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

**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

**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

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**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.
Wells Sampled On and Near the 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)
Basins compartmentalize groundwater aquifers which can change aquifer flow velocity and direction from basin to basin.
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

**Analyzing Information**
- Computer simulations (modeling) of hydrogeology and groundwater flow and contaminant transport
Why Computer Modeling?

- 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
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
Federal Facility Agreement and Consent Order

Groundwater Strategy


NDEP - State of Nevada Division of Environmental Protection
NNSA/NDO - 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
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](http://www.cemp.dri.edu) and posted on bulletin boards at local CEMP stations (see red dots on map).
**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

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**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.

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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.*
Results of Wells Sampled for Tritium

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

U.S. Air Force Land
Nevada National Security Site
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)
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.
Putting Results into Perspective

- 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

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

**Yucca Flat**
- Well ER-2-1 (Winter)
- Well WW-3 (Spring)
- Well WW-2 (Summer)
- Well U-3cn PS 2 (Spring)

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Groundwater Sampling in Frenchman Flat
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

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 Site Specific Advisory Board

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

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

Contact Information
- Phone: 702-630-0522
- Email: NSSAB@nnsa.doe.gov
- Website: www.nv.energy.gov/NSSAB

Poster Exhibited & Staffed by Nevada Site Specific Advisory Board Members
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
The year 2014 marks the fifteenth anniversary of Nye County’s Water Level Measurement Program (WUMP), 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 WUMP was a natural fit. The WUMP 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 allows 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 probably reveal more about changes and issues in the aquifer than we previously knew, due to a concentrated effort to collect high-quality data on a regular basis. The maps are based on data collected during the 2014 field season and interpreted using the ESRI ArcGIS software. The maps and accompanying text were intended to maximize the return on hydrologic information.

WUMP Wells

Not all of the wells in the 15-year history of the WUMP have been consistently measured – some wells have been lost due to destruction, 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 WUMP, 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 WUMP, 30 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 30 USGS NWIS wells, and provides the data to the USGS under the Artesian Integrated Monitoring Network. Additionally, five of the wells measured by the USGS NWIS program are also independently measured as part of the WUMP.

To supplement areas of sparse data, or replace gaps where WUMP wells were lost, water level measurements were restored in wells (either old WUMP or USGS NWIS) that were historically measured. Interpolating between the new and historical measurements in these “recovered” 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 2-year map adds new wells to the program. Not all wells can be utilized in the 10-year change map, since some of them were not part of the WUMP in 2004. For the newest 2-year change map (2012 to 2014) there are an additional 123 new sites, the result of an additional 123 new sites, the result of the contouring algorithm, and may not represent actual water level changes.

10-Year Change Map

In general, the 10-year water level change map (Panel E) shows water level increases in the Pahrump Valley east of Hwy. 160, from north of Wheeler Wash to south of Tract Camp 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 wet years.

Further north along the west side of the Amargosa Farms area, the map generally shows water level declines centered on the Racoon Dary west of the 2014 year period. Similar 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, which is likely due to the depletion of the aquifer during the water using season. Changes observed here are the result of the contouring algorithm, and may not represent actual water level changes.

Change in Water Table Elevation from 2004 to 2014

The 2012 to 2014 change map (Panel E) shows a marked decrease, in both in areal extent and magnitude for the increase on the east side of the Pahrump Valley. This is likely due to the last 4 years of precipitation (2011 to 2015) being lower than normal (2.48, 2.39, and 2.36 inches). This is also reflected in the large decreases (two yellow/green boxes) in the southeastern part of the Valley (NDOT and NDOT South wells), which are located near the southeastern edge of the Valley, and to the north and northeast, as compared to the 2008 to 2010 map. This is likely due to the depletion 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 2012 to 2012 period.

References

Groundwater “Ant Farm” Demonstration

- 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 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.
Aquifer – A geologic layer of permeable material such as sand and gravel, limestone or sandstone, through which groundwater flows and is stored.

Confining Layer – Layer of non-permeable material such as clay which water cannot flow through.

Piezometer – A device used to measure static water level and determine depth to groundwater.

Pumping Well – Extracts water directly from the aquifer.

Artesian Well – When natural pressure from a confined aquifer forces water upward to the surface.

Discharge

Recharge