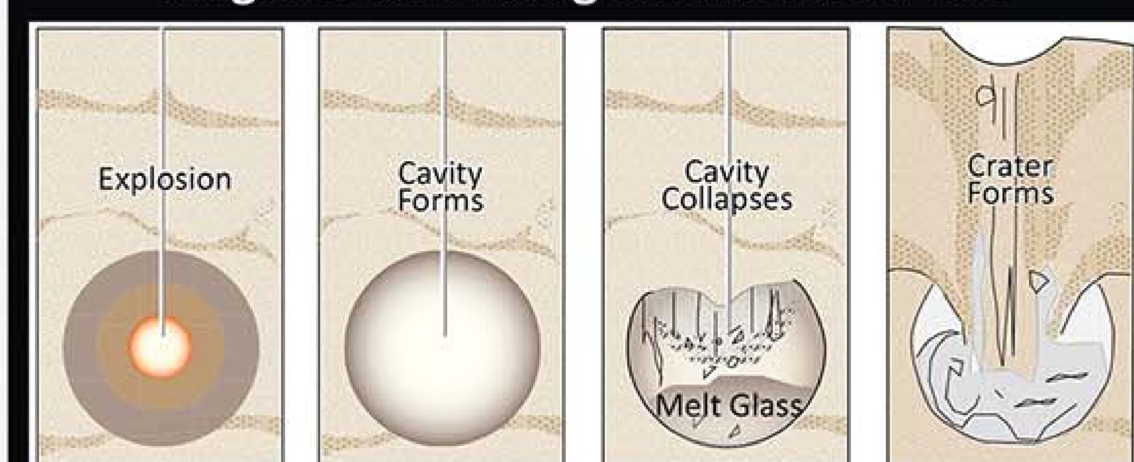
Historic Underground Nuclear Testing and Groundwater at the Nevada National Security Site (NNSS)

Nevada National Security Site

What Occurred

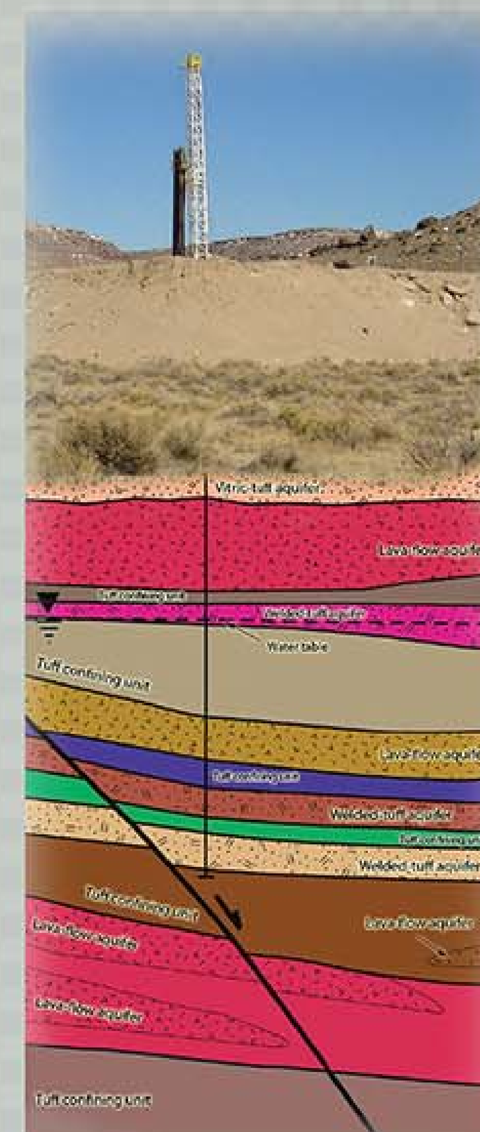
- 828 underground tests from 1951 to 1992
  - 90 to 4,800 feet below the ground surface
  - One-third near, below, or in the water table
  - Some groundwater under the NNSS and surrounding federal land contains radionuclides
  - Radionuclides are also in melt glass, underground rubble and in rocks surrounding the underground cavities

Stages of an Underground Nuclear Test



An underground nuclear explosion vaporizes the surrounding rock resulting in a cavity. As the remaining rock cools, melt glass forms and settles to the bottom of the cavity. This may lead to a collapse of the cavity which forms a depression on the surface, or a subsidence crater.

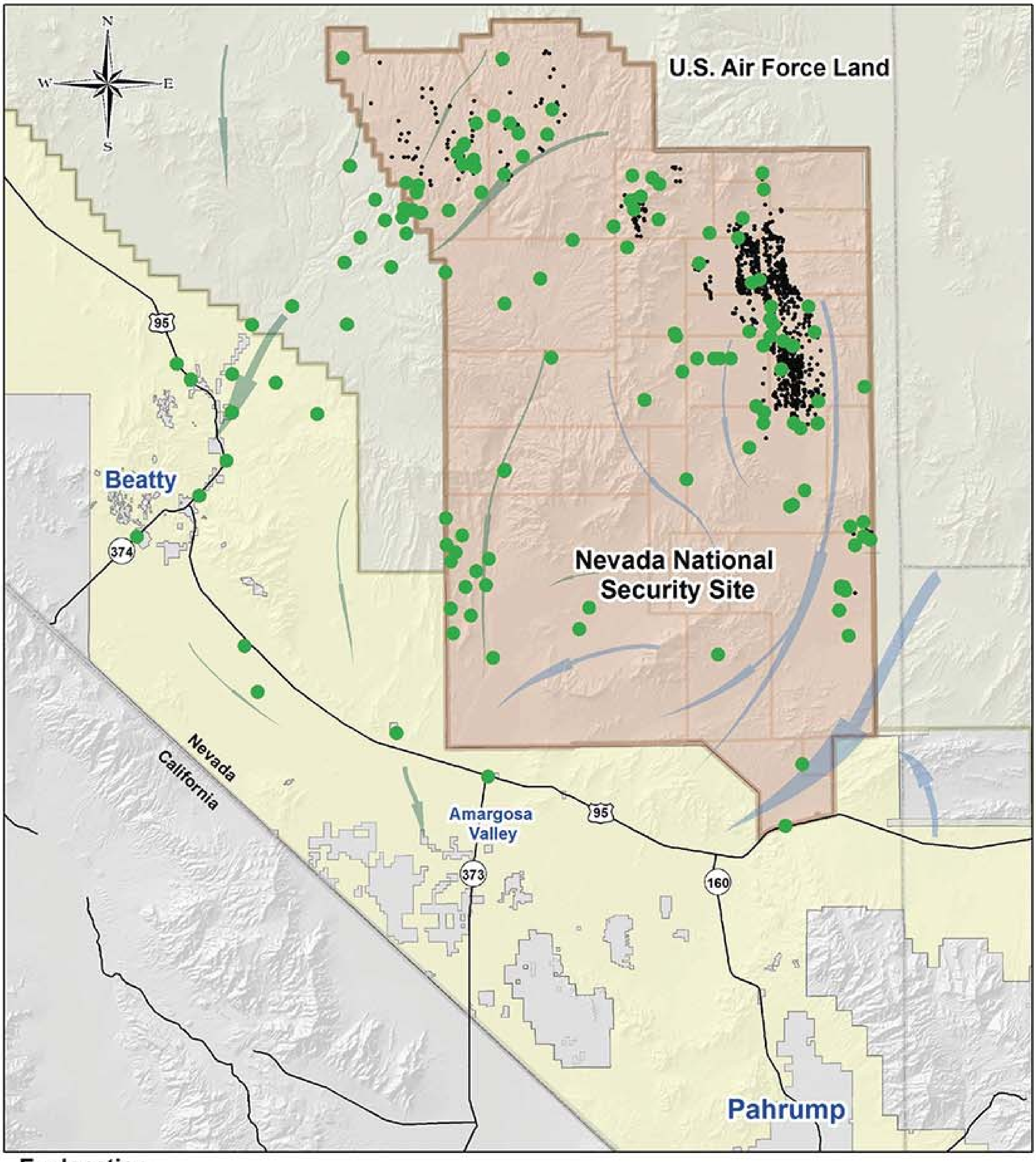
Important Factors



- **The most current scientific data available indicates there is no imminent risk to the public**
- No practical technology for vast-scale contaminant removal
- Extremely complex underground hydrogeology
- Radionuclides are located deep underground
- Not all tests had equal potential to release radionuclides into groundwater

Wells Sampled On and Near the Nevada National Security Site

NNSA
Nevada National Security Site



Explanation

- Well Location
- Underground Nuclear Test Location
- U.S. Bureau of Land Management
- Groundwater flow direction – Arrow width indicates relative flow volume. Green and blue colors denote alluvial-volcanic and carbonate flow systems, respectively. Source: Modified from USGS_PP_1771 (2010)

0 5 10 15 Kilometers

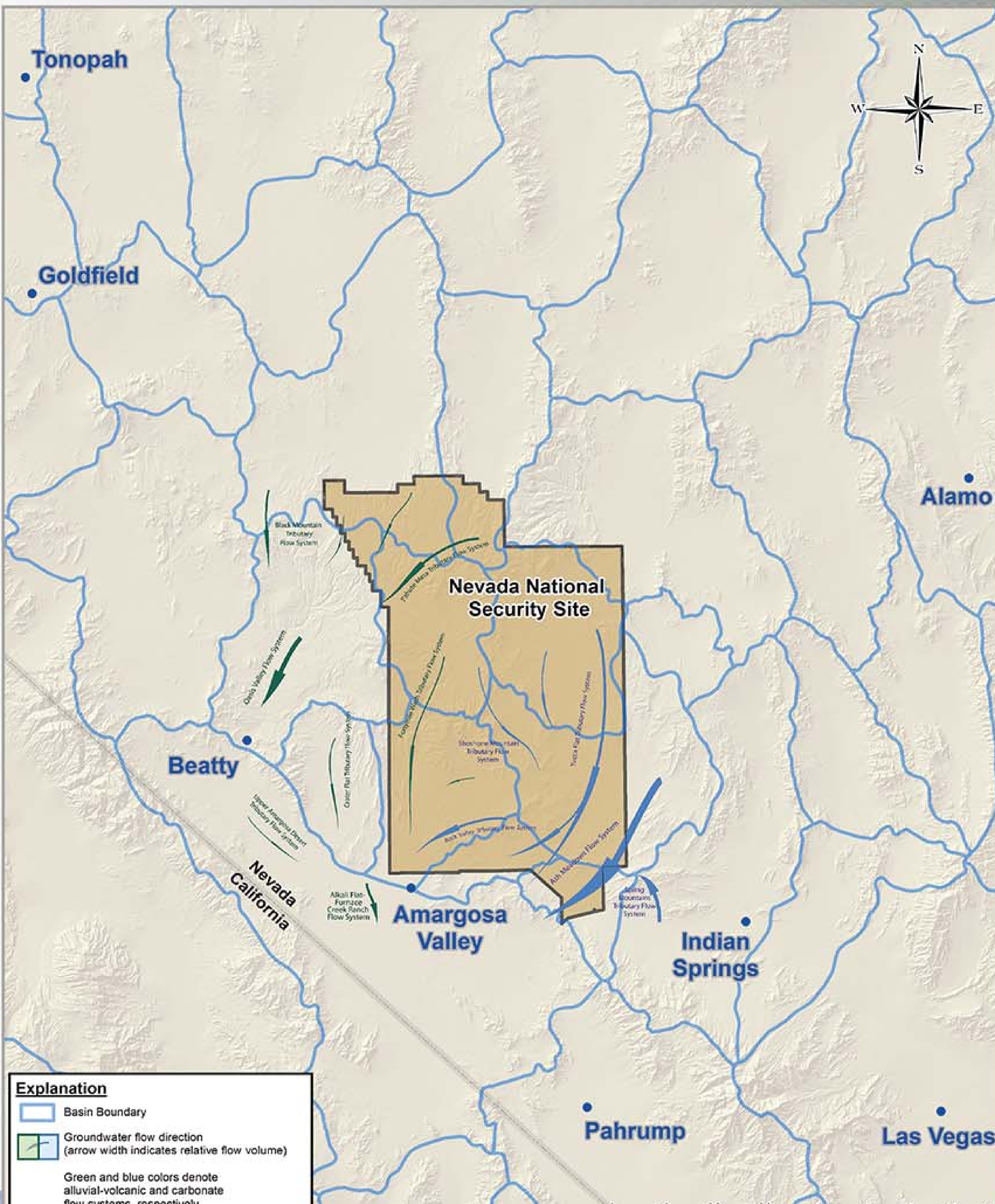
0 3 6 9 Miles

U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office

Log No. 2015-016

Regional Groundwater Flow and Hydrographic Basins

Basins compartmentalize groundwater aquifers which can change aquifer flow velocity and direction from basin to basin



U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office

Log No. 2015-016

Expanding Our Understanding of Groundwater

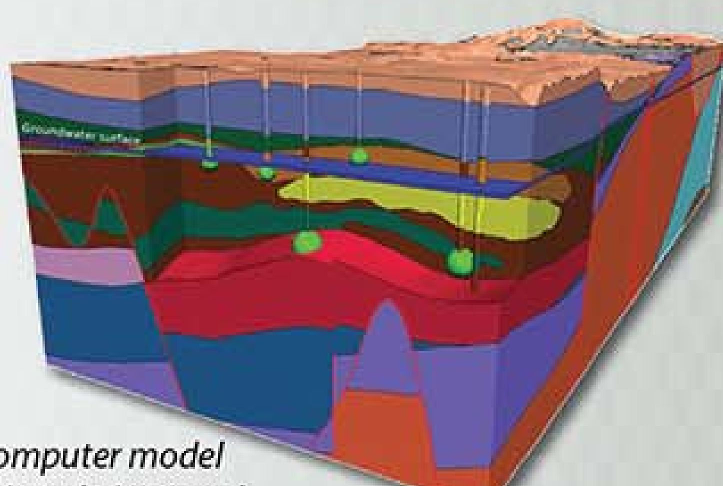
The Nevada Field Office is continuing to gather information to expand knowledge on the location, type, quantity, direction of movement, and flow rate of radionuclides in groundwater. Key steps involve:

Identifying Information

- Geology
- Hydrology
- Groundwater chemistry
- Amount of radionuclides in groundwater

Gathering Information

- Well drilling and construction
- Aquifer testing and water-level monitoring
- Water sample collection



Computer model of Nevada National Security Site subsurface

Analyzing Information

- Computer simulations (modeling) of hydrogeology and groundwater flow and contaminant transport

Log No. 2013-250

Why Computer Modeling?

Nevada National Security Site

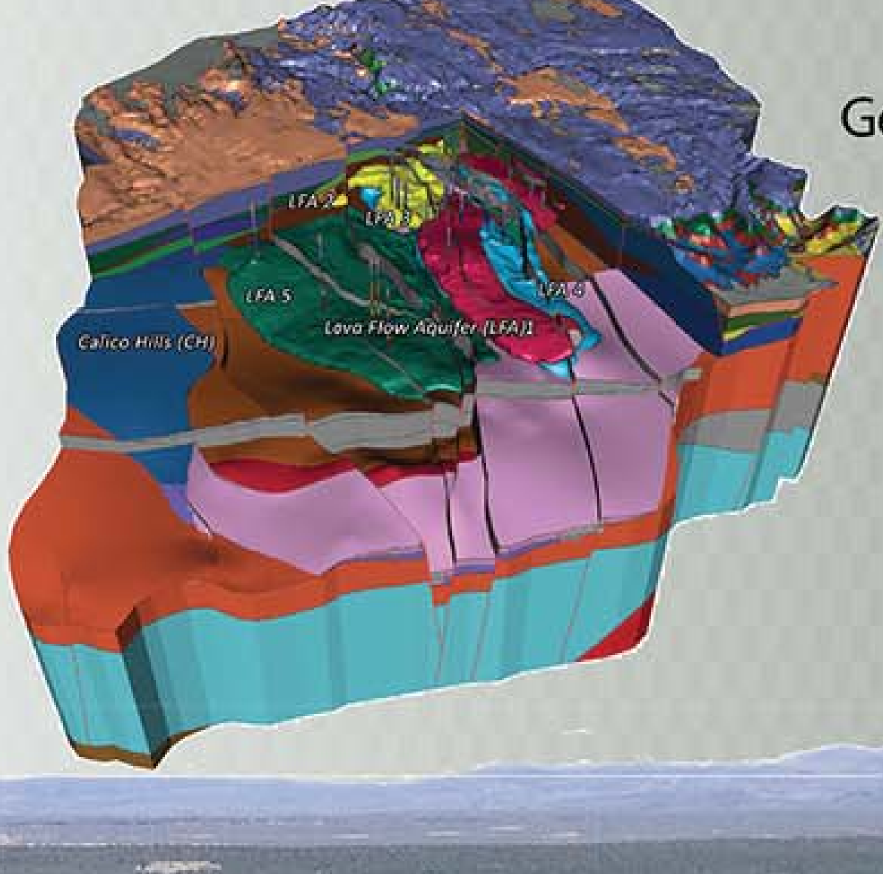
Creates three-dimensional representations of the otherwise inaccessible subsurface

Helps forecast where contamination is moving and how fast

Provides flexibility for integrating available data

Allows for uncertainty and sensitivity analysis

Provides basis for regulatory compliance and risk decisions



Geologic Model

Poster Exhibited & Staffed by State of Nevada Division of Environmental Protection Bureau of Federal Facilities

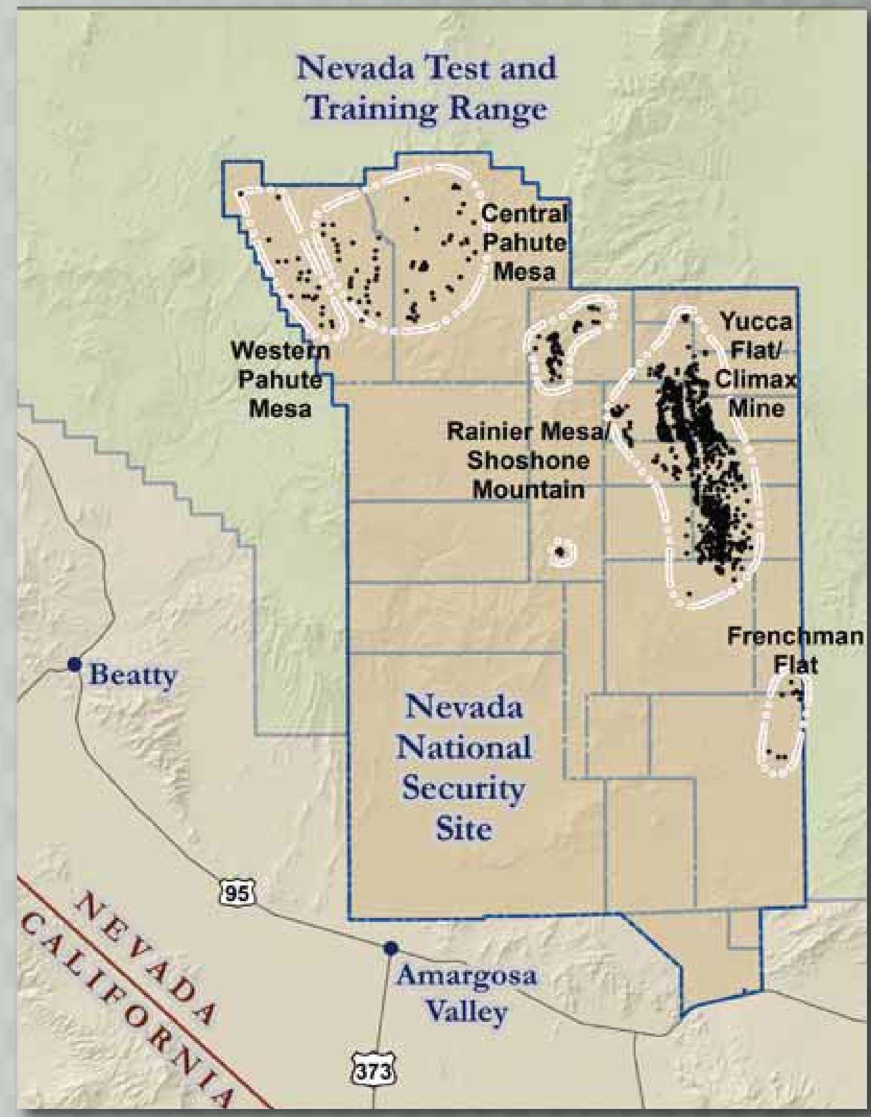
Federal Facility Agreement and Consent Order

Regulatory Strategy

Under a binding legal agreement, the State of Nevada Division of Environmental Protection must review and approve each stage of Nevada National Security Site groundwater characterization activities. Stages include:

Investigation Stage

- Gather new data to enhance models developed for each of the five (5) historic underground nuclear test areas (repeat as necessary)
- Review results: geology, hydrology, source term, groundwater and transport models, modeling approach (repeat as necessary)



Decision/Action Stage

- Develop a model evaluation plan to challenge and refine model forecasts
- Use model evaluation plan to identify locations for new wells or data collection activities
- Use data collected to defend that the corrective action unit is acceptable for closure

Closure Stage

- Negotiate use restrictions and regulatory boundary
- Establish institutional controls and requirements
- Develop long-term closure monitoring program

U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office

Log No. 2013-250

Poster Exhibited & Staffed by State of Nevada Division of Environmental Protection Bureau of Federal Facilities

NNSA

Nevada National Security Site

Federal Facility Agreement and Consent Order

Groundwater Strategy

Legally-binding agreement between the State of Nevada; U.S. Department of Energy, Environmental Management; U.S. Department of Defense; and U.S. Department of Energy, Legacy Management

NDEP - State of Nevada Division of Environmental Protection

NNSA/NFO - U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office

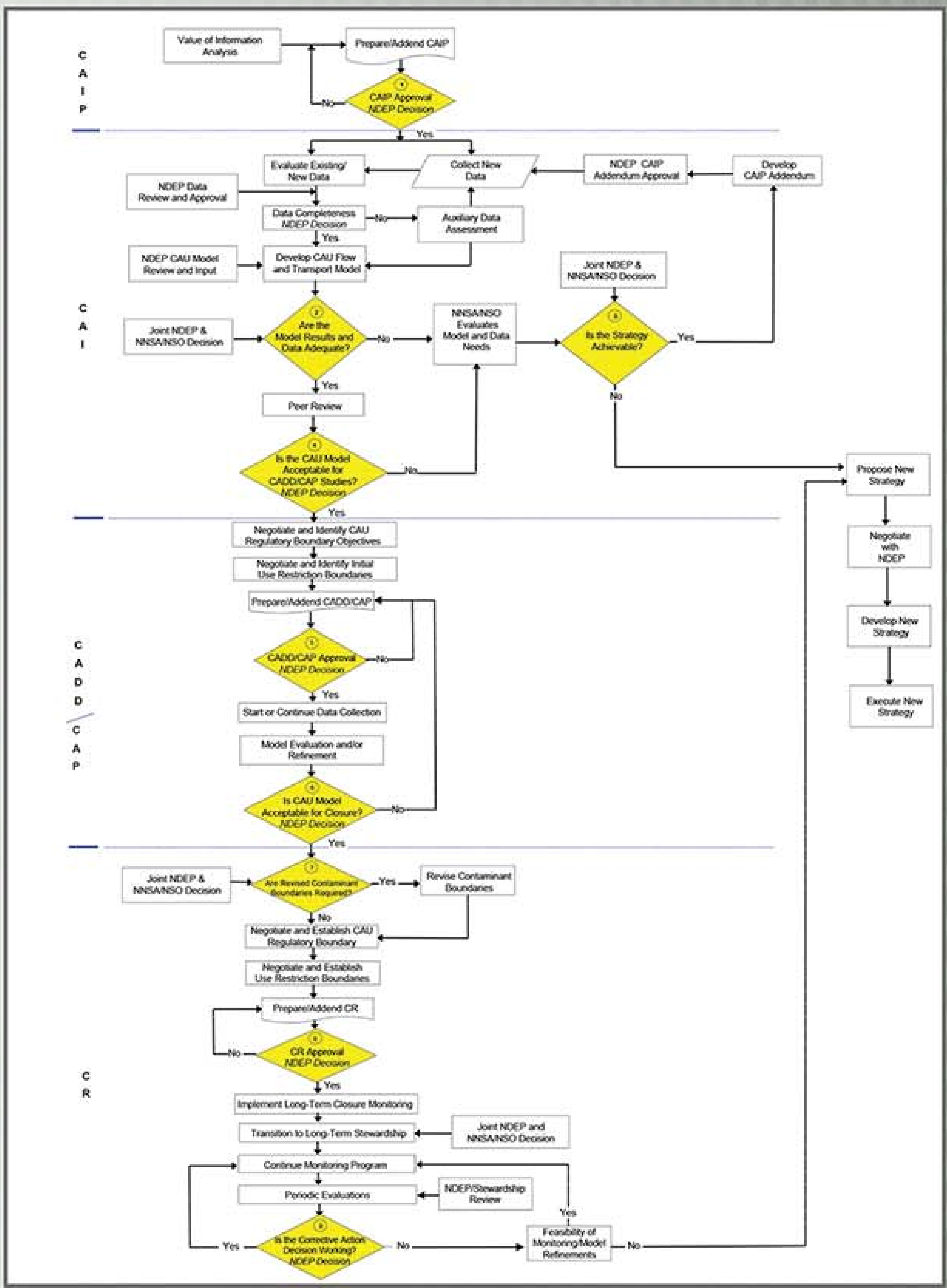
CAU - Corrective Action Unit: group of sites under investigation. There are five CAUs within Underground Test Area (UGTA) activities

CAIP - Corrective Action Investigation Plan: looks at existing information from the weapons testing program, the regional flow model, and one-dimensional transport simulations to determine the best options for site characterization and prioritization

CAI - Corrective Action Investigation: uses the information from the CAIP stage to develop CAU-specific models of flow and transport, taking the uncertainty of each specific hydrogeologic setting into account--these models are then used to forecast contaminant boundaries for 1,000 years

CADD/CAP - Corrective Action Decision Document/Corrective Action Plan: includes developing and negotiating an initial regulatory boundary, developing monitoring programs for model testing and closure, and identifying institutional controls

CR - Closure Report: involves negotiating the final regulatory boundary for CAU closure; developing a closure report, which must be approved by NDEP; and developing and initiating a long-term closure monitoring program



Decision point

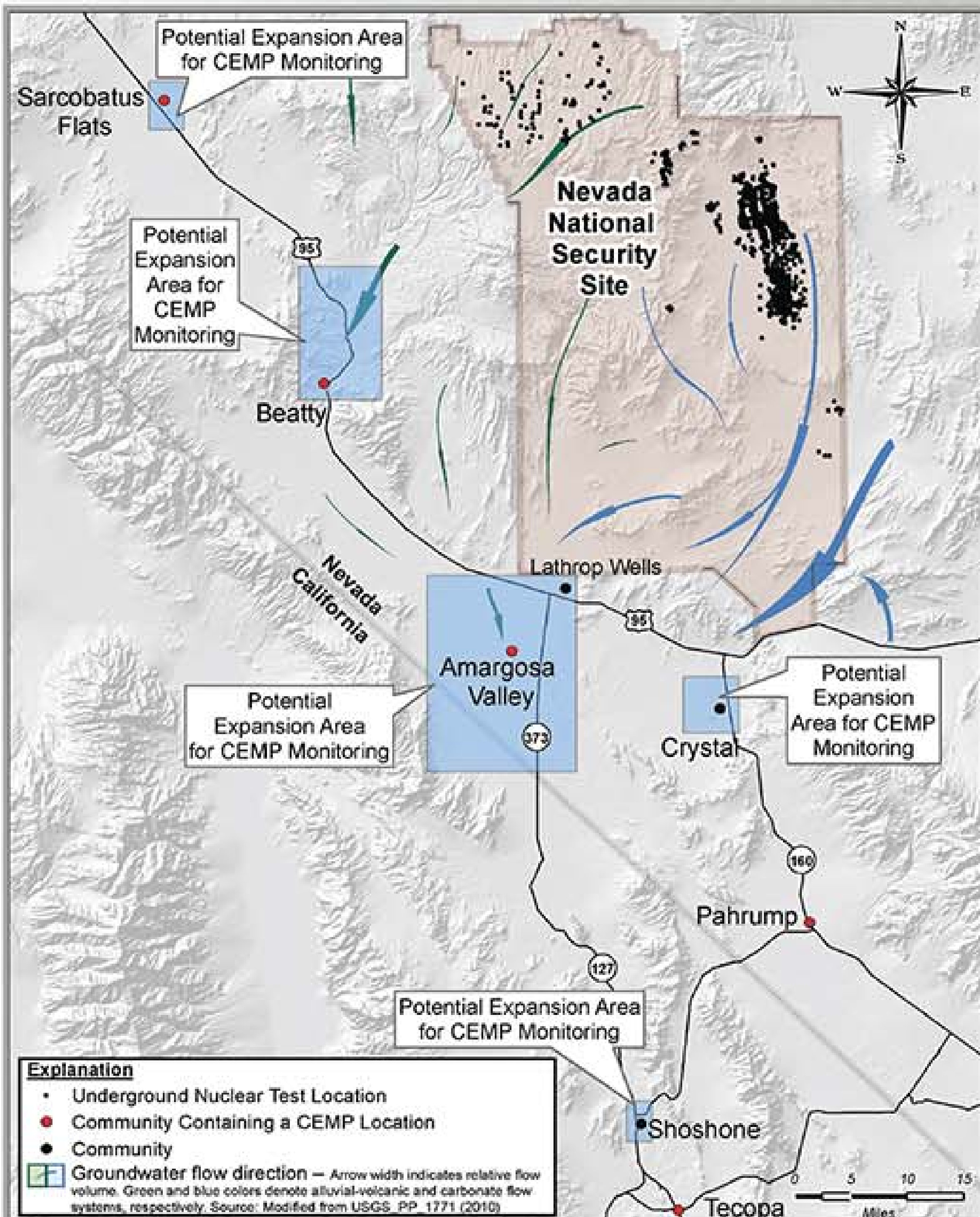
ndep NEVADA DIVISION of ENVIRONMENTAL PROTECTION

protecting the future for generations

U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office

Log No. 2012-192

Community Environmental Monitoring Program (CEMP)



CEMP is currently refocusing its efforts on groundwater monitoring in areas down gradient from the Nevada National Security Site (NNSS)

In 2015, CEMP will begin sampling additional wells and springs for tritium (see blue boxes on map)

The U.S. Department of Energy is currently exploring ways in which Nye County can become involved in CEMP water monitoring

CEMP Facts

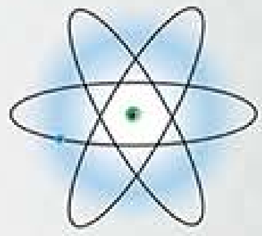
- CEMP is the off-site radiological monitoring program for communities surrounding the NNSS
- The U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office provides funding for the Desert Research Institute (DRI) to administer the program
- CEMP provides a hands-on role for public stakeholders
- Water sampling results are made available on the public website at **www.cemp.dri.edu** and posted on bulletin boards at local CEMP stations (see red dots on map)

U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office

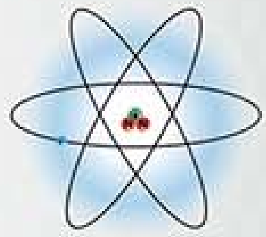
Log No. 2015-016

Understanding Tritium in Water

- Radioactive form of hydrogen with a half-life* of 12.3 years
- Naturally occurs in surface waters, such as Lake Mead, at 10 to 30 picocuries per liter
- Emits a weak form of radiation that cannot penetrate deeply into tissue or travel far in air
- Primarily enters the body when eating food or drinking water containing tritium
- Half of tritium is eliminated from the body about 10 days after exposure
- Regulatory standard for safe drinking water is 20,000 picocuries per liter



Hydrogen Atom
One proton
No neutrons
One electron



Tritium Atom
One proton
Two neutrons
One electron

Why Analyze for Tritium?

More than 95% of the radionuclide inventory (at the time of detonation) is tritium which will decay to nearly zero within 200 years. Since tritium is part of the water molecule, it can easily move in groundwater. Many of the longer-lived radionuclides, such as plutonium, are trapped in the melt glass or attached to rock surfaces which delays their movement in groundwater. Until increased levels of tritium are observed, other longer-lived radionuclides from underground nuclear testing will not be present.

In order to reach the allowable limit under the Safe Drinking Water Act, a person would need to drink 193 gallons of water per year containing 20,000 picocuries of tritium per liter over a 70-year lifetime...A year of drinking water with this amount of contamination would produce approximately the same dose of radiation you would get during a single commercial flight between Los Angeles and New York City.

*Half-life refers to the amount of time it takes for a radioactive substance to lose half of its radioactivity.

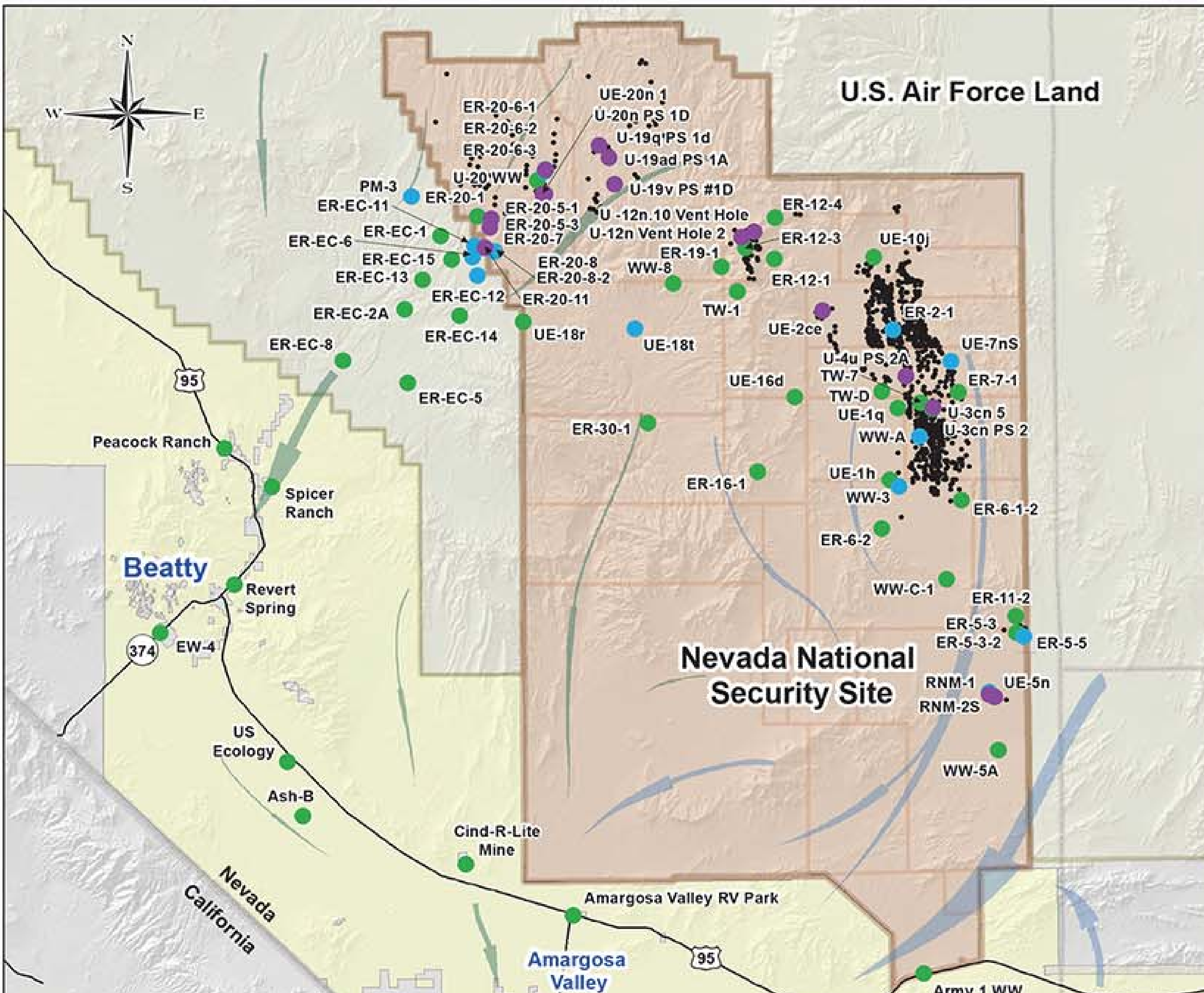
U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office

Log No. 2013-250

Results of Wells Sampled for Tritium

Nevada National Security Site

Calculations show tritium in the groundwater from underground nuclear tests will decay to nearly zero in 200 years



Explanation

Tritium Levels

- Non-Detect
- Below Safe Drinking Water Limit
- At or Above Safe Drinking Water Limit

- Underground Nuclear Test Location
- U.S. Bureau of Land Management
- Groundwater flow direction – Arrow width indicates relative flow volume. Green and blue colors denote alluvial-volcanic and carbonate flow systems, respectively. Source: Modified from USGS PP 1771 (2010)

0 5 10 15 Kilometers

0 3 6 9 Miles

U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office

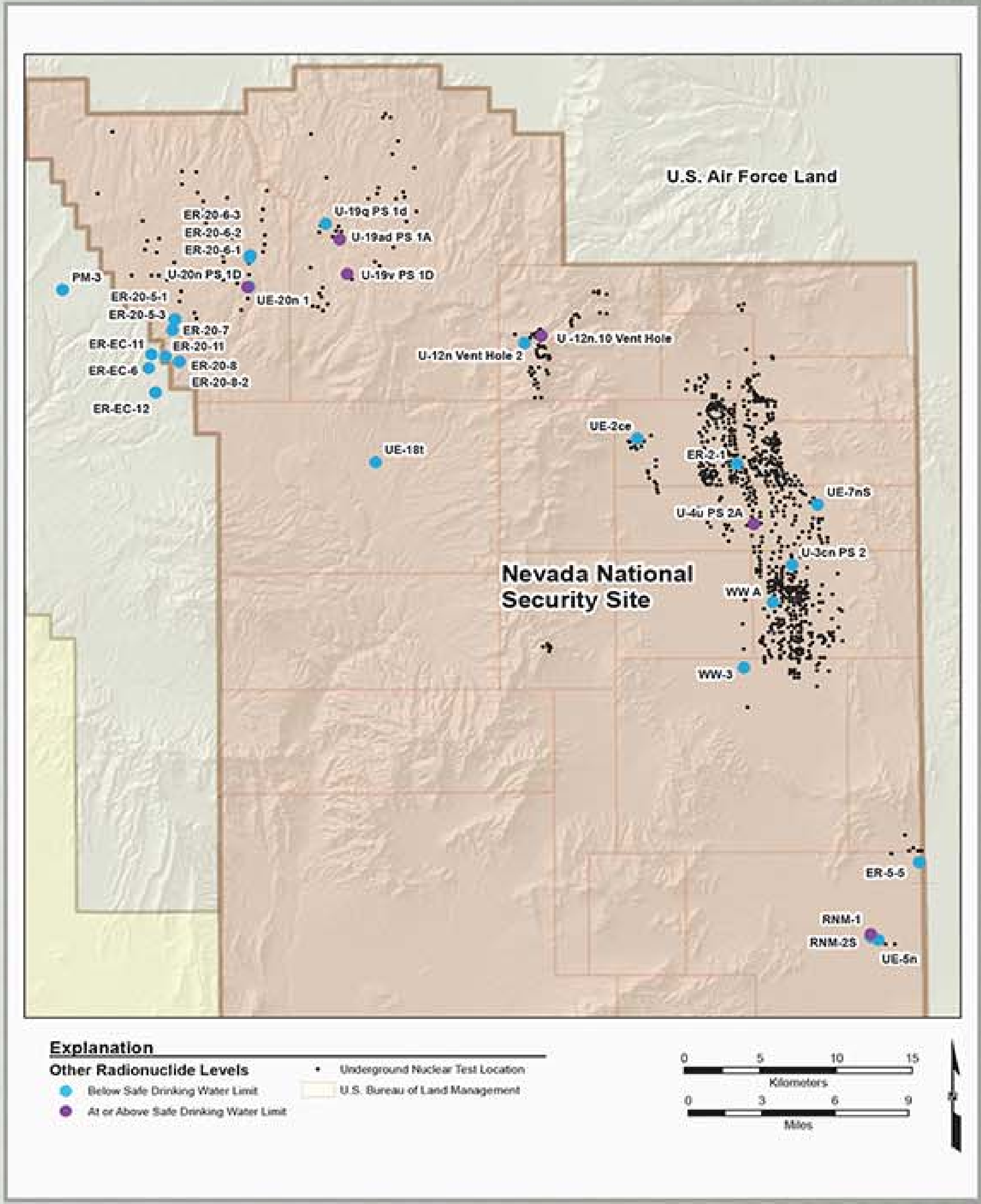
Log No. 2015-016

Sampling Results for Other Radionuclides

- **Other than tritium, no other radionuclides from underground nuclear testing have been detected in wells sampled off the Nevada National Security Site**
- **No radionuclides from underground nuclear testing have been detected beyond U.S. Air Force controlled land**

43 radionuclides produced during nuclear tests considered a potential risk

- 29 radionuclides are trapped in the melt glass formed by the detonation of the underground nuclear device
- Tritium, carbon, iodine, chlorine, technetium are mobile in most subsurface environments
- Cesium and strontium are mobile in a carbonate aquifer system
- Plutonium is transported a limited distance on small particles
- Samples are analyzed for other radionuclides once tritium has been detected

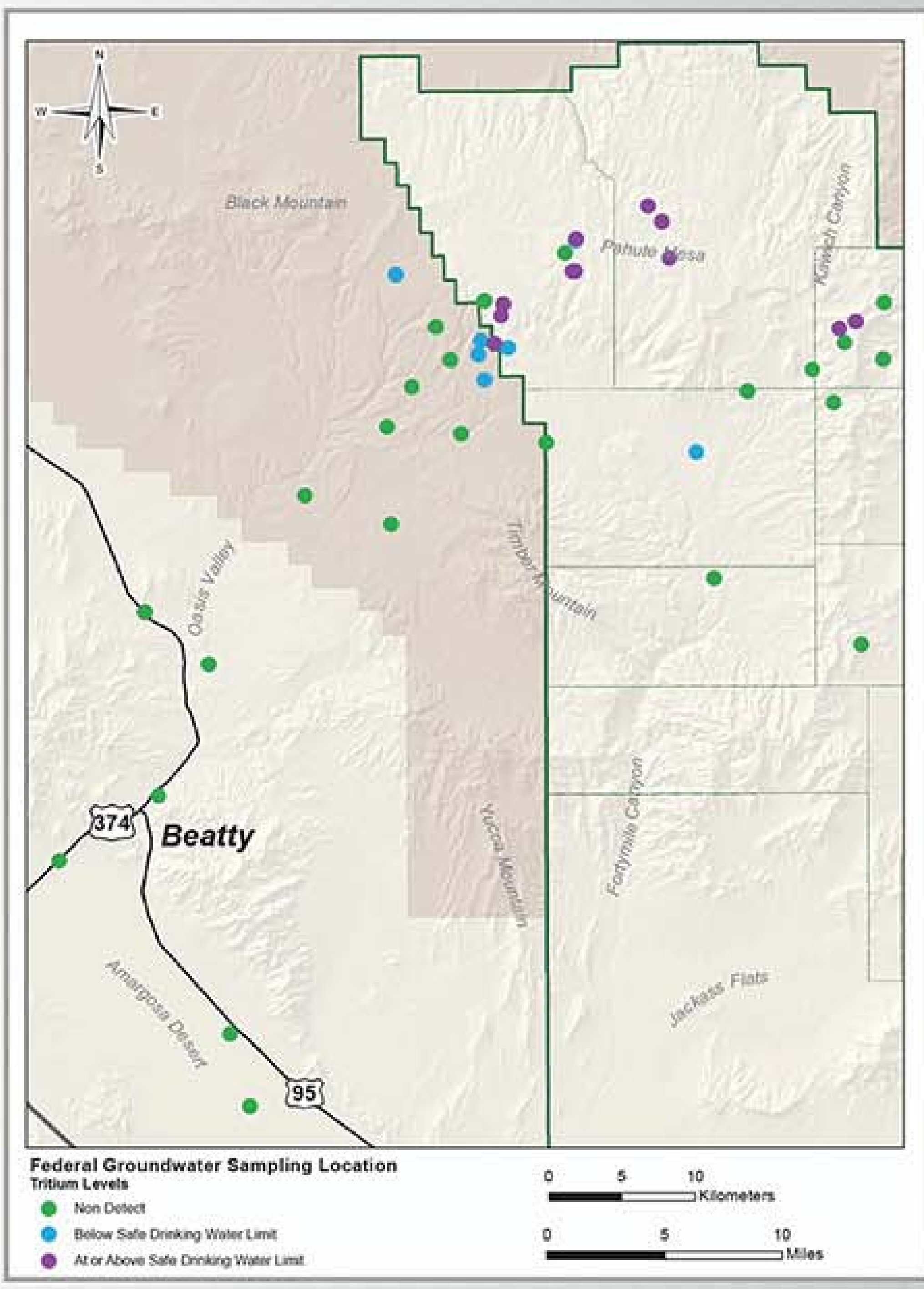


U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office

Log No. 2015-016

Putting Results into Perspective

Nevada National Security Site



- **Based on conservative, scientific calculations and sampling results, it will take at least 100 years for tritium to reach the closest public land boundary**
  - **In approximately 100 years, the concentration of tritium is estimated to be less than Safe Drinking Water Act limits at the closest public land boundary**
  - **In approximately 200 years, the concentration of tritium will be nearly zero at the closest public land boundary**

Protecting the Public

- No public access to contaminated groundwater
  - Large area of federally-controlled land provides buffer zone
- Evolving and conservative computer models provide forecasts to identify potential areas of concern in advance of sampling
- Ongoing monitoring serves as a means for early detection

Current and Upcoming Activities

Scientists continue to collect and analyze data to gain a greater understanding of the complex subsurface environment. This work strengthens public protection.

Pahute Mesa
(investigation stage)

- Analyze data and develop additional computer simulations to forecast groundwater flow and contamination transport
- Drill one well

Rainier Mesa
(investigation stage)

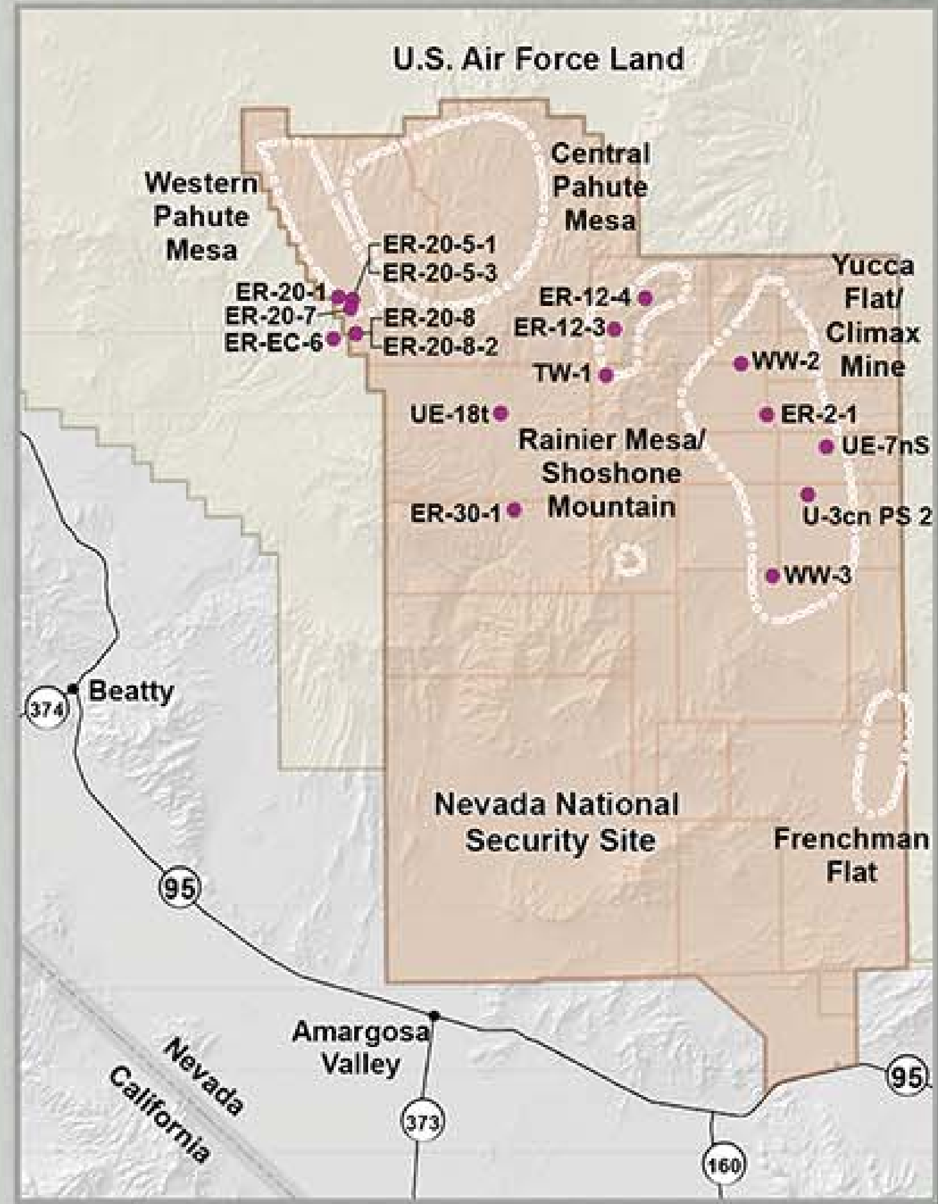
- Update conceptual model

Yucca Flat
(investigation stage)

- Continue independent peer review
- Plan model evaluation strategy (including additional wells)
- Drill one well

Frenchman Flat
(closure stage)

- Develop closure report
- Develop use restriction and regulatory boundaries
- Develop long-term monitoring plan



Groundwater Sampling in Frenchman Flat

Continue Sampling and Water-Level Monitoring

Water-level monitoring at various wells on or near the NNSS, and groundwater sampling at the following wells:

Pahute Mesa

- Well ER-20-8-2 (Fall)
- Well ER-EC-6 (Winter)
- Well ER-20-1 (Winter)
- Well ER-20-7 (Winter)
- Well ER-20-8 (Winter)
- Well ER-20-5-1 (Winter)
- Well ER-20-5-3 (Winter)

Rainier Mesa

- Well ER-30-1 (Spring)
- Well UE-18t (Spring)
- Well ER-12-3 (Summer)
- Well ER-12-4 (Summer)
- Well TW-1 (Summer)

Yucca Flat

- Well ER-2-1 (Winter)
- Well WW-3 (Spring)
- Well UE-7nS (Spring)
- Well U-3cn PS 2 (Spring)
- Well WW-2 (Summer)

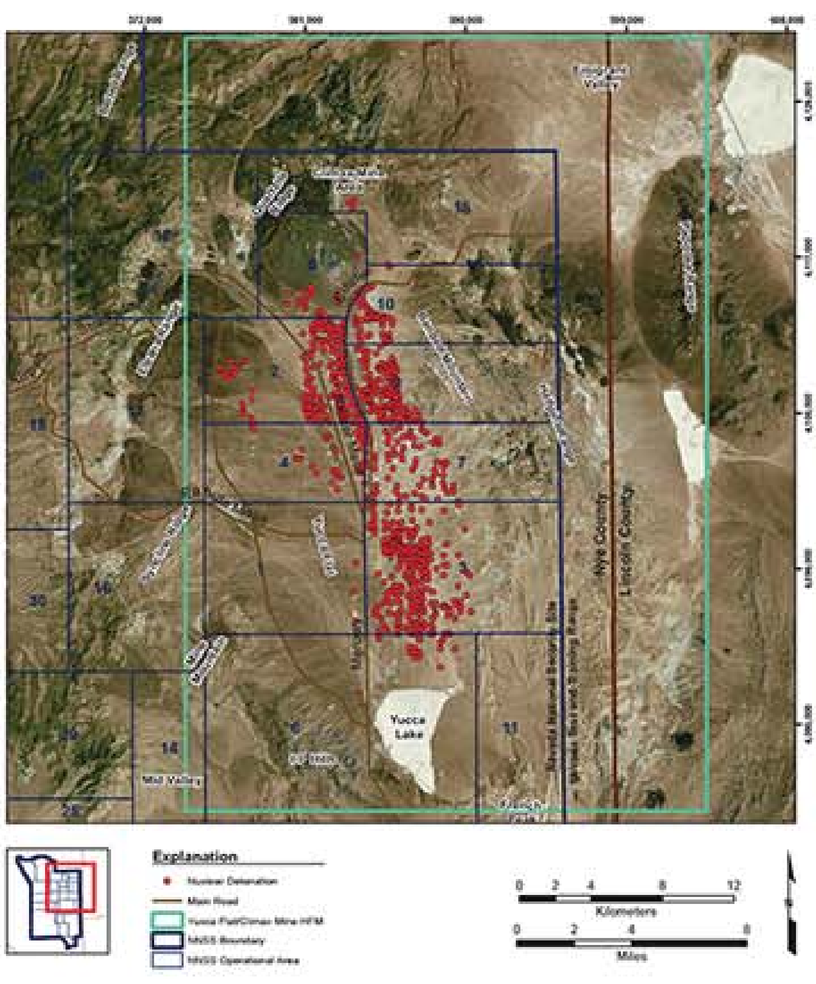
Frenchman Flat Progress

2013-2014

- Data collection, model evaluation, and model refinement ***(investigation stage)***
  - Collected geologic data, water levels, water chemistry, hydraulic tests, radiochemistry, and surface geophysics
  - Developed new conceptual model for groundwater flow and contaminant transport from the PIN STRIPE underground nuclear test
- Model evaluation report accepted by the State of Nevada Division of Environmental Protection, approved going to ***closure stage***

2015

- Developing closure strategy and report ***(closure stage)***
  - Negotiate use-restriction and regulatory boundaries
  - Develop monitoring plan
  - Determine institutional controls



Satellite Image and Physiographic Features of Yucca Flat

Yucca Flat Progress

2014-2015

- Yucca Flat Peer Review completed in December 2014 ***(investigation stage)***
  - Peer review committee recommended moving forward into ***decision/action stage*** with additional analyses and data collection
  - Developing responses to peer review committee recommendations
- Planning is underway to drill new wells to gather additional hydrogeologic and radioisotopic data ***(investigation stage)***

Nevada National Security Site

Poster Exhibited & Staffed by Nevada Site Specific Advisory Board Members

U.S. Department of Energy
NSSAB
Environmental Management

Nevada Site Specific Advisory Board

...citizens working together on environmental issues

What is the NSSAB?

A group of southern Nevada stakeholders providing recommendations to the Department of Energy on cleanup activities at the Nevada National Security Site

Meetings

- All Full Board meetings are open to the public
- While usually held in Las Vegas, Full Board meetings may be held throughout southern Nevada

Member Responsibilities

- Attend Full Board meetings
- Review materials with timely response
- Commit approximately 10 hours per month
- No technical experience is required

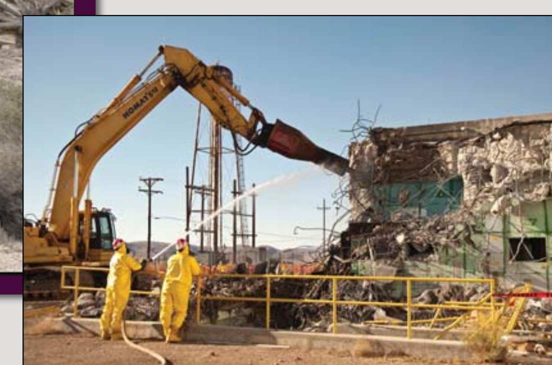
Waste Offloading

Waste Management

Groundwater Sampling

NSSAB Well Visit

Soil Monitoring



Industrial Sites Cleanup

Well Development and Testing

NSSAB Outreach

Phone
702-630-0522

Email
NSSAB@nnsa.doe.gov

Website
www.nv.energy.gov/NSSAB

Areas of Focus

The NSSAB makes recommendations on specific cleanup activities at the Nevada National Security Site

Budget
...reviews and prioritizes funding for cleanup projects

Groundwater
...issues related to groundwater contamination, characterization, drilling and modeling

Industrial Sites
...issues related to decontaminating and disposing of obsolete buildings and facilities

Soils
...cleanup standards used to remediate surface soil contaminated by historic nuclear testing

Transportation/Waste
...issues related to transportation of hazardous and radioactive waste and waste disposal activities

Membership
...recruits new members

Outreach
...increases public awareness of the NSSAB

Poster Exhibited & Staffed by Nevada Site Specific Advisory Board Members

Nevada Site Specific Advisory Board

...citizens working together on environmental issues

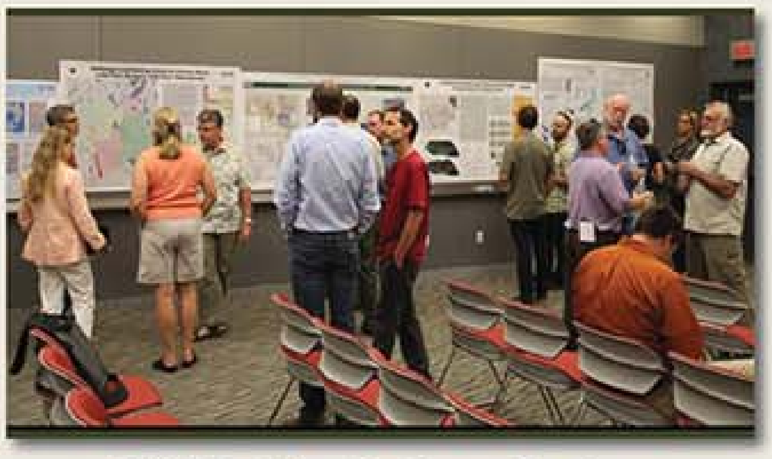
Join us tonight at 6pm to see how the NSSAB is working for our community

(meeting will be held in the adjoining room)

Here are just a few examples of how the Board has been working for our community:

- Helped site a groundwater characterization well on Pahute Mesa
- Made numerous recommendations regarding how to improve communication with stakeholders
- Observed/participated in DOE's internal groundwater planning and execution meetings and develop recommendations for improving the program

NSSAB Observes Groundwater Assessment



NSSAB Attends Groundwater Technical Information Exchange

Groundwater Briefing During NSSAB Tour of the Nevada National Security Site

Log No. 2015-016

Poster Exhibited & Staffed by Nye County Natural Resources Office

Water Level Trends in Southern Nye County – 2014 Update

Nye County Water District

Introduction

The year 2014 marks the fifteenth anniversary of Nye County's Water Level Measurement Program (WLMP), and the first year the Program was funded by the Nye County Water District (NCWD). The mission of the District is to "Provide, protect and preserve water resources in Nye County", so adoption of the WLMP was a natural fit. The WLMP comprises more than 11,000 measurements collected over a period of 15 years in southern Nye County and nearby Inyo County. This volume of data and period of record allow us to look at trends in water level data over time, which show how groundwater conditions are changing. The maps shown here present the best data available for assessing groundwater conditions in southern Nye County, and provide a basis for managing groundwater issues in the Pahrump Valley. All contouring of water table elevation data was done in ArcGIS using the Empirical Bayesian Kriging method. This method has been tested and compared against other methods suitable for contouring water table elevation data and found to produce similar results.

WLMP Wells

Not all of the wells in the 15-year history of the WLMP have been consistently measured – some wells have been lost due to obstructions, collapse, or vandalism; other new wells have been added in areas where data gaps existed or data collection opportunities arose. This year enough data have been collected in a consistent set of wells to create a 10-year water level change map (from 2004 to 2014). September is considered the "index" month for the WLMP, and all changes are calculated around that month (i.e., September 2004 to September 2014).

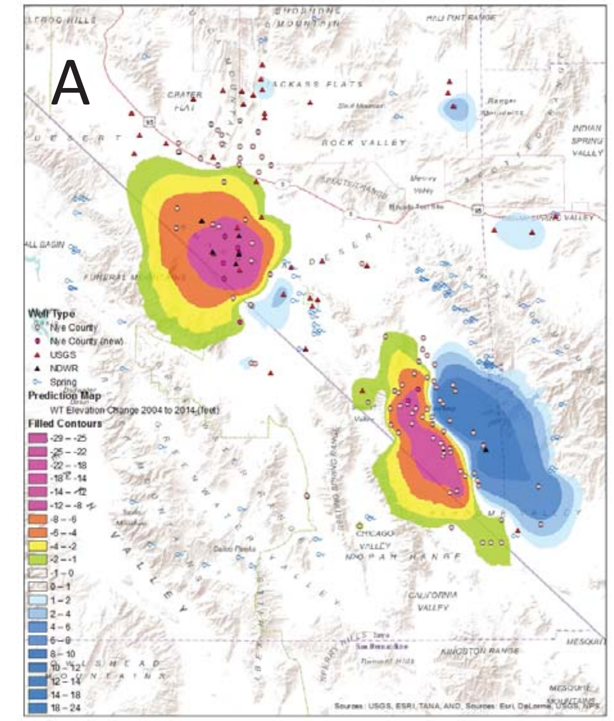
This data set was created by bringing together water level data available from all wells located within the study area that also have data available over the 10-year period. Of these 147 wells, 103 are part of the WLMP, 39 are part of the United States Geologic Survey (USGS) National Water Information System (NWIS), and five are measured by the Nevada Division of Water Resources (NDWR). The Nye County Water District measures 15 of the 39 USGS NWIS wells, and provides the data to the USGS under the Amargosa Integrated Monitoring Network. Additionally, five of the wells measured by the USGS NWIS program are also independently measured as part of the WLMP.

To supplement areas of sparse data, or replace gaps where WLMP wells were lost, water level measurements were restarted in wells (either old WLMP or USGS NWIS) that were historically measured. Interpolating between the new and historical measurements in these "reactivated" wells gives an average change and trend over the period of record. This technique is important because it allows us to expand the water level data set and produce more accurate change maps.

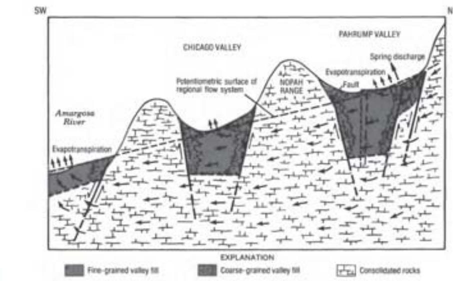
The 2-year water level change maps offer more details on how and where water levels have been changing over time. Each new 2-year map adds new wells as time progresses. Not all wells can be utilized in the 10-year change map, since some of them were not part of the WLMP in 2004. For the newest 2-year change map (2012 to 2014) there are an additional 32 new or reactivated wells added, compared to the 10-year (2004 to 2014) map. Eleven of these 32 new wells were drilled in 2010 under the Department of Energy Ground Water Evaluation grant, in locations intended to maximize the returns on hydrologic information.

10-Year Change Map

In general, the 10-year water level change map (Panel A) shows water level increases in the Pahrump Valley east of Hwy 160, from north of Wheeler Wash to south of Trout Canyon in the alluvial fan aquifer, and water level declines west of Hwy 160 in the valley fill aquifer. Water level increases are believed to be due mainly to precipitation falling on the Spring Mountains, especially during wetter years. Farther north and to the west, in the Amargosa Farms area, the map generally shows water level declines centered on the Rockview Dairy over the 10-year period. Smaller changes are observed in several other locations, but these are not considered significant relative to the larger changes observed in Pahrump and Amargosa Valleys. Water level declines westward into California and increases in the western Spring Mountains where no wells exist are the result of the contouring algorithm, and may not represent actual water level changes.



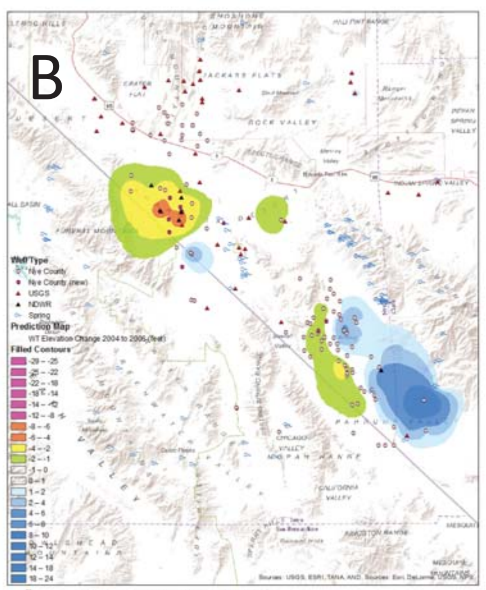
Change in Water Table Elevation from 2004 to 2014



Generalized cross-section across the western Spring Mountains, Pahrump Valley, and Chicago Valley (from Harrill 1986). The coarse- and fine-grained valley-fill aquifers depicted in the section correspond to the alluvial fan and valley-fill sediments (aquifers), respectively, discussed in this poster. All of the WLMP wells described in this poster are completed in either the alluvial fan or valley-fill sediments.

References

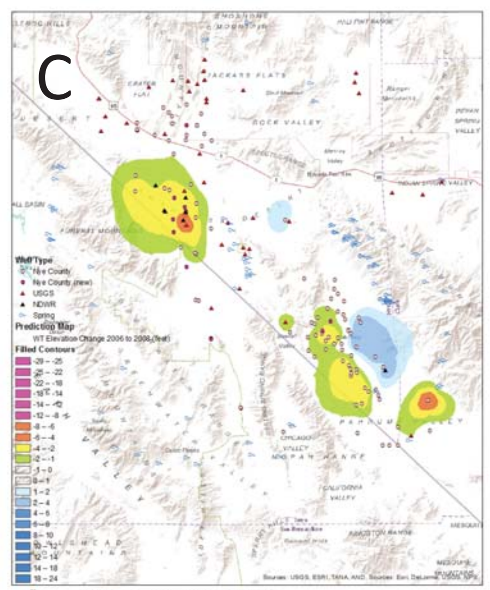
Harrill, J. R., 1986. *Ground-water storage depletion in Pahrump Valley, Nevada-California, 1962-75*. U.S. Geological Survey Water-Supply Paper 2279.



Change in Water Table Elevation from 2004 to 2006

2004 to 2006

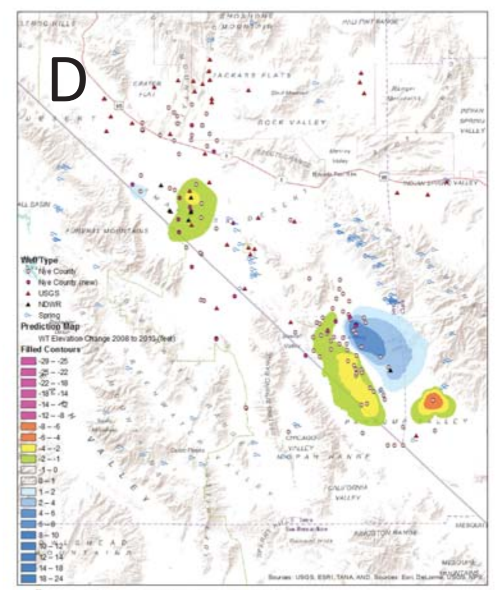
The 2004 to 2006 change map (Panel B) shows the same general character as the 10-year map, except the changes are of reduced magnitude (to be expected due to the shorter time window analyzed). The bulk of the water level increases (blues) in the Pahrump are in the southeast part of the Valley. Decreases (greens) along the central and western part of the Pahrump Valley show a semi-linear NW-SE configuration. This interface between water level decreases and increases is likely the contact between coarser alluvial fan sediments and finer valley-fill sediments, but may also be related to faulting. Water level changes in the Amargosa Farms area are similar to that of the 10-year map, but of a smaller magnitude.



Change in Water Table Elevation from 2006 to 2008

2006 to 2008

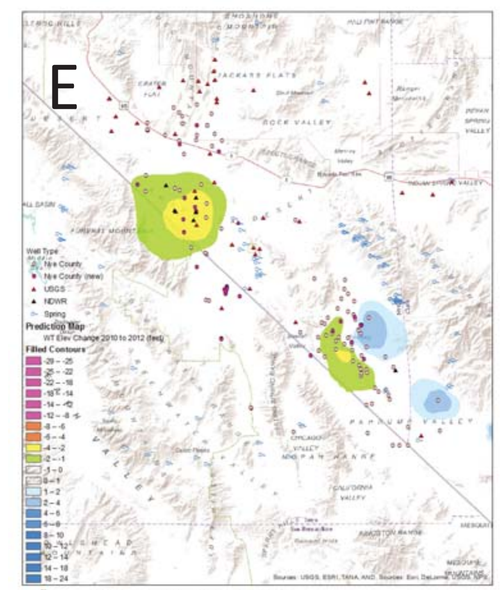
From 2006 to 2008, the 2-year change map (Panel C) shows the water level increase on the east side of the Pahrump Valley moving farther to the north as compared to the 2004 to 2006 map. The decreases on the west side of the valley have become more localized but greater in magnitude. The large decrease (yellow/green bullseye) in the southeast part of the Valley is due to one well, NDOT, and is believed to reflect a drying period after Intermittent Spring had flowed. This spring is known to flow large amounts of water during periods of greater than normal precipitation (i.e., the blue increase on the 2004 to 2006 map). Water level changes in the Amargosa Farms area are similar to that of the previous 2-year period, but with the area of maximum decrease moving farther to the south.



Change in Water Table Elevation from 2008 to 2010

2008 to 2010

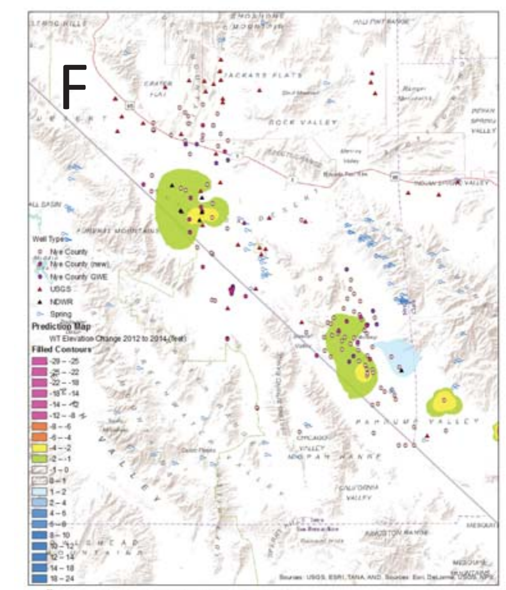
The 2008 to 2010 change map (Panel D) shows similar increases on the east side of the Pahrump Valley as shown in the 2006 to 2008 map; however, the magnitudes of these increases are smaller. On the west side of the Valley, decreases have coalesced and are of smaller magnitude and similar in character to that of the 2006-2008 period. Water level changes in the Amargosa Farms area show a much smaller areal extent as compared to the previous period, and also show water rising (blue contours) to the northwest. This rise may represent an influx of groundwater traveling southward along the course of the Amargosa River.



Change in Water Table Elevation from 2010 to 2012

2010 to 2012

From 2010 to 2012 (Panel E), similar increases on the east side of the Pahrump Valley are observed as in previous periods, but of smaller aerial extent. Decreases on the west side of the Valley are also similar to the previous period, but absent to the southeast. This may be due to the dissipation of the mound on the eastern side of the valley (blue areas), which turned into flow toward the southwest and has effectively reduced the declines observed during previous periods in this area. The large increases in the southeast part of the Valley (NDOT and NDOT South wells) reflect increased groundwater flow from the Spring Mountains, and are believed to be due to higher than normal precipitation during 2010 (7.94 inches versus the average 4.83 inches) for this area. Water level declines dominate throughout the Amargosa Farms area and probably mark the end of the water influx as described in the previous period.



Change in Water Table Elevation from 2012 to 2014

2012 to 2014

The 2012 to 2014 change map (Panel F) shows a marked decrease, in both in aerial extent and magnitude for the increase on the east side of the Pahrump Valley. This is probably due to the last 4 years of precipitation (2011 to 2014) being lower than normal (2.48, 3.29, 2.59, and 2.36 inches). This is also reflected in the large decreases (two yellow/green bullseyes) in the southeast part of the Valley (NDOT and NDOT South wells). Decreases on the west side of the Valley are similar to the previous period and are reduced both to the north and southeast, as compared to the 2008 to 2010 map. This is likely due to dissipation of the eastern mound creating flow both northwesterly and southwesterly and through permeable zones in the alluvial fan/valley-fill contact. Water level changes in the Amargosa Farms area are similar to those observed in the 2010 to 2012 period.

Groundwater "Ant Farm" Demonstration

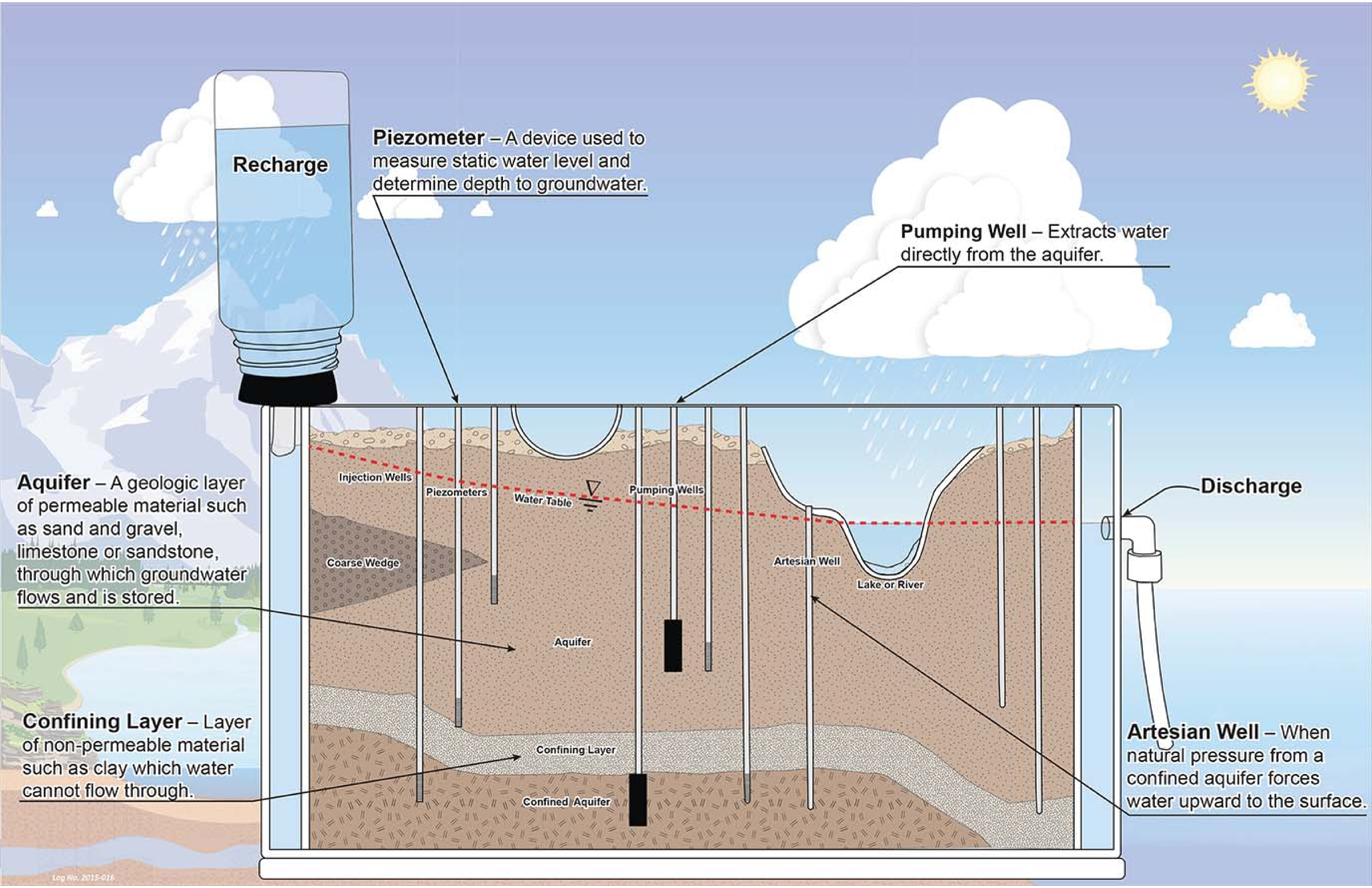
Nevada National Security Site

- The general principles of groundwater flow and transport can be demonstrated visually in the Ant Farm
- The Ant Farm, although not truly representative of the hydrogeologic setting of the Nevada National Security Site, does provide a sense of how groundwater behaves in nature

Groundwater Ant Farm Demonstration at Vanderburg Elementary School

Groundwater is water that has infiltrated from surface sources (rain/snow) and accumulated in the subsurface

- Groundwater moves through pore spaces and fractures in various types of geologic layers
  - Geologic layers range from near surface soils such as sands and gravels to deeper rock units such as limestones and volcanic rocks
- Groundwater moves within geologic layers at different rates and directions based on the properties of the geologic units and differing head pressures


Recharge
Piezometer – A device used to measure static water level and determine depth to groundwater.
Pumping Well – Extracts water directly from the aquifer.
Aquifer – A geologic layer of permeable material such as sand and gravel, limestone or sandstone, through which groundwater flows and is stored.
Discharge
Confining Layer – Layer of non-permeable material such as clay which water cannot flow through.
Artesian Well – When natural pressure from a confined aquifer forces water upward to the surface.
Injection Wells
Piezometers
Water Table
Pumping Wells
Coarse Wedge
Artesian Well
Lake or River
Aquifer
Confining Layer
Confined Aquifer
Log No. 2015-016