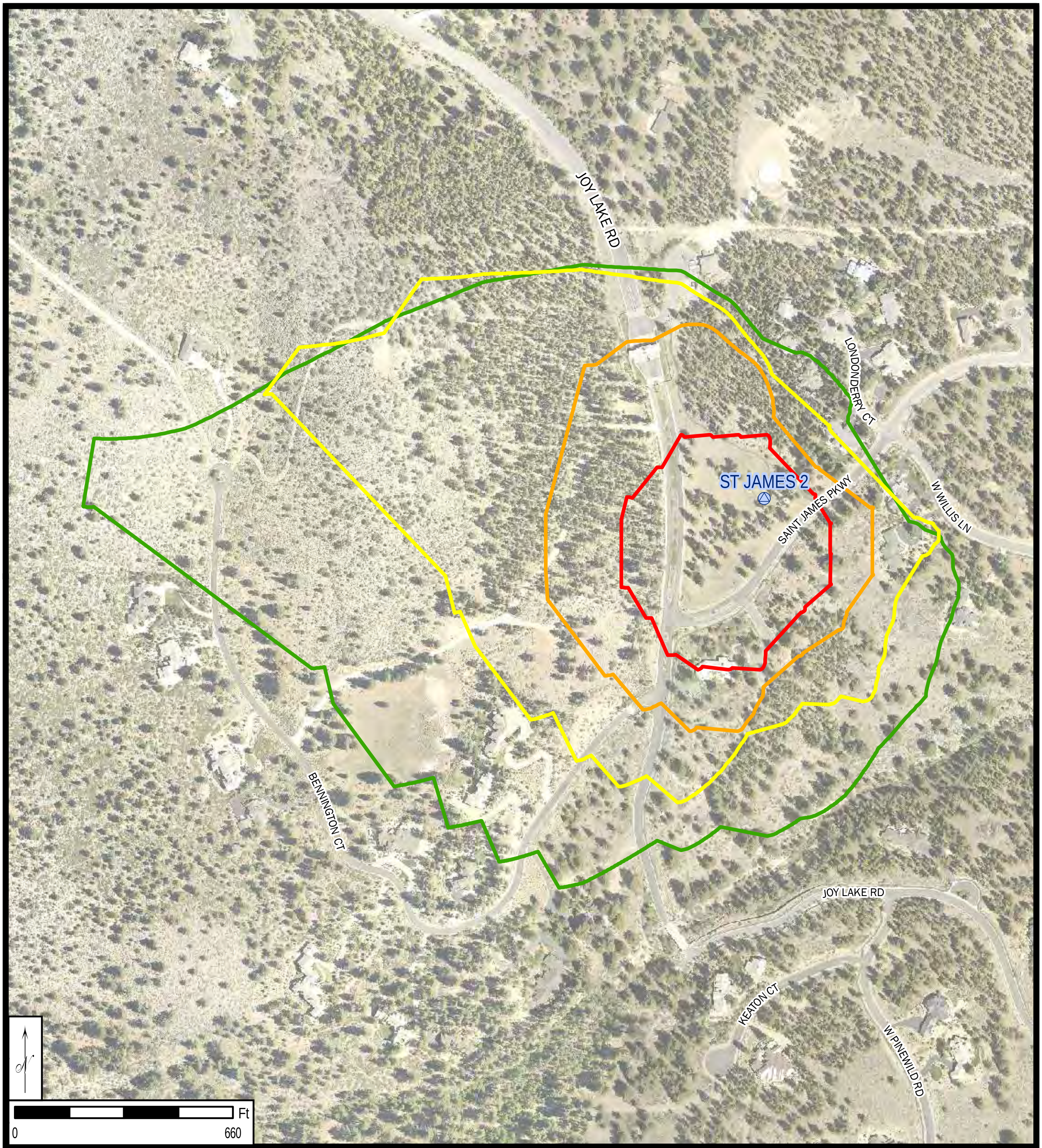

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

PLEASANT VALLEY (BASIN 88) -- FIGURE: 5

ST JAMES 2 WELL SITE

TMWA

△ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE

🟧 5 YEAR CAPTURE ZONE

🟨 10 YEAR CAPTURE ZONE

🟩 20 YEAR CAPTURE ZONE

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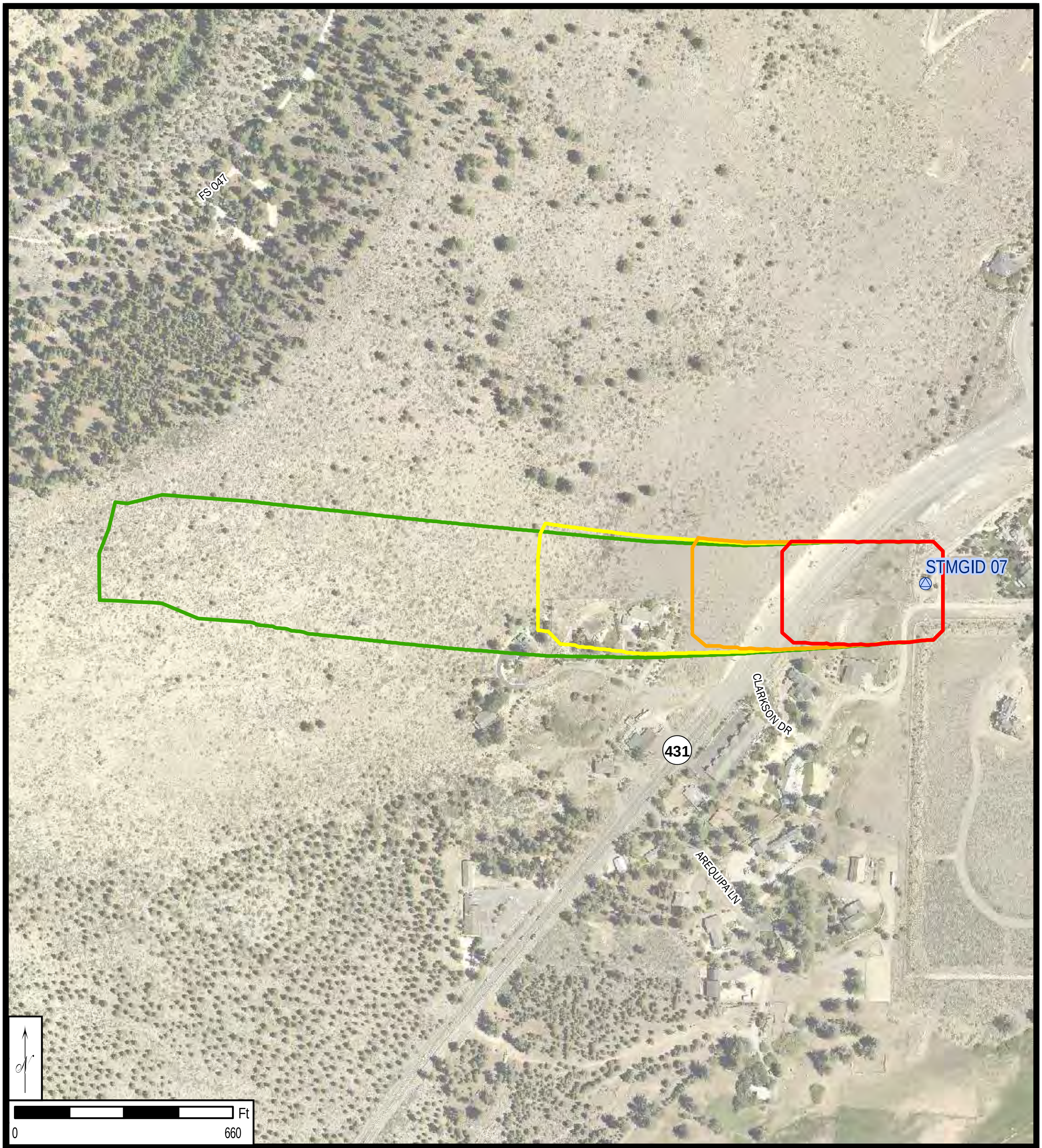

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

PLEASANT VALLEY (BASIN 88) -- FIGURE: 6

STMGID 07 WELL SITE

- △ WATER SUPPLY WELL
- 🟥 2 YEAR CAPTURE ZONE
- 🟧 5 YEAR CAPTURE ZONE
- 🟨 10 YEAR CAPTURE ZONE
- 🟩 20 YEAR CAPTURE ZONE

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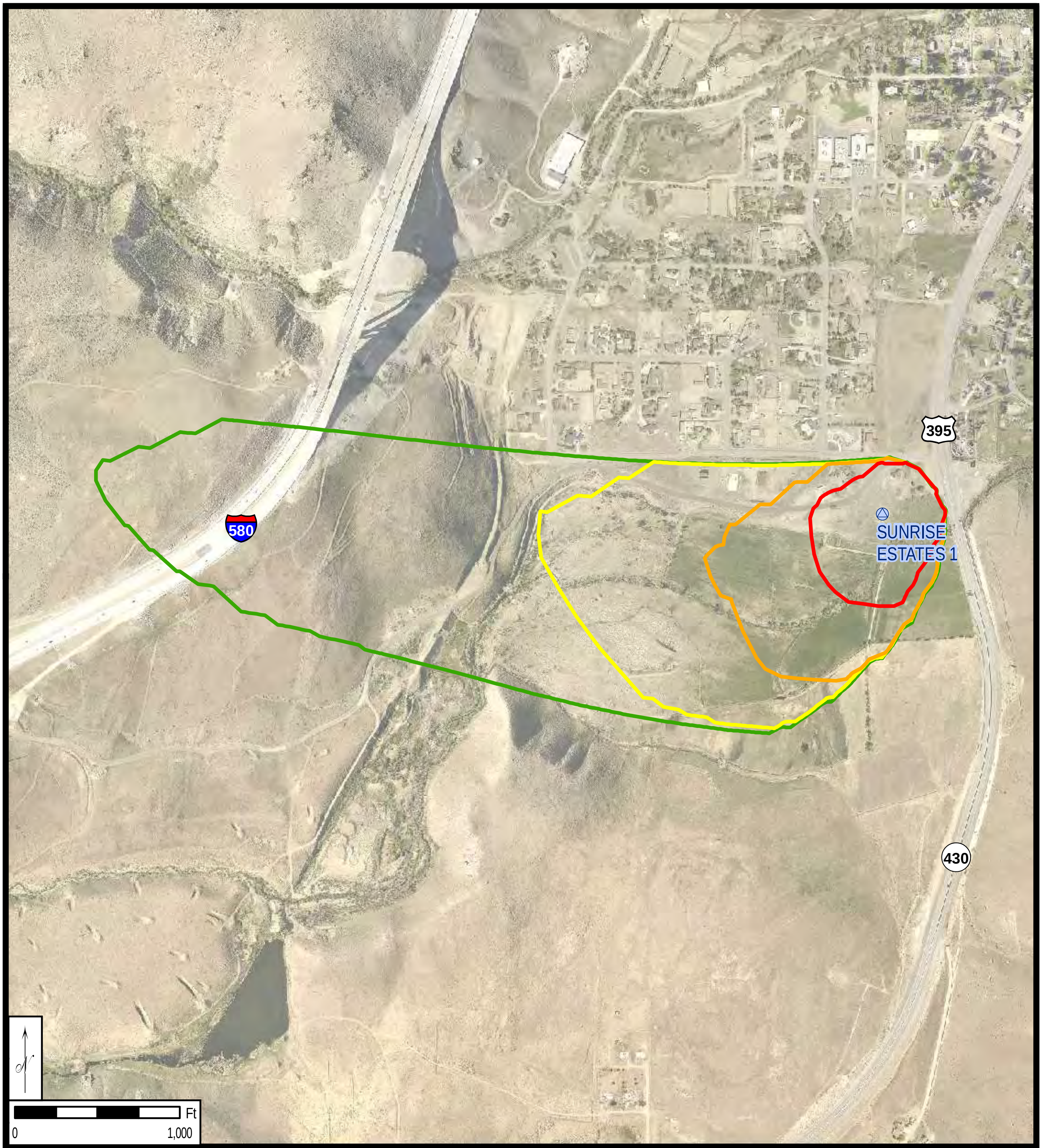

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

PLEASANT VALLEY (BASIN 88) -- FIGURE: 7

SUNRISE ESTATES 1 WELL SITE

△	WATER SUPPLY WELL
🟥	2 YEAR CAPTURE ZONE
🟧	5 YEAR CAPTURE ZONE
🟨	10 YEAR CAPTURE ZONE
🟩	20 YEAR CAPTURE ZONE

TMWA

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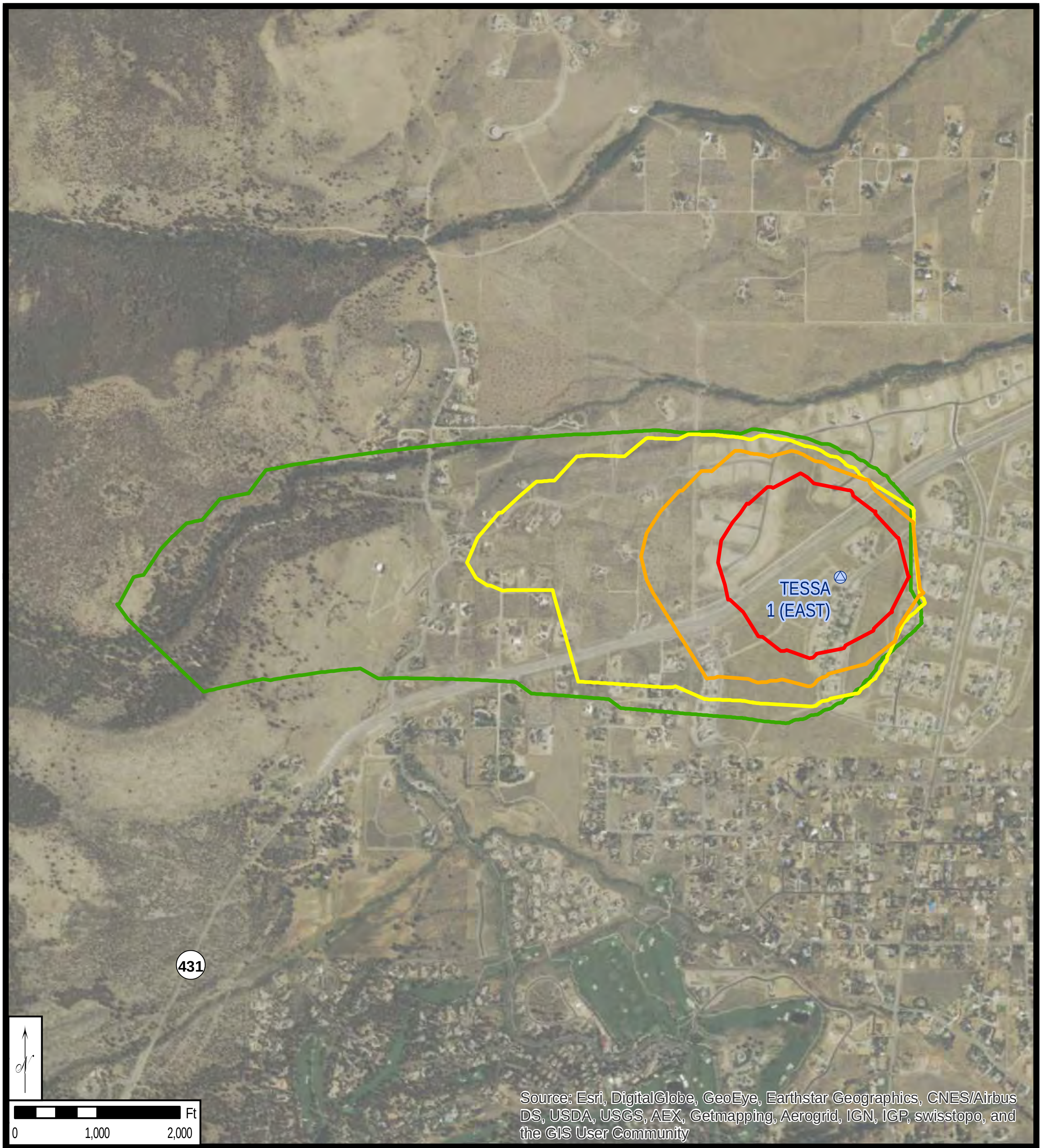

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WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

PLEASANT VALLEY (BASIN 88) -- FIGURE: 8

TESSA 1 (EAST) WELL SITE

△ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE

🟧 5 YEAR CAPTURE ZONE

🟨 10 YEAR CAPTURE ZONE

🟩 20 YEAR CAPTURE ZONE

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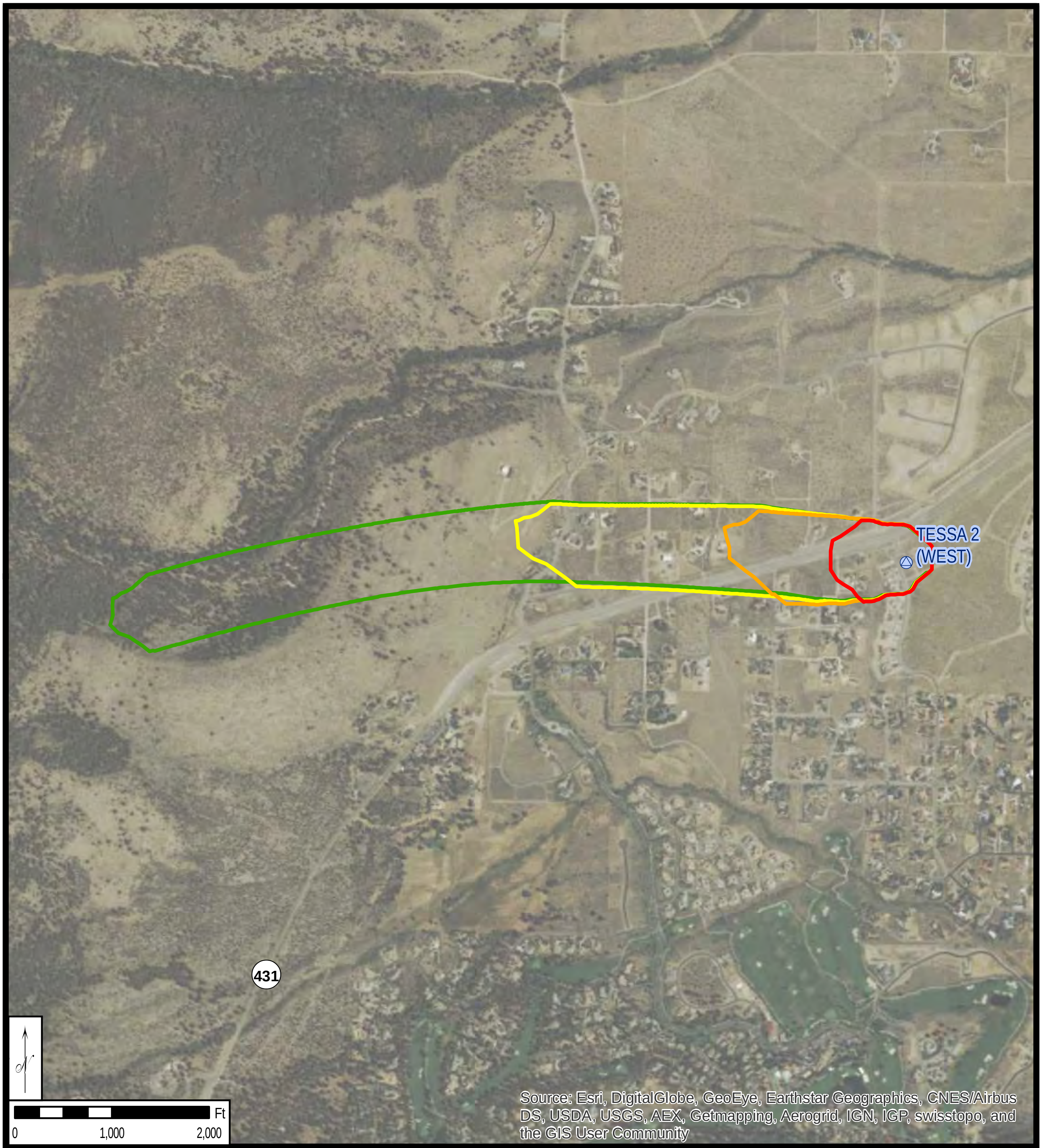

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WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

PLEASANT VALLEY (BASIN 88) -- FIGURE: 9

TESSA 2 (WEST) WELL SITE

TMWA

- △ WATER SUPPLY WELL
- 🟥 2 YEAR CAPTURE ZONE
- 🟧 5 YEAR CAPTURE ZONE
- 🟨 10 YEAR CAPTURE ZONE
- 🟩 20 YEAR CAPTURE ZONE

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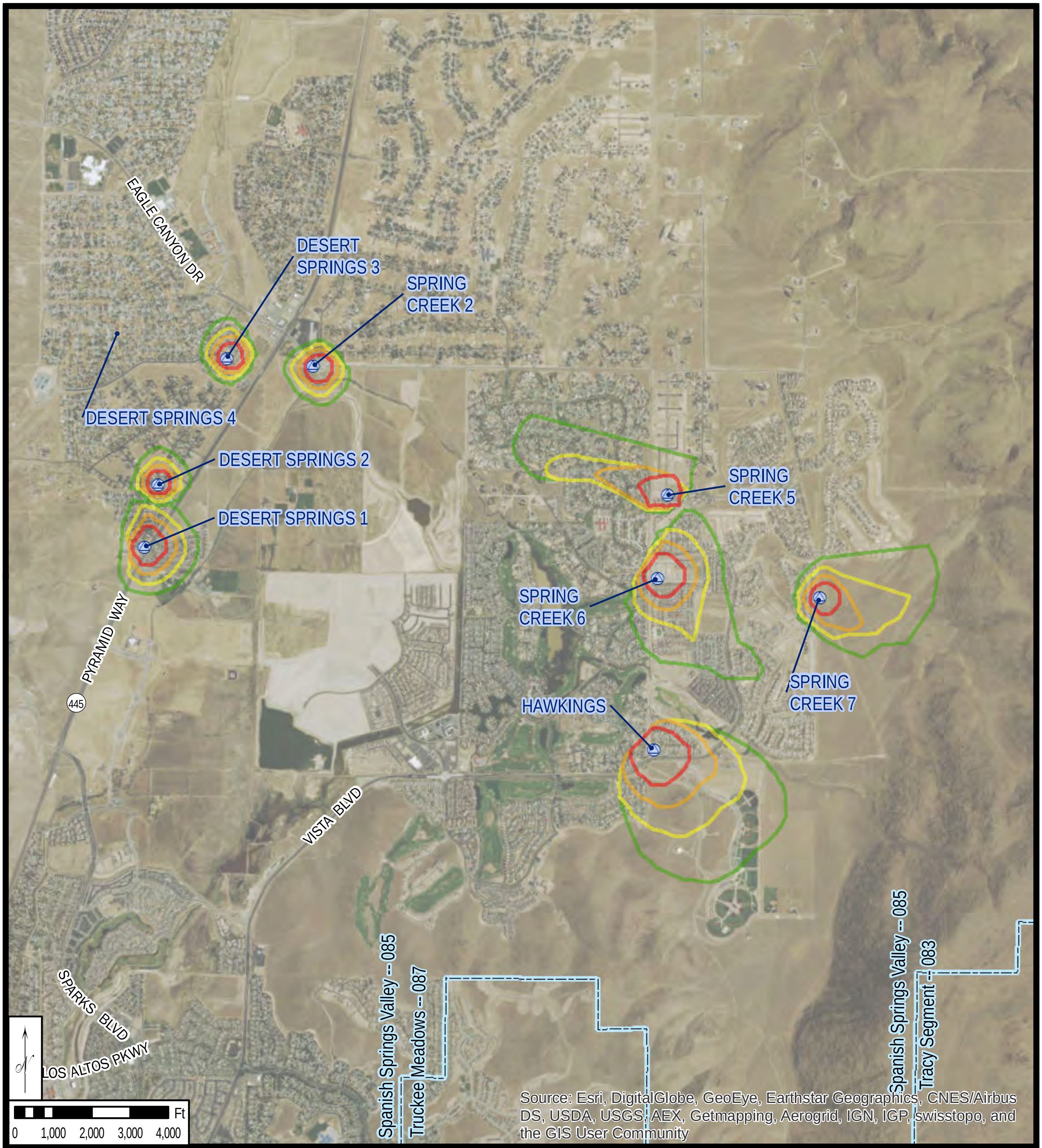

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WELLHEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

SPANISH SPRINGS (BASIN 85) AREA INDEX

TMWA

◬	WATER SUPPLY WELL
🟥	2 YEAR CAPTURE ZONE
🟧	5 YEAR CAPTURE ZONE
🟨	10 YEAR CAPTURE ZONE
🟩	20 YEAR CAPTURE ZONE
▢	NEVADA HYDROBASIN BOUNDARY

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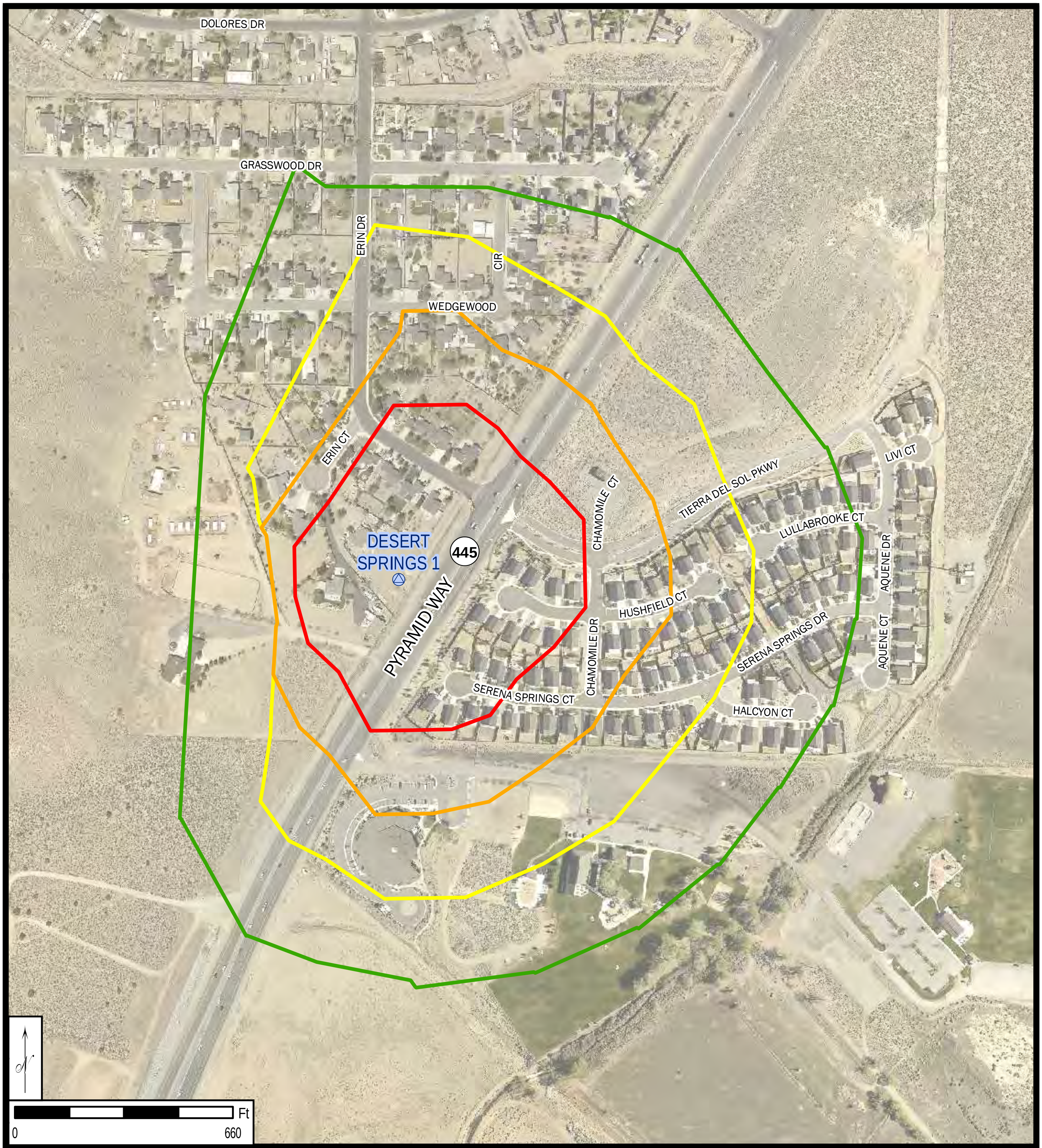

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

SPANISH SPRINGS (BASIN 85) -- FIGURE: 1

DESERT SPRINGS 1 WELL SITE

TMWA

△ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE

🟧 5 YEAR CAPTURE ZONE

🟨 10 YEAR CAPTURE ZONE

🟩 20 YEAR CAPTURE ZONE

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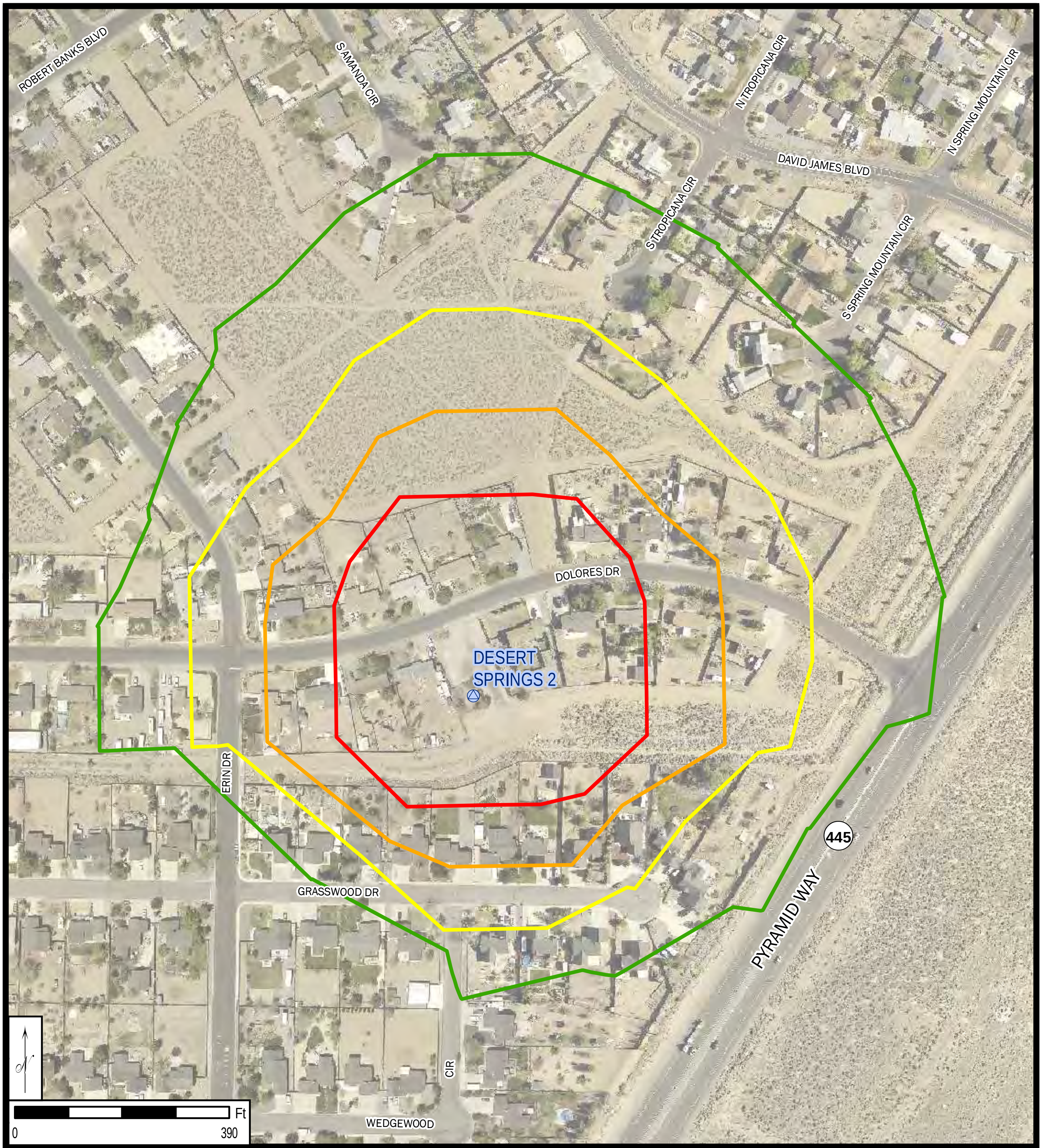

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

SPANISH SPRINGS (BASIN 85) -- FIGURE: 2

DESERT SPRINGS 2 WELL SITE

TMWA

△ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE

🟧 5 YEAR CAPTURE ZONE

🟨 10 YEAR CAPTURE ZONE

🟩 20 YEAR CAPTURE ZONE

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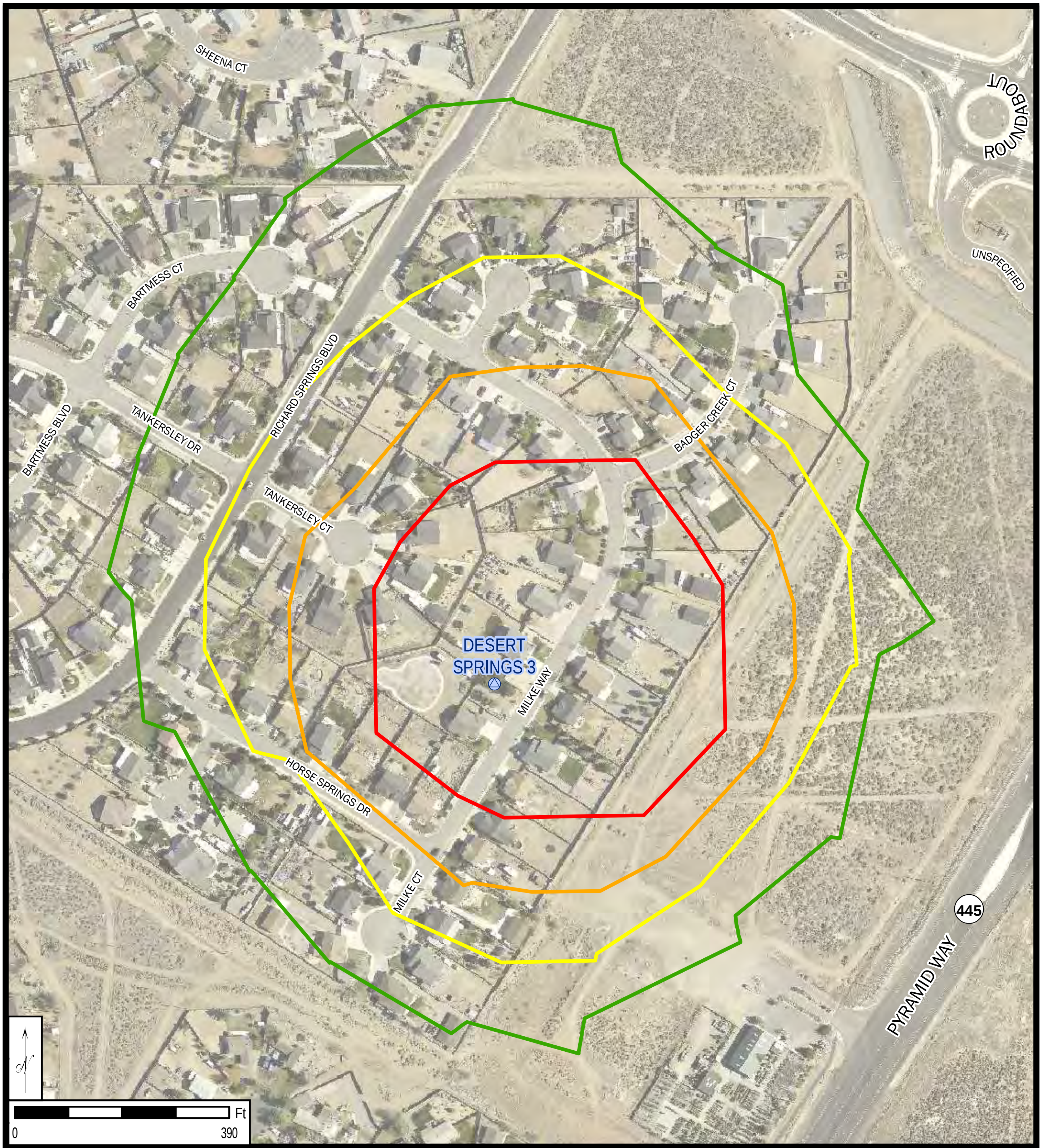

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

SPANISH SPRINGS (BASIN 85) -- FIGURE: 3

DESERT SPRINGS 3 WELL SITE

TMWA

△ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE

🟧 5 YEAR CAPTURE ZONE

🟨 10 YEAR CAPTURE ZONE

🟩 20 YEAR CAPTURE ZONE

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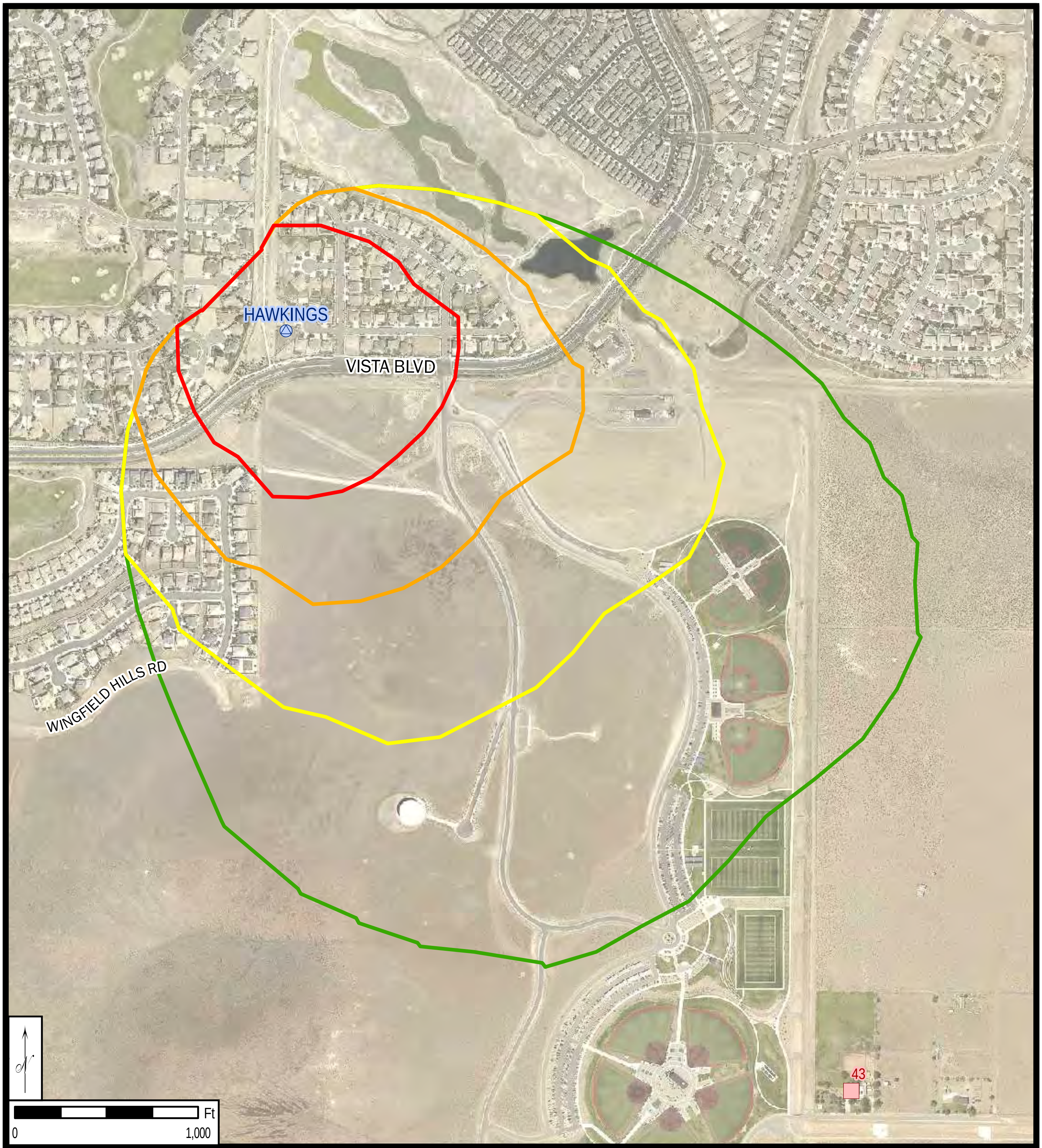

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

SPANISH SPRINGS (BASIN 85) -- FIGURE: 4

HAWKINGS WELL SITE

◬ WATER SUPPLY WELL

🟥 CONTAMINANT RELEASE SITE - ACTIVE (NDEP)

🟥 2 YEAR CAPTURE ZONE

🟧 5 YEAR CAPTURE ZONE

🟨 10 YEAR CAPTURE ZONE

🟩 20 YEAR CAPTURE ZONE

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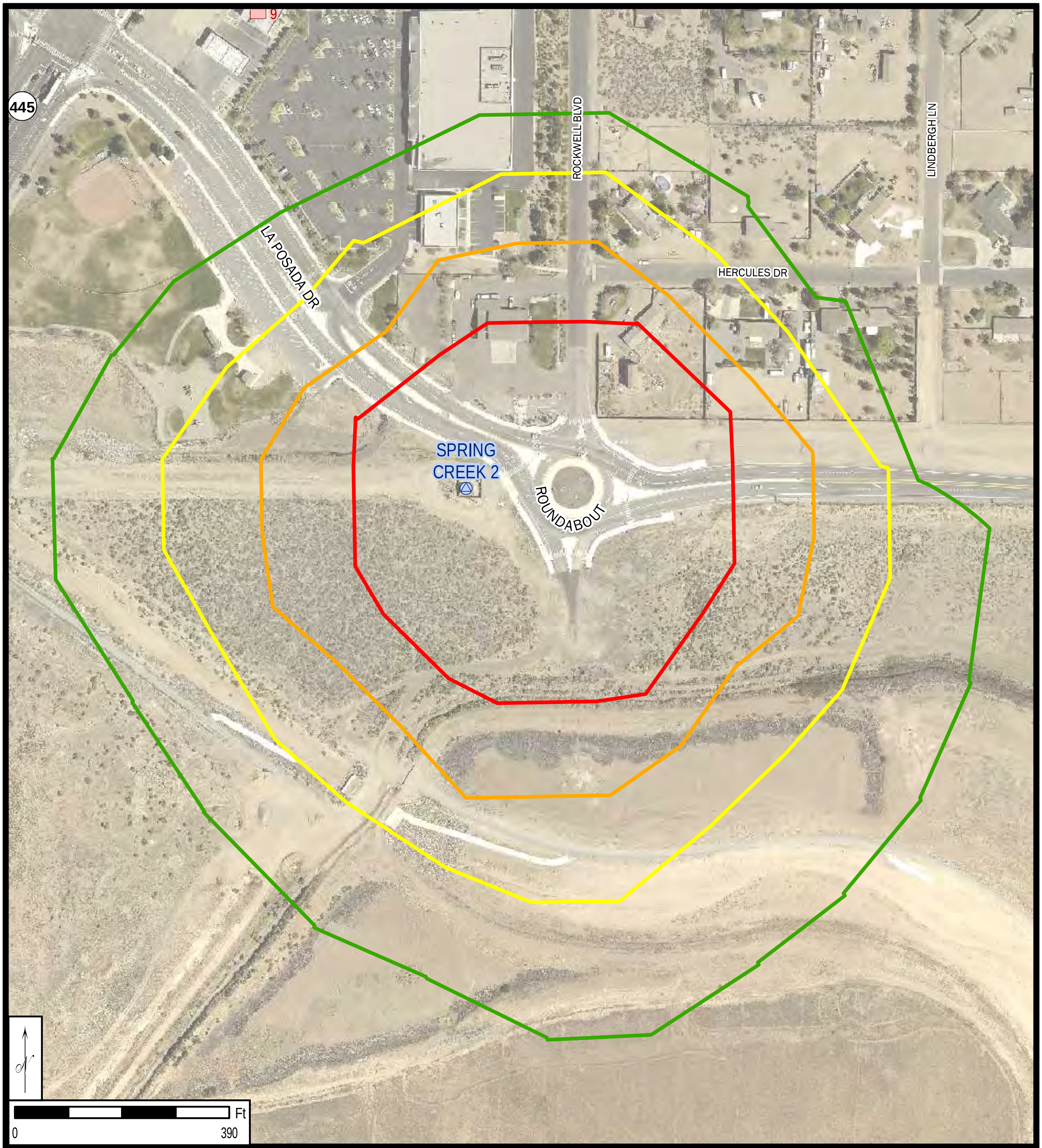

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

SPANISH SPRINGS (BASIN 85) -- FIGURE: 5

SPRING CREEK 2 WELL SITE

TMWA

△	WATER SUPPLY WELL	🟥	2 YEAR CAPTURE ZONE
■	CONTAMINANT RELEASE SITE - ACTIVE (NDEP)	🟧	5 YEAR CAPTURE ZONE
		🟨	10 YEAR CAPTURE ZONE
		🟩	20 YEAR CAPTURE ZONE

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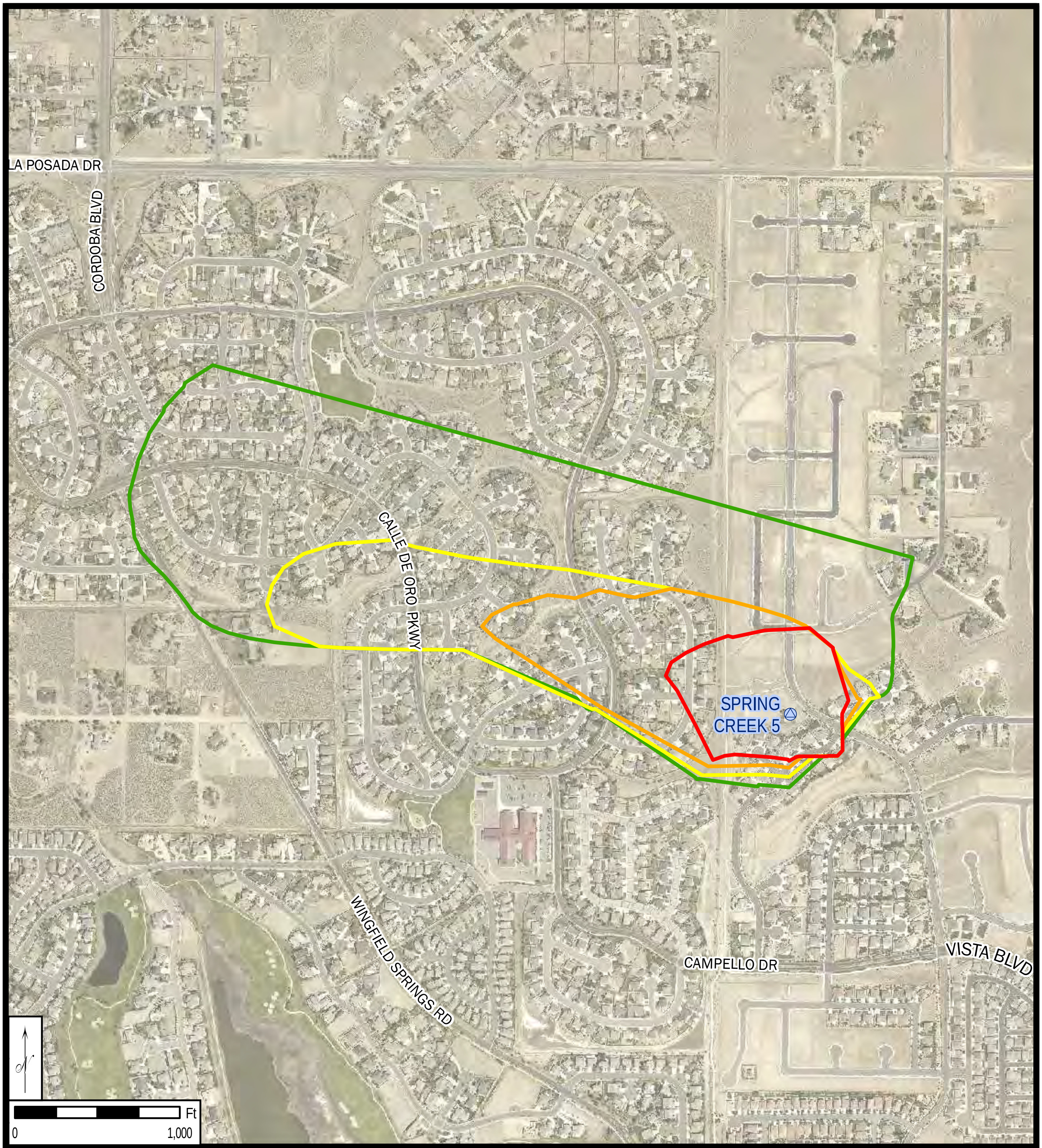

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

SPANISH SPRINGS (BASIN 85) -- FIGURE: 6

SPRING CREEK 5 WELL SITE

TMWA

△ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE

🟧 5 YEAR CAPTURE ZONE

🟨 10 YEAR CAPTURE ZONE

🟩 20 YEAR CAPTURE ZONE

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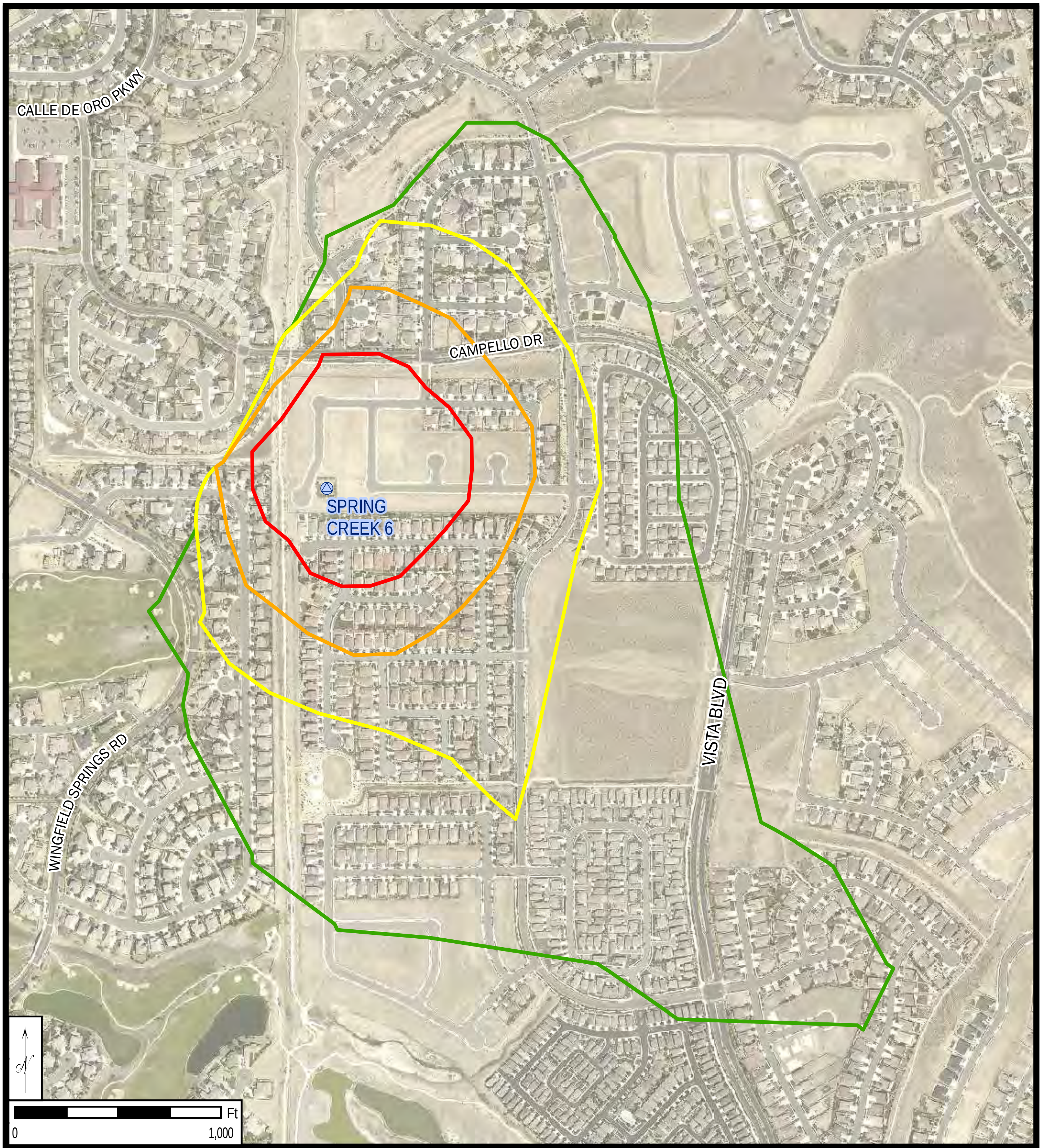

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

SPANISH SPRINGS (BASIN 85) -- FIGURE: 7

SPRING CREEK 6 WELL SITE

△ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE

🟧 5 YEAR CAPTURE ZONE

🟨 10 YEAR CAPTURE ZONE

🟩 20 YEAR CAPTURE ZONE

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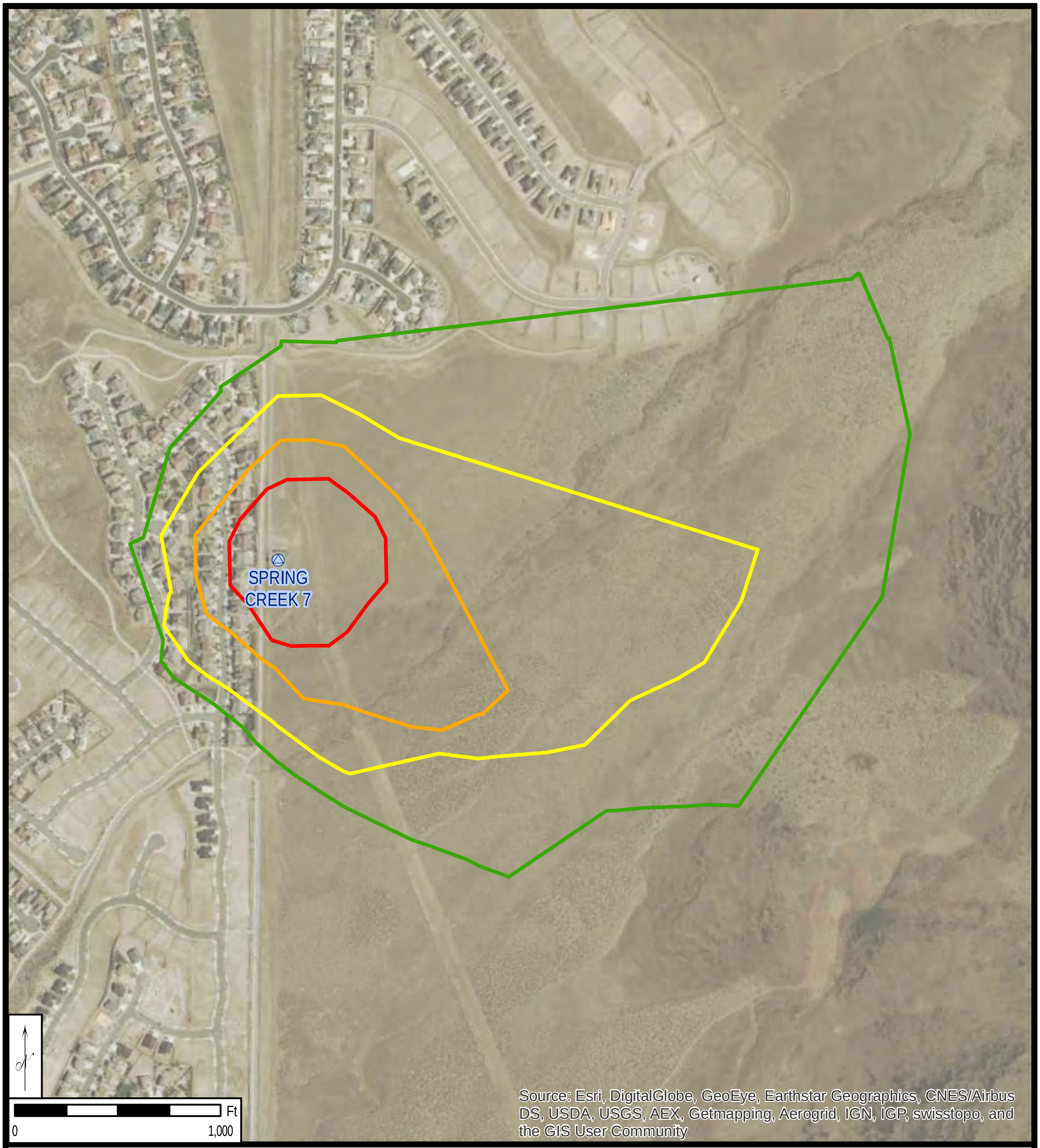

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WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

SPANISH SPRINGS (BASIN 85) -- FIGURE: 8

SPRING CREEK 7 WELL SITE

TMWA

◬	WATER SUPPLY WELL	🟥	2 YEAR CAPTURE ZONE
		🟧	5 YEAR CAPTURE ZONE
		🟨	10 YEAR CAPTURE ZONE
		🟩	20 YEAR CAPTURE ZONE

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WELLHEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRACY SEGMENT (BASIN 83) AREA INDEX

TMWA

△	WATER SUPPLY WELL	▢	1/2 MILE CAPTURE ZONE
		▢	NEVADA HYDROBASIN BOUNDARY

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WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRACY SEGMENT (BASIN 83) -- FIGURE: 1

STAMPMILL 1 WELL SITE

TMWA

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△ WATER SUPPLY WELL ▢ 1/2 MILE CAPTURE ZONE

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WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRACY SEGMENT (BASIN 83) -- FIGURE: 2

STAMPMILL 2 WELL SITE

TMWA

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△ WATER SUPPLY WELL ▢ 1/2 MILE CAPTURE ZONE

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WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRACY SEGMENT (BASIN 83) -- FIGURE: 3

TRUCKEE CANYON 1 WELL SITE

◬	WATER SUPPLY WELL
🟥	CONTAMINANT RELEASE SITE - ACTIVE (NDEP)
▭	1/2 MILE CAPTURE ZONE

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WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRACY SEGMENT (BASIN 83) -- FIGURE: 4

TRUCKEE CANYON 3 WELL SITE

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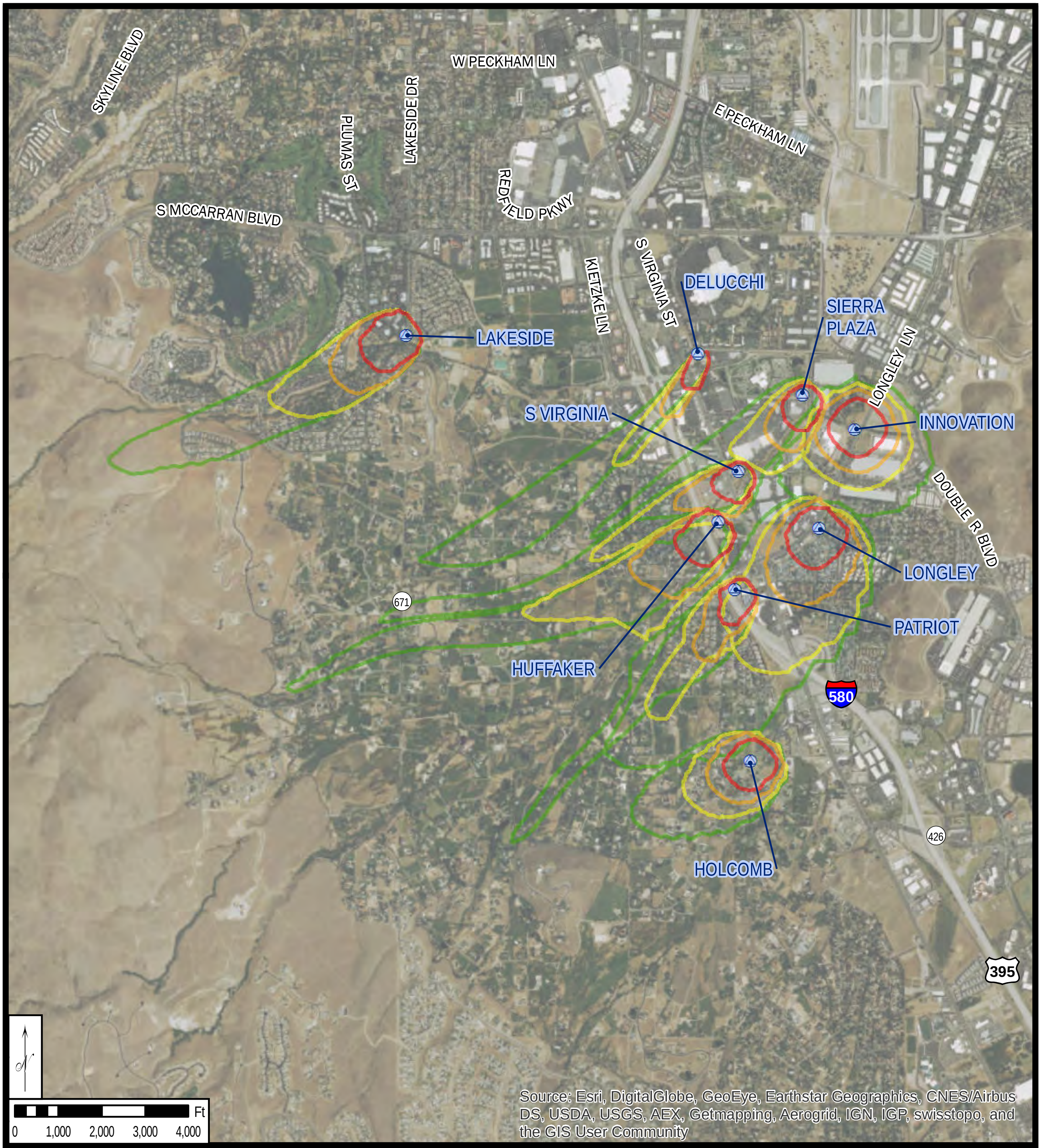
△	WATER SUPPLY WELL	▢	1/2 MILE CAPTURE ZONE
🟥	CONTAMINANT RELEASE SITE - ACTIVE (NDEP)		



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

WELLHEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (CENTRAL) (BASIN 87) AREA INDEX

TMWA

- ▲ WATER SUPPLY WELL
- 🟥 2 YEAR CAPTURE ZONE
- 🟧 5 YEAR CAPTURE ZONE
- 🟨 10 YEAR CAPTURE ZONE
- 🟩 20 YEAR CAPTURE ZONE
- 🟦 NEVADA HYDROBASIN BOUNDARY

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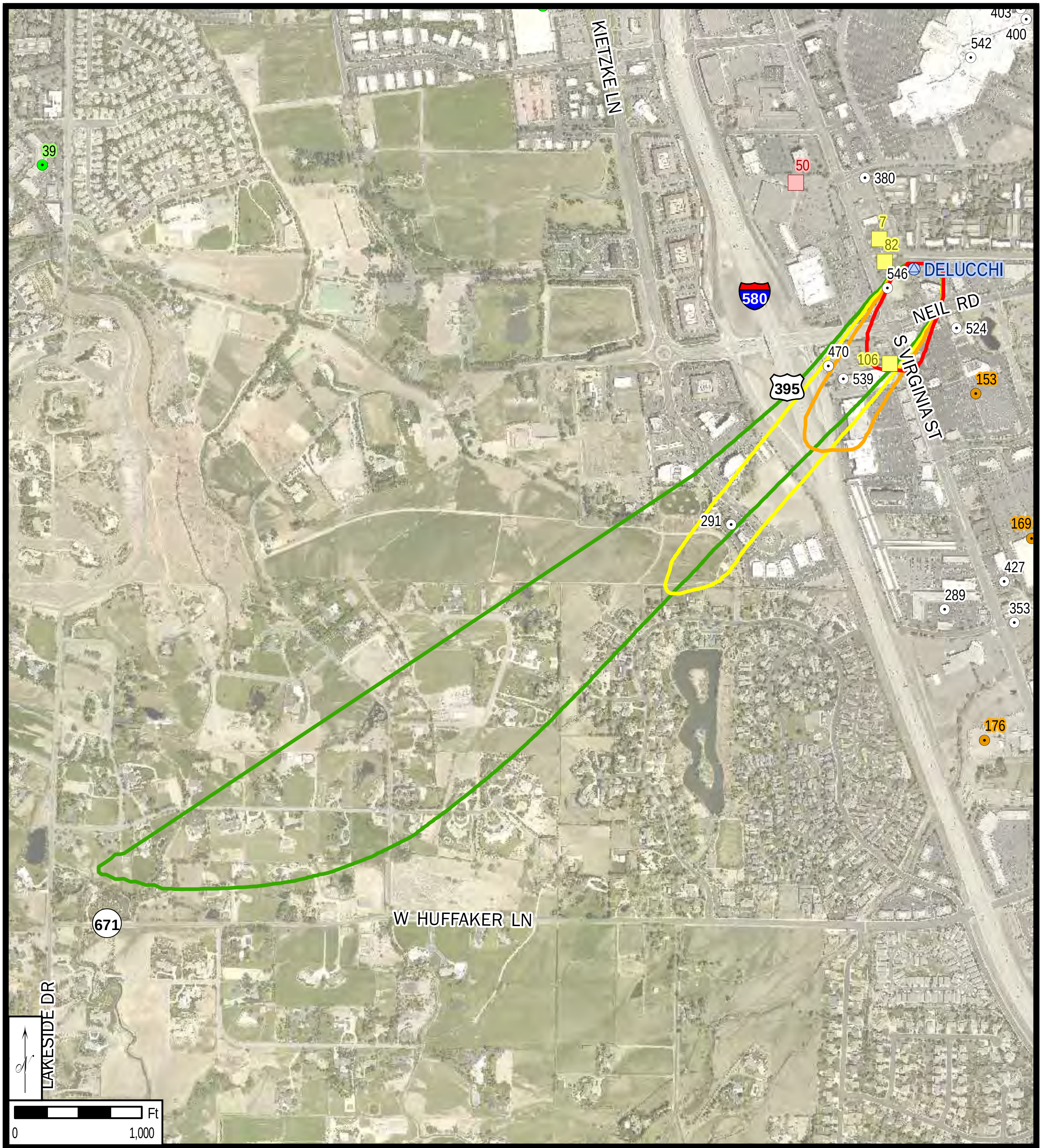

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (CENTRAL) (BASIN 87) -- FIGURE: 1

DELUCCHI WELL SITE

●	POTENTIAL CONTAMINANT SOURCE -- SQG (EPA)	🟥	2 YEAR CAPTURE ZONE
●	POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)	🟧	5 YEAR CAPTURE ZONE
⊙	POTENTIAL CONTAMINANT SOURCE -- (EPA)	🟨	10 YEAR CAPTURE ZONE
△	WATER SUPPLY WELL	🟩	20 YEAR CAPTURE ZONE
■	CONTAMINANT RELEASE SITE - ACTIVE (NDEP)	🟨	CONTAMINANT RELEASE SITE - INACTIVE (NDEP)

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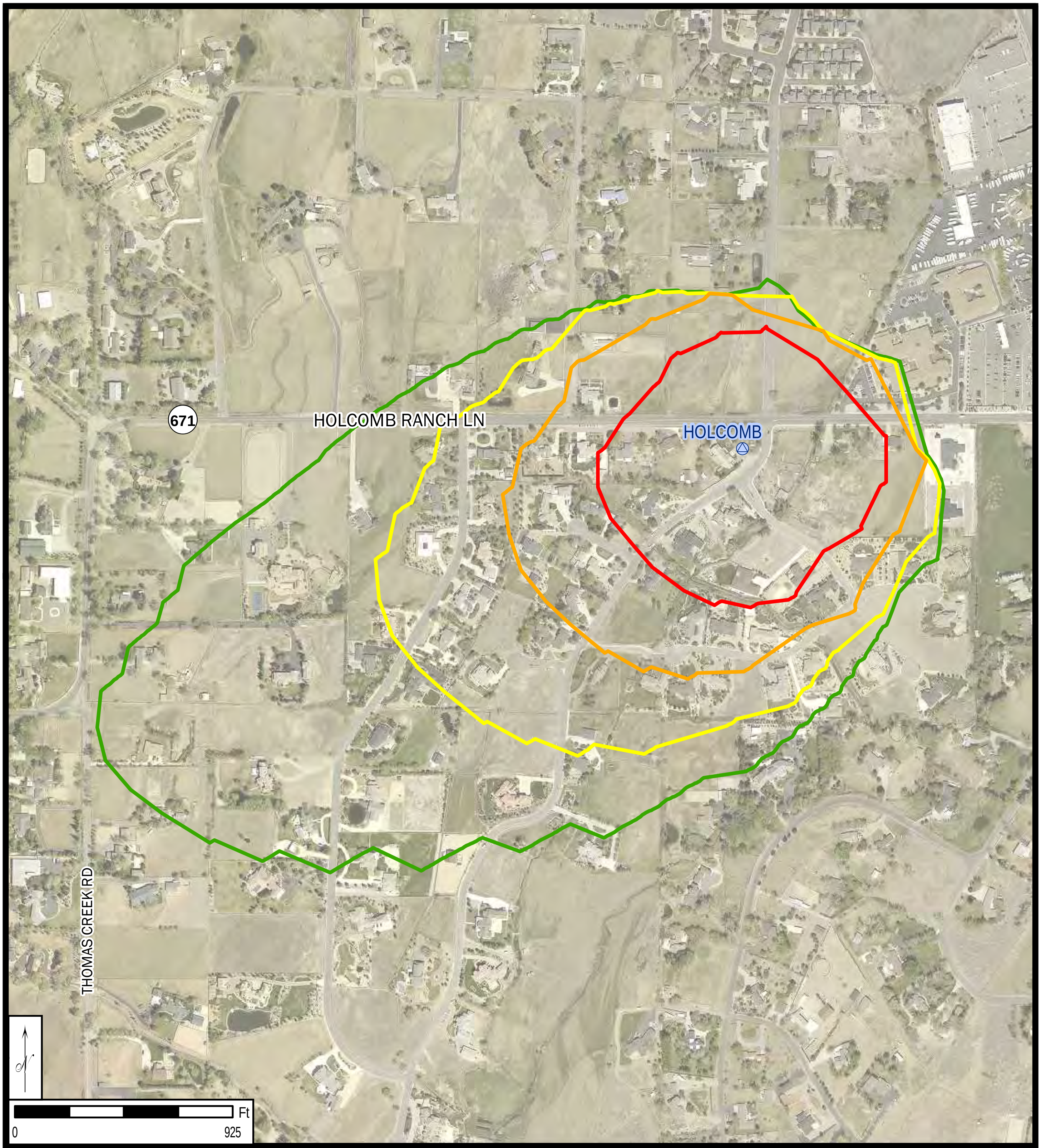

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (CENTRAL) (BASIN 87) -- FIGURE: 2

HOLCOMB WELL SITE

☉	POTENTIAL CONTAMINANT SOURCE -- (EPA)
△	WATER SUPPLY WELL
🟥	2 YEAR CAPTURE ZONE
🟧	5 YEAR CAPTURE ZONE
🟨	10 YEAR CAPTURE ZONE
🟩	20 YEAR CAPTURE ZONE

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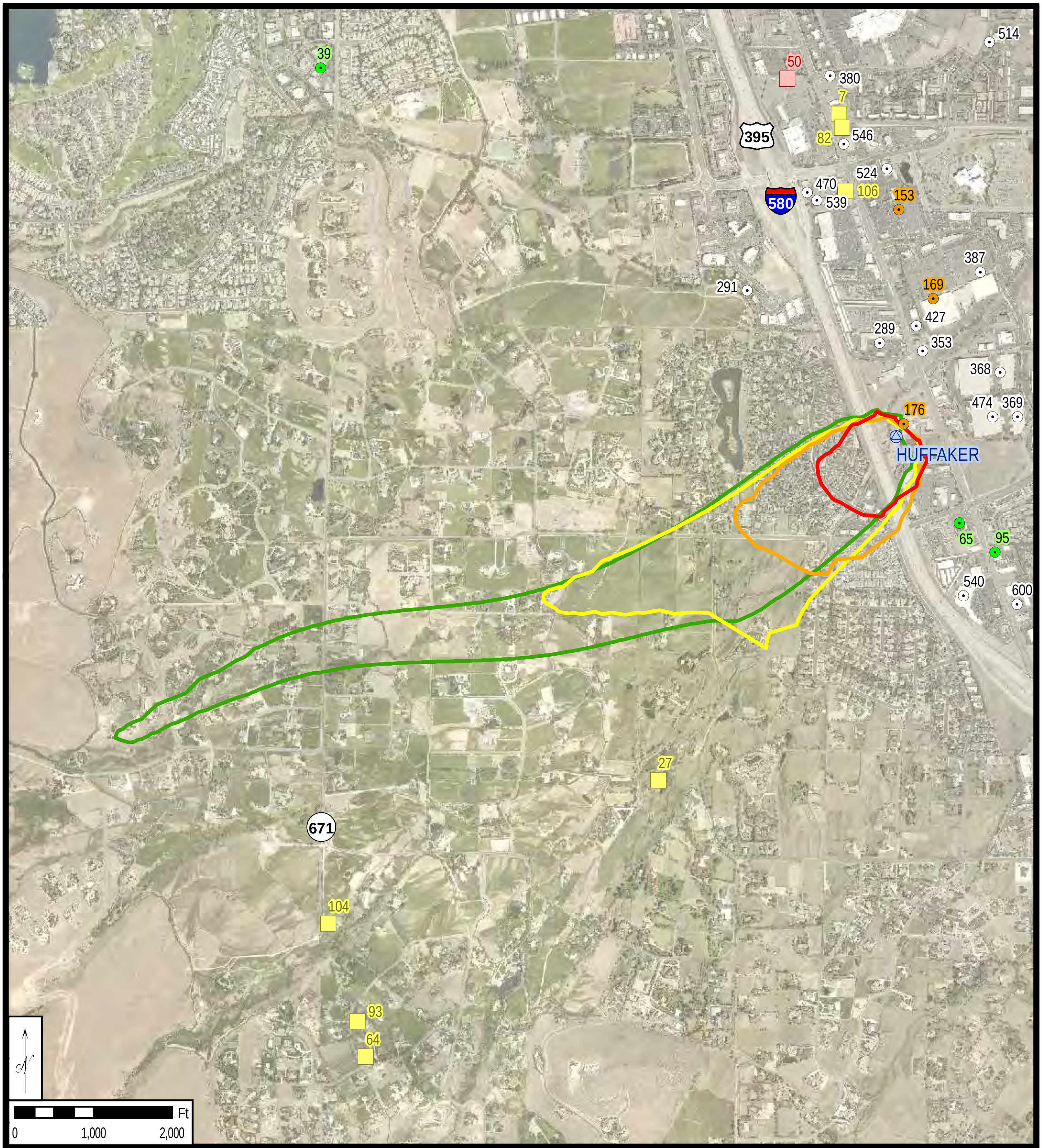

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (CENTRAL) (BASIN 87) -- FIGURE: 3

HUFFAKER WELL SITE

●	POTENTIAL CONTAMINANT SOURCE -- SQG (EPA)	▢	2 YEAR CAPTURE ZONE
●	POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)	▢	5 YEAR CAPTURE ZONE
⊙	POTENTIAL CONTAMINANT SOURCE -- (EPA)	▢	10 YEAR CAPTURE ZONE
△	WATER SUPPLY WELL	▢	20 YEAR CAPTURE ZONE
■	CONTAMINANT RELEASE SITE - ACTIVE (NDEP)	■	CONTAMINANT RELEASE SITE - INACTIVE (NDEP)

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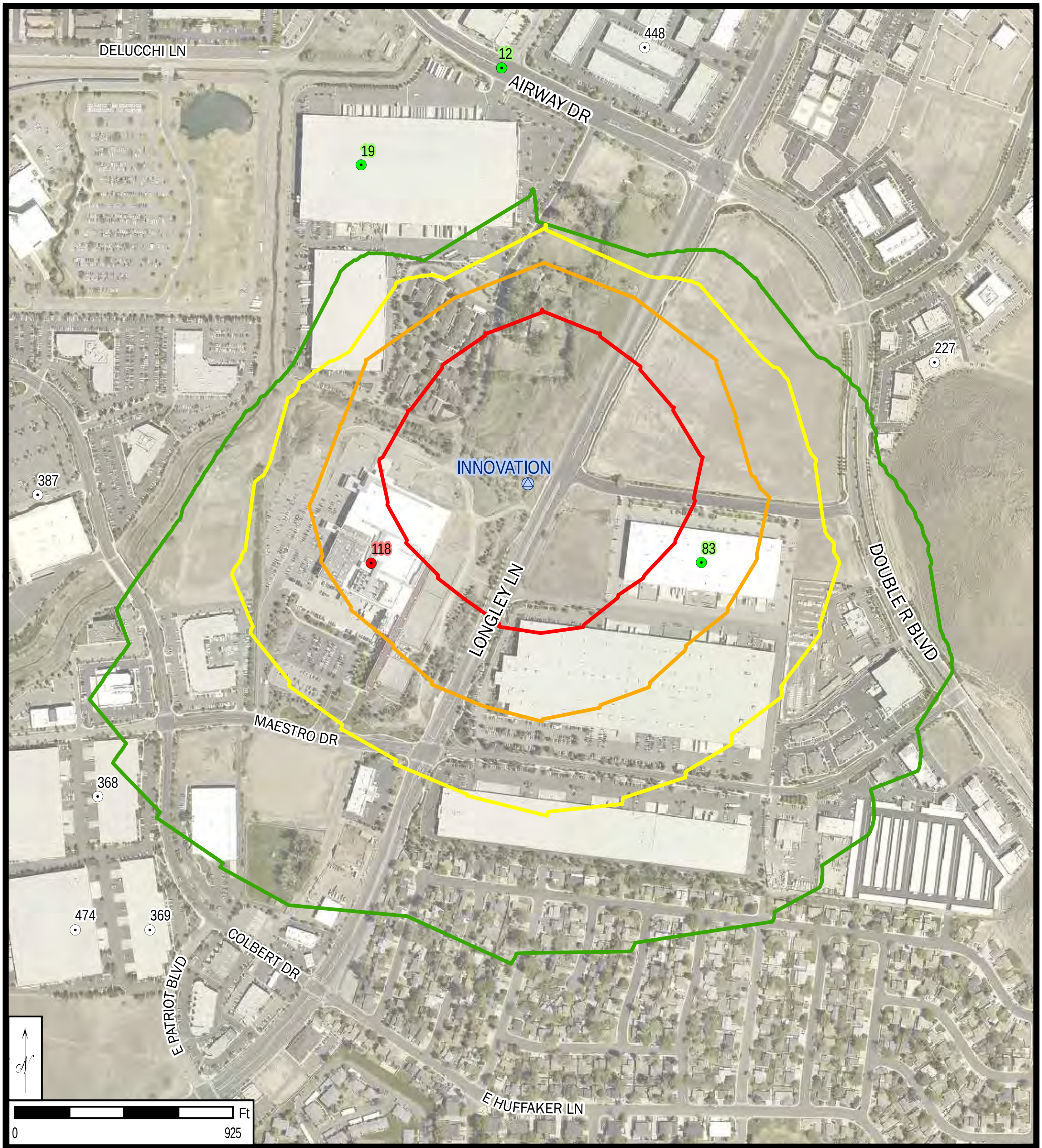

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (CENTRAL) (BASIN 87) -- FIGURE: 4

INNOVATION WELL SITE

- ● POTENTIAL CONTAMINANT SOURCE -- LQG (EPA)
- ● POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)
- ⊙ POTENTIAL CONTAMINANT SOURCE -- (EPA)
- △ WATER SUPPLY WELL
- 🟥 2 YEAR CAPTURE ZONE
- 🟧 5 YEAR CAPTURE ZONE
- 🟨 10 YEAR CAPTURE ZONE
- 🟩 20 YEAR CAPTURE ZONE

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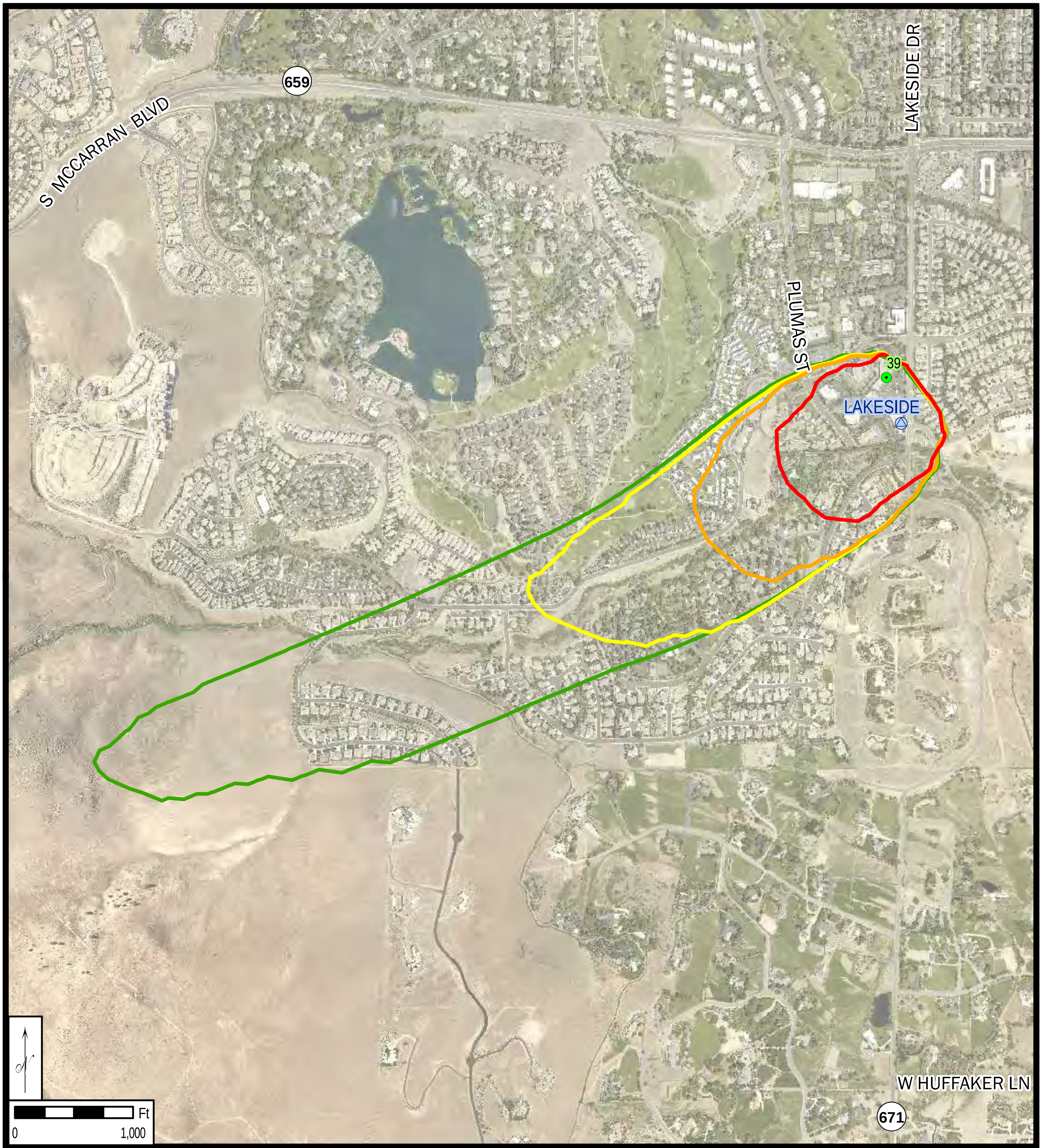

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (CENTRAL) (BASIN 87) -- FIGURE: 5

LAKESIDE WELL SITE

TMWA

- ● POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)
- WATER SUPPLY WELL

- 🟥 2 YEAR CAPTURE ZONE
- 🟧 5 YEAR CAPTURE ZONE
- 🟨 10 YEAR CAPTURE ZONE
- 🟩 20 YEAR CAPTURE ZONE

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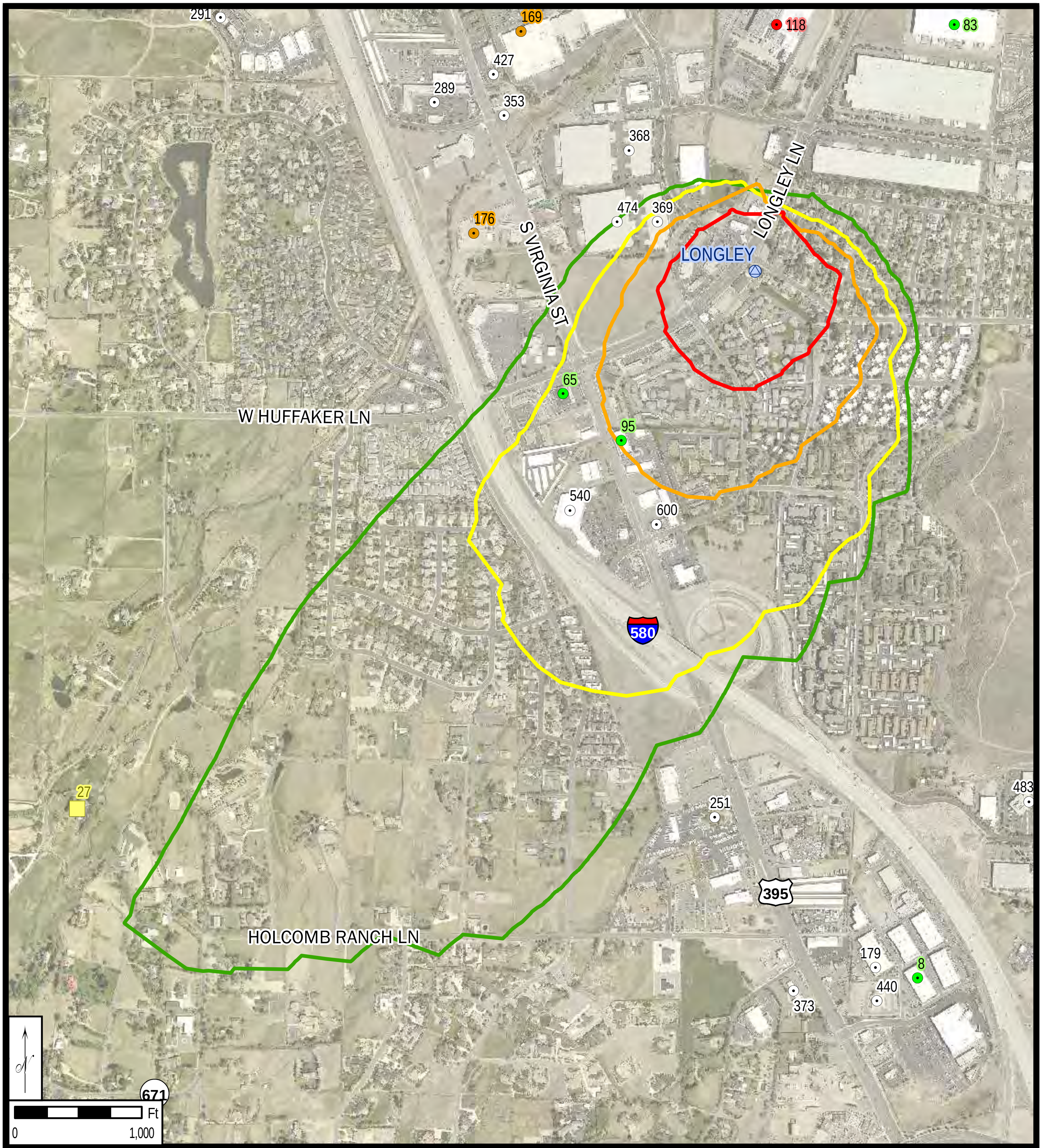

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (CENTRAL) (BASIN 87) -- FIGURE: 6

LONGLEY WELL SITE

●	POTENTIAL CONTAMINANT SOURCE -- LQG (EPA)	▭	2 YEAR CAPTURE ZONE
●	POTENTIAL CONTAMINANT SOURCE -- SQG (EPA)	▭	5 YEAR CAPTURE ZONE
●	POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)	▭	10 YEAR CAPTURE ZONE
⊙	POTENTIAL CONTAMINANT SOURCE -- (EPA)	▭	20 YEAR CAPTURE ZONE
△	WATER SUPPLY WELL	🟨	CONTAMINANT RELEASE SITE - INACTIVE (NDEP)

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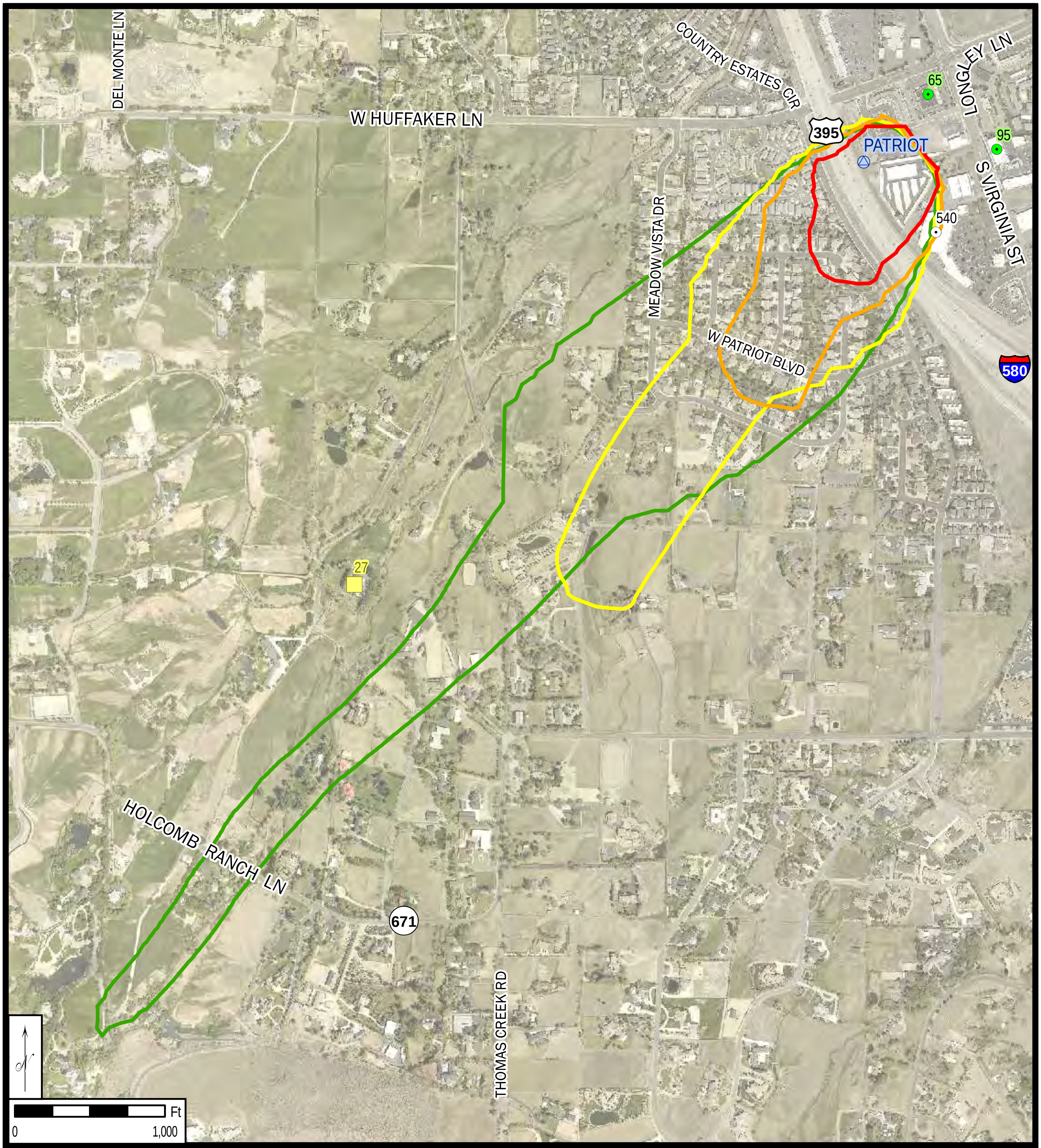

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (CENTRAL) (BASIN 87) -- FIGURE: 7

PATRIOT WELL SITE

TMWA

●	POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)	🟥	2 YEAR CAPTURE ZONE
⊙	POTENTIAL CONTAMINANT SOURCE -- (EPA)	🟧	5 YEAR CAPTURE ZONE
△	WATER SUPPLY WELL	🟨	10 YEAR CAPTURE ZONE
		🟩	20 YEAR CAPTURE ZONE
		🟨	CONTAMINANT RELEASE SITE - INACTIVE (NDEP)

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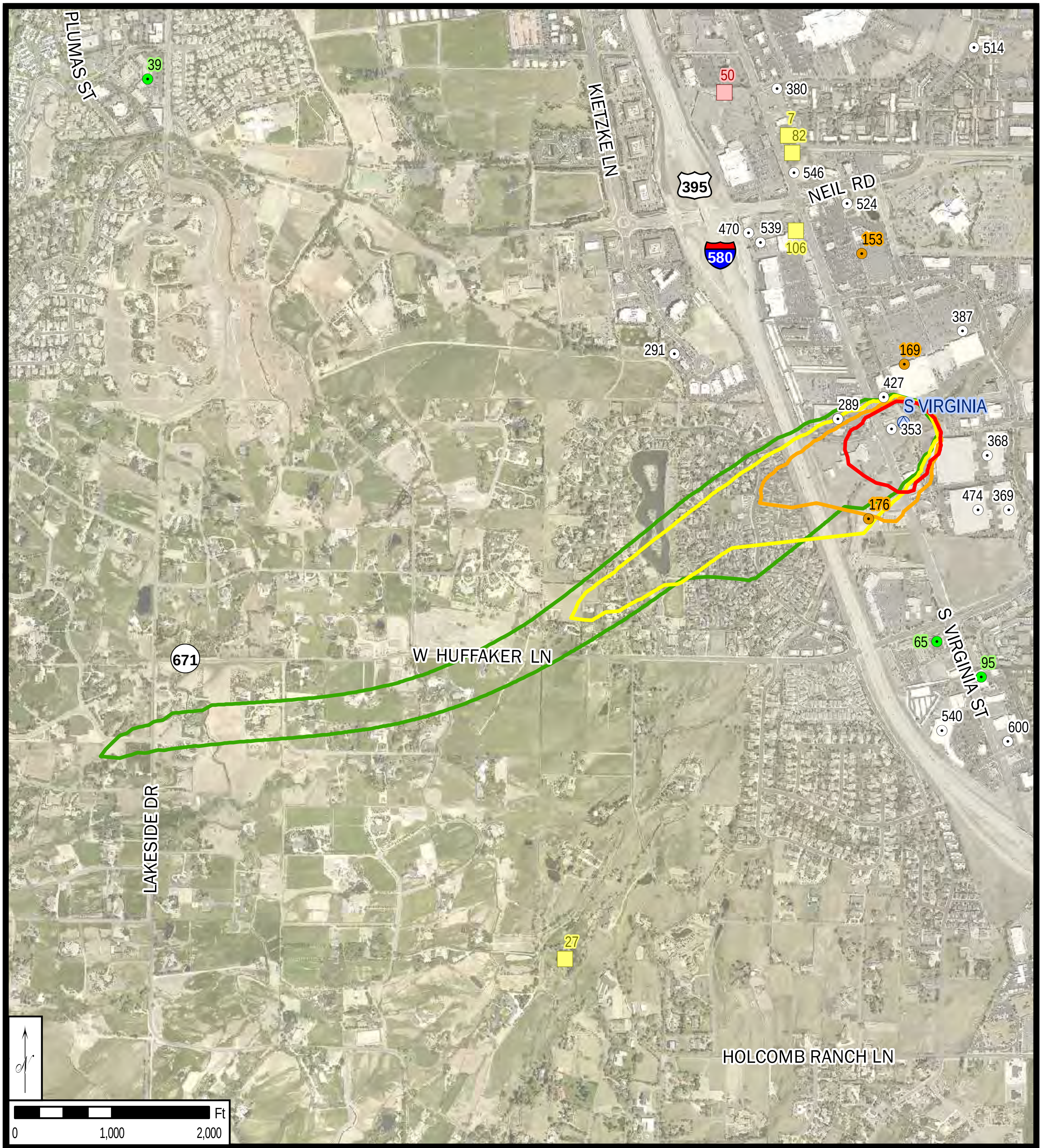

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (CENTRAL) (BASIN 87) -- FIGURE: 8

S VIRGINIA WELL SITE

● POTENTIAL CONTAMINANT SOURCE -- SQG (EPA)
● POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)
⊙ POTENTIAL CONTAMINANT SOURCE -- (EPA)
△ WATER SUPPLY WELL
■ CONTAMINANT RELEASE SITE - ACTIVE (NDEP)

▭ 2 YEAR CAPTURE ZONE
▭ 5 YEAR CAPTURE ZONE
▭ 10 YEAR CAPTURE ZONE
▭ 20 YEAR CAPTURE ZONE
■ CONTAMINANT RELEASE SITE - INACTIVE (NDEP)

TMWA

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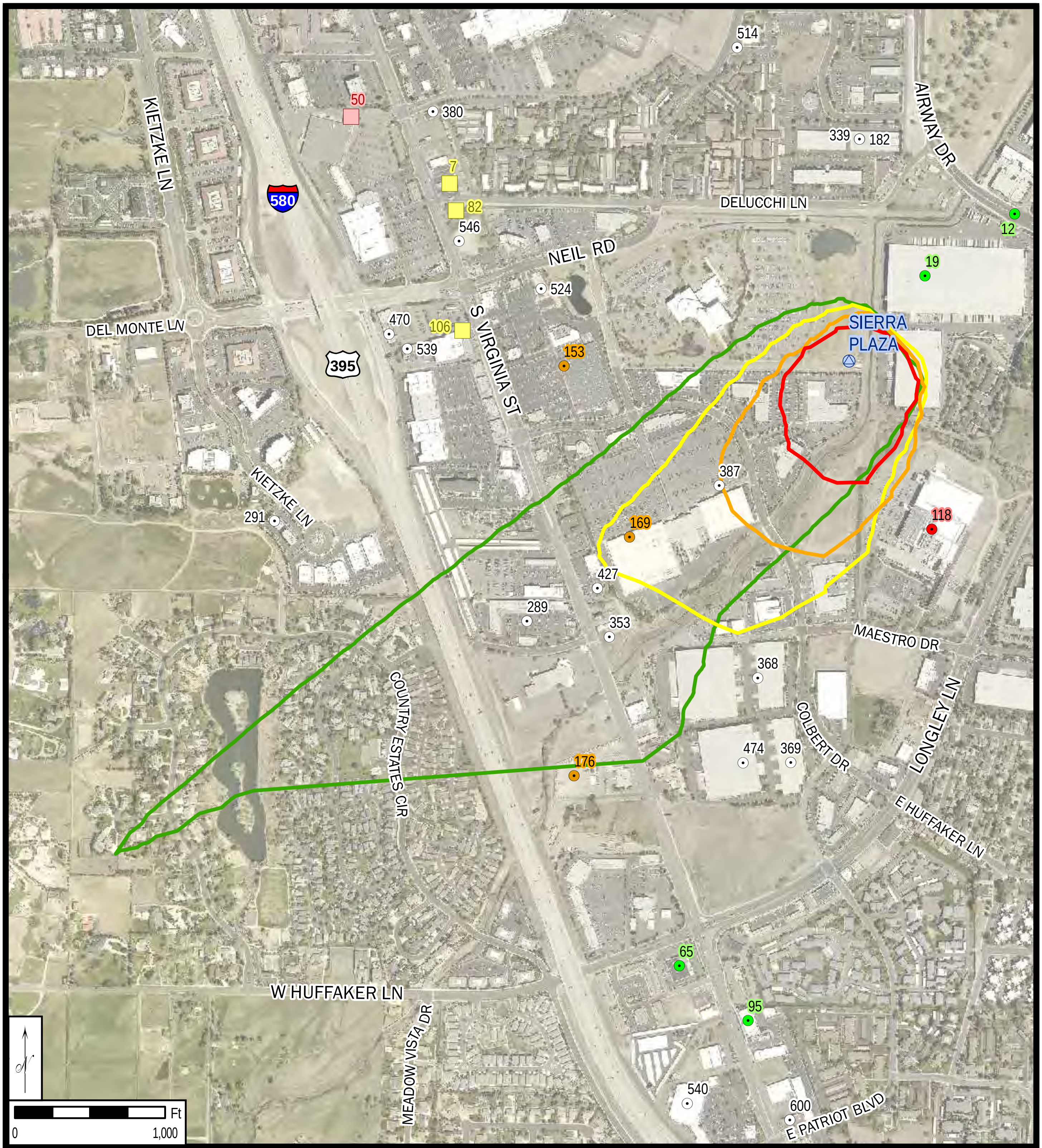

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (CENTRAL) (BASIN 87) -- FIGURE: 9

SIERRA PLAZA WELL SITE

● POTENTIAL CONTAMINANT SOURCE -- LQG (EPA)
● POTENTIAL CONTAMINANT SOURCE -- SQG (EPA)
● POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)
⊙ POTENTIAL CONTAMINANT SOURCE -- (EPA)
△ WATER SUPPLY WELL
🟥 CONTAMINANT RELEASE SITE - ACTIVE (NDEP)

▭ 2 YEAR CAPTURE ZONE
▭ 5 YEAR CAPTURE ZONE
▭ 10 YEAR CAPTURE ZONE
▭ 20 YEAR CAPTURE ZONE
🟨 CONTAMINANT RELEASE SITE - INACTIVE (NDEP)

TMWA

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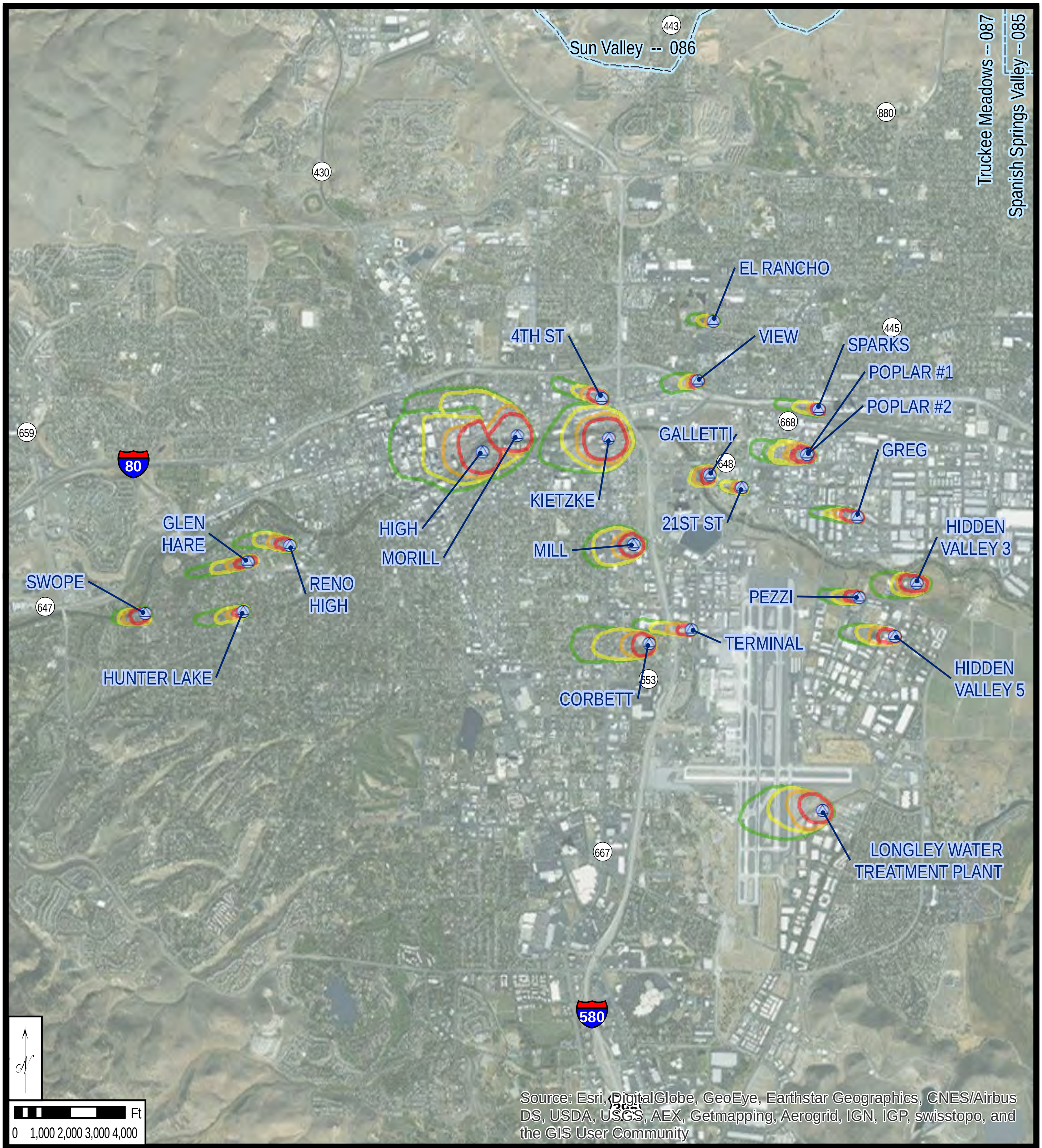

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WELLHEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) AREA INDEX

△ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE

🟧 5 YEAR CAPTURE ZONE

🟨 10 YEAR CAPTURE ZONE

🟩 20 YEAR CAPTURE ZONE

▭ NEVADA HYDROBASIN BOUNDARY

TMWA

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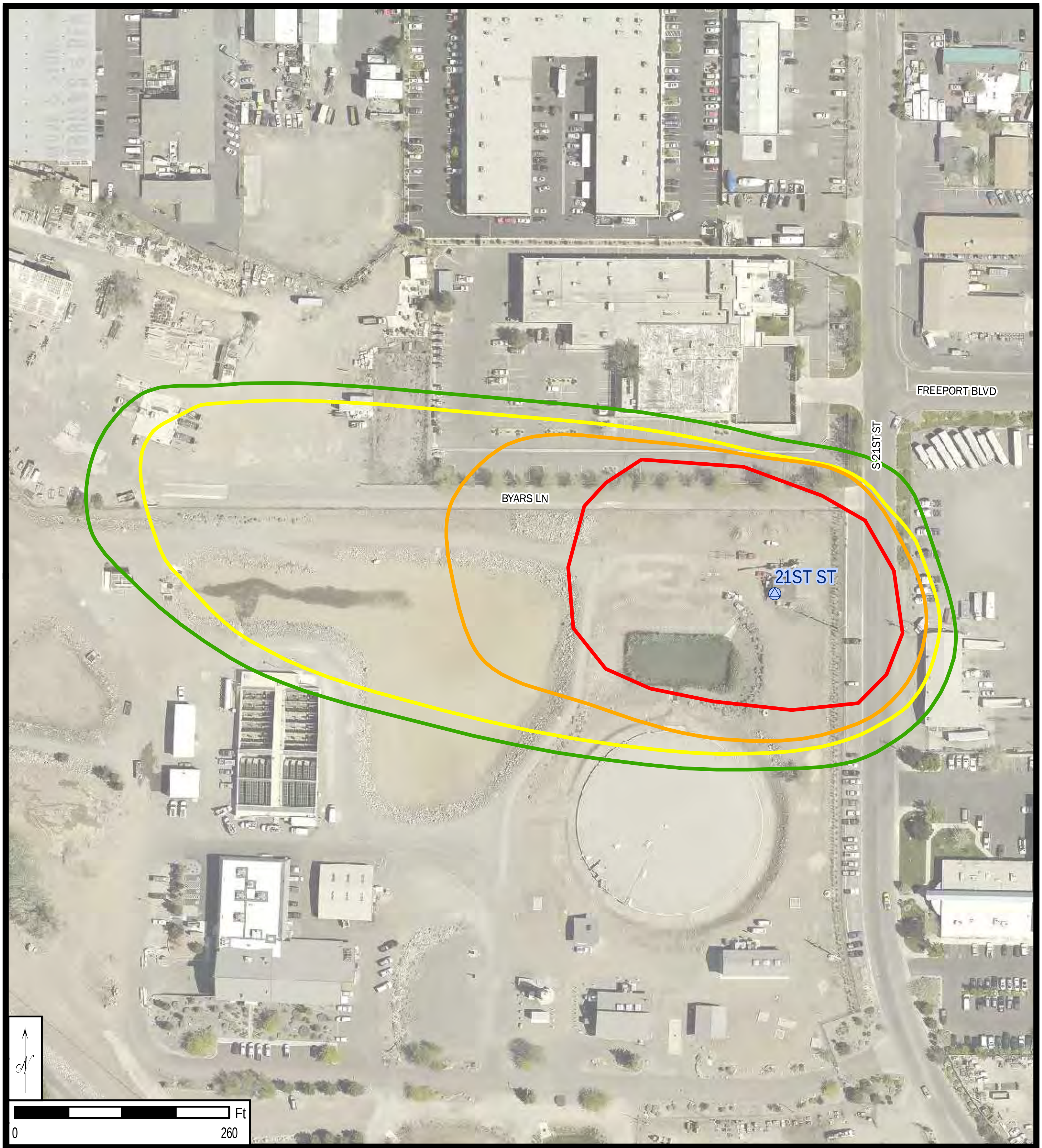

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 1

21ST ST WELL SITE

TMWA

- ◬ WATER SUPPLY WELL
- 🟥 2 YEAR CAPTURE ZONE
- 🟧 5 YEAR CAPTURE ZONE
- 🟨 10 YEAR CAPTURE ZONE
- 🟩 20 YEAR CAPTURE ZONE

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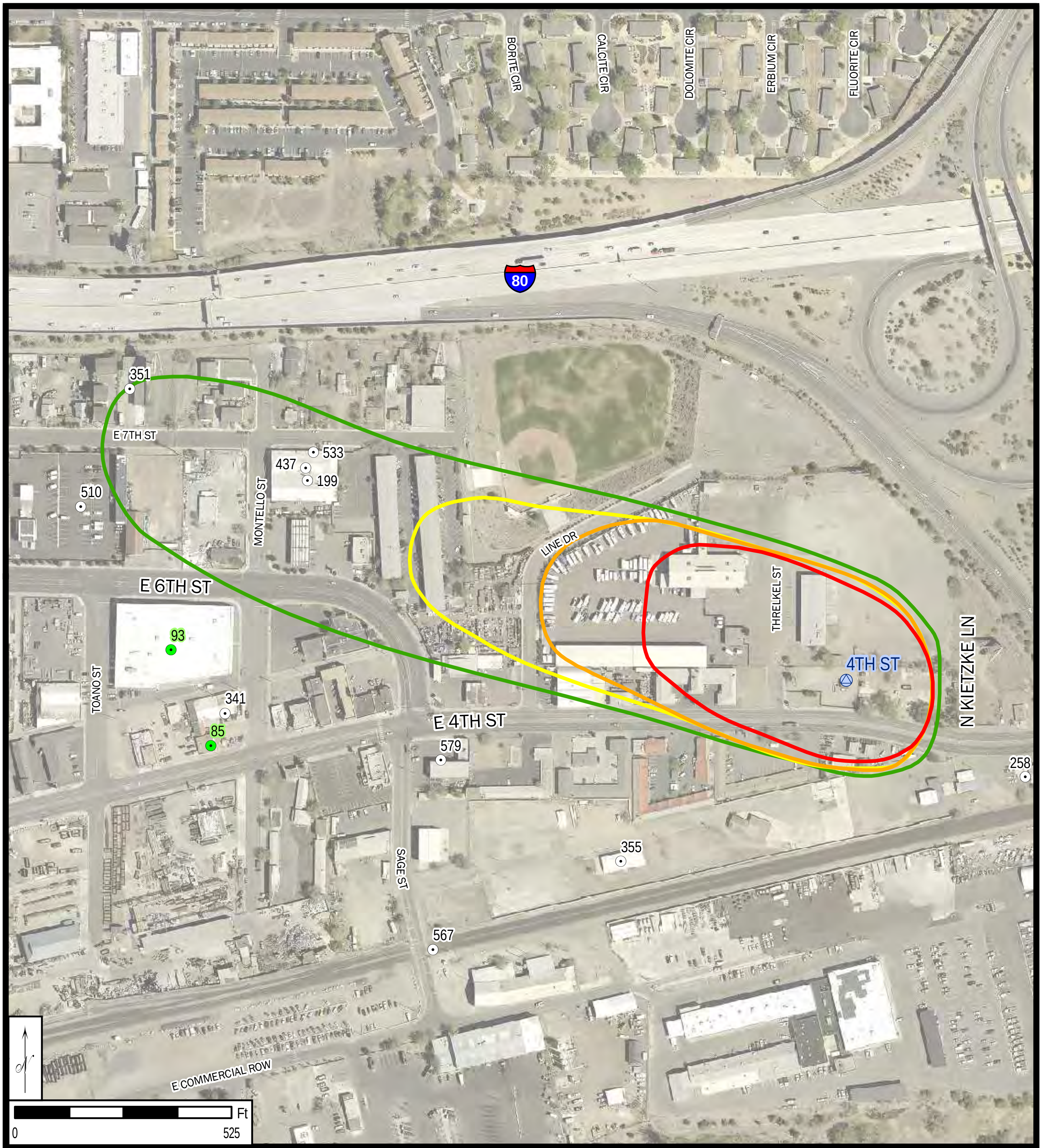

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 2

4TH ST WELL SITE

TMWA

● POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)
⊙ POTENTIAL CONTAMINANT SOURCE -- (EPA)
△ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE
🟧 5 YEAR CAPTURE ZONE
🟨 10 YEAR CAPTURE ZONE
🟩 20 YEAR CAPTURE ZONE

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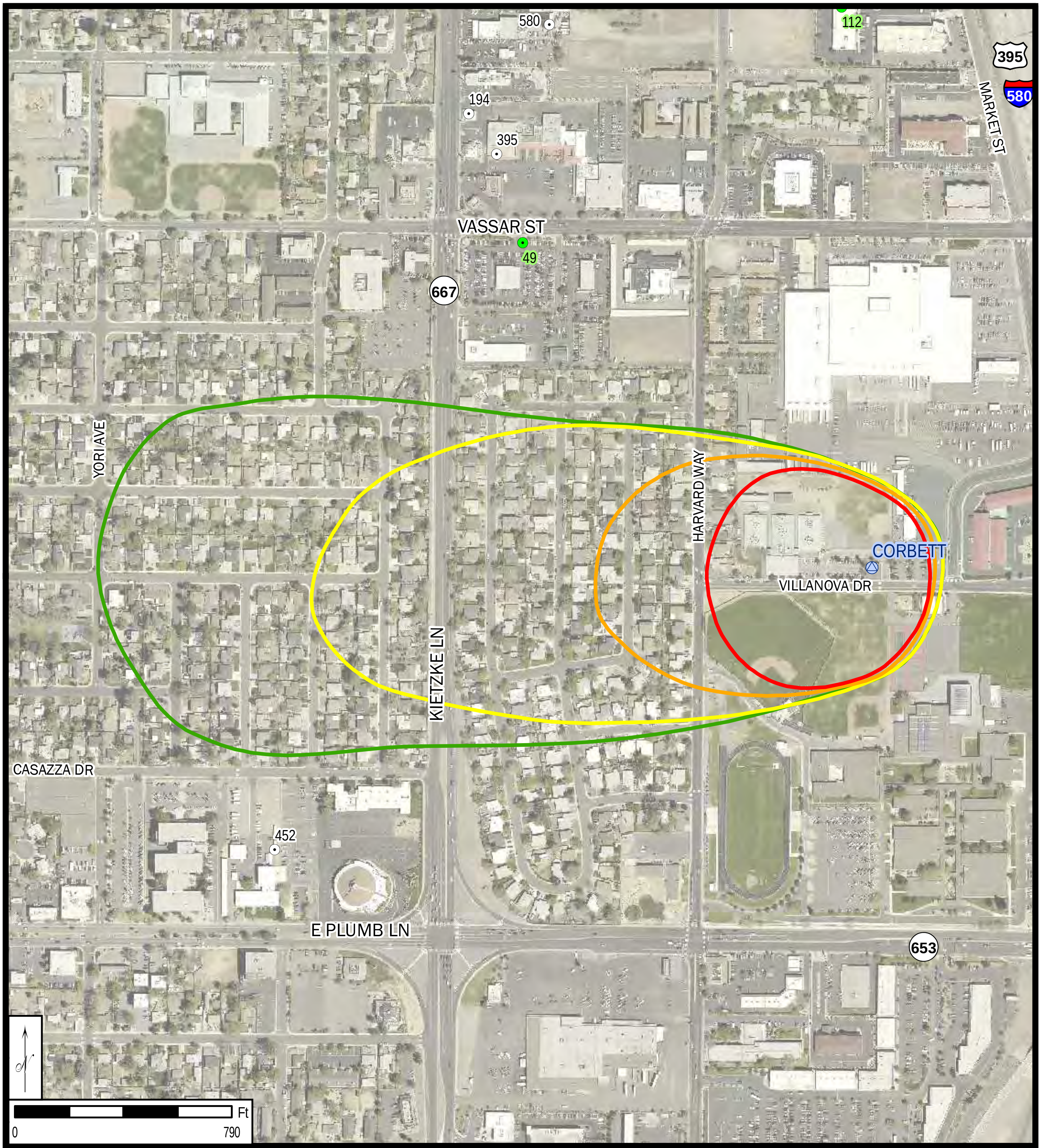

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 3

CORBETT WELL SITE

● POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)

⊙ POTENTIAL CONTAMINANT SOURCE -- (EPA)

△ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE

🟧 5 YEAR CAPTURE ZONE

🟨 10 YEAR CAPTURE ZONE

🟩 20 YEAR CAPTURE ZONE

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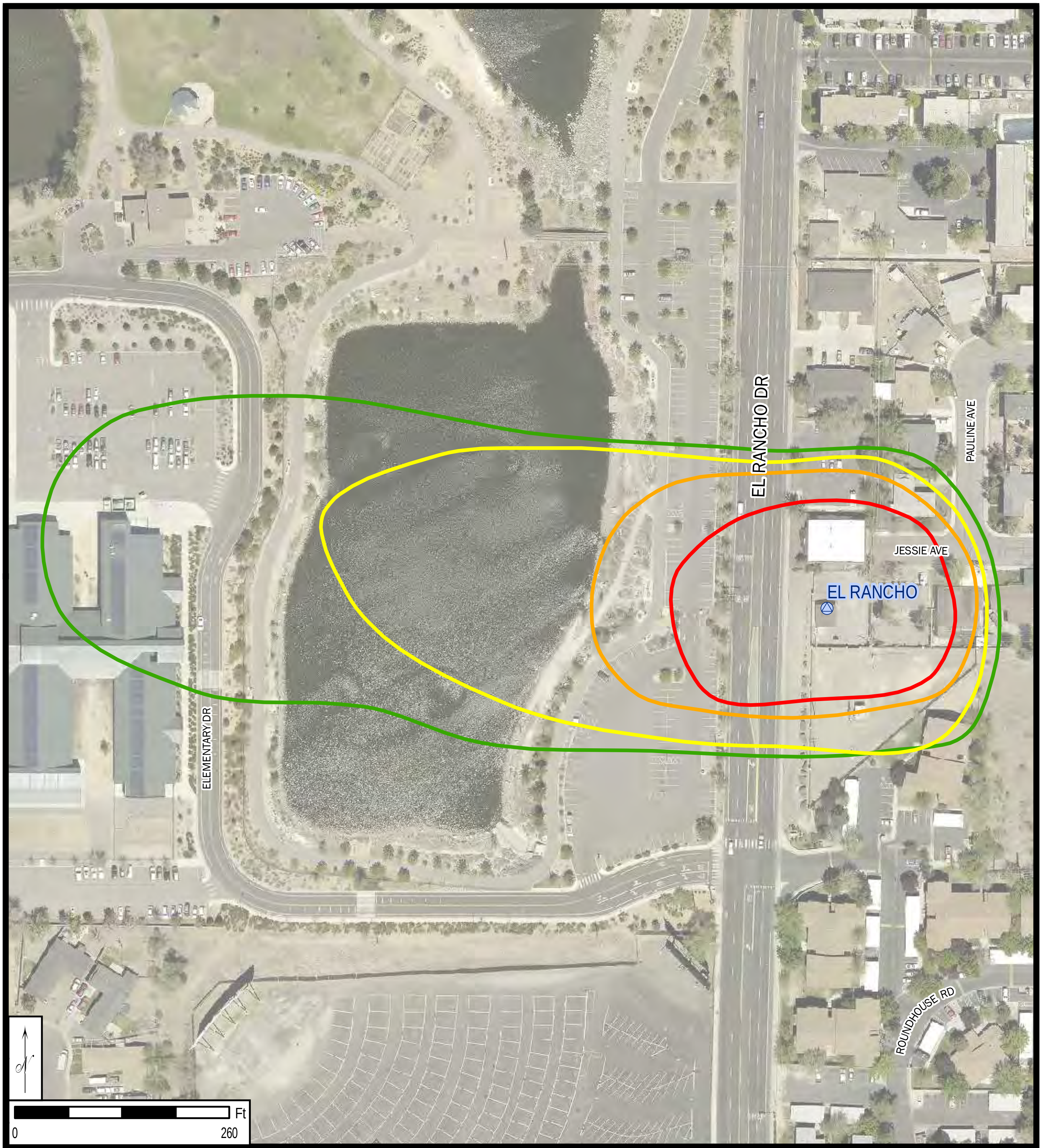

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 4

EL RANCHO WELL SITE

TMWA

△ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE
🟧 5 YEAR CAPTURE ZONE
🟨 10 YEAR CAPTURE ZONE
🟩 20 YEAR CAPTURE ZONE

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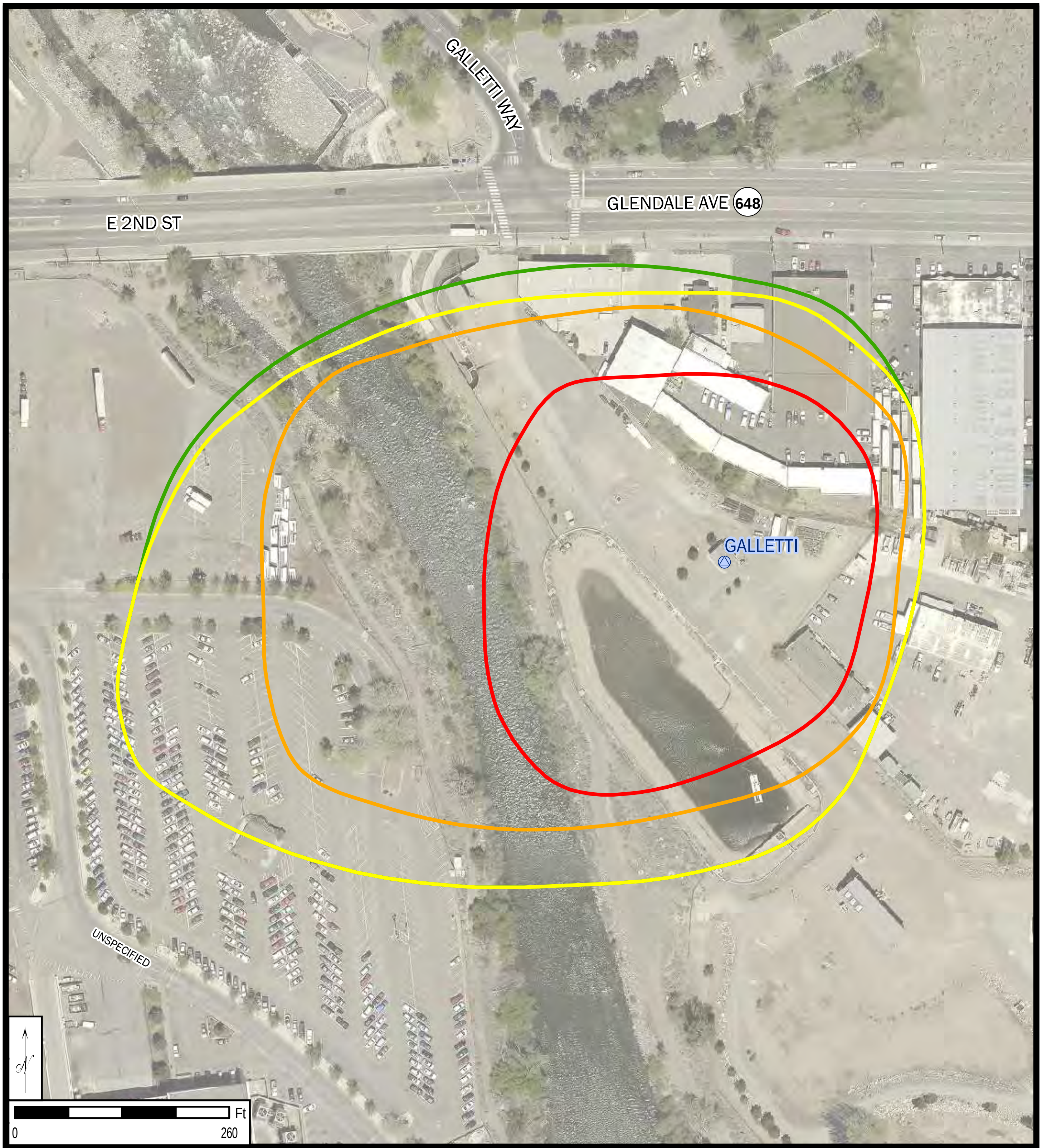

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 5

GALLETTI WELL SITE

TMWA

△ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE
🟧 5 YEAR CAPTURE ZONE
🟨 10 YEAR CAPTURE ZONE
🟩 20 YEAR CAPTURE ZONE

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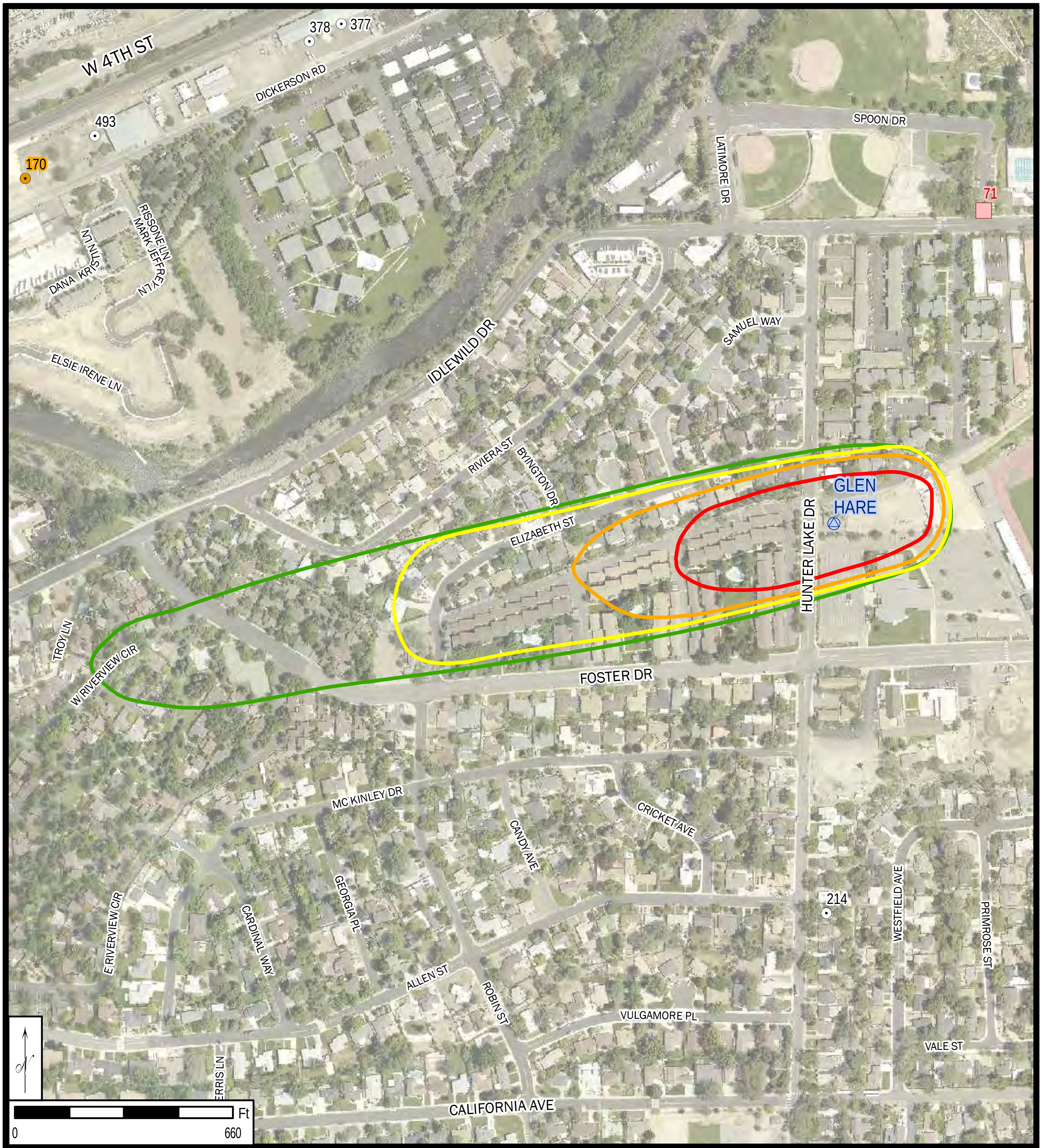

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 6

GLEN HARE WELL SITE

TMWA

●	POTENTIAL CONTAMINANT SOURCE -- SQG (EPA)	🟥	2 YEAR CAPTURE ZONE
⊙	POTENTIAL CONTAMINANT SOURCE -- (EPA)	🟧	5 YEAR CAPTURE ZONE
△	WATER SUPPLY WELL	🟨	10 YEAR CAPTURE ZONE
■	CONTAMINANT RELEASE SITE - ACTIVE (NDEP)	🟩	20 YEAR CAPTURE ZONE

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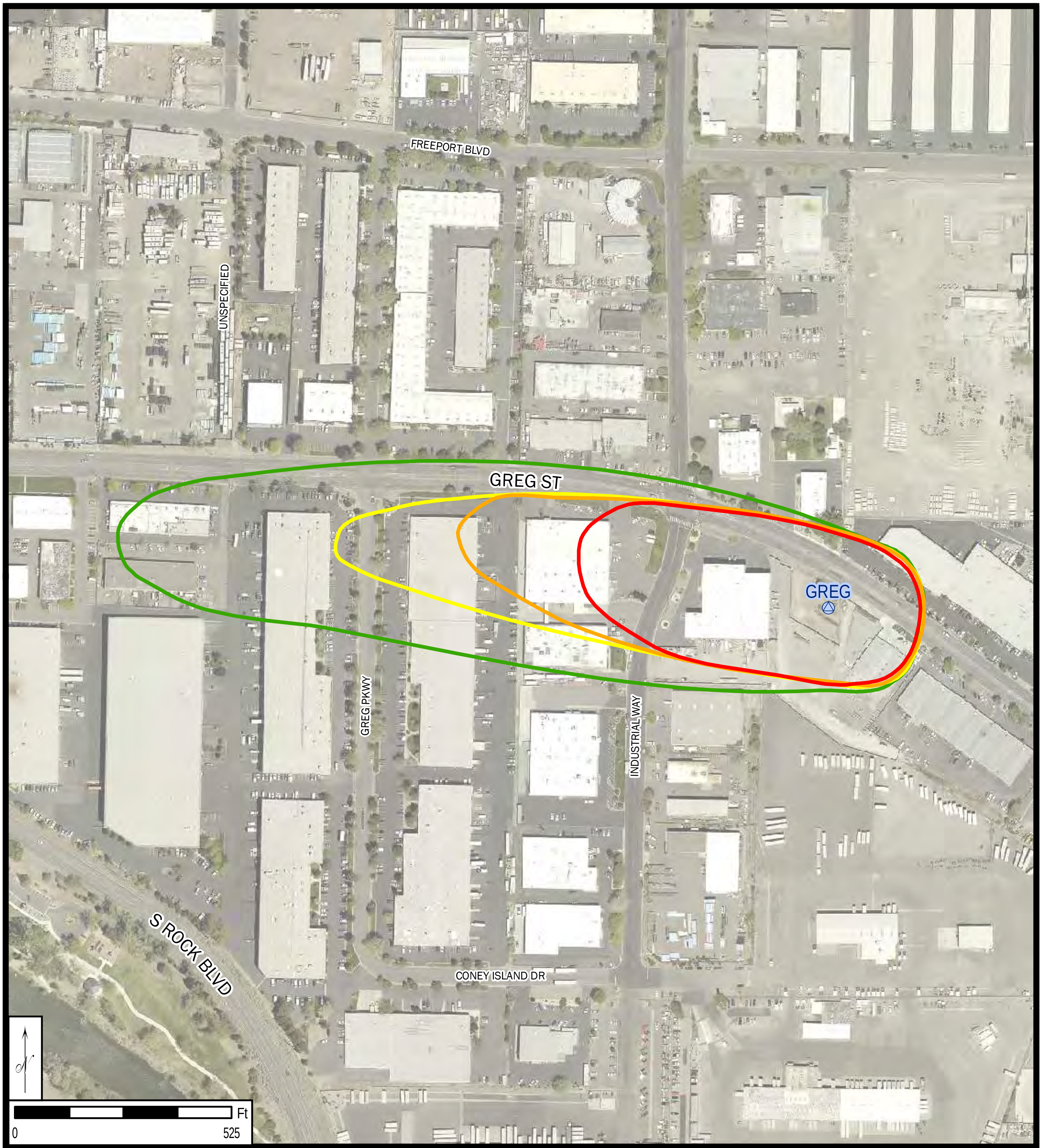

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 7

GREG WELL SITE

△ WATER SUPPLY WELL

- 🟥 2 YEAR CAPTURE ZONE
- 🟧 5 YEAR CAPTURE ZONE
- 🟨 10 YEAR CAPTURE ZONE
- 🟩 20 YEAR CAPTURE ZONE

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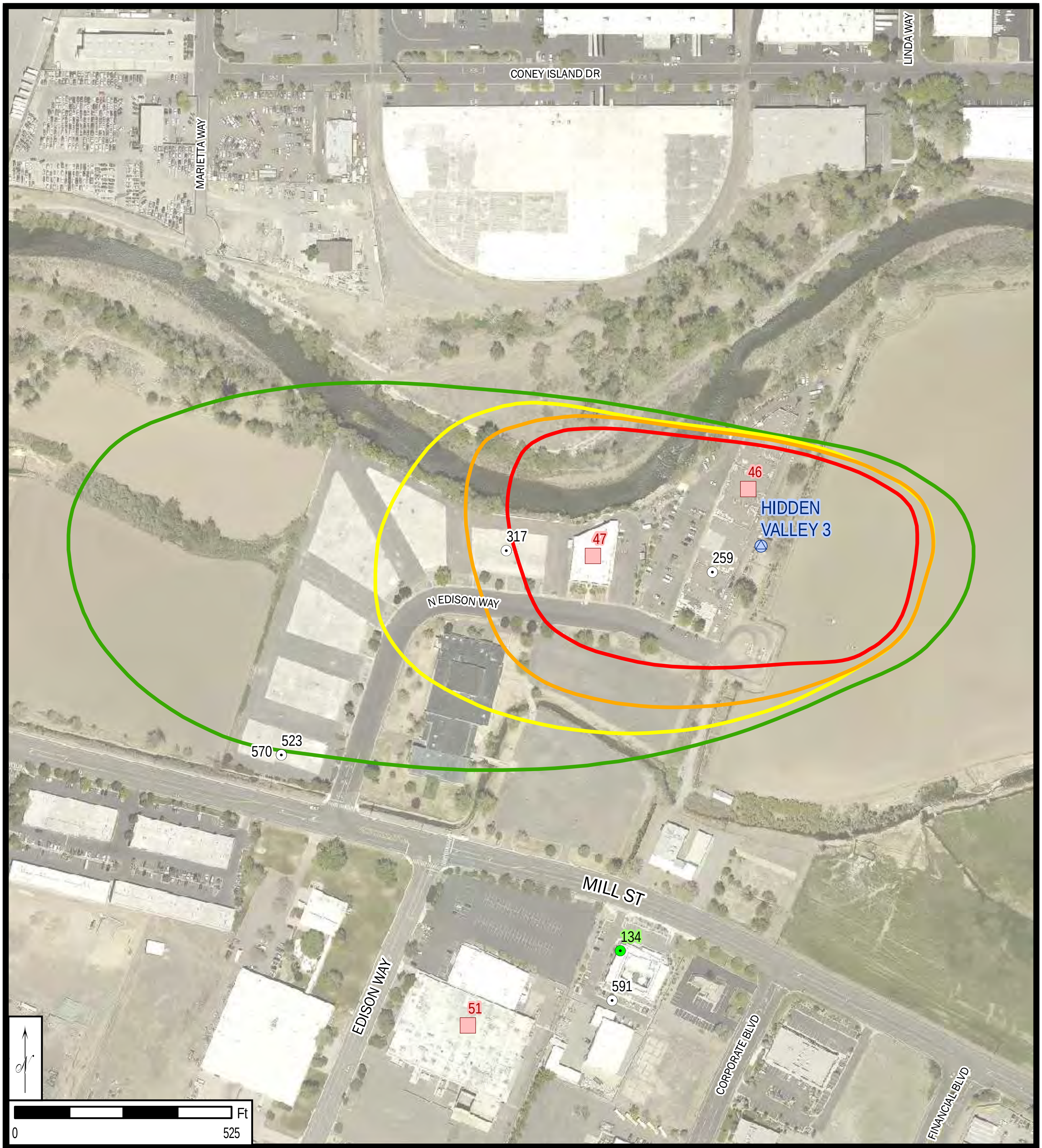

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 8

HIDDEN VALLEY 3 WELL SITE

TMWA

● POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)
⊙ POTENTIAL CONTAMINANT SOURCE -- (EPA)
△ WATER SUPPLY WELL
🟥 CONTAMINANT RELEASE SITE - ACTIVE (NDEP)

🟥 2 YEAR CAPTURE ZONE
🟧 5 YEAR CAPTURE ZONE
🟨 10 YEAR CAPTURE ZONE
🟩 20 YEAR CAPTURE ZONE

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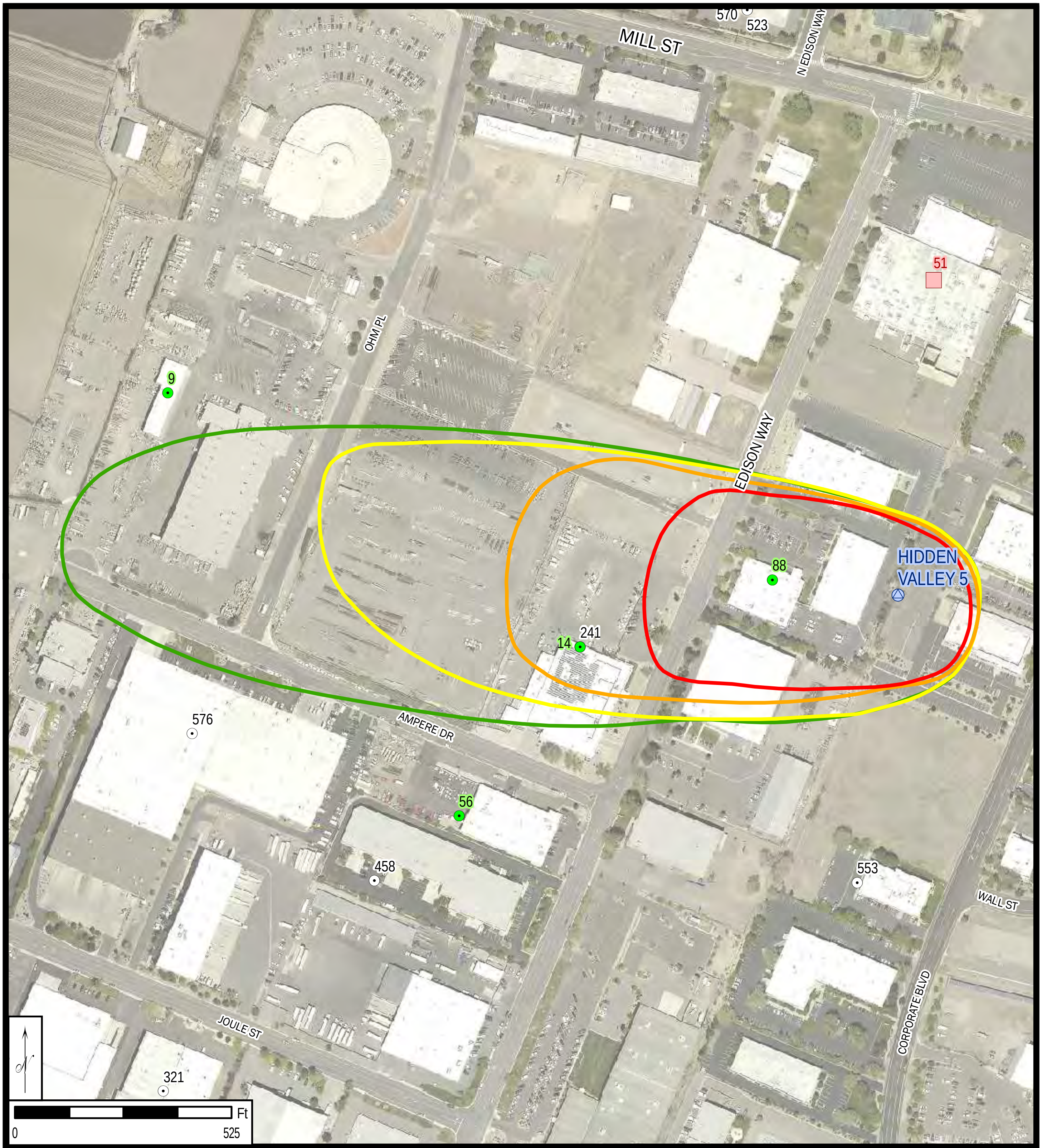

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 9

HIDDEN VALLEY 5 WELL SITE

- ● POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)
- ⊙ POTENTIAL CONTAMINANT SOURCE -- (EPA)
- △ WATER SUPPLY WELL
- ■ CONTAMINANT RELEASE SITE - ACTIVE (NDEP)

- 🟥 2 YEAR CAPTURE ZONE
- 🟧 5 YEAR CAPTURE ZONE
- 🟨 10 YEAR CAPTURE ZONE
- 🟩 20 YEAR CAPTURE ZONE

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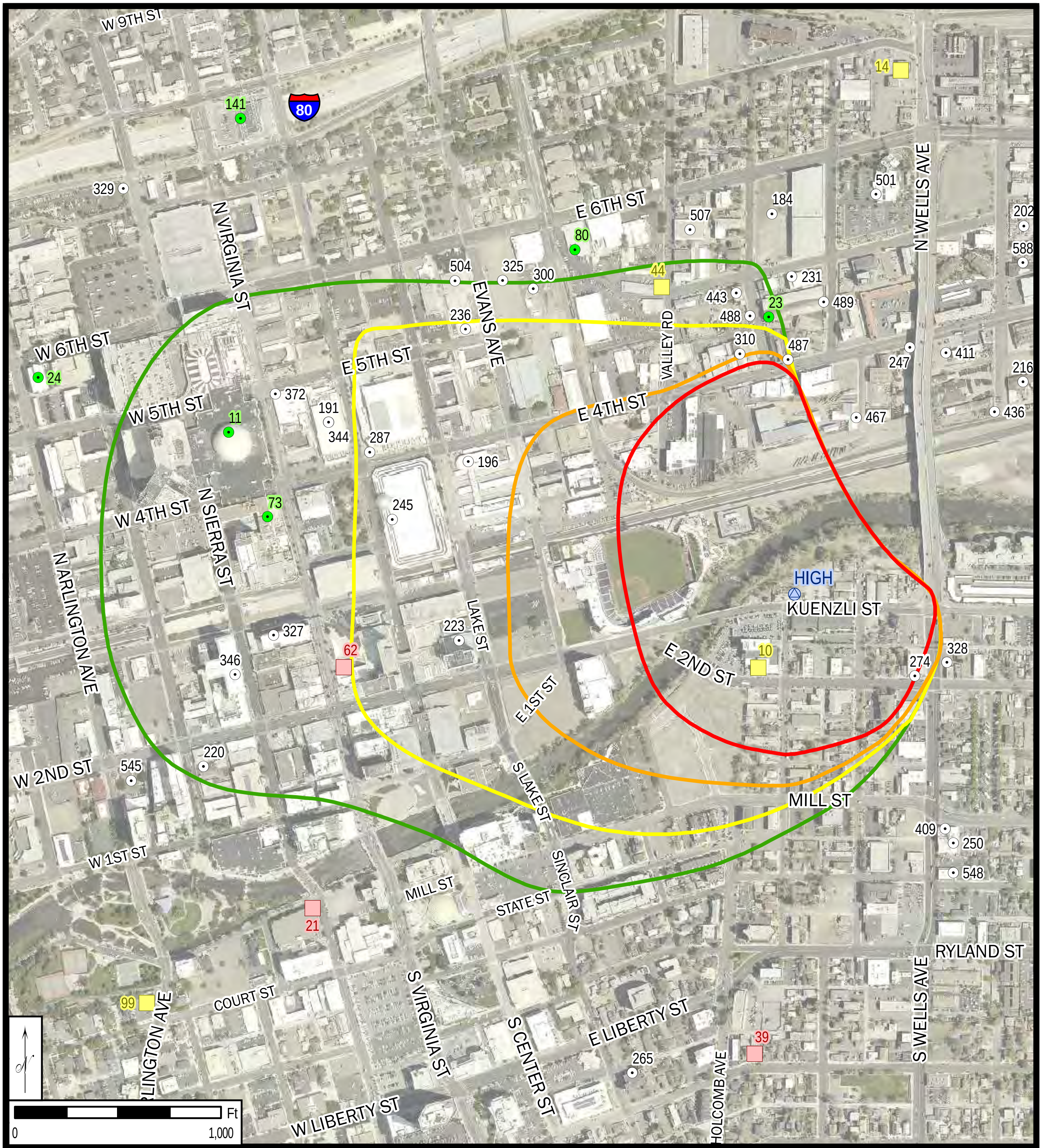

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 10

HIGH WELL SITE

●	POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)	🟥	2 YEAR CAPTURE ZONE
⊙	POTENTIAL CONTAMINANT SOURCE -- (EPA)	🟧	5 YEAR CAPTURE ZONE
△	WATER SUPPLY WELL	🟨	10 YEAR CAPTURE ZONE
■	CONTAMINANT RELEASE SITE - ACTIVE (NDEP)	🟩	20 YEAR CAPTURE ZONE
		■	CONTAMINANT RELEASE SITE - INACTIVE (NDEP)

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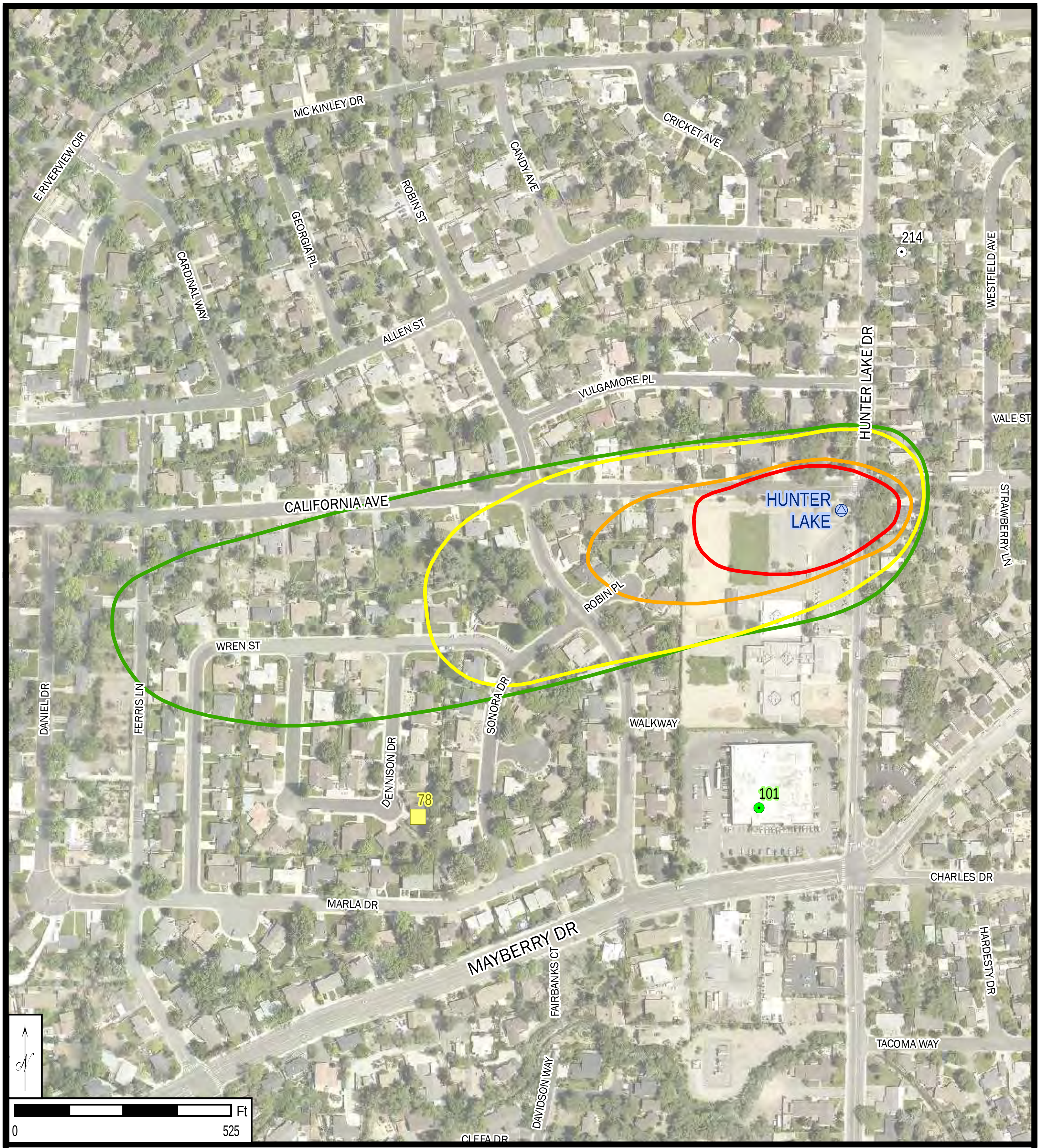

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 11

HUNTER LAKE WELL SITE

●	POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)	▭	2 YEAR CAPTURE ZONE
⊙	POTENTIAL CONTAMINANT SOURCE -- (EPA)	▭	5 YEAR CAPTURE ZONE
△	WATER SUPPLY WELL	▭	10 YEAR CAPTURE ZONE
		▭	20 YEAR CAPTURE ZONE
		■	CONTAMINANT RELEASE SITE - INACTIVE (NDEP)

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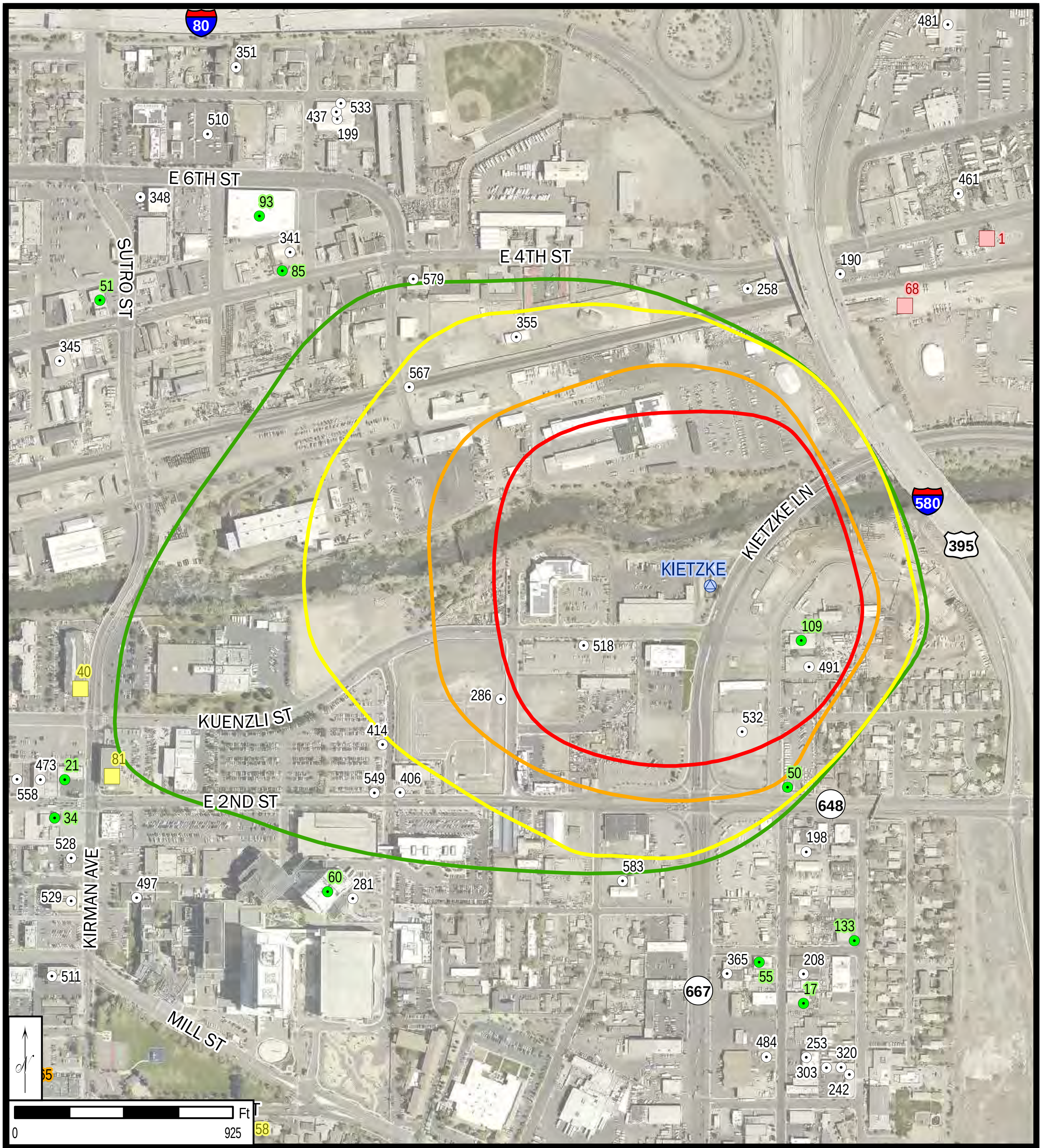

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 12

KIETZKE WELL SITE

● POTENTIAL CONTAMINANT SOURCE -- SQG (EPA)
● POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)
⊙ POTENTIAL CONTAMINANT SOURCE -- (EPA)
△ WATER SUPPLY WELL
🟥 CONTAMINANT RELEASE SITE - ACTIVE (NDEP)

▢ 2 YEAR CAPTURE ZONE
▢ 5 YEAR CAPTURE ZONE
▢ 10 YEAR CAPTURE ZONE
▢ 20 YEAR CAPTURE ZONE
🟨 CONTAMINANT RELEASE SITE - INACTIVE (NDEP)

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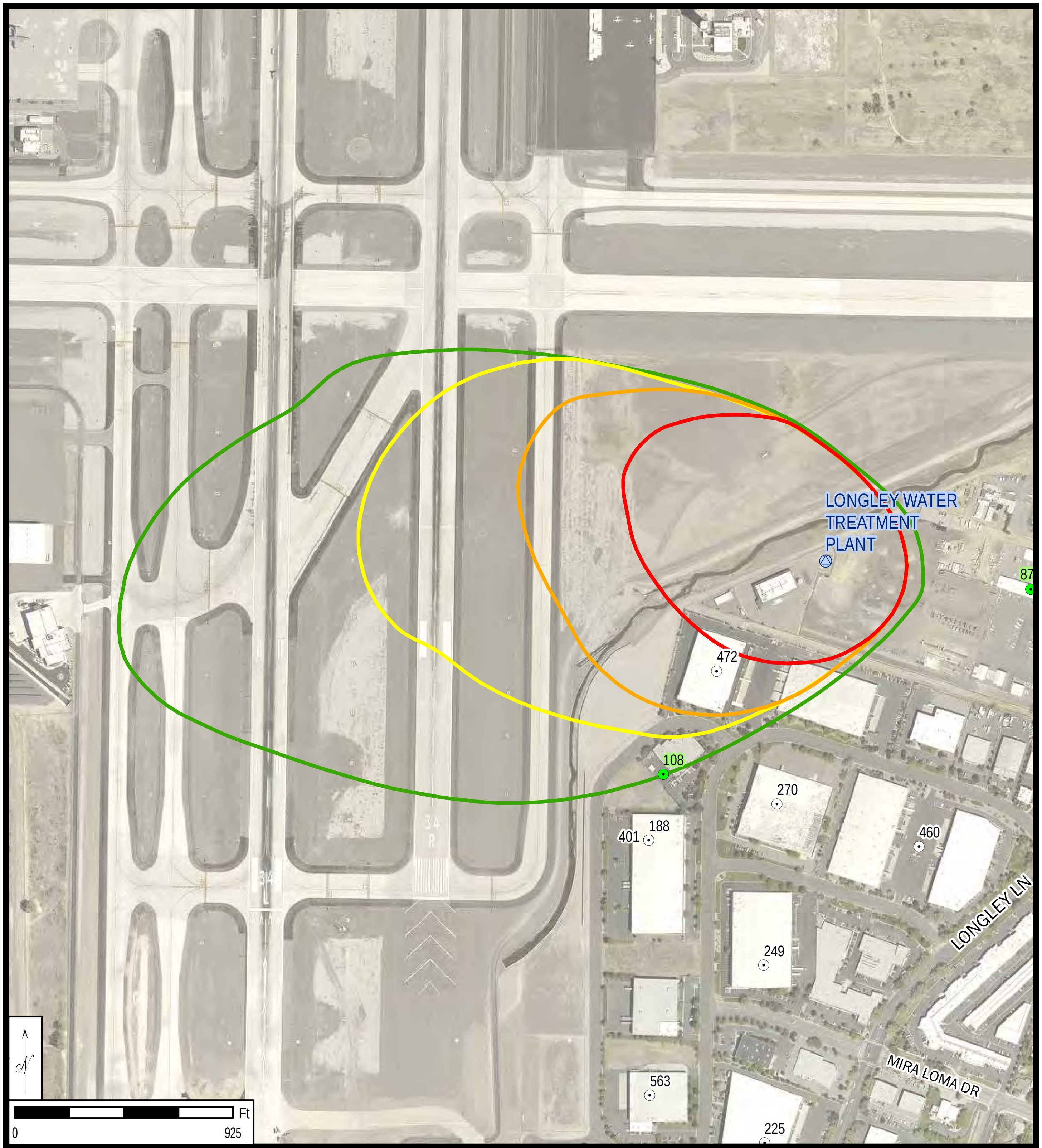

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 13

LONGLEY WATER TREATMENT PLANT WELL SITE

●	POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)	🟥	2 YEAR CAPTURE ZONE
⊙	POTENTIAL CONTAMINANT SOURCE -- (EPA)	🟧	5 YEAR CAPTURE ZONE
△	WATER SUPPLY WELL	🟨	10 YEAR CAPTURE ZONE
		🟩	20 YEAR CAPTURE ZONE

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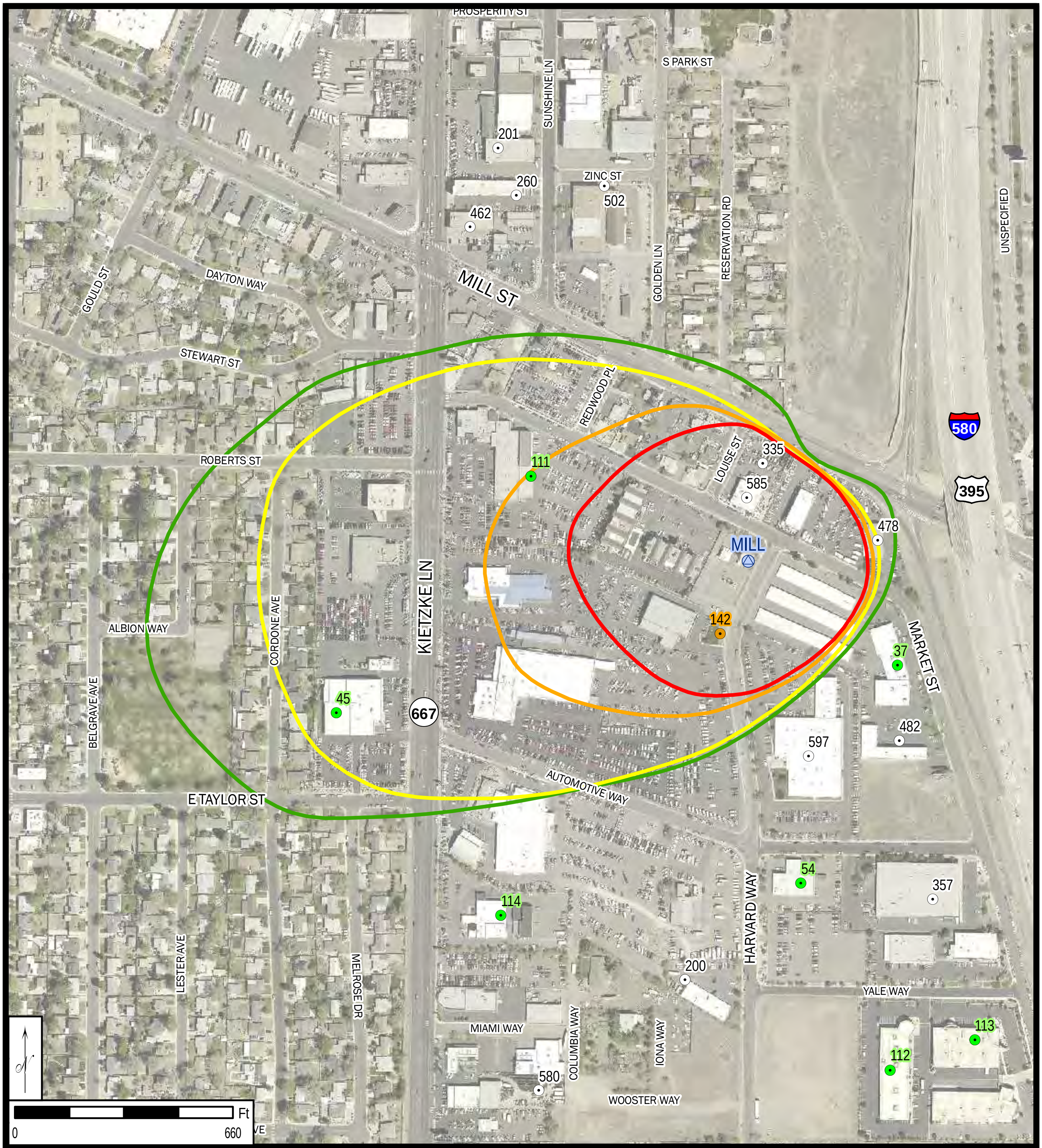

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 14

MILL WELL SITE

●	POTENTIAL CONTAMINANT SOURCE -- SQG (EPA)	🟥	2 YEAR CAPTURE ZONE
🟢	POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)	🟧	5 YEAR CAPTURE ZONE
⊙	POTENTIAL CONTAMINANT SOURCE -- (EPA)	🟨	10 YEAR CAPTURE ZONE
△	WATER SUPPLY WELL	🟩	20 YEAR CAPTURE ZONE

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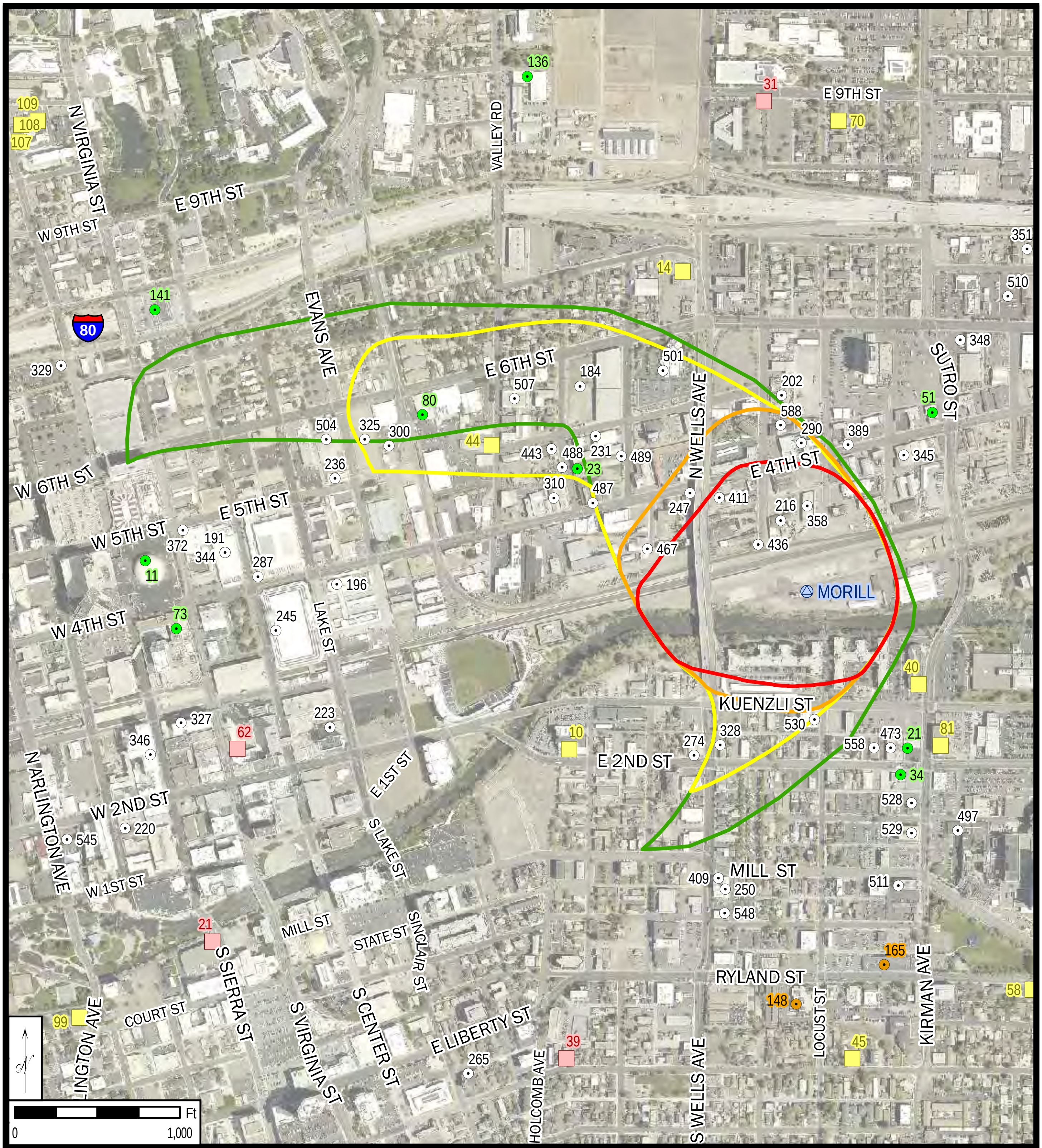

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 15

MORILL WELL SITE

TMWA

- ● POTENTIAL CONTAMINANT SOURCE -- SQG (EPA)
- ● POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)
- ⊙ POTENTIAL CONTAMINANT SOURCE -- (EPA)
- △ WATER SUPPLY WELL
- 🟥 CONTAMINANT RELEASE SITE - ACTIVE (NDEP)
- ▭ 2 YEAR CAPTURE ZONE
- ▭ 5 YEAR CAPTURE ZONE
- ▭ 10 YEAR CAPTURE ZONE
- ▭ 20 YEAR CAPTURE ZONE
- 🟨 CONTAMINANT RELEASE SITE - INACTIVE (NDEP)

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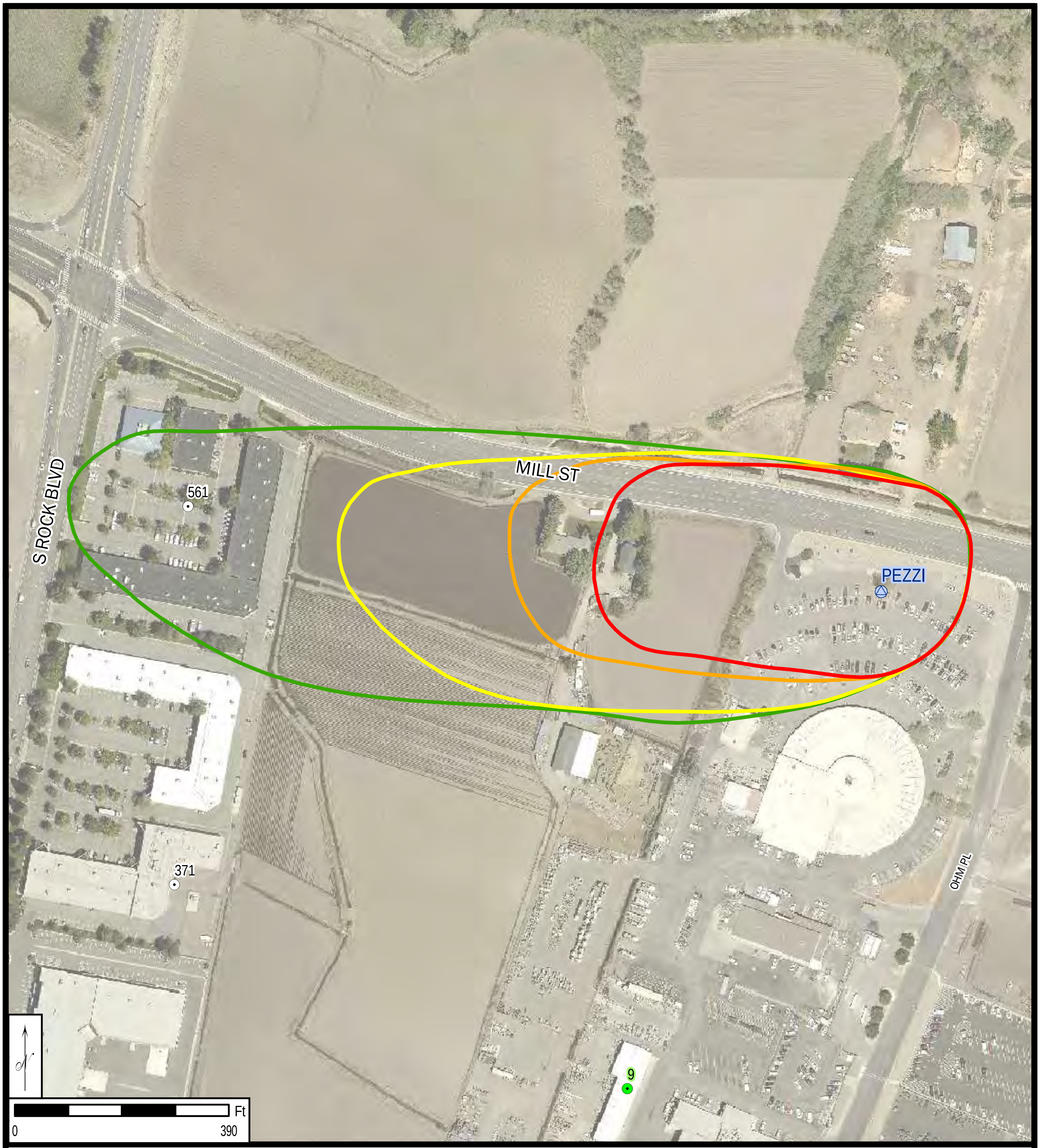

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 16

PEZZI WELL SITE

●	POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)
⊙	POTENTIAL CONTAMINANT SOURCE -- (EPA)
△	WATER SUPPLY WELL
🟥	2 YEAR CAPTURE ZONE
🟧	5 YEAR CAPTURE ZONE
🟨	10 YEAR CAPTURE ZONE
🟩	20 YEAR CAPTURE ZONE

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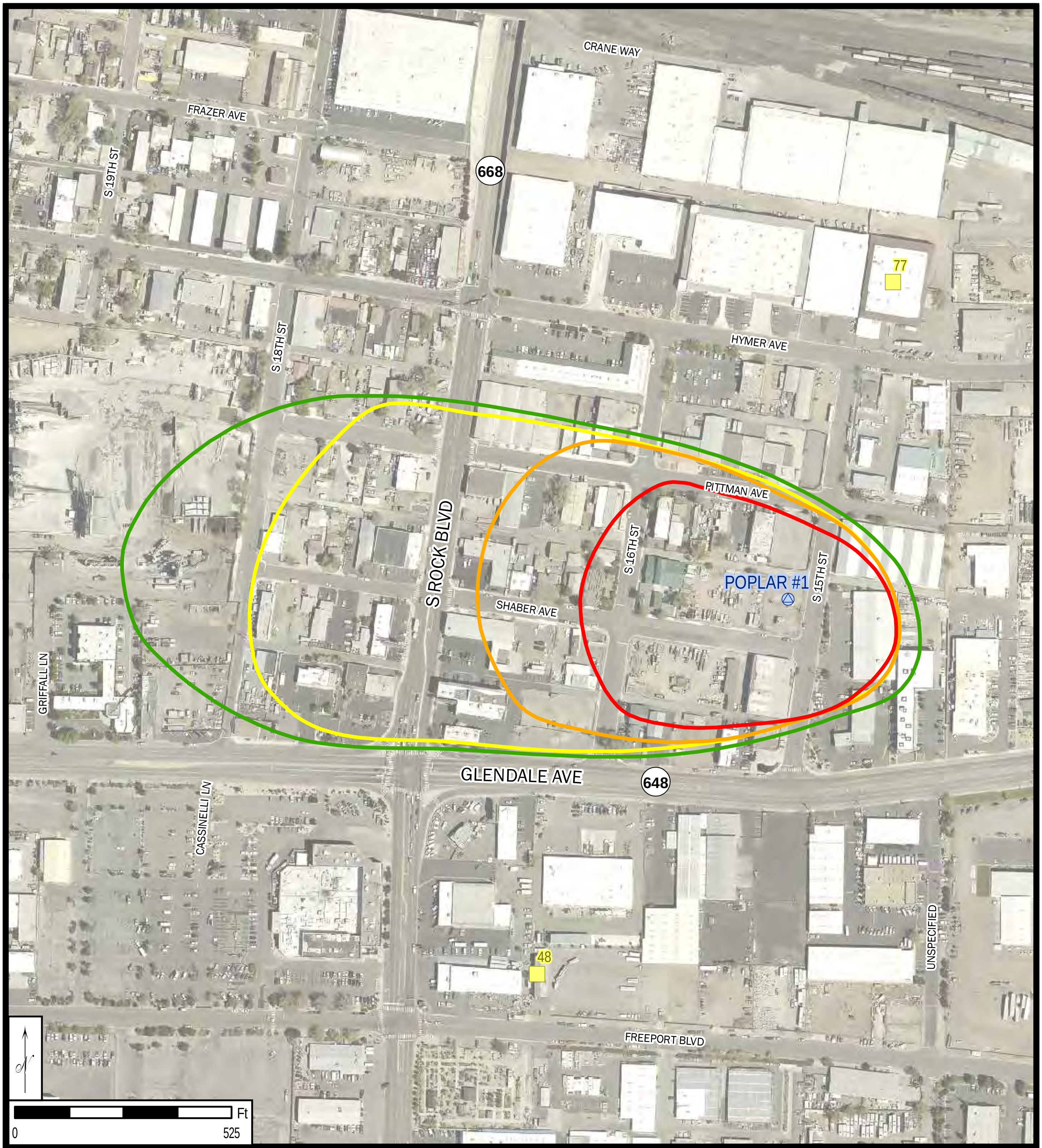

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 17

POPLAR #1 WELL SITE

- △ WATER SUPPLY WELL
- 🟥 CONTAMINANT RELEASE SITE - ACTIVE (NDEP)
- 🟥 2 YEAR CAPTURE ZONE
- 🟧 5 YEAR CAPTURE ZONE
- 🟨 10 YEAR CAPTURE ZONE
- 🟩 20 YEAR CAPTURE ZONE
- 🟨 CONTAMINANT RELEASE SITE - INACTIVE (NDEP)

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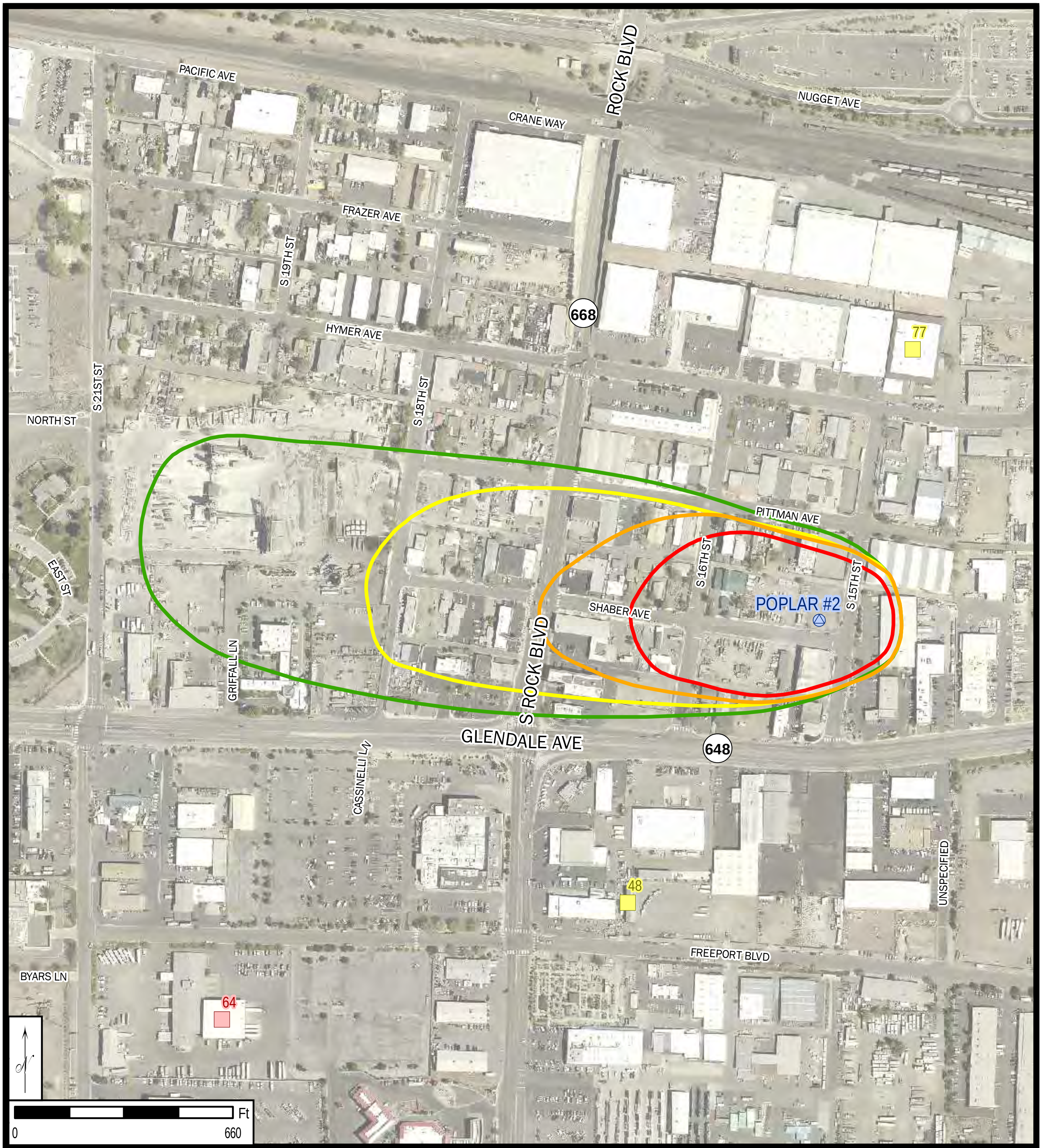

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 18

POPLAR #2 WELL SITE

△	WATER SUPPLY WELL	🟥	2 YEAR CAPTURE ZONE
🟥	CONTAMINANT RELEASE SITE - ACTIVE (NDEP)	🟧	5 YEAR CAPTURE ZONE
		🟨	10 YEAR CAPTURE ZONE
		🟩	20 YEAR CAPTURE ZONE
		🟨	CONTAMINANT RELEASE SITE - INACTIVE (NDEP)

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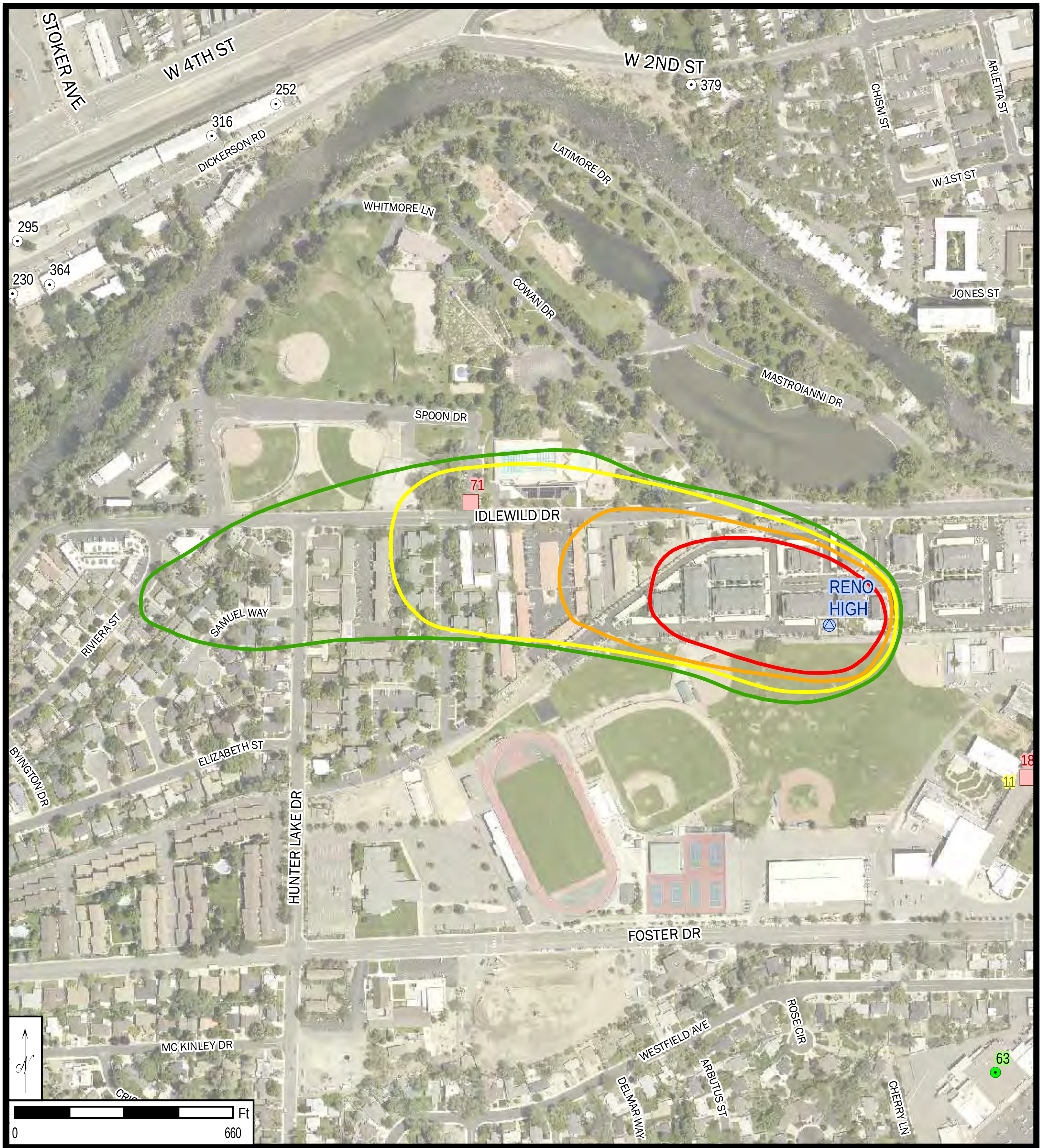

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 19

RENO HIGH WELL SITE

- ● POTENTIAL CONTAMINANT SOURCE -- SQG (EPA)
- ● POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)
- ⊙ POTENTIAL CONTAMINANT SOURCE -- (EPA)
- △ WATER SUPPLY WELL
- 🟥 CONTAMINANT RELEASE SITE - ACTIVE (NDEP)
- ▭ 2 YEAR CAPTURE ZONE
- ▭ 5 YEAR CAPTURE ZONE
- ▭ 10 YEAR CAPTURE ZONE
- ▭ 20 YEAR CAPTURE ZONE
- 🟨 CONTAMINANT RELEASE SITE - INACTIVE (NDEP)

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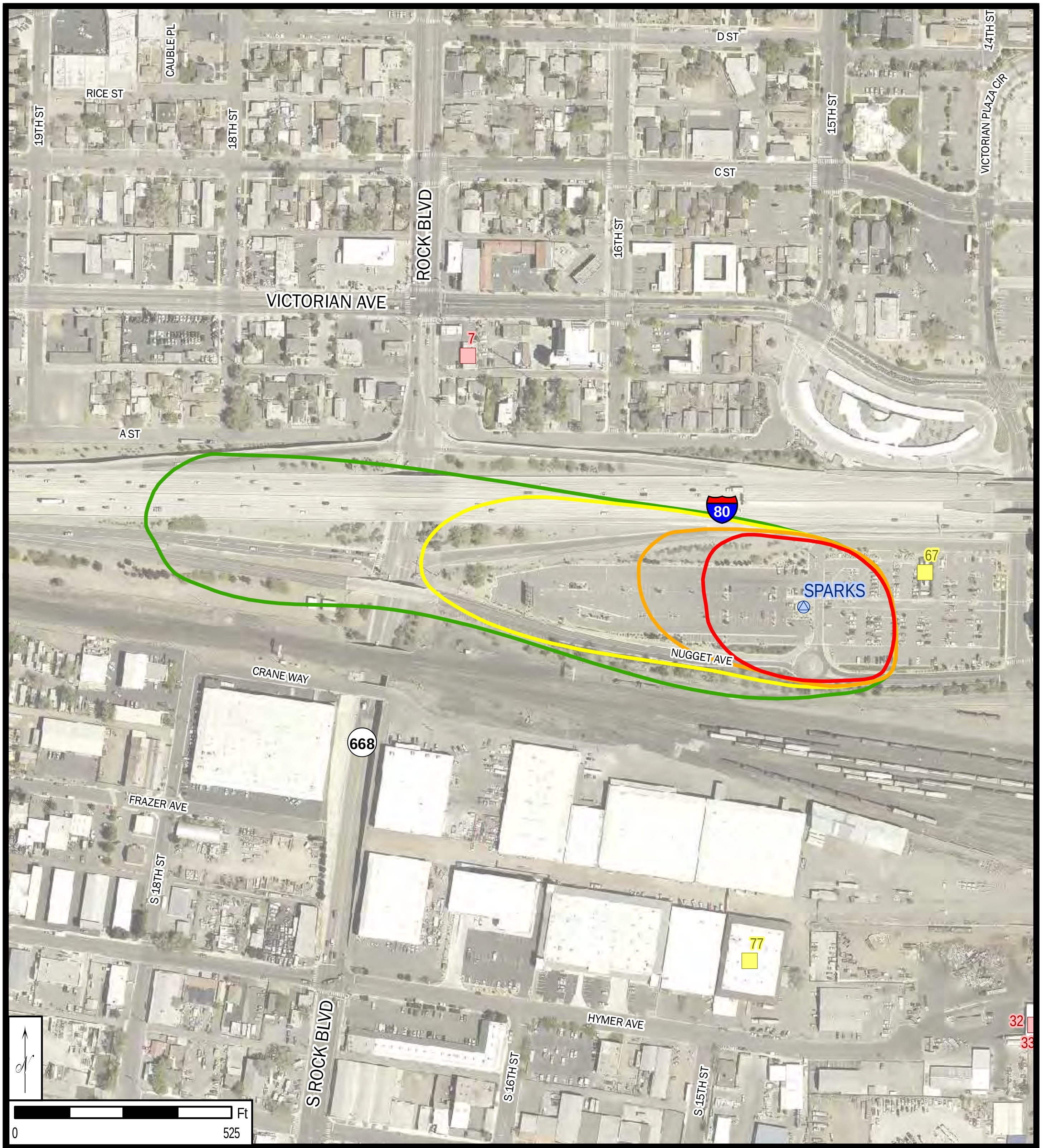

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 20

SPARKS WELL SITE

△ WATER SUPPLY WELL

🟥 CONTAMINANT RELEASE SITE - ACTIVE (NDEP)

○ 2 YEAR CAPTURE ZONE

○ 5 YEAR CAPTURE ZONE

○ 10 YEAR CAPTURE ZONE

○ 20 YEAR CAPTURE ZONE

🟨 CONTAMINANT RELEASE SITE - INACTIVE (NDEP)

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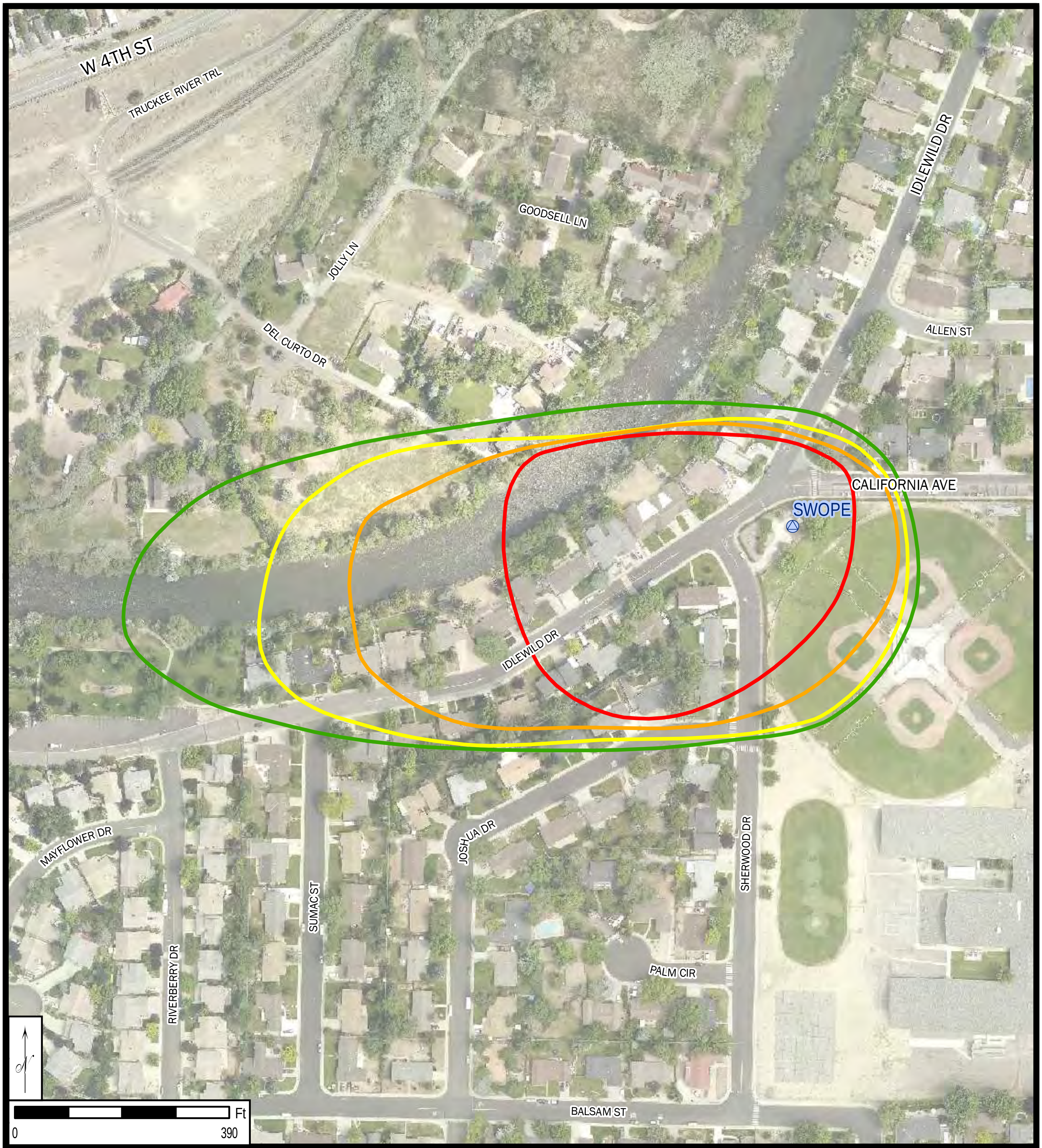

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 21

SWOPE WELL SITE

TMWA

△	WATER SUPPLY WELL
🟥	2 YEAR CAPTURE ZONE
🟧	5 YEAR CAPTURE ZONE
🟨	10 YEAR CAPTURE ZONE
🟩	20 YEAR CAPTURE ZONE

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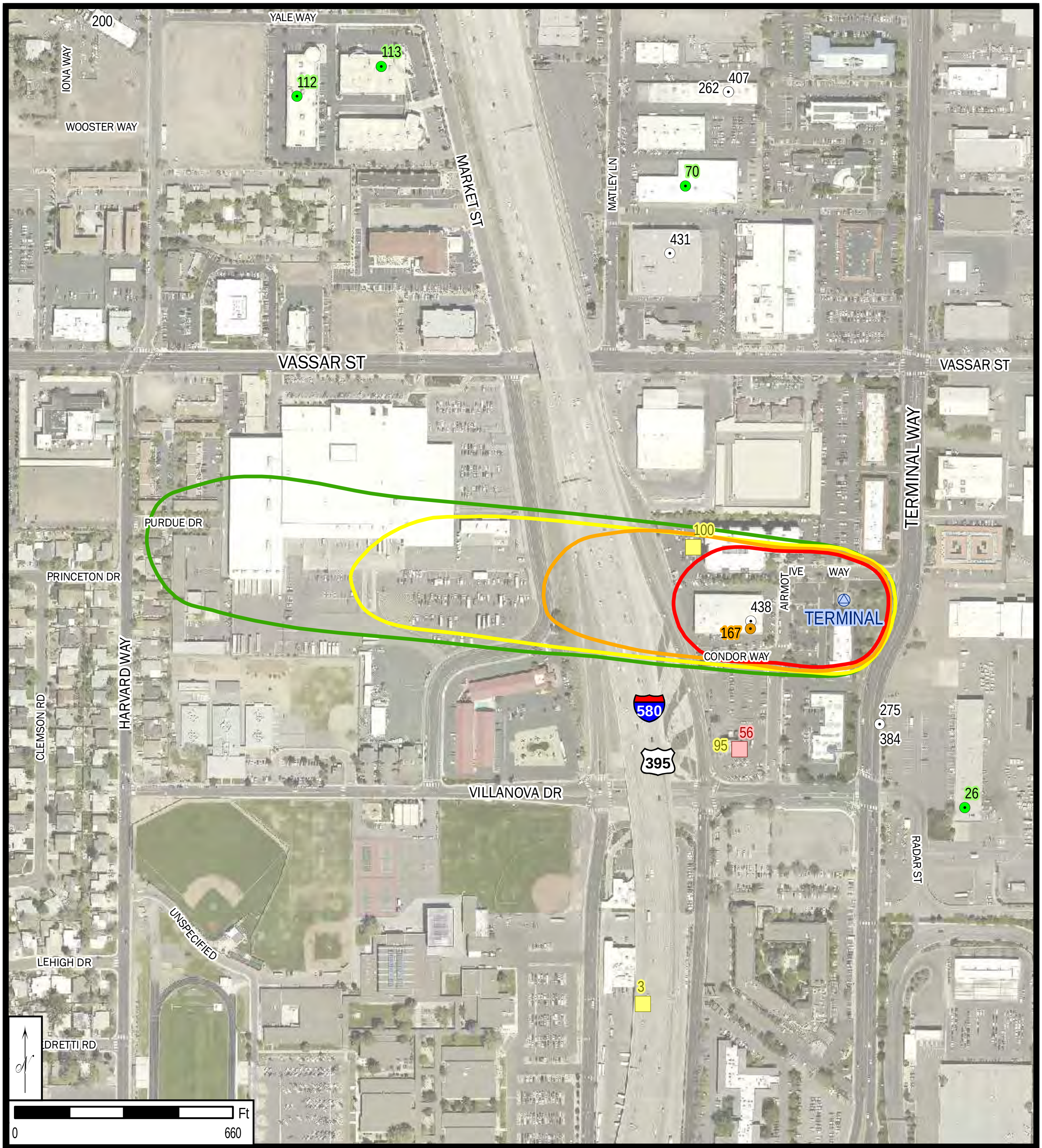

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 22

TERMINAL WELL SITE

● POTENTIAL CONTAMINANT SOURCE -- SQG (EPA)
● POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)
⊙ POTENTIAL CONTAMINANT SOURCE -- (EPA)
△ WATER SUPPLY WELL
🟥 CONTAMINANT RELEASE SITE - ACTIVE (NDEP)

▢ 2 YEAR CAPTURE ZONE
▢ 5 YEAR CAPTURE ZONE
▢ 10 YEAR CAPTURE ZONE
▢ 20 YEAR CAPTURE ZONE
🟨 CONTAMINANT RELEASE SITE - INACTIVE (NDEP)

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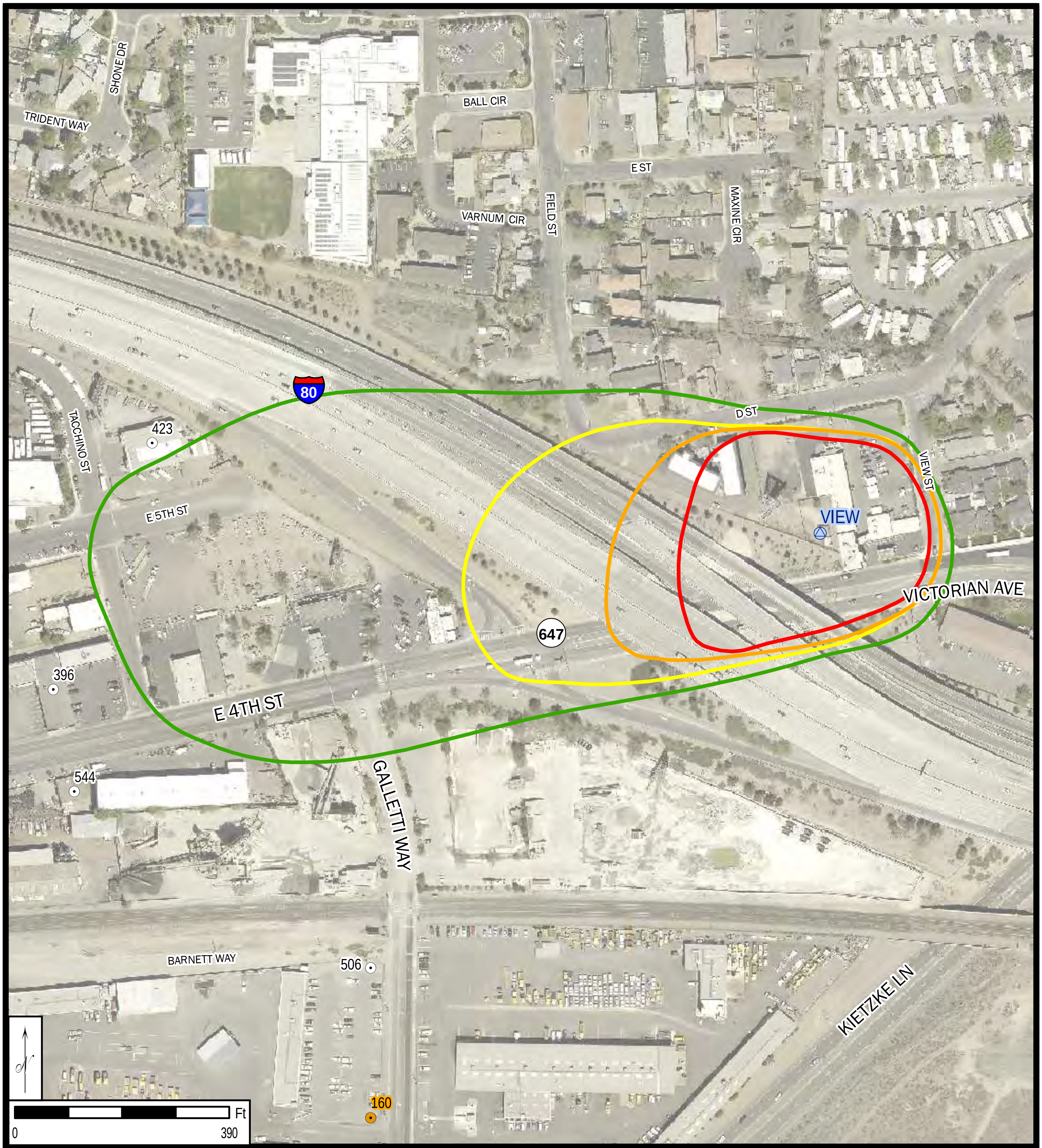

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (NORTH) (BASIN 87) -- FIGURE: 23

VIEW WELL SITE

●	POTENTIAL CONTAMINANT SOURCE -- SQG (EPA)	🟥	2 YEAR CAPTURE ZONE
⊙	POTENTIAL CONTAMINANT SOURCE -- (EPA)	🟧	5 YEAR CAPTURE ZONE
△	WATER SUPPLY WELL	🟨	10 YEAR CAPTURE ZONE
		🟩	20 YEAR CAPTURE ZONE

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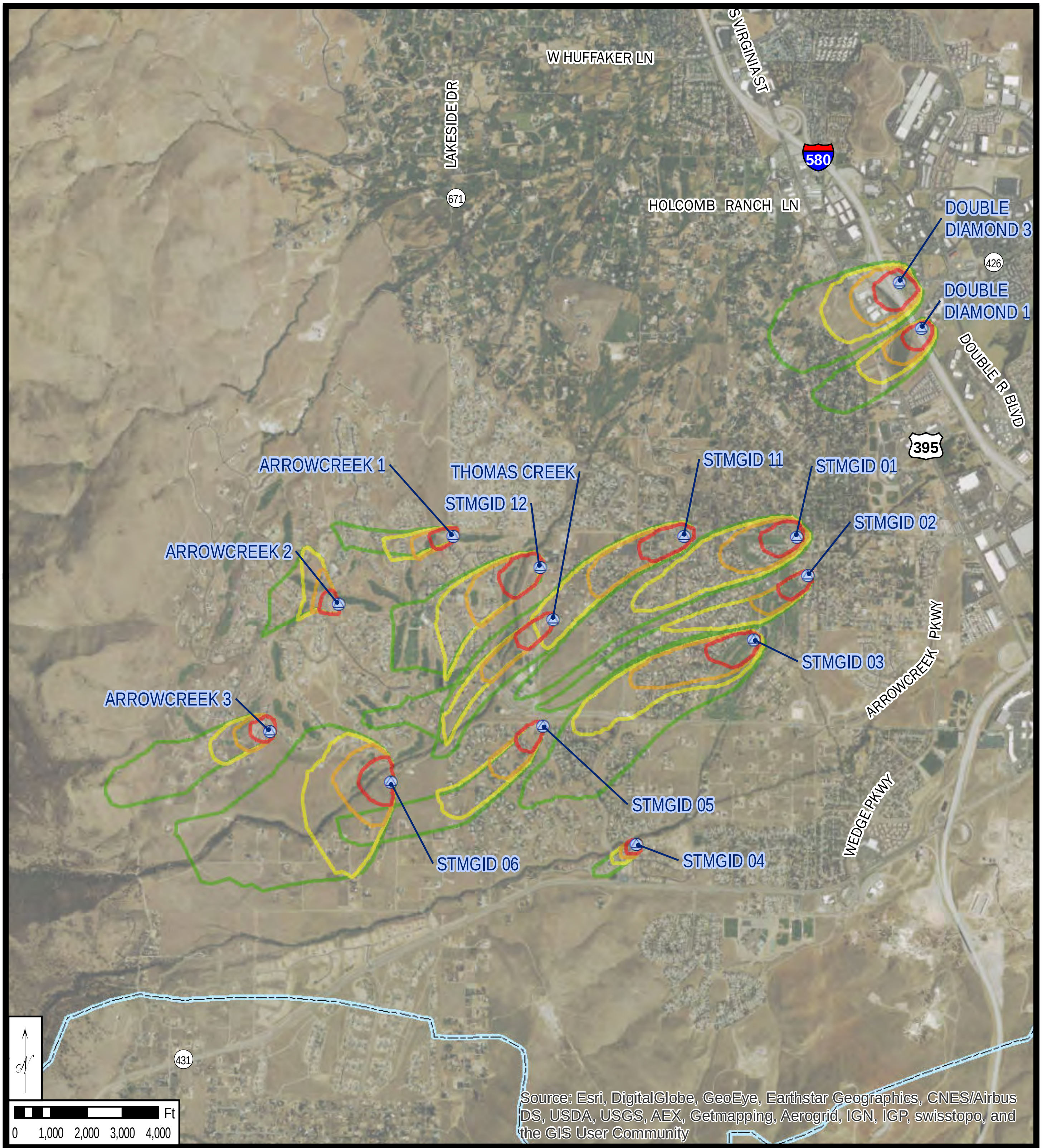

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WELLHEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (SOUTH) (BASIN 87) AREA INDEX

TMWA

△ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE

🟧 5 YEAR CAPTURE ZONE

🟨 10 YEAR CAPTURE ZONE

🟩 20 YEAR CAPTURE ZONE

▭ NEVADA HYDROBASIN BOUNDARY

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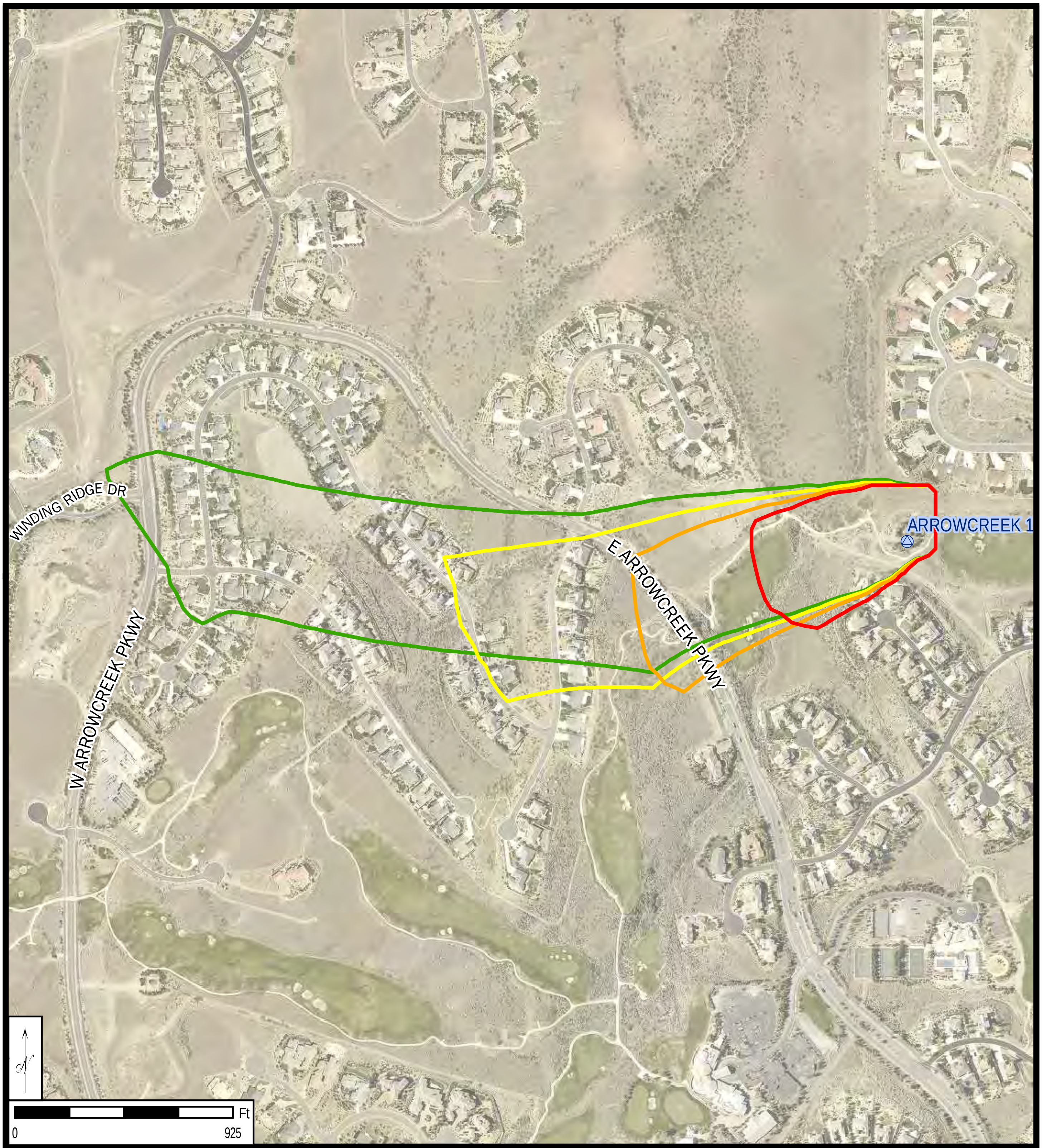

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (SOUTH) (BASIN 87) -- FIGURE: 1

ARROWCREEK 1 WELL SITE

TMWA

▲ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE

🟧 5 YEAR CAPTURE ZONE

🟨 10 YEAR CAPTURE ZONE

🟩 20 YEAR CAPTURE ZONE

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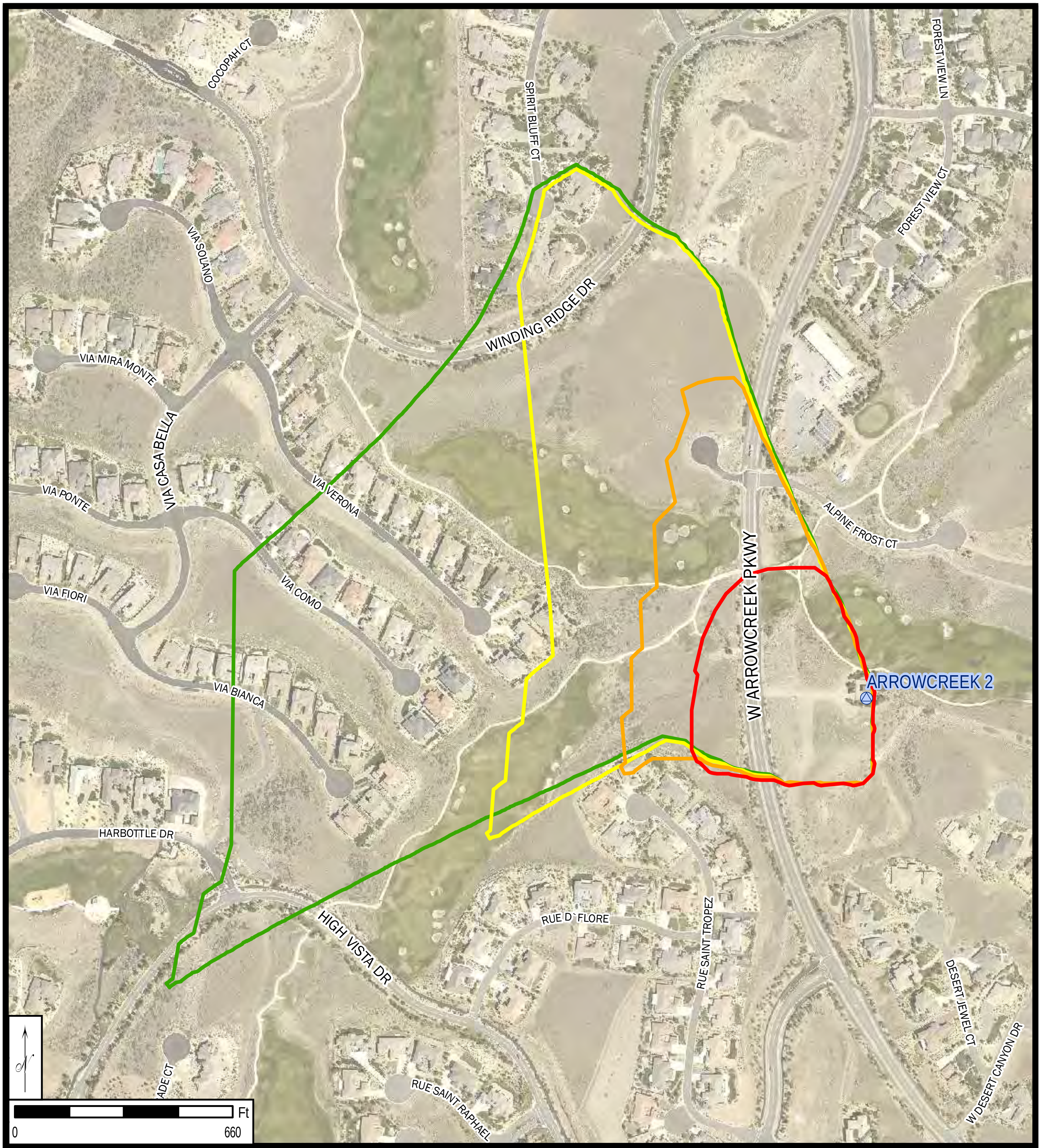

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (SOUTH) (BASIN 87) -- FIGURE: 2

ARROWCREEK 2 WELL SITE

△ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE

🟧 5 YEAR CAPTURE ZONE

🟨 10 YEAR CAPTURE ZONE

🟩 20 YEAR CAPTURE ZONE

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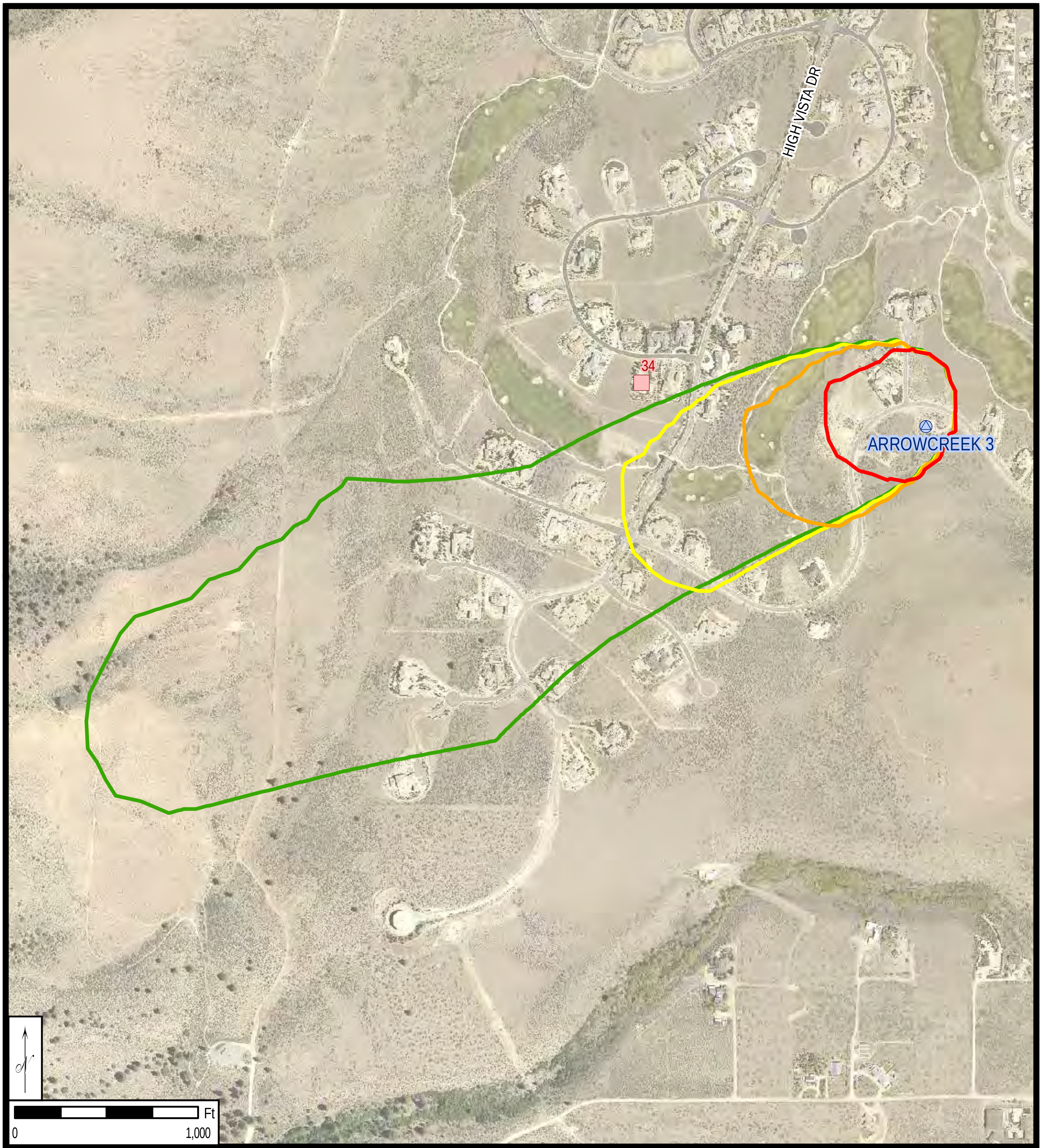

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (SOUTH) (BASIN 87) -- FIGURE: 3

ARROWCREEK 3 WELL SITE

TMWA

△ WATER SUPPLY WELL
■ CONTAMINANT RELEASE SITE - ACTIVE (NDEP)

🟥 2 YEAR CAPTURE ZONE
🟧 5 YEAR CAPTURE ZONE
🟨 10 YEAR CAPTURE ZONE
🟩 20 YEAR CAPTURE ZONE

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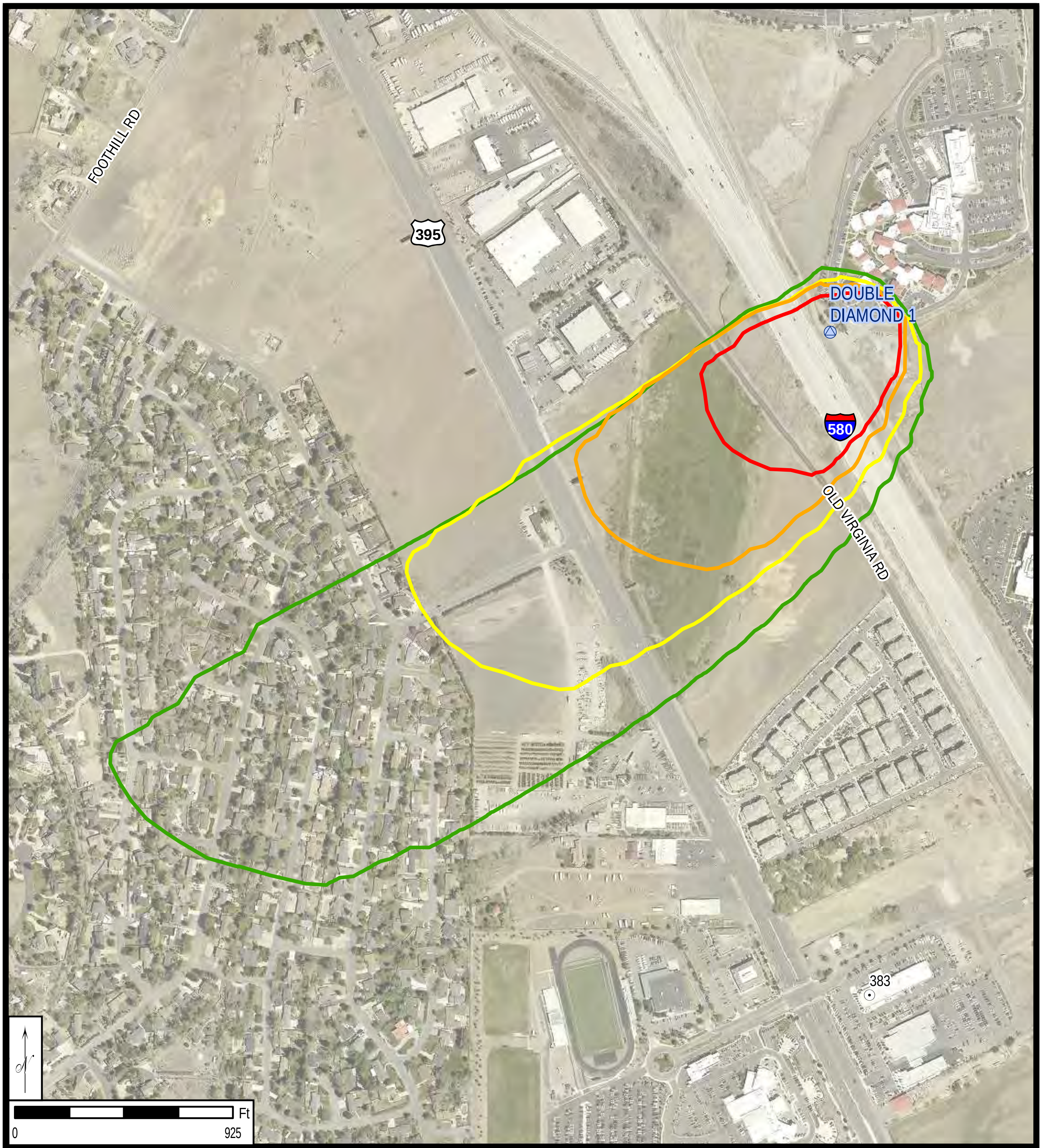

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (SOUTH) (BASIN 87) -- FIGURE: 4

DOUBLE DIAMOND 1 WELL SITE

TMWA

⊙ POTENTIAL CONTAMINANT SOURCE -- (EPA)
△ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE
🟧 5 YEAR CAPTURE ZONE
🟨 10 YEAR CAPTURE ZONE
🟩 20 YEAR CAPTURE ZONE

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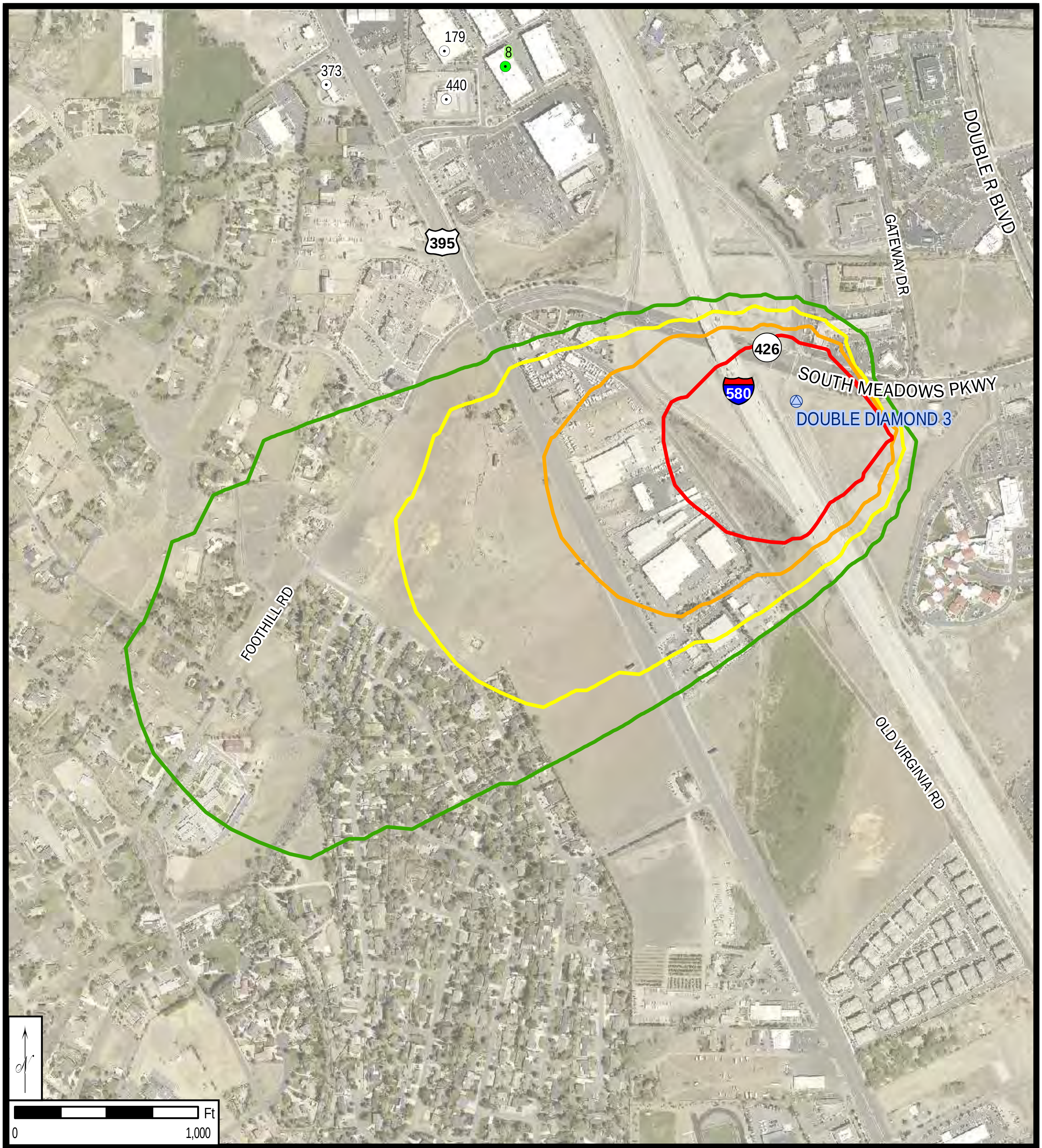

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (SOUTH) (BASIN 87) -- FIGURE: 5

DOUBLE DIAMOND 3 WELL SITE

●	POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)	🟥	2 YEAR CAPTURE ZONE
⊙	POTENTIAL CONTAMINANT SOURCE -- (EPA)	🟧	5 YEAR CAPTURE ZONE
△	WATER SUPPLY WELL	🟨	10 YEAR CAPTURE ZONE
		🟩	20 YEAR CAPTURE ZONE

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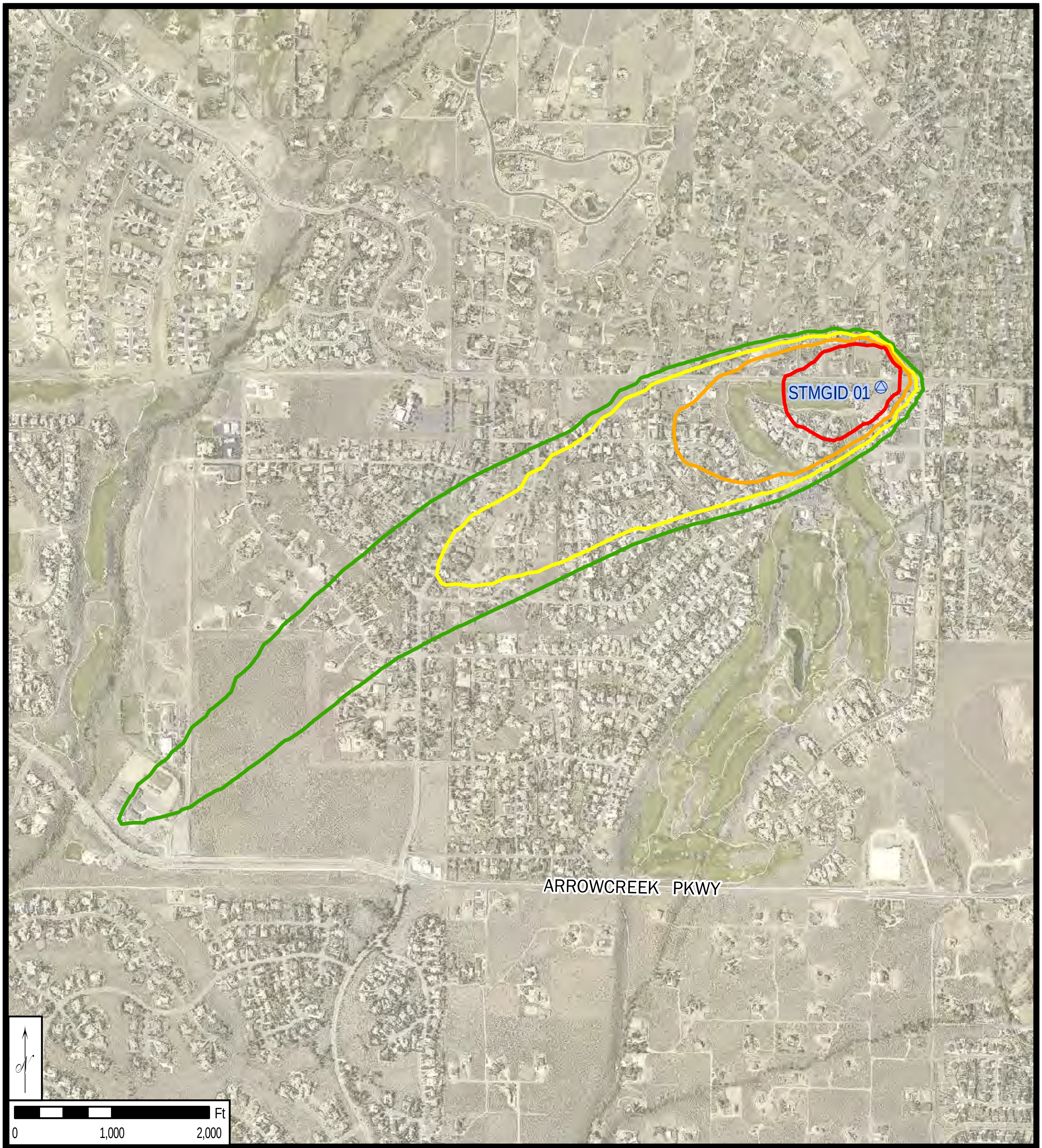

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (SOUTH) (BASIN 87) -- FIGURE: 6

STMGID 01 WELL SITE

TMWA

△ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE

🟧 5 YEAR CAPTURE ZONE

🟨 10 YEAR CAPTURE ZONE

🟩 20 YEAR CAPTURE ZONE

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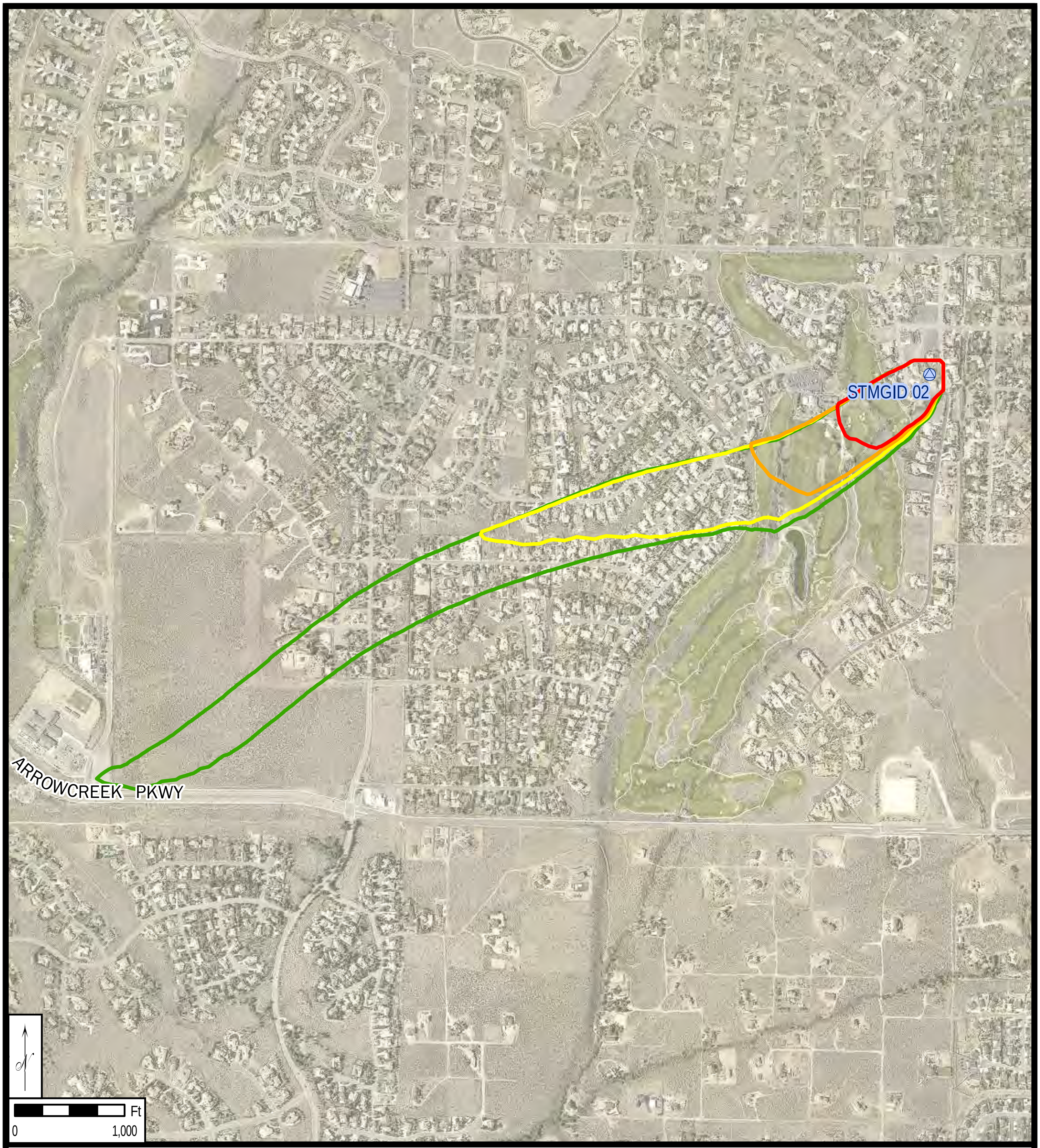

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (SOUTH) (BASIN 87) -- FIGURE: 7

STMGID 02 WELL SITE

TMWA

- △ WATER SUPPLY WELL
- 🟥 2 YEAR CAPTURE ZONE
- 🟧 5 YEAR CAPTURE ZONE
- 🟨 10 YEAR CAPTURE ZONE
- 🟩 20 YEAR CAPTURE ZONE

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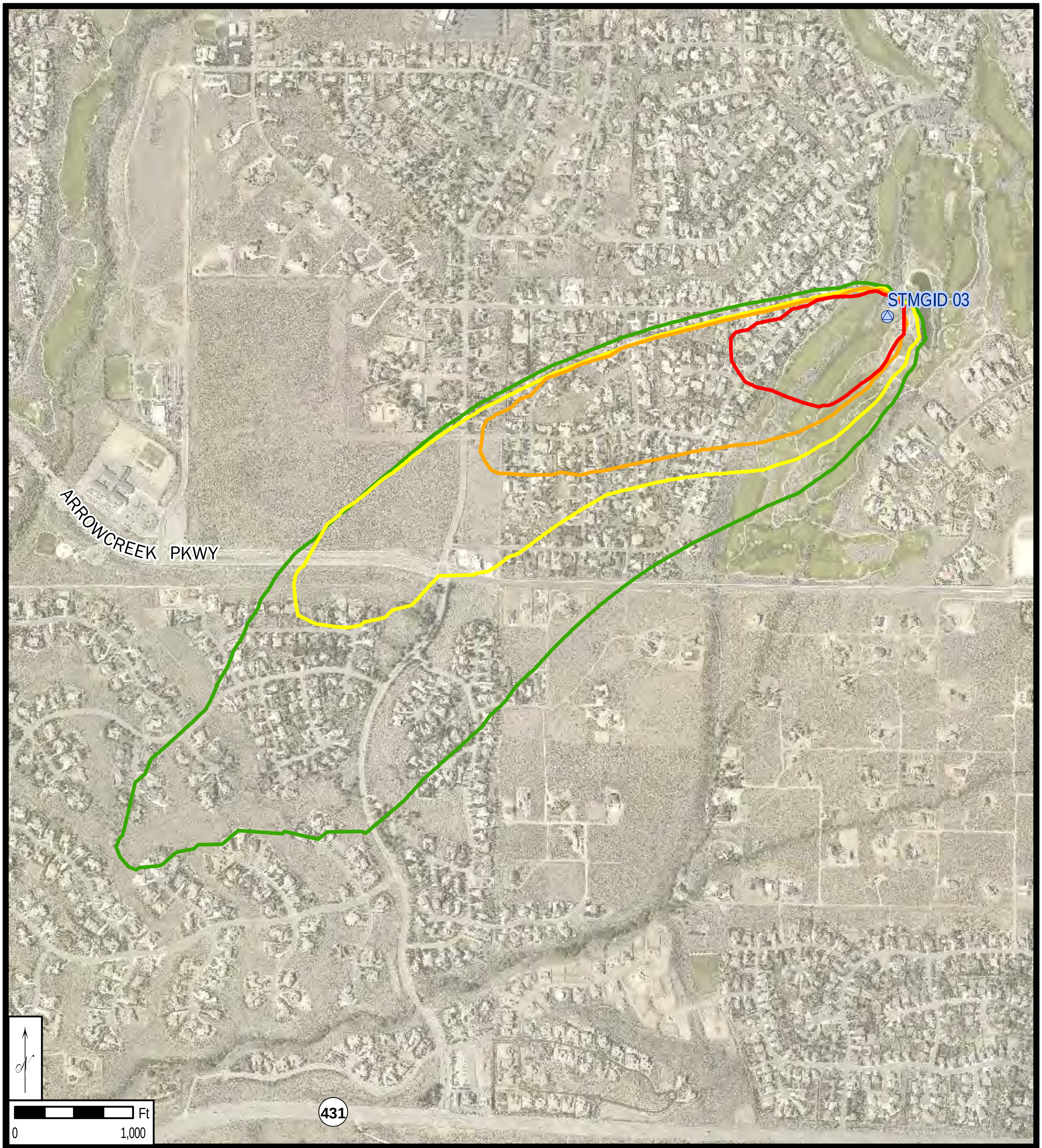

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (SOUTH) (BASIN 87) -- FIGURE: 8

STMGID 03 WELL SITE

TMWA

◬	WATER SUPPLY WELL
🟥	2 YEAR CAPTURE ZONE
🟧	5 YEAR CAPTURE ZONE
🟨	10 YEAR CAPTURE ZONE
🟩	20 YEAR CAPTURE ZONE

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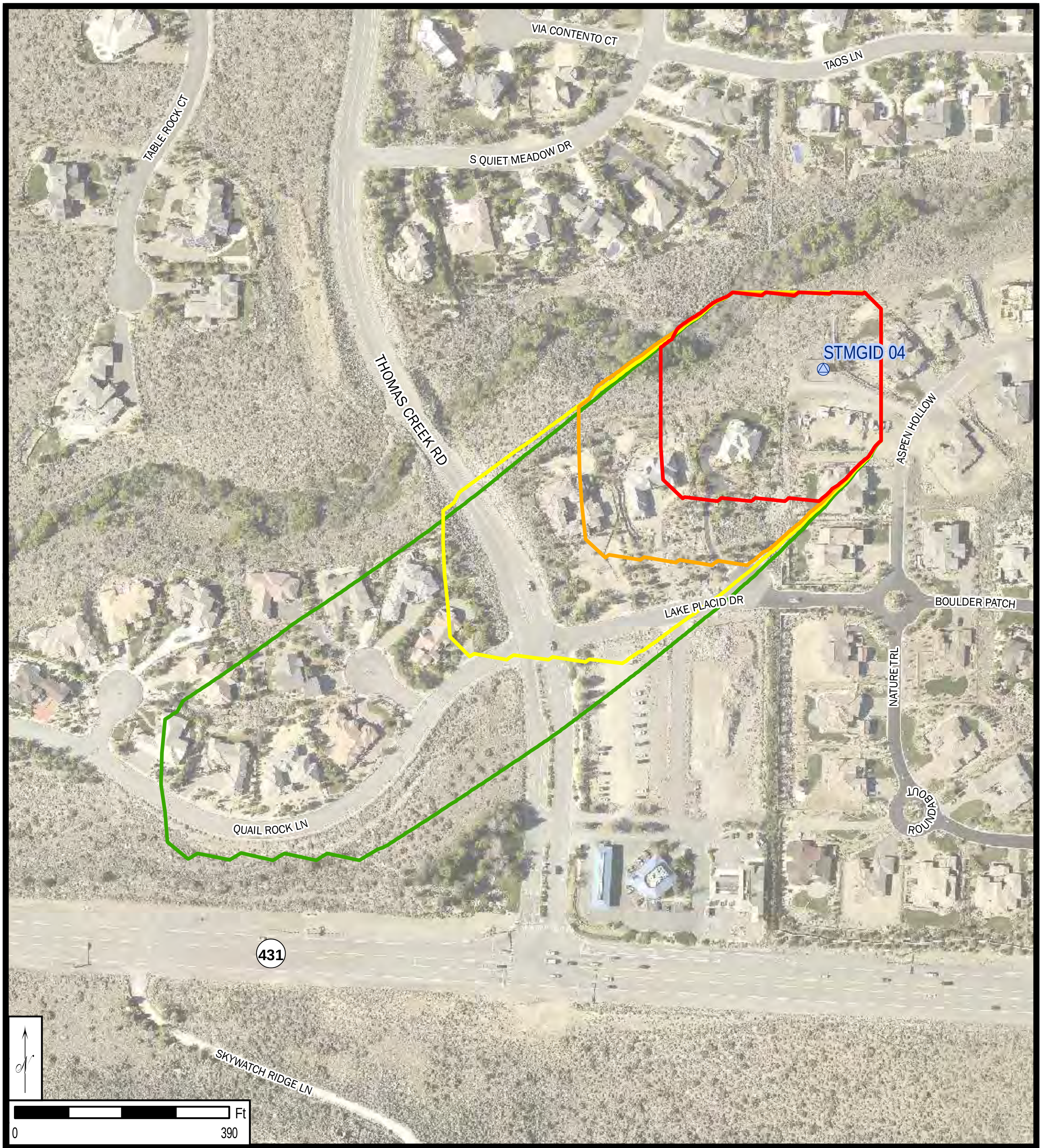

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (SOUTH) (BASIN 87) -- FIGURE: 9

STMGID 04 WELL SITE

TMWA

△	WATER SUPPLY WELL	🟥	2 YEAR CAPTURE ZONE
		🟧	5 YEAR CAPTURE ZONE
		🟨	10 YEAR CAPTURE ZONE
		🟩	20 YEAR CAPTURE ZONE

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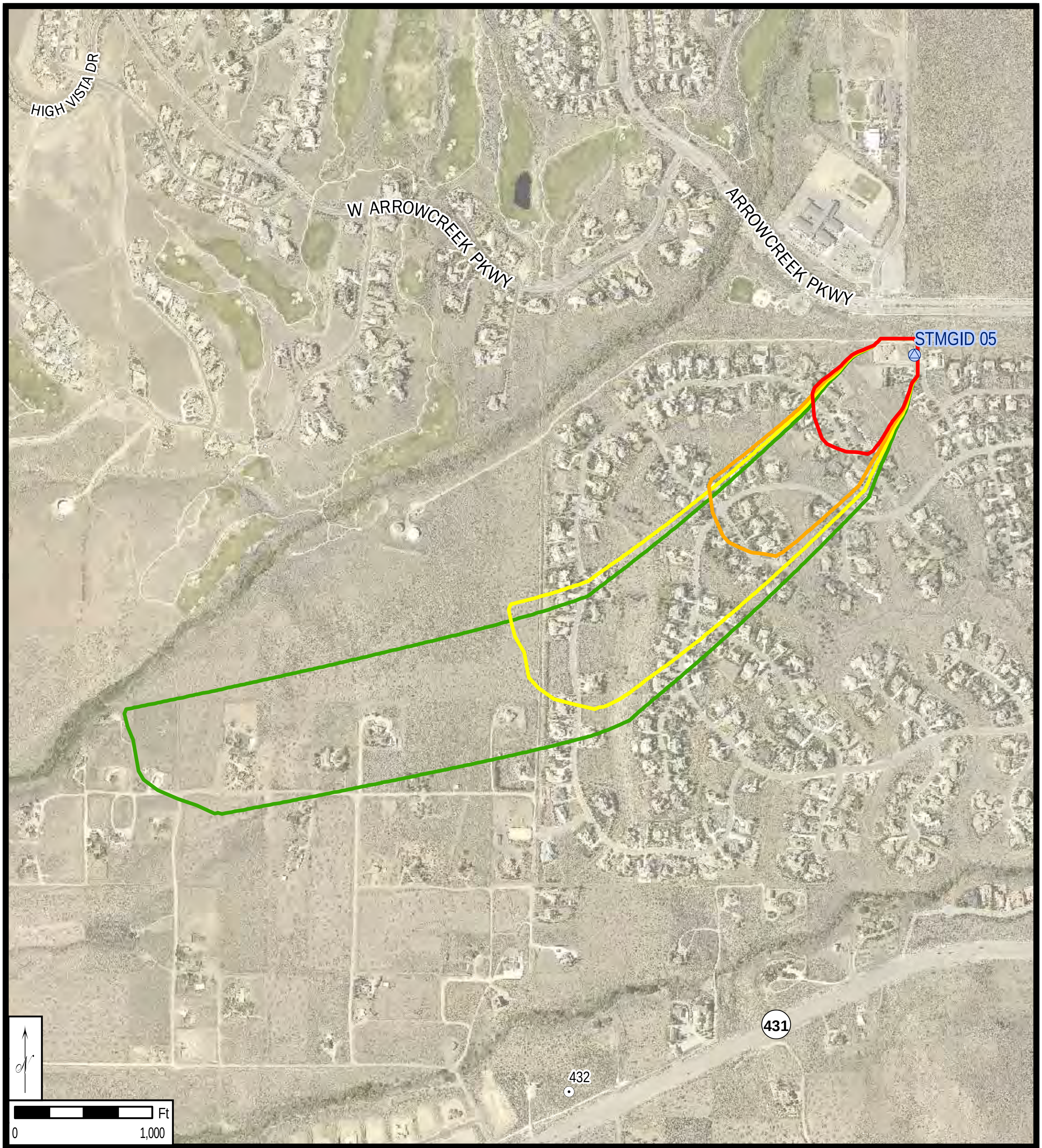

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (SOUTH) (BASIN 87) -- FIGURE: 10

STMGID 05 WELL SITE

☉ POTENTIAL CONTAMINANT SOURCE -- (EPA)

◬ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE

🟧 5 YEAR CAPTURE ZONE

🟨 10 YEAR CAPTURE ZONE

🟩 20 YEAR CAPTURE ZONE

TMWA

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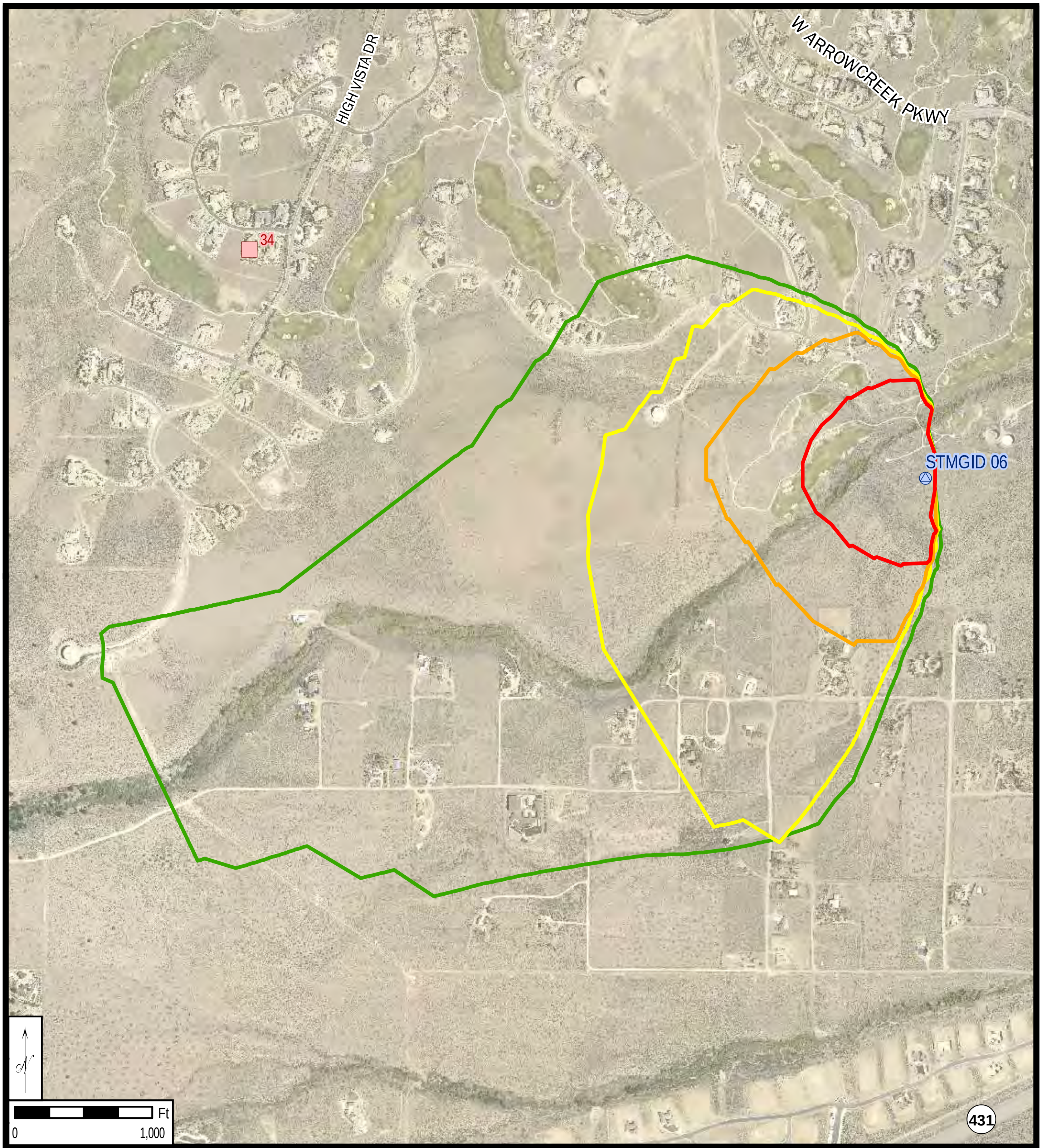

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (SOUTH) (BASIN 87) -- FIGURE: 11

STMGID 06 WELL SITE

TMWA

△ WATER SUPPLY WELL
■ CONTAMINANT RELEASE SITE - ACTIVE (NDEP)

🟥 2 YEAR CAPTURE ZONE
🟧 5 YEAR CAPTURE ZONE
🟨 10 YEAR CAPTURE ZONE
🟩 20 YEAR CAPTURE ZONE

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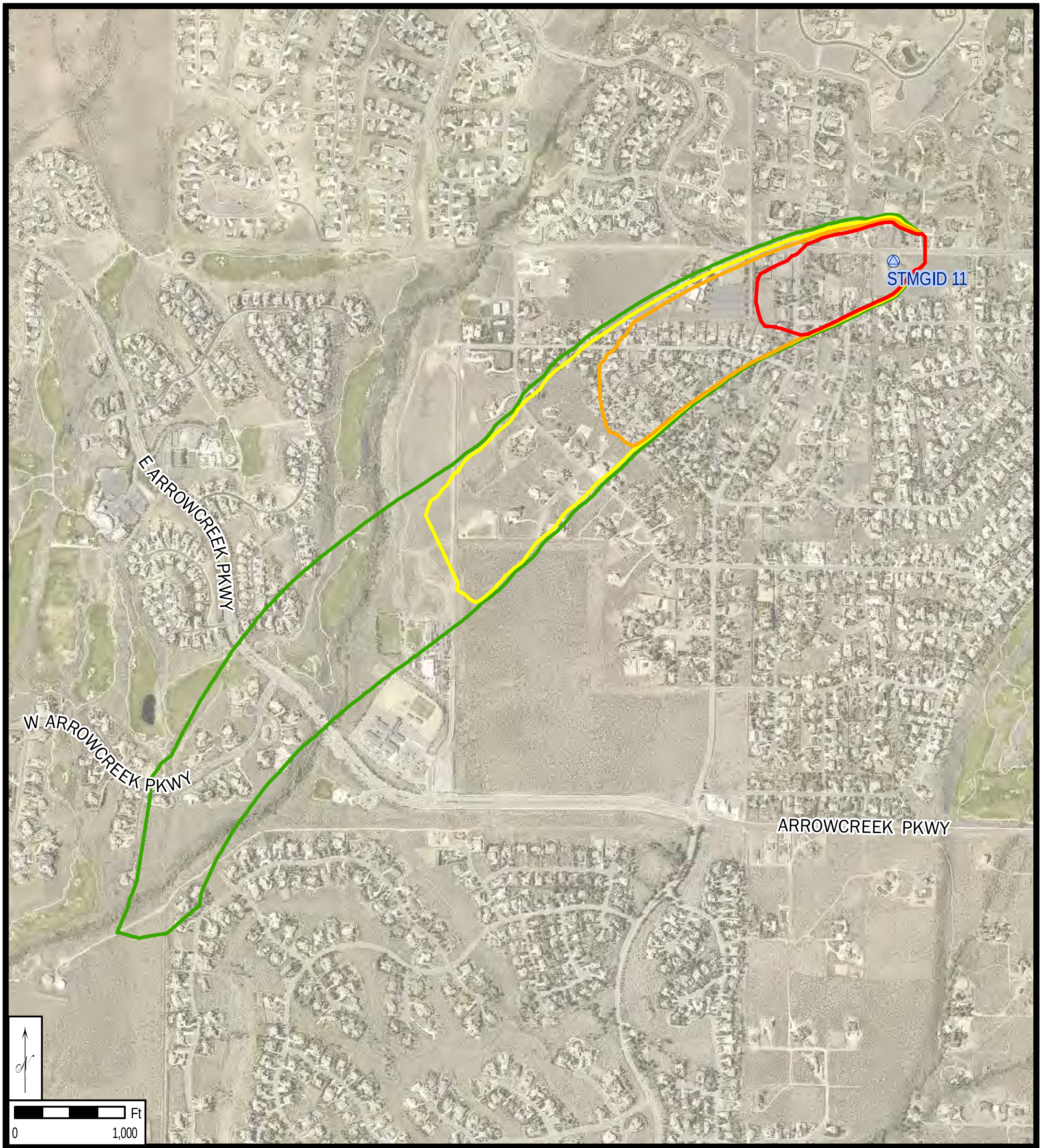

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (SOUTH) (BASIN 87) -- FIGURE: 12

STMGID 11 WELL SITE

◬	WATER SUPPLY WELL
🟥	2 YEAR CAPTURE ZONE
🟧	5 YEAR CAPTURE ZONE
🟨	10 YEAR CAPTURE ZONE
🟩	20 YEAR CAPTURE ZONE

TMWA

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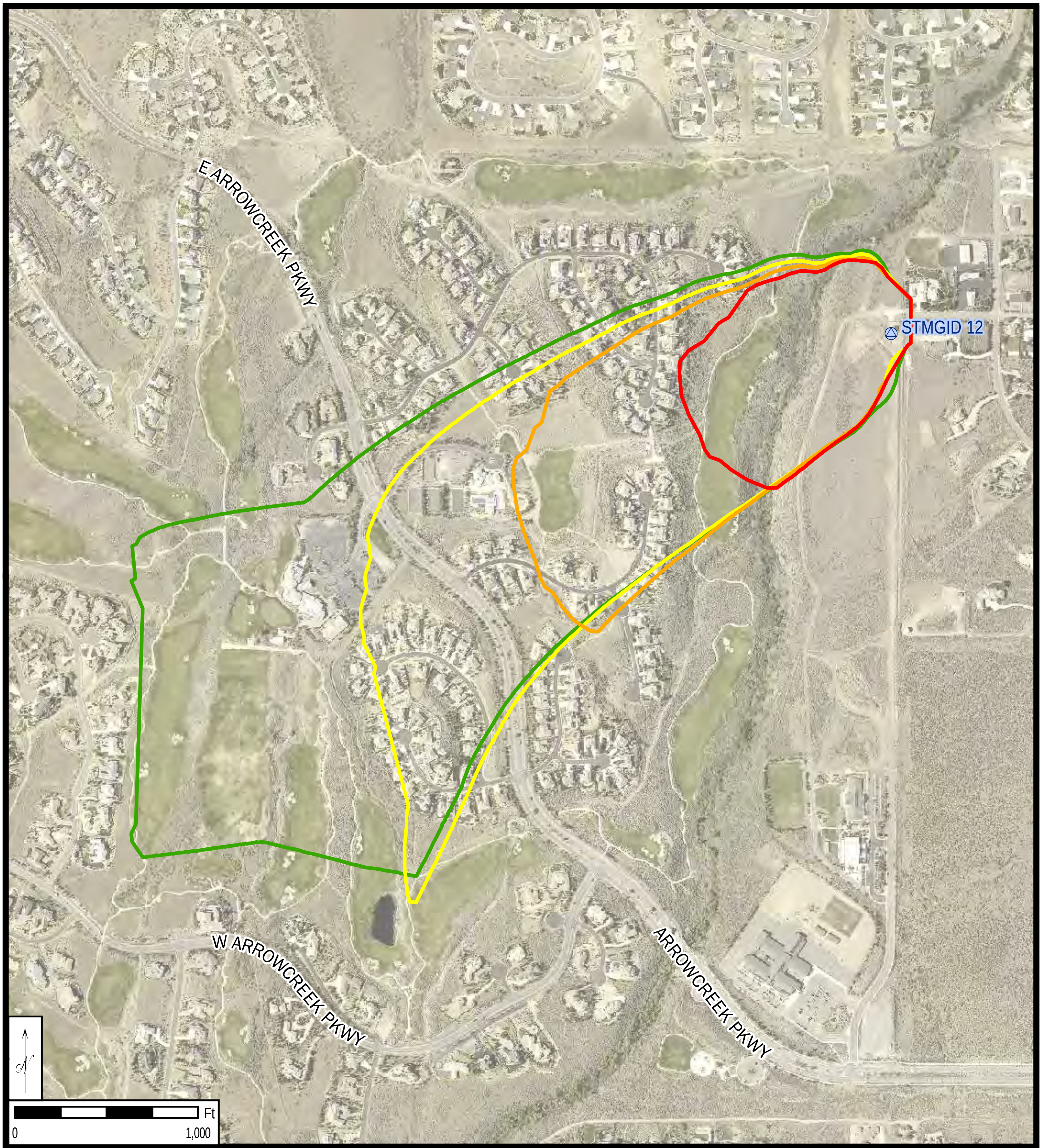

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (SOUTH) (BASIN 87) -- FIGURE: 13

STMGID 12 WELL SITE

◬ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE
🟧 5 YEAR CAPTURE ZONE
🟨 10 YEAR CAPTURE ZONE
🟩 20 YEAR CAPTURE ZONE

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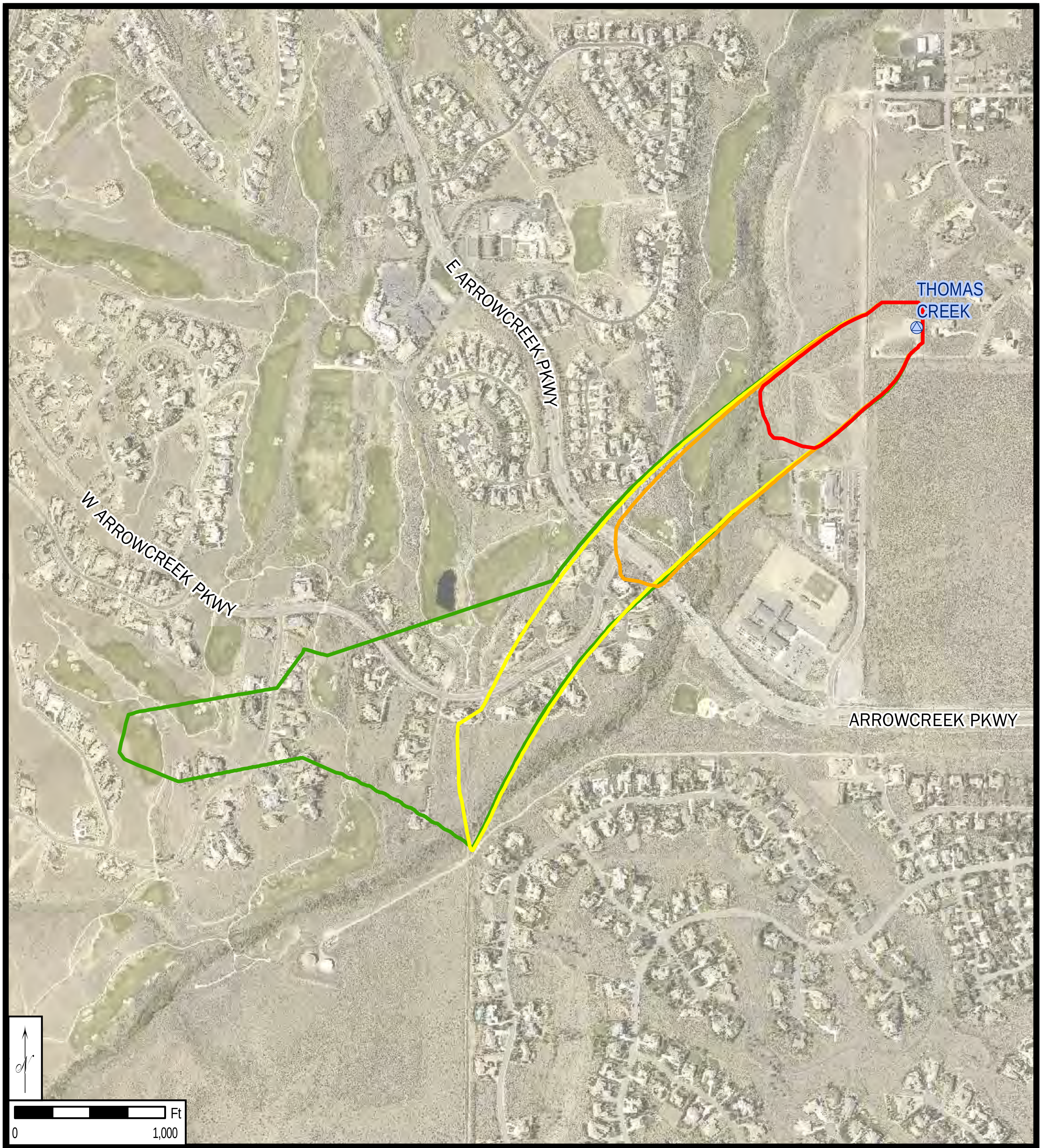

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

TRUCKEE MEADOWS (SOUTH) (BASIN 87) -- FIGURE: 14

THOMAS CREEK WELL SITE

△ WATER SUPPLY WELL

🟥 2 YEAR CAPTURE ZONE

🟧 5 YEAR CAPTURE ZONE

🟨 10 YEAR CAPTURE ZONE

🟩 20 YEAR CAPTURE ZONE

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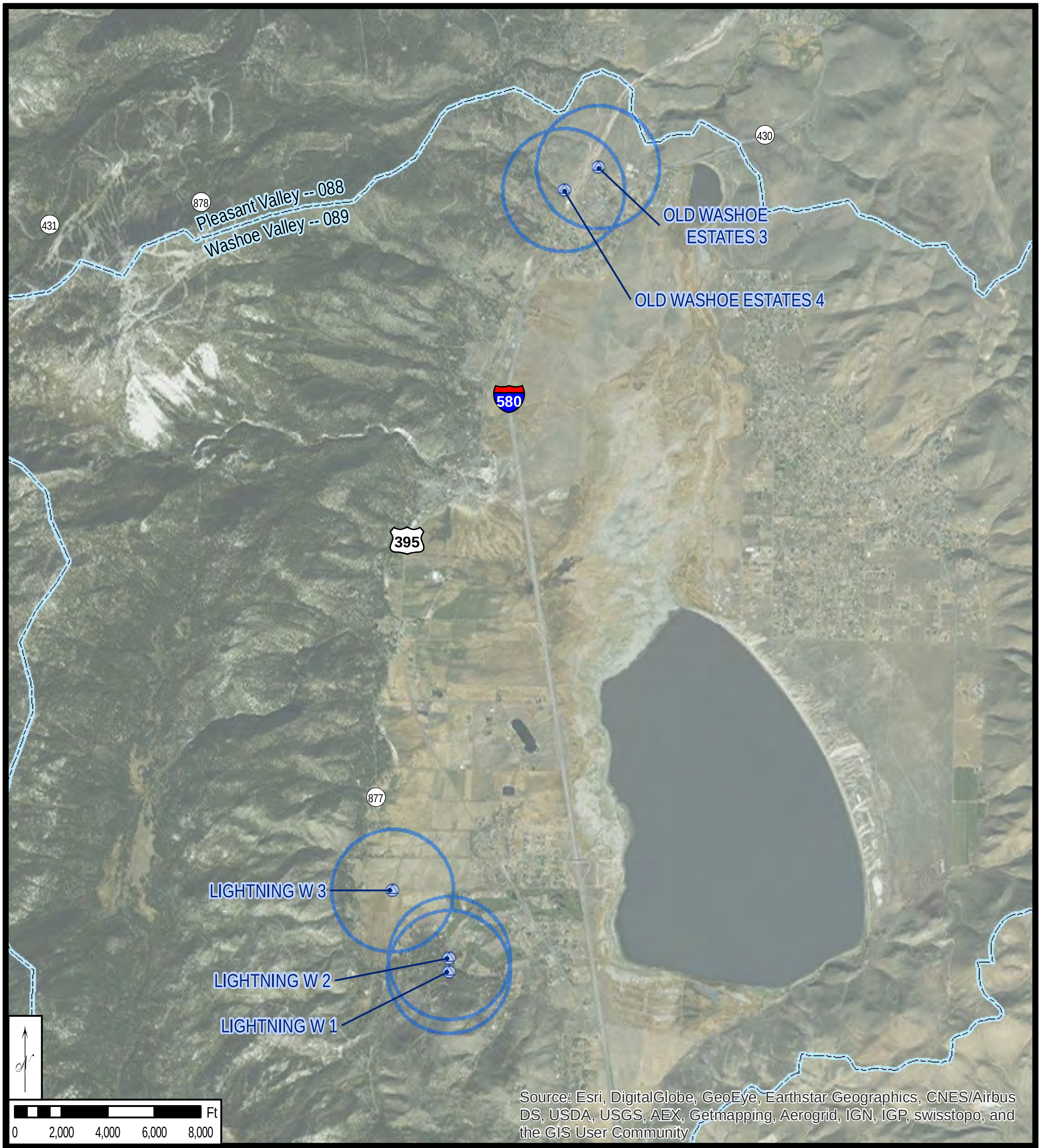

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

WELLHEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

WASHOE VALLEY (BASIN 89) AREA INDEX

TMWA

△ WATER SUPPLY WELL

▢ 1/2 MILE CAPTURE ZONE

▢ NEVADA HYDROBASIN BOUNDARY

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Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

WASHOE VALLEY (BASIN 89) -- FIGURE: 1

LIGHTNING W 1 WELL SITE

TMWA

△ WATER SUPPLY WELL

○ 1/2 MILE CAPTURE ZONE

🟨 CONTAMINANT RELEASE SITE - INACTIVE (NDEP)

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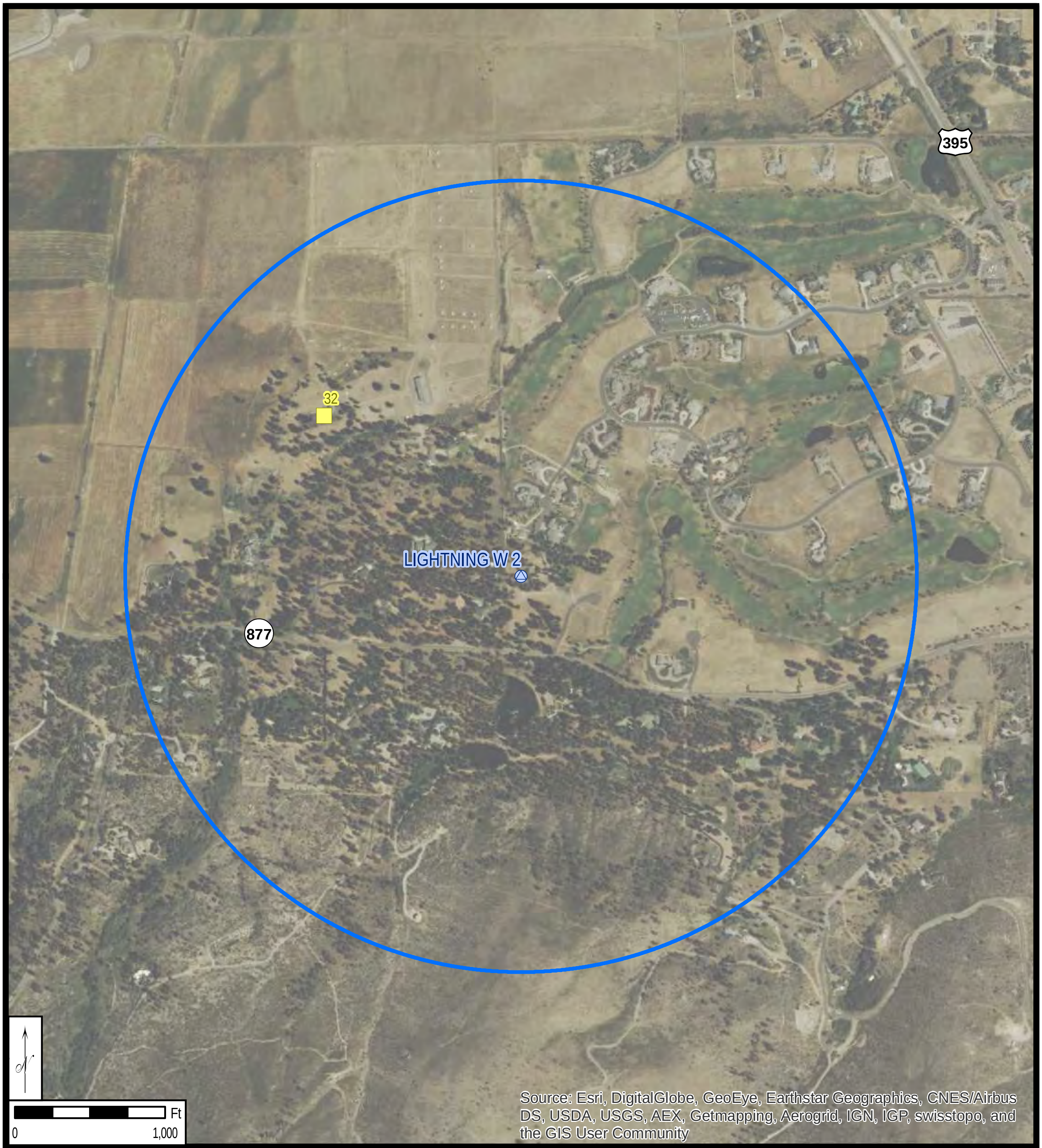

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

WASHOE VALLEY (BASIN 89) -- FIGURE: 2

LIGHTNING W 2 WELL SITE

TMWA

△ WATER SUPPLY WELL

▢ 1/2 MILE CAPTURE ZONE

🟨 CONTAMINANT RELEASE SITE - INACTIVE (NDEP)

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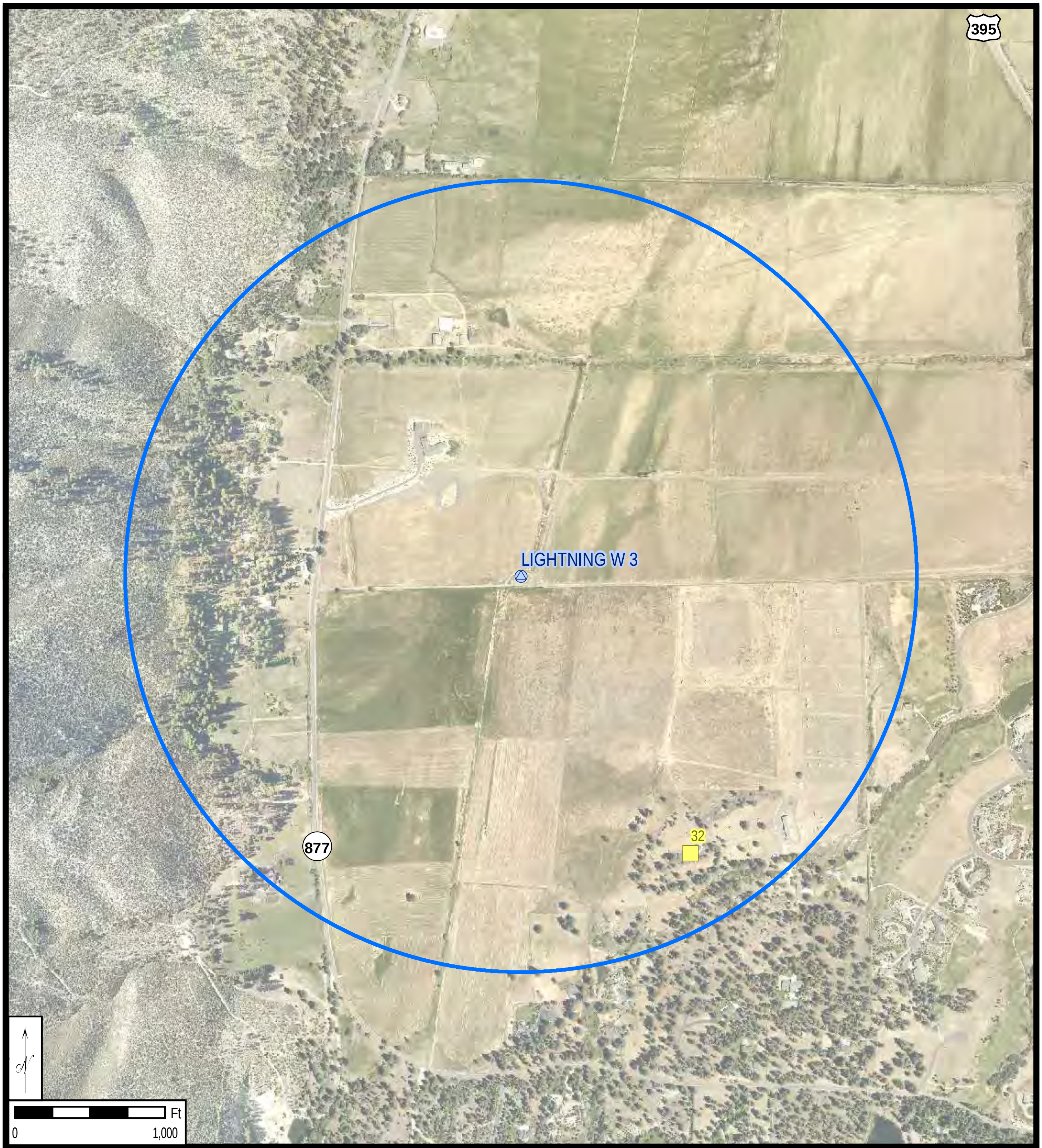

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

WASHOE VALLEY (BASIN 89) -- FIGURE: 3

LIGHTNING W 3 WELL SITE

TMWA

△ WATER SUPPLY WELL

○ 1/2 MILE CAPTURE ZONE

🟨 CONTAMINANT RELEASE SITE - INACTIVE (NDEP)

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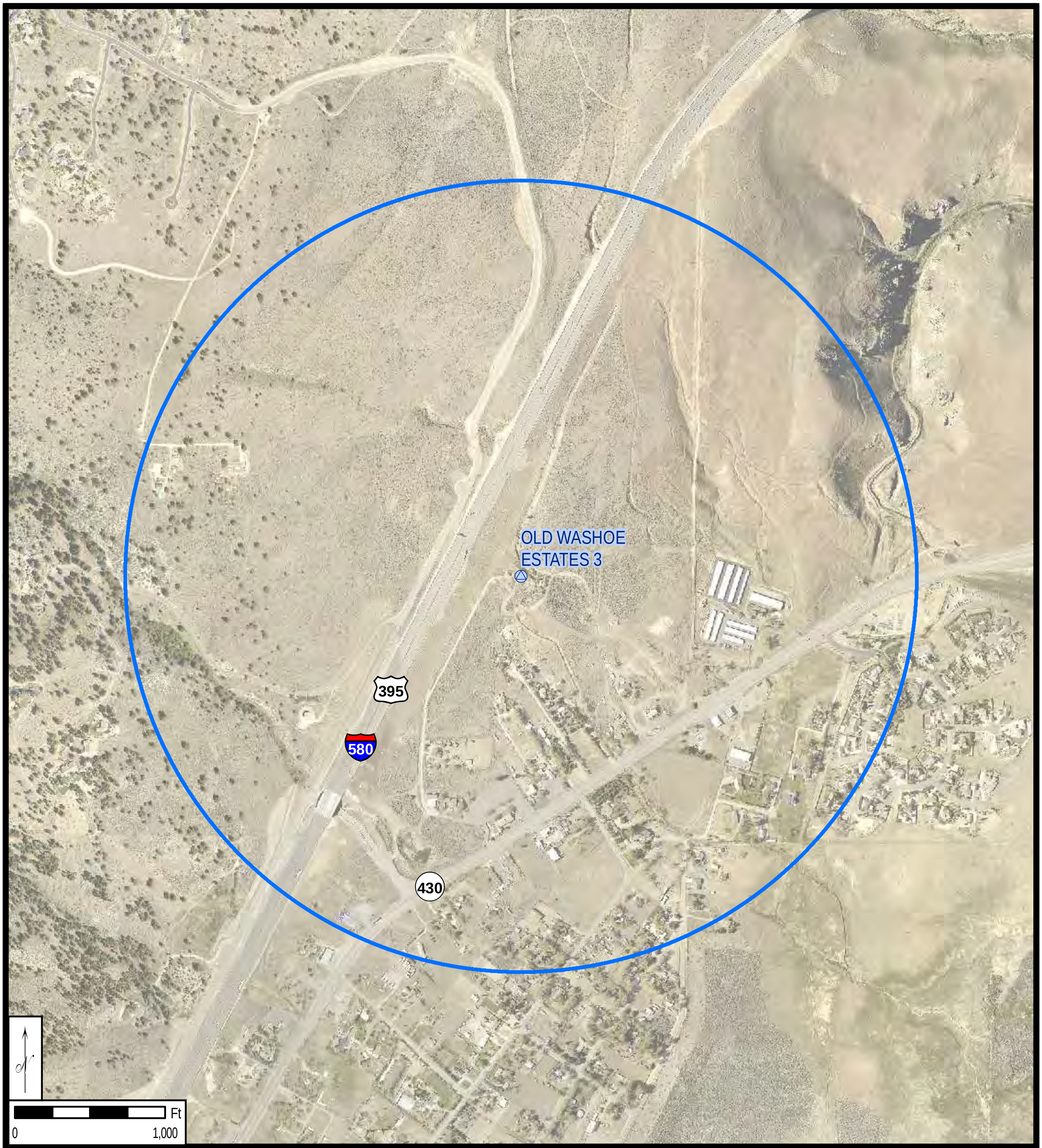

WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

WASHOE VALLEY (BASIN 89) -- FIGURE: 4

OLD WASHOE ESTATES 3 WELL SITE

TMWA

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△ WATER SUPPLY WELL ○ 1/2 MILE CAPTURE ZONE

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WELL HEAD PROTECTION PROGRAM CAPTURE ZONE DELINEATION

WASHOE VALLEY (BASIN 89) -- FIGURE: 5

OLD WASHOE ESTATES 4 WELL SITE

T M W A

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△ WATER SUPPLY WELL ▢ 1/2 MILE CAPTURE ZONE

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APPENDIX C

PCS DATA TABLES

DRAFT

Contaminant Release Sites - Active

ID	Site ID	Facility_Name	Facility_Address	Report_Date	Program	Media	Event	Contaminant
1	4-000003	ALLIED PETROLEUM COMPANY , APN 008-228-01	2500 EAST 4TH STREET, RENO 89512	1/26/1993	LUST	Soil & Ground Water	Confirmed Release	Diesel -- +Gasoline
2	4-000013	ARCO #6017	2240 VICTORIAN AVENUE, SPARKS 89431	1/1/1900	LUST	Ground Water	Confirmed Release	Gasoline
3	4-000053	LUCE & SONS, INC. , APN 003-363-03	2399 VALLEY ROAD, RENO 89512	3/7/2013	LUST	Soil & Ground Water	Confirmed Release	Gasoline
4	4-000061	CHEVRON #94116	947 STATE ROUTE 28, INCLINE VILLAGE 89450	1/1/1900	LUST	Ground Water	Confirmed Release	Gasoline -- Mostly benzene and MtBE
5	4-000135	ALBERS OF NEVADA	755 TIMBER WAY, RENO 89512	11/26/2014	LUST	Soil	Confirmed Release	Diesel
6	4-000185	LAKESHORE ORBIT	560 LAKESHORE BOULEVARD, INCLINE VILLAGE	10/31/2000	LUST	Ground Water	Confirmed Release	Gasoline
7	4-000327	VICTORIAN FOOD MART , APN 032-125-26	1675 VICTORIAN AVENUE, SPARKS 89431	5/7/2009	LUST	Soil	Confirmed Release	Gasoline
8	4-000342	PLUMB LANE SHELL	130 WEST PLUMB LANE, RENO 89509	1/1/1900	LUST	Ground Water	Confirmed Release	Gasoline
9	4-000356	JACKSONS FOOD STORES #145 , APN 534-092-04	8995 LA POSADA DRIVE, SPARKS 89441	1/28/2008	LUST	Soil & Ground Water	Confirmed Release	Gasoline
10	4-000379	7-ELEVEN #15426 , APN 008-073-01	1680 SILVERADA BOULEVARD, RENO 89512	10/21/2010	LUST	Soil & Ground Water	Confirmed Release	Gasoline
11	4-000408	TIME OIL STORE 6-100 , APN 085-851-15	5190 SUN VALLEY BOULEVARD, SUN VALLEY 89433	8/11/2006	LUST	Soil & Ground Water	Confirmed Release	Gasoline
12	4-000475	RANCHO SAN RAFAEL PARK , FORMER LOCATION OF USTS	1502 WASHINGTON STREET, RENO 89503	1/1/1900	LUST	Ground Water	Confirmed Release	Gasoline
13	4-000476	WASHOE COUNTY PUBLIC WORKS DEPARTMENT , APN 021-456-18	3031 LONGLEY LANE, RENO 89502	10/12/2010	non-LUST	Ground Water	Investigation	Solvents -- Trichloroethene
14	4-000502	GO-FER MARKET , APN 003-091-18	4600 NORTH VIRGINIA STREET, RENO 89506	1/1/1900	LUST	Ground Water	Confirmed Release	Gasoline
15	4-000502	GO-FER MARKET	4600 NORTH VIRGINIA STREET, RENO 89506	4/12/2004	LUST	Soil	Investigation	Gasoline
16	4-000503	HERTZ RENT-A-CAR , APN 015-210-34	1551 NATIONAL GUARD WAY, RENO 89502	10/31/2012	LUST	Soil & Ground Water	Confirmed Release	Gasoline
17	4-000519	NATIONAL RENT-A-CAR	1675 NATIONAL GUARD WAY, RENO 89502	1/1/1900	LUST	Ground Water	Confirmed Release	Gasoline
18	4-000594	WASHOE COUNTY SCHOOL DISTRICT , RENO HIGH SCHOOL	395 BOOTH STREET, RENO 89509	6/26/2014	non-LUST	Soil	Confirmed Release	Heating Oil
19	4-000744	CHUCK'S CIRCLE C MARKET , APN 087-283-01	20255 COLD SPRINGS DRIVE, RENO 89508	8/22/2008	LUST	Soil & Ground Water	Confirmed Release	Gasoline
20	4-000830	MAACO AUTO PAINTING & BODY SHOP	2445 EAST 2ND STREET, RENO 89502	4/29/1999	non-LUST	Soil	Investigation	Other -- Diesel, propane, paints, thinners
21	4-000981	MILLS LANE JUSTICE CENTER	1 SOUTH SIERRA STREET, RENO	8/5/2004	non-LUST	Soil & Ground Water	Confirmed Release	TPH
22	4-000984	CONVENIENCE CORNER SHELL , APN 037-030-13	295 SPARKS BOULEVARD, SPARKS 89434	8/7/2008	LUST	Soil & Ground Water	Confirmed Release	Gasoline -- MTBE
23	D-000007	AMERICAN AUTO WRECKING	495 PARR CIRCLE, RENO	7/8/1999	_	Soil	Investigation	Unknown
24	D-000007	AMERICAN AUTO WRECKING	495 PARR CIRCLE, RENO	4/22/2004	non-LUST	Soil	Investigation	Gasoline
25	D-000025	RENO DRAIN OIL SERVICE , APN 084-090-15	11970 I-80 EAST, SPARKS 89434	5/4/2000	Mobile Source	Soil	Confirmed Release	Motor Oil
26	D-000044	SOLARI DECORATING CENTER	1745 WELLS AVENUE, RENO 89505	9/29/1988	non-LUST	Soil & Ground Water	Confirmed Release	Heating Oil
27	D-000086	GLORY TEMPLE CHURCH	16255 SOUTH VIRGINIA STREET, RENO	2/25/2003	_	Soil	Investigation	Other
28	D-000090	GORDON TRUCKING MOBILE SOURCE	HOGE ROAD @ NORTH VIRGINIA STREET, RENO 89506	4/2/2003	_	Soil	Confirmed Release	Diesel
29	D-000092	RYDER TRANSPORTATION MOBILE SOURCE	39 WEBB CIRCLE, RENO 89506	4/30/2003	_	Soil	Confirmed Release	Diesel
30	D-000099	AL EBANS PROPERTY	1629 G STREET, SPARKS	6/2/2003	_	Soil	Investigation	Unknown
31	D-000100	CITY OF RENO REDEVELOPMENT AGENCY	111 MORRILL AVENUE, RENO 89512	4/23/2008	non-LUST	Soil & Ground Water	Confirmed Release	TPH -- oil and tar
32	D-000116	WESTERN NEVADA RECYCLING	1325 HYMER AVENUE, SPARKS	9/15/2003	_	Soil	Confirmed Release	Other -- Non-PCB Mineral Oil
33	D-000116	WESTERN NEVADA RECYCLING	1325 HYMER AVENUE, SPARKS	11/29/2001	non-LUST	Soil	Confirmed Release	TPH -- and Lead
34	D-000142	RENO DISPOSAL/WASTE MANAGEMENT SPILL	5728 RIVER BIRCH DRIVE, RENO 89511	6/2/2004	non-LUST	Soil	Confirmed Release	Diesel
35	D-000561	WELLS MANUFACTURING COMPANY , APN 038-060-09	2 ERIC CIRCLE, VERDI 89439	7/15/1991	non-LUST	Ground Water	Confirmed Release	Solvents -- Trichloroethene and Tetrachloroethene
36	D-000729	ROBERT MCDERMOTT PROPERTY	537 GORDON AVENUE, RENO 89509	10/28/1994	non-LUST	Soil	Confirmed Release	Heating Oil
37	D-000740	RENO OLD TOWN MALL ANNEX	180 WEST PECKHAM LANE, RENO 89509	5/10/2006	non-LUST	Soil & Ground Water	Confirmed Release	Solvents -- Tetrachloroethene
38	D-000749	ARTIST CLEANERS , APN 020-181-10	225 GENTRY WAY, RENO 89502	1/17/2007	non-LUST	Ground Water	Confirmed Release	Solvents -- Tetrachloroethene
39	D-000757	TIMOTHY A. & KRISTINE K. NORTHON PROPERTY	315 STEWART STREET, RENO 89502		_	_	_	_
40	D-000766	RESOLVENT, INC.	831 DEMING WAY, SPARKS 89431	11/15/2007	non-LUST	Ground Water	Confirmed Release	Solvents -- Trichloroethene
41	D-000769	PLUMB LANE PLAZA , RAINBOW CLEANERS	499 EAST PLUMB LANE, RENO 89502	4/13/2004	non-LUST	Ground Water	Investigation	Solvents -- Tetrachloroethene
42	D-000775	ORCHARD PLAZA SHOPPING CENTER , APN 019-160-33	2293 SOUTH VIRGINIA STREET, RENO 89502	9/10/2008	non-LUST	Soil & Ground Water	Confirmed Release	Solvents -- Tetrachloroethene
43	D-000785	THE FOOTHILLS AT WINGFIELD SPRINGS	6500 SPANISH SPRINGS ROAD, SPARKS 89436		_	_	_	_
44	D-000797	FRANKLIN SPARKS, LLC , APN 034-163-03	1300 FRANKLIN WAY, SPARKS 89431	6/19/2009	non-LUST	Soil	Confirmed Release	Other -- Sulfuric Acid
45	D-000807	NEVADA PACIFIC DEVELOPMENT CORPORATION , APN 123-032-01	61 SOMERS LOOP, INCLINE VILLAGE 89451	1/29/2010	non-LUST	Soil	Investigation	Heating Oil
46	D-000808	JOHN DIFRANCESCO PROPERTY , APN 012-272-12	35 NORTH EDISON WAY, RENO 89502	2/17/2010	Brownfields	Unknown	Investigation	Unknown
47	D-000809	JOHN DIFRANCESCO PROPERTY , APN 012-272-10	65 NORTH EDISON WAY, RENO 89502	2/17/2010	Brownfields	Unknown	Investigation	Unknown

48	D-000817	DAVID G. MENCHETTI PROPERTY	1145 LAKESHORE BOULEVARD, INCLINE VILLAGE 89451		_	_	_	_
49	D-000837	DONALD L. SINNAR PROPERTY , APN 011-216-01	604 LANDER STREET, RENO 89509	11/18/2011	non-LUST	Soil	Confirmed Release	Heating Oil
50	D-000852	DEL MONTE PLAZA , APN 040-141-04	6001 SOUTH VIRGINIA STREET, RENO 89502	12/18/2012	non-LUST	_	Confirmed Release	Solvents -- Tetrachloroethene
51	D-000853	ALTAIR NANOTECHNOLOGIES, INC. , APN 012-319-13	204 EDISON WAY, RENO 89502	11/14/2012	non-LUST	Ground Water	Confirmed Release	Solvents -- Trichloroethene, Tetrachloroethene, cis-1,2-Dichloroethene
52	D-000854	ROGER M. MATEOSSIAN RESIDENCE	2245 KOLDEWEY DRIVE, RENO 89509		_	_	_	_
53	D-000857	GARY N. CORNWALL PROPERTY , APN 013-116-10	864 SOUTH WELLS AVENUE, RENO 89502	1/17/2013	non-LUST	Soil	Confirmed Release	Heating Oil
54	D-000862	HAMILTON COMPANY USA	4970 ENERGY WAY, RENO 89502	1/31/2013	non-LUST	Ground Water	Confirmed Release	Solvents -- cis-1,2-Dichloroethene
55	D-000885	BRE/RENO PROPERTY OWNER, LLC , APN 090-051-06	12040 MOYA BOULEVARD, RENO 89506	2/5/2014	non-LUST	Soil	Confirmed Release	TPH -- Transformer Oil
56	D-000891	JON & MICHELLE JENTZ PROPERTY , APN 013-335-04	1395 AIRMOTIVE WAY, RENO 89502	9/11/2014	non-LUST	Soil	Confirmed Release	Motor Oil
57	D-000895	L & G PROPERITES LLC , APN 019-043-30	2044 PLUMAS STREET, RENO 89509	11/19/2014	non-LUST	Soil	Confirmed Release	Heating Oil
58	D-001019	INCLINE DRY CLEANERS , INCLINE VILLAGE	889 TAHOE BOULEVARD, INCLINE VILLAGE	8/6/2013	non-LUST	Ground Water	Confirmed Release	Solvents -- 15 ppb PCE in groundwater
59	D-001120	VIKING METALLURGICAL CORPORATION	1 ERIC CIRCLE, VERDI 89439	12/16/2009	non-LUST	Soil	Confirmed Release	Other -- Hydraulic Oil
60	D-001235	FORMER TEXACO SERVICE STATION , APN 032-065-10	1922 VICTORIAN AVENUE, SPARKS	11/25/1997	non-LUST	Ground Water	Confirmed Release	Gasoline
61	D-001269	TRUCKEE MEADOWS COMMUNITY COLLEGE	7000 DANDINI BOULEVARD, RENO 89512	7/6/1998	_	Soil	Confirmed Release	Other -- transformer oil
62	D-001272	NEVADA CLUB CASINO	224 NORTH VIRGINIA STREET, RENO 89501	7/7/1998	_	Soil	Investigation	15-3700 ppm petroleum product (Phase I)
63	D-001274	ALLIED WASHOE FUEL	2282 LARKIN CIRCLE, SPARKS 89513	7/16/1998	_	_	Confirmed Release	Motor Oil
64	D-001275	BONANZA PRODUCE	1925 FREEPORT BOULEVARD, SPARKS 89431	7/16/1998	_	Soil	Confirmed Release	Gasoline -- Vandalism of company vehicles (Gas & Diesel)
65	D-001277	GIUDICI RESIDENCE	135 CRESTVIEW PLACE, RENO	8/12/1998	_	Soil	Confirmed Release	Heating Oil -- P. Donald monitoring
66	4-000010	SPARKS TERMINAL #1	147 SOUTH STANFORD WAY, SPARKS 89431	12/28/2007	non-LUST	Soil	Confirmed Release	Other -- Ethanol
67	4-000743	UNITED PARCEL SERVICE	369 EAST GLENDALE AVENUE, SPARKS	1/1/1997	non-LUST	Soil	Confirmed Release	Motor Oil
68	4-000917	RMC NEVADA PLANT	2200 BARNETT WAY, RENO	10/13/2004	Mobile Source	Soil & Ground Water	Confirmed Release	Diesel
69	4-001061	EXPRESS SUPERMART #15 , APN 036-540-08	1470 EAST PRATER WAY, SPARKS 89434	6/22/2000	LUST	Soil	Investigation	Gasoline
70	D-000001	COMMERCIAL PROPERTY	9302 PROTOTYPE DRIVE, RENO	4/9/1998	non-LUST	Soil	Confirmed Release	Diesel
71	D-000385	IDLEWILD PARK	1821 IDELWILD DRIVE, RENO 89505	1/1/1900	non-LUST	Soil	Confirmed Release	_

Contaminant Release Sites - Inactive

ID	Site ID	Facility Name	Facility Address	Report Date	Closure Date	Closure Type	Program	Media	Contaminant
1	4-000017	ARCO #0437 , APN 006-121-27	700 Keystone Avenue	5/19/2003	5/31/2013	NAC 445A.22745	LUST	Ground Water	Gasoline
2	4-000046	Budget Car Rental #3801 , APN 015-210-34	1600 National Guard Way	8/9/2005	11/5/2012	Clean w/ Remed	LUST	Ground Water	Gasoline
3	4-000087	Regional Transportation Commission Washoe County	2050 Villanova Drive	2/22/2012	8/9/2013	Clean w/ Remed	non-LUST	Soil	Other
4	4-000340	Shell Service Station	3295 Kietzke Lane	3/24/2003	9/18/2012	NAC 445A.22725 (2)	LUST	Ground Water	Gasoline
5	4-000419	Unocal SS #5614	190 West Plumb Lane	2/15/2005	1/21/2010	NAC 459.9978	LUST	Ground Water	Gasoline
6	4-000476	Washoe County Public Works Department , APN 021-456-18	3031 Longley Lane	6/30/2014	11/10/2014	Petro Constituents	non-LUST	Soil	TPH
7	4-000507	ARCO #4950 , APN 025-290-16	6190 South Virginia Street	1/1/1993	3/6/2013	Clean w/ Remed	LUST	Ground Water	Gasoline
8	4-000512	Buggy Bath Car Wash , APN 019-202-25	2525 South Virginia Street	12/10/2010	2/24/2011	NAC 445A A-K	non-LUST	Soil	Other
9	4-000519	National Rent-A-Car	1675 National Guard Way	1/1/1900	1/23/2015	NAC 445A.22725 (2)	LUST	Ground Water	Gasoline
10	4-000573	City of Reno Police Department	455 East 2nd Street	1/1/1900	3/5/2014	NAC 445A.22725 (2)	LUST	Ground Water	Gasoline
11	4-000594	Washoe County School District , Reno High School	395 Booth Street	6/26/2014	1/16/2015	Petro Constituents	non-LUST	Soil	Heating Oil
12	4-000732	North Valley Satellite Bus Yard , Bus Yard	330 Doubleback Road	1/17/2011	3/22/2011	Clean w/ Remed	Mobile Source	Soil	Diesel
13	4-000826	USA Petroleum Corporation #207	2299 Oddie Boulevard	4/17/2006	3/11/2011	NAC 459.9978	LUST	Soil & Ground Water	Gasoline
14	4-000931	Jacksons Food Stores #19 , APN 008-185-34	695 North Wells Avenue	11/24/2014	12/22/2014	Clean w/ Remed	LUST	Soil	Diesel
15	4-001040	Express Supermart #14 , 021-465-03	4997 Longley Lane	10/4/2004	4/5/2010	NAC 459.9978	LUST	Ground Water	Gasoline
16	D-000117	Union Pacific Railroad Company , Mile Post 245.40	0 Stanford Way	10/27/2010	2/4/2011	NAC 445A A-K	Mobile Source	Soil	Other
17	D-000170	Ormat Technologies, Inc. , Production Well #2-1	1010 Power Plant Road	1/20/2014	4/1/2014	Petro Constituents	non-LUST	Soil	TPH
18	D-000170	Ormat Technologies, Inc. , Production Well #3-3	1010 Power Plant Road	1/6/2014	3/21/2014	Petro Constituents	non-LUST	Soil	TPH
19	D-000170	Ormat Technologies, Inc. , Production Well #3-2	1010 Power Plant Road	2/1/2010	9/2/2010	Clean w/ Remed	non-LUST	Soil	Other
20	D-000170	Ormat Technologies, Inc. , Production Well #1	1010 Power Plant Road	3/15/2013	5/24/2013	Clean w/ Remed	non-LUST	Soil	TPH
21	D-000170	Ormat Technologies, Inc. , Production Well 21-5R	1010 Power Plant Road	11/17/2011	5/25/2012	Clean w/ Remed	non-LUST	Soil	Other
22	D-000170	Ormat Technologies, Inc.	1010 Power Plant Road	7/29/2009	1/6/2010	Clean w/ Remed		Soil	Other
23	D-000207	Sierra Chemical Company , APN 034-171-42	2302 Larkin Circle	12/17/2012	7/15/2013	Clean w/ Remed	non-LUST	Ground Water	Solvents
24	D-000209	John Ascuaga's Nugget , APN 032-172-22	1100 Nugget Avenue	7/16/2010	12/21/2010	Clean w/ Remed	non-LUST	Ground Water	Diesel
25	D-000514	Airport Authority of Washoe County , South end of Runway 14/32 (Near Bravo Ave)	5045 Alpha Avenue	11/1/2013	2/21/2014	Petro Constituents	Mobile Source	Soil	Jet Fuel/Av Gas
27	D-000734	Bruno Benna Residence	8500 Dieringer Road	5/18/2006	9/29/2011	NAC 445A A-K	non-LUST	Soil & Ground Water	Heating Oil
28	D-000759	701 South Virginia LLC , APN 011-232-13	734 South Virginia Street	12/13/2011	1/26/2012	Clean w/ Remed	non-LUST	Soil	Heating Oil
29	D-000759	701 South Virginia LLC , APN 011-232-13	734 South Virginia Street	8/23/2011	10/24/2011	NAC 445A A-K	non-LUST	Soil	Heating Oil
31	D-000791	Cox Enterprises , APN 012-342-18	4920 Brookside Court	5/15/2008	4/23/2010	NAC 445A.22745	non-LUST	Soil & Ground Water	Diesel
32	D-000799	San Antonio Ranch, LLC , APN 005-200-79	7000 Franktown Road	8/18/2009	8/18/2010	NAC 445A A-K	non-LUST	Soil	Heating Oil
33	D-000802	City of Sparks , APN 032-136-06	1212 Victorian Avenue	10/5/2009	3/7/2011	NAC 445A A-K	non-LUST	Soil	Heating Oil
34	D-000804	Lance J. Eklund Property , APN 009-131-52	170 Juniper Hill Road	10/22/2009	3/10/2010	NAC 445A A-K	non-LUST	Soil	Heating Oil
35	D-000810	National Wild Horse and Burro Center , APN 076-251-02	15780 Pyramid Way	2/9/2010	12/8/2010	Clean w/ Remed	non-LUST	Soil	Diesel
36	D-000811	Brian S. Wallace Property , APN 011-265-19	739 Plumas Street	3/25/2010	6/9/2010	Clean w/ Remed	non-LUST	Soil	Heating Oil
37	D-000812	Carol A. Flanagan Residence , APN 011-293-13	1165 Monroe Street	5/19/2010	6/9/2010	Clean w/ Remed	non-LUST	Soil	Heating Oil
38	D-000813	Whitney B. Hackstaff Residence , APN 019-261-05	55 Rancho Manor Drive	6/7/2010	11/5/2010	NAC 445A A-K	non-LUST	Soil	Heating Oil
39	D-000814	Central Oregon Truck Company Mobile Source , APN 037-400-02	1550 East Lincoln Way	5/19/2010	7/13/2010	NAC 445A A-K	Mobile Source	Soil	Diesel
40	D-000815	River Senior Partners , APN 012-051-24	Kuenzli Street @ Sutro Street	7/6/2010	10/21/2010	Clean w/ Remed	non-LUST	Soil	Heating Oil
44	D-000819	Northwest Liquidators Mobile Source , APN 007-303-39	East 5th Street	8/30/2010	2/8/2011	UST Clean Closure	Mobile Source	Soil	Diesel
45	D-000822	Leah C. Silverman Property , APN 013-024-17	759 Stewart Street	12/16/2010	2/14/2011	NAC 445A A-K	non-LUST	Soil	Heating Oil
46	D-000823	Estancia Reno LLC , APN 202-232-11	1424 Hogadon Way	12/28/2010	2/18/2011	Clean w/ Remed	Mobile Source	Soil	Diesel
47	D-000825	Nevada-Utah Conference of Seventh-day Adventists , APN 013-137-10	845 Yori Avenue	6/21/2011	8/12/2011	Clean w/ Remed	non-LUST	Soil	Heating Oil
48	D-000826	Cassinelli Brothers, LLC , APN 034-040-17	1650 Freeport Boulevard	6/29/2011	9/29/2011	Clean w/ Remed	Mobile Source	Soil	Diesel
49	D-000827	Lutheran Church of the Good Shepard , APN 011-152-39	501 California Avenue	7/15/2011	8/3/2011	Clean w/ Remed	non-LUST	Soil	Heating Oil
51	D-000830	Patrick D. Fitzgerald Property , APN 061-090-31	State Route 34	9/6/2011	11/17/2011	Clean w/ Remed	non-LUST	Soil	Diesel
52	D-000830	Patrick D. Fitzgerald Property , APN 061-130-33	State Route 34	9/6/2011	3/14/2012	NAC 445A A-K	non-LUST	Soil	Diesel
53	D-000831	Fort Dearborn Company , APN 037-252-16	295 Lillard Drive	6/21/2011	2/8/2012	Clean w/ Remed	non-LUST	Soil	TPH
54	D-000832	Charles P. Bluth Property , APN 023-121-41	2025 Meadowview Lane	10/11/2011	11/28/2011	Clean w/ Remed	non-LUST	Soil	Heating Oil

55	D-000834	Carl E. Friberg Property , APN 033-042-02	1380 Breaker Way	9/23/2011	10/3/2012	Other	non-LUST	Soil	Heating Oil
57	D-000838	Richard G. Behlmer Residence , APN 018-132-02	1414 Coronet Boulevard	11/29/2011	1/10/2012	NAC 445A A-K	non-LUST	Soil	Heating Oil
58	D-000839	Renown Health , APN 013-031-08	1150 Ryland Street	11/30/2011	11/14/2011	Clean w/ Remed	non-LUST	Soil	Heating Oil
59	D-000840	NV Energy , APN 004-143-02	0 Gaslight Lane	1/26/2012	8/10/2012	Clean w/ Remed	non-LUST	Soil	Diesel
60	D-000841	Nevada Department of Transportation	Interstate 80 @ Vine Street	3/20/2012	6/5/2012	UST Clean Closure	non-LUST	Soil	Heating Oil
61	D-000842	Sylvia Family Properties , APN 088-242-05	0 North Hills Boulevard	5/11/2012	12/6/2012	Clean w/ Remed	Mobile Source	Soil	TPH
62	D-000843	Joseph M. McDonnell Property , APN 019-021-09	1627 Hoyt Street	6/11/2012	8/13/2012	Clean w/ Remed	non-LUST	Soil	Heating Oil
63	D-000844	Lion Mountain Properties, Inc. , APN 020-241-39	1500 Gentry Way	8/1/2012	3/11/2013	NAC 445A A-K	non-LUST	Soil	TPH
64	D-000845	Charles R. Sherven Residence , APN 040-692-09	3705 Lamay Lane	8/13/2012	11/27/2012	Clean w/ Remed	non-LUST	Soil	Heating Oil
66	D-000847	Menachem & Chaya Sara Cunin Residence , APN 023-131-18	3600 Clover Way	10/1/2012	11/27/2012	Clean w/ Remed	non-LUST	Soil	Heating Oil
67	D-000849	North American Van Lines Mobile Source , APN 032-166-14	0 Nugget Avenue	7/12/2012	10/30/2012	Other	Mobile Source	Soil	Diesel
69	D-000851	Rocky Mountain Recycling Mobile Source , APN 026-284-17	2380 Oddie Boulevard	12/3/2012	2/21/2013	Clean w/ Remed	Mobile Source	Soil	Diesel
70	D-000856	Washoe County Public Works Department , APN 008-164-17	842 Spokane Street	1/16/2013	4/29/2013	Clean w/ Remed	non-LUST	Soil	Heating Oil
72	D-000859	NV Energy , APN 021-281-07	4650 Foxfire Drive	4/18/2013	6/21/2013	Clean w/ Remed	non-LUST	Soil	TPH
73	D-000860	Truckee Meadows Business Park , APN 034-410-03	310 Coney Island Drive	4/17/2013	6/21/2013	NAC 445A A-K	non-LUST	Soil	Diesel
74	D-000864	James R. Muff Property , APN 009-111-08	4695 Canyon Drive	5/16/2013	12/6/2013	Clean w/ Remed	non-LUST	Soil	Heating Oil
75	D-000865	Mountain Top Sports	11000 Mount Rose Highway	7/1/2013	7/15/2013	NAC 445A A-K	non-LUST	Soil	Heating Oil
76	D-000866	Blue Crush, LLC , APN 011-212-05	601 South Arlington Avenue	7/30/2013	9/25/2013	Other	non-LUST	Soil	Heating Oil
77	D-000867	Truckee-Tahoe Lumber Company , APN 032-250-30	1550 Hymer Avenue	9/19/2013	10/14/2013	Other	non-LUST	Soil	TPH
78	D-000868	John E. Fitzpatrick Property , APN 010-224-23	1016 Dennison Drive	9/23/2013	10/17/2013	Other	non-LUST	Soil	Heating Oil
79	D-000869	James R. Brown Property , APN 007-111-01 1152 Ralston St.	1152 Ralston Street	10/9/2013	10/29/2013	Clean w/ Remed	non-LUST	Soil	Heating Oil
80	D-000870	Derek Warneke Property , APN 014-211-05	410 West Pueblo Street	10/10/2013	8/19/2014	Petro Constituents	non-LUST	Soil	Heating Oil
81	D-000872	Center for Advanced Medicine , APN 012-371-19	901 East 2nd Street	10/26/2013	12/13/2013	Clean w/ Remed	non-LUST	Soil	TPH
82	D-000873	Sierra View Animal Hospital , APN 025-300-10	6200 South Virginia Street	9/11/2013	11/22/2013	NAC 445A A-K	non-LUST	Soil	Heating Oil
83	D-000874	Washoe County School District , APN 017-011-22	684 State Route 341	11/25/2013	2/20/2014	Petro Constituents	non-LUST	Soil	Diesel
84	D-000875	Arthur L. Farley Property , APN 011-272-19	761 South Virginia Street	12/20/2013	1/13/2014	NAC 445A A-K	non-LUST	Soil	Heating Oil
85	D-000876	U.S. Department of Labor , APN 086-144-01	14175 Mount Charleston Street	12/26/2013	1/30/2014	Clean w/ Remed	non-LUST	Soil	Heating Oil
86	D-000877	JEF Enterprises, LLC , APN 007-011-12	1505 North Virginia Street	1/6/2014	11/14/2014	NAC 445A A-K	non-LUST	Soil	Heating Oil
87	D-000878	Loretta J. Jones Property , APN 016-483-06	14525 Rim Rock Drive	8/9/2013	5/28/2014	Petro Constituents	non-LUST	Soil	Heating Oil
89	D-000882	City of Sparks Redevelopment Agency , APN 037-020-50	550 Marina Gateway Drive	3/6/2014	4/22/2014	Petro Constituents	Brownfields	Soil	Motor Oil
90	D-000883	Landcap Sparks, LLC , APN 037-020-51	650 Marina Gateway Drive	3/6/2014	4/22/2014	Petro Constituents	non-LUST	Soil	Motor Oil
91	D-000884	Jeffrey L. Morby Property , APN 014-204-11	473 West Plumb Lane	3/25/2014	7/9/2014	Petro Constituents	non-LUST	Soil	Heating Oil
92	D-000887	James L. Tuntland Residence , APN 019-261-09	25 Rancho Manor Drive	4/22/2014	7/17/2014	NAC 445A A-K	non-LUST	Soil	Heating Oil
93	D-000888	Daniel G. Buhrmann Residence , APN 040-692-10	4040 Fairview Road	6/24/2014	9/24/2014	Petro Constituents	non-LUST	Soil	Heating Oil
94	D-000890	Charlene M. Herman Property , APN 010-361-42	1785 Adas Street	8/20/2014	9/24/2014	Clean w/ Remed	non-LUST	Soil	Heating Oil
95	D-000891	Jon & Michelle Jentz Property , APN 013-335-04	1395 Airmotive Way	9/11/2014	4/20/2015	Clean w/ Remed	non-LUST	Soil	Motor Oil
96	D-000892	Charlene M. Herman Property , APN 010-361-40	1795 Adas Street	9/23/2014	12/2/2014	Clean w/ Remed	non-LUST	Soil	Heating Oil
97	D-000893	Charles E. Clock Residence , APN 002-344-04	1234 Washington Street	10/15/2014	12/2/2014	Clean w/ Remed	non-LUST	Soil	Heating Oil
98	D-000894	Charles T. Mazza Property , APN 004-233-03	1240 Oliver Avenue	11/13/2014	12/2/2014	Clean w/ Remed	non-LUST	Soil	Heating Oil
99	D-000896	McCarran Mansion LLC , APN 011-101-05	401 Court Street	12/22/2014	1/20/2015	Clean w/ Remed	non-LUST	Soil	Heating Oil
100	D-000898	Airport Gardens Investors, LLC , APN 013-331-15	1325 Airmotive Way	1/8/2015	2/11/2015	Petro Constituents	non-LUST	Soil	Heating Oil
101	D-000899	The Stacie Mathewson Community Wellness Center , APN 007-541-02	580 West 5th Street	1/19/2015	2/5/2015	Clean w/ Remed	non-LUST	Soil	Heating Oil
102	D-000900	Veterans Guest House, Inc. , APN 013-124-19	629 East Taylor Street	1/21/2015	2/11/2015	Petro Constituents	non-LUST	Soil	Heating Oil
103	D-000901	Northern Nevada HOPES , APN 007-541-03	467 Ralston Street	2/3/2015	2/18/2015	Clean w/ Remed	non-LUST	Soil	Heating Oil
104	D-000902	Thomas R. Lamb Property , APN 040-670-11	3600 Holcomb Ranch Lane	2/26/2015	3/31/2015	Petro Constituents	non-LUST	Soil	Heating Oil
105	D-000903	Michael A. Knowles Residence , APN 006-091-16	545 Northstar Drive	2/26/2015	3/31/2015	Petro Constituents	non-LUST	Soil	Heating Oil
106	D-001266	Comp USA Center , Save-on Cleaners	6405 South Virginia Street	3/22/2006	4/30/2013	NAC 445A.22745	non-LUST	Soil & Ground Water	Solvents
107	D-001285	University of Nevada, Reno , 1048 North Sierra Street	Various Locations	4/15/2014	6/19/2014	Petro Constituents	non-LUST	Soil	Heating Oil
108	D-001285	University of Nevada, Reno , 1034 North Sierra Street	Various Locations	2/26/2014	3/25/2014	Petro Constituents	non-LUST	Soil	Heating Oil
109	D-001285	University of Nevada, Reno , 1065 North Sierra Street	Various Locations	2/26/2014	3/26/2014	Petro Constituents	non-LUST	Soil	Heating Oil
110	D-001288	Airport Authority of Washoe County , APN 015-210-34	Various Locations	8/30/2011	12/5/2011	NAC 445A A-K	non-LUST	Soil	TPH

111	D-001288	Airport Authority of Washoe County , SW Cor Mill and S. Rock	Various Locations	10/28/2010	1/24/2011	Invest Closed	non-LUST	Soil	TPH
112	D-001288	Airport Authority of Washoe County , APN 015-210-34	Various Locations	3/19/2013	3/21/2014	NAC 445A A-K	Mobile Source	Soil	Jet Fuel/Av Gas
113	D-001288	Airport Authority of Washoe County	Various Locations	7/26/2011	9/22/2011	Clean w/ Remed	Mobile Source	Soil	Diesel
114	D-001288	Airport Authority of Washoe County , Jet West FBO Center 1880 Gentry Way	Various Locations	7/12/2010	1/21/2011	Clean w/ Remed	non-LUST	Soil	TPH

POTENTIAL CONTAMINANT SOURCE -- CEG (EPA)

ID	Name	Street	CITY	EPA ID
1	LIFETOUCH PORTRAIT STUDIOS	7955 SECURITY CIR	RENO	NVD982041345
2	LITHIA RENO SUBARU DBA LITHIA BODY &	657 GROVE ST	RENO	NVR000078014
3	LITHIA RENO SUBARU	2270 KIETZKE LN	RENO	NVD982461469
4	LOWES H I W INC #321	5075 KIETZKE LN	RENO	NVR000050435
5	MAACO AUTO PAINTING & BODYWORKS	2245 HARVARD WY	RENO	NVR000073775
6	MIDAS MUFFLER	KEYSTONE AVE	RENO	NVR000000927
7	SEPHORA STORE NO.040	13915 S VIRGINIA ST STE 110	RENO	NVR000083402
8	SHERWIN WILLIAMS 8657	9748 S VIRGINIA ST STE G	RENO	NVR000085969
9	SIERRA PACIFIC POWER COMPANY	7 OHM PL	RENO	NVD982373342
10	SILVER STATE AUTOMOTIVE	580 GENTRY WY	RENO	NVD986771707
11	SLIVER LEGACY RESORT CASINO	407 N VIRGINIA ST	RENO	NVR000044982
12	SOUTHGATE CHEVRON AUTOMOTIVE	LOUIE LN STE 5	RENO	NVR000001453
13	SPARKS CITY OF	8500 CLEANWATER WY	RENO	NVD000853465
14	SPPCO - FLEET SERVICES	295 EDISON WY	RENO	NVD047886791
15	STEAMBOAT DEVELOPMENT CORP	1010 POWER PLANT DR	RENO	NVR000083626
16	STEAMBOAT HILLS LLC	20590 WEDGE PKWY	RENO	NVR000084434
17	SUPERGLO AUTO BODY	314 SUNSHINE LANE	RENO	NVR000038588
18	SUREFIRE, LLC	4750 LONGLEY LN, STE 201	RENO	NVR000086686
19	THE AMES COMPANIES INC	3450 AIRWAY DR STE 100	RENO	NVR000089839
20	THE AUTO HOSPITAL	890 GENTRY WAY	RENO	NVD986770410
21	A 1 RADIATOR REPAIR INC	875 E SECOND ST	RENO	NVD981639586
22	A-1 TRANSMISSION INC	670 E GROVE ST	RENO	NVR000078576
23	ADVANCED AUTOMOTIVE	430 ELKO AVE	RENO	NVD986770360
24	ALPINE HEMATOLOGY ONCOLOGY LTD	236 W SIXTH ST STE 400	RENO	NVR000076067
25	AMEC ENVIRONMENT & INFRASTRUCTURE INC	961 MATLEY LANE SUITE 110	RENO	NVR000088237
26	AMERICAN AIRLINES INC	1500 TERMINAL WAY STE I	RENO	NVR000083055
27	ANIXTER INC RENO LOC 333	990 N HILLS BLVD	RENO	NVR000002881
28	ARROW GLOBAL ASSET DISPOSITION INC	9085 MOYA BLVD #100	RENO	NVR000085837
29	AVIATION CLASSICS LTD	4825 TEXAS AVE	RENO	NVD986769016
30	AVIS RENT A CAR	NATL GUARD WY	RENO	NV0000452557
31	HUTCH'S MISSION CAR WASH	6355 S MCCARRAN BLVD	RENO	NVR000076968
32	HV MANUFACTURING	12150 MOYA BLVD	RENO	NVD982436123
33	HVA LLC	12880 MOYA BLVD	RENO	NVR000088484
34	ITAL MOTORS	862 E SECOND ST	RENO	NVD982436321
35	ITRONICS METALLURGICAL INC	14305 MT MCCLELLAN ST	RENO	NVR000043927
36	JOHNS BRITTISH CARS GARAGE	TELEGRAPH UNIT 7	RENO	NVD986776755
37	KELLY MOORE PAINTS	2175 MARKET ST STE A	RENO	NVR000083154
38	KEYSTONE QUALITY PRINTING	W 5TH ST	RENO	NV0000133298
39	LAKERIDGE CLEANERS	6135 LAKESIDE DR SP 107	RENO	NVD982373540
40	TIFFANY CLEANERS	3318 S MCCARRAN BLVD	RENO	NVD982408064
41	TOP HAT CLEANERS	1205 CALIFORNIA AVE	RENO	NVD981673965
42	MOUNT ROSE SKI RESORT	MT ROSE HWY	RENO	NVD986776268
43	NEVADA BELL	1375 CAPITAL BLVD RM 145	RENO	NVD986776904
44	NICKS AUTOMOTIVE	121 LINDEN ST	RENO	NVR000000935

45	NISSAN OF RENO	865 KIETZKE LN	RENO	NVD982477945
46	NORTHWEST TIRE	500 W 4TH ST	RENO	NVD982494122
47	NVARNG HARRY REID COMPLEX	20000 ARMY AVIATION DR	RENO	NVD981575913
48	BARNES DISTRIBUTION	12755 MOYA BLVD	RENO	NVR000081885
49	BARRETT PAINT SUPPLY LTD	1595 VASSAR ST	RENO	NVR000003244
50	BELL LIMOUSINE	1805 E 2ND ST	RENO	NVD986771178
51	BIG O TIRES	1195 E 4TH ST	RENO	NVD986772234
52	BLACK EAGLE CONSULTING INC	1345 CAPITAL BLVD STE A	RENO	NVR000086009
53	BOBS CLEANERS & LAUNDRY	S VIRGINIA ST	RENO	NVD982373433
54	CHAMPION CHEVROLET	2100 AUTOMOTIVE WAY	RENO	NVD986771566
55	CITO AUTO BODY	1890 LEWIS STREET	RENO	NVD982519878
56	CITY OF RENO FIRE DEPARTMENT	315 EDISON WY	RENO	NVD065006058
57	COOPER B-LINE	13755 STEAD BLVD	RENO	NV0000148502
58	CVS PHARMACY #0157	2890 NORTHTOWNE LN	RENO	NVR000085241
59	CVS PHARMACY #6625	1081 STEAMBOAT PKWY	RENO	NVR000086066
60	CVS PHARMACY #7949	75 PRINGLE WY, STE 102	RENO	NVR000086926
61	CVS PHARMACY #8793	285 E PLUMB LN	RENO	NV0000452508
62	CVS PHARMACY #8806	1250 WEST 7TH ST	RENO	NVR000043174
63	CVS PHARMACY #9168	1119 CALIFORNIA AVE	RENO	NVR000073494
64	CVS PHARMACY #9191	5019 S MCCARRAN BLVD	RENO	NVR000038000
65	CVS PHARMACY #9840	8005 S VIRGINIA ST	RENO	NVR000047134
66	CVS PHARMACY #9841	1695 ROBB DR	RENO	NVR000049072
67	CVS PHARMACY #9964	170 LEMMON DR	RENO	NVR000076562
68	CVS PHARMACY #9974	3360 S MCCARRAN BLVD	RENO	NVR000087072
69	DASSAULT AIRCRAFT SERVICES RENO	365 S ROCK BLVD	RENO	NVR000003152
70	DATA FORMS INC	1070 MATLEY LN	RENO	NVD982501835
71	DIPACO DIESEL PARTS USA	E PARR BLVD	RENO	NVR000000083
72	DYNAMIC PAINTERS INC	3550 BARRON WAY STE 6B	RENO	NVR000059030
73	EL DORADO HOTEL CASINO	345 N VIRGINIA	RENO	NVD986769800
74	ELECTRONIC EVOLUTION TECHNOLOGIES, INC	9455 DOUBLE R BLVD	RENO	NVR000074203
75	FAMILY DOLLAR #9174	10525 STEAD BLVD	RENO	NVR000090589
76	FEDERAL EXPRESS	1350 AIR CARGO WY	RENO	NV0000069286
77	FEDERAL EXPRESS - R N O A	1440 CAPITAL BLVD	RENO	NVR000076596
78	FIRESTONE 3581	2515 S VIRGINIA ST	RENO	NVD982445637
79	GENERAL MOTORS LLC	6565 ECHO ST	RENO	NVR000078857
80	GREG'S GARAGE INC	410 E 6TH ST	RENO	NVD986769222
81	H2O ENVIRONMENTAL INC	3510 BARRON WAY STE 200	RENO	NVR000084541
82	HARRAHS RENO HOTEL & CASINO	255 LAKE ST	RENO	NVD982436925
83	HD BUILDER SOLUTIONS GROUP INC FL0065	650 INNOVATION DR STE C	RENO	NVR000080432
84	HERTZ CORP THE	1551 NATIONAL GUARD WAY	RENO	NVD982497612
85	HOGAN'S CARB AND TUNE	1335 E 4TH ST	RENO	NV0000031906
86	WALGREENS STORE NO 4789	3495 S VIRGINIA ST	RENO	NVR000050542
87	WASHOE CNTY - LONGLEY LN SHOPS EQUIPMENT SVCS	3035A LONGLEY LN	RENO	NVR000084814
88	WASHOE COUNTY EDISON COMPLEX	230 EDISON WAY	RENO	NVD986774784
89	WASHOE COUNTY FACILITIES MGMT PAINT SHOP	3021 LONGLEY LN	RENO	NVR000084764
90	WASHOE COUNTY GOLF COURSE	2335 W MOANA LN	RENO	NVD986771632
91	WASHOE COUNTY PARKS & REC	WASHINGTON ST	RENO	NVD982445660

92	WASHOE COUNTY ROAD DEPT	3101 LONGLEY LN	RENO	NVD982497703
93	WEDCO INC	450 TOANO ST	RENO	NVR000086355
94	WEST COAST IMAGING	8985 DOUBLE DIAMOND PKY STE B3	RENO	NVR000081588
95	WESTERN DENTAL	8040 S VIRGINIA ST	RENO	NVR000083410
96	PARAMOUNT AUTO BODY INC	2490 TACCHINO ST	RENO	NVD986770097
97	PENSKE TRUCK LEASING CO LP	14331 LEAR BLVD.	RENO	NVD986771392
98	PLATINUM AVIATION	659 S ROCK BLVD	RENO	NVR000082578
99	PRO LINE PRINTING/RR DONNELLEY	365 PARR CIR	RENO	NVR000079954
100	RALEYS #105	1630 ROBB DR	RENO	NVR000080671
101	RALEYS 103/183	1441 MAYBERRY DR	RENO	NV0000889758
102	RALEYS 104/184	4047 S VIRGINIA	RENO	NV0000895284
103	RALEYS 106/186	701 KEYSTONE AVE	RENO	NVR000000604
104	RALEYS 108/188	18144 WEDGE PARKWAY	RENO	NVR000002501
105	RALEYS 115/195	1075 NORTH HILLS BLVD	RENO	NV0000889741
106	RECREATION PUBLICATIONS	4090 S MC CARRAN BLVD STE E	RENO	NVR000067470
107	REED ELECTRIC	5375 LOUIE LN	RENO	NV0000931907
108	RENO AGRICULTURE AND ELECTRIC	4655 AIRCENTER CIR	RENO	NV0000943894
109	RENO AUTO BODY SHOP INC	1975 KUENZLI LN	RENO	NVD982506446
110	RENO CLEANERS	4910 S VIRGINIA ST	RENO	NVD982373607
111	RENO DODGE SALES INC	700 KIETZKE LN	RENO	NVD981440217
112	RENO HARLELY DAVIDSON - BIG HOUSE	2325 MARKET ST STE C	RENO	NVR000085282
113	RENO HARLEY DAVIDSON	2315 MARKET ST	RENO	NVR000085274
114	SATURN OF RENO	1000 KIETZKE LN	RENO	NVD982436263
115	SEARS A C 1978	MEADOWOOD MALL CIR	RENO	NVR000001388
132	TRUCKEE MEADOWS WTR AUTHORITY - CHALK BLUFF WTF	9605 S MCCARRAN BLVD	RENO	NVR000081075
133	TWO MACS	295 GOLDEN LN	RENO	NVD986771087
134	UNITED CONSTRUCTION CO	MILL ST	RENO	NV0000029298
135	UNIVERSITY OF NEVADA RENO - STEAD	5600 FOX AVE	RENO	NVD982443293
136	UNIVERSITY OF NEVADA RENO - VALLEY	1000 VALLEY RD	RENO	NVD986775039
137	UPS RENO GATEWAY	1395 AIR CARGO WY STE 141	RENO	NVR000082743
138	VEKA WEST INC	14250 LEAR BLVD	RENO	NVR000000711
139	VIEWCREST CLEANERS	3623 KINGS ROW	RENO	NVD982465767
140	VITAL SYSTEMS CORP	4999 AIRCENTER CIR STE 101	RENO	NVR000066001
141	WALGREEN STORE NO. 5295	750 N VIRGINIA ST	RENO	NVR000076984

POTENTIAL CONTAMINANT SOURCE -- SQG (EPA)

ID	Name	Street	CITY	EPAID
131	AMERICAN SIGN & CRANE SERVICE INC	1975 TIMBER WAY	RENO	NVR000084517
142	BILL PEARCE BODY SHOP	745 HARVARD WAY	RENO	NVR000040915
143	BOBBY PAGE'S DRY CLEANERS	1090 SANDHILL RD	RENO	NVR000082297
144	ECO PAK LLC	640 ORRCREST DR	RENO	NVR000088500
145	ENTERPRISE RENO LPG TERMINAL	19975 S RENO PARK BLVD	RENO	NVR000089300
146	FABRIC CARE SPECIALIST	900 W MOANA LN STE 102	RENO	NVD982373508
147	FEDEX SMARTPOST	1175 TRADEMARK DR	RENO	NVR000089383
148	GASTROENTEROLOGY CONSULTANTS PATHOLOGY	880 RYLAND ST	RENO	NVR000085316
149	GGG ENTRP INC DBA CONCOURS BODY SHOP	250 TELEGRAPH ST	RENO	NVD105926539
150	GORDON'S PHOTO SERVICE	5067 S MCCARRAN BLVD	RENO	NVR000053777
151	GORE INDUSTRIES, LLC	4850 JOULE ST STE A2	RENO	NVR000081497
152	HOME DEPOT USA INC HD3304	2955 NORTHTOWNE LN	RENO	NVR000079517
153	HOME DEPOT USA INC HD3310	6590 S VIRGINIA ST	RENO	NVR000000182
154	HOME DEPOT USA INC HD3311	5125 SUMMIT RIDGE CT	RENO	NVR000079525
155	HOME DEPOT USA INC HD8560	1001 STEAMBOAT PKWY	RENO	NVR000080325
156	IGT	9295 PROTOTYPE DR	RENO	NVR000001800
157	KMART DISTRIBUTION CENTER 8272	1402 S MC CARRAN BLVD	RENO	NVR000087528
158	LAWSON PRODUCTS	1381 CAPITAL BLVD	RENO	NVR000085498
159	NCM PAINTING INC	1150 W 1ST ST	RENO	NVR000066019
160	NEVADA AGRICULTURE WAREHOUSE	295 GALLETTI WAY	RENO	NVR000090373
161	NEVADA HISTOLOGY INC	1350 STARDUST ST STE D	RENO	NVR000084707
162	NEVADA SCHOOL & SPORT PHOTOGRAPHY INC	1875 E PECKHAM LANE	RENO	NVR000088450
163	PENTAIR VALVES AND CONTROLS US LP	9025 MOYA BLVD	RENO	NVR000073825
164	PYRAMID LAKE FISHERIES- ADELINE DAVIS RESEARCH LABORATORY	603 SUTCLIFFE DR	RENO	NVR000086330
165	RENOWN FAMILY CARE	975 RYLAND AVE	RENO	NVR000037689
166	RUST BULLET LLC	1186 TELEGRAPH ST UNITS EE2-4	RENO	NVR000089615
167	SHERWIN-WILLIAMS #8645	1375 AIRMOTIVE WY	RENO	NVR000082735
168	SIERRA ENVIRONMENTAL MONITORING INC	1135 FINANCIAL BLVD	RENO	NV0000305649
169	TARGET STORE 1363	6845 SIERRA CENTER PKWY	RENO	NVR000075952
170	UNION PACIFIC RR, MP 238.9 ROSEVILLE SUBDIVISION	2666 DICKERSON RD	RENO	NVR000087395
171	UPS FREIGHT	8900 TERABYTE CT	RENO	NVR000085258
172	WALMART SUPERCENTER 2106	2425 E SECOND ST	RENO	NVR000085670
173	WALMART SUPERCENTER 2189	4855 KIETZKE LN	RENO	NVR000001560
174	WALMART SUPERCENTER 3254	5260 W SEVENTH ST	RENO	NVR000080101
175	WALMART SUPERSTORE 3277	155 DAMONTE RANCH PKWY	RENO	NVR000075887
176	WASHOE COUNTY SCHOOL DISTRICT	7495 S VIRGINIA ST	RENO	NV0000133272

POTENTIAL CONTAMINANT SOURCE -- LQG (EPA)

ID	Name	Street	CITY	EPA ID
116	ALS CHEMEX MINERALS	4977 ENERGY WAY	RENO	NVR000083246
117	CAROLINA LOGISTICS SERVICES LLC	12835 OLD VIRGINA RD	RENO	NVR000076034
118	CHARLES RIVER PRECLINICAL SERVICES NEVADA	6995 LONGLEY LN	RENO	NVR000083097
119	COSTCO NO 25	2200 HARVARD WY	RENO	NVD986776169
120	CVS PHARMACY #9586	55 DAMONTE RANCH PKWY	RENO	NVR000078139
121	DUPONT RENO WESTERN DISTRIBUTI ON CENTER	11535 PRODUCTION DRIVE	RENO	NVR000001495
122	KAPPES CASSIDAY & ASSOCIATES	7950 SECURITY CIRCLE	RENO	NVR000073544
123	LEGACY SUPPLY CHAIN SERVICES	5360 CAPITAL CT STE 100	RENO	NVR000089979
124	MD LOGISTICS	12125 MOYA BLVD	RENO	NVR000089029
125	RR DONNELLEY	14100 LEAR BOULEVARD	RENO	NVD981641434
126	RYDER INTEGRATED LOGISTICS (FOR EASTMAN KODAK AND KODAK ALARIS)	1025 SANDHILL RD #B	RENO	NVR000081471
127	SIERRA PACKAGING AND CONVERTING LLC	11005 STEAD BLVD	RENO	NVR000038869
128	THE SHERIWN-WILLIAMS COMPANY - SIERRA NV DSC	12090 SAGEPOINT CT	RENO	NVR000038737
129	THYSSENKRUPP VDM USA INC RENO	14255 MOUNT BISMARK STREET	RENO	NVD092497999
130	UNIVERSITY OF NEVADA, RENO	1605 EVANS AVE.	RENO	NVD981963549

POTENTIAL CONTAMINANT SOURCE -- (EPA)

ID	Name	Street	CITY	EPA ID
177	AAA AUTO SALES AND SERVICE	5520 SUNVALLEY BLVD	RENO	NV0000039081
178	ABACUS REVIVAL	5350 CAPITAL CT #109	RENO	NVR000076406
179	ABB INC	9716 S VIRGINIA ST	RENO	NVR000085894
180	ADVANCED GRAPHIC DESIGNS	340 WESTERN RD NO 8	RENO	NVR000059667
181	ADVANCED GRAPHICS INC	2890 VASSAR 12B	RENO	NVD982006181
182	ADVANCED IMAGING SYS	5655 RIGGINS CT NO 19	RENO	NVR000001776
183	ADVANCED MOTOR WORKS	2800 WRONDEL WAY	RENO	NVD986769172
184	ADVANCED PETROLEUM RECYCLING	550 ELKO ST	RENO	NV0001037886
185	ADVENT SUPPLY INC	125 CATRON DR	RENO	NVR000002592
186	ADVERTISING SPECIALTY CO	2725 YORI AVE	RENO	NVD986775666
187	AEROLITE PLATING CO	1000 TELEGRAPH ST	RENO	NVD981964596
188	AG SCREEN PRINTING	4673 AIRCENTER CIR	RENO	NVD986769891
189	AIRPORT AUTO BODY	1100 GENTRY WY	RENO	NVR000048215
190	ALCOA RECYCLING CO INC	1970 E 4TH ST	RENO	NVD986776250
191	ALL AUTO AND RV	35 E 4TH ST	RENO	NVD986769941
192	ALL POINTS TOWING	2890 VASSAR STE B11	RENO	NV0000133223
193	ALLSTATE CAR RENTAL AND SALES	3355 KIETZKE LN	RENO	NVD982461295
194	1 HOUR FOTO	1158 KIETZKE LANE	RENO	NVD982411753
195	1 HR FOTO	1085 S VIRGINIA ST	RENO	NVR000042275
196	4TH STREET STATION	200 E. 4TH STREET	RENO	NVR000083634
197	7 TH ST CLEANERS	1265 W 7TH ST	RENO	NVD982373656
198	A & L AUTOMOTIVE	220 SUNSHINE LANE	RENO	NVD986769933
199	A 1 BODY SHOP	680 MONTELLO ST	RENO	NVD981628159
200	A 1 BODY SHOP	935 HARVARD WAY	RENO	NVD982434789
201	A 1 BODY SHOP	591 SUNSHINE LANE	RENO	NVD982496333
202	A ACTION TOW	480 MORRILL AVE	RENO	NVD986777209
203	A 1 BATTERY	2825 2 KIETZKE	RENO	NVD986769008
204	AMERICAN VIDEO	4786 CAUGHLIN PKWY NO 302	RENO	NVD986773299
205	CAROLINA LOGISTICS SERVICES LLC	12835 OLD VIRGINA RD	RENO	NVR000076034
206	CHEVRON USA INC RENO AIRPORT	E PLUMB LN AND TERMINAL WY	RENO	NVT000615500
207	A AND J SERVICES	38 WEBB CIRCLE	RENO	NVR000000166
208	A DELUXE BODY AND FRAME	300 SUNSHINE LN	RENO	NVD982429284
209	A J MCNEIL CO	455 WHISKEY SPRINGS RD	RENO	NVD980889158
210	A M R SERVICES	365 S ROCK BLVD	RENO	NVR000003152
211	A S A P PRINTING AND TYPESETTING	1170 S WELLS AVE UNIT 7	RENO	NVD982446841
212	A SAFE LUBE PLUS	1270 N MCCARRAN BLVD	RENO	NVR000087569
213	A T S INC	5020 TEXAS AVE	RENO	NVD986777217
214	AMALGAMATED RECOVERY SYSTEMS	710 HUNTER LAKE DRIVE	RENO	NVD982321093
215	AMERICAN AIRLINES INC	222 E PLUMB LN	RENO	NVR000063438
216	AMERICAN READY MIX	300 MORRILL ST	RENO	NVR000081026
217	AMERICAN SPEEDY PRINTING CENTERS	5301 LONGLEY LN STE 121	RENO	NV0000148528
218	AMERICAN TIRE	655 VIRGINIA ST	RENO	NVD982428922
219	AMERICAN WATER HEATER CO.	14291 LEAR BLVD.	RENO	NVD009155631
220	COMSTOCK HOTEL CASINO SLOT SHOP	148-1/2 WEST ST	RENO	NV0000269019
221	FASANI PAINTING	1020 LITCH ST	RENO	NVD982429508
222	GREAT BASIN AERIAL SURVEYS	5301 B LONGLEY LANE #52	RENO	NVD982466120
223	HARRAHS RENO HOTEL & CASINO	255 LAKE ST	RENO	NVD982436925
224	ANTENNA SPECIALIST R AND D FACILITY	5401 LONGLEY LN STE B34	RENO	NV0000195933
225	ARMKEL LLC - HOPKINS DISTRIBUTION CENTER	4745 LONGLEY LANE	RENO	NVR000053157
226	ARROW TRANSMISSIONS INCORPORATED	2825 KIETZKE LANE	RENO	NVD982429623

227	ART ASSOCIATES/ELECTROGRAPHICS	5476 RENO CORPORATE DR	RENO	NVR000081216
228	ART CARR PERFORMANCE	14305 MT MCCLELLEN	RENO	NVR000034389
229	AUTO EXPRESS	50 SURGE ST	RENO	NV0000137265
230	AUTO MASTERS	2250 DICKERSON RD	RENO	NVD982461311
231	AUTOMATED REFUSE EQ	650 E FIFTH ST	RENO	NV0000335224
232	AVILAS AUTO AND TRUCK REPAIR	100 GENTRY WY UNIT D12	RENO	NVD982439424
233	B AND B BUS REPAIR	5301 LONGLEY LN UNIT C7	RENO	NVD982466385
234	BAKER & TAYLOR	1160 TRADEMARK DR STE 111	RENO	NVR000073585
235	BALLY DIST OF NEVADA	777 W SECOND	RENO	NVD034954198
236	BARNES AUTO SERVICE	233 E FIFTH ST	RENO	NVD982431587
237	BARRINGER LABORATORIES INC	5301 LONGLEY LN BLDG E	RENO	NVD986769560
238	BAVARIAN AUTO HAUS	2825 KIETZKE LN STE 5	RENO	NVD982437188
239	BEAR REPAIR	572 GENTRY WAY	RENO	NVD986769966
240	BENDER WAREHOUSE	500 PARR BLVD	RENO	NV0000016261
241	BENDIX HVS	295 EDISON WAY	RENO	NVD047886791
242	BILLS QUALITY AUTO SVC	1933 PROSPERITY	RENO	NVD986772416
243	BIOMOLECULAR INC	2325 ROBB DR	RENO	NVD982461998
244	BOBS CLEANERS	1080 SOUTH VIRGINIA ST	RENO	NVU8WC000419
245	BOWLING CONGRESS PHOTOS INC	300 N CENTER ST	RENO	NV0001009927
246	BTS GROUP	4855 LONGLEY LN.	RENO	NVD982479677
247	C AND G AUTO KATZ	385 N WELLS	RENO	NV0000903161
248	C E S MACHINE	7755 SECURITY CIR	RENO	NVR000003145
249	CAL PAK DELIVERY	4674 AIR CTR CIR	RENO	NVD982464174
250	CALLAHANS PRINTING INC	130 S WELLS AVE	RENO	NV0000143859
251	CAMINO CAMPER OF NEVADA INC	9125 S VIRGINIA ST	RENO	NVD982342636
252	CARAVAN CAMPER MFG	1875 DICKERSON RD	RENO	NVD982498354
253	CARLS IMAGING WORKS INC	450 SUNSHINE LN	RENO	NVD982437931
254	CARRIER CORP	121 WOODLAND AVE	RENO	NVR000000067
255	CASE POWER & EQUIPMENT	2620 EAST 5TH ST	RENO	NVD981166549
256	CASINO MOTORS	2890 VASSAR ST NO 10A	RENO	NV0000069294
257	CELESTES ASIAN AUTOMOTIVE REPAIR	1070 GENTRY WY UNIT A	RENO	NVR000001446
258	HOOTEN TIRE	1940 E 4TH	RENO	NVR000000752
259	K TS QUALITY AUTOMOTIVE	35 N EDISON NO 48	RENO	NVR000000539
260	MAJOR AUTO REPAIR	570 A KIETZKE LN	RENO	NVD986770816
261	MERCY AMBULANCE	3010 N SUTRO	RENO	NVD982445678
262	MIRACLE METHOD INC	1040 MATLEY LN NO 11	RENO	NVR000079343
263	CHEVRON PHILLIPS CHEMICAL CO PERFORMANCE PIPE DIV	14381 LEAR BOULEVARD	RENO	NVD982430167
264	CHEVRON USA 9 4323	3499 S VIRGINIA ST	RENO	NVD986775484
265	CITY OF RENO	450 SINCLAIR ST	RENO	NVD986775575
266	KMART SUPERSTORE 4933	4855 SUMMIT RIDGE	RENO	NVR000002287
267	LENNAR HOMES	9603 WESTERN SKIES RD	RENO	NVR000079376
268	RDA INC	2400 TAMPA	RENO	NVD982495210
269	WASHOE KEYSTONE FUEL	1001 W 4TH ST	RENO	NVD986775815
270	CLAIRSON INTERNATIONAL	4660 AIRCENTER CIRCLE	RENO	NVD982017188
271	CLASSIC CLEANERS	190 CALIFORNIA AVE	RENO	NV0000989418
272	CLASSIC CLEANERS	26 CALIFORNIA AVE	RENO	NVD982373458
273	CLASSIC RODS	5325 LOUIE LN STE 10	RENO	NVD986775922
274	CLUTCH HOUSE INC.	645 E. 2ND STREET	RENO	NVD981409444
275	WESTAIR UNITED EXPRESS	1440 TERMINAL WY HGR 10	RENO	NVD986776797
276	JUANS MOBILE AUTO REPAIR	145 HUBBARD WY UNIT C	RENO	NVD986776615
277	KAR PRODUCTS INC DISTRIBUTOR	1085 TELEGRAPH ST	RENO	NVD986776466
278	MAMMOGRAPHY CENTER OF RENO	4600 KIETZKE LN STE E 144	RENO	NV0001025394

279	MASTER-HALCO INC	14331 LEAR BLVD.	RENO	NVD986771392
280	MCCURRYS DISCOUNT CAMERA	1999 S VIRGINIA ST UNIT C	RENO	NVR000001537
281	SIERRA NEVADA LABORATORIES	77 PRINGLE WY LABORATORY	RENO	NVD986776151
282	SOUTH VALLEY TRANSPORTATION	684 HWY 341 GEIGER GRADE	RENO	NVR000002956
283	THE CAMERA BAG	575 E MOANA LN	RENO	NVD986775229
284	COLD CHAIN TECHNOLOGIES	6640 ECHO AVE SUITE E	RENO	NVR000089219
285	COMSTOCK FOREIGN CAR SRV	1070 GENTRY WY	RENO	NVD986770311
286	TONYS SUTRO GARAGE	137 B GIROUX	RENO	NVD986772440
287	UNOCAL SVC STA #0077	103 E 4TH ST	RENO	NVD982042442
288	COPE AND MCPHETRES MARINE	2615 MILL ST	RENO	NVR000000695
289	WINSTON TIRE COMPANY #161	7111 VIRGINIA BLDG B	RENO	NVD981404502
290	CORTESY RADIATOR	945 E 4TH ST	RENO	NVD982415663
291	CREATIVE TOUCH INTERIORS #HDFL0043	5525 KIETZKE LN	RENO	NVR000080341
292	CRESCENT INVESTMENT	485 S ROCK BLVD	RENO	NV0000992990
293	CRUMRINE MANUFACTURING	145 CATRON DR.	RENO	NVD078143377
294	CSAA	199 E MOANA LN	RENO	NV0000561654
295	CUL-MAR PRODUCTS INC	2245 DICKERSON RD	RENO	NVP000073676
296	CUMMINS ALLISON CORP	5301 LONGLEY LN STE B37	RENO	NVD986767317
297	CUSTOM CONCRETE CUTTING SHOP	960 MATLEY	RENO	NV0000939512
298	DAMONTE RANCH HIGH SCHOOL	10500 RIO WRANGLER PKWY	RENO	NVR000079327
299	DEALERS SERVICE DEPT	409 GENTRY WAY	RENO	NVD982477879
300	DESERT MOUNTAIN OIL CO	321 E 5TH	RENO	NVD980892632
301	DOCS SERVICE CENTER	2825 KIETZKE LN #3	RENO	NVD982495228
302	DONREY OUTDOOR ADVERTISING	4945 JOULE ST	RENO	NVD982008534
303	DORANS FOREIGN CAR SERVICE	1921 1921 PROSPERITY	RENO	NVC2WC000330
304	DR BORGMAN REPAIR SERVICE	737 W 3RD ST	RENO	NV0000012146
305	DYNASTY CLEANERS	669 E MOANA LN	RENO	NVD982437154
306	E AND L WELDING DETAIL TRUCK SVC	405 WESTERN RD STE 29	RENO	NVR000000125
307	E T TECHNOLOGIES	750 S ROCK BLVD UNIT B	RENO	NVD982323628
308	E. I. DUPONT DE MEMOURS AND COMPANY	205 PARR BLVD	RENO	NVD980638613
309	EAGLE HARDWARE AND GARDEN NO 475	5075 KIETZKE LANE	RENO	NVR000050435
310	EARL SCHEIB PAINT AND AUTOBODY	559 E 4TH ST	RENO	NVR000078378
311	EATON'S B-LINE BUSINESS	13755 STEAD BLVD	RENO	NV0000148502
312	ECOLAB TEXTILE CARE DIVISION	250 BURGE RD	RENO	NVR000087452
313	ELECTRO GRAPHICS	290 GENTRY WY STE 5	RENO	NVD986774768
314	ELECTROGRAPHICS INC	5450 LOUIE LN	RENO	NVR000048405
315	ELECTRONIC DISPENSERS INTL	400 EDISON WAY	RENO	NVD981989890
316	ELITE CLEANERS	1925 DICKERSON RD	RENO	NVD982510067
317	ELSONS TRANSMISSION	85 N EDISON UNIT 4	RENO	NVD982433930
318	ENVIRONMENTAL MANAGEMENT OF NV INC	9911 N VIRGINIA ST	RENO	NVR000083337
319	ERA HELICOPTER	14505 MT ANDERSON DR	RENO	NVD982318826
320	EXPRESS SMOG	1931 PROSPERITY LN	RENO	NVD981439722
321	FALK DISTRIBUTION CENTER RENO	4970 JOULE ST	RENO	NVD059362723
322	FALLLINE CORP	4802 LONGLEY LANE	RENO	NVD982406134
323	FAST PHOTO	490 E PLUMB LN	RENO	NVD986773679
324	FEDERAL AVIATION ADMINISTRATION	1902 NATIONAL GUARD WAY	RENO	NVR000002261
325	FEDERAL HOSE MFG CORP	550 EVANS ST	RENO	NVD986773638
326	FERRARI COLOR PHOTO IMAGING LLC	333 W MOANA LN	RENO	NVR000032656
327	FITZGERALDS CASINO HOTEL	255 NORTH VIRGINIA ST	RENO	NVD982408056
328	FOOTHILL SALES	40 S WELLS	RENO	NVD986776102
329	FORMER N SIERRA BONUS STATION	707 N SIERRA ST	RENO	NV0000452961
330	FOTO FAST 1 HR	940 W MOANA LN	RENO	NVD982466096

331	FOTO FAST 1HR	5034 S VIRGINIA STREET	RENO	NVD982471682
332	FRAZEE PAINT AND WALLCOVERING #108	4068 KIETZKE LANE	RENO	NVR000081190
333	FRONTIER TOURS RENO	2620 E FIFTH ST	RENO	NVD982433906
334	FUJI PHOTO FILM USA INC	1350 N WELLS AVE	RENO	NVR000078352
335	G K SMOG	2100 MILL ST	RENO	NVD982429300
336	G L J INC DBA SUNNYS MARINE SUPPLY	3771 MILL ST	RENO	NVD986777035
337	GALENA HIGH SCHOOL	3600 BUTCH CASSIDY WY	RENO	NVD986776599
338	GALLI MINERAL ASSOCIATES	940 MATLEY LANE STE 14	RENO	NVD000630319
339	GARDNER MECHANICAL SERVICES	5655 RIGGINS COURT NUMBER 1	RENO	NVD986777019
340	GENERAL TRANSMISSION	2515 SUTRO ST	RENO	NV0000145789
341	GENERATOR EXCHANGE	1395 E 4TH ST	RENO	NVR000000547
342	GLIDDEN CO DBA ICI PAINTS	2600 MILL ST NO 200	RENO	NVR000079905
343	GLOBAL INVESTMENT RECOVERY INC	380 PARR BLVD	RENO	NVR000081893
344	GOLDEN EAGLE AUTOMOTIVE	35 E 4TH STE 9	RENO	NV0000184036
345	GOLDEN EAGLE AUTOMOTIVE	1100 E 4TH ST	RENO	NV0000902734
346	GOLDEN PHOENIX HOTEL	225 N SIERRA ST	RENO	NVR000081125
347	GOODYEAR AUTO SVC CTR	2310 S VIRGINIA	RENO	NVD981665177
348	GOODYEAR TIRE AND RUBBER CO	1250 E 6TH ST	RENO	NVD986770329
349	GORDONS PHOTO SERVICE	180 E PLUMB LANE UNIT A	RENO	NVD986773547
350	GRAND AUTO, INC	4024 KIETZKE LANE	RENO	NVD981398159
351	GREGS GARAGE	1261 E 7TH ST	RENO	NV0000330092
352	GROVE STREET AUTO SERVICE	150 E GROVE ST	RENO	NVD986770071
353	HANNIGAN INC	7250 S VIRGINIA ST	RENO	NVD982445686
354	HANSON INDUSTRIES	750 SOUTH ROCK BLVD	RENO	NVD082108945
355	HARCO	250 1/2 SAGE ST	RENO	NVD982430225
356	HARDING-LAWSON ASSOC	940 MATLEY LN	RENO	NVD067799098
357	HARLEY DAVIDSON OF RENO INC	2295 MARKET ST	RENO	NV0000132647
358	HARNESS PERFORMANCE	315 SPOKANE ST UNIT 5	RENO	NVD986770030
359	HAROLD B CHAPMAN JR IRREVOCABLE TRUST	5600 WHISKEY SPRINGS ROAD	RENO	NVR000083758
360	HARRAHS LAUNDRY	135 LINDEN ST	RENO	NVD981424377
361	HEETRONIX	725 TRADEMARK DR 104	RENO	NVR000079475
362	HERITAGE BANK (FORMERLY NATIONAL STRIPING COMPANY)	9530 N VIRGINIA ST	RENO	NVR000088062
363	HIDDEN VALLEY RANCH FOOD PRODS	12150 MOYA BLVD	RENO	NVD982436123
364	HIGH SIERRA PAINTING AND DECORATING	2220 DICKERSON RD	RENO	NVR000060178
365	HIGHLANDERS GARAGE	300 KIETZKE LN	RENO	NVD986771640
366	HOBBY CORPORATION OF AMERICA	1190 TRADEMARK DR	RENO	NVR000079194
367	HOLIDAY PHOTO	3330 S MCCARRAN BLVD	RENO	NVD986776961
368	HOME DEPOT USA INC HDFL0042	7525 COLBERT LN	RENO	NVR000080333
369	HOME DEPOT USA INC HDFL0048	895 E PATRIOT BLVD SUITES	RENO	NVR000080358
370	HONDAS ETC	3417 MILL ST	RENO	NV0000807271
371	I G T PHOTO LAB	250 SOUTH ROCK BLVD STE 124	RENO	NV0000016253
372	IMPORT TRADING POST INC	490 N VIRGINA ST	RENO	NVD982494106
373	IMPRUVALL TIRE N01	9705 S VIRGINIA ST	RENO	NV0000133314
374	INTERNATIONAL PIPELINE LLC	1000 TELEGRAPH ST UNIT 8	RENO	NVR000083972
375	INTUIT	1225 FINANCIAL BLVD	RENO	NVR000069849
376	J & J VW VANS	260 260 TELEGRAPH STREET	RENO	NVD982431603
377	J J AUTO	2415 DICKERSON RD	RENO	NV0000683219
378	JEFFS MOBILE AUTO RPR	2495 DICKERSON RD	RENO	NV0000039073
379	JEFFS MOBILE REPAIR	1300 W SECOND ST	RENO	NVD982437444
380	JIFFY LUBE	6006 S. VIRGINIA STREET	RENO	NVD982460438
381	JOHNS BRITTISH CARS GARAGE	1000 TELEGRAPH UNIT 7	RENO	NVD986776755
382	MEDCIS	4980 LONGLEY LN #103	RENO	NVR000076513

383	MERCEDES BENZ OF RENO	11500 S VIRGINIA ST	RENO	NVR000082263
384	MERCURY AIR GROUP	1440 TERMINAL WAY	RENO	NVD982439440
385	MERCY AMBULANCE OF RENO	450 EDISON WY	RENO	NV0000137240
386	MERRY X-RAY	295 GENTRY WY STE 24	RENO	NVR000080200
387	MERVYNS STORE	6895 SIERRA CENTER PKWY	RENO	NVR000083824
388	MICHELIN NORTH AMERICA INC	14551 INDUSTRY CIRCLE, SUITE B	RENO	NVR000031575
389	MIDAS MUFFLER	1037 E FOURTH ST	RENO	NVD986771590
390	MIDAS MUFFLER AND BRAKE	3250 S VIRGINIA ST	RENO	NVD986770352
391	MIDTOWN TEXACO XPRESS LUBE	100 GENTRY WY C9	RENO	NVR000080028
392	MIKADO CLEANERS AND LAUNDROMAT	507 WASHINGTON ST	RENO	NVR000040022
393	MIKE MINSCH	8340 CHIPPEWA	RENO	NVD982437162
394	MIKOHN GAMING CORP	4835 LONGLEY LN	RENO	NVR000002394
395	MINUTEMAN PRINTING INC	1535 VASSAR	RENO	NVD986773455
396	MIRACLE AUTO PAINTING	2685 E 4TH ST	RENO	NVD982335762
397	MIRROR IMAGE STUDIOS	4930 ENERGY WY	RENO	NVD986771822
398	KEYSTONE QUALITY PRINTING	890 W 5TH ST	RENO	NV0000133298
399	KIDDIE KANDIDS	4991 S VIRGINIA 104	RENO	NVR000078790
400	KIDDIE KANDIDS	5540 MEADOWOOD MALL CIR #G-112	RENO	NVR000079863
401	KIETCK	4673 AIRCENTER PARKWAY	RENO	NVR000002253
402	KIETEK INTL INC	5325 LOUIE LN NO 7	RENO	NVD986775674
403	KITS CAMERAS 1 HOUR NO 129	5525 MEADOWOOD MALL CIR	RENO	NVR000001081
404	KRAGEN AUTO PARTS 4108	1501 S VIRGINIA	RENO	NVD981398217
405	KRAGEN AUTO PARTS 4113	801 W FIFTH ST	RENO	NVD981639404
406	KROWN RACING	1325 E 2ND ST	RENO	NV0000627927
407	KRUGER PHOTOGRAPHY SVCS	1040 MATLEY LN	RENO	NVD986775443
408	L W AUTOMOTIVE	2415 E 2ND ST	RENO	NVD982433948
409	LABORATORY CORP. OF AMERICA	704 MILL STREET	RENO	NV0000069302
410	LAKESIDE CLEANERS	135 WEST PLUMB LANE	RENO	NVD982373557
411	LANDA MUFFLER	816 E 4TH ST	RENO	NVR000001065
412	LARRYS CAR SERVICE	3413 MILL ST	RENO	NVD986771012
413	LEATHER CONNECTION INC THE	5450 RIGGINS CT NO 5	RENO	NVD986775591
414	LEGEND METALLURGICAL LAB INC	125 MANNEL ST	RENO	NVD982463002
415	LIFESTYLE HOMES INC	6985 PEPPERMINT DR	RENO	NVD986770394
416	LNL PROPERTIES LLC	572 REACTOR WAY	RENO	NVR000083501
417	LUBRICON RENO NEVADA	4795 LONGLEY LANE STE 101	RENO	NVR000000232
418	LUMBERJACK BUILDING MATERIALS	12828 S VIRGINIA	RENO	NVD986774503
419	LUMOS AND ASSOCIATES INC	4200 REWANA WAY #506	RENO	NVD982461287
420	LUMOS AND ASSOCIATES INC	5401 LONGLEY LN STE 13	RENO	NVD986772309
421	LUSTRLUX CLEANERS	454 WASHINGTON	RENO	NVD982373565
422	M AND T GARAGE	208 GENTRY WY	RENO	NVD986776839
423	MAACK DISPOSAL SVC	2695 TACHINNO ST	RENO	NVR000002436
424	MAC BROTHERS AUTOMOTIVE	1520 W 4TH ST	RENO	NVD986775971
425	MAGNUS CORPORATION	475 EDISON WAY	RENO	NVD986774644
426	MOTOR CLASSICS LTD	225 TELEGRAPH #110	RENO	NVD982431629
427	MUSCLE MOTORS A/S	7000 S VIRGINIA ST	RENO	NVR000088633
428	MY MECHANIC	2890 VASSAR ST NO 10 AND 11A	RENO	NV0000071662
429	N C M PAINTING	120 MARY ST	RENO	NVR000057364
430	NATIONAL SEAL CO	525 REACTOR WAY	RENO	NVD982461303
431	NC AUTO PARTS LLC	1150 MATLEY LN	RENO	NVR000085829
432	NEVADA BELL	4940 MT ROSE HWY	RENO	NVT330010422
433	RICH GLO CLEANERS	180 LINDEN ST	RENO	NVD982472482
434	RICKS AUTO REPAIR	128 LINDEN ST	RENO	NVD982494130

435	RITTER PHOTO INC	4830 LONGLEY LN	RENO	NVD986773463
436	WESTERN SEALING & STRIPING	111 MORRILL AVE	RENO	NVR000073957
437	WESTERN X RAY INC	690 MONTELLO ST	RENO	NVD982323610
438	WINDECKER INC	1365 AIRMOTIVE WAY	RENO	NVD982339210
439	NEVADA BELL	3350 LYMBERY	RENO	NVT330010661
440	NEVADA BELL	9700 S VIRGINIA	RENO	NVT330010711
441	NEVADA CARRIAGE COMPANY	205 TELEGRAPH ST	RENO	NVD981967185
442	NEVADA DREAM MACHINE	5301 LONGLEY LN 214 BLDG F	RENO	NVR000002691
443	NEVADA FOREIGN AND DOMESTIC CARS	491 ELKO AVE	RENO	NVD982436305
444	NEVADA TYPESETTING	75 CALIENTE ST	RENO	NVD982486326
445	NEVADA WASTE OIL CO	2005 WATT ST	RENO	NVD981626500
446	NEW FACES CABINETRY	7930 SUGAR PINE CT	RENO	NVR000003111
447	NEW MIKADO CLEANERS	737 WEST FIFTH STREET	RENO	NVD982370157
448	NO NEVADA FLEET SERVICES INC	3555 AIRWAY DR UNIT 310	RENO	NVR000046011
449	NORTH VALLEYS HIGH SCHOOL	1470 E GOLDEN VALLEY RD	RENO	NVR000075903
450	NORTHWEST INC	7900 N VIRGINIA ST #296	RENO	NVD980896203
451	NUGGET 1 HR CLEANERS	237 EAST PLUMB LANE	RENO	NVD982373581
452	NVARNG PLUMB LN ARMORY	685 E PLUMB LN	RENO	NV4210490021
453	OLD TOWN MALL	4001 S VIRGINIA ST	RENO	NVD982007478
454	ORBITBID.COM INC RENO	14551 INDUSTRY CIRCLE STE B	RENO	NVR000085951
455	OUTDOOR POSTERS	2890 VASSAR ST	RENO	NVD982499311
456	P AND L AUTOMOTIVE	2554 WRONDEL ST	RENO	NV0000721555
457	PACE AVIATION LTD	500 EDISON WY	RENO	NVD982350381
458	PALLADIUM ENERGY INC	335 EDISON WY UNIT 9	RENO	NVR000085480
459	PANDA/UPG	2695 MILL ST	RENO	NVD986772044
460	PAP R PRODUCTS COMPANY RENO	3895 CORSAIR ST	RENO	NV0000370205
461	PARAMOUNT AUTO BODY	2375 E 4TH ST	RENO	NVD982411910
462	PARNELLI JONES	590 KIETZKE LN	RENO	NVD986769081
463	PAUL THOMAS ENVIROTRANS INC	3885 BRANT ST	RENO	NVR000046367
464	PAULS AUTOMOTIVE	2552 WRONDEL WY	RENO	NV0000876003
465	PAYLESS CLEANERS	3334 KIETZKE LN	RENO	NVR000082099
466	PERFORMANCE AUTOMOTIVE	555 GENTRY WAY	RENO	NVD982438483
467	PETES AUTO BODY	311 N PARK ST	RENO	NVD986776862
468	PETROSOLUTIONS LLC	14150 MOUNT ANDERSON ST	RENO	NVR000089805
469	PEVCO	9240 PROTOTYPE DR	RENO	NVR000001289
470	PHOTO ONE	6455 S VIRGINIA ST	RENO	NVD986773554
471	PIONEER PHOTO LAB	1715 S WELLS AVE	RENO	NVD982486805
472	PLATINUM AVIATION GROUP INC	4649 AIRCENTER CIR	RENO	NVR000080135
473	PLAZA MACHINE SHOP INC	859 E 2ND ST	RENO	NVD986770402
474	POLYVISION INC DBA POLYCORE OPTICAL	875 E PATRIOT BLVD STE 204	RENO	NVR000003335
475	PORSCHE CARS N AMERICA	1600 HOLCOMB	RENO	NVD982477895
476	POSEIDON TRUCKING INC	10100 DONNAY DR	RENO	NVR000081794
477	PRECISION AUTOMOTIVE INC	1100 W FOURTH ST	RENO	NVD982320947
478	PRECISION TRANSMISSION	2155 MARKET ST	RENO	NVD986770089
479	PRIMARK CORPORATION	4950 JOULE STREET	RENO	NVT330010281
480	PRIMARY IMAGE INC / BML INVESTMENTS	1350 CAPITAL BLVD	RENO	NVR000081430
481	PRIMOS SERVICE	545 DEPAOLI	RENO	NVD982439473
482	PRO AUTO SERVICE	2187 MARKET ST STE F	RENO	NV0001010651
483	PRODUCTION IMAGES INC	9390 GATEWAY DR	RENO	NVR000001016
484	PROSPERITY CLEANERS	401 SUNSHINE LANE	RENO	NVD981982853
485	QUALITY AIR SVCS	5301 LONGLEY LN BLDG B STE 40	RENO	NVR000037085
486	QUICK FIX	700 CASAZZA DR	RENO	NVR000001149

487	R C ENGINES	635 E FOURTH ST	RENO	NVD982461337
488	RAINBO BAKING CO	440 ELKO	RENO	NVD982430712
489	RAINBO BAKING CO	455 EUREKA AVE	RENO	NVD986769958
490	RAINBOW CLEANERS	477 EAST PLUMB LANE	RENO	NVD982413726
491	RALPHS AUTO BODY INC	90 SUNSHINE LN UNIT B	RENO	NVR000000901
492	RECREATION PUBLICATION	2303 KIETZKE LN STE 18	RENO	NVR000001164
493	REDWOOD AUTOBODY NO 2	2625 DICKERSON RD UNIT B	RENO	NVR000000844
494	RELIABLE CLEANERS	727 W 5TH STREET	RENO	NVD982373599
495	REMARC MFG	1995 TAMPA WY	RENO	NV0000069815
496	RENO AUTO SERVICE CENTER	100 GENTRY WY	RENO	NVD986774933
497	RENO BREAST CTR	50 KIRMAN AVE	RENO	NV0000016006
498	RENO COLOR LAB	5401 LONGLEY LN UNIT 12	RENO	NVD986776037
499	RENO COLOR LAB	3330 KIETZKE LN	RENO	NVR000078360
500	RENO CUSTOM CYCLES	3411 MILL ST	RENO	NVD982439465
501	RENO DIAGNOSTIC CENTER	590 EUREKA AVE	RENO	NVD982524308
502	RENO FRAME AND AUTO BODY	1950 ZINC	RENO	NVD986770048
503	RENO PRINTING	940 MATLEY LN STE 3	RENO	NVR000001420
504	RENO REGENCY CONVENTION CENTER	555 EVANS AVE	RENO	NVR000082891
505	RENO SPARKS INDIAN COLONY	2453 E 2ND ST	RENO	NVD986770709
506	RENO SPARKS READY MIX	2200 BARNETT WAY	RENO	NVD986771426
507	RENO TAHOE SPECIALTY INC	550 VALLEY RD	RENO	NVD986770386
508	RENO TYPOGRAPHERS INC	255 BELL ST NO 290	RENO	NVD986773646
509	RENOWN IMAGING @ SOUTH MCCARRAN	6630 S MCCARRAN BLVD STE C27	RENO	NVR000076349
510	RTC ACCESS PARATRANSIT MAINTENANCE FACILITY	600 SUTRO	RENO	NV0000183913
511	RUBENSTEIN RADIOLOGY	890 MILL ST NUMBER 105	RENO	NV0000268961
512	RW STOVALL PRINTING INC	3775 MILL ST	RENO	NV0000133249
513	SPOT CLEANERS	9410 PROTOTYPE DR STE A13	RENO	NVR000034892
514	ST MARYS HEALTHFIRST	5290 NEIL RD	RENO	NVD986774677
515	STAR CLEANERS	2303 S. VIRGINIA ST.	RENO	NVU000085563
516	STRIDE WRITING INSTRUMENTS	1140 CORPORATE BLVD	RENO	NVR000003327
517	SUN CHEMICAL CORP	7970 SECURITY CIRCLE	RENO	NVD981694540
518	SUNSHINE AUTO REPAIR	1670 KUENZLI	RENO	NVR000000315
519	SUPERIOR CLEANERS	18 CHENEY STREET	RENO	NVD982373649
520	SWEDISH AUTO	570-B GENTRY WAY	RENO	NVD986768760
521	RYDER INTEGRATED LOGISTICS/EASTMAN KODAK COMPANY	12035 MOYA BLVD	RENO	NVR000085522
522	VINTAGE SLOT MACHINE AND AMUSEMENT CO	4816 LONGLEY LN	RENO	NVD986769818
523	VITAL SYSTEMS	195 N EDISON WAY UNIT 9	RENO	NVD986771160
524	WALGREENS STORE NO.11446	6450 S VIRGINIA ST	RENO	NVR000082727
525	WALMART 2106	2863 NORTHTOWNE LN	RENO	NV0000593491
526	WASHOE COUNTY SCHOOL DISTRICT	330 DOUBLEBACK RD	RENO	NVD982430910
527	WASHOE IMAGING	350 W SIXTH ST	RENO	NV0000029280
528	WASHOE IMAGING AT 75 KIRMAN	75 KIRMAN AVE	RENO	NV0000026807
529	WASHOE IMAGING AT 85 KIRMAN AVENUE	85 KIRMAN AVENE UNIT 2A	RENO	NV0000029272
530	WASHOE MEDICAL CENTER CLINIC	21 LOCUST ST	RENO	NVR000037697
531	WATERS SEPTIC TANK SERVICE, INC.	4275 REWANA WY	RENO	NV0000123059
532	WEBBS RV	105 SUNSHINE LN	RENO	NV0000133215
533	WEST COAST IMAGING	1400 E 7TH ST	RENO	NVR000076836
534	WINN PRESS	13920 MT MCCLELLAN	RENO	NVD982465528
535	SAV ON DRUG STORE NO 2046	10550 N MCCARRAN	RENO	NVR000001578
536	SAVE MART SUPERMARKETS DBA ALBERTSONS	4995 KIETZKE LN	RENO	NVR000075762
537	SAVE MART SUPERMARKETS DBA ALBERTSONS	195 W PLUMB LN	RENO	NVR000075796
538	SAVE MART SUPERMARKETS DBA ALBERTSONS	525 KEYSTONE AVE	RENO	NVR000075879

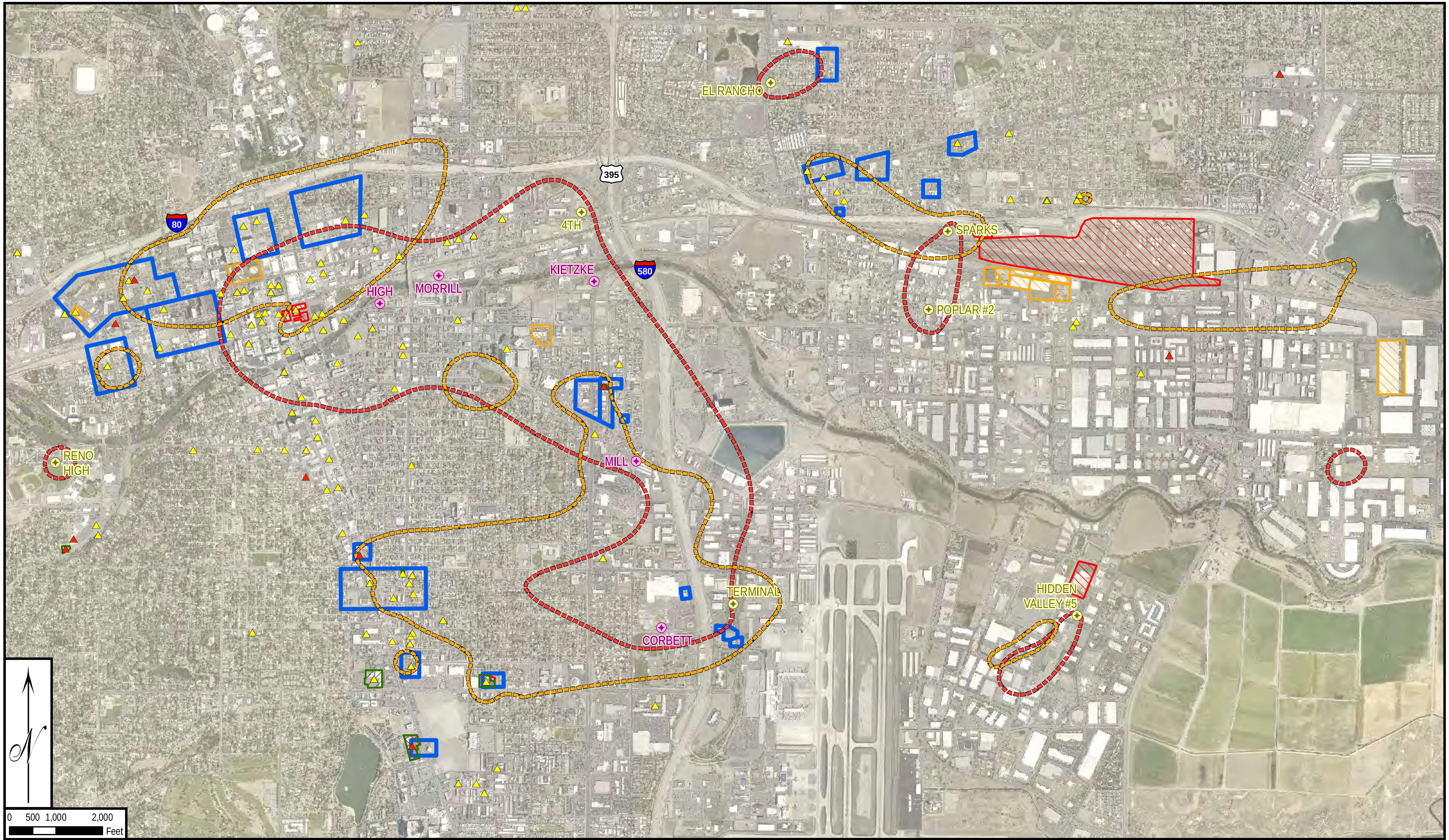
539	SAVE ON CLEANERS LLC	6429 S VIRGINIA ST	RENO	NVR000039669
540	SCOLARIS NO 20	8165 S VIRGINIA	RENO	NVR000000596
541	SEARS A C 1978	5400 MEADOWOOD MALL CIR	RENO	NVR000001388
542	SEPHORA STORE 40 MEADOWOOD	5335 MEADOWOOD MALL CIR	RENO	NVR000078519
543	SEVEN DIAMOND CLEANERS	141 E PUEBLO ST	RENO	NVD982373615
544	SHAMROCK AUTO PARTS INC	2560 E 4TH ST	RENO	NVD986770345
545	SHELL OIL CO	280 W 2ND ST	RENO	NVD981685506
546	SHELL SERVICE STATION 138261	6220 S VIRGINIA	RENO	NVD980676324
547	SHERWIN WILLIAMS CO THE	4818 LONGLEY LN	RENO	NV0000921411
548	SHERWIN-WILLIAMS CO THE	196 SO WELLS AVE	RENO	NVD088848692
549	SHOEMANS CYCLE	1291 E 2ND ST	RENO	NVD982437709
550	SIERRA CYLINDERS INC	490 S ROCK BLVD	RENO	NVD981439284
551	SIERRA DYNAMICS	1150 E CRYSTAL CANYON CT	RENO	NVR000000943
552	SIERRA MAINTENANCE INC	2850 WRONDEL WY UNIT H	RENO	NV0000268979
553	SIERRA OFFICE CONCEPTS	1301 CORPORATE BLVD	RENO	NV0000145771
554	SIERRA OFFICE CONCEPTS	955 S VIRGINIA ST	RENO	NVD981962061
555	SIERRA R P R AND SHARPENING	77 W ARROYO ST	RENO	NVD982430233
556	SIERRA STRIPERS & ASPHALT PAINTING INC	296 PARR BLVD	RENO	NV0000002238
557	SIERRA TRANSMISSIONS	100 GENTRY WY STE A1	RENO	NV0000461939
558	SIERRA X RAY SERVICES	845 E SECOND ST	RENO	NVD982524688
559	SILVER STATE AUTO BROKERS SVC	70 W GROVE UNIT 4	RENO	NVD986776128
560	SILVER STATE CAMERA	538 S VIRGINIA	RENO	NVD986768588
561	SIR SPEEDY PRINTING	220 S ROCK BLVD	RENO	NVD986777175
562	SKYLINE NO.1 TANK TMWA	2855 SKYLINE BLVD	RENO	NVR000084897
563	SMARTRIM INC	4750 TURBO CIRCLE	RENO	NVD982466054
564	SMITH FOOD AND DRUG 1 HOUR PHOTO	3600 VIRGINIA ST	RENO	NVD986773372
565	SMITHRIDGE CLEANERS & LAUNDRY	5023 S MCCARRAN BLVD	RENO	NVD982402885
566	SOCIETY DRY CLEANERS	475 KEYSTONE	RENO	NVD982373631
567	SOUTHERN PACIFIC	222 SAGE ST	RENO	NVR000000745
568	SOUTHWEST COLOR INC	5301 LONGLEY LN A 12	RENO	NVR000003020
569	SOUTHWEST TIRE SVC	3075 S VIRGINIA ST	RENO	NVR000000661
570	SPEED AUTO REPAIR	195 N EDISON UNIT 8	RENO	NVD986776078
571	SPEEDEE OIL CHANGE AND TUNE UP	100 GENTRY WAY STE C	RENO	NVR000000273
572	T N T AUTOMOTIVE INC	405 WESTERN RD UNIT 13	RENO	NV0000993006
573	TEDESCO CONSTRUCTION INC	5395 LOUIE LN	RENO	NVR000075416
574	THE BOEING CO FORMER NFL	2550 WHISKEY SPRINGS RD	RENO	NVR000079228
575	THE SHERWIN WILLIAMS COMPANY	8850 DOUBLE DIAMOND PKWY	RENO	NVR000082784
576	THE SHERWIN-WILLIAMS CO. - RENO WAREHOUSE	4900 AMPERE DR.	RENO	NVD096905724
577	THERMAX PARISE AND SONS INC	5385 ALPHA AVE	RENO	NVD986771830
578	TIME FASTENER CO INC	5301 LONGLEY LN STE G	RENO	NVR000040741
579	TIRE CENTERS INC #9861	1500 E 4TH ST	RENO	NVD982430183
580	TIRES UNLIMITED	1120 KIETZKE UNIT A	RENO	NVD986770964
581	TOM JOHNSON INC	300 WESTERN ROAD UNIT NO.3	RENO	NVR000084715
582	TONY HARRAH	11095 THOMAS CREEK RD	RENO	NVD986776995
583	TRAVELERS RV SERVICE DEPT	1765 LEWIS ST	RENO	NVD986776409
584	TRIM LINE OF RENO	240 TELEGRAPH ST	RENO	NVD982403578
585	TRUCKEE MEADOWS PHOTO	790 LOUISE ST	RENO	NVD986772812
586	TRUCKEE PRECISION	110 WOODLAND AVE	RENO	NVR000000570
587	TRUCKEE PRECISION	1045 TELEGRAPH ST	RENO	NVD981973266
588	TWIN CITY DIESEL AND AUTO REPAIR INC	430 MORRILL AVE	RENO	NVD986771095
589	TYCO ELECTRONICS	980 SANDHILL RD STE 100	RENO	NVR000081083
590	UNITED AERIAL	5295 COGGINS DR	RENO	NVR000047571

591	UNITED CONSTRUCTION CO	5320 MILL ST	RENO	NV0000029298
592	UNITED STATES PLAYING CARD CO THE	195 CATRON DR	RENO	NVD982053985
593	UNITED TECHNOLOGIES OTIS ELEVATOR	940 MATLEY ST STE 17	RENO	NVD982434060
594	UNIVERSITY OF NEVADA MAIN FARM	5894 CLEANWATER WAY	RENO	NV0000050815
595	UNOCAL SERVICE STATION #7207	2515 KIETZKE LANE	RENO	NVD982488835
596	UNOCAL SVC STA #6072	300 W 7TH ST	RENO	NVD982057275
597	USDOI BLM RENO	850 HARVARD WAY	RENO	NVD982329138
598	V LINE AUTOMOTIVE	65 WEBB CIR UNIT A	RENO	NVR000000448
599	VENTURA INTERNATIONAL	5325 LOUIE LN STE 14	RENO	NVR000082776
600	XPRESS LUBE AND TUNE	55 E PATRIOT BLVD	RENO	NVR000001735

APPENDIX D

PCE FIGURE

DRAFT



- PCE TREATED PRODUCTION - TMWA
- PCE IMPACTED PRODUCTION - TMWA
- ▲ DRY CLEANER (CURRENT)
- △ DRY CLEANER (HISTORICAL)

PCE PLUME CONCENTRATION CONTOURS

- SHALLOW ZONE PCE (ESTIMATED)
- DEEP ZONE PCE (ESTIMATED)

- ▨ PCE DETECTED IN SEWER
- ▨ PCE CORRECTIVE ACTION SITE (CURRENT)
- ▨ PCE CORRECTIVE ACTION SITE (HISTORICAL)
- ☐ PCE HIGH MASS AREAS

POTENTIALLY CONTRIBUTORY ACTIVITIES (PCA)
PCE IMPACTED SITES & PCE GROUNDWATER PLUMES

TMWA

NOTE: The scale and configuration of all information shown hereon are approximate only and are not intended as a guide for design or survey work. Reproduction is not permited without prior written permission from Truckee Meadows Water Authority.

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APPENDIX E

SPANISH SPRINGS VALLEY NITRATE FIGURES

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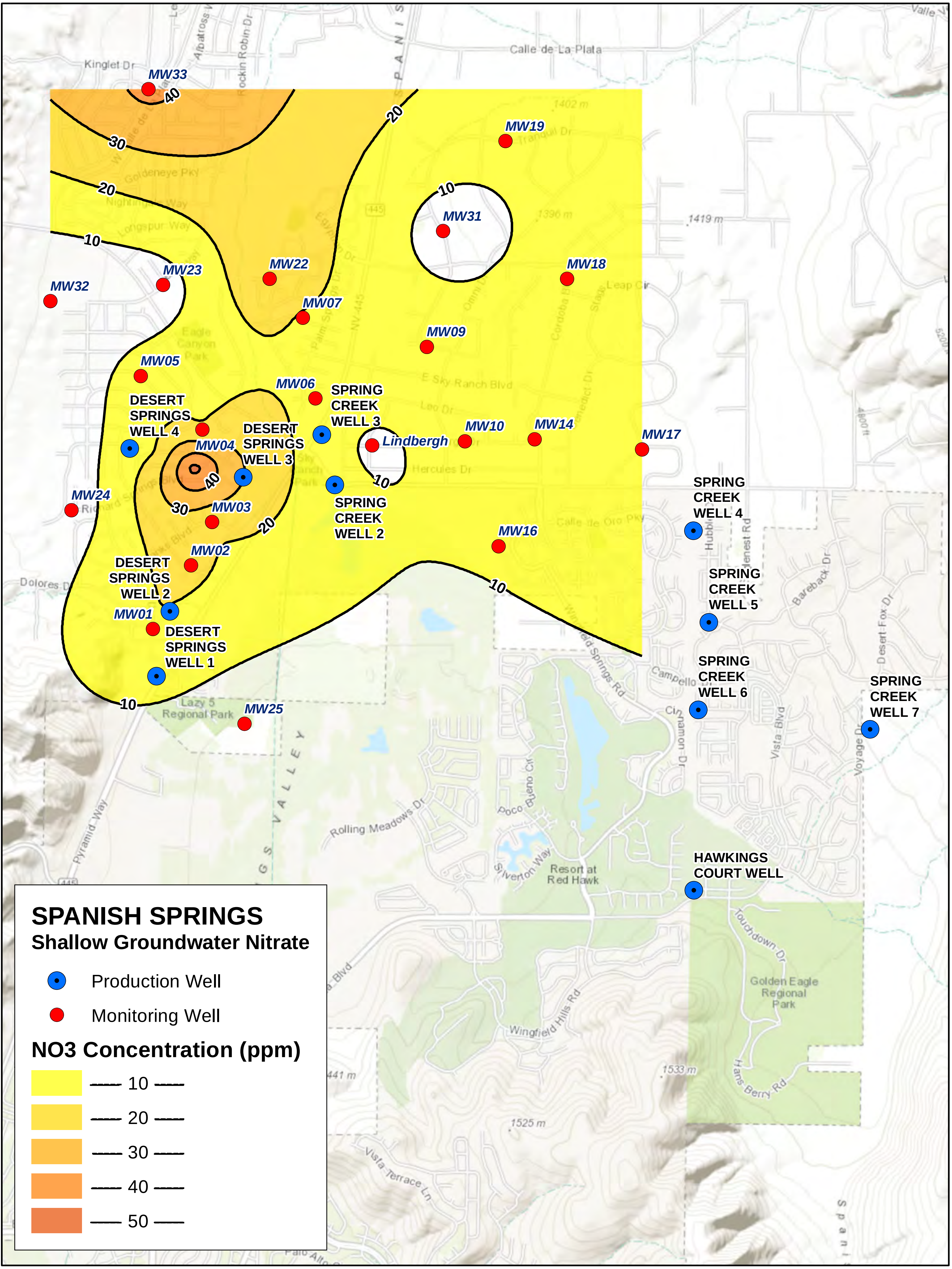

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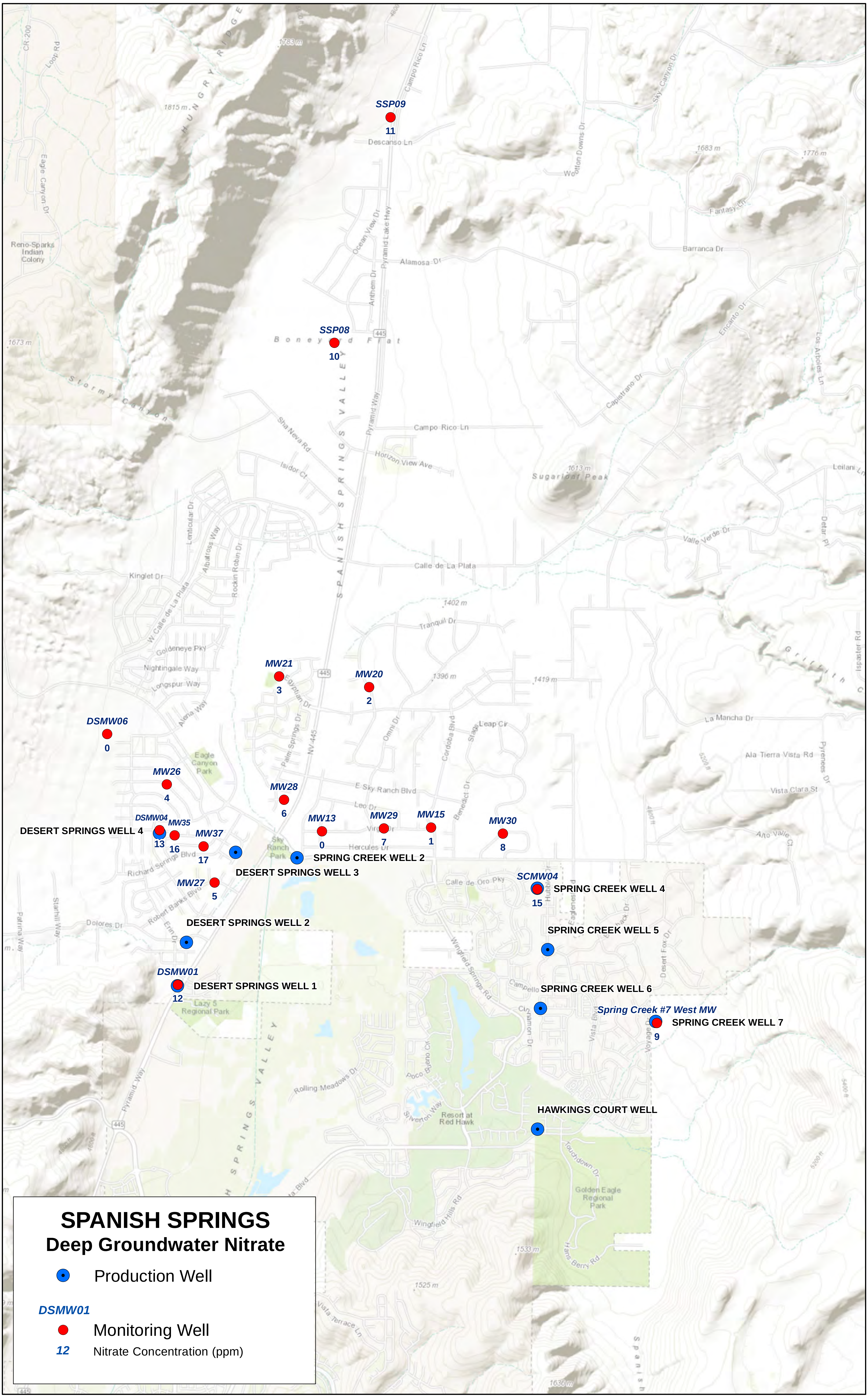

SPANISH SPRINGS

Deep Groundwater Nitrate

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TRUCKEE MEADOWS WATER
AUTHORITY

2016-2035 WATER RESOURCE PLAN

APPENDIX 3

INTEGRATED MANAGEMENT
OF
WATER RESOURCES

TRUCKEE MEADOWS WATER
AUTHORITY

APPENDIX 3-1

AQUIFER STORAGE AND RECOVERY REPORTS

TRUCKEE MEADOWS WATER AUTHORITY

REPORT ON AQUIFER STORAGE AND RECOVERY
WEST LEMMON VALLEY HYDROGRAPHIC BASIN

JANUARY 1 THROUGH JUNE 30, 2015

NDEP PERMIT #UNEV99209

and

NDWR PERMIT #R-15

July 2015

CERTIFICATION

The information contained in this report is true and correct according to the best belief and knowledge of the undersigned.

Certified by

John A. Erwin
Director Natural Resources-Planning & Management
Truckee Meadows Water Authority

Truckee Meadows Water Authority
1355 Capital Boulevard
Reno, Nevada 89502
www.tmwa.com

TABLE OF CONTENTS

TABLES

FIGURES

1.0 SUMMARY

Truckee Meadows Water Authority’s (TMWA) Aquifer Storage and Recovery program (ASR) activities in the West Lemmon Valley Basin are performed under Nevada Department of Environmental Protection (NDEP) Permit Number UNEV99209 issued August 28, 2008, and Division of Water Resources (NDWR) Permit No. R-15 issued November 19, 2008. TMWA’s ASR program in the West Lemmon Valley Basin has grown from 32 acre-feet of treated surface water injected in 2000 to 4,649 acre-feet cumulative total at the end of June, 2015 as shown in the table below.

Table 1. Injection History, West Lemmon Valley Basin (in acre-feet)

Year	Silver Knolls	Army Air Guard	Silver Lake	Total
2000		32		32
2001		242	149	391
2002		205	88	293
2003		180	83	263
2004		157	84	241
2005		137	93	230
2006		163	146	309
2007		136	136	272
2008	32	118	172	322
2009	19	106	191	316
2010	131	150	192	472
2011	130	100	89	319
2012	118	81	63	263
2013	53	38	28	119
2014	114	86	76	276
Jun-15	184	184	163	531
TOTAL	781	2,115	1,753	4,649

Between January 1 and June 30, 2015, TMWA injected 531 acre-feet (173 million gallons) of treated surface water in the west portion of the West Lemmon Valley Basin in TMWA’s Army Air Guard (AAW), Silver Lake (S2W) and Silver Knolls (SKW) Wells (see Table 2A). The average flow rate for AAW was 185 gpm, for S2W was 158 gpm and 236 gpm for SKW. Maximum injection rates attained by AAW, S2W and SKW were 300 gpm; 174 gpm and 311 gpm, respectively. The minimum injection rate was 120 gpm for AAW, 151 gpm for S2W and 186 gpm for SKW. The source was treated Truckee River water from TMWA’s surface water treatment plants, delivered to the Stead area through TMWA’s distribution system.

During first half of 2015, no water was pumped from SKW, while 50.3 acre-feet (16.4 MG) was pumped from AAW and 13.8 acre-feet (4.5 MG) was pumped from S2W (Table 2B).

Table 2A. Monthly Recharge by Well, West Lemmon Valley, (Jan-Jun) 2015

	JAN	FEB	MAR	APR	MAY	JUN	TOTAL RECHARGE	
							MG	AF
Silver Knolls	3.6	10.3	10.5	9.5	26.0	0.0	59.9	183.9
Air Guard	9.7	8.6	8.8	7.0	26.0	0.0	60.0	184.2
Silver Lake	7.1	6.4	7.0	6.7	26.0	0.0	53.1	163.0
	----	----	----	----	----	----	----	----
Total	20.3	25.3	26.3	23.2	78.0	0.0	173.1	531.1

Table 2B. Monthly Production by Well, West Lemmon Valley, (Jan-Jun) 2015

	JAN	FEB	MAR	APR	MAY	JUN	TOTAL PUMPAGE	
							MG	AF
Silver Knolls	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Air Guard	0.0	0.0	0.0	0.0	0.0	16.4	16.4	50.3
Silver Lake	0.0	0.0	0.0	0.0	0.0	4.5	4.5	13.8
	----	----	----	----	----	----	----	----
Total	0.0	0.0	0.0	0.0	0.0	20.9	20.9	64.1

The chemistry of the injection and extracted water showed no adverse effects to the aquifer as evidenced from the low total trihalomethanes and consistent water quality data from the extracted water.

Figure 1 is the map of the recharge and monitoring wells.

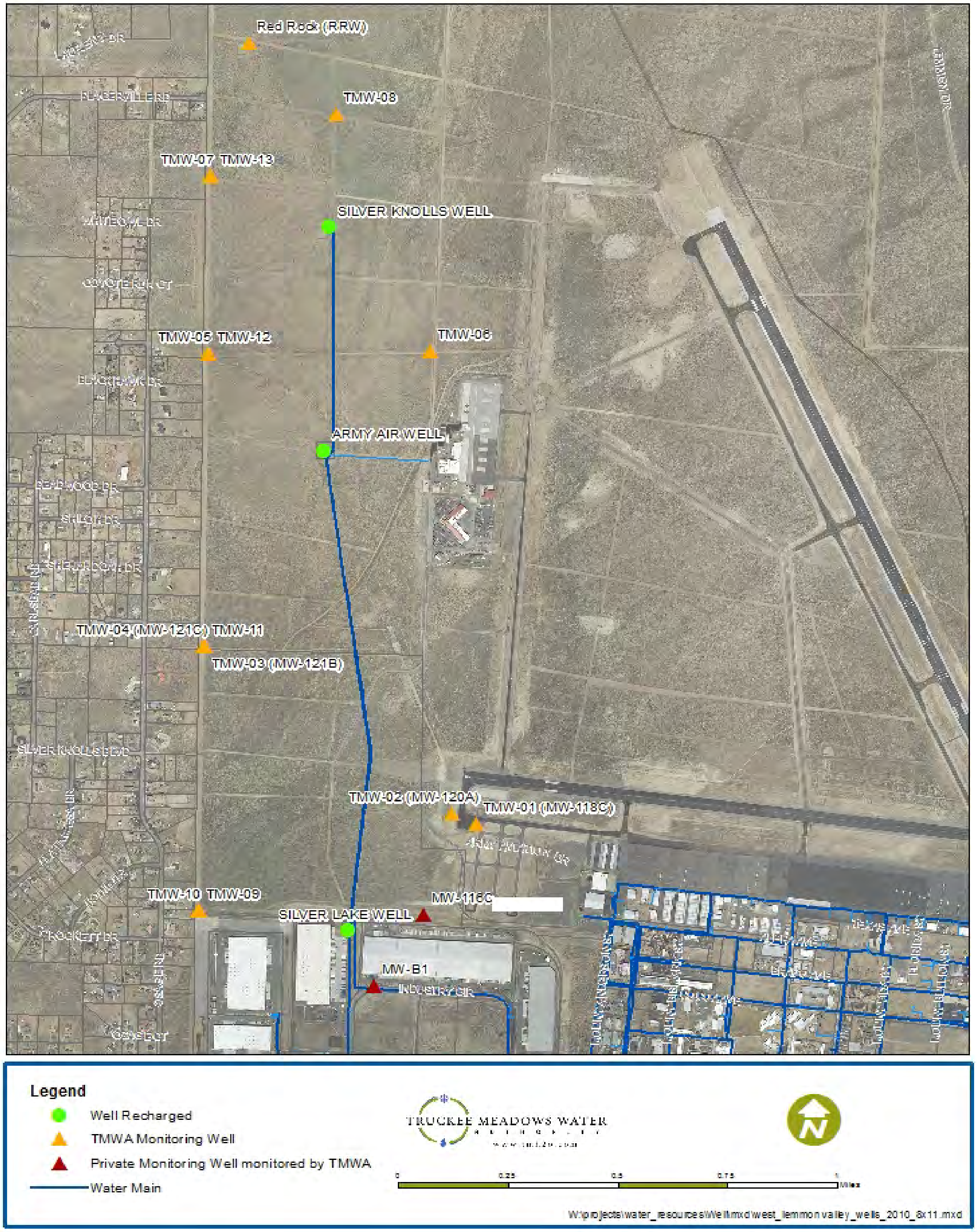


Figure 1. Well Locations - West Lemmon Valley Basin

Figures 2, 3, and 4 are the plots of the water levels, pumping, and injection rates in the three production/injection wells.

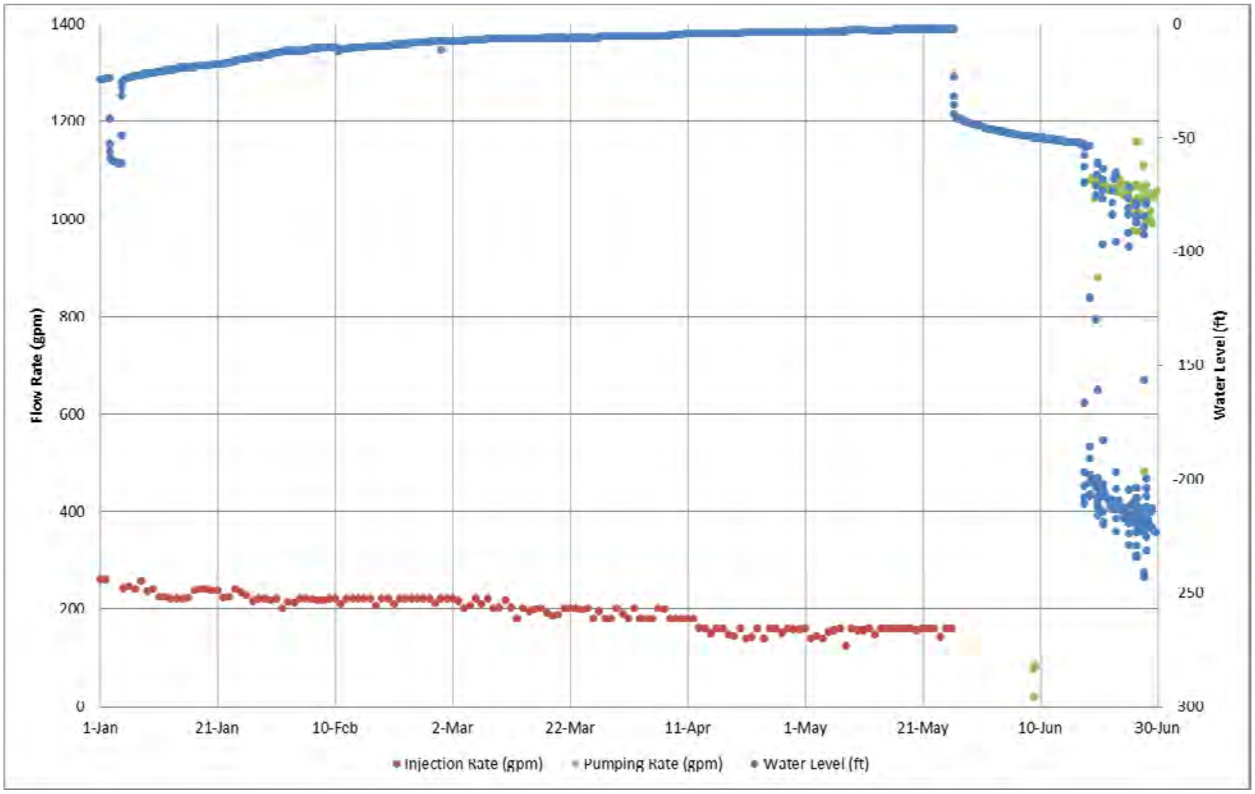


Figure 2. Army Air Guard Well – (Jan-Jun) 2015 Flow Rates and Water Levels

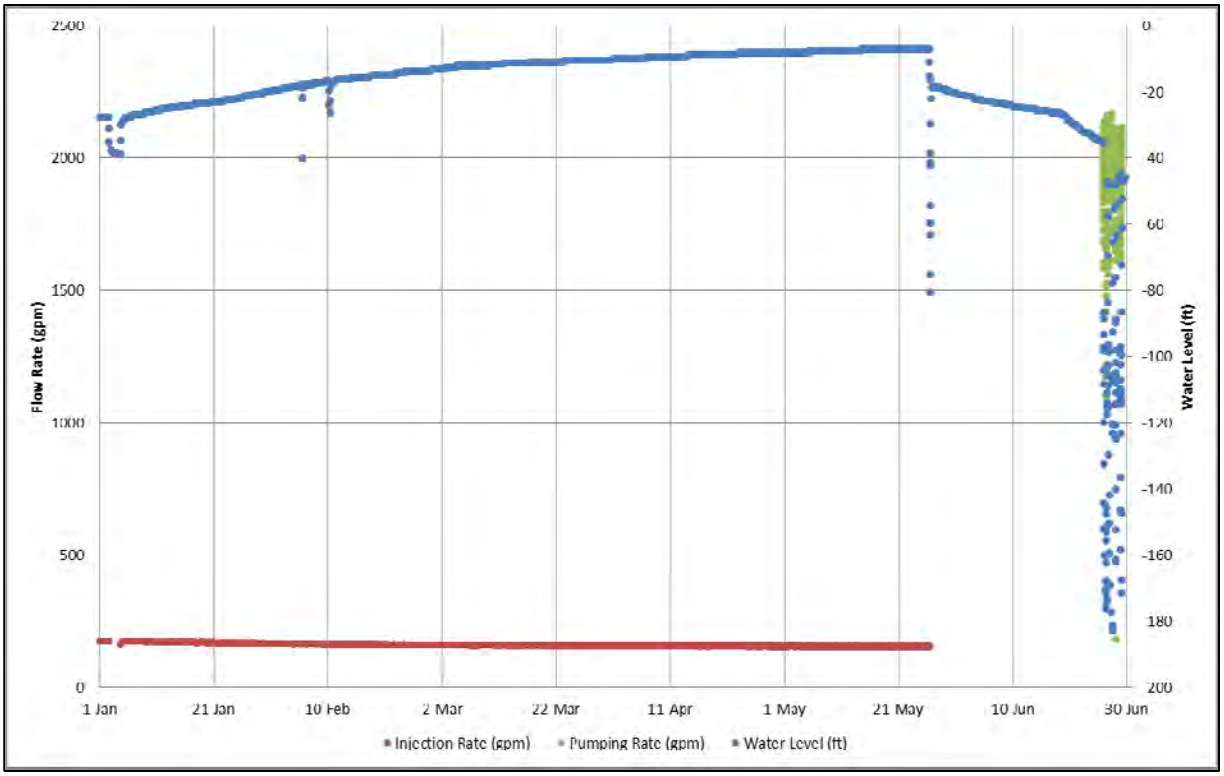


Figure 3. Silver Lake Well – (Jan-Jun) 2015 Flow Rates and Water Levels

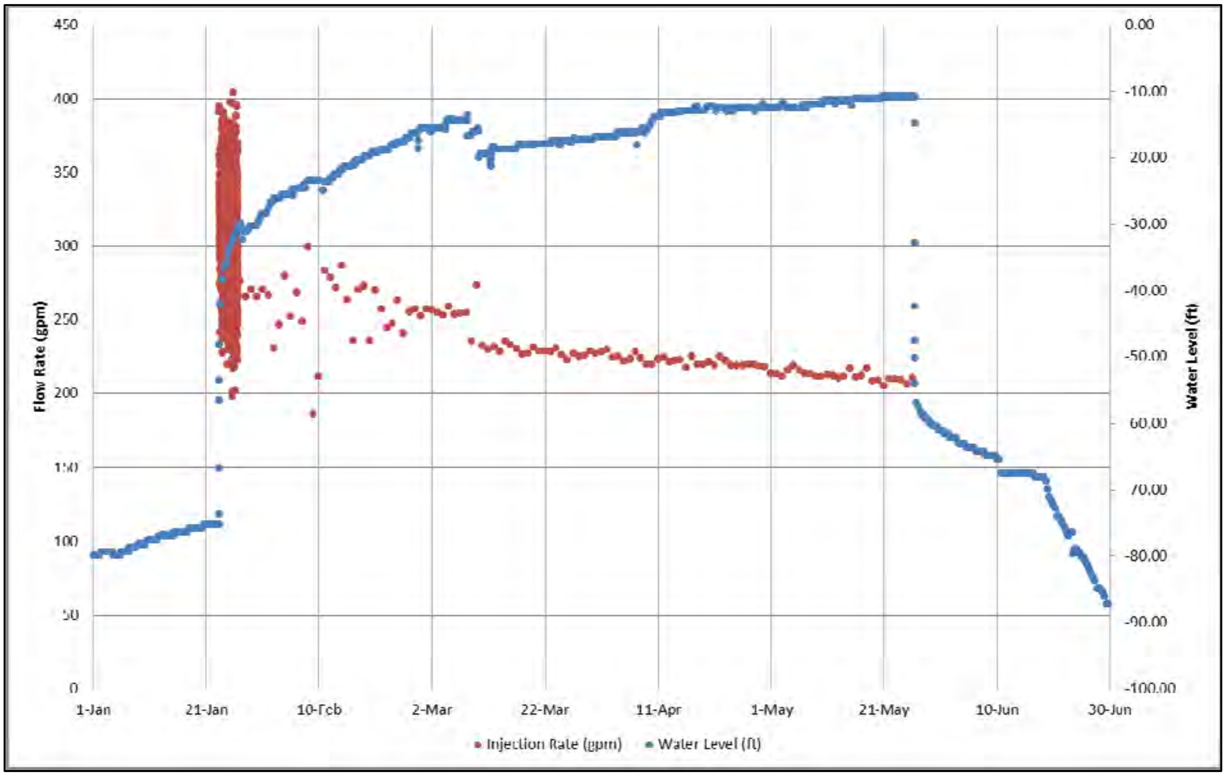


Figure 4. Silver Knolls Well – (Jan-Jun) 2015 Flow Rates and Water Levels

2.0 WATER LEVEL MONITORING

TMWA uses its fifteen monitoring wells plus two private monitoring wells (MW-B1 and MW-116C) as monitoring wells for its West Lemmon Valley ASR program. After drilling four additional wells in 2008, TMWA now has four locations with nested monitoring wells on the west side of the well field to monitor water level changes during injection and pumping in the shallow and deep aquifers. The pairs are, from south to north: TMW-09 (400 ft) and TMW-10 (100 ft); TMW-03 (73 ft), TMW-04 (115 ft) and TMW-11 (400 ft); TMW-05 (400 ft) and TMW-12 (170 ft); and, TMW-07 (400 ft) and TMW-13 (148 ft).

Figure 1 and Tables 3A & B illustrate first half 2015 water levels and water level elevations data. Water levels in all the monitoring wells were measured monthly using electronic water level probes, except in months where the roads were too muddy to access some of the wells. Water levels in the injection wells AAW, S2W and SKW were measured using both an electronic probe and TMWA's SCADA system.

Figure 5A shows water levels and Figure 5B shows the water level elevations in the shallow and the deep wells. Figure 6 shows the differences in water level variations between shallow and deep monitoring wells. In Figure 6, the four pairs of nested wells mentioned above are plotted with the same color. The water level changes in the deep monitoring wells have higher variation between pumping and injection periods than in the shallow ones. This shows that the shallow wells are not as responsive to the injection and pumping activities compared to the deep monitoring wells.

Table 3A. West Lemmon Valley Wells – 1st Half 2015 Water Levels

	MW-B1	MW-116A	TMW-01 (MW-118C)	TMW-02 (MW-120A)	TMW-03 (MW-121B)	TMW-04 (MW-121C)	TMW-05	TMW-06	TMW-07	TMW-08	TMW-09	TMW-10	TMW-11	TMW-12	TMW-13	RRW	AAW	S2W	SKW
01/15/15	-24.34	-32.39	-42.08	-42.21	-47.51	-47.78	-74.58	-63.81	-92.48	-81.65	-33.38	-34.75	-44.56	-77.31	-94.52	-102.43	-18.09	-23.29	-75.21
02/09/15	-23.71		-40.60	-41.21						-71.49							-10.63	-15.74	-23.41
03/09/15	-23.05	-32.11	-39.02	-38.34	-45.57	-44.76	-61.94	-56.73	-79.76	-68.03	-22.51	-31.33	-32.82	-72.97	-90.73	-88.29	-6.94	-10.83	-15.98
04/16/15	-22.80	-32.04	-37.87	-37.27	-44.89	-43.78	-60.43	-55.64	-77.60	-66.63	-20.65	-30.31	-31.18	-72.07	-89.88	-85.45	-5.20	-8.28	-15.84
05/08/15	-22.55	-31.85	-37.29	-36.56	-44.32	-43.23	-59.77	-55.13	-76.42	-65.94	-19.85	-30.18	-30.57	-71.19	-89.11	-83.58	-2.95	-6.40	-11.78
06/05/15	-22.20	-31.68	-37.15	-36.27	-43.98	-43.11	-64.95	-57.13	-71.93	-72.43	-23.61	-30.07	-35.65	-71.74	-91.73	-87.46	-47.59	-21.87	-64.39
Elevation, ft. asl	4975.00	4982.00	4987.00	4983.00	4992.00	4992.00	5021.00	5009.00	5037.00	5028.00	4981.00	4980.00	4992.00	5021.00	5037.00	5043.00	4980.00	4978.00	5020.00
Depth, ft.	34.00	124.00	120.00	57.00	73.00	115.00	400.00	400.00	400.00	400.00	400.00	100.00	400.00	170.00	148.00	672.00	840.00	825.00	647.00
Top of Screen, ft.	30.00	105.00	100.00	37.00	54.00	99.00	200.00	200.00	200.00	200.00	200.00	60.00	360.00	110.00	98.00	328.00	310.00	192.00	328.00

Table 3B. West Lemmon Valley Wells – 1st Half 2015 Water Level Elevations

	MW-B1	MW-116A	TMW-01 (MW-118C)	TMW-02 (MW-120A)	TMW-03 (MW-121B)	TMW-04 (MW-121C)	TMW-05	TMW-06	TMW-07	TMW-08	TMW-09	TMW-10	TMW-11	TMW-12	TMW-13	RRW	AAW	S2W	SKW
01/15/15	4950.78	4949.33	4941.92	4940.39	4944.39	4944.24	4946.82	4945.29	4944.52	4946.65	4946.52	4945.19	4947.42	4943.37	4942.30	4940.17	4986.81	4965.11	4944.39
02/09/15	4951.41		4943.40	4941.39						4956.81							4994.27	4972.66	4996.19
03/09/15	4952.07	4949.61	4944.98	4944.26	4946.33	4947.26	4959.46	4952.37	4957.24	4960.27	4957.39	4948.61	4959.16	4947.71	4946.09	4954.31	4997.96	4977.57	5003.62
04/16/15	4952.32	4949.68	4946.13	4945.33	4947.01	4948.24	4960.97	4953.46	4959.40	4961.67	4959.25	4949.63	4960.80	4948.61	4946.94	4957.15	4999.70	4980.12	5003.76
05/08/15	4952.57	4949.87	4946.71	4946.04	4947.58	4948.79	4961.63	4953.97	4960.58	4962.36	4960.05	4949.76	4961.41	4949.49	4947.71	4959.02	5001.95	4982.00	5007.82
06/05/15	4952.92	4950.04	4946.85	4946.33	4947.92	4948.91	4956.45	4951.97	4965.07	4955.87	4956.29	4949.87	4956.33	4948.94	4945.09	4955.14	4957.31	4966.53	4955.21
Elevation, ft. asl	4975.00	4982.00	4987.00	4983.00	4992.00	4992.00	5021.00	5009.00	5037.00	5028.00	4981.00	4980.00	4992.00	5021.00	5037.00	5043.00	4980.00	4978.00	5020.00
Depth, ft.	34.00	124.00	120.00	57.00	73.00	115.00	400.00	400.00	400.00	400.00	400.00	100.00	400.00	170.00	148.00	672.00	840.00	825.00	647.00
Top of Screen, ft.	30.00	105.00	100.00	37.00	54.00	99.00	200.00	200.00	200.00	200.00	200.00	60.00	360.00	110.00	98.00	328.00	310.00	192.00	328.00

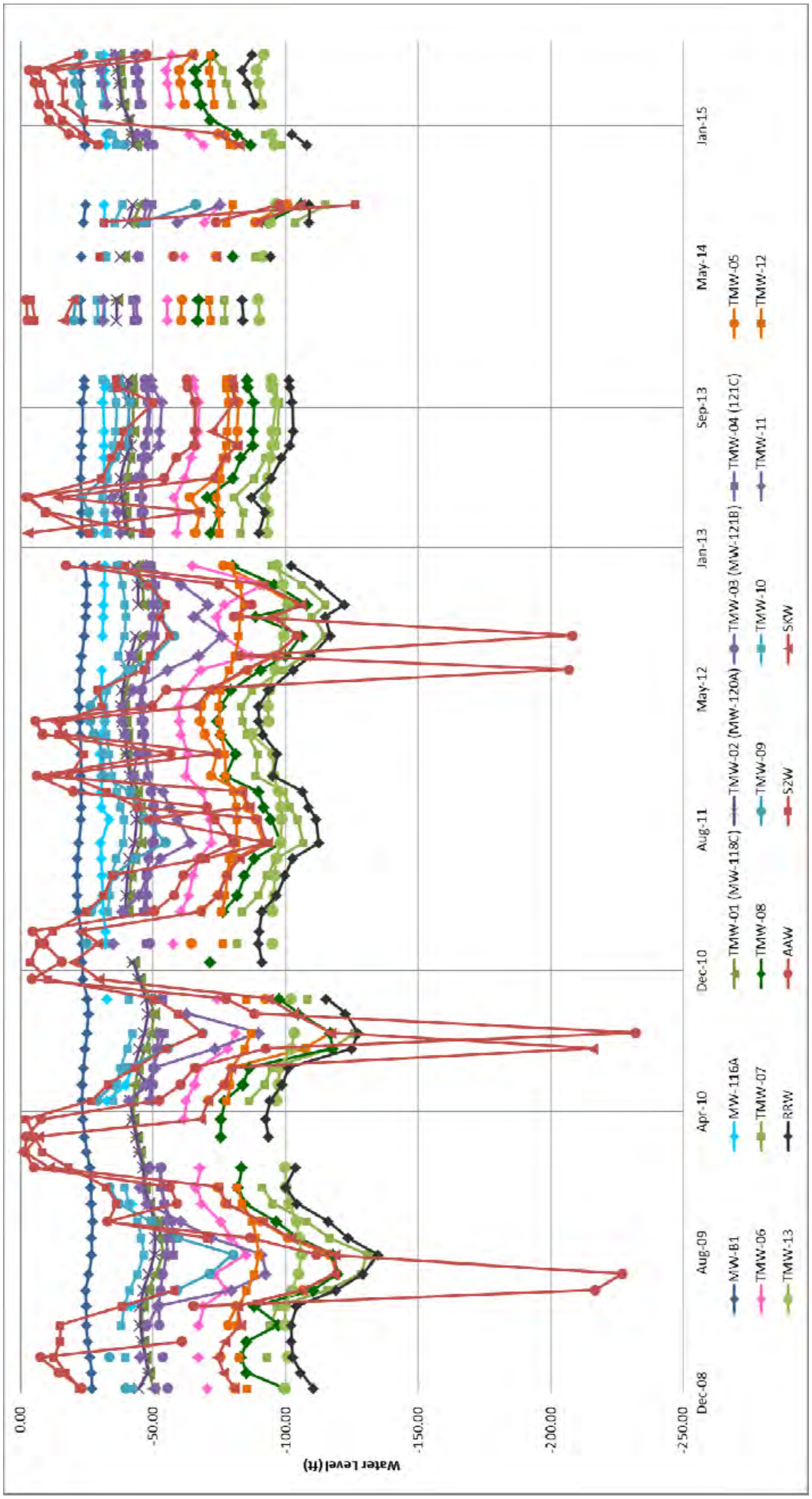


Figure 5A. West Lemmon Valley Wells Water Levels

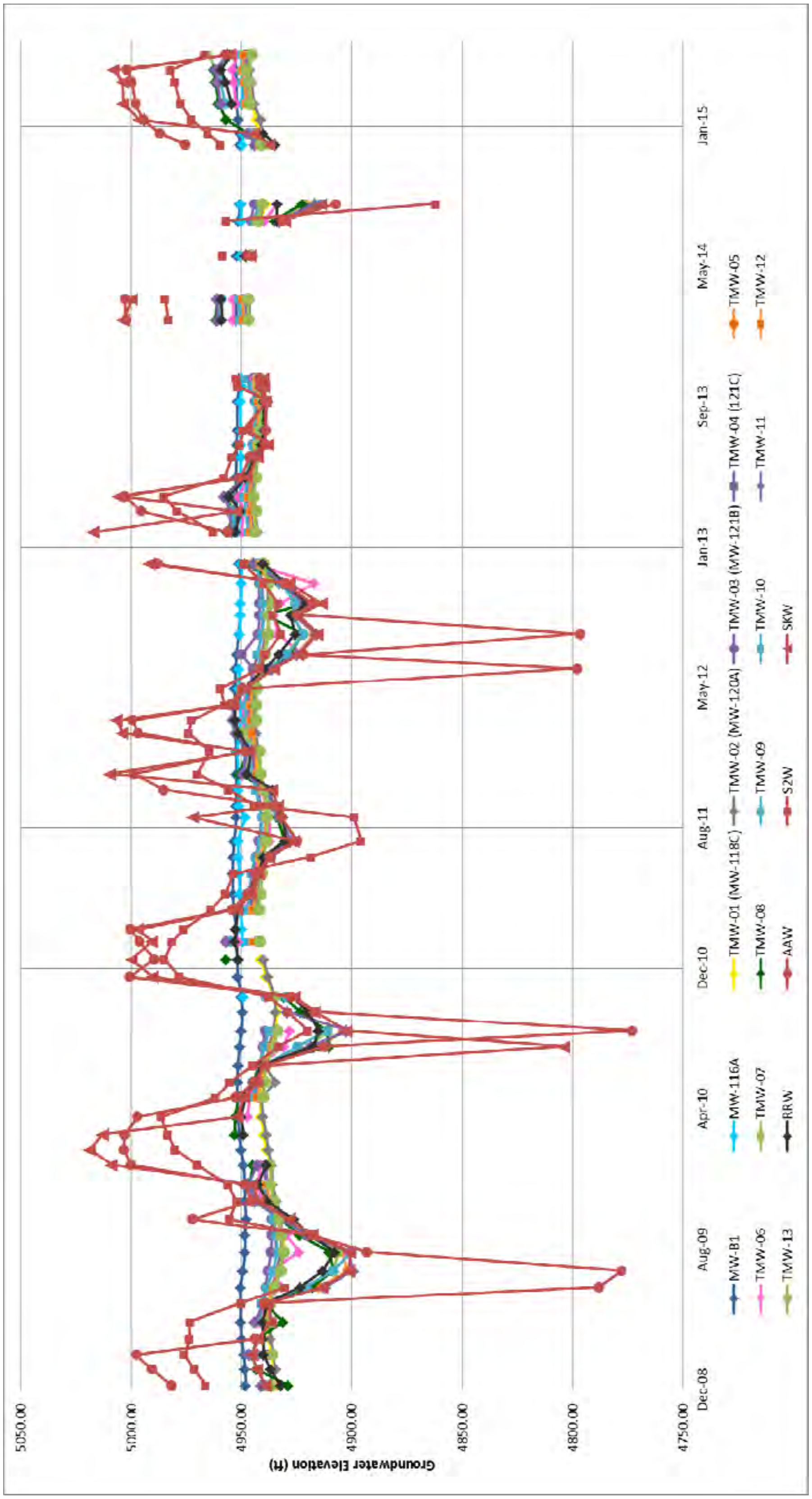


Figure 5B. **West Lemmon Valley Water Level Elevations**

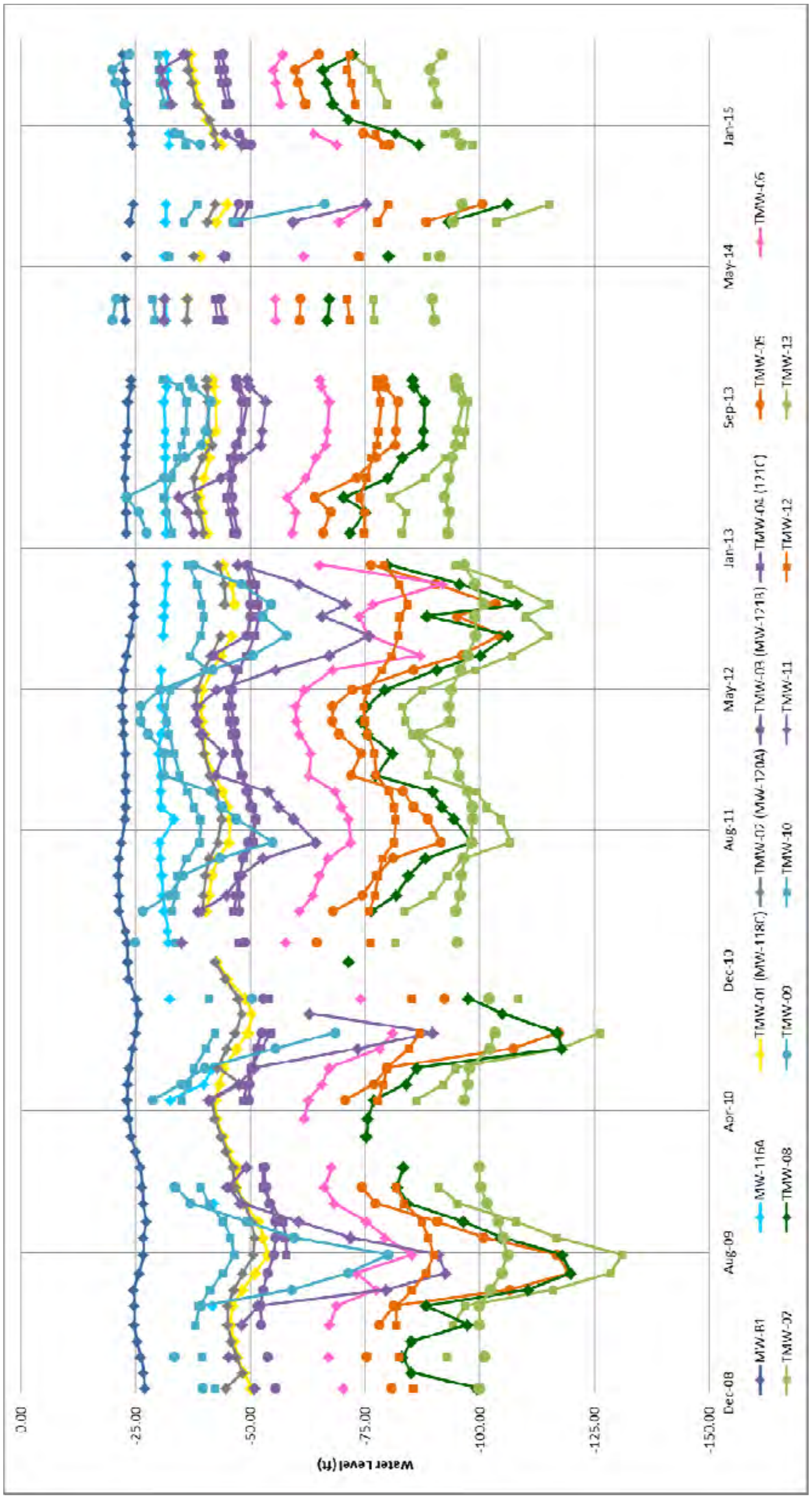


Figure 6. West Lemmon Valley Monitoring Wells Water Levels

3.0 WATER QUALITY

Water sample results of injected water into the Silver Lake Well were taken during the first and second quarters of 2015 and the results are shown in Tables A.1 and A.2 in Appendix A. Two pages of UIC Form U230 follow their respective results table. All the elements analyzed are below the Maximum Contaminant Levels (MCL).

Extracted water sample results taken between January and June 2015 are shown Table A.3 in Appendix A, and in Tables B.1, B.2, and B.3 in Appendix B. The results presented in Tables B.1 and B.2 show first and second quarters (1) Stage 2 HAA5 DBPs concentrations for the twelve sampling locations approved by NDEP for the Truckee Meadows, Lemmon Valley and (2) first and second quarters Stage 2 TTHM DBPs concentrations for the same sampling locations. The system average during the first half of 2015 for TTHM was 35.6 μg/L and for HAA5 was 27.7 μg/L both of which are below the MCLs. The Locational Running Annual Average (LRAA) for the previous four quarters was 29.1 μg/L for TTHM and 21.1 μg/L for HAA5.

Tables B.4 and B.5 show disinfectant residual data for the first and second quarters of 2015. All sample results are in compliance for the drinking water standards. This indicates that injection water is not adversely affecting the aquifer formation water quality in the West Lemmon Valley Basin.

Note that although water was extracted from the Silver Lake Well for four days in late June, the pump failed before a sample could be taken, and produced water sample results for this well are therefore not included in this report.

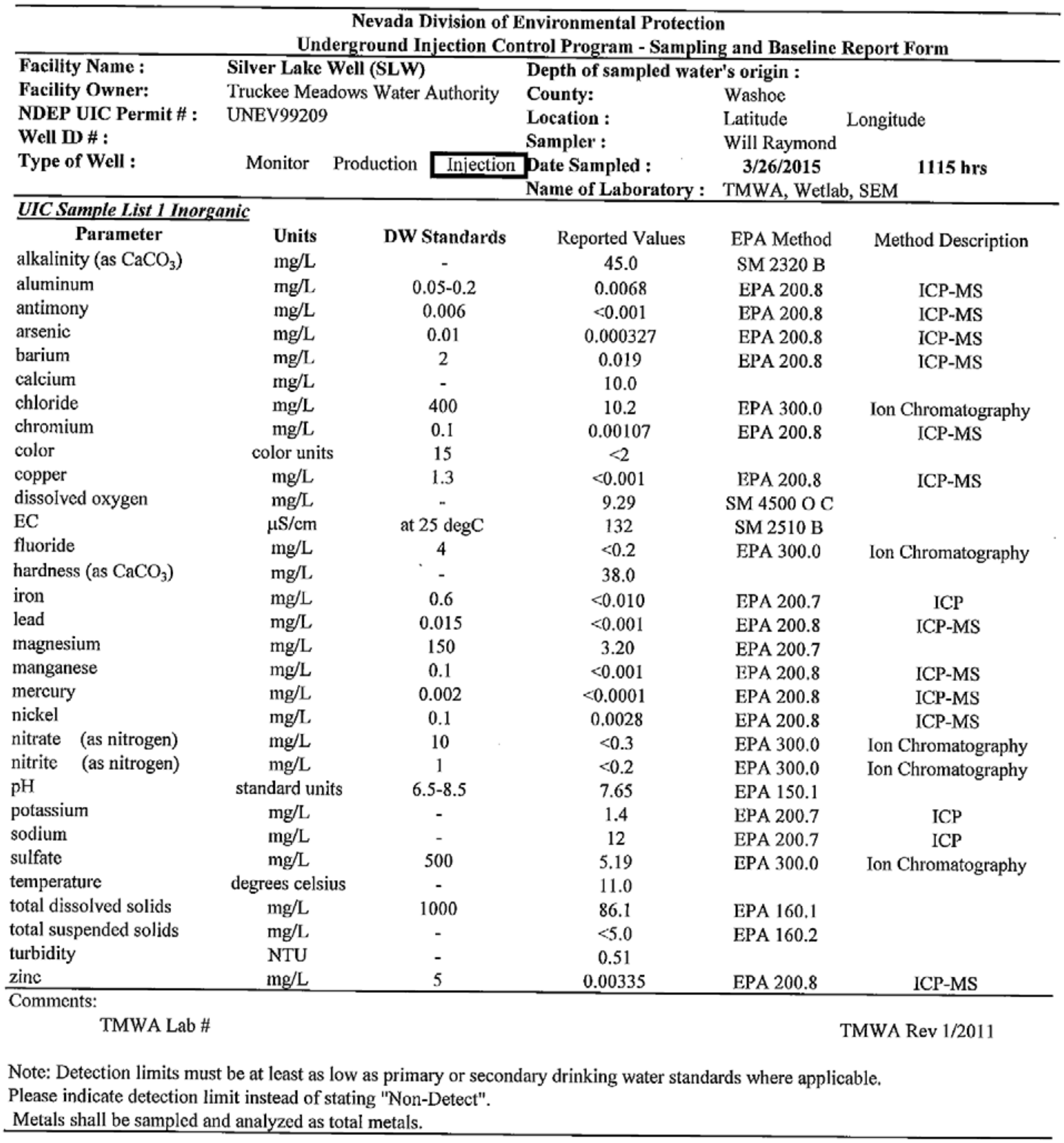
4.0 CONCLUSION

TMWA’s ASR program in the West Lemmon Valley Basin has grown from 32 acre-feet of treated surface water injected in 2000 to 4,649 acre-feet cumulative total at the end of June 2015. The results, as discussed above and shown by various data sheets and charts, show that both injection and pumping activities at S2W, AAW and SKW have very little, if any, effects on the shallow aquifer as demonstrated by water levels in shallow monitoring wells in the vicinity of the injection sites. The data show that where the water level changes were experienced in the shallow wells, the changes were significantly less than the annual historical water level variations in these wells before commencement of the injection tests.

The chemistry of the injection and extracted water shows no adverse effects to the aquifer as evidenced from the low disinfection by-products concentrations and consistent water quality data from the extracted water.

APPENDIX A: WATER QUALITY SAMPLING RESULTS

Table A.1. Zone 5: 1Q 2015 Injected Water Quality, Silver Lake Well



Nevada Division of Environmental Protection

Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name : Silver Lake Well (SLW)

Facility Owner: Truckee Meadows Water Authority

NDEP UIC Permit # : UNEV99209

Well ID # :

Type of Well : Monitor Production [✓ Injection]

Depth of sampled water's origin :

County: Washoe

Location : Latitude Longitude

Sampler : Will Raymond

Date Sampled : **3/26/2015** **1115 hrs**

Name of Laboratory : TMWA, Wetlab, SEM

UIC Sample List 1 Inorganic

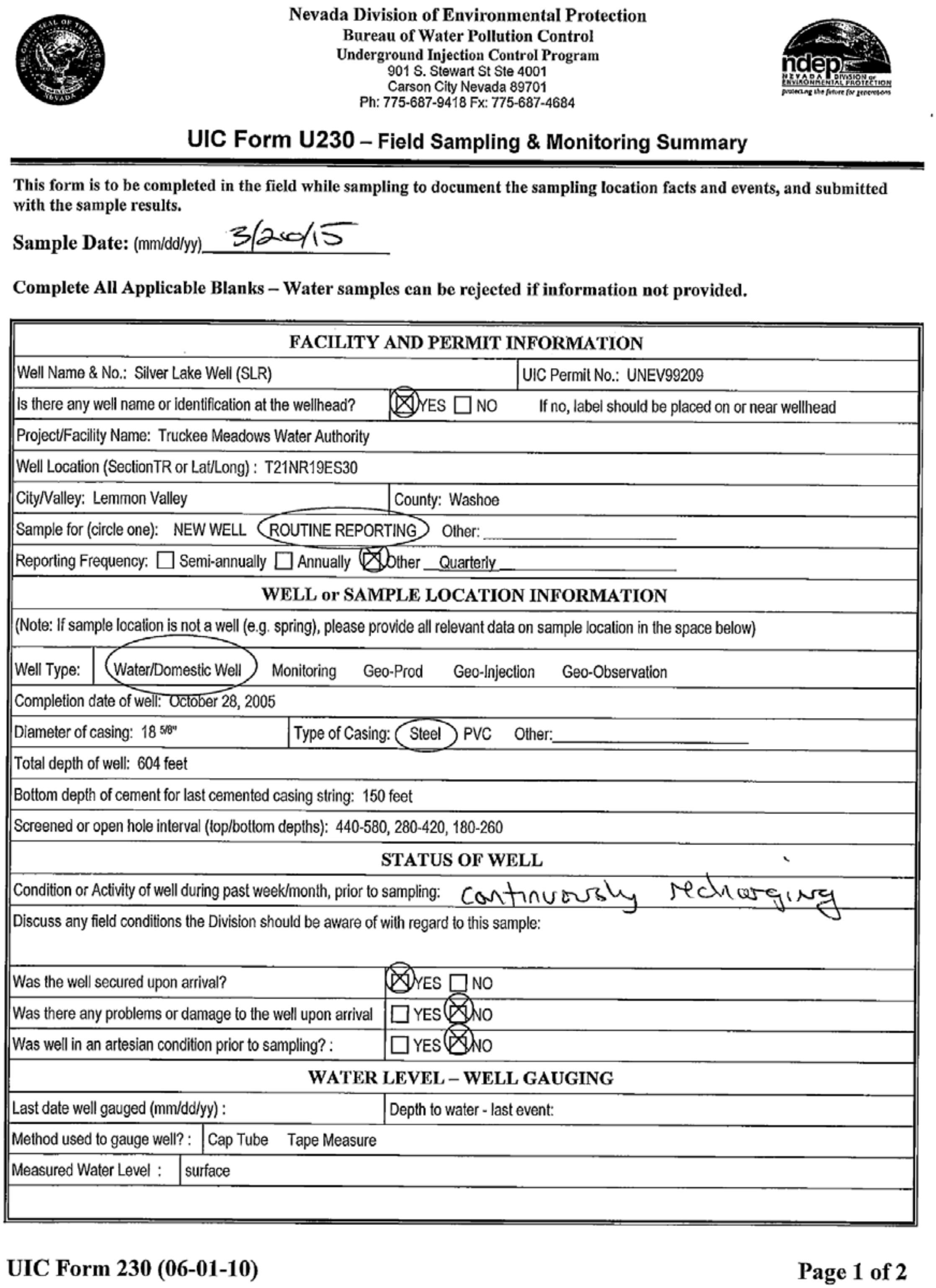
Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	45.0	SM 2320 B	
aluminum	mg/L	0.05-0.2	0.0068	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.001	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	0.000327	EPA 200.8	ICP-MS
barium	mg/L	2	0.019	EPA 200.8	ICP-MS
calcium	mg/L	-	10.0		
chloride	mg/L	400	10.2	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	0.00107	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	<0.001	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	9.29	SM 4500 O C	
EC	µS/cm	at 25 degC	132	SM 2510 B	
fluoride	mg/L	4	<0.2	EPA 300.0	Ion Chromatography
hardness (as $CaCO_3$)	mg/L	-	38.0		
iron	mg/L	0.6	<0.010	EPA 200.7	ICP
lead	mg/L	0.015	<0.001	EPA 200.8	ICP-MS
magnesium	mg/L	150	3.20	EPA 200.7	
manganese	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.0001	EPA 200.8	ICP-MS
nickel	mg/L	0.1	0.0028	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	<0.3	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.2	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.65	EPA 150.1	
potassium	mg/L	-	1.4	EPA 200.7	ICP
sodium	mg/L	-	12	EPA 200.7	ICP
sulfate	mg/L	500	5.19	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	11.0		
total dissolved solids	mg/L	1000	86.1	EPA 160.1	
total suspended solids	mg/L	-	<5.0	EPA 160.2	
turbidity	NTU	-	0.51		
zinc	mg/L	5	0.00335	EPA 200.8	ICP-MS

Comments:

TMWA Lab #

TMWA Rev 1/2011

Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.



Nevada Division of Environmental Protection
Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 3/20/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: Silver Lake Well (SLR) | UIC Permit No.: UNEV99209

Is there any well name or identification at the wellhead? ☒ YES ☐ NO If no, label should be placed on or near wellhead

Project/Facility Name: Truckee Meadows Water Authority

Well Location (SectionTR or Lat/Long) : T21NR19ES30

City/Valley: Lemmon Valley | County: Washoe

Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other: ____

Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type: [✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation

Completion date of well: October 28, 2005

Diameter of casing: 18 5/8" | Type of Casing: [✓ Steel] PVC Other: ____

Total depth of well: 604 feet

Bottom depth of cement for last cemented casing string: 150 feet

Screened or open hole interval (top/bottom depths): 440-580, 280-420, 180-260

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: continuously recharging

Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival? ☒ YES ☐ NO

Was there any problems or damage to the well upon arrival ☐ YES ☒ NO

Was well in an artesian condition prior to sampling? : ☐ YES ☒ NO

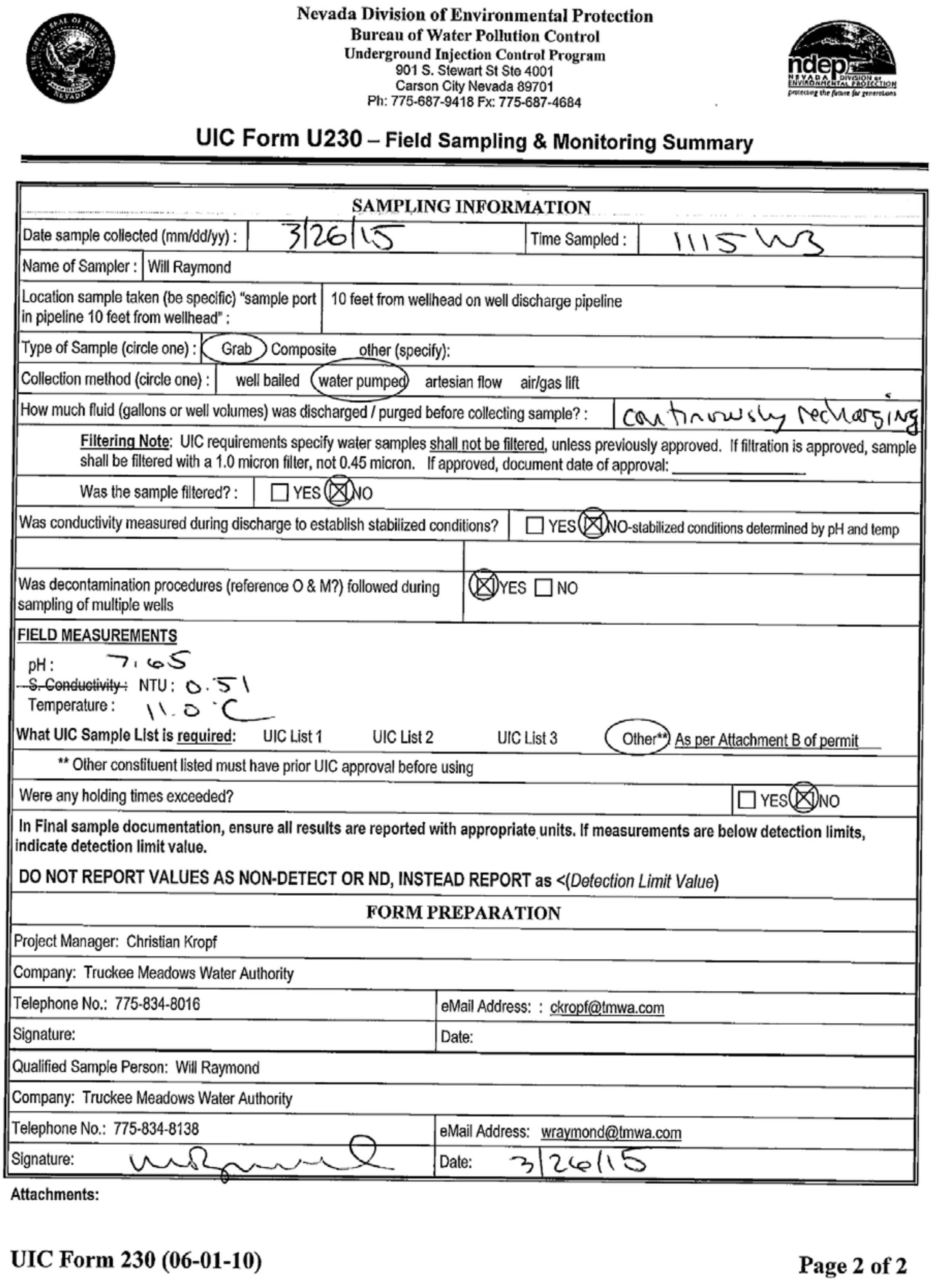
WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) : | Depth to water - last event:

Method used to gauge well? : Cap Tube Tape Measure

Measured Water Level : surface

UIC Form 230 (06-01-10) **Page 1 of 2**



Nevada Division of Environmental Protection
Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

ndep NEVADA DIVISION of ENVIRONMENTAL PROTECTION protecting the future for generations

UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy) : 3/26/15 Time Sampled : 1115 WR

Name of Sampler : Will Raymond

Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead" : 10 feet from wellhead on well discharge pipeline

Type of Sample (circle one) : [✓ Grab] Composite other (specify):

Collection method (circle one) : well bailed [✓ water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was discharged / purged before collecting sample? : continuously recharging

Filtering Note: UIC requirements specify water samples shall not be filtered, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: ________

Was the sample filtered? : ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

FIELD MEASUREMENTS

pH : 7.65

~~S. Conductivity :~~ NTU : 0.51

Temperature : 11.0 °C

What UIC Sample List is required: UIC List 1 UIC List 2 UIC List 3 [✓ Other**] As per Attachment B of permit

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8016 eMail Address: : ckropf@tmwa.com

Signature: Date:

Qualified Sample Person: Will Raymond

Company: Truckee Meadows Water Authority

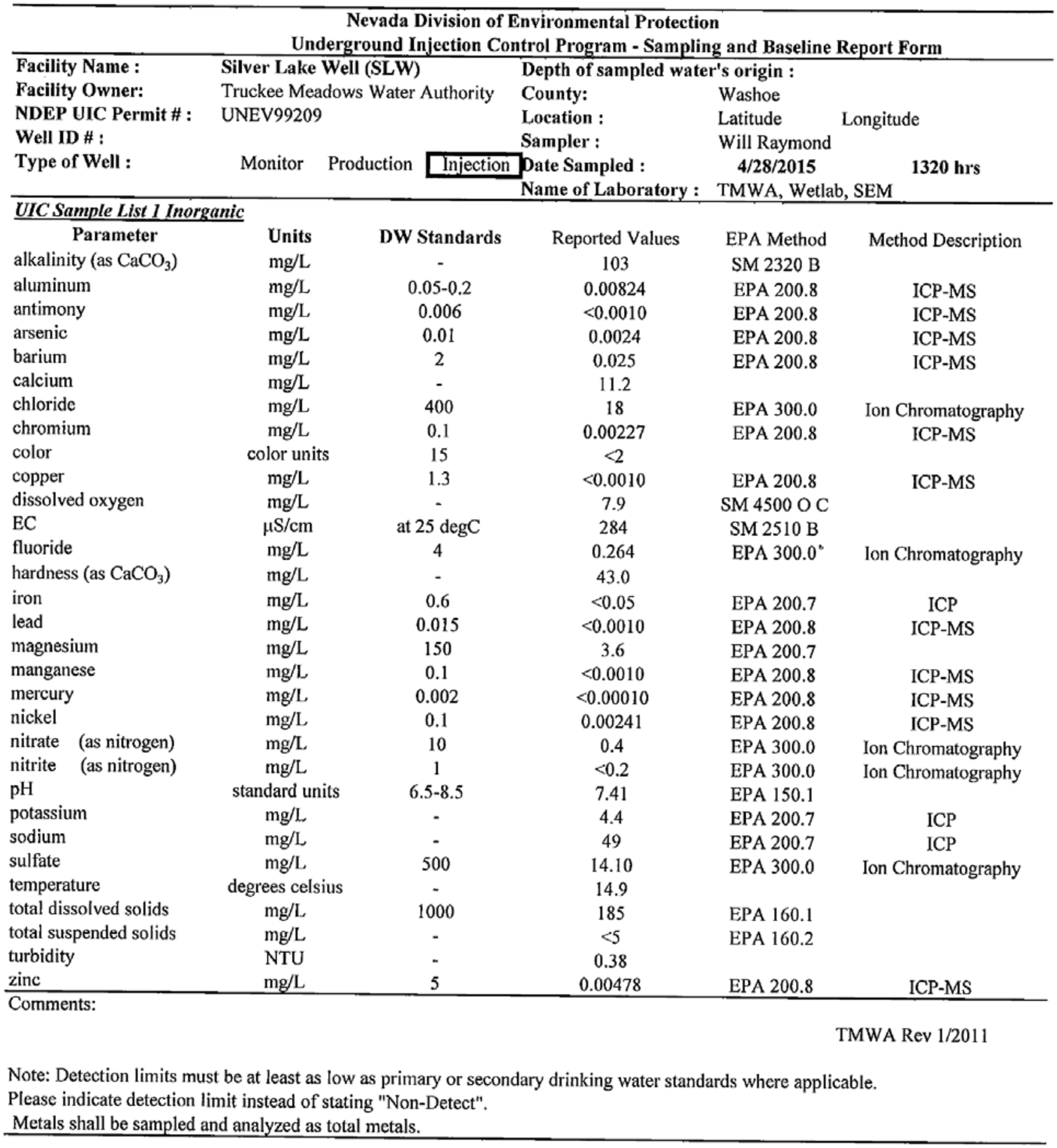
Telephone No.: 775-834-8138 eMail Address: wraymond@tmwa.com

Signature: Date: 3/26/15

Attachments:

UIC Form 230 (06-01-10) **Page 2 of 2**

Table A.2. Zone 5: 2Q 2015 Injected Water Quality, Silver Lake Well



Nevada Division of Environmental Protection

Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**Silver Lake Well (SLW)**	**Depth of sampled water's origin :**	
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe
NDEP UIC Permit # :	UNEV99209	**Location :**	Latitude Longitude
Well ID # :		**Sampler :**	Will Raymond
Type of Well :	Monitor Production [✓ Injection]	**Date Sampled :**	**4/28/2015** **1320 hrs**
		Name of Laboratory :	TMWA, Wetlab, SEM

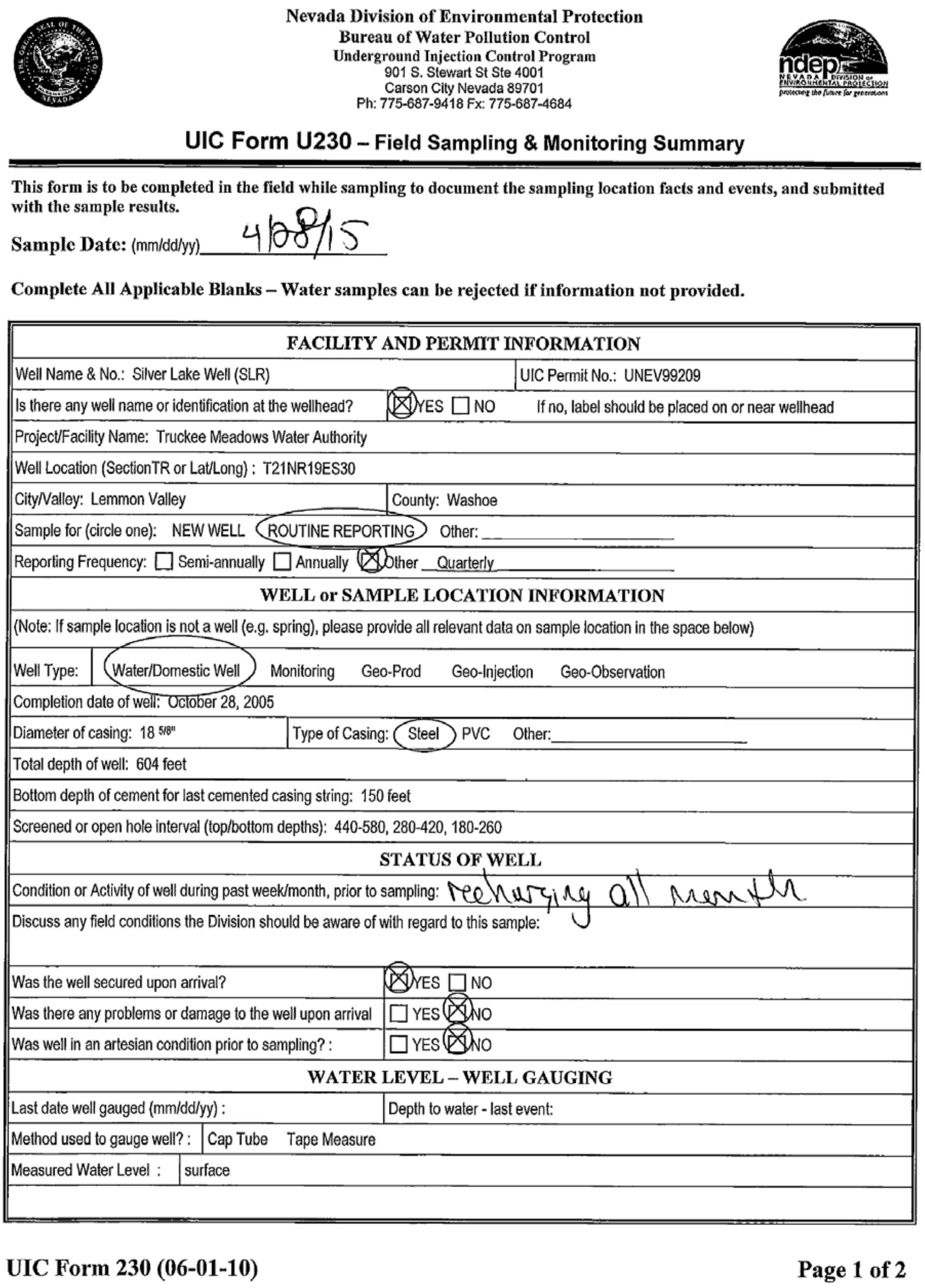
UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	103	SM 2320 B	
aluminum	mg/L	0.05-0.2	0.00824	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.0010	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	0.0024	EPA 200.8	ICP-MS
barium	mg/L	2	0.025	EPA 200.8	ICP-MS
calcium	mg/L	-	11.2		
chloride	mg/L	400	18	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	0.00227	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	<0.0010	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	7.9	SM 4500 O C	
EC	µS/cm	at 25 degC	284	SM 2510 B	
fluoride	mg/L	4	0.264	EPA 300.0	Ion Chromatography
hardness (as $CaCO_3$)	mg/L	-	43.0		
iron	mg/L	0.6	<0.05	EPA 200.7	ICP
lead	mg/L	0.015	<0.0010	EPA 200.8	ICP-MS
magnesium	mg/L	150	3.6	EPA 200.7	
manganese	mg/L	0.1	<0.0010	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.00010	EPA 200.8	ICP-MS
nickel	mg/L	0.1	0.00241	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	0.4	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.2	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.41	EPA 150.1	
potassium	mg/L	-	4.4	EPA 200.7	ICP
sodium	mg/L	-	49	EPA 200.7	ICP
sulfate	mg/L	500	14.10	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	14.9		
total dissolved solids	mg/L	1000	185	EPA 160.1	
total suspended solids	mg/L	-	<5	EPA 160.2	
turbidity	NTU	-	0.38		
zinc	mg/L	5	0.00478	EPA 200.8	ICP-MS

Comments:

TMWA Rev 1/2011

Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.



Nevada Division of Environmental Protection
Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 4/08/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: Silver Lake Well (SLR) — UIC Permit No.: UNEV99209

Is there any well name or identification at the wellhead? ☒ YES ☐ NO — If no, label should be placed on or near wellhead

Project/Facility Name: Truckee Meadows Water Authority

Well Location (SectionTR or Lat/Long) : T21NR19ES30

City/Valley: Lemmon Valley — County: Washoe

Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other: ______

Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type: [✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation

Completion date of well: October 28, 2005

Diameter of casing: 18 5/8" — Type of Casing: [✓ Steel] PVC Other: ______

Total depth of well: 604 feet

Bottom depth of cement for last cemented casing string: 150 feet

Screened or open hole interval (top/bottom depths): 440-580, 280-420, 180-260

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: recharging all month

Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival? ☒ YES ☐ NO

Was there any problems or damage to the well upon arrival ☐ YES ☒ NO

Was well in an artesian condition prior to sampling? : ☐ YES ☒ NO

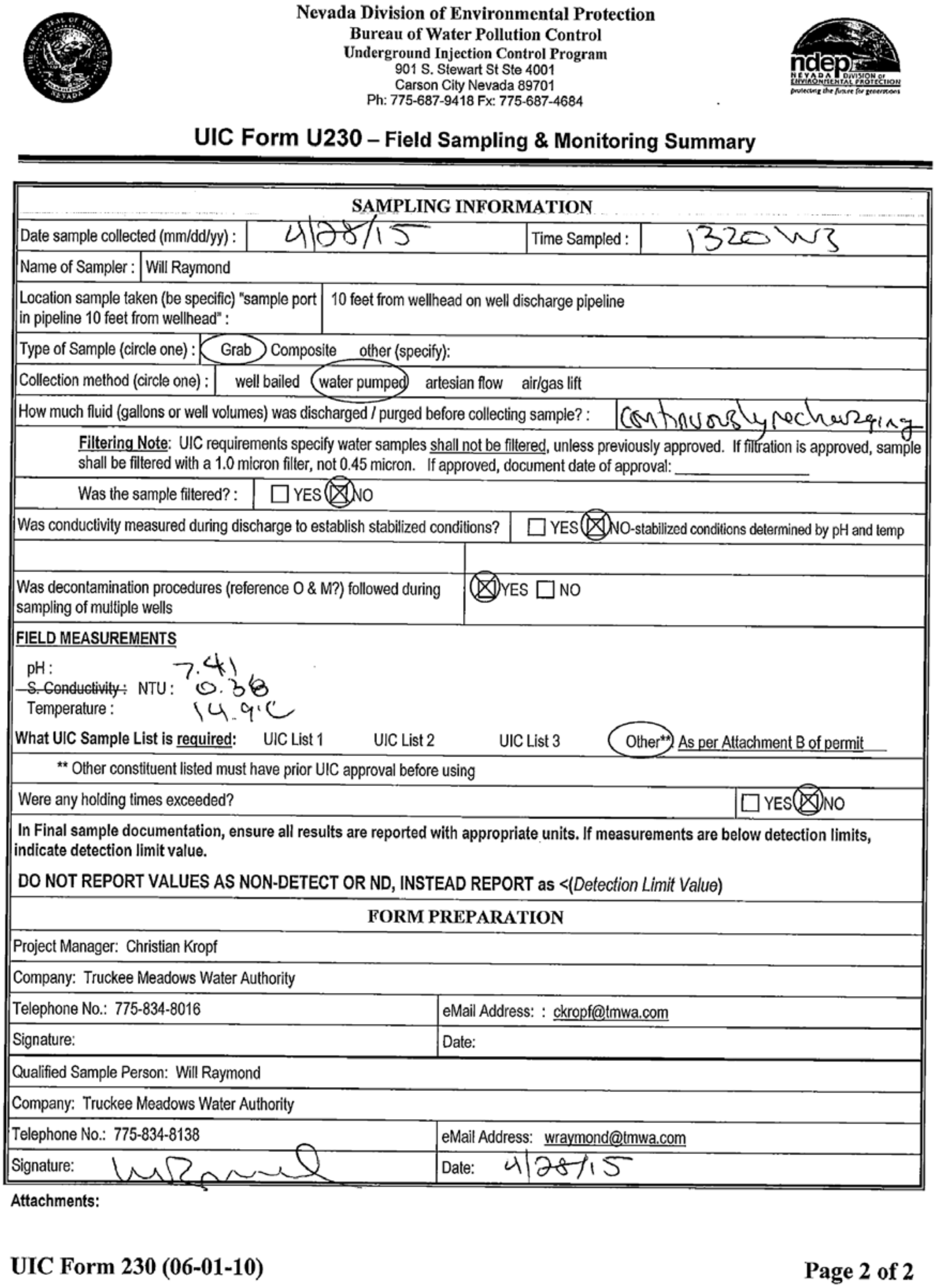
WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) : — Depth to water - last event:

Method used to gauge well? : Cap Tube Tape Measure

Measured Water Level : surface

UIC Form 230 (06-01-10) **Page 1 of 2**



Nevada Division of Environmental Protection
Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy): 4/28/15

Time Sampled: 1320 W3

Name of Sampler: Will Raymond

Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead": 10 feet from wellhead on well discharge pipeline

Type of Sample (circle one): [✓ Grab] Composite other (specify):

Collection method (circle one): well bailed [✓ water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was discharged / purged before collecting sample?: continuously recharging

Filtering Note: UIC requirements specify water samples shall not be filtered, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: ____________

Was the sample filtered?: ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

FIELD MEASUREMENTS

pH: 7.41
~~S. Conductivity:~~ NTU: 0.38
Temperature: 14.9°C

What UIC Sample List is required: UIC List 1 UIC List 2 UIC List 3 [✓ Other**] As per Attachment B of permit

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8016 eMail Address: : ckropf@tmwa.com

Signature: Date:

Qualified Sample Person: Will Raymond

Company: Truckee Meadows Water Authority

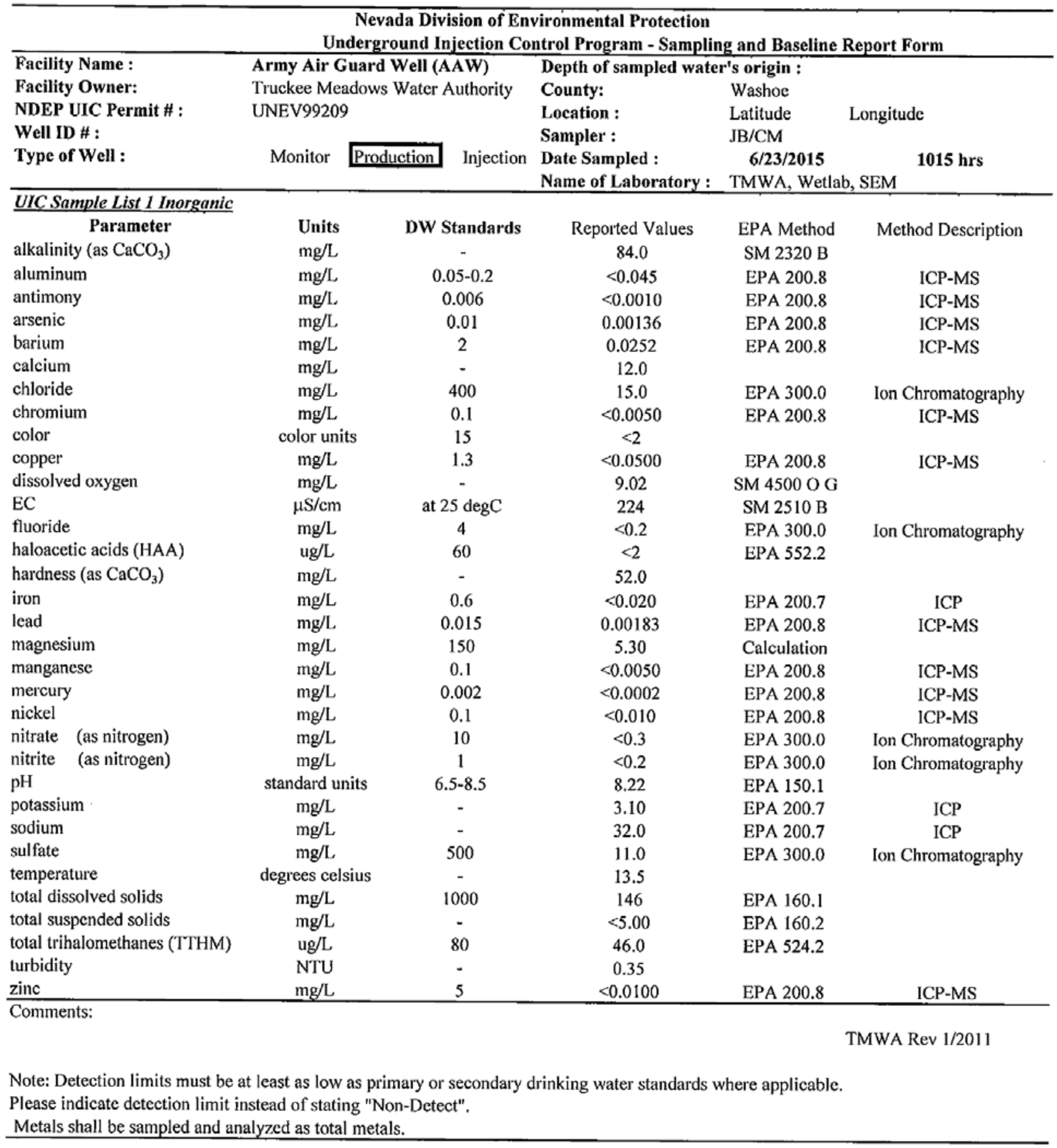
Telephone No.: 775-834-8138 eMail Address: wraymond@tmwa.com

Signature: Date: 4/28/15

Attachments:

UIC Form 230 (06-01-10) **Page 2 of 2**

Table A.3. Zone 5: 2Q 2015 Extracted Water Quality, Army Air Guard Well



Nevada Division of Environmental Protection

Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name : **Army Air Guard Well (AAW)**
Facility Owner: Truckee Meadows Water Authority
NDEP UIC Permit # : UNEV99209
Well ID # :
Type of Well : Monitor [✓ Production] Injection

Depth of sampled water's origin :
County: Washoe
Location : Latitude Longitude
Sampler : JB/CM
Date Sampled : **6/23/2015** **1015 hrs**
Name of Laboratory : TMWA, Wetlab, SEM

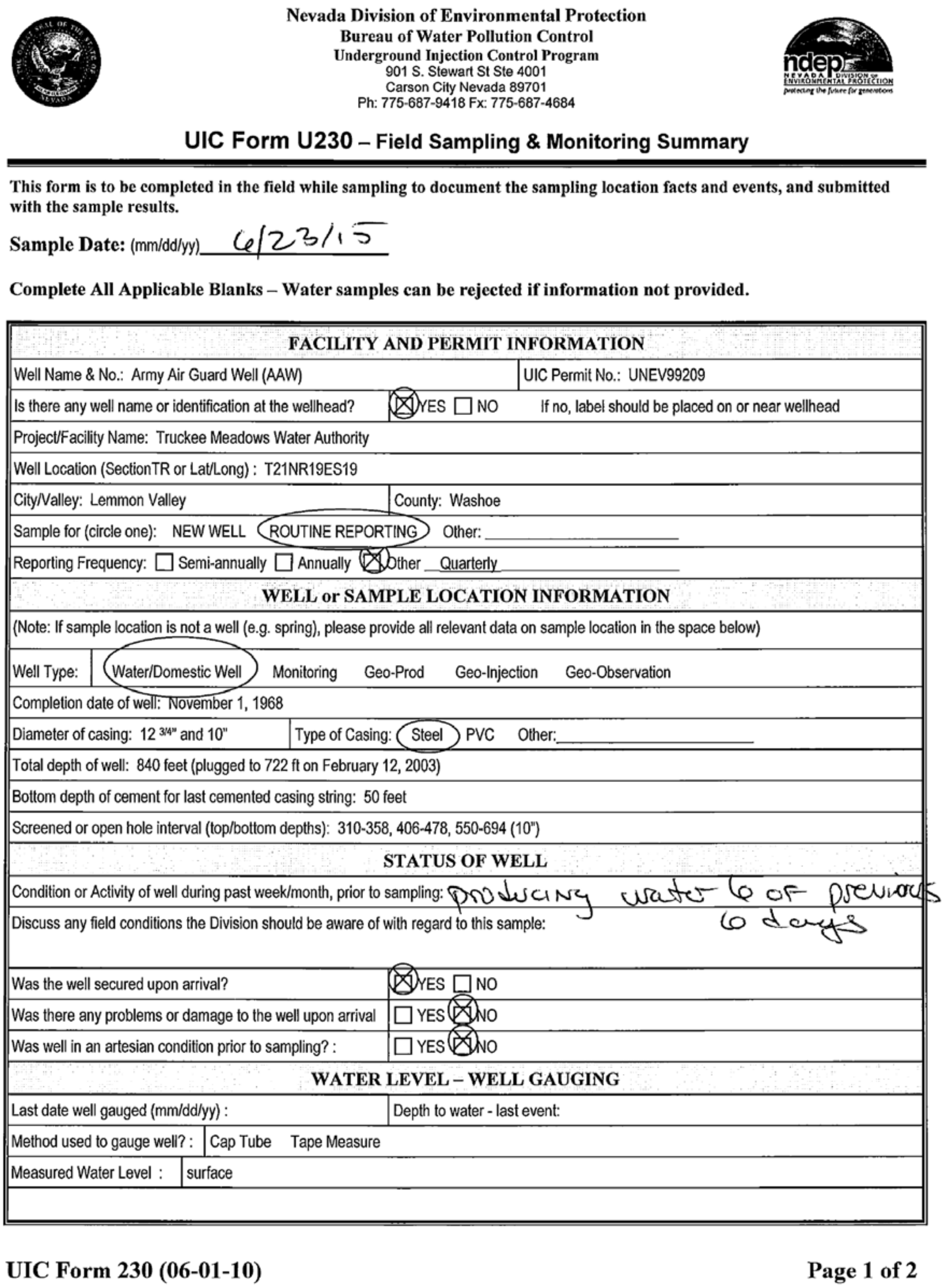
UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	84.0	SM 2320 B	
aluminum	mg/L	0.05-0.2	<0.045	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.0010	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	0.00136	EPA 200.8	ICP-MS
barium	mg/L	2	0.0252	EPA 200.8	ICP-MS
calcium	mg/L	-	12.0		
chloride	mg/L	400	15.0	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	<0.0050	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	<0.0500	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	9.02	SM 4500 O G	
EC	µS/cm	at 25 degC	224	SM 2510 B	
fluoride	mg/L	4	<0.2	EPA 300.0	Ion Chromatography
haloacetic acids (HAA)	ug/L	60	<2	EPA 552.2	
hardness (as $CaCO_3$)	mg/L	-	52.0		
iron	mg/L	0.6	<0.020	EPA 200.7	ICP
lead	mg/L	0.015	0.00183	EPA 200.8	ICP-MS
magnesium	mg/L	150	5.30	Calculation	
manganese	mg/L	0.1	<0.0050	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.0002	EPA 200.8	ICP-MS
nickel	mg/L	0.1	<0.010	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	<0.3	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.2	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	8.22	EPA 150.1	
potassium	mg/L	-	3.10	EPA 200.7	ICP
sodium	mg/L	-	32.0	EPA 200.7	ICP
sulfate	mg/L	500	11.0	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	13.5		
total dissolved solids	mg/L	1000	146	EPA 160.1	
total suspended solids	mg/L	-	<5.00	EPA 160.2	
total trihalomethanes (TTHM)	ug/L	80	46.0	EPA 524.2	
turbidity	NTU	-	0.35		
zinc	mg/L	5	<0.0100	EPA 200.8	ICP-MS

Comments:

TMWA Rev 1/2011

Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.



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Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 6/23/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: Army Air Guard Well (AAW)

UIC Permit No.: UNEV99209

Is there any well name or identification at the wellhead? ☒ YES ☐ NO If no, label should be placed on or near wellhead

Project/Facility Name: Truckee Meadows Water Authority

Well Location (SectionTR or Lat/Long) : T21NR19ES19

City/Valley: Lemmon Valley

County: Washoe

Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other: ______

Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type: [✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation

Completion date of well: November 1, 1968

Diameter of casing: 12 3/4" and 10"

Type of Casing: [✓ Steel] PVC Other: ______

Total depth of well: 840 feet (plugged to 722 ft on February 12, 2003)

Bottom depth of cement for last cemented casing string: 50 feet

Screened or open hole interval (top/bottom depths): 310-358, 406-478, 550-694 (10")

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: producing water 6 of previous 6 days

Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival? ☒ YES ☐ NO

Was there any problems or damage to the well upon arrival ☐ YES ☒ NO

Was well in an artesian condition prior to sampling? : ☐ YES ☒ NO

WATER LEVEL – WELL GAUGING

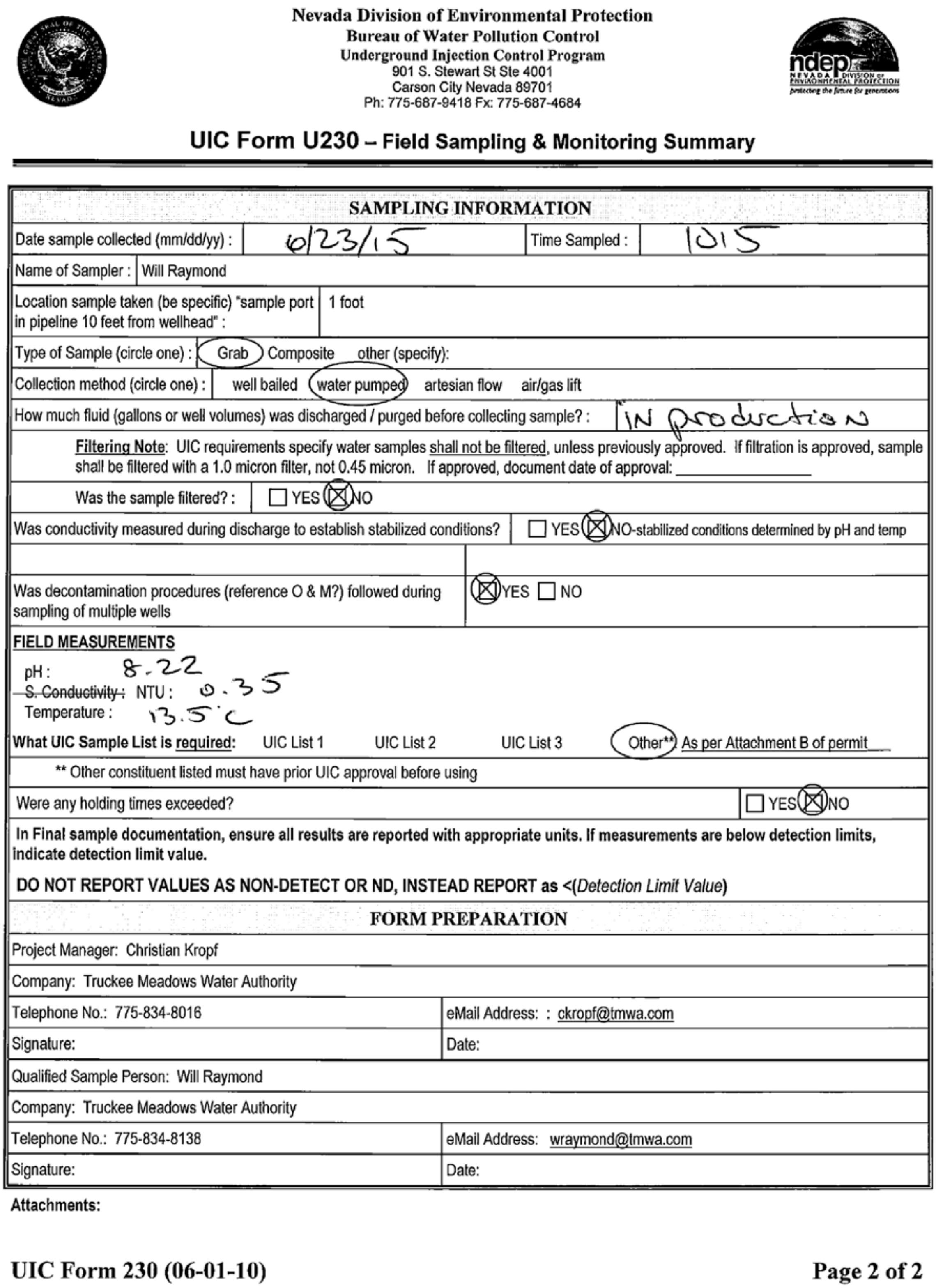
Last date well gauged (mm/dd/yy) :

Depth to water - last event:

Method used to gauge well? : Cap Tube Tape Measure

Measured Water Level : surface

UIC Form 230 (06-01-10) **Page 1 of 2**



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Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy) : 6/23/15 Time Sampled : 1015

Name of Sampler : Will Raymond

Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead" : 1 foot

Type of Sample (circle one) : [✓ Grab] Composite other (specify):

Collection method (circle one) : well bailed [✓ water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was discharged / purged before collecting sample? : IN production

Filtering Note: UIC requirements specify water samples shall not be filtered, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: ________________

Was the sample filtered? : ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

FIELD MEASUREMENTS

pH : 8.22
~~S. Conductivity :~~ NTU : 0.35
Temperature : 13.5°C

What UIC Sample List is required: UIC List 1 UIC List 2 UIC List 3 [✓ Other**] As per Attachment B of permit

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8016 eMail Address: : ckropf@tmwa.com

Signature: Date:

Qualified Sample Person: Will Raymond

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8138 eMail Address: wraymond@tmwa.com

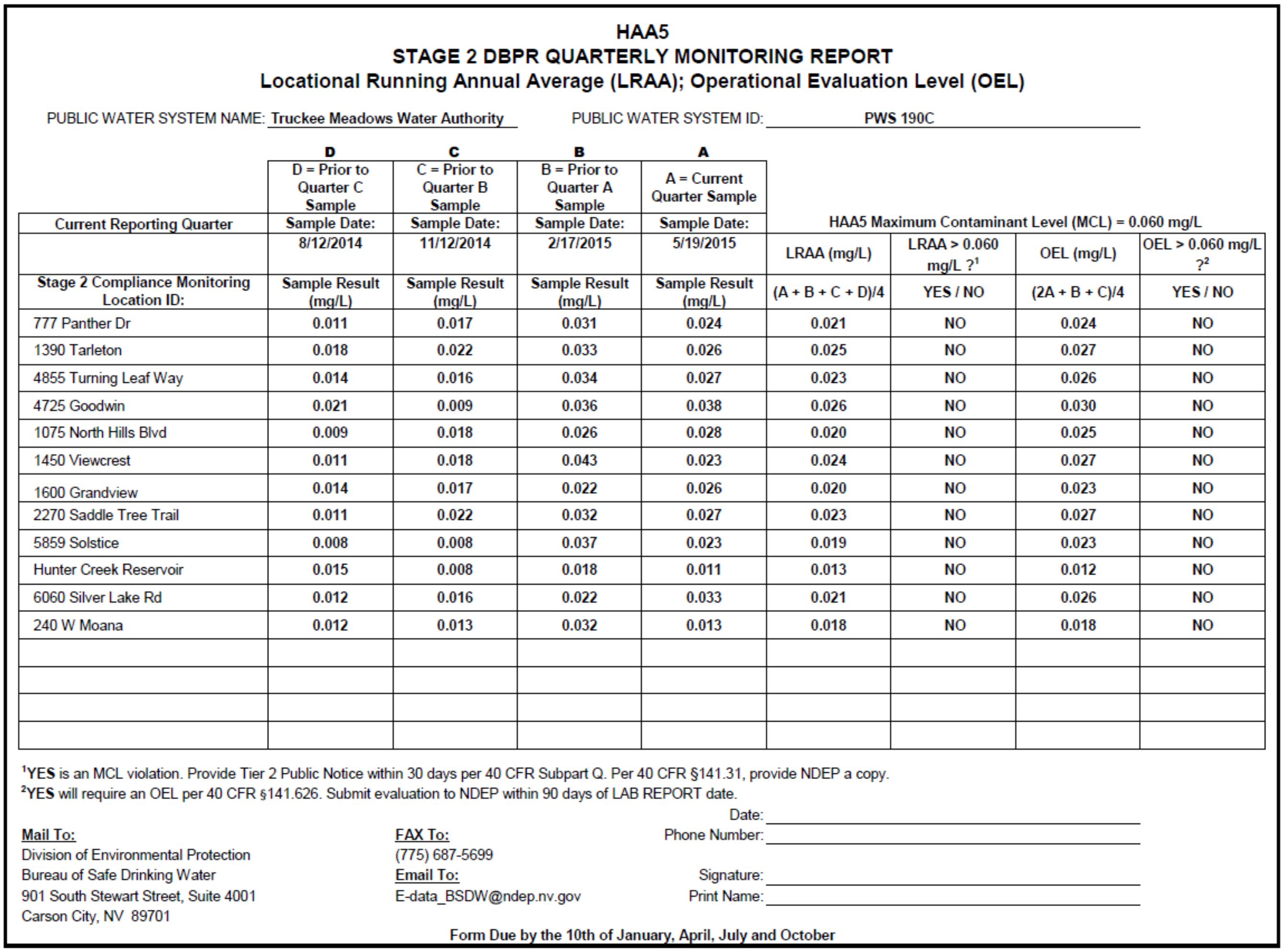
Signature: Date:

Attachments:

UIC Form 230 (06-01-10) **Page 2 of 2**

APPENDIX B: DISINFECTION BY-PRODUCTS AND DISINFECTANT RESIDUAL RESULTS

Table B.1. Disinfection By-Products (DBP) Report – 1st Half 2015: HAA5



HAA5
STAGE 2 DBPR QUARTERLY MONITORING REPORT
Locational Running Annual Average (LRAA); Operational Evaluation Level (OEL)

PUBLIC WATER SYSTEM NAME: **Truckee Meadows Water Authority**

PUBLIC WATER SYSTEM ID: **PWS 190C**

	D	**C**	**B**	**A**				
	D = Prior to Quarter C Sample	C = Prior to Quarter B Sample	B = Prior to Quarter A Sample	A = Current Quarter Sample				
Current Reporting Quarter	**Sample Date:**	**Sample Date:**	**Sample Date:**	**Sample Date:**	**HAA5 Maximum Contaminant Level (MCL) = 0.060 mg/L**			
	8/12/2014	**11/12/2014**	**2/17/2015**	**5/19/2015**	**LRAA (mg/L)**	**LRAA > 0.060 mg/L ?[1]**	**OEL (mg/L)**	**OEL > 0.060 mg/L ?[2]**
Stage 2 Compliance Monitoring Location ID:	**Sample Result (mg/L)**	**Sample Result (mg/L)**	**Sample Result (mg/L)**	**Sample Result (mg/L)**	**(A + B + C + D)/4**	**YES / NO**	**(2A + B + C)/4**	**YES / NO**
777 Panther Dr	**0.011**	**0.017**	**0.031**	**0.024**	**0.021**	**NO**	**0.024**	**NO**
1390 Tarleton	**0.018**	**0.022**	**0.033**	**0.026**	**0.025**	**NO**	**0.027**	**NO**
4855 Turning Leaf Way	**0.014**	**0.016**	**0.034**	**0.027**	**0.023**	**NO**	**0.026**	**NO**
4725 Goodwin	**0.021**	**0.009**	**0.036**	**0.038**	**0.026**	**NO**	**0.030**	**NO**
1075 North Hills Blvd	**0.009**	**0.018**	**0.026**	**0.028**	**0.020**	**NO**	**0.025**	**NO**
1450 Viewcrest	**0.011**	**0.018**	**0.043**	**0.023**	**0.024**	**NO**	**0.027**	**NO**
1600 Grandview	**0.014**	**0.017**	**0.022**	**0.026**	**0.020**	**NO**	**0.023**	**NO**
2270 Saddle Tree Trail	**0.011**	**0.022**	**0.032**	**0.027**	**0.023**	**NO**	**0.027**	**NO**
5859 Solstice	**0.008**	**0.008**	**0.037**	**0.023**	**0.019**	**NO**	**0.023**	**NO**
Hunter Creek Reservoir	**0.015**	**0.008**	**0.018**	**0.011**	**0.013**	**NO**	**0.012**	**NO**
6060 Silver Lake Rd	**0.012**	**0.016**	**0.022**	**0.033**	**0.021**	**NO**	**0.026**	**NO**
240 W Moana	**0.012**	**0.013**	**0.032**	**0.013**	**0.018**	**NO**	**0.018**	**NO**

[1] **YES** is an MCL violation. Provide Tier 2 Public Notice within 30 days per 40 CFR Subpart Q. Per 40 CFR §141.31, provide NDEP a copy.

[2] **YES** will require an OEL per 40 CFR §141.626. Submit evaluation to NDEP within 90 days of LAB REPORT date.

Date: ____________________

Phone Number: ____________________

Signature: ____________________

Print Name: ____________________

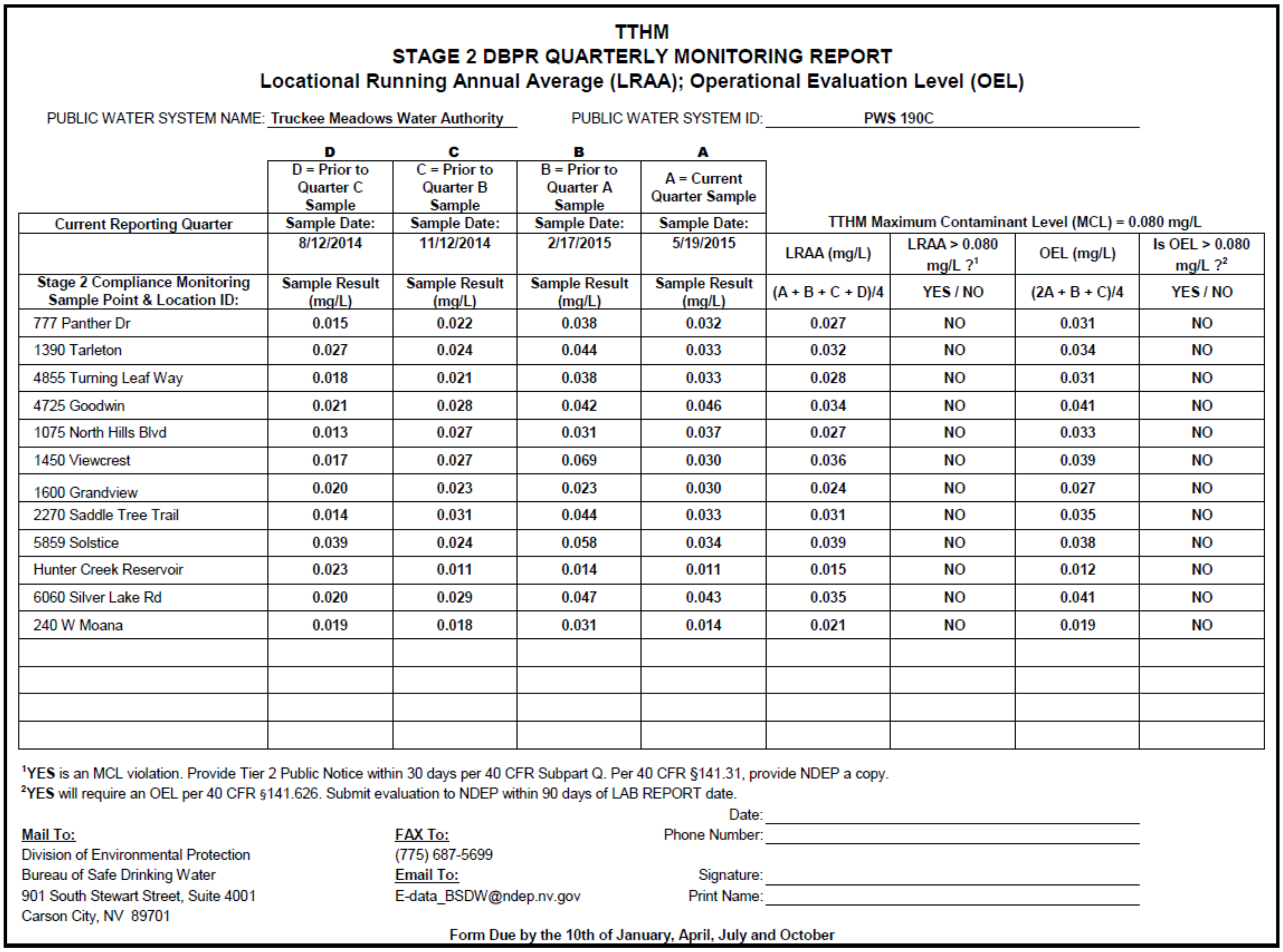
Mail To:
Division of Environmental Protection
Bureau of Safe Drinking Water
901 South Stewart Street, Suite 4001
Carson City, NV 89701

FAX To:
(775) 687-5699

Email To:
E-data_BSDW@ndep.nv.gov

Form Due by the 10th of January, April, July and October

Table B.2. Disinfection By-Products (DBP) Report – 1st Half 2015: TTHM



TTHM
STAGE 2 DBPR QUARTERLY MONITORING REPORT
Locational Running Annual Average (LRAA); Operational Evaluation Level (OEL)

PUBLIC WATER SYSTEM NAME: **Truckee Meadows Water Authority** PUBLIC WATER SYSTEM ID: **PWS 190C**

	D	**C**	**B**	**A**				
	D = Prior to Quarter C **Sample**	C = Prior to Quarter B **Sample**	B = Prior to Quarter A **Sample**	A = Current Quarter Sample	**TTHM Maximum Contaminant Level (MCL) = 0.080 mg/L**			
Current Reporting Quarter	**Sample Date:**	**Sample Date:**	**Sample Date:**	**Sample Date:**				
	8/12/2014	**11/12/2014**	**2/17/2015**	**5/19/2015**	LRAA (mg/L)	**LRAA > 0.080 mg/L ?[1]**	OEL (mg/L)	**Is OEL > 0.080 mg/L ?[2]**
Stage 2 Compliance Monitoring Sample Point & Location ID:	**Sample Result (mg/L)**	**Sample Result (mg/L)**	**Sample Result (mg/L)**	**Sample Result (mg/L)**	**(A + B + C + D)/4**	**YES / NO**	**(2A + B + C)/4**	**YES / NO**
777 Panther Dr	**0.015**	**0.022**	**0.038**	**0.032**	**0.027**	**NO**	**0.031**	**NO**
1390 Tarleton	**0.027**	**0.024**	**0.044**	**0.033**	**0.032**	**NO**	**0.034**	**NO**
4855 Turning Leaf Way	**0.018**	**0.021**	**0.038**	**0.033**	**0.028**	**NO**	**0.031**	**NO**
4725 Goodwin	**0.021**	**0.028**	**0.042**	**0.046**	**0.034**	**NO**	**0.041**	**NO**
1075 North Hills Blvd	**0.013**	**0.027**	**0.031**	**0.037**	**0.027**	**NO**	**0.033**	**NO**
1450 Viewcrest	**0.017**	**0.027**	**0.069**	**0.030**	**0.036**	**NO**	**0.039**	**NO**
1600 Grandview	**0.020**	**0.023**	**0.023**	**0.030**	**0.024**	**NO**	**0.027**	**NO**
2270 Saddle Tree Trail	**0.014**	**0.031**	**0.044**	**0.033**	**0.031**	**NO**	**0.035**	**NO**
5859 Solstice	**0.039**	**0.024**	**0.058**	**0.034**	**0.039**	**NO**	**0.038**	**NO**
Hunter Creek Reservoir	**0.023**	**0.011**	**0.014**	**0.011**	**0.015**	**NO**	**0.012**	**NO**
6060 Silver Lake Rd	**0.020**	**0.029**	**0.047**	**0.043**	**0.035**	**NO**	**0.041**	**NO**
240 W Moana	**0.019**	**0.018**	**0.031**	**0.014**	**0.021**	**NO**	**0.019**	**NO**

[1] **YES** is an MCL violation. Provide Tier 2 Public Notice within 30 days per 40 CFR Subpart Q. Per 40 CFR §141.31, provide NDEP a copy.

[2] **YES** will require an OEL per 40 CFR §141.626. Submit evaluation to NDEP within 90 days of LAB REPORT date.

Date: ____________________

Mail To:
Division of Environmental Protection
Bureau of Safe Drinking Water
901 South Stewart Street, Suite 4001
Carson City, NV 89701

FAX To:
(775) 687-5699
Email To:
E-data_BSDW@ndep.nv.gov

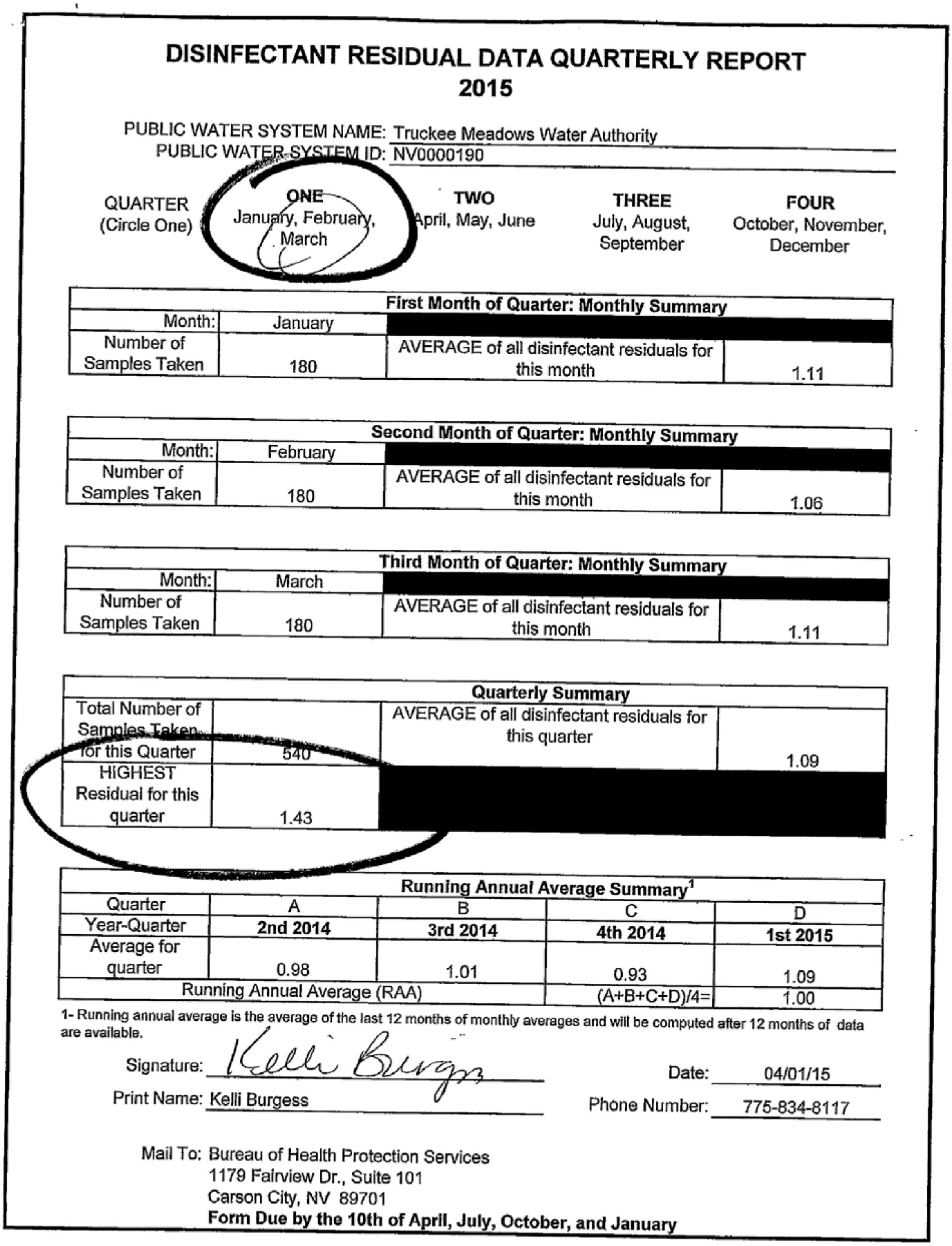
Phone Number: ____________________

Signature: ____________________

Print Name: ____________________

Form Due by the 10th of January, April, July and October

Table B.3. Zone 5: 1Q 2015 Disinfectant Residual Data



DISINFECTANT RESIDUAL DATA QUARTERLY REPORT
2015

PUBLIC WATER SYSTEM NAME: Truckee Meadows Water Authority
PUBLIC WATER SYSTEM ID: NV0000190

QUARTER (Circle One): [✓ **ONE** January, February, March] **TWO** April, May, June **THREE** July, August, September **FOUR** October, November, December

		First Month of Quarter: Monthly Summary	
Month:	January		
Number of Samples Taken	180	AVERAGE of all disinfectant residuals for this month	1.11

		Second Month of Quarter: Monthly Summary	
Month:	February		
Number of Samples Taken	180	AVERAGE of all disinfectant residuals for this month	1.06

		Third Month of Quarter: Monthly Summary	
Month:	March		
Number of Samples Taken	180	AVERAGE of all disinfectant residuals for this month	1.11

		Quarterly Summary	
Total Number of Samples Taken for this Quarter	540	AVERAGE of all disinfectant residuals for this quarter	1.09
HIGHEST Residual for this quarter	1.43		

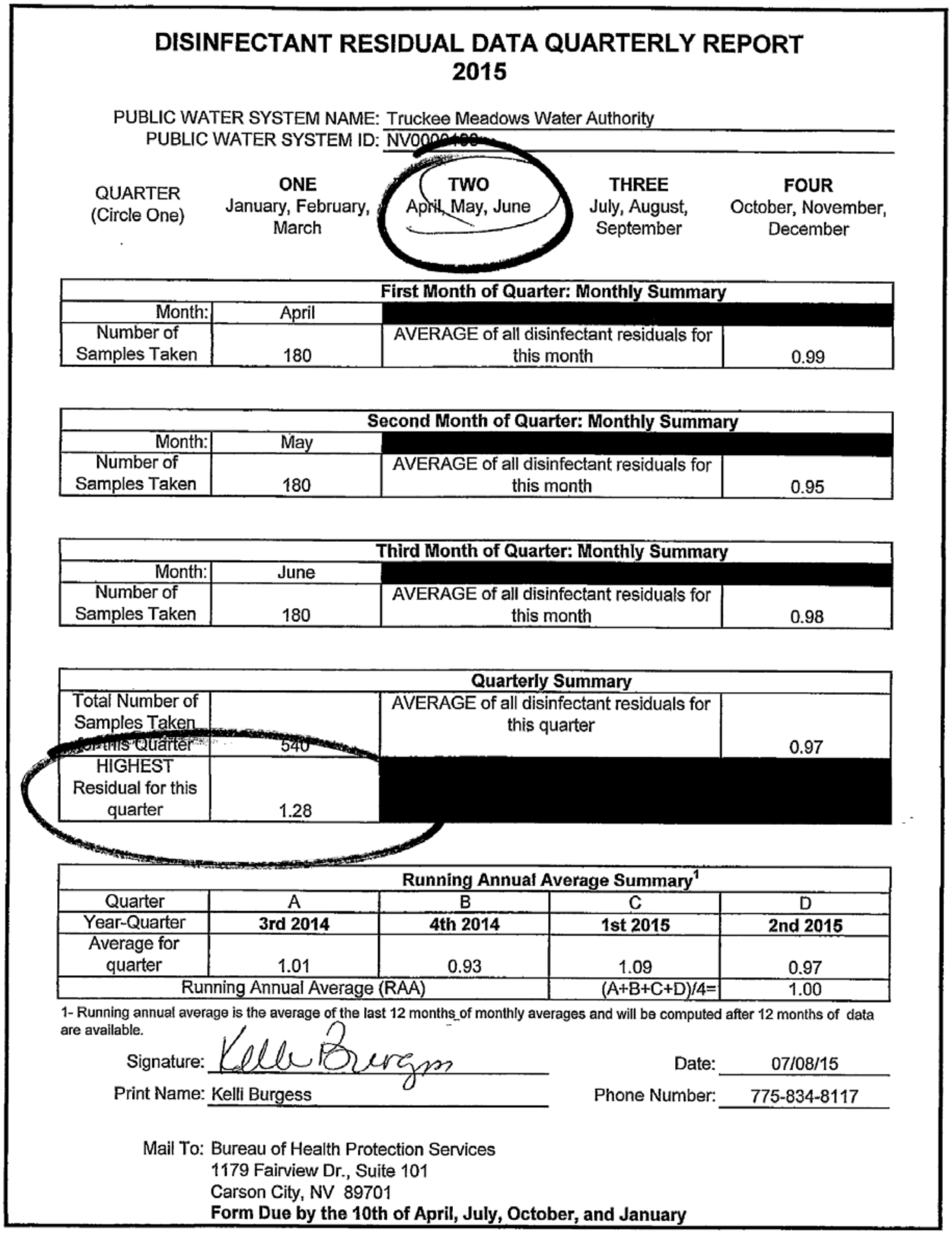
		Running Annual Average Summary[1]		
Quarter	A	B	C	D
Year-Quarter	**2nd 2014**	**3rd 2014**	**4th 2014**	**1st 2015**
Average for quarter	0.98	1.01	0.93	1.09
Running Annual Average (RAA)			(A+B+C+D)/4=	1.00

1- Running annual average is the average of the last 12 months of monthly averages and will be computed after 12 months of data are available.

Signature: Kelli Burgess
Date: 04/01/15
Print Name: Kelli Burgess
Phone Number: 775-834-8117

Mail To: Bureau of Health Protection Services
1179 Fairview Dr., Suite 101
Carson City, NV 89701
Form Due by the 10th of April, July, October, and January

Table B.3. Zone 5: 2Q 2015 Disinfectant Residual Data



DISINFECTANT RESIDUAL DATA QUARTERLY REPORT
2015

PUBLIC WATER SYSTEM NAME: Truckee Meadows Water Authority
PUBLIC WATER SYSTEM ID: NV000[illegible]

QUARTER (Circle One): **ONE** January, February, March [✓ **TWO** April, May, June] **THREE** July, August, September **FOUR** October, November, December

		First Month of Quarter: Monthly Summary	
Month:	April		
Number of Samples Taken	180	AVERAGE of all disinfectant residuals for this month	0.99

		Second Month of Quarter: Monthly Summary	
Month:	May		
Number of Samples Taken	180	AVERAGE of all disinfectant residuals for this month	0.95

		Third Month of Quarter: Monthly Summary	
Month:	June		
Number of Samples Taken	180	AVERAGE of all disinfectant residuals for this month	0.98

		Quarterly Summary	
Total Number of Samples Taken for this Quarter	540	AVERAGE of all disinfectant residuals for this quarter	0.97
HIGHEST Residual for this quarter	1.28		

		Running Annual Average Summary[1]		
Quarter	A	B	C	D
Year-Quarter	**3rd 2014**	**4th 2014**	**1st 2015**	**2nd 2015**
Average for quarter	1.01	0.93	1.09	0.97
Running Annual Average (RAA)			(A+B+C+D)/4=	1.00

[1]- Running annual average is the average of the last 12 months of monthly averages and will be computed after 12 months of data are available.

Signature: Kelli Burgess
Date: 07/08/15
Print Name: Kelli Burgess
Phone Number: 775-834-8117

Mail To: Bureau of Health Protection Services
1179 Fairview Dr., Suite 101
Carson City, NV 89701
Form Due by the 10th of April, July, October, and January

TRUCKEE MEADOWS WATER
AUTHORITY

REPORT ON AQUIFER STORAGE AND RECOVERY
SPANISH SPRINGS VALLEY HYDROGRAPHIC BASIN

JANUARY 1 THROUGH JUNE 30 2015

NDEP PERMIT # UNEV2009202

AND

NDWR PERMIT #R-19

July 2015

CERTIFICATION

The information contained in this report is true and correct according to the best belief and knowledge of the undersigned.

Certified by

John A. Erwin
Director Natural Resources-Planning & Management
Truckee Meadows Water Authority

Truckee Meadows Water Authority
1355 Capital Boulevard
Reno, Nevada 89502
www.tmh20.com

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1.0 SUMMARY

The Truckee Meadows Water Authority ("TMWA") Aquifer and Storage ("ASR") program in Spanish Springs hydrographic basin is performed under Nevada Division of Environmental Protection ("NDEP") Permit #UNEV2009202, issued on December 10, 2009, renewed on March 3, 2015, and valid until March 3, 2020. Nevada Department of Water Resources ("NDWR") issued permit #R-19 on July 27, 2010 for an indefinite period, subject to periodic review by the State Engineer.

TMWA injected 720 acre-feet (234.6 MG) of treated surface water from TMWA's treatment plant at Chuck Bluff into Hawkings Court Well ("HCW") during first half of 2015. During the same period, 111.5 acre-feet (36.3 MG) of water was pumped from HCW (see Table 1). The monthly average, highest and lowest injection rates for Hawkings Court Well are shown in Table 2.

Table 1. Hawkings Court Well –Injection and Pumping, Jan to Jun 2015

	JAN	FEB	MAR	APR	MAY	JUN	TOTAL	
							MG	AF
Recharge	15.6	16.6	86.3	94.1	22.0	0	234.6	720.0
Pumping	0	0	0	0	0	36.3	36.3	111.5

Table 2. Hawkings Court Well – Average, Highest and Lowest Monthly Flow Rates (gpm), Jan to Jun 2015

	JAN	FEB	MAR	APR	MAY	JUN
Recharge						
Average	654	1486	2116	2192	2197	0
Highest	666	2816	2276	2309	2288	0
Lowest	625	80	109	2099	2166	0
Pumping						
Average	0	0	0	0	0	2251
Highest	0	0	0	0	0	2649
Lowest	0	0	0	0	0	989

Figure 1 shows the location of Hawkings Court Well and its monitoring wells plus other production wells in the vicinity. The average injection rate over the injection period was approximately 1729 gpm. Flow rates and water levels in Hawkings Court Well for the first half of 2015 are shown in Figure 2.

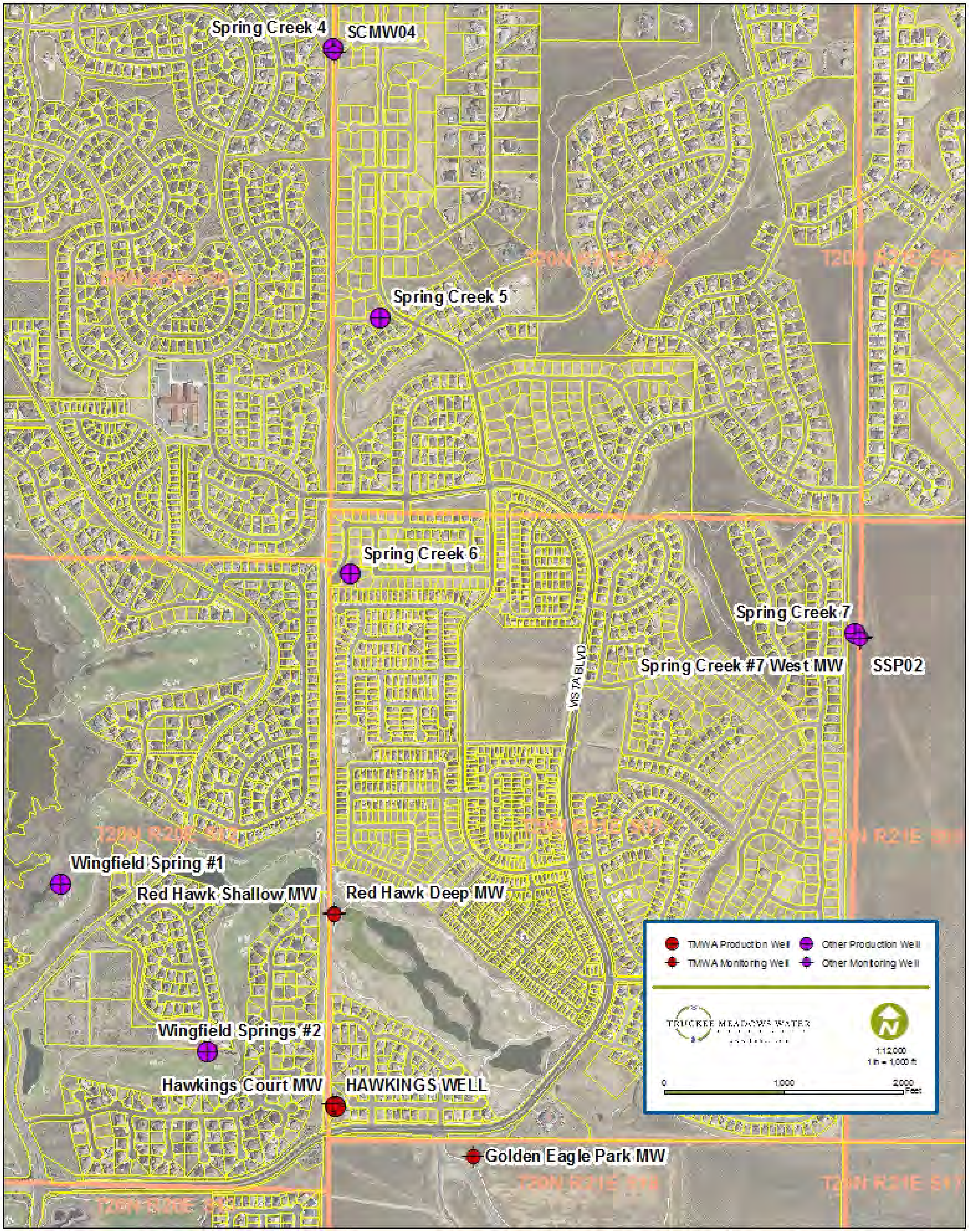

Figure 1: Hawkings Court Well and Nearby Wells

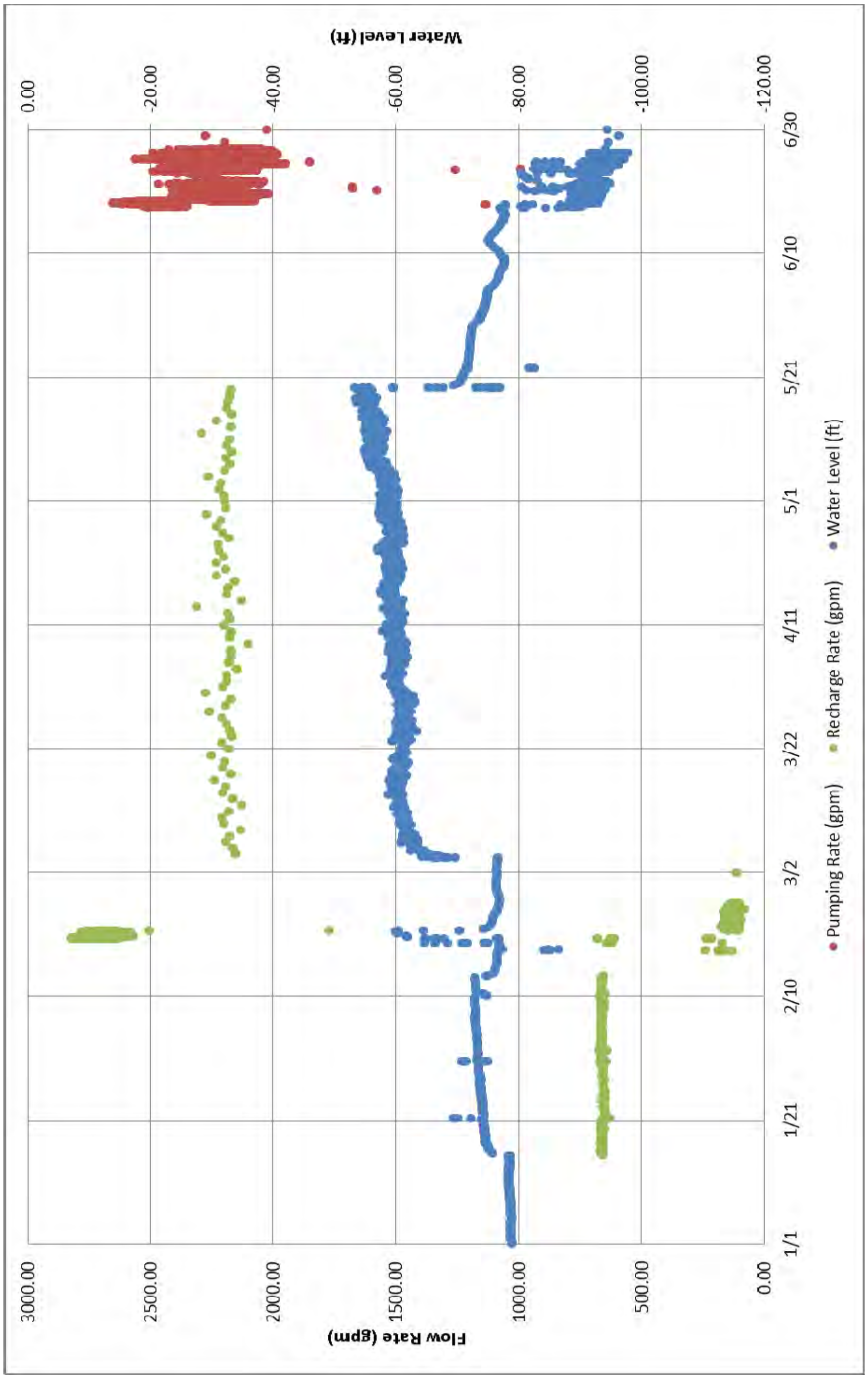

Figure 2: Hawkings Court Well Injection and Pumping Rates and Water Levels, Jan to Jun 2015

Figure 3 shows water levels in the injection/production well and its four monitoring wells. Red Hawk Shallow Monitoring Well ("RHSMW"), which was completed at 140 feet in alluvium, shows less amplitude in water level variation than the deep Red Hawk Deep Monitoring Well ("RHDMW") completed in volcanic rocks as HCW.

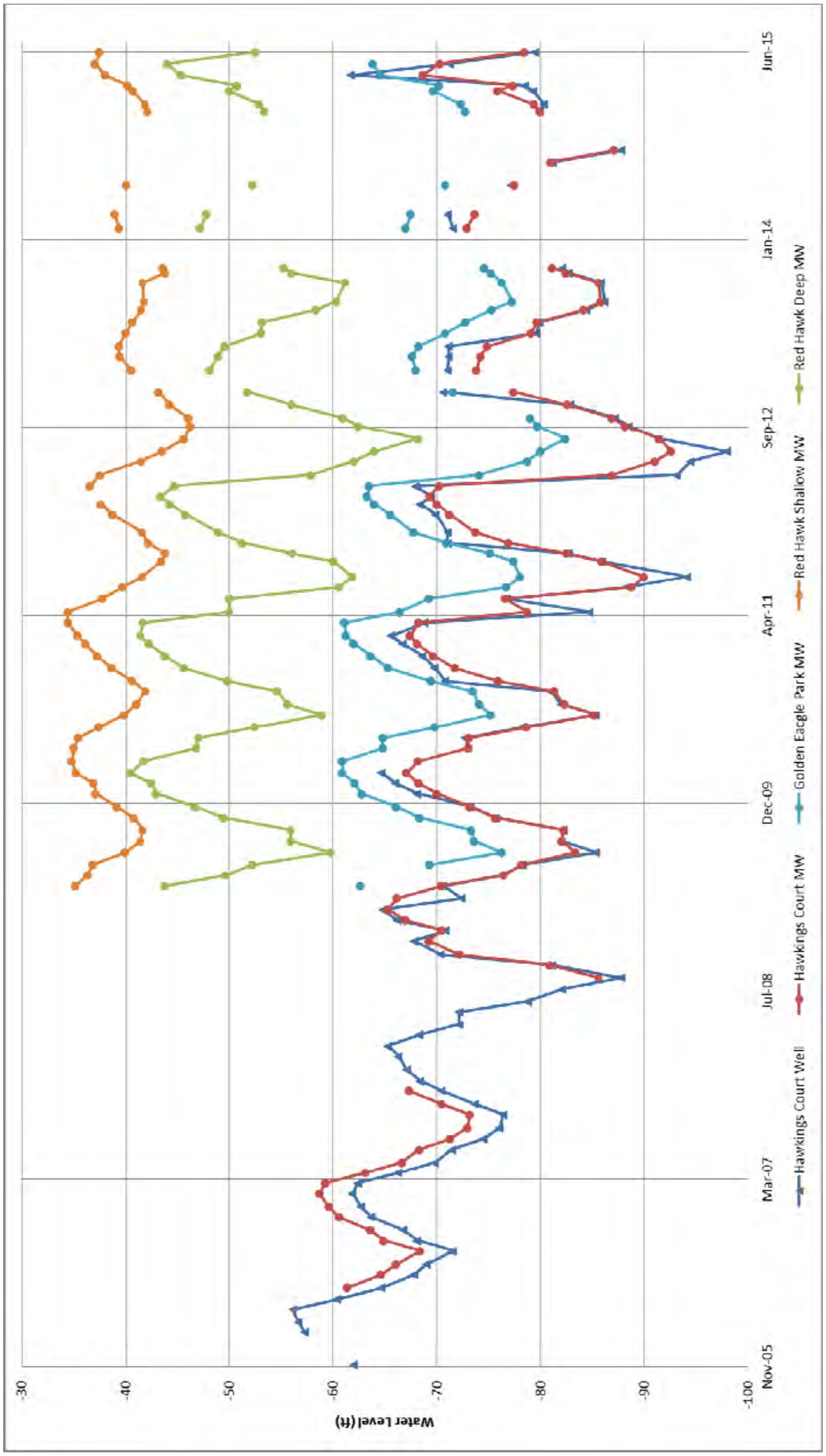

Figure 3: Water Levels for the Hawkings Court Well and its Monitoring Wells

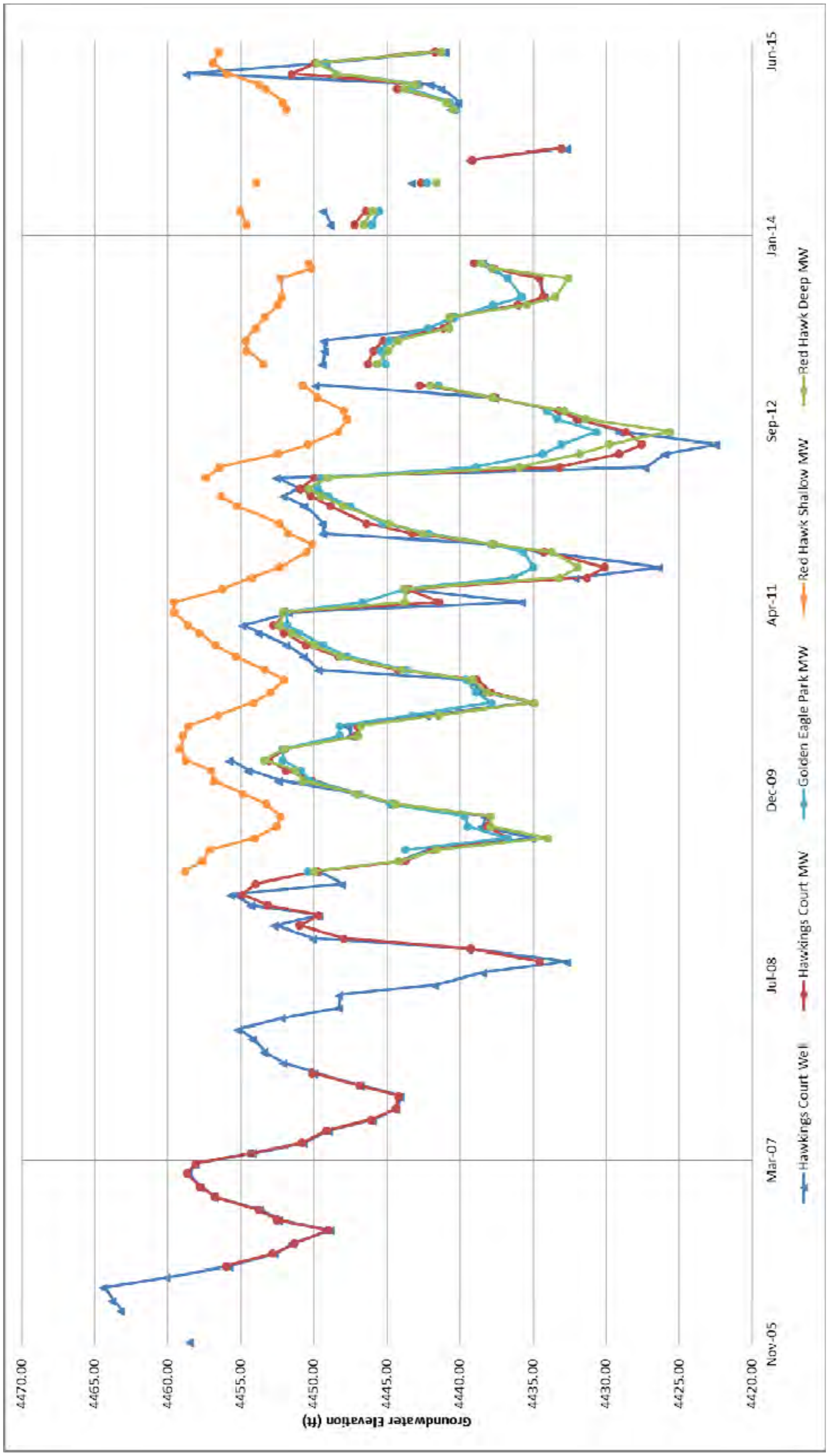

Figure 4: Water Level Elevations for the Hawkings Court Well and its Monitoring Wells

2.0 WATER QUALITY

Following the March 3, 2015 revision to UIC permit UNEV2009202, semi-annual reporting is no longer required. Water quality results will therefore be presented as part of an annual report for the 12-month period ending December 31, 2015, to be submitted no later than February 15th of each year.

3.0 CONCLUSIONS

TMWA injected 720 acre-feet (234.6 MG) of treated surface water in Hawkings Court Well during the first half of 2015 under NDEP Permit number UNEV2009202 and NDWR Permit number R-19. During the first half of CY2015, 111.5 acre-feet (36.3 MG) was pumped from the Hawkings Court Well.

The data and related analysis, as discussed above, continue to demonstrate that active injection of treated Truckee River water into TMWA's Hawkings Court Well has not negatively affected the eastern portion of the aquifer in the Spanish Springs basin. This conclusion is supported by the positive contribution of the volume of injected water to enhance groundwater levels in the aquifer.

TRUCKEE MEADOWS WATER
AUTHORITY

REPORT ON AQUIFER STORAGE AND RECOVERY
TRUCKEE MEADOWS HYDROGRAPHIC BASIN

JANUARY 1 THROUGH JUNE 30, 2015

NDEP PERMIT #UNEV92200

and

NDWR PERMIT #R-16

JULY 2015

CERTIFICATION

The information contained in this report is true and correct according to the best belief and knowledge of the undersigned.

Certified by

John A. Erwin

Director Natural Resources-Planning & Management

Truckee Meadows Water Authority

Truckee Meadows Water Authority

1355 Capital Boulevard

Reno, Nevada 89502

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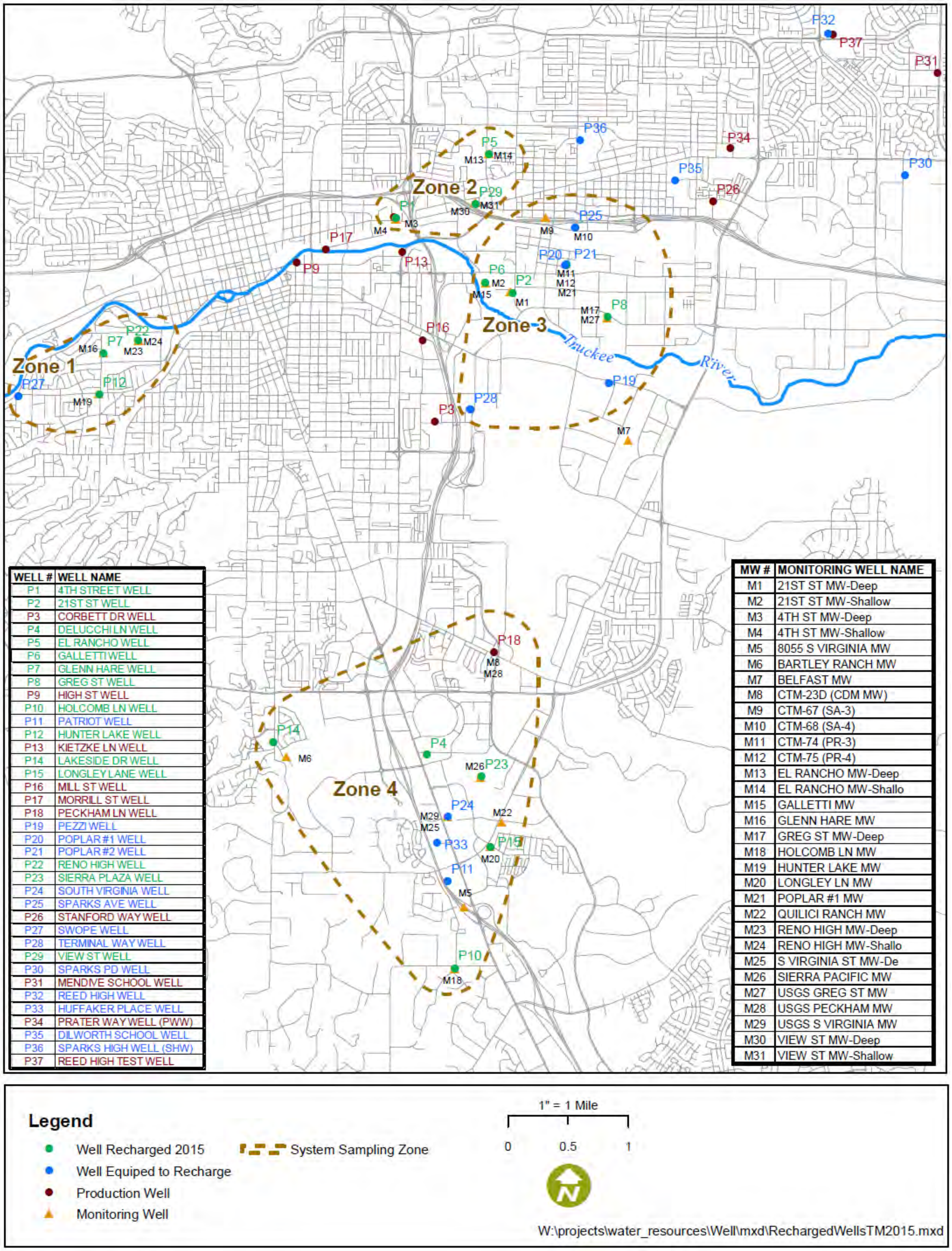
1.0 SUMMARY

The Truckee Meadows Water Authority's (TMWA) Aquifer-Storage and Recovery (ASR) program injects treated surface water into the groundwater aquifer of the Truckee Meadows hydrographic basin in conformance with provisions set out by the Nevada Division of Water Resources (NDWR) and the Nevada Division of Environmental Protection (NDEP). On October 19, 2006, NDWR issued Permit No R-16 authorizing TMWA to annually inject up to 7,000 acre-feet of treated water into 22 wells located within the Truckee Meadows hydrographic basin. This permit is issued for an indefinite period, subject to periodic review by the State Engineer. The corresponding water quality permit is NDEP Permit No. UNEV92200. The permits require TMWA to submit semi-annual and annual reports by summarizing injection activities including water quality, water levels, and injected and extracted volumes for the first half of the year and for the whole year. This is the semi-annual report covering the period between January 1 and June 30, 2015.

Figure 1 shows the locations of TMWA's wells in the Truckee Meadows hydrographic basin and those where recharge occurred during the first half of 2015.

TMWA's ASR in the Truckee Meadows basin has grown from 81 acre-feet of treated surface water injected in 1993 to 25,108 acre-feet cumulative total as of June 30, 2015 (Table 1). During the first half of 2015, TMWA injected 2,548 acre-feet (831 MG) of treated water into fourteen wells in the Truckee Meadows Hydrographic Basin.

Table 2A is the summary of the monthly recharge at the fourteen wells. Table 2B summarizes the amount of water pumped monthly from each of the injection wells. During the first half of 2015, TMWA pumped 816 acre-feet (266 MG) of water from the fourteen recharged wells. Charts of water levels, injection and extraction rates, and historical water level hydrographs for each injection well, and its respective monitoring wells, are included with the discussion on each well.



WELL #	WELL NAME
P1	4TH STREET WELL
P2	21ST ST WELL
P3	CORBETT DR WELL
P4	DELUCCHI LN WELL
P5	EL RANCHO WELL
P6	GALLETTI WELL
P7	GLENN HARE WELL
P8	GREG ST WELL
P9	HIGH ST WELL
P10	HOLCOMB LN WELL
P11	PATRIOT WELL
P12	HUNTER LAKE WELL
P13	KIETZKE LN WELL
P14	LAKESIDE DR WELL
P15	LONGLEY LANE WELL
P16	MILL ST WELL
P17	MORRILL ST WELL
P18	PECKHAM LN WELL
P19	PEZZI WELL
P20	POPLAR #1 WELL
P21	POPLAR #2 WELL
P22	RENO HIGH WELL
P23	SIERRA PLAZA WELL
P24	SOUTH VIRGINIA WELL
P25	SPARKS AVE WELL
P26	STANFORD WAY WELL
P27	SWOPE WELL
P28	TERMINAL WAY WELL
P29	VIEW ST WELL
P30	SPARKS PD WELL
P31	MENDIVE SCHOOL WELL
P32	REED HIGH WELL
P33	HUFFAKER PLACE WELL
P34	PRATER WAY WELL (PWW)
P35	DILWORTH SCHOOL WELL
P36	SPARKS HIGH WELL (SHW)
P37	REED HIGH TEST WELL

MW #	MONITORING WELL NAME
M1	21ST ST MW-Deep
M2	21ST ST MW-Shallow
M3	4TH ST MW-Deep
M4	4TH ST MW-Shallow
M5	8055 S VIRGINIA MW
M6	BARTLEY RANCH MW
M7	BELFAST MW
M8	CTM-23D (CDM MW)
M9	CTM-67 (SA-3)
M10	CTM-68 (SA-4)
M11	CTM-74 (PR-3)
M12	CTM-75 (PR-4)
M13	EL RANCHO MW-Deep
M14	EL RANCHO MW-Shallo
M15	GALLETTI MW
M16	GLENN HARE MW
M17	GREG ST MW-Deep
M18	HOLCOMB LN MW
M19	HUNTER LAKE MW
M20	LONGLEY LN MW
M21	POPLAR #1 MW
M22	QUILICI RANCH MW
M23	RENO HIGH MW-Deep
M24	RENO HIGH MW-Shallo
M25	S VIRGINIA ST MW-De
M26	SIERRA PACIFIC MW
M27	USGS GREG ST MW
M28	USGS PECKHAM MW
M29	USGS S VIRGINIA MW
M30	VIEW ST MW-Deep
M31	VIEW ST MW-Shallow

Figure 1. Truckee Meadows Basin Well Locations

Table 1. Aquifer Storage and Recovery History, Annual Injection Quantity in Acre-feet

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
																							Jan-Jun	
Lakeside Drive	3	9	116	132	111	377	194	246	258	218	292	194	192	213	148	270	198	232	215	104	150	166	349	4387
Hunter Lake	0	0	0	0	0	0	196	290	332	175	246	34	22	0	0	122	253	190	0	0	0	52	284	2196
View Street	0	0	0	0	0	173	327	486	433	260	353	598	264	202	179	291	68	61	78	195	218	158	313	4657
Reno High	0	0	0	0	0	0	61	190	216	142	173	26	50	213	182	256	184	134	0	0	0	86	254	2167
Poplar #1	0	0	0	0	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22
Poplar #2	0	0	0	0	0	0	0	68	46	70	9	44	37	2	0	0	7	3	0	41	5	21	0	353
Kietzke Lane	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26
Morrill Avenue	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27
Fourth Street	25	0	0	0	0	0	0	39	452	309	152	139	82	113	90	160	107	71	15	0	0	190	193	2137
Glen Hare	0	0	0	0	0	0	0	36	117	62	99	15	9	0	0	62	71	70	0	0	0	46	166	753.5
Greg Street	0	0	0	0	0	0	0	76	135	137	177	164	41	0	0	0	16	56	0	191	34	13	198	1238
Terminal Way	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
El Rancho	0	0	0	0	0	0	0	121	216	178	255	139	97	103	62	119	22	76	0	43	136	124	110	1801
Holcomb Lane	0	0	0	0	0	0	0	21	39	187	123	72	17	137	0	40	48	87	0	0	0	72	154	997.3
21st Street	0	0	0	0	0	0	0	61	202	193	259	172	108	151	108	154	116	91	0	0	0	68	125	1808
Galletti Way	0	0	0	0	0	0	0	81	239	234	262	218	119	175	149	225	177	41	0	0	0	99	163	2182
Longley Lane	0	0	0	0	0	0	0	0	10	14	0	0	0	0	0	0	0	0	0	0	0	16	24	64.41
Sparks Avenue	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	18	5	0	14	8	0	0	64
Delucchi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	125	136.6
Sierra Plaza	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	90	89.58
Total	81	9	116	132	133	550	778	1717	2695	2179	2400	1815	1038	1309	918	1718	1285	1117	308	588	551	1123	2548	25108

Table 2A. Monthly Recharge by Well, Jan to Jun 2015

Wells	JAN	FEB	MAR	APR	MAY	JUN	YTD Total	
							MG	AF
Fourth Street	17.1	14.9	1.8	13.0	16.0	0.0	62.8	192.7
View Street	31.2	26.3	28.0	16.5	0.0	0.0	102.0	313.2
Greg Street	11.6	9.2	10.0	7.5	26.0	0.0	64.4	197.5
Delucchi	3.9	3.4	3.7	3.6	26.0	0.0	40.6	124.6
Lakeside Drive	17.8	22.3	24.5	23.2	26.0	0.0	113.8	349.2
Holcomb Lane	7.6	6.7	7.1	7.0	22.0	0.0	50.3	154.3
21st Street	12.8	9.2	12.1	6.5	0.0	0.0	40.6	124.6
Reno High	17.1	14.3	15.6	15.0	21.0	0.0	82.9	254.4
El Rancho	11.6	9.2	7.6	7.3	0.0	0.0	35.7	109.7
Hunter Lake	25.5	21.7	23.8	21.7	0.0	0.0	92.6	284.3
Glen Hare	1.0	8.5	9.5	9.2	26.0	0.0	54.2	166.5
Galletti Way	14.8	13.9	14.2	10.4	0.0	0.0	53.2	163.2
Longley Lane	4.0	2.3	1.3	0.3	0.0	0.0	8.0	24.4
Sierra Plaza	0.0	0.5	1.3	1.4	26.0	0.0	29.2	89.6
Total MG	176.0	162.5	160.3	142.5	189.0	0.0	830.3	
Total AF	540.3	498.6	491.8	437.4	580.0	0.0		2548.1

Table 2B. Monthly Production from Recharged Wells, Jan to Jun 2015

Wells	JAN	FEB	MAR	APR	MAY	JUN	YTD Total	
							MG	AF
Fourth Street	0.0	0.0	0.0	0.0	0.0	16.3	16.3	49.9
View Street	0.0	0.0	0.0	0.0	0.0	27.9	27.9	85.7
Greg Street	0.0	0.0	0.0	0.0	0.0	6.1	6.1	18.7
Delucchi	0.0	0.0	0.0	0.0	0.0	9.5	9.5	29.1
Lakeside Drive	0.0	0.0	0.0	0.0	0.0	11.5	11.5	35.2
Holcomb Lane	0.0	0.0	0.0	0.0	0.0	11.7	11.7	35.8
21st Street	0.0	0.0	0.0	0.0	0.0	25.9	25.9	79.6
Reno High	0.0	0.0	0.0	0.0	0.0	40.9	40.9	125.5
El Rancho	0.0	0.0	0.0	0.0	0.0	10.1	10.1	30.9
Hunter Lake	0.0	0.0	0.0	0.0	0.0	35.9	35.9	110.3
Glen Hare	0.0	0.0	0.0	0.0	0.0	15.6	15.6	48.0
Galletti Way	0.0	0.0	0.0	0.0	0.0	6.6	6.6	20.3
Longley Lane	0.0	0.0	0.0	0.0	0.0	26.0	26.0	79.8
Sierra Plaza	0.0	0.0	0.0	0.0	0.0	22.0	22.0	67.7
Total MG	0.0	0.0	0.0	0.0	0.0	266.0	266.0	
Total AF	0.0	0.0	0.0	0.0	0.0	816.4		816.4

Table 3 shows the average, maximum, and minimum monthly injection rates for the six recharged wells.

Table 3. Average, Highest and Lowest Injection Rates (gpm), Jan to Jun 2015

	January			February			March			April			May			June		
Wells	Ave	High	Low	Ave	High	Low	Ave	High	Low	Ave	High	Low	Ave	High	Low	Ave	High	Low
Fourth Street	384	406	359	371	406	349	367	367	367	337	373	308	318	356	290	0	0	0
View Street	700	733	660	653	673	627	633	644	622	641	722	500	0	0	0	0	0	0
Greg Street	281	307	230	228	234	223	223	227	219	214	235	205	219	232	200	0	0	0
Delucchi	86	88	85	85	86	84	84	84	73	83	83	83	83	83	83	0	0	0
Lakeside Drive	451	645	347	554	650	504	537	638	489	547	634	469	546	627	488	0	0	0
Holcomb Lane	170	174	165	165	168	135	164	193	143	162	165	159	156	162	151	0	0	0
21st Street	288	302	276	272	289	127	271	276	262	206	272	123	0	0	0	0	0	0
Reno High	383	417	358	363	377	338	350	376	330	349	360	323	365	377	357	0	0	0
El Rancho	259	283	212	222	253	187	191	226	10	181	280	8	0	0	0	0	0	0
Hunter Lake	567	589	533	536	543	525	528	539	516	529	539	518	0	0	0	0	0	0
Glen Hare	198	220	120	211	218	205	212	221	204	214	225	204	214	226	203	0	0	0
Galletti Way	330	370	301	345	377	321	327	356	277	314	350	168	0	0	0	0	0	0
Longley Lane	91	96	72	74	103	14	97	108	43	91	93	88	0	0	0	0	0	0
Sierra Plaza	0	0	0	29	31	25	29	32	26	32	36	28	33	36	30	0	0	0

Water quality information is contained under Section 2 of this report.

1.1 Lakeside Well

The Lakeside Well is located in the southeast quarter of the northeast quarter of Section 35, Township 19.

TMWA injected a total of 349.2 acre-feet (113.8 MG) of treated surface water into the groundwater aquifer at the Lakeside Well during first half of 2015 (see Tables 1 and 2A, and Figure 2A). The average injection rate was 527 gpm. The maximum injection rate was 650 gpm and minimum 347 gpm (Table 3). A total of 35.2 acre-feet (11.5 MG) was pumped from the Lakeside Well between January and June 2015 (Table 2B).

Flow rates and water levels during injection and pumping for the reporting period are shown in Figure 2A. Historical monthly water levels for Lakeside Well and Bartley Ranch Monitoring Well are shown in Figure 2B.

Water levels in Bartley Ranch Well follow the same trend as in Lakeside, rising during recharge and dropping during pumping. As a result of recharge activities at the Lakeside Drive Well, water level in Bartley Ranch Well has risen by as much as 60 feet compared to the water level in 1993. This is a positive effect to the aquifer around Lakeside Well. The trend has remained the same since recharge commenced in 1993.

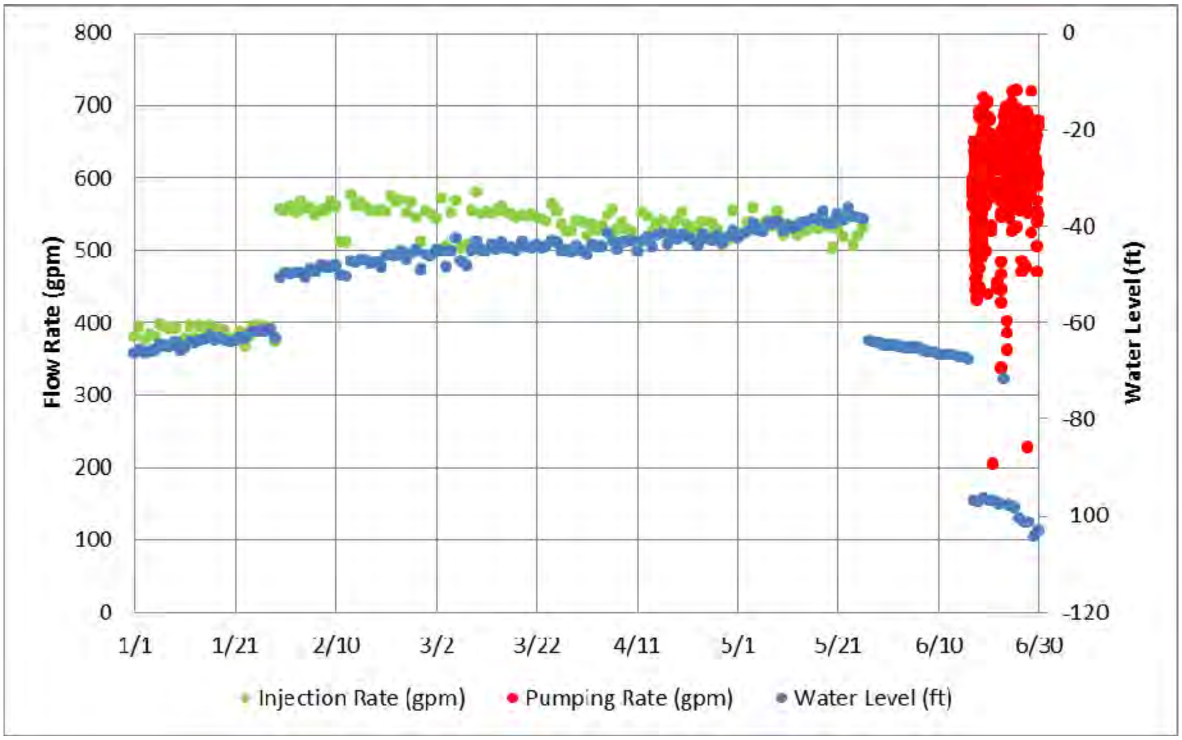


Figure 2A. Lakeside Well - Flow Rates and Water Levels, Jan to Jun 2015

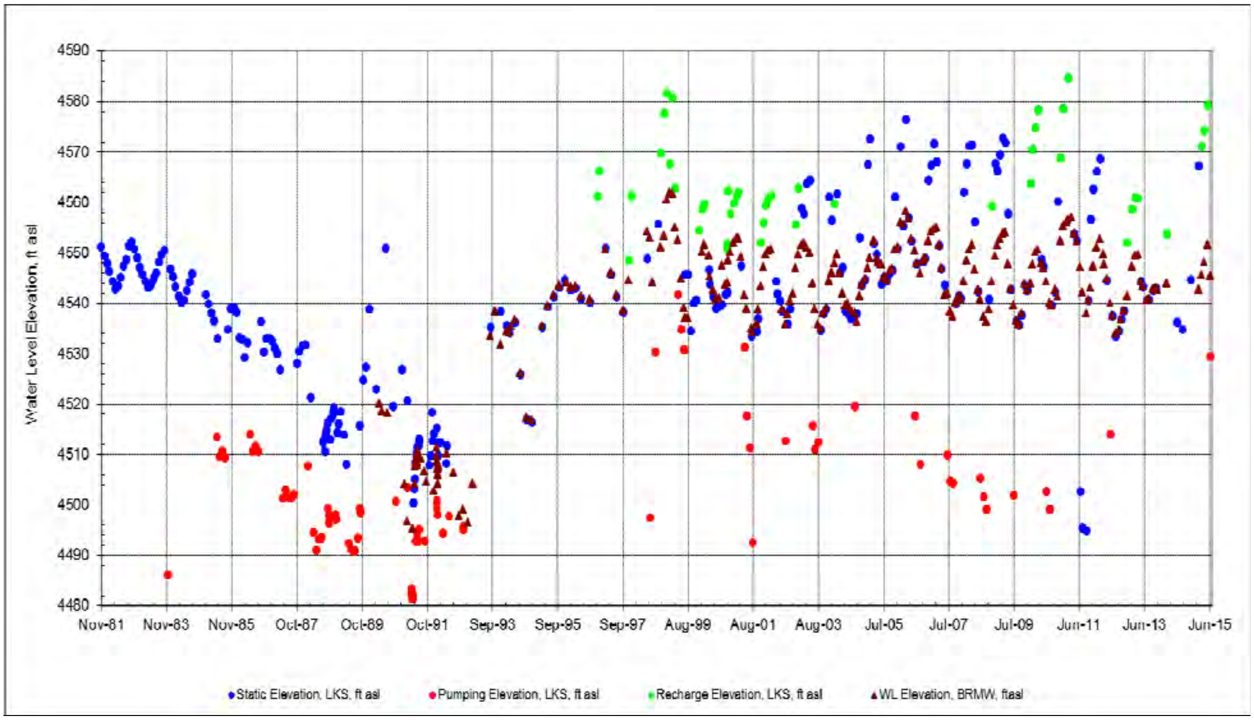


Figure 2B. Lakeside and Bartley Ranch Wells - Water Level Elevations

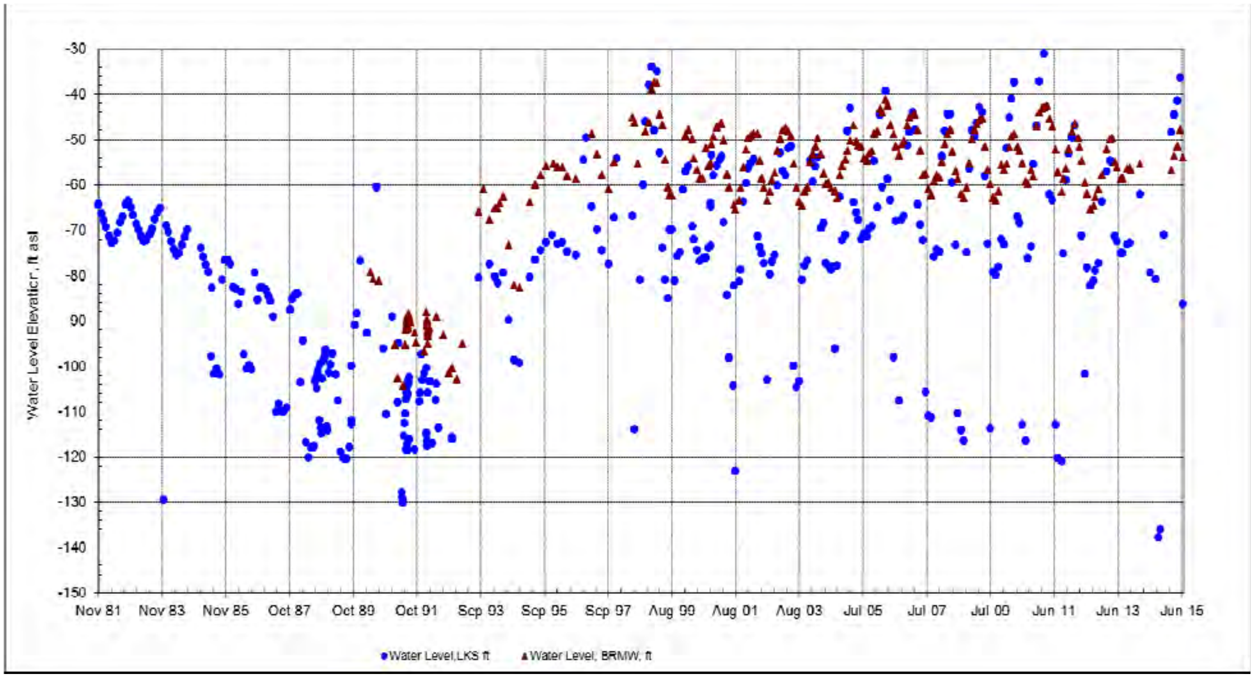


Figure 2C. Lakeside and Bartley Ranch Wells - Water Levels

1.2 View Street Well

TMWA's View Street Well is centrally located in the Truckee Meadows, specifically in the northeast quadrant of the I-80 and US 395 junction, adjacent to I-80.

TMWA injected 313.2 acre-feet (102 MG) of treated surface water into View Street Well during first half of 2015 (Tables 1 and 2A, and Figure 3A). During the same period, 85.7 acre-feet (27.9 MG) of water were pumped from View Street Well (Table 2B).

Historical monthly water level elevations for View Street Well and its monitoring wells are shown in Figure 3B. The hydrographs for the injection/production well as well as those for the shallow and deep monitoring wells are shown in Figure 3C.

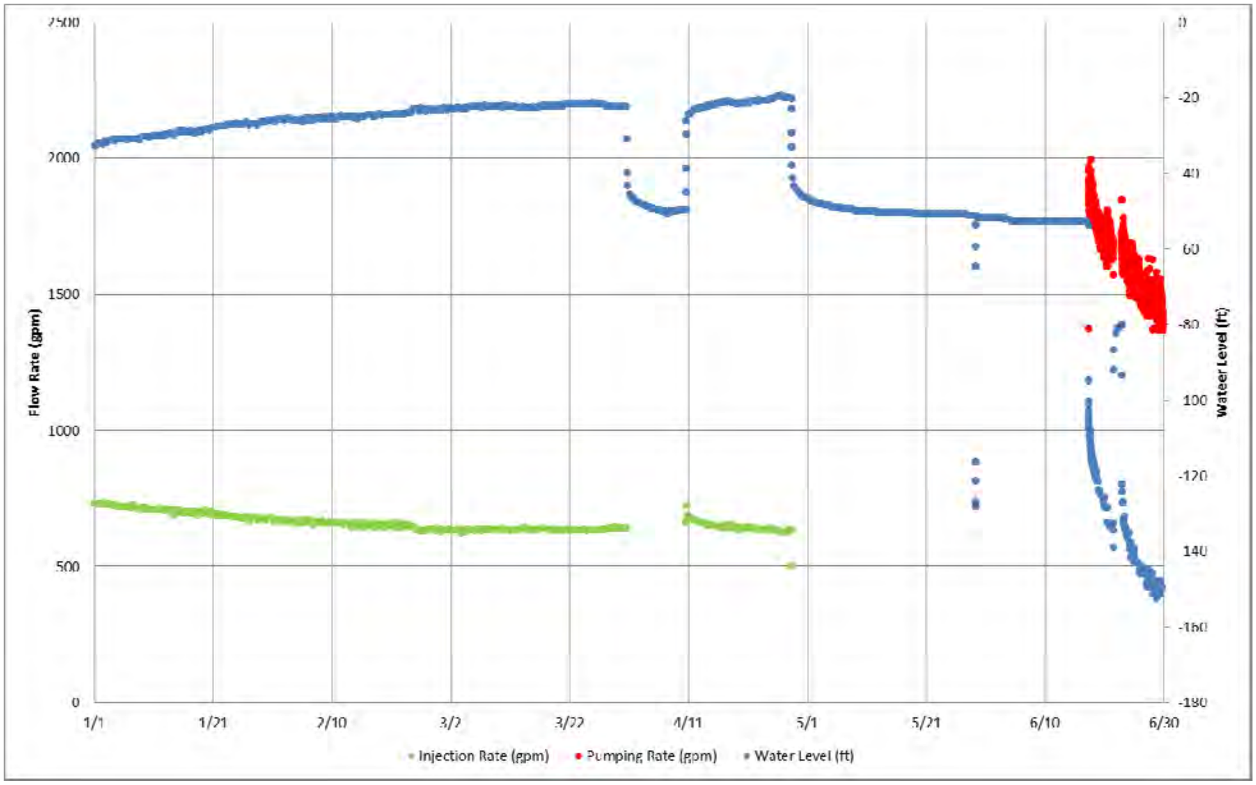


Figure 3A. View Street Well – Flow Rates and Water Levels, Jan to Jun 2015

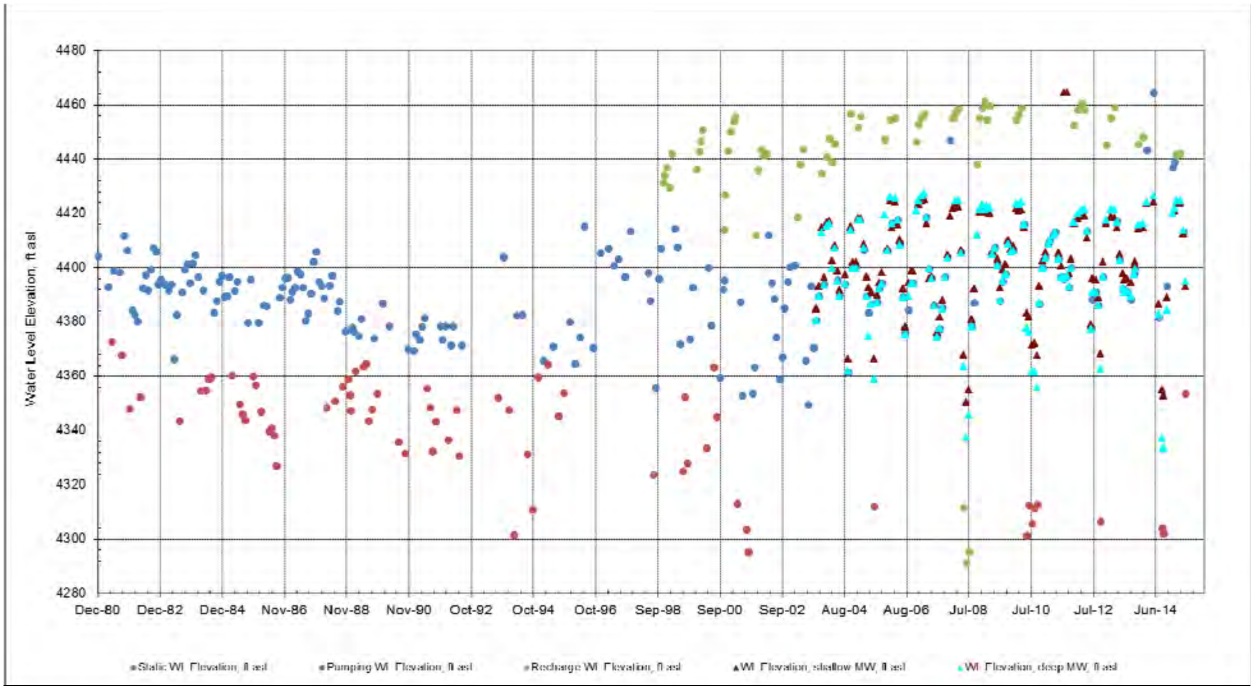


Figure 3B. View Street Production and Monitoring Wells - Water Level Elevations

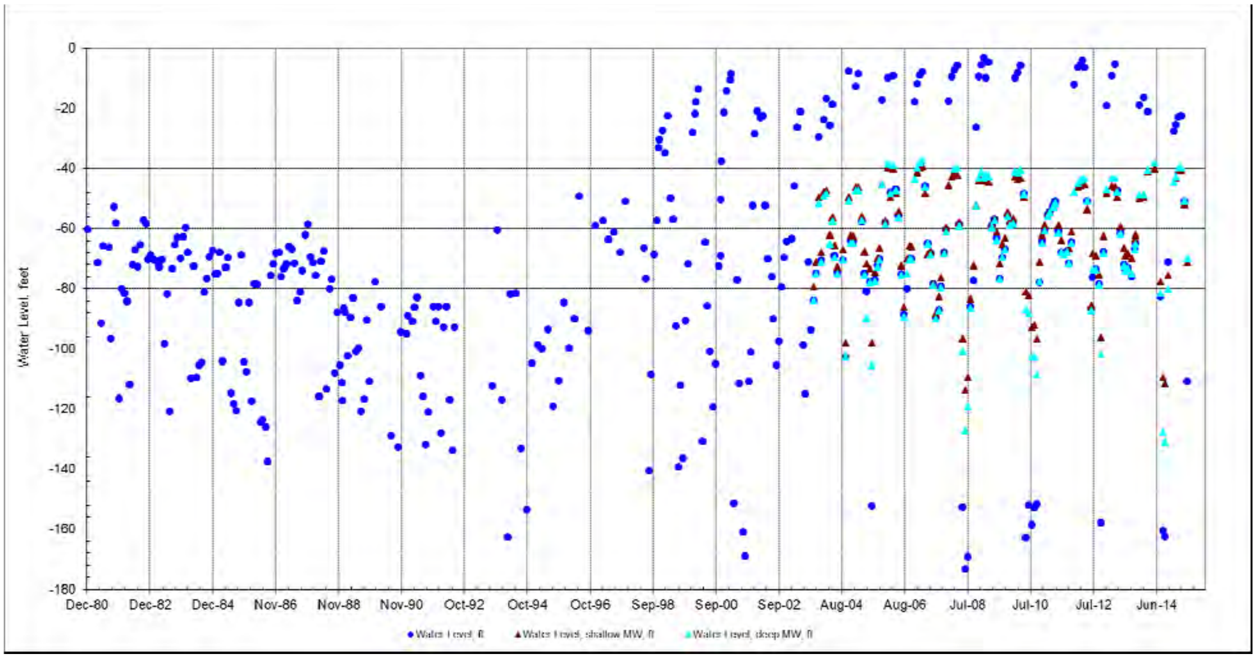


Figure 3C. View Street Production and Monitoring Wells - Water Levels

1.3 El Rancho Well

TMWA's El Rancho Well is centrally located in the Truckee Meadows, specifically in the northeast quarter of the southeast quarter of Section 6, Township 19 North, Range 20 East.

During first half of 2015, 109.7 acre-feet (35.7 MG) of water were injected into El Rancho Drive Well. 30.9 acre-feet (10.1 MG) of water were pumped from the well during the same period (see Tables 1 and 2A, and Figure 4A. Historical monthly water level elevations for El Rancho Well and its monitoring wells are shown in Figure 4B. The water levels for the injection/production well as well as those for the shallow and deep monitoring wells are shown in Figure 4C.

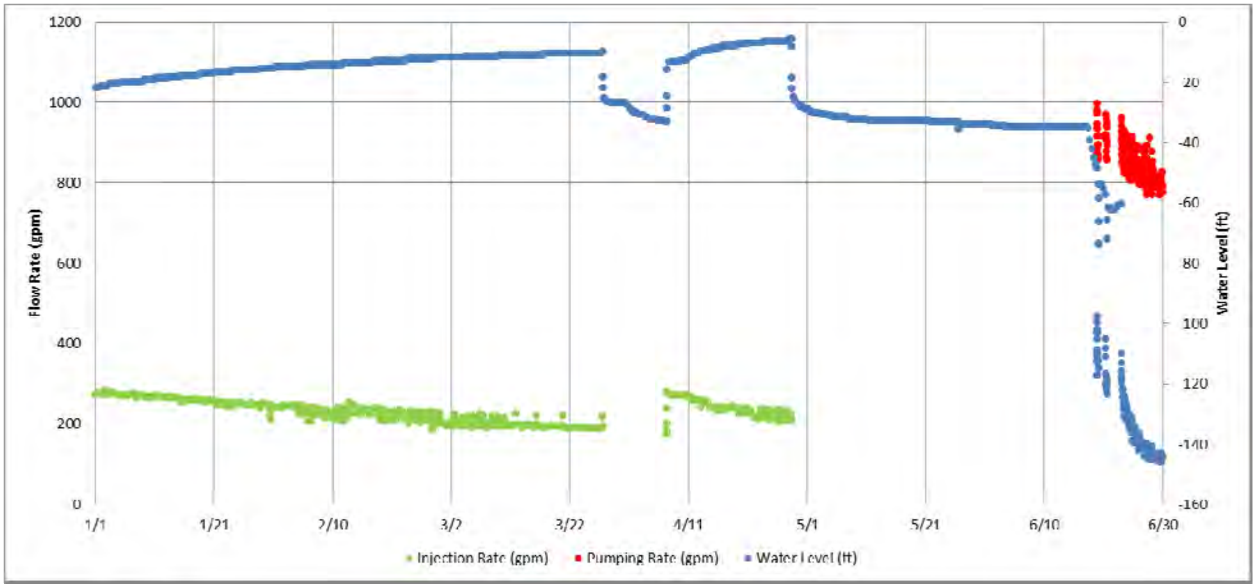


Figure 4A. El Rancho Drive Well –Flows and Water Levels, Jan to Jun 2015

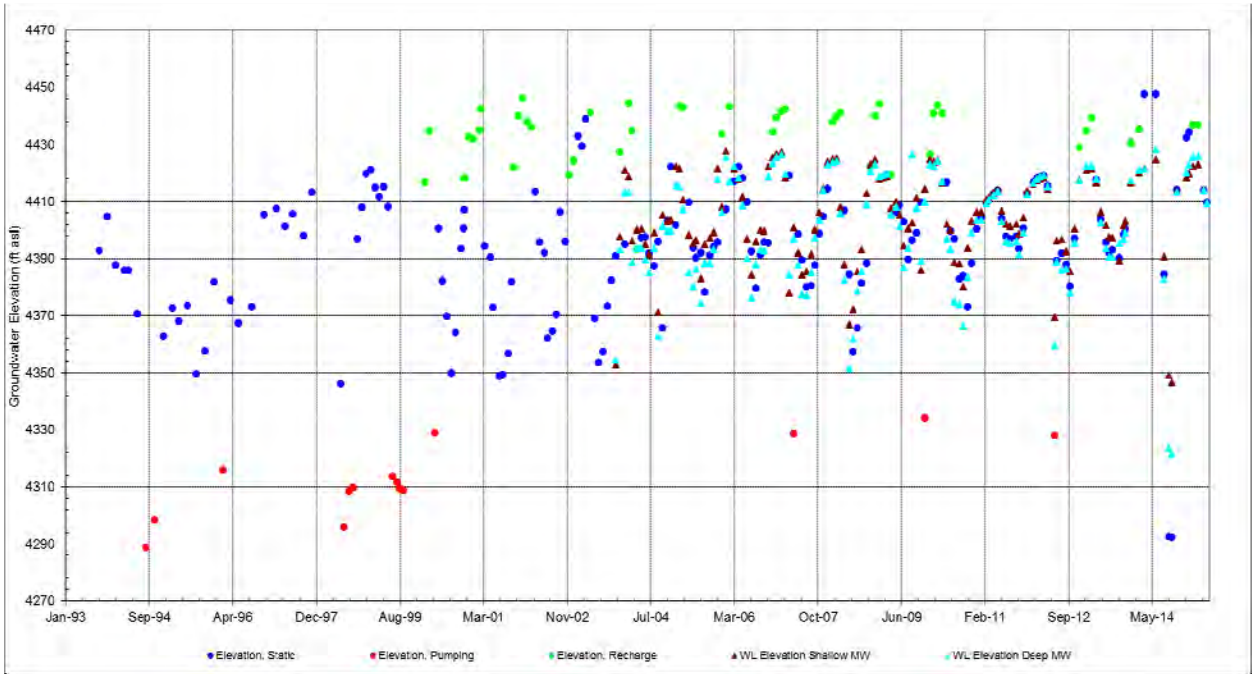


Figure 4B. El Rancho Drive Production and Monitoring Wells - Water Level Elevations

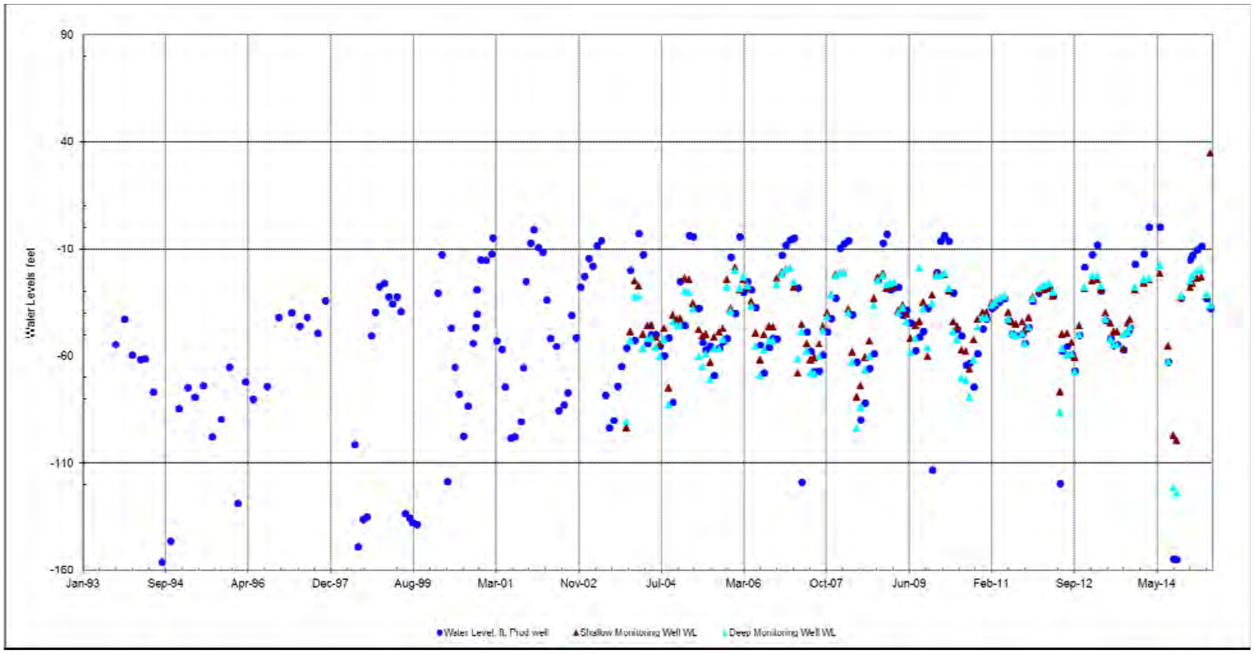


Figure 4C. El Rancho Drive Injection and Monitoring Wells - Water Levels

1.4 Reno High Well

Reno High Well is located on Idlewild Drive, north and adjacent to Reno High School.

During first half of 2015, 254.4 acre-feet (82.9 MG) of water were injected into the Reno High Well. During the same period, 125.5 acre-feet (40.9 MG) of water were pumped from the well (see Tables 1 and 2A, and Figure 5A).

Historical monthly water level elevations for Reno High Well and its monitoring wells are shown in Figure 5B.

The water levels for the injection/production well as well as those for the shallow and deep monitoring wells are shown in Figure 5C.

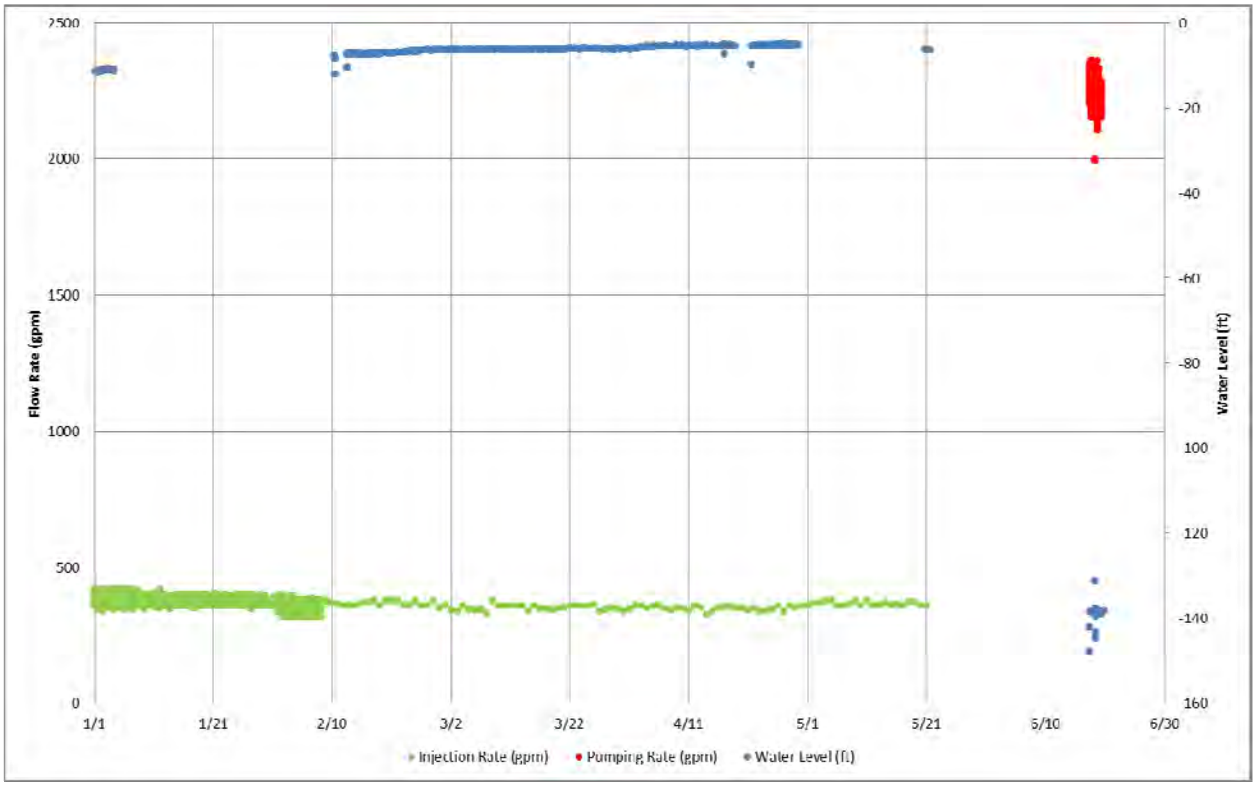


Figure 5A. Reno High Well – Flow Rates and Water Level, Jan to Jun 2015

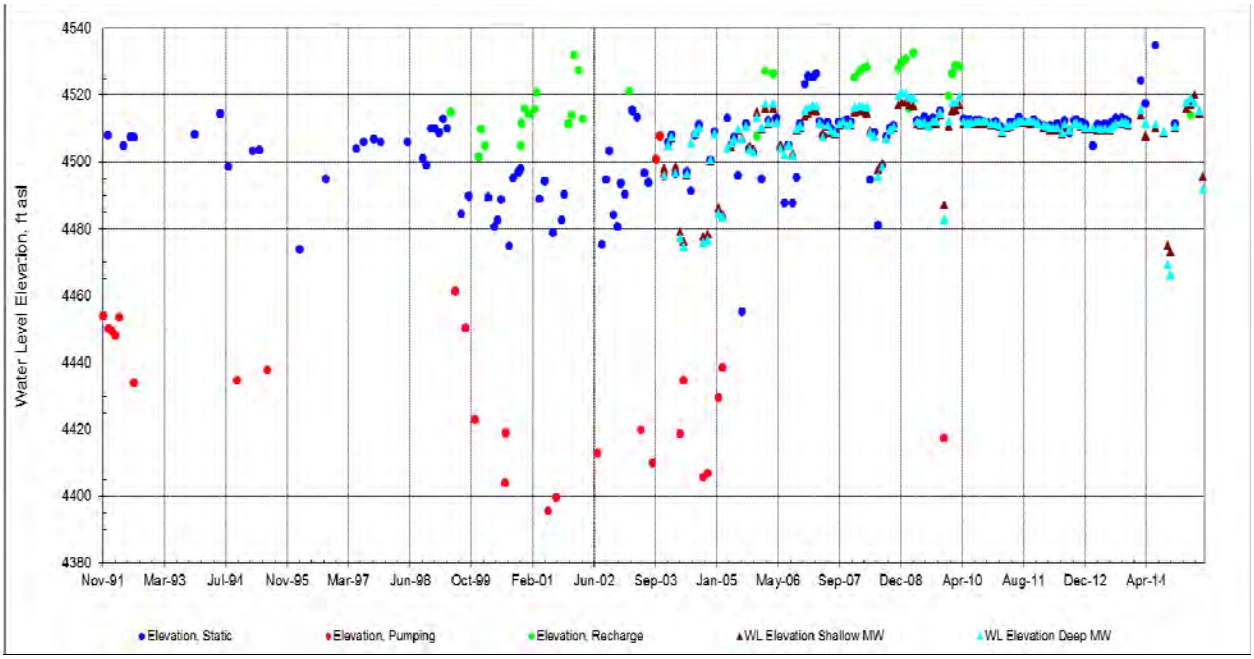


Figure 5B. Reno High Production and Monitoring Wells - Water Level Elevations

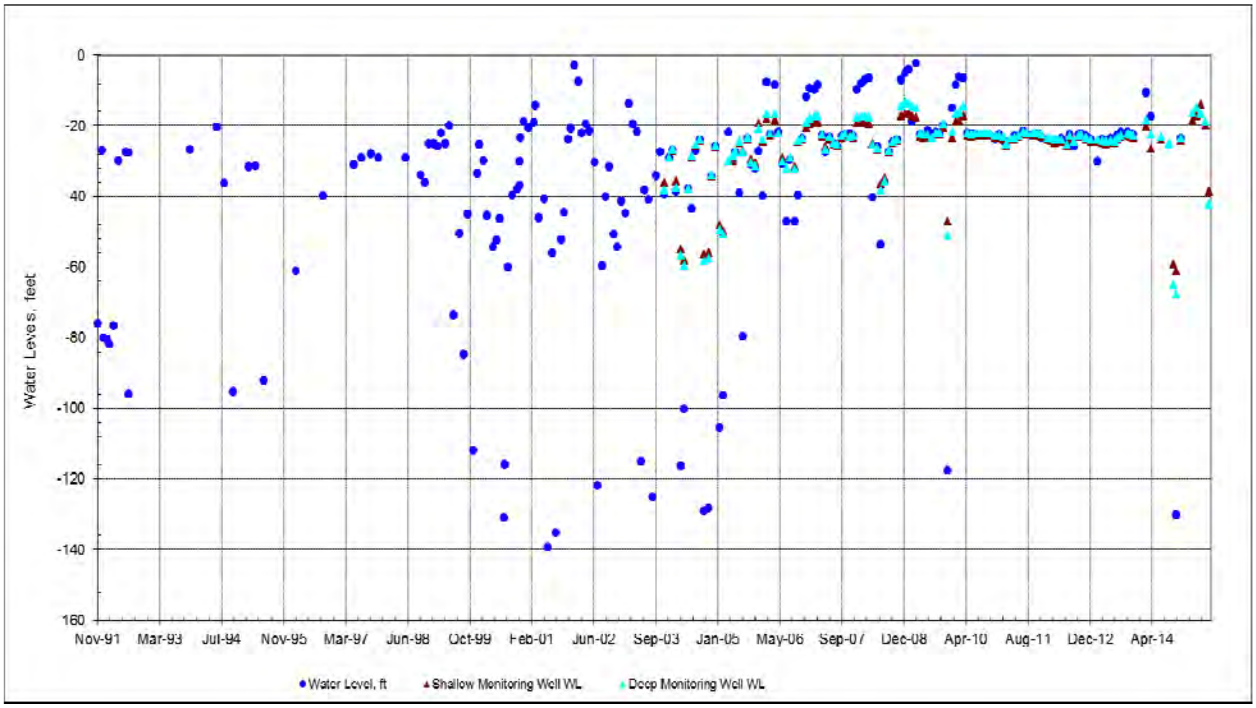


Figure 5C. Reno High Injection and Monitoring Wells - Water Levels

1.5 4th Street Well

The 4th Street Well is located in the northeast quarter of northeast quarter of Section 12, Township 19N, Range 19E, in Washoe County, Nevada, at the northeast corner of East 4th Street and Threlkel Street. The 4th Street Well was one of the first wells to be recharged beginning in 1993, but injection was discontinued because of its proximity to wells containing PCE. Recharge of the well was resumed in 2001 in cooperation with Washoe County Department of Water Resources, which is supervising remediation of PCE contaminated wells near this well.

During first half of 2015, 192.7 acre-feet (62.8 MG) of water were injected into the 4th Street Well. 49.9 acre-feet (16.3 MG) of water were pumped from the well during the same period (see Tables 1, 2A, and Table 2B.

Figure 6A shows water levels and pumping rates for 4th Street Well during the first half of 2015. Historical monthly water level elevations for 4th Street Well and its monitoring wells are shown in Figure 6B. The water levels for the production well as well as those for the shallow and deep monitoring wells are shown in Figure 6C.

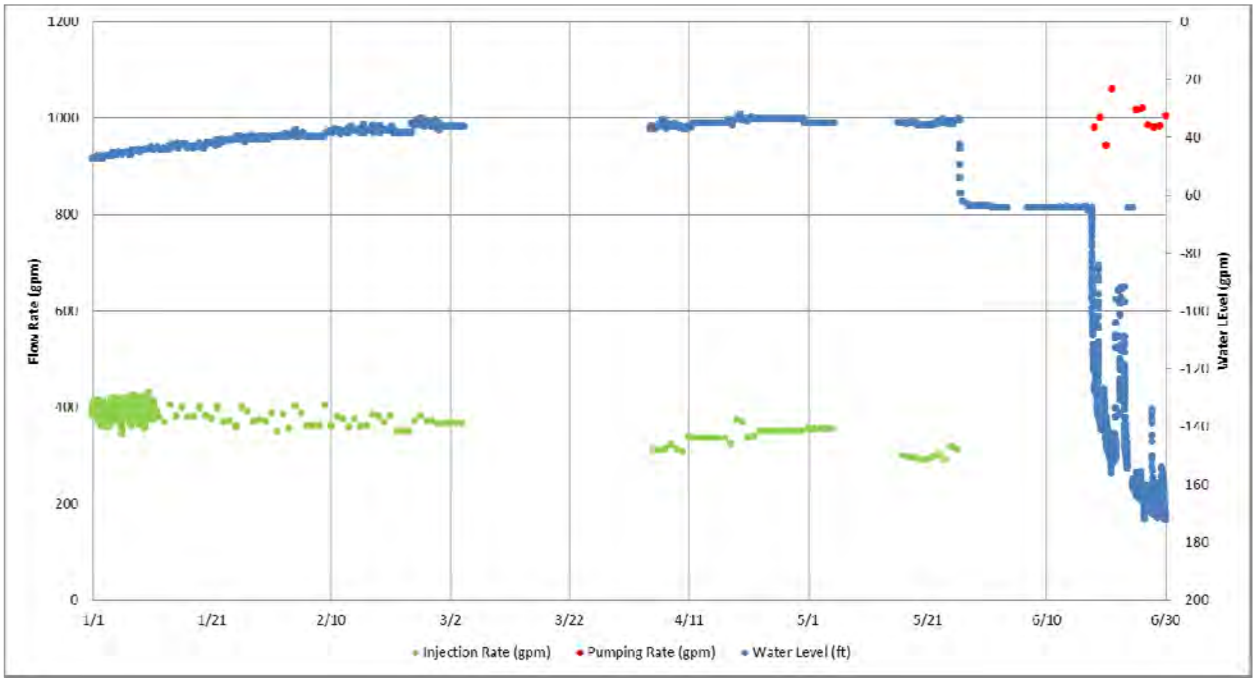


Figure 6A. 4th Street Well – Flow Rates and Water Levels, Jan to Jun 2015

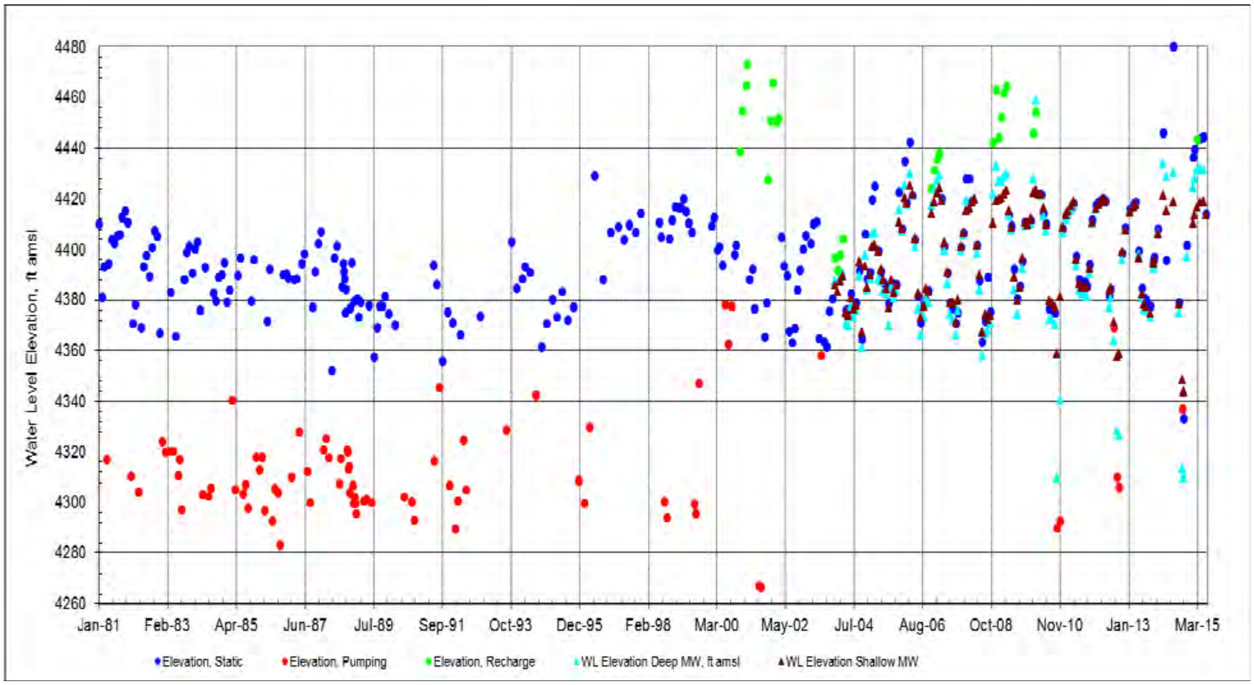


Figure 6B. 4th Street Production and Monitoring Wells - Water Level Elevations

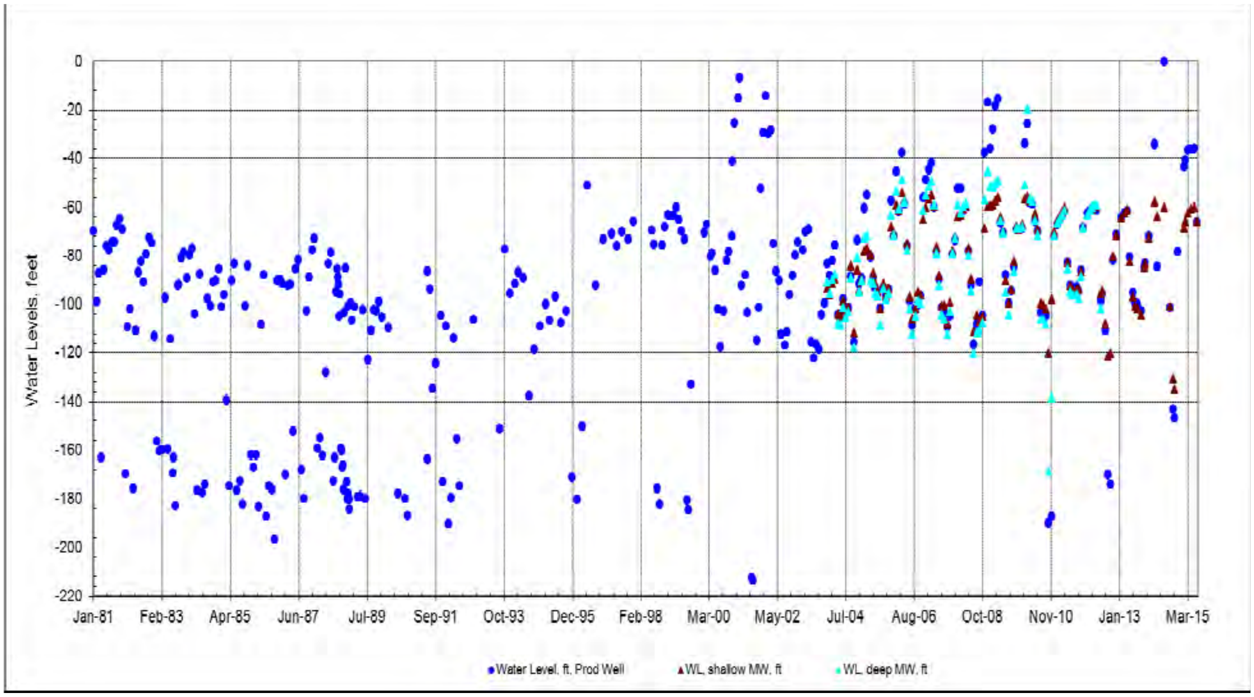


Figure 6C. 4th Street Injection and Monitoring Wells - Water Levels

1.6 21st Street Well

The 21st Street Well is located in the northeast quarter of southeast quarter of Section 7, Township 19N, Range 20E, or at a point from which the east quarter corner of said Section 7 bears north 21 41’00” east, a distance of 945.0 feet, in Washoe County, Nevada.

During first half of 2015, 124.6 acre-feet (40.6 MG) of water were injected into the 21st Street Well. 79.6 acre-feet (25.9 MG) of water were pumped from the well during the same period (see Tables 1, 2A, and 2B. Historical monthly water level elevations for the 21st Street Well and its monitoring wells are shown in Figure 7C.

Figure 7A shows water levels and extraction rates for 21st Street Well. Historical monthly water level elevations for 21st Street Well and its monitoring wells are shown in Figure 7B.

The water levels for the 21st Street Well and its two monitoring wells are shown in Figure 7C. The shallow monitoring well near the injection well is drilled to 60 feet and shows no water level changes due to pumping activities in the 21st Street Well. Water levels in the deep monitoring well which is screened in the same interval as the injection well show the same variations as in the production well.

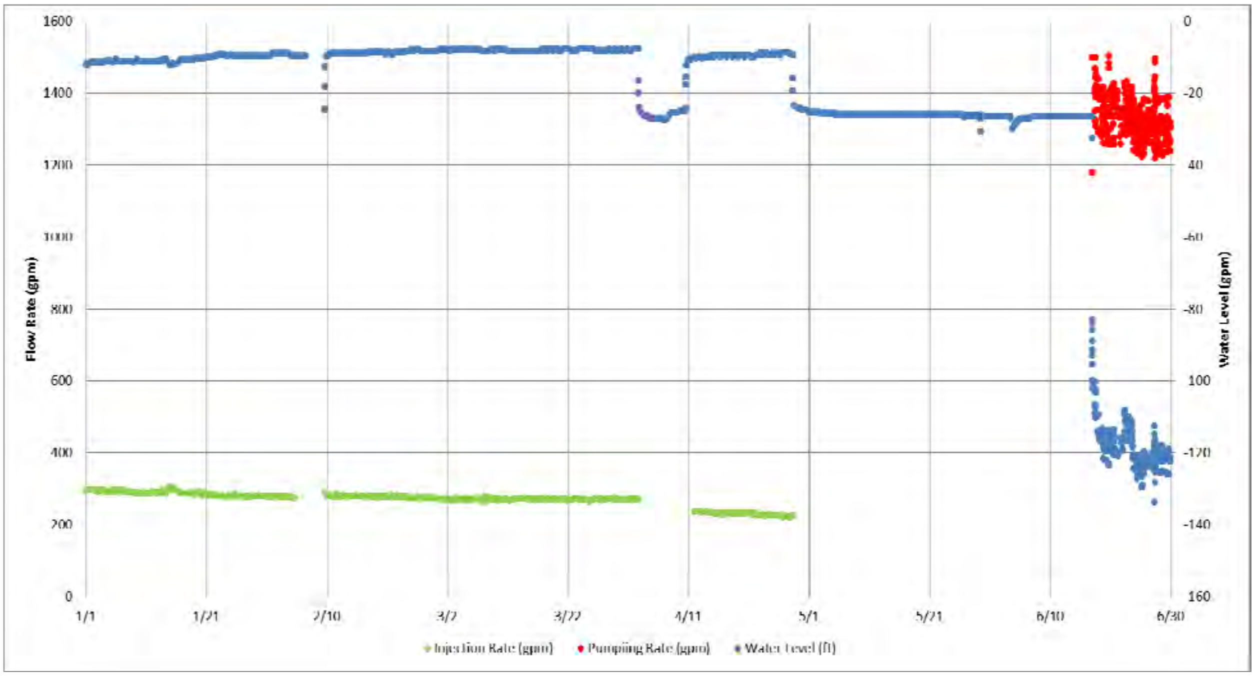


Figure 7A. 21st Street Well – Flow Rates and Water Levels, Jan to Jun 2015

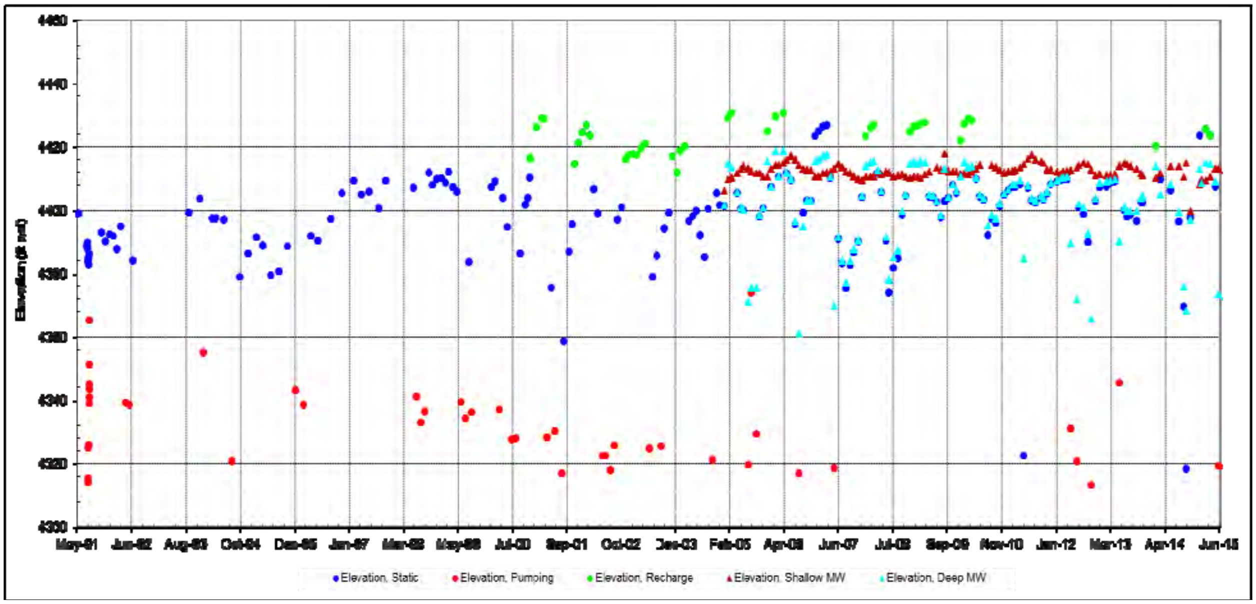


Figure 7B. 21st Street Production and Monitoring Wells - Water Level Elevations

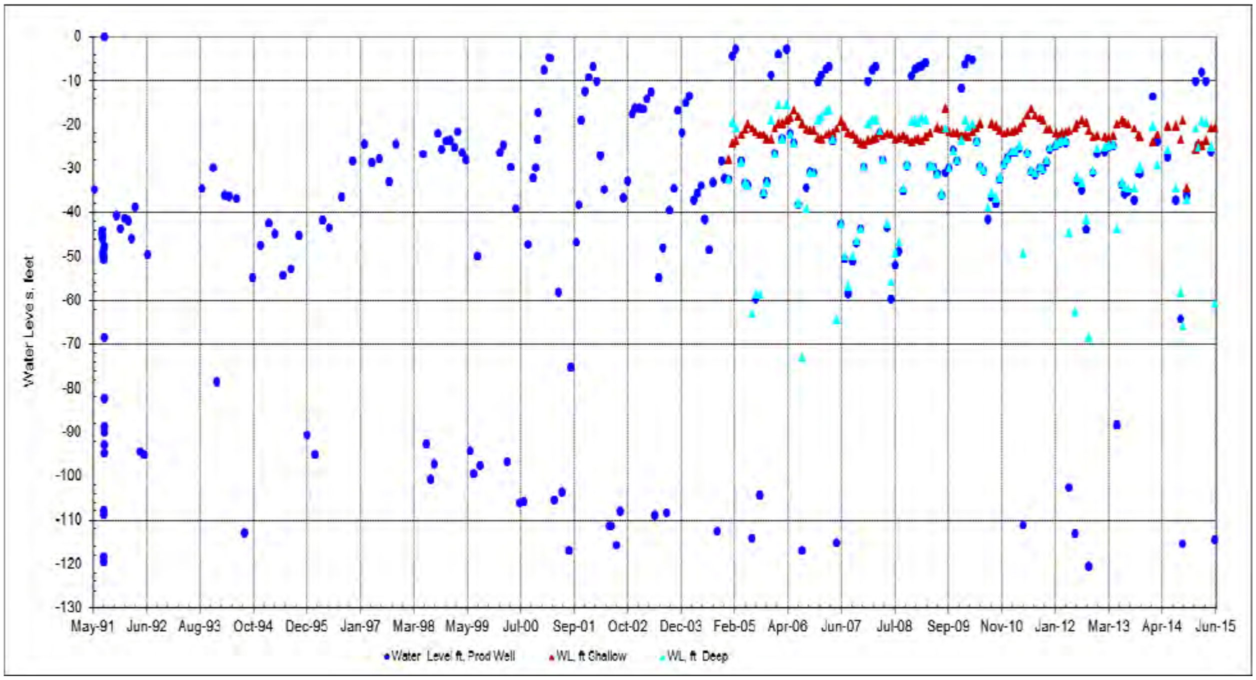


Figure 7C. 21st Street Injection and Monitoring Wells - Water Levels

1.7 Galletti Way Well

Galletti Way Well is located in northwest quarter of southeast quarter of Section 7, Township 19N, Range 20E, or at a point which bears south 85 0’0” west from the east quarter corner of said Section 7, a distance of 1572.6 feet, in Washoe County.

During first half of 2015, 163.2 acre-feet (53.2 MG) of water were injected into the Galletti Way Well, and 20.3 acre-feet (6.6 MG) of water were pumped from the well during the same period (see Tables 1 and 2A, and Figure 8A.)

Galletti Way monitoring well is the monitoring well for the Galletti Way production/injection well. Water level elevations for the Galletti Way injection and monitoring wells are shown in Figure 8B while water levels for the two wells are shown in Figure 8C. Water levels in the monitoring well have the same trend as the production well, which indicates that the two wells are in communication.

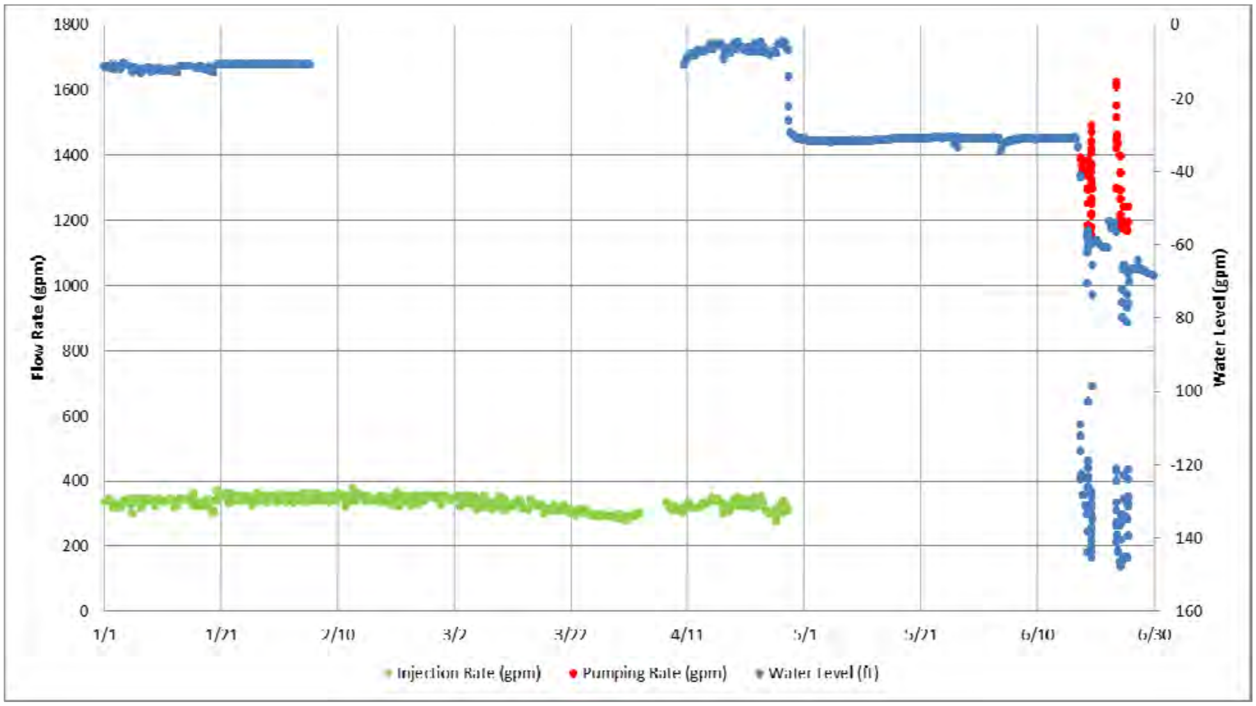


Figure 8A. Galletti Way Well – Flow Rates and Water Levels, Jan to Jun 2015

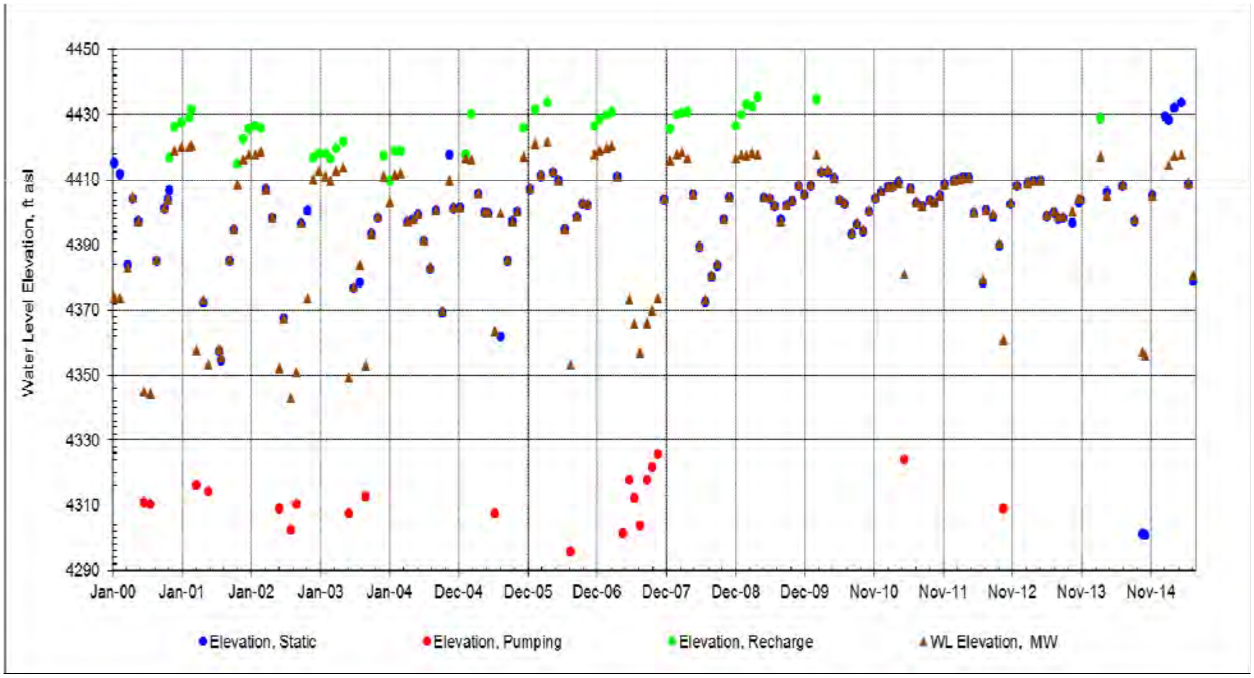


Figure 8B. Galletti Way Production and Monitoring Wells - Water Level Elevations

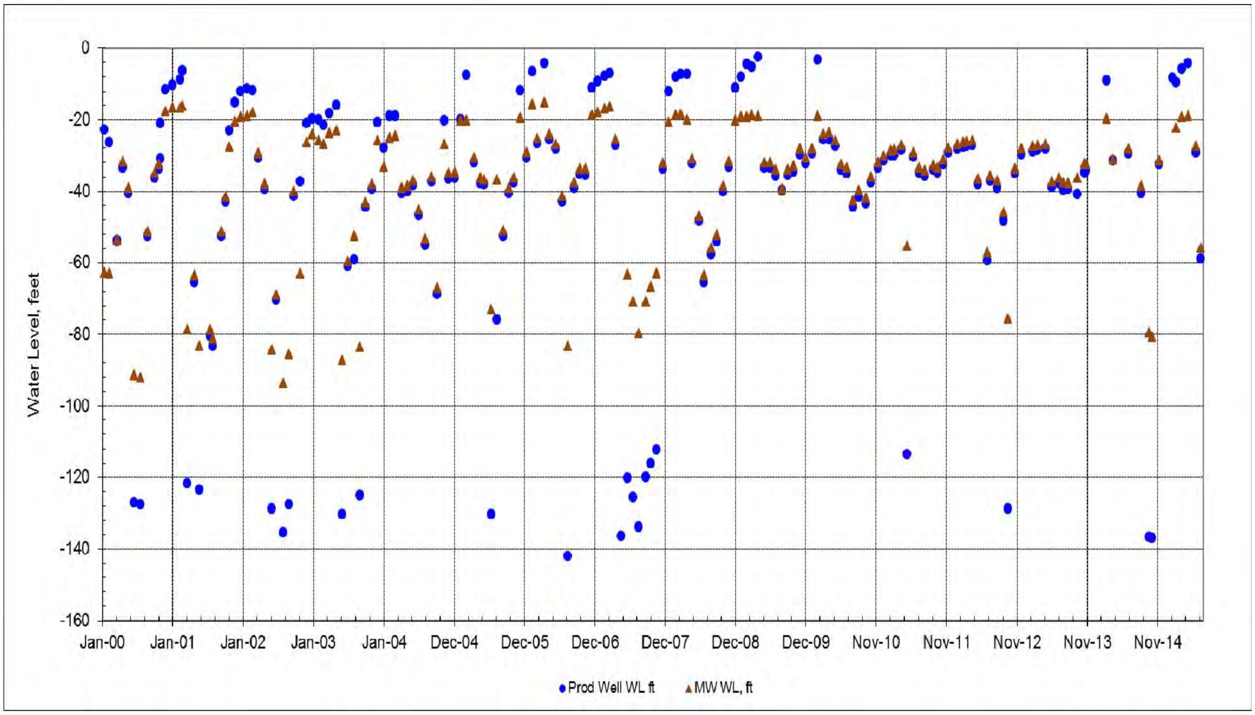


Figure 8C. Galletti Way Production and Monitoring Wells - Water Levels

1.8 Hunter Lake Well

The Hunter Lake Well is located on the Hunter Lake Elementary School property, in Reno, Nevada, at the southwest corner of California Avenue and Hunter Lake Drive.

During first half of 2015, 284.3 acre-feet (92.6 MG) of water were injected into the Hunter Lake Well, and 110.3 acre-feet (35.9 MG) of water were pumped from the well during the same period (see Tables 1 and 2A, and Figure 9A.)

Historical monthly water level elevations for Hunter Lake Well and its monitoring well are shown in Figure 9B while the water levels are shown in Figure 9C. Water levels in the monitoring well have the same trend as the production well, which indicates that the two wells are in communication.

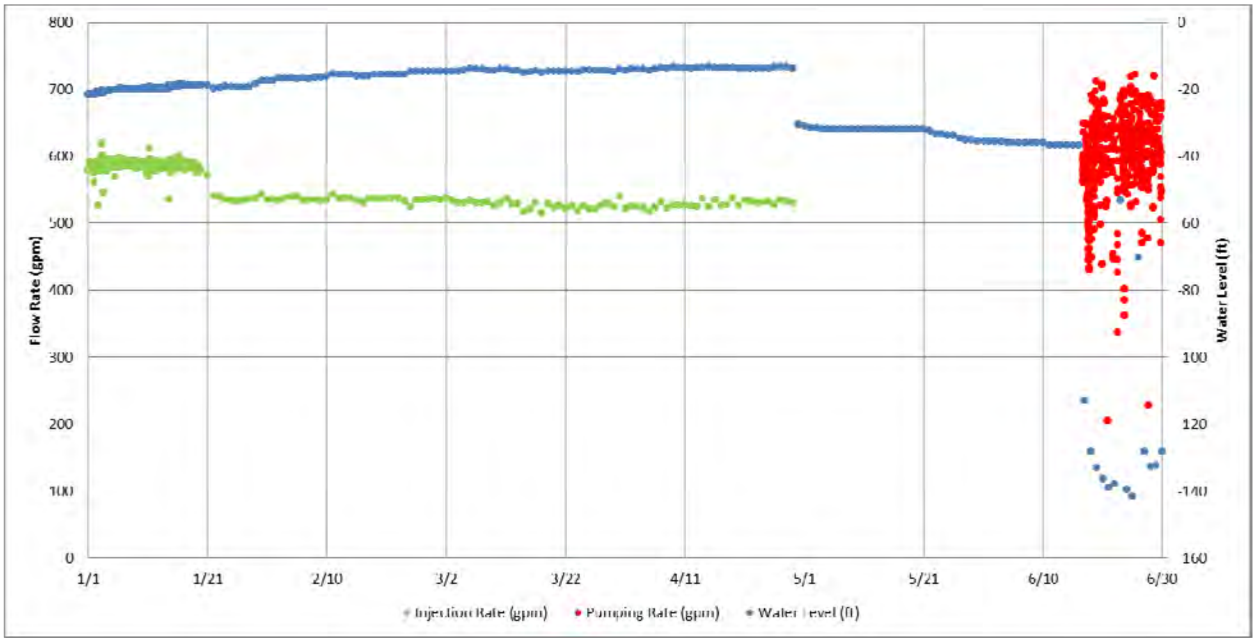


Figure 9A. Hunter Lake Well – Flow Rates and Water Levels, Jan to Jun 2015

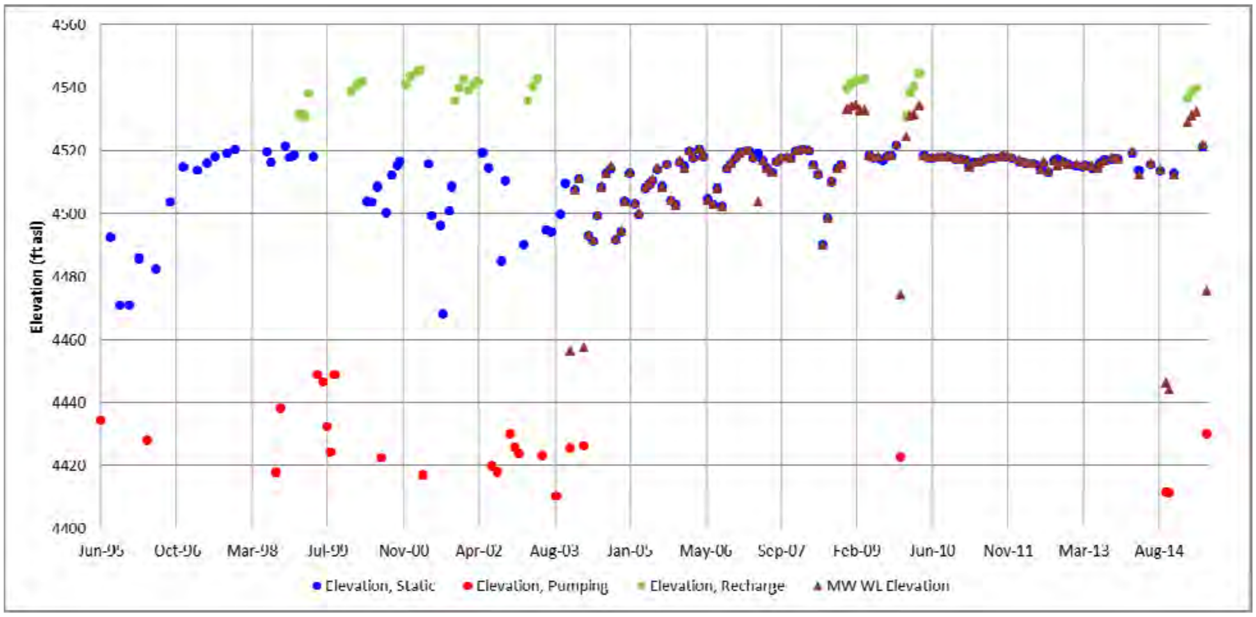


Figure 9B. Hunter Lake Injection and Monitoring Wells - Water Level Elevations

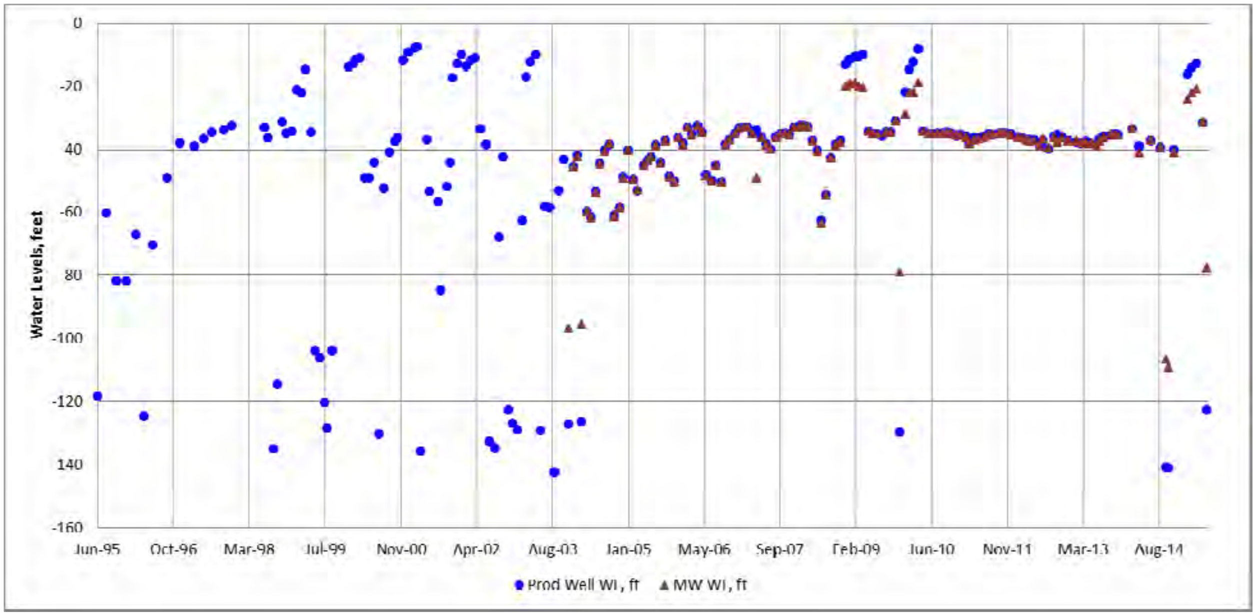


Figure 9C. Hunter Lake Injection and Monitoring Wells - Water Levels

1.9 Glen Hare Well

Glen Hare Well is located in the NW ¼ of NE ¼ of Section 15, T.19N., R.19E., M.D.B.& M., or at a point from which the NE corner of said Section 15 bears North 20 31’00” East, a distance of 2502.35 feet, in Washoe County.

During first half of 2015, 166.5 acre-feet (54.2 MG) of water were injected into the Glen Hare Well (see Tables 1 and 2A, and Figure 10A). During the same period, 48.0 acre-feet (15.6 MG) of water were pumped from the well (Table 2B and Figure 10A).

Glen Hare monitoring well is the monitoring well for the Glen Hare production/injection well. Water level elevations for the Glen Hare injection and monitoring wells are shown in Figure 10B and Figure 10C shows their water levels. Water levels in the monitoring well have the same trend as the production well, which indicates that the two wells are in communication.

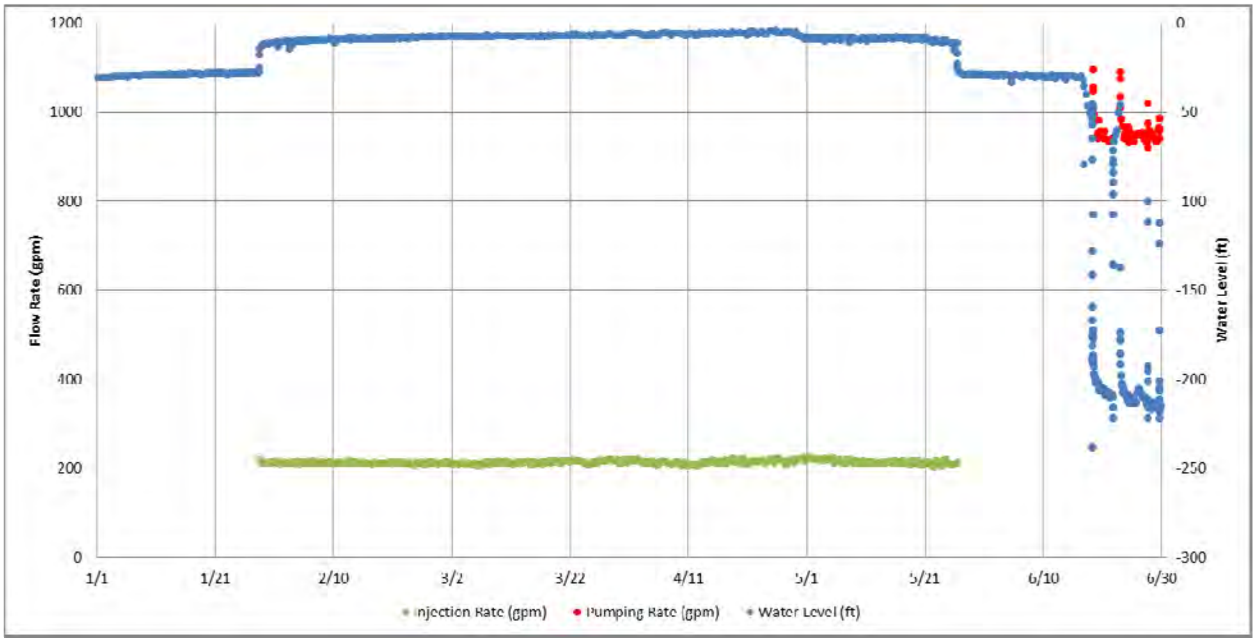


Figure 10A. Glen Hare Well – Flows Rates and Water Levels, Jan to Jun 2015

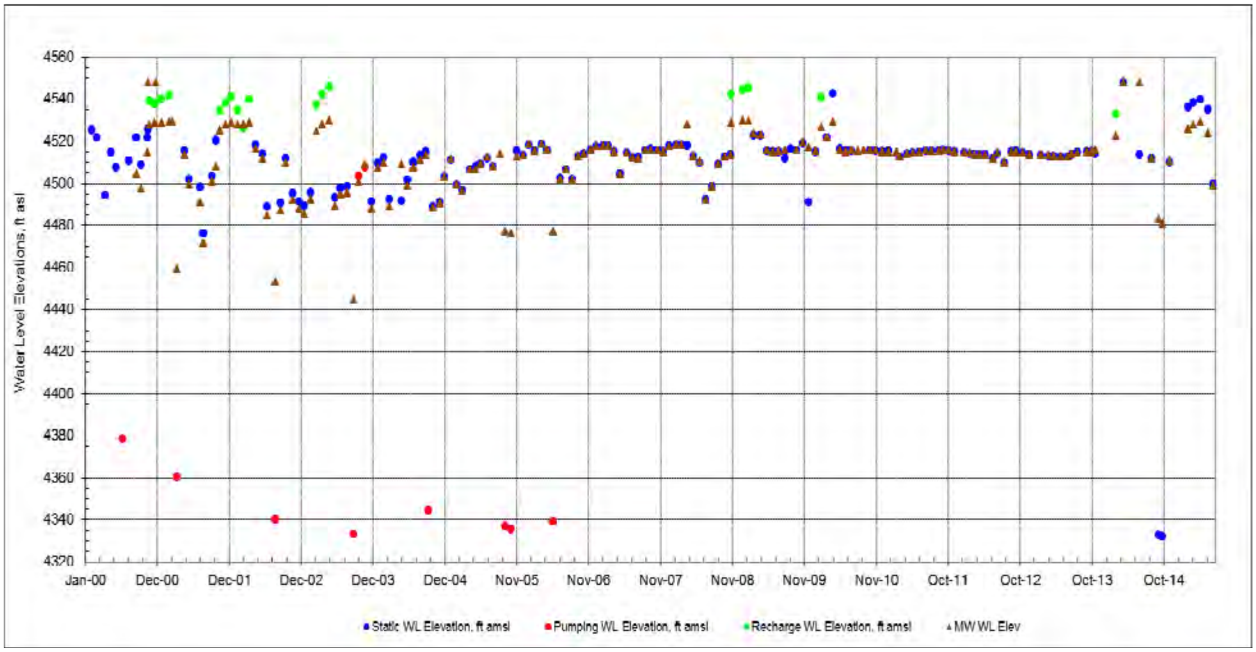


Figure 10B. Glen Hare Injection and Monitoring Wells - Water Level Elevations

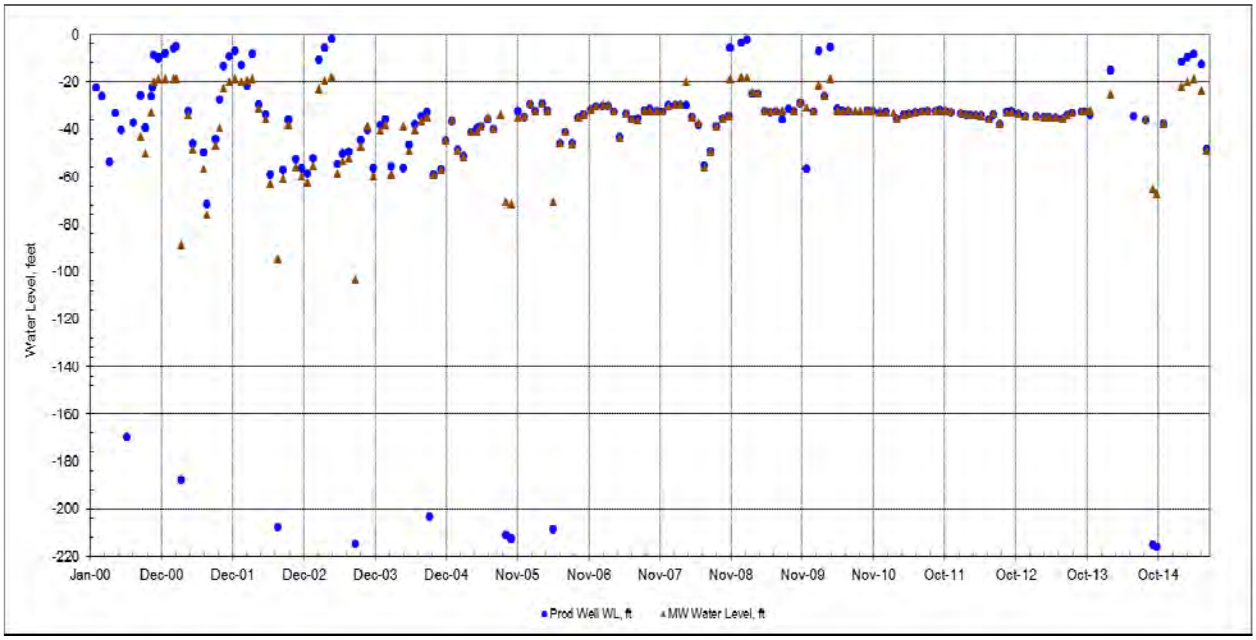


Figure 10C. Glen Hare Injection and Monitoring Wells - Water Levels

1.10 Holcomb Lane Well

Holcomb Lane Well is located at SE 1/4 SW 1/4 of Section 35, T.19N. R.19E, M.D.B.& M., or at a point from which the SW corner of said Section 35 bears South 68 08’20” West, a distance of 2258.30 feet, in Washoe County, Nevada.

During first half of 2015, 154.3 acre-feet (50.3 MG) of water were injected into the Holcomb Lane Well (see Tables 1, 2A and 2B, and Figure 11A). During the same period, 35.8 acre-feet (11.7 MG) of water were pumped from the well (Table 2B and Figure 11A).

Holcomb Lane monitoring well is the monitoring well for the Holcomb Lane production/injection well. Water level elevations for the Holcomb Lane injection and monitoring wells are shown in Figure 11B.

Figure 11C shows their water levels. Water levels in the monitoring well have the same trend as the production well which indicates that the two wells are in communication.

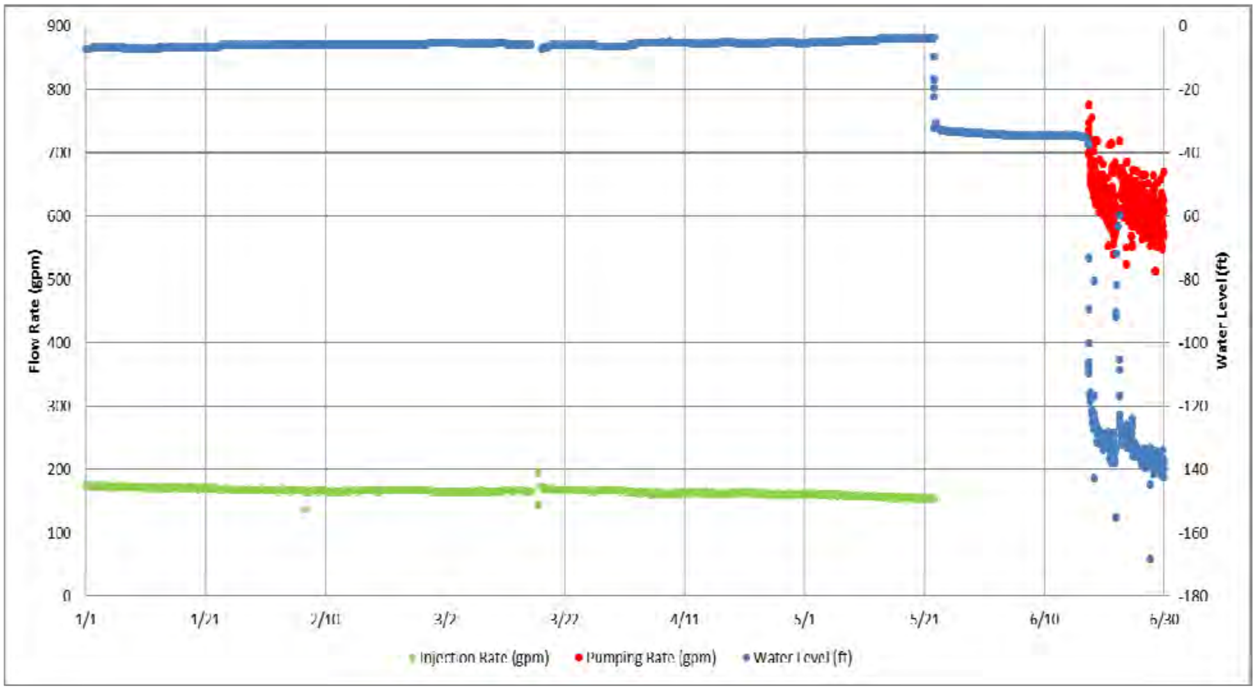


Figure 11A. Holcomb Lane Well – Flow Rates and Water Levels, Jan to Jun 2015

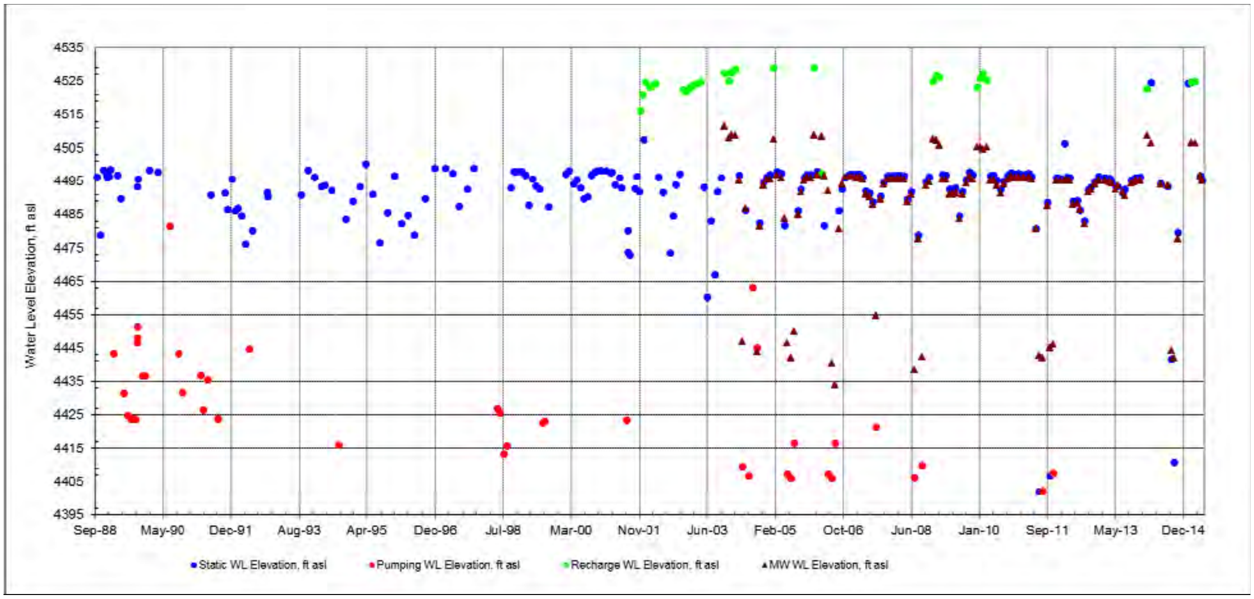


Figure 11B. Holcomb Lane Injection and Monitoring Wells - Water Level Elevations

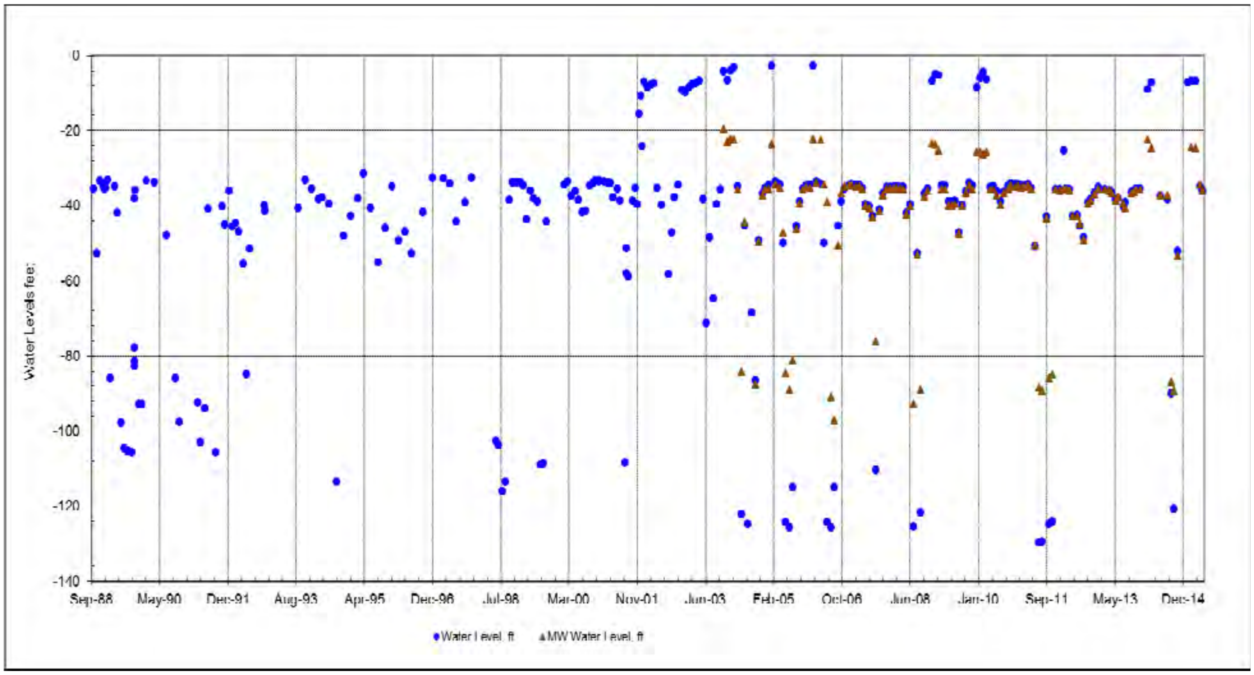


Figure 11C. Holcomb Lane Injection and Monitoring Wells - Water Levels

1.11 Nugget Avenue (Sparks Avenue) Well

Sparks Ave, now known as Nugget Avenue Well, is located in the NE ¼ NW ¼ of Section 8, T. 19N., R. 20E., M.D.B.&M., or at a point from which the North ¼ corner of said Section 8 bears North 03° 01' 25" East, a distance of 549.76 feet, in Washoe County, Nevada.

During the first half of 2015, no water was injected into the Nugget Avenue Well (Tables 1 and 2A, and Figure 12A). During the same period, 26.1 acre-feet (8.5 MG) of water were pumped from the well.

Nugget Avenue Well uses two nested wells belonging to Central Truckee Meadows Remediation District (CTMRD) as its monitoring wells. Water level elevations for the Sparks Avenue injection and monitoring wells are shown in Figure 12B. The water levels are shown in Figure 12C.

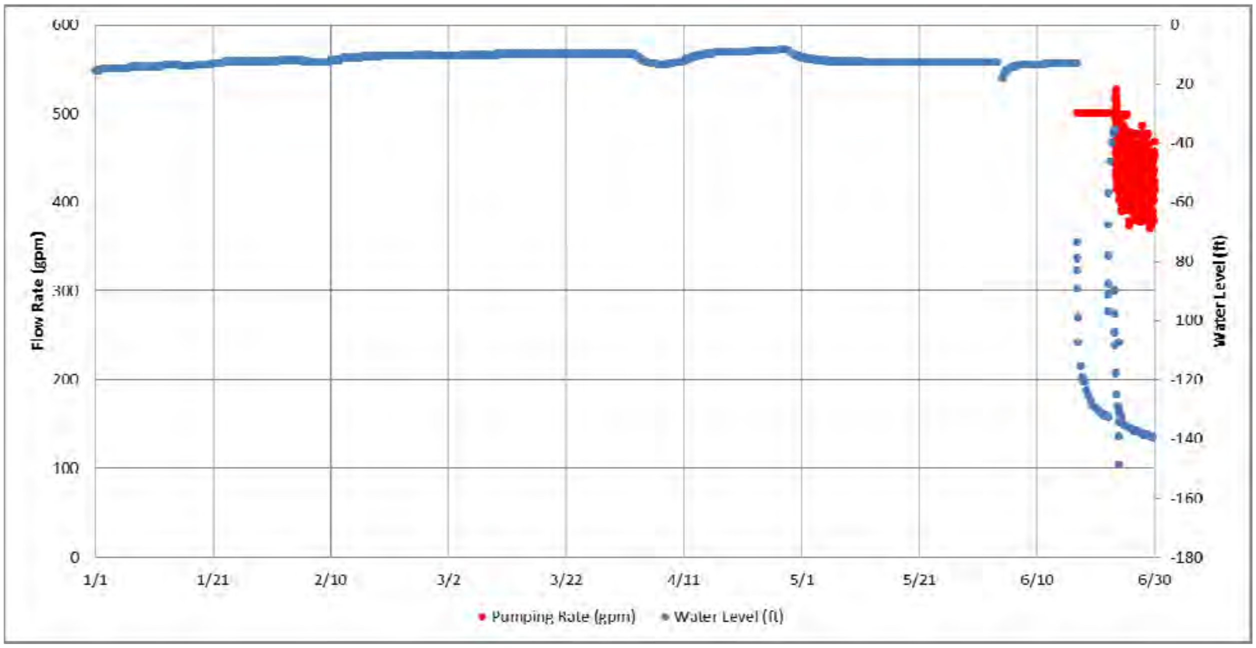


Figure 12A. Nugget Avenue Well – Water Levels, Jan to Jun 2015

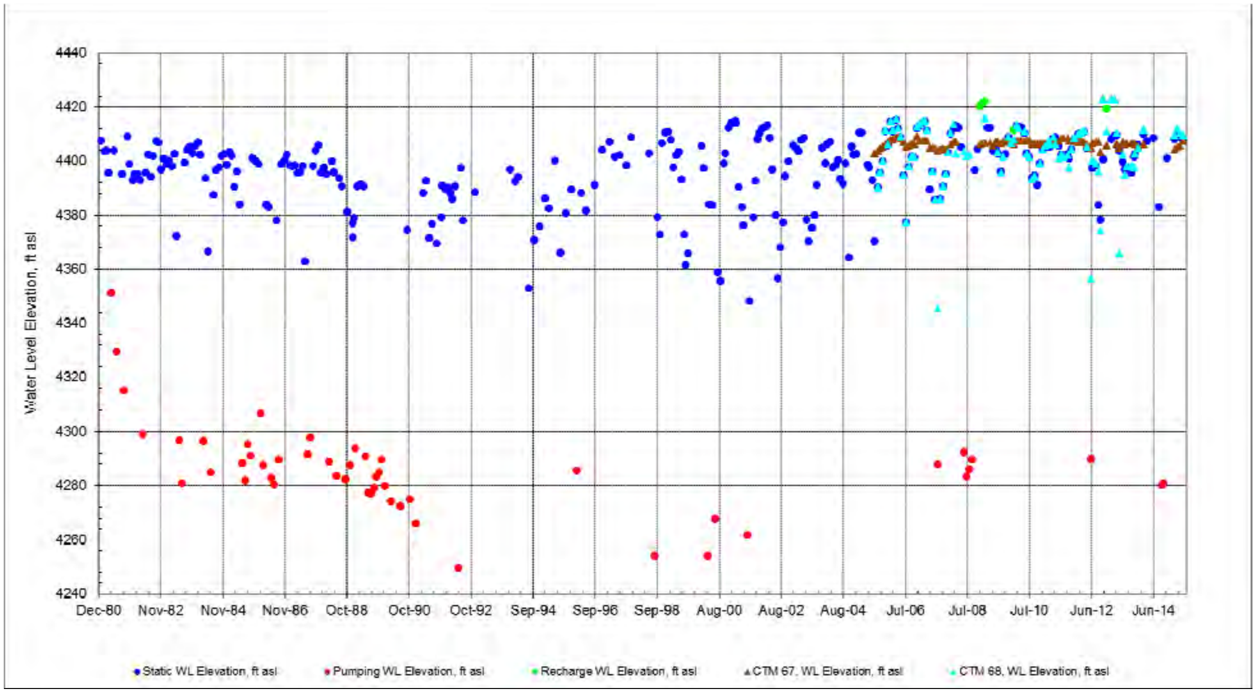


Figure 12B. Nugget Avenue Injection and Monitoring Wells - Water Level Elevations

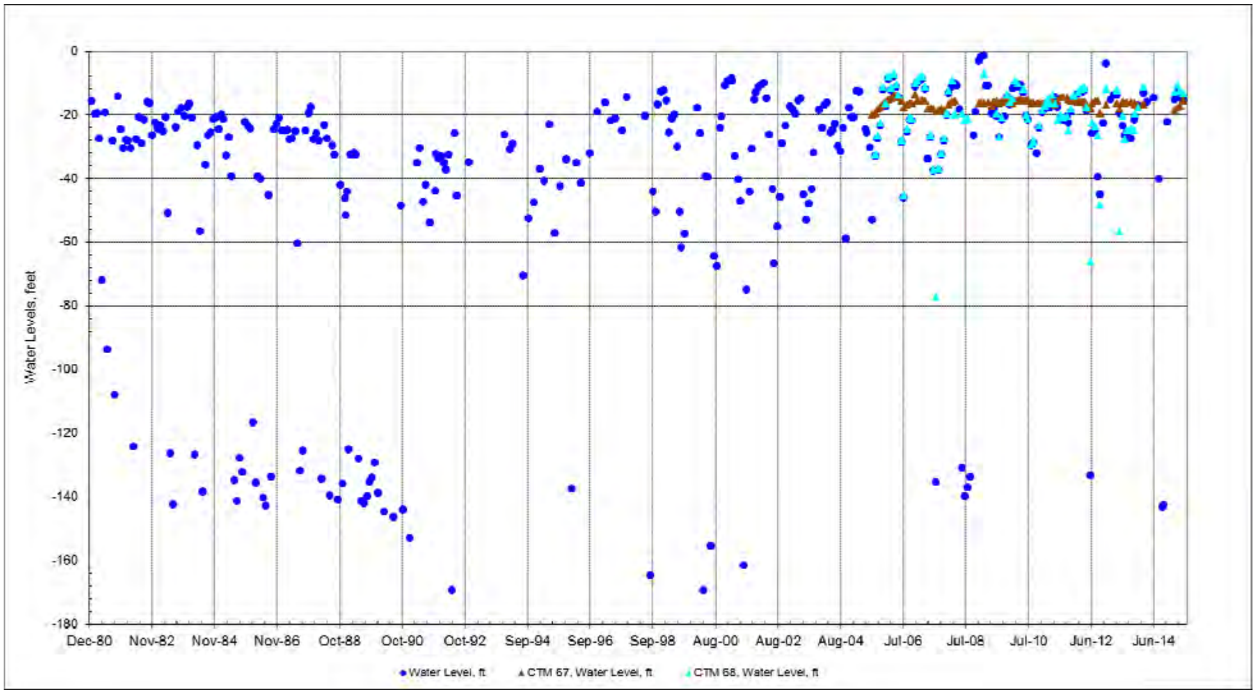


Figure 12C. Nugget Avenue Injection and Monitoring Wells - Water Levels

1.12 Greg Street Well

Greg Street Well is located SE ¼ of SE ¼ of Section 8, T.19N., R.20E., M.D.B.& M., in Washoe County.

During the first half of 2015, 197.5 acre-feet (64.4 MG) of water were injected into Greg Street Well. (Tables 1 and 2A, and Figure 13A). During the same period, 18.7 acre/ft. (6.1 MG) of water were pumped from Greg Street Well (Table 2B and Figure 13A). Monthly water level elevations for Greg Street Well and its two monitoring wells, a shallow (30 feet) and deep (290 feet) wells, are shown in Figure 13B.

Figure 13C shows water levels in the three wells. The water levels in the Greg Street shallow monitoring well are not affected by the recharge or pumping activities in the Greg Street recharge/production well. The deep monitoring well water levels have the same trend as the production/injection well.

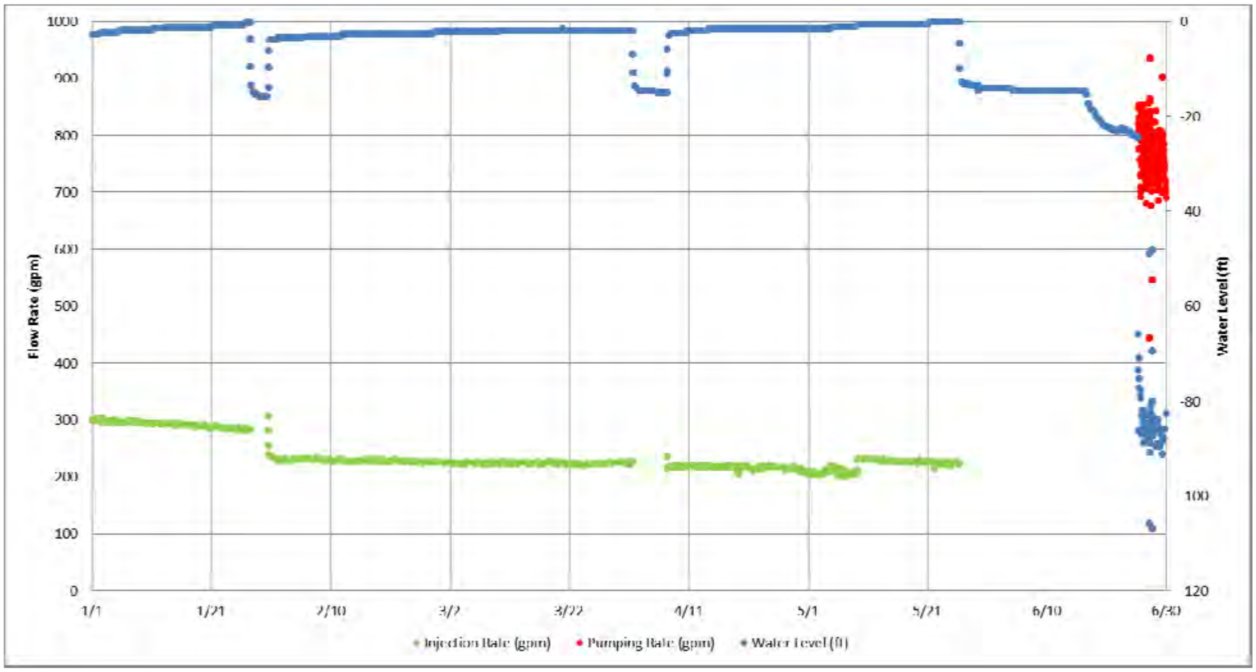


Figure 13A. Greg Street Well –Flow Rates and Water Levels, Jan to Jun 2015

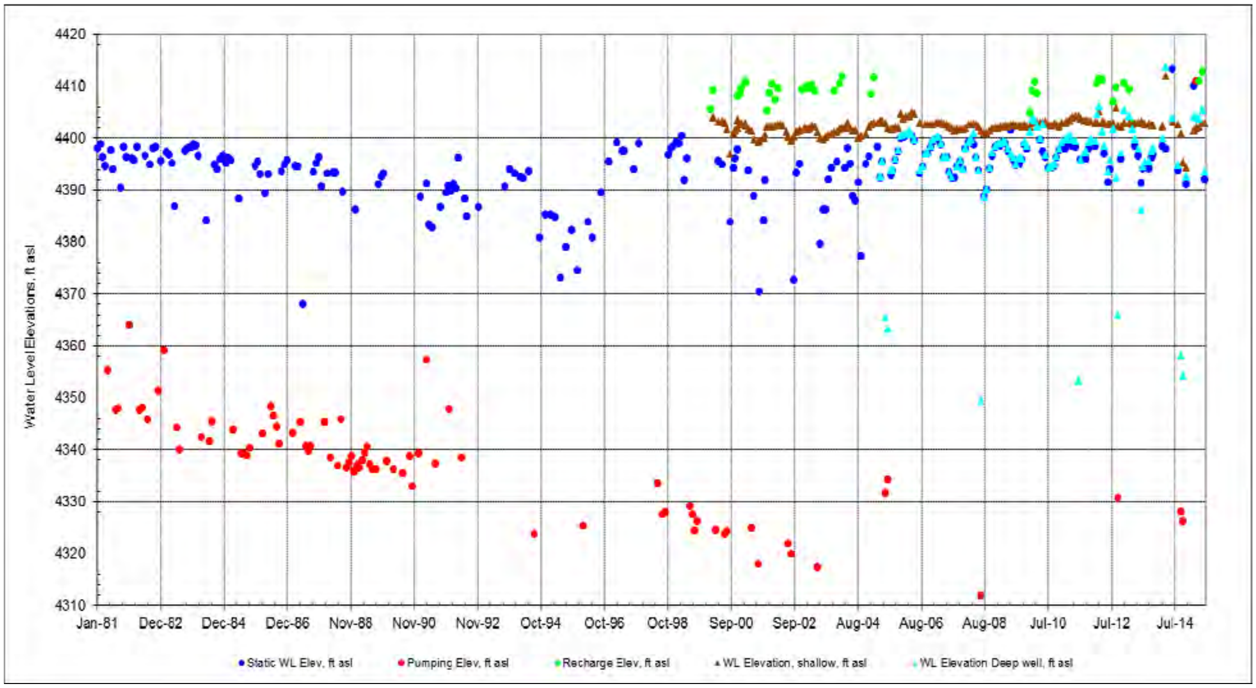


Figure 13B. Greg Street Injection and Monitoring Wells - Water Level Elevations

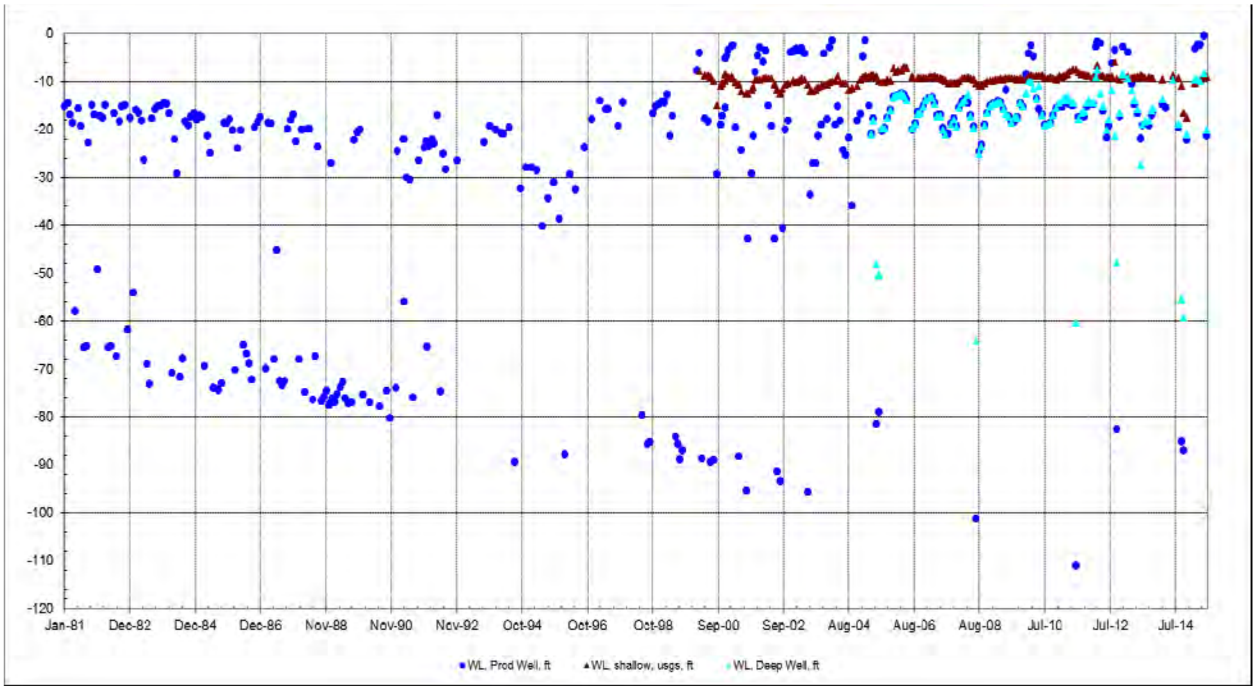


Figure 13C. Greg Street Injection and Monitoring Wells - Water Levels

1.13 Poplar #2 Well

Poplar #2 Well is located at the northwest corner of Shaber Avenue and S. 15th Street in Sparks.

During the first half of 2015, no water was injected into the Poplar #2 Well (Table 1 and Figure 14A). During the same period, 83.8 acre-feet (27.3 MG) of water were pumped from the well.

Poplar #2 Well uses two monitoring wells (CTM 74 and CTM 75), belonging to the Central Truckee Meadows Remediation District (CTMRD) as its monitoring wells. Monthly water level elevations for Poplar #2 Well and its two monitoring wells are shown in Figure 14B and their water levels are shown in Figure 14C. The deep monitoring well (CTM 75) water levels have the same trend as the production/injection well.

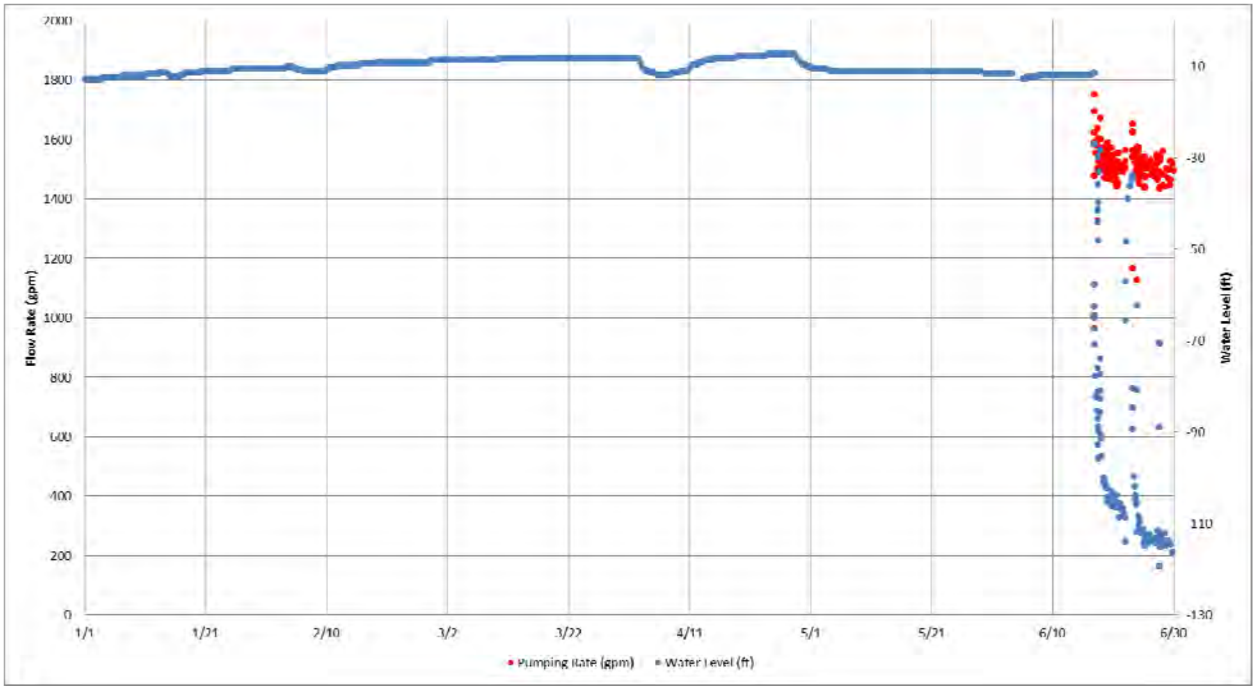


Figure 14A. Poplar #2 Well – Flow Rates and Water Levels, Jan to Jun 2015

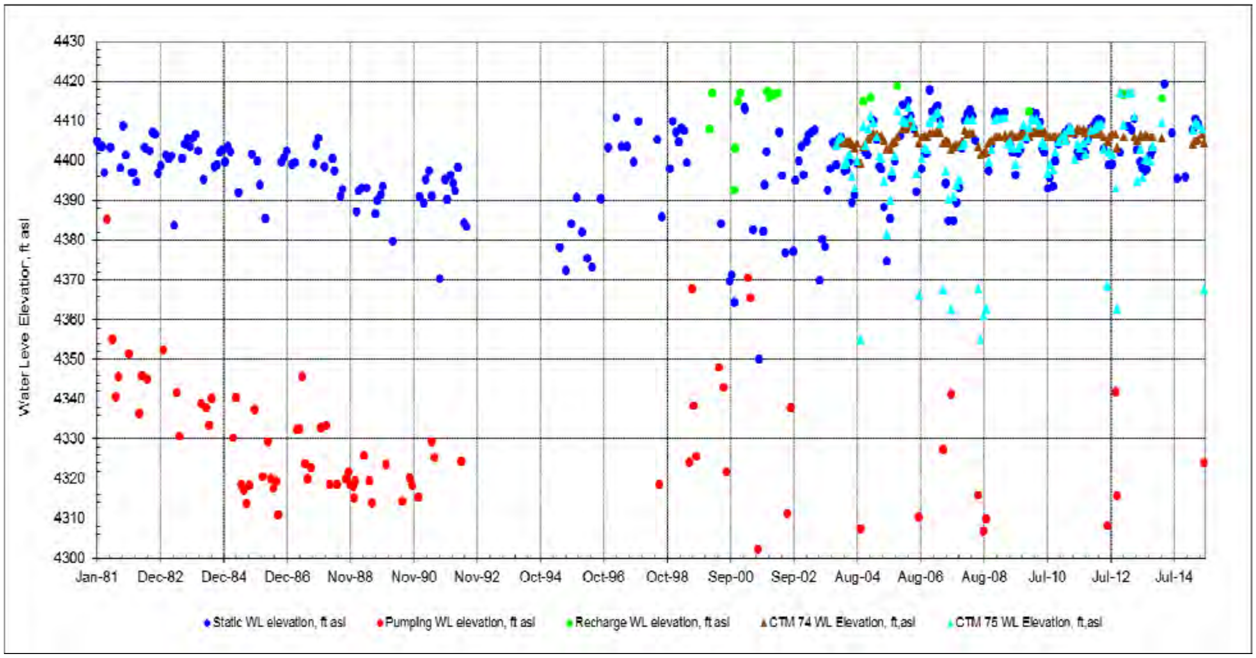


Figure 14B. Poplar #2 Injection and Monitoring Wells - Water Level Elevations

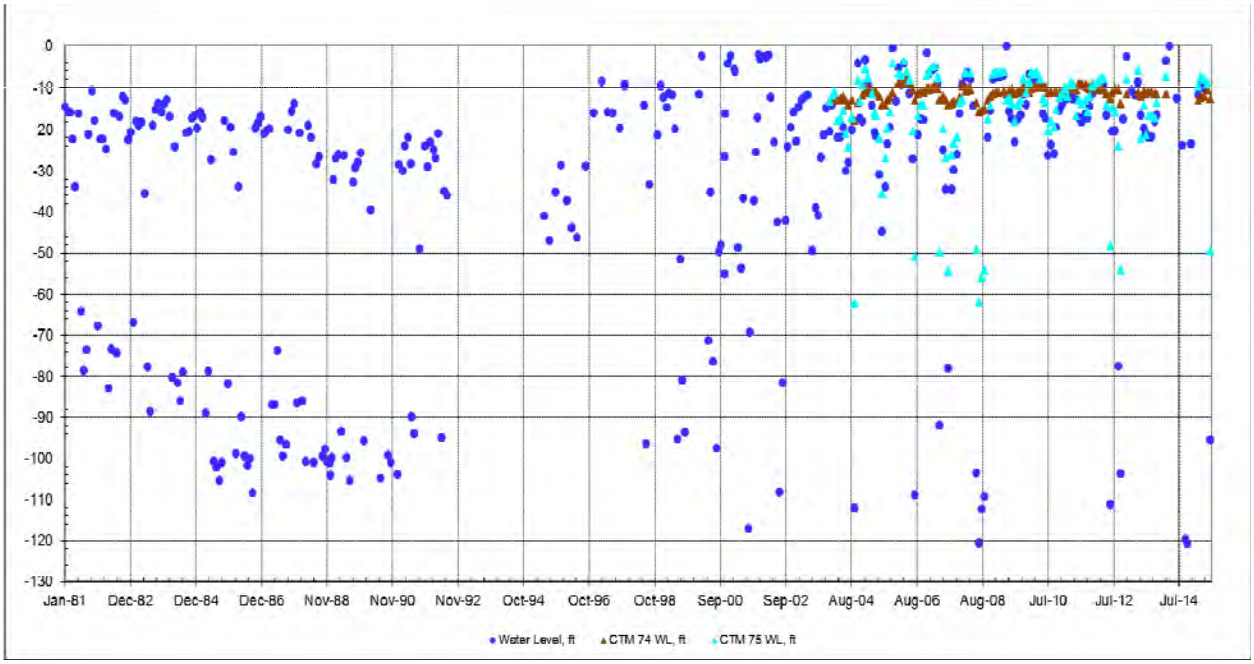


Figure 14C. Poplar #2 Injection and Monitoring Wells - Water Levels

1.14 Delucchi Lane Well

Delucchi Lane Well is situated in the NE ¼ SW ¼ of Section 31, T. 19N., R. 20E., M.D.B.&M., or at a point from which the Northwest corner of said Section 31 bears North 27° 21’ 05” West, a distance of 3,067.64 feet, in Washoe County, Nevada**.**

During the first half of 2015, 124.6 acre-feet (40.6 MG) of water were injected into the Delucchi Lane Well. During the same period, 29.1 acre-feet (9.5 MG) of water were pumped from the well (Tables 1, 2A and 2B and Figure 15A).

There is no monitoring well for Delucchi Lane well. Its historical water level elevations and water levels are shown in Figures 15B and 15C, respectively.

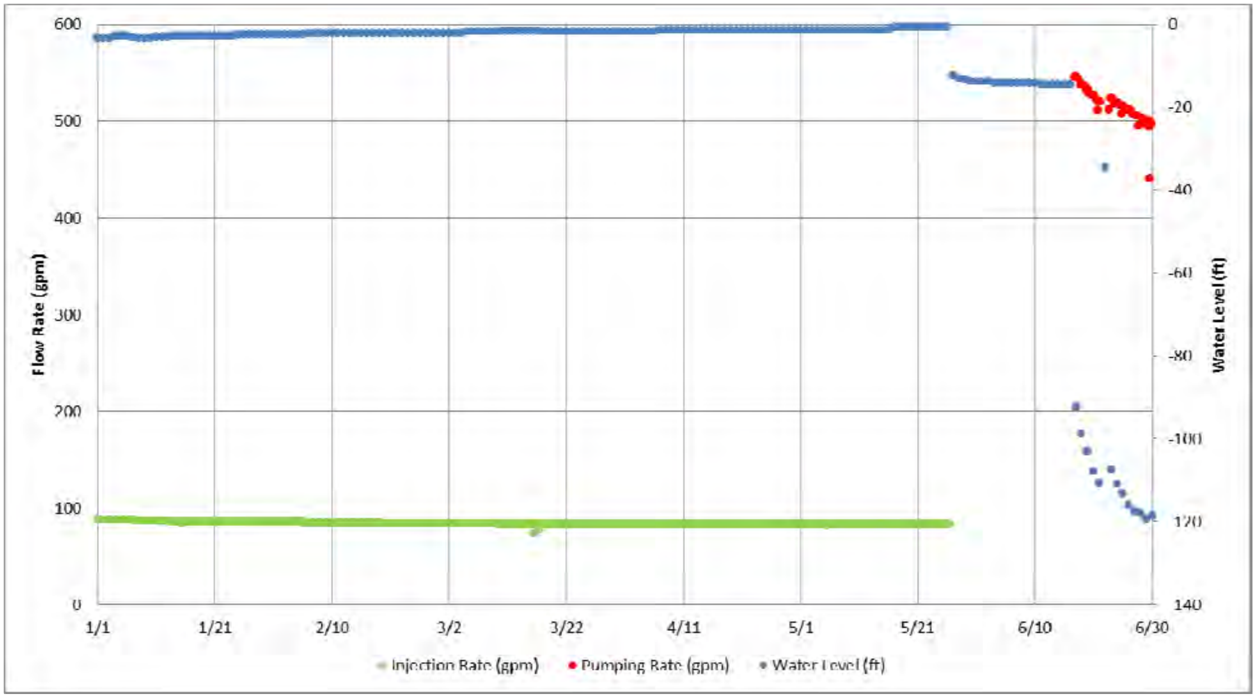


Figure 15A. Delucchi Lane Well – Flow Rates and Water Levels, 2015

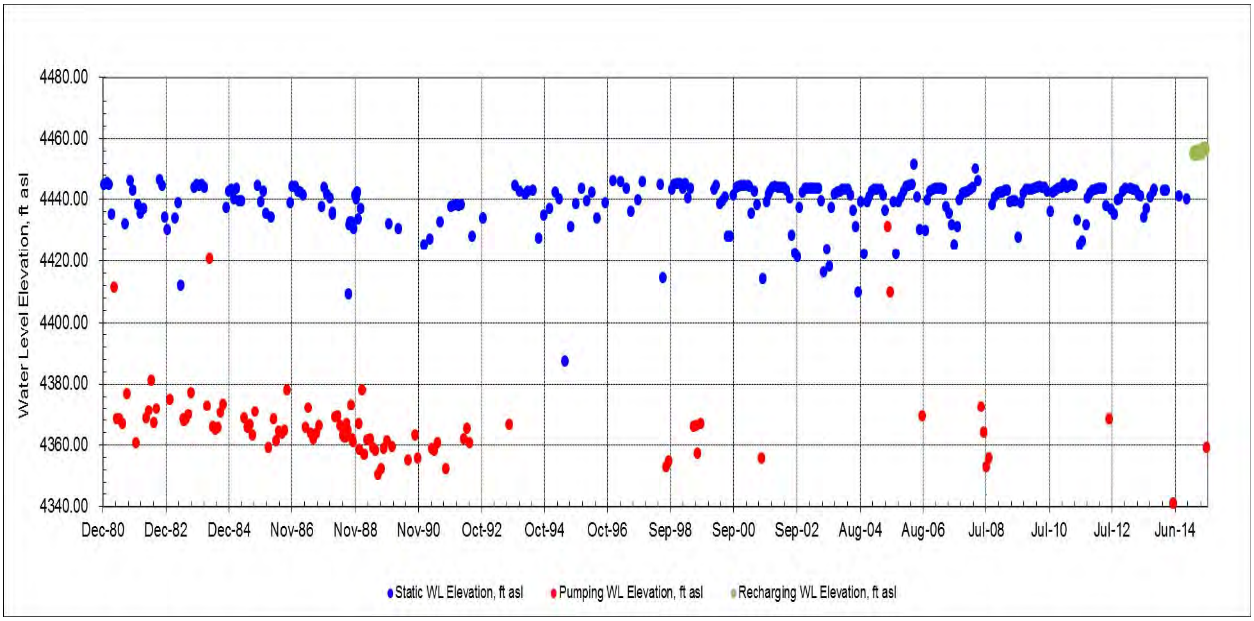


Figure 15B. Delucchi Lane Well - Water Level Elevations

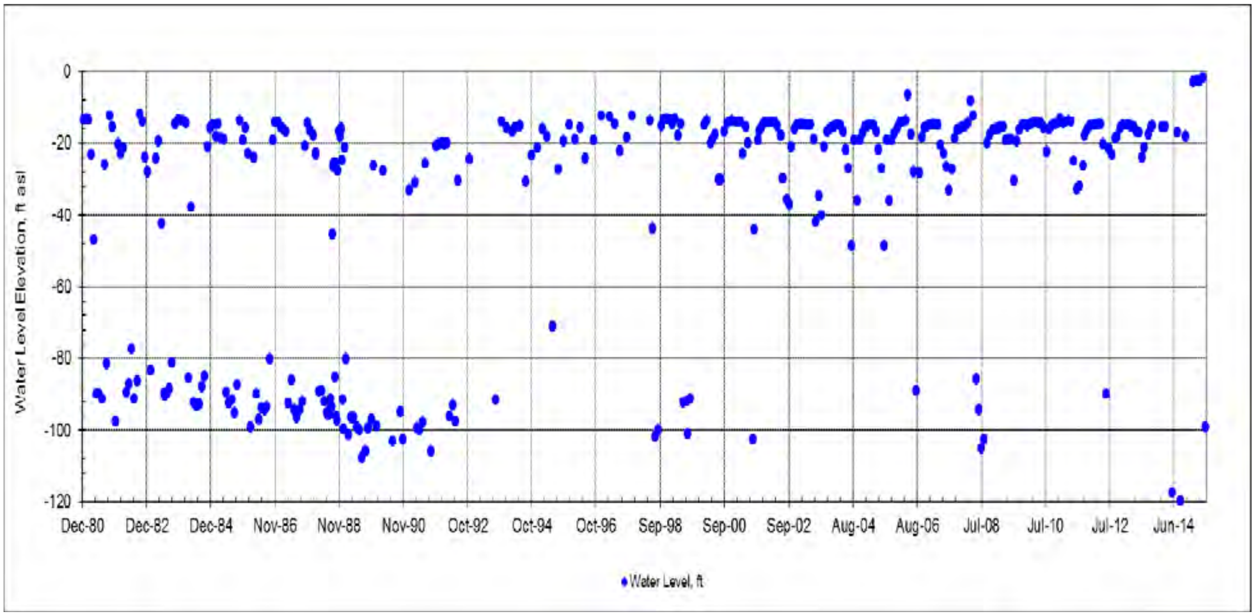


Figure 15C. Delucchi Lane Well - Water Levels

1.15 Longley Lane Well

Longley Lane Well is situated in the NE ¼ NE ¼ of Section 6, T. 18N., R. 20E., M.D.B.&M., or at a point from which the East ¼ corner of said Section 6 bears South 37° 00’ 00” East, a distance of 1,772.76 feet, in Washoe County, Nevada.

During the first half of 2015, 24.4 acre-feet (8.0 MG) of water were injected into the Longley Lane Well. During the same period, 79.8 acre-feet (26.0 MG) were pumped from the well (Tables 1, 2A and 2B and Figure 16A).

Water level elevations and water levels for Longley Lane injection/production and monitoring wells are shown in Figures 16A and 16B, respectively.

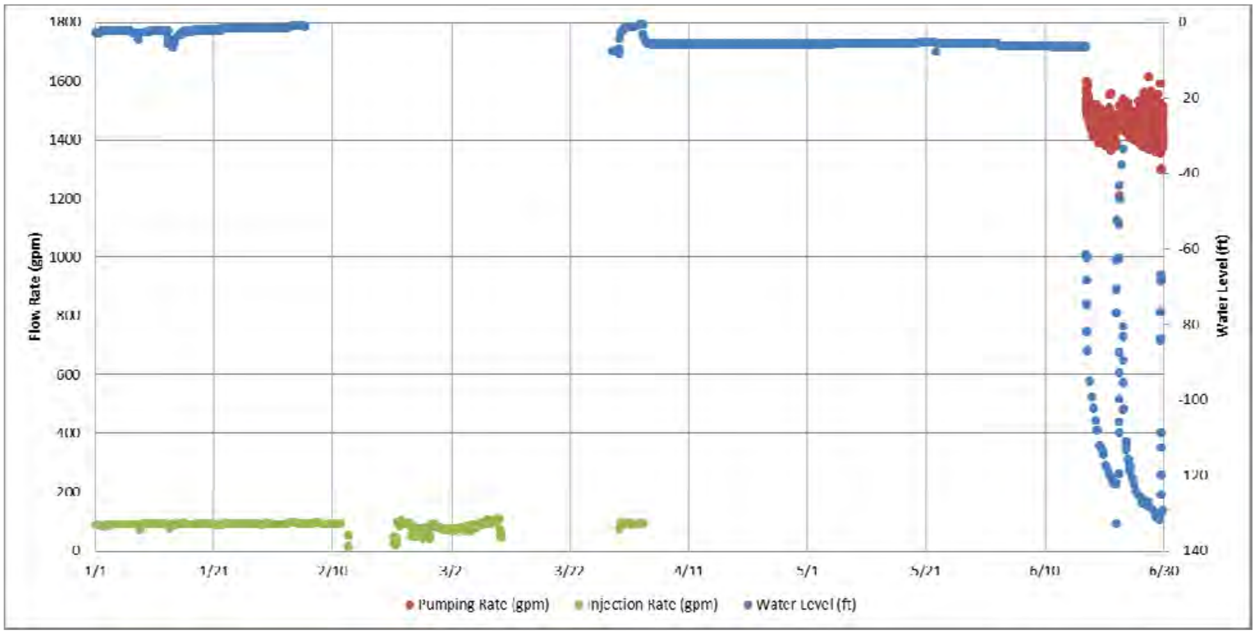


Figure 16A. Longley Lane Well – Flows Rates and Water Levels, 2015

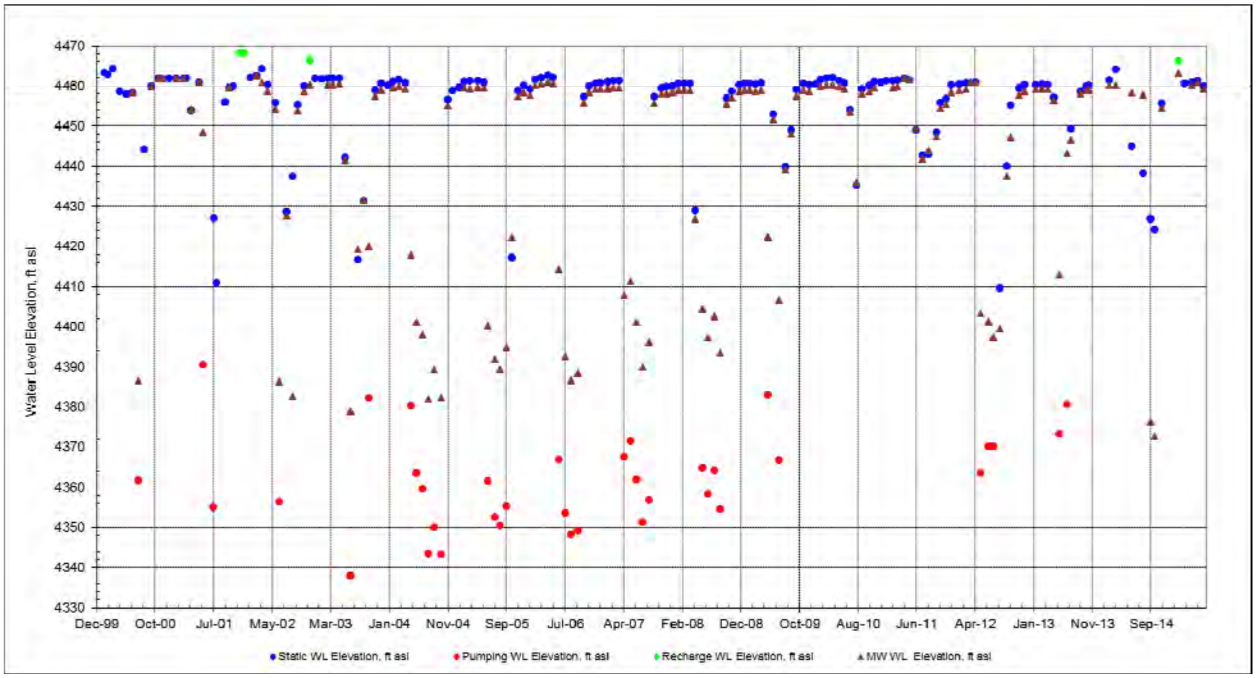


Figure 16B. Longley Lane Injection/Production and Monitoring Wells - Water Level Elevations

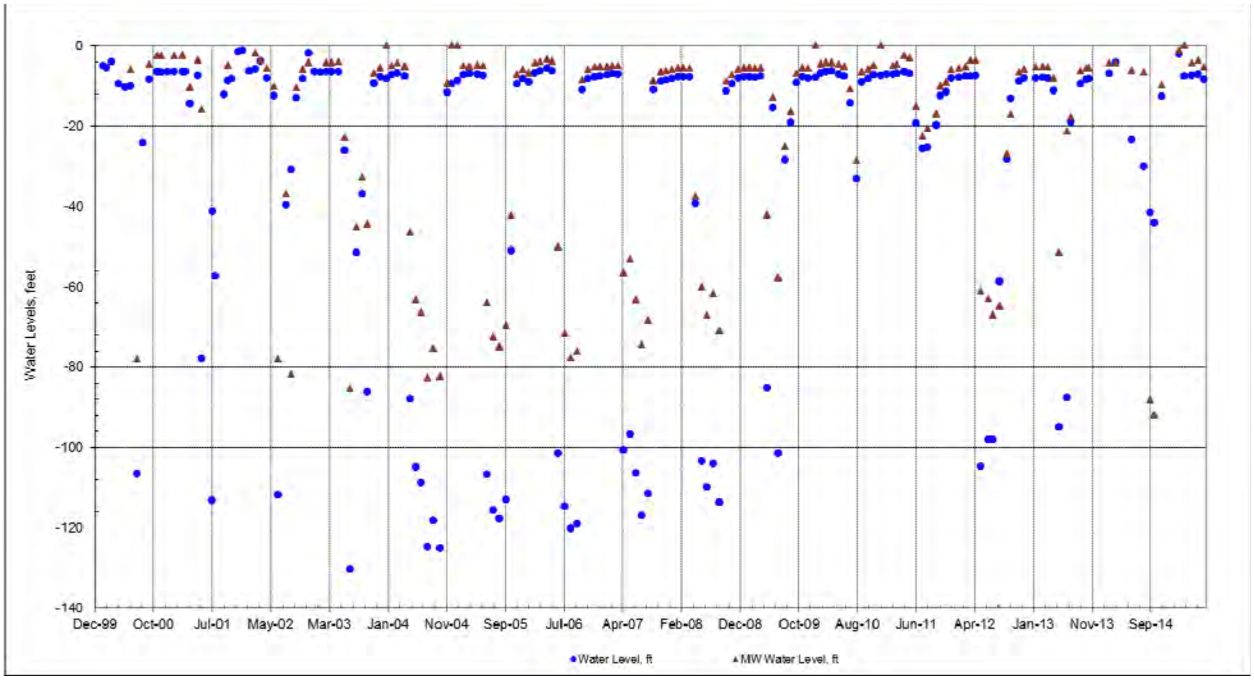


Figure 16C. Longley Lane Injection/Production and Monitoring Wells - Water Levels

1.16 Sierra Plaza Well

Sierra Plaza Well is situated in the NE ¼ SE ¼ of Section 31, T. 19N., R. 20E., M.D.B.&M., or at a point from which the East ¼ corner of Section 6, T. 18N., R.20E., bears South 14° 57’00” East, a distance of 14,933.74 feet in Washoe County, Nevada.

Sierra Plaza well was recharged for the first time during the first half of 2015. During this period, 89.6 acre-feet (29.2 MG) of water were injected into the Sierra Plaza Well. During the same period, 67.7 acre-feet (22.0 MG) were pumped from the well (Tables 1, 2A and 2B and Figure 17A).

Water level elevations and water levels for Sierra Plaza injection/production and monitoring wells are shown in Figures 17A and 17B, respectively.

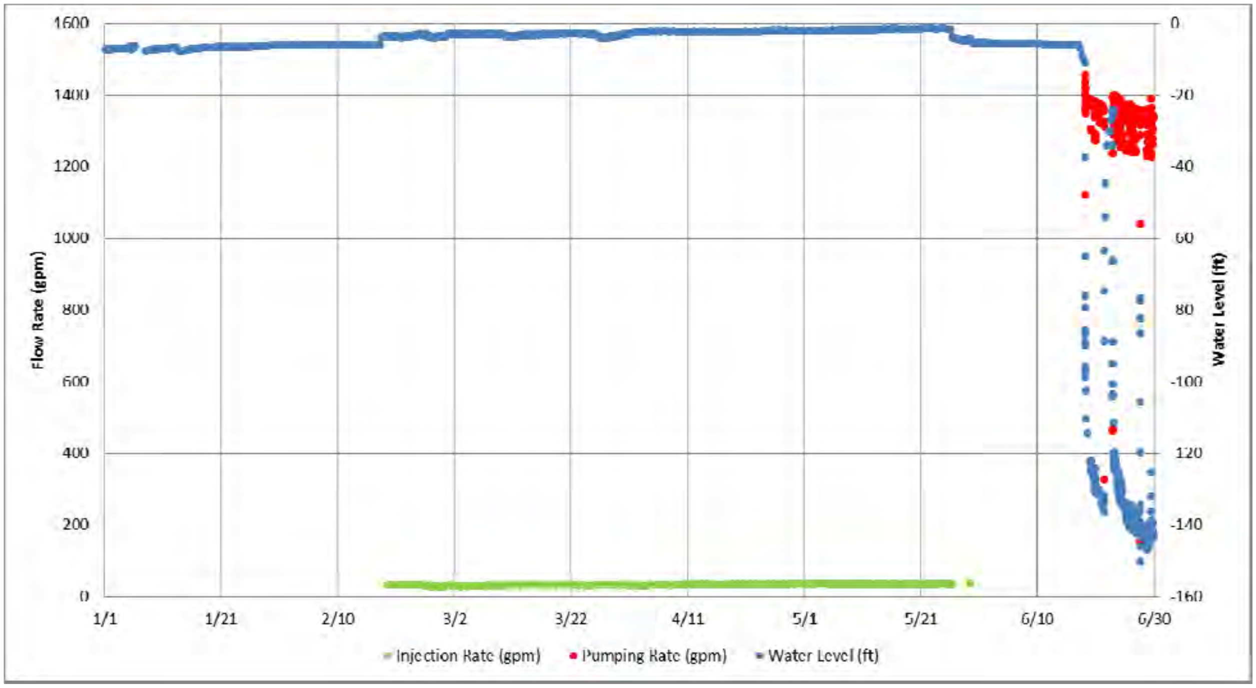


Figure 17A. Sierra Plaza Well – Flow Rates and Water Levels, 2015

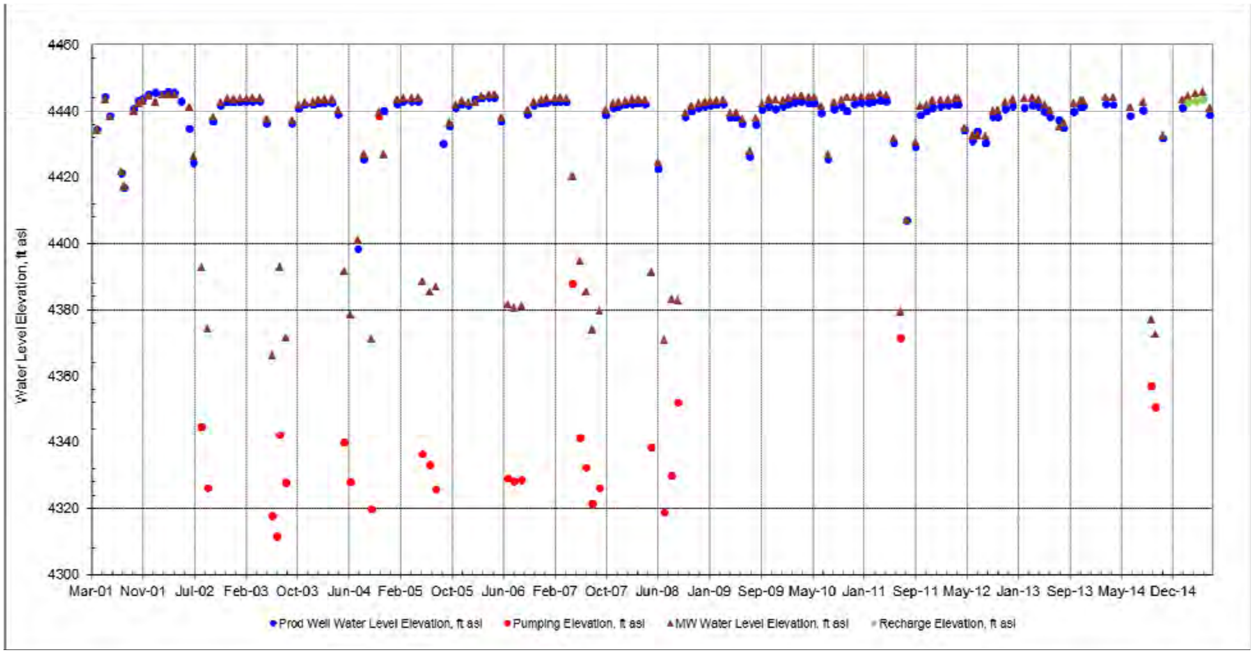


Figure 17B. Sierra Plaza Injection/Production and Monitoring Wells – Water Level Elevations

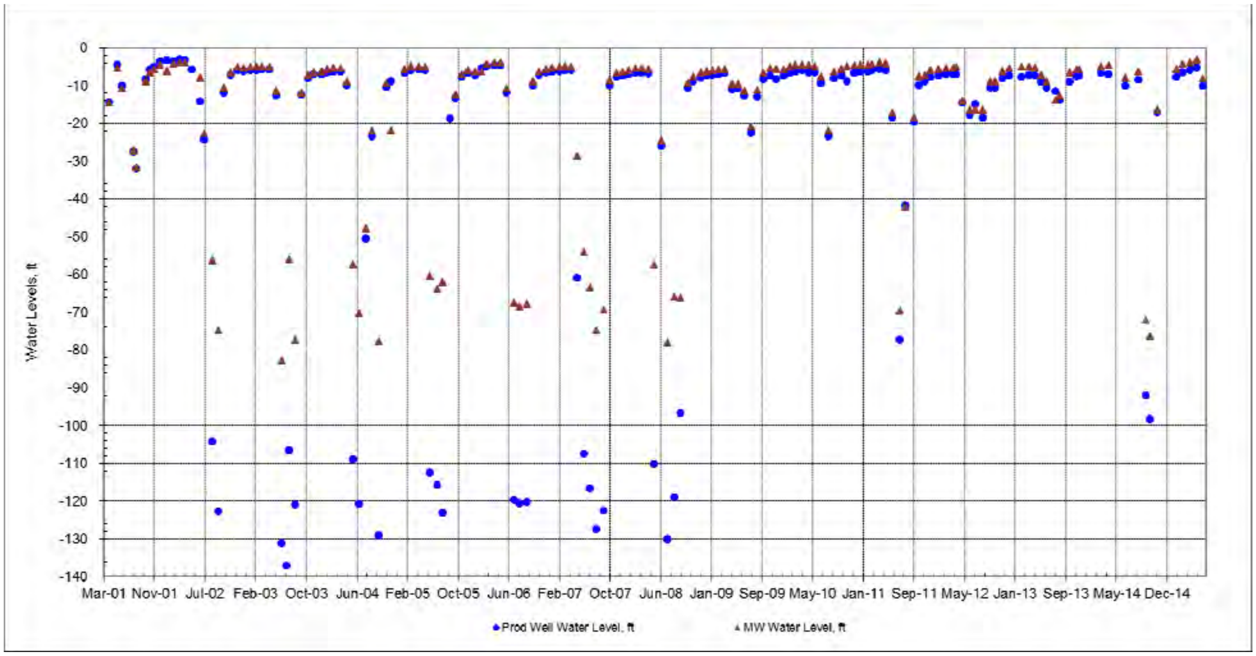


Figure 17C. Sierra Plaza Injection/Production and Monitoring Wells – Water Levels

2.0 WATER QUALITY

The injected water chemistry is shown in Appendix A with their accompanying UIC U230 Forms.

Appendix B shows the Disinfection By-Products (DBPs) concentrations for the first and second quarters, respectively, of the first half of 2015 in TMWA's West Lemmon Valley, Spanish Springs and Truckee Meadows basins distribution systems.

Residual chlorine from all the system water sampling points varies between 0.95 and 1.11 mg/L.

The chemistry of the extracted water, system DBPs and Total Coliforms meet or exceed the Nevada State Drinking Water Standards and does not show any adverse effects to the aquifer water quality from ASR activities. In addition to improving the water quantity of the basin, the water quality results are a secondary yet positive benefit of TMWA's ASR program to the Truckee Meadows basin aquifer.

3.0 CONCLUSION

The number of wells in which TMWA injects treated surface water into its Truckee Meadows wells depends on system operating requirements, facility maintenance schedules, need for water quality mitigation for each particular well, data collection and reporting requirements, and drought/non-drought year conditions. During the first half of 2015, TMWA injected water in fourteen wells: Fourth Street, Lakeside Drive, Hunter Lake, Sierra Plaza, Longley Lane, Delucchi, View Street, Greg Street, Holcomb Lane, 21st Street, Reno High, El Rancho Drive, Glen Hare, and Galletti Wells. A total of 2548.1 acre-feet (830.3 MG) of treated surface water were injected in the fourteen wells during the first half of 2015.

The chemistry of the extracted water meets the Nevada State Drinking Water Standards and does not indicate any adverse effects to the aquifer water quality from ASR activities. The system TTHM, HAA5, residual chlorine and Total Coliform concentrations all meet or exceed Nevada State Drinking Water Standards. In addition to improving the water quantity of the basin, the water quality results are a secondary yet positive benefit of TMWA’s ASR program to the Truckee Meadows basin aquifer.

As shown in this report, TMWA’s ASR program has successfully injected 25,108 acre-feet of water in the Truckee Meadows hydrographic basin since the program inception in 1993. By achieving its annual injection target, TMWA’s ASR programs aim at enhancing drought supplies, provide opportunity to expand water supply service, and improve chemical quality of the groundwater in the Truckee Meadows hydrographic basin.

APPENDIX A: WATER QUALITY

Table A.1. Zone 1: 1Q2015 Injected Water Chemistry

Nevada Division of Environmental Protection

Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**Hunter Lake Well (HLW)**	**Depth of sampled water's origin :**		
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe	
NDEP UIC Permit # :	UNEV92200	**Location :**	Latitude	Longitude
Well ID # :		**Sampler :**	Will Raymond	
Type of Well :	Monitor Production [✓ Injection]	**Date Sampled :**	**3/26/2015**	**1033 hrs**
		Name of Laboratory :	TMWA, Wetlab, SEM	

UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	45.0	SM 2320 B	
aluminum	mg/L	0.05-0.2	0.00766	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.001	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	0.000346	EPA 200.8	ICP-MS
barium	mg/L	2	0.0185	EPA 200.8	ICP-MS
calcium	mg/L	-	10.0		
chloride	mg/L	400	9.69	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	0.00122	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	<0.001	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	8.01	SM 4500 O C	
EC	µS/cm	at 25 degC	130	SM 2510 B	
fluoride	mg/L	4	<0.2	EPA 300.0	Ion Chromatography
hardness (as $CaCO_3$)	mg/L	-	39.0		
iron	mg/L	0.6	<0.010	EPA 200.7	ICP
lead	mg/L	0.015	0.00311	EPA 200.8	ICP-MS
magnesium	mg/L	150	3.40	EPA 200.7	
manganese	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.0001	EPA 200.8	ICP-MS
nickel	mg/L	0.1	0.00355	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	<0.3	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.2	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.62	EPA 150.1	
potassium	mg/L	-	1.5	EPA 200.7	ICP
sodium	mg/L	-	12	EPA 200.7	ICP
sulfate	mg/L	500	5.21	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	11.1		
total dissolved solids	mg/L	1000	84.7	EPA 160.1	
total suspended solids	mg/L	-	<5.0	EPA 160.2	
turbidity	NTU	-	0.21		
zinc	mg/L	5	0.00317	EPA 200.8	ICP-MS

Comments:

TMWA Rev 1/2011

Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.

Nevada Division of Environmental Protection
Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 3/26/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: Hunter Lake Well (HLW)
UIC Permit No.: UNEV92200
Is there any well name or identification at the wellhead? ☒ YES ☐ NO If no, label should be placed on or near wellhead
Project/Facility Name: Truckee Meadows Water Authority
Well Location (SectionTR or Lat/Long) : 14,859,592.99N 2,271,273.25E
City/Valley: Truckee Meadows
County: Washoe
Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other: ____________
Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type: [✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation
Completion date of well: February 1995
Diameter of casing: 16"
Type of Casing: [✓ Steel] PVC Other: ____________
Total depth of well: 480 feet
Bottom depth of cement for last cemented casing string: 470 feet
Screened or open hole interval (top/bottom depths): 210-300, 310-470 feet

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: continuous recharge
Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival? ☒ YES ☐ NO
Was there any problems or damage to the well upon arrival ☐ YES ☒ NO
Was well in an artesian condition prior to sampling? : ☐ YES ☒ NO

WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) :
Depth to water - last event:
Method used to gauge well? : Cap Tube Tape Measure
Measured Water Level : surface

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Nevada Division of Environmental Protection
Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy): 3/20/15 Time Sampled: 1033 hrs

Name of Sampler: Will Raymond

Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead": 1 foot

Type of Sample (circle one): [✓ Grab] Composite other (specify):

Collection method (circle one): well bailed [✓ water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was discharged / purged before collecting sample?: Continuously Recharging

Filtering Note: UIC requirements specify water samples shall not be filtered, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: ________

Was the sample filtered?: ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

FIELD MEASUREMENTS

pH: 7.62
~~S. Conductivity:~~ NTU: 0.21
Temperature: 11.1°C

What UIC Sample List is required: UIC List 1 UIC List 2 UIC List 3 [✓ Other**] As per Attachment B of permit

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8016 eMail Address: ckropf@tmwa.com

Signature: Date:

Qualified Sample Person: Will Raymond

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8138 eMail Address: wraymond@tmwa.com

Signature: Date: 3/20/15

Attachments:

UIC Form 230 (06-01-10) **Page 2 of 2**

Table A.2. Zone 2: 1Q2015 Injected Water Chemistry

Nevada Division of Environmental Protection

Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**El Rancho Well (ERW)**	**Depth of sampled water's origin :**		
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe	
NDEP UIC Permit # :	UNEV92200	**Location :**	Latitude	Longitude
Well ID # :		**Sampler :**	Will Raymond	
Type of Well :	Monitor Production [✓ Injection]	**Date Sampled :**	**3/26/2015**	**1155 hrs**
		Name of Laboratory :	TMWA, Wetlab, SEM	

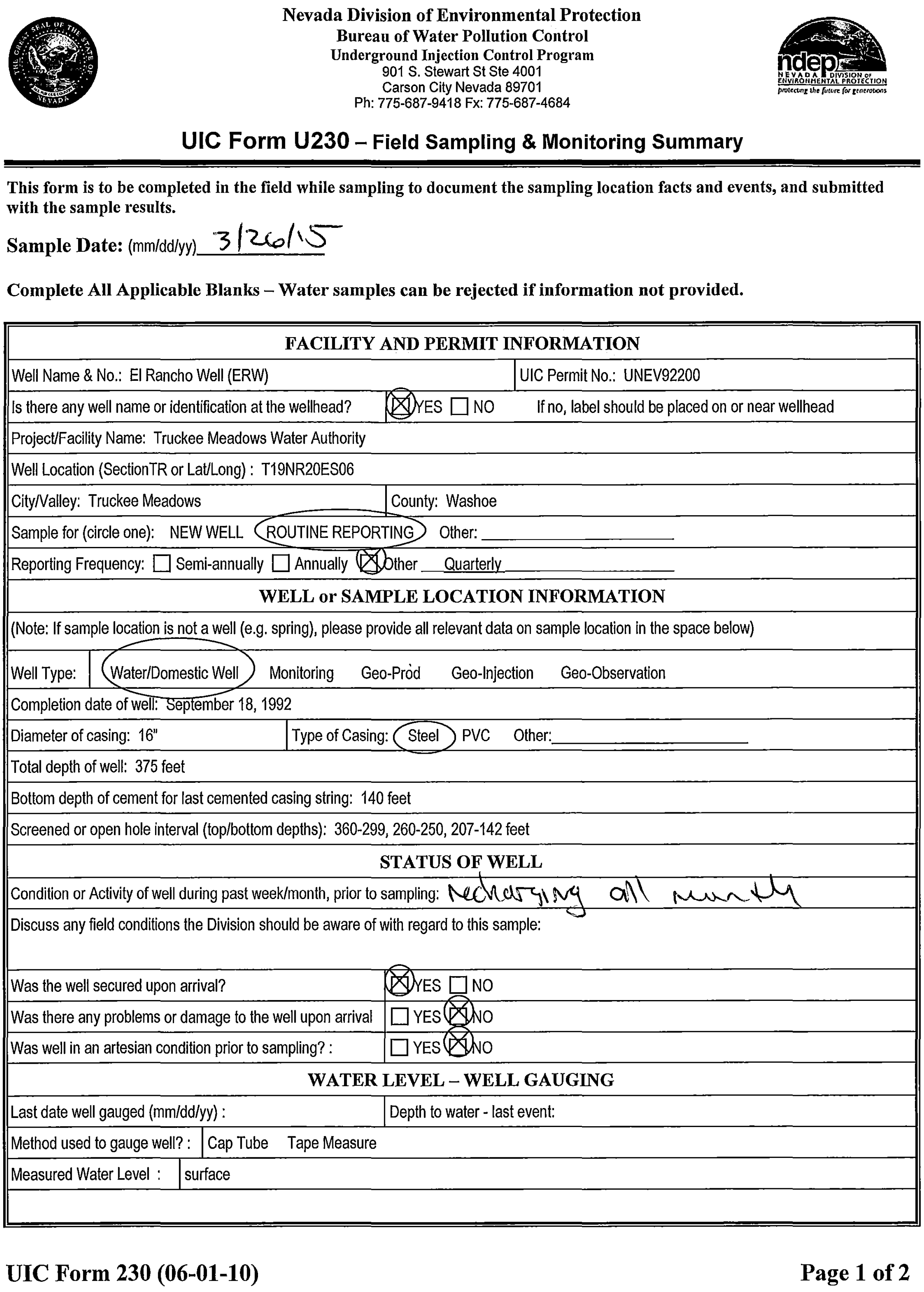
UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as CaCO$_3$)	mg/L	-	46.0	SM 2320 B	
aluminum	mg/L	0.05-0.2	0.0106	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.001	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	0.000227	EPA 200.8	ICP-MS
barium	mg/L	2	0.02	EPA 200.8	ICP-MS
calcium	mg/L	-	9.60		
chloride	mg/L	400	9.70	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	0.00299	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	9.19	SM 4500 O C	
EC	µS/cm	at 25 degC	131	SM 2510 B	
fluoride	mg/L	4	<0.2	EPA 300.0	Ion Chromatography
hardness (as CaCO$_3$)	mg/L	-	40.0		
iron	mg/L	0.6	<0.010	EPA 200.7	ICP
lead	mg/L	0.015	<0.001	EPA 200.8	ICP-MS
magnesium	mg/L	150	3.90	EPA 200.7	
manganese	mg/L	0.1	0.0166	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.0001	EPA 200.8	ICP-MS
nickel	mg/L	0.1	0.00339	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	<0.3	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.2	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.64	EPA 150.1	
potassium	mg/L	-	1.5	EPA 200.7	ICP
sodium	mg/L	-	12	EPA 200.7	ICP
sulfate	mg/L	500	5.22	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	11.8		
total dissolved solids	mg/L	1000	84.9	EPA 160.1	
total suspended solids	mg/L	-	<5.0	EPA 160.2	
turbidity	NTU	-	0.66		
zinc	mg/L	5	0.00477	EPA 200.8	ICP-MS

Comments:

TMWA Rev 1/2011

Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.



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901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 3/26/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: El Rancho Well (ERW)
UIC Permit No.: UNEV92200
Is there any well name or identification at the wellhead? ☒ YES ☐ NO If no, label should be placed on or near wellhead
Project/Facility Name: Truckee Meadows Water Authority
Well Location (SectionTR or Lat/Long) : T19NR20ES06
City/Valley: Truckee Meadows
County: Washoe
Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other: ____
Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type: [✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation
Completion date of well: September 18, 1992
Diameter of casing: 16"
Type of Casing: [✓ Steel] PVC Other: ____
Total depth of well: 375 feet
Bottom depth of cement for last cemented casing string: 140 feet
Screened or open hole interval (top/bottom depths): 360-299, 260-250, 207-142 feet

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: recharging all month
Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival? ☒ YES ☐ NO
Was there any problems or damage to the well upon arrival ☐ YES ☒ NO
Was well in an artesian condition prior to sampling? : ☐ YES ☒ NO

WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) :
Depth to water - last event:
Method used to gauge well? : Cap Tube Tape Measure
Measured Water Level : surface

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Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy): 3/26/15 Time Sampled: 1155 hrs

Name of Sampler: Will Raymond

Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead": 1 foot

Type of Sample (circle one): [✓ Grab] Composite other (specify):

Collection method (circle one): well bailed [✓ water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was discharged / purged before collecting sample?: continuously recharging

Filtering Note: UIC requirements specify water samples shall not be filtered, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: ______________

Was the sample filtered?: ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

FIELD MEASUREMENTS

pH: 7.64
~~S. Conductivity:~~ NTU: 0.66
Temperature: 11.8°C

What UIC Sample List is required: UIC List 1 UIC List 2 UIC List 3 [✓ Other**] As per Attachment B of permit

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8016 eMail Address: : ckropf@tmwa.com

Signature: Date:

Qualified Sample Person: Will Raymond

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8138 eMail Address: wraymond@tmwa.com

Signature: Date: 3/26/15

Attachments:

UIC Form 230 (06-01-10) **Page 2 of 2**

Table A.3. Zone 3: 1Q2015 Injected Water Chemistry

Nevada Division of Environmental Protection
Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**South 21st Street Well (S21)**	**Depth of sampled water's origin :**		
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe	
NDEP UIC Permit # :	UNEV92200	**Location :**	Latitude	Longitude
Well ID # :		**Sampler :**	Will Raymond	
Type of Well :	Monitor Production [✓ Injection]	**Date Sampled :**	**3/26/2015**	**1220 hrs**
		Name of Laboratory :	TMWA, Wetlab, SEM	

UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	47.0	SM 2320 B	
aluminum	mg/L	0.05-0.2	0.00845	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.001	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	0.000221	EPA 200.8	ICP-MS
barium	mg/L	2	0.019	EPA 200.8	ICP-MS
calcium	mg/L	-	8.80		
chloride	mg/L	400	9.70	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	<0.001	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	9.29	SM 4500 O C	
EC	µS/cm	at 25 degC	130	SM 2510 B	
fluoride	mg/L	4	<0.2	EPA 300.0	Ion Chromatography
hardness (as $CaCO_3$)	mg/L	-	38.0		
iron	mg/L	0.6	<0.010	EPA 200.7	ICP
lead	mg/L	0.015	<0.001	EPA 200.8	ICP-MS
magnesium	mg/L	150	3.90	EPA 200.7	
manganese	mg/L	0.1	0.00236	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.0001	EPA 200.8	ICP-MS
nickel	mg/L	0.1	0.00256	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	<0.3	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.2	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.92	EPA 150.1	
potassium	mg/L	-	1.4	EPA 200.7	ICP
sodium	mg/L	-	12	EPA 200.7	ICP
sulfate	mg/L	500	5.24	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	11.2		
total dissolved solids	mg/L	1000	84.7	EPA 160.1	
total suspended solids	mg/L	-	<5.0	EPA 160.2	
turbidity	NTU	-	0.41		
zinc	mg/L	5	0.00377	EPA 200.8	ICP-MS

Comments:

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Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.

Nevada Division of Environmental Protection
Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 3/26/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: South 21st Street Well | UIC Permit No.:UNEV92200

Is there any well name or identification at the wellhead? ☐ YES ☒ NO If no, label should be placed on or near wellhead

Project/Facility Name:Truckee Meadows Water Authority

Well Location (SectionTR or Lat/Long) :T19NR20ES07

City/Valley:Truckee Meadows | County: Washoe

Sample for (circle one): NEW WELL [✓ X ROUTINE REPORTING] Other: ____________________

Reporting Frequency: ☐ Semi-annually ☐ Annually ☐ Other ___Quarterly____________________

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type: [✓ X Municipal Water Well] Monitoring Geo-Prod Geo-Injection Geo-Observation

Completion date of well: April 1, 1991

Diameter of casing: 16" | Type of Casing: [✓ X Steel] PVC Other:____________________

Total depth of well: 250 feet

Bottom depth of cement for last cemented casing string: 116 feet

Screened or open hole interval (top/bottom depths): 245-180, 170-140, 130-120 feet

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: Recharging all month

Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival? ☒ YES ☐ NO

Was there any problems or damage to the well upon arrival ☐ YES ☒ NO

Was well in an artesian condition prior to sampling? : ☐ YES ☒ NO

WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) : | Depth to water - last event:

Method used to gauge well? : Cap Tube Tape Measure

Measured Water Level : surface

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Carson City Nevada 89701
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UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy) :	3/26/15	Time Sampled :	1220 WR

Name of Sampler : Will Raymond

Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead" : 1 ft

Type of Sample (circle one) : [✓ X Grab] Compo~~site other~~ (specify):

Collection method (circle one) : well bailed [✓ X water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was discharg~~ed /~~ purged before collecting sample? : continuously recharging

Filtering Note: UIC requirements specify water samples shall not be filtered, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: ________________

Was the sample filtered? : ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

FIELD MEASUREMENTS

pH : 7.92
~~S. Conductivity :~~ NTU : 0.41
Temperature : 11.2

What UIC Sample List is required: UIC List 1 UIC List 2 UIC List 3 [✓ Other**: As] per Attachment B of the permit_____

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8016 eMail Address: : ckropf@tmwa.com

Signature: Date:

Qualified Sample Person: Will Raymond

Company: Truckee Meadows Water Authority

Telephone No.:775-834-8138 eMail Address: wraymond@tmwa.com

Signature: Date: 3/26/15

Attachments:

UIC Form 230 (06-01-10) **Page 2 of 2**

Table A.4. Zone 4: 1Q2015 Injected Water Chemistry

Nevada Division of Environmental Protection

Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**Lakeside Well (LKS)**	**Depth of sampled water's origin :**	
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe
NDEP UIC Permit # :	UNEV92200	**Location :**	Latitude Longitude
Well ID # :		**Sampler :**	Will Raymond
Type of Well :	Monitor Production [✓ Injection]	**Date Sampled :**	**3/26/2015** **1010 hrs**
		Name of Laboratory :	TMWA, Wetlab, SEM

UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	47.0	SM 2320 B	
aluminum	mg/L	0.05-0.2	0.00755	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.001	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	0.000346	EPA 200.8	ICP-MS
barium	mg/L	2	0.0177	EPA 200.8	ICP-MS
calcium	mg/L	-	10.8		
chloride	mg/L	400	10.1	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	0.00161	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	9.19	SM 4500 O C	
EC	µS/cm	at 25 degC	130	SM 2510 B	
fluoride	mg/L	4	<0.2	EPA 300.0	Ion Chromatography
hardness (as $CaCO_3$)	mg/L	-	38.0		
iron	mg/L	0.6	<0.010	EPA 200.7	ICP
lead	mg/L	0.015	<0.001	EPA 200.8	ICP-MS
magnesium	mg/L	150	2.70	EPA 200.7	
manganese	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.0001	EPA 200.8	ICP-MS
nickel	mg/L	0.1	0.00312	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	<0.3	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.2	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.59	EPA 150.1	
potassium	mg/L	-	1.4	EPA 200.7	ICP
sodium	mg/L	-	12	EPA 200.7	ICP
sulfate	mg/L	500	5.19	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	11.2		
total dissolved solids	mg/L	1000	84.5	EPA 160.1	
total suspended solids	mg/L	-	<5.0	EPA 160.2	
turbidity	NTU	-	0.27		
zinc	mg/L	5	0.0034	EPA 200.8	ICP-MS

Comments:

TMWA Rev 1/2011

Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.

Nevada Division of Environmental Protection
Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy) : 3/26/15 Time Sampled : 1010 hrs

Name of Sampler : Will Raymond

Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead" : <1 foot from wellhead on well discharge pipeline

Type of Sample (circle one) : [✓ Grab] Composite other (specify):

Collection method (circle one) : well bailed [✓ water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was discharged / purged before collecting sample? : continuously recharging

<u>Filtering Note</u>: UIC requirements specify water samples <u>shall not be filtered</u>, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: _______________

Was the sample filtered? : ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

FIELD MEASUREMENTS

pH : 7.59
~~S. Conductivity :~~ NTU : 0.27
Temperature : 11.2C

What UIC Sample List is required: UIC List 1 UIC List 2 UIC List 3 [✓ Other**] As per Attachment B of permit

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8016 eMail Address: : ckropf@tmwa.com

Signature: Date:

Qualified Sample Person: Will Raymond

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8138 eMail Address: wraymond@tmwa.com

Signature: Date: 3/26/15

Attachments:

Nevada Division of Environmental Protection
Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 3/26/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: Lakeside Drive Well (LKS) | UIC Permit No.: UNEV92200

Is there any well name or identification at the wellhead? ☒ YES ☐ NO If no, label should be placed on or near wellhead

Project/Facility Name: Truckee Meadows Water Authority

Well Location (SectionTR or Lat/Long) : T19NR19ES35

City/Valley: Truckee Meadows | County: Washoe

Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other: ____________

Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type: [✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation

Completion date of well: October 15, 1991

Diameter of casing: 12.75" | Type of Casing: [✓ Steel] PVC Other: ____________

Total depth of well: 400 feet

Bottom depth of cement for last cemented casing string: 60 feet

Screened or open hole interval (top/bottom depths): 400-180 feet

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: continuously recharging

Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival? ☒ YES ☐ NO

Was there any problems or damage to the well upon arrival ☐ YES ☒ NO

Was well in an artesian condition prior to sampling? : ☐ YES ☒ NO

WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) : | Depth to water - last event:

Method used to gauge well? : Cap Tube Tape Measure

Measured Water Level : surface

UIC Form 230 (06-01-10) **Page 1 of 2**

Table A.5. Zone 1: 2Q2015 Injected Water Chemistry

Nevada Division of Environmental Protection

Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**Hunter Lake Well (HLW)**	**Depth of sampled water's origin :**		
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe	
NDEP UIC Permit # :	UNEV92200	**Location :**	Latitude	Longitude
Well ID # :		**Sampler :**	Will Raymond	
Type of Well :	Monitor Production [✓ Injection]	**Date Sampled :**	**4/28/2015**	**1420 hrs**
		Name of Laboratory :	TMWA, Wetlab, SEM	

UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	50	SM 2320 B	
aluminum	mg/L	0.05-0.2	0.0201	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.0010	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	0.000477	EPA 200.8	ICP-MS
barium	mg/L	2	<0.0010	EPA 200.8	ICP-MS
calcium	mg/L	-	9.6		
chloride	mg/L	400	9.0	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	0.001	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	<0.0010	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	8.0	SM 4500 O C	
EC	µS/cm	at 25 degC	131.5	SM 2510 B	
fluoride	mg/L	4	0.214	EPA 300.0	Ion Chromatography
hardness (as $CaCO_3$)	mg/L	-	40		
iron	mg/L	0.6	<0.05	EPA 200.7	ICP
lead	mg/L	0.015	<0.0010	EPA 200.8	ICP-MS
magnesium	mg/L	150	3.88	EPA 200.7	
manganese	mg/L	0.1	<0.0010	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.00010	EPA 200.8	ICP-MS
nickel	mg/L	0.1	0.00433	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	<0.3	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.2	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.41	EPA 150.1	
potassium	mg/L	-	1.4	EPA 200.7	ICP
sodium	mg/L	-	13	EPA 200.7	ICP
sulfate	mg/L	500	5.1	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	13.5		
total dissolved solids	mg/L	1000	85.6	EPA 160.1	
total suspended solids	mg/L	-	<5	EPA 160.2	
turbidity	NTU	-	0.94		
zinc	mg/L	5	0.0021	EPA 200.8	ICP-MS

Comments:

TMWA Rev 1/2011

Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.

Nevada Division of Environmental Protection
Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
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UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 4/28/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: Hunter Lake Well (HLW)	UIC Permit No.: UNEV92200
Is there any well name or identification at the wellhead? ☒ YES ☐ NO	If no, label should be placed on or near wellhead
Project/Facility Name: Truckee Meadows Water Authority	
Well Location (SectionTR or Lat/Long) : 14,859,592.99N 2,271,273.25E	
City/Valley: Truckee Meadows	County: Washoe
Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other:	
Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly	

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type:	[✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation
Completion date of well: February 1995	
Diameter of casing: 16"	Type of Casing: [✓ Steel] PVC Other:
Total depth of well: 480 feet	
Bottom depth of cement for last cemented casing string: 470 feet	
Screened or open hole interval (top/bottom depths): 210-300, 310-470 feet	

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: recharging all month

Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival?	☒ YES ☐ NO
Was there any problems or damage to the well upon arrival	☐ YES ☒ NO
Was well in an artesian condition prior to sampling? :	☐ YES ☒ NO

WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) :	Depth to water - last event:
Method used to gauge well? :	Cap Tube Tape Measure
Measured Water Level :	surface

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Nevada Division of Environmental Protection
Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 4/28/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: Hunter Lake Well (HLW)
UIC Permit No.: UNEV92200
Is there any well name or identification at the wellhead? ☒ YES ☐ NO If no, label should be placed on or near wellhead
Project/Facility Name: Truckee Meadows Water Authority
Well Location (SectionTR or Lat/Long) : 14,859,592.99N 2,271,273.25E
City/Valley: Truckee Meadows
County: Washoe
Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other: ____________
Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type: [✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation
Completion date of well: February 1995
Diameter of casing: 16"
Type of Casing: [✓ Steel] PVC Other: ____________
Total depth of well: 480 feet
Bottom depth of cement for last cemented casing string: 470 feet
Screened or open hole interval (top/bottom depths): 210-300, 310-470 feet

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: recharging all month
Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival? ☒ YES ☐ NO
Was there any problems or damage to the well upon arrival ☐ YES ☒ NO
Was well in an artesian condition prior to sampling? : ☐ YES ☒ NO

WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) :
Depth to water - last event:
Method used to gauge well? : Cap Tube Tape Measure
Measured Water Level : surface

Table A.6. Zone 2: 2Q2015 Injected Water Chemistry

Nevada Division of Environmental Protection
Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**View Street Well (VSW)**	**Depth of sampled water's origin :**		
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe	
NDEP UIC Permit # :	UNEV92200	**Location :**	Latitude	Longitude
Well ID # :		**Sampler :**	Will Raymond	
Type of Well :	Monitor Production [✓ Injection]	**Date Sampled :**	**4/22/2015**	**1125 hrs**
		Name of Laboratory :	TMWA, Wetlab, SEM	

UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	49	SM 2320 B	
aluminum	mg/L	0.05-0.2	<0.045	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.0010	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	0.000437	EPA 200.8	ICP-MS
barium	mg/L	2	0.0205	EPA 200.8	ICP-MS
calcium	mg/L	-	10.8		
chloride	mg/L	400	19.7	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	<0.0010	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	<0.0010	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	8.57	SM 4500 O C	
EC	µS/cm	at 25 degC	130	SM 2510 B	
fluoride	mg/L	4	<0.2	EPA 300.0	Ion Chromatography
hardness (as $CaCO_3$)	mg/L	-	42		
iron	mg/L	0.6	<0.020	EPA 200.7	ICP
lead	mg/L	0.015	<0.0010	EPA 200.8	ICP-MS
magnesium	mg/L	150	3.64	EPA 200.7	
manganese	mg/L	0.1	<0.0010	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.00010	EPA 200.8	ICP-MS
nickel	mg/L	0.1	0.00425	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	<0.3	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.2	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.31	EPA 150.1	
potassium	mg/L	-	1.5	EPA 200.7	ICP
sodium	mg/L	-	13	EPA 200.7	ICP
sulfate	mg/L	500	8.14	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	12.8		
total dissolved solids	mg/L	1000	84.5	EPA 160.1	
total suspended solids	mg/L	-	<5.0	EPA 160.2	
turbidity	NTU	-	0.20		
zinc	mg/L	5	0.00318	EPA 200.8	ICP-MS

Comments:

TMWA Rev 1/2011

Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.

Nevada Division of Environmental Protection
Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 4/22/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: South 21st Street Well | UIC Permit No.:UNEV92200

Is there any well name or identification at the wellhead? ☐ YES ☒ NO If no, label should be placed on or near wellhead

Project/Facility Name:Truckee Meadows Water Authority

Well Location (SectionTR or Lat/Long) :T19NR20ES07

City/Valley:Truckee Meadows | County: Washoe

Sample for (circle one): NEW WELL [✓ X ROUTINE REPORTING] Other: ____________________

Reporting Frequency: ☐ Semi-annually ☐ Annually ☐ Other ___Quarterly____________________

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type: [✓ X Municipal Water Well] Monitoring Geo-Prod Geo-Injection Geo-Observation

Completion date of well: April 1, 1991

Diameter of casing: 16" | Type of Casing: [✓ X Steel] PVC Other:____________________

Total depth of well: 250 feet

Bottom depth of cement for last cemented casing string: 116 feet

Screened or open hole interval (top/bottom depths): 245-180, 170-140, 130-120 feet

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: recharging 14 of previous 21 days

Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival? ☒ YES ☐ NO

Was there any problems or damage to the well upon arrival ☐ YES ☒ NO

Was well in an artesian condition prior to sampling? : ☐ YES ☒ NO

WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) : | Depth to water - last event:

Method used to gauge well? : Cap Tube Tape Measure

Measured Water Level : surface

UIC Form 230 (06-01-10) **Page 1 of 2**

Nevada Division of Environmental Protection
Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy) :	4-22-15	Time Sampled :	1125 hrs

Name of Sampler : Will Raymond

Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead" : 1 ft

Type of Sample (circle one) : [✓ X Grab] Compo~~site other~~ (specify):

Collection method (circle one) : well bailed [✓ X water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was dischar~~ged /~~ purged before collecting sample? : continuous recharge

Filtering Note: UIC requirements specify water samples shall not be filtered, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: ______________

Was the sample filtered? : ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

FIELD MEASUREMENTS

pH : 7.31
~~S. Conductivity :~~ NTU : 0.20
Temperature : 12.8

What UIC Sample List is required: UIC List 1 UIC List 2 UIC List 3 [✓ Other**: As per Attachment B of the permit____]

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8016	eMail Address: : ckropf@tmwa.com
Signature:	Date:

Qualified Sample Person: Will Raymond

Company: Truckee Meadows Water Authority

Telephone No.:775-834-8138	eMail Address: wraymond@tmwa.com
Signature:	Date: 4-22-15

Attachments:

UIC Form 230 (06-01-10) **Page 2 of 2**

Table A.7. Zone 3: 2Q2015 Injected Water Chemistry

Nevada Division of Environmental Protection
Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**South 21st Street Well (S21)**	**Depth of sampled water's origin :**		
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe	
NDEP UIC Permit # :	UNEV92200	**Location :**	Latitude	Longitude
Well ID # :		**Sampler :**	Will Raymond	
Type of Well :	Monitor Production [✓ Injection]	**Date Sampled :**	**4/22/2015**	**1155 hrs**
		Name of Laboratory :	TMWA, Wetlab, SEM	

UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	54	SM 2320 B	
aluminum	mg/L	0.05-0.2	<0.045	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.0010	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	0.00086	EPA 200.8	ICP-MS
barium	mg/L	2	0.0237	EPA 200.8	ICP-MS
calcium	mg/L	-	14.0		
chloride	mg/L	400	11.9	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	<0.0010	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	0.00112	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	8.97	SM 4500 O C	
EC	µS/cm	at 25 degC	186	SM 2510 B	
fluoride	mg/L	4	<0.2	EPA 300.0	Ion Chromatography
hardness (as $CaCO_3$)	mg/L	-	66		
iron	mg/L	0.6	<0.020	EPA 200.7	ICP
lead	mg/L	0.015	<0.0010	EPA 200.8	ICP-MS
magnesium	mg/L	150	7.52	EPA 200.7	
manganese	mg/L	0.1	<0.0010	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.00010	EPA 200.8	ICP-MS
nickel	mg/L	0.1	0.00477	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	<0.3	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.2	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.22	EPA 150.1	
potassium	mg/L	-	1.8	EPA 200.7	ICP
sodium	mg/L	-	14	EPA 200.7	ICP
sulfate	mg/L	500	40.3	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	12.0		
total dissolved solids	mg/L	1000	121	EPA 160.1	
total suspended solids	mg/L	-	<5.0	EPA 160.2	
turbidity	NTU	-	0.16		
zinc	mg/L	5	0.00411	EPA 200.8	ICP-MS

Comments:

TMWA Rev 1/2011

Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.

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UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 4/22/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: View Street Well (VSW) | UIC Permit No.: UNEV92200

Is there any well name or identification at the wellhead? ☒ YES ☐ NO If no, label should be placed on or near wellhead

Project/Facility Name: Truckee Meadows Water Authority

Well Location (SectionTR or Lat/Long) : T19NR20ES06

City/Valley: Truckee Meadows | County: Washoe

Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other: ____________________

Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type: [✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation

Completion date of well: January 4, 1969

Diameter of casing: 18" | Type of Casing: [✓ Steel] PVC Other: ____________________

Total depth of well: 530 feet

Bottom depth of cement for last cemented casing string: 140 feet

Screened or open hole interval (top/bottom depths): 518-502, 484-474, 468-450, 432-397, 390-356 (12"), 298-288, 284-244, 236-206, 190-182, 176-166, 162-148 (18") feet

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: recharging For previous 22 days

Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival? ☒ YES ☐ NO

Was there any problems or damage to the well upon arrival ☐ YES ☒ NO

Was well in an artesian condition prior to sampling? : ☐ YES ☒ NO

WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) : | Depth to water - last event:

Method used to gauge well? : Cap Tube Tape Measure

Measured Water Level : surface

UIC Form 230 (06-01-10) **Page 1 of 2**

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UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy) :	4/22/15	Time Sampled :	1155
Name of Sampler :	Will Raymond		
Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead" :	Sample tap <1 foot from wellhead on well discharge pipeline		

Type of Sample (circle one) : [✓ Grab] Composite other (specify):

Collection method (circle one) : well bailed [✓ water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was discharged / purged before collecting sample? : continuously recharging

Filtering Note: UIC requirements specify water samples shall not be filtered, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: ______________

Was the sample filtered? : ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

FIELD MEASUREMENTS

pH : 7.22
~~S. Conductivity :~~ NTU : 0.16
Temperature : 12.0°C

What UIC Sample List is required: UIC List 1 UIC List 2 UIC List 3 [✓ Other**] As per Attachment B of permit

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf	
Company: Truckee Meadows Water Authority	
Telephone No.: 775-834-8016	eMail Address: : ckropf@tmwa.com
Signature:	Date:
Qualified Sample Person: Will Raymond	
Company: Truckee Meadows Water Authority	
Telephone No.: 775-834-8138	eMail Address: wraymond@tmwa.com
Signature:	Date: 4/22/15

Attachments:

UIC Form 230 (06-01-10) **Page 2 of 2**

Table A.8. Zone 4: 2Q2015 Injected Water Chemistry

Nevada Division of Environmental Protection
Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**Lakeside Well (LKS)**	**Depth of sampled water's origin :**		
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe	
NDEP UIC Permit # :	UNEV92200	**Location :**	Latitude	Longitude
Well ID # :		**Sampler :**	Will Raymond	
Type of Well :	Monitor Production [✓ Injection]	**Date Sampled :**	**4/28/2015**	**1355 hrs**
		Name of Laboratory :	TMWA, Wetlab, SEM	

UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	50	SM 2320 B	
aluminum	mg/L	0.05-0.2	0.0203	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.0010	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	0.000451	EPA 200.8	ICP-MS
barium	mg/L	2	0.0207	EPA 200.8	ICP-MS
calcium	mg/L	-	10.4		
chloride	mg/L	400	9.0	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	0.00111	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	<0.0010	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	8.8	SM 4500 O C	
EC	µS/cm	at 25 degC	132	SM 2510 B	
fluoride	mg/L	4	<0.2	EPA 300.0	Ion Chromatography
hardness (as $CaCO_3$)	mg/L	-	40		
iron	mg/L	0.6	<0.05	EPA 200.7	ICP
lead	mg/L	0.015	<0.0010	EPA 200.8	ICP-MS
magnesium	mg/L	150	3.39	EPA 200.7	
manganese	mg/L	0.1	<0.0010	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.00010	EPA 200.8	ICP-MS
nickel	mg/L	0.1	0.0043	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	<0.3	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.2	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.81	EPA 150.1	
potassium	mg/L	-	1.4	EPA 200.7	ICP
sodium	mg/L	-	13	EPA 200.7	ICP
sulfate	mg/L	500	5.1	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	13.7		
total dissolved solids	mg/L	1000	85.6	EPA 160.1	
total suspended solids	mg/L	-	<5	EPA 160.2	
turbidity	NTU	-	0.26		
zinc	mg/L	5	0.00276	EPA 200.8	ICP-MS

Comments:

TMWA Rev 1/2011

Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.

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UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 4/28/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION	
Well Name & No.: Lakeside Drive Well (LKS)	UIC Permit No.: UNEV92200
Is there any well name or identification at the wellhead?	☒ YES ☐ NO If no, label should be placed on or near wellhead
Project/Facility Name: Truckee Meadows Water Authority	
Well Location (SectionTR or Lat/Long) : T19NR19ES35	
City/Valley: Truckee Meadows	County: Washoe
Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other:	
Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly	
WELL or SAMPLE LOCATION INFORMATION	
(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)	
Well Type:	[✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation
Completion date of well: October 15, 1991	
Diameter of casing: 12.75"	Type of Casing: [✓ Steel] PVC Other:
Total depth of well: 400 feet	
Bottom depth of cement for last cemented casing string: 60 feet	
Screened or open hole interval (top/bottom depths): 400-180 feet	
STATUS OF WELL	
Condition or Activity of well during past week/month, prior to sampling: recharging all month	
Discuss any field conditions the Division should be aware of with regard to this sample:	
Was the well secured upon arrival?	☒ YES ☐ NO
Was there any problems or damage to the well upon arrival	☐ YES ☒ NO
Was well in an artesian condition prior to sampling? :	☐ YES ☒ NO
WATER LEVEL – WELL GAUGING	
Last date well gauged (mm/dd/yy) :	Depth to water - last event:
Method used to gauge well? :	Cap Tube Tape Measure
Measured Water Level :	surface

UIC Form 230 (06-01-10) **Page 1 of 2**

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UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy) :	4/28/15	Time Sampled :	1355 WJ

Name of Sampler : Will Raymond

Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead" : <1 foot from wellhead on well discharge pipeline

Type of Sample (circle one) : [✓ Grab] Composite other (specify):

Collection method (circle one) : well bailed [✓ water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was discharged / purged before collecting sample? : continuously recharging

Filtering Note: UIC requirements specify water samples shall not be filtered, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: ________________

Was the sample filtered? : ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

FIELD MEASUREMENTS

pH : 7.81
~~S. Conductivity :~~ NTU : 0.24
Temperature : 13.7

What UIC Sample List is required: UIC List 1 UIC List 2 UIC List 3 [✓ Other**] As per Attachment B of permit

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8016	eMail Address: : ckropf@tmwa.com
Signature:	Date:

Qualified Sample Person: Will Raymond

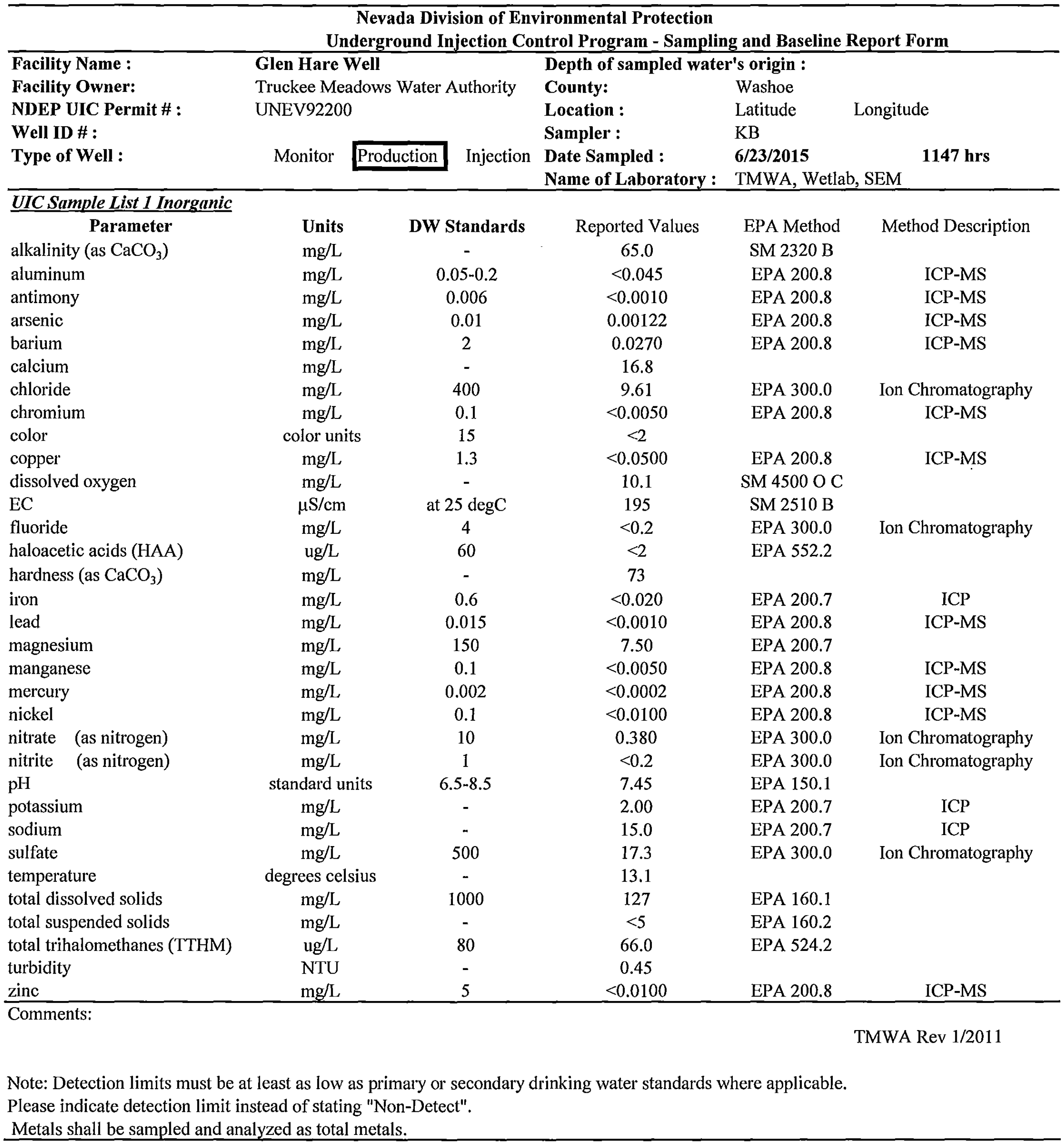
Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8138	eMail Address: wraymond@tmwa.com
Signature:	Date: 4/28/15

Attachments:

UIC Form 230 (06-01-10) **Page 2 of 2**

Table A.9. Zone 1: 2Q2015 Extracted Water Chemistry – Glen Hare



Nevada Division of Environmental Protection

Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**Glen Hare Well**	**Depth of sampled water's origin :**	
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe
NDEP UIC Permit # :	UNEV92200	**Location :**	Latitude Longitude
Well ID # :		**Sampler :**	KB
Type of Well :	Monitor [✓ Production] Injection	**Date Sampled :**	**6/23/2015** **1147 hrs**
		Name of Laboratory :	TMWA, Wetlab, SEM

UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	65.0	SM 2320 B	
aluminum	mg/L	0.05-0.2	<0.045	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.0010	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	0.00122	EPA 200.8	ICP-MS
barium	mg/L	2	0.0270	EPA 200.8	ICP-MS
calcium	mg/L	-	16.8		
chloride	mg/L	400	9.61	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	<0.0050	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	<0.0500	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	10.1	SM 4500 O C	
EC	µS/cm	at 25 degC	195	SM 2510 B	
fluoride	mg/L	4	<0.2	EPA 300.0	Ion Chromatography
haloacetic acids (HAA)	ug/L	60	<2	EPA 552.2	
hardness (as $CaCO_3$)	mg/L	-	73		
iron	mg/L	0.6	<0.020	EPA 200.7	ICP
lead	mg/L	0.015	<0.0010	EPA 200.8	ICP-MS
magnesium	mg/L	150	7.50	EPA 200.7	
manganese	mg/L	0.1	<0.0050	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.0002	EPA 200.8	ICP-MS
nickel	mg/L	0.1	<0.0100	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	0.380	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.2	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.45	EPA 150.1	
potassium	mg/L	-	2.00	EPA 200.7	ICP
sodium	mg/L	-	15.0	EPA 200.7	ICP
sulfate	mg/L	500	17.3	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	13.1		
total dissolved solids	mg/L	1000	127	EPA 160.1	
total suspended solids	mg/L	-	<5	EPA 160.2	
total trihalomethanes (TTHM)	ug/L	80	66.0	EPA 524.2	
turbidity	NTU	-	0.45		
zinc	mg/L	5	<0.0100	EPA 200.8	ICP-MS

Comments:

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Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.

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UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 6/23/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: Glen Hare Well (GHW) | UIC Permit No.: UNEV92200

Is there any well name or identification at the wellhead? ☒ YES ☐ NO If no, label should be placed on or near wellhead

Project/Facility Name: Truckee Meadows Water Authority

Well Location (SectionTR or Lat/Long) : T19NR19E

City/Valley: Truckee Meadows | County: Washoe

Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other: ____

Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type: [✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation

Completion date of well: July 2, 1999

Diameter of casing: 18" | Type of Casing: [✓ Steel] PVC Other: ____

Total depth of well: 470 feet

Bottom depth of cement for last cemented casing string: 120 feet

Screened or open hole interval (top/bottom depths): 441-421(16"), 411-246 (16"), 241-221 (16"), 200-180 ft

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: in production for 6 previous days

Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival? ☒ YES ☐ NO

Was there any problems or damage to the well upon arrival ☐ YES ☒ NO

Was well in an artesian condition prior to sampling? : ☐ YES ☒ NO

WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) : | Depth to water - last event:

Method used to gauge well? : Cap Tube Tape Measure

Measured Water Level : surface

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UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy) : 6/23/15 Time Sampled : 1147

Name of Sampler : Will Raymond

Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead" : <1 foot from wellhead on well discharge pipeline

Type of Sample (circle one) : [✓ Grab] Composite other (specify):

Collection method (circle one) : well bailed [✓ water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was discharged / purged before collecting sample? : in production

Filtering Note: UIC requirements specify water samples shall not be filtered, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: ________________

Was the sample filtered? : ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

FIELD MEASUREMENTS

pH : 7.45
~~S. Conductivity :~~ NTU : 0.45
Temperature : 13.1

What UIC Sample List is required: UIC List 1 UIC List 2 UIC List 3 [✓ Other**] As per Attachment B of permit

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8016 eMail Address: : ckropf@tmwa.com

Signature: Date:

Qualified Sample Person: Will Raymond

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8138 eMail Address: wraymond@tmwa.com

Signature: Date:

Attachments:

UIC Form 230 (06-01-10) **Page 2 of 2**

Table A.10. Zone 1: 2Q2015 Extracted Water Chemistry – Hunter Lake

Nevada Division of Environmental Protection
Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**Hunter Lake Well (HLW)**	**Depth of sampled water's origin :**		
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe	
NDEP UIC Permit # :	UNEV92200	**Location :**	Latitude	Longitude
Well ID # :		**Sampler :**	WR/JG	
Type of Well :	Monitor [✓ Production] Injection	**Date Sampled :**	**6/22/2015**	**1055 hrs**
		Name of Laboratory :	TMWA, Wetlab, SEM	

UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	71.0	SM 2320 B	
aluminum	mg/L	0.05-0.2	<0.05	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.001	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	0.002	EPA 200.8	ICP-MS
barium	mg/L	2	0.024	EPA 200.8	ICP-MS
calcium	mg/L	-	16.0		
chloride	mg/L	400	11.0	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	<0.001	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	8.30	SM 4500 O C	
EC	µS/cm	at 25 degC	260	SM 2510 B	
fluoride	mg/L	4	<0.1	EPA 300.0	Ion Chromatography
haloacetic acids (HAA)	ug/L	60	<2	EPA 552.2	
hardness (as $CaCO_3$)	mg/L	-	64.3		
iron	mg/L	0.6	<0.05	EPA 200.7	ICP
lead	mg/L	0.015	<0.001	EPA 200.8	ICP-MS
magnesium	mg/L	150	5.90	EPA 200.7	
manganese	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.0001	EPA 200.8	ICP-MS
nickel	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	0.460	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.05	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.13	EPA 150.1	
potassium	mg/L	-	2.10	EPA 200.7	ICP
sodium	mg/L	-	17.0	EPA 200.7	ICP
sulfate	mg/L	500	14.0	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	11.5		
total dissolved solids	mg/L	1000	110	EPA 160.1	
total suspended solids	mg/L	-	<5	EPA 160.2	
total trihalomethanes (TTHM)	ug/L	80	64.0	EPA 524.2	
turbidity	NTU	-	0.23		
zinc	mg/L	5	<0.01	EPA 200.8	ICP-MS

Comments:

TMWA Rev 1/2011

Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.

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UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 6/22/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: Hunter Lake Well (HLW) | UIC Permit No.: UNEV92200

Is there any well name or identification at the wellhead? ☒ YES ☐ NO If no, label should be placed on or near wellhead

Project/Facility Name: Truckee Meadows Water Authority

Well Location (SectionTR or Lat/Long): 14,859,592.99N 2,271,273.25E

City/Valley: Truckee Meadows | County: Washoe

Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other: __________

Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type: [✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation

Completion date of well: February 1995

Diameter of casing: 16" | Type of Casing: [✓ Steel] PVC Other: __________

Total depth of well: 480 feet

Bottom depth of cement for last cemented casing string: 470 feet

Screened or open hole interval (top/bottom depths): 210-300, 310-470 feet

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: in production 7 of last 7 days

Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival? ☒ YES ☐ NO

Was there any problems or damage to the well upon arrival ☐ YES ☒ NO

Was well in an artesian condition prior to sampling? : ☐ YES ☒ NO

WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) : | Depth to water - last event:

Method used to gauge well? : Cap Tube Tape Measure

Measured Water Level : surface

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ndep NEVADA DIVISION OF ENVIRONMENTAL PROTECTION
protecting the future for generations

UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy) : 6/22/15 Time Sampled : 1055

Name of Sampler : Will Raymond

Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead" : 1 foot

Type of Sample (circle one) : [✓ Grab] Composite other (specify):

Collection method (circle one) : well bailed [✓ water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was discharged / purged before collecting sample? : In production

Filtering Note: UIC requirements specify water samples shall not be filtered, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: ________________

Was the sample filtered? : ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

FIELD MEASUREMENTS

pH : 7.13

~~S. Conductivity :~~ NTU : 0.23

Temperature : 11.5°C

What UIC Sample List is required: UIC List 1 UIC List 2 UIC List 3 [✓ Other**] As per Attachment B of permit

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8016 eMail Address: ckropf@tmwa.com

Signature: Date:

Qualified Sample Person: Will Raymond

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8138 eMail Address: wraymond@tmwa.com

Signature: Date: 6/22/15

Attachments:

UIC Form 230 (06-01-10) **Page 2 of 2**

Table A.11. Zone 1: 2Q2015 Extracted Water Chemistry – Reno High

Nevada Division of Environmental Protection
Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**Reno High Well**	**Depth of sampled water's origin :**		
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe	
NDEP UIC Permit # :	UNEV92200	**Location :**	Latitude	Longitude
Well ID # :		**Sampler :**	WR/JG	
Type of Well :	Monitor [✓ Production] Injection	**Date Sampled :**	**6/22/2015**	**1025 hrs**
		Name of Laboratory :	TMWA, Wetlab, SEM	

UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	79.0	SM 2320 B	
aluminum	mg/L	0.05-0.2	<0.05	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.001	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	<0.001	EPA 200.8	ICP-MS
barium	mg/L	2	0.027	EPA 200.8	ICP-MS
calcium	mg/L	-	19.0		
chloride	mg/L	400	10.0	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	0.003	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	7.60	SM 4500 O C	
EC	µS/cm	at 25 degC	290	SM 2510 B	
fluoride	mg/L	4	<0.1	EPA 300.0	Ion Chromatography
haloacetic acids (HAA)	ug/L	60	<2	EPA 552.2	
hardness (as $CaCO_3$)	mg/L	-	74.7		
iron	mg/L	0.6	<0.05	EPA 200.7	ICP
lead	mg/L	0.015	<0.001	EPA 200.8	ICP-MS
magnesium	mg/L	150	6.60	EPA 200.7	
manganese	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.0001	EPA 200.8	ICP-MS
nickel	mg/L	0.1	0.003	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	0.680	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.05	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.18	EPA 150.1	
potassium	mg/L	-	2.30	EPA 200.7	ICP
sodium	mg/L	-	17.0	EPA 200.7	ICP
sulfate	mg/L	500	20.0	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	12.5		
total dissolved solids	mg/L	1000	140	EPA 160.1	
total suspended solids	mg/L	-	<5	EPA 160.2	
total trihalomethanes (TTHM)	ug/L	80	54.0	EPA 524.2	
turbidity	NTU	-	0.10		
zinc	mg/L	5	0.01	EPA 200.8	ICP-MS

Comments:

TMWA Rev 1/2011

Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.

Nevada Division of Environmental Protection
Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 6/22/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: Reno High Well (RHW) | UIC Permit No.: UNEV92200

Is there any well name or identification at the wellhead? ☒ YES ☐ NO If no, label should be placed on or near wellhead

Project/Facility Name: Truckee Meadows Water Authority

Well Location (SectionTR or Lat/Long) : T19NR19ES15

City/Valley: Truckee Meadows | County: Washoe

Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other: ____________

Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type: [✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation

Completion date of well: June 6, 1991

Diameter of casing: 16" | Type of Casing: [✓ Steel] PVC Other: ____________

Total depth of well: 456 feet

Bottom depth of cement for last cemented casing string: 1750 feet

Screened or open hole interval (top/bottom depths): 420-380, 370-240, 230-1800 feet

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: in production for previous 6 days

Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival? ☒ YES ☐ NO

Was there any problems or damage to the well upon arrival ☐ YES ☒ NO

Was well in an artesian condition prior to sampling? : ☐ YES ☒ NO

WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) : | Depth to water - last event:

Method used to gauge well? : Cap Tube Tape Measure

Measured Water Level : surface

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Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy) : 6/22/15 Time Sampled : 1025 WR

Name of Sampler : Will Raymond

Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead" : 1 foot

Type of Sample (circle one) : [✓ Grab] Composite other (specify):

Collection method (circle one) : well bailed [✓ water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was discharged / purged before collecting sample? : in production

Filtering Note: UIC requirements specify water samples shall not be filtered, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: ______________

Was the sample filtered? : ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

FIELD MEASUREMENTS

pH : 7.18
~~S. Conductivity :~~ NTU : 0.10
Temperature : 12.5

What UIC Sample List is required: UIC List 1 UIC List 2 UIC List 3 [✓ Other**] As per Attachment B of permit

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8016 eMail Address: : ckropf@tmwa.com

Signature: Date:

Qualified Sample Person: Will Raymond

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8138 eMail Address: wraymond@tmwa.com

Signature: Date: 6/22/15

Attachments:

UIC Form 230 (06-01-10) **Page 2 of 2**

Table A.12. Zone 2: 2Q2015 Extracted Water Chemistry – Fourth Street

Nevada Division of Environmental Protection

Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**Fourth Street Well**	**Depth of sampled water's origin :**		
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe	
NDEP UIC Permit # :	UNEV92200	**Location :**	Latitude	Longitude
Well ID # :		**Sampler :**	JB/CM	
Type of Well :	Monitor [✓ Production] Injection	**Date Sampled :**	**6/23/2015**	**0637 hrs**
		Name of Laboratory :	TMWA, Wetlab, SEM	

UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	52	SM 2320 B	
aluminum	mg/L	0.05-0.2	<0.045	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.0010	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	<0.0010	EPA 200.8	ICP-MS
barium	mg/L	2	<0.0215	EPA 200.8	ICP-MS
calcium	mg/L	-	11.2		
chloride	mg/L	400	9.85	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	<0.0050	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	<0.0500	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	10.4	SM 4500 O C	
EC	µS/cm	at 25 degC	140	SM 2510 B	
fluoride	mg/L	4	<0.2	EPA 300.0	Ion Chromatography
haloacetic acids (HAA)	ug/L	60	<2	EPA 552.2	
hardness (as $CaCO_3$)	mg/L	-	50		
iron	mg/L	0.6	<0.020	EPA 200.7	ICP
lead	mg/L	0.015	<0.0010	EPA 200.8	ICP-MS
magnesium	mg/L	150	5.30	EPA 200.7	
manganese	mg/L	0.1	<0.0050	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.0002	EPA 200.8	ICP-MS
nickel	mg/L	0.1	<0.0100	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	<0.3	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.2	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.89	EPA 150.1	
potassium	mg/L	-	2.00	EPA 200.7	ICP
sodium	mg/L	-	15.0	EPA 200.7	ICP
sulfate	mg/L	500	5.78	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	13.1		
total dissolved solids	mg/L	1000	89.2	EPA 160.1	
total suspended solids	mg/L	-	<5	EPA 160.2	
total trihalomethanes (TTHM)	ug/L	80	69.0	EPA 524.2	
turbidity	NTU	-	0.21		
zinc	mg/L	5	<0.0100	EPA 200.8	ICP-MS

Comments:

TMWA Rev 1/2011

Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.

Nevada Division of Environmental Protection
Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 6/23/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: Fourth Street Well (FSW) | UIC Permit No.: UNEV92200

Is there any well name or identification at the wellhead? ☒YES ☐ NO If no, label should be placed on or near wellhead

Project/Facility Name: Truckee Meadows Water Authority

Well Location (SectionTR or Lat/Long) : T19NR19ES12

City/Valley: Truckee Meadows | County: Washoe

Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other: ____________

Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type: [✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation

Completion date of well: October 26, 1971

Diameter of casing: 18" | Type of Casing: [✓ Steel] PVC Other: ____________

Total depth of well: 456 feet

Bottom depth of cement for last cemented casing string: 168 feet

Screened or open hole interval (top/bottom depths): 456-438, 434-406, 396-350 (12☺, 344-334, 304-274, 270-250, 239-216, 213-176 (18") feet

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: in production for previous 7 days

Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival? ☒YES ☐ NO

Was there any problems or damage to the well upon arrival ☐ YES ☒NO

Was well in an artesian condition prior to sampling? : ☐ YES ☒NO

WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) : | Depth to water - last event:

Method used to gauge well? : Cap Tube Tape Measure

Measured Water Level : surface

UIC Form 230 (06-01-10) **Page 1 of 2**

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Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy) : 6/23/15 Time Sampled : 0637 WR

Name of Sampler : Will Raymond

Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead" : <1 foot from wellhead on well discharge pipeline

Type of Sample (circle one) : [✓ Grab] Composite other (specify):

Collection method (circle one) : well bailed [✓ water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was discharged / purged before collecting sample? : in production

<u>Filtering Note</u>: UIC requirements specify water samples <u>shall not be filtered</u>, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: ______________

Was the sample filtered? : ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

<u>FIELD MEASUREMENTS</u>

pH : 7.89
~~S. Conductivity :~~ NTU : 0.21
Temperature : 13.1°C

What UIC Sample List is <u>required</u>: UIC List 1 UIC List 2 UIC List 3 [✓ Other**] <u>As per Attachment B of permit</u>

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8016 eMail Address: : <u>ckropf@tmwa.com</u>

Signature: Date:

Qualified Sample Person: Will Raymond

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8138 eMail Address: <u>wraymond@tmwa.com</u>

Signature: Date:

Attachments:

UIC Form 230 (06-01-10) **Page 2 of 2**

Table A.13. Zone 2: 2Q2015 Extracted Water Chemistry – View Street

Nevada Division of Environmental Protection

Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**View Street Well (VSW)**	**Depth of sampled water's origin :**		
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe	
NDEP UIC Permit # :	UNEV92200	**Location :**	Latitude	Longitude
Well ID # :		**Sampler :**	KB	
Type of Well :	Monitor [✓ Production] Injection	**Date Sampled :**	**6/23/2015**	**1014 hrs**
		Name of Laboratory :	TMWA, Wetlab, SEM	

UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	50.0	SM 2320 B	
aluminum	mg/L	0.05-0.2	<0.045	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.0010	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	0.00213	EPA 200.8	ICP-MS
barium	mg/L	2	0.0206	EPA 200.8	ICP-MS
calcium	mg/L	-	10.8		
chloride	mg/L	400	9.58	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	<0.0050	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	<0.0500	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	9.95	SM 4500 O C	
EC	µS/cm	at 25 degC	135	SM 2510 B	
fluoride	mg/L	4	<0.2	EPA 300.0	Ion Chromatography
haloacetic acids (HAA)	ug/L	60	<2	EPA 552.2	
hardness (as $CaCO_3$)	mg/L	-	41		
iron	mg/L	0.6	<0.020	EPA 200.7	ICP
lead	mg/L	0.015	<0.0010	EPA 200.8	ICP-MS
magnesium	mg/L	150	3.40	EPA 200.7	
manganese	mg/L	0.1	<0.0050	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.0002	EPA 200.8	ICP-MS
nickel	mg/L	0.1	<0.0100	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	<0.3	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.2	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.38	EPA 150.1	
potassium	mg/L	-	1.6	EPA 200.7	ICP
sodium	mg/L	-	12	EPA 200.7	ICP
sulfate	mg/L	500	5.31	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	10.5		
total dissolved solids	mg/L	1000	87.9	EPA 160.1	
total suspended solids	mg/L	-	<5	EPA 160.2	
total trihalomethanes (TTHM)	ug/L	80	60.0	EPA 524.2	
turbidity	NTU	-	0.28		
zinc	mg/L	5	<0.0100	EPA 200.8	ICP-MS

Comments:

TMWA Rev 1/2011

Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.

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901 S. Stewart St Ste 4001
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NDEP NEVADA DIVISION of ENVIRONMENTAL PROTECTION
protecting the future for generations

UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 6/23/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: View Street Well (VSW)	UIC Permit No.: UNEV92200
Is there any well name or identification at the wellhead? ☒ YES ☐ NO If no, label should be placed on or near wellhead	
Project/Facility Name: Truckee Meadows Water Authority	
Well Location (SectionTR or Lat/Long) : T19NR20ES06	
City/Valley: Truckee Meadows	County: Washoe
Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other:	
Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly	

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type:	[✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation
Completion date of well: January 4, 1969	
Diameter of casing: 18"	Type of Casing: [✓ Steel] PVC Other:
Total depth of well: 530 feet	
Bottom depth of cement for last cemented casing string: 140 feet	
Screened or open hole interval (top/bottom depths): 518-502, 484-474, 468-450, 432-397, 390-356 (12"), 298-288, 284-244, 236-206, 190-182, 176-166, 162-148 (18") feet	

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: producing water 6 of

Discuss any field conditions the Division should be aware of with regard to this sample: previous 7 days

Was the well secured upon arrival?	☒ YES ☐ NO
Was there any problems or damage to the well upon arrival	☐ YES ☒ NO
Was well in an artesian condition prior to sampling? :	☐ YES ☒ NO

WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) :	Depth to water - last event:
Method used to gauge well? :	Cap Tube Tape Measure
Measured Water Level :	surface

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Nevada Division of Environmental Protection
Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy) : 6/23/15 Time Sampled : 1014

Name of Sampler : Will Raymond

Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead" : Sample tap <1 foot from wellhead on well discharge pipeline

Type of Sample (circle one) : [✓ Grab] Composite other (specify):

Collection method (circle one) : well bailed [✓ water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was discharged / purged before collecting sample? : IN production

Filtering Note: UIC requirements specify water samples shall not be filtered, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: ______________

Was the sample filtered? : ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

FIELD MEASUREMENTS

pH : 7.38
~~S. Conductivity :~~ NTU : 0.28
Temperature : 10.5

What UIC Sample List is required: UIC List 1 UIC List 2 UIC List 3 [✓ Other**] As per Attachment B of permit

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <*(Detection Limit Value***)**

FORM PREPARATION

Project Manager: Christian Kropf

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8016 eMail Address: : ckropf@tmwa.com

Signature: Date:

Qualified Sample Person: Will Raymond

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8138 eMail Address: wraymond@tmwa.com

Signature: Date:

Attachments:

UIC Form 230 (06-01-10) **Page 2 of 2**

Table A.14. Zone 2: 2Q2015 Extracted Water Chemistry – El Rancho

Nevada Division of Environmental Protection

Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**El Rancho Well**	**Depth of sampled water's origin :**		
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe	
NDEP UIC Permit # :	UNEV92200	**Location :**	Latitude	Longitude
Well ID # :		**Sampler :**	JB/CM	
Type of Well :	Monitor [✓ Production] Injection	**Date Sampled :**	**6/23/2015**	**0655 hrs**
		Name of Laboratory :	TMWA, Wetlab, SEM	

UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	53.0	SM 2320 B	
aluminum	mg/L	0.05-0.2	<0.045	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.0010	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	0.00135	EPA 200.8	ICP-MS
barium	mg/L	2	0.0228	EPA 200.8	ICP-MS
calcium	mg/L	-	12.4		
chloride	mg/L	400	11.8	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	<0.0050	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	<0.0500	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	10.9	SM 4500 O C	
EC	µS/cm	at 25 degC	155	SM 2510 B	
fluoride	mg/L	4	<0.2	EPA 300.0	Ion Chromatography
haloacetic acids (HAA)	ug/L	60	22.0	EPA 552.2	
hardness (as $CaCO_3$)	mg/L	-	46		
iron	mg/L	0.6	0.240	EPA 200.7	ICP
lead	mg/L	0.015	0.00130	EPA 200.8	ICP-MS
magnesium	mg/L	150	3.60	EPA 200.7	
manganese	mg/L	0.1	<0.0050	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.0002	EPA 200.8	ICP-MS
nickel	mg/L	0.1	<0.0100	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	<0.3	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.2	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.78	EPA 150.1	
potassium	mg/L	-	1.60	EPA 200.7	ICP
sodium	mg/L	-	13.0	EPA 200.7	ICP
sulfate	mg/L	500	10.0	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	13.2		
total dissolved solids	mg/L	1000	101	EPA 160.1	
total suspended solids	mg/L	-	<5	EPA 160.2	
total trihalomethanes (TTHM)	ug/L	80	79.0	EPA 524.2	
turbidity	NTU	-	0.22		
zinc	mg/L	5	0.0106	EPA 200.8	ICP-MS

Comments:

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Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.

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UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 6/23/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: El Rancho Well (ERW)
UIC Permit No.: UNEV92200
Is there any well name or identification at the wellhead? ☒ YES ☐ NO If no, label should be placed on or near wellhead
Project/Facility Name: Truckee Meadows Water Authority
Well Location (SectionTR or Lat/Long) : T19NR20ES06
City/Valley: Truckee Meadows
County: Washoe
Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other: ____________
Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type: [✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation
Completion date of well: September 18, 1992
Diameter of casing: 16"
Type of Casing: [✓ Steel] PVC Other: ____________
Total depth of well: 375 feet
Bottom depth of cement for last cemented casing string: 140 feet
Screened or open hole interval (top/bottom depths): 360-299, 260-250, 207-142 feet

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: in production 4 of previous 6 days
Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival? ☒ YES ☐ NO
Was there any problems or damage to the well upon arrival ☐ YES ☒ NO
Was well in an artesian condition prior to sampling? : ☐ YES ☒ NO

WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) :
Depth to water - last event:
Method used to gauge well? : Cap Tube Tape Measure
Measured Water Level : surface

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UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy) :	6/23/15	Time Sampled :	0655 WR

Name of Sampler : Will Raymond

Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead" : 1 foot

Type of Sample (circle one) : [✓ Grab] Composite other (specify):

Collection method (circle one) : well bailed [✓ water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was discharged / purged before collecting sample? : In production

<u>Filtering Note</u>: UIC requirements specify water samples shall not be filtered, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: ________

Was the sample filtered? : ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

FIELD MEASUREMENTS

pH : 7.78
~~S. Conductivity :~~ NTU : 0.22
Temperature : 13.2°C

What UIC Sample List is required: UIC List 1 UIC List 2 UIC List 3 [✓ Other**] As per Attachment B of permit

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8016	eMail Address: : ckropf@tmwa.com
Signature:	Date:

Qualified Sample Person: Will Raymond

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8138	eMail Address: wraymond@tmwa.com
Signature:	Date:

Attachments:

UIC Form 230 (06-01-10) **Page 2 of 2**

Table A.15. Zone 3: 2Q2015 Extracted Water Chemistry – Galletti Way

Nevada Division of Environmental Protection
Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**Galetti Way Well**	**Depth of sampled water's origin :**		
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe	
NDEP UIC Permit # :	UNEV92200	**Location :**	Latitude	Longitude
Well ID # :		**Sampler :**	WR	
Type of Well :	Monitor [✓ Production] Injection	**Date Sampled :**	**6/25/2015**	**1445 hrs**
		Name of Laboratory :	TMWA, Wetlab, SEM	

UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	54.0	SM 2320 B	
aluminum	mg/L	0.05-0.2	<0.05	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.0010	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	0.00121	EPA 200.8	ICP-MS
barium	mg/L	2	0.0242	EPA 200.8	ICP-MS
calcium	mg/L	-	11.0		
chloride	mg/L	400	9.80	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	<0.0050	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	<0.0500	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	8.30	SM 4500 O C	
EC	µS/cm	at 25 degC	160	SM 2510 B	
fluoride	mg/L	4	<0.1	EPA 300.0	Ion Chromatography
haloacetic acids (HAA)	ug/L	60	<2	EPA 552.2	
hardness (as $CaCO_3$)	mg/L	-	42.0		
iron	mg/L	0.6	<0.05	EPA 200.7	ICP
lead	mg/L	0.015	<0.0010	EPA 200.8	ICP-MS
magnesium	mg/L	150	3.60	EPA 200.7	
manganese	mg/L	0.1	<0.0050	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.0002	EPA 200.8	ICP-MS
nickel	mg/L	0.1	<0.0100	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	<0.05	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.05	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.09	EPA 150.1	
potassium	mg/L	-	1.5	EPA 200.7	ICP
sodium	mg/L	-	13	EPA 200.7	ICP
sulfate	mg/L	500	3.5	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	11.2		
total dissolved solids	mg/L	1000	106	EPA 160.1	
total suspended solids	mg/L	-	<5	EPA 160.2	
total trihalomethanes (TTHM)	ug/L	80	53.0	EPA 524.2	
turbidity	NTU	-	0.89		
zinc	mg/L	5	<0.0100	EPA 200.8	ICP-MS

Comments:

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Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.

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UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 6/25/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: Galletti Way Well (GWW) | UIC Permit No.: UNEV92200

Is there any well name or identification at the wellhead? ☒ YES ☐ NO If no, label should be placed on or near wellhead

Project/Facility Name: Truckee Meadows Water Authority

Well Location (SectionTR or Lat/Long) : T19NR20ES07

City/Valley: Truckee Meadows | County: Washoe

Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other: ____________________

Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type: [✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation

Completion date of well: January 7, 2000

Diameter of casing: 16" | Type of Casing: [✓ Steel] PVC Other: ____________________

Total depth of well: 250 feet

Bottom depth of cement for last cemented casing string: 116 feet

Screened or open hole interval (top/bottom depths): 240-210, 200-162, 148-120 feet

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: in production 6 of previous 10 days

Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival? ☒ YES ☐ NO

Was there any problems or damage to the well upon arrival ☐ YES ☒ NO

Was well in an artesian condition prior to sampling? : ☐ YES ☒ NO

WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) : | Depth to water - last event:

Method used to gauge well? : Cap Tube Tape Measure

Measured Water Level : surface

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UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy) : 6/25/15 Time Sampled : 1445 WR

Name of Sampler : Will Raymond

Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead" : 1 foot

Type of Sample (circle one) : [✓ Grab] Composite other (specify):

Collection method (circle one) : well bailed [✓ water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was discharged / purged before collecting sample? :

Filtering Note: UIC requirements specify water samples shall not be filtered, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: ________

Was the sample filtered? : ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

FIELD MEASUREMENTS

pH : 7.09
~~S. Conductivity :~~ NTU : 0.89
Temperature : 11.2°C

What UIC Sample List is required: UIC List 1 UIC List 2 UIC List 3 [✓ Other**] As per Attachment B of permit

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8016 eMail Address: : ckropf@tmwa.com

Signature: Date:

Qualified Sample Person: Will Raymond

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8138 eMail Address: wraymond@tmwa.com

Signature: Date: 6/25/15

Attachments:

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Table A.16. Zone 3: 2Q2015 Extracted Water Chemistry – Greg Street

Nevada Division of Environmental Protection
Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**Greg Street Well**	**Depth of sampled water's origin :**		
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe	
NDEP UIC Permit # :	UNEV92200	**Location :**	Latitude	Longitude
Well ID # :		**Sampler :**		
Type of Well :	Monitor [✓ Production] Injection	**Date Sampled :**	**6/25/2015**	**1445 hrs**
		Name of Laboratory :	TMWA, Wetlab, SEM	

UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	51	SM 2320 B	
aluminum	mg/L	0.05-0.2	<0.05	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.0010	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	<0.0010	EPA 200.8	ICP-MS
barium	mg/L	2	0.0211	EPA 200.8	ICP-MS
calcium	mg/L	-	10.0		
chloride	mg/L	400	9.90	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	0.00176	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	<0.0500	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	8.10	SM 4500 O C	
EC	µS/cm	at 25 degC	150	SM 2510 B	
fluoride	mg/L	4	<0.1	EPA 300.0	Ion Chromatography
haloacetic acids (HAA)	ug/L	60	20.0	EPA 552.2	
hardness (as $CaCO_3$)	mg/L	-	39.0		
iron	mg/L	0.6	<0.05	EPA 200.7	ICP
lead	mg/L	0.015	<0.0010	EPA 200.8	ICP-MS
magnesium	mg/L	150	3.30	EPA 200.7	
manganese	mg/L	0.1	<0	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.0050	EPA 200.8	ICP-MS
nickel	mg/L	0.1	<0.0100	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	<0.05	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.05	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.11	EPA 150.1	
potassium	mg/L	-	1.4	EPA 200.7	ICP
sodium	mg/L	-	12	EPA 200.7	ICP
sulfate	mg/L	500	4.0	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	14.3		
total dissolved solids	mg/L	1000	99.0	EPA 160.1	
total suspended solids	mg/L	-	<5	EPA 160.2	
total trihalomethanes (TTHM)	ug/L	80	63.0	EPA 524.2	
turbidity	NTU	-	0.31		
zinc	mg/L	5	<0.0100	EPA 200.8	ICP-MS

Comments:

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Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.

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UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 6/25/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: Greg Street Well (GSW) | UIC Permit No.: UNEV92200

Is there any well name or identification at the wellhead? ☒ YES ☐ NO If no, label should be placed on or near wellhead

Project/Facility Name: Truckee Meadows Water Authority

Well Location (SectionTR or Lat/Long) : T19NR20ES8

City/Valley: Truckee Meadows | County: Washoe

Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other: ________

Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type: [✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation

Completion date of well: October 15, 1991

Diameter of casing: 12.75" | Type of Casing: [✓ Steel] PVC Other: ________

Total depth of well: 400 feet

Bottom depth of cement for last cemented casing string: 60 feet

Screened or open hole interval (top/bottom depths): 400-180 feet

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: day 1 of production for the year

Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival? ☒ YES ☐ NO

Was there any problems or damage to the well upon arrival ☐ YES ☒ NO

Was well in an artesian condition prior to sampling? : ☐ YES ☒ NO

WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) : | Depth to water - last event:

Method used to gauge well? : Cap Tube Tape Measure

Measured Water Level : surface

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UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy) : 6/25/15 Time Sampled : 1445

Name of Sampler : Will Raymond

Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead" : <1 foot from wellhead on well discharge pipeline

Type of Sample (circle one) : [✓ Grab] Composite other (specify):

Collection method (circle one) : well bailed [✓ water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was discharged / purged before collecting sample? : in production

Filtering Note: UIC requirements specify water samples shall not be filtered, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: _______________

Was the sample filtered? : ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

FIELD MEASUREMENTS

pH : 7.11
~~S. Conductivity :~~ NTU : 0.31
Temperature : 14.3C

What UIC Sample List is required: UIC List 1 UIC List 2 UIC List 3 [✓ Other**] As per Attachment B of permit

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8016 eMail Address: : ckropf@tmwa.com

Signature: Date:

Qualified Sample Person: Will Raymond

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8138 eMail Address: wraymond@tmwa.com

Signature: Date: 6/25/15

Attachments:

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Table A.17. Zone 3: 2Q2015 Extracted Water Chemistry – South 21st Street

Nevada Division of Environmental Protection
Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**South 21st Street Well (S21)**	**Depth of sampled water's origin :**		
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe	
NDEP UIC Permit # :	UNEV92200	**Location :**	Latitude	Longitude
Well ID # :		**Sampler :**	WR/JG	
Type of Well :	Monitor [✓ Production] Injection	**Date Sampled :**	**6/22/2015**	**1130 hrs**
		Name of Laboratory :	TMWA, Wetlab, SEM	

UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	56.0	SM 2320 B	
aluminum	mg/L	0.05-0.2	<0.05	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.001	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	0.001	EPA 200.8	ICP-MS
barium	mg/L	2	0.020	EPA 200.8	ICP-MS
calcium	mg/L	-	11.0		
chloride	mg/L	400	10.0	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	<0.001	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	8.40	SM 4500 O C	
EC	µS/cm	at 25 degC	190	SM 2510 B	
fluoride	mg/L	4	<0.1	EPA 300.0	Ion Chromatography
haloacetic acids (HAA)	ug/L	60	<2	EPA 552.2	
hardness (as $CaCO_3$)	mg/L	-	43.2		
iron	mg/L	0.6	<0.05	EPA 200.7	ICP
lead	mg/L	0.015	<0.001	EPA 200.8	ICP-MS
magnesium	mg/L	150	3.80	EPA 200.7	
manganese	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.0001	EPA 200.8	ICP-MS
nickel	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	0.100	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.05	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.14	EPA 150.1	
potassium	mg/L	-	1.60	EPA 200.7	ICP
sodium	mg/L	-	14.0	EPA 200.7	ICP
sulfate	mg/L	500	4.60	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	11.1		
total dissolved solids	mg/L	1000	95.0	EPA 160.1	
total suspended solids	mg/L	-	<5	EPA 160.2	
total trihalomethanes (TTHM)	ug/L	80	64.0	EPA 524.2	
turbidity	NTU	-	0.18		
zinc	mg/L	5	<0.01	EPA 200.8	ICP-MS

Comments:

TMWA Rev 1/2011

Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.

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UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 6/22/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION	
Well Name & No.: South 21st Street Well	UIC Permit No.:UNEV92200
Is there any well name or identification at the wellhead?	☐ YES ☒ NO If no, label should be placed on or near wellhead
Project/Facility Name:Truckee Meadows Water Authority	
Well Location (SectionTR or Lat/Long) :T19NR20ES07	
City/Valley:Truckee Meadows	County: Washoe
Sample for (circle one): NEW WELL [✓ X ROUTINE REPORTING] Other: ____________	
Reporting Frequency: ☐ Semi-annually ☐ Annually ☐ Other ___Quarterly____________	
WELL or SAMPLE LOCATION INFORMATION	
(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)	
Well Type:	[✓ X Municipal Water Well] Monitoring Geo-Prod Geo-Injection Geo-Observation
Completion date of well: April 1, 1991	
Diameter of casing: 16"	Type of Casing: [✓ X Steel] PVC Other:____________
Total depth of well: 250 feet	
Bottom depth of cement for last cemented casing string: 116 feet	
Screened or open hole interval (top/bottom depths): 245-180, 170-140, 130-120 feet	
STATUS OF WELL	
Condition or Activity of well during past week/month, prior to sampling: in production 6 of previous 7 days	
Discuss any field conditions the Division should be aware of with regard to this sample:	
Was the well secured upon arrival?	☒ YES ☐ NO
Was there any problems or damage to the well upon arrival	☐ YES ☒ NO
Was well in an artesian condition prior to sampling? :	☐ YES ☒ NO
WATER LEVEL – WELL GAUGING	
Last date well gauged (mm/dd/yy) :	Depth to water - last event:
Method used to gauge well? :	Cap Tube Tape Measure
Measured Water Level :	surface

UIC Form 230 (06-01-10) **Page 1 of 2**

Nevada Division of Environmental Protection
Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy) :	6/22/15	Time Sampled :	1130 WR
Name of Sampler :	Will Raymond		
Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead" :	1 ft		

Type of Sample (circle one) : [✓ X Grab] Composite ~~other~~ (specify):

Collection method (circle one) : well bailed [✓ X water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was ~~discharged /~~ purged before collecting sample? : In production

Filtering Note: UIC requirements specify water samples shall not be filtered, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: ______________

Was the sample filtered? : ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

FIELD MEASUREMENTS

pH : 7.14
~~S. Conductivity :~~ NTU : 0.18
Temperature : 11.1

What UIC Sample List is required: UIC List 1 UIC List 2 UIC List 3 [✓ Other**]: As per Attachment B of the permit_____

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf	
Company: Truckee Meadows Water Authority	
Telephone No.: 775-834-8016	eMail Address: : ckropf@tmwa.com
Signature:	Date:
Qualified Sample Person: Will Raymond	
Company: Truckee Meadows Water Authority	
Telephone No.:775-834-8138	eMail Address: wraymond@tmwa.com
Signature: WRaymond	Date: 6-22-15

Attachments:

UIC Form 230 (06-01-10) **Page 2 of 2**

Table A.18. Zone 4: 2Q2015 Extracted Water Chemistry – Longley Lane

Nevada Division of Environmental Protection
Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**Longley Lane Well**	**Depth of sampled water's origin :**		
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe	
NDEP UIC Permit # :	UNEV92200	**Location :**	Latitude	Longitude
Well ID # :		**Sampler :**	**6/22/2015**	**1345 hrs**
Type of Well :	Monitor [✓ Production] Injection	**Date Sampled :**	**WR/JG**	
		Name of Laboratory :	TMWA, Wetlab, SEM	

UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	110	SM 2320 B	
aluminum	mg/L	0.05-0.2	<0.05	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.001	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	0.002	EPA 200.8	ICP-MS
barium	mg/L	2	0.072	EPA 200.8	ICP-MS
calcium	mg/L	-	17.0		
chloride	mg/L	400	5.00	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	0.001	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	5.00	SM 4500 O C	
EC	µS/cm	at 25 degC	270	SM 2510 B	
fluoride	mg/L	4	0.100	EPA 300.0	Ion Chromatography
haloacetic acids (HAA)	ug/L	60	<2	EPA 552.2	
hardness (as $CaCO_3$)	mg/L	-	92.0		
iron	mg/L	0.6	<0.05	EPA 200.7	ICP
lead	mg/L	0.015	<0.001	EPA 200.8	ICP-MS
magnesium	mg/L	150	12.0	EPA 200.7	
manganese	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.0001	EPA 200.8	ICP-MS
nickel	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	1.00	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.05	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.06	EPA 150.1	
potassium	mg/L	-	5.00	EPA 200.7	ICP
sodium	mg/L	-	11.0	EPA 200.7	ICP
sulfate	mg/L	500	3.80	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	15.0		
total dissolved solids	mg/L	1000	160	EPA 160.1	
total suspended solids	mg/L	-	<5	EPA 160.2	
total trihalomethanes (TTHM)	ug/L	80	6.40	EPA 524.2	
turbidity	NTU	-	0.33		
zinc	mg/L	5	<0.01	EPA 200.8	ICP-MS

Comments:

TMWA Rev 1/2011

Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.

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901 S. Stewart St Ste 4001
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Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 6/22/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: Longley Lane Well (LLW) | UIC Permit No.: UNEV92200

Is there any well name or identification at the wellhead? ☒ YES ☐ NO If no, label should be placed on or near wellhead

Project/Facility Name: Truckee Meadows Water Authority

Well Location (SectionTR or Lat/Long) : NE ¼, NE1/4, Sec 6, T18, N20E

City/Valley: Truckee Meadows | County: Washoe

Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other: ____________

Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type: [✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation

Completion date of well: January 18, 2000

Diameter of casing: 16" | Type of Casing: [✓ Steel] PVC Other: ____________

Total depth of well: 310'

Bottom depth of cement for last cemented casing string: 115'

Screened or open hole interval (top/bottom depths): 120'-135', 142'-172', 190'-215', 260'-290'

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: in production for previous 6 days

Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival? ☒ YES ☐ NO

Was there any problems or damage to the well upon arrival ☐ YES ☒ NO

Was well in an artesian condition prior to sampling? : ☐ YES ☒ NO

WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) : | Depth to water - last event:

Method used to gauge well? : Cap Tube Tape Measure

Measured Water Level : surface

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Carson City Nevada 89701
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UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy) :	6/22/15	Time Sampled :	1345
Name of Sampler :	Will Raymond		
Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead" :	<1 foot from wellhead on well discharge pipeline		
Type of Sample (circle one) :	[✓ Grab] Composite other (specify):		
Collection method (circle one) :	well bailed [✓ water pumped] artesian flow air/gas lift		
How much fluid (gallons or well volumes) was discharged / purged before collecting sample? :	in production		

Filtering Note: UIC requirements specify water samples shall not be filtered, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: _______________

Was the sample filtered? :	☐ YES ☒ NO
Was conductivity measured during discharge to establish stabilized conditions?	☐ YES ☒ NO-stabilized conditions determined by pH and temp
Was decontamination procedures (reference O & M?) followed during sampling of multiple wells	☒ YES ☐ NO

FIELD MEASUREMENTS

pH : 7.06
~~S. Conductivity:~~ NTU : 0.33
Temperature : 15.0 C

What UIC Sample List is required: UIC List 1 UIC List 2 UIC List 3 [✓ Other**] As per Attachment B of permit

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded?	☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf	
Company: Truckee Meadows Water Authority	
Telephone No.: 775-834-8016	email Address: : ckropf@tmwa.com
Signature:	Date:
Qualified Sample Person: Will Raymond	
Company: Truckee Meadows Water Authority	
Telephone No.: 775-834-8138	email Address: wraymond@tmwa.com
Signature: WRaymond	Date: 6/22/15

Attachments:

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Table A.19. Zone 4: 2Q2015 Extracted Water Chemistry – Sierra Plaza

Nevada Division of Environmental Protection

Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**Sierra Plaza Well (GOW)**	**Depth of sampled water's origin :**		
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe	
NDEP UIC Permit # :	UNEV92200	**Location :**	Latitude	Longitude
Well ID # :		**Sampler :**	KB	
Type of Well :	Monitor [✓ Production] Injection	**Date Sampled :**	**6/23/2015**	**1055 hrs**
		Name of Laboratory :	TMWA, Wetlab, SEM	

UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	112	SM 2320 B	
aluminum	mg/L	0.05-0.2	<0.045	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.0010	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	0.00550	EPA 200.8	ICP-MS
barium	mg/L	2	0.0845	EPA 200.8	ICP-MS
calcium	mg/L	-	18.4		
chloride	mg/L	400	3.15	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	<0.0050	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	<0.0500	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	5.67	SM 4500 O C	
EC	µS/cm	at 25 degC	222	SM 2510 B	
fluoride	mg/L	4	<0.2	EPA 300.0	Ion Chromatography
haloacetic acids (HAA)	ug/L	60	<2	EPA 552.2	
hardness (as $CaCO_3$)	mg/L	-	93.0		
iron	mg/L	0.6	<0.020	EPA 200.7	ICP
lead	mg/L	0.015	<0.0010	EPA 200.8	ICP-MS
magnesium	mg/L	150	11.4	EPA 200.7	
manganese	mg/L	0.1	<0.0050	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.0002	EPA 200.8	ICP-MS
nickel	mg/L	0.1	<0.0100	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	0.464	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.2	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.57	EPA 150.1	
potassium	mg/L	-	4.60	EPA 200.7	ICP
sodium	mg/L	-	13.0	EPA 200.7	ICP
sulfate	mg/L	500	4.87	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	17.3		
total dissolved solids	mg/L	1000	144	EPA 160.1	
total suspended solids	mg/L	-	<5	EPA 160.2	
total trihalomethanes (TTHM)	ug/L	80	5.7	EPA 524.2	
turbidity	NTU	-	0.19		
zinc	mg/L	5	<0.0100	EPA 200.8	ICP-MS

Comments:

TMWA Rev 1/2011

Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.

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Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 6/23/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: Sierra Plaza Well (GOW) | UIC Permit No.: UNEV92200

Is there any well name or identification at the wellhead? ☒ YES ☐ NO If no, label should be placed on or near wellhead

Project/Facility Name: Truckee Meadows Water Authority

Well Location (SectionTR or Lat/Long) : NE ¼, NE1/4, Sec 6, T18, N20E

City/Valley: Truckee Meadows | County: Washoe

Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other: ____________

Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type: [✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation

Completion date of well: November 14, 2000

Diameter of casing: 16" | Type of Casing: [✓ Steel] PVC Other: ____________

Total depth of well: 315'

Bottom depth of cement for last cemented casing string: 132'

Screened or open hole interval (top/bottom depths): 134'-179', 193'-208', 265'-300'

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: producing water 5 of previous 6 days

Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival? ☒ YES ☐ NO

Was there any problems or damage to the well upon arrival ☐ YES ☒ NO

Was well in an artesian condition prior to sampling? : ☐ YES ☒ NO

WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) : | Depth to water - last event:

Method used to gauge well? : Cap Tube Tape Measure

Measured Water Level : surface

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UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy) :	6/23/15	Time Sampled :	1055
Name of Sampler :	Will Raymond		
Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead" :	<1 foot from wellhead on well discharge pipeline		

Type of Sample (circle one) : [✓ Grab] Composite other (specify):

Collection method (circle one) : well bailed [✓ water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was discharged / purged before collecting sample? : in production

Filtering Note: UIC requirements specify water samples shall not be filtered, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: ______________

Was the sample filtered? : ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

FIELD MEASUREMENTS

pH : 7.57
~~S. Conductivity :~~ NTU : 0.19
Temperature : 17.3°C

What UIC Sample List is required: UIC List 1 UIC List 2 UIC List 3 [✓ Other**] As per Attachment B of permit

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf
Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8016	email Address: : ckropf@tmwa.com
Signature:	Date:

Qualified Sample Person: Will Raymond
Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8138	email Address: wraymond@tmwa.com
Signature:	Date:

Attachments:

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Table A.20. Zone 4: 2Q2015 Extracted Water Chemistry – Delucchi Lane

Nevada Division of Environmental Protection

Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**Delucchi Lane Well**	**Depth of sampled water's origin :**		
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe	
NDEP UIC Permit # :	UNEV92200	**Location :**	Latitude	Longitude
Well ID # :		**Sampler :**	WR/JG	
Type of Well :	Monitor [✓ Production] Injection	**Date Sampled :**	**6/22/2015**	**1400 hrs**
		Name of Laboratory :	TMWA, Wetlab, SEM	

UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	62.0	SM 2320 B	
aluminum	mg/L	0.05-0.2	<0.05	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.001	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	0.002	EPA 200.8	ICP-MS
barium	mg/L	2	0.033	EPA 200.8	ICP-MS
calcium	mg/L	-	12.0		
chloride	mg/L	400	9.10	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	<0.001	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	8.20	SM 4500 O C	
EC	µS/cm	at 25 degC	180	SM 2510 B	
fluoride	mg/L	4	<0.1	EPA 300.0	Ion Chromatography
haloacetic acids (HAA)	ug/L	60	4.20	EPA 552.2	
hardness (as $CaCO_3$)	mg/L	-	47.0		
iron	mg/L	0.6	<0.05	EPA 200.7	ICP
lead	mg/L	0.015	<0.001	EPA 200.8	ICP-MS
magnesium	mg/L	150	4.20	EPA 200.7	
manganese	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
mercury	mg/L	0.002	0.0001	EPA 200.8	ICP-MS
nickel	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	<0.05	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.05	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	6.94	EPA 150.1	
potassium	mg/L	-	1.80	EPA 200.7	ICP
sodium	mg/L	-	15.0	EPA 200.7	ICP
sulfate	mg/L	500	3.80	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	12.7		
total dissolved solids	mg/L	1000	110	EPA 160.1	
total suspended solids	mg/L	-	<5	EPA 160.2	
total trihalomethanes (TTHM)	ug/L	80	44.0	EPA 524.2	
turbidity	NTU	-	0.24		
zinc	mg/L	5	<0.01	EPA 200.8	ICP-MS

Comments:

TMWA Rev 1/2011

Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.

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UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 6/22/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: Delucchi Lane Well (DLW) | UIC Permit No.: UNEV92200
Is there any well name or identification at the wellhead? ☒ YES ☐ NO If no, label should be placed on or near wellhead
Project/Facility Name: Truckee Meadows Water Authority
Well Location (SectionTR or Lat/Long) : APN2546003
City/Valley: Truckee Meadows | County: Washoe
Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other: ____________
Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type: [✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation
Completion date of well: March 1972
Diameter of casing: 14" | Type of Casing: [✓ Steel] PVC Other: ____________
Total depth of well: 323'
Bottom depth of cement for last cemented casing string: 106'
Screened or open hole interval (top/bottom depths): 114'-126', 130'-148', 160'-208', 232'-308'

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: IN production 7 of previous 7 days
Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival? ☒ YES ☐ NO
Was there any problems or damage to the well upon arrival ☐ YES ☒ NO
Was well in an artesian condition prior to sampling? : ☐ YES ☒ NO

WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) : | Depth to water - last event:
Method used to gauge well? : Cap Tube Tape Measure
Measured Water Level : surface

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Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy) : 6/22/15 Time Sampled : 1400 WR

Name of Sampler : Will Raymond

Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead" : <1 foot from wellhead on well discharge pipeline

Type of Sample (circle one) : [✓ Grab] Composite other (specify):

Collection method (circle one) : well bailed [✓ water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was discharged / purged before collecting sample? : in production

Filtering Note: UIC requirements specify water samples shall not be filtered, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: ______________

Was the sample filtered? : ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

FIELD MEASUREMENTS

pH : 6.94
~~S. Conductivity :~~ NTU : 0.24
Temperature : 12.7°C

What UIC Sample List is required: UIC List 1 UIC List 2 UIC List 3 [✓ Other**] As per Attachment B of permit

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8016 email Address: : ckropf@tmwa.com

Signature: Date:

Qualified Sample Person: Will Raymond

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8138 email Address: wraymond@tmwa.com

Signature: Date: 6/22/15

Attachments:

UIC Form 230 (06-01-10) **Page 2 of 2**

Table A.21. Zone 4: 2Q2015 Extracted Water Chemistry – Holcomb Lane

Nevada Division of Environmental Protection

Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**Holcomb Lane Well**	**Depth of sampled water's origin :**		
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe	
NDEP UIC Permit # :	UNEV92200	**Location :**	Latitude	Longitude
Well ID # :		**Sampler :**	WR/JG	
Type of Well :	Monitor [✓ Production] Injection	**Date Sampled :**	**6/22/2015**	**1415 hrs**
		Name of Laboratory :	TMWA, Wetlab, SEM	

UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	58.0	SM 2320 B	
aluminum	mg/L	0.05-0.2	<0.05	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.001	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	<0.001	EPA 200.8	ICP-MS
barium	mg/L	2	0.021	EPA 200.8	ICP-MS
calcium	mg/L	-	10.0		
chloride	mg/L	400	9.20	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	0.005	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	7.90	SM 4500 O C	
EC	µS/cm	at 25 degC	170	SM 2510 B	
fluoride	mg/L	4	<0.1	EPA 300.0	Ion Chromatography
haloacetic acids (HAA)	ug/L	60	<2	EPA 552.2	
hardness (as $CaCO_3$)	mg/L	-	40.0		
iron	mg/L	0.6	<0.05	EPA 200.7	ICP
lead	mg/L	0.015	<0.001	EPA 200.8	ICP-MS
magnesium	mg/L	150	3.60	EPA 200.7	
manganese	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.0001	EPA 200.8	ICP-MS
nickel	mg/L	0.1	0.002	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	0.110	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.05	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.44	EPA 150.1	
potassium	mg/L	-	1.60	EPA 200.7	ICP
sodium	mg/L	-	14.0	EPA 200.7	ICP
sulfate	mg/L	500	3.30	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	13.1		
total dissolved solids	mg/L	1000	90.0	EPA 160.1	
total suspended solids	mg/L	-	<5	EPA 160.2	
total trihalomethanes (TTHM)	ug/L	80	47.0	EPA 524.2	
turbidity	NTU	-	0.27		
zinc	mg/L	5	<0.01	EPA 200.8	ICP-MS

Comments:

TMWA Rev 1/2011

Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.

Nevada Division of Environmental Protection
Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 6/22/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: Holcomb Lane Well (HO1) | UIC Permit No.: UNEV92200

Is there any well name or identification at the wellhead? ☒ YES ☐ NO If no, label should be placed on or near wellhead

Project/Facility Name: Truckee Meadows Water Authority

Well Location (SectionTR or Lat/Long) : T19NR19E

City/Valley: Truckee Meadows | County: Washoe

Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other:

Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type: [✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation

Completion date of well: April 28, 1988

Diameter of casing: 14" | Type of Casing: [✓ Steel] PVC Other:

Total depth of well: 341 feet

Bottom depth of cement for last cemented casing string: 128 feet

Screened or open hole interval (top/bottom depths): 326-299, 289-257, 237-182, 178-148, 141-137

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: in production 6 of previous 6 days

Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival? ☒ YES ☐ NO

Was there any problems or damage to the well upon arrival ☐ YES ☒ NO

Was well in an artesian condition prior to sampling? : ☐ YES ☒ NO

WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) : | Depth to water - last event:

Method used to gauge well? : Cap Tube Tape Measure

Measured Water Level : surface

Nevada Division of Environmental Protection
Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy) :	6/22/15	Time Sampled :	1415

Name of Sampler : Will Raymond

Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead" : <1 foot from wellhead on well discharge pipeline

Type of Sample (circle one) : [✓ Grab] Composite other (specify):

Collection method (circle one) : well bailed [✓ water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was discharged / purged before collecting sample? : in production

Filtering Note: UIC requirements specify water samples shall not be filtered, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: ______________

Was the sample filtered? : ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

FIELD MEASUREMENTS

pH : 7.44
~~S. Conductivity :~~ NTU : 0.27
Temperature : 13.1

What UIC Sample List is required: UIC List 1 UIC List 2 UIC List 3 [✓ Other**] As per Attachment B of permit

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8016	eMail Address: : ckropf@tmwa.com
Signature:	Date:

Qualified Sample Person: Will Raymond

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8138	eMail Address: wraymond@tmwa.com
Signature:	Date: 6/22/15

Attachments:

UIC Form 230 (06-01-10) **Page 2 of 2**

Table A.22. Zone 4: 2Q2015 Extracted Water Chemistry – Lakeside

Nevada Division of Environmental Protection
Underground Injection Control Program - Sampling and Baseline Report Form

Facility Name :	**Lakeside Well (LKS)**	**Depth of sampled water's origin :**		
Facility Owner:	Truckee Meadows Water Authority	**County:**	Washoe	
NDEP UIC Permit # :	UNEV92200	**Location :**	Latitude	Longitude
Well ID # :		**Sampler :**	WR/JG	
Type of Well :	Monitor [✓ Production] Injection	**Date Sampled :**	**6/22/2015**	**1220 hrs**
		Name of Laboratory :	TMWA, Wetlab, SEM	

UIC Sample List 1 Inorganic

Parameter	**Units**	**DW Standards**	Reported Values	EPA Method	Method Description
alkalinity (as $CaCO_3$)	mg/L	-	54.0	SM 2320 B	
aluminum	mg/L	0.05-0.2	<0.05	EPA 200.8	ICP-MS
antimony	mg/L	0.006	<0.001	EPA 200.8	ICP-MS
arsenic	mg/L	0.01	0.001	EPA 200.8	ICP-MS
barium	mg/L	2	0.020	EPA 200.8	ICP-MS
calcium	mg/L	-	11.0		
chloride	mg/L	400	9.50	EPA 300.0	Ion Chromatography
chromium	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
color	color units	15	<2		
copper	mg/L	1.3	0.003	EPA 200.8	ICP-MS
dissolved oxygen	mg/L	-	8.60	SM 4500 O C	
EC	µS/cm	at 25 degC	170	SM 2510 B	
fluoride	mg/L	4	<0.1	EPA 300.0	Ion Chromatography
haloacetic acids (HAA)	ug/L	60	5.80	EPA 552.2	
hardness (as $CaCO_3$)	mg/L	-	43.0		
iron	mg/L	0.6	<0.05	EPA 200.7	ICP
lead	mg/L	0.015	<0.001	EPA 200.8	ICP-MS
magnesium	mg/L	150	3.70	EPA 200.7	
manganese	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
mercury	mg/L	0.002	<0.0001	EPA 200.8	ICP-MS
nickel	mg/L	0.1	<0.001	EPA 200.8	ICP-MS
nitrate (as nitrogen)	mg/L	10	<0.05	EPA 300.0	Ion Chromatography
nitrite (as nitrogen)	mg/L	1	<0.05	EPA 300.0	Ion Chromatography
pH	standard units	6.5-8.5	7.37	EPA 150.1	
potassium	mg/L	-	1.80	EPA 200.7	ICP
sodium	mg/L	-	14.0	EPA 200.7	ICP
sulfate	mg/L	500	4.90	EPA 300.0	Ion Chromatography
temperature	degrees celsius	-	13.7		
total dissolved solids	mg/L	1000	93.0	EPA 160.1	
total suspended solids	mg/L	-	<5	EPA 160.2	
total trihalomethanes (TTHM)	ug/L	80	49.0	EPA 524.2	
turbidity	NTU	-	0.25		
zinc	mg/L	5	0.01	EPA 200.8	ICP-MS

Comments:

TMWA Rev 1/2011

Note: Detection limits must be at least as low as primary or secondary drinking water standards where applicable.
Please indicate detection limit instead of stating "Non-Detect".
Metals shall be sampled and analyzed as total metals.

Nevada Division of Environmental Protection
Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

This form is to be completed in the field while sampling to document the sampling location facts and events, and submitted with the sample results.

Sample Date: (mm/dd/yy) 6/22/15

Complete All Applicable Blanks – Water samples can be rejected if information not provided.

FACILITY AND PERMIT INFORMATION

Well Name & No.: Lakeside Drive Well (LKS) | UIC Permit No.: UNEV92200

Is there any well name or identification at the wellhead? ☒ YES ☐ NO If no, label should be placed on or near wellhead

Project/Facility Name: Truckee Meadows Water Authority

Well Location (SectionTR or Lat/Long) : T19NR19ES35

City/Valley: Truckee Meadows | County: Washoe

Sample for (circle one): NEW WELL [✓ ROUTINE REPORTING] Other: ____________

Reporting Frequency: ☐ Semi-annually ☐ Annually ☒ Other Quarterly

WELL or SAMPLE LOCATION INFORMATION

(Note: If sample location is not a well (e.g. spring), please provide all relevant data on sample location in the space below)

Well Type: [✓ Water/Domestic Well] Monitoring Geo-Prod Geo-Injection Geo-Observation

Completion date of well: October 15, 1991

Diameter of casing: 12.75" | Type of Casing: [✓ Steel] PVC Other: ____________

Total depth of well: 400 feet

Bottom depth of cement for last cemented casing string: 60 feet

Screened or open hole interval (top/bottom depths): 400-180 feet

STATUS OF WELL

Condition or Activity of well during past week/month, prior to sampling: production started within last 7 days

Discuss any field conditions the Division should be aware of with regard to this sample:

Was the well secured upon arrival? ☒ YES ☐ NO

Was there any problems or damage to the well upon arrival ☐ YES ☒ NO

Was well in an artesian condition prior to sampling? : ☐ YES ☒ NO

WATER LEVEL – WELL GAUGING

Last date well gauged (mm/dd/yy) : | Depth to water - last event:

Method used to gauge well? : Cap Tube Tape Measure

Measured Water Level : surface

UIC Form 230 (06-01-10) **Page 1 of 2**

Nevada Division of Environmental Protection
Bureau of Water Pollution Control
Underground Injection Control Program
901 S. Stewart St Ste 4001
Carson City Nevada 89701
Ph: 775-687-9418 Fx: 775-687-4684

UIC Form U230 – Field Sampling & Monitoring Summary

SAMPLING INFORMATION

Date sample collected (mm/dd/yy) : 6/22/15 Time Sampled : 1220 WR

Name of Sampler : Will Raymond

Location sample taken (be specific) "sample port in pipeline 10 feet from wellhead" : <1 foot from wellhead on well discharge pipeline

Type of Sample (circle one) : [✓ Grab] Composite other (specify):

Collection method (circle one) : well bailed [✓ water pumped] artesian flow air/gas lift

How much fluid (gallons or well volumes) was discharged / purged before collecting sample? : in production

<u>Filtering Note</u>: UIC requirements specify water samples <u>shall not be filtered</u>, unless previously approved. If filtration is approved, sample shall be filtered with a 1.0 micron filter, not 0.45 micron. If approved, document date of approval: _______________

Was the sample filtered? : ☐ YES ☒ NO

Was conductivity measured during discharge to establish stabilized conditions? ☐ YES ☒ NO-stabilized conditions determined by pH and temp

Was decontamination procedures (reference O & M?) followed during sampling of multiple wells ☒ YES ☐ NO

<u>FIELD MEASUREMENTS</u>

pH : 7.37
~~S. Conductivity :~~ NTU : 0.25
Temperature : 13.7

What UIC Sample List is <u>required</u>: UIC List 1 UIC List 2 UIC List 3 [✓ Other**] <u>As per Attachment B of permit</u>

** Other constituent listed must have prior UIC approval before using

Were any holding times exceeded? ☐ YES ☒ NO

In Final sample documentation, ensure all results are reported with appropriate units. If measurements are below detection limits, indicate detection limit value.

DO NOT REPORT VALUES AS NON-DETECT OR ND, INSTEAD REPORT as <(*Detection Limit Value*)

FORM PREPARATION

Project Manager: Christian Kropf

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8016 eMail Address: : <u>ckropf@tmwa.com</u>

Signature: Date:

Qualified Sample Person: Will Raymond

Company: Truckee Meadows Water Authority

Telephone No.: 775-834-8138 eMail Address: <u>wraymond@tmwa.com</u>

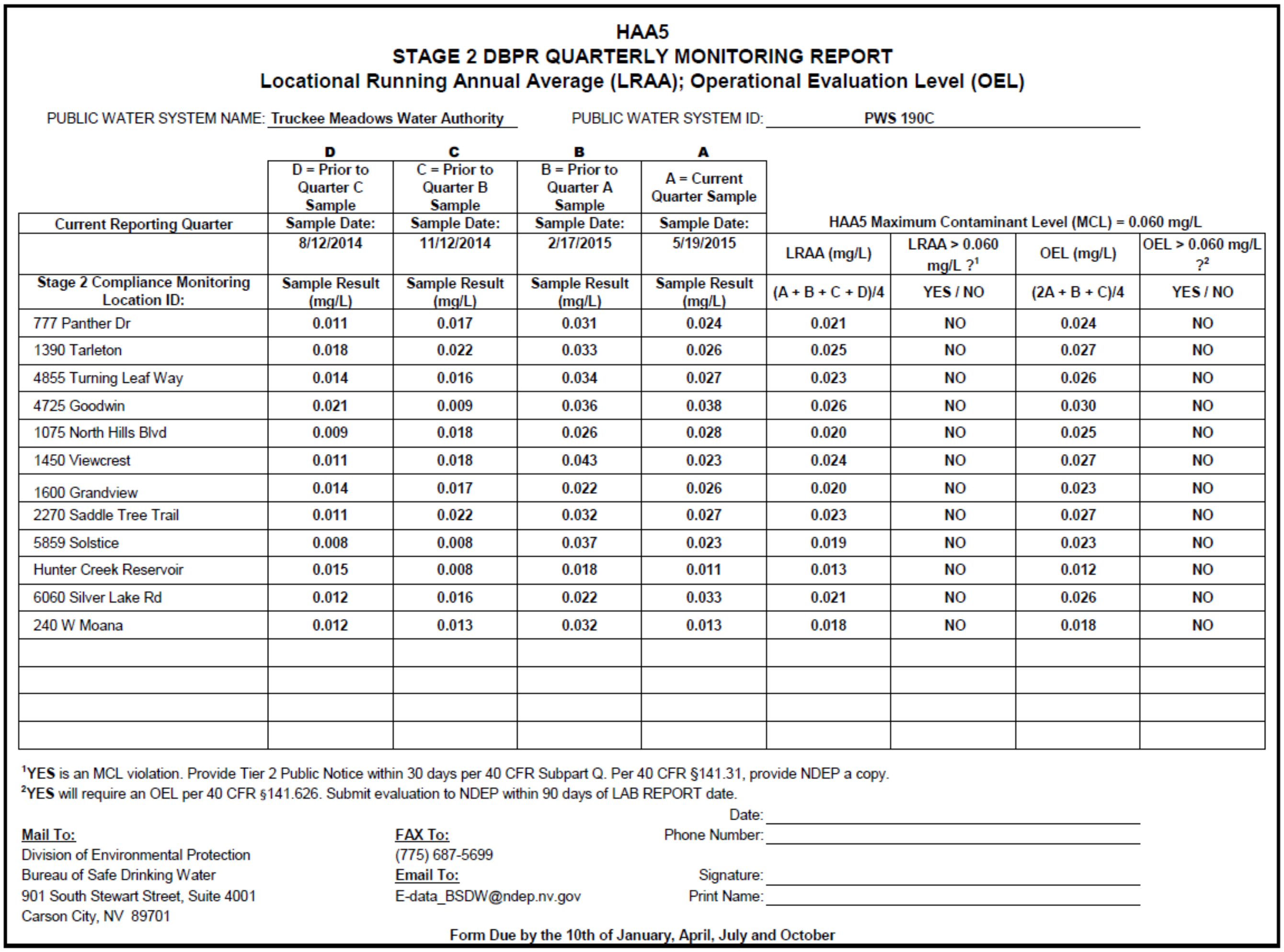
Signature: Date: 6/22/15

Attachments:

UIC Form 230 (06-01-10) **Page 2 of 2**

APPENDIX B: DISINFECTION BY-PRODUCTS

Table B.1. Disinfection By-Products (DBP) Report – 1st Half 2015: HAA5



HAA5
STAGE 2 DBPR QUARTERLY MONITORING REPORT
Locational Running Annual Average (LRAA); Operational Evaluation Level (OEL)

PUBLIC WATER SYSTEM NAME: **Truckee Meadows Water Authority** PUBLIC WATER SYSTEM ID: **PWS 190C**

	D	**C**	**B**	**A**				
	D = Prior to Quarter C Sample	C = Prior to Quarter B Sample	B = Prior to Quarter A Sample	A = Current Quarter Sample				
Current Reporting Quarter	**Sample Date:**	**Sample Date:**	**Sample Date:**	**Sample Date:**	**HAA5 Maximum Contaminant Level (MCL) = 0.060 mg/L**			
	8/12/2014	11/12/2014	2/17/2015	5/19/2015	LRAA (mg/L)	LRAA > 0.060 mg/L ?[1]	OEL (mg/L)	OEL > 0.060 mg/L ?[2]
Stage 2 Compliance Monitoring Location ID:	**Sample Result (mg/L)**	**Sample Result (mg/L)**	**Sample Result (mg/L)**	**Sample Result (mg/L)**	(A + B + C + D)/4	YES / NO	(2A + B + C)/4	YES / NO
777 Panther Dr	0.011	0.017	0.031	0.024	0.021	NO	0.024	NO
1390 Tarleton	0.018	0.022	0.033	0.026	0.025	NO	0.027	NO
4855 Turning Leaf Way	0.014	0.016	0.034	0.027	0.023	NO	0.026	NO
4725 Goodwin	0.021	0.009	0.036	0.038	0.026	NO	0.030	NO
1075 North Hills Blvd	0.009	0.018	0.026	0.028	0.020	NO	0.025	NO
1450 Viewcrest	0.011	0.018	0.043	0.023	0.024	NO	0.027	NO
1600 Grandview	0.014	0.017	0.022	0.026	0.020	NO	0.023	NO
2270 Saddle Tree Trail	0.011	0.022	0.032	0.027	0.023	NO	0.027	NO
5859 Solstice	0.008	0.008	0.037	0.023	0.019	NO	0.023	NO
Hunter Creek Reservoir	0.015	0.008	0.018	0.011	0.013	NO	0.012	NO
6060 Silver Lake Rd	0.012	0.016	0.022	0.033	0.021	NO	0.026	NO
240 W Moana	0.012	0.013	0.032	0.013	0.018	NO	0.018	NO

[1] **YES** is an MCL violation. Provide Tier 2 Public Notice within 30 days per 40 CFR Subpart Q. Per 40 CFR §141.31, provide NDEP a copy.

[2] **YES** will require an OEL per 40 CFR §141.626. Submit evaluation to NDEP within 90 days of LAB REPORT date.

Date:

Phone Number:

Signature:

Print Name:

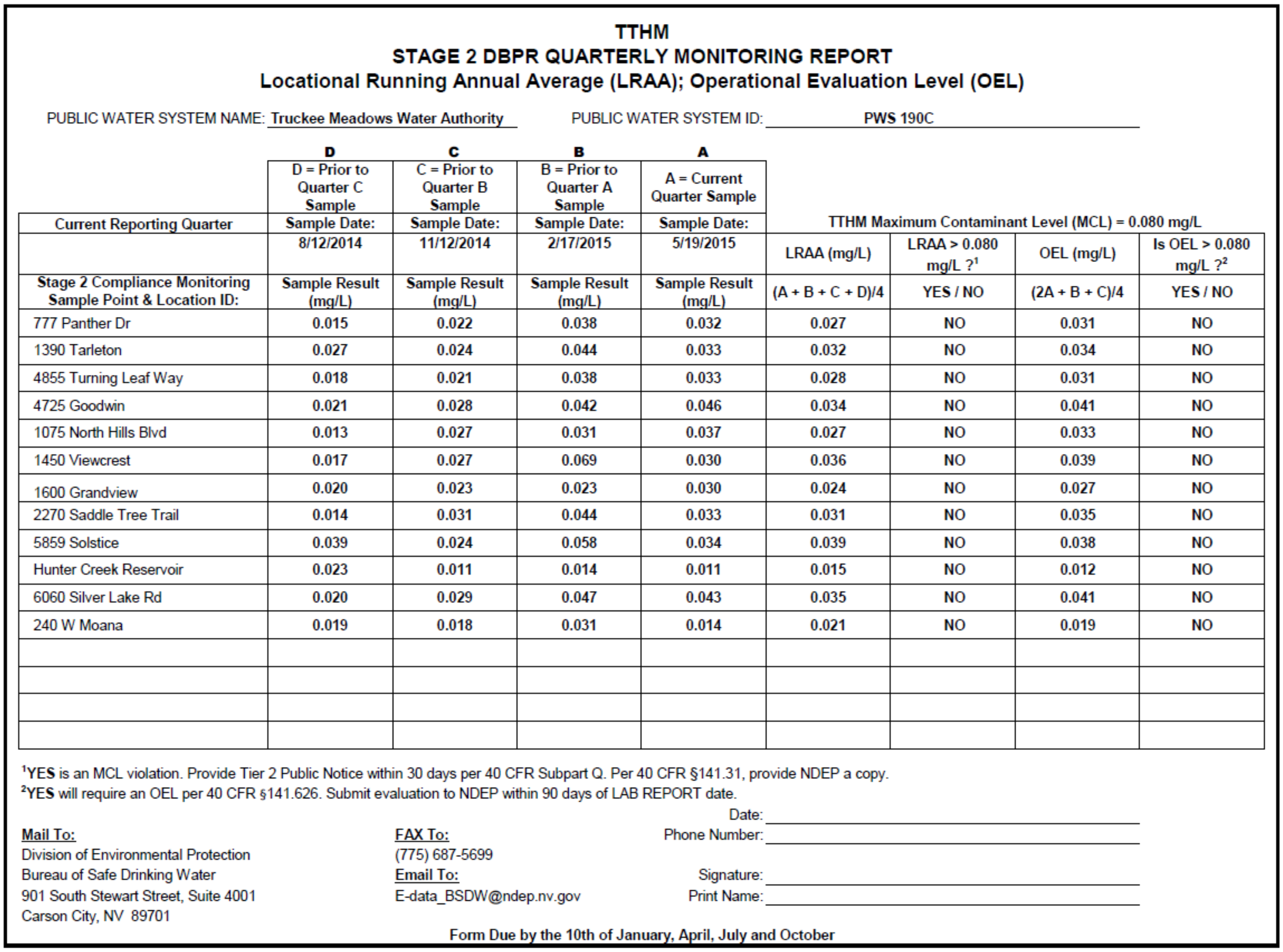
Mail To:
Division of Environmental Protection
Bureau of Safe Drinking Water
901 South Stewart Street, Suite 4001
Carson City, NV 89701

FAX To:
(775) 687-5699

Email To:
E-data_BSDW@ndep.nv.gov

Form Due by the 10th of January, April, July and October

Table B.2. Disinfection By-Products (DBP) Report – 1st Half 2015: TTHM



TTHM
STAGE 2 DBPR QUARTERLY MONITORING REPORT
Locational Running Annual Average (LRAA); Operational Evaluation Level (OEL)

PUBLIC WATER SYSTEM NAME: Truckee Meadows Water Authority PUBLIC WATER SYSTEM ID: **PWS 190C**

	D	**C**	**B**	**A**				
	D = Prior to Quarter C **Sample**	C = Prior to Quarter B **Sample**	B = Prior to Quarter A **Sample**	A = Current Quarter Sample				
Current Reporting Quarter	**Sample Date:**	**Sample Date:**	**Sample Date:**	**Sample Date:**	**TTHM Maximum Contaminant Level (MCL) = 0.080 mg/L**			
	8/12/2014	11/12/2014	2/17/2015	5/19/2015	LRAA (mg/L)	LRAA > 0.080 mg/L ?[1]	OEL (mg/L)	Is OEL > 0.080 mg/L ?[2]
Stage 2 Compliance Monitoring Sample Point & Location ID:	**Sample Result (mg/L)**	**Sample Result (mg/L)**	**Sample Result (mg/L)**	**Sample Result (mg/L)**	(A + B + C + D)/4	YES / NO	(2A + B + C)/4	YES / NO
777 Panther Dr	0.015	0.022	0.038	0.032	0.027	NO	0.031	NO
1390 Tarleton	0.027	0.024	0.044	0.033	0.032	NO	0.034	NO
4855 Turning Leaf Way	0.018	0.021	0.038	0.033	0.028	NO	0.031	NO
4725 Goodwin	0.021	0.028	0.042	0.046	0.034	NO	0.041	NO
1075 North Hills Blvd	0.013	0.027	0.031	0.037	0.027	NO	0.033	NO
1450 Viewcrest	0.017	0.027	0.069	0.030	0.036	NO	0.039	NO
1600 Grandview	0.020	0.023	0.023	0.030	0.024	NO	0.027	NO
2270 Saddle Tree Trail	0.014	0.031	0.044	0.033	0.031	NO	0.035	NO
5859 Solstice	0.039	0.024	0.058	0.034	0.039	NO	0.038	NO
Hunter Creek Reservoir	0.023	0.011	0.014	0.011	0.015	NO	0.012	NO
6060 Silver Lake Rd	0.020	0.029	0.047	0.043	0.035	NO	0.041	NO
240 W Moana	0.019	0.018	0.031	0.014	0.021	NO	0.019	NO

[1] **YES** is an MCL violation. Provide Tier 2 Public Notice within 30 days per 40 CFR Subpart Q. Per 40 CFR §141.31, provide NDEP a copy.
[2] **YES** will require an OEL per 40 CFR §141.626. Submit evaluation to NDEP within 90 days of LAB REPORT date.

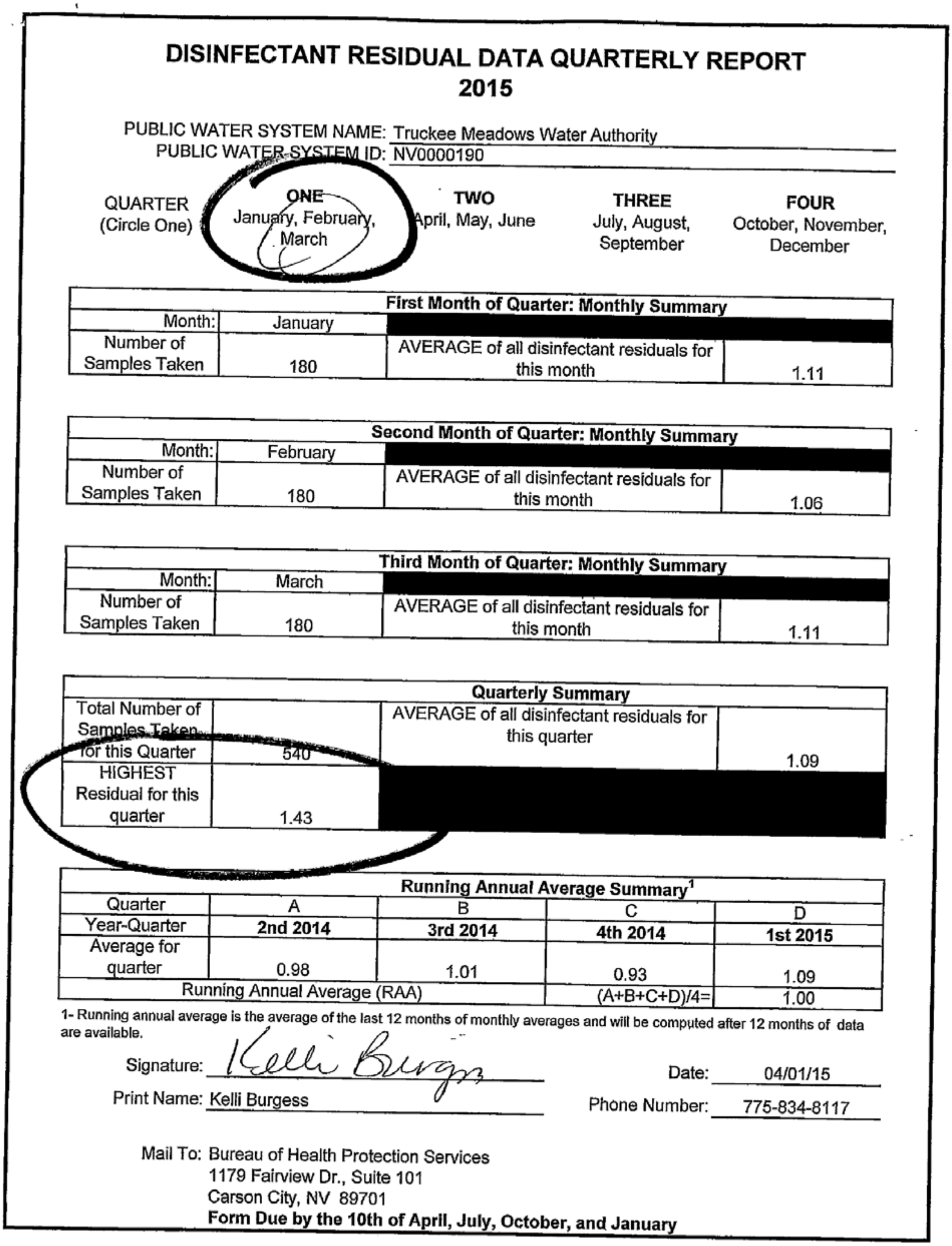
Date: ______________________
Phone Number: ______________________
Signature: ______________________
Print Name: ______________________

Mail To:
Division of Environmental Protection
Bureau of Safe Drinking Water
901 South Stewart Street, Suite 4001
Carson City, NV 89701

FAX To:
(775) 687-5699
Email To:
E-data_BSDW@ndep.nv.gov

Form Due by the 10th of January, April, July and October

Table B.3. Zone 5: 1Q 2015 Disinfectant Residual Data



DISINFECTANT RESIDUAL DATA QUARTERLY REPORT
2015

PUBLIC WATER SYSTEM NAME: Truckee Meadows Water Authority
PUBLIC WATER SYSTEM ID: NV0000190

QUARTER (Circle One) [✓ **ONE** January, February, March] **TWO** April, May, June **THREE** July, August, September **FOUR** October, November, December

		First Month of Quarter: Monthly Summary	
Month:	January		
Number of Samples Taken	180	AVERAGE of all disinfectant residuals for this month	1.11

		Second Month of Quarter: Monthly Summary	
Month:	February		
Number of Samples Taken	180	AVERAGE of all disinfectant residuals for this month	1.06

		Third Month of Quarter: Monthly Summary	
Month:	March		
Number of Samples Taken	180	AVERAGE of all disinfectant residuals for this month	1.11

		Quarterly Summary	
Total Number of Samples Taken for this Quarter	540	AVERAGE of all disinfectant residuals for this quarter	1.09
HIGHEST Residual for this quarter	1.43		

			Running Annual Average Summary[1]	
Quarter	A	B	C	D
Year-Quarter	**2nd 2014**	**3rd 2014**	**4th 2014**	**1st 2015**
Average for quarter	0.98	1.01	0.93	1.09
Running Annual Average (RAA)			(A+B+C+D)/4=	1.00

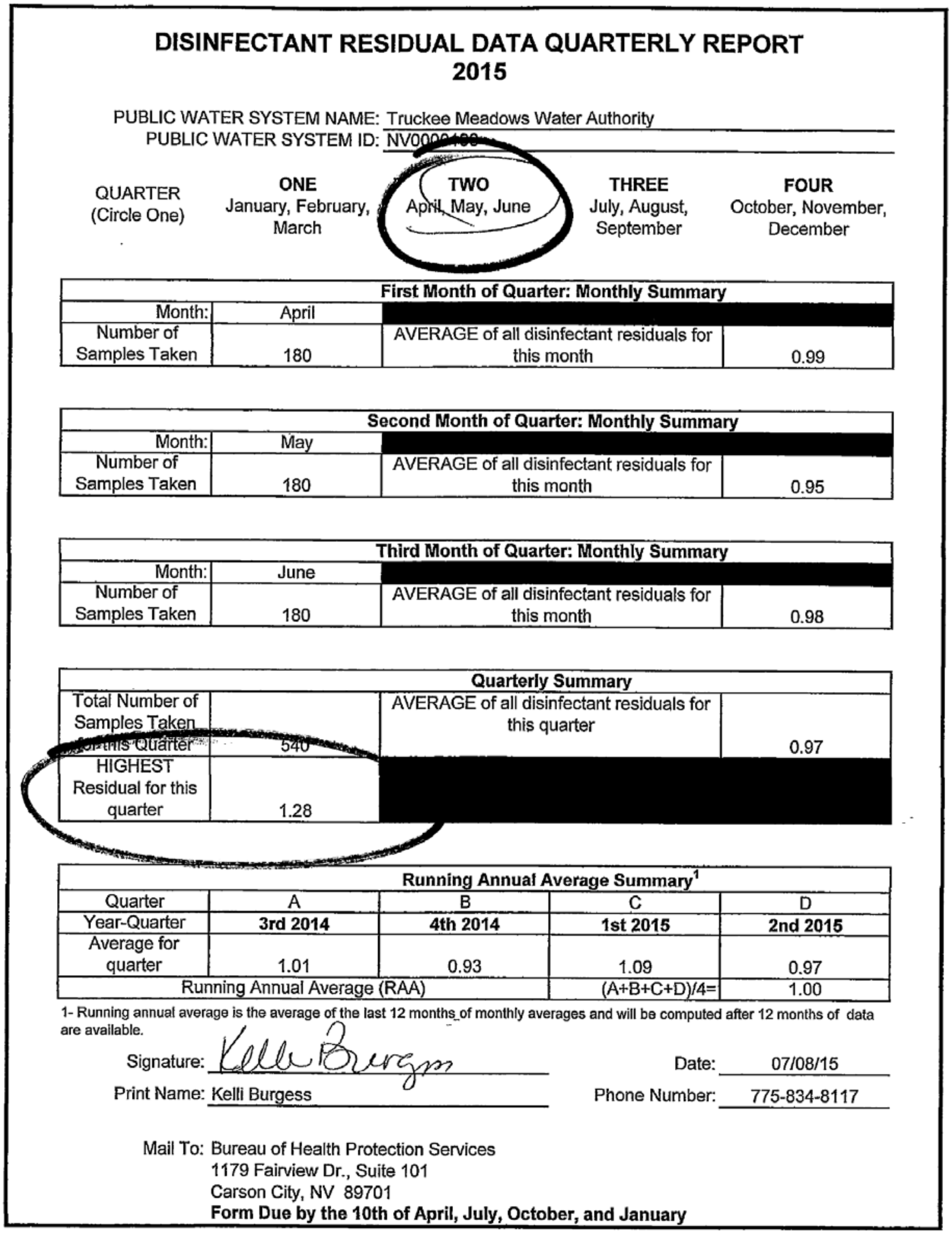
1- Running annual average is the average of the last 12 months of monthly averages and will be computed after 12 months of data are available.

Signature: Kelli Burgess
Date: 04/01/15

Print Name: Kelli Burgess
Phone Number: 775-834-8117

Mail To: Bureau of Health Protection Services
1179 Fairview Dr., Suite 101
Carson City, NV 89701
Form Due by the 10th of April, July, October, and January

Table B.3. Zone 5: 2Q 2015 Disinfectant Residual Data



DISINFECTANT RESIDUAL DATA QUARTERLY REPORT
2015

PUBLIC WATER SYSTEM NAME: Truckee Meadows Water Authority
PUBLIC WATER SYSTEM ID: NV0000190

QUARTER (Circle One)	ONE	[✓ TWO]	THREE	FOUR
	January, February, March	[✓ April, May, June]	July, August, September	October, November, December

First Month of Quarter: Monthly Summary			
Month:	April		
Number of Samples Taken	180	AVERAGE of all disinfectant residuals for this month	0.99

Second Month of Quarter: Monthly Summary			
Month:	May		
Number of Samples Taken	180	AVERAGE of all disinfectant residuals for this month	0.95

Third Month of Quarter: Monthly Summary			
Month:	June		
Number of Samples Taken	180	AVERAGE of all disinfectant residuals for this month	0.98

Quarterly Summary			
Total Number of Samples Taken for this Quarter	540	AVERAGE of all disinfectant residuals for this quarter	0.97
HIGHEST Residual for this quarter	1.28		

Running Annual Average Summary[1]				
Quarter	A	B	C	D
Year-Quarter	**3rd 2014**	**4th 2014**	**1st 2015**	**2nd 2015**
Average for quarter	1.01	0.93	1.09	0.97
Running Annual Average (RAA)			(A+B+C+D)/4=	1.00

1- Running annual average is the average of the last 12 months of monthly averages and will be computed after 12 months of data are available.

Signature: Kelli Burgess
Date: 07/08/15
Print Name: Kelli Burgess
Phone Number: 775-834-8117

Mail To: Bureau of Health Protection Services
1179 Fairview Dr., Suite 101
Carson City, NV 89701
Form Due by the 10th of April, July, October, and January

TRUCKEE MEADOWS WATER
AUTHORITY

APPENDIX 3-2

MULTI-CENTURY EVALUATION

OF

SIERRA NEVADA SNOWPACK

CORRESPONDENCE:

Multi-century evaluation of Sierra Nevada snowpack

To the Editor — California is currently experiencing a record-setting drought that started in 2012 and recently culminated in the first ever mandatory state-wide water restriction[1]. The snowpack conditions in the Sierra Nevada mountains present an ominous sign of the severity of this drought: the 1 April 2015 snow water equivalent (SWE) was at only 5% of its historical average[2]. In the Mediterranean climate of California, with 80% of the precipitation occurring during winter months, Sierra Nevada snowpack plays a critical role in replenishing the state's water reservoirs and provides 30% of its water supply[3]. As a result, a multi-year and severe snowpack decline can acutely impact human and natural systems, including urban and agricultural water supplies, hydroelectric power[4] and wildfire risk[5].

The exceptional character of the 2012–2015 drought has been revealed in millennium-length palaeoclimate records[6], but no long-term historical context is available for the recent snowpack decline. Here, we present an annually resolved reconstruction of 1 April SWE conditions over the whole Sierra Nevada range for the past 500 years (Fig. 1). We combined an extensive compilation of blue oak tree-ring series that reflects large-scale California winter precipitation anomalies[7] (Supplementary Information and Supplementary Fig. 1) with a tree-ring-based California February–March temperature record[8] in a reconstruction that explains 63% of the Sierra Nevada SWE variance over the instrumental period (Supplementary Table 1). Our reconstruction shows strong statistical skill (Supplementary Table 2), but underestimates anomalously high SWE values over the instrumental period (for example, in 1952 and 1969). However, SWE lows (for example, in 1934 and 1977) are reliably captured and our reconstruction reveals that the 2015 low is unprecedented in the context of the past 500 years (Fig. 1). Our error estimation indicates that there is a possibility that a few (primarily sixteenth century) years exceeded the 2015 low, but the estimated return interval for the 2015 SWE value — as calculated based on a generalized extreme value (GEV) distribution (Supplementary Information) — is 3,100 years and confirms its exceptional character. GEV-estimated return intervals

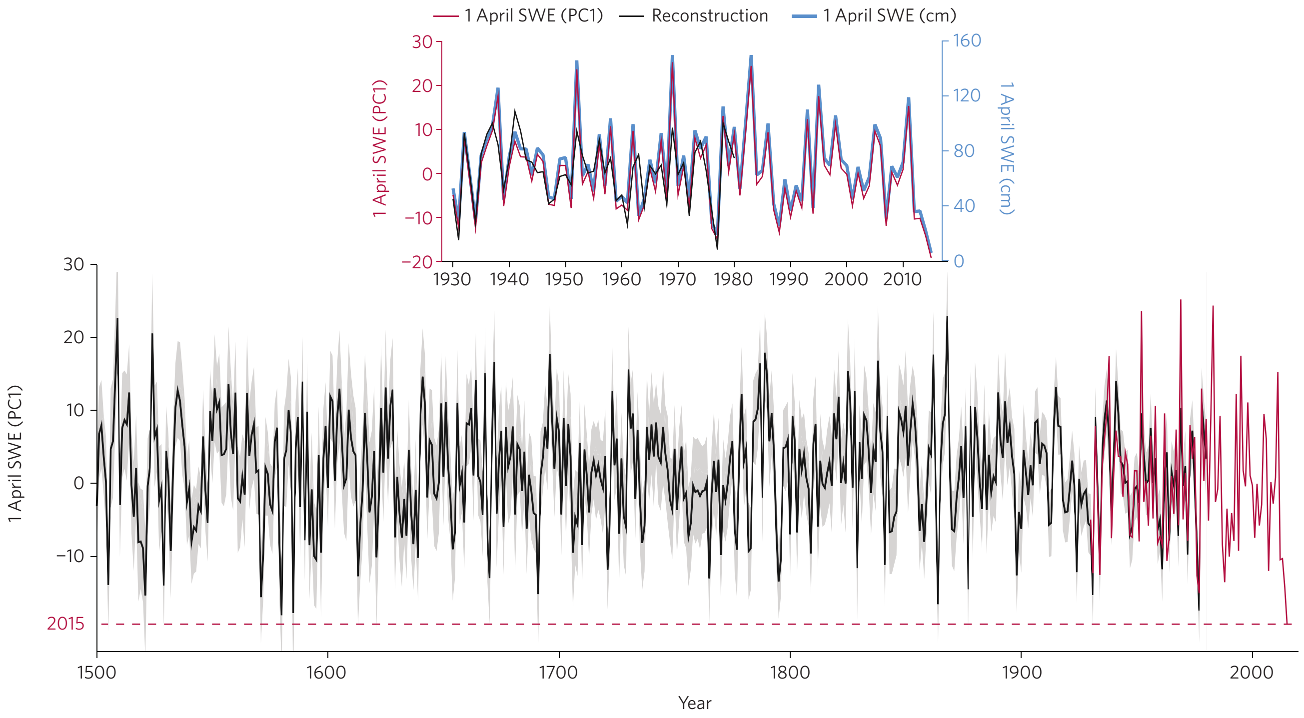


Figure 1 | Sierra Nevada 1 April snow water equivalent reconstruction (1500–1980). Bottom: instrumental (1930–2015; red curve) and reconstructed (1500–1980; black curve) first Principal Component (PC1) of Sierra Nevada 1 April snow water equivalent (SWE) values. The SWE reconstruction was calibrated against the PC1 of 1 April SWE measurements from 108 Sierra Nevada stations and explains 63% of its variance over the period of overlap (1930–1980; top). The 108-station average SWE value (in cm; 1930–2015) is plotted for comparison (blue curve; top). The grey shading around the reconstruction (bottom) indicates the combined error estimation (Supplementary Information). The 2015 SWE value is indicated by the red dashed line.

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can have large confidence intervals (Supplementary Fig. 2), but the 2015 SWE value exceeds the 95% confidence interval for a 500-year return period (Supplementary Fig. 3). In comparison, the previous lowest SWE reading (in 1977) exceeds the 95% confidence interval for only a 60-year return period. We also find that the 2015 SWE value is strongly exceptional — exceeding the 95% confidence interval for a 1,000-year return period — at low-elevation Sierra Nevada sites where winter temperature has strong control over SWE[9], but less so at high-elevation sites, where it exceeds the 95% confidence interval for only a 95-year return period (Supplementary Information and Supplementary Fig. 2).

The 2015 record low snowpack coincides with record high California January–March temperatures[10] and highlights the modulating role of temperature extremes in Californian drought severity. Snowpack lows, among other drought metrics, are driven by the co-occurrence of precipitation deficits and high temperature extremes[11], and we find that the exacerbating effect of warm winter temperatures[12] is stronger at low than at high Sierra Nevada elevations. Anthropogenic warming is projected to further increase the probability of severe drought events[13], advance the timing of spring snowmelt and increase rain-to-snow ratios[14]. The ongoing and projected role of temperature in the amount and duration of California's primary natural water storage system thus foreshadows major future impacts on the state's water supplies. ❐

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Acknowledgements

This work was supported by a National Science Foundation CAREER grant (AGS-1349942), a grant from the Department of the Interior Southwest Climate Science Center (US Geological Survey; G13AC00339) and a Swiss National Science Foundation grant (P300P2_154543). We are grateful to Kevin Anchukaitis for discussion and useful input.

Additional information

Supplementary information is available in the online version of the paper.

Author contributions

S.B., F.B. and V.T. conceived and designed the study, and wrote the Correspondence with input from E.R.W. and D.W.S. E.R.W. and D.W.S. contributed data and S.B. and F.B. performed the analyses with input from V.T. All authors contributed to the interpretation of the data set and discussion.

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TRUCKEE MEADOWS WATER AUTHORITY

APPENDIX 3-3

MULTIYEAR MODEL SIMULATIONS UNDER TROA OPERATIONS

STAFF REPORT

TO: Board of Directors
FROM: Bill Hauck, Senior Hydrologist
DATE: September 7, 2015
SUBJECT: **Presentation and Discussion of TROA Operations During Drought Periods**

FINDINGS

- Under the Truckee River Operating Agreement (TROA) operations, TMWA's projected upstream drought reserve storage is more than adequate to meet customer demand for an additional five (5) years at current demands with repetitive 2015 hydrology, and actually improves with each successive year under the modeled worse-case scenario.
- Under current non-TROA operations, TMWA's projected upstream drought reserves are adequate for another two years at the current demand levels with repetitive 2015 hydrology, but are projected to begin falling short by late September 2017 as reserves are used up. In year eight (8) of the modeled worse-than-worse-case drought, upstream reserves are projected to completely run out during the summer 2018. TMWA would not be able to meet customer demand in years 2018-2020 at current levels under a non-TROA operation.

INTRODUCTION

In order to test the robustness of the region's water supply (in particular the back-up water supply) a hypothetical, five-year worse-than-worse-case hydrologic scenario was developed and processed through a RiverWare Truckee River operations model with actual initial starting conditions, under both a TROA and non-TROA operating regime.

The last four years (2012, 2013, 2014, and 2015) have been the driest back-to-back winters in recorded history, producing the smallest amount of runoff ever seen over a four year period in the Truckee River system. Out of 115 years of actual hydrologic data available for the Truckee River, 2015 was the driest on record. It had the lowest recorded snowpack and the lowest recorded natural runoff. It was also 12% drier than the previous driest year on record which was 1977. Water year 2015 is by any definition the worst water year on record. Creating a hypothetical hydrology that repeats actual 2015 hydrologic conditions for an additional five (5) years could be considered a worse-than-worse-case drought.

What was developed then modeled is in essence a nine-year drought with actual conditions through the first four years (2012-2015) with a repeat of 2015 hydrology for an additional five years (2016-2020). The 9-year drought used for these purposes to test the resiliency of the region's water supply is over two times more severe than the drought of record (1987-1994) plus the additional dry year (1987) currently used for planning purposes. The hypothetical drought has a total April-July runoff volume of just 590 thousand acre-feet (KAF) over the nine-year period compared to an April-July runoff total of 1,271 KAF for the drought of record (with a repeat of 1987) for a total of nine years.

DISCUSSION

The hypothetical drought with actual initialized starting conditions were processed in a RiverWare operations model developed by US Bureau of Reclamation in consultation with the TROA parties to simulate Truckee River operations under both TROA and non-TROA conditions.

The elevation of Lake Tahoe would not be any different under a TROA or non-TROA scenario as the elevation of the lake is currently below its natural outlet. With a repeat of 2015 hydrology for another five years, the elevation of Tahoe would continue to decline under both a TROA and non-TROA condition so that by the end of the fifth modeled year (December 31, 2020) it would be almost eight (8) feet below its natural outlet elevation of 6223.00 feet. See Figure 1 below which shows the continued decline in Tahoe's elevation over the next five years.

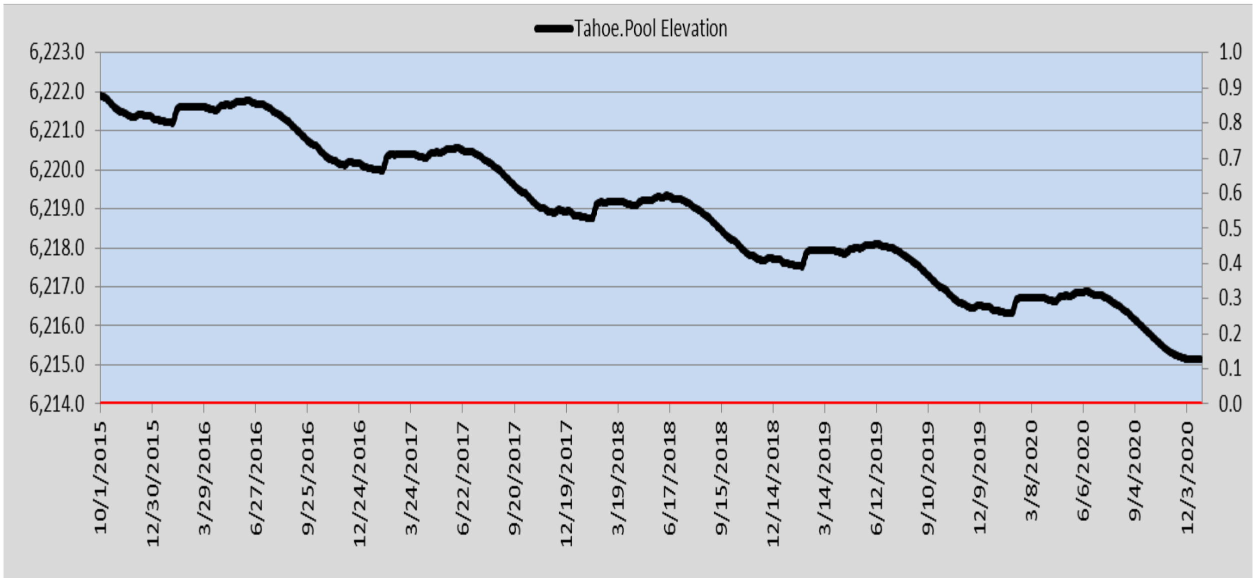

Figure 1. Lake Tahoe: TROA or non-TROA Scenario

The operation of Donner Lake would look very similar in either a TROA or non-TROA scenario also. The usable storage would continue to be released as part of TMWA's drought reserves to meet customer demand beginning on or about September 01 of each year. The lake would then be re-filled again in the spring so that by June 01 of each year storage would be approximately 80% of capacity. See Figure 2 which shows projected storage in acre-feet (2015-2020).

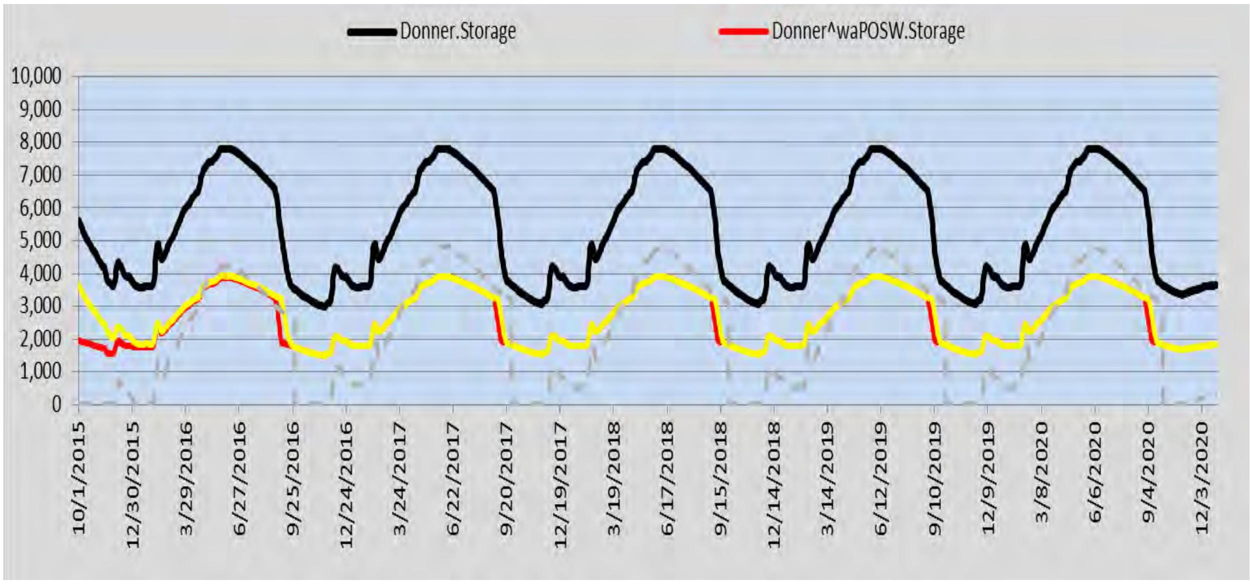

Figure 2. Donner Lake: TROA or non-TROA Scenario

Independence Lake would continue to be operated much like it has been to this point under a TROA scenario as well. See Figure 3 below which shows projected reservoir storage in acre-feet through 2020.

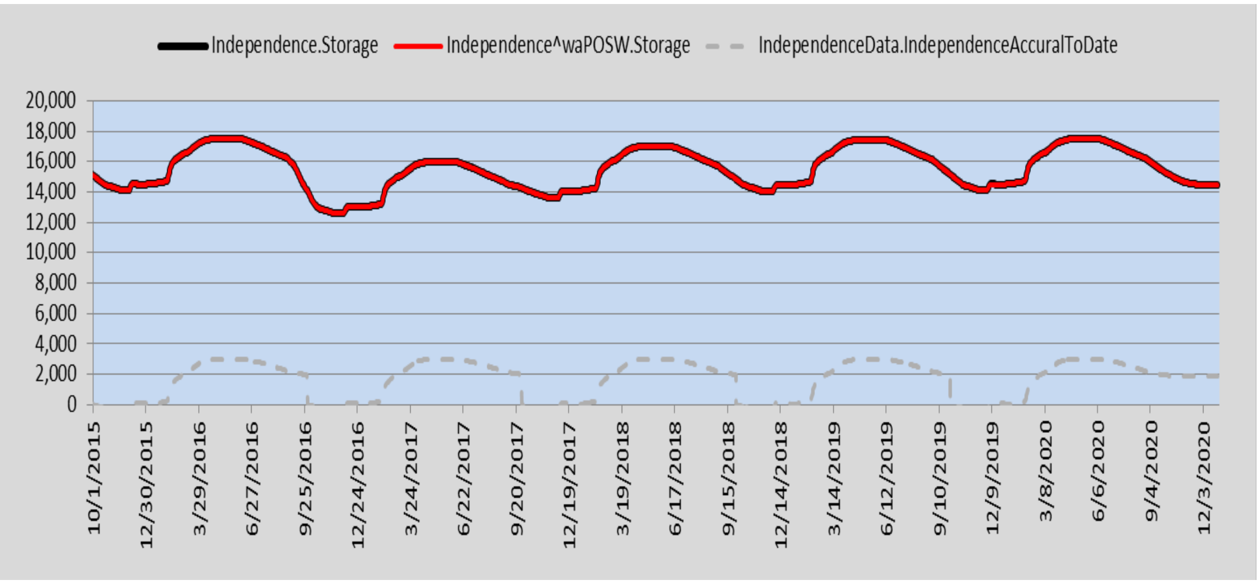

Figure 3. Independence Lake: TROA Scenario

The elevation of Independence Lake would be drawn down each fall as water is released to make room for upcoming spring runoff season and moved down into Stampede Reservoir. The lake would then be re-filled again each spring as usual.

Stampede Reservoir operations, however, would look significantly different under a TROA scheme. Under TROA (as conditions allow), TMWA will be able to begin holding back (in

Stampede Reservoir, among others) the consumptive use fraction of some of its previously unexercised water rights of up to 11,600 acre-feet per year. Figure 4 for example shows projected Stampede Reservoir storage for the next five years. The model shows that TMWA is able to store water throughout the entire planning window (2015-2020) building up drought reserves each year, and continuing to accrue more and more water each successive year.

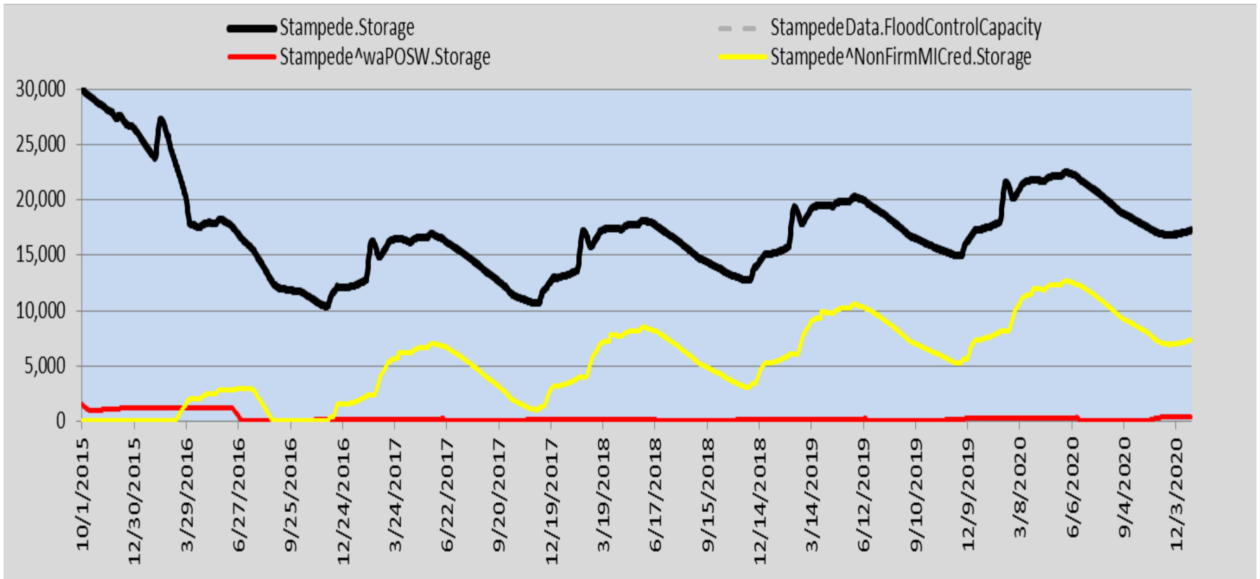

Figure 4. Stampede Reservoir: TROA Scenario

Between Stampede, Boca and Prosser reservoirs, the model results show that TMWA is able to establish the full 11,600 acre-feet each year. This is in addition to TMWA privately-owned water stored in Donner and Independence Lakes. Figure 5 illustrates this point and shows the cumulative surface water sources available each year through 2020 which TMWA would own and/or have available. It can be seen that throughout the course of the year TMWA fills, releases and re-fills these various buckets of water to create a water supply. And that in each year TMWA is using less drought reserve water than it requires or a portion of the total on-hand to meet customer demand, and is actually able continue to accrue and build-up storage, improving its upstream water supply position each year under a TROA operation.

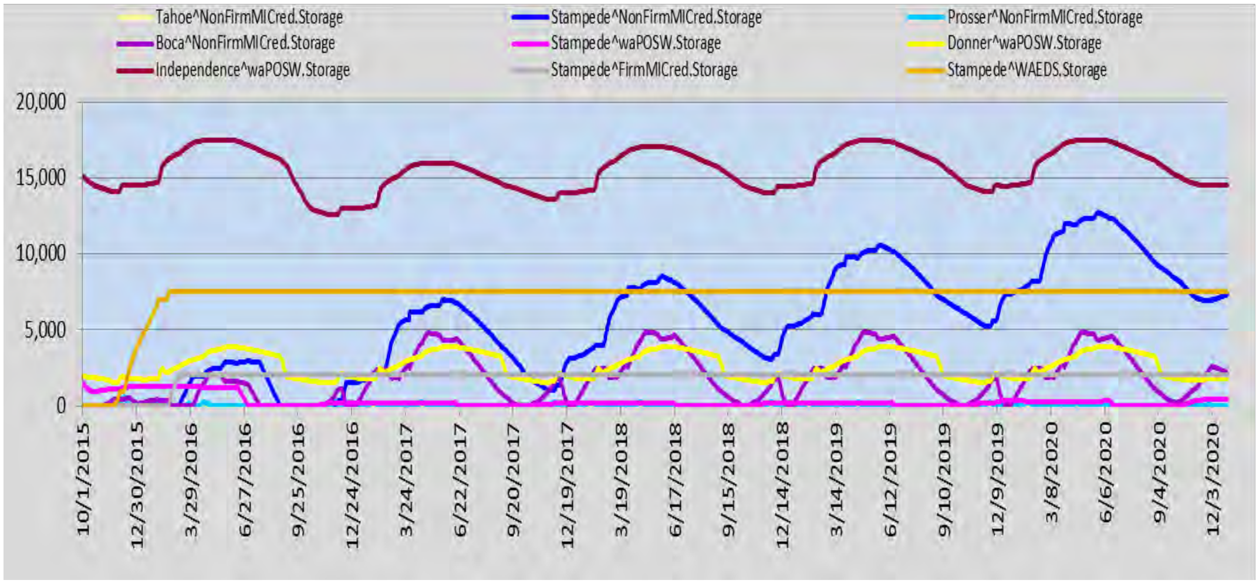

Figure 5. TMWA Total Surface Water Storage: TROA Scenario

Model results show that by the summer of 2020 (June 1st) TMWA would have over 46,000 acre-feet of combined stored surface water in reserve and available for backup (almost double what TMWA had going into the summer of 2015) at current demand levels. This occurs despite a repeat of the worst hydrological conditions for an additional four years (2016-2019). By the end of 2020 (Dec 31, 2020) TMWA would still have almost 34,000 acre-feet in reserve stored between Stampede and Boca Reservoirs and Independence Lake.

The non-TROA modeled scenario on the other hand, while quite resilient is not robust enough to withstand a repeat of 2015 hydrology for another five consecutive years. The results of the model show that TMWA can basically only make it through another two years at current demand levels. The model shows TMWA using roughly 12,000 acre-feet of Independence Lake storage next summer (2016) in order to meet customer demand. This would bring storage down to around 5,500 acre-feet just prior to the winter months of 2016/2017. See Figure 6. TMWA would go into the summer of 2017 with approximately 8,500 acre-feet of storage in Independence Lake which would then be used directly to meet customer demand starting on or about July 1, 2017.

The water stored in Independence Lake along with TMWA's drought reserves in Donner Lake would be relied upon heavily and begin to run out by the end of September 2017. Figure 7 shows that by October 1, 2017 the model predicts that TMWA has no surface water left in storage. Note that the water shown as "Donner^waPOSW" in Figure 7 on Oct 1 is what is defined as dead storage (i.e. water that cannot be released to meet demand because it is below the natural outlet of the lake).

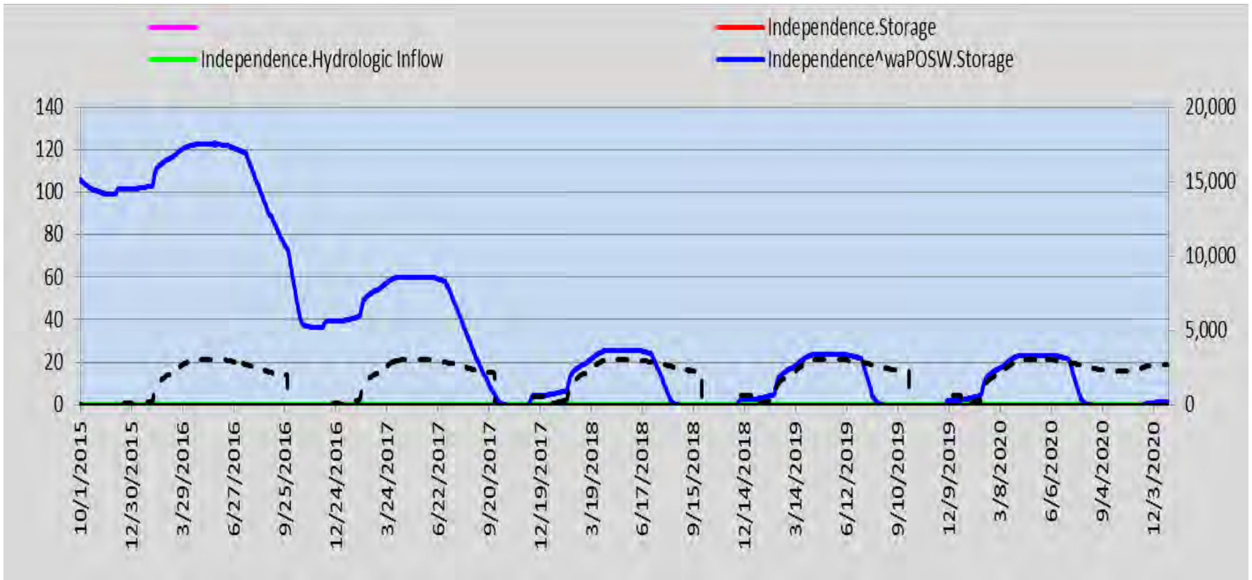

Figure 6. Independence Lake: non-TROA Scenario

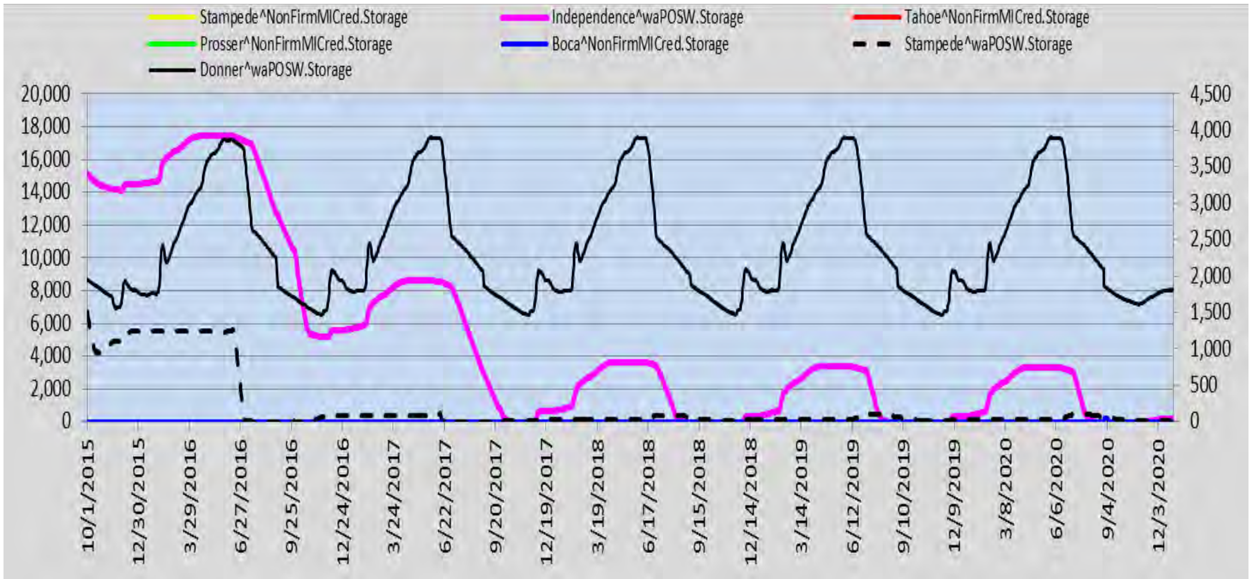

Figure 7. TMWA Total Surface Water Storage: non-TROA Scenario

SUMMARY

The results of the model runs show that with TROA the region can withstand a hypothetical drought more than 2 times as severe as the drought of record - the 1987-1994 drought plus additional dry year (1987) added onto the back end to create a nine-year event.

Under TROA operations, by the end of the nine-year simulated drought, the model shows that TMWA would still have almost twice as much upstream drought storage as it did going into the summer of 2015. The hypothetical hydrology created for this analysis repeated actual 2015 hydrology for an additional five years onto the end of the current four-year drought (2012-2015).

The additional 5 year worse-than-worse-case hydrology makes for a hypothetical drought unlike the Truckee River system has ever seen in recorded history.

Under a Non-TROA scenario the regional water supply would be able to hold up for another two years (through 2017) under modeled hydrological conditions. But by the October 1, 2017 TMWA would have exhausted its drought reserves. This means that TMWA would run out of drought storage by mid-summer 2018.

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Memorandum

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P 775.834.8080 F 775.834.8003

TO: File

FROM: Bill Hauck, Senior Hydrologist

DATE: February 1, 2016

SUBJECT: TROA worse-than-worse planning scenarios using 2016-2035 Water Resource Plan projected demands and (1) repeat of the 1987- 1994 plus 1987 hydrology and (2) repeat of 2015 hydrology for the planning horizon

---

FINDINGS

- This report is a follow-up to the September 2015 Board Report which analyzed TMWA's upstream drought reserves under TROA and Non-TROA operations using repeated 2015 hydrological conditions for an additional 5 years to simulate worse-than-worst-case condition.
- In order to *further* test the resiliency of the region's water supply in terms of upstream drought storage and meeting customer demand, two (2) additional hypothetical *20 year* worse-than-worse case drought scenarios were modeled to put TROA to the test.
- The results of the first model run suggest that TMWA's upstream water supplies are adequate to withstand a worse than worst case hypothetical drought consisting of repeated 2015 hydrological conditions for 20 years. The results of the second model run show that TMWA's water supplies are also resilient enough under TROA to withstand a repeat of actual 1987-1994 drought conditions repeated two and a half more times (2 ½) for a total of 20 years (1987-1994 +1987-1994+1987-1990).
- The modeling used as the basis of this report takes water supply planning to a level never before contemplated. The results of the modeling efforts indicate that under TROA operations TMWA's conjunctive use of TROA integrated surface and ground water supplies are tremendously resilient.

INTRODUCTION

Following the presentation of the results of the first analysis at the September 2015 Board meeting, it was suggested to staff that maybe TMWA's drought planning studies didn't go far enough.

So, in order to take TMWA's drought planning to the next level and stress test the resiliency of the region's water supply even further, two hypothetical *20 year* worse-than-worse-case hydrologic scenarios were developed and modeled here.

Since last September, the Truckee River Operating Agreement (TROA) was implemented on December 1, 2015 and TMWA began credit storing water the same day. And even though river flows in the Truckee River were significantly below average, TMWA began building up and accruing over 5,100 acre feet (AF) of drought reserves over the first two months the Agreement was in effect. This fact supports the results of previous modeling efforts which suggested that TMWA could continue to build-up drought reserves even in exceptionally dry years.

Water supply planning Scenario No.1 used the same model as the September water supply planning study did. A hypothetical hydrology that repeated actual 2015 hydrologic conditions for twenty (20) years was used, thus adding an additional fifteen (15) years of worse-than-worst-case hydrology to the previous 5 year simulation done in September. Out of 115 years of actual hydrologic data available for the Truckee River, 2015 was the driest on record. It had both the lowest recorded snowpack and the lowest recorded natural runoff and was 12% drier than the previous driest year on record which was 1977. With initial starting conditions for the model run beginning October 1, 2016 (which was the conclusion to the four driest back to back years on record), what was modeled was actually a 24 year-long mega-drought of statistically improbable proportions.

Water supply planning Scenario No. 2 used the same model with a hypothetical repeat of the 1987-1994 drought for 20 years (1987-1994 plus 1987-1994 plus 1987-1990). What was modeled in this scenario was a hypothetical drought two and half times as long and the same intensity as the historic drought of record. The 1987-1994 drought plus the additional dry year of 1987 for a total of 9 years, has historically been used as the standard for TMWA's water planning efforts.

DISCUSSION

Besides the hydrological inputs, several underlying assumptions were built into the model for each water supply planning run. Demands were based on TMWA's projected demand developed for the 2016-2035 Water Resource Plan. Actual groundwater capacity figures were used based on pumping metrics observed during the summer of 2015. A conservative assumption for future groundwater development was also used; these model runs assumed that no new groundwater (GW) development would occur over the first 10 years, and after that point that only one new well would be developed each year for a total of 15 million gallons of new GW capacity over the final ten years of the 20 year model run period. This assumption is very conservative as far as future GW development is concerned and only further stress tests the use of Truckee River water supplies.

The elevation of Lake Tahoe would continue to fall over the 20 year simulation period in both scenarios that were run through the model. To get an idea of the severe nature of those model runs, one need look no further than the elevation of Lake Tahoe itself. By the end of the 20 year simulation in Scenario No. 1 (2015 repeat hydrology), the elevation of Lake Tahoe is projected to be 26.7 feet below its natural outlet. See Figure 1. Since 1900 (115 years of record keeping)

Lake Tahoe has never been below 6220.3 feet (2.7 feet below the natural outlet). Running a hydrological scenario through the model brings the elevation of Lake Tahoe down almost 24 feet *below* the lowest point ever seen in recorded history is quite extreme indeed, and only further illustrates the severe nature of these planning scenarios. This fact also bolsters the notion that these are *worse-than-worst case planning scenarios* by any measure.

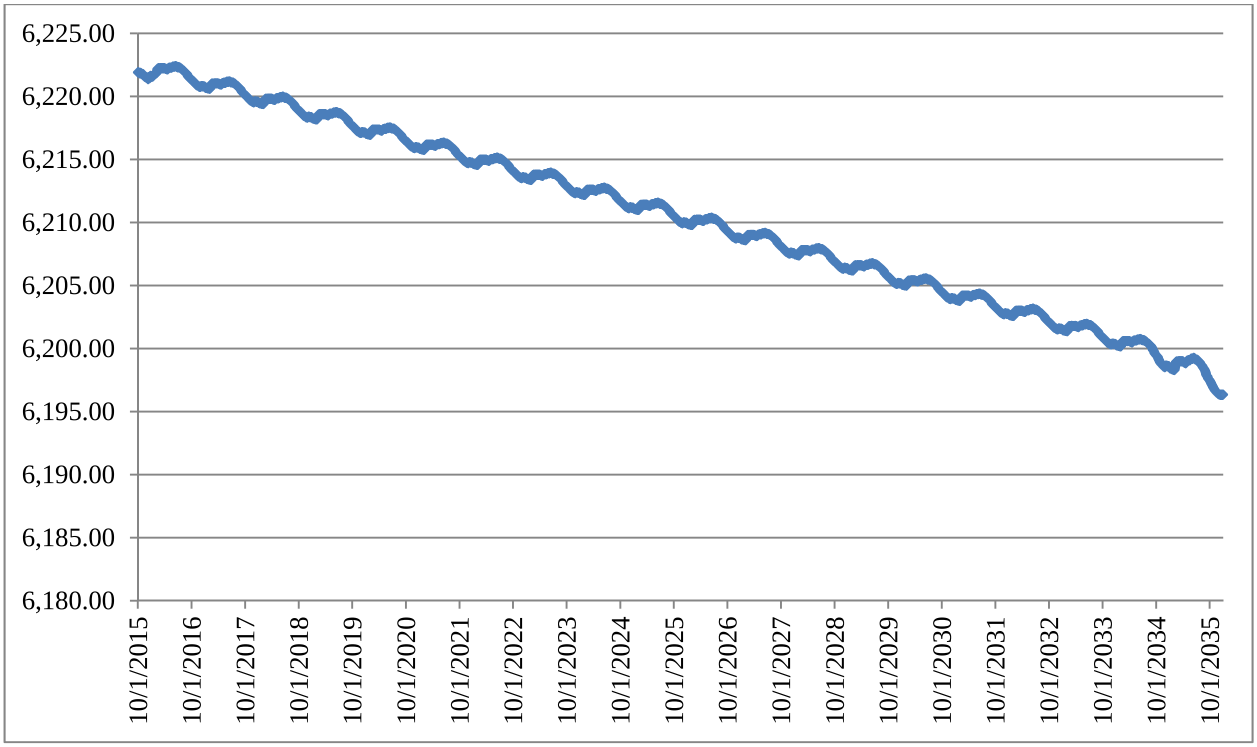

Figure 1. Lake Tahoe Elevation Projection (2015 repeat hydrology x 20 years)

Under Scenario No. 1 (2015 repeat hydrology) model results show that upstream storage totals would level off 15 years out, then begin to drop off slightly. Regardless, by the summer of 2035 (June 1st) TMWA is projected to still have over 54,000 AF of combined surface water stored in reserve and available for backup supply. See Figure 2.

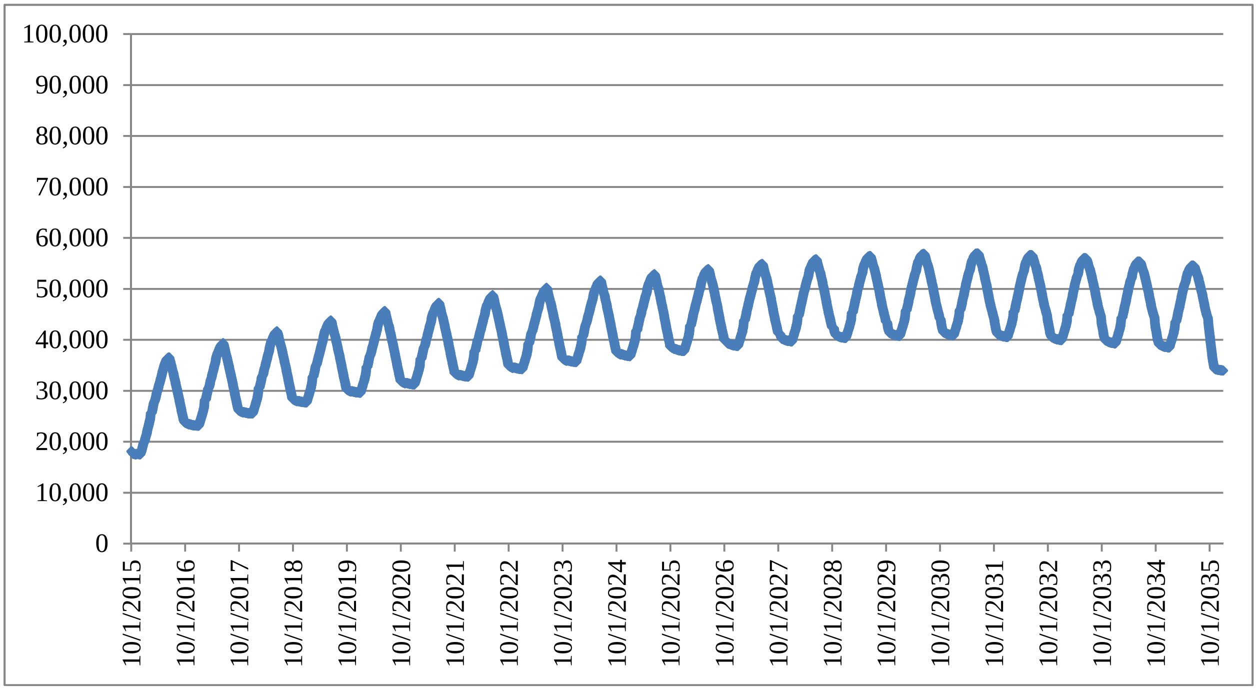

Figure 2. TMWA's Total Surface Storage under Scenario No.1 (2015 repeat hydrology)

This occurs despite a repeat of the worst hydrological conditions ever seen for an additional twenty years (2016-2035), increasing customer demands, and a very conservative projection for future groundwater development. By the end of 2035 (Dec 31, 2035) TMWA would still have almost 34,000 AF in reserve stored between Stampede and Boca reservoirs and Independence and Donner lakes.

Under Scenario No. 2 (1987-1994 repeat hydrology) model results show upstream drought reserve totals would continue to climb and that by the summer of 2035 (June 1st) TMWA would have over 92,000 AF of combined surface water stored in reserve and available for backup supply. See Figure 3.

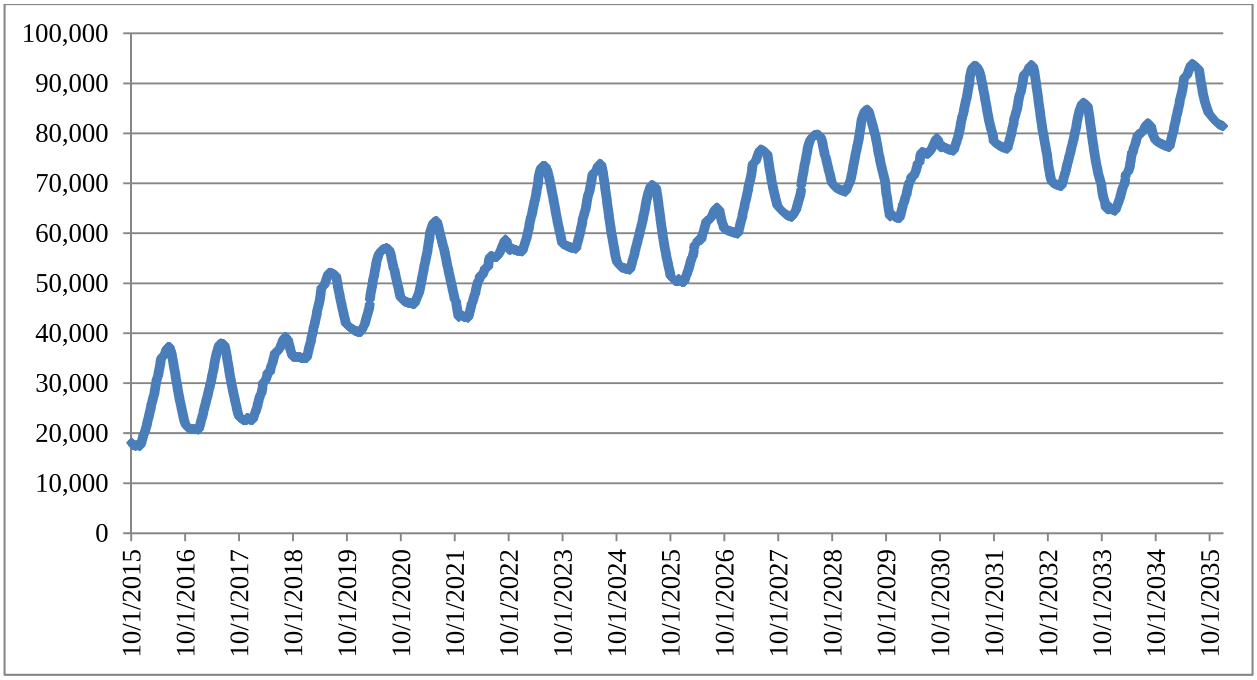

Figure 3. TMWA's Total Surface Storage under Scenario No.2 (1987-1994 repeat hydrology)

This occurs despite a repeat of the worst extended period of hydrological conditions the region has seen (1987-1994 + 1987-1994 + 1987-1990) for a total of 20 years, increasing customer demand, and a very conservative projection for future groundwater development. By the end of 2035 (Dec 31, 2035), TMWA would still have almost 81,500 AF in reserve stored between Stampede and Boca reservoirs and Independence and Donner lakes.

SUMMARY

The results of the model runs demonstrate the resiliency of TMWA's water supply under the newly implemented TROA. With TROA the region is *more than capable* of withstanding a worse-than-worst case drought of statistically improbable conditions for more than 20 years. If the initial starting conditions are factored in, then you could say that the model run was under statistically improbable conditions for at least 24 years, because the four years prior to initial starting conditions were the driest four back to back ever seen.

TMWA's upstream water supplies are more than adequate to withstand a worse than worst case hypothetical drought consisting of repeated 2015 hydrological conditions for 20 years and/or a repeat of actual 1987-1994 drought conditions repeated two and a half more times (2 ½) for a total of 20 years (1987-1994 +1987-1994+1987-1990). The modeling used as the basis of this report takes water supply planning to a level never before contemplated. The modeling results indicate that under TROA operations TMWA's conjunctive use of TROA integrated surface and ground water supplies are tremendously resilient.

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2016-2035 WATER RESOURCE PLAN

APPENDIX 4

WATER DEMAND PROJECTIONS

TRUCKEE MEADOWS WATER
AUTHORITY

APPENDIX 4-1

TPEM SERIES NO. 6:

WASHOE COUNTY POPULATION PROJECTION

2015 TO 2060 (EXPANDED)

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Ⓟ 775.834.8080 ● Ⓕ 775.834.8003

TO: File

FROM: Shawn Stoddard, Ph.D. Senior Resource Economist

DATE: September 1, 2015

SUBJECT: TPEM Series No. 6: Washoe County Population Projection 2015 to 2060 (Expanded)

Findings

- Washoe County population projection is updated with 2014 population estimates.
- 2014 population is 436,797, a 4.7% increase compared to 2010's population of 417,379 persons.
- Washoe County population from 1950 to 2014 continues to be well modeled by a logistic curve.
- Projected populations for 2015 to 2060 are presented here:

Year	Population	Year	Population
2014	436,797	2038	554,358
2015	443,729	2039	557,241
2016	450,488	2040	559,995
2017	457,072	2041	562,624
2018	463,476	2042	565,133
2019	469,699	2043	567,526
2020	475,740	2044	569,807
2021	481,596	2045	571,981
2022	487,267	2046	574,052
2023	492,754	2047	576,024
2024	498,058	2048	577,901
2025	503,178	2049	579,688
2026	508,118	2050	581,387
2027	512,879	2051	583,003
2028	517,463	2052	584,539
2029	521,874	2053	585,999
2030	526,115	2054	587,387
2031	530,188	2055	588,705
2032	534,099	2056	589,956
2033	537,850	2057	591,145
2034	541,445	2058	592,273
2035	544,890	2059	593,344
2036	548,187	2060	594,359
2037	551,342		

Discussion

TPEM Series No. 4 describes prior population forecasting models and their results. This analysis is an update to prior studies, provides a review of population tend, and compares the most recent consensus and State Demographer's ("SD's") projections. Appendix A provides graphs of prior population projects for review.

Logistic Curve Model

The logistic curve model for Washoe County population was developed in TPEM No. 1 is defined as:

$$Pop_t = \alpha / \left(1 + \beta 1 * e^{-\beta 2 * t}\right)$$

Where *t* is time index (1950 = 1), Pop_t is population in time *t*, α is population ceiling, $\beta 1$ and $\beta 2$ are shape parameters.

Using population values from 1950 to 2014 the model was estimated as:

$$Pop_t = 612{,}579.8 / \left(1 + 11.93398 * e^{-0.0536284 * t}\right)$$

Where t is time in years starting at *t* = 1 for 1950. The $R^2 = 0.9995$ shows that this model is a very good fit to the historic data. Figure 1 plots the results of this model. This model estimates the long-run population ceiling of 612,579 persons estimated to occur after 2100 with a 95% confidence interval between 576,493 to 648,666 persons. Appendix A provides the historic population used, the population values predicted by the model, and the model regression results.

Figure 1, shows a comparison of TMWA's population model with historic population values. It can be seen over time that population closely follows the model with periods when the population trends above and below the model. The recent population levels are below the model and trending back towards the model. This requires that the population projections be calibrated in such a way that the first year of the projection is equal to observed population while holding the projected population ceiling constant. This is done by estimating the following model iteratively until the calibration parameter is less than 1.

$$Pop_t + Calibrate = 612{,}579 / \left(1 + 15.30176 * e^{-.0559722 * t}\right)$$

Calibrate is the difference between the predicted model population and the actual population in 2014. As the model is solved and the calibration term added to the population, the model converges to a shape that forces the model trend to pass through the observed 2014 population. The converged model has an $R^2 = 0.9992$. The 95% confidence interval is estimated using the same process and is provided for in Appendix B.

Figure 2 shows the population model, the calibrated model, the State Demographer's 2014 projection and the 2014 Consensus Forecast.

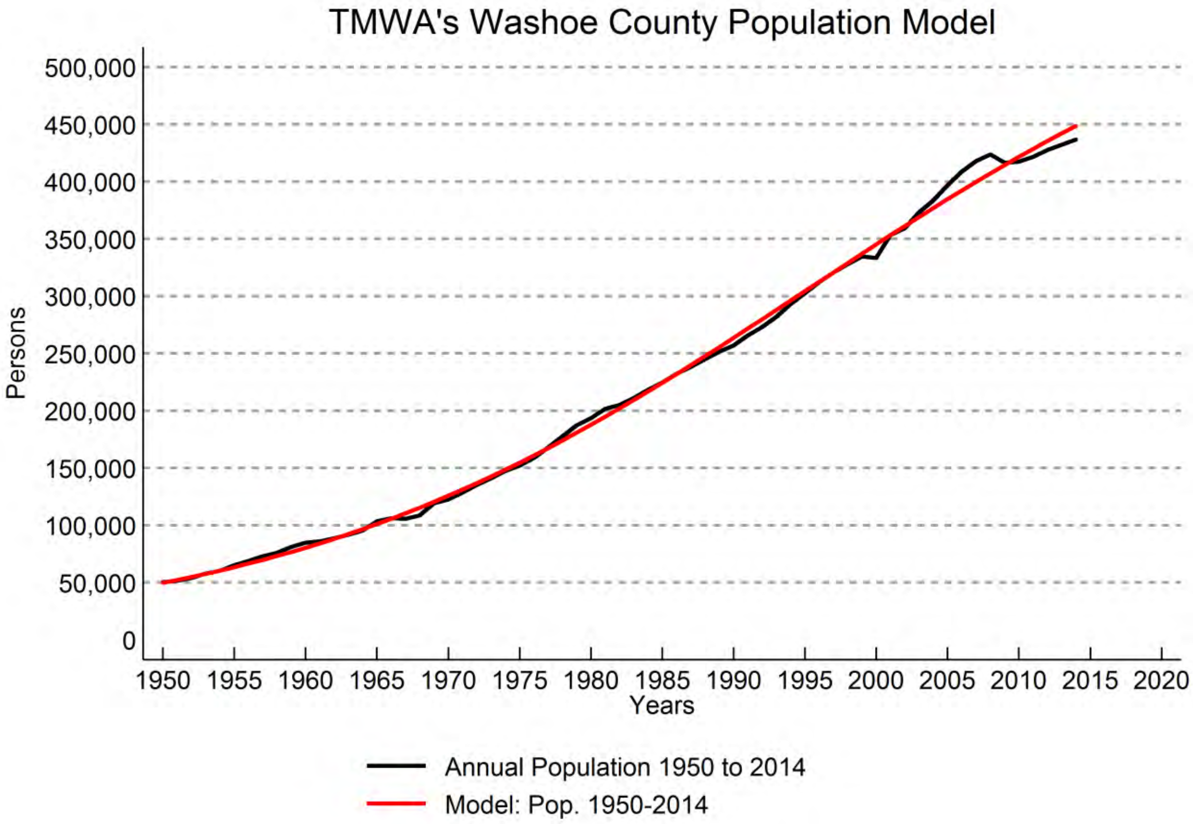


Figure 1: Washoe County Population Model 1950 to 2014.

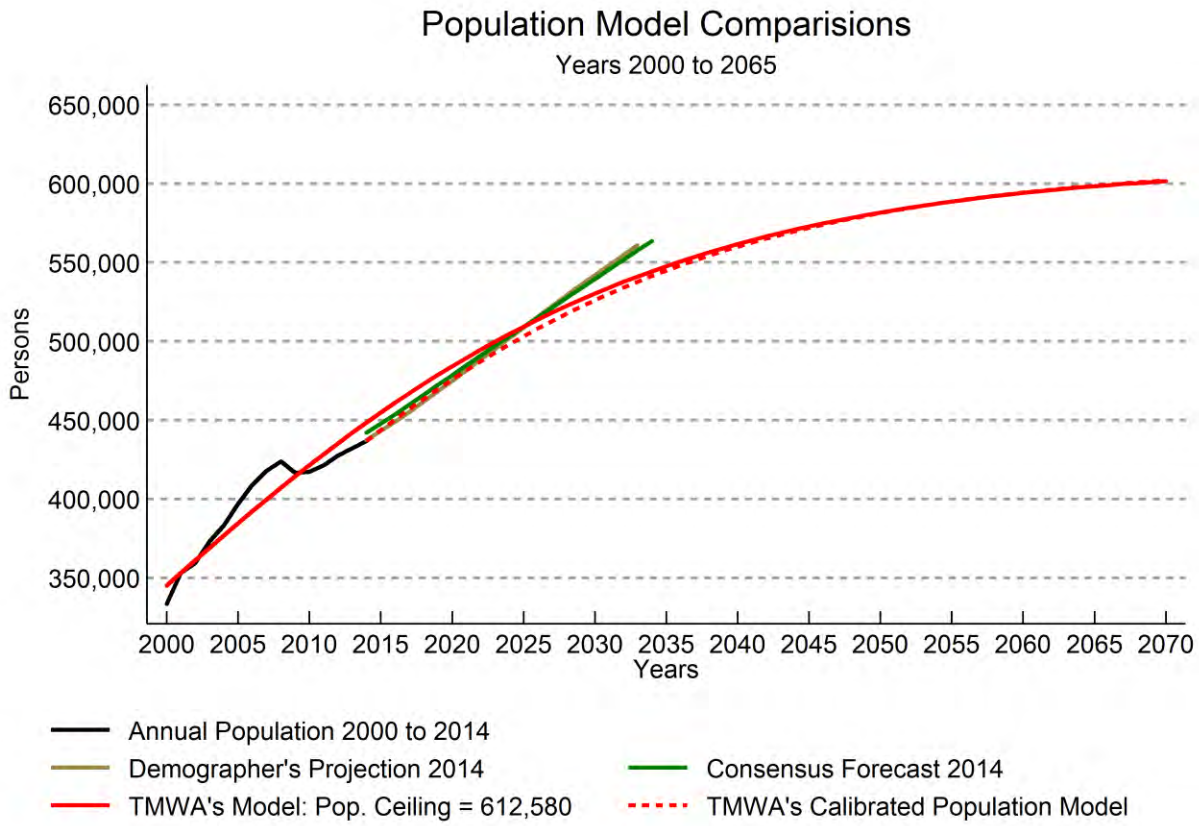


Figure 2: Comparisons of local population models.

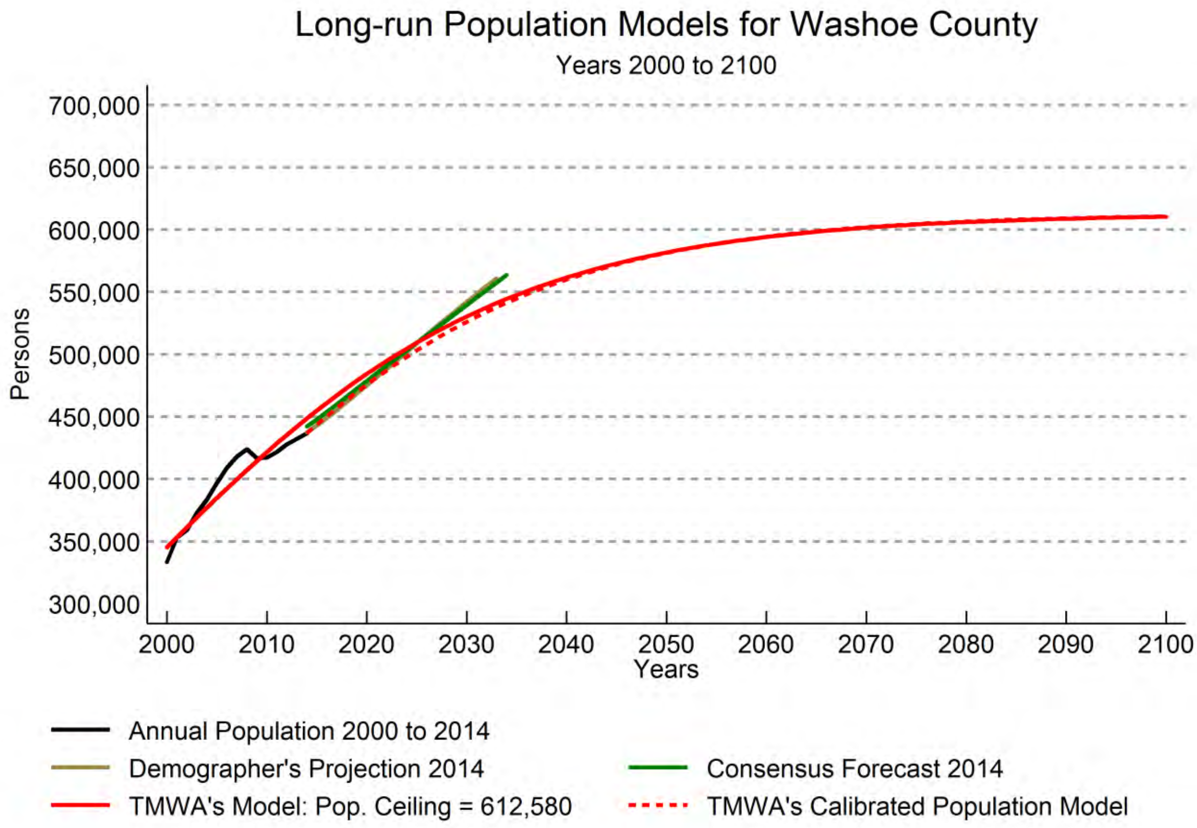


Figure 3: Long run population projection.

Figure 3 shows how the population is expected to level out at about 610,000 persons. This slowing of growth is expected to start occurring around year 2060. TMWA's and SD's projections intersect in the year 2025. For the first 10 years of the projection TMWA's and SD's projections are very similar, the SD projection includes estimated impacts of the Tesla plant, while the TMWA model is expected to capture those impacts as they happen over time. This result in TMWA's model predicting a slowing of growth after 2025 when compared with the SD model. Figure 4 shows that the SD's model is within TMWA's 95% confidence ranges and thus both models are statistically similar.

Figure 4 shows the 95% confidence level for the TMWA's model. In the long-run the population of Washoe County has a 95% probability of being between 576,493 and 648,666 persons.

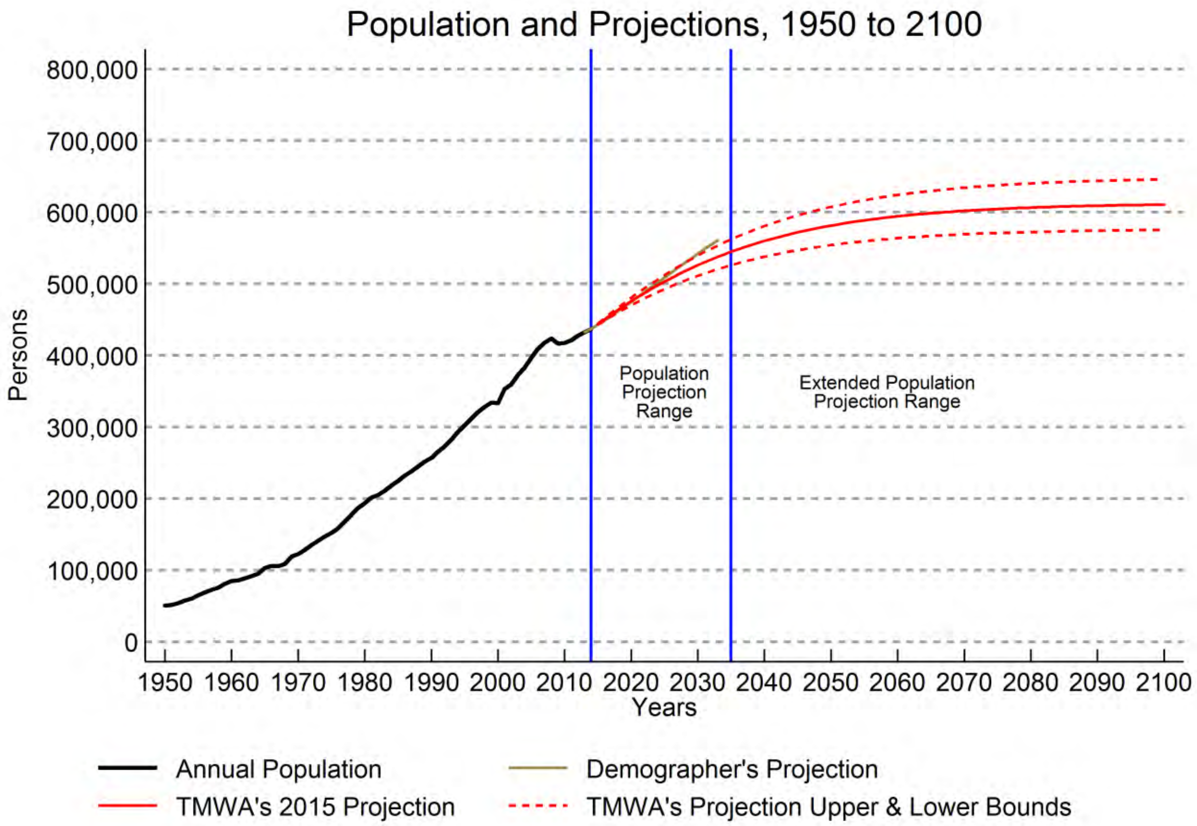


Figure 4: 95% Confidence Boundaries on Population Model.

Attached are appendices of supporting reference material.

Appendix A: Graphs of prior population projections.

Appendix B: Table of historic population, TMWA population model predicted population, and TMWA's projected population.

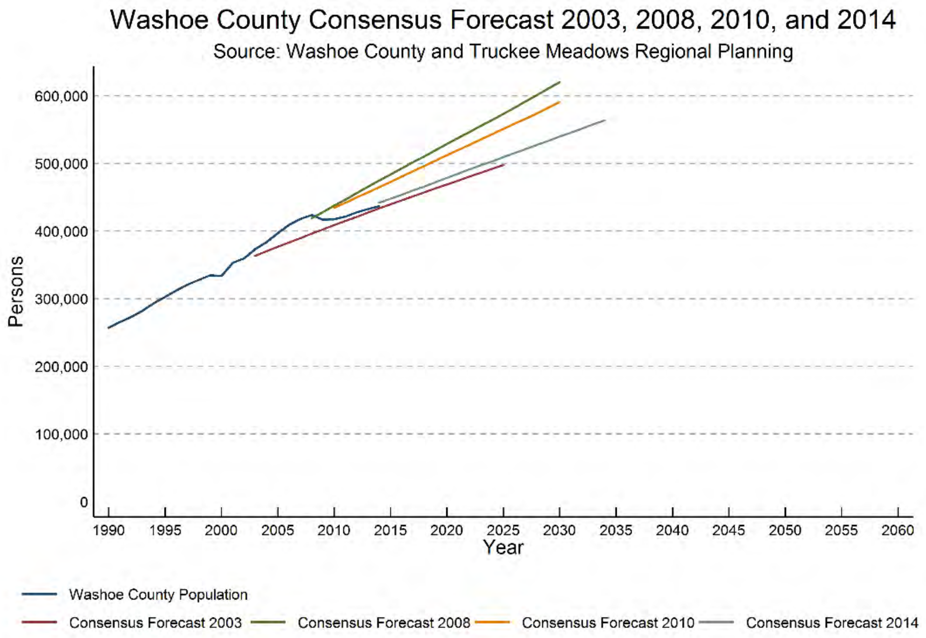
Appendix C: TMWA's nonlinear regression result for TMWA's population models.

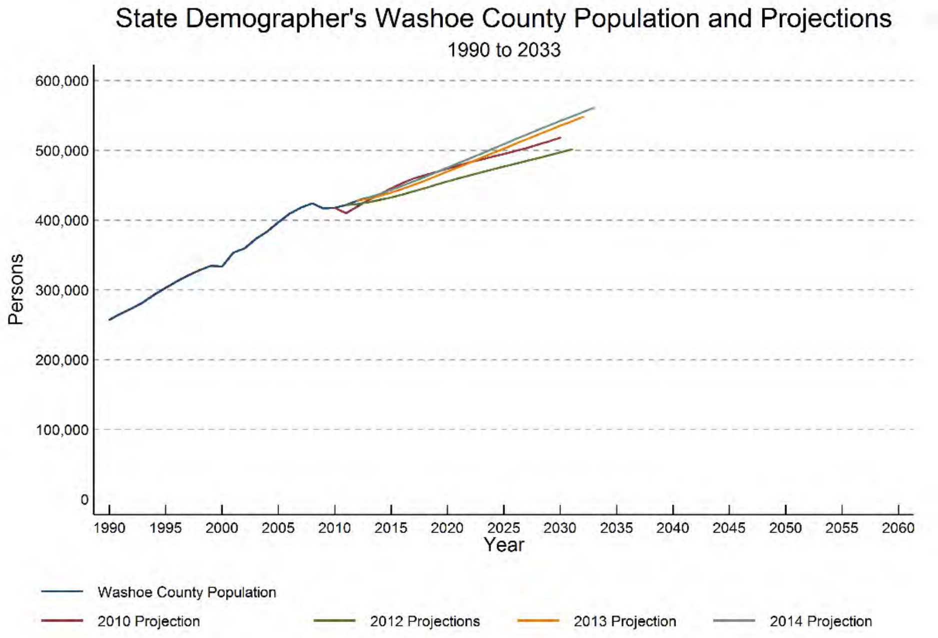
Appendix D: STATA source code used for estimating the population projection.

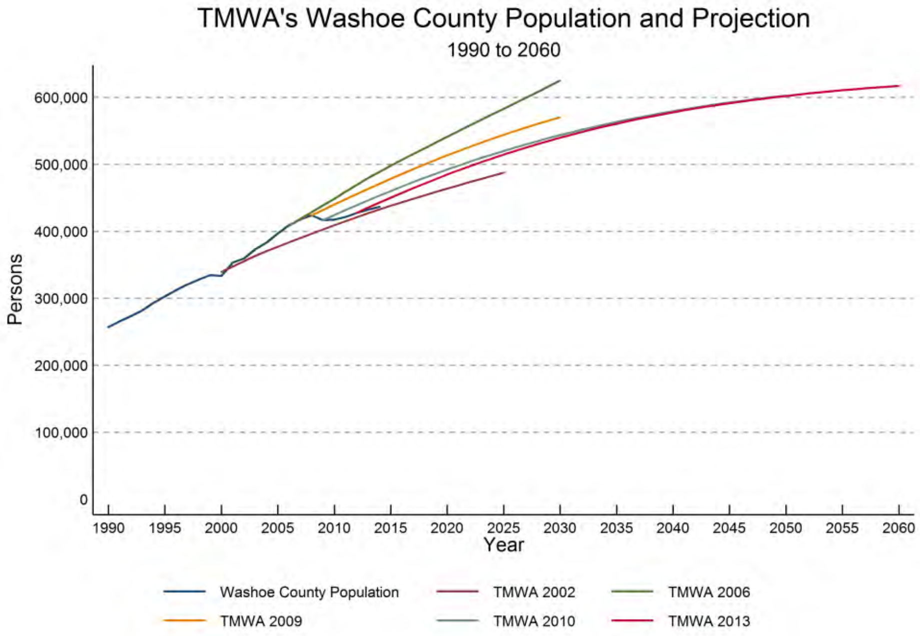
Appendix E: STATA Log file for model estimation.

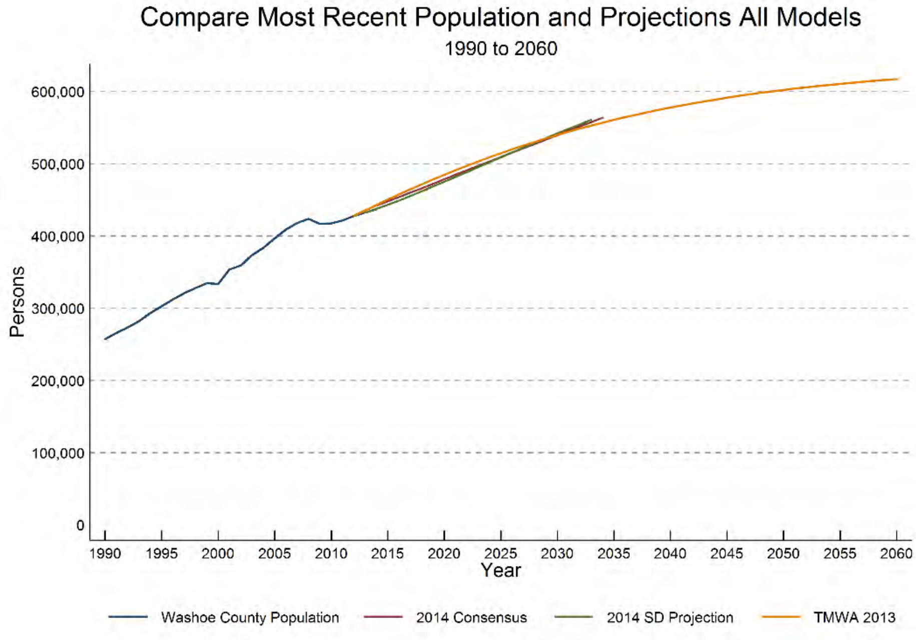
Appendix A: Graphical Review of Past Population Projections.

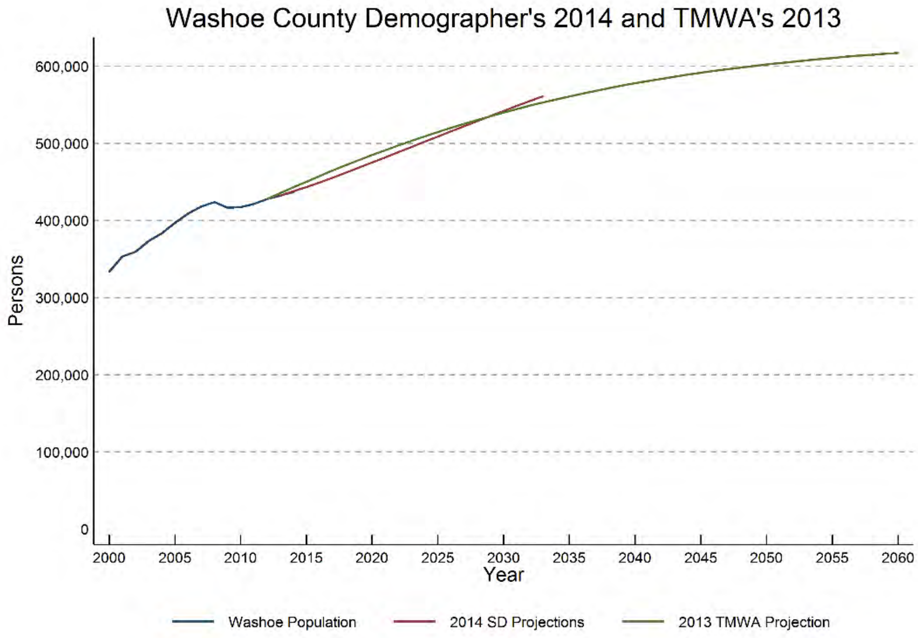
The following graphs compare past population projections prior to estimating TMWA's 2015 population projection.






TMWA's Washoe County Population and Projection
1990 to 2060
Persons
600,000
500,000
400,000
300,000
200,000
100,000
0
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
Year
Washoe County Population
TMWA 2002
TMWA 2006
TMWA 2009
TMWA 2010
TMWA 2013


Compare Most Recent Population and Projections All Models
1990 to 2060
Persons
600,000
500,000
400,000
300,000
200,000
100,000
0
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
Year
Washoe County Population
2014 Consensus
2014 SD Projection
TMWA 2013


Washoe County Demographer's 2014 and TMWA's 2013
Persons
600,000
500,000
400,000
300,000
200,000
100,000
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
Year
Washoe Population
2014 SD Projections
2013 TMWA Projection

Appendix B: Population Data and Population Model Results

Time Index	Year	Population	Population Model	Calibrated Model	Time Index	Year	Population Model	Calibrated Model
1	1950	50,484	49,759		77	2026	513,887	508,118
2	1951	51,600	52,267		78	2027	518,247	512,879
3	1952	54,000	54,888		79	2028	522,448	517,463
4	1953	58,100	57,628		80	2029	526,493	521,874
5	1954	60,500	60,489		81	2030	530,385	526,115
6	1955	65,200	63,476		82	2031	534,127	530,188
7	1956	68,900	66,593		83	2032	537,723	534,099
8	1957	73,000	69,844		84	2033	541,176	537,850
9	1958	76,000	73,232		85	2034	544,490	541,445
10	1959	81,300	76,761		86	2035	547,669	544,890
11	1960	84,988	80,434		87	2036	550,716	548,187
12	1961	85,969	84,256		88	2037	553,635	551,342
13	1962	88,648	88,229		89	2038	556,431	554,358
14	1963	91,705	92,357		90	2039	559,107	557,241
15	1964	95,289	96,643		91	2040	561,667	559,995
16	1965	103,420	101,088		92	2041	564,115	562,624
17	1966	106,356	105,697		93	2042	566,455	565,133
18	1967	105,541	110,470		94	2043	568,691	567,526
19	1968	108,776	115,409		95	2044	570,827	569,807
20	1969	119,192	120,516		96	2045	572,865	571,981
21	1970	122,574	125,792		97	2046	574,811	574,052
22	1971	128,600	131,238		98	2047	576,668	576,024
23	1972	135,400	136,853		99	2048	578,438	577,901
24	1973	141,000	142,637		100	2049	580,127	579,688
25	1974	147,400	148,589		101	2050	581,736	581,387
26	1975	152,200	154,708		102	2051	583,269	583,003
27	1976	158,700	160,991		103	2052	584,730	584,539
28	1977	167,800	167,436		104	2053	586,122	585,999
29	1978	177,600	174,040		105	2054	587,447	587,387
30	1979	187,200	180,798		106	2055	588,708	588,705
31	1980	193,623	187,707		107	2056	589,908	589,956
32	1981	201,680	194,760		108	2057	591,050	591,145
33	1982	205,130	201,953		109	2058	592,137	592,273
34	1983	210,990	209,278		110	2059	593,171	593,344
35	1984	218,320	216,728		111	2060	594,154	594,359
36	1985	224,580	224,296		112	2061	595,088	595,323
37	1986	232,270	231,974		113	2062	595,977	596,238
38	1987	238,360	239,752		114	2063	596,821	597,105
39	1988	244,890	247,621		115	2064	597,624	597,927
40	1989	251,580	255,572		116	2065	598,387	598,707
41	1990	257,120	263,593		117	2066	599,112	599,446
42	1991	265,762	271,675		118	2067	599,800	600,146
43	1992	273,178	279,806		119	2068	600,454	600,810
44	1993	282,214	287,974		120	2069	601,076	601,439
45	1994	293,141	296,169		121	2070	601,666	602,035
46	1995	302,748	304,378		122	2071	602,226	602,600
47	1996	312,366	312,590		123	2072	602,758	603,134
48	1997	320,828	320,793		124	2073	603,263	603,641
49	1998	327,899	328,975		125	2074	603,742	604,121
50	1999	334,601	337,125		126	2075	604,198	604,575
51	2000	333,566	345,231		127	2076	604,630	605,006
52	2001	353,271	353,282		128	2077	605,040	605,413
53	2002	359,423	361,266		129	2078	605,429	605,799
54	2003	373,233	369,175		130	2079	605,798	606,164
55	2004	383,453	376,997		131	2080	606,148	606,510
56	2005	396,844	384,722		132	2081	606,481	606,837
57	2006	409,085	392,342		133	2082	606,796	607,147
58	2007	418,061	399,849		134	2083	607,096	607,440
59	2008	423,833	407,233		135	2084	607,380	607,718
60	2009	416,632	414,488		136	2085	607,649	607,981
61	2010	417,379	421,607		137	2086	607,904	608,229
62	2011	421,593	428,584		138	2087	608,147	608,464
63	2012	427,704	435,412		139	2088	608,377	608,687
64	2013	432,324	442,089		140	2089	608,595	608,898
65	2014	436,797	448,608	436,798	141	2090	608,802	609,097
66	2015		454,967	443,729	142	2091	608,998	609,286
67	2016		461,163	450,488	143	2092	609,184	609,464
68	2017		467,193	457,072	144	2093	609,360	609,633
69	2018		473,055	463,476	145	2094	609,527	609,792
70	2019		478,749	469,699	146	2095	609,686	609,943
71	2020		484,273	475,740	147	2096	609,836	610,086
72	2021		489,628	481,596	148	2097	609,979	610,222
73	2022		494,814	487,267	149	2098	610,114	610,350
74	2023		499,831	492,754	150	2099	610,243	610,471
75	2024		504,682	498,058	151	2100	610,364	610,585
76	2025		509,366	503,178				

Appendix C: Regression Results

Population model estimation using population from 1950 to 2014.

```
nl (washoe = {a} / (1 + {b} * exp( -1* {c} * t) ) ),
>     variables(washoe t) initial(a 400000 b 5.0 c .5) vce(hc2);
(obs = 65)

Iteration 0:  residual SS =  9.92e+11
…
Iteration 10:  residual SS =  2.13e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9995
                                                    Adj R-squared =     0.9995
                                                    Root MSE      =   5867.404
                                                    Res. dev.     =   1309.422

------------------------------------------------------------------------------
             |             Robust HC2
      washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /a |   612579.8   18052.65    33.93   0.000     576493.1    648666.5
          /b |   11.93398   .2642083    45.17   0.000     11.40584    12.46213
          /c |   .0536284   .0009682    55.39   0.000     .0516931    .0555637
------------------------------------------------------------------------------
```

Final Population model calibration run.

```
Model run:  11
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.66e+12
…
Iteration 16:  residual SS =  2.98e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9992
                                                    Adj R-squared =     0.9992
                                                    Root MSE      =   6872.086
                                                    Res. dev.     =    1331.01

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   15.30176   .3678767    41.59   0.000     14.56662    16.03691
          /c |   .0559722   .0006613    84.64   0.000     .0546507    .0572937
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = -.625
```

Final population model calibration of lower boundary.

```
Model run:  10
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.90e+12
…
Iteration 16:  residual SS =  2.08e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9995
                                                    Adj R-squared =     0.9994
                                                    Root MSE      =   5741.476
                                                    Res. dev.     =   1307.642

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   13.48568   .2308535    58.42   0.000     13.02435      13.947
          /c |   .0575634   .0005257   109.49   0.000     .0565128     .058614
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = .71875
```

Final population model calibration of upper boundary.

```
Model run:  11
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.50e+12
…
Iteration 11:  residual SS =  4.88e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9986
                                                    Adj R-squared =     0.9986
                                                    Root MSE      =   8796.797
                                                    Res. dev.     =   1363.109

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   16.93727   .5465811    30.99   0.000     15.84501    18.02952
          /c |   .0546618   .0008361    65.38   0.000     .0529911    .0563326
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = -.65625
```

Appendix D: STATA Source Code for Model Estimation.

```
/*       1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
********************************************************************************
*  Program Name:   Population2015_02.do
*  Created by:     Shawn Stoddard
*  Created on:     4/9/2014
*  Abstract:       Estimate the Logistic Curve model
*
*  Datafiles Used:
*  WashoeDataAll_01.dta: Historic population and all prior projections.
*
*  Datafiles Created:
*  WashoeDataAll_02.dta contains the new population projection
*
*  Updated on: 04/14/2015
*   New population projection for 2015 water resource plan
*
*
*******************************************************************************/
#delimit;
clear;
set more off;
capture log close;
set linesize 90;
local logpath Logs/ ;
local filename Population2015_02 ;
local logfile = "`logpath'" + "`filename'" ;
log using "`logfile'", replace text;
/*****************************************************************************/;
/* System variables and parameters                                           */;
local dpath Data/;
local gpath Graphs/;

local endyr = 2100;
scalar conv = 1;

/*****************************************************************************/;
/* Open and prep data file for projection                                    */;
/*****************************************************************************/;
use year washoe sdf2013 sdf2014 wcf2014 tmwa2013
  using `dpath'WashoeDataAll_01, clear;
/* expand the data to year 2100 as defined by endyr                          */;
local r = `endyr' - 1949;
set obs `r';
/* create a time index 1950 == 1                                             */;
gen t = _n ;
replace year = 1949 + t if year == .;
order t year washoe wcf2014 sdf2013 sdf2014 tmwa2013, first;

/*****************************************************************************/;
/* Population Logistic Curve Fitting                                         */;
/*****************************************************************************/;
/*****************************************************************************/;
/* Building this model requires three stages:                                */;
/* Stage 1: Estimate Logistic Curve using population start in 1950 to current*/;
/*          Store the steady state population estimate with 95% bounds.      */;
/*          This is the long run population model.                           */;
/* Stage 2: Remodel the population holding steady state population constant  */;
/*          and calibrate model by shifting population data and re-estimate  */;
/*          using a loop to converge the model population and launch year    */;
/*          population.  This creates a calibrated population model that     */;
```

```
/*          projects the population path that returns to the long-run model  */;
/*          The final population project is the calibrated model.            */;
/* Stage 3: Estimate 95% upper and lower bounds using the same calibrated    */;
/*          process as developed in stage 2.  95% bounds are forced to equal */;
/*          launch year.                                                     */;
/*****************************************************************************/;
/* get row number of last year of population data                            */;
summarize t if washoe != ., meanonly;
local lrow = r(max);
display "last row of population data = `lrow'";

/*****************************************************************************/;
/* Stage 1: Population model steady state estimates                          */;
/*****************************************************************************/;
nl (washoe = {a} / (1 + {b} * exp( -1* {c} * t) ) ),
    variables(washoe t) initial(a 400000 b 5.0 c .5) vce(hc2);

/* Store the steady state population estimate with 95% upper and lower limits*/;
matrix rtable = r(table);
matrix list rtable;
global a   = string(rtable[1,1],"%10.0fc") /* Steady State */;
global lba = string(rtable[5,1],"%10.0fc") /* Lower Bound  */;
global uba = string(rtable[6,1],"%10.0fc") /* Upper Bound  */;
predict lrpop_mod;
label var lrpop_mod "Keyfitz Logistic Model: Long-Run";
replace lrpop_mod = round(lrpop_mod,1);
display "$a .. $lba .. $uba";

/*****************************************************************************/;
/* Calibrate population trend for steady state                               */;
/*****************************************************************************/;
local calib = washoe[`lrow'] - lrpop_mod[`lrow'];
display "Calib = `calib'";
* generate wpop_prj = round(wpop_model + `calib', 1);

/* calibrate model by shifting the data */;
gen _washoe = washoe;
local i = 1;
while `calib' <= -1*conv | `calib' >= conv {;
    local i = `i' + 1;
  display "Model run:  `i'";
  replace _washoe = _washoe + `calib';
  nl (_washoe = rtable[1,1] / (1 + {b} * exp( -1* {c} * t) ) ),
      variables(_washoe t) initial( b 5.0 c .5) vce(hc2);
  capture drop cpop_mod;
  predict cpop_mod;
  label var cpop_mod "Model Calibrate";
  local calib = washoe[`lrow'] - cpop_mod[`lrow'];
  display "Calib = `calib'";
};
replace cpop_mod = round(cpop_mod, 1);
replace cpop_mod = . if _n < `lrow';

/*****************************************************************************/;
/* Calibrate the Lower population bound model                                */;
/*****************************************************************************/;
replace _washoe = washoe;
local calib = washoe[`lrow'] - lrpop_mod[`lrow'];
display "Calib = `calib'";

local i = 1;
while `calib' <= -1*conv | `calib' >= conv {;
  local i = `i' + 1;
```

```
  display "Model run:  `i'";
  replace _washoe = _washoe + `calib';
nl (_washoe = rtable[5,1] / (1 + {b} * exp( -1* {c} * t) ) ),
      variables(_washoe t) initial( b 5.0 c .5) vce(hc2);
  capture drop llpop_mod;
  predict llpop_mod;
  label var llpop_mod "Model Calibrate Lower Bound";
  local calib = washoe[`lrow'] - llpop_mod[`lrow'];
  display "Calib = `calib'";
};
replace llpop_mod = round(llpop_mod, 1);
replace llpop_mod = . if _n < `lrow';

/****************************************************************************/;
/* Calibrate the upper population bound model                              */;
/****************************************************************************/;
replace _washoe = washoe;
local calib = washoe[`lrow'] - lrpop_mod[`lrow'];
display "Calib = `calib'";

local i = 1;
while `calib' <= -1*conv | `calib' >= conv {;
  local i = `i' + 1;
  display "Model run:  `i'";
  replace _washoe = _washoe + `calib';
nl (_washoe = rtable[6,1] / (1 + {b} * exp( -1* {c} * t) ) ),
      variables(_washoe t) initial( b 5.0 c .5) vce(hc2);
  capture drop ulpop_mod;
  predict ulpop_mod;
  label var ulpop_mod "Model Calibrate Upper Bound";
  local calib = washoe[`lrow'] - ulpop_mod[`lrow'];
  display "Calib = `calib'";
};

replace ulpop_mod = round(ulpop_mod, 1);
replace ulpop_mod = . if _n < `lrow';

drop _washoe;
/****************************************************************************/;
/* Document data file                                                      */;
/****************************************************************************/;
notes _dta: Started with WashoeDataAll_01.dta, kept only year, population
 wcf2010, sdf2013, and tmwa2010 projections.;
notes _dta: lrpop_mod is results of long-run population projection.;
notes _dta: cpop_mod is the calibrated results that match launch year and
 long-run trend. cpop_mod will be TMWA2014 projection.;
notes _dta: llpop_mod and lupop_mod are the 95% confidence ranges.;
notes _dta: This file updated on TS by S. Stoddard.;

save `dpath'WashoeDataAll_02, replace;
notes;
/****************************************************************************/;
/* Export Data for Excel Table                                             */;
/****************************************************************************/;
export excel t year washoe lrpop_mod cpop_mod using `dpath'ModelData.xls,
   firstrow(varl) datestring("%tyCCYY") replace;

log close;
exit;
****************************************************************************
```

Appendix E: STATA Log File.

```
-------------------------------------------------------------------------------------
----
      name:  <unnamed>
       log:  S:\PrjStata\Population2015\Work\Logs/Population2015_02.log
  log type:  text
 opened on:   2 Sep 2015, 08:15:33

. /************************************************************************/;
. /* System variables and parameters                                      */;
. local dpath Data/;

. local gpath Graphs/;

. local endyr = 2100;

. scalar conv = 1;

. /************************************************************************/;
. /* Open and prep data file for projection                               */;
. /************************************************************************/;
. use year washoe sdf2013 sdf2014 wcf2014 tmwa2013
>   using `dpath'WashoeDataAll_01, clear;
(Demographer's Population Estimates 1950 to 2012)

. /* expand the data to year 2100 as defined by endyr                     */;
. local r = `endyr' - 1949;

. set obs `r';
number of observations (_N) was 151, now 151

. /* create a time index 1950 == 1                                        */;
. gen t = _n ;

. replace year = 1949 + t if year == .;
(0 real changes made)

. order t year washoe wcf2014 sdf2013 sdf2014 tmwa2013, first;

. /************************************************************************/;
. /* Population Logistic Curve Fitting                                    */;
. /************************************************************************/;
. /************************************************************************/;
. /* Building this model requires three stages:                          */;
. /* Stage 1: Estimate Logistic Curve using population start in 1950 to current*/;
. /*          Store the steady state population estimate with 95% bounds.     */;
. /*          This is the long run population model.                      */;
. /* Stage 2: Remodel the population holding steady state population constant  */;
. /*          and calibrate model by shifting population data and re-estimate  */;
. /*          using a loop to converge the model population and launch year    */;
. /*          population.  This creates a calibrated population model that     */;
. /*          projects the population path that returns to the long-run model  */;
. /*          The final population project is the calibrated model.       */;
. /* Stage 3: Estimate 95% upper and lower bounds using the same calibrated    */;
. /*          process as developed in stage 2.  95% bounds are forced to equal */;
. /*          launch year.                                                */;
. /************************************************************************/;
. /* get row number of last year of population data                       */;
. summarize t if washoe != ., meanonly;

. local lrow = r(max);
```

```
. display "last row of population data = `lrow'";
last row of population data = 65

. /*****************************************************************************/;
. /* Stage 1: Population model steady state estimates                          */;
. /*****************************************************************************/;
. nl (washoe = {a} / (1 + {b} * exp( -1* {c} * t) ) ),
>     variables(washoe t) initial(a 400000 b 5.0 c .5) vce(hc2);
(obs = 65)

Iteration 0:  residual SS =  9.92e+11
Iteration 1:  residual SS =  4.76e+11
Iteration 2:  residual SS =  4.42e+11
Iteration 3:  residual SS =  1.13e+11
Iteration 4:  residual SS =  1.04e+11
Iteration 5:  residual SS =  8.96e+10
Iteration 6:  residual SS =  2.78e+10
Iteration 7:  residual SS =  2.20e+09
Iteration 8:  residual SS =  2.13e+09
Iteration 9:  residual SS =  2.13e+09
Iteration 10:  residual SS =  2.13e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9995
                                                    Adj R-squared =     0.9995
                                                    Root MSE      =   5867.404
                                                    Res. dev.     =   1309.422

------------------------------------------------------------------------------
             |             Robust HC2
      washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /a |   612579.8   18052.65    33.93   0.000     576493.1    648666.5
          /b |   11.93398   .2642083    45.17   0.000     11.40584    12.46213
          /c |   .0536284   .0009682    55.39   0.000     .0516931    .0555637
------------------------------------------------------------------------------

. /* Store the steady state population estimate with 95% upper and lower limits*/;
. matrix rtable = r(table);

. matrix list rtable;

rtable[9,3]
                a:         b:         c:
            _cons      _cons      _cons
     b  612579.81  11.933985  .05362839
    se  18052.648  .26420825  .00096817
     t  33.932962  45.168858  55.391673
pvalue  9.430e-42  3.727e-49  1.620e-54
    ll  576493.08   11.40584  .05169306
    ul  648666.54   12.46213  .05556373
    df         62         62         62
  crit  1.9989715  1.9989715  1.9989715
 eform          0          0          0

. global a   = string(rtable[1,1],"%10.0fc") /* Steady State */;

. global lba = string(rtable[5,1],"%10.0fc") /* Lower Bound  */;

. global uba = string(rtable[6,1],"%10.0fc") /* Upper Bound  */;
```

```
. predict lrpop_mod;
(option yhat assumed; fitted values)

. label var lrpop_mod "Keyfitz Logistic Model: Long-Run";

. replace lrpop_mod = round(lrpop_mod,1);
(143 real changes made)

. display "$a .. $lba .. $uba";
612,580 .. 576,493 .. 648,667

. /*************************************************************************/;
. /* Calibrate population trend for steady state                           */;
. /*************************************************************************/;
. local calib = washoe[`lrow'] - lrpop_mod[`lrow'];

. display "Calib = `calib'";
Calib = -11811

. * generate wpop_prj = round(wpop_model + `calib', 1);
. /* calibrate model by shifting the data */;
. gen _washoe = washoe;
(86 missing values generated)

. local i = 1;

. while `calib' <= -1*conv | `calib' >= conv {;
  2.     local i = `i' + 1;
  3.   display "Model run:  `i'";
  4.   replace _washoe = _washoe + `calib';
  5.   nl (_washoe = rtable[1,1] / (1 + {b} * exp( -1* {c} * t) ) ),
>       variables(_washoe t) initial( b 5.0 c .5) vce(hc2);
  6.   capture drop cpop_mod;
  7.             predict cpop_mod;
  8.   label var cpop_mod "Model Calibrate";
  9.   local calib = washoe[`lrow'] - cpop_mod[`lrow'];
 10.   display "Calib = `calib'";
 11. };
Model run:  2
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.85e+12
Iteration 1:  residual SS =  3.85e+12
Iteration 2:  residual SS =  3.85e+12
Iteration 3:  residual SS =  3.85e+12
Iteration 4:  residual SS =  2.84e+12
Iteration 5:  residual SS =  2.78e+12
Iteration 6:  residual SS =  2.66e+12
Iteration 7:  residual SS =  2.62e+12
Iteration 8:  residual SS =  2.24e+12
Iteration 9:  residual SS =  1.50e+12
Iteration 10:  residual SS =  2.97e+11
Iteration 11:  residual SS =  5.23e+10
Iteration 12:  residual SS =  3.85e+09
Iteration 13:  residual SS =  2.41e+09
Iteration 14:  residual SS =  2.40e+09
Iteration 15:  residual SS =  2.40e+09
Iteration 16:  residual SS =  2.40e+09


Nonlinear regression                               Number of obs =         65
                                                   R-squared     =     0.9994
```

```
                                                    Adj R-squared =     0.9994
                                                    Root MSE      =   6177.791
                                                    Res. dev.     =   1317.164

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   13.90555   .2754198    50.49   0.000     13.35516    14.45593
          /c |   .0550443   .0005758    95.60   0.000     .0538937    .0561949
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = -4399.875
Model run:  3
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.73e+12
Iteration 1:  residual SS =  3.73e+12
Iteration 2:  residual SS =  3.73e+12
Iteration 3:  residual SS =  1.36e+12
Iteration 4:  residual SS =  4.13e+11
Iteration 5:  residual SS =  4.70e+10
Iteration 6:  residual SS =  4.38e+09
Iteration 7:  residual SS =  2.73e+09
Iteration 8:  residual SS =  2.72e+09
Iteration 9:  residual SS =  2.72e+09
Iteration 10:  residual SS =  2.72e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9993
                                                    Adj R-squared =     0.9992
                                                    Root MSE      =   6574.637
                                                    Res. dev.     =   1325.257

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   14.75845   .3292868    44.82   0.000     14.10042    15.41648
          /c |   .0556181   .0006263    88.81   0.000     .0543666    .0568696
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = -1642.625
Model run:  4
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.69e+12
Iteration 1:  residual SS =  3.69e+12
Iteration 2:  residual SS =  3.69e+12
Iteration 3:  residual SS =  3.69e+12
Iteration 4:  residual SS =  2.87e+12
Iteration 5:  residual SS =  1.44e+11
Iteration 6:  residual SS =  5.22e+10
Iteration 7:  residual SS =  4.83e+09
Iteration 8:  residual SS =  2.88e+09
Iteration 9:  residual SS =  2.88e+09
Iteration 10:  residual SS =  2.88e+09
Iteration 11:  residual SS =  2.88e+09
```

```
Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9992
                                                    Adj R-squared =     0.9992
                                                    Root MSE      =   6756.012
                                                    Res. dev.     =   1328.795

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   15.09573   .3528773    42.78   0.000     14.39056     15.8009
          /c |   .0558389   .0006478    86.20   0.000     .0545444    .0571335
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = -613.53125
Model run:  5
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.67e+12
Iteration 1:  residual SS =  3.67e+12
Iteration 2:  residual SS =  3.65e+12
Iteration 3:  residual SS =  1.37e+12
Iteration 4:  residual SS =  1.32e+12
Iteration 5:  residual SS =  1.12e+12
Iteration 6:  residual SS =  8.15e+11
Iteration 7:  residual SS =  2.94e+11
Iteration 8:  residual SS =  8.72e+10
Iteration 9:  residual SS =  8.63e+09
Iteration 10:  residual SS =  2.99e+09
Iteration 11:  residual SS =  2.94e+09
Iteration 12:  residual SS =  2.94e+09
Iteration 13:  residual SS =  2.94e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9992
                                                    Adj R-squared =     0.9992
                                                    Root MSE      =   6828.113
                                                    Res. dev.     =   1330.175

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   15.22447   .3621979    42.03   0.000     14.50068    15.94826
          /c |   .0559223   .0006562    85.22   0.000      .054611    .0572337
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = -229.1875
Model run:  6
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.67e+12
Iteration 1:  residual SS =  3.66e+12
Iteration 2:  residual SS =  3.66e+12
Iteration 3:  residual SS =  3.59e+12
Iteration 4:  residual SS =  1.18e+12
Iteration 5:  residual SS =  1.10e+12
Iteration 6:  residual SS =  1.03e+12
Iteration 7:  residual SS =  8.69e+11
Iteration 8:  residual SS =  6.37e+11
```

```
Iteration 9:  residual SS =  5.81e+11
Iteration 10:  residual SS =  9.79e+10
Iteration 11:  residual SS =  1.38e+10
Iteration 12:  residual SS =  3.11e+09
Iteration 13:  residual SS =  2.96e+09
Iteration 14:  residual SS =  2.96e+09
Iteration 15:  residual SS =  2.96e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9992
                                                    Adj R-squared =     0.9992
                                                    Root MSE      =   6855.639
                                                    Res. dev.     =   1330.698

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   15.27296   .3657528    41.76   0.000     14.54206    16.00386
          /c |   .0559536   .0006594    84.86   0.000      .054636    .0572713
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = -85.625
Model run:  7
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.67e+12
Iteration 1:  residual SS =  3.66e+12
Iteration 2:  residual SS =  3.66e+12
Iteration 3:  residual SS =  3.64e+12
Iteration 4:  residual SS =  2.17e+12
Iteration 5:  residual SS =  2.07e+12
Iteration 6:  residual SS =  2.07e+12
Iteration 7:  residual SS =  1.76e+12
Iteration 8:  residual SS =  1.23e+12
Iteration 9:  residual SS =  1.41e+11
Iteration 10:  residual SS =  5.65e+10
Iteration 11:  residual SS =  4.99e+09
Iteration 12:  residual SS =  2.98e+09
Iteration 13:  residual SS =  2.97e+09
Iteration 14:  residual SS =  2.97e+09
Iteration 15:  residual SS =  2.97e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9992
                                                    Adj R-squared =     0.9992
                                                    Root MSE      =   6866.005
                                                    Res. dev.     =   1330.894

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   15.29113   .3670913    41.65   0.000     14.55755     16.0247
          /c |   .0559653   .0006606    84.72   0.000     .0546453    .0572854
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = -32
Model run:  8
(65 real changes made)
```

```
(obs = 65)

Iteration 0:  residual SS =  3.67e+12
Iteration 1:  residual SS =  3.66e+12
Iteration 2:  residual SS =  3.66e+12
Iteration 3:  residual SS =  3.65e+12
Iteration 4:  residual SS =  2.93e+12
Iteration 5:  residual SS =  2.83e+12
Iteration 6:  residual SS =  2.67e+12
Iteration 7:  residual SS =  2.52e+12
Iteration 8:  residual SS =  2.28e+12
Iteration 9:  residual SS =  7.65e+11
Iteration 10:  residual SS =  3.25e+11
Iteration 11:  residual SS =  1.97e+10
Iteration 12:  residual SS =  3.93e+09
Iteration 13:  residual SS =  2.97e+09
Iteration 14:  residual SS =  2.97e+09
Iteration 15:  residual SS =  2.97e+09
Iteration 16:  residual SS =  2.97e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9992
                                                    Adj R-squared =     0.9992
                                                    Root MSE      =   6869.891
                                                    Res. dev.     =   1330.968

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   15.29792   .3675933    41.62   0.000     14.56335     16.0325
          /c |   .0559697    .000661    84.67   0.000     .0546488    .0572907
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = -11.9375
Model run:  9
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.67e+12
Iteration 1:  residual SS =  3.66e+12
Iteration 2:  residual SS =  3.66e+12
Iteration 3:  residual SS =  3.65e+12
Iteration 4:  residual SS =  3.10e+12
Iteration 5:  residual SS =  3.00e+12
Iteration 6:  residual SS =  2.84e+12
Iteration 7:  residual SS =  2.68e+12
Iteration 8:  residual SS =  2.43e+12
Iteration 9:  residual SS =  9.44e+11
Iteration 10:  residual SS =  4.09e+11
Iteration 11:  residual SS =  1.66e+10
Iteration 12:  residual SS =  4.10e+09
Iteration 13:  residual SS =  2.98e+09
Iteration 14:  residual SS =  2.97e+09
Iteration 15:  residual SS =  2.97e+09
Iteration 16:  residual SS =  2.97e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9992
                                                    Adj R-squared =     0.9992
                                                    Root MSE      =   6871.342
```

```
                                                    Res. dev.     =   1330.995

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   15.30046   .3677805    41.60   0.000     14.56551    16.03541
          /c |   .0559714   .0006612    84.65   0.000     .0546501    .0572926
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = -4.46875
Model run:  10
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.67e+12
Iteration 1:  residual SS =  3.66e+12
Iteration 2:  residual SS =  3.66e+12
Iteration 3:  residual SS =  3.65e+12
Iteration 4:  residual SS =  3.15e+12
Iteration 5:  residual SS =  3.05e+12
Iteration 6:  residual SS =  2.89e+12
Iteration 7:  residual SS =  2.74e+12
Iteration 8:  residual SS =  2.48e+12
Iteration 9:  residual SS =  1.00e+12
Iteration 10:  residual SS =  4.44e+11
Iteration 11:  residual SS =  1.55e+10
Iteration 12:  residual SS =  4.18e+09
Iteration 13:  residual SS =  2.98e+09
Iteration 14:  residual SS =  2.98e+09
Iteration 15:  residual SS =  2.98e+09
Iteration 16:  residual SS =  2.98e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9992
                                                    Adj R-squared =     0.9992
                                                    Root MSE      =   6871.885
                                                    Res. dev.     =   1331.006

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   15.30141   .3678507    41.60   0.000     14.56632     16.0365
          /c |    .055972   .0006613    84.64   0.000     .0546505    .0572934
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = -1.65625
Model run:  11
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.66e+12
Iteration 1:  residual SS =  3.66e+12
Iteration 2:  residual SS =  3.66e+12
Iteration 3:  residual SS =  3.65e+12
Iteration 4:  residual SS =  3.17e+12
Iteration 5:  residual SS =  3.07e+12
Iteration 6:  residual SS =  2.91e+12
Iteration 7:  residual SS =  2.75e+12
Iteration 8:  residual SS =  2.50e+12
Iteration 9:  residual SS =  1.02e+12
```

```
Iteration 10:  residual SS =  4.57e+11
Iteration 11:  residual SS =  1.52e+10
Iteration 12:  residual SS =  4.21e+09
Iteration 13:  residual SS =  2.98e+09
Iteration 14:  residual SS =  2.98e+09
Iteration 15:  residual SS =  2.98e+09
Iteration 16:  residual SS =  2.98e+09


Nonlinear regression                               Number of obs =         65
                                                   R-squared     =     0.9992
                                                   Adj R-squared =     0.9992
                                                   Root MSE      =   6872.086
                                                   Res. dev.     =    1331.01

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   15.30176   .3678767    41.59   0.000     14.56662    16.03691
          /c |   .0559722   .0006613    84.64   0.000     .0546507    .0572937
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = -.625

. replace cpop_mod = round(cpop_mod, 1);
(148 real changes made)

. replace cpop_mod = . if _n < `lrow';
(64 real changes made, 64 to missing)

. /**************************************************************************/;
. /* Calibrate the Lower population bound model                             */;
. /**************************************************************************/;
. replace _washoe = washoe;
(65 real changes made)

. local calib = washoe[`lrow'] - lrpop_mod[`lrow'];

. display "Calib = `calib'";
Calib = -11811

. local i = 1;

. while `calib' <= -1*conv | `calib' >= conv {;
  2.   local i = `i' + 1;
  3.   display "Model run:  `i'";
  4.   replace _washoe = _washoe + `calib';
  5. nl (_washoe = rtable[5,1] / (1 + {b} * exp( -1* {c} * t) ) ),
>       variables(_washoe t) initial( b 5.0 c .5) vce(hc2);
  6.   capture drop llpop_mod;
  7.            predict llpop_mod;
  8.   label var llpop_mod "Model Calibrate Lower Bound";
  9.   local calib = washoe[`lrow'] - llpop_mod[`lrow'];
 10.   display "Calib = `calib'";
 11. };
Model run:  2
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.85e+12
Iteration 1:  residual SS =  3.85e+12
Iteration 2:  residual SS =  3.85e+12
```

```
Iteration 3:  residual SS =  3.77e+12
Iteration 4:  residual SS =  7.95e+11
Iteration 5:  residual SS =  7.41e+11
Iteration 6:  residual SS =  7.17e+11
Iteration 7:  residual SS =  6.14e+11
Iteration 8:  residual SS =  4.90e+11
Iteration 9:  residual SS =  1.79e+11
Iteration 10:  residual SS =  4.04e+09
Iteration 11:  residual SS =  2.09e+09
Iteration 12:  residual SS =  2.08e+09
Iteration 13:  residual SS =  2.08e+09
Iteration 14:  residual SS =  2.08e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9995
                                                    Adj R-squared =     0.9994
                                                    Root MSE      =   5751.489
                                                    Res. dev.     =   1307.868

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   13.78389   .2421034    56.93   0.000     13.30008    14.26769
          /c |   .0577615   .0005333   108.32   0.000     .0566959    .0588272
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = 954.78125
Model run:  3
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.88e+12
Iteration 1:  residual SS =  3.87e+12
Iteration 2:  residual SS =  3.87e+12
Iteration 3:  residual SS =  3.87e+12
Iteration 4:  residual SS =  3.87e+12
Iteration 5:  residual SS =  5.70e+11
Iteration 6:  residual SS =  5.29e+11
Iteration 7:  residual SS =  4.88e+11
Iteration 8:  residual SS =  4.72e+11
Iteration 9:  residual SS =  4.11e+11
Iteration 10:  residual SS =  3.82e+11
Iteration 11:  residual SS =  1.97e+11
Iteration 12:  residual SS =  4.77e+09
Iteration 13:  residual SS =  2.09e+09
Iteration 14:  residual SS =  2.08e+09
Iteration 15:  residual SS =  2.08e+09
Iteration 16:  residual SS =  2.08e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9995
                                                    Adj R-squared =     0.9994
                                                    Root MSE      =    5742.66
                                                    Res. dev.     =   1307.669

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   13.60605   .2352085    57.85   0.000     13.13603    14.07608
```

```
          /c |   .0576437   .0005285   109.06   0.000     .0565875    .0586999
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = 389.34375
Model run:  4
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.89e+12
Iteration 1:  residual SS =  3.88e+12
Iteration 2:  residual SS =  3.88e+12
Iteration 3:  residual SS =  3.88e+12
Iteration 4:  residual SS =  5.73e+11
Iteration 5:  residual SS =  2.30e+11
Iteration 6:  residual SS =  1.74e+11
Iteration 7:  residual SS =  1.14e+11
Iteration 8:  residual SS =  2.77e+09
Iteration 9:  residual SS =  2.08e+09
Iteration 10:  residual SS =  2.08e+09
Iteration 11:  residual SS =  2.08e+09
Iteration 12:  residual SS =  2.08e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9995
                                                    Adj R-squared =     0.9994
                                                    Root MSE      =    5741.48
                                                    Res. dev.     =   1307.642

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   13.53445   .2325875    58.19   0.000     13.06967    13.99924
          /c |    .057596   .0005268   109.33   0.000     .0565432    .0586488
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = 158.78125
Model run:  5
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.89e+12
Iteration 1:  residual SS =  3.89e+12
Iteration 2:  residual SS =  3.89e+12
Iteration 3:  residual SS =  3.89e+12
Iteration 4:  residual SS =  3.87e+12
Iteration 5:  residual SS =  9.97e+11
Iteration 6:  residual SS =  9.72e+11
Iteration 7:  residual SS =  9.24e+11
Iteration 8:  residual SS =  8.63e+11
Iteration 9:  residual SS =  8.30e+11
Iteration 10:  residual SS =  7.06e+11
Iteration 11:  residual SS =  5.41e+11
Iteration 12:  residual SS =  1.77e+11
Iteration 13:  residual SS =  3.91e+09
Iteration 14:  residual SS =  2.09e+09
Iteration 15:  residual SS =  2.08e+09
Iteration 16:  residual SS =  2.08e+09
Iteration 17:  residual SS =  2.08e+09

Nonlinear regression                                Number of obs =         65
```

```
                                                    R-squared     =     0.9995
                                                    Adj R-squared =     0.9994
                                                    Root MSE      =   5741.399
                                                    Res. dev.     =    1307.64

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   13.50541   .2315499    58.33   0.000     13.04269    13.96812
          /c |   .0575766   .0005262   109.43   0.000     .0565251     .058628
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = 64.75
Model run:  6
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.90e+12
Iteration 1:  residual SS =  3.89e+12
Iteration 2:  residual SS =  3.89e+12
Iteration 3:  residual SS =  3.89e+12
Iteration 4:  residual SS =  3.88e+12
Iteration 5:  residual SS =  5.03e+11
Iteration 6:  residual SS =  4.60e+11
Iteration 7:  residual SS =  4.51e+11
Iteration 8:  residual SS =  3.98e+11
Iteration 9:  residual SS =  3.31e+11
Iteration 10:  residual SS =  2.56e+11
Iteration 11:  residual SS =  1.23e+11
Iteration 12:  residual SS =  2.97e+09
Iteration 13:  residual SS =  2.08e+09
Iteration 14:  residual SS =  2.08e+09
Iteration 15:  residual SS =  2.08e+09
Iteration 16:  residual SS =  2.08e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9995
                                                    Adj R-squared =     0.9994
                                                    Root MSE      =   5741.433
                                                    Res. dev.     =   1307.641

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   13.49359   .2311318    58.38   0.000     13.03171    13.95547
          /c |   .0575687   .0005259   109.47   0.000     .0565177    .0586196
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = 26.40625
Model run:  7
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.90e+12
Iteration 1:  residual SS =  3.89e+12
Iteration 2:  residual SS =  3.89e+12
Iteration 3:  residual SS =  3.89e+12
Iteration 4:  residual SS =  3.89e+12
Iteration 5:  residual SS =  6.89e+11
Iteration 6:  residual SS =  6.51e+11
```

```
Iteration 7:  residual SS =  6.06e+11
Iteration 8:  residual SS =  5.98e+11
Iteration 9:  residual SS =  5.19e+11
Iteration 10:  residual SS =  4.51e+11
Iteration 11:  residual SS =  1.94e+11
Iteration 12:  residual SS =  4.59e+09
Iteration 13:  residual SS =  2.09e+09
Iteration 14:  residual SS =  2.08e+09
Iteration 15:  residual SS =  2.08e+09
Iteration 16:  residual SS =  2.08e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9995
                                                    Adj R-squared =     0.9994
                                                    Root MSE      =   5741.457
                                                    Res. dev.     =   1307.641

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   13.48877   .2309622    58.40   0.000     13.02723    13.95031
          /c |   .0575655   .0005258   109.48   0.000     .0565147    .0586162
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = 10.78125
Model run:  8
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.90e+12
Iteration 1:  residual SS =  3.89e+12
Iteration 2:  residual SS =  3.89e+12
Iteration 3:  residual SS =  3.89e+12
Iteration 4:  residual SS =  3.89e+12
Iteration 5:  residual SS =  7.38e+11
Iteration 6:  residual SS =  7.01e+11
Iteration 7:  residual SS =  6.54e+11
Iteration 8:  residual SS =  6.52e+11
Iteration 9:  residual SS =  5.65e+11
Iteration 10:  residual SS =  4.84e+11
Iteration 11:  residual SS =  1.95e+11
Iteration 12:  residual SS =  4.56e+09
Iteration 13:  residual SS =  2.09e+09
Iteration 14:  residual SS =  2.08e+09
Iteration 15:  residual SS =  2.08e+09
Iteration 16:  residual SS =  2.08e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9995
                                                    Adj R-squared =     0.9994
                                                    Root MSE      =   5741.469
                                                    Res. dev.     =   1307.642

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |    13.4868   .2308931    58.41   0.000      13.0254    13.94821
          /c |   .0575641   .0005258   109.49   0.000     .0565135    .0586148
------------------------------------------------------------------------------
```

```
(option yhat assumed; fitted values)
Calib = 4.40625
Model run:  9
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.90e+12
Iteration 1:  residual SS =  3.89e+12
Iteration 2:  residual SS =  3.89e+12
Iteration 3:  residual SS =  3.89e+12
Iteration 4:  residual SS =  3.89e+12
Iteration 5:  residual SS =  7.53e+11
Iteration 6:  residual SS =  7.15e+11
Iteration 7:  residual SS =  6.69e+11
Iteration 8:  residual SS =  6.67e+11
Iteration 9:  residual SS =  5.79e+11
Iteration 10:  residual SS =  4.93e+11
Iteration 11:  residual SS =  1.95e+11
Iteration 12:  residual SS =  4.55e+09
Iteration 13:  residual SS =  2.09e+09
Iteration 14:  residual SS =  2.08e+09
Iteration 15:  residual SS =  2.08e+09
Iteration 16:  residual SS =  2.08e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9995
                                                    Adj R-squared =     0.9994
                                                    Root MSE      =   5741.474
                                                    Res. dev.     =   1307.642

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |     13.486   .2308649    58.42   0.000     13.02465    13.94735
          /c |   .0575636   .0005257   109.49   0.000      .056513    .0586142
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = 1.78125
Model run:  10
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.90e+12
Iteration 1:  residual SS =  3.89e+12
Iteration 2:  residual SS =  3.89e+12
Iteration 3:  residual SS =  3.89e+12
Iteration 4:  residual SS =  3.89e+12
Iteration 5:  residual SS =  7.58e+11
Iteration 6:  residual SS =  7.20e+11
Iteration 7:  residual SS =  6.73e+11
Iteration 8:  residual SS =  6.72e+11
Iteration 9:  residual SS =  5.83e+11
Iteration 10:  residual SS =  4.96e+11
Iteration 11:  residual SS =  1.96e+11
Iteration 12:  residual SS =  4.54e+09
Iteration 13:  residual SS =  2.09e+09
Iteration 14:  residual SS =  2.08e+09
Iteration 15:  residual SS =  2.08e+09
Iteration 16:  residual SS =  2.08e+09
```

```
Nonlinear regression                                   Number of obs =         65
                                                       R-squared     =     0.9995
                                                       Adj R-squared =     0.9994
                                                       Root MSE      =   5741.476
                                                       Res. dev.     =   1307.642

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   13.48568   .2308535    58.42   0.000     13.02435      13.947
          /c |   .0575634   .0005257   109.49   0.000     .0565128     .058614
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = .71875

. replace llpop_mod = round(llpop_mod, 1);
(143 real changes made)

. replace llpop_mod = . if _n < `lrow';
(64 real changes made, 64 to missing)

. /***************************************************************************/;
. /* Calibrate the upper population bound model                              */;
. /***************************************************************************/;
. replace _washoe = washoe;
(65 real changes made)

. local calib = washoe[`lrow'] - lrpop_mod[`lrow'];

. display "Calib = `calib'";
Calib = -11811

. local i = 1;

. while `calib' <= -1*conv | `calib' >= conv {;
  2.   local i = `i' + 1;
  3.   display "Model run:  `i'";
  4.   replace _washoe = _washoe + `calib';
  5. nl (_washoe = rtable[6,1] / (1 + {b} * exp( -1* {c} * t) ) ),
>       variables(_washoe t) initial( b 5.0 c .5) vce(hc2);
  6.   capture drop ulpop_mod;
  7.             predict ulpop_mod;
  8.   label var ulpop_mod "Model Calibrate Upper Bound";
  9.   local calib = washoe[`lrow'] - ulpop_mod[`lrow'];
 10.   display "Calib = `calib'";
 11. };
Model run:  2
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.85e+12
Iteration 1:  residual SS =  3.85e+12
Iteration 2:  residual SS =  3.85e+12
Iteration 3:  residual SS =  3.85e+12
Iteration 4:  residual SS =  3.08e+12
Iteration 5:  residual SS =  1.07e+12
Iteration 6:  residual SS =  1.94e+11
Iteration 7:  residual SS =  3.38e+10
Iteration 8:  residual SS =  4.03e+09
Iteration 9:  residual SS =  3.04e+09
Iteration 10:  residual SS =  3.04e+09
Iteration 11:  residual SS =  3.04e+09
```

```
Iteration 12:  residual SS =  3.04e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9992
                                                    Adj R-squared =     0.9992
                                                    Root MSE      =   6943.107
                                                    Res. dev.     =   1332.346

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   14.11662   .3195805    44.17   0.000     13.47798    14.75525
          /c |   .0528094   .0006376    82.83   0.000     .0515353    .0540835
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = -8715.34375
Model run:  3
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.62e+12
Iteration 1:  residual SS =  3.62e+12
Iteration 2:  residual SS =  3.62e+12
Iteration 3:  residual SS =  3.61e+12
Iteration 4:  residual SS =  3.29e+12
Iteration 5:  residual SS =  4.44e+11
Iteration 6:  residual SS =  9.33e+10
Iteration 7:  residual SS =  8.26e+09
Iteration 8:  residual SS =  4.13e+09
Iteration 9:  residual SS =  4.10e+09
Iteration 10:  residual SS =  4.10e+09
Iteration 11:  residual SS =  4.10e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9989
                                                    Adj R-squared =     0.9988
                                                    Root MSE      =    8065.48
                                                    Res. dev.     =   1351.826

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   15.87439   .4530864    35.04   0.000     14.96897    16.77981
          /c |   .0539921   .0007594    71.09   0.000     .0524745    .0555097
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = -3024.59375
Model run:  4
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.54e+12
Iteration 1:  residual SS =  3.54e+12
Iteration 2:  residual SS =  3.54e+12
Iteration 3:  residual SS =  3.54e+12
Iteration 4:  residual SS =  3.53e+12
Iteration 5:  residual SS =  3.46e+12
Iteration 6:  residual SS =  3.42e+12
Iteration 7:  residual SS =  1.42e+12
```

```
Iteration 8:  residual SS =  1.06e+12
Iteration 9:  residual SS =  2.99e+10
Iteration 10:  residual SS =  8.78e+09
Iteration 11:  residual SS =  4.60e+09
Iteration 12:  residual SS =  4.59e+09
Iteration 13:  residual SS =  4.59e+09
Iteration 14:  residual SS =  4.59e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9987
                                                    Adj R-squared =     0.9987
                                                    Root MSE      =   8532.949
                                                    Res. dev.     =    1359.15

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   16.55657   .5120767    32.33   0.000     15.53327    17.57987
          /c |   .0544256   .0008085    67.32   0.000     .0528099    .0560413
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = -1052.25
Model run:  5
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.52e+12
Iteration 1:  residual SS =  3.51e+12
Iteration 2:  residual SS =  3.37e+12
Iteration 3:  residual SS =  2.38e+12
Iteration 4:  residual SS =  2.17e+12
Iteration 5:  residual SS =  1.84e+12
Iteration 6:  residual SS =  3.22e+11
Iteration 7:  residual SS =  2.02e+11
Iteration 8:  residual SS =  2.27e+10
Iteration 9:  residual SS =  5.26e+09
Iteration 10:  residual SS =  4.77e+09
Iteration 11:  residual SS =  4.77e+09
Iteration 12:  residual SS =  4.77e+09
Iteration 13:  residual SS =  4.77e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9986
                                                    Adj R-squared =     0.9986
                                                    Root MSE      =   8703.947
                                                    Res. dev.     =    1361.73

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   16.80352   .5343357    31.45   0.000     15.73573     17.8713
          /c |   .0545793   .0008264    66.05   0.000     .0529279    .0562307
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = -366.28125
Model run:  6
(65 real changes made)
(obs = 65)
```

```
Iteration 0:  residual SS =  3.51e+12
Iteration 1:  residual SS =  3.50e+12
Iteration 2:  residual SS =  3.50e+12
Iteration 3:  residual SS =  3.49e+12
Iteration 4:  residual SS =  2.71e+12
Iteration 5:  residual SS =  1.49e+12
Iteration 6:  residual SS =  5.12e+10
Iteration 7:  residual SS =  1.80e+10
Iteration 8:  residual SS =  4.98e+09
Iteration 9:  residual SS =  4.84e+09
Iteration 10:  residual SS =  4.84e+09
Iteration 11:  residual SS =  4.84e+09
Iteration 12:  residual SS =  4.84e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9986
                                                    Adj R-squared =     0.9986
                                                    Root MSE      =   8764.444
                                                    Res. dev.     =    1362.63

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   16.89069   .5423027    31.15   0.000     15.80698    17.97439
          /c |   .0546331   .0008327    65.61   0.000     .0529691    .0562971
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = -127.53125
Model run:  7
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.50e+12
Iteration 1:  residual SS =  3.50e+12
Iteration 2:  residual SS =  3.50e+12
Iteration 3:  residual SS =  3.49e+12
Iteration 4:  residual SS =  1.33e+12
Iteration 5:  residual SS =  1.13e+12
Iteration 6:  residual SS =  8.43e+11
Iteration 7:  residual SS =  5.90e+11
Iteration 8:  residual SS =  1.15e+11
Iteration 9:  residual SS =  1.69e+10
Iteration 10:  residual SS =  5.03e+09
Iteration 11:  residual SS =  4.86e+09
Iteration 12:  residual SS =  4.86e+09
Iteration 13:  residual SS =  4.86e+09
Iteration 14:  residual SS =  4.86e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9986
                                                    Adj R-squared =     0.9986
                                                    Root MSE      =   8785.625
                                                    Res. dev.     =   1362.944

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   16.92118   .5451037    31.04   0.000     15.83188    18.01049
          /c |   .0546519   .0008349    65.46   0.000     .0529835    .0563203
```

```
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = -44.40625
Model run:  8
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.50e+12
Iteration 1:  residual SS =  3.50e+12
Iteration 2:  residual SS =  3.50e+12
Iteration 3:  residual SS =  3.49e+12
Iteration 4:  residual SS =  7.16e+11
Iteration 5:  residual SS =  6.43e+11
Iteration 6:  residual SS =  2.93e+11
Iteration 7:  residual SS =  6.45e+09
Iteration 8:  residual SS =  4.88e+09
Iteration 9:  residual SS =  4.87e+09
Iteration 10:  residual SS =  4.87e+09
Iteration 11:  residual SS =  4.87e+09


Nonlinear regression                               Number of obs =         65
                                                   R-squared     =     0.9986
                                                   Adj R-squared =     0.9986
                                                   Root MSE      =   8793.014
                                                   Res. dev.     =   1363.053

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   16.93182   .5460781    31.01   0.000     15.84057    18.02307
          /c |   .0546585   .0008357    65.41   0.000     .0529885    .0563284
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = -15.46875
Model run:  9
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.50e+12
Iteration 1:  residual SS =  3.50e+12
Iteration 2:  residual SS =  3.50e+12
Iteration 3:  residual SS =  3.49e+12
Iteration 4:  residual SS =  5.59e+11
Iteration 5:  residual SS =  4.85e+11
Iteration 6:  residual SS =  2.45e+11
Iteration 7:  residual SS =  5.90e+09
Iteration 8:  residual SS =  4.88e+09
Iteration 9:  residual SS =  4.87e+09
Iteration 10:  residual SS =  4.87e+09
Iteration 11:  residual SS =  4.87e+09


Nonlinear regression                               Number of obs =         65
                                                   R-squared     =     0.9986
                                                   Adj R-squared =     0.9986
                                                   Root MSE      =   8795.589
                                                   Res. dev.     =   1363.091

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
```

```
-------------+----------------------------------------------------------------
          /b |   16.93553   .5464207    30.99   0.000      15.8436    18.02747
          /c |   .0546608   .0008359    65.39   0.000     .0529903    .0563313
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = -5.375
Model run:  10
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.50e+12
Iteration 1:  residual SS =  3.50e+12
Iteration 2:  residual SS =  3.50e+12
Iteration 3:  residual SS =  3.49e+12
Iteration 4:  residual SS =  5.12e+11
Iteration 5:  residual SS =  4.40e+11
Iteration 6:  residual SS =  2.30e+11
Iteration 7:  residual SS =  5.75e+09
Iteration 8:  residual SS =  4.88e+09
Iteration 9:  residual SS =  4.87e+09
Iteration 10:  residual SS =  4.87e+09
Iteration 11:  residual SS =  4.87e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9986
                                                    Adj R-squared =     0.9986
                                                    Root MSE      =   8796.485
                                                    Res. dev.     =   1363.105

------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   16.93682   .5465396    30.99   0.000     15.84465    18.02899
          /c |   .0546616    .000836    65.38   0.000     .0529909    .0563322
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = -1.875
Model run:  11
(65 real changes made)
(obs = 65)

Iteration 0:  residual SS =  3.50e+12
Iteration 1:  residual SS =  3.50e+12
Iteration 2:  residual SS =  3.50e+12
Iteration 3:  residual SS =  3.49e+12
Iteration 4:  residual SS =  4.96e+11
Iteration 5:  residual SS =  4.26e+11
Iteration 6:  residual SS =  2.25e+11
Iteration 7:  residual SS =  5.69e+09
Iteration 8:  residual SS =  4.88e+09
Iteration 9:  residual SS =  4.88e+09
Iteration 10:  residual SS =  4.88e+09
Iteration 11:  residual SS =  4.88e+09


Nonlinear regression                                Number of obs =         65
                                                    R-squared     =     0.9986
                                                    Adj R-squared =     0.9986
                                                    Root MSE      =   8796.797
                                                    Res. dev.     =   1363.109
```

```
------------------------------------------------------------------------------
             |             Robust HC2
     _washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   16.93727   .5465811    30.99   0.000     15.84501    18.02952
          /c |   .0546618   .0008361    65.38   0.000     .0529911    .0563326
------------------------------------------------------------------------------
(option yhat assumed; fitted values)
Calib = -.65625

. replace ulpop_mod = round(ulpop_mod, 1);
(146 real changes made)

. replace ulpop_mod = . if _n < `lrow';
(64 real changes made, 64 to missing)

. drop _washoe;

. /***********************************************************************/;
. /* Document data file                                                  */;
. /***********************************************************************/;
. notes _dta: Started with WashoeDataAll_01.dta, kept only year, population
>  wcf2010, sdf2013, and tmwa2010 projections.;

. notes _dta: lrpop_mod is results of long-run population projection.;

. notes _dta: cpop_mod is the calibrated results that match launch year and
>  long-run trend. cpop_mod will be TMWA2014 projection.;

. notes _dta: llpop_mod and lupop_mod are the 95% confidence ranges.;

. notes _dta: This file updated on TS by S. Stoddard.;

. save `dpath'WashoeDataAll_02, replace;
file Data/WashoeDataAll_02.dta saved

. notes;

_dta:
  1.  Years 1950 to 1986 is from an Excel file provide by the Demographer's office.
  2.  Years 1986 to 2008 is from Nevada County Populaton estimates 1986 to 2008.
  3.  Years 1950, 1960, 1970 data from U.S. Census only.
  4.  Year 2009 from State Demographer's Draft 2009 Estimates.
  5.  Year 2010 from State Demographer's Estimates for 2001 to 2010.
  6.  Estimate of population as of July 1 of each year.
  7.  Data from 2000 to 2012 from 2012 State Demographer's Estimates.
  8.  Some population values for year 2000 were updated using 2012 report.
  9.  This file contains all prior population projections.
 10.  This file was last updated on 21 Apr 2015 09:22 by S. Stoddard as part of TMWA
2015
      population projection
 11.  Started with WashoeDataAll_01.dta, kept only year, population wcf2010, sdf2013,
and
      tmwa2010 projections.
 12.  lrpop_mod is results of long-run population projection.
 13.  cpop_mod is the calibrated results that match launch year and long-run trend.
      cpop_mod will be TMWA2014 projection.
 14.  llpop_mod and lupop_mod are the 95% confidence ranges.
 15.  This file updated on 21 Apr 2015 09:23 by S. Stoddard.
 16.  This file was last updated on 21 Apr 2015 10:17 by S. Stoddard as part of TMWA
2015
      population projection
 17.  This file updated on 21 Apr 2015 10:17 by S. Stoddard.
```

```
 18.  This file contains all prior population projections.
 19.  This file was last updated on 1 Sep 2015 17:10 by S. Stoddard as part of TMWA
2015
      population projection
 20.  Started with WashoeDataAll_01.dta, kept only year, population wcf2010, sdf2013,
and
      tmwa2010 projections.
 21.  lrpop_mod is results of long-run population projection.
 22.  cpop_mod is the calibrated results that match launch year and long-run trend.
      cpop_mod will be TMWA2014 projection.
 23.  llpop_mod and lupop_mod are the 95% confidence ranges.
 24.  This file updated on 2 Sep 2015 08:15 by S. Stoddard.

. /***********************************************************************/;
. /* Export Data for Excel Table                                         */;
. /***********************************************************************/;
. export excel t year washoe lrpop_mod cpop_mod using `dpath'ModelData.xls,
>    firstrow(varl) datestring("%tyCCYY") replace;
file Data/ModelData.xls saved

. log close;
      name:  <unnamed>
       log:  S:\PrjStata\Population2015\Work\Logs/Population2015_02.log
  log type:  text
 closed on:   2 Sep 2015, 08:15:52
-------------------------------------------------------------------------------------
----
```

TRUCKEE MEADOWS WATER
AUTHORITY

APPENDIX 4-2

TPEM SERIES NO. 7:

WASHOE COUNTY BUILDING PROJECTIONS

TRUCKEE MEADOWS WATER AUTHORITY
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Memorandum

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Ⓟ775.834.8080 ● Ⓕ 775.834.8003

TO: File

FROM: Shawn Stoddard, Ph.D. Senior Resource Economist

DATE: September 9, 2015

SUBJECT: TPEM Series No. 7: Washoe County Building Projections

Introduction

The memorandum "TPEM Series No. 6: Washoe County Population Projection 2014 to 2060", updated a population projection model based on the fitting of a logistic curve model to past population and project that population to the year 2100. That was the first of three steps to developing a water demand projection. The second step, described in this memorandum is the development of a Washoe County inventory of buildings that consume water, and then use that inventory time series to project future building inventories as a function of population. The third step is the estimation of water demand as a function of building inventories and historic water use coefficients. The water demand projection will be described in TPEM Series No 8.

This report will present the results in the following manner:

1. Graphical presentation of projections of new dwellings and commercial building as a function of projected population resulting from a statistical vector autoregression ("VAR") model developed for projecting future dwelling units and commercial buildings as a function of current building inventory trends and projected population, and an ordinary least squares regression was estimated to provide a trend of developed land used as a function of projected population..
2. Tabular presentation of the County projection, and disaggregation to the TMWA service area and hydrographic basins.
3. Discussion of the methodology and statistic used to develop each of these models.
4. Appendices of statistical outputs.

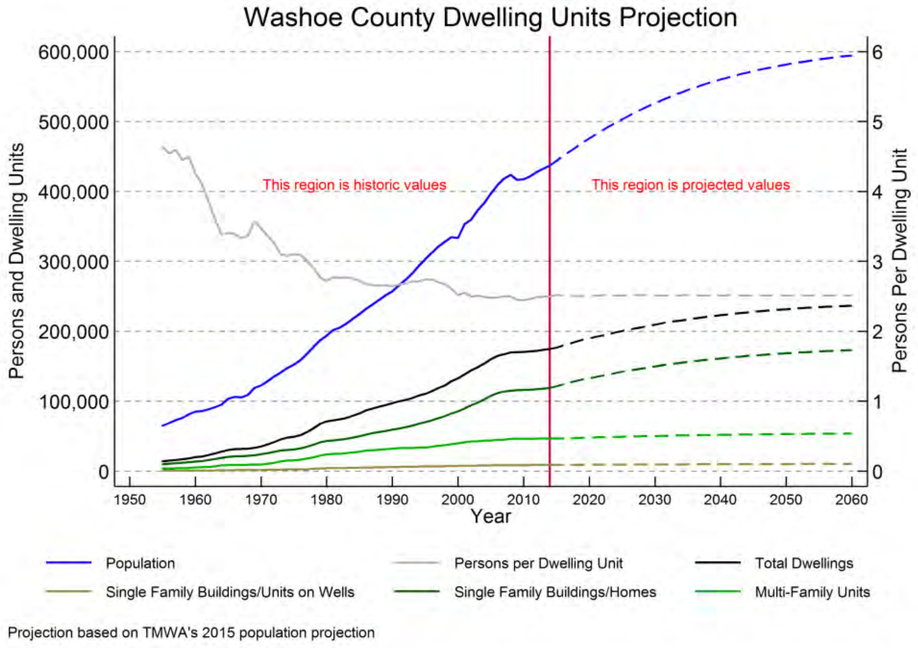


Figure : Washoe County Dwelling Unit Projections 2014 to 2060

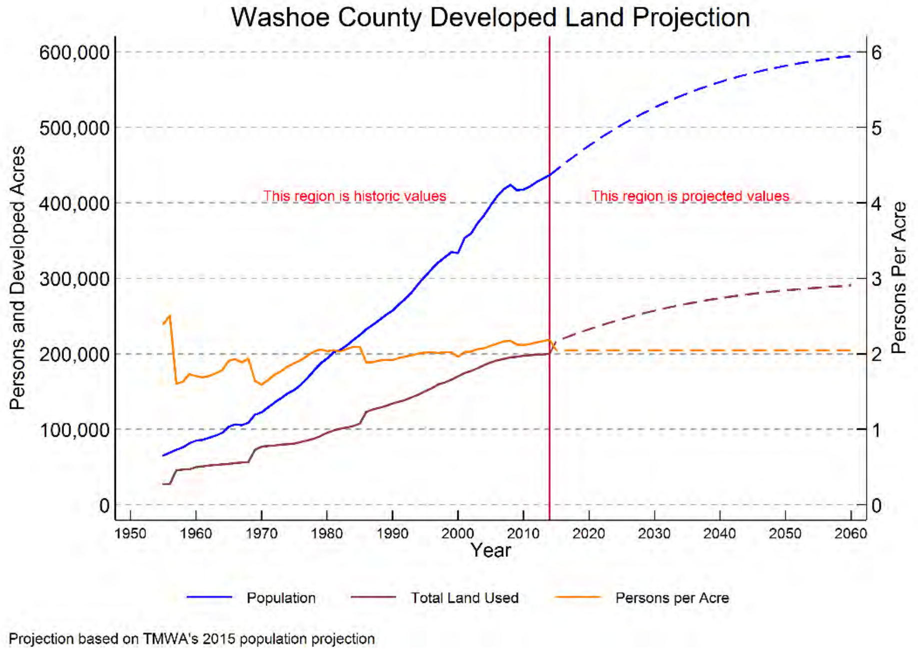


Figure 1: Washoe County Developed Land Projection 2014 to 2060

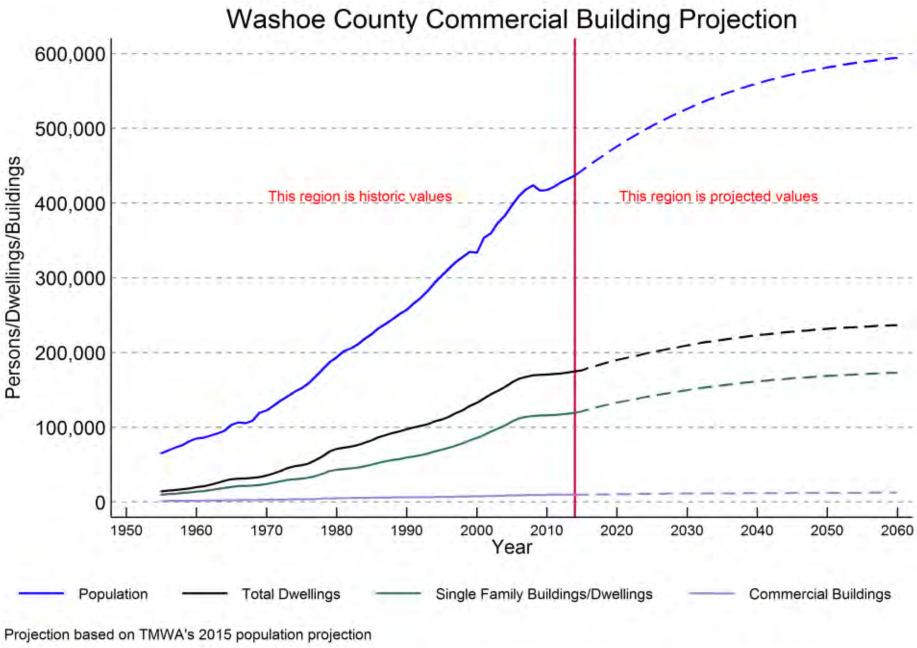


Figure 2: Washoe County Commercial Building Projection 2014 to 2060

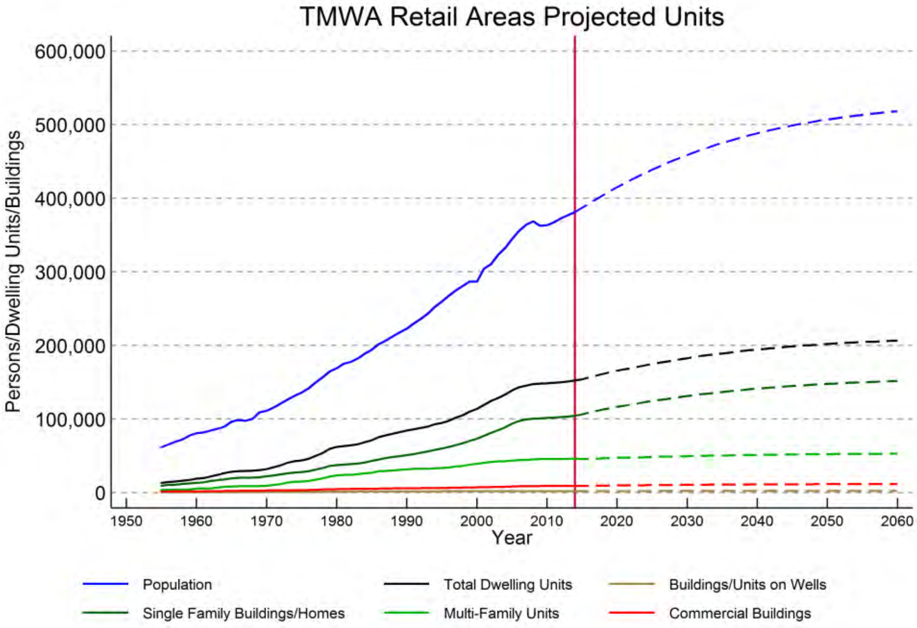
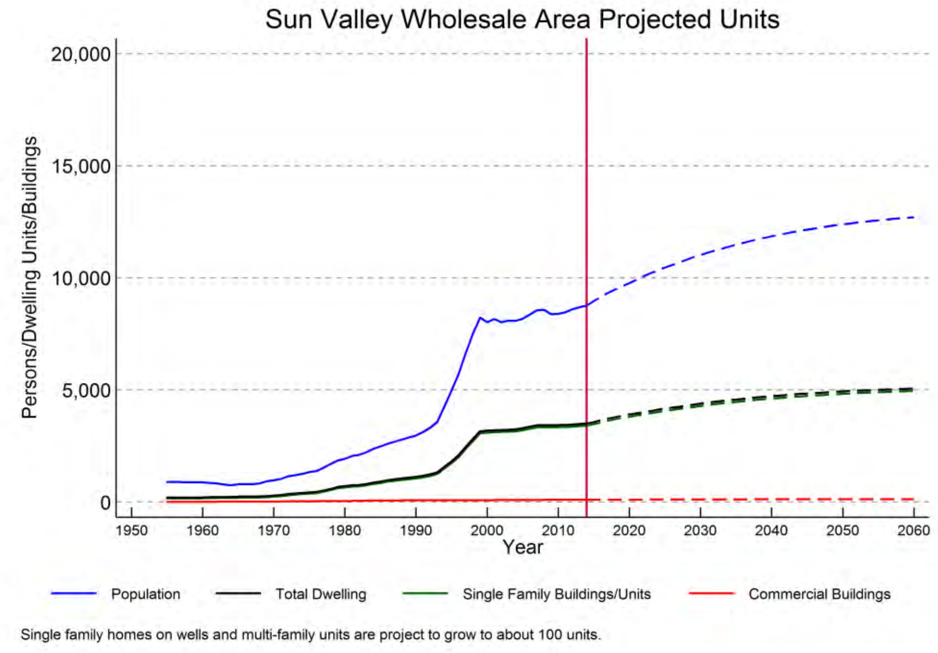


Figure 3: TMWA Retail Service Area Building Projection 2014 to 2060



Single family homes on wells and multi-family units are project to grow to about 100 units.

Figure 4: TMWA Wholesale Area (Sun Valley) Building Projections 2014 to 2060

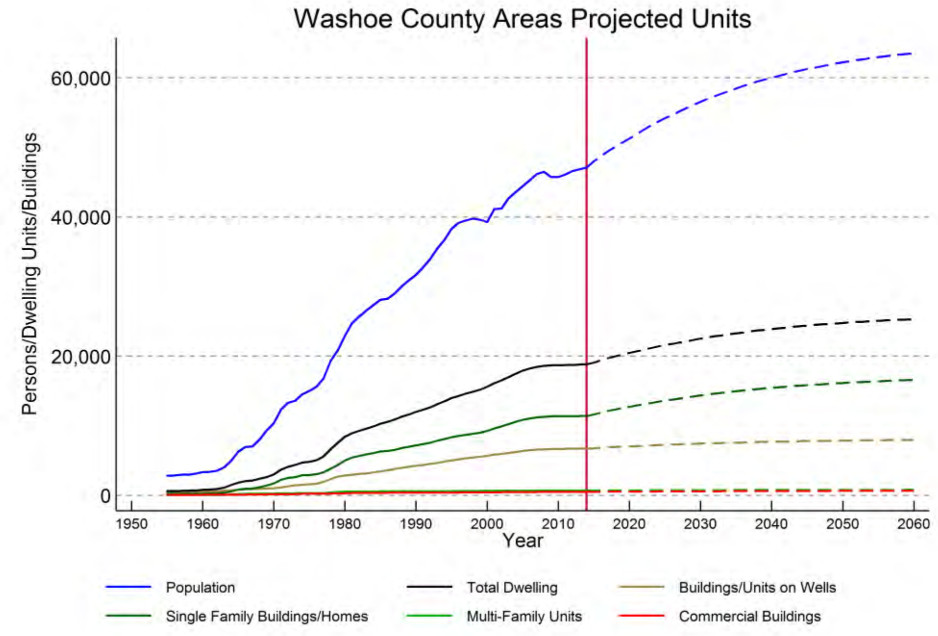


Figure 5: Washoe County/Non-TMWA Areas Building Projections 2014 to 2060

Table 1: Washoe County Population and Building Projections 2014 to 2060

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings	Developed Land ac.
2014	436,797	8,626	119,227	46,897	174,750	9,554	199,925
2015	443,729	8,676	121,297	46,383	176,356	9,632	216,837
2016	450,488	8,748	124,131	46,589	179,468	9,743	220,140
2017	457,072	8,824	126,728	46,729	182,281	9,884	223,357
2018	463,476	8,898	128,942	47,266	185,106	10,057	226,487
2019	469,699	8,964	130,987	47,769	187,720	10,172	229,528
2020	475,740	9,008	132,896	48,088	189,992	10,246	232,480
2021	481,596	9,052	134,713	48,251	192,016	10,306	235,341
2022	487,267	9,112	136,568	48,248	193,928	10,383	238,113
2023	492,754	9,175	138,482	48,438	196,095	10,499	240,794
2024	498,058	9,243	140,404	48,781	198,428	10,624	243,386
2025	503,178	9,296	142,086	49,080	200,462	10,732	245,888
2026	508,118	9,330	143,578	49,451	202,359	10,813	248,302
2027	512,879	9,368	145,056	49,660	204,084	10,867	250,629
2028	517,463	9,407	146,567	49,726	205,700	10,924	252,869
2029	521,874	9,458	148,190	49,924	207,572	11,004	255,024
2030	526,115	9,518	149,797	50,094	209,409	11,097	257,097
2031	530,188	9,564	151,253	50,380	211,197	11,198	259,087
2032	534,099	9,603	152,571	50,728	212,902	11,279	260,998
2033	537,850	9,632	153,732	50,884	214,248	11,334	262,831
2034	541,445	9,655	154,861	51,054	215,570	11,383	264,588
2035	544,890	9,691	156,059	51,151	216,901	11,431	266,271
2036	548,187	9,729	157,248	51,211	218,188	11,495	267,882
2037	551,342	9,767	158,414	51,446	219,627	11,571	269,424
2038	554,358	9,804	159,472	51,622	220,898	11,636	270,898
2039	557,241	9,826	160,375	51,798	221,999	11,692	272,307
2040	559,995	9,847	161,242	51,985	223,074	11,732	273,653
2041	562,624	9,869	162,087	52,006	223,962	11,764	274,937
2042	565,133	9,891	162,951	52,101	224,943	11,808	276,163
2043	567,526	9,923	163,850	52,219	225,992	11,856	277,333
2044	569,807	9,950	164,665	52,302	226,917	11,908	278,448
2045	571,981	9,970	165,410	52,508	227,888	11,958	279,510
2046	574,052	9,990	166,086	52,614	228,690	11,991	280,522
2047	576,024	10,002	166,694	52,675	229,371	12,020	281,486
2048	577,901	10,018	167,336	52,786	230,140	12,049	282,403
2049	579,688	10,039	167,977	52,792	230,808	12,078	283,276
2050	581,387	10,056	168,591	52,889	231,536	12,118	284,106
2051	583,003	10,077	169,187	53,019	232,283	12,154	284,896
2052	584,539	10,091	169,690	53,067	232,848	12,184	285,647
2053	585,999	10,100	170,154	53,193	233,447	12,211	286,360
2054	587,387	10,113	170,615	53,233	233,961	12,228	287,038
2055	588,705	10,123	171,049	53,240	234,412	12,249	287,682
2056	589,956	10,136	171,511	53,337	234,984	12,275	288,294
2057	591,145	10,152	171,948	53,356	235,456	12,299	288,875
2058	592,273	10,161	172,329	53,433	235,923	12,326	289,426
2059	593,344	10,172	172,698	53,532	236,402	12,346	289,949
2060	594,359	10,180	173,015	53,529	236,724	12,360	290,445

Table 2: Population and Building Data and Projection - TMWA Retail Areas (1955 to 2007)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
1955	61,491	263	9,431	3,587	13,281	1,232
1956	65,171	269	10,297	3,773	14,339	1,283
1957	69,163	275	10,859	3,921	15,055	1,336
1958	72,166	294	11,819	4,104	16,217	1,382
1959	77,297	317	12,429	4,435	17,181	1,436
1960	80,762	337	13,369	5,279	18,985	1,582
1961	81,714	347	14,112	5,442	19,901	1,732
1962	84,305	378	15,620	5,871	21,869	1,794
1963	86,908	414	16,935	6,792	24,141	1,881
1964	89,584	445	18,070	7,997	26,512	1,999
1965	96,391	479	19,358	8,422	28,259	2,108
1966	98,629	509	19,971	8,597	29,077	2,381
1967	97,713	530	20,199	8,623	29,352	2,452
1968	99,944	549	20,442	8,710	29,701	2,517
1969	108,971	576	20,934	8,997	30,507	2,589
1970	111,253	594	22,160	9,289	32,043	2,715
1971	115,274	631	23,281	10,406	34,318	2,767
1972	120,966	661	24,892	11,576	37,129	2,839
1973	126,228	684	26,361	13,608	40,653	2,974
1974	131,665	713	27,214	14,877	42,804	3,293
1975	135,886	740	27,854	15,212	43,806	3,393
1976	141,706	791	29,109	15,930	45,830	3,492
1977	149,482	904	31,088	17,736	49,728	3,648
1978	156,571	1,056	33,496	19,308	53,860	4,289
1979	164,498	1,157	36,344	21,949	59,450	4,462
1980	168,813	1,210	37,380	23,428	62,018	4,658
1981	174,815	1,233	37,938	23,871	63,042	4,794
1982	177,340	1,253	38,649	24,166	64,068	4,875
1983	182,244	1,289	39,476	25,027	65,792	4,979
1984	188,638	1,320	41,037	26,164	68,521	5,095
1985	194,004	1,363	42,863	26,916	71,142	5,183
1986	201,454	1,399	44,950	28,989	75,338	5,313
1987	206,687	1,450	46,869	29,383	77,702	5,431
1988	212,092	1,485	48,377	30,052	79,914	5,577
1989	217,778	1,511	49,519	30,903	81,933	5,699
1990	222,491	1,526	51,087	31,600	84,213	5,814
1991	229,853	1,544	52,448	32,192	86,184	5,906
1992	235,896	1,560	54,035	32,262	87,857	5,962
1993	243,198	1,584	55,840	32,350	89,774	6,034
1994	252,147	1,605	58,184	33,083	92,872	6,126
1995	259,494	1,629	59,877	33,200	94,706	6,227
1996	267,480	1,643	61,903	34,110	97,656	6,439
1997	274,696	1,654	64,412	35,598	101,664	6,598
1998	280,650	1,662	67,024	36,269	104,955	6,756
1999	286,730	1,671	70,357	38,041	110,069	6,948
2000	286,324	1,679	73,144	38,933	113,756	7,099
2001	303,931	1,694	76,959	40,489	119,142	7,274
2002	310,164	1,713	81,052	41,599	124,364	7,428
2003	322,447	1,725	84,622	42,169	128,516	7,631
2004	331,855	1,743	88,580	42,845	133,168	7,899
2005	344,269	1,759	93,642	43,361	138,762	8,162
2006	355,417	1,774	97,353	44,013	143,140	8,484
2007	363,408	1,789	99,287	44,287	145,363	8,666

Table 3: Population and Building Data and Projection - TMWA Retail Areas (2008 to 2060)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
2008	368,712	1,802	100,410	45,332	147,544	8,784
2009	362,588	1,816	100,922	45,378	148,116	8,828
2010	363,299	1,817	101,329	45,382	148,528	8,853
2011	367,083	1,819	101,803	45,538	149,160	8,876
2012	372,592	1,820	102,412	45,644	149,876	8,896
2013	376,749	1,825	103,328	45,909	151,062	8,938
2014	381,030	1,835	104,407	46,170	152,412	8,963
2015	386,752	1,845	106,208	45,664	153,717	9,036
2016	392,607	1,861	108,689	45,867	156,417	9,140
2017	398,383	1,877	110,963	46,005	158,845	9,272
2018	403,965	1,893	112,902	46,533	161,328	9,434
2019	409,397	1,907	114,692	47,029	163,628	9,542
2020	414,720	1,916	116,364	47,343	165,623	9,612
2021	419,797	1,925	117,955	47,503	167,383	9,668
2022	424,740	1,938	119,579	47,500	169,017	9,740
2023	429,457	1,952	121,255	47,687	170,894	9,849
2024	434,052	1,966	122,938	48,025	172,929	9,966
2025	438,515	1,977	124,411	48,319	174,707	10,068
2026	442,905	1,984	125,717	48,685	176,386	10,144
2027	447,048	1,993	127,011	48,890	177,894	10,194
2028	451,094	2,001	128,334	48,955	179,290	10,248
2029	454,825	2,012	129,755	49,150	180,917	10,323
2030	458,450	2,024	131,162	49,318	182,504	10,410
2031	462,016	2,034	132,437	49,599	184,070	10,505
2032	465,610	2,043	133,591	49,942	185,576	10,581
2033	468,748	2,049	134,608	50,095	186,752	10,632
2034	472,037	2,054	135,596	50,263	187,913	10,678
2035	474,929	2,061	136,645	50,358	189,064	10,723
2036	477,712	2,069	137,686	50,417	190,172	10,783
2037	480,497	2,077	138,707	50,649	191,433	10,855
2038	483,278	2,085	139,634	50,822	192,541	10,916
2039	485,708	2,090	140,424	50,995	193,509	10,968
2040	488,085	2,094	141,183	51,179	194,456	11,006
2041	490,398	2,099	141,923	51,200	195,222	11,036
2042	492,545	2,104	142,680	51,293	196,077	11,077
2043	494,637	2,111	143,467	51,410	196,988	11,122
2044	496,646	2,116	144,181	51,491	197,788	11,171
2045	498,606	2,121	144,833	51,694	198,648	11,218
2046	500,363	2,125	145,425	51,798	199,348	11,249
2047	502,057	2,127	145,957	51,859	199,943	11,276
2048	503,752	2,131	146,519	51,968	200,618	11,303
2049	505,389	2,135	147,081	51,974	201,190	11,330
2050	506,785	2,139	147,618	52,069	201,826	11,368
2051	508,225	2,143	148,140	52,197	202,480	11,402
2052	509,457	2,146	148,581	52,244	202,971	11,430
2053	510,795	2,148	148,987	52,369	203,504	11,455
2054	512,116	2,151	149,390	52,408	203,949	11,471
2055	513,095	2,153	149,771	52,415	204,339	11,491
2056	514,356	2,156	150,175	52,510	204,841	11,515
2057	515,373	2,159	150,558	52,529	205,246	11,538
2058	516,199	2,161	150,891	52,605	205,657	11,563
2059	517,261	2,164	151,214	52,702	206,080	11,582
2060	518,160	2,165	151,492	52,699	206,356	11,595

Table 4: Population and Building Data and Projection - Sun Valley Wholesale Area (1955 to 2007)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
1955	889	2	153	37	192	5
1956	882	2	155	37	194	5
1957	891	2	155	37	194	5
1958	868	2	156	37	195	5
1959	877	2	156	37	195	5
1960	868	2	165	37	204	6
1961	854	2	169	37	208	6
1962	825	2	175	37	214	8
1963	778	2	177	37	216	8
1964	743	2	181	37	220	8
1965	791	2	187	43	232	11
1966	801	3	190	43	236	12
1967	792	3	192	43	238	12
1968	831	3	201	43	247	14
1969	922	3	212	43	258	16
1970	972	3	234	43	280	17
1971	1,024	4	258	43	305	20
1972	1,140	5	302	43	350	23
1973	1,195	5	337	43	385	26
1974	1,252	5	359	43	407	29
1975	1,331	5	380	44	429	30
1976	1,379	7	397	42	446	32
1977	1,527	8	457	43	508	32
1978	1,695	9	530	44	583	33
1979	1,851	10	616	43	669	36
1980	1,924	10	654	43	707	39
1981	2,058	11	687	44	742	52
1982	2,095	13	702	42	757	55
1983	2,216	14	742	44	800	59
1984	2,370	18	800	43	861	62
1985	2,476	19	845	44	908	62
1986	2,599	19	909	44	972	65
1987	2,689	23	946	42	1,011	67
1988	2,787	24	983	43	1,050	68
1989	2,873	25	1,012	44	1,081	68
1990	2,956	27	1,050	42	1,119	68
1991	3,126	27	1,102	43	1,172	70
1992	3,313	30	1,161	43	1,234	70
1993	3,579	31	1,247	43	1,321	70
1994	4,273	32	1,498	44	1,574	70
1995	4,962	32	1,735	44	1,811	70
1996	5,711	36	2,007	42	2,085	70
1997	6,666	39	2,385	43	2,467	72
1998	7,503	43	2,719	44	2,806	75
1999	8,214	44	3,066	43	3,153	76
2000	8,012	44	3,095	44	3,183	78
2001	8,161	46	3,112	41	3,199	81
2002	8,013	47	3,124	42	3,213	81
2003	8,094	47	3,136	43	3,226	81
2004	8,082	48	3,151	44	3,243	85
2005	8,167	49	3,199	44	3,292	87
2006	8,360	50	3,272	45	3,367	88
2007	8,550	51	3,324	45	3,420	89

Table 5: Population and Building Data and Projection - Sun Valley Wholesale Area (2008 to 2060)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
2008	8,567	51	3,336	41	3,428	90
2009	8,375	51	3,329	41	3,421	91
2010	8,397	51	3,341	41	3,433	93
2011	8,458	51	3,344	42	3,437	94
2012	8,592	52	3,362	42	3,456	94
2013	8,692	53	3,390	42	3,485	94
2014	8,763	53	3,410	42	3,505	94
2015	8,967	53	3,469	42	3,564	94
2016	9,149	53	3,550	42	3,645	95
2017	9,330	54	3,624	42	3,720	97
2018	9,478	54	3,688	43	3,785	99
2019	9,618	55	3,746	43	3,844	100
2020	9,763	55	3,801	43	3,899	100
2021	9,909	55	3,853	43	3,951	101
2022	10,065	56	3,906	43	4,005	102
2023	10,205	56	3,961	44	4,061	103
2024	10,331	56	4,016	44	4,116	104
2025	10,454	57	4,064	44	4,165	105
2026	10,566	57	4,106	45	4,208	106
2027	10,683	57	4,149	45	4,251	106
2028	10,804	57	4,192	45	4,294	107
2029	10,913	58	4,238	45	4,341	108
2030	11,020	58	4,284	45	4,387	109
2031	11,117	58	4,326	45	4,429	110
2032	11,213	59	4,364	46	4,469	111
2033	11,300	59	4,397	46	4,502	111
2034	11,389	59	4,429	46	4,534	112
2035	11,475	59	4,463	46	4,568	112
2036	11,560	59	4,497	46	4,602	113
2037	11,639	60	4,531	46	4,637	113
2038	11,714	60	4,561	46	4,667	114
2039	11,782	60	4,587	47	4,694	115
2040	11,845	60	4,612	47	4,719	115
2041	11,914	60	4,636	47	4,743	115
2042	11,975	60	4,660	47	4,767	116
2043	12,038	61	4,686	47	4,794	116
2044	12,095	61	4,709	47	4,817	117
2045	12,146	61	4,731	47	4,839	117
2046	12,194	61	4,750	47	4,858	118
2047	12,241	61	4,767	47	4,875	118
2048	12,291	61	4,786	48	4,895	118
2049	12,341	61	4,804	48	4,913	118
2050	12,382	61	4,822	48	4,931	119
2051	12,419	61	4,839	48	4,948	119
2052	12,457	62	4,853	48	4,963	119
2053	12,490	62	4,866	48	4,976	120
2054	12,530	62	4,880	48	4,990	120
2055	12,560	62	4,892	48	5,002	120
2056	12,593	62	4,905	48	5,015	120
2057	12,625	62	4,918	48	5,028	121
2058	12,648	62	4,929	48	5,039	121
2059	12,673	62	4,939	48	5,049	121
2060	12,701	62	4,948	48	5,058	121

Table 6: Population and Building Data and Projection - Washoe County / Non-TMWA Served Areas (1955 to 2007)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
1955	2,824	388	174	48	610	53
1956	2,845	402	176	48	626	55
1957	2,954	412	183	48	643	57
1958	2,977	431	190	48	669	57
1959	3,122	441	205	48	694	57
1960	3,361	494	242	54	790	61
1961	3,392	525	247	54	826	63
1962	3,520	587	272	54	913	69
1963	4,032	679	387	54	1,120	69
1964	4,954	743	578	145	1,466	75
1965	6,256	816	825	193	1,834	91
1966	6,937	864	954	227	2,045	99
1967	7,038	906	981	227	2,114	106
1968	8,002	945	1,194	239	2,378	126
1969	9,316	971	1,398	239	2,608	138
1970	10,364	1,021	1,704	260	2,985	148
1971	12,314	1,160	2,240	266	3,666	157
1972	13,306	1,307	2,492	285	4,084	161
1973	13,600	1,453	2,631	296	4,380	172
1974	14,503	1,527	2,877	311	4,715	220
1975	14,989	1,596	2,926	310	4,832	224
1976	15,608	1,688	3,047	313	5,048	229
1977	16,798	1,956	3,315	317	5,588	235
1978	19,326	2,360	3,853	435	6,648	258
1979	20,869	2,679	4,373	490	7,542	278
1980	22,903	2,863	5,025	526	8,414	296
1981	24,768	2,977	5,427	528	8,932	333
1982	25,648	3,081	5,653	532	9,266	349
1983	26,559	3,158	5,887	543	9,588	355
1984	27,335	3,311	6,075	543	9,929	358
1985	28,104	3,457	6,296	553	10,306	360
1986	28,256	3,603	6,396	568	10,567	364
1987	29,010	3,791	6,545	570	10,906	366
1988	30,027	3,955	6,789	570	11,314	367
1989	30,923	4,084	6,976	574	11,634	369
1990	31,670	4,237	7,170	580	11,987	385
1991	32,780	4,362	7,351	578	12,291	388
1992	33,987	4,509	7,570	579	12,658	391
1993	35,458	4,658	7,851	580	13,089	393
1994	36,737	4,851	8,100	580	13,531	396
1995	38,283	5,012	8,361	599	13,972	401
1996	39,146	5,157	8,534	601	14,292	408
1997	39,484	5,323	8,688	602	14,613	413
1998	39,781	5,425	8,850	602	14,877	417
1999	39,622	5,556	8,991	663	15,210	421
2000	39,288	5,689	9,258	662	15,609	433
2001	41,117	5,831	9,624	663	16,118	435
2002	41,218	5,946	9,917	664	16,527	441
2003	42,633	6,097	10,230	665	16,992	446
2004	43,558	6,248	10,569	662	17,479	468
2005	44,437	6,370	10,880	661	17,911	473
2006	45,275	6,493	11,057	684	18,234	474
2007	46,183	6,578	11,211	684	18,473	481

Table 7: Population and Building Data and Projection - Washoe County / Non-TMWA Served Areas (2008 to 2060)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
2008	46,466	6,628	11,284	682	18,594	488
2009	45,712	6,650	11,341	682	18,673	488
2010	45,721	6,664	11,346	682	18,692	489
2011	46,095	6,686	11,359	685	18,730	489
2012	46,595	6,699	11,362	682	18,743	491
2013	46,852	6,720	11,385	681	18,786	496
2014	47,083	6,738	11,410	685	18,833	497
2015	47,993	6,778	11,620	677	19,075	502
2016	48,709	6,834	11,892	680	19,406	508
2017	49,448	6,893	12,141	682	19,716	515
2018	50,065	6,951	12,353	690	19,994	524
2019	50,663	7,003	12,549	697	20,249	530
2020	51,257	7,037	12,731	702	20,470	534
2021	51,868	7,071	12,906	704	20,681	537
2022	52,534	7,118	13,083	704	20,905	541
2023	53,130	7,168	13,267	707	21,142	547
2024	53,674	7,221	13,451	712	21,384	554
2025	54,193	7,262	13,612	717	21,591	559
2026	54,654	7,289	13,755	722	21,766	563
2027	55,133	7,318	13,896	725	21,939	566
2028	55,644	7,349	14,041	726	22,116	569
2029	56,100	7,389	14,197	729	22,315	573
2030	56,563	7,435	14,351	731	22,517	578
2031	56,969	7,471	14,490	736	22,697	583
2032	57,353	7,502	14,616	741	22,859	588
2033	57,720	7,525	14,728	743	22,996	591
2034	58,085	7,542	14,836	745	23,123	593
2035	58,449	7,571	14,950	747	23,268	596
2036	58,811	7,600	15,064	748	23,412	599
2037	59,128	7,630	15,176	751	23,557	603
2038	59,462	7,659	15,277	754	23,690	606
2039	59,728	7,676	15,364	756	23,796	609
2040	59,984	7,692	15,447	759	23,898	611
2041	60,280	7,710	15,528	759	23,997	613
2042	60,537	7,727	15,611	761	24,099	615
2043	60,794	7,752	15,697	762	24,211	618
2044	61,047	7,773	15,775	764	24,312	620
2045	61,249	7,789	15,846	767	24,402	623
2046	61,452	7,804	15,911	768	24,483	625
2047	61,650	7,814	15,969	769	24,552	626
2048	61,841	7,826	16,031	771	24,628	628
2049	62,059	7,842	16,092	771	24,705	629
2050	62,220	7,856	16,151	772	24,779	631
2051	62,384	7,872	16,208	774	24,854	633
2052	62,534	7,883	16,256	775	24,914	635
2053	62,670	7,890	16,301	777	24,968	636
2054	62,830	7,900	16,345	777	25,022	637
2055	62,953	7,908	16,386	777	25,071	638
2056	63,096	7,918	16,431	779	25,128	640
2057	63,235	7,931	16,473	779	25,183	641
2058	63,320	7,938	16,509	780	25,227	642
2059	63,433	7,946	16,544	782	25,272	643
2060	63,553	7,953	16,575	782	25,310	644

Table 8: Population and Building Data and Projection - Basin 83 Tracy Segment (1955 to 2007)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
1955	245	28	18	7	53	8
1956	245	29	18	7	54	8
1957	248	29	18	7	54	8
1958	240	29	18	7	54	8
1959	252	31	18	7	56	8
1960	238	31	18	7	56	8
1961	226	31	17	7	55	8
1962	216	31	18	7	56	9
1963	202	32	17	7	56	9
1964	213	35	19	9	63	9
1965	211	35	18	9	62	9
1966	214	35	19	9	63	9
1967	203	35	17	9	61	9
1968	212	37	17	9	63	9
1969	232	38	18	9	65	9
1970	222	38	17	9	64	9
1971	218	38	18	9	65	9
1972	225	40	19	10	69	9
1973	205	40	18	8	66	9
1974	209	41	18	9	68	9
1975	217	42	19	9	70	10
1976	226	43	20	10	73	11
1977	216	46	17	9	72	11
1978	221	47	19	10	76	11
1979	213	51	17	9	77	12
1980	223	55	17	10	82	12
1981	236	57	18	10	85	12
1982	238	58	18	10	86	12
1983	238	58	18	10	86	12
1984	240	60	19	8	87	12
1985	245	62	20	8	90	12
1986	233	62	16	9	87	12
1987	231	62	16	9	87	12
1988	239	64	17	9	90	12
1989	239	64	17	9	90	12
1990	243	64	18	10	92	13
1991	245	64	18	10	92	13
1992	269	65	25	10	100	13
1993	274	65	26	10	101	14
1994	353	66	54	10	130	14
1995	364	67	56	10	133	14
1996	375	69	58	10	137	14
1997	373	71	60	7	138	14
1998	356	71	55	7	133	14
1999	359	72	58	8	138	15
2000	357	74	60	8	142	16
2001	352	76	54	8	138	18
2002	352	77	56	8	141	18
2003	364	77	59	9	145	19
2004	371	79	61	9	149	19
2005	355	80	54	9	143	19
2006	360	80	56	9	145	20
2007	368	81	57	9	147	20

Table 9: Population and Building Data and Projections - Basin 83 Tracy Segment (2008 to 2060)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
2008	370	81	58	9	148	21
2009	367	83	58	9	150	21
2010	367	83	58	9	150	21
2011	369	83	58	9	150	21
2012	380	85	59	9	153	21
2013	397	91	59	9	159	21
2014	403	92	60	9	161	21
2015	410	93	61	9	163	21
2016	414	94	62	9	165	21
2017	416	94	63	9	166	22
2018	421	95	64	9	168	22
2019	428	96	65	10	171	22
2020	431	96	66	10	172	23
2021	436	97	67	10	174	23
2022	440	97	68	10	175	23
2023	445	98	69	10	177	23
2024	449	99	70	10	179	23
2025	452	99	71	10	180	24
2026	457	100	72	10	182	24
2027	460	100	73	10	183	24
2028	463	101	73	10	184	24
2029	465	101	74	10	185	24
2030	470	102	75	10	187	24
2031	472	102	76	10	188	25
2032	474	103	76	10	189	25
2033	477	103	77	10	190	25
2034	477	103	77	10	190	25
2035	482	104	78	10	192	25
2036	485	104	79	10	193	25
2037	487	105	79	10	194	25
2038	489	105	80	10	195	26
2039	489	105	80	10	195	26
2040	492	105	81	10	196	26
2041	495	106	81	10	197	26
2042	495	106	81	10	197	26
2043	497	106	82	10	198	26
2044	497	106	82	10	198	26
2045	505	107	83	11	201	26
2046	505	107	83	11	201	26
2047	505	107	83	11	201	26
2048	507	107	84	11	202	27
2049	507	107	84	11	202	27
2050	510	108	84	11	203	27
2051	512	108	85	11	204	27
2052	512	108	85	11	204	27
2053	512	108	85	11	204	27
2054	512	108	85	11	204	27
2055	515	108	86	11	205	27
2056	515	108	86	11	205	27
2057	517	109	86	11	206	27
2058	517	109	86	11	206	27
2059	517	109	86	11	206	27
2060	520	109	87	11	207	27

Table 10: Population and Building Data and Projection - Basin 85, Spanish Springs Valley (1955 to 2007)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
1955	46	10	0	0	10	1
1956	50	11	0	0	11	1
1957	51	11	0	0	11	1
1958	49	11	0	0	11	1
1959	54	11	1	0	12	1
1960	55	12	1	0	13	1
1961	53	12	1	0	13	1
1962	54	12	2	0	14	1
1963	54	13	2	0	15	1
1964	51	13	2	0	15	1
1965	44	13	0	0	13	1
1966	44	13	0	0	13	1
1967	43	13	0	0	13	1
1968	44	13	0	0	13	1
1969	50	14	0	0	14	1
1970	49	14	0	0	14	1
1971	47	14	0	0	14	1
1972	49	15	0	0	15	1
1973	47	15	0	0	15	1
1974	46	15	0	0	15	1
1975	47	15	0	0	15	1
1976	46	15	0	0	15	1
1977	48	16	0	0	16	1
1978	58	20	0	0	20	1
1979	410	28	120	0	148	1
1980	702	34	224	0	258	2
1981	987	39	317	0	356	3
1982	1,107	44	356	0	400	3
1983	1,338	50	433	0	483	3
1984	1,655	60	541	0	601	3
1985	2,116	66	710	0	776	3
1986	2,254	75	768	0	843	4
1987	2,391	84	815	0	899	4
1988	2,670	96	910	0	1,006	4
1989	2,974	107	1,012	0	1,119	4
1990	3,604	113	1,251	0	1,364	6
1991	4,414	120	1,535	0	1,655	6
1992	5,681	126	1,990	0	2,116	6
1993	7,423	142	2,598	0	2,740	7
1994	9,524	173	3,335	0	3,508	8
1995	10,565	204	3,652	0	3,856	10
1996	12,304	232	4,260	0	4,492	16
1997	14,280	243	5,042	0	5,285	21
1998	16,271	253	5,832	0	6,085	24
1999	18,699	269	6,758	151	7,178	32
2000	19,610	279	7,361	151	7,791	37
2001	22,260	286	8,288	152	8,726	52
2002	25,010	297	9,579	152	10,028	52
2003	28,111	315	10,739	150	11,204	70
2004	31,020	336	11,960	152	12,448	74
2005	33,650	357	13,056	150	13,563	93
2006	37,034	362	14,217	336	14,915	147
2007	39,370	366	14,842	540	15,748	211

Table 11: Population and Building Projections - Basin 85, Spanish Springs Valley (2008 to 2060)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
2008	40,901	368	15,161	838	16,367	232
2009	40,372	370	15,283	839	16,492	246
2010	40,503	371	15,349	839	16,559	248
2011	40,966	372	15,437	837	16,646	250
2012	41,653	372	15,544	839	16,755	253
2013	42,253	372	15,731	839	16,942	256
2014	42,938	372	15,964	839	17,175	262
2015	43,894	374	16,242	830	17,446	264
2016	44,758	377	16,621	834	17,832	267
2017	45,608	380	16,969	836	18,185	271
2018	46,311	384	17,265	846	18,495	276
2019	46,988	386	17,539	855	18,780	279
2020	47,686	388	17,795	861	19,044	281
2021	48,384	390	18,038	864	19,292	282
2022	49,112	393	18,286	864	19,543	284
2023	49,770	395	18,543	867	19,805	288
2024	50,378	398	18,800	873	20,071	291
2025	50,966	401	19,025	879	20,305	294
2026	51,506	402	19,225	885	20,512	296
2027	52,059	404	19,423	889	20,716	298
2028	52,635	405	19,625	890	20,920	299
2029	53,159	408	19,843	894	21,145	302
2030	53,669	410	20,058	897	21,365	304
2031	54,133	412	20,253	902	21,567	307
2032	54,573	414	20,429	908	21,751	309
2033	54,997	415	20,585	911	21,911	311
2034	55,430	416	20,736	914	22,066	312
2035	55,842	418	20,896	916	22,230	313
2036	56,249	419	21,056	917	22,392	315
2037	56,611	421	21,212	921	22,554	317
2038	56,977	423	21,353	924	22,700	319
2039	57,291	424	21,474	927	22,825	320
2040	57,592	424	21,590	931	22,945	321
2041	57,924	425	21,703	931	23,059	322
2042	58,223	426	21,819	933	23,178	324
2043	58,514	428	21,940	935	23,303	325
2044	58,793	429	22,049	936	23,414	326
2045	59,030	430	22,148	940	23,518	328
2046	59,266	431	22,239	942	23,612	329
2047	59,496	431	22,320	943	23,694	329
2048	59,719	432	22,406	945	23,783	330
2049	59,961	433	22,492	945	23,870	331
2050	60,148	433	22,574	947	23,954	332
2051	60,333	434	22,654	949	24,037	333
2052	60,506	435	22,721	950	24,106	334
2053	60,669	435	22,784	952	24,171	335
2054	60,852	436	22,845	953	24,234	335
2055	60,997	436	22,903	953	24,292	336
2056	61,160	437	22,965	955	24,357	336
2057	61,311	438	23,024	955	24,417	337
2058	61,417	438	23,075	956	24,469	338
2059	61,545	438	23,124	958	24,520	338
2060	61,680	439	23,167	958	24,564	339

Table 12: Population and Building Projections - Basin 86, Sun Valley (1955 to 2007)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
1955	889	2	153	37	192	5
1956	882	2	155	37	194	5
1957	891	2	155	37	194	5
1958	868	2	156	37	195	5
1959	877	2	156	37	195	5
1960	868	2	165	37	204	6
1961	854	2	169	37	208	6
1962	825	2	175	37	214	9
1963	778	2	177	37	216	9
1964	743	2	181	37	220	9
1965	791	2	187	43	232	12
1966	807	3	192	43	238	13
1967	799	3	194	43	240	13
1968	838	3	203	43	249	15
1969	936	3	216	43	262	17
1970	996	3	241	43	287	18
1971	1,068	4	271	43	318	21
1972	1,192	5	318	43	366	24
1973	1,273	6	361	43	410	27
1974	1,341	6	387	43	436	30
1975	1,452	6	418	44	468	31
1976	1,503	8	436	42	486	33
1977	1,695	9	512	43	564	33
1978	1,898	10	599	44	653	34
1979	2,072	12	694	43	749	38
1980	2,153	12	736	43	791	41
1981	2,296	13	771	44	828	55
1982	2,392	16	806	42	864	58
1983	2,532	17	853	44	914	62
1984	2,827	21	963	43	1,027	65
1985	2,962	22	1,020	44	1,086	65
1986	3,126	22	1,103	44	1,169	68
1987	3,290	26	1,169	42	1,237	70
1988	3,434	27	1,224	43	1,294	71
1989	3,554	28	1,265	44	1,337	71
1990	3,746	30	1,346	42	1,418	71
1991	3,995	30	1,425	43	1,498	73
1992	4,232	33	1,500	43	1,576	74
1993	4,535	34	1,597	43	1,674	74
1994	5,237	35	1,850	44	1,929	74
1995	5,968	35	2,099	44	2,178	74
1996	6,973	38	2,383	125	2,546	74
1997	7,938	41	2,770	127	2,938	77
1998	8,966	45	3,120	188	3,353	80
1999	9,631	46	3,461	190	3,697	81
2000	9,396	46	3,497	190	3,733	83
2001	9,574	48	3,516	189	3,753	86
2002	9,395	49	3,528	190	3,767	86
2003	9,471	49	3,537	189	3,775	86
2004	9,475	50	3,560	192	3,802	90
2005	9,549	51	3,609	189	3,849	92
2006	9,776	52	3,697	188	3,937	93
2007	9,968	53	3,745	189	3,987	94

Table 13: Population and Building Projections - Basin 86, Sun Valley (2008 to 2060)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
2008	10,003	53	3,761	189	4,003	95
2009	9,790	53	3,757	189	3,999	96
2010	9,816	53	3,771	189	4,013	99
2011	9,859	53	3,763	190	4,006	100
2012	10,011	54	3,783	190	4,027	100
2013	10,128	55	3,815	191	4,061	100
2014	10,185	55	3,827	192	4,074	100
2015	10,416	56	3,894	190	4,140	101
2016	10,622	56	3,985	191	4,232	102
2017	10,825	56	4,068	192	4,316	104
2018	10,993	57	4,139	194	4,390	106
2019	11,154	57	4,205	196	4,458	107
2020	11,321	58	4,266	197	4,521	108
2021	11,487	58	4,324	198	4,580	108
2022	11,660	58	4,384	198	4,640	109
2023	11,819	59	4,445	199	4,703	110
2024	11,963	59	4,507	200	4,766	112
2025	12,101	59	4,561	201	4,821	113
2026	12,234	60	4,609	203	4,872	114
2027	12,364	60	4,656	204	4,920	114
2028	12,502	60	4,705	204	4,969	115
2029	12,628	61	4,757	205	5,023	116
2030	12,746	61	4,808	205	5,074	117
2031	12,859	61	4,855	207	5,123	118
2032	12,964	61	4,898	208	5,167	118
2033	13,067	62	4,935	209	5,206	119
2034	13,168	62	4,971	209	5,242	120
2035	13,266	62	5,009	210	5,281	120
2036	13,364	62	5,048	210	5,320	121
2037	13,451	63	5,085	211	5,359	121
2038	13,539	63	5,119	212	5,394	122
2039	13,612	63	5,148	212	5,423	123
2040	13,685	63	5,176	213	5,452	123
2041	13,763	63	5,203	213	5,479	124
2042	13,836	63	5,231	214	5,508	124
2043	13,906	64	5,260	214	5,538	124
2044	13,971	64	5,286	214	5,564	125
2045	14,028	64	5,310	215	5,589	126
2046	14,084	64	5,331	216	5,611	126
2047	14,139	64	5,351	216	5,631	126
2048	14,190	64	5,371	216	5,651	127
2049	14,248	64	5,392	216	5,672	127
2050	14,295	64	5,412	217	5,693	127
2051	14,337	64	5,431	217	5,712	128
2052	14,382	65	5,447	218	5,730	128
2053	14,420	65	5,462	218	5,745	128
2054	14,463	65	5,477	218	5,760	128
2055	14,499	65	5,491	218	5,774	129
2056	14,539	65	5,506	219	5,790	129
2057	14,574	65	5,520	219	5,804	129
2058	14,598	65	5,532	219	5,816	129
2059	14,628	65	5,544	219	5,828	130
2060	14,659	65	5,554	219	5,838	130

Table 14: Populaton and Building Projections - Basin 87, Truckee Meadows (1955 to 2007)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
1955	60,236	360	9,053	3,597	13,010	1,205
1956	63,935	366	9,918	3,783	14,067	1,255
1957	67,941	376	10,482	3,931	14,789	1,305
1958	69,856	400	11,184	4,114	15,698	1,351
1959	74,949	420	11,794	4,445	16,659	1,404
1960	78,554	451	12,726	5,289	18,466	1,532
1961	79,574	461	13,467	5,452	19,380	1,678
1962	82,250	497	14,958	5,881	21,336	1,740
1963	85,010	548	16,264	6,802	23,614	1,826
1964	87,817	588	17,394	8,007	25,989	1,944
1965	94,198	626	18,574	8,416	27,616	2,048
1966	96,207	663	19,109	8,591	28,363	2,321
1967	95,346	689	19,335	8,617	28,641	2,391
1968	97,575	716	19,577	8,704	28,997	2,453
1969	106,424	742	20,061	8,991	29,794	2,524
1970	108,111	770	21,085	9,283	31,138	2,647
1971	111,915	794	22,124	10,400	33,318	2,699
1972	117,278	820	23,607	11,570	35,997	2,768
1973	122,421	853	25,003	13,571	39,427	2,901
1974	127,854	879	25,844	14,842	41,565	3,219
1975	131,897	902	26,442	15,176	42,520	3,312
1976	137,427	931	27,621	15,894	44,446	3,406
1977	145,040	983	29,582	17,685	48,250	3,561
1978	150,690	1,044	31,534	19,259	51,837	4,201
1979	157,188	1,116	33,790	21,902	56,808	4,374
1980	161,238	1,163	34,697	23,375	59,235	4,565
1981	166,946	1,181	35,203	23,820	60,204	4,695
1982	169,141	1,207	35,854	24,045	61,106	4,771
1983	173,654	1,237	36,655	24,799	62,691	4,875
1984	179,628	1,273	38,038	25,937	65,248	4,989
1985	184,277	1,312	39,573	26,690	67,575	5,075
1986	191,581	1,365	41,517	28,764	71,646	5,202
1987	196,452	1,428	43,271	29,155	73,854	5,313
1988	201,399	1,481	44,637	29,767	75,885	5,454
1989	206,689	1,516	45,626	30,619	77,761	5,570
1990	210,575	1,557	46,829	31,317	79,703	5,679
1991	216,510	1,592	47,795	31,794	81,181	5,766
1992	220,959	1,623	48,806	31,865	82,294	5,815
1993	226,321	1,666	49,924	31,954	83,544	5,883
1994	232,608	1,695	51,331	32,649	85,675	5,968
1995	238,476	1,728	52,544	32,763	87,035	6,060
1996	244,105	1,754	53,877	33,491	89,122	6,259
1997	248,870	1,776	55,392	34,938	92,106	6,407
1998	252,083	1,794	56,933	35,545	94,272	6,552
1999	254,475	1,813	58,868	37,006	97,687	6,731
2000	252,614	1,835	60,629	37,899	100,363	6,870
2001	265,653	1,866	63,101	39,170	104,137	7,022
2002	268,122	1,894	65,385	40,228	107,507	7,171
2003	276,384	1,915	67,484	40,758	110,157	7,336
2004	281,352	1,947	69,612	41,343	112,902	7,598
2005	289,610	1,967	72,906	41,858	116,731	7,833
2006	295,986	1,989	74,894	42,322	119,205	8,092
2007	301,005	2,011	75,999	42,392	120,402	8,199

Table 15: Population and Building Projections - Basin 87, Truckee Meadow (2008 to 2006)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
2008	304,548	2,017	76,725	43,126	121,868	8,295
2009	299,246	2,037	77,039	43,165	122,241	8,323
2010	299,774	2,039	77,349	43,169	122,557	8,344
2011	302,954	2,043	77,733	43,326	123,102	8,361
2012	307,501	2,044	78,212	43,437	123,693	8,379
2013	310,910	2,048	78,916	43,699	124,663	8,416
2014	314,170	2,057	79,715	43,896	125,668	8,435
2015	318,480	2,069	81,099	43,414	126,582	8,504
2016	323,004	2,086	82,994	43,607	128,687	8,602
2017	327,477	2,105	84,730	43,738	130,573	8,727
2018	331,965	2,122	86,211	44,241	132,574	8,879
2019	336,339	2,138	87,578	44,712	134,428	8,981
2020	340,574	2,148	88,854	45,010	136,012	9,046
2021	344,577	2,159	90,069	45,163	137,391	9,099
2022	348,407	2,173	91,309	45,160	138,642	9,167
2023	352,109	2,188	92,589	45,338	140,115	9,270
2024	355,760	2,204	93,874	45,659	141,737	9,380
2025	359,319	2,217	94,999	45,939	143,155	9,475
2026	362,857	2,225	95,996	46,286	144,507	9,547
2027	366,144	2,234	96,984	46,482	145,700	9,594
2028	369,306	2,244	97,995	46,544	146,783	9,645
2029	372,235	2,256	99,080	46,729	148,065	9,715
2030	375,072	2,270	100,154	46,888	149,312	9,798
2031	377,918	2,281	101,128	47,156	150,565	9,887
2032	380,816	2,290	102,009	47,481	151,780	9,958
2033	383,300	2,297	102,785	47,627	152,709	10,007
2034	385,919	2,303	103,540	47,787	153,630	10,050
2035	388,177	2,311	104,341	47,877	154,529	10,092
2036	390,337	2,320	105,136	47,933	155,389	10,149
2037	392,559	2,329	105,916	48,153	156,398	10,216
2038	394,770	2,338	106,623	48,318	157,279	10,273
2039	396,716	2,344	107,227	48,483	158,054	10,323
2040	398,621	2,349	107,806	48,658	158,813	10,358
2041	400,420	2,354	108,371	48,678	159,403	10,386
2042	402,108	2,359	108,949	48,767	160,075	10,425
2043	403,754	2,367	109,550	48,877	160,794	10,468
2044	405,333	2,373	110,095	48,955	161,423	10,514
2045	406,916	2,378	110,593	49,147	162,118	10,558
2046	408,314	2,383	111,045	49,247	162,675	10,587
2047	409,647	2,385	111,452	49,304	163,141	10,612
2048	410,995	2,389	111,881	49,408	163,678	10,638
2049	412,259	2,394	112,309	49,413	164,116	10,664
2050	413,366	2,398	112,720	49,504	164,622	10,699
2051	414,519	2,403	113,118	49,626	165,147	10,731
2052	415,488	2,407	113,455	49,671	165,533	10,757
2053	416,567	2,409	113,765	49,789	165,963	10,781
2054	417,607	2,412	114,073	49,826	166,311	10,796
2055	418,358	2,414	114,363	49,833	166,610	10,815
2056	419,367	2,417	114,672	49,923	167,012	10,838
2057	420,156	2,421	114,964	49,941	167,326	10,859
2058	420,814	2,423	115,219	50,013	167,655	10,883
2059	421,675	2,426	115,466	50,106	167,998	10,900
2060	422,373	2,428	115,678	50,103	168,209	10,913

Table 16: Population and Building Data and Projections - Basin 88E, Pleasant Valley East (1955 to 2007)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
1955	106	20	1	2	23	0
1956	141	28	1	2	31	0
1957	147	29	1	2	32	0
1958	174	36	1	2	39	0
1959	189	39	1	2	42	0
1960	187	41	1	2	44	0
1961	255	59	1	2	62	0
1962	293	72	2	2	76	0
1963	320	85	2	2	89	0
1964	355	101	2	2	105	0
1965	409	118	0	2	120	0
1966	424	123	0	2	125	0
1967	459	134	2	2	138	0
1968	471	136	2	2	140	0
1969	507	138	2	2	142	0
1970	510	143	2	2	147	0
1971	534	154	3	2	159	0
1972	547	163	3	2	168	0
1973	553	174	3	1	178	0
1974	581	181	6	2	189	0
1975	605	187	6	2	195	0
1976	618	191	7	2	200	0
1977	658	207	10	2	219	0
1978	846	278	11	2	291	0
1979	836	292	8	2	302	0
1980	841	298	9	2	309	0
1981	868	302	9	2	313	0
1982	902	315	9	2	326	0
1983	914	318	9	3	330	1
1984	944	326	14	3	343	1
1985	968	332	20	3	355	1
1986	979	337	26	3	366	1
1987	998	339	33	3	375	1
1988	1,011	344	34	3	381	1
1989	1,026	348	35	3	386	1
1990	1,052	359	36	3	398	1
1991	1,075	363	37	3	403	1
1992	1,106	371	38	3	412	1
1993	1,146	381	39	3	423	1
1994	1,178	390	41	3	434	1
1995	1,189	396	35	3	434	1
1996	1,205	401	36	3	440	1
1997	1,208	405	38	4	447	1
1998	1,206	408	39	4	451	1
1999	1,196	414	41	4	459	1
2000	1,158	422	34	4	460	1
2001	1,217	441	36	0	477	1
2002	1,217	450	38	0	488	1
2003	1,242	456	39	0	495	1
2004	1,246	459	41	0	500	1
2005	1,275	471	43	0	514	1
2006	1,321	487	45	0	532	1
2007	1,350	494	46	0	540	1

Table 17: Population and Building Data and Projections - Basin 88E Pleasant Valley East (2008 to 2060)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
2008	1,364	500	46	0	546	1
2009	1,337	500	46	0	546	1
2010	1,340	502	46	0	548	1
2011	1,351	502	47	0	549	1
2012	1,365	502	47	0	549	1
2013	1,377	505	47	0	552	1
2014	1,415	506	60	0	566	1
2015	1,434	509	61	0	570	1
2016	1,446	514	62	0	576	1
2017	1,457	518	63	0	581	1
2018	1,467	522	64	0	586	1
2019	1,479	526	65	0	591	1
2020	1,490	529	66	0	595	1
2021	1,500	531	67	0	598	1
2022	1,515	535	68	0	603	1
2023	1,528	539	69	0	608	1
2024	1,539	543	70	0	613	1
2025	1,549	546	71	0	617	1
2026	1,557	548	72	0	620	1
2027	1,566	550	73	0	623	1
2028	1,573	552	73	0	625	1
2029	1,581	555	74	0	629	1
2030	1,593	559	75	0	634	1
2031	1,599	561	76	0	637	1
2032	1,606	564	76	0	640	1
2033	1,611	565	77	0	642	1
2034	1,618	567	77	0	644	1
2035	1,625	569	78	0	647	1
2036	1,633	571	79	0	650	1
2037	1,637	573	79	0	652	1
2038	1,644	575	80	0	655	1
2039	1,649	577	80	0	657	1
2040	1,654	578	81	0	659	1
2041	1,658	579	81	0	660	1
2042	1,663	581	81	0	662	1
2043	1,667	582	82	0	664	1
2044	1,672	584	82	0	666	1
2045	1,677	585	83	0	668	1
2046	1,679	586	83	0	669	1
2047	1,682	587	83	0	670	1
2048	1,687	588	84	0	672	1
2049	1,691	589	84	0	673	1
2050	1,692	590	84	0	674	1
2051	1,699	592	85	0	677	1
2052	1,699	592	85	0	677	1
2053	1,702	593	85	0	678	1
2054	1,705	594	85	0	679	1
2055	1,707	594	86	0	680	1
2056	1,710	595	86	0	681	1
2057	1,713	596	86	0	682	1
2058	1,712	596	86	0	682	1
2059	1,714	597	86	0	683	1
2060	1,720	598	87	0	685	1

Table 18: Population and Building Data and Projections - Basin 88W, Pleasant Valley West (1955 to 2007)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
1955	139	17	11	2	30	2
1956	136	17	11	2	30	2
1957	138	17	11	2	30	2
1958	134	17	11	2	30	2
1959	139	17	12	2	31	2
1960	149	19	14	2	35	2
1961	148	19	15	2	36	2
1962	158	25	14	2	41	3
1963	176	31	16	2	49	3
1964	169	33	15	2	50	3
1965	191	36	18	2	56	3
1966	197	37	19	2	58	3
1967	210	42	19	2	63	3
1968	215	42	20	2	64	3
1969	229	42	20	2	64	3
1970	233	43	22	2	67	4
1971	225	44	21	2	67	4
1972	225	45	22	2	69	4
1973	214	47	21	1	69	4
1974	255	57	24	2	83	4
1975	335	72	34	2	108	4
1976	402	82	46	2	130	4
1977	529	104	70	2	176	4
1978	637	134	83	2	219	4
1979	689	156	91	2	249	4
1980	724	165	99	2	266	4
1981	790	168	115	2	285	4
1982	853	175	131	2	308	4
1983	873	178	134	3	315	4
1984	939	185	153	3	341	4
1985	1,025	193	180	3	376	4
1986	1,054	198	193	3	394	4
1987	1,152	213	217	3	433	4
1988	1,213	218	236	3	457	4
1989	1,292	224	259	3	486	4
1990	1,379	234	285	3	522	4
1991	1,491	239	317	3	559	4
1992	1,606	250	345	3	598	4
1993	1,715	260	370	3	633	4
1994	1,873	267	420	3	690	4
1995	2,000	272	455	3	730	4
1996	2,128	274	500	3	777	6
1997	2,229	278	543	4	825	8
1998	2,350	278	597	4	879	8
1999	2,373	281	626	4	911	9
2000	2,419	282	675	4	961	10
2001	2,597	282	736	0	1,018	10
2002	2,636	285	772	0	1,057	10
2003	2,745	291	803	0	1,094	10
2004	2,903	295	870	0	1,165	10
2005	3,258	300	1,013	0	1,313	10
2006	3,451	307	1,083	0	1,390	11
2007	3,618	309	1,138	0	1,447	11

Table 19: Population and Building Data and Projections - Basin 88W Pleasant Valley West (2008 to 2060)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
2008	3,689	314	1,162	0	1,476	11
2009	3,628	314	1,168	0	1,482	11
2010	3,635	314	1,172	0	1,486	11
2011	3,696	314	1,188	0	1,502	11
2012	3,751	314	1,195	0	1,509	11
2013	3,791	315	1,205	0	1,520	11
2014	3,865	318	1,228	0	1,546	11
2015	3,948	320	1,249	0	1,569	1
2016	4,021	323	1,279	0	1,602	1
2017	4,091	326	1,305	0	1,631	1
2018	4,147	328	1,328	0	1,656	1
2019	4,203	331	1,349	0	1,680	1
2020	4,259	332	1,369	0	1,701	1
2021	4,319	334	1,388	0	1,722	1
2022	4,380	336	1,407	0	1,743	1
2023	4,435	339	1,426	0	1,765	1
2024	4,485	341	1,446	0	1,787	1
2025	4,533	343	1,463	0	1,806	1
2026	4,578	344	1,479	0	1,823	1
2027	4,624	346	1,494	0	1,840	1
2028	4,672	347	1,510	0	1,857	1
2029	4,714	349	1,526	0	1,875	1
2030	4,758	351	1,543	0	1,894	1
2031	4,797	353	1,558	0	1,911	1
2032	4,830	354	1,571	0	1,925	1
2033	4,864	355	1,583	0	1,938	1
2034	4,901	356	1,595	0	1,951	1
2035	4,936	358	1,607	0	1,965	1
2036	4,971	359	1,620	0	1,979	1
2037	5,000	360	1,632	0	1,992	1
2038	5,033	362	1,643	0	2,005	1
2039	5,058	363	1,652	0	2,015	1
2040	5,080	363	1,661	0	2,024	1
2041	5,107	364	1,669	0	2,033	1
2042	5,132	365	1,678	0	2,043	1
2043	5,158	366	1,688	0	2,054	1
2044	5,180	367	1,696	0	2,063	1
2045	5,201	368	1,704	0	2,072	1
2046	5,221	369	1,711	0	2,080	1
2047	5,238	369	1,717	0	2,086	1
2048	5,258	370	1,724	0	2,094	1
2049	5,275	370	1,730	0	2,100	1
2050	5,291	371	1,736	0	2,107	1
2051	5,309	372	1,743	0	2,115	1
2052	5,321	372	1,748	0	2,120	1
2053	5,336	373	1,753	0	2,126	1
2054	5,348	373	1,757	0	2,130	1
2055	5,363	374	1,762	0	2,136	1
2056	5,376	374	1,767	0	2,141	1
2057	5,389	375	1,771	0	2,146	1
2058	5,397	375	1,775	0	2,150	1
2059	5,407	375	1,779	0	2,154	1
2060	5,419	376	1,782	0	2,158	1

Table 20: Population and Building Data and Projections - Basin 89, Washoe Valley (1955 to 2007)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
1955	565	106	10	6	122	1
1956	568	109	10	6	125	1
1957	574	109	10	6	125	1
1958	570	112	10	6	128	1
1959	603	116	12	6	134	1
1960	642	134	11	6	151	1
1961	653	141	12	6	159	1
1962	713	168	11	6	185	1
1963	810	209	10	6	225	1
1964	841	232	11	6	249	1
1965	972	269	10	6	285	1
1966	1,045	291	11	6	308	1
1967	1,072	305	11	6	322	1
1968	1,117	315	11	6	332	2
1969	1,218	324	11	6	341	2
1970	1,240	339	12	6	357	2
1971	1,394	396	13	6	415	2
1972	1,593	472	11	6	489	2
1973	1,667	519	12	6	537	2
1974	1,726	543	12	6	561	2
1975	1,824	570	12	6	588	3
1976	1,936	606	13	7	626	3
1977	2,176	705	14	5	724	3
1978	2,427	814	15	6	835	4
1979	2,579	906	17	9	932	4
1980	2,640	943	17	10	970	4
1981	2,792	979	18	10	1,007	4
1982	2,859	1,005	18	10	1,033	4
1983	2,911	1,023	18	10	1,051	4
1984	2,973	1,053	19	8	1,080	4
1985	3,052	1,091	20	8	1,119	4
1986	3,123	1,126	21	21	1,168	4
1987	3,213	1,165	22	21	1,208	4
1988	3,323	1,209	22	21	1,252	4
1989	3,408	1,237	23	22	1,282	6
1990	3,495	1,276	24	23	1,323	6
1991	3,648	1,318	30	20	1,368	6
1992	3,756	1,348	31	20	1,399	6
1993	3,893	1,378	39	20	1,437	6
1994	4,040	1,421	47	20	1,488	6
1995	4,170	1,453	49	20	1,522	8
1996	4,276	1,482	58	21	1,561	9
1997	4,296	1,500	68	22	1,590	10
1998	4,297	1,514	71	22	1,607	10
1999	4,202	1,528	66	19	1,613	10
2000	4,158	1,555	77	20	1,652	11
2001	4,306	1,586	81	21	1,688	11
2002	4,272	1,607	85	21	1,713	11
2003	4,378	1,626	98	21	1,745	11
2004	4,401	1,642	102	22	1,766	11
2005	4,421	1,663	97	22	1,782	11
2006	4,497	1,688	101	22	1,811	11
2007	4,613	1,708	114	23	1,845	13

Table 21: Population and Building Data and Projections - Basin 89, Washoe Valley (2008 to 2060)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
2008	4,641	1,719	115	23	1,857	13
2009	4,561	1,724	116	23	1,863	13
2010	4,564	1,727	116	23	1,866	13
2011	4,605	1,731	117	23	1,871	13
2012	4,659	1,734	117	23	1,874	13
2013	4,689	1,739	118	23	1,880	13
2014	4,705	1,744	119	19	1,882	13
2015	4,765	1,754	121	19	1,894	13
2016	4,799	1,769	124	19	1,912	14
2017	4,840	1,784	127	19	1,930	14
2018	4,875	1,799	129	19	1,947	14
2019	4,911	1,813	131	19	1,963	14
2020	4,940	1,821	133	19	1,973	14
2021	4,976	1,830	135	19	1,984	14
2022	5,021	1,842	137	19	1,998	15
2023	5,056	1,855	138	19	2,012	15
2024	5,093	1,869	140	20	2,029	15
2025	5,125	1,880	142	20	2,042	15
2026	5,150	1,887	144	20	2,051	15
2027	5,174	1,894	145	20	2,059	15
2028	5,206	1,902	147	20	2,069	15
2029	5,229	1,912	148	20	2,080	15
2030	5,263	1,925	150	20	2,095	16
2031	5,284	1,934	151	20	2,105	16
2032	5,307	1,942	153	20	2,115	16
2033	5,326	1,948	154	20	2,122	16
2034	5,343	1,952	155	20	2,127	16
2035	5,366	1,960	156	20	2,136	16
2036	5,386	1,967	157	20	2,144	16
2037	5,407	1,975	158	21	2,154	16
2038	5,427	1,982	159	21	2,162	16
2039	5,442	1,987	160	21	2,168	16
2040	5,454	1,991	161	21	2,173	16
2041	5,474	1,996	162	21	2,179	16
2042	5,486	2,000	163	21	2,184	17
2043	5,502	2,006	164	21	2,191	17
2044	5,519	2,012	165	21	2,198	17
2045	5,527	2,016	165	21	2,202	17
2046	5,540	2,020	166	21	2,207	17
2047	5,549	2,022	167	21	2,210	17
2048	5,559	2,026	167	21	2,214	17
2049	5,574	2,030	168	21	2,219	17
2050	5,582	2,033	169	21	2,223	17
2051	5,592	2,038	169	21	2,228	17
2052	5,600	2,040	170	21	2,231	17
2053	5,605	2,042	170	21	2,233	17
2054	5,617	2,045	171	21	2,237	17
2055	5,622	2,047	171	21	2,239	17
2056	5,630	2,049	172	21	2,242	17
2057	5,640	2,053	172	21	2,246	17
2058	5,642	2,055	172	21	2,248	17
2059	5,650	2,057	173	21	2,251	17
2060	5,655	2,058	173	21	2,252	17

Table 22: Population and Building Data and Projections - Basin 92 Lemmon Valley (1955 to 2007)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
1955	2,236	47	426	10	483	26
1956	2,200	48	426	10	484	27
1957	2,233	51	425	10	486	30
1958	3,320	54	682	10	746	30
1959	3,379	58	683	10	751	31
1960	3,284	68	694	10	772	50
1961	3,199	72	697	10	779	54
1962	3,111	82	715	10	807	54
1963	2,992	95	726	10	831	55
1964	2,848	101	732	10	843	55
1965	3,326	112	837	26	975	60
1966	3,596	120	914	26	1,060	60
1967	3,559	126	917	26	1,069	62
1968	3,654	143	917	26	1,086	67
1969	3,947	157	922	26	1,105	68
1970	4,593	176	1,121	26	1,323	71
1971	4,985	257	1,201	26	1,484	71
1972	5,441	318	1,326	26	1,670	74
1973	5,729	387	1,402	56	1,845	78
1974	5,786	415	1,410	56	1,881	79
1975	6,021	436	1,449	56	1,941	86
1976	6,373	489	1,517	55	2,061	90
1977	6,857	659	1,551	71	2,281	92
1978	8,939	922	2,084	69	3,075	93
1979	10,230	1,092	2,533	72	3,697	95
1980	10,333	1,169	2,553	74	3,796	101
1981	10,712	1,214	2,573	76	3,863	106
1982	10,972	1,232	2,588	144	3,964	112
1983	11,459	1,266	2,623	248	4,137	112
1984	11,725	1,327	2,683	249	4,259	114
1985	12,081	1,385	2,795	250	4,430	116
1986	12,164	1,436	2,864	249	4,549	118
1987	12,473	1,505	2,935	249	4,689	125
1988	12,779	1,551	2,954	310	4,815	130
1989	12,931	1,589	2,967	309	4,865	136
1990	13,099	1,618	3,031	309	4,958	141
1991	13,730	1,646	3,082	420	5,148	146
1992	14,220	1,674	3,201	421	5,296	152
1993	14,829	1,701	3,351	422	5,474	154
1994	15,560	1,744	3,525	462	5,731	160
1995	16,232	1,763	3,701	460	5,924	166
1996	16,790	1,788	3,782	560	6,130	172
1997	17,287	1,822	3,978	598	6,398	177
1998	17,798	1,845	4,213	598	6,656	187
1999	18,928	1,859	4,648	759	7,266	190
2000	19,338	1,878	5,044	761	7,683	195
2001	21,416	1,891	5,462	1,042	8,395	201
2002	22,331	1,907	5,947	1,100	8,954	206
2003	23,311	1,933	6,222	1,136	9,291	225
2004	24,798	1,950	6,773	1,228	9,951	246
2005	25,976	1,963	7,282	1,225	10,470	255
2006	27,266	1,984	7,762	1,235	10,981	262
2007	27,818	1,995	7,899	1,233	11,127	275

Table 23: Population and Building Data and Projections - Basin 92, Lemmon Valley (2008 to 2060)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
2008	28,024	2,006	7,960	1,248	11,214	279
2009	27,643	2,009	8,034	1,249	11,292	281
2010	27,635	2,009	8,040	1,249	11,298	282
2011	27,844	2,014	8,051	1,249	11,314	286
2012	28,149	2,017	8,059	1,247	11,323	287
2013	28,272	2,020	8,066	1,250	11,336	292
2014	28,555	2,025	8,084	1,313	11,422	293
2015	29,085	2,037	8,224	1,299	11,560	296
2016	29,553	2,054	8,416	1,304	11,774	299
2017	30,026	2,072	8,592	1,308	11,972	303
2018	30,434	2,089	8,742	1,323	12,154	309
2019	30,835	2,105	8,881	1,338	12,324	312
2020	31,227	2,115	9,010	1,346	12,471	315
2021	31,626	2,125	9,134	1,351	12,610	316
2022	32,038	2,139	9,259	1,351	12,749	319
2023	32,415	2,154	9,389	1,356	12,899	322
2024	32,768	2,170	9,519	1,366	13,055	326
2025	33,107	2,183	9,633	1,374	13,190	329
2026	33,424	2,191	9,735	1,385	13,311	332
2027	33,737	2,200	9,835	1,390	13,425	334
2028	34,062	2,209	9,937	1,392	13,538	335
2029	34,356	2,221	10,047	1,398	13,666	338
2030	34,651	2,235	10,156	1,403	13,794	341
2031	34,919	2,246	10,255	1,411	13,912	344
2032	35,174	2,255	10,344	1,420	14,019	346
2033	35,416	2,262	10,423	1,425	14,110	348
2034	35,663	2,267	10,500	1,430	14,197	349
2035	35,891	2,275	10,581	1,432	14,288	351
2036	36,120	2,284	10,661	1,434	14,379	353
2037	36,327	2,293	10,740	1,440	14,473	355
2038	36,543	2,302	10,812	1,445	14,559	357
2039	36,721	2,307	10,873	1,450	14,630	359
2040	36,897	2,312	10,932	1,456	14,700	360
2041	37,082	2,317	10,989	1,456	14,762	361
2042	37,250	2,322	11,048	1,459	14,829	363
2043	37,416	2,330	11,109	1,462	14,901	364
2044	37,575	2,336	11,164	1,464	14,964	366
2045	37,715	2,341	11,215	1,470	15,026	367
2046	37,851	2,346	11,261	1,473	15,080	368
2047	37,979	2,348	11,302	1,475	15,125	369
2048	38,104	2,352	11,345	1,478	15,175	370
2049	38,243	2,357	11,389	1,478	15,224	371
2050	38,348	2,361	11,430	1,481	15,272	372
2051	38,458	2,366	11,471	1,485	15,322	373
2052	38,554	2,369	11,505	1,486	15,360	374
2053	38,644	2,371	11,536	1,489	15,396	375
2054	38,755	2,375	11,568	1,491	15,434	375
2055	38,833	2,377	11,597	1,491	15,465	376
2056	38,923	2,380	11,628	1,493	15,501	377
2057	39,011	2,384	11,658	1,494	15,536	378
2058	39,071	2,386	11,684	1,496	15,566	378
2059	39,146	2,388	11,709	1,499	15,596	379
2060	39,219	2,390	11,730	1,499	15,619	379

Table 24: Population and Building Data and Projections - Basin 000, Rest of Washoe County (1955 to 2007)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
1955	741	63	86	11	160	42
1956	736	63	88	11	162	44
1957	781	65	94	11	170	46
1958	792	66	101	11	178	46
1959	864	66	115	11	192	46
1960	1,012	75	146	17	238	49
1961	1,006	77	151	17	245	51
1962	1,037	78	174	17	269	54
1963	1,368	80	283	17	380	54
1964	2,247	85	474	106	665	60
1965	3,271	86	719	154	959	76
1966	3,826	91	849	188	1,128	84
1967	3,842	92	874	188	1,154	90
1968	4,634	92	1,085	200	1,377	107
1969	5,640	92	1,287	200	1,579	119
1970	6,618	92	1,593	221	1,906	128
1971	8,223	94	2,127	227	2,448	137
1972	8,859	95	2,378	246	2,719	141
1973	8,899	101	2,508	257	2,866	150
1974	9,613	108	2,746	271	3,125	198
1975	9,818	111	2,783	271	3,165	200
1976	10,148	121	2,887	274	3,282	205
1977	10,584	139	3,103	279	3,521	210
1978	11,901	156	3,542	396	4,094	232
1979	12,977	193	4,050	447	4,690	248
1980	14,770	244	4,702	480	5,426	264
1981	16,036	268	5,031	484	5,783	300
1982	16,650	295	5,230	490	6,015	315
1983	17,085	314	5,357	497	6,168	320
1984	17,421	344	5,486	498	6,328	323
1985	17,875	376	5,670	509	6,555	325
1986	17,822	400	5,753	512	6,665	329
1987	18,200	442	5,887	513	6,842	331
1988	18,875	474	6,126	512	7,112	332
1989	19,475	507	6,303	517	7,327	332
1990	19,944	539	6,488	522	7,549	346
1991	20,659	561	6,663	522	7,746	349
1992	21,386	609	6,836	520	7,965	352
1993	22,089	646	6,987	521	8,154	354
1994	22,817	697	7,185	522	8,404	357
1995	23,737	755	7,367	541	8,663	361
1996	24,188	798	7,491	542	8,831	366
1997	24,367	880	7,594	544	9,018	368
1998	24,625	922	7,741	546	9,209	372
1999	24,695	989	7,887	604	9,480	376
2000	24,566	1,041	8,113	606	9,760	387
2001	25,801	1,095	8,413	606	10,114	389
2002	26,060	1,140	8,704	605	10,449	395
2003	27,140	1,207	9,005	605	10,817	400
2004	27,978	1,281	9,341	605	11,227	403
2005	28,735	1,326	9,652	604	11,582	408
2006	29,327	1,368	9,817	626	11,811	409
2007	29,995	1,401	9,971	626	11,998	412

Table 25: Population and Building Data and Projections - Basin 000, Rest of Washoe County (2008 to 2060)

Year	Population	Units on Wells	Single Family	Multi-Family Units	Total Dwelling	Commercial Buildings
2008	30,215	1,423	10,042	626	12,091	415
2009	29,763	1,427	10,104	627	12,158	415
2010	29,758	1,434	10,105	627	12,166	416
2011	29,980	1,444	10,113	625	12,182	416
2012	30,319	1,449	10,121	626	12,196	416
2013	30,454	1,453	10,133	625	12,211	418
2014	30,628	1,457	10,170	624	12,251	418
2015	31,281	1,464	10,347	622	12,433	431
2016	31,847	1,476	10,588	624	12,688	436
2017	32,416	1,489	10,810	626	12,925	442
2018	32,885	1,501	10,999	633	13,133	450
2019	33,339	1,512	11,173	640	13,325	455
2020	33,804	1,520	11,336	644	13,500	458
2021	34,272	1,527	11,491	647	13,665	461
2022	34,762	1,537	11,649	647	13,833	464
2023	35,207	1,548	11,813	649	14,010	469
2024	35,614	1,559	11,976	654	14,189	475
2025	36,008	1,568	12,120	658	14,346	480
2026	36,369	1,574	12,247	663	14,484	483
2027	36,735	1,580	12,373	665	14,618	486
2028	37,124	1,587	12,502	666	14,755	488
2029	37,474	1,596	12,641	669	14,906	492
2030	37,818	1,606	12,778	671	15,055	496
2031	38,127	1,613	12,902	675	15,190	501
2032	38,423	1,620	13,014	680	15,314	504
2033	38,704	1,625	13,113	682	15,420	507
2034	38,994	1,629	13,210	684	15,523	509
2035	39,268	1,635	13,312	685	15,632	511
2036	39,539	1,641	13,413	686	15,740	514
2037	39,784	1,648	13,513	689	15,850	517
2038	40,032	1,654	13,603	692	15,949	520
2039	40,240	1,658	13,680	694	16,032	523
2040	40,441	1,661	13,754	697	16,112	524
2041	40,664	1,665	13,826	697	16,188	526
2042	40,863	1,669	13,900	698	16,267	528
2043	41,055	1,674	13,976	700	16,350	530
2044	41,246	1,679	14,046	701	16,426	532
2045	41,402	1,682	14,109	704	16,495	535
2046	41,558	1,685	14,167	705	16,557	536
2047	41,713	1,687	14,219	706	16,612	537
2048	41,861	1,690	14,274	707	16,671	539
2049	42,023	1,694	14,328	707	16,729	540
2050	42,150	1,696	14,381	709	16,786	542
2051	42,273	1,700	14,432	710	16,842	543
2052	42,389	1,702	14,475	711	16,888	545
2053	42,497	1,704	14,514	713	16,931	546
2054	42,617	1,706	14,553	713	16,972	547
2055	42,715	1,708	14,590	713	17,011	548
2056	42,825	1,710	14,630	715	17,055	549
2057	42,926	1,713	14,667	715	17,095	550
2058	42,996	1,714	14,700	716	17,130	551
2059	43,082	1,716	14,731	717	17,164	552
2060	43,169	1,717	14,758	717	17,192	552

Data Development and Graphical Analysis

The development of a time series projection requires a time series data source from which trends and relationships can be modeled and used to project future trends. As a general rule, the time series needs to be at least as long as the projection horizon and longer if possible. The planning horizon for the 2035 Water Resource plan is 22 years, 2014 to 2035. Building off the model developed for the 2010 tot 2030 Water Resource Plan, the Washoe County Assessor's data was again used to construct the required annualized data using building records and the construction year for each building.

For land area analysis a geographic information system ("GIS") was used to compute annualized land development by computing the parcel land area for each parcel and year the building was constructed. GIS was also used to assign spatial attributes to each parcel to facilitate the disaggregation of the County Projects to smaller sub areas. Each parcel was assigned the following attributes: X and Y location, name of utility service area, and hydrographic water basin name and number. The spatial attributes provide the means to allocate the County projections to sub areas and maintain the condition that all county sub area projection must sum back to the county total projection.

The analysis and model estimation process followed the following steps:

- Convert Assessor's database in to a time series for analysis.
- Estimate statistical models and refine to obtain the best statistical performance.
- Perform share / ratio analysis on each sub area.
- Project sub area shares through planning horizon.
- Disaggregate projections using sub county shares.
- Develop graphs and tables for water resource plan.

Each of these steps is described in detail below.

Convert Assessor's database to a time series.

The Assessor's parcel data files were downloaded, imported into a statistical database. The complete download contains a number of different data tables and various support tables. The full data dictionary and the most recent version of the data can be downloaded from, http://www.washoecounty.us/assessor/dl.htm. From this download the Property File and Quickinfo tables are used for analysis. The GIS parcel data is provided to TMWA as part of a data license, however the parcel data can also be purchased by visiting, http://www.co.washoe.nv.us/gis/datawarehouse.htm. Overlaying the Nevada State Engineer hydrographic and TMWA's service area boundaries on the parcel allows assignment of service areas and basins names.

The time series data needs to be able to provide a count of new buildings by year by building type. In the data there are several dates stored with each parcel; in the property table there is the year of original construction and average year of construction. The building table has the year when a building was constructed and each parcel can have more than one building. Using the various combination of dates, four possible measures for when a parcel of land is considered developed. 1) Acres by the year of the first building constructed. 2) acres by the year of the last building constructed. 3) the average year of all buildings on a parcel and 4) the midpoint between the first and last year.

A review of Figure 6 shows that all measures converge and provide a reasonable trend in land development. One event that stands out is what looks to be the development of very large tracts of land. This can be seen as sharp shift or steps in the land development curve. This would happen when a large parcel of land has its first building constructed and develop continues for several years. The blue line, "Cumulative Acres by First Year", provide a clear trend line from about 1970 to 2014. This line is consistent with the other measures of year developed and provides the longest time series for analysis.

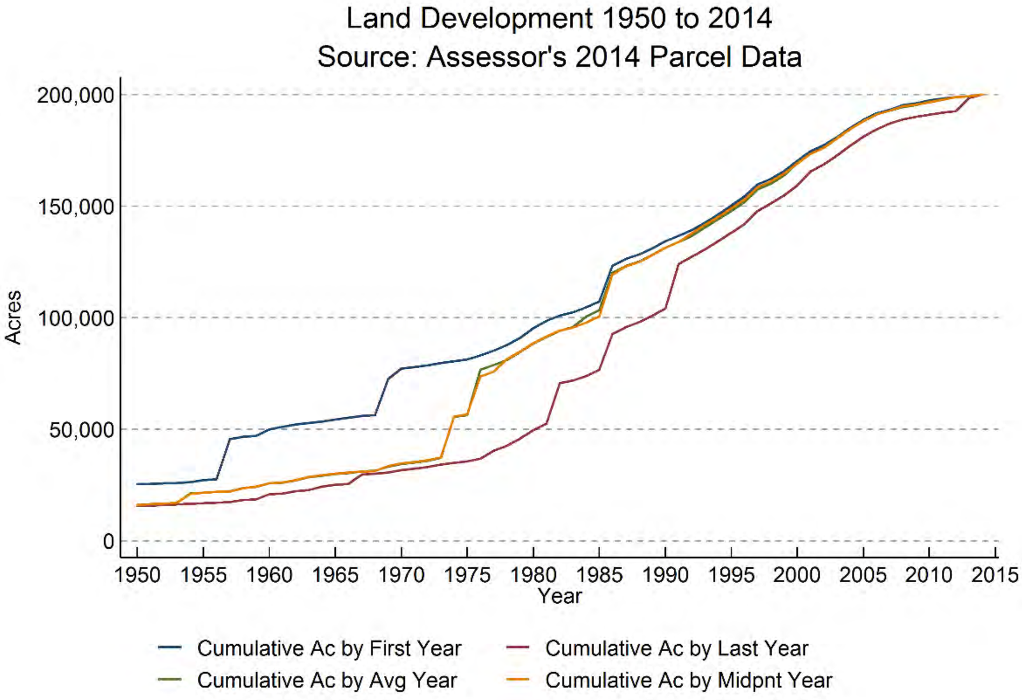


Figure 6: Land development trends by year of buildings.

Figure 7 is a view of population, dwelling, and developed land data. The historic and projected population is shown to determine how its trend might relate to the developed land and total dwelling units. The total developed land shows a strong relationship over time. The persons per dwelling unit, and persons per developed acre of land is also computed. The graph shows that since about 1980 the trend has been relatively constant for these two measures. The measures prior to 1980 suggest that the housing data when compared to population might not present a complete picture. It is both possible and expected that over time older properties might be redeveloped. This results in a count of dwelling units for these year as being too low relative to population, hence, the large person per dwelling units.

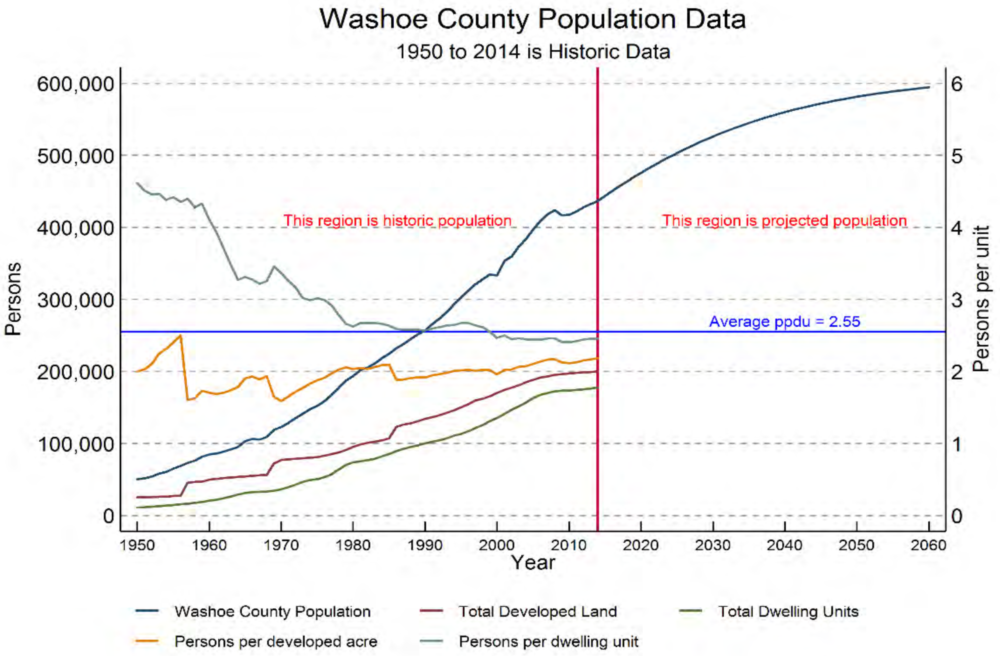


Figure 7: Washoe County population, dwelling units, and developed land data.

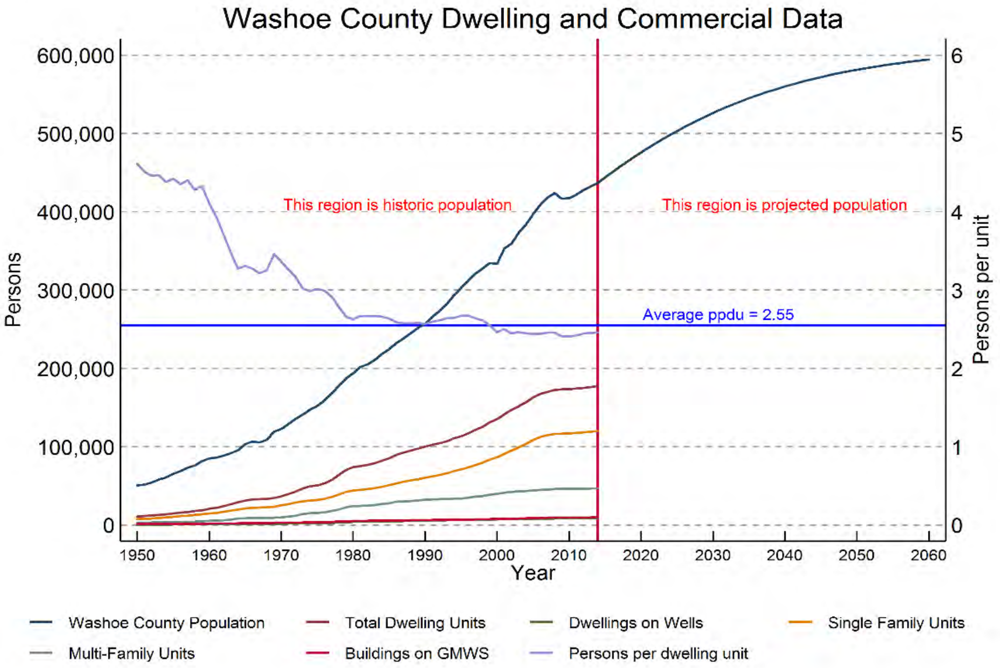


Figure 8: Washoe County population, dwelling units, and commercial buildings data.

The parcel and building data was reclassified into four major classes of building: dwellings on well, single family buildings/units, multi-family dwelling units, and commercial buildings (Figure 8). These classifications correspond to TMWA's classes of water customer. Dwellings on wells are generally single family homes on a domestic wells. Single family units correspond to TMWA's residential metered water service ("RMWS"), and the multi-family units correspond to the multi-unit metered rates ("MMWS"). The commercial buildings are members of the general metered water service ("GMWS"). Irrigation service are not directly estimated from the parcel data.

Of note in the data is the lines for dwelling on wells and GMWS builds are very close but are not the same.

The chart clearly shows that there should be a statistical relationship between population and the defined classes of dwelling units and commercial buildings.

The review of the data graphs clearly shows strong relationships between the variables and with time. Therefore, a time series analysis is the best approach to developing a projection model.

Model Estimations

The data created for this analysis is a multivariate time series where multiple variables have interdependencies. The interdependent variables are: population, dwelling units as described above, developed land, and commercial buildings. Population is treated as an exogenous variable while the all other variables are considered endogenous to the model.

The graphs above show a clear trend in the data over time, this is evidence of autocorrelation in each of the variables. Autocorrelation is generally defined as the statistical correlation between values of a variable at different points in time, hence the time trend. The presence of a time trend and autocorrelation requires that the data be processed to correct for the autocorrelation and thus making it possible to model the relationship between the variables. The required transformation is to take the first difference between two time periods or compute the annual change in each variable.

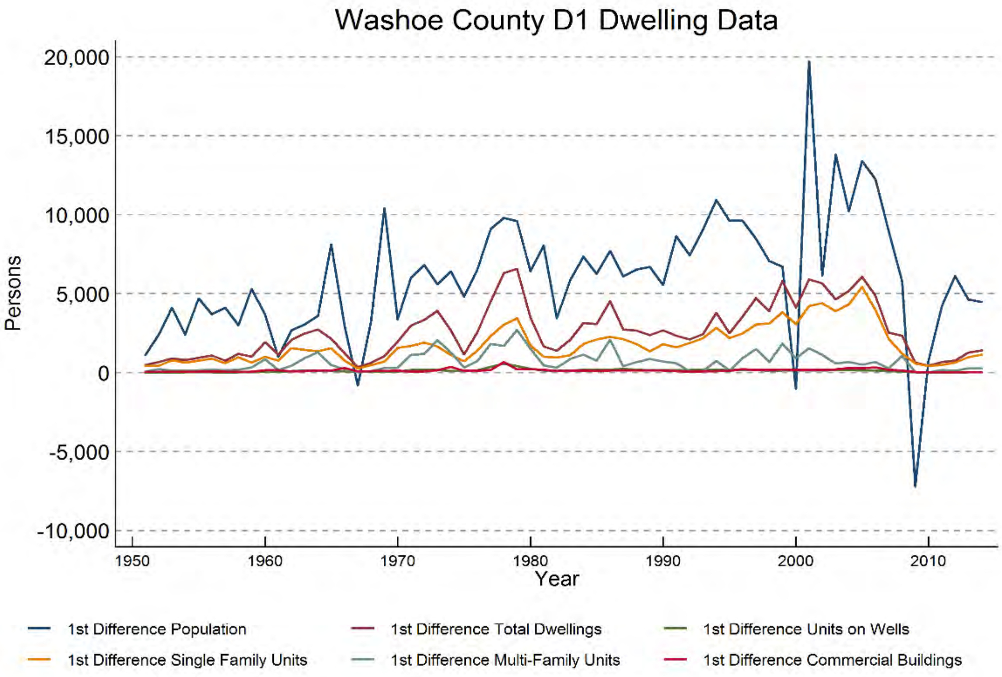


Figure 9: First difference or annual change in Washoe County dwelling units.

Figure 9 show the results of first differencing the dwelling and commercial building data presented in Figure 8. The first differenced process is referred to as “D(1)”. This data is free of autocorrelation and is considered stationary, this is a requirement for estimating any time series model.

Data that conforms to multiple time series that are interdependent are generally modeled using vector autoregression (“VAR”) models. In a VAR, all the variables are treated symmetrically by including each variable in an equation explaining its evolution based on its own lags and the lags of all the other variables in the model including the exogenous variables. Based on this feature, the VAR model can be used as a theory-free method to estimate economic relationships.

There are a large number of good descriptions of VARs on the Internet, one such reference is the VAR page on Wikipedia. To simplify the discussion of the modeling process, this memo will skip the mathematical notation and describe the commands used and an explanation of the model results. All data processing and statistical estimations were performed using a statistical software program call STATA, from www.stata.com. STATA is a robust software system with modules designed for the analysis of time series data. All commands used here where tested with version 14 on Windows 8.0 64-bit platform

STATA’s “var” command was used to estimate all vector autoregressive models. The var fits a multivariate time series regression of each dependent variable on lags of itself and on lags of all the other dependent variables. The var also has the ability to fit models that include exogenous variables such as population.

Three models were estimated in the process of building a model that provides a balance of good fit to the data, stable statistical properties, and ability to create a useful projection.

1. VAR of dwellings on wells, single family, multi-family units, lag years 1 to 4, and population as an exogenous variable. This first model used non-difference data and served to provide a baseline measure of stability and autocorrelation.
2. VAR of first differenced dwelling unit variables, lag years 1 to 4, population is exogenous. Developed using output from Model 1.
3. Expanded Model 2 to include a variable for developed land.
4. Expanded Model 3 to include commercial buildings variables.
5. Using results from Model 4, this model was developed to project commercial buildings as a function single family dwelling units.

Model 1 Estimation

Model 1 used data that was not corrected for autocorrelation and thus had a clear time trend. While this could not be used for any projections, it was useful in diagnostic of the data to determine the extent of autocorrelation and other starting parameters useful in fitting the VAR models. The results of model 1 (Apendix A) suggested using only the data from 1980 to 2014 in the projection model. While this model did have an adjusted R^2 equal 0.9999, it confirmed the existence of autocorrelation and was found to be unstable, these results were expected.

Model 2 Estimation

Mode1 2 was estimated using first differenced data for dwelling units and population. The first difference is the same as the number of new units built in a given year. Figure 9 shows the data used in Model 2 for the years 1955 to 2009. Full statistical output is shown Appendix B. This model is the result of a number of different statistical trials used to fine tune the model parameters. Through the testing it was found that the model performed best with first, second, and third year lags with current year d1 population and third year lag on d1 population.

```
var d1cdwell0 d1cdwell1 d1cdwell2 if tin(1979, 2014), lags(1 2 3) exog(d1pop
L3.d1pop) noconstant
```

The model results did show lower performance for multi-family dwelling units. The selection-order criteria show that the model did require lags 1 and 3. The Lagrange-multiplier test for autocorrelation show no autocorrelation was found. The last test, Jarque-Bera test for normality in the residuals found that the residuals are normally distributed.

Summary of final form of Model 2 is presented below. The full regression model is provided in Appendix 2.

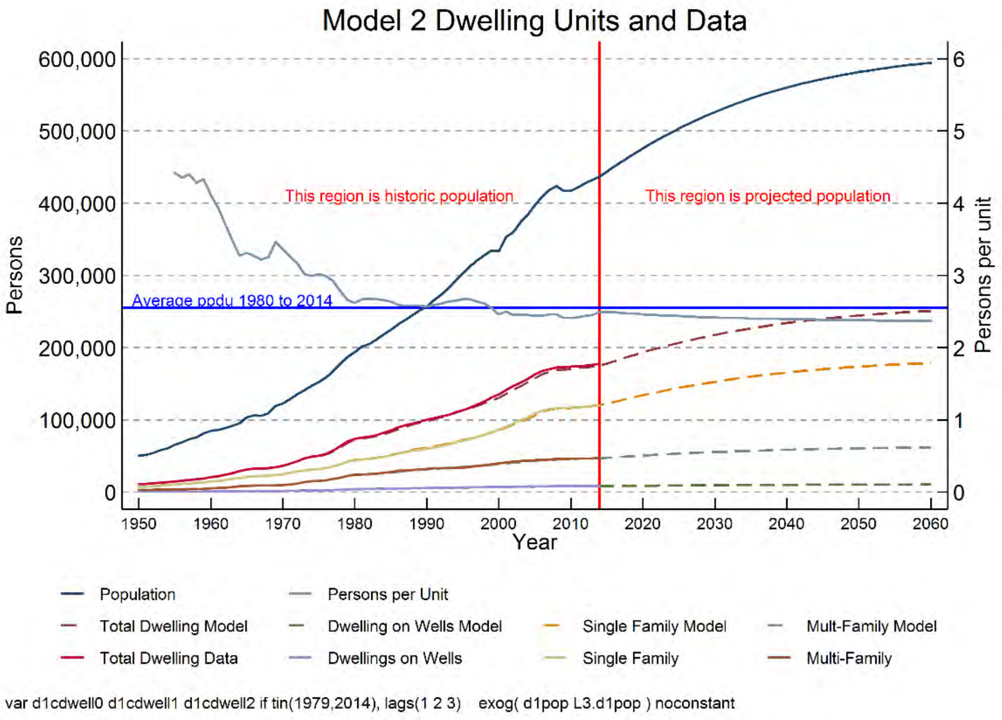
```
. var d1cdwell0 d1cdwell1 d1cdwell2 if tin(1979,2014),
>     lags(1 2 3) exog( d1pop L3.d1pop ) noconstant;

Vector autoregression

Sample:  1979 - 2014                             Number of obs     =        36
Log likelihood =  -706.0762                      AIC               =  41.05979
FPE            =   1.45e+14                      HQIC              =  41.56642
Det(Sigma_ml)  =   2.18e+13                      SBIC              =  42.51135

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
d1cdwell0            11     33.2177   0.9687   1113.525   0.0000
d1cdwell1            11     563.631   0.9672   1060.375   0.0000
d1cdwell2            11     493.333   0.8197   163.6727   0.0000
```

Figure 10 shows that Model 2 fits the data well and provides what appears to be a reasonable projection of future dwelling units. There is no autocorrelation at any of the lags and the VAR satisfies stability conditions. However a model is required that has the ability to project dwelling units, land used, and commercial buildings. Working with Model 2 as a base, this model is extended in Model 3 to include developed land.



var d1cdwell0 d1cdwell1 d1cdwell2 if tin(1979,2014), lags(1 2 3) exog(d1pop L3.d1pop) noconstant

Figure 10: Results of Model 2.

Model 3 Estimation

Model 3 started with Model 2 and was expanded to include both commercial buildings and developed land. This initial model did not perform well, was generally unstable and could not be used for projections. As a result of these trials, dwelling units were replaced with buildings for units on wells and single family units. The assumption is that most parcels had a one to one relationship between units and buildings and thus, should still provide good results. As a result of this change a various, different VAR models were estimated with the following model found to provide the best fit to the data.
This model uses buildings on wells (d1build0), single family buildings (d1build1), multi-family dwelling units (d1cdwell2), commercial buildings (d1build4) and population (d1pop). The independent variables are lagged one to five years, because of the recent economic recession, it was necessary to include longer lags to connect to the relationships that can model the economic recovery. Population is the exogenous variable that drives the projection and includes lags for 1 to 4 years.

Final form for Model 3 is:

```
. var d1build0 d1build1 d1cdwell2 d1build4 if tin(1979,2014),
>     lags(1 2 3 4 5)
>     exog(d1pop L1.d1pop L2.d1pop L3.d1pop l4.d1pop)
>     noconstant;

Vector autoregression

Sample:  1979 - 2014                           Number of obs     =        36
Log likelihood =  -807.7143                    AIC               =  50.42857
FPE            =   3.42e+17                    HQIC              =  51.96382
Det(Sigma_ml)  =   3.62e+14                    SBIC              =  54.82723

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
d1build0             25      27.088   0.9916   4264.812   0.0000
d1build1             25     569.135   0.9852   2402.234   0.0000
d1cdwell2            25     499.769   0.9186     406.19   0.0000
d1build4             25     29.6007   0.9891   3272.902   0.0000
----------------------------------------------------------------
```

This model shows very high R^2 values for all variables indicating good ability to explain the historic data and thus provide a good projecting model. Full model results are provided in Appendix 3. Testing for stability condition found the model to be stable. The test for autocorrelation did not find any autocorrelation, but the test for normally distributed residuals found that for all but the multi-family units, the residuals were normally distributed. The multi-family was on the margin and the effects do not directly affect the predictions.

Model 4 Estimation

Model 4 is a simple ordinary least squares regression of population and developed land use. This is not very precise and only serves to provide an indication of the relationship between population and developed land. Figure 11 shows the graphical projections using Models 3 and 4.

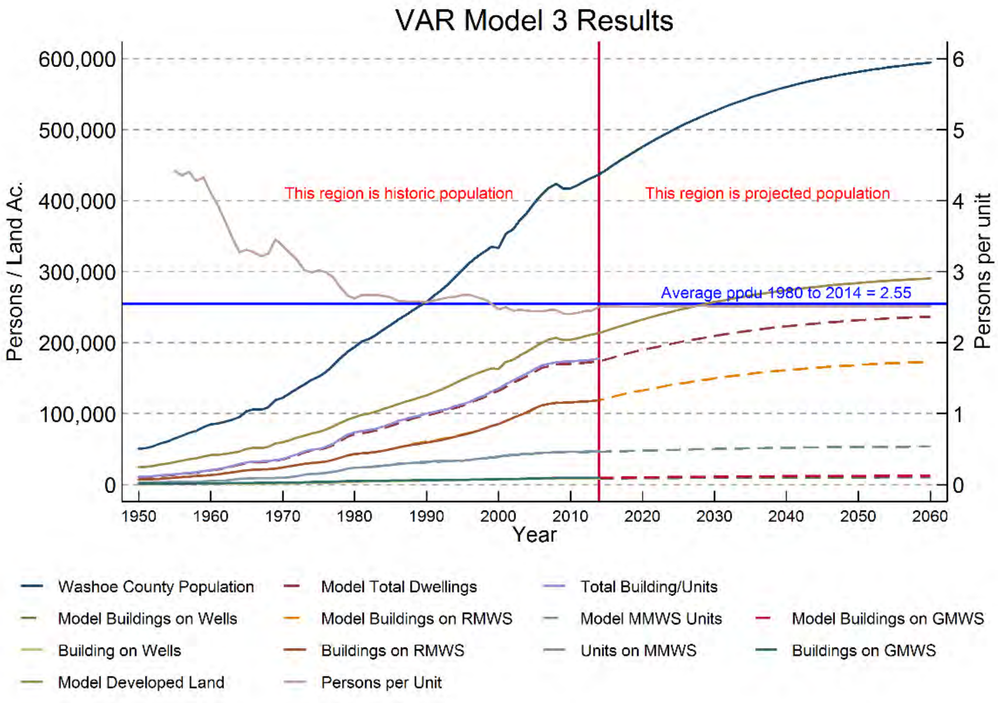


Figure 11: Results of Models 3 and 4.

The model does a very good job of fitting the historic data and provides a projection that is dependent on the population projection. The full statistical output for models 3 and 4 is included in Appendix C.

Appendix A: Statistical Output for Model 1.

Variables used:

- cdwell0
- cdwell1
- cdwell2
- population

Stata commands:

```
   1. var  cdwell0 cdwell1 cdwell2 if tin(1980,2014), lags(1/4) exog(population)
   2. varlmar, mlag(5)
   3. varstable
```

```
. var  cdwell0 cdwell1 cdwell2 if tin(1980,2014), lags(1/4) exog(population);


Vector autoregression

Sample:  1980 - 2014                            Number of obs     =         35
Log likelihood =  -649.7748                     AIC               =   39.52999
FPE            =   3.40e+13                     HQIC              =   40.17427
Det(Sigma_ml)  =   2.68e+12                     SBIC              =   41.39641

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
cdwell0              14     22.2495   0.9999     239089   0.0000
cdwell1              14     491.143   0.9998   170769.2   0.0000
cdwell2              14     332.303   0.9988   30055.63   0.0000
----------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
cdwell0      |
     cdwell0 |
         L1. |   1.078319   .1471932     7.33   0.000     .7898258    1.366812
         L2. |  -.0317921   .2467712    -0.13   0.897    -.5154548    .4518706
         L3. |  -.2750804   .1716857    -1.60   0.109    -.6115782    .0614174
         L4. |   .1559313   .0782609     1.99   0.046     .0025427    .3093199
             |
     cdwell1 |
         L1. |   .0025842   .0077737     0.33   0.740    -.0126519    .0178203
         L2. |  -.0001537   .0133747    -0.01   0.991    -.0263676    .0260603
         L3. |  -.0101541   .0134363    -0.76   0.450    -.0364887    .0161805
         L4. |   .0004115   .0061814     0.07   0.947    -.0117039    .0125269
             |
     cdwell2 |
         L1. |    .012974   .0089008     1.46   0.145    -.0044712    .0304192
         L2. |  -.0110775   .0100011    -1.11   0.268    -.0306793    .0085243
         L3. |   .0097696   .0102326     0.95   0.340    -.0102859    .0298251
         L4. |   .0045926   .0077428     0.59   0.553    -.0105831    .0197683
             |
  population |   .0015695   .0011481     1.37   0.172    -.0006807    .0038197
       _cons |   35.58218    91.5261     0.39   0.697    -143.8057      214.97
-------------+----------------------------------------------------------------
```

```
cdwell1      |
     cdwell0 |
         L1. |  -7.419519   3.249183    -2.28   0.022     -13.7878   -1.051238
         L2. |   7.878678   5.447297     1.45   0.148    -2.797828    18.55518
         L3. |  -6.413637   3.789839    -1.69   0.091    -13.84158    1.014311
         L4. |   4.011426   1.727554     2.32   0.020      .625483    7.397369
             |
     cdwell1 |
         L1. |   1.590175   .1715981     9.27   0.000     1.253849    1.926501
         L2. |   -1.29197   .2952371    -4.38   0.000    -1.870624   -.7133161
         L3. |   .7193505   .2965961     2.43   0.015     .1380328    1.300668
         L4. |   -.287041   .1364509    -2.10   0.035    -.5544798   -.0196021
             |
     cdwell2 |
         L1. |   .2396577   .1964782     1.22   0.223    -.1454325    .6247479
         L2. |   .3964238   .2207676     1.80   0.073    -.0362728    .8291204
         L3. |  -.1885468    .225877    -0.83   0.404    -.6312576    .2541639
         L4. |  -.2599827   .1709175    -1.52   0.128    -.5949749    .0750094
             |
  population |   .1040675   .0253427     4.11   0.000     .0543968    .1537382
       _cons |   -5485.95   2020.373    -2.72   0.007    -9445.808   -1526.091
-------------+----------------------------------------------------------------
cdwell2      |
     cdwell0 |
         L1. |  -6.311204   2.198374    -2.87   0.004    -10.61994   -2.002471
         L2. |   13.32098   3.685602     3.61   0.000     6.097332    20.54463
         L3. |  -14.33884   2.564178    -5.59   0.000    -19.36454   -9.313149
         L4. |    8.38945    1.16885     7.18   0.000     6.098545    10.68035
             |
     cdwell1 |
         L1. |   .1099244    .116102     0.95   0.344    -.1176313    .3374802
         L2. |  -.1678668   .1997553    -0.84   0.401      -.55938    .2236464
         L3. |    .264159   .2006748     1.32   0.188    -.1291563    .6574744
         L4. |  -.2052309   .0923217    -2.22   0.026    -.3861781   -.0242837
             |
     cdwell2 |
         L1. |   .8400319   .1329357     6.32   0.000     .5794827    1.100581
         L2. |   .1644702   .1493698     1.10   0.271    -.1282892    .4572296
         L3. |  -.2381601   .1528267    -1.56   0.119     -.537695    .0613749
         L4. |  -.1604853   .1156415    -1.39   0.165    -.3871386    .0661679
             |
  population |   .0107912   .0171467     0.63   0.529    -.0228156    .0443981
       _cons |   4968.228    1366.97     3.63   0.000     2289.017    7647.439
------------------------------------------------------------------------------

. /* test for autocorrelation                                                 */;
. varlmar, mlag(5);

   Lagrange-multiplier test
  +--------------------------------------+
  | lag  |      chi2    df   Prob > chi2 |
  |------+-------------------------------|
  |   1  |   15.7684     9     0.07188   |
  |   2  |    6.5602     9     0.68280   |
  |   3  |    8.6257     9     0.47251   |
  |   4  |    8.0047     9     0.53367   |
  |   5  |    4.4081     9     0.88256   |
  +--------------------------------------+
   H0: no autocorrelation at lag order


There is autocorrelation found at lag 1
. varstable;
```

```
  Eigenvalue stability condition
 +----------------------------------------+
 |        Eigenvalue        |   Modulus   |
 |--------------------------+-------------|
 |   1.007817               |   1.00782   |
 |   .8685095 +  .3757166i  |   .946294   |
 |   .8685095 -  .3757166i  |   .946294   |
 |   .3596037 +   .673815i  |   .763768   |
 |   .3596037 -   .673815i  |   .763768   |
 |   .6369474 +  .3876514i  |   .745638   |
 |   .6369474 -  .3876514i  |   .745638   |
 |  -.4623924 +  .4366802i  |      .636   |
 |  -.4623924 -  .4366802i  |      .636   |
 | -.00243245 +  .3939851i  |   .393993   |
 | -.00243245 -  .3939851i  |   .393993   |
 |  -.2997625               |   .299763   |
 +----------------------------------------+
  At least one eigenvalue is at least 1.0.
  VAR does not satisfy stability condition.
```

Appendix B: Model 2 Estimation Results

```
. var d1cdwell0 d1cdwell1 d1cdwell2 if tin(1979,2014),
>     lags(1 2 3) exog( d1pop L3.d1pop ) noconstant;

Vector autoregression

Sample:  1979 - 2014                            Number of obs     =         36
Log likelihood =  -706.0762                     AIC               =   41.05979
FPE            =   1.45e+14                     HQIC              =   41.56642
Det(Sigma_ml)  =   2.18e+13                     SBIC              =   42.51135

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
d1cdwell0            11     33.2177   0.9687   1113.525   0.0000
d1cdwell1            11     563.631   0.9672   1060.375   0.0000
d1cdwell2            11     493.333   0.8197   163.6727   0.0000
----------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
d1cdwell0    |
   d1cdwell0 |
         L1. |   .8336061   .1123906     7.42   0.000     .6133246    1.053888
         L2. |  -.3864635   .1457355    -2.65   0.008    -.6720998   -.1008271
         L3. |   .1219205   .1002136     1.22   0.224    -.0744946    .3183356
             |
   d1cdwell1 |
         L1. |   .0026101   .0096279     0.27   0.786    -.0162603    .0214805
         L2. |  -.0032765   .0131974    -0.25   0.804    -.0291428    .0225899
         L3. |  -.0116734   .0094168    -1.24   0.215      -.03013    .0067833
             |
   d1cdwell2 |
         L1. |   .0164624   .0121691     1.35   0.176    -.0073885    .0403133
         L2. |  -.0078004   .0108819    -0.72   0.473    -.0291284    .0135277
         L3. |    .013668   .0103259     1.32   0.186    -.0065703    .0339063
             |
       d1pop |
         --. |   .0051843   .0014062     3.69   0.000     .0024282    .0079405
         L3. |   .0033337   .0014454     2.31   0.021     .0005007    .0061667
-------------+----------------------------------------------------------------
d1cdwell1    |
   d1cdwell0 |
         L1. |   .7021808    1.90702     0.37   0.713     -3.03551    4.439872
         L2. |  -2.630972    2.47281    -1.06   0.287    -7.477591    2.215646
         L3. |  -2.158563   1.700405    -1.27   0.204    -5.491295    1.174169
             |
   d1cdwell1 |
         L1. |   .9212032   .1633647     5.64   0.000     .6010144    1.241392
         L2. |  -.5880104   .2239302    -2.63   0.009    -1.026906   -.1491152
         L3. |   .2278987   .1597828     1.43   0.154    -.0852697    .5410672
             |
   d1cdwell2 |
         L1. |   .2046417    .206482     0.99   0.322    -.2000556    .6093389
         L2. |     .31407   .1846412     1.70   0.089    -.0478201    .6759601
         L3. |   .1210757    .175207     0.69   0.490    -.2223237    .4644751
             |
       d1pop |
         --. |   .1151728   .0238604     4.83   0.000     .0684072    .1619384
         L3. |     .03953   .0245257     1.61   0.107    -.0085395    .0875995
```

```
-------------+----------------------------------------------------------------
d1cdwell2    |
   d1cdwell0 |
         L1. |   1.170182    1.66917     0.70   0.483    -2.101332    4.441696
         L2. |   2.968292   2.164393     1.37   0.170    -1.273841    7.210424
         L3. |  -4.502716   1.488324    -3.03   0.002    -7.419778   -1.585653
             |
   d1cdwell1 |
         L1. |   .0225646   .1429893     0.16   0.875    -.2576893    .3028184
         L2. |  -.2240753   .1960009    -1.14   0.253    -.6082301    .1600794
         L3. |    .098917   .1398541     0.71   0.479    -.1751921     .373026
             |
   d1cdwell2 |
         L1. |    .199871   .1807289     1.11   0.269    -.1543511    .5540931
         L2. |   .2957038   .1616121     1.83   0.067    -.0210502    .6124577
         L3. |   .1141029   .1533546     0.74   0.457    -.1864665    .4146724
             |
       d1pop |
         --. |   .0397847   .0208845     1.90   0.057    -.0011481    .0807175
         L3. |   .0372385   .0214668     1.73   0.083    -.0048356    .0793126
------------------------------------------------------------------------------

. /* that model is stable */;

varstable;

   Eigenvalue stability condition
  +----------------------------------------+
  |        Eigenvalue        |   Modulus   |
  |--------------------------+-------------|
  |   .8479512               |   .847951   |
  |   .3430737 +  .5821517i  |   .675722   |
  |   .3430737 -  .5821517i  |   .675722   |
  |   .6001586 +  .2736383i  |   .659597   |
  |   .6001586 -  .2736383i  |   .659597   |
  |  -.4120117 +  .4176205i  |   .586652   |
  |  -.4120117 -  .4176205i  |   .586652   |
  |   .0221439 +    .52989i  |   .530353   |
  |   .0221439 -    .52989i  |   .530353   |
  +----------------------------------------+
   All the eigenvalues lie inside the unit circle.
   VAR satisfies stability condition.

. /* lag selection */;
. varsoc, maxlag(5) exog(d1pop L3.d1pop);

   Selection-order criteria
   Sample:  1979 - 2014                         Number of obs      =        36
  +---------------------------------------------------------------------------+
  |lag |    LL      LR      df    p      FPE       AIC      HQIC      SBIC    |
  |----+----------------------------------------------------------------------|
  |  0 | -773.508                      1.3e+15   43.306   43.3981   43.5699  |
  |  1 | -723.493  100.03    9  0.000  1.3e+14*  41.0274*  41.2577*  41.6872* |
  |  2 | -714.853  17.281    9  0.044  1.4e+14   41.0474   41.4158    42.103  |
  |  3 | -706.076  17.553*   9  0.041  1.4e+14   41.0598   41.5664   42.5113  |
  |  4 | -700.077  11.999    9  0.213  1.8e+14   41.2265   41.8713   43.0739  |
  |  5 | -694.984  10.185    9  0.336  2.6e+14   41.4436   42.2265   43.6869  |
  +---------------------------------------------------------------------------+
   Endogenous:  d1cdwell0 d1cdwell1 d1cdwell2
    Exogenous:  d1pop L3.d1pop

. /* test for autocorrelation */;
. varlmar, mlag(5);
```

```
   Lagrange-multiplier test
  +--------------------------------------+
  | lag  |      chi2    df   Prob > chi2 |
  |------+-------------------------------|
  |   1  |   11.8730     9     0.22056   |
  |   2  |   11.1370     9     0.26643   |
  |   3  |    8.3157     9     0.50267   |
  |   4  |    3.5692     9     0.93742   |
  |   5  |    3.7157     9     0.92911   |
  +--------------------------------------+
   H0: no autocorrelation at lag order

. /* test for normality in the residuals */;
. varnorm, jbera;

   Jarque-Bera test
  +--------------------------------------------------------+
  |           Equation |           chi2   df   Prob > chi2 |
  |--------------------+-----------------------------------|
  |          d1cdwell0 |           1.082   2    0.58225    |
  |          d1cdwell1 |           0.225   2    0.89365    |
  |          d1cdwell2 |           0.351   2    0.83900    |
  |                ALL |           1.658   6    0.94834    |
  +--------------------------------------------------------+

. /* test that lags are significant */;
. varwle;

   Equation: d1cdwell0
  +------------------------------------+
  | lag |    chi2      df  Prob > chi2 |
  |-----+------------------------------|
  |   1 |  81.16623     3     0.000    |
  |   2 |  9.603486     3     0.022    |
  |   3 |  4.318308     3     0.229    |
  +------------------------------------+

   Equation: d1cdwell1
  +------------------------------------+
  | lag |    chi2      df  Prob > chi2 |
  |-----+------------------------------|
  |   1 |  61.71784     3     0.000    |
  |   2 |   11.5781     3     0.009    |
  |   3 |   3.84709     3     0.278    |
  +------------------------------------+

   Equation: d1cdwell2
  +------------------------------------+
  | lag |    chi2      df  Prob > chi2 |
  |-----+------------------------------|
  |   1 |  3.431322     3     0.330    |
  |   2 |  4.838764     3     0.184    |
  |   3 |  9.199165     3     0.027    |
  +------------------------------------+

   Equation: All
  +------------------------------------+
  | lag |    chi2      df  Prob > chi2 |
  |-----+------------------------------|
  |   1 |   133.987     9     0.000    |
  |   2 |  27.02197     9     0.001    |
  |   3 |  20.33796     9     0.016    |
```

```
  +------------------------------------+

. /* Granger causality test */;
. vargranger;

   Granger causality Wald tests
  +------------------------------------------------------------------+
  |          Equation           Excluded |   chi2     df Prob > chi2 |
  |--------------------------------------+---------------------------|
  |         d1cdwell0          d1cdwell1 |  5.7876     3    0.122    |
  |         d1cdwell0          d1cdwell2 |   3.906     3    0.272    |
  |         d1cdwell0                ALL |   9.492     6    0.148    |
  |--------------------------------------+---------------------------|
  |         d1cdwell1          d1cdwell0 |  9.2175     3    0.027    |
  |         d1cdwell1          d1cdwell2 |  5.2781     3    0.153    |
  |         d1cdwell1                ALL |  10.224     6    0.116    |
  |--------------------------------------+---------------------------|
  |         d1cdwell2          d1cdwell0 |  15.095     3    0.002    |
  |         d1cdwell2          d1cdwell1 |  2.3408     3    0.505    |
  |         d1cdwell2                ALL |  19.868     6    0.003    |
  +------------------------------------------------------------------+
```

Appendix C: Models 3 and 4 Estimation Results

```
. var d1build0 d1build1 d1cdwell2 d1build4 if tin(1979,2014),
>     lags(1 2 3 4 5)
>     exog(d1pop L1.d1pop L2.d1pop L3.d1pop l4.d1pop)
>     noconstant;

Vector autoregression

Sample:  1979 - 2014                            Number of obs     =        36
Log likelihood =  -807.7143                     AIC               =  50.42857
FPE            =   3.42e+17                     HQIC              =  51.96382
Det(Sigma_ml)  =   3.62e+14                     SBIC              =  54.82723

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
d1build0             25     27.088   0.9916   4264.812   0.0000
d1build1             25    569.135   0.9852   2402.234   0.0000
d1cdwell2            25    499.769   0.9186     406.19   0.0000
d1build4             25    29.6007   0.9891   3272.902   0.0000
----------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
d1build0     |
    d1build0 |
         L1. |   .5941005   .1468572     4.05   0.000     .3062657    .8819352
         L2. |   .0977356   .1734473     0.56   0.573    -.2422149    .4376861
         L3. |   .1869275   .1929796     0.97   0.333    -.1913055    .5651606
         L4. |  -.6249921   .2029267    -3.08   0.002    -1.022721   -.2272631
         L5. |   .5119232   .1300753     3.94   0.000     .2569803    .7668661
             |
    d1build1 |
         L1. |  -.0028178   .0083646    -0.34   0.736    -.0192121    .0135765
         L2. |   .0134421   .0102205     1.32   0.188    -.0065897    .0334739
         L3. |  -.0119531   .0114881    -1.04   0.298    -.0344694    .0105633
         L4. |   .0133259    .013646     0.98   0.329    -.0134198    .0400717
         L5. |  -.0142157   .0080656    -1.76   0.078    -.0300239    .0015926
             |
   d1cdwell2 |
         L1. |   .0103977   .0086295     1.20   0.228    -.0065158    .0273111
         L2. |   .0088104   .0089421     0.99   0.324    -.0087157    .0263366
         L3. |    .004399   .0096782     0.45   0.649    -.0145699    .0233678
         L4. |   .0009963   .0103592     0.10   0.923    -.0193074    .0212999
         L5. |   .0017667   .0080727     0.22   0.827    -.0140554    .0175888
             |
    d1build4 |
         L1. |   .0178609    .054243     0.33   0.742    -.0884535    .1241752
         L2. |  -.3163983   .0551551    -5.74   0.000    -.4245004   -.2082963
         L3. |  -.0947074   .0686035    -1.38   0.167    -.2291678     .039753
         L4. |   .2109803   .0555655     3.80   0.000     .1020739    .3198867
         L5. |   -.084773   .0581754    -1.46   0.145    -.1987947    .0292487
             |
       d1pop |
         --. |   .0036275   .0013117     2.77   0.006     .0010566    .0061984
         L1. |  -.0007272   .0013539    -0.54   0.591    -.0033808    .0019265
         L2. |    .001018   .0011559     0.88   0.379    -.0012476    .0032836
         L3. |   .0028659   .0013041     2.20   0.028     .0003098     .005422
         L4. |  -.0004465   .0012976    -0.34   0.731    -.0029897    .0020967
-------------+----------------------------------------------------------------
d1build1     |
```

```
    d1build0 |
         L1. |  -8.141603   3.085558    -2.64   0.008    -14.18919    -2.09402
         L2. |   7.283505   3.644233     2.00   0.046     .1409398    14.42607
         L3. |  -6.662869   4.054618    -1.64   0.100    -14.60977    1.284036
         L4. |  -.8950379   4.263612    -0.21   0.834    -9.251564    7.461489
         L5. |   2.182606   2.732961     0.80   0.425    -3.173898    7.539111
             |
    d1build1 |
         L1. |   .8846254   .1757454     5.03   0.000     .5401707     1.22908
         L2. |  -.6406204   .2147388    -2.98   0.003    -1.061501   -.2197401
         L3. |   .3803938   .2413725     1.58   0.115    -.0926877    .8534752
         L4. |   -.118682   .2867116    -0.41   0.679    -.6806265    .4432624
         L5. |  -.0758752   .1694627    -0.45   0.654    -.4080161    .2562656
             |
   d1cdwell2 |
         L1. |   .2586554   .1813104     1.43   0.154    -.0967065    .6140172
         L2. |   .8026186   .1878783     4.27   0.000     .4343839    1.170853
         L3. |   .0256669   .2033443     0.13   0.900    -.3728806    .4242143
         L4. |   .2866401   .2176531     1.32   0.188    -.1399522    .7132324
         L5. |  -.0807196   .1696113    -0.48   0.634    -.4131517    .2517125
             |
    d1build4 |
         L1. |    2.12417   1.139679     1.86   0.062    -.1095595    4.357899
         L2. |  -4.240287   1.158842    -3.66   0.000    -6.511576   -1.968998
         L3. |  -2.087136   1.441401    -1.45   0.148     -4.91223    .7379587
         L4. |  -.7124648   1.167465    -0.61   0.542    -3.000655    1.575725
         L5. |  -.0068534   1.222301    -0.01   0.996    -2.402519    2.388812
             |
       d1pop |
         --. |   .0860509   .0275594     3.12   0.002     .0320354    .1400664
         L1. |   .0467117   .0284469     1.64   0.101    -.0090432    .1024667
         L2. |   .0089418   .0242871     0.37   0.713      -.03866    .0565436
         L3. |   .0727159   .0274009     2.65   0.008     .0190112    .1264206
         L4. |   .0558441    .027263     2.05   0.041     .0024097    .1092785
-------------+----------------------------------------------------------------
d1cdwell2    |
    d1build0 |
         L1. |  -5.011775    2.70949    -1.85   0.064    -10.32228    .2987284
         L2. |   11.16452   3.200074     3.49   0.000     4.892494    17.43655
         L3. |  -8.523174   3.560441    -2.39   0.017    -15.50151   -1.544838
         L4. |   3.434697   3.743963     0.92   0.359    -3.903336    10.77273
         L5. |   3.468661   2.399868     1.45   0.148    -1.234993    8.172314
             |
    d1build1 |
         L1. |   .3000806   .1543256     1.94   0.052     -.002392    .6025531
         L2. |  -.3041549   .1885664    -1.61   0.107    -.6737383    .0654285
         L3. |   .6668568    .211954     3.15   0.002     .2514345    1.082279
         L4. |  -.4156555   .2517672    -1.65   0.099    -.9091101    .0777991
         L5. |   .0293241   .1488086     0.20   0.844    -.2623354    .3209836
             |
   d1cdwell2 |
         L1. |   .2027929   .1592123     1.27   0.203    -.1092574    .5148432
         L2. |   .3880183   .1649797     2.35   0.019     .0646641    .7113725
         L3. |   -.344873   .1785607    -1.93   0.053    -.6948455    .0050994
         L4. |  -.1769812   .1911256    -0.93   0.354    -.5515805     .197618
         L5. |   -.114859   .1489391    -0.77   0.441    -.4067743    .1770563
             |
    d1build4 |
         L1. |   1.588567   1.000775     1.59   0.112    -.3729156    3.550049
         L2. |  -1.847792   1.017603    -1.82   0.069    -3.842257    .1466721
         L3. |  -.4151842   1.265723    -0.33   0.743    -2.895956    2.065587
         L4. |  -1.136777   1.025175    -1.11   0.267    -3.146083     .872528
         L5. |   1.275034   1.073327     1.19   0.235    -.8286475    3.378716
```

```
             |
       d1pop |
         --. |     -.0065    .0242005    -0.27   0.788    -.0539321    .0409321
         L1. |  -.0338317    .0249798    -1.35   0.176    -.0827912    .0151278
         L2. |  -.0162485     .021327    -0.76   0.446    -.0580486    .0255516
         L3. |  -.0036758    .0240613    -0.15   0.879     -.050835    .0434834
         L4. |  -.0199645    .0239401    -0.83   0.404    -.0668863    .0269573
-------------+----------------------------------------------------------------
d1build4     |
    d1build0 |
         L1. |  -1.001085    .1604797    -6.24   0.000    -1.315619   -.6865502
         L2. |   .9230398    .1895363     4.87   0.000     .5515554    1.294524
         L3. |  -.0932834    .2108804    -0.44   0.658    -.5066014    .3200346
         L4. |   .1497549    .2217502     0.68   0.499    -.2848675    .5843772
         L5. |  -.2013494    .1421411    -1.42   0.157    -.4799409     .077242
             |
    d1build1 |
         L1. |   .0455232    .0091405     4.98   0.000     .0276082    .0634383
         L2. |   .0059296    .0111685     0.53   0.595    -.0159604    .0278195
         L3. |   .0173929    .0125538     1.39   0.166    -.0072121    .0419978
         L4. |  -.0344817    .0149119    -2.31   0.021    -.0637084    -.005255
         L5. |   .0030601    .0088137     0.35   0.728    -.0142145    .0203348
             |
   d1cdwell2 |
         L1. |  -.0037205    .0094299    -0.39   0.693    -.0222028    .0147619
         L2. |   .0352696    .0097715     3.61   0.000     .0161178    .0544215
         L3. |  -.0253628    .0105759    -2.40   0.016    -.0460912   -.0046344
         L4. |   .0360503    .0113201     3.18   0.001     .0138633    .0582373
         L5. |   .0359599    .0088215     4.08   0.000     .0186702    .0532497
             |
    d1build4 |
         L1. |   .2025828    .0592746     3.42   0.001     .0864067    .3187589
         L2. |  -.1640768    .0602713    -2.72   0.006    -.2822064   -.0459472
         L3. |   -.367475    .0749672    -4.90   0.000    -.5144079    -.220542
         L4. |  -.1970927    .0607198    -3.25   0.001    -.3161013   -.0780841
         L5. |   .2345407    .0635718     3.69   0.000     .1099423    .3591391
             |
       d1pop |
         --. |  -.0033581    .0014334    -2.34   0.019    -.0061675   -.0005488
         L1. |   .0010993    .0014795     0.74   0.457    -.0018006    .0039991
         L2. |   .0010016    .0012632     0.79   0.428    -.0014741    .0034774
         L3. |    .005465    .0014251     3.83   0.000     .0026718    .0082582
         L4. |   .0035323    .0014179     2.49   0.013     .0007531    .0063114
------------------------------------------------------------------------------

. varstable ;

   Eigenvalue stability condition
  +----------------------------------------+
  |        Eigenvalue        |   Modulus   |
  |--------------------------+-------------|
  |  -.6851594 +  .7159409i  |   .990967   |
  |  -.6851594 -  .7159409i  |   .990967   |
  |   .5520444 +  .7591526i  |   .938651   |
  |   .5520444 -  .7591526i  |   .938651   |
  |   .9137428               |   .913743   |
  |   .8196103 +  .3065398i  |   .875059   |
  |   .8196103 -  .3065398i  |   .875059   |
  |   .5315896 +  .6228696i  |   .818874   |
  |   .5315896 -  .6228696i  |   .818874   |
  |  -.7258782 +   .305657i  |   .787607   |
  |  -.7258782 -   .305657i  |   .787607   |
  |   -.264619 +  .6902049i  |   .739193   |
```

```
  |   -.264619 -  .6902049i  |   .739193   |
  |  .02126862 +  .6967377i  |   .697062   |
  |  .02126862 -  .6967377i  |   .697062   |
  |   .4387303 +  .4001748i  |   .593822   |
  |   .4387303 -  .4001748i  |   .593822   |
  |  -.4444522 +  .2304609i  |    .50065   |
  |  -.4444522 -  .2304609i  |    .50065   |
  |   .4840899               |    .48409   |
  +----------------------------------------+
   All the eigenvalues lie inside the unit circle.
   VAR satisfies stability condition.

.         varlmar, mlag(6);

   Lagrange-multiplier test
  +--------------------------------------+
  | lag  |      chi2    df   Prob > chi2 |
  |------+-------------------------------|
  |   1  |   15.6094    16     0.48054   |
  |   2  |   20.4841    16     0.19920   |
  |   3  |   19.4348    16     0.24676   |
  |   4  |   14.6698    16     0.54894   |
  |   5  |   21.6999    16     0.15315   |
  |   6  |   13.0215    16     0.67119   |
  +--------------------------------------+
   H0: no autocorrelation at lag order

. varsoc, maxlag(6) exog(d1pop L1.d1pop L2.d1pop L3.d1pop l4.d1pop);

   Selection-order criteria
   Sample:  1979 - 2014                         Number of obs      =        36
  +---------------------------------------------------------------------------+
  |lag |    LL      LR      df    p      FPE       AIC      HQIC      SBIC    |
  |----+----------------------------------------------------------------------|
  |  0 | -944.937                      2.3e+18   53.6076   53.9147   54.4874  |
  |  1 | -891.871  106.13   16  0.000  3.0e+17   51.5484   52.1011   53.1319* |
  |  2 | -870.038  43.667   16  0.000  2.4e+17*  51.2243   52.0227   53.5116  |
  |  3 | -856.392  27.292   16  0.038  3.3e+17   51.3551   52.3991   54.3462  |
  |  4 | -830.126  52.532   16  0.000  2.6e+17   50.7848   52.0744   54.4796  |
  |  5 | -807.714  44.823   16  0.000  3.4e+17   50.4286   51.9638   54.8272  |
  |  6 | -766.212  83.004*  16  0.000  2.7e+17   49.0118*  50.7927*  54.1142  |
  +---------------------------------------------------------------------------+
   Endogenous:  d1build0 d1build1 d1cdwell2 d1build4
    Exogenous:  d1pop L.d1pop L2.d1pop L3.d1pop L4.d1pop

. varnorm, jbera;

   Jarque-Bera test
  +--------------------------------------------------------+
  |           Equation |           chi2   df  Prob > chi2 |
  |--------------------+-----------------------------------|
  |           d1build0 |           0.230   2    0.89139   |
  |           d1build1 |           1.226   2    0.54183   |
  |          d1cdwell2 |           7.239   2    0.02679   |
  |           d1build4 |           1.499   2    0.47265   |
  |                ALL |          10.193   8    0.25171   |
  +--------------------------------------------------------+

. varwle;

   Equation: d1build0
  +-----------------------------------+
  | lag |    chi2      df  Prob > chi2 |
```

```
  |-----+------------------------------|
  |   1 |  34.24709     4     0.000    |
  |   2 |   51.3959     4     0.000    |
  |   3 |  2.791147     4     0.593    |
  |   4 |  22.95005     4     0.000    |
  |   5 |   18.1731     4     0.001    |
  +------------------------------------+

   Equation: d1build1
  +------------------------------------+
  | lag |    chi2      df  Prob > chi2 |
  |-----+------------------------------|
  |   1 |  50.01865     4     0.000    |
  |   2 |  45.19877     4     0.000    |
  |   3 |  11.46389     4     0.022    |
  |   4 |  4.116811     4     0.390    |
  |   5 |   1.07002     4     0.899    |
  +------------------------------------+

   Equation: d1cdwell2
  +------------------------------------+
  | lag |    chi2      df  Prob > chi2 |
  |-----+------------------------------|
  |   1 |  14.17138     4     0.007    |
  |   2 |  18.42308     4     0.001    |
  |   3 |  12.66918     4     0.013    |
  |   4 |  9.681341     4     0.046    |
  |   5 |  12.37026     4     0.015    |
  +------------------------------------+

   Equation: d1build4
  +------------------------------------+
  | lag |    chi2      df  Prob > chi2 |
  |-----+------------------------------|
  |   1 |  68.26491     4     0.000    |
  |   2 |  42.15841     4     0.000    |
  |   3 |  32.60828     4     0.000    |
  |   4 |  26.45316     4     0.000    |
  |   5 |  25.49967     4     0.000    |
  +------------------------------------+

   Equation: All
  +------------------------------------+
  | lag |    chi2      df  Prob > chi2 |
  |-----+------------------------------|
  |   1 |  132.6547    16     0.000    |
  |   2 |  147.0807    16     0.000    |
  |   3 |  56.72874    16     0.000    |
  |   4 |  70.24753    16     0.000    |
  |   5 |   57.6402    16     0.000    |
  +------------------------------------+

. vargranger;

   Granger causality Wald tests
  +------------------------------------------------------------------+
  |          Equation           Excluded |   chi2     df Prob > chi2 |
  |--------------------------------------+---------------------------|
  |          d1build0           d1build1 |  4.0736     5    0.539    |
  |          d1build0          d1cdwell2 |  3.0537     5    0.692    |
  |          d1build0           d1build4 |  57.625     5    0.000    |
  |          d1build0                ALL |  85.545    15    0.000    |
  |--------------------------------------+---------------------------|
```

```
  |          d1build1           d1build0 |  25.799     5    0.000    |
  |          d1build1          d1cdwell2 |  24.265     5    0.000    |
  |          d1build1           d1build4 |  22.895     5    0.000    |
  |          d1build1                ALL |  63.864    15    0.000    |
  |--------------------------------------+---------------------------|
  |         d1cdwell2           d1build0 |  35.863     5    0.000    |
  |         d1cdwell2           d1build1 |  12.107     5    0.033    |
  |         d1cdwell2           d1build4 |  13.364     5    0.020    |
  |         d1cdwell2                ALL |  72.749    15    0.000    |
  |--------------------------------------+---------------------------|
  |          d1build4           d1build0 |  44.786     5    0.000    |
  |          d1build4           d1build1 |  41.118     5    0.000    |
  |          d1build4          d1cdwell2 |  47.347     5    0.000    |
  |          d1build4                ALL |     142    15    0.000    |
  +------------------------------------------------------------------+

. /**************************************************************************/;
. /* Model 4 is created to provide an estimate of land development as f(pop)   */;
. /**************************************************************************/;
. regress cdevland population, noconstant;

      Source |       SS           df       MS      Number of obs   =        65
-------------+----------------------------------   F(1, 64)        =  18653.52
       Model |  9.9772e+11         1  9.9772e+11   Prob > F        =    0.0000
    Residual |  3.4232e+09        64  53486805.3   R-squared       =    0.9966
-------------+----------------------------------   Adj R-squared   =    0.9965
       Total |  1.0011e+12        65  1.5402e+10   Root MSE        =    7313.5

------------------------------------------------------------------------------
    cdevland |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  population |   .4886699    .003578   136.58   0.000     .4815221    .4958177
------------------------------------------------------------------------------
```

TRUCKEE MEADOWS WATER
AUTHORITY

APPENDIX 4-3

TPEM SERIES NO. 3:

TMWA WATER DEMAND PROJECTIONS

TRUCKEE MEADOWS WATER
AUTHORITY
www.tmh2o.com

Memorandum

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P 775.834.8080 • F 775.834.8003

TO: File

FROM: **Laine Christman, Resource Economist**

DATE: Sept., 29, 2015

SUBJ: TPEM Series No. 3: TMWA Water Demand Projections

SUMMARY

- Water demand projections for TMWA's Retail Service are estimated from 2015 to 2060 and are broken out by hydrographic basin.

- Water demand projections are a function of current active services, average water demand, and future building projections.
- Total demand for water is expected to increase from approximately 81,700 acre feet in 2015 to 101,400 by 2035.
- Residential Metered Water Services ("RMWS") account for approximately 95 percent of single-family unit counts.
- Multi-family Metered Water Services ("MMWS") account for approximately 95 percent of multi-family unit counts.
- General Metered Water Services ("GMWS") account for approximately 75 percent of commercial building counts.
- RMWS and MMWS account for approximately 57.9 and 7.4 percent of the total projected demand, respectively, through 2035.
- Water demand by RMWS is expected to increase by 2 percent by 2035.
- MMWS, GMWS, and MIS water demands are expected to decrease by 1 percent by 2035.
- Figure 1 illustrates water demands between 2015 and 2060
- Table 1 provides water demands, between 2015 and 2060 for the entire TMWA service area
- Table 2 breaks out total water demands projections for hydrographic basins in the Truckee River Resource Area (TRA) and non-TRA basins.
- Table 3 breaks out water demand projections by service type of each hydrographic basin.

DISCUSSION

TPEM memo no. 1 provides a population projection for Washoe County. Memo no. 1's projections are used in memo no. 2 with the Washoe County Assessors data to model building construction and create projections of new residential dwelling units and commercial buildings. The county-level building and population projections were then disaggregated using sub-area shares of the past building inventories.

This memo documents the process of using the projections produced in memos no. 1 and 2, combined with the recent active billing histories to 1) project new retail water services; 2) estimate annual water use per water service; and 3) project water demand through the year 2060.

Data for projecting water services

The data used to project the water demands include service connection data, billing history data, assessor information, and future building projections.

Active Service Counts - data on the location (i.e., hydrographic basin) of each service connection is merged with billing history data to identify active services for each basin, between 2003 and 2014. Table 4 provides the active service counts within each basin in TMWA's service area.

Active Service Ratios – The number of dwellings/buildings within each hydrographic basin is merged with active service information. The associated tax assessor information on the building attributes is also merged with MMWS to capture the number of units within each multi-family service. Since MMWS provide water to more than one dwelling unit, this information is used to determine the average number of units multi-family water connections serve. Since the number of active water services is generally less than total number of buildings, a percentage of active service, based on previous services, is calculate. This information allows the projection of future active service for residential metered services, multi-family dwelling units, and general metered water services. Table 5 provides the service ratios by year and Table provides the service ratios by basin.

For metered irrigation water services ("MIS") there is no clear correlation to any one land use or building type in the Assessors data. Many if not most MIS services are associated with multi-family properties or commercial properties, therefore, it stands to reason that multi-family and/or commercial water services should be able to statistically explain the MIS services and thus, project future MIS services using projected MMWS and GMWS data.

Three regression models were estimated: MIS as a function of multi-family services, MIS as a function of commercial services, and MIS as a function of both MF services and GMWS services. All three models are statistically significant (see regression results below). However, projection of MIS just using MF or GMWS as the independent variable results in similar short term projections but very different long term projections. The third model using both MF and GMWS results in a projection that reflects an average and is used for the service projection. Since it is assumed no MIS would result if no GMWS or MMWS services exist, the intercept is suppressed in each model. The regression output for all three models can be found in Table 7. Table 4 provides the MIS projections by basin.

Demand Coefficients - using the billing history information on active services, average water demand coefficients are calculates by taking the average, per-service, water usage between 2009 and 2014. Water usage prior to 2009 is not considered in this calculation, since pre-2009 there were higher levels of flat-rate customers. Moreover, water usage, in general, has been on the decline in the last ten years. Therefore, water usage in 2009 forward more accurately reflects future water consumption.

Active Service Projections – active service projections are estimate by multiplying building projections and ratios. Table 8 provides the individual service projections for TMWA's service area. Tables 9.1 – 9.8 provide the projections within each basin.

Water Demand Projections – future demands are estimated by multiplying the water demand coefficients by their associated service projections within each respective basin. Table 1 provides the water demand projections for each of the following metered services: RMWS, MMWS, GMWS, and MIS. Table 2 provides the total demand projections for each basin within the TRA and non-TRA areas. Tables 3.1 – 3.8 provide the projections, per service type, for each basin within TMWA service area.

Estimating Water Use Projections by Service Type

RMWS Projection Steps:

1. Identify active service counts in each year, 2003 to 2014, for each basin.
2. Calculate an active service ratio equal to (active services/total number of RMWS dwellings) in each year, 2003 to 2014, for each basin.
3. Calculate the average active service ratio across years for each basin.
4. Estimate a water demand coefficient equal to the average annual use, 'per RMWS service', for each year, 2009 to 2014, for each basin.
5. Calculate the average of the annual water demand coefficients within the five years for each basin.
6. Estimate the annual number of active service projections as equal to (average active service ratio * building projects) for each basin for 2015 through 2060.
7. For each basin, estimate projections on annual water use for 2015 through 2060 as equal to (average water demand coefficient * service projections).

MMWS Projection Steps:

1. Identify active service counts between 2003 and 2014 for each basin.
2. Calculate a active service ratio equal to [active services / (total number of MMWS dwellings/average number of units)] for each year, 2003 to 2014, for each basin.
3. Calculate the average active service ratio across years for each basin.
4. Estimate water demand coefficient as the average annual use, 'per MMWS service', for each year, 2009 to 2014, for each basin.
5. Calculate the average of the water demand coefficients within the five years.
6. Estimate the annual number of active service projections as equal to (average active service ratio * building projects) for each basin for 2015 through 2060.
7. For each basin, estimate projections on annual water use for 2015 through 2060 as equal to (average water demand coefficient * service projections).

GMWS Projection Steps:

1. Identify active service counts in each year, 2003 to 2014, for each basin.
2. Calculate an active service ratio equal to (active services/total number of GMWS dwellings) in each year, 2003 to 2014, for each basin.
3. Calculate the average active service ratio across years for each basin.

4. Estimate a water demand coefficient equal to the average annual use, ‘per GMWS service’, for each year, 2009 to 2014, for each basin.
5. Calculate the average of the annual water demand coefficients within the five years for each basin.
6. Estimate the annual number of active service projections as equal to (average active service ratio * building projects) for each basin for 2015 through 2060.
7. For each basin, estimate projections on annual water use for 2015 through 2060 as equal to (average water demand coefficient * service projections).

MIS Projection Steps:

1. Estimate the amount of MIS services as a function of GMWS and MMWS active services between 2003 and 2014 using an ordinary least square regression model.
2. Estimate a water demand coefficient as the average annual use, ‘per MIS service’, in each year, 2009 to 2014, within each basin.
3. For each basin, calculate the average water demand coefficient across the five years.
4. Estimate the annual number of active MIS service projections as equal to (0.323* number of active GMWS services) + (0.289 * number of active MMWS services) for each basin for 2015 through 2060.
5. For each basin, estimate projections on annual water use for 2015 through 2060 as equal to (average water demand coefficient * service projections).

Wholesale Water Service (LVS) Use Projection Steps:

1. Determine the annual water usage for LVS service in 2015
2. Assume use will increase till a demand of 4180 acre feet is achieved in 2060. This demand is the maximum possible under the water rights for this service.
3. Calculate percent increase in the demand, annually, until 2060.
4. Project water use between 2015 and 2060 as constant percentage increase until total demand is reached in 2060.

System Loss Projection Steps:

1. Sum all water demand projections (RMWS, MMWS, GMWS, MIS, LVS) on an annual basis.
2. Assume an average of 6% water loss.
3. Estimate water loss as equal to (total water demand * 0.06) between 2015 through 2060.

Total System Production Projection Steps:

1. Sum total water demand + system loss on an annual basis between 2015 through 2060.

Figure 1: TMWA Projected Water Demand (2015 to 2060)

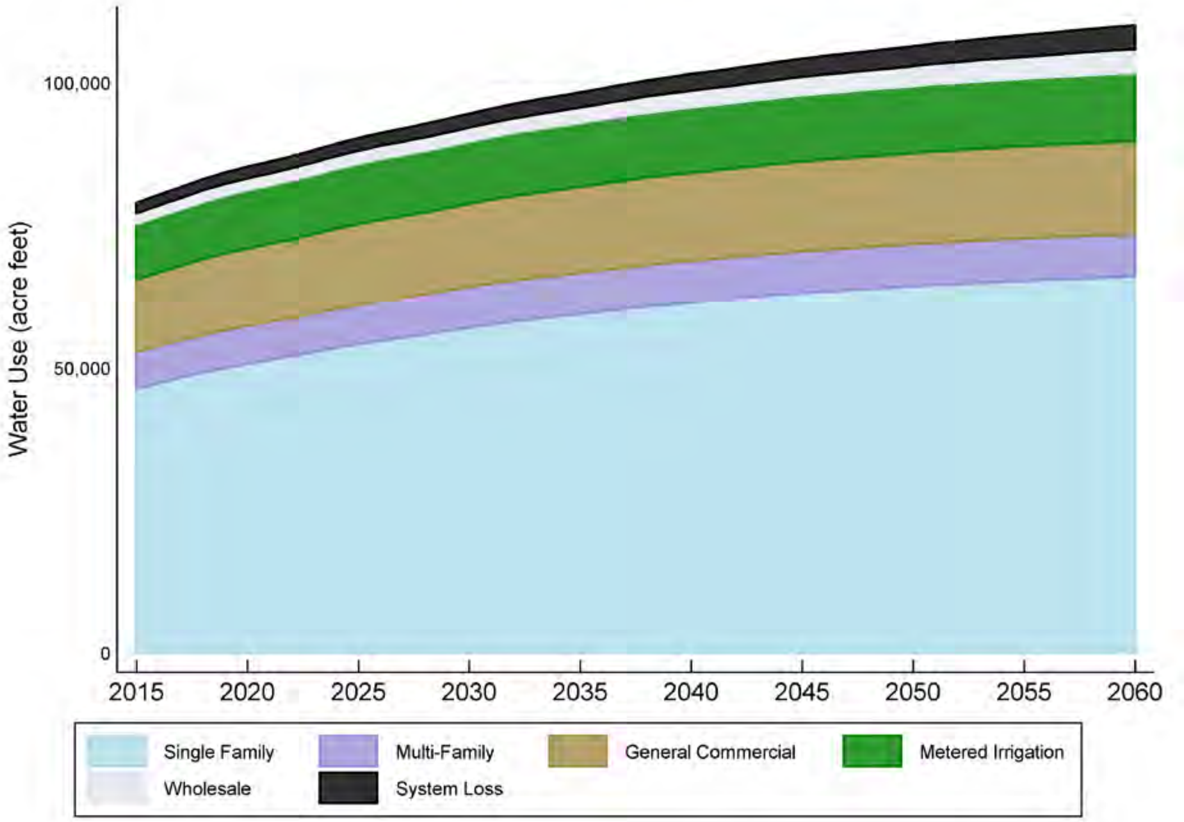


Table 1: Water Demand Projections for Truckee Meadows Service Area (2015 to 2060)

Year	RMWS	MMWS	GMWS	MIS	LVS	Total Retail	System Loss	Total Production
2015	46,252	6,494	12,716	9,777	1,869	77,108	4,626	81,735
2016	47,332	6,523	12,864	9,860	1,903	78,481	4,709	83,190
2017	48,321	6,541	13,050	9,952	1,937	79,801	4,788	84,589
2018	49,165	6,617	13,277	10,101	1,972	81,131	4,868	85,999
2019	49,945	6,687	13,429	10,209	2,007	82,277	4,937	87,213
2020	50,674	6,730	13,527	10,283	2,043	83,259	4,996	88,254
2021	51,366	6,755	13,604	10,330	2,080	84,136	5,048	89,184
2022	52,074	6,755	13,707	10,374	2,118	85,028	5,102	90,129
2023	52,803	6,782	13,860	10,458	2,156	86,058	5,163	91,221
2024	53,537	6,829	14,026	10,563	2,195	87,150	5,229	92,379
2025	54,178	6,870	14,167	10,649	2,234	88,098	5,286	93,383
2026	54,747	6,924	14,275	10,726	2,274	88,947	5,337	94,283
2027	55,311	6,951	14,345	10,779	2,315	89,701	5,382	95,083
2028	55,886	6,962	14,420	10,814	2,357	90,440	5,426	95,866
2029	56,504	6,988	14,526	10,879	2,399	91,296	5,478	96,774
2030	57,118	7,013	14,651	10,947	2,443	92,172	5,530	97,703
2031	57,673	7,052	14,784	11,030	2,486	93,026	5,582	98,608
2032	58,175	7,099	14,888	11,108	2,531	93,802	5,628	99,431
2033	58,619	7,123	14,964	11,155	2,577	94,438	5,666	100,105
2034	59,049	7,147	15,027	11,196	2,623	95,042	5,703	100,745
2035	59,506	7,160	15,090	11,232	2,670	95,658	5,739	101,398
2036	59,959	7,168	15,175	11,274	2,718	96,294	5,778	102,072
2037	60,403	7,202	15,274	11,340	2,767	96,987	5,819	102,806
2038	60,807	7,228	15,360	11,392	2,817	97,603	5,856	103,459
2039	61,151	7,252	15,434	11,442	2,868	98,147	5,889	104,036
2040	61,482	7,277	15,488	11,484	2,920	98,652	5,919	104,571
2041	61,803	7,280	15,530	11,501	2,972	99,086	5,945	105,031
2042	62,134	7,295	15,588	11,533	3,026	99,576	5,975	105,550
2043	62,477	7,310	15,651	11,573	3,080	100,092	6,005	106,097
2044	62,787	7,322	15,721	11,608	3,135	100,574	6,034	106,608
2045	63,071	7,351	15,787	11,658	3,192	101,059	6,064	107,122
2046	63,330	7,367	15,830	11,686	3,249	101,462	6,088	107,549
2047	63,561	7,375	15,867	11,705	3,308	101,815	6,109	107,924
2048	63,806	7,389	15,907	11,736	3,367	102,204	6,132	108,337
2049	64,049	7,389	15,944	11,749	3,428	102,560	6,154	108,714
2050	64,284	7,404	15,998	11,782	3,490	102,957	6,177	109,135
2051	64,511	7,422	16,045	11,816	3,553	103,347	6,201	109,547
2052	64,703	7,430	16,083	11,838	3,616	103,671	6,220	109,891
2053	64,880	7,447	16,121	11,863	3,682	103,992	6,240	110,232
2054	65,056	7,452	16,142	11,876	3,748	104,274	6,256	110,531
2055	65,222	7,453	16,170	11,891	3,815	104,551	6,273	110,825
2056	65,398	7,467	16,205	11,915	3,884	104,869	6,292	111,162
2057	65,564	7,469	16,237	11,929	3,954	105,153	6,309	111,463
2058	65,709	7,480	16,271	11,948	4,025	105,433	6,326	111,759
2059	65,851	7,494	16,298	11,968	4,098	105,708	6,342	112,050
2060	65,972	7,494	16,316	11,979	4,171	105,933	6,356	112,289

Table 2: Total Demand (acre feet) per Hydrographic Basin (2015 to 2060)

	Truckee River Resource Ares (TRA) Basins						Non- TRA Basins			
Year	85	86	87	88W	92	TRA Total	83	88E	89	Non-TRA Total
2015	8,961	224	64,940	1,030	4,388	79,543	25	46	140	211
2016	9,160	228	66,042	1,054	4,473	80,957	26	46	144	216
2017	9,343	233	67,115	1,075	4,550	82,315	27	46	147	220
2018	9,506	239	68,221	1,094	4,625	83,685	27	47	150	224
2019	9,652	242	69,163	1,112	4,690	84,858	28	48	152	228
2020	9,786	245	69,946	1,128	4,751	85,856	28	49	154	232
2021	9,911	248	70,641	1,143	4,802	86,745	28	50	156	234
2022	10,042	251	71,339	1,159	4,857	87,647	29	51	158	237
2023	10,179	255	72,173	1,174	4,916	88,696	29	51	159	240
2024	10,321	258	73,059	1,191	4,980	89,809	30	52	162	244
2025	10,441	261	73,829	1,205	5,034	90,769	30	53	164	247
2026	10,545	263	74,514	1,218	5,084	91,623	30	53	166	250
2027	10,651	265	75,105	1,230	5,126	92,378	31	54	166	251
2028	10,753	268	75,682	1,243	5,169	93,115	31	54	169	253
2029	10,875	271	76,355	1,256	5,218	93,975	31	55	170	256
2030	10,985	273	77,055	1,271	5,269	94,853	31	56	174	260
2031	11,091	276	77,740	1,282	5,320	95,709	32	56	175	263
2032	11,185	278	78,364	1,293	5,362	96,482	32	56	177	265
2033	11,271	279	78,855	1,303	5,398	97,105	32	57	178	268
2034	11,348	281	79,321	1,312	5,433	97,695	32	57	180	269
2035	11,429	283	79,790	1,323	5,470	98,296	33	58	181	271
2036	11,516	285	80,280	1,333	5,504	98,918	33	59	181	272
2037	11,601	287	80,826	1,343	5,542	99,599	33	59	182	274
2038	11,675	292	81,301	1,352	5,578	100,197	34	60	183	277
2039	11,740	293	81,716	1,359	5,609	100,718	34	60	184	278
2040	11,806	294	82,096	1,367	5,633	101,196	34	61	186	280
2041	11,863	296	82,411	1,373	5,656	101,599	34	61	187	281
2042	11,924	297	82,773	1,381	5,685	102,060	34	61	188	283
2043	11,989	298	83,161	1,389	5,710	102,548	35	61	189	284
2044	12,045	300	83,519	1,395	5,739	102,999	35	61	190	286
2045	12,102	302	83,883	1,402	5,763	103,452	35	61	190	286
2046	12,149	303	84,173	1,408	5,784	103,818	35	61	192	288
2047	12,190	304	84,421	1,412	5,802	104,129	35	61	193	289
2048	12,238	305	84,694	1,418	5,822	104,477	35	62	193	290
2049	12,282	306	84,938	1,423	5,841	104,790	35	62	193	290
2050	12,325	307	85,221	1,429	5,863	105,144	35	62	194	291
2051	12,371	308	85,497	1,434	5,880	105,489	36	63	194	293
2052	12,406	308	85,712	1,438	5,900	105,764	36	63	195	294
2053	12,438	309	85,932	1,442	5,913	106,035	36	63	195	294
2054	12,469	310	86,113	1,446	5,925	106,263	36	63	196	295
2055	12,503	311	86,283	1,450	5,938	106,484	36	64	196	296
2056	12,534	311	86,492	1,453	5,956	106,747	36	64	198	297
2057	12,565	312	86,671	1,457	5,969	106,974	36	64	198	297
2058	12,592	313	86,852	1,460	5,979	107,195	36	64	198	297
2059	12,618	313	87,024	1,464	5,990	107,408	36	64	199	299
2060	12,644	314	87,146	1,466	5,998	107,568	36	65	199	300

Table 3.1: Water Demand (acre feet) by Service Type for Basin 83 (2015 to 2060)

Year	RMWS	MMWS	GMWS	MIS	Total Retail	System Loss	Total Retail	Total Production
2015	21	-	2	0	24	1	24	25
2016	22	-	2	0	24	1	24	26
2017	22	-	3	1	25	2	25	27
2018	22	-	3	1	26	2	26	27
2019	22	-	3	1	26	2	26	28
2020	23	-	3	1	27	2	27	28
2021	23	-	3	1	27	2	27	28
2022	23	-	3	1	27	2	27	29
2023	24	-	3	1	28	2	28	29
2024	24	-	3	1	28	2	28	30
2025	24	-	3	1	28	2	28	30
2026	25	-	3	1	28	2	28	30
2027	25	-	3	1	29	2	29	31
2028	25	-	3	1	29	2	29	31
2029	26	-	3	1	29	2	29	31
2030	26	-	3	1	29	2	29	31
2031	26	-	3	1	30	2	30	32
2032	26	-	3	1	30	2	30	32
2033	27	-	3	1	30	2	30	32
2034	27	-	3	1	30	2	30	32
2035	27	-	3	1	31	2	31	33
2036	27	-	3	1	31	2	31	33
2037	27	-	3	1	31	2	31	33
2038	28	-	3	1	32	2	32	34
2039	28	-	3	1	32	2	32	34
2040	28	-	3	1	32	2	32	34
2041	28	-	3	1	32	2	32	34
2042	28	-	3	1	32	2	32	34
2043	28	-	3	1	33	2	33	35
2044	28	-	3	1	33	2	33	35
2045	28	-	3	1	33	2	33	35
2046	28	-	3	1	33	2	33	35
2047	28	-	3	1	33	2	33	35
2048	29	-	3	1	33	2	33	35
2049	29	-	3	1	33	2	33	35
2050	29	-	3	1	33	2	33	35
2051	29	-	3	1	34	2	34	36
2052	29	-	3	1	34	2	34	36
2053	29	-	3	1	34	2	34	36
2054	29	-	3	1	34	2	34	36
2055	30	-	3	1	34	2	34	36
2056	30	-	3	1	34	2	34	36
2057	30	-	3	1	34	2	34	36
2058	30	-	3	1	34	2	34	36
2059	30	-	3	1	34	2	34	36
2060	30	-	3	1	34	2	34	36

Table 3.2: Water Demand (acre feet) by Service Type for Basin 85 (2015 to 2060)

Year	RMWS	MMWS	GMWS	MIS	Total Retail	System Loss	Total Retail	Total Production
2015	7,710	96	274	374	8,454	507	8,454	8,961
2016	7,890	97	277	378	8,642	518	8,642	9,160
2017	8,055	97	281	381	8,814	529	8,814	9,343
2018	8,195	98	286	388	8,968	538	8,968	9,506
2019	8,325	99	289	392	9,105	546	9,105	9,652
2020	8,447	99	291	395	9,233	554	9,233	9,786
2021	8,562	101	292	395	9,350	561	9,350	9,911
2022	8,680	101	294	399	9,473	568	9,473	10,042
2023	8,802	101	298	402	9,603	576	9,603	10,179
2024	8,924	102	302	409	9,737	584	9,737	10,321
2025	9,030	102	305	413	9,850	591	9,850	10,441
2026	9,125	103	307	413	9,948	597	9,948	10,545
2027	9,220	103	309	416	10,048	603	10,048	10,651
2028	9,315	103	310	416	10,144	609	10,144	10,753
2029	9,419	104	313	423	10,259	616	10,259	10,875
2030	9,521	104	315	423	10,363	622	10,363	10,985
2031	9,613	105	318	427	10,463	628	10,463	11,091
2032	9,697	105	320	430	10,552	633	10,552	11,185
2033	9,771	106	322	434	10,633	638	10,633	11,271
2034	9,842	106	323	434	10,705	642	10,705	11,348
2035	9,919	106	324	434	10,783	647	10,783	11,429
2036	9,995	106	326	437	10,864	652	10,864	11,516
2037	10,069	107	328	441	10,945	657	10,945	11,601
2038	10,136	107	330	441	11,014	661	11,014	11,675
2039	10,193	107	331	444	11,076	665	11,076	11,740
2040	10,248	108	333	448	11,137	668	11,137	11,806
2041	10,302	108	334	448	11,192	672	11,192	11,863
2042	10,357	108	336	448	11,249	675	11,249	11,924
2043	10,414	108	337	451	11,311	679	11,311	11,989
2044	10,466	108	338	451	11,364	682	11,364	12,045
2045	10,513	109	340	455	11,417	685	11,417	12,102
2046	10,556	109	341	455	11,462	688	11,462	12,149
2047	10,594	109	341	455	11,500	690	11,500	12,190
2048	10,635	109	342	458	11,545	693	11,545	12,238
2049	10,676	109	343	458	11,587	695	11,587	12,282
2050	10,715	109	344	458	11,627	698	11,627	12,325
2051	10,753	110	345	462	11,671	700	11,671	12,371
2052	10,785	110	346	462	11,703	702	11,703	12,406
2053	10,815	110	347	462	11,734	704	11,734	12,438
2054	10,844	110	347	462	11,763	706	11,763	12,469
2055	10,871	110	348	465	11,795	708	11,795	12,503
2056	10,901	110	348	465	11,825	709	11,825	12,534
2057	10,929	110	349	465	11,854	711	11,854	12,565
2058	10,953	110	350	465	11,879	713	11,879	12,592
2059	10,976	112	350	465	11,903	714	11,903	12,618
2060	10,997	112	351	469	11,928	716	11,928	12,644

Table 3.3: Water Demand (acre feet) by Service Type for Basin 86 (2015 to 2060)

Year	RMWS	MMWS	GMWS	MIS	Total Retail	System Loss	Total Retail	Total Production
2015	182	8	5	16	211	13	211	224
2016	186	8	5	16	215	13	215	228
2017	190	8	5	16	219	13	219	233
2018	193	8	6	18	225	14	225	239
2019	196	8	6	18	229	14	229	242
2020	199	8	6	18	231	14	231	245
2021	202	8	6	18	234	14	234	248
2022	205	8	6	18	237	14	237	251
2023	208	9	6	18	240	14	240	255
2024	210	9	6	18	243	15	243	258
2025	213	9	6	18	246	15	246	261
2026	215	9	6	18	248	15	248	263
2027	217	9	6	18	250	15	250	265
2028	220	9	6	18	253	15	253	268
2029	222	9	6	18	255	15	255	271
2030	225	9	6	18	258	15	258	273
2031	227	9	6	18	260	16	260	276
2032	229	9	6	18	262	16	262	278
2033	230	9	6	18	264	16	264	279
2034	232	9	6	18	265	16	265	281
2035	234	9	6	18	267	16	267	283
2036	236	9	6	18	269	16	269	285
2037	237	9	6	18	271	16	271	287
2038	239	9	6	20	275	17	275	292
2039	240	9	6	20	276	17	276	293
2040	242	9	6	20	278	17	278	294
2041	243	9	6	20	279	17	279	296
2042	244	9	6	20	280	17	280	297
2043	246	9	6	20	282	17	282	298
2044	247	9	7	20	283	17	283	300
2045	248	9	7	20	285	17	285	302
2046	249	9	7	20	285	17	285	303
2047	250	9	7	20	286	17	286	304
2048	251	9	7	20	288	17	288	305
2049	252	9	7	20	288	17	288	306
2050	253	9	7	20	289	17	289	307
2051	254	9	7	20	290	17	290	308
2052	254	9	7	20	291	17	291	308
2053	255	9	7	20	292	18	292	309
2054	256	9	7	20	292	18	292	310
2055	257	9	7	20	293	18	293	311
2056	257	9	7	20	294	18	294	311
2057	258	9	7	20	294	18	294	312
2058	258	9	7	20	295	18	295	313
2059	259	9	7	20	295	18	295	313
2060	260	9	7	20	296	18	296	314

Table 3.4: Water Demand (acre feet) by Service Type for Basin 87 (2015 to 2060)

Year	RMWS	MMWS	GMWS	MIS	Total Retail	System Loss	Total Retail	Total Production
2015	34,308	6,040	11,899	9,018	61,264	3,676	61,264	64,940
2016	35,109	6,066	12,037	9,092	62,304	3,738	62,304	66,042
2017	35,844	6,084	12,211	9,177	63,316	3,799	63,316	67,115
2018	36,470	6,155	12,423	9,312	64,360	3,862	64,360	68,221
2019	37,048	6,220	12,566	9,413	65,248	3,915	65,248	69,163
2020	37,589	6,261	12,658	9,479	65,987	3,959	65,987	69,946
2021	38,102	6,283	12,731	9,526	66,643	3,999	66,643	70,641
2022	38,627	6,283	12,826	9,564	67,301	4,038	67,301	71,339
2023	39,168	6,308	12,970	9,641	68,087	4,085	68,087	72,173
2024	39,712	6,352	13,125	9,735	68,924	4,135	68,924	73,059
2025	40,188	6,390	13,257	9,814	69,650	4,179	69,650	73,829
2026	40,610	6,440	13,358	9,889	70,296	4,218	70,296	74,514
2027	41,028	6,467	13,424	9,935	70,854	4,251	70,854	75,105
2028	41,455	6,476	13,496	9,971	71,398	4,284	71,398	75,682
2029	41,914	6,500	13,593	10,026	72,033	4,322	72,033	76,355
2030	42,369	6,523	13,709	10,092	72,693	4,362	72,693	77,055
2031	42,781	6,560	13,834	10,166	73,340	4,400	73,340	77,740
2032	43,154	6,605	13,932	10,238	73,928	4,436	73,928	78,364
2033	43,482	6,626	14,002	10,281	74,391	4,463	74,391	78,855
2034	43,801	6,648	14,062	10,320	74,831	4,490	74,831	79,321
2035	44,140	6,660	14,121	10,353	75,274	4,516	75,274	79,790
2036	44,476	6,668	14,200	10,391	75,736	4,544	75,736	80,280
2037	44,806	6,699	14,293	10,452	76,251	4,575	76,251	80,826
2038	45,105	6,722	14,373	10,499	76,699	4,602	76,699	81,301
2039	45,361	6,744	14,443	10,542	77,091	4,625	77,091	81,716
2040	45,606	6,769	14,493	10,581	77,449	4,647	77,449	82,096
2041	45,845	6,772	14,532	10,597	77,746	4,665	77,746	82,411
2042	46,089	6,784	14,586	10,628	78,088	4,685	78,088	82,773
2043	46,344	6,800	14,647	10,663	78,454	4,707	78,454	83,161
2044	46,574	6,810	14,711	10,696	78,792	4,727	78,792	83,519
2045	46,785	6,837	14,773	10,740	79,135	4,748	79,135	83,883
2046	46,976	6,852	14,813	10,768	79,409	4,765	79,409	84,173
2047	47,148	6,859	14,848	10,787	79,643	4,779	79,643	84,421
2048	47,329	6,874	14,885	10,812	79,900	4,794	79,900	84,694
2049	47,511	6,874	14,920	10,825	80,130	4,808	80,130	84,938
2050	47,685	6,887	14,971	10,856	80,397	4,824	80,397	85,221
2051	47,853	6,903	15,015	10,886	80,658	4,839	80,658	85,497
2052	47,995	6,910	15,050	10,905	80,861	4,852	80,861	85,712
2053	48,127	6,927	15,085	10,930	81,068	4,864	81,068	85,932
2054	48,257	6,932	15,106	10,944	81,239	4,874	81,239	86,113
2055	48,379	6,933	15,132	10,955	81,399	4,884	81,399	86,283
2056	48,510	6,945	15,165	10,977	81,596	4,896	81,596	86,492
2057	48,634	6,947	15,194	10,990	81,765	4,906	81,765	86,671
2058	48,742	6,958	15,227	11,010	81,936	4,916	81,936	86,852
2059	48,846	6,971	15,252	11,029	82,098	4,926	82,098	87,024
2060	48,936	6,971	15,269	11,037	82,213	4,933	82,213	87,146

Table 3.5: Water Demand (acre feet) by Service Type for Basin 88E (2015 to 2060)

Year	RMWS	MMWS	GMWS	MIS	Total Retail	System Loss	Total Retail	Total Production
2015	43	-	-	-	43	3	43	46
2016	44	-	-	-	44	3	44	46
2017	44	-	-	-	44	3	44	46
2018	45	-	-	-	45	3	45	47
2019	45	-	-	-	45	3	45	48
2020	46	-	-	-	46	3	46	49
2021	47	-	-	-	47	3	47	50
2022	48	-	-	-	48	3	48	51
2023	48	-	-	-	48	3	48	51
2024	49	-	-	-	49	3	49	52
2025	50	-	-	-	50	3	50	53
2026	50	-	-	-	50	3	50	53
2027	51	-	-	-	51	3	51	54
2028	51	-	-	-	51	3	51	54
2029	52	-	-	-	52	3	52	55
2030	52	-	-	-	52	3	52	56
2031	53	-	-	-	53	3	53	56
2032	53	-	-	-	53	3	53	56
2033	54	-	-	-	54	3	54	57
2034	54	-	-	-	54	3	54	57
2035	55	-	-	-	55	3	55	58
2036	56	-	-	-	56	3	56	59
2037	56	-	-	-	56	3	56	59
2038	56	-	-	-	56	3	56	60
2039	56	-	-	-	56	3	56	60
2040	57	-	-	-	57	3	57	61
2041	57	-	-	-	57	3	57	61
2042	57	-	-	-	57	3	57	61
2043	57	-	-	-	57	3	57	61
2044	57	-	-	-	57	3	57	61
2045	58	-	-	-	58	3	58	61
2046	58	-	-	-	58	3	58	61
2047	58	-	-	-	58	3	58	61
2048	59	-	-	-	59	4	59	62
2049	59	-	-	-	59	4	59	62
2050	59	-	-	-	59	4	59	62
2051	59	-	-	-	59	4	59	63
2052	59	-	-	-	59	4	59	63
2053	59	-	-	-	59	4	59	63
2054	59	-	-	-	59	4	59	63
2055	60	-	-	-	60	4	60	64
2056	60	-	-	-	60	4	60	64
2057	60	-	-	-	60	4	60	64
2058	60	-	-	-	60	4	60	64
2059	60	-	-	-	60	4	60	64
2060	61	-	-	-	61	4	61	65

Table 3.6: Water Demand (acre feet) by Service Type for Basin 88W (2015 to 2060)

Year	RMWS	MMWS	GMWS	MIS	Total Retail	System Loss	Total Retail	Total Production
2015	965	-	3	3	971	58	971	1,030
2016	988	-	3	3	994	60	994	1,054
2017	1,008	-	3	3	1,014	61	1,014	1,075
2018	1,026	-	3	3	1,032	62	1,032	1,094
2019	1,043	-	3	3	1,049	63	1,049	1,112
2020	1,058	-	3	3	1,064	64	1,064	1,128
2021	1,073	-	3	3	1,079	65	1,079	1,143
2022	1,087	-	3	3	1,093	66	1,093	1,159
2023	1,102	-	3	3	1,108	66	1,108	1,174
2024	1,118	-	3	3	1,124	67	1,124	1,191
2025	1,131	-	3	3	1,137	68	1,137	1,205
2026	1,143	-	3	3	1,149	69	1,149	1,218
2027	1,155	-	3	3	1,161	70	1,161	1,230
2028	1,167	-	3	3	1,173	70	1,173	1,243
2029	1,179	-	3	3	1,185	71	1,185	1,256
2030	1,193	-	3	3	1,199	72	1,199	1,271
2031	1,204	-	3	3	1,210	73	1,210	1,282
2032	1,214	-	3	3	1,220	73	1,220	1,293
2033	1,223	-	3	3	1,229	74	1,229	1,303
2034	1,232	-	3	3	1,238	74	1,238	1,312
2035	1,242	-	3	3	1,248	75	1,248	1,323
2036	1,251	-	3	3	1,257	75	1,257	1,333
2037	1,261	-	3	3	1,267	76	1,267	1,343
2038	1,269	-	3	3	1,275	77	1,275	1,352
2039	1,276	-	3	3	1,282	77	1,282	1,359
2040	1,284	-	3	3	1,290	77	1,290	1,367
2041	1,289	-	3	3	1,295	78	1,295	1,373
2042	1,297	-	3	3	1,303	78	1,303	1,381
2043	1,305	-	3	3	1,311	79	1,311	1,389
2044	1,310	-	3	3	1,316	79	1,316	1,395
2045	1,317	-	3	3	1,323	79	1,323	1,402
2046	1,322	-	3	3	1,328	80	1,328	1,408
2047	1,326	-	3	3	1,332	80	1,332	1,412
2048	1,332	-	3	3	1,338	80	1,338	1,418
2049	1,337	-	3	3	1,343	81	1,343	1,423
2050	1,342	-	3	3	1,348	81	1,348	1,429
2051	1,347	-	3	3	1,353	81	1,353	1,434
2052	1,351	-	3	3	1,357	81	1,357	1,438
2053	1,355	-	3	3	1,361	82	1,361	1,442
2054	1,358	-	3	3	1,364	82	1,364	1,446
2055	1,362	-	3	3	1,368	82	1,368	1,450
2056	1,365	-	3	3	1,371	82	1,371	1,453
2057	1,368	-	3	3	1,374	82	1,374	1,457
2058	1,372	-	3	3	1,378	83	1,378	1,460
2059	1,375	-	3	3	1,381	83	1,381	1,464
2060	1,377	-	3	3	1,383	83	1,383	1,466

Table 3.7: Water Demand (acre feet) Service Type for Basin 89 (2015 to 2060)

Year	RMWS	MMWS	GMWS	MIS	Total Retail	System Loss	Total Retail	Total Production
2015	126	-	6	0	132	8	132	140
2016	128	-	7	1	136	8	136	144
2017	131	-	7	1	139	8	139	147
2018	134	-	7	1	141	8	141	150
2019	136	-	7	1	143	9	143	152
2020	138	-	7	1	146	9	146	154
2021	139	-	7	1	147	9	147	156
2022	141	-	7	1	149	9	149	158
2023	143	-	7	1	150	9	150	159
2024	145	-	7	1	152	9	152	162
2025	147	-	7	1	155	9	155	164
2026	149	-	7	1	157	9	157	166
2027	149	-	7	1	157	9	157	166
2028	152	-	7	1	159	10	159	169
2029	153	-	7	1	160	10	160	170
2030	155	-	8	1	164	10	164	174
2031	156	-	8	1	165	10	165	175
2032	158	-	8	1	167	10	167	177
2033	160	-	8	1	168	10	168	178
2034	161	-	8	1	169	10	169	180
2035	162	-	8	1	171	10	171	181
2036	162	-	8	1	171	10	171	181
2037	163	-	8	1	172	10	172	182
2038	164	-	8	1	173	10	173	183
2039	165	-	8	1	174	10	174	184
2040	166	-	8	1	175	11	175	186
2041	167	-	8	1	176	11	176	187
2042	169	-	8	1	177	11	177	188
2043	170	-	8	1	179	11	179	189
2044	171	-	8	1	180	11	180	190
2045	171	-	8	1	180	11	180	190
2046	172	-	8	1	181	11	181	192
2047	173	-	8	1	182	11	182	193
2048	173	-	8	1	182	11	182	193
2049	173	-	8	1	182	11	182	193
2050	174	-	8	1	183	11	183	194
2051	174	-	8	1	183	11	183	194
2052	175	-	8	1	184	11	184	195
2053	175	-	8	1	184	11	184	195
2054	177	-	8	1	185	11	185	196
2055	177	-	8	1	185	11	185	196
2056	178	-	8	1	186	11	186	198
2057	178	-	8	1	186	11	186	198
2058	178	-	8	1	186	11	186	198
2059	179	-	8	1	188	11	188	199
2060	179	-	8	1	188	11	188	199

Table 3.8: Water Demand (acre feet) by Service Type for Basin 92 (2015 to 2060)

Year	RMWS	MMWS	GMWS	MIS	Total Retail	System Loss	Total Retail	Total Production
2015	2,898	350	527	365	4,140	248	4,140	4,388
2016	2,965	352	533	370	4,220	253	4,220	4,473
2017	3,027	352	540	373	4,292	258	4,292	4,550
2018	3,080	355	550	378	4,363	262	4,363	4,625
2019	3,129	359	555	381	4,424	265	4,424	4,690
2020	3,175	361	561	386	4,482	269	4,482	4,751
2021	3,218	363	562	386	4,530	272	4,530	4,802
2022	3,262	363	568	388	4,582	275	4,582	4,857
2023	3,308	365	574	391	4,638	278	4,638	4,916
2024	3,354	367	581	396	4,698	282	4,698	4,980
2025	3,394	369	586	399	4,749	285	4,749	5,034
2026	3,430	373	592	401	4,797	288	4,797	5,084
2027	3,465	373	594	404	4,836	290	4,836	5,126
2028	3,501	375	596	404	4,876	293	4,876	5,169
2029	3,540	375	601	407	4,923	295	4,923	5,218
2030	3,578	377	607	409	4,971	298	4,971	5,269
2031	3,613	379	612	414	5,019	301	5,019	5,320
2032	3,645	381	616	417	5,059	304	5,059	5,362
2033	3,673	383	620	417	5,092	306	5,092	5,398
2034	3,700	385	621	420	5,126	308	5,126	5,433
2035	3,728	385	625	422	5,160	310	5,160	5,470
2036	3,756	385	629	422	5,192	312	5,192	5,504
2037	3,784	387	633	425	5,228	314	5,228	5,542
2038	3,809	389	636	427	5,262	316	5,262	5,578
2039	3,831	391	640	430	5,292	318	5,292	5,609
2040	3,852	391	642	430	5,314	319	5,314	5,633
2041	3,872	391	644	430	5,336	320	5,336	5,656
2042	3,893	393	645	433	5,364	322	5,364	5,685
2043	3,914	393	647	433	5,387	323	5,387	5,710
2044	3,934	395	651	435	5,414	325	5,414	5,739
2045	3,951	395	653	438	5,437	326	5,437	5,763
2046	3,968	397	655	438	5,457	327	5,457	5,784
2047	3,982	397	657	438	5,473	328	5,473	5,802
2048	3,997	397	658	440	5,493	330	5,493	5,822
2049	4,013	397	660	440	5,510	331	5,510	5,841
2050	4,027	398	662	443	5,531	332	5,531	5,863
2051	4,042	398	664	443	5,547	333	5,547	5,880
2052	4,054	400	666	446	5,566	334	5,566	5,900
2053	4,065	400	668	446	5,578	335	5,578	5,913
2054	4,076	400	668	446	5,590	335	5,590	5,925
2055	4,086	400	669	446	5,602	336	5,602	5,938
2056	4,097	402	671	448	5,619	337	5,619	5,956
2057	4,108	402	673	448	5,631	338	5,631	5,969
2058	4,117	402	673	448	5,641	338	5,641	5,979
2059	4,126	402	675	448	5,651	339	5,651	5,990
2060	4,133	402	675	448	5,659	340	5,659	5,998

Table 4. Active Service Counts by Basin (2003 to 2014)

Year	RMWS	RFWS	MMWS	MRFS	MRIS	GMWS	MIS
Basin 83							
2003	35					3	1
2004	37					4	1
2005	37					4	1
2006	38					4	1
2007	42					4	1
2008	42					4	1
2009	42					4	1
2010	42					4	1
2011	42					4	1
2012	42					4	1
2013	42					4	1
2014	42					4	1
Basin 85							
2003	9421	2	254			65	108
2004	11335	2	254			72	113
2005	12812	5	241			80	126
2006	14558	3	413			141	137
2007	14895	1	613			190	149
2008	14711	1	619			233	157
2009	14668	2	885			263	158
2010	14579	1	885			255	163
2011	14627	1	901			257	164
2012	14733	1	901			259	165
2013	14956	1	901			262	167
2014	15298	1	909			263	164
Basin 86							
2003	321	318	124	16		10	6
2004	392	249	124	16		9	6
2005	442	187	124	16		8	6
2006	480	135	124	16		8	7
2007	489	103	124	16		8	7
2008	504	97	124	16		10	8
2009	524	80	124	16		10	8
2010	531	59	140	16		10	8
2011	533	47	140			10	8
2012	543	40	140			10	8
2013	548	34	140			10	8
2014	550	28	140			10	8
Basin 87							
2003	37358	30277	13688	3772	2061	5273	1929
2004	47676	25080	16719	3773	2236	5431	2078
2005	54916	18655	17425	2626	2172	5638	2262
2006	59618	14169	17753	2433	2193	5764	2347
2007	61772	11860	18024	2428	2189	5866	2414
2008	63500	10685	19044	2422	2207	5927	2476
2009	65630	9750	21453	2416	2106	5964	2525
2010	67373	7640	25313	1954	1883	5994	2552
2011	68489	6431	26006	1720	1810	6041	2582
2012	69539	5601	24989	1685	1664	6038	2596
2013	70796	4969	25875	1685	1642	6045	2607
2014	72194	4544	26425	1913	1589	6108	2614

Table 4 cont. Active Service Counts by Basin (2003 to 2014)

Year	RMWS	RFWS	MMWS	MRFS	MRIS	GMWS	MIS
Basin 88E							
2003	30						
2004	33						
2005	35						
2006	37						
2007	38						
2008	38						
2009	38						
2010	40						
2011	42						
2012	44						
2013	45						
2014	50						
Basin 88W							
2003	628					8	5
2004	754					9	5
2005	846					9	6
2006	977					10	5
2007	1027					10	5
2008	1050					10	4
2009	1067					11	4
2010	1101					11	4
2011	1112					11	4
2012	1134					11	4
2013	1178					11	3
2014	1213					11	3
Basin 89							
2003	76					3	1
2004	86					4	1
2005	93					4	1
2006	98					4	
2007	102					5	
2008	103					6	2
2009	104					6	2
2010	105					5	2
2011	105					5	2
2012	106					5	2
2013	107					5	2
2014	110					5	2
Basin 92							
2003	5307	1474	1201	70	6	226	109
2004	6132	1196	1368	70	12	233	123
2005	6648	1014	1368	70	14	237	132
2006	7234	914	1368	70	12	247	143
2007	7527	879	1368	70	11	256	150
2008	7599	852	1384	70	9	260	153
2009	7911	723	1384	70	7	265	155
2010	7863	437	1384	70	6	265	154
2011	7916	389	1383	70	7	278	155
2012	7950	355	1383	70	7	277	156
2013	7993	323	1383	70	8	287	164
2014	8043	302	1570	70	6	285	165

Table 5: Ratio of Active Services by Year

Year	Average Number of Multi-Family Units	Ratio of Active Single Family Units (RMWS)	Ratio of Active Multi-Family Units (MMWS)	Ratio of Active Commercial Units (GMWS)
2009	10.123	0.853	1.104	0.725
2010	10.269	0.865	1.144	0.726
2011	10.260	0.873	1.121	0.731
2012	10.235	0.879	1.085	0.729
2013	10.225	0.886	1.086	0.727
2014	10.207	0.894	1.086	0.732
2015	10.201	0.964	1.125	0.738

Table 6: Ratio of Active Services within Hydrographic Basin

Hydrobasin	RMWS	MMWS	GMWS
083	0.752		0.252
085	0.955	1.074	1.033
086	0.154	0.748	0.101
087	0.954	1.102	0.721
088E	0.895		
088W	0.959		2.571
089	0.914		0.418
092	1.040	1.408	0.966

Table 7: Regression Results for Predicting Active MIS

Restricted Model 1 - GMWS only		Restricted Model 2 -Multi-Family only		Unrestricted Model	
VARIABLES	MIS		MIS		MIS
GMWS	0.435***	MMWS/MRFS	0.956***	GMWS	0.289***
	(0.00545)		(0.0201)		(0.0339)
				MMWS/MRFS	0.323***
					(0.0746)
Observations	13		13		13
R-squared	0.998		0.995		0.999

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 8: Water Use Coefficient per Hydrographic Basin (2015 to 2060)

RMWS	MMWS	GMWS	MIS	Average*	HydroBasin
				149.57	083
161.96	359.94	326.90	1140.28		085
98.80	191.03	171.50	735.50		086
144.49	421.01	632.30	895.30		087
254.78					088E
262.59		301.55	1036.00		088W
368.75		375.80	118.00		089
110.45	636.46	600.94	849.24		092

* Average used for basins with very small service counts.

Table 9: Total Service Projections for Truckee Meadows Service Area 2015 to 2060

Year	RMWS	MMWS	GMWS	MIS	Total
2015	101156	4955	6696	3534	116341
2016	103519	4977	6774	3565	118835
2017	105682	4991	6873	3598	121144
2018	107528	5049	6993	3653	123223
2019	109235	5102	7072	3692	125101
2020	110827	5135	7124	3719	126805
2021	112342	5154	7164	3735	128395
2022	113888	5154	7218	3752	130012
2023	115484	5175	7299	3781	131739
2024	117088	5211	7386	3819	133504
2025	118491	5242	7460	3850	135043
2026	119736	5283	7517	3879	136415
2027	120969	5304	7554	3897	137724
2028	122228	5312	7594	3910	139044
2029	123581	5332	7650	3934	140497
2030	124922	5351	7716	3958	141947
2031	126136	5381	7786	3988	143291
2032	127234	5417	7841	4016	144508
2033	128203	5435	7880	4033	145551
2034	129144	5453	7913	4048	146558
2035	130144	5463	7946	4061	147614
2036	131135	5469	7991	4076	148671
2037	132106	5495	8043	4099	149743
2038	132990	5515	8089	4119	150713
2039	133742	5533	8128	4137	151540
2040	134466	5553	8156	4151	152326
2041	135169	5555	8178	4158	153060
2042	135891	5566	8209	4170	153836
2043	136642	5578	8242	4184	154646
2044	137319	5587	8279	4197	155382
2045	137942	5609	8314	4215	156080
2046	138506	5621	8337	4225	156689
2047	139012	5627	8356	4232	157227
2048	139548	5638	8377	4243	157806
2049	140081	5638	8397	4248	158364
2050	140594	5649	8424	4260	158927
2051	141091	5663	8449	4271	159474
2052	141511	5669	8470	4280	159930
2053	141898	5682	8489	4289	160358
2054	142283	5686	8500	4293	160762
2055	142645	5687	8516	4298	161146
2056	143030	5697	8533	4307	161567
2057	143393	5699	8550	4312	161954
2058	143712	5707	8569	4320	162308
2059	144020	5718	8582	4326	162646
2060	144286	5718	8592	4330	162926

Table 10.1: Service Projections for Basin 83 (2015 to 2060)

Year	RMWS	MMWS	GMWS	MIS	Total
2015	46	0	5	1	52
2016	47	0	5	1	53
2017	47	0	6	2	55
2018	48	0	6	2	56
2019	49	0	6	2	57
2020	50	0	6	2	58
2021	50	0	6	2	58
2022	51	0	6	2	59
2023	52	0	6	2	60
2024	53	0	6	2	61
2025	53	0	6	2	61
2026	54	0	6	2	62
2027	55	0	6	2	63
2028	55	0	6	2	63
2029	56	0	6	2	64
2030	56	0	6	2	64
2031	57	0	6	2	65
2032	57	0	6	2	65
2033	58	0	6	2	66
2034	58	0	6	2	66
2035	59	0	6	2	67
2036	59	0	6	2	67
2037	59	0	6	2	67
2038	60	0	7	2	69
2039	60	0	7	2	69
2040	61	0	7	2	70
2041	61	0	7	2	70
2042	61	0	7	2	70
2043	62	0	7	2	71
2044	62	0	7	2	71
2045	62	0	7	2	71
2046	62	0	7	2	71
2047	62	0	7	2	71
2048	63	0	7	2	72
2049	63	0	7	2	72
2050	63	0	7	2	72
2051	64	0	7	2	73
2052	64	0	7	2	73
2053	64	0	7	2	73
2054	64	0	7	2	73
2055	65	0	7	2	74
2056	65	0	7	2	74
2057	65	0	7	2	74
2058	65	0	7	2	74
2059	65	0	7	2	74
2060	65	0	7	2	74

Table 10.2: Service Projections for Basin 85 (2015 to 2060)

Year	RMWS	MMWS	GMWS	MIS	Total
2015	15511	87	273	107	15978
2016	15873	88	276	108	16345
2017	16205	88	280	109	16682
2018	16488	89	285	111	16973
2019	16749	90	288	112	17239
2020	16994	90	290	113	17487
2021	17226	91	291	113	17721
2022	17463	91	293	114	17961
2023	17708	91	297	115	18211
2024	17954	92	301	117	18464
2025	18168	92	304	118	18682
2026	18359	93	306	118	18876
2027	18549	93	308	119	19069
2028	18741	93	309	119	19262
2029	18950	94	312	121	19477
2030	19155	94	314	121	19684
2031	19341	95	317	122	19875
2032	19509	95	319	123	20046
2033	19658	96	321	124	20199
2034	19802	96	322	124	20344
2035	19955	96	323	124	20498
2036	20108	96	325	125	20654
2037	20257	97	327	126	20807
2038	20392	97	329	126	20944
2039	20507	97	330	127	21061
2040	20618	98	332	128	21176
2041	20726	98	333	128	21285
2042	20837	98	335	128	21398
2043	20952	98	336	129	21515
2044	21056	98	337	129	21620
2045	21151	99	339	130	21719
2046	21238	99	340	130	21807
2047	21315	99	340	130	21884
2048	21397	99	341	131	21968
2049	21479	99	342	131	22051
2050	21558	99	343	131	22131
2051	21634	100	344	132	22210
2052	21698	100	345	132	22275
2053	21758	100	346	132	22336
2054	21817	100	346	132	22395
2055	21872	100	347	133	22452
2056	21931	100	347	133	22511
2057	21987	100	348	133	22568
2058	22036	100	349	133	22618
2059	22083	101	349	133	22666
2060	22124	101	350	134	22709

Table 10.3: Service Projections for Basin 86 (2015 to 2060)

Year	RMWS	MMWS	GMWS	MIS	Total
2015	600	14	10	7	631
2016	614	14	10	7	645
2017	627	14	10	7	658
2018	638	14	11	8	671
2019	648	14	11	8	681
2020	657	14	11	8	690
2021	666	14	11	8	699
2022	675	14	11	8	708
2023	685	15	11	8	719
2024	694	15	11	8	728
2025	703	15	11	8	737
2026	710	15	11	8	744
2027	717	15	11	8	751
2028	725	15	12	8	760
2029	733	15	12	8	768
2030	741	15	12	8	776
2031	748	15	12	8	783
2032	755	15	12	8	790
2033	760	15	12	8	795
2034	766	15	12	8	801
2035	772	15	12	8	807
2036	778	15	12	8	813
2037	783	15	12	8	818
2038	789	16	12	9	826
2039	793	16	12	9	830
2040	797	16	12	9	834
2041	802	16	12	9	839
2042	806	16	12	9	843
2043	810	16	12	9	847
2044	814	16	13	9	852
2045	818	16	13	9	856
2046	821	16	13	9	859
2047	824	16	13	9	862
2048	828	16	13	9	866
2049	831	16	13	9	869
2050	834	16	13	9	872
2051	837	16	13	9	875
2052	839	16	13	9	877
2053	842	16	13	9	880
2054	844	16	13	9	882
2055	846	16	13	9	884
2056	848	16	13	9	886
2057	850	16	13	9	888
2058	852	16	13	9	890
2059	854	16	13	9	892
2060	856	16	13	9	894

Table 10.4: Service Projections for Basin 87 (2015 to 2060)

Year	RMWS	MMWS	GMWS	MIS	Total
2015	77368	4675	6132	3282	91457
2016	79176	4695	6203	3309	93383
2017	80832	4709	6293	3340	95174
2018	82245	4764	6402	3389	96800
2019	83549	4814	6476	3426	98265
2020	84767	4846	6523	3450	99586
2021	85926	4863	6561	3467	100817
2022	87109	4863	6610	3481	102063
2023	88330	4882	6684	3509	103405
2024	89556	4916	6764	3543	104779
2025	90629	4946	6832	3572	105979
2026	91580	4984	6884	3599	107047
2027	92523	5005	6918	3616	108062
2028	93487	5012	6955	3629	109083
2029	94522	5031	7005	3649	110207
2030	95547	5049	7065	3673	111334
2031	96476	5077	7129	3700	112382
2032	97317	5112	7180	3726	113335
2033	98057	5128	7216	3742	114143
2034	98777	5145	7247	3756	114925
2035	99541	5155	7277	3768	115741
2036	100300	5161	7318	3782	116561
2037	101044	5185	7366	3804	117399
2038	101718	5203	7407	3821	118149
2039	102295	5220	7443	3837	118795
2040	102847	5239	7469	3851	119406
2041	103386	5241	7489	3857	119973
2042	103937	5251	7517	3868	120573
2043	104511	5263	7548	3881	121203
2044	105031	5271	7581	3893	121776
2045	105506	5292	7613	3909	122320
2046	105937	5303	7634	3919	122793
2047	106325	5309	7652	3926	123212
2048	106734	5320	7671	3935	123660
2049	107143	5320	7689	3940	124092
2050	107535	5330	7715	3951	124531
2051	107915	5343	7738	3962	124958
2052	108236	5348	7756	3969	125309
2053	108532	5361	7774	3978	125645
2054	108826	5365	7785	3983	125959
2055	109102	5366	7798	3987	126253
2056	109397	5375	7815	3995	126582
2057	109676	5377	7830	4000	126883
2058	109919	5385	7847	4007	127158
2059	110155	5395	7860	4014	127424
2060	110357	5395	7869	4017	127638

Table 10.5: Service Projections for Basin 88E (2015 to 2060)

Year	RMWS	MMWS	GMWS	MIS	Total
2015	55	0	0	0	55
2016	56	0	0	0	56
2017	56	0	0	0	56
2018	57	0	0	0	57
2019	58	0	0	0	58
2020	59	0	0	0	59
2021	60	0	0	0	60
2022	61	0	0	0	61
2023	62	0	0	0	62
2024	63	0	0	0	63
2025	64	0	0	0	64
2026	64	0	0	0	64
2027	65	0	0	0	65
2028	65	0	0	0	65
2029	66	0	0	0	66
2030	67	0	0	0	67
2031	68	0	0	0	68
2032	68	0	0	0	68
2033	69	0	0	0	69
2034	69	0	0	0	69
2035	70	0	0	0	70
2036	71	0	0	0	71
2037	71	0	0	0	71
2038	72	0	0	0	72
2039	72	0	0	0	72
2040	73	0	0	0	73
2041	73	0	0	0	73
2042	73	0	0	0	73
2043	73	0	0	0	73
2044	73	0	0	0	73
2045	74	0	0	0	74
2046	74	0	0	0	74
2047	74	0	0	0	74
2048	75	0	0	0	75
2049	75	0	0	0	75
2050	75	0	0	0	75
2051	76	0	0	0	76
2052	76	0	0	0	76
2053	76	0	0	0	76
2054	76	0	0	0	76
2055	77	0	0	0	77
2056	77	0	0	0	77
2057	77	0	0	0	77
2058	77	0	0	0	77
2059	77	0	0	0	77
2060	78	0	0	0	78

Table 10.6: Service Projections for Basin 88W (2015 to 2060)

Year	RMWS	MMWS	GMWS	MIS	Total
2015	1198	0	3	1	1202
2016	1226	0	3	1	1230
2017	1251	0	3	1	1255
2018	1273	0	3	1	1277
2019	1294	0	3	1	1298
2020	1313	0	3	1	1317
2021	1331	0	3	1	1335
2022	1349	0	3	1	1353
2023	1367	0	3	1	1371
2024	1387	0	3	1	1391
2025	1403	0	3	1	1407
2026	1418	0	3	1	1422
2027	1433	0	3	1	1437
2028	1448	0	3	1	1452
2029	1463	0	3	1	1467
2030	1480	0	3	1	1484
2031	1494	0	3	1	1498
2032	1506	0	3	1	1510
2033	1518	0	3	1	1522
2034	1529	0	3	1	1533
2035	1541	0	3	1	1545
2036	1553	0	3	1	1557
2037	1565	0	3	1	1569
2038	1575	0	3	1	1579
2039	1584	0	3	1	1588
2040	1593	0	3	1	1597
2041	1600	0	3	1	1604
2042	1609	0	3	1	1613
2043	1619	0	3	1	1623
2044	1626	0	3	1	1630
2045	1634	0	3	1	1638
2046	1641	0	3	1	1645
2047	1646	0	3	1	1650
2048	1653	0	3	1	1657
2049	1659	0	3	1	1663
2050	1665	0	3	1	1669
2051	1671	0	3	1	1675
2052	1676	0	3	1	1680
2053	1681	0	3	1	1685
2054	1685	0	3	1	1689
2055	1690	0	3	1	1694
2056	1694	0	3	1	1698
2057	1698	0	3	1	1702
2058	1702	0	3	1	1706
2059	1706	0	3	1	1710
2060	1709	0	3	1	1713

Table 10.7: Service Projections for Basin 89 (2015 to 2060)

Year	RMWS	MMWS	GMWS	MIS	Total
2015	111	0	5	1	117
2016	113	0	6	2	121
2017	116	0	6	2	124
2018	118	0	6	2	126
2019	120	0	6	2	128
2020	122	0	6	2	130
2021	123	0	6	2	131
2022	125	0	6	2	133
2023	126	0	6	2	134
2024	128	0	6	2	136
2025	130	0	6	2	138
2026	132	0	6	2	140
2027	132	0	6	2	140
2028	134	0	6	2	142
2029	135	0	6	2	143
2030	137	0	7	2	146
2031	138	0	7	2	147
2032	140	0	7	2	149
2033	141	0	7	2	150
2034	142	0	7	2	151
2035	143	0	7	2	152
2036	143	0	7	2	152
2037	144	0	7	2	153
2038	145	0	7	2	154
2039	146	0	7	2	155
2040	147	0	7	2	156
2041	148	0	7	2	157
2042	149	0	7	2	158
2043	150	0	7	2	159
2044	151	0	7	2	160
2045	151	0	7	2	160
2046	152	0	7	2	161
2047	153	0	7	2	162
2048	153	0	7	2	162
2049	153	0	7	2	162
2050	154	0	7	2	163
2051	154	0	7	2	163
2052	155	0	7	2	164
2053	155	0	7	2	164
2054	156	0	7	2	165
2055	156	0	7	2	165
2056	157	0	7	2	166
2057	157	0	7	2	166
2058	157	0	7	2	166
2059	158	0	7	2	167
2060	158	0	7	2	167

Table 10.8: Service Projections for Basin 92 (2015 to 2060)

Year	RMWS	MMWS	GMWS	MIS	Total
2015	8549	179	286	140	9154
2016	8749	180	289	142	9360
2017	8932	180	293	143	9548
2018	9087	182	298	145	9712
2019	9232	184	301	146	9863
2020	9366	185	304	148	10003
2021	9495	186	305	148	10134
2022	9625	186	308	149	10268
2023	9760	187	311	150	10408
2024	9895	188	315	152	10550
2025	10014	189	318	153	10674
2026	10120	191	321	154	10786
2027	10224	191	322	155	10892
2028	10330	192	323	155	11000
2029	10444	192	326	156	11118
2030	10557	193	329	157	11236
2031	10660	194	332	159	11345
2032	10753	195	334	160	11442
2033	10835	196	336	160	11527
2034	10915	197	337	161	11610
2035	10999	197	339	162	11697
2036	11082	197	341	162	11782
2037	11164	198	343	163	11868
2038	11239	199	345	164	11947
2039	11303	200	347	165	12015
2040	11364	200	348	165	12077
2041	11423	200	349	165	12137
2042	11485	201	350	166	12202
2043	11548	201	351	166	12266
2044	11605	202	353	167	12327
2045	11658	202	354	168	12382
2046	11706	203	355	168	12432
2047	11749	203	356	168	12476
2048	11793	203	357	169	12522
2049	11839	203	358	169	12569
2050	11882	204	359	170	12615
2051	11924	204	360	170	12658
2052	11960	205	361	171	12697
2053	11992	205	362	171	12730
2054	12025	205	362	171	12763
2055	12055	205	363	171	12794
2056	12088	206	364	172	12830
2057	12119	206	365	172	12862
2058	12146	206	365	172	12889
2059	12172	206	366	172	12916
2060	12194	206	366	172	12938

TRUCKEE MEADOWS WATER AUTHORITY

2016-2035 WATER RESOURCE PLAN

APPENDIX 5

WATER CONSERVATION PLAN

TRUCKEE MEADOWS WATER AUTHORITY

APPENDIX 5-1

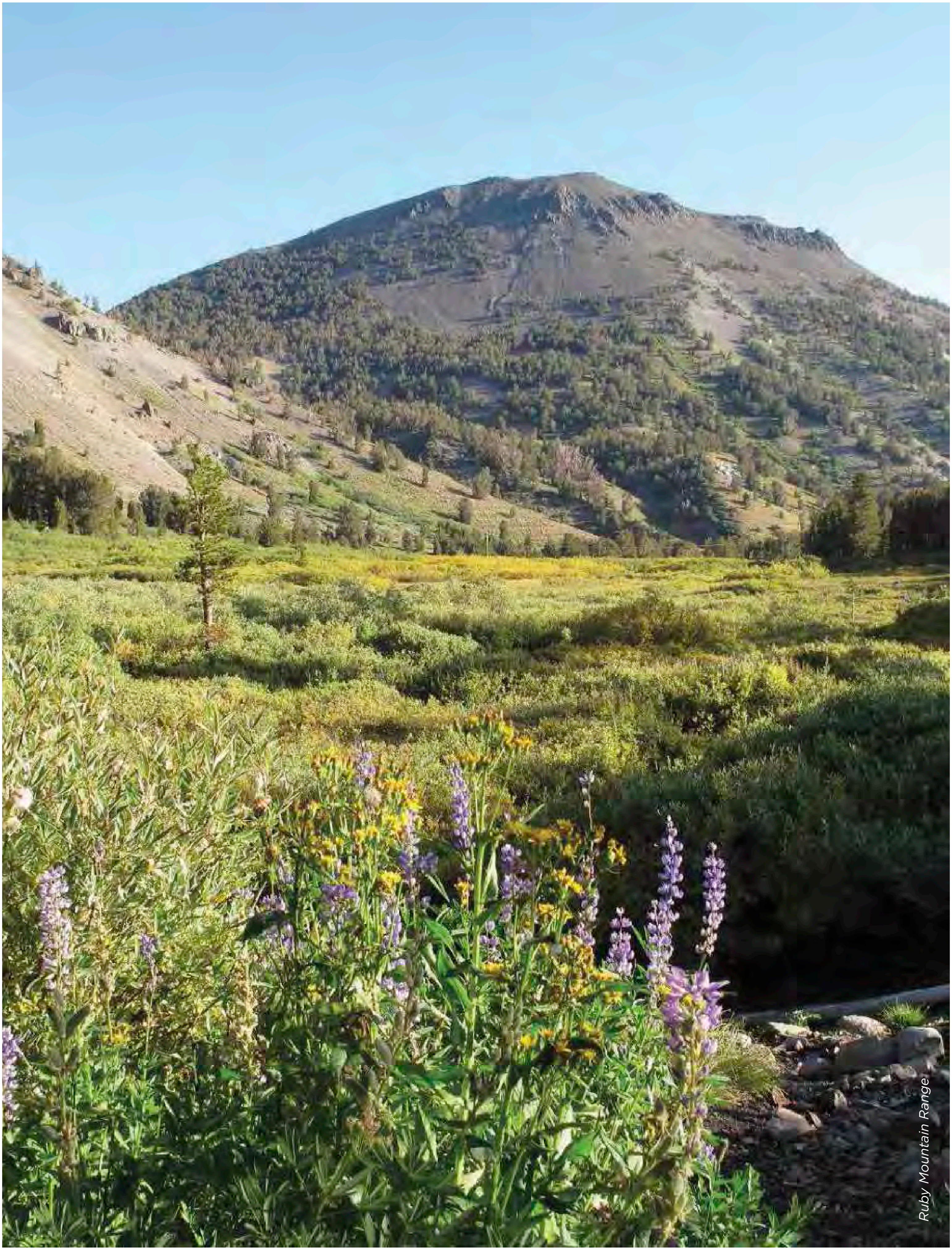
NEVADA DROUHT FORUM:

RECOMMENDATIONS REPORT

NEVADA DROUGHT FORUM

Nevada Drought Forum: *Recommendations Report*

Presented to ***Governor Brian Sandoval*** *• December 2015*



Ruby Mountain Range

Nevada Drought Forum Members

Leo Drozdoff, P.E. (Chairman)
Director, Nevada Department of Conservation and Natural Resources

John Entsminger (Vice Chairman)
General Manager, Southern Nevada Water Authority

Jim Barbee
Director, Nevada Department of Agriculture

Jason King, P.E.
State Engineer, Nevada Division of Water Resources

Dr. Douglas Boyle
Nevada State Climatologist, University of Nevada, Reno

Dr. Mark Walker
Dean, University of Nevada Cooperative Extension

Dr. Justin Huntington
Associate Research Professor, Desert Research Institute

Caleb Cage
Chief, Nevada Division of Emergency Management

The Nevada Drought Forum would like to express its sincere gratitude to the many stakeholders who helped the Forum to better understand the issues, challenges and opportunities related to drought response in Nevada.

Brian Sandoval, Governor

Wheeler Peak

Executive Summary

The Nevada Drought Forum (Forum) was formed by Governor Brian Sandoval in April 2015 through Executive Order 2015-03 to address water resource challenges related to severe and sustained drought conditions that have affected much of the state. The Forum was directed to facilitate a statewide dialogue among interested stakeholders and identify best practices for drought policy, preparedness and management.

As part of its responsibilities, the Forum prepared a Summary of Current and Future Actions, received a monthly Statewide Situation Report, participated in the 2015 Governor's Drought Summit, reviewed and considered the Western Governor's Association (WGA) Drought Forum Final Report, and met with stakeholders throughout the state to better understand issues and challenges, as well as to identify opportunities to enhance Nevada's drought response efforts.

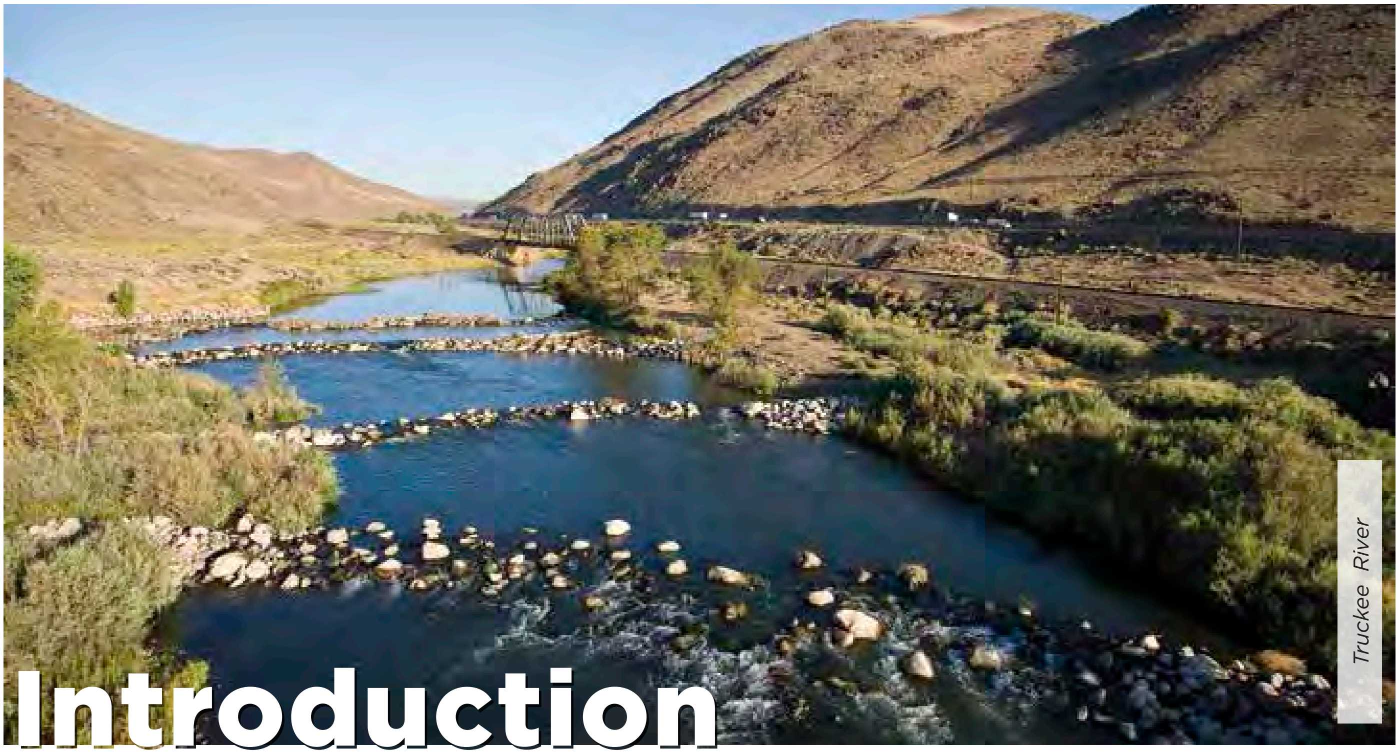
The Forum met six times from June through November 2015. Meetings were broadcast to multiple locations throughout the state to provide transparency and encourage public involvement. As part of its meeting process, the Forum invited representatives from various stakeholder groups to share information on drought impacts, mitigation efforts and current or anticipated obstacles to doing business during drought. Additionally, Forum members participated individually in the Governor's Drought Summit, which further explored stakeholder drought response efforts, water conservation efforts, conservation barriers, and opportunities to improve conditions and/or Nevada drought resiliency moving forward. These efforts are detailed more fully herein, with supporting information available in the appendices and online at **drought.nv.gov**.

Together, these discussions provided a strong foundation for deliberations by the Forum. As the Forum worked to develop recommendations, members agreed that meaningful investments in time, coordination and funding in the following key areas could improve Nevada's overall drought response and long-term resilience:

- Water Conservation
- Nevada Water Law
- Monitoring and Research Data
- Financial and Technical Assistance
- Supply Augmentation and Long-Range Planning
- Information Sharing and Outreach
- Drought Declarations/Emergency Actions

As described within the balance of this report, the Forum recommended specific actions that allow for consideration of next steps. The Forum believes that the Governor's leadership in addressing water conservation and drought for the long-term benefit of the state and its residents, together with further consideration and possible implementation of some or all of these recommendations, will provide a substantial and meaningful step toward managing statewide drought impacts and maintaining sustainable water supplies.


Denio
McDermitt
Black Rock Desert
Santa Rosa Range
Humboldt
R
Winnemucca
Independence Mts
Wells
Elko
80
Battle Mountain
Ruby Mts
Pyramid
Lake
Trinity Range
Lovelock
Stillwater Range
G R E A T
80
Carson
Sink
Shoshone Mts
Reno
Sparks
Fallon
Austin
Eureka
Egan Range
Schell Creek Range
Virginia City
Toiyabe Range
Monitor Range
Ruth
Ely
Lake
Tahoe
Carson City
Yerington
Hot Creek Range
Snake Ra
Wheeler Pk
13063
Gardnerville
Walker
Lake
Mt Grant
11239
Round Mountain
Hawthorne
Grant Range
B A S I N
Tonopah
Boundary Pk
13140
Pioche
Panaca
Caliente
Pahute Mesa
Beatty
Sheep Range
Mesquite
15
Indian Springs
Charleston Pk
11918
Lake
Mead
North Las Vegas
Las Vegas
Henderson
River
Boulder City
Colorado
Lake
Mohave
Laughlin



Truckee River

Introduction

Nevada is known for its rich and diverse landscape; it is also known for its harsh climate and hydrological extremes. The state is characterized as semi-arid to arid, with precipitation varying widely across its more than 500-mile stretch from northern to southern boundary. Temperatures can reach -40° F in some parts of the state and exceed 120° F in others. With nine inches of average precipitation annually, Nevada is the driest state in the nation.

Droughts and floods are common in the state—a place where water users have long coped with the dramatic changes that can occur from year to year. Despite its hardiness in responding to difficult water resource challenges, current conditions have tested Nevada's drought resiliency and are requiring unprecedented levels of action.

Four years of extremely dry conditions and below average snowpack in northern Nevada's mountain ranges have resulted in significant impacts to the Humboldt, Carson, Walker and Truckee river systems, as well as associated surface and groundwater water supplies. In the southern portion of the state, a 15-year drought in the Colorado River Basin has caused Lake Mead to drop by more than 130 feet. The reservoir is at its lowest point since it began filling during the 1930s, and further water level decline is expected. Central portions of the state have also experienced drier conditions. This has resulted in reduced recharge to groundwater basins, as well as inflow reductions to springs, seeps and streams that support healthy rangeland conditions and provide habitat for Nevada wildlife.

Little Truckee River

Nevada Drought Forum

To address the state's evolving water supply and demand challenges brought upon by severe drought, Governor Brian Sandoval established the Nevada Drought Forum (Forum) in April 2015 by Executive Order 2015-03 (Appendix A). The Forum was created to facilitate a statewide dialogue among interested stakeholders and to help identify best practices for drought policy, preparedness and management.

As part of its responsibilities, the Forum prepared a Summary of Current and Future Actions, which describes the current and planned activities of local, state and federal entities (Appendix B). The Forum also received a monthly Statewide Situation Report (Appendix C); participated in the September 2015 Governor's Drought Summit (Appendix D); reviewed and considered the Western Governors' Association (WGA) Drought Forum Final Report (Appendix E); invited stakeholders throughout the state to participate in Forum meetings (Appendix F) and received communications through the Drought Forum website (Appendix G).

These efforts helped establish a better understanding of how drought-related issues are affecting water users, industry and the environment, and informed the development of recommendations as presented in the latter portion of this document. The following provides a brief overview of the Drought Forum and key efforts since its formation.

DROUGHT FORUM REPRESENTATION

As established in the Governor's Executive Order, the Nevada Drought Forum is comprised of the following members:

- The Director of the Nevada Department of Conservation and Natural Resources
- The Director of the Nevada Department of Agriculture
- The State Engineer of the Nevada Division of Water Resources
- The Chief of the Nevada Division of Emergency Management
- The Nevada State Climatologist
- The Dean of the University of Nevada Cooperative Extension
- A representative of the Desert Research Institute
- A representative of the Southern Nevada Water Authority

SUMMARY OF CURRENT AND PLANNED ACTIONS:

In May 2015, the Forum issued a questionnaire to local, state and federal stakeholders. Respondents were asked to provide information on: water supply sources (groundwater, surface water, other); area of service (size, number of customers served, location); drought impacts on operations, resource availability and/or planning activities; actions taken, underway or planned; and, topics/issues for possible future discussion by the Forum.

The questionnaire was issued to more than 235 water users throughout Nevada, including municipal, state and federal agencies as well as private and other water users. Respondent information was summarized and posted to the Nevada Drought Forum website, **drought.nv.gov**, in August 2015.

The following describes reported impacts as well as current and planned drought response measures by user type.

Local Agencies:

Local agencies reported drought impacts that range in nature from no impact to significant impact. Several respondents noted higher customer water use due to drought conditions, as well as declining ground and/or surface water levels. For some, declining water levels do not have an immediate impact, but have the potential for impact if conditions persist. Others indicated that declining water levels have significantly affected water supply availability, facilities and operations.

Drought response measures vary by agency to include one or more of the following: water conservation plans, education/outreach, landscape development codes, irrigation audits, water budgets, watering restrictions, water waste prohibitions/enforcement, leak detection/repair, metered use/rates, incentive/rebate programs, industry partnerships, facility modifications/new facilities, new supply acquisition/development and other actions.

Other Water Purveyors:

Other water purveyors, including irrigation districts and private water companies, reported financial impacts due to decreased water use and declining groundwater levels.

Current and planned drought response measures varied to include one or more of the following: water conservation plans, outreach, landscape development codes, watering restrictions, water waste restrictions, cooling system restrictions, leak detection/repair, rebate programs, facility modifications and vegetative management.

State Agencies:

State agencies reported impacts that include water supply disruptions and facility failures due to reduced precipitation and/or inflow to surface and groundwater systems; impacts/potential future impacts on wildlife and environmental resources, recreation (boating), game (hunting and fishing) and park visitation; increased potential for wildfire; and drought-related impacts to finances/operations.

Current and planned drought response measures vary by agency to include one or more of the following: new/improved storage, stabilization of water levels, securing new resources/facilities, outreach, increased irrigation/watering restrictions, plumbing/infrastructure improvements, monitoring and mitigation, and drought-related assistance.

Governor Sandoval announces formation of Drought Forum and discusses Nevada's changing landscape in the face of persistent drought conditions.

Federal Agencies:

Federal agencies reported drought impacts to wildlife, recreation, cultural resources, success and magnitude of restoration efforts, minerals, rangeland/livestock forage (including impacts to grazing allotments), loss of agricultural production, livestock herd reductions and tree health. Potential impacts reported include health and resiliency of timber stands due to insects/ disease, as well as fire hazards.

Current and planned response measures vary by agency to include one or more of the following: education/outreach, monitoring/mitigation, financial assistance, conservation compliance and other efforts.

The Summary of Current and Planned Actions is provided in Appendix B. Individual response forms submitted by agency/respondent are available at **drought.nv.gov**.

STATEWIDE SITUATION REPORT:

Between March and June 2015, the Nevada State Emergency Operations Center issued a monthly Statewide Drought Emergency Situation Report (Appendix C). Each report included a copy of the month's current U.S. Drought Monitor, which contained a listing of severity designations by county; information on emergency disaster programs; water level data; wildfire information; and other drought-related information and resources.

DROUGHT FORUM MEETINGS:

The Nevada Drought Forum held a total of six meetings between June and November 2015. Meetings were open to public and noticed in accordance with Open Meeting Law. Meetings were also broadcast to multiple locations throughout the state to provide transparency and encourage public involvement in the Forum's discussion and deliberations.

As part of its July 17, 2015 meeting, the Forum invited sector representatives from gaming, hospitality, mining, development, energy, commercial, industrial, tourism, recreation and general business to share information on drought impacts to operations, drought mitigation efforts, and current or anticipated obstacles to doing business because of drought conditions. The Forum continued this discussion at its August 19, 2015 meeting as it considered information from agricultural producers, tribal nations, non-governmental organizations, and public and private water providers/water authorities.

Meeting agendas and minutes, including a summary from presenters at the July and August Forum meetings, are included in Appendix F. Letters, comments and other meeting materials are available by meeting date at **drought.nv.gov**.

GOVERNORS DROUGHT SUMMIT:

Forum members attended and individually participated in the Governor's Drought Summit, September 21 – 23, 2015, at the Nevada State Legislative Building in Carson City. The Summit was opened by Governor Sandoval and included facilitated discussions involving more than 50 presenters, many of whom are national and state experts. The Summit also featured an evening at the Governor's Mansion that further advanced the valuable cross-sector discussions and idea sharing that occurred throughout the three days of meetings.

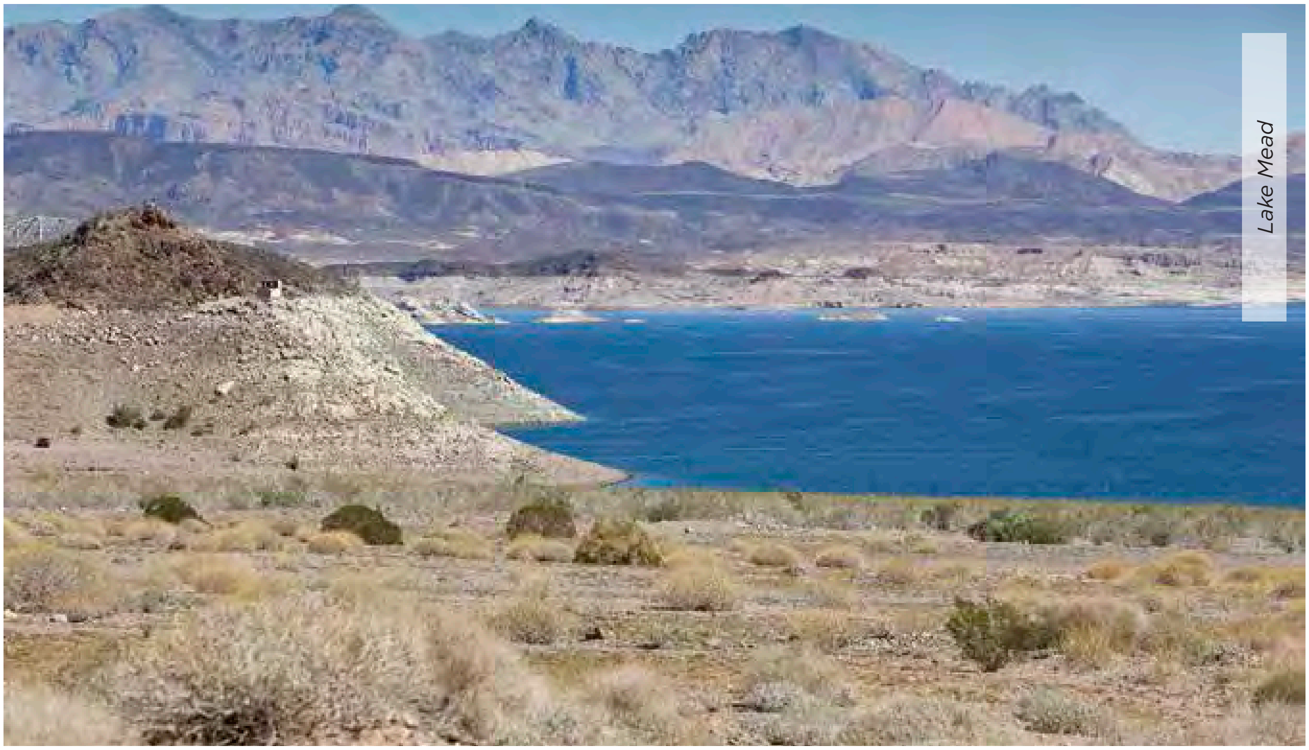
The Summit's panel discussions included such topics as defining and predicting drought; water history, law and past/current users; Nevada challenges; conservation success stories, which included participation by the media; water conservation communications/messaging; and a case study on regional water partnerships and solutions.

Participants were asked to share information on drought impacts, water conservation efforts, conservation barriers, and opportunities to improve conditions and/or Nevada drought resiliency moving forward. Members of the public were encouraged to submit questions and comments. Video recordings of the Summit are available at **drought.nv.gov**. The Summit program, together with comment cards submitted by attendees, is provided in Appendix D.

WESTERN GOVERNORS' ASSOCIATION DROUGHT FORUM FINAL REPORT:

Forum members received and reviewed the Western Governors' Association (WGA) Drought Forum final report released in June 2015, an initiative of 2015 WGA Chairman, Governor Sandoval. The WGA Drought Forum was created under Governor Sandoval's leadership to provide a framework for states, industries and communities to share best practices and policy options for drought response. Key themes identified for future exploration of the WGA Drought Forum include data and analysis; produced, reuse and brackish water; forest health and soil stewardship; water conservation and efficiency; infrastructure and investment; working within institutional frameworks to manage drought; and communication and collaboration.

The Forum discussed the report during its deliberations and agreed that most of the topics identified in the report generally correspond with many of the Forum's recommendations, as well as Nevada's challenges and opportunities. The WGA Report is provided in Appendix E.



Lake Mead

Carson City Area

Drought Forum Recommendations

The Forum listened to and considered numerous perspectives as part of its meeting process. Strong and sometimes conflicting views were presented on how to address the state's water resource challenges. Within this continuum, the Forum agreed there existed both opportunity and common ground—places where investments in time, coordination and funding could vastly improve Nevada's overall drought response and resilience.

The recommendations provided herein detail actions that the Forum believes can be taken now to bring about necessary and meaningful change. Governor Sandoval's leadership in addressing drought for the benefit of the state and its residents, along with further consideration and implementation of the Forum's recommendations, provide substantial and significant steps to help secure Nevada's water future.

1 WATER CONSERVATION

Water conservation is an important tool to help water users manage demands and extend the use of available resources. In many cases, conservation can help to ease the impact of water supply shortages during drought and reduce needs for additional water supplies.

In 1991, the state enacted laws requiring municipal, industrial and domestic water suppliers to adopt water conservation plans based on the climate and living conditions of their service area. For public water systems, NRS 540.121 through 540.151 was added to specify content requirements of the plans and the process and timeframes to be followed. NRS 704.662 through 704.6624 was also added to establish conservation plan requirements for those utilities regulated by the Public Utilities Commission of Nevada.

The Forum reviewed existing statutes and agreed that additional provisions could be enacted to increase water efficiency, while still recognizing regional differences in climate and other factors. The Forum recommended changes to water conservation plan requirements that include new provisions for watering restrictions, metering, conservation water rate structures and water efficiency standards for new development. The Forum agreed that technical support should be provided to help water suppliers develop meaningful and actionable plans (see also "Financial and Technical Assistance"), and compliance with submission requirements should be enforced.

The Forum also discussed the need for additional water conservation actions among agricultural water users by encouraging agricultural producers to continue to pursue water saving technology and/or best management practices. The Forum also agreed that metering all water uses in the state would be an appropriate next step. This action could significantly enhance overall water use efficiency among all water users and allow for better accounting of the state's limited water resources.

Nevada's appropriative rights system was another key conversation topic among the Forum and agricultural producers. Many producers discussed perceived risks associated with conservation, including potential loss of unused water saved as part of conservation efforts. Nevada water law is based on a "use it or lose it" doctrine (see also, "Nevada Water Law"), which requires users to demonstrate a beneficial use of water and restricts users from speculating in water rights or holding on to water rights that they do not intend to place for beneficial use in a timely manner. The Forum agreed that these provisions should be reviewed to promote conservation efforts among agricultural users and help resolve potential conflicts.

The Forum also discussed and recommended implementation of a policy directive addressing water efficiency within the power industry, and recommended strategies to improve conservation efforts within homeowner associations.

RECOMMENDATIONS

- Amend the current statute that requires all water purveyors to submit a water conservation plan to the Division of Water Resources. Amendments would add the following additional areas that purveyors must require as part of their plan, unless the requirement is deemed unnecessary by the State Engineer:
    - Meters on all connections
    - Water efficiency standards for new development
    - Tiered rate structures to promote water conservation
    - Time-of-day and day-of-week watering restrictions
- Ensure compliance with water conservation plan submittal requirements by amending the water conservation plans statute to provide enforcement capability for the State Engineer after attempts to achieve submittal compliance, including technical assistance, are unsuccessful.
- Clarify and strengthen the law to allow the State Engineer to require the installation of water meters for all water uses in the state, including domestic wells, unless such installation is deemed unnecessary by the State Engineer.

- Review potential changes and clarifications to the "use it or lose it" provisions in Nevada water law to increase opportunities and incentives for water conservation during drought and non-drought conditions.
- Encourage development and use of water saving technology and/or best management practices by agricultural and livestock producers (including, but not limited to, crop covering, drip irrigation, variable rate irrigation, center pivot irrigation, laser leveling and crop selection).
- Issue a state policy directive that requires all newly developed thermoelectric power plant projects, or all additions to existing thermoelectric facilities, to utilize dry cooling or other similar water efficient technology.
- Request local political subdivisions to explore implementation of water conservation measures where Home Owner Association Covenants, Conditions and Restrictions (CC&Rs) are to the contrary.

2 NEVADA WATER LAW

Nevada's first water law was passed in 1866 and has been amended many times since. The Office of the State Engineer was created in 1903 to protect existing water rights and to improve methods for utilizing the state's limited water resources. The State Engineer is responsible for administering and enforcing Nevada water law, which includes the appropriation of surface and groundwater in the state, and the adjudication of pre-statutory vested rights, dam safety and other duties.

Nevada water law is considered one of the most comprehensive water laws in the western United States. It is based on two basic principles: prior appropriation and beneficial use. Prior appropriation—also known as "first in time, first in right"—allows for the orderly use of the state's water resources by granting priority to senior water rights in times of shortage. This concept helps to ensure senior water users are protected, even as new uses for water are allocated.

The Forum's meetings and the Drought Summit generated significant discussion regarding Nevada water law, particularly in regard to the management of over appropriated basins; pumping impacts to senior groundwater right holders by junior pumpers; the relationship between groundwater pumping and surface water flows; adaptive management through monitoring, management and mitigation ("3M Plans"); and the nexus between Nevada's "use it or lose it" doctrine and water conservation needs (see also "Water Conservation"). Other conversations centered on place of use; management of supplemental water rights; terms of use for temporary rights; and the need for greater flexibility to manage resources during times of drought to help minimize impacts.

Forum members and participants generally agreed that current drought conditions have intensified the conversation, particularly in light of declining stream and groundwater levels, as well as dwindling storage reserves. These issues have the potential to create and/or exacerbate conflict, particularly in over-appropriated basins. The time it takes to resolve conflicts through the courts is also a concern, especially since many fundamental water management principles are not clearly defined in statutes. The Drought Forum agreed that these issues need to be addressed, with an incremental approach to guard against unintended consequences.

To help ease drought-related impacts, the Forum recommended changes to Nevada water law that clarify and strengthen the State Engineer's authority related to water management tools such as 3M Plans, Critical Management Areas and Groundwater Management Plans. Members also agreed that in times of curtailment (when water supplies are reduced or restricted), access to water for indoor use by domestic well users should be preserved.

The Forum also discussed the topic of rainwater collection and use for domestic or wildlife needs. NRS 533.030 does not specifically address the permissibility of rainwater capture and use, but does limit the diversion and use of water in the state to those entities that have a granted water right. The Forum agreed that changes to law could be implemented to allow for the use of small-scale precipitation capture devices without significant


East Fork Carson River

impacts to state resources, although limitations must be defined to restrict the magnitude of these activities.

RECOMMENDATIONS

- Continue refinement of Nevada water law to strengthen the State Engineer's ability to address Critical Management Areas and provide flexibility in the development of Groundwater Management Plans for over-appropriated basins.
- Clarify Nevada water law related to the State Engineer's inherent authority to provide for adaptive water management through implementation of 3M Plans.
- Clearly define fundamental water management principles in statute.
- Seek an addition to Nevada water law that clarifies that, in times of curtailment, only outdoor use by domestic well users may be prohibited.
- Explore changing water law to allow for the use of small scale precipitation capture devices in areas where capture increases the water supply and does not conflict with existing rights.

3 MONITORING AND RESEARCH DATA

Produced by the National Drought Mitigation Center, the U.S. Drought Monitor provides summary information on the location and intensity of drought conditions occurring across the United States and Puerto Rico. The map is updated weekly by combining data and local expert input. The Drought Monitor is produced by a rotating group from the U.S. Department of Agriculture, the National Oceanic and Atmospheric Administration, and the National Drought Mitigation Center, incorporating the review from a group of 250 climatologists, extension agents and others across the nation.

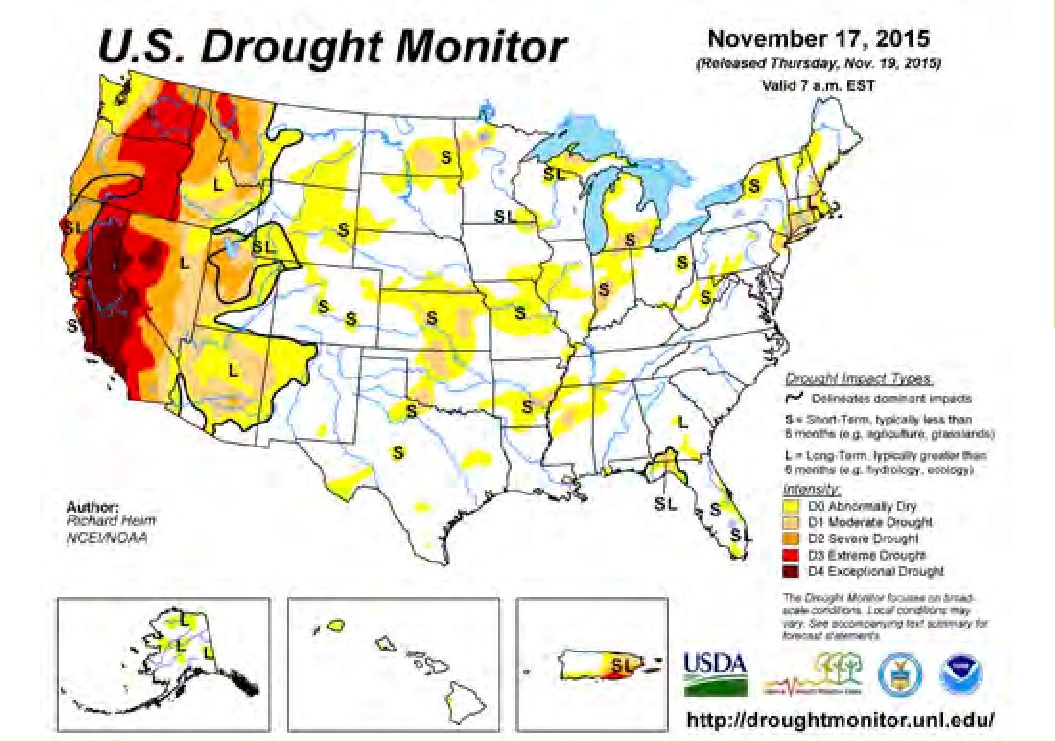
Within Nevada, the Drought Monitor is used by state and federal agencies to establish policy and management tools and to assist local planning agencies and other water users with real-time information on hydrological conditions. While the Drought Monitor is a useful tool for reporting current hydrological conditions, participants at the Forum meetings and the Summit agreed that additional information and analysis is needed to improve decision-making efforts related to livestock grazing, as well as land and environmental resource management.

The Forum agreed that narrowing information gaps through additional data collection and monitoring could significantly improve coordination between various stakeholder groups throughout the state and allow for the development of more flexible resource management strategies. As such, the Forum recommended the formation of a working group to set monitoring and research goals, and to assess monitoring recommendations. The work group's efforts will complement and enhance the applicability, value and effectiveness of the U.S. Drought Monitor through the development of new tools to increase the accuracy and accessibility of data, and improve drought forecasting through technology. The Forum agreed these coordinated efforts may help to defray expenses on mutually beneficial projects, make better use of limited staffing resources, reduce duplication of efforts and enhance interagency/stakeholder coordination and cooperation.

The Forum recognized that enhanced forecasting and monitoring tools may also be of value to other western states that are experiencing significant drought conditions. To this end, members recommended that the U.S. Drought Monitor be expanded to include multiple indicators, including state impact reporting. They also supported the addition of another Drought Monitor author in the western states and other drought-related research.

RECOMMENDATIONS

- Direct the formation of a working group of climate professionals and other relevant disciplines to set goals and assess recommendations for drought monitoring, including information gaps/site needs, prioritization of efforts, implementation strategies, and cost identification/funding strategies. This working group is encouraged to:
    - Develop a statewide monitoring network that utilizes diverse information sources to strengthen Nevada information sharing and monitoring coordination as well as centralized availability of real-time data.
    - Partner among network organizations to increase and enhance the accuracy of data, in part, by establishing standards for data collection and reporting.
    - Work with other organizations (such as NIDIS—National Integrated Drought Information System) and/or explore implementation of new technologies to improve drought monitoring, drought early warning systems and forecasts.
- Work with other western Governors to request an additional U.S. Drought Monitor author to represent western states and encourage expansion of the U.S. Drought Monitor to include multiple indicators (vegetative and hydrologic drought), including state impact reporting.
- Support development of research data related to the impacts of drought, including state tourism's offer to include questions related to drought and visitation as part of its scheduled research efforts.



As of November 17, 2015, much of Nevada is categorized to be in "moderate" to "exceptional" drought (D1 – D4).

4 FINANCIAL AND TECHNICAL ASSISTANCE

Incentive and retrofit programs have had much success in certain parts of the state, and could serve as a model for other users. However, such programs often require significant levels of funding, a limiting factor that many stakeholders face. As such, the Forum recommended that state agencies identify high-priority funding programs (including incentive programs) and associated resource needs.

The Forum also agreed that additional staffing resources will likely be needed to implement recommendations for monitoring and enforcement, as well as to provide technical assistance to water users/suppliers. Likewise, members discussed the importance of individual water users to investigate independent funding options for drought relief and conservation efficiency, including existing grants, state revolving loan funds and/or other federal emergency assistance programs.

RECOMMENDATIONS

- Direct appropriate state agencies to investigate and develop budget proposals that improve Nevada's drought response and resiliency, including possible incentive and/or rebate programs.
- Establish adequate bond funding for the state's Water Grants Program, under the purview of the Board for Financing Water Projects, for necessary capital improvements to aged water infrastructure above and beyond what a community can demonstrably afford.
- Enhance state water resources staffing capacity to support increased metering, monitoring/inventories and enforcement, as well as technical assistance in areas such as water conservation planning.
- Direct appropriate state agencies to identify and prioritize the resources needed to implement those recommendations of the Drought Forum selected by the Governor.

5 SUPPLY AUGMENTATION AND LONG-RANGE PLANNING

In addition to exploring ways to reduce water use and improve overall efficiency, the Forum also considered opportunities to augment existing water supplies and improve drought response efforts through long-range planning.

The Forum agreed that the recharge and recovery of drought affected water supplies—including river, storage and groundwater systems—is an important priority to improve Nevada's resilience to future drought events and recommended exploring ways to enhance system recovery. While these efforts are unlikely to provide near-term drought relief due to time and financial constraints that would need to be addressed, the Forum agreed that additional steps should be taken to identify strategies that can be implemented to improve recovery of impacted systems, as well as enhance the state's long-term resiliency.

Likewise, the Forum recommended that local governments work with water purveyors to develop long-range water plans that consider both water supply and demand projections. Such planning efforts are a valuable tool in anticipating future water resource needs, as well as identify needed management strategies for use during both drought and non-drought conditions.

The Forum also agreed that the reuse of treated waste water is a valuable resource that should be explored to augment existing water supplies. As such, the Forum recommended support for the state's Water Reuse Steering Committee in exploring possible changes to reuse regulations, particularly in cases where implementation of reuse extends available water supplies. Likewise, the Forum also supported the continued monitoring of technology and other advancements that could potentially increase water supplies and/or reduce evaporative losses.

RECOMMENDATIONS

- Ask appropriate staff to explore the feasibility of additional management measures that can help to expedite the recharge and recovery of impacted river, storage and groundwater systems.

- Without affecting the inherent authority of the Nevada State Engineer, support and encourage the development of local and regional water plans that include long-term supply and demand projections in order to ensure a sustainable water supply.
- Support the work of the state's Water Reuse Steering Committee in exploring possible changes to water reuse regulations in cases where reuse extends supplies.
- Direct continued monitoring of advances, efficacy and cost efficiencies related to desalination of brackish water, cloud seeding and evaporative controls.

6 INFORMATION SHARING AND OUTREACH

The Forum discussed the availability and use of information in decision-making processes, particularly as it relates to drought response (see also "Monitoring and Research Data"). Members agreed that additional outreach tools are needed and recommended ways to better inform the public and other decision-makers of current conditions, policy intent and other drought-related issues. Implementation of these recommendations is designed to provide for more flexibility and predictability in responding to Nevada's water supply challenges, and to ensure a more consistent understanding among interested parties.

The Forum also agreed that communication with the public and other stakeholders should occur on an ongoing basis, regardless of the state's drought status. To support this effort, the Forum recommended staff resources to support current and ongoing coordination, information sharing and outreach needs.

RECOMMENDATIONS

- Work with federal partners on what climate information/data will trigger federal management actions, with the goal of enhancing predictability for asset managers and the development of a more flexible response in evolving drought conditions.
- Identify high-level messages on drought conditions and responses that can be delivered statewide to ensure consistency of messaging to all Nevada water users by state agencies, water purveyors and other stakeholders.
- Maintain a focus on water conservation messaging in Nevada even in non-drought conditions.
- Explore opportunities for judicial education on water law, such as the New Mexico Water Judges Seminar.
- Establish dedicated state staff to handle public information coordination statewide, including outreach to elected and appointed officials, as well as education programs, web site maintenance and enhancement, and assistance with information on best practices and technology transfers.

7 DROUGHT DECLARATIONS/ EMERGENCY ACTIONS

The State Drought Response Plan, updated in April 2012, was developed to define and address drought in Nevada, and to help mitigate associated impacts. The plan established a framework of actions based on three stages of drought: Drought Watch (stage 1), Drought Alert (stage 2) and Drought Emergency (stage 3). A Drought Response Committee was also formed to monitor drought conditions, collect data associated with drought, oversee intergovernmental coordination, disseminate information, report to the Governor, and work with the State Emergency Operation Center on drought response.

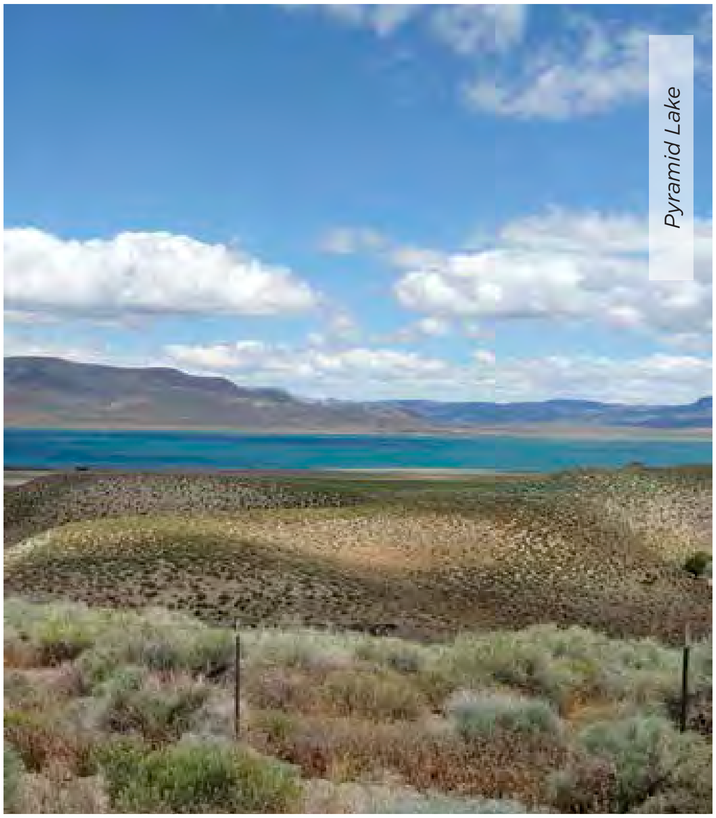
Subsequent to this action, the U.S. Department of Agriculture issued a final ruling that updated its disaster regulation process for drought-affected areas. The rule includes provisions for automatic disaster designations in the case of severe drought. It also removes the requirement for a State Governor to request a Secretarial disaster designation before a designation can be made. According to the rule, a drought disaster will be declared for any county that: 1) has a drought intensity value of at least D2 (Severe Drought) as reported in the U.S. Drought Monitor for eight consecutive weeks; or 2) has a drought intensity value of D3 (Extreme Drought) or higher at any time in the growing season of the affected crops.

The Forum agreed that objective Nevada criteria are needed to define drought stages. Further, members agreed that the state's current Drought Response Plan should be updated to include definitions and other relevant drought response mitigation efforts resulting from the Forum's work. The Forum also recommended that the Committee review existing laws concerning water emergencies to ensure consistency.

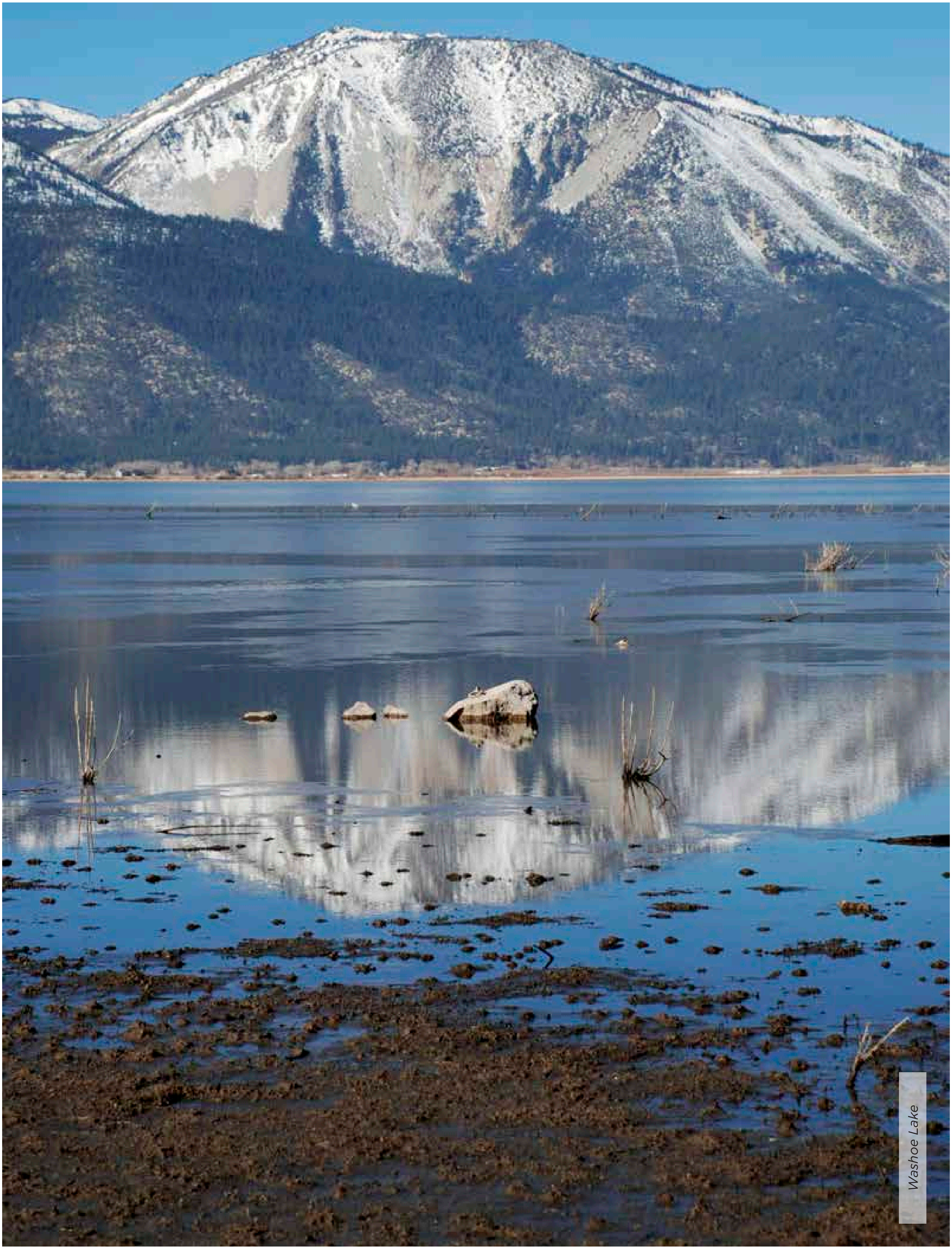
As part of this discussion, the Forum recognized the diversity of the state's climate, water supply sources and users' overall ability to respond to drought. Members cautioned against implementing measures on a statewide basis unless conditions warranted such action and noted that emergency measures enacted should serve to preserve access to supplies. Users/suppliers that have made appropriate reductions or implemented other tools to ensure sufficient resources are available should not be penalized.

RECOMMENDATIONS

- Currently, the State Drought Response Committee consists of the State Climatologist, State Engineer and the Chief of Nevada's Division of Emergency Management. The Forum recommends expanding this committee to include representatives from TMWA, SNWA and the Nevada Department of Agriculture and directing the newly expanded State Drought Response Committee to develop broad-based, objective Nevada criteria specifically for a Governor's Drought Declaration in lieu of a declaration based solely on a U.S. Department of Agriculture determination.
- Require the Committee to further refine and define the Nevada criteria for Drought Warnings and Drought Alerts, and to clarify in the Drought Response Plan the distinctions between Drought Alerts, Drought Warnings and a Governor Drought Declaration, and a proclamation of water emergency as outlined in NRS 416.050.
- Require the Committee to update the current Drought Response Plan in light of information gathered through the Drought Forum and Governor's Drought Summit.
- Direct the Committee to explore the steps necessary for response measures such as a State Engineer's temporary suspension of forfeiture provisions or imposition of shared curtailment, as well as temporary suspension by state Environmental Protection of non-public health water quality standards.
- Direct the Committee to also review, from a water perspective, NRS Chapter 416 *Emergencies Concerning Water or Energy*, to align the chapter with the Drought Response Plan, including possible amendment of NRS 416.060 to add the term "statutes" to "rescind any regulation or order" in narrowly defined water emergencies.
- The Committee shall invite experts and make recommendations to the Governor for adding additional members as needed.



Pyramid Lake



Washoe Lake

TRUCKEE MEADOWS WATER AUTHORITY

APPENDIX 5-2

PRIORITIZED MAIN REPLACEMENT PROGRAM

Prioritized Main Replacement Program

August 2015

TRUCKEE MEADOWS WATER AUTHORITY

www.tmwa.com

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List of Tables and Figures

Executive Summary

The United States has entered the replacement era in which we need to begin rebuilding our water system infrastructure installed by earlier generations according to the American Water Works Association. Much of our drinking water infrastructure is nearing the end of its useful life and approaching the age at which it needs to be replaced. Significant investment will be required if we are to maintain the current level of water service Americans enjoy today.

The purpose of this inaugural effort was to ensure the viability, integrity and reliability of the water system for our community by developing prioritized short-term and long-term plans for water main renewal. Truckee Meadows Water Authority (TMWA) staff inventoried and analyzed existing water main infrastructure condition and service level. A scoring system was developed for prioritization primarily driven by 24 years of leak history as the best indicator of existing pipe condition. Finally, TMWA performance levels were compared to national metrics in order to guide ongoing best practices and decision making in regards to water main rehabilitation and replacement.

Results show TMWA's exceptional reliability and water main infrastructure integrity when compared nationally to public water system annual break rates, service levels and water produced but not billed. Coordination with local agencies should continue as this approach has proved to be the most cost effective and least disruptive to main replacement and rehabilitation for TMWA customers and the community. Furthermore, the current $5 million dollar annual funding level is appropriate while expenditure requirements are expected to grow to $18 million dollars annually by 2050. TMWA debt management activities will allow greater cash flow to fund water main rehabilitation and replacement expenditures into the future.

Findings and Recommendations

Short-Term Plan:

- Continue to coordinate water main rehabilitation and replacement projects with the City of Reno, City of Sparks, RTC, NDOT and Washoe County street reconstruction and utility projects. Integrating utility work prior to or concurrently with other agencies' projects has proved to be the most cost efficient and least disruptive approach to water main renewal for TMWA customers. TMWA may move forward independently with some priority projects as budgets allow.

- TMWA delivers exceptional reliability as measured by a low leak rate system-wide as well as for the top prioritized mains. TMWA's top 10 prioritized mains offer service levels of 0.3 to 1.1 leaks per 1,000 feet per year. When considering only internal costs, three breaks per 1,000 feet per year justify open-trench replacement while rehabilitation technologies can be cost-effective at two breaks per year. Therefore, no immediate action is warranted to address TMWA's prioritized mains outside of current best practices.

- Where rehabilitation or replacement are considered, priority should be focused on steel, cast iron, concrete cylinder and riveted steel water mains installed prior to 1960. These pipe materials makeup 12 percent of TMWA's water system inventory but account for 60 percent of recorded leaks. In addition, 90 percent of resulting prioritized mains were installed before 1960.

Long-Term Plan:

- Monitor leak/break rates as a measurement of pipe condition, performance, and durability. Consider rehabilitation or replacement as service levels decline or field investigations and maintenance experience validate deteriorating pipe condition and increase the risk of failure.

- Continue to collect and maintain data necessary to build a comprehensive asset management and prioritization program. Incorporate merger-acquired water mains with future updates.

- Budget and plan for increasing water main rehabilitation and replacement costs as facilities age and approach the end of their expected service life. Expenditures are expected to grow to over $18 million dollars annually by 2050. Debt management activities under consideration will allow greater cash flow to fund rehabilitation and replacement expenditures into the future.

Methodology

The purpose of this inaugural effort was to inventory and analyze existing TMWA water main infrastructure condition and service level to develop prioritized short-term and long-term plans for water main renewal. Water services were not included in this analysis. Stated goals and objectives were to:

1. Incorporate the likelihood and consequence of water main failure to reduce total system risk, associated unplanned outages and emergency repair costs.
2. Prioritize main rehabilitation and replacements based on risk and coordination with local agencies to maximize benefits and minimize costs.
3. Ensure the viability, integrity and reliability of the water system for our community.

To identify priority mains in TMWA's distribution system, the likelihood and consequence of failure for each pipe segment was estimated using data contained in our geographic information system (GIS). The likelihood of failure included such attributes as material, age, leak history, soil condition, proximity to railroads and fault lines and higher static pressure areas. The consequence of failure included diameter, hydraulic criticality, and high volume users. Each criterion was scored and mains subsequently ranked according to risk.

The results of this initial effort were driven primarily by the likelihood of failure and specifically, the leak history data as the best indicator of existing pipe condition. Datasets including critical customers, difficult access for maintenance, potential damage to surrounding high-value areas, the extent of customer outages and traffic interruptions were not available but may be incorporated in future updates. Locate the full methodology in Appendix A.

Short-Term Prioritization Plan

Street and Highway Program

Coordination with local agencies has proved to be the most cost effective and least disruptive approach to main replacement and rehabilitation for TMWA customers and the community. The Street and Highway Main Replacement Program has been funded at an average rate of $5 million dollars per year since the inception of TMWA in 2001. The average rate of main replacement under this program has been 8,000 feet per year. TMWA works cooperatively with our local agencies to keep projects on time and within budget.

Break and Leak Rates, Service Level, and Non-Revenue Water

The American Society of Civil Engineers' *2013 Report Card for America's Infrastructure* graded the nation's water infrastructure a D+ and reported that there are an estimated 240,000 water main breaks per year in the United States. Division results in an average break rate of 24 breaks per 100 miles annually since it is estimated that there are a little over one million miles of water mains installed in the U.S.

According to the American Water Works Association (AWWA), the median level of breaks and leaks has ranged from 26 to 49 per 100 miles since 2004 (*Benchmarking Performance Indicators for Water and Wastewater Utilities: 2013 Survey Data and Analyses Report)*. The 75th percentile ranged up to 89 while the 25th percentile was down to zero in one year. More typically the break rate is in the range of 15 to 20 leaks and breaks per 100 miles annually. While TMWA has not differentiated between leaks and breaks historically, the AWWA defines leaks and breaks as follows:

Leak: A leak refers to an opening in a distribution pipeline, valve, hydrant, appurtenance or service connection that is continuously losing water.

Break: A break refers to physical damage to a pipe, valve, hydrant, or other appurtenance that result in an abrupt loss of water.

TMWA's system-wide water main leak rate is very low at 3 leaks per 100 miles annually indicating very high service levels currently exist. This leak rate is based on 24 years of leak history data collected beginning in March of 1989 through February of 2013. In all, 1,067 leaks on water mains have been documented in that time (including 63 leaks due to third party damage) equating to an average total number of 45 leaks annually.

Another way to express service level is the number of leaks per year per 1,000 feet of installed water main. The TMWA system-wide rate is 0.006 leaks per 1,000 feet per year while the rates for our top 10 prioritized mains vary from 0.3 to 1.1 leaks per year. According to an AWWA Research Foundation Report, one to three breaks per 1,000 feet per year justify open trench replacement, depending on the number of services and traffic disruption involved. Rehabilitation is cost effective at 0.5 to two breaks per 1,000 feet per year according to this report. These decision threshold recommendations take into account the internal and external costs involved and customer attitudes and acceptance of the frequency and duration of service disruptions (*Customer Acceptance of Water Main Structural Reliability*, AWWA Research Foundation, 2005). Therefore, no immediate action is warranted to address TMWA's prioritized mains outside of current best practices.

View TMWA's top 10 prioritized mains in Table 1. All are steel or cast iron pipes installed prior to 1950 and have leak rates of 0.3 to 1.1 leaks per 1,000 feet per year.

Table 1: TMWA's Top 10 Prioritized Mains

Main Location	Diameter and Material	Length (ft)	Year Installed	Number of Leaks (1989-2013)	Number of Services	Leak Rate (annual leaks per 1,000 feet)
Plumas Street	12-inch steel	3,900	1948	28	32	0.3
Washington Street	6-inch steel	1,700	1925	36	60	0.9
Southridge Drive	6-inch steel	1,600	1947	19	20	0.5
Stewart Street	6-inch steel	440	1920	12	23	1.1
Moran Street	4-inch cast iron	400	1926	10	17	1.0
Haskell Alley	4-inch cast iron	400	1926	8	15	0.8
Haskell Street	6-inch steel	310	1947	8	1	1.1
Humboldt Street	6-inch steel	310	1923	7	9	0.9
Daniel Drive	6-inch steel	1,080	1947	11	25	0.4
Bartlett Street	6-inch cast iron	820	1948	9	24	0.5

TMWA's low leak rate is also reflected in TMWA's comparatively small non-revenue water use. Non-revenue water refers to water that is produced but not billed or accounted for in customers' meters. Non-revenue water can be authorized (firefighting, hydrant testing, flushing) or result from unauthorized use and leakage. The national annual average public water system non-revenue water use is 16 percent per *Water Audits and Water Loss Control for Public Water Systems,* USEPA July 2013. TMWA's non-revenue water use has been estimated at 6 percent annually.

An exhibit showing TMWA's prioritized mains displayed geographically is included in Appendix B. Exhibits showing TMWA's top 10 prioritized mains in more detail are attached in Appendix C. A table listing the top 100 prioritized mains is shown in Appendix D. Appendices F through K exhibit criterion used in the prioritization including leak history.

Prioritized Water Main Materials - Steel, Cast Iron, Concrete Cylinder, Riveted Steel

TMWA's water system consists of approximately 539 miles of polyvinyl chloride (PVC) pipe, 517 miles of asbestos cement (AC) or Transite pipe, 123 miles of ductile iron (DI) pipe, 89 miles of cast iron (CI) pipe, 72 miles of steel pipe, and a small amount of concrete cylinder pipe. The figure on the next page shows the percentage of pipe by material in TMWA's system.

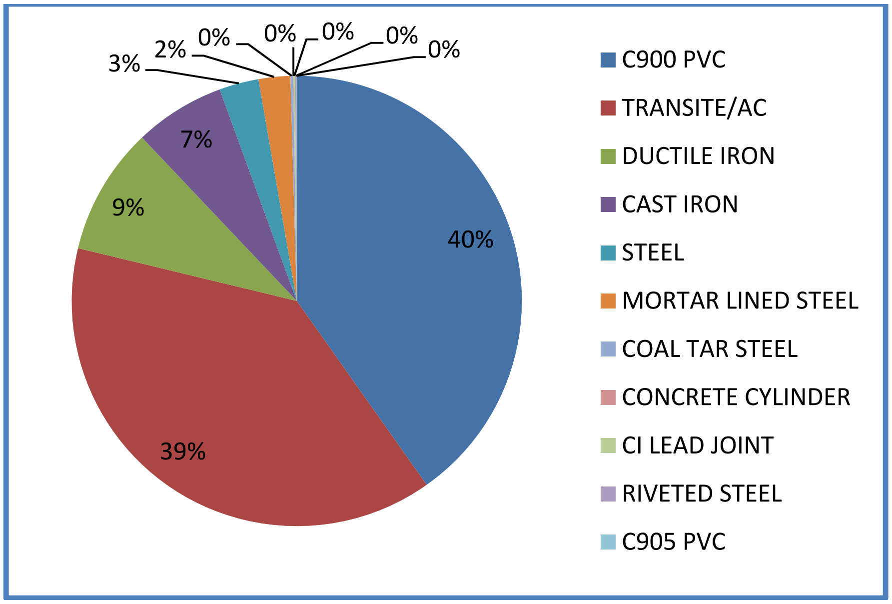

Figure 1: Percentage of Main by Material

The following two figures show the percentage of leaks by material and by type of failure. Leaks on steel mains are most commonly caused by corrosion while cracking is most common on cast iron and asbestos cement materials.

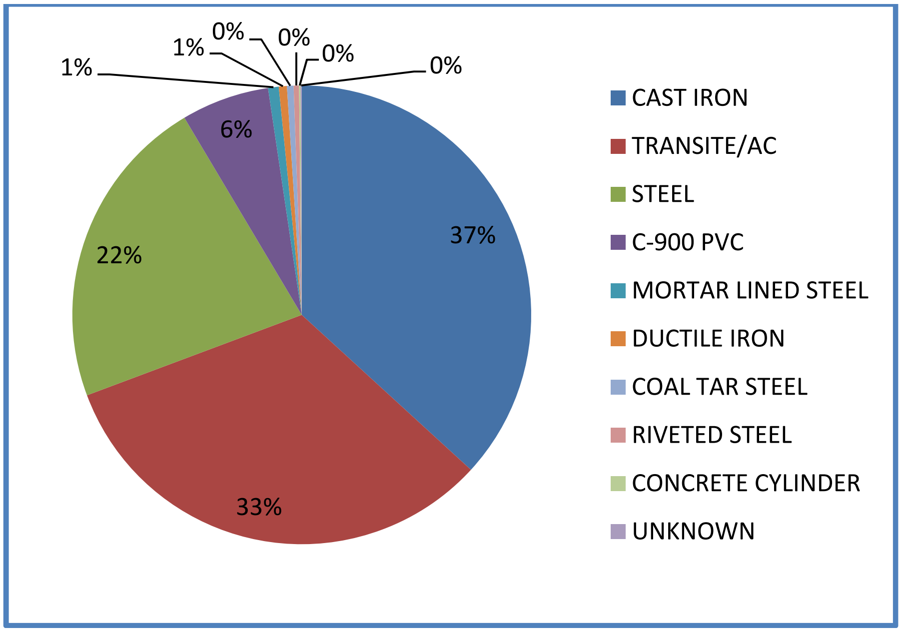

Figure 2: Percentage of Leaks by Material

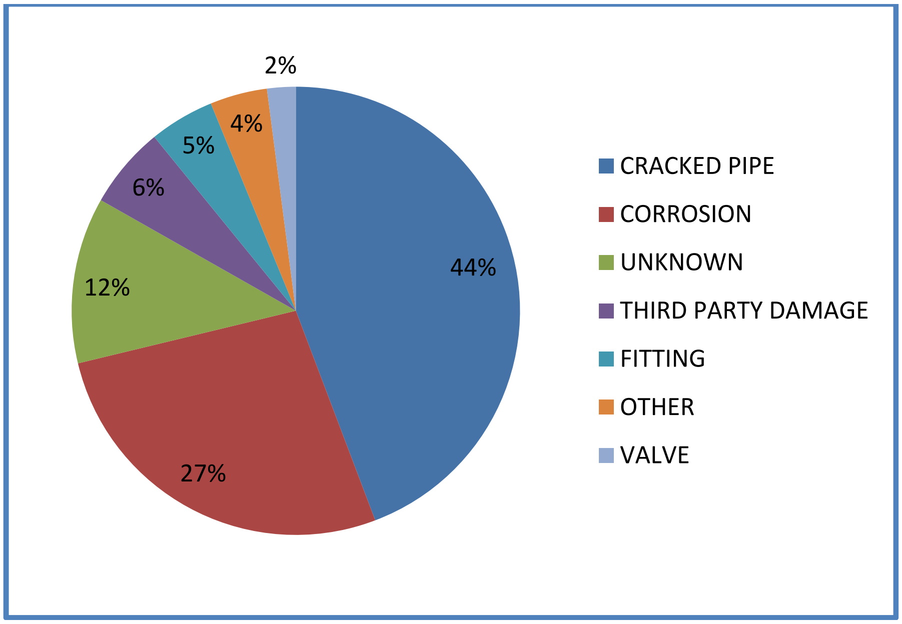

Figure 3: Percentage of Leaks by Type

The graphic below illustrates that steel, cast iron, concrete cylinder, and riveted steel pipes have the highest number of leaks per mile by material and, therefore, should be the focus of TMWA's prioritized main replacement program. As previously mentioned, these pipe materials makeup only 12 percent of TMWA's water system inventory but account for 60 percent of recorded water main leaks.

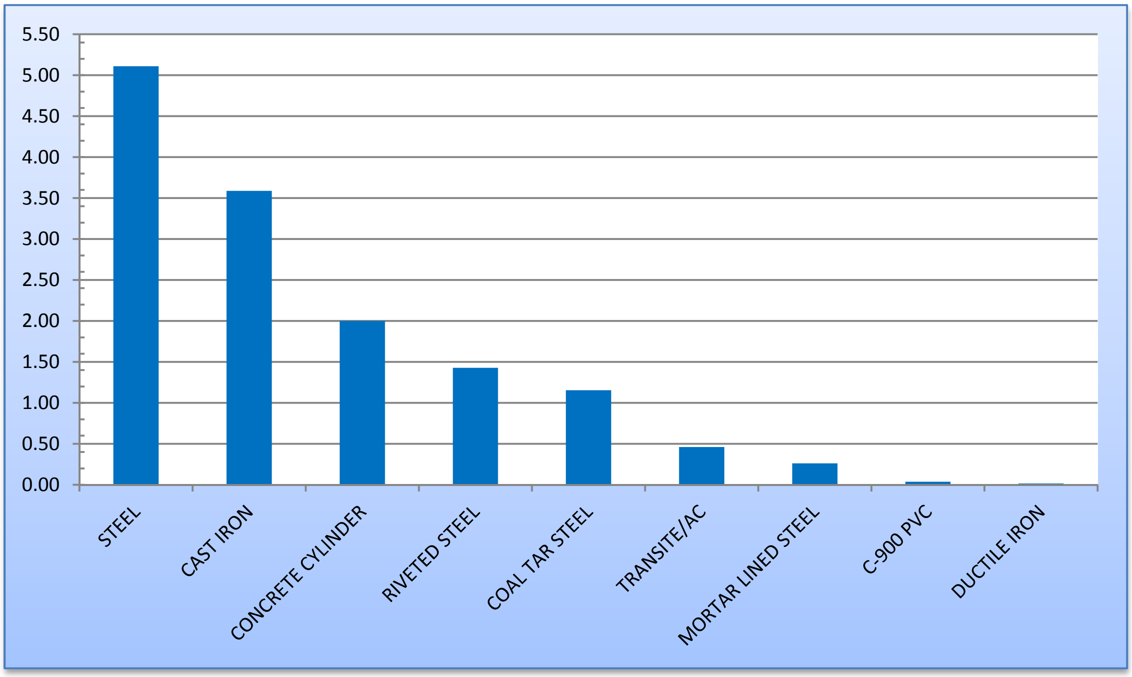

Figure 4: Number of Leaks per Mile by Material

Additionally, the age of pipe installations, as well as soil conditions and early laying practices, are linked to prioritized main results. Ninety percent of resultant prioritized mains from this analysis were installed prior to 1960. The table below shows that TMWA has 28.5 miles of these mains that were installed prior to 1960.

Table 2: Steel, Cast Iron, Concrete Cylinder Pipe Installed Prior to 1960

	Length in Feet Installed Prior to 1960					Total by Size
Main Diameter	Steel	Cast Iron	Riveted Steel	MLS	CCP	(feet)
4"	0	569	0	0	0	569
6"	3,596	52,071	0	0	0	55,667
8"	696	26,194	0	0	0	26,890
10"	1,074	702	1,130	0	0	2,906
12"	62	2,990	10,625	0	0	13,677
14"	12,687	0	0	0	1,063	13,750
16"	0	0	0	1,217	0	1,217
18"	31	0	0	0	0	31
22"	5	0	0	0	0	5
24"	34,757	0	0	1,122	0	35,879
42"	50	0	0	0	0	50
Total Feet	52,958	82,526	11,755	2,339	1,063	150,641
					Total Miles	28.5

Why Not Prioritize Asbestos Cement Mains?

While asbestos cement water mains account for 33 percent of recorded water main leaks at TMWA, the number of leaks is low at less than 0.5 per mile. The exhibit in Appendix E shows asbestos cement pipe leak history appears quite random geographically making it is difficult to predict where future leaks might occur. Asbestos cement mains should be replaced if determined necessary based on information for a specific main in conjunction with the Street and Highway Main Replacement Program.

Long-Term Prioritization Plan

Continue Service Level Monitoring

TMWA will continue to monitor leak rates as a measurement of pipe condition, performance, and durability. Rehabilitation or replacement will be evaluated as service levels decline or field investigations and maintenance efforts validate deteriorating pipe condition and increased risk of failure. Engineering staff will perform alternatives evaluations to determine whether or not priority pipes can be abandoned, rerouted, or should be rehabilitated or replaced. Replacements will continue under the existing Street and Highway Main Replacement Program budget item or will be capitalized as necessary.

Data Collection and Maintenance

Beyond TMWA’s existing GIS and computerized maintenance management system Cityworks, additional data and analyses tools will be necessary for more advanced approaches to a long-term main prioritization plan. Ultimately, a life cycle planning approach including development of aging functions and determination of the effective useful service life at the pipe level could prove useful. Future updates will also include newly acquired water mains in the analyses.

Projection of Investment Requirements by Year to 2050

Much of the drinking water infrastructure nationwide is nearing the end of its useful life and approaching the age at which it needs replacement. Fortunately, TMWA's assets are generally newer than those in the eastern United States and Midwest. The figure below shows the age of installed length of main in TMWA's system by decade.

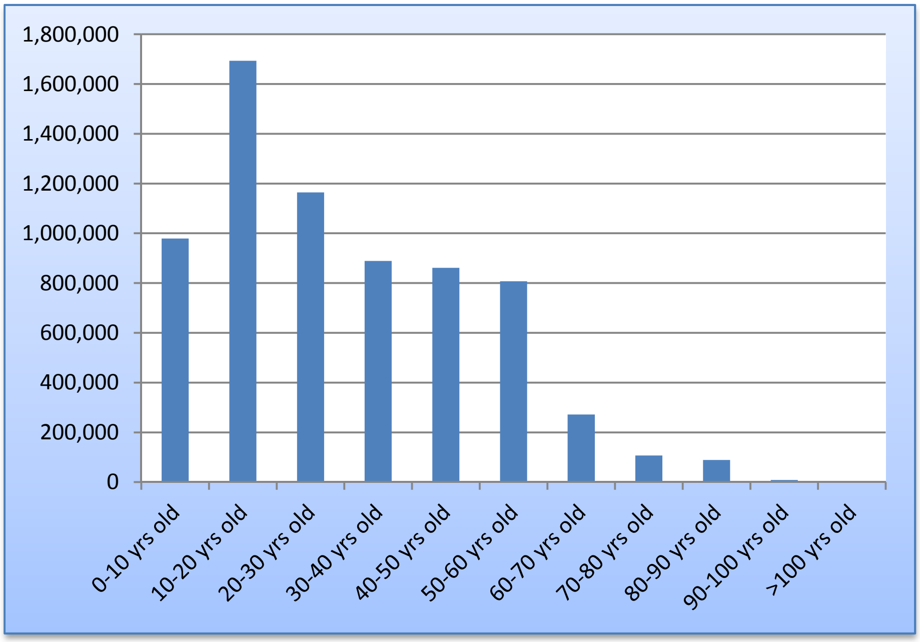

Figure 5: Age of Installed Length of Main in Feet

Nevertheless, significant investment will be required if we are to maintain the current level of water service Americans enjoy today. The AWWA has produced a report and tool for use by water utilities to project asset replacement costs through 2050 called the *Buried No Longer Pipe Replacement Modeling Tool (*Copyright 2013 AWWA*)*. This tool scales the outcomes of the larger report for specific utility criteria such as size, replacement costs, pipe age, and materials. TMWA's results estimate the growth of replacement expenditures for water mains to approximately $18 million dollars per year by 2050 (in 2012 dollars). Debt management activities under consideration will allow greater cash flow to fund rehabilitation and replacement expenditures into the future. Find the full results in Appendix L.

Further Reading

http://www.infrastructurereportcard.org/a/#p/drinking-water/overview

http://www.infrastructurereportcard.org/a/#p/state-facts/nevada

http://water.epa.gov/type/drink/pws/smallsystems/upload/epa816f13002.pdf

http://www.awwa.org/Portals/0/files/legreg/documents/BuriedNoLonger.pdf

Appendix A

Prioritized Main Replacement Analyses Methodology

Main Rehabilitation and Replacement Prioritization Methodology

Purpose:
Identify, budget and plan main rehabilitation or replacements based on risk. Coordinate with local agencies for maximum benefit and minimum cost to ensure the viability, integrity, and reliability of the water system for TMWA customers.

Task:
Develop a prioritized main replacement program using currently available information and technology incorporating the likelihood and consequence of failure to reduce total system risk, associated unplanned outages, and emergency repair costs.

Part 1 Methodology:

1. Estimate the likelihood of pipe failure:
    - a. Physical
        1. material
        2. age
        3. distribution staff field experience
    - b. Historical
        1. leak and break history
        2. maintenance records*
    - c. Spatial
        1. soil conditions
        2. proximity to railroads, fault lines
    - d. Hydraulic
        1. high static pressure areas
2. Estimate the consequence of pipe failure:
    - a. Physical
        1. diameter
    - b. Spatial
        1. potential damage to surrounding high-value areas*
        2. difficult access for maintenance or repairs*
    - c. Hydraulic
        1. pipe hydraulic criticality
    - d. Customer and Public Relations
        1. outages to critical customers*/high volume users
        2. extent of customer outages/population density/traffic interruptions*
3. Calculate risk of failure and develop a prioritized list of main replacements

Part 2 Methodology:

1. Budget and plan renewal based on risk and coordination with local agencies.
    - a. Annually correlate to planned street and highway repair or utility work
    - b. Engineering alternatives evaluation
        1. abandon, reroute, rehabilitate or replace
    - c. Perform selected field condition assessments
    - d. Prepare preliminary designs and cost estimates

Note: * Items were not included in this analysis.

Appendix B

Prioritized Mains by Risk Score

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HOMELAND SECURITY INFORMATION

(NRS 239C.210)

Appendix C

Top 10 Prioritized Mains

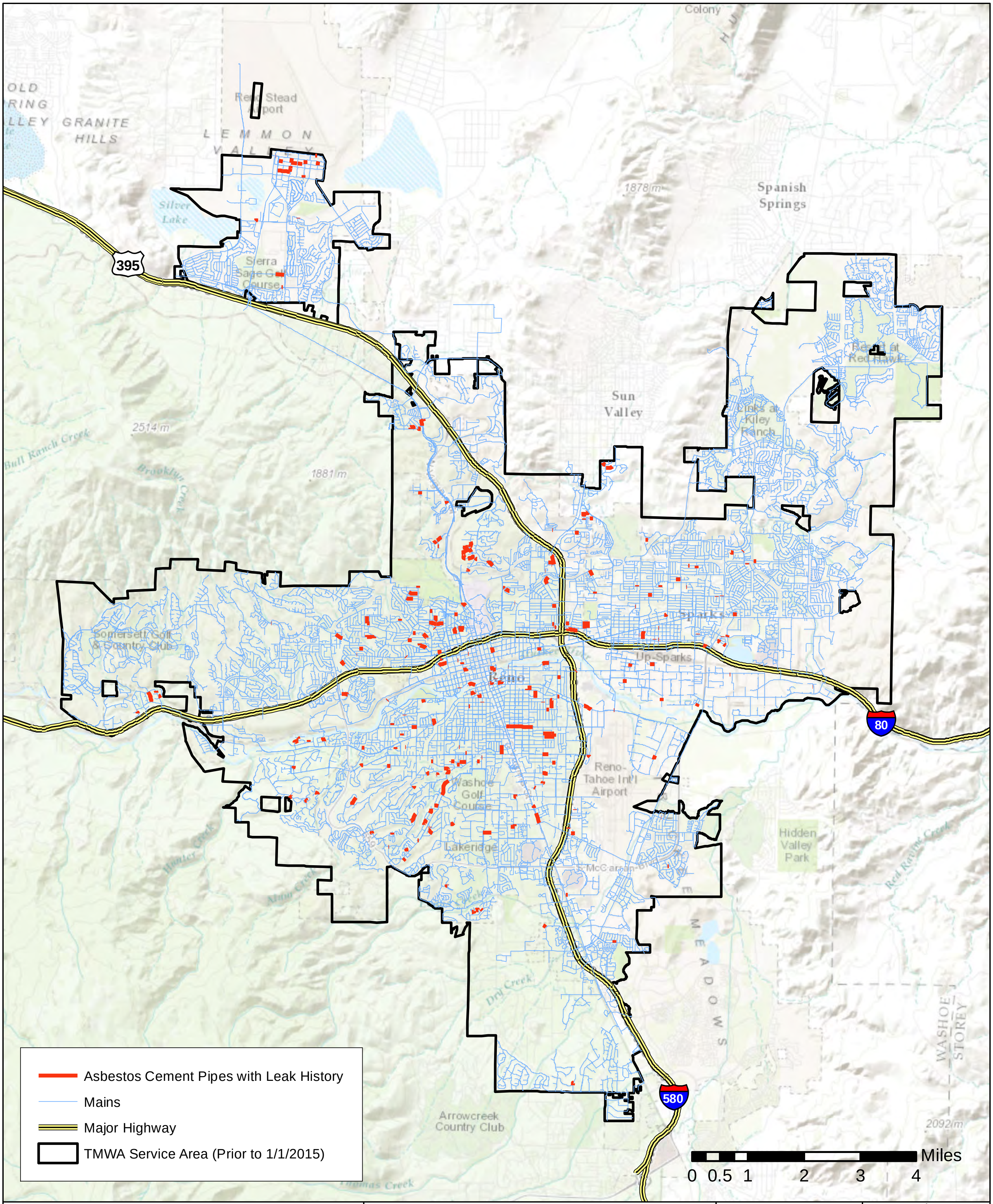
Main Location	Diameter	Material	Year Installed	Number of Leaks
PLUMAS ST	12-inch	steel	1948	28
WASHINGTON ST	6-inch	steel	1925	36
SOUTHRIDGE DR	6-inch	steel	1947	19
STEWART ST	6-inch	steel	1920	12
MORAN ST	4-inch	cast iron	1926	10
HASKELL ALLEY	4-inch	cast iron	1926	8
HASKELL ST	6-inch	steel	1947	8
HUMBOLDT ST	6-inch	steel	1923	7
DANIEL DR	6-inch	steel	1947	11
BARTLETT ST	6-inch	cast iron	1948	9
JUNIPER HILL RD	4-inch	steel	1948	6
BON REA WAY	4-inch	cast iron	1926	8
STEWART ST	6-inch	cast iron	1947	6
K ST	6-inch	cast iron	1952	6
W MOANA LN	12-inch	steel	1948	4
GENTRY WAY	8-inch	steel	1948	4
WHEELER AVE	8-inch	steel	1912	6
G ST	6-inch	steel	1947	4
LANDER ST	6-inch	cast iron	1930	4
COMSTOCK DR	6-inch	cast iron	1963	6
BASQUE LN	24-inch	steel	1960	4
MARY ST	4-inch	cast iron	1928	4
COLLEGE CT	4-inch	cast iron	1931	5
GRASSLAND PL	6-inch	cast iron	1955	5
KEYSTONE AVE	6-inch	cast iron	1950	5
MORAN ST	10-inch	steel	1917	3
WHITFIELD WAY	8-inch	cast iron	1951	3
4TH ST	4-inch	cast iron	1947	4
WASHINGTON ST	4-inch	steel	1924	3
MONROE ST	4-inch	cast iron	1928	4
STOKER AVE	6-inch	cast iron	1952	4
TOLICA ST	6-inch	steel	1947	3
WHITFIELD WAY	8-inch	steel	1949	3
WESLEY DR	6-inch	cast iron	1949	3
LODGE AVE	6-inch	cast iron	1952	10
SHANGRI-LA DR	6-inch	cast iron	1950	4
HILLSIDE DR	4-inch	cast iron	1929	5
4TH ST	6-inch	cast iron	1957	3
HASKELL ST	4-inch	cast iron	1928	3
CRANLEIGH DR	6-inch	cast iron	1951	3
E 4TH ST	8-inch	cast iron	1964	3
HUNTER LAKE DR	12-inch	steel	1954	2
HELENA AVE	8-inch	steel	1948	2

Main Location	Diameter	Material	Year Installed	Number of Leaks
HELVETIA AVE	6-inch	cast iron	1936	3
MILL ST	16-inch	MLS	1962	2
WATT ST	6-inch	steel	1947	4
ROBERTS ST	4-inch	steel	1917	2
FIELD ST	6-inch	steel	1947	2
WILLOW ST	4-inch	cast iron	1929	2
S VIRGINIA ST	4-inch	cast iron	1924	3
ROCK ALLEY	4-inch	cast iron	1930	3
N SIERRA ST	12-inch	cast iron	1949	2
EMERALD PL	6-inch	cast iron	1955	3
WILKINSON AVE	6-inch	cast iron	1950	5
N VIRGINIA ST	14-inch	steel	1959	2
WRIGHT ST	6-inch	steel	1947	2
MONROE ST	24-inch	steel	1948	2
E PRATER WAY	24-inch	coal tar steel	1978	2
CHENEY ST	4-inch	cast iron	1927	2
N CENTER ST	6-inch	steel	1919	2
COLLEGE DR	4-inch	cast iron	1927	3
ROBIN PL	4-inch	cast iron	1953	2
WESLEY DR	6-inch	cast iron	1949	2
TACOMA WAY	4-inch	cast iron	1947	2
WESTGATE RD	6-inch	steel	1947	2
W 11TH ST	6-inch	cast iron	1953	2
S MARSH AVE	6-inch	cast iron	1948	2
WRIGHT ST	6-inch	steel	1947	2
S ARLINGTON AVE	8-inch	cast iron	1932	2
TONOPAH ST	4-inch	cast iron	1928	2
SAINT LAWRENCE AVE	4-inch	cast iron	1929	2
PHILLIPS ST	6-inch	cast iron	1936	2
COLORADO RIVER BLVD	6-inch	cast iron	1946	2
MORRILL AVE	4-inch	cast iron	1929	2
WILDER ST	6-inch	cast iron	1942	2
G ST PARKING LOT	6-inch	cast iron	1952	2
HILLSIDE DR	4-inch	cast iron	1929	2
STANFORD WAY	6-inch	cast iron	1947	2
OXFORD AVE	6-inch	cast iron	1950	2
GENTRY WAY	6-inch	cast iron	1957	2
I ST	6-inch	cast iron	1950	2
MORAN ST	6-inch	cast iron	1931	2
E K ST	6-inch	cast iron	1957	2
J ST	6-inch	cast iron	1951	2
BALZAR CIR	6-inch	cast iron	1946	2
ROBIN ST	6-inch	cast iron	1951	2

Main Location	Diameter	Material	Year Installed	Number of Leaks
TRENTHAM WAY	6-inch	cast iron	1940	2
W PLUMB LN	24-inch	steel	1948	1
PALISADE DR	6-inch	cast iron	1951	2
CANYON DR	6-inch	cast iron	1955	2
BROWN ST	6-inch	cast iron	1949	2
MILL ST	6-inch	cast iron	1952	2
WILLOW ST	4-inch	cast iron	1927	2
CANYON DR	6-inch	cast iron	1950	2
FAIRFIELD AVE	6-inch	cast iron	1955	2
CLOUGH RD	4-inch	steel	1946	2
ROBIN ST	6-inch	cast iron	1950	2
SHARON WAY	24-inch	steel	1948	1
WALKER AVE	6-inch	cast iron	1953	2

Appendix E

Asbestos Cement Mains with Leak History



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TRUCKEE MEADOWS WATER
AUTHORITY
Quality. Delivered.

ASBESTOS CEMENT PIPES with LEAK HISTORY
33% of Recorded Leaks 1989 to 2013

Truckee Meadows Water Authority
Service Area

DATE 06/12/2015

MAP BY: JK

REQUESTED BY: LK

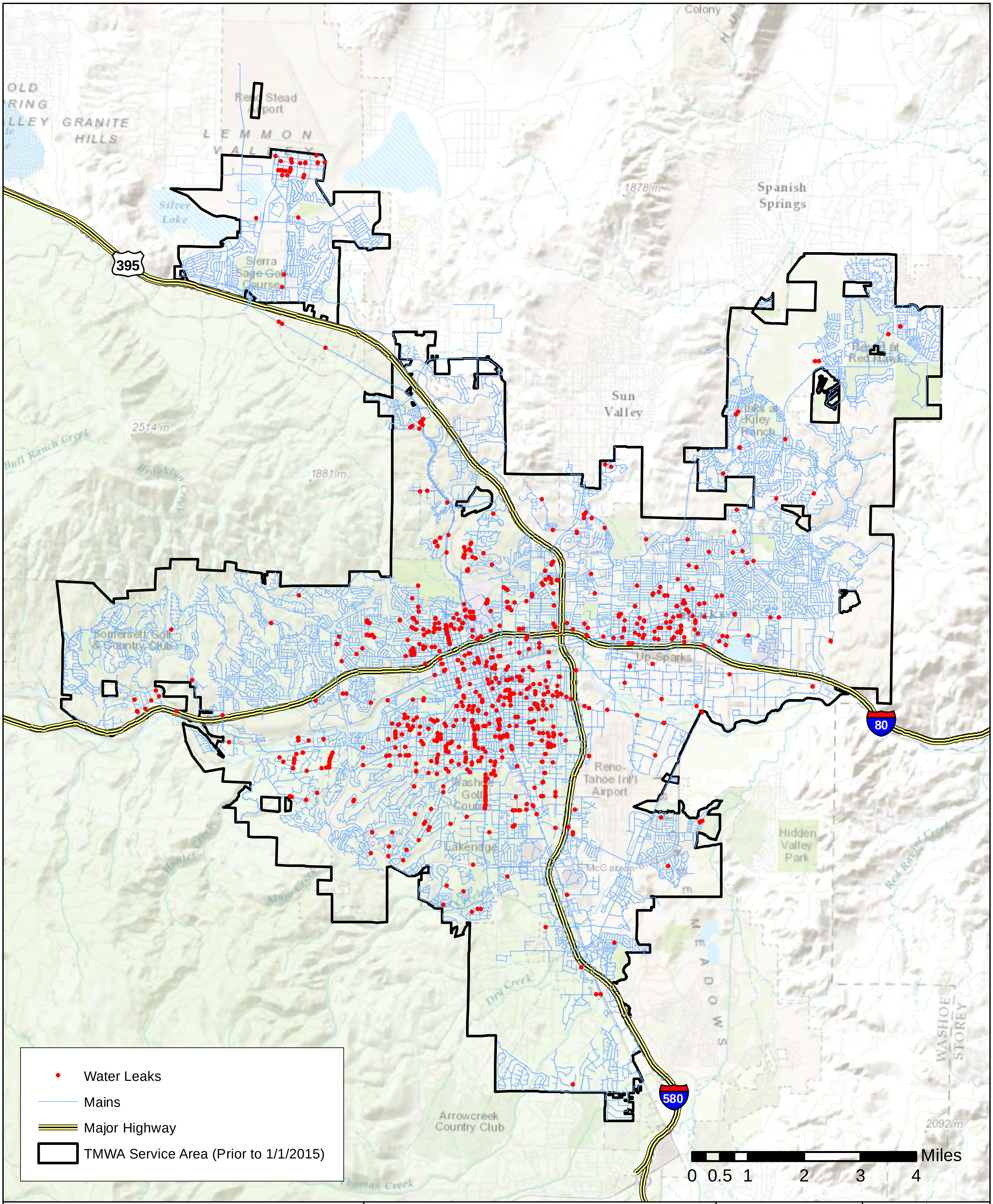
SCALE: 1 in = 2 miles

NORTH

NAD 83 NEVADA STATE
PLANE WEST FEET

Appendix F

Water Main Leaks 1989-2013



TRUCKEE MEADOWS WATER
AUTHORITY
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WATER LEAKS ON MAINS
1989 to 2013

Truckee Meadows Water Authority
Service Area

DATE 06/12/2015

MAP BY: JK

REQUESTED BY: LK

SCALE: 1 in = 2 miles

NORTH

NAD 83 NEVADA STATE
PLANE WEST FEET

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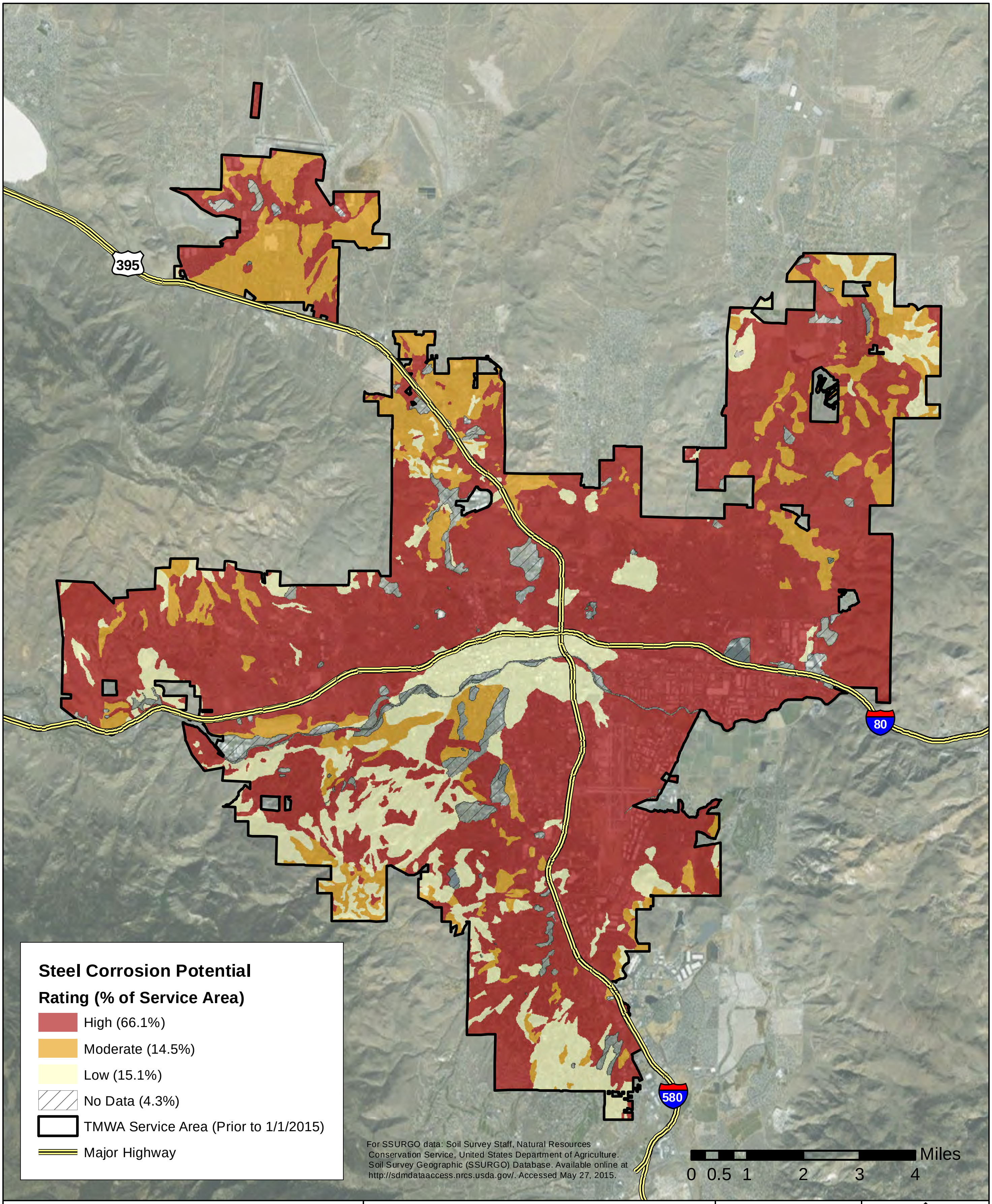
Appendix G

Soil Conditions – Steel and Concrete Corrosion Potential



For SSURGO data: Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database. Available online at http://sdmdataaccess.nrcs.usda.gov/. Accessed May 27, 2015.

W:\projects\Engineering\Main Replacement Project Mapping\SoilsExhibit_8.5x11_2015_TMWA.mxd

TRUCKEE MEADOWS WATER AUTHORITY

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CORROSION OF STEEL

Truckee Meadows Water Authority Service Area

DATE 05/27/2015

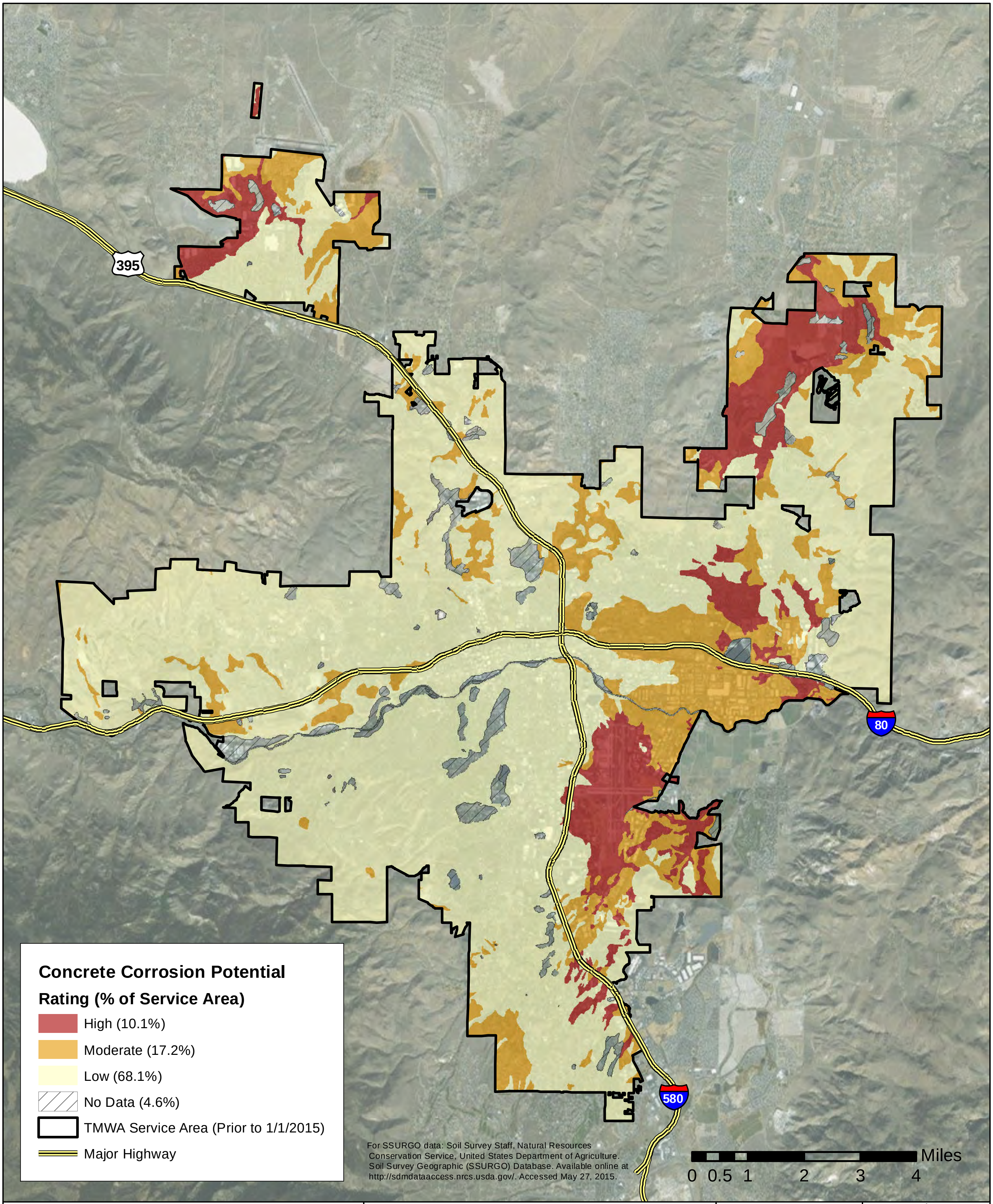
MAP BY: JK

REQUESTED BY: LK

SCALE: 1 in = 2 miles

NORTH

NAD 83 NEVADA STATE PLANE WEST FEET



For SSURGO data: Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database. Available online at http://sdmdataaccess.nrcs.usda.gov/. Accessed May 27, 2015.

TRUCKEE MEADOWS WATER AUTHORITY

Quality. Delivered.

CORROSION OF CONCRETE

Truckee Meadows Water Authority Service Area

DATE 05/27/2015

MAP BY: JK

REQUESTED BY: LK

SCALE: 1 in = 2 miles

NORTH

NAD 83 NEVADA STATE PLANE WEST FEET

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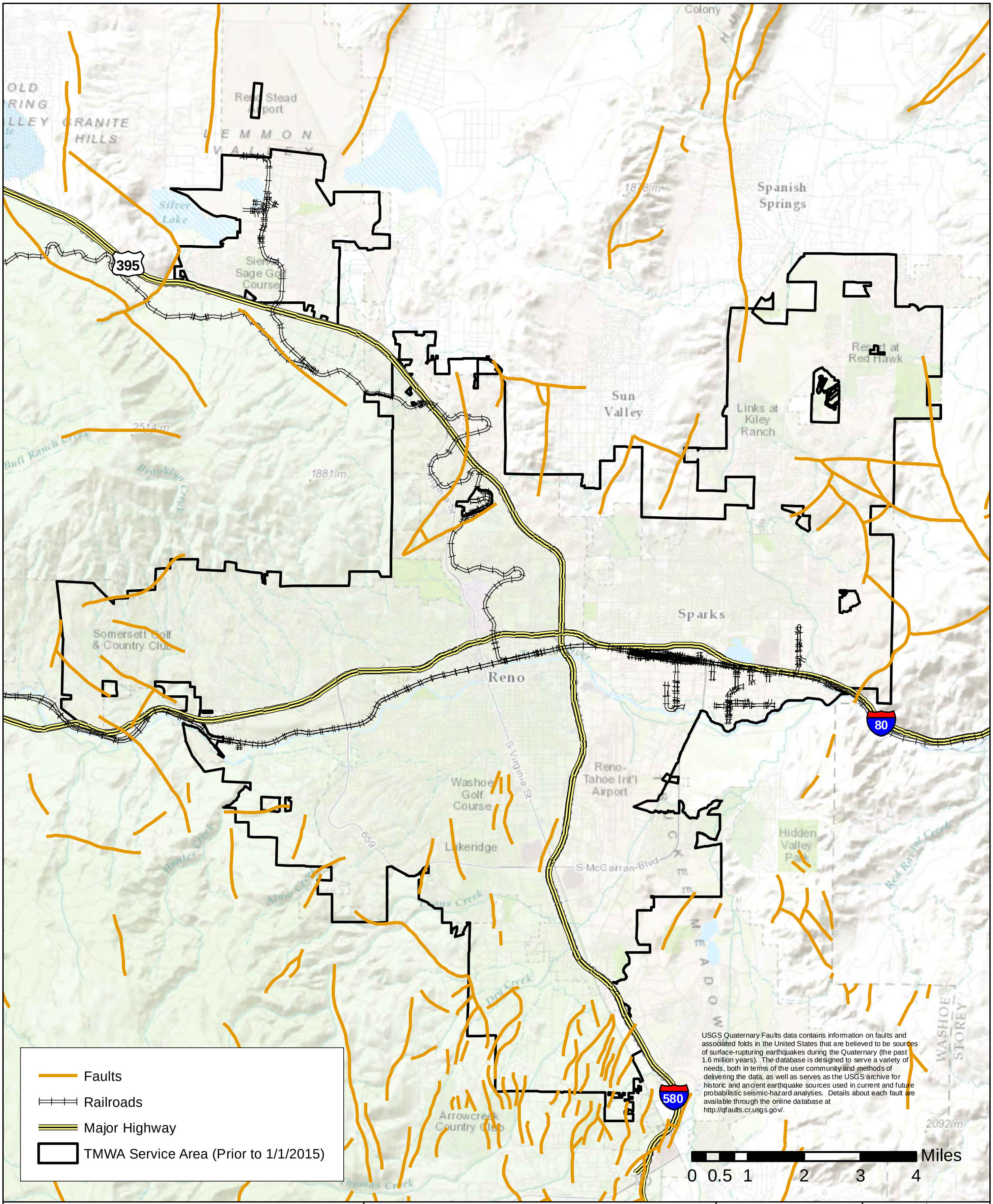
Appendix H

Railroads and Fault Lines in the Truckee Meadows



USGS Quaternary Faults data contains information on faults and associated folds in the United States that are believed to be sources of surface-rupturing earthquakes during the Quaternary (the past 1.6 million years). The database is designed to serve a variety of needs, both in terms of the user community and methods of delivering the data, as well as serves as the USGS archive for historic and ancient earthquake sources used in current and future probabilistic seismic-hazard analyses. Details about each fault are available through the online database at http://qfaults.cr.usgs.gov/.

W:\projects\Engineering\Main Replacement Project Mapping\RR_Faults_Exhibit_8.5x11_2015_TMWA.mxd

TRUCKEE MEADOWS WATER AUTHORITY

Quality. Delivered.

RAILROADS AND FAULT LINES

Truckee Meadows Water Authority Service Area

DATE 06/10/2015

MAP BY: JK

REQUESTED BY: LK

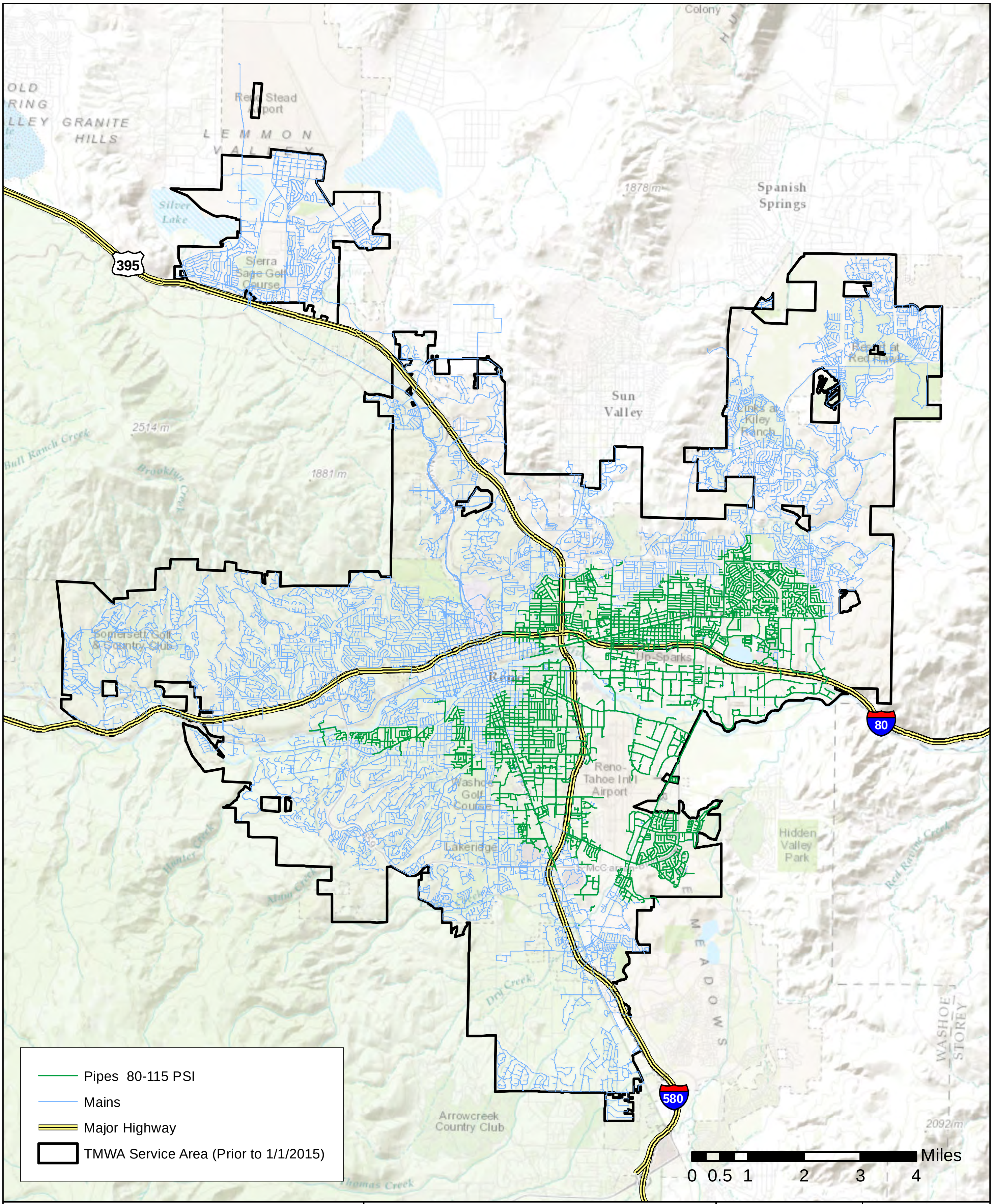
SCALE: 1 in = 2 miles

NORTH

NAD 83 NEVADA STATE PLANE WEST FEET

Appendix I

Static Pressure 80-115 psi



TRUCKEE MEADOWS WATER
AUTHORITY
Quality. Delivered.

STATIC PRESSURE 80-115 PSI

Truckee Meadows Water Authority
Service Area

DATE 06/11/2015

MAP BY: JK

REQUESTED BY: LK

SCALE: 1 in = 2 miles

NORTH

NAD 83 NEVADA STATE PLANE WEST FEET

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Appendix J

Hydraulically Critical Mains

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HOMELAND SECURITY INFORMATION

(NRS 239C.210)

Appendix K

High Volume Users

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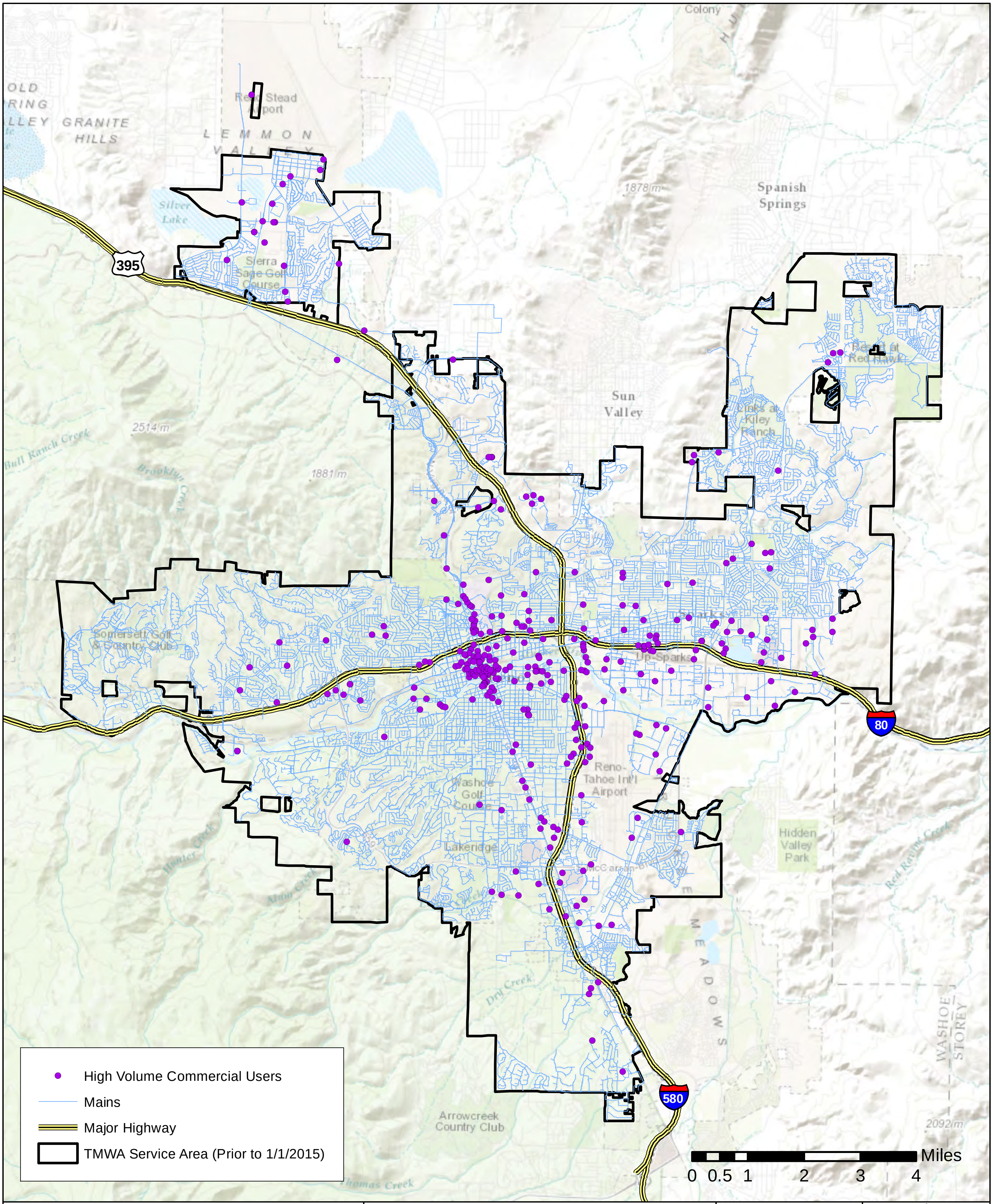
HOMELAND SECURITY INFORMATION

(NRS 239C.210)



● High Volume Commercial Users
Mains
Major Highway
TMWA Service Area (Prior to 1/1/2015)

TRUCKEE MEADOWS WATER AUTHORITY

Quality. Delivered.

HIGH VOLUME COMMERCIAL USERS

Truckee Meadows Water Authority Service Area

DATE 06/12/2015

MAP BY: JK

REQUESTED BY: LK

SCALE: 1 in = 2 miles

NORTH

NAD 83 NEVADA STATE PLANE WEST FEET

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Appendix L

AWWA Buried No Longer Pipe Replacement Modeling Tool Results

Buried No Longer™

Pipe Replacement
MODELING TOOL

- Terms and Conditions
- User Guide
- FAQ
- Buried No Longer Report
- BNL Modeling Tool for Excel 2003
- BNL Modeling Tool for Excel 2007 or later

American Water Works Association

NESSIE MODEL

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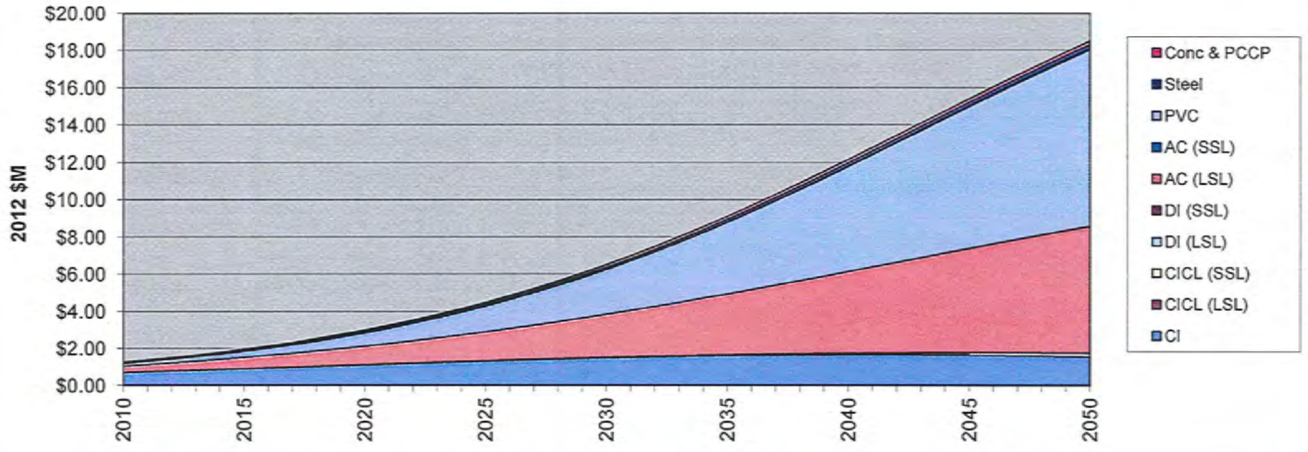
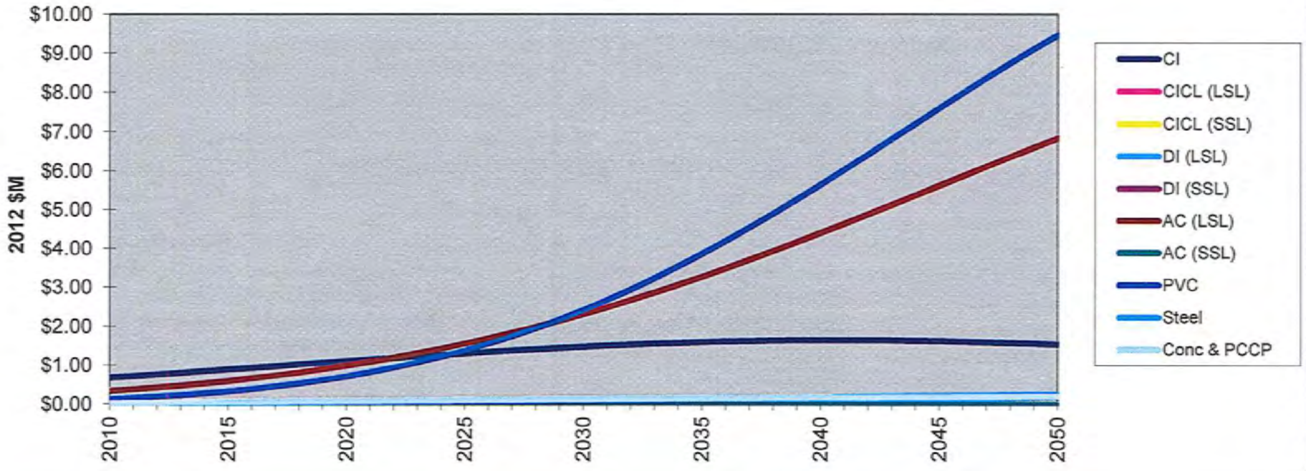
Estimated Replacement Expenditure by Pipe Material



Estimated Replacement Expenditure by Pipe Material: Comparative



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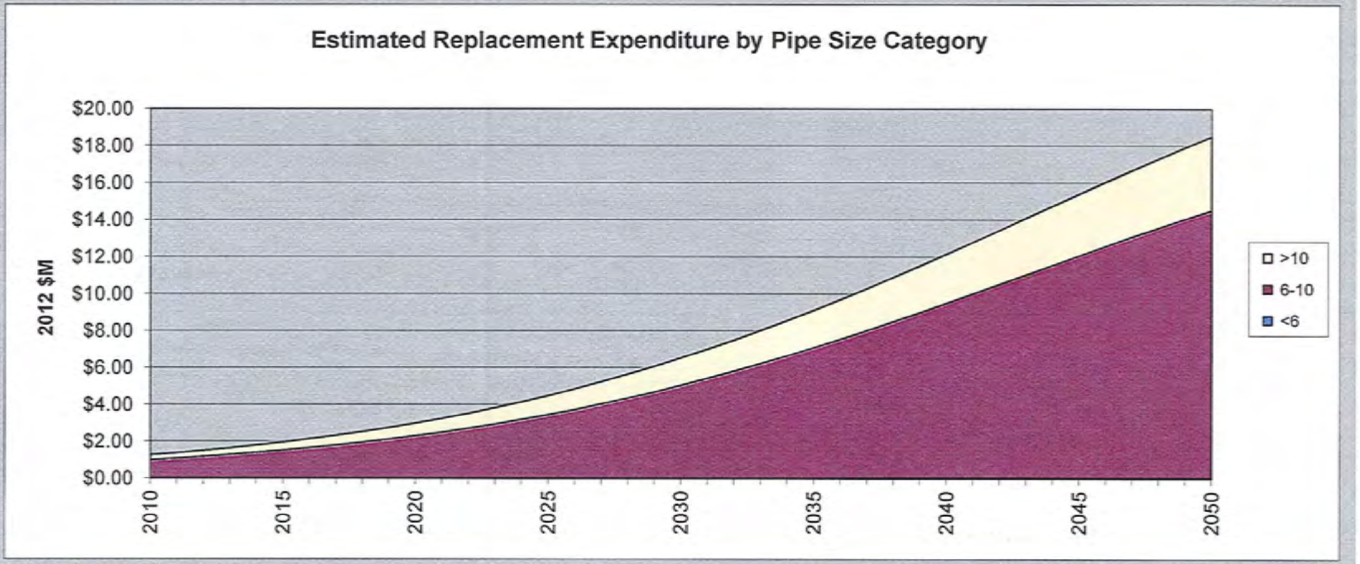
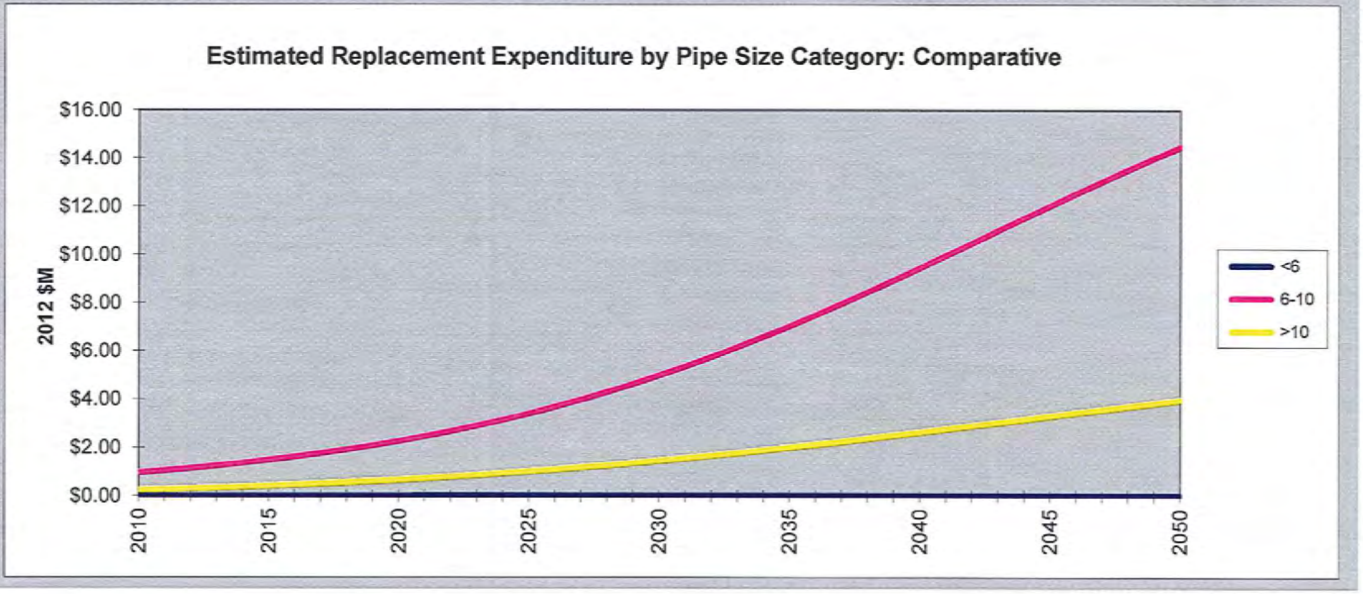


Estimated Replacement Expenditure by Pipe Size Category



Estimated Replacement Expenditure by Pipe Size Category: Comparative

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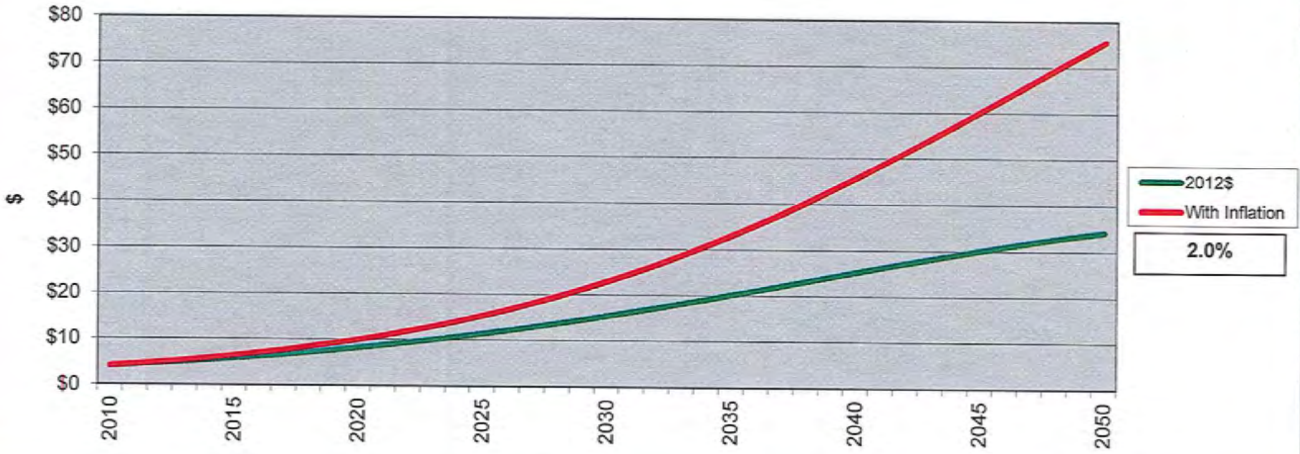
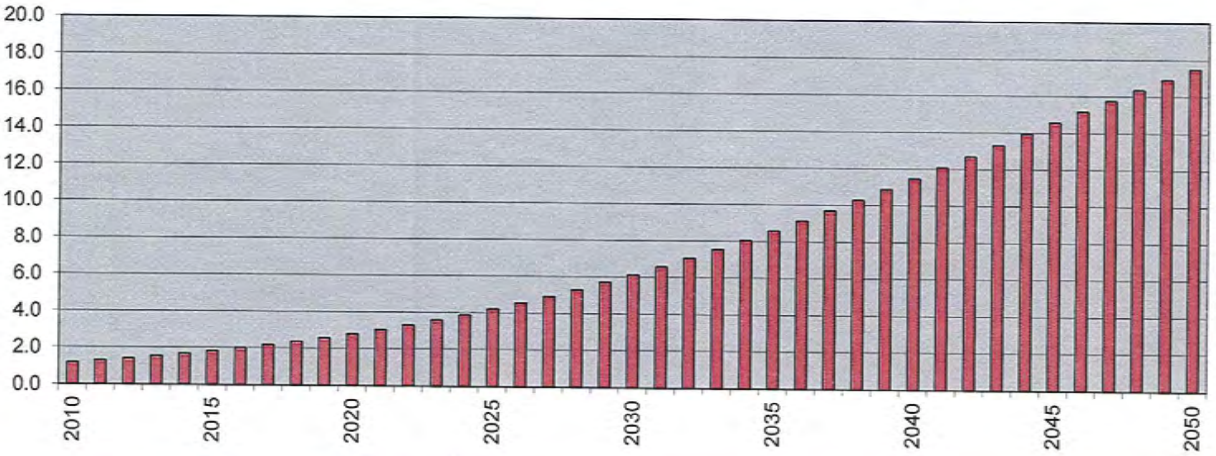
Estimated Replacement Expenditure per Capita of Population Served



Estimated Replacement in Miles per Year



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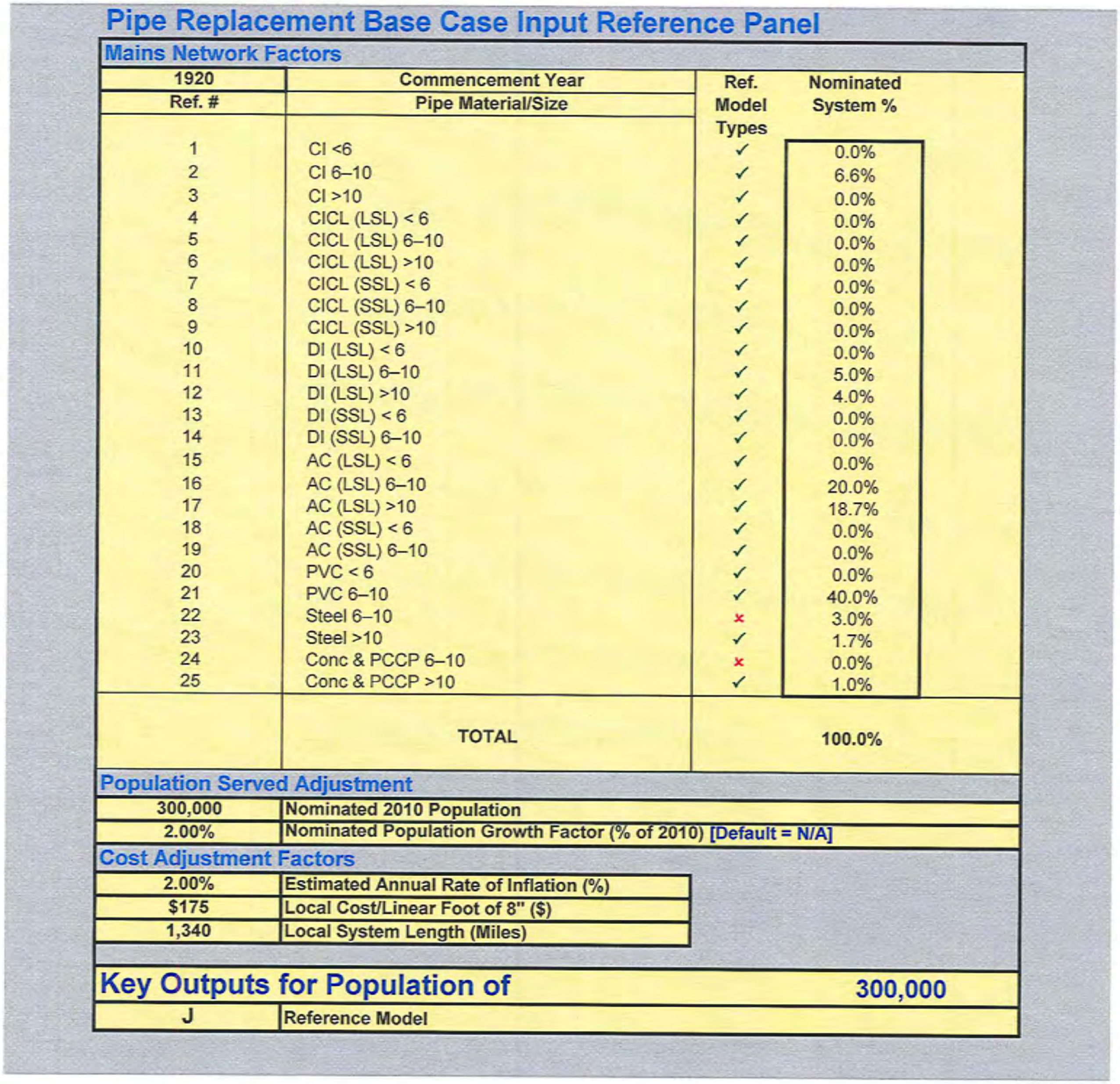

Pipe Replacement Base Case Input Reference Panel

Mains Network Factors

1920	Commencement Year	Ref. Model Types	Nominated System %
Ref. #	Pipe Material/Size		
1	CI <6	✓	0.0%
2	CI 6–10	✓	6.6%
3	CI >10	✓	0.0%
4	CICL (LSL) < 6	✓	0.0%
5	CICL (LSL) 6–10	✓	0.0%
6	CICL (LSL) >10	✓	0.0%
7	CICL (SSL) < 6	✓	0.0%
8	CICL (SSL) 6–10	✓	0.0%
9	CICL (SSL) >10	✓	0.0%
10	DI (LSL) < 6	✓	0.0%
11	DI (LSL) 6–10	✓	5.0%
12	DI (LSL) >10	✓	4.0%
13	DI (SSL) < 6	✓	0.0%
14	DI (SSL) 6–10	✓	0.0%
15	AC (LSL) < 6	✓	0.0%
16	AC (LSL) 6–10	✓	20.0%
17	AC (LSL) >10	✓	18.7%
18	AC (SSL) < 6	✓	0.0%
19	AC (SSL) 6–10	✓	0.0%
20	PVC < 6	✓	0.0%
21	PVC 6–10	✓	40.0%
22	Steel 6–10	✗	3.0%
23	Steel >10	✓	1.7%
24	Conc & PCCP 6–10	✗	0.0%
25	Conc & PCCP >10	✓	1.0%
	TOTAL		100.0%

Population Served Adjustment

300,000	Nominated 2010 Population
2.00%	Nominated Population Growth Factor (% of 2010) [Default = N/A]

Cost Adjustment Factors

2.00%	Estimated Annual Rate of Inflation (%)
$175	Local Cost/Linear Foot of 8" ($)
1,340	Local System Length (Miles)

Key Outputs for Population of 300,000

J	Reference Model

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Glossary

Region/System Size	Code
Northeast Large	A
Northeast Medium & Small	B
Northeast Very Small	C
Midwest Large	D
Midwest Medium & Small	E
Midwest Very Small	F
South Large	G
South Medium & Small	H
South Very Small	I
West Large	J
West Medium & Small	K
West Very Small	L

System Size Category	Population
Large	> 50,000
Medium	10,000 – 50,000
Small	3,300 – 9,999
Very Small	< 3,300

	Pipe Descriptions
AC	Asbestos Cement
CI	Cast Iron
CICL	Cast Iron Concrete Lined
Conc.	Concrete (incl. Reinforced)
DI	Ductile Iron
PCCP	Prestressed Concrete Cylinder Pipe
PVC	Polyvinyl Chloride*
LSL	Long Service Life (Benign operating conditions and/or enhanced laying practices.)
SSL	Short Service Life (Aggressive operating conditions and/or early laying practices.)
Steel	Steel
*Note	"PVC" used as a 'catch-all' for later pipe types such as Glass Reinforced Plastic (GRP) and High Density Polyethylene (HDPE) which are not expected to impact significantly on replacement in the modeling period.

The Charts

Base Case Review Set
The Base Case outcomes illustrate the predicted levels of expenditure required to meet replacement requirements if current utility practices for main replacement are maintained.

Deferral Review Set
The Deferral outcomes illustrate what impact a deferral of a portion of the expenditure (possibly due to financial constraints) would have, with due regard to a subsequent 'catch-up' period for the water mains replacement program.

1. Estimated Replacement Expenditure by Pipe Material
This stacked chart shows the total expenditure expected each year of the modeling period (in constant 2012 $s) subdivided into the expected contribution by each pipe type.

2. Estimated Replacement Expenditure by Pipe Material: Comparative
This chart shows the same information with respect to the projected expenditure for each pipe type as shown in '1' above, but each pipe type is plotted individually.

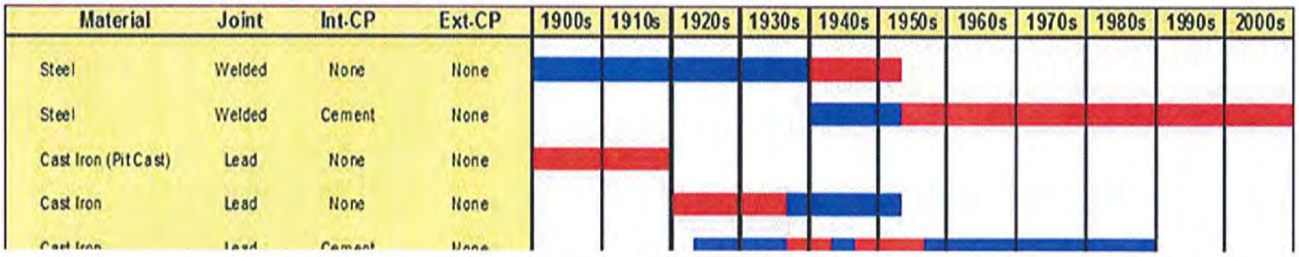
3. Estimated Replacement Expenditure by Pipe Size Category
As per '1' above but subdivided in terms of pipe size categories.

4. Estimated Replacement Expenditure by Pipe Size Category: Comparative
This chart shows the same information with respect to the projected expenditure for each pipe size category as shown in '3' above, but each pipe category is plotted individually.

5. Estimated Replacement Expenditure per Head of Population Served
This chart shows expected per capita expenditure on replacement based on the population served; it should not be interpreted as a direct proxy for changes in household bills, as commercial and industrial sector customers are not taken into account.
The expected outcome is presented both in terms of constant 2010 dollars (as is the case for chart types 1–4 above) and what the actual cost would be in each individual year assuming an average annual inflation rate (selected by the user in the "Input" Tab).

6. Estimated Replacement in Miles per Year
Quantifies the expected asset replacement challenge in terms of miles of pipe to be replaced.

Pipe-Material Installation Eras



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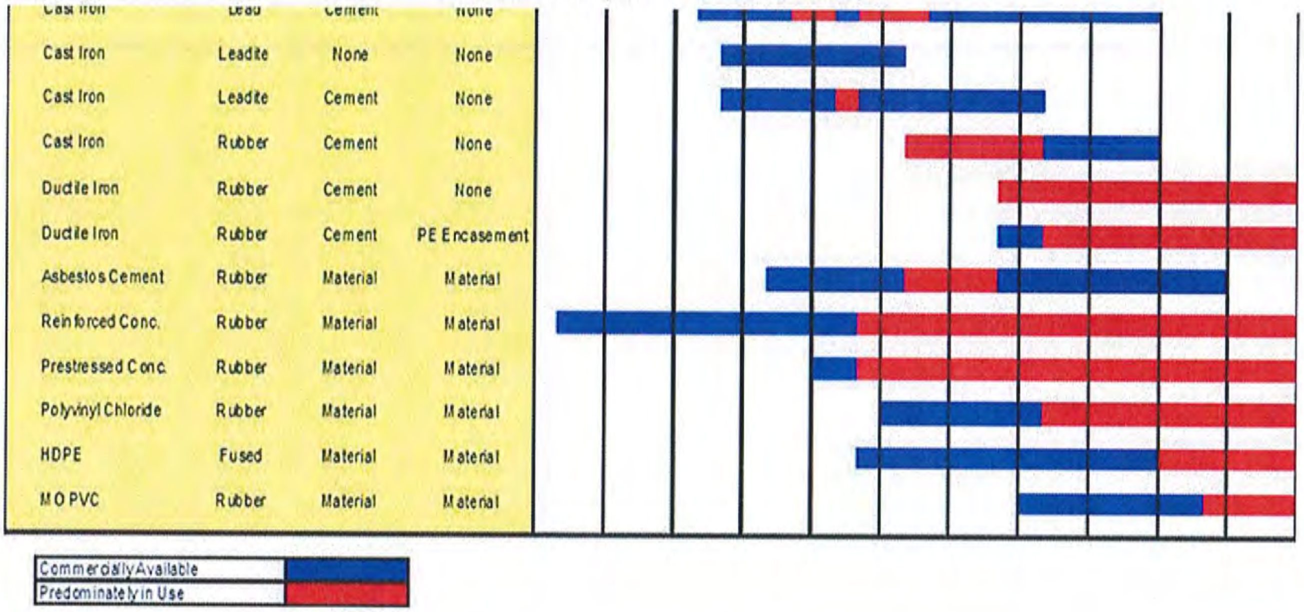

Derived Current Service Lives for Installed Mains

Pipe life estimates are based on pipe quality and maintenance practices between 1870 and 1970, not those of pipes purchased and installed today.

Derived Current Service Lives (Years)	CI	CICL (LSL)	CICL (SSL)	DI (LSL)	DI (SSL)	AC (LSL)	AC (SSL)	PVC	Steel	Conc & PCCP
Northeast Large	130	120	100	110	50	80	80	100	100	100
Midwest Large	125	120	85	110	50	100	85	55	80	105
South Large	110	100	100	105	55	100	80	55	70	105
West Large	115	100	75	110	60	105	75	70	95	75
Northeast Medium & Small	115	120	100	110	55	100	85	100	100	100
Midwest Medium & Small	125	120	85	110	50	70	70	55	80	105
South Medium & Small	105	100	100	105	55	100	80	55	70	105
West Medium & Small	105	100	75	110	60	105	75	70	95	75
Northeast Very Small	115	120	100	120	60	100	85	100	100	100
Midwest Very Small	135	120	85	110	60	80	75	55	80	105
South Very Small	130	110	100	105	55	100	80	55	70	105
West Very Small	130	100	75	110	60	105	65	70	95	75

LSL indicates a relatively long service life for the material resulting from some combination of benign ground conditions and evolved laying practices etc.

SSL indicates a relatively short service life for the material resulting from some combination of harsh ground conditions and early laying practices, etc.

TRUCKEE MEADOWS WATER AUTHORITY

APPENDIX 5-3

FREE TO CHOOSE:

PROMOTING CONSERVATION BY RELAXING OUTDOOR WATERING RESTRICTIONS

Journal of Economic Behavior & Organization xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Journal of Economic Behavior & Organization

journal homepage: www.elsevier.com/locate/jebo

Free to choose: Promoting conservation by relaxing outdoor watering restrictions

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Multi-equation system
Bayesian estimation
Posterior simulation

ABSTRACT

Many water utilities use outdoor watering restrictions based on assigned weekly watering days to promote conservation and delay costly capacity expansions. We find that such policies can lead to unintended consequences – customers who adhere to the prescribed schedule use more water than those following a more flexible irrigation pattern. For our application to residential watering in a high-desert environment, this "rigidity penalty" is robust to an exogenous policy change that allowed an additional watering day per week. Our findings contribute to the growing literature on leakage effects of regulatory policies. In our case inefficiencies arise as policies limit the extent to which agents can temporally re-allocate actions.

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1. Introduction

Water consumption across the globe has tripled in the last 50 years, and is expected to continue to rise rapidly. Water scarcity is expected to be further exacerbated by global warming via prolonged droughts and increasing system losses (Cromwell et al., 2007). The United Nations predicts that by 2030 almost half of the world's population will be living in areas of high water stress (World Water Assessment Programme, 2009) and nearly every region in the United States has experienced drought induced water shortages over the last five to ten years (Environmental Protection Agency, 2008). The sustainable provision of water is thus one of the most critical challenges facing policy-makers in both the U.S. and world at

---

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[1] Part of this research was conducted while Moeltner was a Visiting Scholar at the Luskin Center for Innovation, School of PublicAffairs, University of California, Los Angeles.

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large. Residential households consume close to two thirds of all publicly supplied water in the United States (Environmental Protection Agency, 2002). On average, approximately 15% of residential use is allocated to landscape and lawn irrigation. However, in the arid west and south this proportion can be as large as 30–35%. In total, an estimated seven billion gallons of publicly provided water are allocated for this purpose daily (Environmental Protection Agency, 2008, 2008). Policy makers and water utilities have thus directed considerable efforts to the management of residential outdoor irrigation. In most cases these efforts focus on outdoor watering restrictions (OWRs) that limit the timing, length, and frequency of sprinkler use.[2]

Such OWRs have been implemented in many areas within and outside the United States. As noted in Table A.9 in Appendix A, most of these regimes limit weekly watering to between one and three assigned days determined by street address. Moreover, most of these regimes (see, e.g., San Antonio or the State of Georgia) follow a paradigm whereby the number of assigned days is reduced under progressively severe drought conditions.

To date, economists have primarily focused on two aspects of OWR policies: (i) the overall impact on water demand, and (ii) the welfare effects for residential consumers. For example, Shaw and Maidment (1987) find that a one-per-five days watering restriction reduced overall demand by 3–5% during the 1984–1985 drought years in Austin, Texas. Renwick and Green (2000) examine monthly consumption for eight California water utilities during the 1985–1992 drought period and find that OWRs of a general nature generated an approximate 30% reduction in use. The second set of studies focus on welfare implications of OWRs and other drought-related water use restrictions. Typically, these studies employ non-market valuation techniques to elicit households' willingness-to-pay (WTP) to avoid such restrictions (Griffin and Mjelde, 2000; Hensher et al., 2006), or an increased risk of future restrictions (Howe and Smith, 1994; Griffin and Mjelde, 2000).

Despite the growing importance of OWRs as a Demand-Side Management (DSM) intervention, surprisingly little is known about the relative performance of different OWR implementation strategies. Given that OWRs vary substantially across communities, such omission is particularly noteworthy. This study seeks to fill this gap in the literature. We examine daily consumption data for thousands of customers in the Reno/Sparks area of Northern Nevada during the 2008 and 2010 summer months. This temporal break affords a unique opportunity to examine an exogenous policy change in OWRs that allowed households an added assigned watering day each week during the 2010 watering season.

Our analysis uncovers an unintended consequence associated with the use of assigned watering schedules – weekly water use and peaks are significantly higher during weeks that include all officially assigned watering days compared to weeks with an equal number of watering days but a more flexible pattern of use. These "rigidity penalties" are substantial, amounting to 20–25% of weekly consumption and 30–40% of weekly peaks for the typical customer. Although the 2010 policy change had a noticeable impact on daily peaks, it had no discernible effect on weekly consumption of the associated "rigidity penalties".

Viewed in its totality, our data call into question the efficacy of OWRs that limit watering to assigned days. In this regard, our analysis extends prior work exploring the unintended consequences of policy actions that either introduce heterogeneity in standards across factories or regions (Felder and Rutherford, 1993; Fowlie, 2009) or nested state and federal regulation (McGuinness and Ellermann, 2008; Goulder and Stavins, 2011; Goulder et al., 2012).[3] Whereas the cited work focuses on leakages that arise through the spatial reallocation of actions, our paper highlights that a similar phenomena can arise if policies limit the extent to which agents can *temporally* reallocate actions. In our setting, adherence to the official water schedule requires households to ignore time-varying conditions such as high wind events that reduce the efficiency of irrigation systems.

2. Empirical background and data

Water provision in the Reno/Sparks urban area is managed by the Truckee Meadows Water Authority (TMWA), a non-profit, community-owned public utility. TMWA first implemented OWRs in 1992 in reaction to a prolonged drought. They became permanent in 1996 to guard against future droughts and assure adequate flows of the Truckee River. The watering regulations allow sprinkler use during the morning and evening of assigned days determined by the last digit of a resident's address.[4] Prior to 2010, the policy allowed households two assigned watering days per week. During the 2010 watering season, the OWR was relaxed and allowed a third weekly watering day. These OWRs are only mildly enforced with infrequent water patrols and nominal fines (up to $75) for repeated violations in the same calendar year.

In 2008 TMWA initiated the collection of daily water consumption data for a large, representative sample of customers. Meter readings were obtained via nightly drive-by's using remote sensing devices. Two teams of readers covered the same

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[2] Given the price inelastic nature of water demand, such regulatory interventions are more effective means to influence consumption than price-based policies (Renwick and Green, 2000; Mansur and Olmstead, 2007; Olmstead et al., 2007; Worthington and Hoffman, 2008). Furthermore, there are generally fewer equity concerns and less political resistance to OWRs than to price-based policies (Renwick and Archibald, 1998; Timmins, 2003; Brennan et al., 2007).

[3] Unintended consequences have also been documented in a number of other settings. For example, Davis and Kahn (2010) show that while trade in used vehicles between Mexico and the United States following the passage of NAFTA lowers average vehicle emissions per mile in both countries, aggregate greenhouse gas emissions rise due to lower retirement rates of used cars in Mexico. Bento et al. (2011) show how policy changes in California that allowed single-occupancy, ultra-low emission vehicles access to HOV lanes significantly increased travel times for carpoolers and had no impact on travel times for those in non-HOV lanes.

[4] There are no restrictions on watering via *hand-held* hoses.

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Table 1
Sample sizes for 2008 and 2010.

Intact weeks	2008				2010			
	HHs	%	obs	%	HHs	%	obs	%
5	3567	40.8	17,835	33.9	2084	27.2	10,420	21.5
6	2284	26.1	13,704	26.0	826	10.8	4956	10.2
7	2041	23.3	14,287	27.1	4739	61.9	33,173	68.3
8	855	9.8	6840	13.0	3	0.0	24	0.0
Total	8747	100.0	52,666	100.0	7652	100.0	48,573	100.0

Intact weeks	Overlap[a], 2008				Overlap, 2010			
	HHs	%	obs	%	HHs	%	obs	%
5	679	38.4	3395	31.6	1061	60.1	5305	52.4
6	435	24.6	2610	24.3	121	6.9	726	7.2
7	463	26.2	3241	30.1	584	33.1	4088	40.4
8	189	10.7	1512	14.1	0	0.0	0	0.0
Total	1766	100.0	10,758	100.0	1766	100.0	10,119	100.0

[a] "Overlap" comprises households sampled in both 2008 and 2010.

route for 63 consecutive days between June 22 and August 23, 2008.[5] The same exercise was repeated between June 20 and August 21, 2010 although the routes differed somewhat from the 2008 itineraries due to construction activities.[6]

Overall, we observe approximately 1.9 million daily meter readings from approximately 20,000 unique residential customers. In preparing the final data set, we eliminate premises with ownership changes or multiple ownerships during a given year's research period. We further drop households with a total of 14 or more readings of zero consumption and customers with four or more consecutive zero readings anywhere in the daily series to lower the risk of including non-permanent residences and vacation homes. These cleaning steps truncated the set of eligible residents by approximately 15% for each year.

Given our focus on weekly watering frequencies, only weeks for which we obtain a full set of readings for a given household are usable. Further, to identify a household's watering days and weekly watering patterns, a minimum number of intact weeks (MIW) was required. Yet, to maximize the number of residents present in both sample periods, we had to consider the relationship between the stringency of our MIW criterion and the size of our overlap sample. In balancing these requirements we settle for an MIW threshold of five full weeks of daily readings. After eliminating a few isolated cases with obvious water leaks or missing information on basic building characteristics we generate a final sample that includes 52,666 weekly observations from 8747 residents for 2008 and 48,573 observations from 7652 unique residents for 2010. Of these households, 1766 appear in both the 2008 and 2010 samples and comprise our "overlap" sample. Table 1 shows the distribution of intact weeks for both the full and overlap samples by year.

The top half of Table 2 depicts basic household characteristics for the two full samples. The 2010 sample comprises, on average, slightly smaller and older properties. There is also a 44% decline in average tax-assessed property value from 2008 to 2010 reflecting the severe economic downturn in Nevada over the sample period.

We combine our household data with the following basic climate indicators: average, minimum, and maximum daily temperature (in degF), average wind speed (over 24 hourly measurements, in knots), and maximum sustained wind speed (in knots, measured for ten minutes every hour). As is common in arid high-dessert climates, there were no noteworthy rainfall events during our sampling periods. Climate statistics are shown in the bottom half of Table 2. Although the summer of 2010 was slightly cooler than the summer of 2008, the wind statistics are very similar for the two sampling periods.

3. Identification of policy effects

3.1. Definition of treatments

We aim at identifying the impact of two design features of the Truckee Meadows OWRs on weekly water use and peak (maximum daily consumption in a given week)[7]: (i) the total number of permissible watering days per week and (ii) the

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[5] The readings were obtained between the hours of 9pm and 3am. According to TMWA, the vast majority of households complete watering by 9pm.

[6] Drivers were instructed to proceed no slower than the posted speed limit to assure adequate spatial coverage. While this resulted in a large number of customers being included in the sample, it also generated some missing readings due to parked vehicles or other obstacles preventing a clean line-of-sight. Therefore, a completely uninterrupted series of readings is available only for a small subset of the sample.

[7] System-wide consumption peaks are important to utilities as they are closely related to the cost of water provision. Specifically, lower peak demand can be satisfied via stored water, distributed by gravity. Storage units can then be replenished at night at lower pumping costs. In contrast, high peak use

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Table 2
Household and climate characteristics.

	2008				2010			
	Mean	Std.	Min.	Max.	Mean	Std.	Min.	Max.
Age	20.9	17.6	1.0	104.0	23.1	16.4	2.0	106.0
Lot size (1000 sqft)	10.1	7.0	0.0	49.7	7.6	3.3	0.0	48.8
Sqft (1000s)	2.0	0.8	0.5	15.2	1.8	0.6	0.5	7.7
Value ($10,000s)	270.5	160.2	69.4	2637.4	150.7	65.6	33.8	762.8
Fixtures	12.0	3.4	0.0	64.0	11.1	2.8	0.0	27.0
Bedrms	3.3	0.9	0.0	23.0	3.2	0.7	0.0	8.0
Bathrms.	2.4	0.7	0.0	16.0	2.2	0.6	0.0	6.0
Avg. temp (F)	77.9	3.3	69.4	84.2	75.8	4.7	61.7	85.4
Min. temp	59.9	3.5	53.1	66.0	58.9	4.8	44.6	69.1
Max. temp	95.7	3.0	89.1	102.0	92.8	5.2	78.8	102.2
Avg. wind (knots)	5.2	1.4	2.8	9.3	5.7	1.3	2.5	8.3
Max. wind	16.2	4.2	7.0	29.9	16.8	4.2	8.9	32.1
Max. gust	23.3	4.1	15.0	30.9	24.5	5.0	14.0	37.9

"pinning" of the allowable number of days to specific days of the week (say, Wednesday, Saturday), versus letting households choose their watering days in a more flexible fashion.

For the former objective, we hypothesize that granting more watering days will induce a more even distribution of weekly irrigation, and thus reduce weekly peaks for the typical household. In addition, this smoother distribution, by reducing the gap between permitted days, may curb losses due to runoff and evaporation, as households are less likely to over-soak their lawn on assigned days.

For the latter objective, we separate weekly watering patterns into three categories: (i) "Schedule" (*S*), (ii) "Schedule-plus" (*SP*), and (iii) "Off-schedule" (*OS*). The first group comprises weeks with watering patterns that correspond *exactly* to the assigned TMWA schedule. The second category describes weeks that include *all assigned days*, plus some additional ("illegal") days of outdoor use. The third group exhibits the most varied weekly watering patterns, with the common feature of *non*-watering on at least one of the assigned days. For ease of exposition we will at times combine the first two groups under the heading "Schedule-based" (SB). Thus, $S \cup SP = SB$, and $SB \cup OS =$ entire sample. This centers the analytical focus squarely on the degree to which the official schedule influences or "guides" irrigation patterns.

We hypothesize that *S* types are nudged inadvertently towards wasteful behavior for two main reasons: First, they face the "large gaps" problem mentioned above, which can lead to over-watering and corresponding losses to runoff and evaporation. Second, adherence to the official schedule requires that such households ignore time-varying natural conditions such as (common) high wind events that can further exacerbate irrigation inefficiency. Both effects are likely to increase weekly consumption and, especially, weekly peaks.

In comparison, *SP* types may be less prone to over-watering, as they distribute weekly irrigation over more-than-permitted days, but may still experience wind losses in their persistence to incorporate the assigned days. In contrast, we surmise that *OS* types pay the least attention to the official schedule, and more attention to their yard's actual water needs and/or random fluctuations in weather conditions. This makes them the most disobedient, but perhaps also the most efficient TMWA customers.

In summary, we set forth to explore whether compliance with Reno's OWR policy introduces unintended consequences that compromise conversation aims. We will henceforth refer to water losses induced by the day-of-week assignment as "*rigidity effect*".

3.2. Identification strategy

We have exogenous variation in the number of permitted watering days – the policy change from two to three assigned days between 2008 and 2010. Ideally, we would have also been able to exogenously randomize the flexibility with which a household can allocate these days over the course of a week, i.e. assignment to *S*, *SP*, and *OS* categories. Unfortunately, such exogenous policy variation did not occur during our research period.

Instead, we rely upon an alternate strategy for identification – other exogenous shocks that sort a given household into one type or other in an given week. Conditional on the existence of such shocks we can then exploit both cross-sectional and within household variation in weekly watering patterns to estimate the rigidity effect. This is because there are relatively few customers that follow the same weekly irrigation strategy (*S*, *SP*, or *OS*) for the entire observation period. Most households display a mixed pattern of weekly irrigation, both in terms of frequency and timing. Therefore, identification can draw on both within and between household variation.

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forces daytime pumping, when electricity costs are highest. If this occurs frequently, the utility may have to undergo costly capacity expansions for water storage. Therefore, a utility generally tries to implement water use policies that reduce daily peaks at the household level.

The challenge at hand is thus to (i) identify plausible exogenous drivers that induce customers to change watering patterns, and (ii) convincingly rule out confounding effects that could drive both weekly watering patterns and outcomes of interest, i.e. weekly use and peak.

With respect to exogenous factors we provide some evidence in the empirical section that *SB* versus *OS* choices are likely driven by randomly fluctuating daily wind patterns. Specifically, a given household may want to avoid wind-induced water losses – a common problem in this rain shadow/foothill location – by transferring watering events from a windy day to the next calm day. For the Reno/Sparks case this usually means foregoing the evening application and instead watering on the next (potentially unassigned) day. *Inter*-household differences in "wind awareness" or ability to flexibly manipulate irrigation systems then drives much of the observed cross-household variation in adherence to the official schedule. Naturally, some customers may also be intrinsically more reluctant to break the official rules, and may require "stronger wind shocks" to transfer watering to an off-day. This would add additional cross-sectional variation in observed behavior.

In addition, there may be *intra*-household, time-varying differences in the daily ability to react to the threat of irrigation losses due to wind. For example, the entire household or the person in charge of the irrigation system may not be at home or unavailable on a given day to adjust the system. Similarly, on a given day the household may anticipate being unable to irrigate the next morning, and thus be reluctant to skip that day's evening application despite windy conditions. This would explain intra-household variations in the observed weekly irrigation patterns.

Regarding potentially confounding effects, our econometric specification controls for unobserved, invariant household effects, as well as weekly climate conditions. Therefore, the main concern in this respect would be confounding effects that vary both over time and across households. Most notably, one might surmise that whenever a household anticipates a week with high water need, it may switch to a more conservative watering pattern consistent with official regulations to lower the risk of fines. This would confound any causal link between the degree of adherence to the official schedule and water use. This conjecture builds on two underlying assumptions: (i) Households' weekly irrigation needs change from week to week in a heterogeneous fashion and (ii) households care about enforcement and fines. We argue that neither one is very likely.

To start, the most plausible reason that could drive a sudden need to use more water in a given week for *irrigation* purposes would be an extreme climate event, such as the anticipation of a very hot or dry week. Perhaps some households are more vulnerable to such extreme events than others, given vegetation cover, soil quality, and other landscape-related features. However, as is evident from Table 2 the local climate during our summer research period is uniformly hot and dry. There is not a single day of precipitation, and the daily temperature range is quiet narrow. The only variation comes through *daily* and rather random wind patterns, and those cannot be anticipated on a weekly basis. Thus, it is rather unlikely that any given customer experiences pronounced changes in weekly irrigation *demand* over our research period.

In addition, it is equally unlikely that the threat of a penalty would induce customers to switch from a flexible to a compliant weekly pattern, even if such heterogeneous, time-varying changes in water need existed. As stated above, the enforcement of the official watering schedule is very lenient, and fines are nominal. A household receives two warnings for blatant violations before a fine of $75 is issued. Thus, it is rather unlikely that the threat of low fine, collected with low probability, is sufficient to induce a change in behavior, irrespective of weekly water need.

Appendix B provides further evidence against this "comply if anticipated use is high" hypothesis. In summary, we feel confident to proceed with our analysis even in absence of an ideal setting with exogenous policy variation for all treatments of interest.

4. Descriptive analysis

4.1. Classification of weekly irrigation patterns

Establishing a link between consumption and weekly watering patterns requires the identification of outdoor watering events for a given household and day. Specifically, our objective is to sort the daily observations for each household into two categories: (i) days with some outdoor water use and (ii) days with indoor-only water use.

This categorization is challenging since we only observe total daily use rather than usage for different purposes. Ideally, outdoor watering days should be clearly identifiable as pronounced spikes in a customer's series of observed consumption days. However, the distinction between categories becomes blurred for households with limited need for outdoor watering or high fluctuations in indoor use. We therefore use a series of household-specific *K*-means clustering algorithms (MacQueen, 1967) to sort daily observations into a low use ("indoor only") and high use ("indoor plus some outdoor watering") category. The details of this identification strategy are given in Appendix B.

4.2. Descriptive results

Our analysis of OWR design effects requires aggregating the daily sample to a weekly format. Table 3 provides a summary of cell counts and sample percentages for the different week-type categories and watering frequencies. For ease of exposition

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Table 3
Cell counts and percentages by watering frequency and week-type.

Weekly watering days	2008			2010		
	Count	% of sample	% all w/in	Count	% of sample	% all w/in
Schedule-based						
2[a]	14,497	27.5	42.8	–	–	–
3[b]	6374	12.1	9.2	12,625	26.0	35.1
4	5595	10.6	16.1	3650	7.5	3.3
>4	6053	11.5	11.6	6001	12.4	15.7
Total	32,519	61.7	25.8	22,276	45.9	24.7
Off-schedule						
0	2924	5.6	0.0	2822	5.8	0.0
1	4198	8.0	1.6	3979	8.2	0.9
2	4795	9.1	5.5	8004	16.5	9.9
3	4257	8.1	7.4	6256	12.9	8.4
4	2610	5.0	6.1	3518	7.2	7.4
>4	1363	2.6	6.5	1718	3.5	2.5
Total	20,147	38.3	4.4	26,297	54.1	6.3
All						
0	2924	5.6	0.0	2822	5.8	0.0
1	4198	8.0	1.6	3979	8.2	0.9
2	19,292	36.6	35.5	8004	16.5	9.9
3	10,631	20.2	9.0	18,881	38.9	28.9
4	8205	15.6	13.2	7168	14.8	5.4
>4	7416	14.1	10.8	7719	15.9	12.9
Total	52,666	100.0	18.5	48,573	100.0	15.8

[a] "Schedule" group for 2008.
[b] "Schedule" group for 2010.

we combine *S* and *SP* weeks into the broader *SB* category, as defined above.[8] The sparsely populated weekly frequencies of five and higher are captured as a single ">4" category. The first half of the table shows results for 2008, while the second provides summaries for 2010. The table has three blocks of rows, corresponding to *SB* weeks, *OS* weeks, and the combined sample. The "percent of sample" column relates row counts to the entire sample size for each year. For example, *SB* weeks with twice watering (i.e. the *S* group by our definition above) comprise 27.5% of the entire 2008 sample. Overall, watering patterns that are perfectly compliant with the official schedule comprise the largest sample share and account for just over a quarter of all sample weeks.

The "percent all within" column reports the percentage share for a given row count that corresponds to households that have *all* their observations in that very category. For example, approximately 42.8% of the observations in the *S* category for 2008 come from households that *always* water twice and on their assigned days. Yet, the majority of customers exhibit seasonal water patterns that include a mix of different week-types and frequencies – only 18.5% of sample weeks in 2008 and 15.5% in 2010 are associated with customers that always water with the same weekly frequency. This is important for our analysis below as it suggests that the observed differences in use and peaks between SB and OS *week*-types are *not* driven by unobserved household characteristics.

Table 4 depicts weekly use and peak by frequency and week-type. We stress three key results captured by this table. First, regardless of watering pattern, consumption increases with weekly frequency. This is consistent with prior work showing that capping weekly watering frequency reduces total use. Second, peaks remain relatively stable across frequencies in the two to four applications range. Third – and most importantly – weekly consumption and peaks are substantially higher for weeks that include all assigned days ("schedule-based") compared to weeks *of identical frequency* with more flexible watering patterns ("off-schedule"). In 2008, these differences amount to 30–40% for weekly consumption and 50–60% for weekly peak. In 2010 these differentials are slightly attenuated amounting to 25–30% for use and 24–26% for peak.[9]

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[8] We stress that our classification into different watering patterns applies to a given *household-week*, not a specific *household* across the entire research period. As discussed in the next section, the majority of households switches frequently between weekly watering patterns. Therefore, there does not exist a clear and systematic classification at the household level that distinguishes along this key dimension of decreasing schedule-adherence. However, we do control for observable and unobservable household characteristics in our econometric specification.

[9] The patterns captured in Tables 3 and 4 are qualitatively similar for the overlap sample. Consumption is approximately 25–35% higher for the *SB* group than the *OS* group at all frequencies. Similarly, *SB* peaks exceed*OS* peaks by 45–55%. Summary statistics for the overlap sample are available from the authors upon request.

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Table 4
Weekly use and peak by watering frequency and week-type.

Weekly watering days	Weekly use (1000 gals.)				Weekly peak (1000 gals.)			
	2008		2010		2008		2010	
	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.
	Schedule-based				*Schedule-based*			
2	5.84	(3.67)	–	–	2.34	(1.68)	–	–
3	6.72	(4.56)	5.39	(2.44)	2.30	(1.85)	1.65	(0.83)
4	7.24	(5.04)	5.95	(2.89)	2.19	(1.86)	1.67	(0.96)
>4	9.83	(7.73)	7.32	(4.41)	2.43	(2.26)	1.70	(1.14)
Total	6.99	(5.26)	6.00	(3.26)	2.32	(1.86)	1.66	(0.95)
	Off-schedule				*Off-schedule*			
0	2.44	(2.20)	2.03	(1.52)	0.55	(0.48)	0.46	(0.34)
1	3.38	(2.61)	2.73	(1.85)	1.30	(1.29)	1.04	(0.94)
2	4.20	(3.20)	3.82	(2.23)	1.46	(1.39)	1.37	(0.98)
3	4.80	(3.61)	4.32	(2.58)	1.42	(1.28)	1.31	(0.95)
4	5.52	(4.64)	4.75	(3.00)	1.47	(1.47)	1.31	(1.04)
>4	6.99	(5.80)	5.65	(4.53)	1.67	(1.63)	1.37	(1.24)
Total	4.26	(3.71)	3.83	(2.71)	1.30	(1.32)	1.20	(0.99)
	All				*All*			
0	2.44	(2.20)	2.03	(1.52)	0.55	(0.48)	0.46	(0.34)
1	3.38	(2.61)	2.73	(1.85)	1.30	(1.29)	1.04	(0.94)
2	5.43	(3.63)	3.82	(2.23)	2.12	(1.65)	1.37	(0.98)
3	5.95	(4.31)	5.03	(2.54)	1.95	(1.70)	1.53	(0.89)
4	6.69	(4.98)	5.36	(3.01)	1.96	(1.78)	1.49	(1.01)
>4	9.31	(7.50)	6.95	(4.49)	2.29	(2.18)	1.63	(1.17)
Total	5.95	(4.91)	4.82	(3.17)	1.93	(1.75)	1.41	(1.00)

5. Econometric framework

To examine if these descriptive results hold up when controlling for climate variations, household characteristics, and unobserved household effects we now turn to our econometric analysis. We assume that over the course of a week a given household makes daily choices on watering occurrence and total use, given watering. From the analyst's perspective these choices will be observed as joint weekly outcomes on frequency, use, and peak. We thus define such an *observed* weekly irrigation scheme (IR) by household i in period p as a bundle of frequency y_{1ip} (zero to seven), total use y_{2ip}, weekly peak y_{3ip}, and schedule-based pattern (SB vs. OS), i.e.

$$IR_{ip} = IR(y_{1ip}, y_{2ip}, y_{3ip}, SB_{ip}), \quad i = 1, \ldots, N, \; p = 1, \ldots, P \tag{1}$$

where SB_{ip} is an indicator equal to one if the weekly irrigation pattern corresponds to a schedule-based implementation, and equal to zero for an off-schedule pattern.

Thus, we have three outcomes of interest – y_{1ip}, y_{2ip}, and y_{3ip}. The first outcome, the number of watering days in a given week, takes the form of an integer that is naturally truncated from above at $U = 7$. The remaining outcomes, weekly consumption and peak, are continuous with support over $\mathfrak{R}^+$. We wish to identify the effect of weekly watering frequency and degree-of-adherence to the OWR on use and peak. If household decisions on use and peak were completely independent from decisions related to weekly frequency, the three outcomes of interest could, in theory, be analyzed via independent estimation. For example, the use and peak equations could be estimated via simple random effects (RE) regression that includes difference-in-difference type interaction terms to capture the incremental effects of weekly frequency, irrigation pattern (SB vs. OS) and policy change (2008 vs. 2010).

However, if the frequency equation shares common unobservables with either or both of the use or peak equation, such naïve independent analysis would produce misleading results, as the right-hand-side variable "frequency" would introduce endogeneity problems. We find this to indeed be the case in comparative estimation runs.[10] Thus, a plausible econometric model for this application must accommodate the following key features: (i) limitations on the natural range of the dependent variable, (ii) household-specific effects to control for unobserved heterogeneity, and (iii) an ex-ante unrestricted covariance matrix for these unobserved effects, i.e. full correlation of all three equations. To incorporate these modeling challenges in a computationally tractable fashion we deviate from a standard linear regression framework and classical estimation, and turn instead to a hierarchical system approach, estimated via Bayesian tools.

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[10] The results for these RE regressions and a discussion thereof are provided in Appendix E.

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As point of departure, we combine a truncated Poisson density for the watering frequency equation with two exponential densities for weekly consumption and peak [see e.g. Munkin and Trivedi, 2003].[11] Adding the household effects yields our full specification, which we label the Hierarchical Truncated Poisson–Exponential (HTPE) model. The Hierarchical Truncated Poisson (HTP) component of the HTPE is given as

$$\begin{aligned} &f(y_{1ip}|\lambda_{1ip}, 0 \le y_{1ip} \le U) = \frac{\exp(-\lambda_{1ip})\lambda_{1ip}^{y_{1ip}}}{y_{1ip}!(\sum_{k=0}^{U}\lambda_{1ip}{}^{k}/k!)} \quad \text{with} \\ &E(y_{1ip}) = \lambda_{1ip} = \exp(\mathbf{x}_{1ip}{}'\boldsymbol{\beta}_1 + u_{1i}) \end{aligned} \tag{2}$$

where the log of the untruncated expectation, λ_{1ip}, is a linear function of vector $\mathbf{x}_{ip}$ containing household and climate variables, and individual-specific effect u_{1i}.[12]

The Hierarchical Exponential (HE) part is specified as

$$\begin{aligned} &f(y_{jip}|\lambda_{jip}) = \lambda_{jip} \times \exp(-\lambda_{jip}y_{jip}) \\ &\lambda_{jip} = \exp(-\mathbf{z}_{jip}{}'\boldsymbol{\psi}_j - \mathbf{d}_{ip}{}'\boldsymbol{\delta}_j - u_{ji}) \\ &E(y_{jip}) = \lambda_{jip}^{-1} = \exp(\mathbf{z}_{jip}{}'\boldsymbol{\psi}_j + \mathbf{d}_{ip}{}'\boldsymbol{\delta}_j + u_{ji}), \quad j = 2, 3 \end{aligned} \tag{3}$$

where the **z**-vectors capture again household and climate information, the random terms are as in (2) and E denotes the expectation operator. Importantly, vector $\mathbf{d}_{ip}$ comprises a set of U indicator variables, one for each possible value of y_{1ip} that exceeds zero. The element of $\mathbf{d}_{ip}$ corresponding to the observed value of y_{1ip} is set to one, all others to zero. More concisely:

$$d_{ip,k} = \begin{cases} 1 & \text{if } y_{1ip} = k, \\ 0 & \text{otherwise} \end{cases} \quad k = 1, \ldots, U \tag{4}$$

Thus, we are allowing the intercept of the logged expectation of y_{jip}, $j = 2, 3$, to shift with the observed number of watering days compared to the implicit baseline of zero outdoor watering. This implies a proportional change of $exp(\mathbf{d}_{ip}{}'\boldsymbol{\delta}_j)$ for the expectation in absolute terms.

The model is completed by stipulating a joint density for the household effect:

$$\mathbf{u}_i = u_{i1} \quad u_{i2} \quad u_{i3}{}' \sim mvn(\mathbf{0}, \mathbf{V}_u) \tag{5}$$

where mvn denotes the multivariate normal density, and the variance matrix is ex ante unrestricted. As mentioned above, if this matrix contains non-zero covariances, a naïve model ignoring the linkage across the three equations would be plagued by endogeneity bias, since the frequency indicator $\mathbf{d}_{ip}$ appears on the right hand side of both the use and peak equation.[13]

Letting $\boldsymbol{\beta}_2 = [\boldsymbol{\psi}_2{}' \quad \boldsymbol{\delta}_2{}']{}'$, $\boldsymbol{\beta}_3 = [\boldsymbol{\psi}_3{}' \quad \boldsymbol{\delta}_3{}']{}'$, $\boldsymbol{\beta} = [\boldsymbol{\beta}_1{}' \quad \boldsymbol{\beta}_2{}' \quad \boldsymbol{\beta}_3{}']{}'$, and collecting all outcomes and explanatory data in vector **y** and matrix **X**, respectively, the likelihood function for our model over all individuals $i = 1, \ldots, N$, unconditional on error terms, takes the following form:

$$p(\mathbf{y}|\boldsymbol{\beta}, \mathbf{V}_u, \mathbf{X}) = \prod_{i=1}^{N} \int_{\mathbf{u}_i} \left(\prod_{p=1}^{P} \left(\frac{\lambda_{1ip}^{y_{1ip}}}{y_{1ip}!(\sum_{k=0}^{U}\lambda_{1ip}{}^{k}/k!)} \lambda_{2ip}\lambda_{3ip} \exp(-(\lambda_{2ip}y_{2ip} + \lambda_{3ip}y_{3ip})) \right) \right) f(\mathbf{u}_i|\mathbf{V}_u)d\mathbf{u}_i \tag{6}$$

Given the N multi-dimensional integrals over $\mathbf{u}_i$ this model would be challenging to estimate using conventional Maximum Likelihood procedures. We therefore employ a Bayesian estimation framework.

We begin by specifying the prior distribution for the primary model parameters, $\boldsymbol{\beta}$ and $\mathbf{V}_u$. We choose a standard multivariate normal prior for $\boldsymbol{\beta}$, and inverse Wishart (IW) priors for $\mathbf{V}_u$, i.e. $\boldsymbol{\beta} \sim mvn(\boldsymbol{\mu}_0, \mathbf{V}_0)$, $\mathbf{V}_u \sim IW(\psi_0, \boldsymbol{\Psi}_0)$. The IW parameters are the degrees of freedom and scale matrix, respectively. The IW density is parameterized such that $E(\mathbf{V}_u) = (\psi_0 - k_r - 1)^{-1}\boldsymbol{\Psi}_0$. We facilitate the implementation of our posterior simulator (Gibbs Sampler) by augmenting the model with draws of the error components $\{\mathbf{u}_i\}_{i=1}^{N}$.[14] The augmented posterior distribution is proportional to the priors times the augmented likelihood, i.e.

$$p(\boldsymbol{\beta}, \mathbf{V}_u, \{\mathbf{u}_i\}_{i=1}^{N}, |\mathbf{y}, \mathbf{X}) \propto p(\boldsymbol{\beta}) \times p(\mathbf{V}_u) \times p(\{\mathbf{u}_i\}_{i=1}^{N}||\mathbf{V}_u) \times p(\mathbf{y}|\boldsymbol{\beta}, \{\mathrm{u}_i\}_{i=1}^{N}, \mathbf{X}) \tag{7}$$

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[11] The exponential component has similar distributional characteristics as the familiar log-normal regression model, but exhibits more desirable mixing properties in our Bayesian estimation framework.

[12] It should be noted that the restrictive mean–variance equality that is a prominent feature of the standard Poisson density no longer holds under truncation (e.g. Rider, 1953). A second reason for the mean–variance equality to break down is the inclusion of the random household effect. See, for example Hausman et al. (1984).

[13] We also included an observation-specific error in an earlier specification. The parameter estimates generated by that model were virtually identical to those produced by the single-error specification, and both variances and covariances associated with the observational error emerged of negligible magnitude compared to the variance component for the individual-level effect.

[14] The data augmentation step circumvents the need to directly evaluate the integrals in (6). A general discussion of the merits of this technique of data augmentation is given in Tanner and Wong (1987). Applications with data augmentation involving hierarchical count data models include Chib et al. (1998) and Munkin and Trivedi (2003).

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Table 5
Estimation results for frequency equation and error terms.

	Mean	Std.	Prob(>0)
Constant	−4.415	(0.519)	0.000
mintemp	−0.050	(0.050)	0.161
maxtemp	0.151	(0.048)	0.999
avgwind	−0.988	(0.281)	0.000
maxwind	0.407	(0.134)	1.000
gdd	0.022	(0.012)	0.958
lnland	0.087	(0.007)	1.000
lnvalue	0.237	(0.010)	1.000
year2010	4.129	(0.731)	1.000
mintemp × 2010	−0.198	(0.064)	0.001
maxtemp × 2010	−0.395	(0.086)	0.000
avgwind × 2010	0.760	(0.295)	0.997
maxwind × 2010	−0.281	(0.139)	0.019
gdd × 2010	0.061	(0.019)	0.999
Std.'s and corr.'s for $\mathbf{u}_i$			
σ_1	0.434	0.004	1.000
ρ_{12}	0.056	0.014	1.000
σ_2	0.477	0.005	1.000
ρ_{13}	−0.005	0.014	0.364
ρ_{23}	0.985	0.001	1.000
σ_3	0.527	0.005	1.000

Mean = posterior mean; std. = posterior standard deviation; prob(>0) = share of posterior density to the right of zero.

where the last term describes the likelihood function conditioned on all error terms.

The Gibbs Sampler draws consecutively and repeatedly from the conditional posterior distributions $p(\boldsymbol{\beta}|\{\mathbf{u}_i\}_{i=1}^N, \mathbf{y}, \mathbf{X})$, $p(\mathbf{V}_u|\{\mathbf{u}_i\}_{i=1}^N)$, and $p(\{\mathbf{u}_i\}_{i=1}^N|\boldsymbol{\beta}, \mathbf{V}_u, \mathbf{y}, \mathbf{X})$. Draws of $\boldsymbol{\beta}$ and $\{\mathbf{u}_i\}_{i=1}^N$ require Metropolis–Hastings (MH) subroutines in the Gibbs Sampler. Posterior inference is based on the marginals of the joint posterior distribution.[15]

6. Estimation results

6.1. Posterior results

The regressors in the parameterized expectation of the frequency equation include a combination of home characteristics and climatic variables to control for temperature and wind speed, in addition to an indicator for the 2010 irrigation season and the interaction of this indicator with the various climate variables. The parameterized mean functions for use and peak include additional home characteristics that control for indoor water use and exclude some of the climate variables for identification purpose. These equations also feature indicators for weekly watering frequency, the interaction of these terms with indicators for the 2010 watering season and schedule based weekly watering patterns, and the two-fold interaction of the schedule based and 2010 indicators with both our frequency variables and different wind measures.[16]

We estimate all models using the following vague but proper parameter settings for our priors: $\boldsymbol{\mu}_0 = 0$, $\mathbf{V}_0 = 100 \times I_k$, $\psi_0 = 5$, and $\boldsymbol{\Psi}_0 = I_3$. We discard the first 20,000 draws generated by the Gibbs Sampler as "burn-ins", and retain the following 10,000 draws for posterior inference. We assess convergence of the posterior simulator using Geweke's (1992) convergence diagnostics (CD). These scores clearly indicate convergence for all parameters. To gauge the degree of serial correlation in our Markov chains we also compute autocorrelation coefficients at different lags for all model parameters. These AC values drop below 0.25 by the 10th lag for most parameters, and by the 20th lag for all model elements. This indicates that our posterior simulator has reasonably efficient mixing properties.

The posterior results for the frequency equation are shown in Table 5. The table also captures the results for the elements of the error variance matrix $\boldsymbol{\Sigma}$, expressed as standard deviations and correlations. For each parameter we report posterior means, posterior standard deviations, and the probability mass of a given marginal posterior that lies above the zero-threshold. The effects of our various climatic controls are as expected. For example, the frequency of weekly watering events is higher on weeks with higher maximum daily temperatures and lower on weeks with higher average daily wind speeds. Interesting, however, the effect of such controls are attenuated for the 2010 season. Taken jointly, our data thus suggest that climate conditions have a more pronounced effect on the variability of watering frequency when the official OWR ceiling is lower.

Turning to the elements of $\boldsymbol{\Sigma}$ in the lower half of Table 5, we note that with exception of ρ_{13} all terms are estimated with high precision (i.e. exhibit low posterior standard deviation relative to the mean). The standard deviations (labeled σ_j, $j = 1$,

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[15] The detailed steps of the posterior simulator and the Matlab code to implement this model are available from the authors upon request.

[16] Details on household and climate regressors are provided in Appendix D.

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Table 6
Estimation results for use and peak equations.

	Weekly use			Weekly peak		
	Mean	Std.	Prob(>0)	Mean	Std.	Prob(>0)
Constant	−10.766	(0.773)	0.000	−12.706	(0.766)	0.000
freq1	0.392	(0.025)	1.000	0.883	(0.026)	1.000
freq2	0.584	(0.025)	1.000	0.980	(0.026)	1.000
freq3	0.720	(0.026)	1.000	0.989	(0.027)	1.000
freq4	0.821	(0.029)	1.000	0.992	(0.031)	1.000
freq567	0.967	(0.036)	1.000	1.048	(0.036)	1.000
SB × freq2	0.208	(0.066)	1.000	0.379	(0.068)	1.000
SB × freq3	0.197	(0.066)	0.999	0.334	(0.068)	1.000
SB × freq4	0.179	(0.068)	0.995	0.307	(0.071)	1.000
SB × freq567	0.200	(0.071)	0.999	0.233	(0.072)	0.999
year2010	0.185	(0.740)	0.593	−0.178	(0.730)	0.403
freq1 × 2010	−0.010	(0.036)	0.393	−0.009	(0.036)	0.385
freq2 × 2010	0.034	(0.035)	0.837	0.073	(0.035)	0.978
freq3 × 2010	0.045	(0.036)	0.895	0.071	(0.036)	0.977
freq4 × 2010	0.053	(0.041)	0.901	0.092	(0.041)	0.990
freq567 × 2010	0.038	(0.049)	0.786	0.064	(0.048)	0.909
SB × freq3 × 2010	−0.052	(0.144)	0.361	−0.257	(0.147)	0.039
SB × freq4 × 2010	−0.049	(0.146)	0.357	−0.244	(0.150)	0.049
SB × freq567 × 2010	−0.041	(0.147)	0.395	−0.200	(0.151)	0.088

Results for household and climate variables are omitted for brevity, but are given in Appendix D. Mean = posterior mean; Std. = posterior standard deviation; Prob(>0) = share of posterior density to the right of zero.

. . ., 3) are of non-negligible magnitude, which confirms the presence of unobserved household effects in all three equations. Household unobservables are highly correlated for equations two and three, and we find a mild, positive correlation between the frequency and the use equations.[17]

Posterior results for the weekly use and peak equations are summarized in Table 6. Regarding weekly use, the table captures three main results. First, consumption increases clearly with weekly frequency. Furthermore, this result remains essentially unchanged in 2010. Second, weeks associated with schedule-based (*SB*) watering exhibit increased use compared to the implicit off-schedule (*OS*) baseline at *any* frequency. These rigidity penalties amount to 20–23%, and are highest for weeks that follow the official schedule exactly.[18] Third, controlling for frequency and watering pattern, the residual policy effect is of negligible magnitude.

The results for weekly peak are given in the last three columns of the table. In contrast to use, peaks do not change much over frequency in either year. However, as for use, peaks are substantially larger for *SB*-type weeks compared to *OS*-type patterns in 2008, and this difference is greater at lower frequency levels. This gap diminishes in 2010, as peaks for *SB*-type implementations decrease by 18–23% compared to the 2008 season, and peaks for *OS*-types increase slightly (by 6–9%). The reduction in the "rigidity penalty" for peaks in 2010 compared to 2008 likely reflects the additional flexibility afforded to compliant customers by the revised OWRs. Schedule-adherent households now have more options to reduce daily watering on windy days and are less likely to face the dilemma of incurring wind losses or violating official rules by making up for a skipped application on non-assigned days.

However, we also acknowledge that to some extent this reduction in rigidity gap, especially via increased peaks for *OS*-types, might be an artifact of our classification scheme: Some 2010 customers may have been sluggish to adjust to the new schedule. As a result, the "rigid" weeks produced by these residents, classified as *SB* in 2008, are counted as *OS*-types in 2010.[19] As such, our estimates can be interpreted an upper bound on the effect of the policy change on the rigidity penalty for peak use.

The remaining findings for the peak model mirror those from the weekly use equation: namely, there are no noteworthy residual policy effects. Overall, we conclude that the results produced by our complete econometric specification support the descriptive findings from the preceding section.

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[17] As illustrated in the Appendix E, this linkage via unobservables between equations one and two is sufficient to produce inconsistent parameter estimates for both use and peak models if the system is estimated via independent random effects regressions.

[18] We use the conversion formula of $\exp(\beta) - 1$ suggested by Halvorsen and Palmquist (1980) to interpret marginal effects associated with binary variables, given the log-normal form of the parameterized mean function.

[19] Recall that every *SB* designated week must include outdoor use on *all* assigned days. Hence, any 2008 schedule-adherent household who fails to adjust to the new OWRs by watering on the third allowable day and switching to the new assigned week-days during 2010 would produce *OS*-type weeks for that year – even if there was no change in the actual watering pattern relative to the 2008 season.

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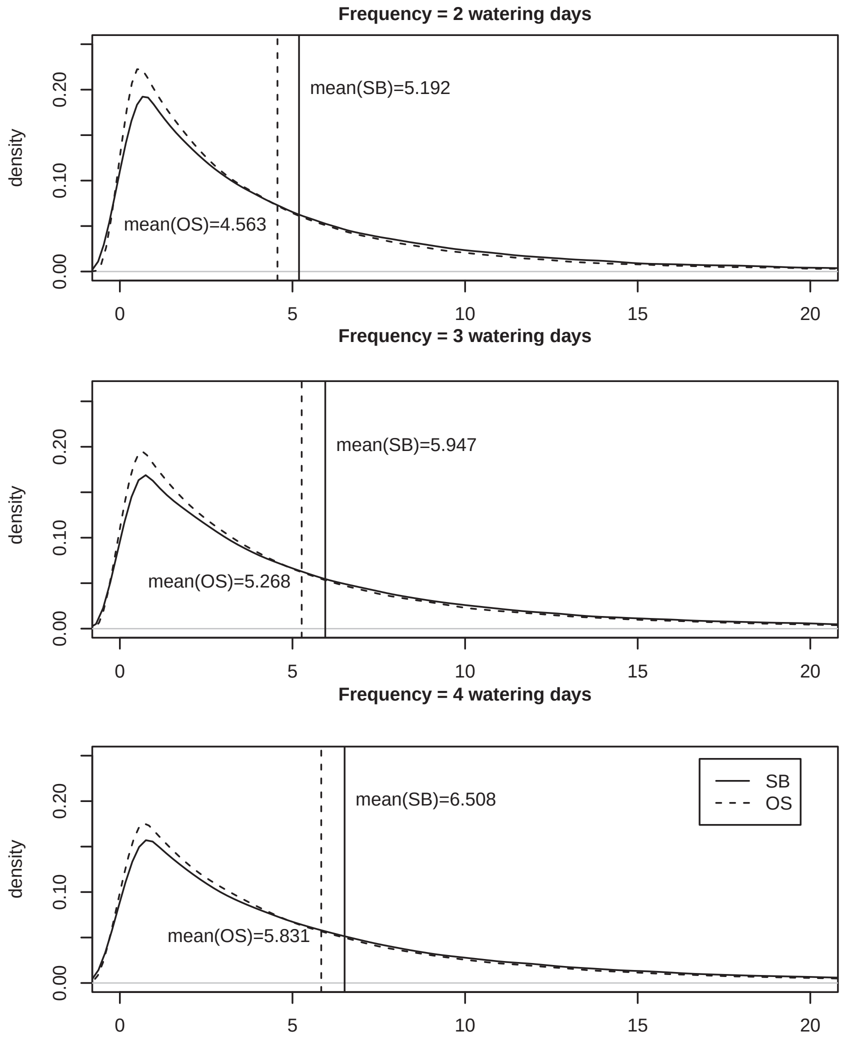

Fig. 1. Predictive distributions of weekly use for a typical household (1000 gallons).

6.2. Predictive analysis

For a more direct comparison of weekly consumption and peak across weeks with different watering patterns we generate posterior predictive densities (PPDs) for each irrigation type (*SB* vs. *OS*). Formally, these PPDs are given as

$$p(y_j|\mathbf{x}_{\mathrm{tf}}) = \int_{\boldsymbol{\theta}} \left(\int_{u_{ij}} ((y_j|\mathbf{x}_{\mathrm{tf}}, \boldsymbol{\beta}, u_{ji}) f(u_{ji}|\mathbf{V}_u)) du_{ij} \right)) p(\boldsymbol{\theta}|\mathbf{y}, \mathbf{X}) d\boldsymbol{\theta}, \quad j = 2, 3, \tag{8}$$

where $\mathbf{x}_{\mathrm{tf}}$ denotes a specific combination of watering pattern $t \in \{SB, OS\}$ and frequency $f \in \{2, 3, 4\}$, and vector $\boldsymbol{\theta}$ comprises the entire set of model parameters. In practice, we simulate these PPDs by (i) drawing 10 random coefficients from $f(u_{ji}|\mathbf{V}_u)$), (ii) computing λ_{ij} for each u_{ij} as given in (2), and (iii) drawing y_j from the exponential density with expectation λ_{ij}. We repeat steps (ii) and (iii) for all 10 draws of u_{ij}, and steps (i) through (iv) for all 10,000 draws of $\boldsymbol{\theta}$ from the original Gibbs Sampler.

Except for the combination $t = SB, f = 2$, which is only meaningful for 2008, we derive separate PPDs for $y_j|\mathbf{x}_{\mathrm{tf}}$ for 2008 and 2010 by setting the 2010 indicator and interaction terms accordingly in the covariate matrix for the use and peak equations. We combine these year-specific PPDs for final analysis as there is discernible difference in watering behavior across these years once we control for climatic and household specific variables. The latter are set to their grand sample means for this predictive analysis.

The resulting PPDs are depicted in Fig. 1 for use and Fig. 2 for peak. Each subplot shows PPDs for *SB* and *OS* types for a given frequency. Posterior predictive expectations are superimposed as vertical lines and labeled with their respective numerical value (in 1000 gallons). As is evident from Fig. 1, the *SB* pattern produces higher expected use than the *OS* pattern

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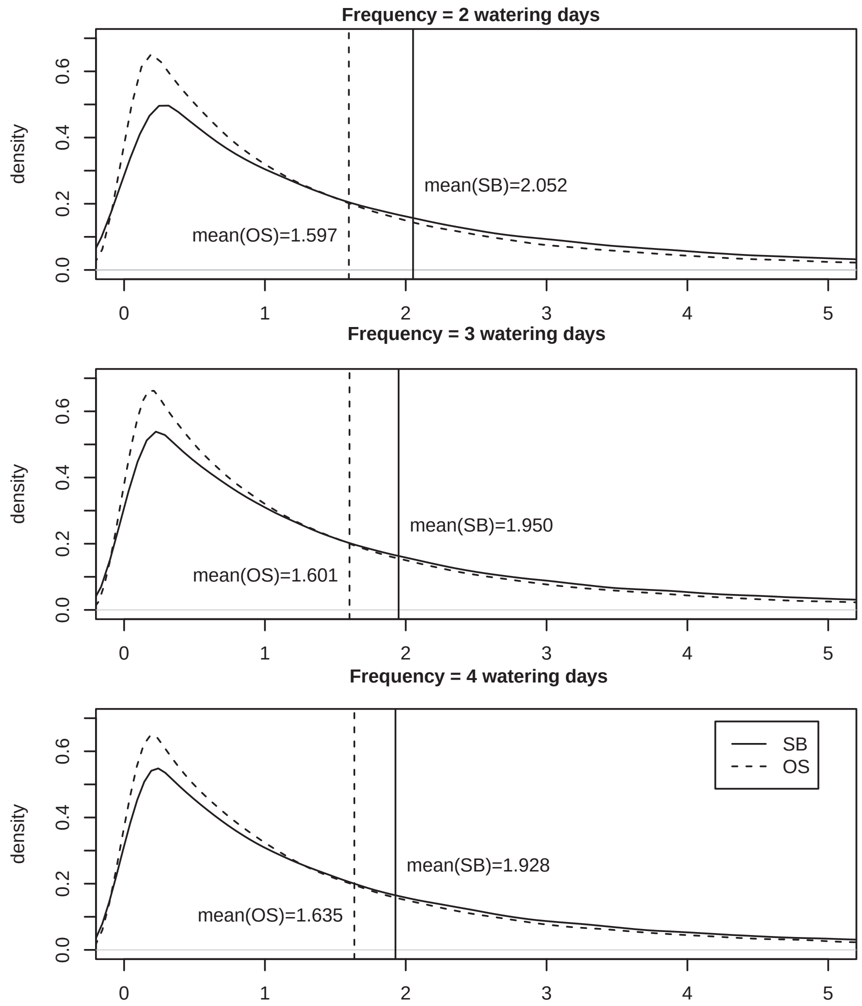
Frequency = 2 watering days

Frequency = 3 watering days

Frequency = 4 watering days

Fig. 2. Predictive distributions of weekly peak for a typical household (1000 gallons).

at all frequencies, with a slightly decreasing relative gap from 14% at $f = 2 - 12\,\%$ at $f = 4$. As shown in Fig. 2 these differences in posterior predictive expectation are even more pronounced for peak. At two watering days, the *SB* pattern generates a peak that is approximately 28% higher than the *OS* peak. At three watering days, this difference reduces to 22%, and at a frequency of four it amounts to close to 18%. Overall, these predictive results support our descriptive and analytical findings – a watering pattern that closely follows the officially assigned days produces noticeably higher weekly consumption and substantially higher peaks than a more flexible distribution of *the same number of watering days* across a given week.

7. The wind effect

As mentioned at the onset, we believe that the assignment of household-weeks into different watering patterns is largely driven by exogenous shocks in the form of high wind events. Specifically, some customers switch to more flexible irrigation patterns to avoid wind-induced water losses. Conversely, households that follow the assigned schedule are more likely to water under adverse natural conditions such as high wind events. This increases both use and peak, as it takes more water per week and per daily application to provide adequate irrigation for a given landscape.

To explore this conjecture in greater detail, we compute the percentage of watering days that fall on either a windy or very windy day.[20] The results are captured in Table 7. In 2008 the average watering day had a 51% chance of occurring on a windy day and an 18% chance of coinciding with a very windy day. Importantly, these percentages are higher for the *SB* group compared to the *OS* segment at essentially all frequencies. In 2008, this difference is especially pronounced for the

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[20] "Windy days" are those with a maximum sustained wind speed that exceeds the sample mean (16.51 knots). "Very windy" days are defined as those with a maximum sustained wind speed at the 75th percentile (19 knots) or higher.

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Table 7
Wind events by watering frequency and week type.

Weekly watering days	2008		2010		All	
	% windy	% very windy	%windy	% very windy	%windy	% very windy
Schedule-based						
2	57.02	21.40	–	–	57.02	21.40
3	52.32	19.50	48.82	18.09	50.00	18.57
4	52.21	19.37	48.58	17.66	50.78	18.69
>4	46.75	15.29	47.09	17.34	46.92	16.32
Total	51.71	18.58	48.08	17.72	50.06	18.19
Off-schedule						
2	50.68	19.08	47.73	18.38	48.83	18.65
3	48.65	16.60	46.94	17.67	47.63	17.24
4	49.51	17.18	46.99	17.25	48.07	17.22
>4	47.40	15.14	46.58	16.42	46.94	15.85
Total	49.14	17.09	47.11	17.57	47.94	17.37
All						
2	55.44	20.82	47.73	18.38	53.18	20.11
3	50.85	18.34	48.20	17.95	49.15	18.09
4	51.35	18.67	47.80	17.46	49.70	18.11
>4	46.86	15.27	46.99	17.16	46.93	16.23
Total	51.00	18.17	47.70	17.66	49.35	17.91

Table 8
Random effects probit estimation of daily watering decision (translated into marginal effects).

2008				2010			
	Coeff.	s.e.	*z*		Coeff.	s.e.	*z*
	Weekly frequ. = 2 (n = 135,044)						
Windy	0.074	0.004	17.870				
Windy × SB	0.049	0.004	12.070				
Avg. temp.	0.011	0.000	25.190				
	Weekly frequ. = 3 (n = 74,417)				*Weekly frequ. = 3 (n = 132,167)*		
Windy	0.033	0.005	6.290	Windy	0.003	0.004	0.670
Windy × SB	0.053	0.005	9.900	Windy × SB	0.013	0.004	3.030
Avg. temp.	0.005	0.001	8.380	avg. temp.	0.001	0.000	2.730
	Weekly frequ. = 4 (n = 57,435)				*Weekly frequ. = 4 (n = 50,176)*		
Windy	0.055	0.006	8.510	Windy	0.000	0.006	0.070
Windy × SB	0.053	0.006	8.430	Windy× SB	0.016	0.006	2.470
Avg. temp.	0.009	0.001	12.310	avg. temp.	0.001	0.000	1.450

S category – the share of windy days exceeds the correponding value for *OS*/twice a week by over 6%. In general, *SB* type weeks were 3–6% more likely to occur on a windy day and 2–3% more likely to fall on a very windy day than *OS* type weeks of comparable frequency. In 2010, which had slightly fewer windy days overall compared to 2008, the difference in the relative frequency of wind events across week-types reduces to 1–2% for windy days and falls below the 1% mark for very windy days. However, as for 2008, the *S* category experiences the highest risk of wind exposure.

To provide more rigorous support for this “wind hypothesis” we estimate a Probit models of *daily* watering decision on average daily temperature (F), an indicator for “windy day” (with max. sustained speed exceeding the sample mean of 16 knots), an interaction term for “windy” and “SB”, and a random household effect. We estimate separate models for the two sample years, and weekly frequencies of 2, 3, and 4 watering days.

The results are captured in Table 8. For ease of interpretation, the estimated coefficients are presented as marginal effects, conditional on a random effect of zero. As can be seen from the table, in 2008 the probability of a observed watering day to coincide with above-average wind conditions is approximately 5% higher for an “SB” type HW compared to an “OS” type. This difference shrinks to 1–3% in 2010, but is still significant. Thus, the Probit estimates pair up well with our descriptive insights in supporting the conjecture that wind events may well be the main driver of the observed variability in weekly watering patterns, and associated differences in use and peaks across irrigation types.[21]

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[21] Irrigation losses due to wind can easily amount to 40–50% in arid climates, even under moderate wind speeds of 10 mph (8–9 knots) or less (Bauder, 2000; Duble, 2013). Naturally, these losses are further exacerbated if even the water that hits the ground completely misses its target, which is a common occurrence for the relatively small yards in our research area.

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8. Conclusion

This study is the first to examine how the *design* of outdoor watering restrictions impacts residential water use at the houehold level. Using a unique, customer specific data set of daily consumption over multiple irrigation seasons that include an inter-season policy change, we arrive at several important and novel findings. Most centrally, both the cap on weekly frequency *and* the address-based assignment of specific watering days matter for conservation outcomes. While the former is confirmed to be necessary for curbing consumption, the latter undermines conservation goals.

We find that higher frequencies unambiguously translate into higher weekly use. However, we uncover an unintended consequence of OWRs with days-of-week assignments: weekly use and peak are higher the more closely a given households follows the assigned schedule. These “rigidity penalties” are substantial and amount to approximately 20–25% of weekly consumption and 30–40% of weekly peaks.

The policy change from two to three assigned days per week produced two main effects. First, it induced the intended switch in watering patterns for a considerable segment of customer-weeks. Second, we observe a pronounced reduction in peaks at the system-wide level – an effect driven predominantly by lower peaks for schedule-based weeks. In contrast, overall weekly use changes little in reaction to the new policy.

For policy-makers, our results suggest that adjusting existing OWRs to allow for flexible watering patterns could produce substantial water savings at relatively low implementation costs. Moreover, as inefficiency penalties are highest at low frequencies, our findings also cast doubt on the effectiveness of policies that reduce the number of assigned days under progressively severe drought conditions. In such situations, a frequency reduction combined with a “free-to-choose” policy is likely to promote greater conservation. Naturally, violations of allowed weekly frequencies would be more difficult to detect under such a policy, since permissible applications would no longer be pegged to a given day-of-week for a given address. However, the fact that many current customers adhere – at least loosely – to the official regulations despite weak enforcement by the utility suggests that social norms and “neighborly supervision” may be stronger drivers of compliance than officially posted fines. These norms would still be in force under more flexible policies, as nearby neighbors can easily keep track of other households’ weekly watering frequency.

Our analysis extends prior work exploring the unintended consequences of nested policies, and those that introduce heterogeneous standards across firms and/or regions. Whereas the extant literature focuses on leakages generated by the spatial reallocation of effort, our paper highlights another channel through which leakages may arise – by hampering the temporal reallocation of effort. In our setting, adherence to the official watering schedule requires households to ignore time-varying weather patterns that reduce the efficacy of outdoor watering.

It is easy to envision other domains where similar patterns could arise. For example, many utilities have explored time-of-day pricing as a means to manage residential energy consumption and associated greenhouse gas emissions. To the extent that such pricing schemes cause a shift in demand from peak to non-peak hours, the overall impact on carbon could fall short of expectations as the marginal fuel source during peak hours is often less carbon intensive than base load generators (the marginal fuel source during non-peak periods). The identification of such temporal leakages and the design of policies that are robust to such unintended consequences should provide ample opportunities for future research.

Appendix A. Outdoor watering restrictions in the United States

See Table A.9.

Appendix B. Evidence against confounding effects

If there were any other time-varying factors that drive water need in a heterogeneous fashion we should see pronounced variation over time in the fraction of different watering types. Table B.10 shows, for each week of our research period, the number of households included in the sample, and the percentage of watering types. The last two columns of the table capture the two types we use in our empirical model, *SB* and *OS*. For additional insight, we also show the percentage, of the total sample, of perfectly compliant types, or *S* types (which are nested within *SB*). We further split these *S* types into the percentage of household-weeks (HWs) that come from households that *always* follow the schedule (labeled as “always” in the table), and the remaining share of HWs contributed by “occasional” perfect compliers (labeled as “occ”) in the table.

As can be seen from the table, there are no pronounced shifts in the proportion of type assignments over time. This puts in question the proposition that a substantial share of *OS* types become *SB* types due to a systematic weekly shock that affects water need. Table 2 in the main text and Table B.10 combined also show that the hottest weeks in 2008 (week 3) and 2010 (week 4) do *not* produce the highest proportion of *S* or *SB* types in the overall watering pattern.

It is also obvious from Table B.10 that perfectly compliant HWs, or *S* types constitute the minority of *SB* types in any given week. Most HWs that are *SB* have a watering pattern that adds one or more days to the official schedule. In other words, they are already cheating to some extent. Throughout our analysis we compare *SB* types and *OS* types *conditional on the same weekly frequency*. This means that an *OS* type cheats just slightly more than an *SB* type of the same frequency. Therefore, the probability of detection and fines should not be all that different between the two types.

Furthermore, if the “behave to avoid fines when water needs are high” conjecture were to hold, we would expect to see higher use for *S* types compared to one-off *SB* types. For example, in 2008, an *S* type would water exactly twice. We can then

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Table A.9
Examples of cities with outdoor watering restrictions (as of June 1, 2010).

City	Population (1000s)	Utility	Restriction period	Time-of-day restrictions	Days per week restrictions for sprinklers	Assigned watering days for sprinklers	Other restrictions	Special rules for manual watering
CALIFORNIA								
Los Angeles	4095	L.A. Dept. of Water and Power	Ongoing, since June 2009, year-round	No watering 9am–4pm	2 days/week	Mo, Thu only, all addresses	15 min. max. runtime per cycle	None
San Diego	1376	The City of San Diego	Ongoing since June 1, 2009, restrictions change across seasons	No watering 10am–6pm	3 days/week	Assigned by address	10 min. max. run-time per cycle	No restrictions on run-time
Fresno	505	City of Fresno	Ongoing, restrictions change across seasons	No watering 6am–7pm	3 days/week	Assigned by address	Restrictions on landscaping (no bluegrass)	None
Long Beach	495	Long Beach Water	Ongoing	No watering 9am–4pm	3 days/week	Mo, Thu, Sat only, all addresses	10 min. max. run-time per cycle	None
NEVADA								
Las Vegas	478	Las Vegas Valley Water District	Ongoing, since 2002, restrictions change across seasons	No watering 11am–7pm (summer only)	3 days/week (spring, fall only)	Assigned by address	None	Allowed any time, any day
Reno/Sparks	419	Truckee Meadows Water Authority	Ongoing, since 1996, summer only	No watering noon to 6pm	3 days/week[a]	Assigned by address	None	Allowed any time, any day
COLORADO								
Denver	555	Denver Water	May 1–Oct. 1	No watering 10am–6pm	None	N/A	No watering during strong winds or rain; limitations on run-time per cycle	None
TEXAS								
Dallas	1189	Dallas Water Utilities	April 1–Oct. 31	No watering 10am–6pm	None	N/A	No watering during rain	Allowed any time, any day
San Antonio	1145	San Antonio Water System	Year-round (severity of restrictions based on aquifer level)	No watering 10am–8pm	1 day/week ("Stages 1, 2")	Assigned by address	None	Allowed any time, any day
Austin	657	Austin Water	Ongoing, since Nov.21, 2009	No watering 10am–7pm	2 days/week	Assigned by address	None	Allowed any time, any day
GEORGIA								
Entire State placed under non-drought schedule as of June 1, 2010	9829	Environmental Protection Division	Ongoing, since June 1, 2010 (restrictions become more severe during declared drought)	None	3 days/week	Assigned by address	None	None
FLORIDA								
Jacksonville	835	St. John's River Water Management District	Ongoing, restrictions change across seasons	No watering 10am–4pm	2 days/week (summer schedule)	Assigned by address	60 min. max. run-time per cycle	None
Miami	391	Miami-Dade Water and Sewer Department	Ongoing, year-round	No watering 10am–4pm	2 days/week (summer schedule)	Assigned by address	None	Allowed daily for 10 min.
Tampa	331	City of Tampa Water Department	Ongoing, year-round	No watering 10am–6pm	1 day/week	Assigned by address	Only one cycle allowed per day	Same as sprinkler rules for lawns, else unrestricted

[a] 2 days 1996–2009, 3 days as of 2010.

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Table B.10
Percentages of watering types over time.

		S				
Week	Sample	Always	occ.	Total	SB	OS
2008						
1	8468	12%	15%	28%	60%	40%
2	8270	13%	16%	29%	61%	39%
3	8572	12%	16%	28%	64%	36%
4	2488	9%	15%	24%	58%	42%
5	3163	9%	15%	25%	60%	40%
6	5825	10%	16%	26%	59%	41%
7	7774	12%	17%	29%	62%	38%
8	7235	12%	14%	26%	66%	34%
9	871	14%	16%	30%	63%	37%
2010						
1	5765	9%	14%	24%	38%	62%
2	7338	9%	15%	24%	43%	57%
3	1853	9%	15%	24%	47%	53%
4	7317	9%	17%	26%	48%	52%
5	7420	9%	18%	27%	48%	52%
6	6074	9%	19%	28%	50%	50%
7	5512	9%	18%	27%	44%	56%
8	7294	9%	18%	27%	47%	53%

SB = schedule-based (all assigned days are used); OS = off-schedule (not all assigned days are used); S = schedule-exact, perfect compliance; S/always = from households that always show perfect compliance; S/occ. = from households that occasionally show perfect compliance.

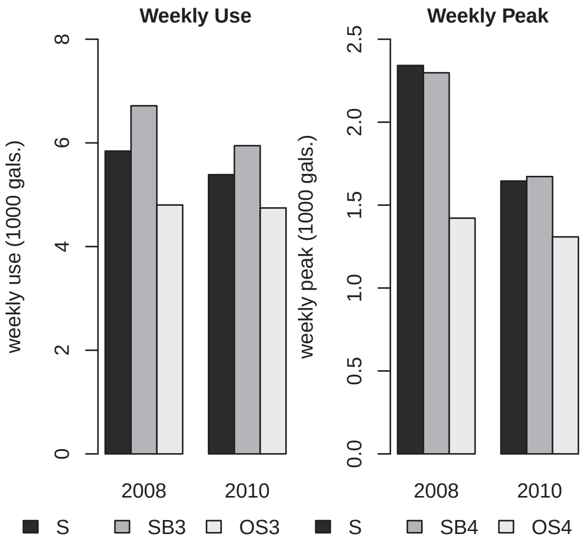

Fig. 3. Weekly use and peak for *S* and “one-off” types.

compare the resulting weekly use to that of an $SB-3$ type that uses one additional day. In the same vein, we can compare an *S* type for 2010 (3 allowable watering days) to an $SB-4$ type. In both cases we would expect use to increase under the *S* regime under the conjecture.

However, as is evident from Fig. 3, the one-off *SB* types use *more* water than perfect compliers and have comparable peaks to *S* types in both years. This picture is more consistent with the notion that when a households needs more water, it simply adds an additional day. This directly contradicts the “revert to *S* when need is high” hypothesis.

Appendix C. Identification of outdoor watering days

Our identification of outdoor watering days thus proceeds in the following steps:

1. We start with a simple *K*-means clustering algorithm (MacQueen, 1967) at the household level to classify each day as a “high use” or “low use” occurrence. Our objective is to confidently interpret high use days as days with outdoor irrigation, and low-use days as days with strictly non-irrigation consumption. We use six different clustering algorithms. The first

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three are based on actual daily use, the second set of three on logged use.[22] Within each set, the first algorithm uses the Euclidean distance between observation points and the current pair of cluster centroids as a sorting criterion, the second uses Euclidean distance squared, and the third absolute distance (Vinod, 1969; Massart et al., 1983). In each case we use the mean consumption on assigned and unassigned days, respectively, as starting values for the cluster centroids.

We find that within each triplet all three algorithms agree on sorting for every single observation in both the 2008 and 2010 data sets. This indicates robustness to the choice of similarity measure, which is reassuring. As expected, the versions based on logged use, which are less sensitive to outliers and thus lower the threshold for observations to fall into the higher category, identify about 10–15% more observations as watering days than the versions based on actual use in gallons in each data set.

However, *all six versions* are in complete agreement for all daily observations associated with 1644 (18.8%) of households in 2008, and 890 households (11.7%) in 2010. These are likely customers that exclusively water via automated sprinkler systems, producing very pronounced differences in usage between irrigation and non-irrigation days. Within these subgroups, the sorting into watering and non-watering days perfectly aligns with *assigned* watering days for 604 (6.9%) of customers in 2008, and 422 (5.5%) of customers in 2010. For these households we can be especially confident that the observations flagged as non-watering days truly and exclusively capture indoor, or non-irrigation, use. In the following, we label these households as "Full Agreement, Full Compliance" (FAFC) cases.

An inspection of sample statistics on basic building and lot characteristics assures us that these FAFC cases are not systematically different in measurable ways from the remainder of the data set.[23] Thus, we deem them suitable as a representative sub-sample that provides reliable and important information on non-irrigation use.

2. Our next goal is to utilize information on winter use and the fact that the Reno/Sparks climate precludes any water use for outdoor irrigation during the cold season to validate the cluster analysis results. Specifically, using available data on monthly consumption during the January-March period preceding our summer data collections, we compute *average daily winter use* and the ratio of daily summer use to average daily winter use for each household in both data sets. Focusing again on the FAFC observations, we then inspect the sample distribution of this ratio for unassigned days. For 2008, the mean and standard deviation for this ratio amount to 2.3 and 2.4, respectively. For 2010, the mean equals 1.85, and the standard deviation is 1.7. According to TMWA, indoor use is higher in summer for the typical household due to factors such as a larger average daily household size as school and college-age children spend more time at home, a higher level of outdoor and athletic activities, increasing water use for drinking, cleaning, laundry, and showers, increased use for the watering of indoor plants, and water use for cooling units. The lower average for 2007 is likely due to the slightly cooler summer that year, as described in the main text.
3. We interpret the above results as indicative of the typical household in the Reno/Sparks area consuming approximately twice as much water per day for non-irrigation purposes in summer than in winter. Based on the standard deviations for the FAFC segment given above, we would further expect daily non-irrigation use *for any household* not to exceed a ratio to winter use in excess of $3 \times 2.4 = 7.2$ in 2008 and of $3 \times 1.7 = 5.1$ in 2010.
4. For our final classification step we generally adopt the cluster analysis results based on absolute use, but we recode all observations flagged as "non-watering" days that exceed the three-standard deviation thresholds given above as "watering days". This results in 19,479 changes (8.2% of observations originally flagged as non-watering) for the 2008 data, and 17,818 changes (8.6% of observations originally flagged as non-watering) for the 2010 set. These recoded observations are likely associated with households that employ some *daily* baseline watering system, as mentioned above. Due to the latency of the baseline irrigation the cluster analysis fails to identify these non-sprinkler days as irrigation days. Adding information on winter use to our analysis allows us to correct this shortcoming.

Appendix D. Details on econometric specification and results

The household and climate regressors in the frequency equation are: log of lot size in square feet ("lnland"), log of tax-assessed land value ("lnvalue"), the weekly average of, respectively, daily minimum and maximum temperature ("mintemp", "maxtemp"), the weekly average of daily average wind in knots ("avgwind"), the weekly average of maximum daily sustained wind ("maxwind"), and total weekly growing degree days ("gdd"). For a given calendar day, the latter is computed as (maximum daily temperature + minimum daily temperature)/2 − 50. All climate indicators are measured in units of 10 for a more balanced scaling of the regressor matrix.

Equations two (weekly use) and three (weekly peak) include the additional home features log of square footage ("lnsf"), number of bedrooms, number of water fixtures, and age plus age squared. The dropped climate variables (for identification purpose) are "mintemp", "maxtemp", and "gdd".

The full results for equations two and three are given in Table D.11.

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[22] We add an increment of one gallon to each zero-usage observation before taking logs

[23] These comparison tables are available from the authors upon request

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Table D.11
Estimation results for use and peak equations, Bayesian model.

	weekly use			weekly peak		
	Mean	Std.	Prob(>0)	Mean	Std.	Prob(>0)
Constant	−10.766	(0.773)	0.000	−12.706	(0.766)	0.000
freq1	0.392	(0.025)	1.000	0.883	(0.026)	1.000
freq2	0.584	(0.025)	1.000	0.980	(0.026)	1.000
freq3	0.720	(0.026)	1.000	0.989	(0.027)	1.000
freq4	0.821	(0.029)	1.000	0.992	(0.031)	1.000
freq567	0.967	(0.036)	1.000	1.048	(0.036)	1.000
SB × freq2	0.208	(0.066)	1.000	0.379	(0.068)	1.000
SB × freq3	0.197	(0.066)	0.999	0.334	(0.068)	1.000
SB × freq4	0.179	(0.068)	0.995	0.307	(0.071)	1.000
SB × freq567	0.200	(0.071)	0.999	0.233	(0.072)	0.999
lnland	0.389	(0.010)	1.000	0.439	(0.011)	1.000
lnsf	0.170	(0.033)	1.000	0.154	(0.036)	1.000
lnvalue	0.294	(0.028)	1.000	0.344	(0.030)	1.000
fixtures	−0.002	(0.003)	0.324	−0.005	(0.004)	0.079
bedrooms	0.042	(0.009)	1.000	0.032	(0.009)	1.000
age	0.218	(0.011)	1.000	0.280	(0.012)	1.000
age2	−0.020	(0.001)	0.000	−0.025	(0.002)	0.000
avgtemp	0.051	(0.081)	0.735	−0.007	(0.079)	0.470
avgwind	−0.070	(0.453)	0.442	−0.064	(0.462)	0.453
maxwind	0.050	(0.184)	0.615	0.008	(0.188)	0.506
avgwind × SB	−0.222	(0.563)	0.349	0.002	(0.575)	0.500
maxwind × SB	0.032	(0.199)	0.567	−0.058	(0.204)	0.386
year2010	0.185	(0.740)	0.593	−0.178	(0.730)	0.403
freq1 × 2010	−0.010	(0.036)	0.393	−0.009	(0.036)	0.385
freq2 × 2010	0.034	(0.035)	0.837	0.073	(0.035)	0.978
freq3 × 2010	0.045	(0.036)	0.895	0.071	(0.036)	0.977
freq4 × 2010	0.053	(0.041)	0.901	0.092	(0.041)	0.990
freq567 × 2010	0.038	(0.049)	0.786	0.064	(0.048)	0.909
SB × freq3 × 2010	−0.052	(0.144)	0.361	−0.257	(0.147)	0.039
SB × freq4 × 2010	−0.049	(0.146)	0.357	−0.244	(0.150)	0.049
SB × freq567 × 2010	−0.041	(0.147)	0.395	−0.200	(0.151)	0.088
avgtemp × 2010	−0.025	(0.082)	0.391	0.016	(0.080)	0.583
avgwind × 2010	0.333	(0.486)	0.76	0.515	(0.500)	0.848
maxwind × 2010	−0.109	(0.187)	0.258	−0.143	(0.192)	0.240
avgwind × SB × 2010	−0.020	(0.063)	0.372	−0.033	(0.065)	0.304
maxwind × SB × 2010	0.010	(0.021)	0.688	0.021	(0.021)	0.837

mean = posterior mean; std. = posterior standard deviation; prob(>0) = share of posterior density to the right of zero.

Appendix E. Independent random effects regressions

If the random household effects were not correlated across the three equations, the parameters in the use and peak models could in theory be consistently estimated via simple, independent random effects regressions. For the coefficients in the mean function consistency in such a naïve independent framework would hold even if equations two and three were correlated, as long as their respective correlations with equation one is truly zero. This is because the dependent variable of equation one, weekly watering frequency, enters the other two equations on the right hand side (in form of binary indicators), and would thus cause endogeneity problems if there existed a link between equation one and the other two models via the unobservable household effects.

From Table 5 in the main text we see that ρ_{13} is negligible with large posterior uncertainty, but ρ_{12}, while small, is positive and estimated with relatively high precision. To examine to what extent ignoring this correlation would affect parameter estimates, we run two independent random effects (RE) regressions for weekly use and peak with the exact same regressors as in our Bayesian Hierarchical Exponential (HE) models. The dependent variables are in log-form.

If endogeneity is not an issue, the two frameworks, Bayesian HE, and classical RE, should produce asymptotically identical results for the following reasons: (i) both are based on the same log-linear parameterized mean function, which assures the same interpretation for marginal effects, (ii) the normal density, which forms the basis for the RE regressions, and the exponential density which underlies the HE model, are both in the family of linear exponential distributions. Therefore, a mis-specification of the (combined) variance of error terms in the likelihood function should not affect consistency of coefficient estimates in the parameterized mean function [see e.g. Cameron and Trivedi, 2005, ch. 5], and (iii) while the RE regression has an additional normally distributed idiosyncratic error, both preliminary runs of an expanded Bayesian model and the RE results indicate that the variance of that error term is small compared to the variance of the household effect.[24] Finally, with over 100,000 observations, we would expect good asymptotic properties from both frameworks.

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[24] The RE output indicates that 82–86% of total error variability is assigned to the household effect.

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Table E.12
Estimation results for the independent RE regressions.

	Weekly use		Weekly peak	
	Mean	Std.	Mean	Std.
Constant	−8.039	(0.255)***	−10.186	(0.301)***
freq1	0.457	(0.006)***	0.870	(0.008)***
freq2	0.669	(0.006)***	0.980	(0.008)***
freq3	0.818	(0.007)***	1.026	(0.008)***
freq4	0.935	(0.008)***	1.056	(0.009)***
freq567	1.076	(0.009)***	1.118	(0.011)***
SB × freq2	0.101	(0.015)***	0.186	(0.019)***
SB × freq3	0.099	(0.015)***	0.151	(0.019)***
SB × freq4	0.089	(0.016)***	0.116	(0.019)***
SB × freq567	0.136	(0.016)***	0.093	(0.020)***
lnland	0.426	(0.009)***	0.482	(0.009)***
lnsf	0.258	(0.027)***	0.266	(0.030)***
lnvalue	0.134	(0.019)***	0.176	(0.022)***
fixtures	0.005	(0.003)***	0.001	(0.003)
bedrooms	0.021	(0.007)***	0.012	(0.008)
age	0.019	(0.001)***	0.025	(0.001)***
age2	0.000	(0.000)***	0.000	(0.000)***
avgtemp	0.011	(0.002)***	0.007	(0.002)***
avgwind	−0.026	(0.011)***	−0.020	(0.013)
maxwind	0.015	(0.004)***	0.010	(0.005)*
avgwind × SB	−0.014	(0.013)	−0.003	(0.016)
maxwind × SB	0.002	(0.004)	−0.003	(0.006)
year2010	0.530	(0.174)***	0.288	(0.215)
freq1 × 2010	−0.004	(0.009)	0.007	(0.011)
freq2 × 2010	0.013	(0.009)	0.040	(0.011)***
freq3 × 2010	0.015	(0.009)	0.045	(0.011)***
freq4 × 2010	0.026	(0.010)**	0.063	(0.013)***
freq567 × 2010	0.006	(0.012)	0.031	(0.015)**
SB × freq3 × 2010	−0.002	(0.033)	−0.164	(0.041)***
SB × freq4 × 2010	−0.005	(0.034)	−0.147	(0.042)***
SB × freq567 × 2010	−0.009	(0.034)	−0.128	(0.042)***
avgtemp × 2010	−0.007	(0.002)***	−0.004	(0.002)*
avgwind × 2010	0.043	(0.012)***	0.051	(0.014)***
maxwind × 2010	−0.019	(0.005)***	−0.021	(0.006)***
avgwind × SB × 2010	−0.021	(0.015)	−0.027	(0.018)
maxwind × SB × 2010	0.009	(0.005)**	0.016	(0.006)***

* significant at the 10% level.
** significant at the 5% level.
*** significant at the 1% level.

Table E.12 depicts the full results for the RE regressions. Comparing these results to the posterior means in Table 1, we see that the RE models systematically under-estimate the incremental increase in use and peak at any frequency for SB-type weeks (variables "SB × freq2" through "SB × freq567"). Expressed in percentage terms, this bias is of considerable magnitude, ranging from 7 to 11% for use and 15 to 21% for peak.

Furthermore, the RE models estimates pure policy effects for use peak ("year2010") that are 30–40% larger, respectively, than the small effects produced by the correlated Bayesian system.

Finally, the RE model under-estimates the reduction in peak for SB-types compared to 2008 ("SB × freq3 × 2010" through "SB × freq567 × 2010") by approximately 5%. We thus conclude that the additional complexitities in estimation from switching to a fully correlated triple-equation system are justified for our application.

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TRUCKEE MEADOWS WATER AUTHORITY

APPENDIX 5-4

LANDSCAPE CODES:

FINDINGS AND RECOMMENDATIONS

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TRUCKEE MEADOWS WATER AUTHORITY

STAFF REPORT

TO: **Chairman and Board Members**
FROM: **Laine Christman**
DATE: **January 12, 2016**
SUBJECT: **Report on review of Reno, Sparks and Washoe County landscape and water conservation ordinances and discussion, action and direction to staff on recommendations to local governments for landscape and water conservation ordinance amendments**

Discussion: In August 2004, Truckee Meadows Water Authority's ("TMWA") staff examined the landscape ordinances of local governments and provided recommendations regarding changes to those ordinances to increase water conservation. In July of 2005, a staff report was produced on the findings and recommendations of that analysis. See the Appendix for details of this report.

As directed by TMWA's Board, in April of 2015 municipal landscaping ordinances were reexamined by staff to determine what changes had been made concerning landscaping in new and existing developments. Overall, municipal landscaping ordinances remained unchanged since 2005.

Through September, a series of meetings were held with TMWA staff, municipal planners, staff from the Washoe County District Health Department, and representatives from the building industry to address the following issues raised by TMWA staff:

1. Increasing customer inquiries regarding discrepancies between TMWA's conservation goals and municipal ordinances for drought-tolerant landscaping.

2. Deviations in water conservation and landscape ordinances between municipalities.

As a result of those discussions, staff has identified new recommendations for the TMWA's Board's consideration regarding possible recommendations for revisions to the existing municipal ordinances. This report presents those findings and recommendations for potential government action (see pages 3 and 4).

Special thanks goes to the following staff members and consultants who provided valuable input during the course of these meetings:

Claudia Hanson, City of Reno
Armando Ornelas, City of Sparks
Roger Rundle, City of Sparks
William Whitney, Washoe County
Roger Pelham, Washoe County
Bob Webb, Washoe County Community Services Department
Jeff Jeppson, Washoe County Health District
Jim Smitherman, Northern Nevada Water Planning Commission
Angela Fuss, CFA
Jess Traver, BANN
Ryan Hansen, Hansen Landscape Architects

Municipal Ordinances - Findings and Recommendations

		CITY OF RENO		WASHOE COUNTY		CITY OF SPARKS		
Row	**Category**	**Description**	**Code**	**Description**	**Code**	**Description**	**Code**	**Recommendations***
	I. Landscaping Ordinances - Findings							
1	***A. Turf Standards***							
2	Width Requirements	5ft minimum	Section 18.12.1210	5ft minimum	Section 110.412.60	8ft minimum	Section 20.32.090	To reduce potential for overspray and runoff onto streets/storm drains, the **minimum width of narrow turf strips within all municipalities should be expanded to 8ft plus a 2ft setback** from impervious surfaces which drain to the street. Any landscaping strips that cannot meet this requirement should contain drip irrigation only.
3	Total Area Requirements	50% maximum in multi-fam, industrial, model homes.	Section 18.12.1210	50% minimum in multi-family	Section 110.412.60	80% maximum of landscaped area	Section 20.32.090	Industrial - 0% max allowable turf Commerical - 25% max allowable turf Multi-family - 50% max allowable turf Single Family - 50% max allowable turf
4	Slope Ratio Requirements	3:1	Section 18.12.1210	4:1	Section 110.412.60	4:1	Section 20.32.090	None
5	***B. Water Conservation Standards***							
6	Water Efficient Plants Requirements	Promoted	Section 18.12.1201	Encouraged	Section 110.412.20 Section 110.412.35	Requires use of resource-efficient guidelines and principles. Resource-efficient materials are any living material that is drought-tolerant or low-water use.	Section 20.32.010	Modify ordinances **to require a percentage of water efficient planting** within new developments. Collaborate with Cooperative Extension/Nevada Landscape Association to identify a list of acceptable drought-tolerant vegetation.
7	Hydro-zoning (grouping vegetation by water requirements)	Not specified	N/A	Required	Section 110.412.65	Encouraged	Section 20.32.010	Require use of hydro-zoning practices whenever applicable.
8	***C. Non-living material Standards***							
9	Area	25% maximum	Section 18.12.1209	50% maximum	Section 110.412.60	10% maximum	Section 20.32.090	None
10	***D. Tree Standards***							
11	Minimum spacing between trees	One tree and six shrubs per 300sqft	Section 18.12.1209	One tree every 50 feet	Section 110.412.35 Section 110.412.40 Section 110.412.45	One tree every 300ft (residential) and one tree evrey 500 ft (other zones)	Section 20.32.090	None
12	Width of planting area	10ft minimum	Section 18.12.1205	8ft minimum	Section 110.412.60	10ft minimum	Section 20.32.090	None

* Recommendations only apply to new developments. No recommendations for existing developments are advocated that this time

Municipal Ordinances - Findings and Recommendations

		CITY OF RENO		WASHOE COUNTY		CITY OF SPARKS		
Row	**Category**	**Description**	**Code**	**Description**	**Code**	**Description**	**Code**	**Recommendations***
13	***E. Total Landscape Standards***							
14	Residential	20%	Section 18.12.1205	20%	Section 110.412.35	20%	Section 20.32.080TBL	None
15	Commerical	15-20%	Section 18.12.1205	20%	Section 110.412.40	10-25%	Section 20.32.080TBL	None
16	Industrial/Agriculture	Industrial - minimum of the front area	Section 18.12.1205	10%	Section 110.412.45	6%	Section 20.32.080TBL	None
17	***F. Soil Standards***							
18	Soil analysis	Not specified	N/A	Encouraged	Section 110.412.15	Not specified	N/A	Require a soil analysis during development planning phase to determine potential for runoff and necessary mulch/irrigation
19	Soil depth	Loosened 8 inch minimum with 2 inch organic soil on top	Section 18.12.1210	Not specified		Loosened 8 inch minimum with 2 inch organic soil on top	Section 20.32.090	None
20	Mulch	4 inch minimum in all landscape areas with there is no ground cover	Section 18.12.1209	3 inch minimum in all landscape areas with there is no ground cover	Section 110.412.60	4 inch minimum in all landscape areas with there is no ground cover	Section 20.32.090	None
21	**II. Irrigation Ordinances - Findings**							
22	***A. Watering schedules***							
23	Prohibited days for watering lawn	(1) Premises with even addresses - Tuesday, Thursday, and Saturday (2) Premises with odd addresses - Wednesday, Friday, Sunday	Section 12.14.085	(1) Premises with even addresses - Tuesday, Thursday, and Saturday (2) Premises with odd addresses - Wednesday, Friday, Sunday	Chapter 40.225	1. Residences with **even** addresses—Wednesday and Saturday or on Monday in lieu of one of these two days; 2. Residences with **odd** addresses—Thursday and Sunday or on Monday in lieu of one of these two days; and 3. Commercial customers—Tuesday and Friday.	Section 13.50.075	Revise Sparks' ordinance to reflect TMWA's regulations.
24	Water Schedule violation fines	1rst violation -$0; 2nd violation $25; 3rd violation $75	Section 12.14.210	1rst violation -$0; 2nd violation $25; 3rd violation $75	Chapter 40.266	1rst offense: $25; 2nd offense: $50; 3rd offense: $100	Section 13.50.110	Penalty structures should reflect TMWA's water waster penalty structure. More information on TMWA's rules that pertain to water waste (Rule 2) can be found at http://tmwa.com/customer_services/waterrules/.
25	***B. Irrigation System Design***							
26	Moisture sensors/rain shutoff equipment	Not specified	N/A	encouraged	Section 110.412.65	Not specified	N/A	None
27	Use of efficient irrigation system	Required	Section 18.12.1210	Not specified	N/A	Not specified	N/A	Require use of efficient irrigation system whenever possible

* Recommendations only apply to new developments. No recommendations for existing developments are advocated that this time

TRUCKEE MEADOWS WATER AUTHORITY

APPENDIX 5-5

ENHANCED DEMAND-SIDE MANAGEMENT PROGRAMS AND ACTIONS

Enhanced Demand-Side Management Programs and Actions

Extended drought periods can result in severe consequences to socio-ecologic systems. As experiences in 2014 and 2015, within the TMWA service area (and most of the western U.S.), prolonged, dry hydrologic periods can occur. In order to enact policy that mitigates potential vulnerabilities to local water resources, TMWA must consider management tactics to mitigate drought periods that extend beyond those experienced over the past century (see Chapter 2 for a discussion of effects of local climate change). Should prolonged, dry hydrologic conditions persist, there are a myriad of possible programs not included in TMWA's current Conservation Plan that could be deployed to further reduce demand for water.

TMWA's Conservation Plan is oriented around efficient use by its customers **every year**. In periods of extended drought, TMWA's demand-side management programs ("DMPs") can be enhanced and oriented toward targeted reductions in monthly water use. Depending on projected use of drought reserves, TMWA first defines the target reduction needed to ensure drought reserves are adequate to serve its customers over that year and multiple succeeding years. For example, starting in May of 2015 TMWA asked its customer to reduce their water use by *at least* 10 percent compared to their monthly usage in 2013. Once a target is established, then a suite of actions that will facilitate this reduction are selected and implemented within a specified timeline. These programs and measures can have significant administration costs and lengthy timelines in order to be implemented, and/or require additional action(s) by local governments. Moreover, some actions can have adverse, long-term economic impacts to TMWA and the community at large; therefore TMWA weighs all the costs and potential benefits each action might have when creating the suite of actions it will deploy.

Conjunctive implementation of the appropriate types of actions is the key to successfully meeting the targeted water use reduction goal. Any decision on a new suite of conservation actions must also considers how interdependent individual actions can have with one another. For example, should additional watering restrictions or moratoriums be put into place, monitoring and enforcement must be enhanced to ensure compliance is met. Similarly, if rebates are considered, such as those designed to reduced turf or increase the use of water efficient technology, changes in local laws might be necessary to guarantee future development reflect the desired outcome(s) (i.e., restricting the amount of turf new properties can have or requiring the use water efficient irrigation technology).

Table 1 provides a list of various enhanced demand-side management actions ("*e*DMPs"), which, in addition to TMWA standard programs described in Chapter 5, could be deployed depending on projected use of drought reserves. The table lists qualitative estimates of the associated costs and benefit potentials based on prior studies for each *e*DMP.

Table 1: Potential Enhanced Demand-side Management Programs and Associated Costs and Benefits

Type	Action Taken	Program Costs[1]	Level of Effort to Implement[2]	Level of Customer Participation	Level of Water Savings Per Customer	Benefit Potential[3]
Customer Education	Information on Water Usage	Moderate	Moderate	High	Moderate	at least a 6% reduction in demand
Pricing Mechanism	Rate Schedule Adjustment (marginal increase)	Low	Moderate	High	Low	2% reduction for a 10% increase in the block rate
Pricing Mechanism	Rate Schedule Adjustment (moderate increase)	Low	Moderate	High	Moderate	2% reduction for a 10% increase in the block rate
Pricing Mechanism	Rate Schedule Adjustment (significant increase)	Low	Moderate	High	High	2% reduction for a 10% increase in the block rate
Pricing Mechanism	Seasonal Drought Rate (marginal increase)	Low	Moderate	High	Low	2% reduction for a 10% increase in the block rate
Pricing Mechanism	Seasonal Drought Rates (moderate increase)	Low	Moderate	High	Moderate	2% reduction for a 10% increase in the block rate
Pricing Mechanism	Seasonal Drought Rate (significant increase)	Low	Moderate	High	High	2% reduction for a 10% increase in the block rate
Pricing Mechanism	Violation Fines (marginal increase)	Moderate	High	Low	Low	2% reduction for a 10% increase in the block rate
Pricing Mechanism	Violation Fines (moderate increase)	Moderate	High	Low	Moderate	2% reduction for a 10% increase in the block rate
Pricing Mechanism	Violation Fines (significant increase)	Moderate	High	Low	High	2% reduction for a 10% increase in the block rate
Enhanced Metering	Daily meter reading of all customers	High	High	High	Low	Reduction potential not quantified
Enhanced Metering	Metering of all domestic wells	High	High	Low	Low	Reduction potential not quantified
Rebate	Rebate: Turf Conversion	High	High	Low	Moderate	~30% reduction in use per service
Rebate	Rebate: Efficient Irrigation Technology	Moderate	Moderate	Moderate	Moderate	20-50% improvement in irrigation efficiency
Rebate	Rebate: Low-flow Appliances	Moderate	Moderate	Moderate	Low to Moderate	High variability in savings depending on appliance
Watering Restrictions	Restrictions on Business	Moderate	Moderate	Moderate	Low	Reduction potential not quantified
Watering Restrictions	Weekly watering: 1	Moderate	High	High	Moderate	Reduction potential not quantified
Watering Restrictions	Weekly watering: NONE	Moderate	High	High	High	~75% reduction in water use per service with irrigation
Watering Restrictions	Moratorium on Car Washing	Low	High	High	Low	Reduction potential not quantified
Watering Restrictions	Mandatory Water Budgets	Moderate	High	High	Moderate to High	Reduction dependent upon budget amount
Landscape Requirements	Ordinances: Xeriscape Requirement (some xeriscape)	Moderate	Low	Moderate	High	~30% reduction in use per service
Landscape Requirements	Ordinances: Turf Requirements (no new turf)	Moderate	Low	Moderate	High	~30+% reduction in use per service
Landscape Requirements	Ordinances: Efficient Irrigation Technology	Moderate	Low	Low	Moderate to High	20-50% improvement in irrigation efficiency
Landscape Requirements	Ordinances: Certified Car Wash Program	Moderate	Low	Low	Low	Reduction potential not quantified
Landscape Requirements	Ordinances: Water Capture Requirements	Moderate	Low	Low	Low	Reduction potential not quantified
Landscape Requirements	Ordinances: Homeowner Association Restrictions (new developments)	Moderate	Low	Low	High	~30% reduction in use per service
Landscape Requirements	Ordinances: Homeowner Association Restrictions (all developments)	Moderate	Low	Moderate	High	~30% reduction in use per service

1. Cost includes but is not limited to increases in number of personnel, vehicles, IT support, messaging/advertising, local entity enforcement, or administrative support.

2. Level of effort to implement includes but is not limited to how/type/frequency of messaging/advertising delivered, numbers of personnel required to deploy, public hearings, community resistance.

3. Benefit potential is based on results from previous studies.

Customer Education

Information on Water Usage. Information can be a very powerful tool to help consumers make more informed decisions. Different types of information can be used to promote additional customer savings in various ways including: cost-saving information, targeted analytics, and social norms persuasion. As of the writing of this WRP, TMWA is engaged in a sample study to determine the effect of several informational products on customer water conservation, in order to determine if such programs are effective means of conservation during droughts.

- Cost-saving Information. Educating customers about water waste has been a major part of TMWA's past conservation efforts. In the future, customers can be provided with even more specific information on the cost-saving nature of different water saving practices.
- Targeted Analytics. Providing customers with tailored information regarding their water use can be a power mechanism for changing water usage behavior. Highly customized informational products gives customers' knowledge beyond their monthly usage by providing daily usage, comparing current usage to past usage, and indicating whether customers have met any established conservation goals. This knowledge gives customers a great ability to identify where they can alter their behavior to use water more efficiently.
- Social Norms Persuasion. Customers can also be supplied with information about how their usage compares with similar properties in their neighborhood. Research has suggested that such "social pressure" leads many above-average water users to conserve more water in order to better fit in with their neighborhood.

Pricing Mechanisms

Rate Schedule Adjustment. Water rates provide a pricing signal to customers so that they use water efficiently. For example, in the TMWA service area, on average, customers who converted from a monthly-flat-rate schedule to a metered rate reduced their water consumption by 39 percent. Moreover, a reduction in usage was seen in both indoor water use, as well as, outdoor use, indicating many aspects of the customer's water usage behavior were altered toward more efficient use. Since increasing water rate prices is a market-based approach to water reduction, it implies reductions are voluntary. A customer decides how much he/she wants to conserve based on their bottom line. A study conducted by the Economics Department at the University of Nevada on single-family metered water user in Washoe County indicates that a 10 percent increase in metered rates is associated with a two percent decrease in water use, on average (Lott et al. 2013). Currently TMWA only adjusts rates in order to meet the cost of service, which requires an in-depth cost of service study. However, TMWA could evaluate rate adjustments as a method to conservation without creating negative impacts to its revenues.

Seasonal Drought Surcharge. A drought surcharge could be a potential method to encourage enhanced water conservation. Like rate adjustments, a drought surcharge is a market-based approach meaning any water conservation as a result is voluntary. A drought surcharge is an adjustment that is temporary as it only applies during periods when TMWA must use storage reserves to meet demands (typically during the irrigation season). Once the system's reserves are reestablished, the drought surcharge is lifted and prices would return to the normal rate schedules. Due to this flexibility, it can be seen as a more attractive option than a permanent rate increase to reduce water demand. A drought surcharge is also flexible in that it can have a variety of different structures, i.e., it can be a flat surcharge, a variable surcharge based on the percentage of use, or can be integrated directly into the tiered rate schedule (i.e., applied only to certain blocks of water use). A well-thought out drought surcharge structure has to consider ease of implementation, customer classes affected, equity within and between customer classes, and the long-term consequences to demands and revenues.

Water Violation Penalty Adjustment. Preliminary analysis on TMWA's Water Watcher program indicates, on average, residential customers who were issued a penalty for water waste violations *did not* decrease water consumption after the fine was issued. In some cases residential violators increased use after a penalty was issued. Results indicate residential violators are typically wealthier and live on larger lots compared to TMWA's typical residential customer. The current penalty schedule's fee structure likely does not prohibit water violations because of the average socio-economic status of the offenders (i.e., the penalty amount may be perceived as nominal). Increasing the amount a violator would pay would provide more of a monetary incentive to abide by TMWA's water usage regulations. Penalty adjustments could be made depending on the severity of the violation and the severity of drought periods. The inclination for TMWA to issue a penalty (as opposed to taking other, non-punitive measures) could also be directly correlated to any additional water use restrictions, such as watering day restrictions, moratoriums on car washing, etc. To determine an optimal water violation penalty structure that would achieve the desired results, more analysis about how the penalty structure alters the customers' propensity to save water is warranted.

Rebates

Turf Conversion. Turf-dominated properties use approximately four times more water than xeriscaped properties. Replacing turf with a more water-conscious landscape is a method for long-lasting water conservation. A turf conversion rebate program incentivizes residents to replace their turf by offsetting the cost of re-landscaping by providing a rebate based on the per-square-foot amount of lawn removed. Some studies on turf conversion programs indicate a residential customer can reduce his/her water consumption by approximately 30 percent. The main reason such a program can be effective is because it usually implies a more efficient irrigation system is used (i.e., a sprinkler-dominated irrigation system often is converted to drip-dominated system). Turf conversion programs are typically implemented by the water purveyor or water-controlling municipality using funded from new development fees, customer rate revenues, or local/state grants. In order to have a significant effect of reducing water consumption, tens of millions of square feet of turf must be converted at costs in the tens of millions as well. In addition to the total cost of the rebates, administrative costs are associated with the program's implementation and oversight including the application process, rebate administration, and compliance checks.

Efficient Irrigation Technology. Overuse of water in irrigation is due, in part, to inefficiencies in the water delivery system. Since irrigation controls are predominately automated, once water timers are set, they are often forgotten about. However, over the irrigation season precipitation and/or wind events can occur during watering times. Unless the customer is able to manually adjust timers accordingly, the result is the application of water when irrigation is not necessary or highly inefficient. Many of the existing irrigation controllers utilize technology that predate the era of "smart" devices. High efficiency irrigation technology such as "smart" controllers can make real-time adjustments to irrigation schedules based on weather information, saving 20-50 percent of the water relative to standard controllers. Such technology is ideal for commercial applications because it eliminates the need for travel to multiple controller sites. The downside to "smart" controllers is the cost. For commercial applications when considering the saving in the monthly water bill and labor costs associated with manually changing watering schedules, savings could be achieved in as little as one irrigation season. A cheaper alternative to the "smart" controller is a rain sensor. Like the "smart" controller, a rain sensor will prohibit watering during precipitation events. For residential applications, this technology could be preferable since it is a fraction of the cost of "smart" controllers. A program that provides rebates for purchases of "smart" irrigation controllers or rain sensors could help replace older technology and increase irrigation efficiency on existing residential and commercial properties. Unlike, turf conversion rebate programs, these rebate programs would require substantially less funding and administrative oversight overall. Such automatic changes in watering times can conflict with assigned watering day schedules, so variances for watering during off-schedule times should be considered along with the accompanying administrative cost to manage those with variances.

Low-Flow Appliances. As with irrigation technology, many existing homes that predate enhanced standards in plumbing codes have appliances (e.g., toilets, dishwashers, washing machines, etc.) that are considered inefficient by current standards. For example, dishwashers made before 1994 use ten gallons more water than modern dishwashers. New, water-efficient toilets can provide overflow prevention and leak detection, and use approximately 20 percent less water than the standard 1.6 gallons per flush toilets. Similarly, water-efficient washing machines use up to 50 percent less water than older machines. A program that provides rebates for purchases of water-efficient appliances could incentive some customers to replace existing inefficient appliances. This would lower indoor water consumption overall, as well as, reduce peak day demands. However, the overall effectiveness of the program relative to the total cost to TMWA must be considered. Indoor use only account for a small percentage of monthly water use during periods of drought when reserves are be used. If the goal is to target reduced use during periods of drought, this option might not be as effective as other options. If the goal is a campaign to reduce water usage long-term, then such an option might be practical.

Enhanced Metering

Daily Metering of All Customers. Currently the majority of meters on TMWA's service connections provide readings on water usage aggregated at the monthly level (approximately 23 - 37 days). However, new water meter technology allows for the collection of daily meter readings. Water measurement at this level of granularity would provide TMWA with information that would be helpful in identifying more water violations (i.e., irrigating on incorrect days or incorrect times), the ability to provide better information on customer water use (e.g. targeted analytics), as well as, the ability to notify customers of potential leaks in real-time. This level of monitoring would ensure water efficient behavior is consistent across the TMWA service area. Given that the majority of TMWA service connections do not have this type of meter installed, a retrofit program to switch out the existing meters would be in the millions of dollars range over a multi-year timeline.

Metering of Domestic Wells. While TMWA provides meters for all its service connections, properties that obtain water from domestic wells do not have meters to track groundwater pumping. While these individuals are not TMWA customers, they share the same groundwater resources and therefore should conserve water like the rest of the community. In order to monitor private groundwater extraction, meters could be installed on all domestic wells. Such an action would require statutory change in the NRS and a method of funding the program.

Water Restrictions

Restrictions on Businesses. Should drought periods persist and a state of emergency be declared in Washoe County, TMWA could ask all businesses within the food industry serve all items on paper plates and provide disposable utensils in order to remove the need to wash dishes. As well, TMWA could ask that all cleaning services utilize cleaning products that don't require water. Within the hotel industry, TMWA could be asking that establishments restrict their laundry services to only what is absolutely necessary. TMWA could also place restrictions on water used in fountains and water features. While these actions would reduce commercial demand, in order to comply such restrictions could place additional financial stress on businesses. For compliance to be uniform, additional monitoring and enforcement mechanisms would need to be in place.

Moratorium on Washing Cars. In the event that a drought emergency is declared, TMWA could place restrictions on using potable water to wash cars, restricting the activity to only commercial car wash businesses that have a certified water reclamation system. Customers caught violating this requirement would be fined accordingly; such as action would require additional monitoring and enforcement to ensure compliance.

Mandatory Water Budgets. Currently, all conservation by TMWA customers is strictly voluntary. However, should extended drought periods persist; all customers could be given individualized water budget (i.e., a set amount that may be used within a month). Should a customer exceed the budgeted usage specified, a penalty surcharge could be incurred. Individualized water budget amounts could be estimated based on historic averages for each service connection and scaled down to achieve a targeted reduction goal. Implementation of individualized water budgets would be a long process. Increased communication and educational programs would be necessary to inform customers of the change. There is a potential for an impact TMWA's revenue stream which could result in a dramatic increase in the cost customers pay for water.

Once-Per-Week Watering. In the event that a drought emergency is declared, TMWA could change the three-day-a-week water schedule to a once-per-week watering scheduling. Customers caught violating this requirement would be fined accordingly. This action could drastically reduce water usage but could result in adverse consequences including a spike in peak day usage, severe overwatering, and damage to property owners' landscaping.

Moratorium on All Outdoor Watering. In the event that a drought emergency is declared, TMWA could place a temporary moratorium on *all* outdoor watering. Customers caught violating this requirement would be fined accordingly. Since irrigation uses the majority of the water used by a service during the warmer months, this actions would ensure adequate drinking water is available during that time. However, the impacts to TMWA's revenue stream could result in a dramatic spike in the cost customers pay for water. Furthermore, this action could result in irreparable damage to property owners' landscaping causing widespread economic losses.

Landscape Requirements

The next water conservation programs discussed below *are not* actions TMWA could take directly to promote conservation. However, in the past TMWA has worked with local municipalities to promote water-conscious local ordinance. The following paragraphs discuss potential water saving actions local municipalities can take with respect to future development. The savings such actions would have vary depending on the number of properties which would be impacted by the changes.

New Development Landscape Requirements. Turfed landscape is often over-watered and prone it inefficient irrigation (over-spray, evaporation loss, etc.), with as little as 40 percent of the water that is applied to turfed areas actually being used by the grass. Within TMWA's service area, local municipal ordinances dictate minimum amounts of turfed area properties must have (based on jurisdiction and zoning district). As the region grows and new developments are established, these ordinances could be amended to set limits on the maximum amount of turf a new property could have. Ordinances could also prohibit the laying of sod or planting of new grass seed during drought periods. If drought periods persist indefinitely, a moratorium on any new turfed areas could be implemented as a last resort. Such amendments to local ordinances could be paired with a rebate program for existing property owners, in order to gain maximum effectiveness.

Xeriscape requirements. Studies have indicated xeriscape is a water-conserving alternative to turf. Drought-tolerant vegetation (often native plants) can survive on less water (approximately 30 percent less than turf) and often become dormant (i.e., do not grow) during the hottest part of the summer. Currently, while local ordinances encourage the use of drought-tolerant landscape practices, none require xeriscaping on properties. Landscape ordinances could be amended to require the use of drought-tolerant plants for new buildings and minimum areas of xeriscape could be specified to ensure the majority of new landscaping is water-conscious.

Efficient Irrigation Technology requirements. As discussed previous in the Rebates section, new technology on efficient irrigation systems is readily available. Landscaping ordinances could be amended to require the use of "smart" controllers in all new commercial buildings and rain sensors in all residential developments. Such amendments could be paired with a rebate program for existing commercial and residential owners in order to gain maximum effectiveness.

Water-Capture Device Requirements. During precipitation events most of the water that falls on impervious surfaces is channeled to storm drains and eventually to the Truckee River. While significant rainstorms are not common in Washoe County, some climate change predictions indicate rain will become more frequent in the future. Water capturing devices such as rain barrels and onsite storage tanks can capture rain water to be used in irrigation at a later date. While retrofitting existing building with such devices would be relatively cost-prohibitive, amending building codes to require the installation of water-capture devices on new buildings and residences could reduce the amount of water required on a given property. Similarly, much of the water used inside a building is not consumed and could be reused onsite. This "gray water" that results from washing, cleaning, and similar activities could be recycled and used on irrigation. This action not only would conservation the amount of potable water supplied to services, but would also lower the amount of water (and associated costs) the Truckee Meadow Water Reclamation Facility would have to process. The benefits of such a requirement depend heavily on the amount of rainfall expected over time. Should rain events become more commonplace, such a requirement could help lower demand for potable water.

Certified Car Wash Program. Practices within the car wash industry vary. Standards on high pressure nozzles, water capture and disposal systems, and leak detection can change from business to business. In order to ensure the highest standard for water conservation is achieved uniformly, municipalities could partner with the local car wash industry to develop a water-saving car wash standardization program that identifies Best Management Practices. A provision that requires all businesses within the car wash industry adhere to these practices would ensure compliance is met.

Homeowner Associations Restrictions. Currently, rules and regulations within private agreements for residential planned unit developments ("PUD") supersede city and county landscaping ordinances. Private agreements under Homeowner Associations can either help or hinder efforts by restricting how occupants can manage their properties. Approval of future developments could require all private agreements associated with PUDs are consistent with municipal ordinances regarding water conservation and landscaping requirements. Allowing property owners under current private agreements the option to convert existing turf on their landscape to a water conserving alternative would facilitate an even greater reduction in water usage. Per NRS 116.330 property owners have the right to install or maintain drought tolerant landscaping on their properties so long as it is compatible with the community design and is approved by the governing body. Local government entities could work with Homeowners Association to ensure such transitions could be made by residents on existing properties whom are interested in doing so.

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