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The Yucca Mountain Legacy Project

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About H🌎ME: Healing Ourselves & Mother Earth

H🌎ME is a nonprofit organization formed in 2000. H🌎ME's goal is to make radiation and health information accessible and understandable to everyone, especially in impacted rural communities. We explore the links and cumulative exposures that connect communities of uranium miners, downwinders, downstreamers, Atomic Veterans, and DOE workers to the latest stakeholders: communities near proposed or existing nuclear waste facilities. We review all aspects of federal nuclear policy in the context of environmental justice and the United States' legal obligations through treaties with other nations abroad, and with Native Nations among us.

H🌎ME uses an extensive website (www.h-o-m-e.org) and a 30 foot mobile teaching vehicle. H🌎ME is the only organization focusing extensively on the impacts Yucca Mountain will have on California, only 17 miles downstream. In 2002, H🌎ME and the San Luis Obispo Grandmothers for Peace brought together members of communities with nuclear reactors and proposed nuclear dump communities/tribes for a three day Peoples' Nuclear Waste Forum. The purpose was to identify common goals and agreements regarding sound and safe nuclear policy in the United States, while initiating a dialogue about concerns that needed further exploration. Collaborative work resulted in the fifteen point Peoples' Nuclear Waste Policy.

About the Authors

Jennifer Olaranna Viereck is the Executive Director of H🌎ME, and has been working on Yucca Mountain issues since 1988, in support of Western Shoshone concerns about sovereignty, resource preservation, treaty rights and impacts on health and habitat. She is currently a local resident of the Yucca Mountain bioregion and watershed.

John Hadder is the President of the Board of Directors for H🌎ME, and has been employed by Citizen Alert since 1997 as the resident expert on the Yucca Mt. Repository and other nuclear concerns in the state of Nevada. He has a Masters of Science degree in Physical Chemistry, and also teaches at Truckee Meadows Community College.

George Rice is a groundwater hydrologist specializing in contaminant fate and transport. As a consultant to the Southwest Research Institute he participated in the evaluation of Yucca Mountain's suitability as a nuclear waste repository. Mr. Rice has a M.S. in Hydrology from the University of Arizona.

We greatly appreciate the patience, generosity and resourcefulness of the many people and agencies who shared data and publications, ideas and equipment with us to make this project possible. Special thanks are due to the Amargosa Valley well owners, especially Mel Bauer and Shelley Kadrmas, without whom this study would not exist. Thanks are also due to Vernon Brechin, Jacob Paz, Genne Nelson, Tom Buqo, Citizen Alert, the Nevada Nuclear Waste Task Force, the Nye County NV Early Warning Drilling Program staff, the Inyo County CA Yucca Mountain staff and Hydrodynamics Group, the Desert Research Institute, and to George English.

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CD copies of this report include additional documents such as background reports, lab analysis reports, forms, field data logs and photographs of the water sampling process. They can be ordered through our website www.h-o-m-e.org, by contacting H🌎ME at heal@h-o-m-e.org or 760.852.4151 or PO Box 420, Tecopa CA 92389. The report can also be downloaded.

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1. Executive Summary

1.1 Why Environmental/Health Baseline Data is Needed

Since the dawn of the nuclear age, the emphasis in all nuclear programs has focused on the development of new technologies and weapons. There was little concern over radioactive contamination. It was assumed that the accumulating radioactive waste would be handled as needed in the future. Now, the future has arrived. One serious consequence of this careless approach was that workers in the government nuclear weapons complex were exposed to radiation and ingested radionuclides. The general public was exposed as well.

> *"For many years, the government promoted a legacy of neglect toward those [nuclear weapons] workers who helped build the strongest national security in the world. We failed to take care of our workers who became sick."*
>
> *Former Energy Secretary Bill Richardson, January 11, 2001.*

Many of the nuclear weapons sites are amongst the most contaminated areas in the United States. Unfortunately, the extent of contamination has only been fully realized in the past 15 years. Thus, many people living in and around those areas have most likely been exposed to radiation. Without documented history of the level of contamination, and an environmental baseline, or starting point, prior to the onset of contamination, it has been virtually impossible to know whether ill health was related to exposure from various weapons sites. One of the few exceptions was a county-by-county national study relating weather patterns to nuclear testing fallout from the Nevada Test Site (NTS), and determining exposure factors for one radionuclide, Iodine-131.[1]

H🌎ME has observed that most communities near nuclear weapons sites have not had an adequate baseline from which to interpret a rise in suspected health problems. The baseline provides the backdrop for comparison necessary to determine the source of environmental exposure and to track health histories. With the baseline in hand, people living near these potentially contaminated sites will be better able to assess if they have been impacted by the site, and better equipped to take actions on their own behalf.

H🌎ME envisions the Yucca Mountain Legacy Project as a proactive initiative to develop an environmental/health baseline before contamination from the NTS or the proposed Yucca Mountain Repository reaches surrounding communities. Phase I of the project is a stakeholder

[1] Due to the path specific nature of iodine, a clear connection has been established between radioactive iodine releases from nuclear weapons site, most notably the above ground nuclear weapons testing. National Cancer Institute, *Estimated Exposures and Thyroid Doses Received by the American People from Iodine-131 in Fallout Flowing Nevada Atmospheric Nuclear Bomb Tests*, U.S. Dept. of Health and Human Services, October 1997; Energy Employee Occupational Illness Compensation Program Act in October 2000.

driven process to assist current residents immediately downstream. Our study will also be important to future generations who will be downgradient of the Pahute Mesa underground nuclear weapons testing area.

1.2 Potential Contaminant Sources in the Region

Nevada Test Site activities have had a demonstrated impact on former employees, Atomic Veterans and "downwind" communities from the above ground nuclear weapons testing era.[2] However, it is yet to be seen how the underground testing of nuclear weapons will affect people living nearby. Since 1962, about one third of the 921 underground nuclear explosions at the Test Site were detonated below the water table. For many years the Department of Energy (DOE) has assumed that the radioisotopes released in underground detonations become essentially trapped in the vitrified rock mass that results from the enormous heat released in these explosions. However, the discovery of tritium and plutonium away from the detonation sites clearly shows that the DOE's assumption was incorrect.

In a prior Citizen's Monitoring and Technical Assessment study, the Nevada organization Citizen Alert assessed the viability of the existing DOE water monitoring system for the Nevada Test Site[3]. This report demonstrated that the DOE has not properly placed water monitoring wells in a judicious manner so as to guarantee intercepting potential radioactive plumes from the Pahute Mesa. Thus, groundwater contamination from the NTS may already have reached areas off of the test site (off-site), and represents a future health risk. In another part of NTS, tritium contamination (radioactive hydrogen) from the Yucca Flats testing area may flow downward through valley fill layers to the Lower Carbonate Aquifer, and could have reached the Ash Meadows spring complex within ten years.[4]

The US Ecology waste facility outside of Beatty, Nevada, has had tritium contamination leak into the groundwater to high levels, detected as early as 1982[5], and this could also continue to move with the groundwater to the Amargosa Valley residents only ten miles away.

The other potentially enormous regional source of contamination is the proposed Yucca Mountain Repository. If the site opens at the currently allowed capacity of 70,000 metric tons,[6] this amounts to some 11 billion curies of radioactivity.[7] This assumes that the current legal cap of 70,000 metric tons for Yucca Mountain is not removed, which the Bush Administration would like to do. In a bill drafted by the administration this year, "the Nuclear Fuel Management and

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[2] I-131 study, and Compensation Act

[3] Citizen Alert, *Analysis of the Nevada Test Site Early Warning System for Groundwater Contamination Potentially Migrating from Pahute Mesa to Oasis Valley, Nevada,* March 2004.

[4] Laczniak, R.J., J.C. Cole, D.A. Sawyer, and D.A. Trudeau, 1996, *Summary of Hydrogeologic Controls on Ground-Water Flow at the Nevada Test Site, Nye County, Nevada,* USGS Water-Resources Investigations Report 96-4109

[5] United States General Accounting Office (GAO), Letter to Senator Barbara Boxer and Representative George Miller, Radioactive Waste: Answers to Questions Related to the Proposed Ward Valley Low-Level Radioactive Waste Disposal Facility, May 22, 1998, page 5. URL: http://www.nirs.org/radwaste/llw/gaoqsonwdvalley1998seepp49521606911.pdf.

[6] A metric ton, which is 1.1 English tons, is in this case specifically defined as "metric tons heavy metal" and to date there is still ambiguity as to how that definition will apply to the volume of existing liquid radioactive waste at DOE weapons sites.

[7] State of Nevada, Office of the Governor, Agency for Nuclear Projects, Nuclear Waste Project Office, 1761 E., College Parkway, Suite 118, Carson City, NV 89706-7954.

Disposal Act," the cap would be lifted, opening the door to at least double the capacity of the repository. As with the NTS, the radionuclides in the waste destined for Yucca Mountain will have various rates of mobility in the natural environment, and longevities, with half-lives ranging from a few decades to many thousands of years. In addition, the containment canisters themselves and proposed titanium drip shields are composed of hundreds of thousands of tons of heavy metals which will become toxic as they break down and begin to move into the environment. Despite the "best" efforts to contain the waste, the natural setting inside Yucca Mountain will eventually corrode the disposal containers, releasing the heavy metals and radioactive elements. They will be carried by water and air to the accessible environment. There are widely differing estimates as to when the contaminants will actually reach nearby communities and natural habitat.

1.3 Taking Proactive Measures for Health and Habitat

Given the likely future contamination of environmental resources near the NTS, US Ecology, and the Yucca Mountain Repository, H🌎ME is initiating the establishment of an environmental baseline. We hope to provide some useful data, as well as illustrate the larger and ongoing need. H🌎ME wishes to encourage other agencies to continue this line of work, and hope to contribute in the future again ourselves.

It is important to understand that since there is no feasible method to clean up the radiation-laced water, the recourse, in the event that dangerous levels of radionuclides are found in groundwater, is for the DOE and Nye County to provide an early warning system that will detect radionuclides advancing towards fresh water wells with sufficient time to take action to protect the public by either importing water, or by relocating residents.

1.4 The Legacy Project Water Sampling Program

As a first step in H🌎ME's baseline process, a number of residential wells and springs in the Amargosa Valley were identified that are strategically located downgradient of the NTS, US Ecology and Yucca Mountain for water sampling and analysis. The wells represent new water quality sampling points, and the springs overlap with some past water sampling by governmental agencies. The nearest government monitoring wells to those H🌎ME selected are part of Nye County's Early Warning Drilling Program. They are aligned perpendicular to water flow paths from Yucca Mountain and are intended to provide site characterization information related to the Yucca Mountain Project, and an early warning to residents of contamination as a result of the repository. H🌎ME's sampling data were expected to compliment the existing Nye County water data, with some overlapping analysis to allow for comparison of similarities and differences.

Eight wells and two springs were sampled for this report. Field data was taken from one additional well. All of the wells are completed in the valley fill aquifer. The springs are on the northern end of Ash Meadows. The water that flows from these springs is believed to originate in the Lower Carbonate Aquifer[8].

[8] Laczniak et al, page 8 and figure 4.

The quality of all the samples was good. None of the measured parameters exceeded any of the drinking water standards established by the US Environmental Protection Agency (EPA) (see tables 10.1, 10.2 and 10.3). Generally, the radioactivities and non-radioactive analyte concentrations were comparable to those of Nye County's water samples. There were some differences in average beta radiation activity, and a possible inconsistency in the uranium isotope results that would require additional sampling and analysis to resolve.

1.5 Concerns and Recommendations

Both the DOE and Nye County monitoring programs are designed for early warning, to allow time for remedial action in the event of contamination, and not specifically for health baseline assessment. Although Nye County uses the term "environmental baseline" in their description of the Early Warning Drilling Program, and indeed there is much useful information in their data, H🌎ME believes that more detail is needed for a health baseline. As H🌎ME understands the Nye County approach to early warning, generally when gross alpha or beta radiation levels are "abnormally" high or above EPA action levels, a more detailed analysis is triggered. Otherwise, the radionuclide contribution to the gross radiation levels is not determined.[9] The most recent analysis that has been posted by Nye County shows tritium, gross alpha and beta, isotopic oxygen and nitrogen, and radiocarbon data, but does not show a detailed breakdown. A breakdown of the radionuclide contributions to the overall radioactivity is needed to fully understand which radioisotopes are being ingested and to what level.

H🌎ME is concerned that a contaminant from the NTS and/or Yucca Mountain Repository could enter the water supply, but not raise the gross alpha or beta levels sufficiently to trigger a more detailed analysis by local governmental agencies. There is enough local variation in radiation readings to obscure more subtle changes in the radionuclide profile of the water. If the water analysis included specific discernment of radionuclide contributions, especially those that could isolate the source as either the Yucca Mountain Repository or the Nevada Test Site, there would be little doubt when a contaminant entered the water system and of what nature. There would be a clear history of what chemical species had been ingested over time, and the point of contamination would be identified as promptly as possible.

Overall, despite the extensive resources that have been dedicated to studying and attempting to understand the movement and contamination of groundwater in the Yucca Mountain and NTS region, as well as detection of radioactive isotopes potentially migrating off the NTS, significant uncertainties in both areas still exist. Further "surprises", such as the detection of plutonium nearly a mile from an underground test location,[10] may again result as time goes by. Through this study, H🌎ME hopes to encourage as thorough and complete a program of water monitoring as possible in the future, in light of all the uncertainties in the understanding of groundwater movement and contamination, and possible "gaps" in the existing monitoring network.

[9] Discussion with Kathy Gilmore, Geoscientist II, Nye County Nuclear Waste Repository Project Office, Pahrump Office, 1210 East Basin Road #6, Pahrump, Nevada 89060, (775) 727-7727.

[10] Barnard, Jeff, "Plutonium In Water Near Test Site, Radiation from Deep Nuke Tests Seeps Up," The Associated Press, January 6, 1998.

2. The Yucca Mountain Legacy Project

The Yucca Mountain Legacy Project is a stakeholder effort to identify and address critical gaps in the protection of health and habitat in the bioregion surrounding the proposed Yucca Mountain High Level Nuclear Waste Repository. This includes Nevada, California, the Timbisha Shoshone tribe, and treaty lands of the Western Shoshone Nation.

Unlike other Department of Energy facilities in the United States, at Yucca Mountain the opportunity exists to record detailed technical data about the condition of the area now, before high-level nuclear waste is brought on site and new contaminants are introduced.

H🌎ME posed this simple question to many people: "*Given our unique situation, what should we be doing now to protect our future generations, which no one may be thinking of?*"

2.1 Phase I: Groundwater Chemistry and Baseline Data

Based on responses from scientific experts and members of citizen advocacy groups at other DOE weapons facilities, we have identified a series of essential steps. In light of the reasonable expectation that groundwater will be the primary path for radionuclide migration off-site, our first priority was establishing a baseline for key water-born contaminants in the closest accessible off-site locations for comparison to future water supplies.

2.2 What The Health Baseline Study Will Accomplish

H🌎ME's purpose is to:

1. Offer the downgradient community current chemistry data about their drinking water;
2. Establish a sound technical baseline so that in the future the problem is quantifiable;
3. Set a precedent for ongoing isotopic water analysis so that impacts are predictable and therefore preventable;
4. Provide a working model for other communities and groups who may face similar circumstances if DOE moves forward with new nuclear weapons, reactors or waste facilities.

We are providing concerned residents with more detailed information than has been available so far about the existing quality of their drinking water. We are also providing future generations with important tools to safeguard their health from potential exposure to radionuclide contamination and subsequent impacts on habitat and health. Future generations will be able to discern whether contaminants from Yucca Mountain and/or the Test Site are reaching their water supplies. This is important to estimate exposure and dose reconstruction. Even more important is establishing a precedent for concern, to ensure that an ongoing sampling and analysis regimen is installed that would provide early warning and allow for needed remedial action, thus preventing contaminant induced illness.

2.3 Why Water Chemistry Baseline Data Is Important

The Yucca Mountain Repository provides a unique situation, in terms of health and habitat safety. Most nuclear site communities never had the opportunity to establish baseline or background data before contaminating activities occurred. This region is poised between nuclear eras. The Yucca Mountain area rests between two other potential radioactive contamination sources covered in detail in this report: The Nevada Nuclear Weapons Test Site (NTS) to the north and east, and the US Ecology low-level nuclear waste and hazardous materials site to the west.

This region has already absorbed the unprecedented burden of 1,021[11] detonated nuclear weapons at NTS since January 27, 1951, classified by the U.S. government as 928 separate tests. According to researcher Vernon Brechin, over 14 million tons of melted, fractured tuff surrounding individual bomb blast sites should be minimally classified as low-level or transuranic nuclear waste[12] (see table 12.2). At US Ecology, studies identified off-site migration of tritium as early as 1982[13]. The area is now proposed to additionally entomb the nation's burden of high-level irradiated reactor fuel and military waste.

Past nuclear testing and other existing contamination must be factored into any future risk scenarios. Future contamination will be the result of:

- the movement of existing contamination to new off-site areas,
- the introduction of new contaminants from new sources such as Yucca Mountain,
- a combination of the two.

If contamination is detected in the region in the future, without accurate baseline data to determine what is from other sources and what may be from Yucca Mountain, no meaningful risk assessment or dose reconstruction can take place.

3. How the Water Baseline Study Was Structured

We began by researching what data existed already, and what data was still needed for our purposes. Since the Yucca Mountain Repository is only in research phase, the only reason to test for Yucca Mountain-specific contamination now is to establish baseline data. There would be no reason to expect that such contaminants existed in the region. We found that prior studies did not generally reflect the level of water chemistry detail we needed to establish data on specific

[11] U.S. Department of Energy, *United States Nuclear Tests, July 1945 through September 1992*, Nevada Operations Office DOE/NV – 209-REV 15, page xv. Detonation is defined by the Department of Energy as: "A single nuclear device explosion; one or more comprise a test."

[12] Brechin, Vernon, private communication, 12/4/2004 and 4/25/2006, Mountain View, CA.

[13] United States General Accounting Office (GAO), Letter to Senator Barbara Boxer and Representative George Miller, Radioactive Waste: Answers to Questions Related to the Proposed Ward Valley Low-Level Radioactive Waste Disposal Facility, May 22, 1998, page 5. URL: http://www.nirs.org/radwaste/llw/gaoqsonwdvalley1998seepp49521606911.pdf.

markers for identifying site-specific contaminants far in the future. (See Section 8). It is our hope that our data can enhance the data collected by many other agencies.

Through laboratory analysis of samples from eight domestic wells and two springs, we established some detailed baseline data about groundwater chemistry immediately down gradient of the mountain. We were able to compare some data with past studies, to draw broader conclusions about the overall regional water chemistry (see Section 10.4). We especially focused on areas already inhabited and farmed for food production. This will be important in the future for comparison, and to calculate risk and exposure, should radioactive or other toxic releases ever occur.

3.1 The Study Followed These Basic Steps

1. Develop an overall understanding of the region's geology, hydrology, habitat and human use through site visits (the entire team, January 2005).
2. Conduct extensive background research of existing studies and literature.
3. Identify the most likely water flow pathways for carrying contaminants.
4. Identify all potential contamination sources and determine the best water sampling sites.
5. Identify what analytes are most important to sample for:
    i. key isotopic constituents and daughter products that are most likely to remain from nuclear testing in the Pahute Mesa area of the Nevada Test Site;
    ii. constituents that may have traveled off-site from the US Ecology low-level nuclear waste area;
    iii. isotopic constituents and daughter products most likely to escape containment from the Yucca Mountain Repository system;
    iv. toxic metal contaminants that would be released as the stainless steel and nickel-based Alloy-22 nuclear waste packaging canisters deteriorate.
6. Identify and approach local residents interested in providing access to collect water samples from domestic wells. Collect initial well and site data and anecdotal reports.
7. Locate reliable independent laboratories with the capacity for conducting advanced isotopic testing. Determine correct EPA and DOE protocols, and any requirements of the NRC Yucca Mountain licensing process.
8. Acquire correct field equipment and sample collection bottles, shipping procedure instructions, and forms.
9. Identify sites using GPS equipment for future identification, since property owners' names will change over time.
10. Conduct collection of field data and water samples, following all required protocols to ensure samples are representative of existing conditions. Ship per laboratory specifications.
11. Review all laboratory analysis results and prepare final report.
12. Determine and fulfill distribution and archive plan for report and baseline data that will best inform current stakeholders, NGOs and agencies, and protect future generations.

4. The Regional Setting of the Baseline Study

The study area is in southeastern Nevada, approximately 80 miles west of Las Vegas and just north of the California border. It is approximately seven miles south of the Nevada Test Site (NTS) and 20 miles northeast of Death Valley (See figures 4.0.1 and 4.0.2). The study area is about 18 miles long and extends from the western portion of the Amargosa Farms area to the northern portion of the Ash Meadows National Wildlife Refuge.

4.1 Geology and Hydrology

The study area lies within the Death Valley regional flow system (DVRFS). Groundwater in the DVRFS generally flows southward and naturally discharges (surfaces) at Ash Meadows, Oasis Valley, Alkali Flat, and Death Valley[14] (See figure 4.1.1). Groundwater is also pumped via wells for agricultural, industrial, and domestic purposes.

The geology of the DVRFS near the study area is complex. The geologic formations that make up the subsurface have been deformed or shifted as the result of faulting and large scale uplifting, compression, and extension. Volcanic activity has produced lava flows, deposits of volcanic ash (tuff), cinder cones, and large craters (calderas)[15]. Valleys are filled with alluvium[16] eroded from surrounding uplands.

Figure 4.0.1 Study Area within Death Valley Regional Flow System (DVRWS)
(Adapted from San Juan et al., 2004)

[14] Laczniak, R.J., J.C. Cole, D.A. Sawyer, and D.A. Trudeau, 1996, *Summary of Hydrogeologic Controls on Ground-Water Flow at the Nevada Test Site, Nye County, Nevada,* USGS Water-Resources Investigations Report 96-4109, page 4.
[15] Laczniak et al., 1996, page 6.
[16] Alluvium is material deposited by streams. It consists of clay, silt, sand, and gravel.

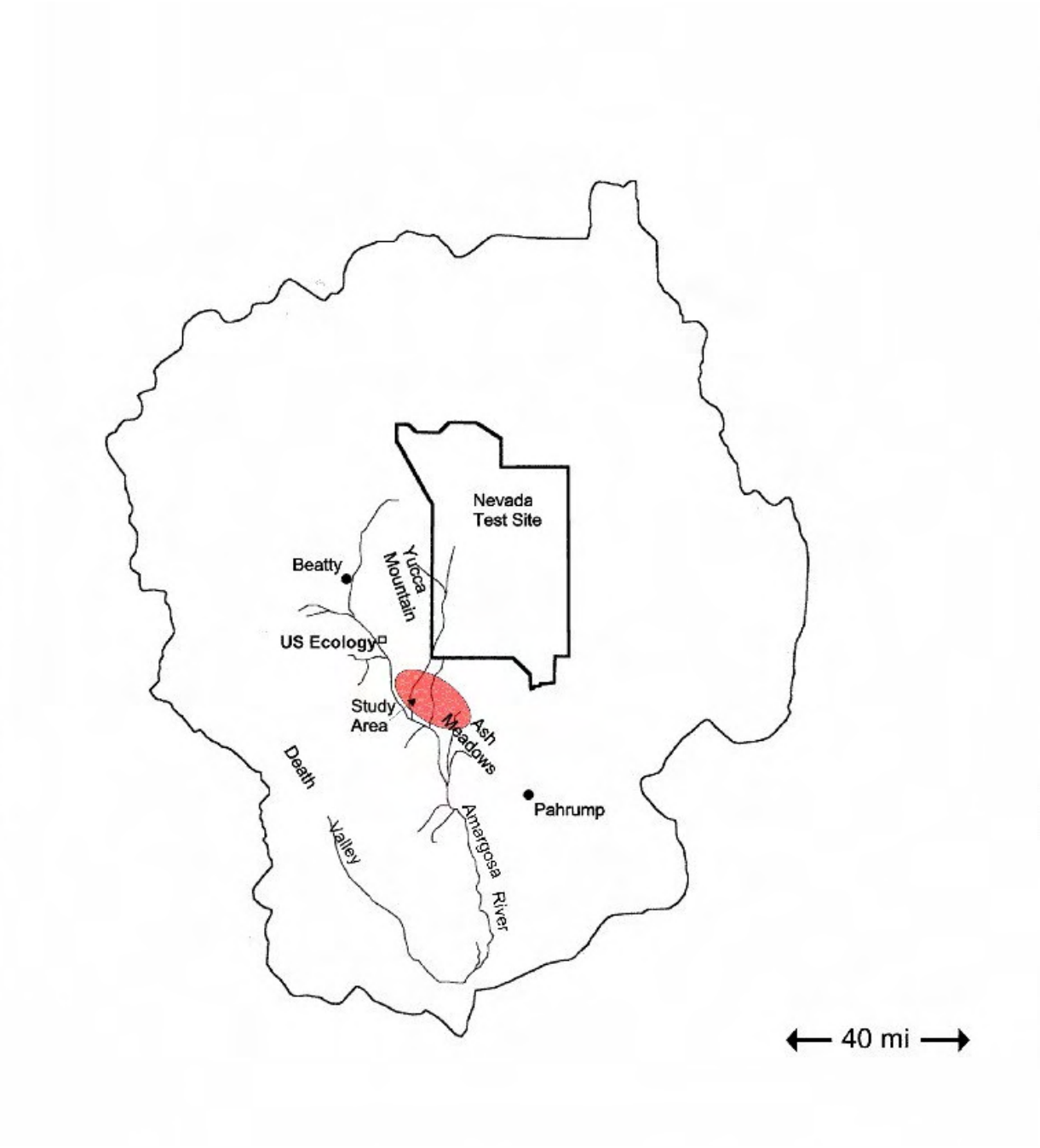

Figure 4.0.2 Key Features of Study Area
(Adapted from Belcher, 2004, Figure A-1)

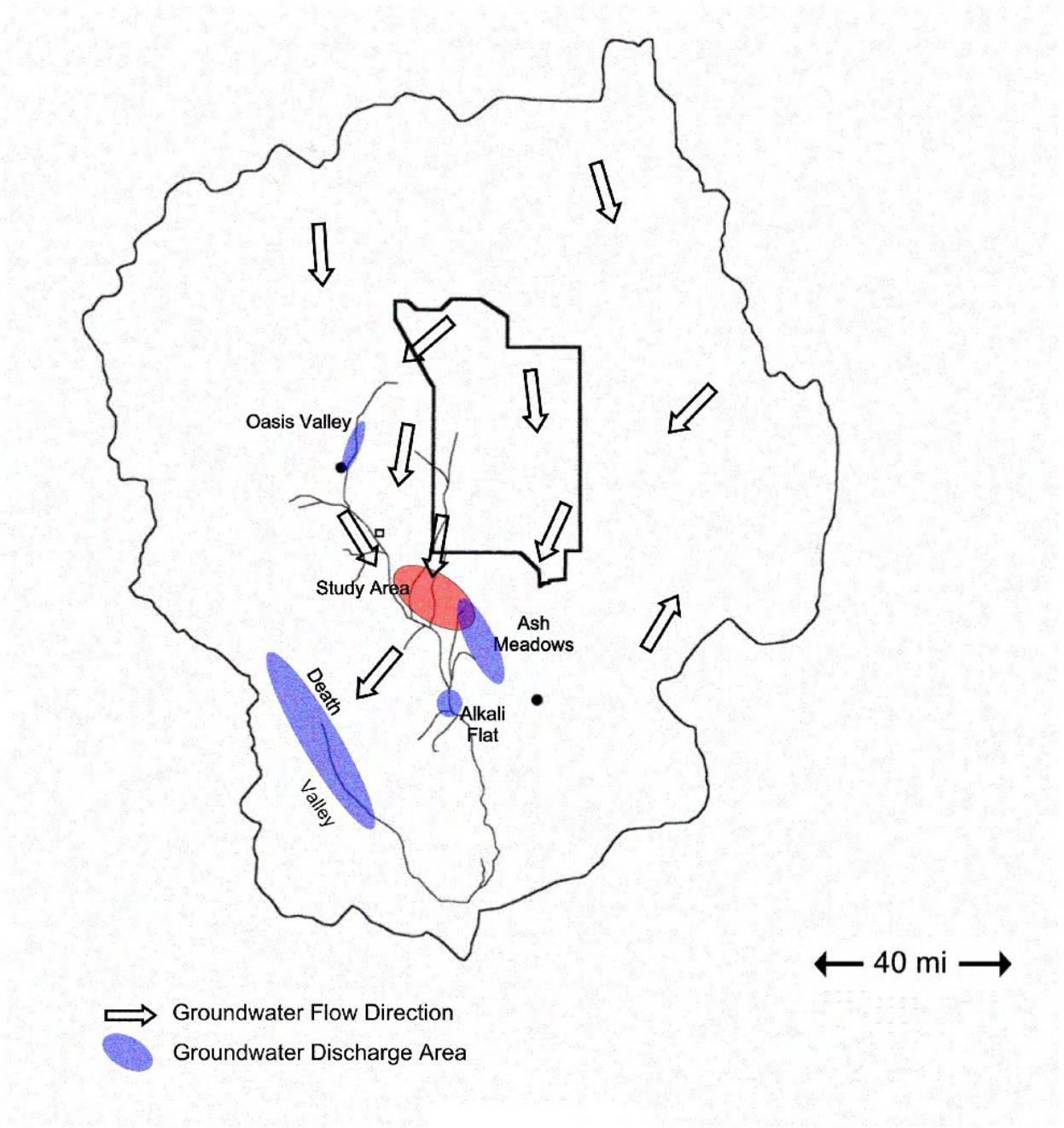

Figure 4.1.1 Groundwater Flow Directions and Natural Discharge Areas in the Vicinity of the Study Area

(Adapted from Belcher, 2004, Figure A-1; and Laczniak, 1996, Figure 6 and Plate 1)

4.2 Major Hydrogeologic Units in the Vicinity of the Study Area

Table 4.2 presents a generalized description of the major hydrogeologic units that exist in the region near the study area. The units are listed in descending order with the uppermost units listed first. The table also identifies those units that transmit significant amounts of groundwater (aquifers).

Table 4.2

Hydrogeologic Unit	**Aquifer?**
Valley Fill	Yes
Volcanic Rock	Yes
Elena Confining Unit	No
Lower Carbonate Aquifer	Yes
Precambrian Confining Unit	No

The hydrogeologic units listed in Table 4.2 do not extend uniformly throughout the region. Some of the units do not exist in some portions of the region near the study area. See Figure 4.2 for a schematic[17] cross-section of the region surrounding the study area. It extends from north of Yucca Mountain, through the study area, to the Funeral Mountains.

4.2.1 Valley Fill Aquifer

The valley fill aquifer primarily consists of alluvium eroded from the surrounding uplands. Water levels in the Amargosa Farms area range from about 60 to 120 feet below land surface[18]. At Amargosa Farms, water levels in the valley fill aquifer declined up to 30 feet between 1950 and 2000[19]. The alluvium is more than 3000 feet thick in some areas[20]. Water from the volcanic aquifers and the Lower Carbonate Aquifer is believed to flow into the valley fill aquifer[21]. All of the wells sampled for this report derive their water from the valley fill aquifer.

4.2.2. Volcanic Rock Aquifers

The volcanic rock aquifers are found to the north of the study area. They are composed primarily of tuff[22] with some lava flows[23]. In the vicinity of the study area, the major volcanic units are (in

[17] This schematic representation only depicts the broad outlines of the major hydrogeologic units. It does not show the faulting or the other units that exist in the area. A more detailed depiction of the subsurface may be found in Laczniak et al., 1996, plate 2.

[18] As reported by well drillers and owners of wells sampled for this report.

[19] Fenelon, J. M., and M. T. Moreo, 2002, *Trend Analysis of Ground-Water Levels and Spring Discharge in the Yucca Mountain Region, Nevada and California, 1960–2000*, Water-Resources Investigations Report 02-4178, page 53.

[20] Laczniak, R.J., J.C. Cole, D.A. Sawyer, and D.A. Trudeau, 1996, *Summary of Hydrogeologic Controls on Ground-Water Flow at the Nevada Test Site, Nye County, Nevada,* USGS Water-Resources Investigations Report 96-4109, plate 2; Belcher, W.R., C.C. Faunt, and F.A. D'Agnese, 2002, *Three-Dimensional Hydrogeologic Framework Model for Use With a Steady-State Numerical Ground-Water Flow Model of the Death Valley Regional Flow System, Nevada and California*, Water-Resources Investigations Report 01-4254, figure 9.(A).

[21] U.S. Dept. of Energy, 2002, *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*, February 2002, pages 3-40 and 3-47; Fenelon and Moreo, 2002, pages 7 and 9.

[22] Tuff is solidified volcanic ash. When the ash is so hot that it melts after it falls to the ground, it is called welded tuff.

[23] U.S. Dept. of Energy, 2002, figure 3-17 and page 3-57.

descending order) the Topopah Spring tuff[24], the Calico Hills Formation, and the Prow Pass tuff[25].

At Yucca Mountain, the top of the aquifer (water table) is about 2500 feet below ground surface[26]. The depth to water is shallower in the valleys. Just to the east of Yucca Mountain, in Jackass Flats, the water table is approximately 750 feet below land surface[27]. South of Yucca Mountain, depth to water is less than 400 feet[28]. The thickness of the aquifer ranges from a few feet to more than 3000 feet[29]. Water flows through fractures in the welded tuffs. Groundwater in the volcanic aquifers near Yucca Mountain is believed to flow into the valley fill aquifer[30].

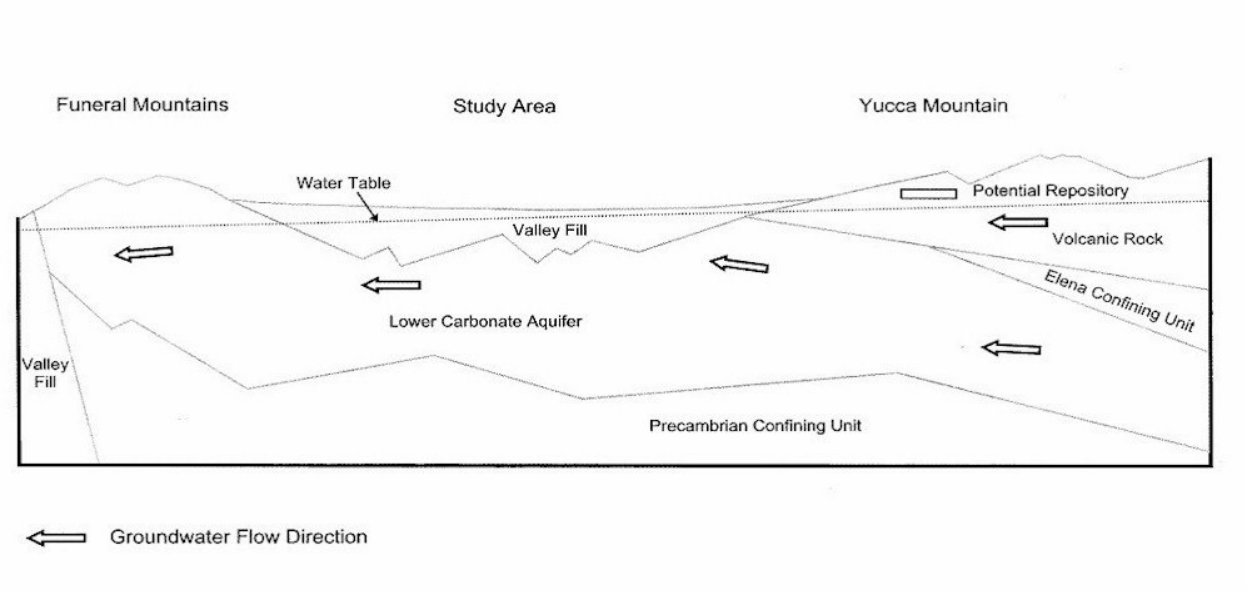

Figure 4.2 Schematic Cross Section Through Study Area
(Based on Laczniak et al., 1996, Plate 2; Parizek, 2005; and DOE, 2002, Figure 3-18)

4.2.3 Lower Carbonate Aquifer

The Lower Carbonate Aquifer consists of limestone and dolomite, and is part of a large system that extends far beyond the study area. The aquifer underlies the carbonate-rock province, which covers approximately 100,000 mi^2 in Nevada, Utah, Idaho, and California[31]. In the vicinity of the study area the aquifer may be up to 16,000 feet thick[32]. The depth to the top of the Lower

[24] The proposed Yucca Mountain repository is in the Topopah Spring tuff. This unit is unsaturated at Yucca Mountain but is below the water table to the south and east of Yucca Mountain (DOE, 2002, page 3-57).
[25] U.S. Dept. of Energy, 2002, pages 3-52 and 3-57, and figure 3-16.
[26] U.S. Dept. of Energy, 2002, page 3-50.
[27] Fenelon and Moreo, 2002, figure 21.
[28] Nye County, 2006, Early Warning Drilling Program, information available at: http://www.nyecounty.com/index.htm. Well Completion Summary Information for EWDP Phases I and II, well 1S.
[29] Belcher et al., 2002, figure 12.(A).
[30] U.S. Dept. of Energy, 2002, pages 3-40 and 3-57.
[31] Prudic, D.E., J.R. Harrill, and T.J. Burbey, 1995, *Conceptual Evaluation of Regional Ground-water Flow in the Carbonate-Rock Province of the Great Basin, Nevada, Utah, and Adjacent States*, USGS Professional Paper 1409-D, page D1 and figure 1.
[32] Belcher et al., 2002, figure 24.(A); U.S. Dept. of Energy, 2005, *Nevada Test Site Environmental Report 2004*, October 2005, page A-15.

Carbonate Aquifer varies from near land surface at Ash Meadows to more than 3000 feet beneath the thicker portions of the valley fill[33]. This aquifer transmits more groundwater than any other aquifer in the DVRFS[34]. Water flows through fractures and solution openings that form as the limestone dissolves. The Lower Carbonate Aquifer is believed to transmit water from the NTS to the springs at Ash Meadows[35].

4.3 Ash Meadows

Ash Meadows is the only natural discharge area in the study area (Figure 4.1.1). Groundwater emerges from more than 30 springs and seeps that occur along a ten-mile long trace that runs roughly northwest-southeast[36]. The largest spring, Crystal pool, discharges up to 3000 gallons per minute. Estimates of the combined discharge of all the springs range from 10,500 to 13,000 gallons per minute (17,000 to 21,000 acre feet per year)[37]. Both of the springs sampled for this report (Fairbanks and Longstreet) are in Ash Meadows.

Groundwater in the Lower Carbonate Aquifer flows toward Ash Meadows from the north and northeast. Groundwater is believed to be forced to land surface by a series of faults that underlie the area[38].

Springflows have been fairly constant except for a period in the 1960s and 1970s when large amounts of groundwater were pumped from the area for agriculture. This caused local water levels and springflows to decline, and threatened the existence of the pupfish, a federally listed endangered species. A ruling by the U.S. Supreme Court resulted in a large reduction in pumping. Water levels and springflows have recovered since the pumping was curtailed[39].

4.4 Groundwater Flow Rates

There are few estimates of groundwater flow rates for the aquifers in the study area. Laczniak gives a range of less than 40 ft/yr to more than 36,000 ft/yr, with the higher rates occurring in the Lower Carbonate Aquifer[40]. Flow rates in the volcanic aquifer in the northwestern portion of the NTS have been estimated to range from 7 ft/yr to 270 ft/yr[41].

Belcher presents hydraulic conductivities for the aquifers in the vicinity of the study area[42]. For the valley-fill aquifer, the estimates range from less than 0.001 ft/day to more than 400 ft/day. The low values probably represent silts and clays while the higher values probably represent

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[33] Laczniak et al., 1996, plate 2.
[34] Laczniak et al., 1996, page 6.
[35] Laczniak et al., 1996, page 6.
[36] Laczniak, R.J, G.A. DeMeo, S.R. Reiner, J.L. Smith, and W.E. Nylund, 1999, *Estimates of Ground-Water Discharge as Determined from Measurements of Evapotranspiration, Ash Meadows Area, Nye County, Nevada*, USGS Water-Resources Investigations Report 99-4079, page 7 and figure 3.
[37] Laczniak et al., 1999, pages 7 and 47.
[38] Laczniak et al., 1999, page 8 and figure 4.
[39] Laczniak et al., 1999, page 7.
[40] Laczniak et al., 1996, page 10. High groundwater flow rates are not uncommon in limestone aquifers where water flows through solution channels. These are known as karst aquifers. In the Edwards Aquifer, a karst limestone aquifer in south-central Texas, groundwater flow rates have been measured at more than several thousand feet per day.
[41] Laczniak et al., 1996, page 21.
[42] Belcher, 2004, page 122.

sands and gravels. Using these hydraulic conductivities, and reasonable assumptions for porosities and hydraulic gradients[43], flow rates in the valley fill aquifer are calculated to range from 0.008 ft/yr to 3500 ft/yr.

5. Potential Sources of Contamination Already in the Study Area

There are two potential sources of radioactive contaminants in the study area, the NTS and US Ecology's hazardous waste treatment and disposal facility. If the proposed Yucca Mountain nuclear waste repository opens, it will also be a potential source of radioactive contaminants.

5.1 The Nevada Test Site

The NTS is north-northeast of the study area (See Figure 4.0.2). It occupies 1,375 square miles[44]. Nuclear devices have been tested (detonated) at the NTS since the early 1950s[45]. Both above ground and underground tests were conducted until 1962. Since then, all tests have been conducted in underground shafts and tunnels[46]. A total of 828 underground tests, (consisting of 921 weapons detonations) were conducted between 1951 and 1992[47]. Approximately one third of those tests were conducted near or below the water table[48]. Most of the tests were conducted in the valley fill and volcanic rock units[49]. The last nuclear explosion at the NTS occurred in 1992[50]. The DOE currently conducts subcritical nuclear tests at the NTS [51].

The tests generated large amounts of tritium[52] as well as other radioactive contaminants. Groundwater samples collected from eight wells installed in and near detonation cavities[53] have displayed tritium activities between 113,000 pCi/L and 160,000,000 pCi/L[54]. These activities are extremely high[55]. The areas where the high tritium activities have been detected are in the northwest portion (Pahute Mesa) and the east-central portion (Yucca Flat) of the NTS[56].

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[43] The following assumptions were used to calculate the flow rates: effective porosity = 0.25, hydraulic gradient = 0.006 (this is the slope of the Amargosa River in an 18 mile reach between Beatty and the study area).
[44] U.S. Dept. of Energy, 2005, page 1-1.
[45] U.S. Dept. of Energy, 2005, page 1-5.
[46] Laczniak et al., 1996, page 3.
[47] U.S. Dept. of Energy, 2005, page 1-5.
[48] U.S. Dept. of Energy, 2005, page 1-5.
[49] Laczniak et al., 1996, page 26; and DOE, 2005, page A-16.
[50] Laczniak et al., 1996, page 3.
[51] U.S. Dept. of Energy, 2005, page 1-5. Subcritical tests do not result in nuclear explosions (U.S. Dept. of Energy, 2004, page D-7).
[52] U.S. Dept. of Energy, 2003, *Nevada Test Site Environmental Report 2002*, October 2003. page 8-6.
[53] The nuclear explosions melt the surrounding rock, creating subsurface cavities. The diameters of these cavities range from about 100 feet to more than 700 feet (Laczniak et al., 1996, page 21).
[54] U.S. Dept. of Energy 2005, page 4-19; and DOE, 2004, page 3-17.
[55] The U.S. EPA drinking water standard for tritium is 20,000 pCi/L (DOE, 2005, page 4-15).
[56] U.S. Dept. of Energy 2005, page 4-19 and figure 4-12.

Lower tritium activities have been found in groundwater on other parts of the NTS, as well as in groundwater down-gradient of (in the direction of flow from) the NTS. These areas include Pahute Mesa, both within the NTS and just west of the NTS boundary[57], the central portion of the NTS, the northeastern portion (Yucca Flat), and the southeastern portion (Frenchman Flat). Tritium activities in these areas ranged from 20 pCi/L to 564 pCi/L[58]. These tritium activities could be the result of the atmospheric testing of nuclear weapons rather than underground testing (see Appendix 12.2). However, their proximity to underground nuclear detonation sites makes it likely that they are associated with these detonations.

In addition to tritium, gross alpha and gross beta activities have been detected in samples from wells on and near the NTS. These activities may be due either to the decay of naturally occurring radionuclides, or radionuclides produced by nuclear testing. It is likely that testing caused some of the higher activities[59].

Contaminated groundwater also occurs around the E-tunnel in the north-central portion of the NTS. The tunnel was the site of nuclear tests. Groundwater seeps out of the tunnel and the seepage is collected in five basins down slope of the tunnel portal[60]. Tunnel seepage contains high tritium activities as well as strontium-90, cesium-137, plutonium-238, plutonium-239/240, and americium-241[61].

Groundwater beneath the NTS flows to the south or southwest toward natural discharge areas[62] and the study area (see Figure 4.1.1). At Yucca Flat, data indicate that groundwater in the valley fill and volcanic units flows downward to the Lower Carbonate Aquifer, and then southwestward[63].

Is it possible for contaminants from the NTS to have reached the study area? Yes. According to Laczniak groundwater from the Yucca Flat portion of the NTS may flow through the Lower Carbonate Aquifer to Ash Meadows[64]. Yucca Flat is approximately 40 miles from Ash Meadows[65] and groundwater at Yucca Flat is contaminated with tritium. Groundwater flow rates in the Lower Carbonate Aquifer may are rapid, possibly more than 36,000 ft/yr. Therefore, contaminated groundwater from Yucca Flats could have reached the springs at Ash Meadows in

[57] 20 pCi/L tritium was detected in well PM-3, approximately 2 miles west of the boundary (DOE, 2005, page 4-8 and figure 4-2). No tritium was detected in a duplicate sample from this well.
[58] U.S. Dept. of Energy 2003, table 8.2; and DOE 2005, pages 4-8, 4-12, and 4-15.
[59] This is the case for well U-19 BH on Pahute Mesa. It contained 66 pCi/L gross alpha and 99 pCi/L gross beta. The U.S. EPA drinking water standard for gross alpha is 15 pCi/L and the EPA 'level of concern' for gross beta is 50 pCi/L. Tritium has also been detected in this well (32 pCi/L) (U.S. Dept. of Energy, 2005, page 4-15).
[60] U.S. Dept. of Energy 2005, page 4-16 and figure 4-3.
[61] Highest measured activities (pCi/L): tritium = 946,000, strontium-90 = 1.49, cesium-137 = 62.7, plutonium-238 = 0.44, plutonium-239/240 = 4.96, americium-241 = 0.26 (U.S. Dept. of Energy, 2003, pages 5-41 – 5-42; U.S. Dept. of Energy, 2004, page 3-14, and U.S. Dept. of Energy 2005, pages 4-16 and 4-17).
[62] Laczniak et al., 1999, page 2; U.S. Dept. of Energy, 2005, page A-9.
[63] Laczniak et al., 1996, page 26.
[64] Laczniak et al., 1996, page 26.
[65] Laczniak et al., 1996, figure 1.

less than ten years. However, there is no evidence (i.e., elevated tritium activities[66]) that this has occurred (see Section 10).

There are also two predictions that place tritium contamination already in Oasis Valley, 12 miles from the NTS boundary, coming off the underground test area of Pahute mesa[67]. The Purvance study has shown that the leading edge of a radioactive plume can migrate up to 25 times faster than the center of mass of the plume, which means that contamination could arrive soon in Oasis Valley. This concerns people as far away as California as well, since upwelling springs in the Oasis Valley are an important water source for the southward flowing Amargosa River.[68] A good summary of the groundwater characteristics of the NTS can be found in the *Technical Peer Review Report: Strategy for Remediation of Groundwater Contamination at the NTS*.[69]

Area 3 and Area 5 of the NTS are also used as shallow burial disposal sites for imported low-level nuclear waste materials, shipped by truck from other DOE weapons complex facilities involved in a cleanup process around the United States. Some transuranic wastes over and above the 1600 barrels recently shipped from the NTS to the Waste Isolation Pilot Plant (WIPP) in Carlsbad NM are also being considered for shallow burial also at this time.[70]

5.2 US Ecology's[71] Hazardous Waste Facility

US Ecology's hazardous waste facility is near the Amargosa River, approximately ten miles upstream from the study area (see Figure 4.0.2). It began accepting low-level nuclear wastes in 1962[72]. The low-level waste facility appears to have been poorly run. Some of the nuclear wastes disposed at the facility were liquid, even though the disposal of liquid wastes was prohibited by the facility's license73. Liquid wastes were drained directly from tanker trucks into unlined trenches74. Some of US Ecology's employees stole materials intended for disposal

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[66] In the vicinity of the study area, elevated tritium activities are defined as activities greater than 1400 pCi/L (see appendix 12.4).

[67] Daniels, J.I., Editor, Pilot Study Risk Assessment for Selected Problems at the Nevada Test Site, UCRL-LR-113891, Lawence Livermore National Laboratory, June 1993; Purvance, David T., *Travel times of non-local dispersion and their geoelectric approximation in Nevada's fractured welded tuffs*, Water Resources Research, Vol. 37, No. 12, p. 2915, 2001. 2001.

[68] Christian, Bill, "The Amargosa River Conservancy Effort," Nature Conservancy presentation to Devil's Hole Workshop, Death Valley National Park, April 27, 2006.

[69] American Society of Mechanical Engineers, *Technical Peer Review Report: Strategy for Remediation of Groundwater Contamination at the Nevada Test Site*, November 2001.

[70] NTS Citizen's Advisory Board Public Meeting, January 8, 2006, Bob Ruud Community Center, Pahrump NV.

[71] US Ecology was formerly known as the Nuclear Engineering Company (NECO) (GAO, 1998, page 34).

[72] Prudic, D.E., D.A. Stonestrom, and R.G. Striegl, 1997, *Tritium, Deuterium, and Oxygen-18 in Water Collected From Unsaturated Sediments Near a Low-Level Radioactive Waste Burial Site South of Beatty, Nevada,* U.S. Geological Survey Water-Resources Investigations Report 97-4062, page 4. Although this was a low-level nuclear waste facility, some materials not generally considered by the public to be low-level waste (although considered as such by regulatory agencies) were disposed at the facility. This includes 47 pounds of plutonium (GAO, 1998, page 53).

[73] U.S. General Accounting Office (GAO), 1998, Letter to Senator Barbara Boxer and Representative George Miller, Radioactive Waste: Answers to Questions Related to the Proposed Ward Valley Low-Level Radioactive Waste Disposal Facility, May 22, 1998, page 5. URL: http://www.nirs.org/radwaste/llw/gaoqsonwdvalley1998seepp49521606911.pdf.

[74] U.S. General Accounting Office, 1998, pages 34 and 46.

and used them for personal purposes or sold them to others[75]. US Ecology also forgot where it buried some of the wastes. When it later constructed a fence around the disposal facility, one of its disposal trenches was left outside of the fence[76]. In 1992 the nuclear waste portion of the facility was closed by order of the Governor of Nevada[77]. The facility still receives hazardous wastes[78].

The US Ecology facility was excavated into the alluvium along the Amargosa River. This alluvium is part of the valley fill aquifer. Groundwater in the valley fill aquifer is approximately 360 feet below ground surface[79]. US Ecology has contaminated unsaturated alluvium and groundwater with tritium.

Water vapor in the unsaturated alluvium between land surface and the water table contains high tritium concentrations. In a test hole approximately 300 feet south of the facility, tritium activities range from about 50,000 pCi/L near the surface (depth approximately 5 feet) to about 5600 pCi/L just above the water table (depth approximately 357 feet)[80]. Tritium activities in the unsaturated zone near the facility increased significantly between 1994 and 1997[81]. The reason for the increase is unknown.

In 1982, high tritium activities (410,000 pCi/L) were found in a well near the southern boundary of the facility[82]. Tritium activities decreased over a period of about two years until tritium was no longer detected[83]. Since that time, groundwater from several wells on and near the facility has been sampled but little tritium has been detected[84]. The high initial tritium concentrations would not have decayed to undetectable levels in a few years[85]. The most likely explanation for the disappearance of the tritium is that it was transported down-gradient by the groundwater. Hydraulic gradients in the alluvium along the Amargosa River are not available. However, in hydrologic settings such as this it is common for groundwater to flow roughly parallel to the stream channel, in the downstream direction. If this were the case, the tritium from the US Ecology facility would be moving toward the study area.

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[75] U.S. General Accounting Office, 1998, pages 7 and 49.

[76] U.S. General Accounting Office (GAO), 1999, *GAO Report to the Chairman, Committee on Energy and Natural Resources, U.S. Senate Low-Level Radioactive Wastes, States Are Not Developing Disposal Facilities*, GAO/RCED-99-238 September 1999. pages 7, 8, and 49.

[77] U.S. General Accounting Office, 1999, page 16.

[78] American Ecology, 2006, Beatty, NV – Hazardous Waste Treatment & Disposal Facility, URL: http://www.americanecology.com/locations/beatty/INDEX.ASP

[79] Prudic et al., 1997, page 4.

[80] Striegl, R.G., R.W. Healy, R.L. Michel, and D.E. Prudic, 1997, *Tritium in Unsaturated Zone Gases and Air at the Amargosa Desert Research Site, and in Spring and River Water, Near Beatty, Nevada*, USGS Open-File Report 97-778, May 1997, page 11.

[81] Striegl et al., 1997, figure 4. The last available tritium data were collected in 1997.

[82] U.S. General Accounting Office, 1998, page 48.

[83] U.S. General Accounting Office, 1998, page 48. A sample collected three months after the initial sample had a tritium activity of 48,900 pCi/L. Eighteen months later the tritium activity was 2100 pCi/L. After 27 months (January 1985) tritium was below the detection limit.

[84] Prudic et al., 1997, page 11 and table 5. Since January 1985 the highest measured tritium activity in groundwater was 3.8 pCi/L.

[85] The half-life of tritium, that is the amount of time required for one half of the tritium present to decay, is 12.36 years (U.S. Dept of Energy, 2005, page C-2).

Is it possible for contaminants from US Ecology's facility to have reached the study area? Yes. The facility is approximately ten miles from the study area and it is likely that groundwater flows from the facility toward the study area. The facility is known to have contaminated groundwater in the valley fill aquifer with tritium. Groundwater in the aquifer may travel as fast as 3500 ft/yr. Since 1962, the contaminated groundwater could have traveled more than 25 miles. Therefore, contaminants from US Ecology's facility could have reached the study area. However, there is no evidence (i.e., elevated tritium activities[86]) that this has occurred (see Section 10).

6. The Yucca Mountain High Level Nuclear Waste Repository

The proposed Yucca Mountain Nuclear Waste Repository is located in southwest Nevada, just north of Death Valley National Park, and 17 miles from the California border (See Figure 4.0.1). Since 1987, its proposed purpose is to contain 70,000 metric tons of used commercial reactor fuel rods and military high-level nuclear waste in below ground tunnels.[87] If Yucca Mountain becomes the nation's High Level Waste (HLW) repository, there is a possibility that the groundwater under Yucca Mountain will become contaminated with radionuclides. Large uncertainties exist as to when these radionuclides will appear in drinking and irrigation water wells.[88] Even within the parameters of the Nuclear Regulatory Commission (NRC) licensing process, uncertainties could still remain large enough to warrant concern for future generations.[89] This is particularly germane, due to the 'first of its kind' nature of the Yucca Mountain Project, where unanticipated Earth processes could arise, impacting the rate of radionuclide release over the one million years of regulatory concern.

6.1 Potential Impacts on Health and Habitat

Although the waste storage method proposed for Yucca Mountain is called "Deep Geological Burial", actual calculation of the height of the mountain and the depth of the tunnels shows that waste storage will be approximately 1,000 feet above the heads of nearby residents and farms in Amargosa Valley. There are at least 33 known earthquake faults within the study area for the repository, with at least two of the faults actually cutting through the proposed repository site.[90] To date, much uncertainty still exists about the combination of heat (generated from nuclear

[86] In the vicinity of the study area, elevated tritium activities are defined as activities greater than 1400 pCi/L (see Appendix 12.4).

[87] See Appendix 12.3, Table 12.3, Vernon Brechin, Radionuclide Inventory in Pressure Water Reactor Fuel.

[88] U.S. Dept of Energy, *Update on Uncertainties*, Nuclear Waste Technical Review Board meeting, January 30-31, 2001, Amargosa Valley, NV. Ewing, Rodney C., *Less Geology in the Geological Disposal of Nuclear Waste*, SCIENCE, Vol. 286. pg. 415, Oct. 15, 1999. Nuclear Waste Technical Review Board, January 24, 2002 letter to Secretary Spencer Abraham, U. S. Dept. of Energy.

[89] NRC, Title 10 CFR Part 63 - *Disposal Of High–Level Radioactive Wastes In A Geologic Repository At Yucca Mountain, Nevada*.

[90] State of Nevada, "Scientific and Technical Concerns," Office of the Governor, Agency for Nuclear Projects, Nuclear Waste Project Office, 1761 E., College Parkway, suite 118, Carson City, NV 89706-7954.

waste) and humidity causing additional fracturing of the rock over time, leading to possible escape pathways for water-born contaminants to the communities beyond[91].

It has already been demonstrated to the best of DOE science, and independently verified by the State of Nevada, that Yucca Mountain provides less than 1% containment of the waste over the current 10,000 year licensing period.[92] Premature container failure could result in the contamination of aquifers down-gradient of the proposed repository. Current calculations estimate that once the waste containers have been breached, radionuclides could be expected to reach regional wells within 500 to 1,000 years.[93] While the DOE claims the waste will be retrievable for at least the first 300 years after waste emplacement, there is no planned procedure for retrieval once the repository is sealed[94]. Despite the DOE's plan for ongoing monitoring after closure, once monitoring equipment in Yucca Mountain fails, there will be no warning of container failure until radionuclides are detected 18 kilometers offsite, at the point of compliance with the Environmental Protection Agency's (EPA) exposure standards. There would be no recourse to arrest the problem.

Until recently, the area had a relatively low population density. However, Las Vegas NV, about 90 miles away, is now the fastest growing city in the United States. Pahrump NV, about 40 miles away, is the fastest growing rural town. All this growth requires water, and the most plentiful water in question comes from aquifers in the Yucca Mountain area. In fact, in the next few years, water grabs in the region are likely to be the hottest political issue.

6.2 Additional Impacts from Heavy Metals in Waste Canisters

An additional concern at Yucca Mountain is the heavy metals introduced into the biosphere from canister corrosion. The proposed waste packages have been designed with an inner layer of stainless steel and an outer layer of complex nickel-based alloy (Alloy-22) to prevent corrosion for as long as possible. However, when corrosion does ultimately occur, enormous amounts of heavy metals will be released (see Table 6.2), followed by radionuclides from the degrading fuel assemblies. The combination of these metals with radionuclides should be considered as a Mixed Waste problem under U.S. law, according to Dr. Jacob Paz, who has researched this issue extensively.[95]

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[91] Long, Jane C.S. and Rodney C. Ewing, "YUCCA MOUNTAIN: Earth-Science Issues at a Geologic Repository for High-Level Nuclear Waste," Annu. Rev. Earth Planet. Sci. 2004. 32:363–401; Nuclear Waste Technical Review Board, Transcript of the September 20, 2004 meeting, Las Vegas, NV.

[92] U.S. Dept. of Energy, NWTRB Repository Panel meeting; Postclosure Defense in Depth in the Design Selection Process, presentation for the Nuclear Waste Technical Review Board Panel for the Repository, January 25, 1999.

[93] U.S. Dept. of Energy, *Yucca Mountain Science and Engineering Report, Technical Information Supporting Site Recommendation Consideration*, DOE/RW-0539, May 2001, Office of Civilian Radioactive Waste Management, Washington, DC 20585.

[94] U. S. Dept. of Energy, *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada,* DOE/EIS-0250, February, 2002.

[95] Paz, Jacob and Delbert Barth, Written Comments to the EPA on Proposed Revisions to the Safe Drinking Water Act, 11/10/2005, page 1.

Table 6.2 Metals of Concern in Waste Canisters

86,000 Tons Of Alloy 22		140,000 Tons Of Stainless Steel	
Chromium	22.5%	Chromium	17%
Molybdenum	14.5%	Molybdenum	2.5%
Nickel	57.2%	Nickel	12%
Vanadium	0.35%		

These figures do not include the additional Titanium Drip Shields proposed to cover each canister. Dr. Paz also questions the validity of DOE sorption data on how rock, clay and soil will react to radionuclides, if heavy metals have already been deposited, and how they will react in combination, in the ground and in the groundwater. The Yucca Mountain Final Environmental Impact Statement does not address this issue, or what the potential health impacts could be. Furthermore, new proposed DOE canister design would double the thickness of the canister from 1" to 2". This would double the amount of heavy metals to be deposited at Yucca Mountain to about 300,000 to 400,000 tons.[96]

6.3 Potential Impacts on Inyo County, California

Impacts on California, only 17 miles away, have not been researched by the DOE. Although water is likely to be the primary method of transport for escaping radioactive particles over time, and surface and groundwater flows south and southwest into California, the repository site has been mainly characterized as a Nevada concern.

Yucca Mountain is centered between the two main branches of the Amargosa River watershed (see Figure 4.0.2). Fed by hundreds of springs along the way, including Oasis Valley and ash Meadows, the Amargosa River flows year-round along some segments in both Nevada and California[97]. Below ground surface, groundwater flows in the alluvium that the river has deposited over many millennia. Local residents believe that large channels exist through the western portion of the Amargosa Valley, and three different well drillers tell of losing bits into unexpected voids and never recovering them[98].

Surface water travels south directly to California via the Amargosa River drainage, and then doubles back near the Dumont Dunes north of Baker to head north into Death Valley. Finally, it sinks into 9,000 feet of alluvium or evaporates in the Badwater Basin, Death Valley's lowest point. Groundwater flowing beneath Yucca Mountain is thought to reach California more directly, by traveling southwest underneath the Amargosa Valley and surfacing in a range of springs on the southwest flank of the Funeral Mountains (see figures 4.0.2 and 4.1.1).[99] California's Inyo County has been conducting studies to determine direction of water flow through test wells and springs. To date, water chemistry studies has served mainly to identify flow paths. Isotopic testing for possible radionuclide contamination from the Nevada Nuclear Test Site, immediately east of Yucca Mountain, has been minimal.

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[96] Paz and Barth, 2005

[97] Brown, Brian, "The Amargosa River: An Overview and Tour of a Unique Natural Resource," The Amargosa Conservancy presentation at Devil's Hole Workshop, Death Valley National Park, April 27, 2006.

[98] Anecdotal information offered during well owner interviews, recorded on Sampling Well Information Forms.

[99] King, Michael, "The Lower Carbonate Aquifer as a Barrier to Radionuclide Transport," , Hydrodynamics Group presentation at Devil's Hole Workshop, Death Valley National Park, April 27, 2006.

6.4 Additional Related Environmental Justice Concerns

6.4.1 Possible Degradation of Western Shoshone Homeland and Natural Resources

One of the key issues to be addressed when the DOE does apply to the Nuclear Regulatory Commission (NRC) for a license to operate the Yucca Mountain Repository, currently scheduled for 2008, is the issue of land title, or the legal right to use the site. This land is within the boundaries of the Western Shoshone Nation, recognized and ratified by the United States Congress in the 1863 Treaty of Ruby Valley. Our cover photo includes Shoshone girls at an annual spring renewal ceremony, still held each year on the western flank of the mountain. The Shoshone name for the mountain means "Serpent Swimming West", and is indicative of both its shape and seismic instability.[100]

By all accounts, the Yucca Mountain site will eventually be contaminated by the release of both heavy metals and radionuclides. On March 10, 2006, Shoshone title was further upheld by the decision of the United Nations Committee on the Elimination of Racial Discrimination (CERD), in which the United States was "urged to pay particular attention to the right to health and cultural rights of the Western Shoshone... which may be infringed upon by activities threatening the environment..."[101]

6.4.2 Timbisha Shoshone Reservation Lands and Water

The Timbisha Shoshone Tribe lost their homeland in 1933 when Death Valley National Monument was first created. In 2000, the Timbisha Shoshone Homeland Act finally restored rights and three separate parcels of land[102]. It is believed that the lower carbonate aquifer provides up to 90% of the water in the Texas and Travertine Springs, the source of all domestic water for the Timbisha and Furnace Creek area.[103]

6.4.3 Additional Health Risks through Cultural Practices

The Nuclear Risk Management Program, conducted for many years in Nevada and Utah by the Childhood Cancer Research Institute and an alliance of Native American tribes and organizations, documented the additional exposure and health risk to traditional Native Americans in Nevada and elsewhere, through their use of locally harvested healing herbs and traditional foods such as sage, chaparral, pinion nuts, rabbit and deer. These herbs and animals can absorb contaminants and pass them on. For example, meat from a deer captured near the Test Site in 1992 had 580,000 picocuries per liter of tritium in a single sample, 29 times the drinking water standard.[104]

6.4.4 The EPA Safe Drinking Water Standard is Inadequate for Desert Dwellers

The EPA Safe Drinking Water Standard is based on water consumption of two liters per day. In the Death Valley region, this is insufficient for survival, even for a sedentary lifestyle. Summer temperatures can be above 130 F. Many people work outside, even in this extreme climate. Consumption of two, four or even more times the volume of water used in EPA calculations

[100] Private discussion with Western Shoshone Spiritual Leader Corbin Harney and other tribal Elders.
[101] United Nations Committee to End Racial Discrimination Statement, March 10, Geneva, Switzerland
[102] Pahrump Valley Gazette, "Timbisha Tribe Gets OK ," April 13, 2000.
[103] Michael King, Devil's Hole Workshop, April 27, 2006.
[104] Las Vegas Sun, *Radioactive Deer Meat Called Possible*, October 1992

results in significantly more potential exposure to contaminants. The standard also assumes exposure limited to a thirty year period. Tribal families whose lands lie within reservation boundaries are bound to a specific location, not just for their lifetime, bur for consecutive generations. Cumulative genetic mutation could be a factor of concern. Author Viereck's revised EPA calculations show that a person drinking a minimum level of four liters a day of water with plutonium 239/240 contamination at maximum "safe" levels over a 70 year lifetime could have a total exposure of almost 100 rem. An outdoor worker drinking twelve liters of water a day at the same levels would have a maximum exposure level of almost 300 rem.

6.4.5 Environmental Protection Standards are Not Extended to All Forms of Life

The environmental impact of mankind upon the health and habitat of all living beings has been profoundly negative. This is particularly obvious in places like Yucca Mountain and the Nevada Nuclear Test Site. The fact that environmental protection standards for food sources and water at these sites are not even considered, let alone enforced, for any life forms except for human beings is considered unethical and deeply troubling by all traditional people.

7. Agencies Studying Water Chemistry Now

Knowledge of the regional ground water characteristics stems largely from four sources:

1. Studies conducted by the United States Geological Survey (USGS),
2. NTS studies (Atomic Energy Agency, US Department of Energy, Nevada Operations, National Nuclear Security Agency, Nevada)[105],
3. US Department of Energy, Yucca Mountain Project[106], and
4. Nye County Early Warning Drilling Program.[107]

7.1 The United States Geological Survey (USGS)

The USGS has conducted a number of groundwater studies in the vicinity of the study area. Those that were most useful in preparing this report include: studies by Laczniak et al. on the springs at Ash Meadows and groundwater flow at the NTS (Laczniak et al., 1996 & 1999); groundwater modeling studies of the DVRFS by Belcher et al, (Belcher et al, 2002 & 2004); and studies conducted in the vicinity of US Ecology's hazardous waste facility by personnel of the Amargosa Desert Research Site (Striegl et al., 1997).

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[105] Hersey, Ronald L., and David Gillespie, *Review of Present Groundwater Monitoring Programs at the Nevada Test Site, Water Resources Center Desert Research Institute, University of Nevada System, Publication #45116*, prepared for the U. S. Department of Energy, Nevada Operations Office September 1993. DOE/NV/10845-32 UC-700

[106] U. S. Department of Energy, Office of Repository Development, 1551 Hillshire Drive, Las Vegas, NV 89134. http://www.ocrwm.doe.gov/ymp

[107] Nye County Nuclear Waste Repository Project Office, Independent Scientific Investigations Program – Early Warning Drilling Program, 1210 East Basin Road #6, Pahrump, Nevada 89060. http://www.nyecounty.com

7.2 Nevada Test Site Studies

Studies at the NTS were conducted by a variety of NTS contractors over the years of test site operations. However, the first formal work began around 1972 with the EPA's Long Term Hydrological Monitoring Program (LTHMP), which had four major objectives:

1. assure public safety,
2. document compliance with standards and regulations,
3. detect the migration of radioactivity,
4. disseminate information to the public, news media, and scientific community. [108]

Thus, many wells were drilled to facilitate long-term monitoring and better understanding of groundwater contamination. As of 1996, LTHMP routinely monitored only 21 wells on the NTS, and just 12 wells, 9 springs, and one water body off the NTS. Figures 7.2.1 and 7.2.2 show monitoring locations as of 2003. However, none of the 12 off-site wells as of 2002 were designed to be monitoring wells. Consideration of these wells was based on "point of opportunity" and not upon judicious selection for detection of contamination for point of compliance and/or early warning.[109] The general paradigm of thought at the NTS has been that groundwater moves very slowly, and that radionuclides have remained in the near field of the underground test cavities, thus remaining on-site of the NTS.

7.3 The Underground Test Area Program (UGTA)

In 1989 the Department of Energy Environmental Management (DOE/EM) Nevada Operations Office created the Underground Test Area Program (UGTA). According to Mr. Carl Gertz, then assistant manager of the DOE/EM program for the NTS, it was "established to evaluate the extent of contamination in the groundwater due to underground weapons testing." Certainly, the potential for contamination at the NTS is considerable; during the forty years of nuclear weapons testing there were some 921 underground nuclear explosions, releasing an estimated 300 million curies of radioactivity. [110]

While the stated goal of the UGTA is to understand the extent of contamination, most of the effort has been to develop a regional groundwater model. This has been criticized for insufficient hard well data to substantiate details of the model.[111] In general, groundwater movements can only be understood with confidence on a gross scale. Further, according to the Citizen Alert report, the early warning system in place by NNSA/NV (then DOE/NV) may not be strategically sited to maximize radionuclide detection. This is of particular concern because, as stated in Section 5.1, the potential exists for tritium to have reached off-site locations. It also reinforces the need for a detailed and ongoing regimen of water testing.

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[108] Citizen Alert, *Analysis of the Nevada Test site Early Warning System for Groundwater Contamination Potentially Migrating from Pahute Mesa to Oasis Valley, Nevada*, March 2004, Las Vegas, Nevada, 89114. http://www.citizenalert.org

[109] Citizen Alert , pg 14.

[110] Bangerter, Robert, Presentation at UGTA Perr Review meeting in Las Vegas, June 12, 2001.

[111] External Peer Review Group report on Frenchman Flat Data Analysis and Modeling Task, Underground Test Area Project, 16 Sept. 1999, ITLV 113052-077, IT Corporation; reference 4 and citations within.

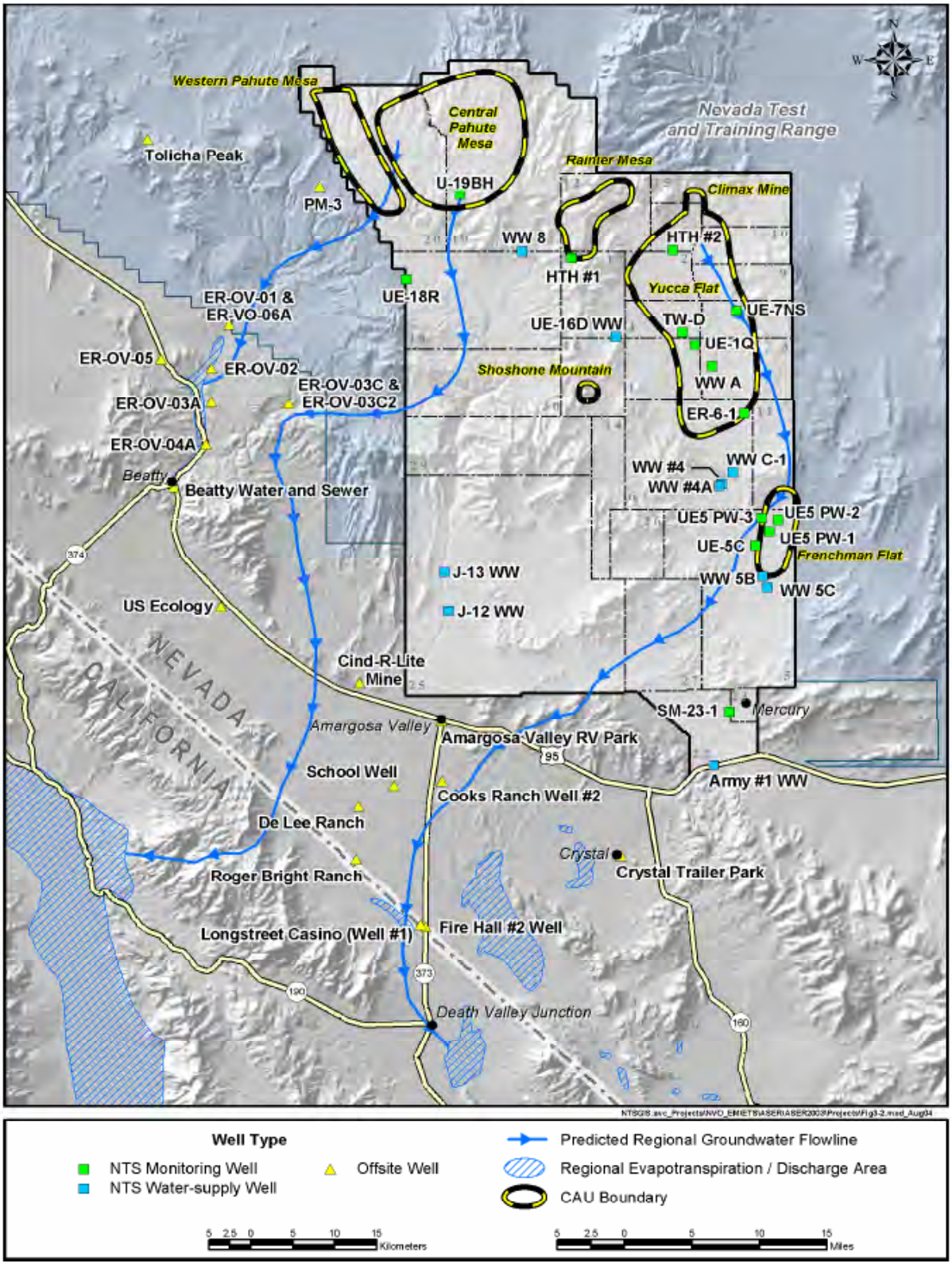

Figure 7.2.1. Routine Radiological Environmental Monitoring Plan (2003)
Groundwater monitoring locations on and off the NTS.
Source: Annual Site Environmental Report for the Nevada Test Site, 2003.

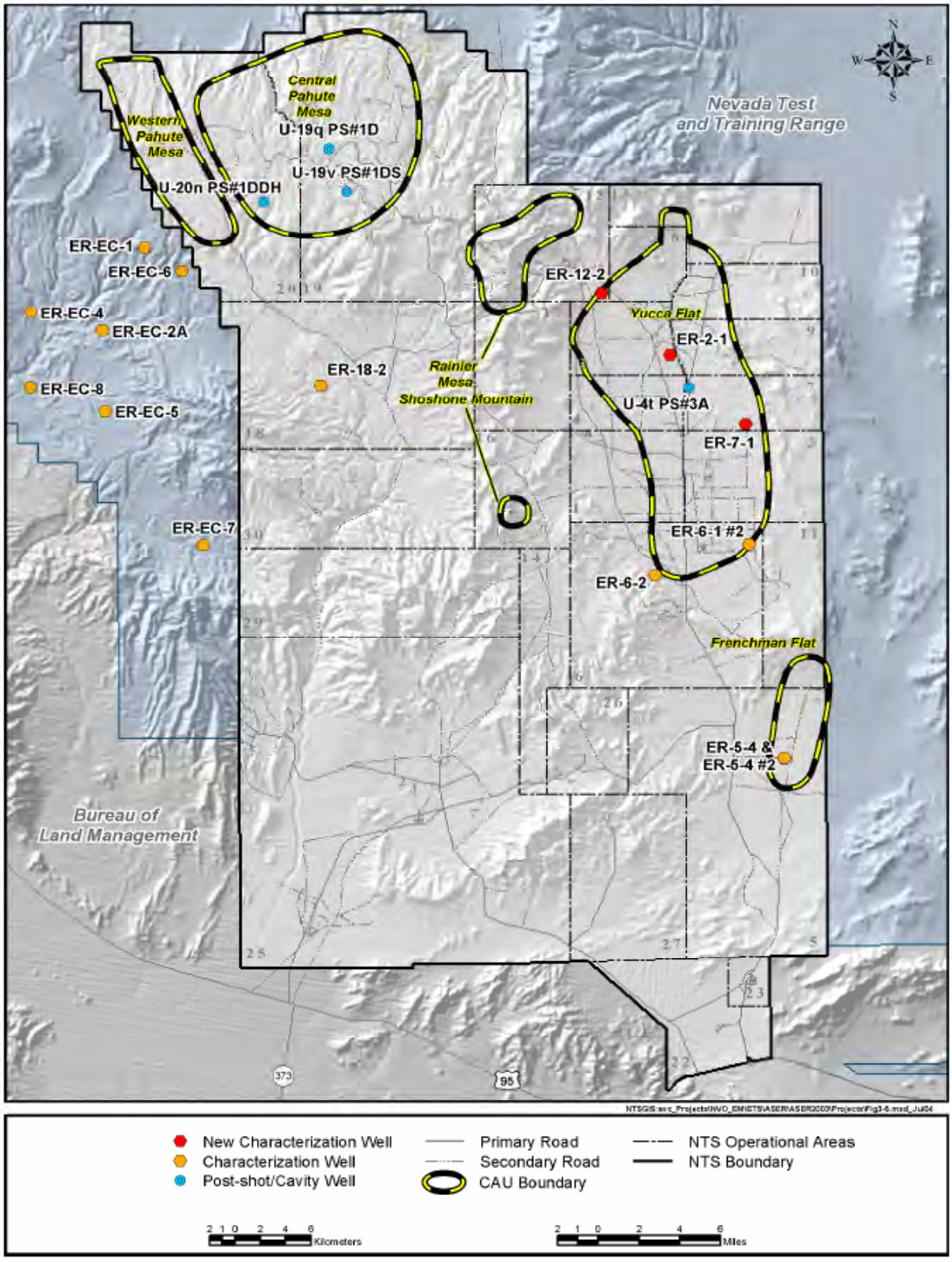

Figure 7.2.2. Wells recently drilled or sampled for the UGTA Project.
Source: Annual Site Environmental Report for the Nevada Test Site, 2003, pg 3-16.

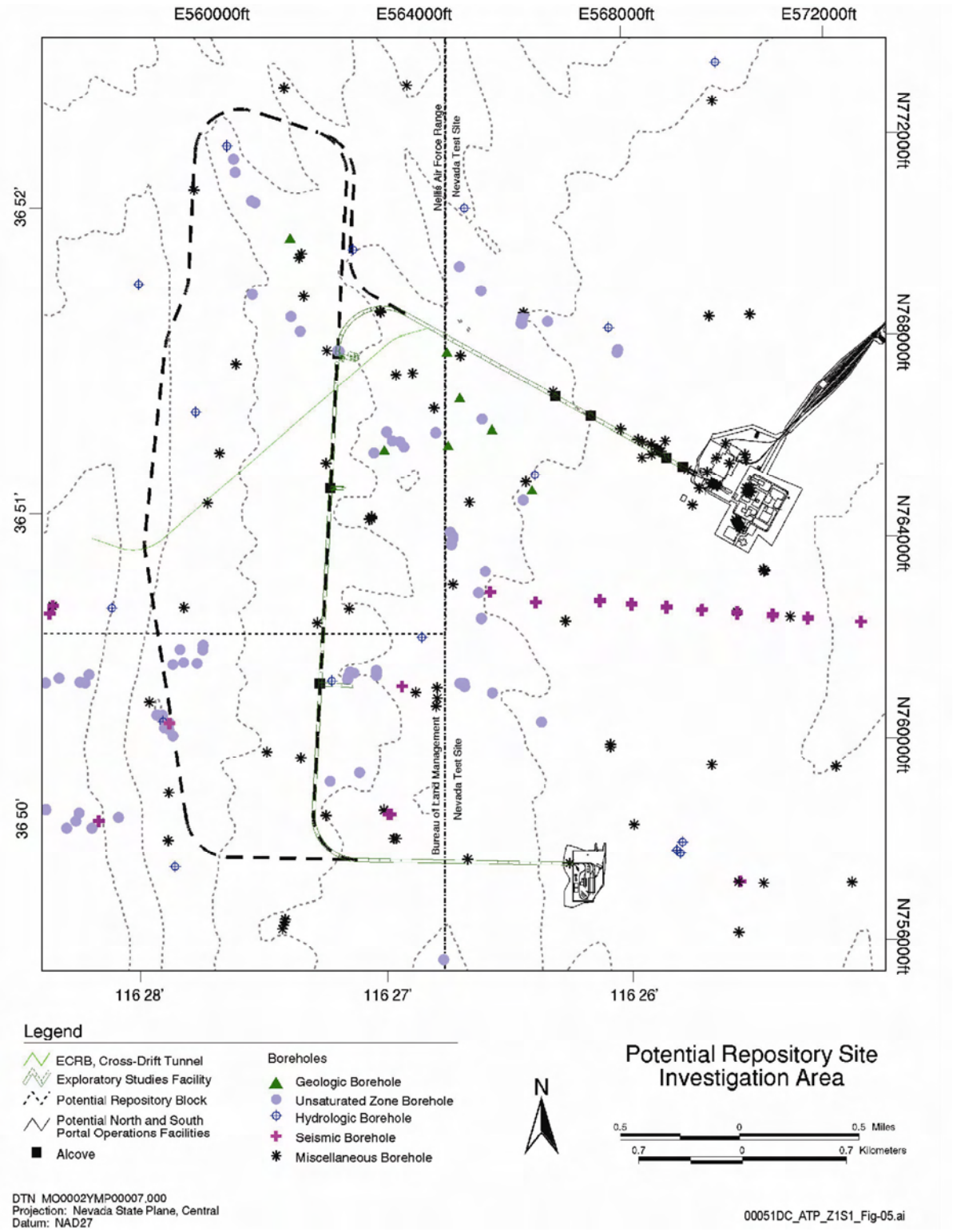

Figure 7.3. Yucca Mountain Site Investigation Area

Showing Location of the Surface-Based and Underground Test Facilities at Yucca Mountain, Including Boreholes and Underground Excavation.

(Source: DOE Yucca Mountain Science and Engineering Report, pg. 1-17)

7.3 The US DOE Yucca Mountain Project

The US DOE Yucca Mountain Project has been studying the regional hydrology and geochemistry around Yucca Mountain for over 25 years. Until the 1990's, very slow water penetration through Yucca Mountain was assumed, just as with the NTS. In fact the DOE's Environmental Assessment in 1986 estimated that groundwater travel through Yucca Mountain from the repository to the accessible environment would take an average of about 40,000 years, with a maximum of 80,235 and minimum of 9,485 years. The travel time through rock unsaturated with water (i.e. above the water table) accounts for all but about 140 years.[112]

In the early 1990s, evidence[113] was uncovered that indicated a much faster water transport mechanism than previously assumed by the DOE.[114] As a result of this evidence, the DOE modified its water transit model considerably, from an unsaturated zone travel time minimum of about 9,000 years, to figures ranging from tens to about 1,000 years.[115] More current estimates of water travel times show that approximately 20% of unretarded technicium-99[116] would take an average of about 300 years (with a range of 20 to 40,000) to reach the water table from the repository horizon.[117] The wide range of times is an indication of the DOE's expected duel mechanisms for water transport: the historically assumed slow diffusion through the rock strata, and the more recently realized fast fracture flow pathways.

The wide range of water travel times also underscores uncertainties inherent in knowledge of the water movement and expected arrival of contamination in Amargosa Valley. For example, if there is a catastrophic failure of the disposal casks, radionuclides could arrive within 550 years by the DOE's own estimates.[118] Subsequent isotopic analysis for chlorine-36 have not been able to fully duplicate the 1995 results, and the question of whether the chlorine-36 in Yucca

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[112] U.S. Department of Energy, *Environmental Assessment Yucca Mountain Site*, *Nevada Research and Development Area, Nevada*, May 1986, Office of Civilian Radioactive Waste Management, Washington, DC 20585.

[113] Elevated levels of radioactive isotopes such as chlorine-36 connected to nuclear weapons explosions conducted in the Pacific Ocean in the 1950's were discovered in exploratory tunnels inside Yucca Mountain at or near the repository horizon. The presence of these higher than "normal" levels pointed to a fast water (~50 years) transit pathway essentially from the surface of Yucca Mountain to the exploratory tunnels.

[114] Lui, Beiling, June Fabryka-Martin, Andy Wolfsberg, Bruce Robinson, Los Alamos National Laboratory, Los Alamos, NM, and Pankaj Sharma, PRIME Laboratory, Physics Dept., Purdue University, West Lafayette, IN, "Significance of apparent Discrepancies in Water Ages Derived From Atmospheric Radionuclides at Yucca Mountain, Nevada," Proceedings of 1995 American Institute of Hydrology, Annual Meeting, May 1995, Denver, CO.

[115] U.S. Dept. of Energy, *Viability Assessment of a Repository at Yucca Mountain, Total System Performance Assessment*, Vol. 3, DOE/RW-0508, Office of Civilian Radioactive Waste Management, Washington, DC 20585.

[116] The Dept. of Energy uses technecium-99 as an indicator isotope for water transit times, since it is not expected to adhere to the rock strata, and therefore moves with the water.

[117] Bodvarsson, Bo, and Yvonne Tsang, "Yucca Mountain Unsaturated Zone Flow and Transport." Lawrence Berkeley national Laboratory/BSC, Presented for the U.S. Dept. of Energy, September 16, 2003, Nuclear Waste Technical Review Board meeting, Amargosa Valley, Nevada.

[118] U.S. Dept. of Energy, *Yucca Mountain Science and Engineering Report, Technical Information Supporting Site Recommendation Consideration*, DOE/RW-0539, May 2001, Office of Civilian Radioactive Waste Management, Washington, DC 20585.

Mountain is from atmospheric nuclear weapons tests is not sufficiently resolved, so the DOE continues to assume that the fast pathways exist.[119]

Currently, there is no radionuclide contamination at Yucca Mountain, and the focus of the work there has been to understand how radionuclides will migrate from the proposed repository to the accessible environment. As can be seen in Figure 7.3, the DOE has drilled numerous boreholes in the immediate vicinity of Yucca Mountain for various purposes. Most are not dedicated to water characterization; although geochemistry characteristics are well known.[120]

7.4 Nye County Early Warning Drilling Program (EWDP)

Nye County, as part of its Independent Scientific Investigations Program (ISIP) has an ongoing Early Warning Drilling Program (EWDP) conducting routine water baseline analysis. The objectives of the ISIP are:

1. collection of baseline data on a comprehensive suite of chemical parameters,
2. the identification of potential flow paths from Yucca Mountain to potential receptors in Amargosa Valley, and
3. the development of a defensible groundwater chemistry monitoring network, downgradient of Yucca Mountain suitable for long-term performance confirmation monitoring.[121]

Currently, the EWDP analyzes the following parameters:

- in the field:
  - pH, electrical conductivity, temperature,
  - turbidity, dissolved oxygen, and oxidation-reduction potential;
- by testing laboratories:
  - major anions and cations, total dissolved solids, and field indicator parameters
  - approximately 20 trace elements (See Figure 7.4.2)
  - nutrients, including total phosphate, nitrite plus nitrate, and ammonium
  - stable isotope analyses of nitrogen and oxygen in nitrate, oxygen and hydrogen in water, and carbon in stable inorganic matter
  - tritium and radiocarbon
  - gross alpha and beta radiation

Previous studies dated from 1999 have also analyzed chlorine-36, stable isotopes of oxygen and sulfur in sulfate, and isotopes of uranium, strontium, and lead. Discussions with Nye County staff revealed that these radioisotopes were dropped from analysis largely from cost considerations, and found unnecessary for the County's interests.[122]

The strategy of Nye County, as understood by H🌎ME, is to establish a baseline, and investigate anomalies that arise; such as, elevated alpha or beta radiation counts. At that point, further and

[119] Nuclear Waste Technical Review Board, transcripts from the September 16, 2003 meeting, Amargosa Valley, Nevada.
[120] U.S. Dept of Energy, 2001, Science and Engineering Report (fig 1-3, pg 1-17)
[121] Nye County Nuclear Waste Repository Project Report, Workplan, *"Groundwater Chemistry Sampling and Analysis,"* Rev. 0 9/28/03, WP4.
[122] Phone discussion on 4/4/06 with Kathy Gilmore, Geochemist II, Nye Co.

more detailed testing of water would be pursued to determine if there is a need to take action to protect residents from contamination. Inspection of the well monitoring locations (see Figure 7.4.1) and general underground water flow patterns (Figure 4.1.1), shows a clear line of intersection of downgradient water from Yucca Mountain, but not of water moving from some of the underground testing areas such as Pahute Mesa. If the analysis contained in the Citizen Alert report is correct, then radioactive contamination could slip past both the NTS and Nye County early warning monitoring wells, leaving a gap in the early warning system.

7.5 Summary of the Sampling Programs

Overall, despite the extensive resources that have been dedicated to studying and attempting to understand the movement and contamination of groundwater in the region including and surrounding the NTS and Yucca Mountain, as well as detection of radioactive isotopes potentially migrating off the NTS, significant uncertainties still exist.

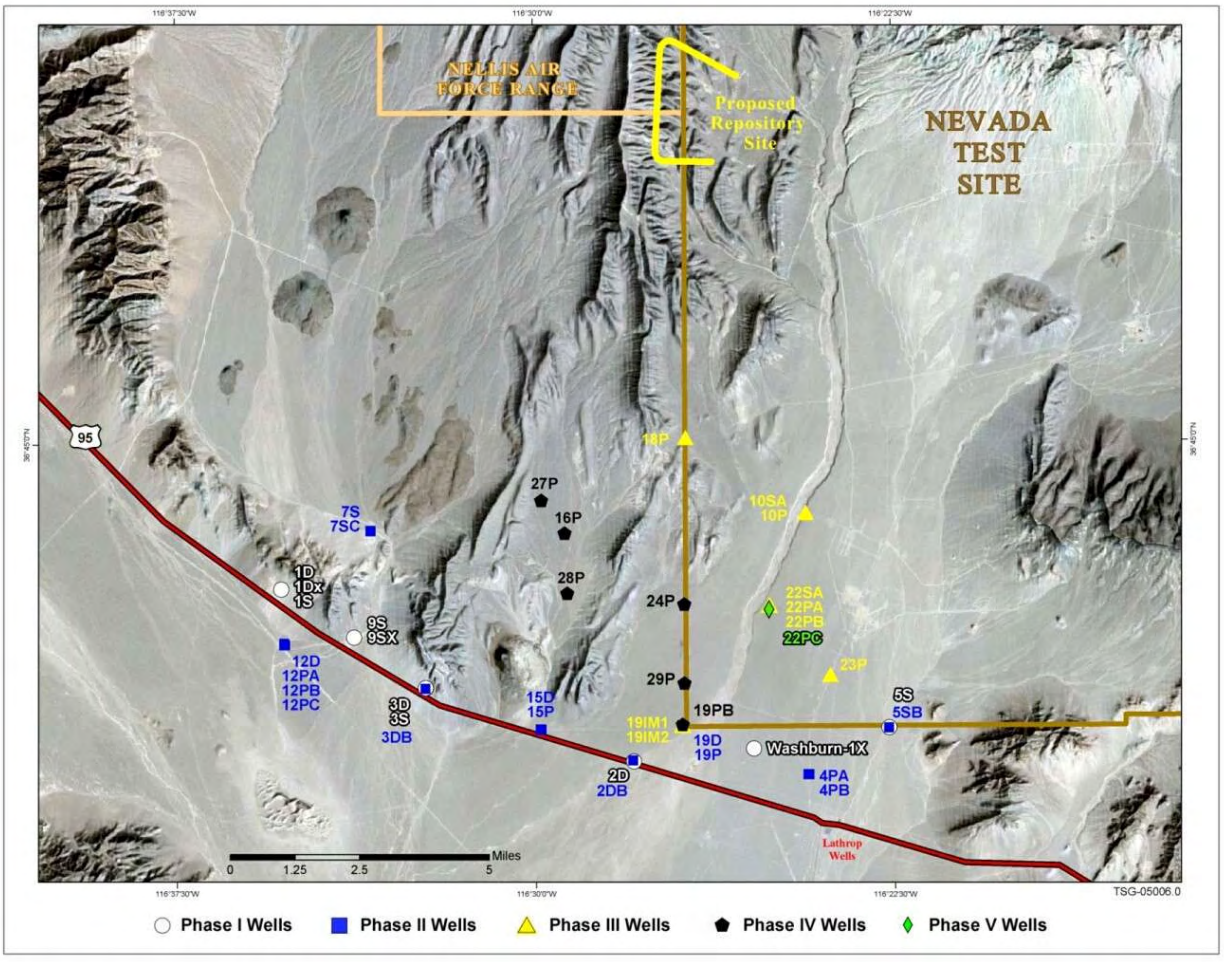

Figure 7.4.1. Existing and proposed EWDP well locations.
(Source: Nye County Dept. of Natural Resources and Federal Facilities, Nuclear Waste Repository Project Office, "Final Nye County Proposal for Additional Independent Scientific Investigations Program Activities for fiscal Years 2002-2006," February 2002.)

Water Chemistry Analyses

Analyte	Method Detection Limit		Detection Method
Alkalinity	0.5	mg/l[a]	Titration
Aluminum	0.002	mg/l	ICP-MS[b]
Ammonium	0.010	mg/l	Colorimetry
Antimony	0.002	mg/l	ICP-MS
Arsenic	0.002	mg/l	ICP-MS
Barium	0.002	mg/l	ICP-MS
Beryllium	0.002	mg/l	ICP-MS
Boron	0.1	mg/l	ICP-OES[c]
Bromide	0.02	mg/l	Ion Chromatography
SIRA[d] of carbon in TDIC[e]	0.2	permil	McCrea, 1950
Cadmium	0.002	mg/l	ICP-MS
Calcium	0.035	mg/l	Atomic Absorption
Cerium	0.002	mg/l	ICP-MS
Chloride	0.092	mg/l	Ion Chromatography
Chromium	0.002	mg/l	ICP-MS
Cobalt	0.002	mg/l	ICP-MS
Copper	0.002	mg/l	ICP-MS
SIRA of oxygen and hydrogen in water	2.0	permil	Coleman, et al., 1982 and Fritz et al., 1987
Enriched Tritium	0.8	Tritium units	Liquid Scintillation
Fluoride	0.029	mg/l	Ion Specific Electrode
Gross Alpha	0.4	pCi/l[f]	Co-precipitation
Gross Beta	0.1	pCi/l	Co-precipitation
Iodide, as I	0.008	mg/l	Ion Specific Electrode
Iron	0.01	mg/l	Atomic Absorption
Lead	0.002	mg/l	ICP-MS
Lithium	0.002	mg/l	ICP-MS
Magnesium	0.015	mg/l	Atomic Absorption
Manganese	0.002	mg/l	ICP-MS
Molybdenum	0.002	mg/l	ICP-MS
SIRA of nitrogen and oxygen in nitrate	0.2	permil	To be determined
Nickel	0.002	mg/l	ICP-MS
Nitrate plus Nitrite, as N	0.010	mg/l	Colorimetry
pH	pH units		Titration
Potassium	0.072	mg/l	Atomic Absorption
Radiocarbon (i.e., C-14)	0.3	pmC[g]	Liquid Scintillation
Rubidium	0.002	mg/l	ICP-MS
Scandium	0.002	mg/l	ICP-MS
Selenium	0.01	mg/l	ICP-MS
Silver	0.002	mg/l	ICP-MS
Sodium	0.075	mg/l	Atomic Absorption
Specific Conductivity	3.12	µS/cm[h]	Probe
Strontium	0.002	mg/l	ICP-MS
Sulfate	0.076	mg/l	Ion Chromatography
Thallium	0.002	mg/l	ICP-MS
Titanium	0.002	mg/l	ICP-MS
Total Dissolved Solids	0.1	mg/l	Sample Reduction
Total Dissolved Phosphorous	0.010	mg/l	Digestion, Colorimetry
Vanadium	0.002	mg/l	ICP-MS
Zinc	0.002	mg/l	ICP-MS

[a] Milligrams per liter.
[b] Inductively Coupled Plasma – Mass Spectrometry.
[c] Inductively Coupled Plasma – Optical Emission Spectroscopy.
[d] Stable isotope ratio analysis.
[e] Total dissolved inorganic carbon.
[f] Picocuries per liter.
[g] Percent modern carbon.
[h] Microsiemens per centimeter.

Figure 7.4.2 Nye County EWDP Water Chemistry Analysis

Source: Nye County Nuclear Waste Repository Project Report, Workplan 11, "Groundwater Chemistry Sampling and Analysis", Rev. 09/28/03 WP4

8. Analyte Selection for the Baseline Study

There were a number of factors that influenced H⊕ME's analyte selection. We had to balance the costs against the need to address potential source term radionuclides and non-radioactive contaminants from the Nevada Test Site, the U.S. Ecology site, and potential Yucca Mountain Repository contaminants. Amongst the potential radionuclides and non-radioactive elements, we gauged their potential hazard, based largely upon:

- the US EPA Maximum Contaminant Levels (MCLs)[123],
- the mass and/or curies of each potential contaminant, and
- the expected mobility within the regional aquifer.

Mobility studies by the Department of Energy[124], while useful, are still in question,[125] and may change upon future well water analysis. Therefore, H⊕ME preferred to exercise the "precautionary principle" in light of these uncertainties, which is particularly germane when considering the toxic lifetimes of many of the radionuclides and non-radioactive contaminants.

We adopted the approach of analyzing for many elements that are complimentary to existing groundwater studies, mainly those conducted by Nye County as part of its early warning system. In this way, H⊕ME has to some extent augmented Nye County's groundwater data. We did perform some of the same tests as Nye County, to provide some overlap for comparison, such as gross alpha and beta, which we expected to reveal an effective background radiation comparison. However, the cost of performing more of the same standard water analysis that Nye County has done would not have allowed us to examine other potential longer term hazards not specifically addressed by Nye County or the DOE NTS studies.

In order to facilitate analyte selection, H⊕ME constructed an analyte assessment table (see Appendix 12.1). The table lists principle source term species from the NTS and proposed Yucca Mountain Repository. Each specie received a check if it was a priority for the NTS study[126], the DOE Yucca Mountain analysis[127], required for the EPA Safe Drinking Standard, and of interest to H⊕ME, which are the columns in the table labeled as YMP, NTS2, 40CFR141, and Home anal. respectively. Also listed are available MCLs for each specie, and a rough measure of

[123] U.S. Environmental Protection Agency, *2004 Edition of the Drinking Water Standards and Health Advisories*, EPA 822-R-04-005, Winter 2004.
[124] U.S. Dept. of Energy, Science and Engineering Report, 2002.
[125] CA report, 2004, citations regarding uncertainties in DOE analysis, Pu transit, and other reference.
[126] American Society of Mechanical Engineers 2001.
[127] U.S. Dept. of Energy, Science and Engineering Report, pg. 4-365, 2002 For more details see *Inventory Abstraction.* ANL-WIS-MD-000006 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000414.0643.

solubility[128]. However, the more specific solubility and radionuclide transport analysis in references 128 and 129 were prominent in our evaluation.

We then created a ranking of 1, 2, or 3 (1 being the highest priority) for each analyte. Those that received the most check marks (Y) in the four categories discussed above were given the highest priority. Thus, those analytes that had four check marks were initially given a rating of 1 and were our highest priority for the first cut, and those that had three were initially given a rating of 2 and so on. We then scrutinized the ranking, making adjustments based on H🌎ME's project goals. Specifically:

- Some of the Yucca Mountain Project selections were included, such as Thorium-229, since it is a significant intermediate daughter product of Plutonium-240, 239, & 238. Uranium-232 & 233, Americium-241, and Neptumium-237 decay with fairly large half lives (on the order of thousands of years). They are expected to contribute to long term doses, which necessitated including them in the first rank list.

- Lead-210 is also a daughter intermediate product from the Uranium-238 decay chain; however relatively short lived (21 year half life). Other lead isotopes are probably better to focus on like Lead-206 and 208, which are the end products of uranium and plutonium decay.

- Actinium-227 was on the DOE list, most likely included because of the potential disruptive and human intrusion scenarios.[129] This isotope is very toxic, so it could present a substantial hazard if either of these scenarios were to occur. Otherwise, it is not likely to be a hazard, since the inventory of Actinium-227 is not large, has a short half life (2.2 years), and its mobility in groundwater could also be rather small. For this reason, we decided not to grant it a rating of one.

- Technecium-99, Neptunium-237, and Americium-241 & 243 are all good indicators of repository and NTS source contamination. Nevada Test Site underground testing resulted in very small amounts of Americium-243, so this isotope could differentiate the two sources. Calcium-41 could be used as a NTS tracer, as it has a relatively long half life; although it is likely not to be very mobile in the water system, and other isotopes were considered more important to the baseline goal., so it was not included.

- Europium-154 contributes much of the short term radioactivity. It may not reach water supplies or will have decayed between exposure and illness realization, so Gadolinium-154, the stable daughter product, is worth analysis. Gadolinium-154 could also serve as a YMP/NTS tracer. The cost of analysis of this stable isotope required that we drop it from the analysis list, as there are other isotopes that can serve as tracers, and could also contribute to the long term dose. The same could apply to Strontium-90 and Cesium-137, which have comparable lifetimes, but exist in very

[128] *Principles of Radiological Health and Safety*, James E. Martin and Chul Lee, Wiley-Interscience, John Wiley and Sons, Inc., Hoboken, New Jersey, 2003.
[129] TRW Environmental Safety Systems Inc., "Waste Form Degradation Process Model Report," TDR-WIS-MD-000001 REV 00 ICN 01, 1180 Town Center Drive Las Vegas, Nevada 89144-6363, July 2000.

large mass amounts as well as curies. Thus, it is prudent to analyze for Barium-137 and Zirconium-90, the stable daughter products of Cesium-137 and Strontium-90. It should be noted that not many analytical laboratories can analyze for these stable isotopes, and the precise isotopic analysis that is necessary to discern these stable isotopes is very costly, so we could not analyze for these.

- The communication from Paz cites many references within that reveal a need to assess concentrations of a number of heavy metal elements that are or suspected to have intrinsic toxicity, and which could exacerbate radiotoxic effects.[130] Chromium, molybdenum, titanium, nickel, and zirconium will exist in very large quantities as part of the Yucca Mountain Repository as canister corrosion occurs[131]. They will most likely appear in the water system at potentially high enough levels to cause health impacts, and are therefore included in the analyte list. Chromium toxicity is well known, as specifically considered in the EPA Safe Drinking Water Standard.

- Tritium (H-3), potassium-40, and carbon-14 are all quite mobile, especially tritium, which has also been produced to very large quantities. All are easily ingested through water and air. All already exist in the background at some level, and so are important to the baseline goal. Potassium-40 could also be a marker for the repository, and not the NTS, so elevated levels of this isotope could serve to distinguish between contamination coming from the repository versus NTS.

- Uranium and to a lesser extent thorium are naturally occurring to various extents in the region, as well as many other parts of the Great Basin, and should be part of the baseline. An isotopic breakdown is preferred for these isotopes, which we attempted to do, cost permitting.

- Iodine-129 would be present in the repository in large amounts and is also expected to be quite mobile. It is expected to contribute to the long term dose from the repository, but it is also a potential contaminant from the NTS.

- A gamma spectrum analysis was fairly inexpensive, and many isotopes can be analyzed simultaneously without much added cost. For example, cobalt-60 could be analyzed with the cesium-137, so we included it.

Considering all of the above along with cost constraints, we narrowed the list down further. In making our final choices, we saw it as important to have species on our analyte list which were distinct markers for the Yucca Mountain Repository and the NTS. In other words, while potential contaminants from each location have some analytes in common, we wanted to identify and establish baseline data for analytes that could only have come from one source or another. H🌎ME's final choices are seen in Tables 10.2 and 10.3, showing analysis results.

[130] Paz, Jacob D, William G. Culbreth, and Delbert Barth, A Review of Health Risks due to Complex Mixtures and Canister Corrosion at Yucca Mountain, private communication, publication process.
[131] Paz, Jacob and Delbert Barth, Comments to the EPA on Proposed Revisions to the Safe Drinking Water Act, 11/10/2005, see Table 6.2.

9. Additional Steps of the Water Sampling Process

9.1 Water Sampling Site Selection

Since the financial constraint of laboratory analysis cost limited the number of potential sampling sites, it was important that we select them as carefully as possible. Much time was spent weighing the factors of desired analytes, differing laboratory price lists, and the desired sampling locations.

The table below identifies the sample sites by the numbers in Figure 9.1, established early in the project. The sites are listed from west to east. The numbers are not contiguous, since some proposed sample sites were eliminated later on in the process.

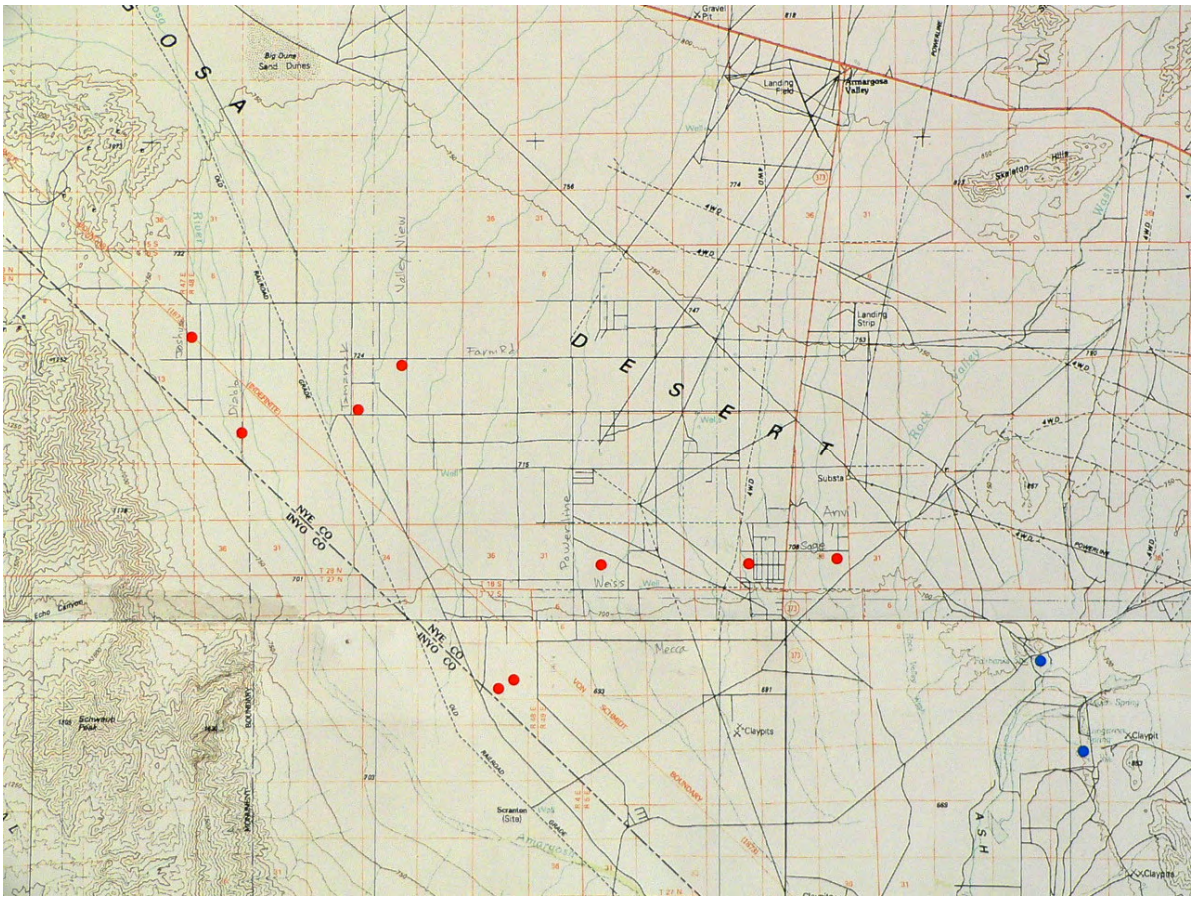

Figure 9.1 Sample Site Locations

Table 9.1 GPS Data And Sample Identification Key

Well 10 Rose	**Well 8 Stengel**	**Well 1 Cady**	**Well 2 Vassar**	**Well 4 Kadrmas**	**Well 3 Bauer**
N 36˚ 34' 29.8"	N 36˚ 32' 35.9"	N 36˚ 33' 45.4"	N 36˚ 34' 05.1"	N 36˚ 29' 27.4"	N 36˚ 29' 32.7"
W 116˚ 36' 48.7"	W 116˚ 35' 48.6"	W 116˚ 33' 38.2"	W 116˚ 32' 37.4"	W 116˚ 30' 56.2"	W 116˚ 30' 50.0"
Well 6 Bray	**Well 5 Quirk**	**Well 9 Cameron**	**11. Fairbanks Spring**	**12. Longstreet Spring**	**Equipment Blank**
N 36˚ 30' 44.3"	N 36˚ 31' 25.1"	N 36˚ 31' 29.3"	N 36˚ 29' 25.4"	N 36˚ 28' 02.7"	N/A
W 116˚ 28' 46.7"	W 116˚ 25' 48.4"	W 116˚ 24' 16.8"	W 116˚ 20' 32.0"	W 116˚ 19' 35.3"	N/A

Criteria used to select sampling sites were:

- proximity to the Yucca Mountain Repository;
- proximity to either existing contaminant source, the Test Site and US Ecology;
- proximity to known surface water channels, such as the Amargosa River, Forty Mile Wash, and the northernmost Ash Meadows spring complex.

H🌎ME initially publicized the offer for free well water analysis to the Amargosa Valley community through announcements at public meetings and a series of local newspaper articles. Through additional meetings with reporter and historian Melvin Bauer and Shelley Kadrmas, Amargosa Valley Town Clerk and member of a multi-generation well-drilling family, we identified a number of potential contacts with wells that created an optimal east-west and north-south grid, in relation to existing geological formations and surface drainages. Their help was critical to the success of this project.

Based on initial telephone interviews, well log data and further recommendations by the individuals contacted, we refined the final list. We also selected two springs closest to the Test Site from the Ash Meadows complex, Fairbanks Spring and Longstreet Spring.

9.2 Lab Selection

H🌎ME spent a lot of time researching potential laboratories through consultation with known health and radiation experts, government websites, and extensive internet research on a number of labs in the US and Canada. Final laboratory selection was based on:

- sufficient financial independence from the DOE, to assure unbiased results,
- proof of certification and grasp of relevant protocols,
- recommendations from reputable experts and organizations with prior sampling experience,
- ability to conduct required analysis in a timely manner,
- comparative cost for the same procedures.

Two different laboratories were selected for two independent series of tests, ACZ Laboratory in Steamboat Springs, CO, and Eberline Services in Richmond, CA. Each lab conducted a discrete series of tests on samples from all locations and for equipment blanks. There was no overlap in the tests conducted.

9.3 Actual Sampling Activity

Between January 13th and January 16th, 2006, samples were collected from eight domestic wells and two springs. Field data was collected from one additional well. Equipment was pre-cleaned by hydrologist George Rice, as described in Appendix 12.5. The samples were collected by George Rice, John Hadder, and Jennifer Viereck. A range of samples were collected at each site for each of the two laboratories used, and prepared for shipping. Also, some field data was collected and recorded on site. The sampling procedure is described in detail in Appendix 12.6.

Sampling log forms developed for this purpose were used to ensure consistency at each location. GPS readings were also collected for each site. This is important for long term future site identification. The baseline chemistry data may not be needed for a long time, if at all. Property owners and even well sites will change over time, but the identifying GPS data should remain stable. H⊕ME greatly appreciates the patience, generosity and resourcefulness of all the Amargosa Valley residents involved.

10. Analysis Results & Discussion

Eight wells and two springs were sampled for this report. An additional well was sampled for field data only. All of the wells are completed in the valley fill aquifer. The springs are both on the northern end of Ash Meadows. The water that flows from these springs is believed to originate in the Lower Carbonate Aquifer[132]. The quality of all the samples was good. None of the measured parameters exceeded any of the drinking water standards established by the US EPA.

[132] Laczniak et al., 1999, page 8 and figure 4.

10.1 Standards for Drinking Water and Detectable Limits, for Comparison[133]

Table 10.1 Standards for Drinking Water and Detectable Limits

Constituent/Parameter	EPA Drinking Water Standard[134]	Detectable Limits[135]
pH	6.5 – 8.5 (secondary)[136]	
Cadmium (mg/L)	0.005 mg/L (MCL)[137]	0.005 mg/L
Chromium (mg/L)	0.1 mg/L (MCL)	0.010 mg/L
Lead (mg/L)	0.015 mg/L (AL)[138]	0.040 mg/L
Molybdenum (mg/L)	0.04 mg/L (Lifetime HA)[139]	0.010 mg/L
Nickel (mg/L)	0.1 mg/L (Lifetime HA)	0.010 mg/L
Titanium (mg/L)	NA	0.005 mg/L
Zirconium (mg/L)	NA	0.001 mg/L
Gross Alpha (pCi/L)	15 pCi/L (MCL)	1.8 – 3.3 pCi/L
Gross Beta (pCi/L)	50 pCi/L (LOC)[140]	2.8 – 4.5 pCi/L
Tritium (pCi/L)	20,000 pCi/L[141] (MCL)	94 – 98 pCi/L
Carbon-14 (pCi/L)	3,200 pCi/L (MCL)	57 – 61 pCi/L
Strontium-89 (pCi/L)	599 pCi/L (MCL)	0.76 – 5.3 pCi/L
Strontium 90 (pCi/L)	8 pCi/L (MCL)	0.39 – 1.1 pCi/L
Technecium-99 (pCi/L)	3,790 pCi/L (MCL)	3.4 – 15 pCi/L
Iodine-129 (pCi/L)	21 pCi/L (MCL)	3.6 – 8.8 pCi/L
Plutonium-238 (pCi/L)	15 pCi/L (MCL)	0.034 – 0.22 pCi/L
Plutonium-239/240 (pCi/L)	15 pCi/L (MCL)	0.026 – 0.18 pCi/L
Potassium-40 (pCi/L)	NA	77 – 530 pCi/L
Cobalt 60 (pCi/L)	218 pCi/L (MCL)	7.4 – 18 pCi/L
Cesium-137 (pCi/L)	119 pCi/L (MCL)	7.4 – 17 pCi/L
Radium-226 (pCi/L)	5 pCi/L (MCL)[142]	14 – 41 pCi/L
Thorium-228 (pCi/L)	15 pCi/L (MCL)	12 – 32 pCi/L
Thorium-232 (pCi/L)	15 pCi/L (MCL)	29 – 84 pCi/L
Europium-152 (pCi/L)	841 pCi/L (MCL)	21 – 43 pCi/L
Europium-154 (pCi/L)	573 pCi/L (MCL)	21 – 53 pCi/L
Americium-241 (pCi/L)	19 pCi/L (MCL)	36 – 140 pCi/L
Uranium-234 (pCi/L)	20 pCi/L (MCL)	0.9 – 1.1 pCi/L
Uranium-235 (pCi/L)	20 pCi/L (MCL)	0.9 – 1.1 pCi/L
Uranium-238 (pCi/L)	20 pCi/L (MCL)	0.9 – 1.1 pCi/L

[133] Source of standard is EPA, 2004, except as noted.

[134] NA designates not available. Note that gross alpha, gross beta, tritium, strontium, and radium are explicitly in the EPA Safe Drinking Water Standard. All other MCL's for radionuclides were calculated by the EPA in support of the 4 millirem per year effective dose equivalent.

[135] Due to normal sample and experimental variation the minimum detection limits varied from sample to sample for the radionuclides, so the detection limits are the reported ranges from all the analyses.

10.2 Radionuclides in HOME Groundwater Samples

Sample sites are listed from west to east by geographic location. See Figure 9.1 for locations.

Table 10.2, Section 1 Radionuclides in Groundwater Samples[143]

Sample ID	Rose	Stengel	Cady	Vassar
Tritium	< 96	< 95	< 94	< 97
Carbon-14	< 59	< 59	< 58	< 58
Strontium-89	< 0.87	< 0.76	< 1.7	< 0.95
Strontium 90	< 0.52	< 0.44	< 1.1	< 0.71
Technetium-99	< 3.9	< 3.6	< 3.8	< 3.9
Iodine-129	< 4.2	< 7.6	< 3.8	< 7.5
Plutonium-238	< 0.14	< 0.17	< 0.11	< 0.10
Plutonium-239/240	< 0.14	< 0.17	< 0.11	< 0.10
Potassium-40	< 180	< 220	< 190	< 180
Cobalt-60	< 10	< 14	< 10	< 11
Cesium-137	< 9.1	< 13	< 10	< 12
Radium-226	< 17	< 22	< 19	< 20
Thorium-228	< 12	< 19	< 32	< 16
Thorium-232	< 37	< 56	< 46	< 47
Europium-152	< 21	< 36	< 25	< 29
Europium-154	< 23	< 33	< 32	< 30
Americium-241	< 39	< 46	< 74	< 38
Uranium-234	5.7	6.1	3.5	2.9
Uranium-235	< 1	< 0.9	< 1	< 1
Uranium-238	2.15	1.34	< 1	< 1
Gross Alpha	7.5	8.3	4.8	4.0
Gross Beta	11.0	15.0	6.2	7.0

[136] Secondary standards are not health-based and are not legally enforceable. They are generally based on aesthetic considerations.

[137] MCLs (maximum contaminant level) are the highest level of a contaminant allowed in drinking water. MCLs are health-based and are legally enforceable (EPA 2004, page iv).

[138] AL (action level). If a water system exceeds the action level in more than 10% of the homes tested, the water system must treat the water delivered to its customers (EPA 2004, page iii).

[139] Lifetime HA (health advisory). The concentration of a contaminant that is not expected to cause adverse health affects for a lifetime of exposure. The lifetime HA is based on a 154 lb adult drinking two liters of water per day (EPA 2004, page iv).

[140] LOC (level of concern), source: DOE, 2005, page 4-15.

[141] Source of MCL: DOE, 2005, page 4-15.

[142] MCL is for combined radium 226 & 228.

[143] All units = pCi/L. Entries that were below the detection limit of the analytical method are list as "< detection limit." Note that the detection limit varied from sample to sample for a given analyte, which is a consequence of differences in the physical and chemical characteristics of the water sample and normal variation in each laboratory measurement. For example, pH, and ionic concentration will vary. Each laboratory guaranteed an advertised detection limit, which was greater that the method detection limit.

Table 10.2, Section 2 Radionuclides in Groundwater Samples

Sample ID	**Bauer**	**Bray**	**Quirk**	**Cameron**
Tritium	< 96	< 98	< 96	< 96
Carbon-14	< 59	< 57	< 60	< 59
Strontium-89	< 0.85	< 0.89	< 0.78	< 0.87
Strontium 90	< 0.45	< 0.52	< 0.45	< 0.52
Technetium-99	< 3.8	< 3.7	< 3.7	< 3.9
Iodine-129	< 9.8	< 4.8	< 3.6	< 84.9
Plutonium-238	< 0.10	< 0.11	< 0.11	< 0.22
Plutonium-239/240	< 0.10	< 0.11	< 0.11	< 0.18
Potassium-40	< 190	< 210	< 77	< 530
Cobalt-60	< 8.9	< 11	< 8.2	< 18
Cesium-137	< 9.2	< 11	< 7.7	< 17
Radium-226	< 18	< 22	< 14	< 41
Thorium-228	< 14	< 17	< 12	< 28
Thorium-232	< 42	< 49	< 29	< 84
Europium-152	< 25	< 28	< 23	< 43
Europium-154	< 28	< 32	< 21	< 53
Americium-241	< 69	< 85	< 39	< 140
Uranium-234	5.2	4.5	3.0	2.2
Uranium-235	< 1	< 1.1	< 1	< 0.97
Uranium-238	1.78	< 1.1	1.39	1.22
Gross Alpha	6.5	3.0	< 2.5	4.3
Gross Beta	18.0	10.0	15.0	20.0

Table 10.2, Section 3 Radionuclides in Groundwater Samples

Sample ID	Cameron (duplicate)[144]	Fairbanks Spring	Longstreet Spring	Equipment Blank[145]
Tritium	< 95	< 97	< 97	< 960
Carbon-14	< 61	< 59	< 58	< 59
Strontium-89	< 0.82	< 0.84	< 0.77	< 0.69
Strontium 90	< 0.39	< 0.48	< 0.48	< 0.48
Technetium-99	< 3.9	< 3.5	< 3.4	< 4.2
Iodine-129	< 5.4	< 4.4	< 8.7	< 3.9
Plutonium-238	< 0.053	< 0.034	< 0.16	< 0.055
Plutonium-239/240	< 0.026	< 0.029	< 0.12	< 0.034
Potassium-40	< 82	< 190	< 77	< 79
Cobalt-60	< 9.7	< 12	< 7.4	< 6.9
Cesium-137	< 9.4	< 11	< 7.4	< 7.5
Radium-226	< 17	< 20	< 14	< 14
Thorium-228	< 14	< 16	< 12	< 12
Thorium-232	< 42	< 47	< 29	< 29
Europium-152	< 25	< 30	< 24	< 22
Europium-154	< 30	< 32	< 22	< 21
Americium-241	< 66	< 36	< 38	< 38
Uranium-234	NA[146]	4.2	5	< 0.9
Uranium-235	NA	< 1.1	0.24	< 0.9
Uranium-238	NA	1.53	1.79	< 0.9
Gross Alpha	NA	5.5	4.1	< 1.8
Gross Beta	NA	11.0	9.8	< 2.8

Table 10.3, Section 1 Field Measurements and Metals in Groundwater Samples[147]

Sample ID	Rose	Stengel	Cady	Vassar
Temperature	23	22.3	23.5	25.2
pH	7.32	7.2	8.14	8.03
EC	932	1124	518	338

[144] Eberline Services provided one duplicate analysis from the same original sample. We selected this well, as it is the closest to the Nevada Test Site.

[145] An equipment blank is a quality control sample. It is a sample of pure water that is collected using the same equipment that was used to collect the normal samples. It is analyzed to determine whether the sampling equipment is adding any contaminants to the samples.

[146] NA = not analyzed.

[147] All units = mg/L except temperature (C), pH (SU), and EC (µmhos).

Cadmium	< 0.005	< 0.005	< 0.005	< 0.005
Chromium	0.010	0.010	< 0.010	< 0.010
Lead	< 0.040	< 0.040	< 0.040	< 0.040
Molybdenum	< 0.010	< 0.010	< 0.010	< 0.010
Nickel	< 0.010	< 0.010	< 0.010	< 0.010
Titanium	< 0.005	< 0.005	< 0.005	< 0.005
Zirconium	< 0.001	< 0.001	0.004	0.001

Table 10.3, Section 2 Field Measurements and Metals in Groundwater Samples

Sample ID	**Kadrmas**	**Bauer**	**Bray**	**Quirk**
Temperature	22.7	24.4	23.5	22.8
pH	7.13	7.13	8.05	7.32
EC	1075	1071	323	868
Cadmium	NA[148]	< 0.005	< 0.005	< 0.005
Chromium	NA	< 0.010	< 0.010	< 0.010
Lead	NA	< 0.040	< 0.040	< 0.040
Molybdenum	NA	< 0.010	< 0.010	< 0.010
Nickel	NA	< 0.010	< 0.010	< 0.010
Titanium	NA	< 0.005	< 0.005	< 0.005
Zirconium	NA	0.003	< 0.001	0.002

Table 10.3, Section 3 Field Measurements and Metals in Groundwater Samples

Sample ID	**Cameron**	**Fairbanks Spring**	**Longstreet Spring**	**Equipment Blank**
Temperature	22.7	26.5	26.9	NA
pH	7.29	7.22	7.16	NA
EC	882	679	646	NA
Cadmium	< 0.005	< 0.005	< 0.005	< 0.005
Chromium	< 0.010	< 0.010	< 0.010	< 0.010
Lead	< 0.040	< 0.040	< 0.040	< 0.040
Molybdenum	0.020	< 0.010	< 0.010	< 0.010
Nickel	< 0.010	< 0.010	< 0.010	< 0.010
Titanium	< 0.005	< 0.005	< 0.005	< 0.005
Zirconium	0.005	< 0.001	< 0.001	< 0.001

[148] NA = not analyzed. This well was sampled for field data only. Samples were not submitted to laboratories.

10.4 Reviewing the Analysis Results

H⊕ME's water analysis did not show unusually elevated levels of any of the analytes. All analytes were within EPA safe drinking water standards. Most radionuclides were below method detection levels, with the exception of uranium 238 and 234 isotopes. There was a substantial variation in the gross beta counts, ranging from a low of 6.2 pCi/L for Cady to a high of 20 pCi/L for Cameron. The gross alpha and uranium 238 activities showed less relative variation, at most a factor of two. Uranium 234 had a relatively high variation, from 2.2 pCi/L for Cameron to 6.1 for Stengel. Interestingly, Cameron also had the highest beta activity. In general, these ranges are not unlike those seen for the Nye County data, which are the nearest sampled and analyzed wells.

Of the non-radiological elements, only chromium, zirconium, and in one case molybdenum were not below detection limits. Chromium was only seen for the two westernmost wells, Cady and Stengel, but just at the detection limit. Zirconium, on the other hand, was detected in several wells at up to 5 times the detection level, but this is still a very low concentration. Again, the highest level was Cameron. Nye County did analyze for zirconium in 2000, but none was detected, so our data could be a significant deviation from the water upgradient. However, these levels are still very low and quite close to the detection limits, so these results could be atypical.

There is also an apparent inconsistency between the gross alpha activity of some of the sites; Bray, Quirk, and Cady. We would expect the gross alpha activity to be greater than the sum of the uranium isotopic combined activities, which are both alpha emitters. The most notable of the three data is for Quirk, where the gross alpha was below the detection level of 2.5 pCi/L, and the combined uranium 238, 234 activity was 4.49. It seems as though at least a measurable reading should have been obtained from the gross alpha. Again, the observed levels are near to the detection limits, and this anomaly, or inconsistency, is within the range of experimental error. Further sampling and analysis would be necessary to resolve this issue.

10.4.1 Comparison with Nye County EWDP Data

In comparison to the Nye County water analysis of the EWDP wells, we see that H⊕ME's results for the same analytes are similar. In both cases, there is wide variation in the gross alpha and beta radiation from sample to sample, and the radiation activity for our samples is within the range seen from Nye County's data. In general, our sites showed somewhat more elevated levels of gross beta activity, with a median activity of 11 pCi/L, relative to that of Nye County.

In many of Nye County's data, isotopic ratios were obtained[149]. One such ratio was U-238/U-234, which ranged from about 2400 to 9500. This can also be calculated from our data as:

$$\frac{U-238}{U-234} = \frac{A_{238}}{A_{234}} \times \frac{T_{238}}{T_{234}}$$

, where A represents the activity in pCi/L, and T is the half-life in years.[150,151]

[149] For example: NC-EWDP-05s, 2/8/99; Bond Gold Mining Well 13, 7/19/99; NC-EWDP-01s, 5/17/99; NC-EWDP-01s, 5/18/99; NC-EWDP-09sx, 5/18/99; NC-EWDP-09sx, 5/19/99; NC-EWDP-09sx, 5/19/99; NC-EWDP-09sx, 5/19/99; NC-EWDP-03s, 5/20/99; NC-EWDP-03s, 5/20/99; NC-EWDP-01dx, 5/24/99; NC-EWDP-03d, 2/17/99

The average U-238/U-234 ratio for all our data is 599 with a range from 255 to 1012. For the Well 1 data we get: $\frac{U-238}{U-234} = \frac{2.15\,pCi/L}{5.7\,pCi/L} \times \frac{4.468 \cdot 10^9\,yr}{2.45 \cdot 10^6\,yr} = 687$. The Rose ratio is a minimum of four times smaller than any of the Nye County data.

We can also estimate the total uranium concentration in parts per billion (ppb, or micrograms per liter, μg/L) from our data. This assumes that approximately 99.2% of the total uranium is from U-238[152] using the following relation:

$ppb = A(pCi/L) \cdot (1{,}166{,}832\,particles/year) \cdot \left(\frac{T}{\ln(2)}\right) \cdot \frac{\mathcal{M}}{\mathcal{a}} \cdot \left(\frac{1\mu g}{10^{-6} g}\right)$, where $\mathcal{M}$ is the gram atomic mass, and $\mathcal{a}$ is Avogadro's number.[153]

We get for the Rose data:

$$6.22\,ppb = 2.15(pCi/L) \cdot (1{,}166{,}832\,particles/year) \cdot \left(\frac{4.468 \cdot 10^9\,yr}{\ln(2)}\right) \cdot \frac{238.0508\,g/mole}{6.0221 \cdot 10^{23}\,particles/mole} \cdot \left(\frac{1\mu g}{10^{-6} g}\right)$$

which is within the range of ppb values obtained from Nye county data sampled from 12/12/98 to 1/27/99 (rid4385 online label). We see that the total uranium ranged from 1 ppb (sample NC-EWDP-02d) to 7.7 ppb (NC-EWDP-01d).

Based on this analysis, the U-238 concentrations for H🌎ME's samples are comparable to those available from Nye County. So, the difference in the isotopic ratios above would have to be due to a substantial difference in the U-234 concentrations. Thus, the wells H🌎ME sampled are expected to be approximately 4 to 13 times higher in U-234 than those cited here from Nye County. This assumes that the total U-238 and U-238/U-234 ratios are comparable for the various wells cited here, which may not be valid given the general variation within the Nye County data.

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[150] The derivation of this formula is directly from the radioactive decay law: $N(t) = N_0 e^{-\beta t}$, where *N(t)* is the number of radioactive nuclei remaining at some time, *t*, after the initial time, defined as zero, N_0 is the number of nuclei at time = 0, and β is the radioactive decay constant. Activity is the number nuclei decaying per unit time, so the first derivative of the decay law gives: $\frac{dN(t)}{dt} = -N_0 \beta e^{-\beta t} = -\beta N(t) \equiv A$. The decay constant is given by the half-life as: $\beta = \ln 2 / T$, so the number of nuclei remaining upon substitution for β, and solving for *N(t)* is: $N(t) = \frac{-A \cdot T}{\ln(2)}$, and the negative sign expected since mathematically activities are inherently negative (this is because the number of nuclei is decreasing in time); however, activity is measured in counts per second as a positive quantity, and the negative is thus absorbed into *A*. Therefore, the ratio of U-238 nuclei to U-234 nuclei is just: $\frac{N_{238}}{N_{234}} = \frac{A_{238} \cdot T_{238} / \ln(2)}{A_{234} \cdot T_{234} / \ln(2)} = \frac{A_{238} \cdot T_{238}}{A_{234} \cdot T_{234}}$, where the specific units of activity are not important, since this is a ratio.

[151] Half-life data obtained from Bodansky, David, *Nuclear Energy, Principles, Practices, and Prospects,* American Institute of Physics Press, Woodbury, N.Y., 1996.

[152] This is certainly a valid assumption based on natural abundances and from our isotopic activity data.

[153] Avogadro's number and U-238 mass obtained from *Handbook of Chemistry and Physics,* CRC Press, 61st Ed. 1980-1981.

In general, the U-238/U-234 isotopic ratio data for both the Nye County and H⊕ME's samples is low relative to the natural abundance of the isotopes. [154] We can calculate the isotopic ratio expected from naturally occurring uranium as:

$$^{155}U-238/U-234 = 99.275\%/0.005\% = 19{,}855$$, which is 10 to 20 times the ratios that

appear in the Nye County data, and about 30 times the average value obtained from our data. Since, the gross alpha counts are not high, in fact, well below the EPA action level, this is not a case of high amounts of uranium, but rather high amounts of U-234 relative to U-238. There are many mineral deposits in the region, and uranium deposits are likely as well, so we are not surprised to see some uranium in the groundwater. However, we do not have an explanation for the unexpected isotopic ratios, and H⊕ME has inquired with Nye County without an answer to date.

H⊕ME is also waiting for an explanation from Nye County regarding a number of very high gross alpha and gross beta results that are posted on the Early Warning Drilling Program website. For example, readings of 25 pCi/L alpha activity were reported for data set Rid439, sampled in November 1999. Such readings should trigger a more detailed investigation, since they could be above the Safe Drinking Water standard of 15 pCi/L (not including uranium or radon).

10.4.2 Comparison of H⊕ME's Analytical Results for Fairbanks Spring

H⊕ME collected water samples from Fairbanks Spring in January 2006. Several federal agencies have also collected samples from Fairbanks Spring[156]. The analytical results obtained by H⊕ME are similar to those obtained by the federal agencies. Analytical results are compared in table 10.4.2.

[154] Uranium, like most elements that exist in nature, is a mixture of different isotopes which have the same chemical properties. In the case of uranium, all the naturally occurring isotopes are radioactive. Natural abundance refers to the number of nuclei of a particular isotope.

[155] Abundances are from *Handbook of Chemistry and Physics,* CRC Press, 61st Ed. 1980-1981.

[156] U.S. Dept. of Energy, EPA, USGS (U.S. Dept. of Energy, *Radioactivity in FY 1997 Groundwater Samples From Wells and Springs Near Yucca Mountain*, by TRW Inc., August 1998.).

Table 10.4.2 Fairbanks Spring Comparison of Analytical Results

Radionuclide	H🌎ME Results[157]	Range of Federal Agency Results[158]
Tritium (pCi/L)	< 400	ND[159]
Carbon-14 (pCi/L)	< 200	ND
Strontium-89 (pCi/L)	< 1.0	0.81
Strontium 90 (pCi/L)	< 1.0	0.70
Technetium-99 (pCi/L)	< 15	1.9
Iodine-129 (pCi/L)	< 5.0	ND
Gross Alpha (pCi/L)	5.5	ND – 1.48
Gross Beta (pCi/L)	11.0	10.4 – 16.0

11. Conclusion and Recommendations

Our analyte data showed levels well within expected concentrations, and below EPA MCLs, i.e., action levels. Some uranium and the low but positive reading for some of the trace metals is also expected, due to all the mineral deposits in the region.

Our data corroborates the results of Nye County, illustrating a wide variation in groundwater chemistry and radiation activity. We think this is significant in understanding the environmental baseline, which could also vary substantially within the region. To fully understand factors influencing residents in the region downgradient of the NTS and potential Yucca Mountain Repository, H🌎ME believes that existing water sampling should be expanded to encompass the spectrum of water chemistry that influences public health.

Another possible consequence of the wide variation in gross alpha and beta readings is that the profile of radioactive elements in the groundwater could vary, without triggering action for a more detailed analysis. H🌎ME envisions the possibility of contamination from either the NTS or Yucca Mountain repository moving off-site and into the water supply, without activating the warning system. Residents could then be ingesting contaminants at low levels, but nonetheless possibly concentrating them in their bodies over time, well before it is known that these contaminants are in the water.

H🌎ME also sees a need to determine the source of the radioactive variation within our analysis, and to a greater extent, within Nye County's data. Is the variation due to localized pockets of

[157] See Table 10.2 Section 2.
[158] U.S. Dept. of Energy, 1998; and DOE, *Environmental Baseline File for Public Health*, by TRW Inc., June 1999.
[159] ND = not detected.

mineral deposits, or does the geochemistry influence the existing radioactivity that is dissolved in the water? In other words, is there a non-uniform binding mechanism in play with the naturally occurring radioisotopes, like uranium, radium, thorium, etc? If these mechanisms exist, then they could affect the appearance and movement of contaminants coming from the NTS or Yucca Mountain Repository.

The significance of the small U-238/U-234 ratios, relative to natural isotopic abundances seen in the area, is not clear to us at this time. It does not seem to be of much concern to Nye County, as we have not received a response to our queries. Again, this may point to our perception that the Early Warning Drilling Program is not focused on an environmental baseline.

While the Nye County and Nevada Test Site early warning systems may effectively intercept elevated radionuclide contamination, neither seems to track the breakdown of various radioactive isotopes in sufficient detail to reconstruct the overall radiation count in the groundwater, or, therefore, the intake profiles of the residents in the area. H🌎ME understands that it is crucial to establish an environmental baseline and connect health patterns to environmental factors. One such process is radiation dose reconstruction, which is near to impossible without this detailed baseline.

H🌎ME, through this study, hopes to encourage water monitoring agencies to conduct a thorough and complete program of water monitoring and ongoing analysis well into the future. Research must also continue to address the uncertainties in the understanding of groundwater movement and contamination, and the possible "gaps" in the existing monitoring network. This must include key analytes to protect health and habitat, both now and in the future.

12. Appendices

12.1 Element Analysis Assessment, Compiled by John Hadder 3/11/05

Key for Table 12.1:

YMP - Y indicates that the element was included in the DOE's analysis for the 2000 TSPA for the Site Recommendation[160]

NTS, 1 - Y indicates that the element was a candidate for contamination at the NTS and satisfied one or more criterion; amount *produced*, *mobility* in the groundwater, and *health impacts*.[161]

NTS, 2 - Y indicates elements for final consideration of NTS contamination.

40CFR141 - Y indicates that this element (isotope) is required for compliance with the Safe Drinking Water Standard[162]

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[160] U.S. Dept. of Energy, OCRWM, Yucca Mountain Science and Engineering Report, DOE/RW-0539, May 2001.

[161] The American Society of Engineers, *Strategy for Remediation of Groundwater Contamination at the Nevada Test Site,* Technical Peer Review Report (Report of the Review Panel, CRTD-Vol. 62, 2001.

Home Anal. - a simple numerical tally was done combining the top thirty radionuclides in each of three categories; total curies, potential solubility, and EPA MCL's based on effective dose equivalent of 4 mrem/yr for beta and photon emitters, and 15pCi/L for alpha emitters. Any radioisotopes with a tally of three or two was included in the consideration list and is designated with a Y.
M, NTS and H, NTS - indicates mobility and health respectively; Y designates that the element satisfied that criterion by the peer review panel.
Ci - approx. total curies determined from the YM FEIS[163] (commercial spent fuel inventory, significant DOE owned amounts under the "proposed action," and unclassified amounts for 76 underground tests in Areas 19 and 20 below or within 100 meters of the water table.[164]
EPA (pCi/L) - MCL's in picocuries per liter obtained for 4 mrem/yr and 15 pCi/L for beta/photon and alpha emitters respectively with a risk assumption of approximately 1-5 $x10^{-4}$.[165]; MCL's for uranium isotopes are based on kidney toxicity, as it is lower than MCL's for cancer.
Solubility - potential solubility in considering ingestion of radionuclides[166]
Half life - mostly from YM FEIS, and some from Brechin, Martin

Table 12.1 Section 1: Element Analysis Assessment Table

Element	Rank	YMP	NTS, 1	NTS, 2	40CFR141	Home Anal.	M, NTS	H, NTS	Ci	EPA (pCi/l)	Solu-bility	Half life (yr)
Ameri-cium-241	1	Y	Y	Y		Y		Y	2.21E+08	1.90E+01	1.00E-03	4.30E+02
Ameri-cium-243	1	Y				Y			1.90E+06	1.90E+01	1.00E-03	7.40E+03
Carbon-14	1	Y	Y	Y				Y	1.05E+05	3.20E+03	1.00E+00	5.70E+03
Cesium-137	1	Y	Y	Y	Y	Y		Y	5.43E+09	1.19E+02	1.00E+00	3.00E+01
Curium-244	1					Y			1.21E+08	2.30E+01	1.00E-03	1.80E+01
Europium-154	1		Y			Y			1.20E+08	5.73E+02	1.00E-03	8.60E+00
Tritium	1		Y	Y	Y	Y	Y		1.60E+07	6.09E+04	1.00E+00	1.23E+01
Iodine-129	1	Y	Y	Y	Y	Y	Y	Y	2.44E+03	2.10E+01	1.00E+00	1.70E+07
Neptun-ium-237	1	Y	Y	Y		Y	Y	Y	3.06E+04	3.20E+01	1.00E-03	2.10E+06
Plutonium-238	1	Y				Y			2.43E+08	1.50E+01	1.00E-05	8.80E+01

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[162] U.S. EPA, Title 40 Code of Federal Regulations Part 141, National Primary Drinking Water Regulations
[159] U.S. Dept. of Energy, *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High Level Radioactive Waste at Yucca Mountain, Nye County , Nevada, Vol. II,* DOE/EIS-0250F, February 2002.
[164] Brechin, Vernon, private communication, Mountain View, California.
[165] U.S. EPA , Radionuclides Notice of Data Availability Technical Support Document, Targeting and Analysis Branch Standards and Risk Management Division Office of Ground Water and Drinking Water United States EPA, March 2000.
[166] Martin, James E. and Chul Lee, *Principles of Radiological Health and Safety*, Table 9-9, pp 306-310, John Wiley Sons, Inc., Hoboken, New Jersey, 2003.

Plutonium-239	1	Y	Y	Y		Y		Y	2.44E+07	1.50E+01	1.00E-03	2.40E+04
Plutonium-240	1	Y	Y			Y		Y	3.63E+07	1.40E+01	1.00E-03	6.50E+03
Plutonium-242	1	Y				Y			1.40E+05	1.50E+01	1.00E-03	3.80E+05
Radium-226	1	Y			Y				na	5.00E+00	2.00E-01	1.60E+03
Radium-228	1				Y				na	2.00E+00	2.00E-01	5.75E+00
Strontium-89	1				Y				na	5.99E+02	1.00E+00	1.38E-01
Strontium-90	1	Y	Y	Y	Y	Y		Y	3.38E+09	4.20E+01	1.00E+00	3.00E+01
Technecium-99	1	Y	Y			Y	Y		1.00E+06	3.79E+03	8.00E-01	2.10E+05
Thorium-229	1	Y							2.89E+01	9.00E+00	2.00E-04	7.90E+03
Uranium-232	1	Y			Y				3.88E+03	2.00E+01	2.00E-03	6.90E+01
Uranium-233	1	Y			Y				1.28E+04	2.00E+01	2.00E-03	1.60E+05
Uranium-234	1	Y	Y		Y			Y	8.95E+04	2.00E+01	2.00E-03	2.50E+05
Uranium-235	1	Y			Y	Y				2.00E+01	2.00E-03	
Uranium-236	1	Y			Y				1.80E+04	2.00E+01	2.00E-03	2.30E+07
Uranium-238	1	Y	Y	Y	Y			Y	2.11E+04	2.00E+01	2.00E-03	4.50E+09
Non-radiological												
Barium-137	1											
Chromium	1				Y							
Gadolinium-154	1											
Lead, and 206, 208	1			Y	Y							
Molybdenum	1											
Zirconium	1											
Zirconium-90	1											

Table 12.1 Section 2: Element Analysis Assessment Table (Concluded)

Element	Rank	YMP	NTS 1	NTS 2	40CFR141	Home Anal.	M, NTS	H, NTS	Ci	EPA (pCi/l)	Solu-bility	half life (yr)
Actinium-227	2	y							1.01E+02	1.00E+00	1.00E-03	2.20E+00
Ameri-cium-242/242m	2	y				Y			1.60E+06	1.09E+03	1.00E-03	1.40E+02
Antimony-125	2		Y			Y	Y		3.60E+06	1.94E+03	1.00E-02	2.80E+00
Cesium-134	2		Y			Y		Y	5.89E+06	8.10E+01	1.00E+00	2.10E+00
Chorine-36	2		Y						1.13E+03	1.85E+03	1.00E+00	3.00E+05
Cobalt-60	2		Y			Y	Y		2.73E+07	2.18E+02	5.00E-02	5.30E+00
Europium-152	2		Y						4.33E+02	8.41E+02	1.00E-03	1.35E+01
Europium-155	2		Y			Y			2.20E+07	3.59E+03	1.00E-03	4.80E+00
Krypton-85	2		Y				Y		1.52E+08	na	na	1.07E+01
Lead-210	2	y							na	1.00E+00	2.00E-01	2.26E+01
Protactium-231	2	y							2.10E+01	8.00E+00	1.00E-03	3.30E+04
Ruthen-ium-106	2		Y			Y	Y		1.04E+05	2.03E+02	5.00E-02	1.00E+00
Samarium-151	2		y						3.17E+07	1.41E+04	na	9.00E+01
Thorium-230	2	Y							1.85E+01	2.10E+01	2.00E-04	7.50E+04
Cadmium-113m	3					Y			1.50E+06	5.24E+04	5.00E-02	1.40E+01
Curium-242	3					Y			1.30E+06	5.10E+01	1.00E-03	4.50E-01
Curium-243	3					Y			1.30E+06	2.10E+01	1.00E-03	2.90E+01
Iron-55	3					Y			4.20E+05	9.25E+03	1.00E-01	2.70E+00
Nickel-59	3					Y			1.61E+05	2.70E+04	5.00E-02	7.60E+04
Nickel-63	3					Y			2.20E+07	9.91E+03	5.00E-02	1.00E+02
Plutonium-241	3					Y			3.20E+09	1.50E+01	1.00E-03	1.40E+01
Zirconium-93	3					Y			1.94E+05	5.09E+03	2.00E-03	1.50E+06
Non-radio-logical												
Cadmium	2				Y							
Nickel	2				Y							
Titanium	2											
Vanadium	2											

Table 12.2 Unclassified Radionuclide Inventory for 828 Underground Nuclear Tests (921 Detonations) at the NTS. Reported in Curies; Decay Corrected to 9/23/92[167]

Compiled by Vernon Brechin, December 11, 2004

Radionuclide	Isotope Symbol	Half-life (t 1/2; years)	Radioactivity Level (Curies)	Mass (2)[168] (grams)
Tritium	H-3	12.3	125,600,000	12,910
Carbon-14	C-14	5,730	2,841	635.0
Aluminum-26	Al-26	730,000	0.1084	5.73
Chlorine-36	CL-36	3,010,000	615.8	18,590
Argon-39	Ar-39	269	3,205	93.66
Potassium-40	K-40	1,280,000,000	811.2	115,700,000[169]
Calcium-41	Ca-41	103,000	4,429	52,100
Nickel-59	Ni-59	76,000	113.4	1,416
Nickel-63	Ni-63	100	12,790	224.0
Krypton-85	Kr-85	10.7	177,800	451.7
Strontium-90	Sr-90	29.1	2,179,000	15,900
Zirconium-93	Zr-93	1,500,000	76.41	29,691
Niobium-93m	Nb-93m	16.1	15,430	64.35
Niobium-94	Nb-94	20,000	399.9	2,094
Technetium-99	Tc-99	213,000	570.6	33,520
Paladium-107	Pd-107	6,500,000	3.420	6,626
Cadmium-113m	Cd-113m	14.1	1,933	8.579
Tin-121m	Sn-121m	~55.0	7,165	132.8
Tin-126	Sn-126	~100,000	33.13	1,163
Iodine-129	I-129	15,700,000	1.759	9,923
Cesium-135	Cs-135	2,300,000	59.97	51,870
Cesium-137	Cs-137	30.2	2,857,000	32,890
Samarium-151	Sm-151	90.0	106,800	4,043
Europium-150	Eu-150	36.0	14,790	222.5
Europium-152	Eu-152	13.5	150,800	860.7
Europium-154	Eu-154	8.59	106,000	390.6
Holmium-166m	Hm-166m	1,200	146.9	81.51
Thorium-232	Th-232	14,000,000,000	58.95	533,400
Uranium-232	U-232	70.0	721.1	32.62
Uranium-233	U-233	159,000	466.4	48,190
Uranium-234	U-234	246,000	716.9	115,000
Uranium-235	U-235	704,000,000	8.593	3,960,000

[167] "Nevada Test Site Radionuclide Inventory, 1951--1992" (LA-13859-MS), September 2001, Los Alamos National Laboratory, Los Alamos, New Mexico 87545. See Total column in Table V on paper page 21 or PDF Page 22. http://www.nv.doe.gov/news&pubs/publications/envm/pdfs/LA13859MS.pdf

[168] These mass values were derived using the following standard equation. Radioactivity level (Curies) / (359,000 / ((t 1/2; years) x atomic weight))) = mass of radionuclide (grams). The half-life values were derived from the following report. "Unclassified Radiologic Source Term for Nevada Test Site Areas 19 and 20" (UCRL-ID-141706), December 1, 2000, D. K. Smith, W. Goishi, Analytical and Nuclear Chemistry Division, Lawrence Livermore National Laboratory, U.S. Department of Energy. http://www.llnl.gov/tid/lof/documents/pdf/246157.pdf , page 7.

[169] The K-40, Th-232, U-234, U-235 and U-238 values include the naturally-occurring isotopes that existed in the thousands of tons of rock that was, subsequently, melted by the nuclear detonations. The total values were derived by excluding the values of these five radionuclides since these values are not representative of the radionuclides that resulted from the nuclear detonations.

Uranium-236	U-236	23,400,000	9.381	144,400	
Uranium-238	U-238	4,470,000,000	44.49	133,300,000	
Neptunium-237	Np-237	2,140,000	48.65	68,730	
Plutonium-238	Pu-238	87.7	39,500	2,297	
Plutonium-239	Pu-239	24,100	160,000	2,567,000	
Plutonium-240	Pu-240	6,560	41,930	183,900	
Plutonium-241	Pu-241	14.4	591,400	5,717	
Plutonium-242	Pu-242	375,000	16.18	4,090	
Americium-241	Am-241	433	37,100	10,870	
Americium-243	Am-243	7,370	7.078	35.31	
Curium-244	Cm-244	18.1	7,529	92.62	
Totals (3):			132,120,730 Ci	3,311,262 g (~3.3 metric tons)	

Average value per test (3): (arithmetic mean value for 828 tests)	159,567 Ci	3,999 g

Note from authors: This table includes a radionuclide inventory for all underground nuclear tests conducted at the Nevada Test Site. For the purposes of this study, we used that portion of the inventory that pertains to tests below or within 100 meters of the water table.

12.3 Acronyms Used in this Report

CERD: [UN] Committee to End Racial Discrimination

DOE: Department of Energy

DOE/EM: Department of Energy Environmental Management

DVRFS: Death Valley Regional Flow System

EPA: Environmental Protection Agency

EWDP: Early Warning Drilling Program

FEIS: Final Environmental Impact Statement

HLW: High Level Waste

ISIP: Independent Scientific Investigations Program

LCA: Lower Carbonate Aquifer

LTHMP: Long Term Hydrological Monitoring Program

NNSA: National Nuclear Security Agency

NRC: Nuclear Regulatory Commission

NTS: Nevada Test Site

NWTRB: Nuclear Waste Technical Review Board

TSPA: Total System Performance Assessment

UGTA: Underground Test Area

USGS: United States Geological Survey

YMP: Yucca Mountain Project

12.4 Supplemental Information About Tritium

Tritium is a radioactive form of hydrogen. The name refers to the fact that this form of hydrogen contains three particles in the nucleus; two neutrons and one proton (^{3}H). Normal hydrogen contains only a proton (^{1}H).

Tritium has a half-life of 12.36 years[170]. That is, after 12.36 years half the tritium present in a sample will be gone. It radioactively decays to helium. Tritium is produced naturally in the upper atmosphere by cosmic radiation. It is also produced artificially by nuclear explosions, and in nuclear reactors and high-energy accelerators.

Chemically, tritium acts like normal hydrogen. It forms water just as hydrogen does. Because it usually exists as part of a water molecule it travels at the same speed as the water. That is, it is not subject to the forces that tend to slow the transport of many contaminants. This makes tritium a useful tracer because it will be one of the first contaminants to arrive at an affected site.

Atmospheric nuclear tests produced large amounts of tritium in the atmosphere. The tritium activities resulting from the tests were much higher than natural levels. This 'bomb pulse' tritium has been falling to earth in rain and snow since atmospheric testing began. Bomb pulse tritium activities peaked in the mid-1960s. Thus, precipitation that infiltrated the subsurface and became groundwater in the mid-1960s would contain higher tritium concentrations than precipitation that infiltrated the subsurface before or after. The preceding statement is correct unless there is another source of tritium. In the vicinity of the study area, other potential sources of tritium are the NTS and US Ecology's hazardous waste facility.

Figure 12.4 is reconstructed data for tritium in precipitation in the vicinity of Yucca Mountain. There has been no long-term measurement of tritium in precipitation near the study area. The data used in figure 12.4 are from a report by Fabryka-Martin. Fabryka-Martin used tritium data from Albuquerque to reconstruct tritium activities in precipitation near Yucca Mountain[171]. The reconstructed period includes the peak of the bomb-pulse for atmospheric tritium (mid 1960s). Fabryka-Martin decay-corrected the Albuquerque tritium to 1990[172]. For this report, the same data were decay-corrected to 2006. That is, the activities shown are what they would be in 2006, not what they were when the precipitation infiltrated the subsurface.

As shown in Figure 12.4, maximum bomb-pulse tritium activities in vicinity of the study area are now less than 1400 pCi/L. Thus, tritium activities greater than 1400 pCi/L are an indication of a non-bomb-pulse source. Near the study area, tritium activities greater than 1400 pCi/L would indicate that the groundwater had been contaminated by either the NTS or US Ecology's hazardous waste facility.

[170] U.S. Dept. of Energy, 2005, page C-2.
[171] Fabryka-Martin et al., 1998, table D-4.
[172] Fabryka-Martin et al., 1998, table D-4.

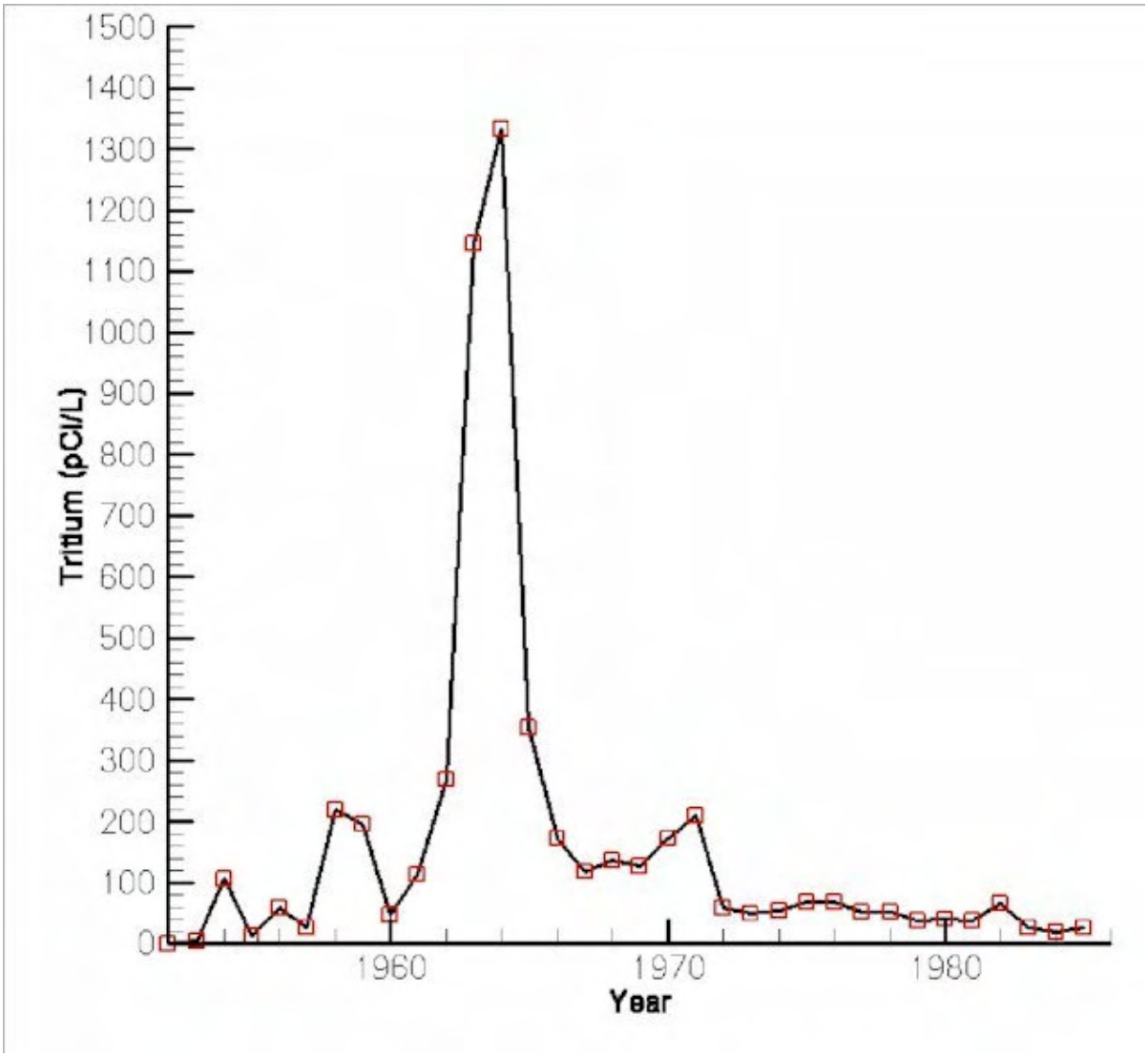


Figure 12.4 Reconstructed Tritium in Precipitation at Yucca Mountain
Decay corrected to 2006. Adapted from Fabryka-Martin et al., 1998.

12.5 H🌎ME Tubing Cleaning Procedure

Peristaltic pump tubing was cleaned as described below. All tubing was new Tygon except for approximately two inches of new Teflon tubing used to connect the filter to the Tygon tubing. Cleaning solutions were pumped through the tubing with a peristaltic pump.

- Rinse outside and inside of tubing with Alconox and distilled water solution.
- Rinse inside and outside with distilled water.
- Rinse inside with nitric acid and HPLC[173] water solution (10% nitric acid).
- Rinse inside with distilled water.
- Rinse inside with HPLC water.

[173] High performance liquid chromatograph.

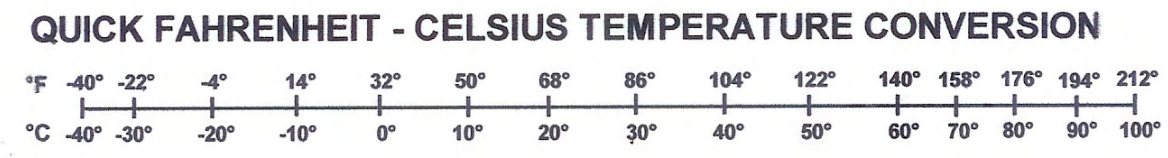
12.6 H🌎ME Sample Collection Procedure

Between January 13th and January 16th, 2006, samples were collected from eight wells and two springs. The samples were collected by George Rice, John Hadder, and Jennifer Viereck. The sampling procedure is described below.

- A minimum of three bore volumes were purged from each well before any sample water was collected. Bore volumes were calculated based on information provided by the well owner (total depth, depth to water, diameter).
- Water was pumped from each well by the owner's submersible pump.
- Samples were collected from brass or plastic faucets a few feet from the wellhead. A few faucets were as far as 25 feet from the wellhead. In one case water was collected from a PVC pipe 125 feet from the wellhead.
- Storage tanks were bypassed. Water flowed from the well, through a PVC pipe, to the faucet or end of the pipe. In some cases faucets were connected to a short length of galvanized steel pipe.
- At each well, a new, pre-cleaned one-liter HDPE[174] bottle was filled with sample water.
- Water was pumped from the HDPE bottle into the sample containers with a peristaltic pump.
- New, pre-cleaned, peristaltic pump tubing (Tygon) was used at each sample location.
- All samples were filtered through an in-line, 0.45 µm, disposable filter.
- All sample containers were new, pre-cleaned bottles. Metals and most radionuclide samples were collected in HDPE bottles. Each HDPE bottle contained a small amount of nitric acid. The nitric acid was added by the analytical laboratory or the bottle supplier. A combined tritium and carbon-14 sample was collected in a 500 ml, pre-cleaned glass bottle. The glass bottle contained no nitric acid. An additional 50 ml sample was collected in a plastic vial. This sample was collected at the request of the analytical laboratory. The vial contained no nitric acid.
- Spring samples were collected as described above except that the intake end of the tygon tubing was submerged directly in the spring pool.
- Temperature, pH, and electrical conductivity were measured at each sample location.

Additional information regarding the collection of samples at each location can be found on the sample collection forms.

12.7 Temperature Conversion Chart



[174] High density polyethylene

12.8 Radioactive Terminology

AL: Action Level- if a drinking water system exceeds the action level in more than 10% of the homes tested, the water system must treat the water delivered to its customers. Unfortunately, the same protection is not extended to wildlife.

ACTIVITY: rate of radiation release in the number of particles per second. The greater the *activity* the more radioactive is the material. The standard unit is the Becquerel, defined as one emission (disintegration) per second. Also, see Curie, below.

ACTIVATION PRODUCTS: those materials that have become radioactive because of the radiation in a reactor, like nickel-59, carbon-14, and cobalt-60.

ALPHA RADIATION: a particle composed of two protons and two neutrons, ejected when a nucleus reduces it's mass and transforms itself into a different element. Slow-moving alpha particles cannot penetrate paper or skin, but are very dangerous when substances emitting them are ingested or inhaled. (See Figure in Appendix 12.9, Figure 12.9)

BACKGROUND RADIATION: refers to the radiation we receive from our everyday lives, and is usually associated with radiation from natural sources. Typical background radiation doses range from 100 to 200 millirem per year depending upon geographic location and lifestyle.

BETA RADIATION: an electron emitted when a neutron becomes a proton, moving at nearly the speed of light. Beta particles can penetrate paper or several millimeters of skin, and like alpha particles, are very dangerous when substances emitting them are ingested or inhaled.

CRITICAL MASS: the mass (amount) and configuration (shape) of a given fissionable element needed to spontaneously undergo nuclear fission and sustain a nuclear chain reaction. Thus, a *critical mass* is the amount needed to make a bomb, even a "dirty bomb."

CURIE: an older and still widely used unit of activity, which is equal to 37 billion emissions per second. A picocurie, used widely in water analysis as picocuries per liter or pCi/L, is 10^{-12} curies.

DECAY: when a substance on its own releases radiation, and in the process becomes a difference substance. After one substance has decayed to another, it could still be radioactive. Anything that is radioactive is in a process of *decay* (*radioactive decay*).

DOSE: is a measure of how much radiation is absorbed by a person and the health effects. A common unit used in relation to biological exposure is the rem. The standard unit of dose is the sievert, which is 100 rem, and a typical chest X-ray is a dose of 10 millirems (0.100 rem) or 1 millisievert. A dose of one rem is a large dose for a single exposure.

GAMMA RADIATION: a short, intense burst of electromagnetic energy, emitted by an unstable nucleus. With high energy and no electrical charge, gamma rays have great penetrating

power. Not even a thick piece of lead or concrete will stop all of them, and they pass easily into the human body, damaging tissue in the process.

GEIGER COUNTER: a device for measuring radiation.

FISSION PRODUCTS: these are the highly radioactive fragments that result from splitting the atom. They tend to have half-lives of less than 1,000 years.

HALF-LIFE: refers to the time required for half of the radioactive substance to decay away. If the half-life is large then the activity is small.

IONIZING RADIATION: any of a type of radiation that can induce ionization; knock electrons off of atoms. *Ionizing radiation* is the most harmful kind of radiation.

ISOTOPES: nuclei of the same element but differing in the number of neutrons; for example uranium-238 (U-238) and U-235 are the same element but vary in mass. Isotopes have almost exactly the same chemical properties, and the body is unable to distinguish between isotopes.

KILOTON, MEGATON: 1,000 and 1,000,000 tons of TNT equivalent. These terms are typically used to refer to the explosive force of nuclear weapons.

LIFETIME HA: Health Advisory- the concentration of a contaminant that is not expected to cause adverse health affects for a lifetime of exposure. The lifetime HA is based on a 154 lb adult drinking two liters of water per day.

MCL: Maximum Contaminant Level- the highest level of a contaminant allowed in drinking water at one time. MCLs are health-based and are legally enforceable.

NUCLEAR TEST VERSUS DETONATION: Detonation is defined by the Department of Energy as: "A single nuclear device explosion; one or more comprise a test." In at least one test, five nuclear weapons were detonated at the same time. At the Nevada Test Site, 1021 bombs were exploded, or detonated. 100 were above ground, before 1963. 828 tests were conducted below ground, which involved exploding, or detonating, 921 nuclear bombs.

NUCLEAR FISSION: the splitting of an atom fragments (**fission products**). Any atom that is capable of fission is know as **fissile.** Fission products are highly radioactive, and always result from *nuclear fission*.

NUCLEAR PROLIFERATION: refers to human actives that increase the amount of radioactive materials that are used to make nuclear weapons; mostly plutonium-239 and uranium-235.

PLUTONIUM: a radionuclide that is almost entirely human-made and has become the substance of choice for making nuclear weapons. It is also one of the most toxic materials known, and has a half life of about 24,000 years. *Plutonium* is also in radioactive waste from nuclear power reactors.

RADIONUCLIDE: any atom (nucleus, actually) that is unstable, meaning it will decay, and hence is radioactive.

RADIATION: most generally refers to energetic particles. Sunlight is a form of radiation, and so is the heat from a campfire. When a substance is in the process of radioactive decay, it will give off *radiation*. Five general types of radiation are given off from the decay process: gamma, x-rays, neutrons, beta particles, and alpha particles. Any of these can be harmful.

SPENT NUCLEAR FUEL (SNF): this is the nuclear waste from a reactor. After nuclear fuel has been in the reactor for about four years, it is considered, "spent," hence *spent nuclear fuel*. It is very radioactive due to "fission products".

SUBCRITICAL TEST: an experiment that uses high explosives and some amount of plutonium (typically) that will simulate the conditions in a nuclear weapons test, but leads just to the point of the nuclear explosion (nuclear chain reaction) without triggering the chain reaction. Thus, the mass of plutonium is below criticality, hence subcritical.

TRANSPORTATION CASK: a "dumbell shaped" container, used for transporting the waste from reactors.

TRANSMUTATION: is the general changing of one atom (nucleus) into another. All decay is *transmutation*, but not all transmutation is decay; for example, nuclear fission in a power reactor is *transmutation*, but not decay. Plutonium is formed from uranium in a reactor, so the uranium is *transmuted* into plutonium.

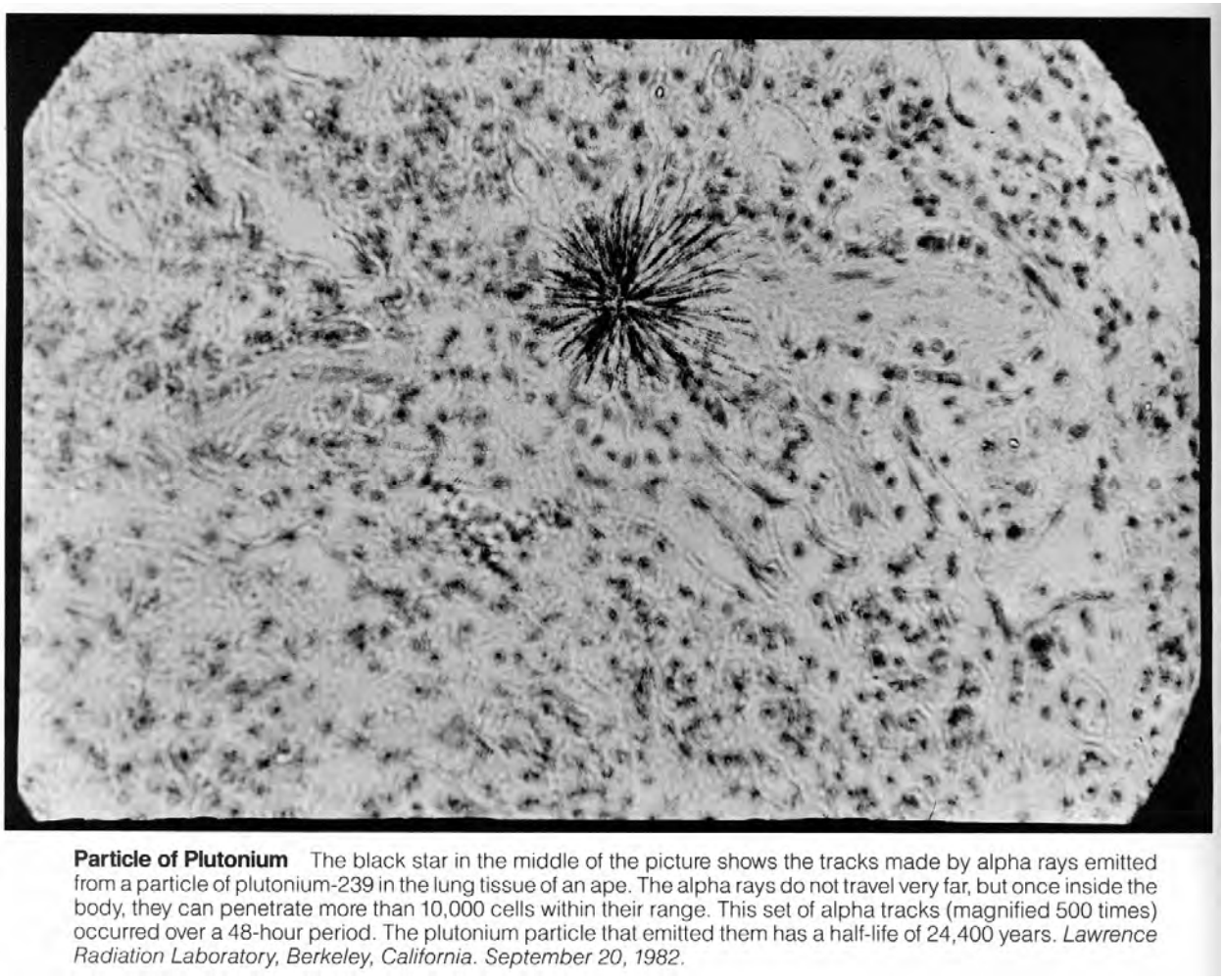
TRANSURANIC: any element (type of atom) larger (in the number of protons, atomic number) than uranium; plutonium is an example of a transuranic element.

WASTE CASK OR CANISTER: the containers to be used to hold nuclear waste in a long term repository (dump).

WEAPONS COMPLEX: all the facilities in the US that are involved in the production of nuclear weapons. These facilities are run by the Department of Defense and the Department of Energy, and now the National Nuclear Safety Administration (NNSA).

X-RAYS: a form of cosmic radiation or man-made, produced by firing electrons at a heavy metal target. X-rays are somewhat less penetrating than gamma rays, though their effects are similar.

12.9 Potential Impacts of Radionuclides on the Human Body[175]



Particle of Plutonium The black star in the middle of the picture shows the tracks made by alpha rays emitted from a particle of plutonium-239 in the lung tissue of an ape. The alpha rays do not travel very far, but once inside the body, they can penetrate more than 10,000 cells within their range. This set of alpha tracks (magnified 500 times) occurred over a 48-hour period. The plutonium particle that emitted them has a half-life of 24,400 years. *Lawrence Radiation Laboratory, Berkeley, California. September 20, 1982.*

Figure 12.9 Effects of Plutonium Alpha Radiation in Lung Tissue in 48 Hours[176]

12.9.1 Plutonium 239 Health Effects:

Insoluble plutonium particles that can be inhaled are retained in the respiratory tract (lungs and esophagus). Lung cancer has been observed in animal tests. 27 micrograms has been known to cause cancer[177]. 27 micrograms is about 1 millionth of an ounce. Plutonium travels from the lungs to the blood and lymph system.

[175] Adapted from Nuclear Risk Management for Native Communities, 1997.
[176] U.S. Dept. of Energy Office of Environmental Management, "Closing the Circle on the Splitting of the Atom", 1996, Page 39.
[177] Institute for Energy and Environmental Research, *Plutonium, Deadly Gold of the Nuclear Age*, pp. 14-18, International Physicians Press, Cambridge Massachusetts, 1992.

Soluble plutonium enters the blood quickly and deposits on bone surfaces and in the liver. About 40% of the plutonium that enters blood goes to bone surfaces, 40% to the liver, and the rest to muscles. Bone and liver cancer can result, because plutonium is retained in these tissues for long periods. Leukemia, a cancer of the blood, may be caused by plutonium retention in the bone marrow.

The alpha particles emitted from plutonium can also cause genetic damage. Plutonium workers at British Nuclear Fuels, Sellafield, England, have experienced chromosome aberrations due to plutonium inhalation. Rocky Flats workers have increased cases of brain cancer. Plutonium has also been associated with pituitary and other rarer cancers.

In general, plutonium has a long time lapse between exposure and when cancers are diagnosed of about 30 years, but this can vary according to the does received.

12.9.2 Tritium Health Effects

Tritium can be inhaled, ingested through air and food, or absorbed through the skin. Tritium is biologically concentrated in tissues as it passed through the food chain, from plants to herbivores to carnivores. In animal tests, it can pass to a fetus or through mother's milk. Tritiated water can pass through the human body in 12 days. But when it unites with carbon in living tissues, becoming what is known as "organically bound tritium" or OBT, it can remain in human tissue for 450 to 650 days. OBT contributes 90% of the radiation dose.

After entering the body, tritium mixes with body water to create a whole body dose, and irradiates the body somewhat uniformly. Fetal tissue, testes and bone marrow are damaged most easily by this method. Tritium also accumulates in the blood, heart, and kidney cells. It seems to be retained longest in muscle tissue. High internal dosage of tritium is possibly associated with leukemia, blood disorders, and testicular cancer.

12.9.3 Strontium-90 Health Effects

Strontium-90 has been found in the top ten centimeters of soil downwind from the Nevada Test Site and Chernobyl. Radioactive strontium is biologically retained in human bones. Chemically, it resembles calcium (or natural strontium) and the human body does a poor job of distinguishing between the two. Cancer of the bone and leukemia was observed in exposed animals. Leukemia was caused more readily by continuous low doses than by a single high dose. High doses caused disproportionately more bone cancers than low doses. There is also evidence for a weakening of the immune system.

12.9.4 Cesium-137 Health Effects

Strontium-90 has been found in the top ten centimeters of soil downwind from the Nevada Test Site and Chernobyl, especially in areas where it rained after nuclear events. Cesium has been found in harvestable plant materials, such as tobacco and mushrooms. It is thought to be the second major contributor to radiation dose after the short-lived iodine-131 has decayed. It is easily absorbed into the blood and contributes to a whole-body dose of radiation. Cesium is similar to potassium, and when cesium is ingested, it may impede functioning of potassium in the nervous system. Potassium is essential for proper nerve functioning, but no such health effects have been proven.

High doses of injected cesium result in death from bone marrow destruction, much like high doses of X-rays. Lower doses of cesium cause cancer in animals, particularly liver cancer.

12.9.5 Uranium (All Isotopes) Health Effects[178]

Outside the body, plutonium and uranium pose minimal risks to human health unless exposure is on a sustained basis. This is because the main type of radiation from both materials, alpha radiation, is very short-range and is stopped by the outer dead layer of skin. However, if plutonium or uranium gets into the body, the high-energy alpha radiation can damage cells and cause cell mutations that can lead to cancer. Like plutonium, uranium is a health hazard when small particles are inhaled or absorbed through wounds. But uranium is also more easily absorbed than plutonium though the gastrointestinal tract. Animal studies suggest that uranium-like plutonium, may damage reproductive organs, may harm a developing fetus, and may increase the risk of leukemia and soft tissue cancers. Uranium is far less radioactive and therefore less carcinogenic than plutonium, and uranium can cause acute damage to the kidneys by heavy metal poisoning well before radiation effects are manifest.

One of the most serious health hazards associated with uranium is uranium mining. A study of uranium miners conducted by the U.S. Public Health Service between 1948 and 1982 showed significant excesses of respiratory cancers; by 1978, white underground miners in the study suffered five times the expected rate of such cancers. The cancer risk from uranium mining is mainly due to exposure to the decay products of radon, which is itself a decay product of uranium-238.

Uranium used to produce enriched uranium for U.S. nuclear warheads was mined before the mid-1960s. Mines operating since then have produced uranium for commercial purposes and to a lesser extent for the reactors that propel some naval vessels.

Most uranium mines in the U.S. have been shut down, but the radioactive wastes from uranium processing still pose a health risk to segments of the U.S. population. These wastes, called mill tailings, contain long-lived radioactive isotopes. As of the late 1980s, some 220 million metric tons of mill tailings had accumulated from uranium production for nuclear weapons and nuclear power.

According to the Environmental Protection Agency, groundwater has become contaminated at virtually all mill tailings sites.

[178] STAR Foundation, 66 Newtown Lane, Ste. 3, P.O. Box 4206, East Hampton, New York 11937.

12.10 Probable Health Effects Resulting from Exposure to Ionizing Radiation[179]

Dose in rems (whole body)	Health Effects - Immediate	Health Effects - Delayed
1,000 or more	Immediate death. "Frying of the brain".	None
600-1,000	Weakness, nausea, vomiting and diarrhea followed by apparent improvement. After several days: fever, diarrhea, blood discharge from the bowels, hemorrhage of the larynx, trachea, bronchi or lungs, vomiting of blood and blood in the urine.	Death in about 10 days. Autopsy shows destruction of hematopoietic tissues, including bone marrow, lymph nodes and spleen; swelling and degeneration of epithelial cells of the intestines, genital organs, and endocrine glands.
250-600	Nausea, vomiting, diarrhea, epilation (loss of hair), weakness, malaise, vomiting of blood, bloody discharge from the bowels or kidneys, nose bleeding, bleeding from gums and genitals, subcutaneous bleeding, fever, inflammation of the pharynx and stomach, and menstrual abnormalities. Marked destruction of bone marrow, lymph nodes and spleen causes decrease in blood cells especially granulocytes and thrombocytes.	Radiation-induced atrophy of the endocrine glands including the pituitary, thyroid, and adrenal glands. From the third to fifth week after exposure, death is closely correlated with degree of leukocytopenia. More than 50% die in this time period. Survivors experience keloids, ophthalmological disorders, blood dyscrasis, malignant tumors, and psychoneurological disturbances.
150-250	Nausea and vomiting on the first day. Diarrhea and probable skin burns. Apparent improvement for about two weeks thereafter. Fetal or embryonic death if pregnant.	Symptoms of malaise as indicated above. Persons in poor health prior to exposure, or those who develop a serious infection, may not survive. The healthy adult recovers to somewhat normal health in about three months. He or she may have permanent health damage, may develop cancer or benign tumors, and will probably have a shortened lifespan. Genetic and teratogenic effects.
50-150	Acute radiation sickness and burns are less severe than at the higher exposure dose. Spontaneous abortion or stillbirth.	Tissue damage effects are less severe. Reduction in lymphocytes and neutrophils leaves the individual temporarily very vulnerable to infection. There may be genetic damage to offspring, benign or malignant tumors, premature ageing, and shortened lifespan. Genetic and teratogenic effects.
10-50	Most persons experience little or no immediate reaction. Sensitive individuals may experience radiation sickness.	Transient effects in lymphocytes and neutrophils. Premature ageing, genetic effects and some risk of tumors.
0-10	None	Premature ageing, mild mutations in offspring, some risk of excess tumors. Genetic and teratogenic effects.

[179] Source: "Nuclear Radiation and its Biological Effects" Center for Nuclear Responsibility, P.O. Box 421993 , San Francisco, CA 94143 NOTE: 1 rem = 1000 millirems. A standard chest x-ray is a dose of 10 millirems.