TECHNICAL SUMMATION

Recommendations
For Proposed Well Locations
In The Pahute Mesa Area
At The
Nevada Test Site

The Community Advisory Board
for Nevada Test Site Programs

...Citizens Working Together on Environmental Issues

NEVADA TEST SITE COMMUNITY ADVISORY BOARD (NTS CAB) REPORT

FOR PROPOSED WELL LOCATIONS IN THE PAHUTE MESA AREA

ABSTRACT

In 2002, the U.S. Department of Energy Nevada Site Office Environmental Management (DOE NSO EM) offered the NTS CAB, hereinafter referred to as CAB, an opportunity to identify a site to drill a well in response to stakeholder concerns about the potential movement of radionuclides in groundwater from past nuclear weapons tests on Pahute Mesa. The purpose of this paper is to summarize the groundwater issues that the CAB Underground Test Area (UGTA) committee studied and to provide justification for our recommended well sites. The committee strongly supports continued research in this area and recommends that DOE make every effort to secure added resources to collect additional hard data. This would demonstrate their commitment to the protection of public health, safety, and the environment for residents living near Western Pahute Mesa.

I. INTRODUCTION

The objectives of this paper are to identify groundwater uncertainties for nearby communities and provide the DOE with background for the CAB letter of February 2005[1] which recommended drilling three additional wells in the northwestern part of the Nevada Test Site[2] (NTS). Following the framework outlined by the Federal Facility Agreement and Consent Order (FFACO 1996),[3] the DOE and the Nevada Division of Environmental Protection (NDEP) agreed to work together to prioritize projects dealing with environmental contamination at the NTS that "…protect the public health, safety, and the environment."[4] A major focus of this cooperative effort is based upon the work of scientists from multiple disciplines[5] who are working together to identify current groundwater contamination boundaries[6] for the NTS. This includes the Central and Western Pahute Mesa region, the location of 82 underground nuclear tests[7] with radioactive contamination[8] consisting of long-lived radionuclides such as plutonium.[9] Due to current technological limitations and the prohibitive cost of cleanup,[10] they have chosen to use a modeling/monitoring approach.[11] Identifying boundaries for long-lived radionuclides is a difficult task given the limited number of wells and multiple uncertainties with respect to geology, hydrology, and migration of radionuclides.

As part of their overall strategy, scientists use "flow paths from existing models for determining future or new well locations"[12] in order to collect data for characterization of the region.[13] Residents of Oasis Valley, Beatty, and Amargosa and members of the CAB questioned whether the models[14] and plans for data collection meet nearby residents' immediate concerns given their dependence on the use of well water. They question whether these models are able to predict optimal well locations that may provide scientists with data to support or reject the hypothesis that the contamination has boundaries.

In support of the stakeholder concerns, consider the following three excerpts from the American Society of Mechanical Engineers (ASME) 2001 technical peer evaluation where the experts identify concerns with respect to the strategy to locate wells.

> "The fundamental problem with the above steps and decision points is that 'consensus is required concerning the adequacy of data and data analysis prior to proceeding with the next phase or step of corrective action activities.' This requirement is not achievable without iterations between three activities: 1) data acquisition; 2) modeling; and 3) early verification of modeling predictions….. However, no information was given that suggested plans for interactions between modeling and early verification of modeling predictions."[15]

The experts continue with the following statement

> "Interaction between modeling and near-term confirmation of the models is recommended. This interaction should be based on the transition region between the near field and the far field."[16]

Finally, consider the ASME report recommendation 3, at p. 189 where

> "The sensitivity of the regional flow model to boundary effects in the Oasis Valley/Pahute Mesa area should be investigated further. The central location of many of the CAUs relative to the regional flow model reduces the significance of model boundary effects and allows reasonable assurance

> for developing flow pathways. The one remaining concern is the proximity of Oasis Valley and Pahute Mesa to the northwest boundary of the regional flow model domain. The sensitivity of the regional flow model to edge effects is not known."[17]

These quotes from the technical peer review in 2001 all provide support for additional data.

Furthermore, some experts have identified problems with relying on models that have a relatively small number of observations for a large area, missing observations for large areas, and multiple uncertainties in the underground environment.[19] Responding to these concerns, in 2002, Carl Gertz, Assistant Manager of DOE NSO EM offered the CAB an opportunity to locate a well.[21]

This paper is organized as follows: Section II provides background on groundwater contamination issues for residents living near Western Pahute Mesa; Section III identifies the area of focus for the CAB UGTA committee; Section IV reports three well location recommendations and supporting evidence; Section V presents a brief discussion and Section VI provides conclusions to this paper.[22]

II. BACKGROUND

The purpose of this section is to provide a brief description of information the CAB UGTA committee examined with respect to what is known about the potential movement of radioactive contaminants in groundwater near Pahute Mesa. We identify maps that illustrate the proximity of nearby communities to Pahute Mesa as well as models for the area. We summarize the unexpected findings of Kersting et al. (1999)[23] where they discovered that plutonium, a radionuclide, moved southward in groundwater under Pahute Mesa near the NTS boundary. Next we report uncertainties with respect to geological, hydrological, chemical, and radiological data, as well as the potential for data gaps in this very large area. We end this section with a discussion of several uncertainties.

(a) What is known about the area between Oasis Valley and Pahute Mesa?

The communities of Oasis Valley, Beatty, and Amargosa Valley are the closest communities to Pahute Mesa. For perspective, consider the following maps produced by Laczniak et al. (1996),[24] Mankinen et al. (2003),[25] Stoller-Navarro (2006)[26] and Fridrich et al.

(2007)[27] which we identify as figures 1 through 4b. Figure 1 shows the Pahute and Western Pahute Mesa corrective action units in the northwestern corner of the NTS where there were 64 and 18 underground nuclear tests, respectively.[28] Nuclear tests on Pahute Mesa account for 61 percent of the total radionuclide inventory for the entire NTS.[29] Figure 2 is a map that shows mainly volcanic rock and some valley fill in the area between Pahute Mesa and Beatty. Figure 3 shows geophysical data including the Silent Canyon and Timber Mountain caldera complexes with dashed lines and the "inferred position of the Thirsty Canyon Fault zone" with "wavy pattern, queried where uncertain…" This map in figure 3 highlights the Thirsty Canyon Fault zone and springs near Springdale and Beatty. Mankinen et al. (2003),[30] the authors of this figure, report that "[a]mong the many, potentially important features characterized, the Thirsty Canyon fault zone provides one of the most direct routes for groundwater flowing from the northwestern part of the Nevada Test Site to reach inhabited areas to the southwest and warrants special attention for monitoring efforts." Figures 4, 4a, and 4b were produced by Fridrich et al.(2007). Figure 4 shows the Thirsty Canyon Fault trending southwest to the spring discharge area just north of Beatty. Figures 4a and 4b provide details for Figure 4 with respect to the multiple domains near Beatty and illustrate the complex geology and hydrology of the area.

Following the FFACO, see Figure 5, the UGTA scientists created a regional flow model for the entire NTS area[31] and later a smaller model commonly referred to as the Pahute Mesa and Oasis Valley model.[32] This second model covers an area of approximately 1,042 square miles[33] and is based on data from 180 wells and springs for the Pahute Mesa region.[34][35] Figure 6 is a map that shows the area of the latest Pahute Mesa and Oasis Valley Groundwater Flow Model produced by Stoller-Navarro (2006). Our focus is on the area between Pahute Mesa and nearby communities of Oasis Valley and Beatty where 7 wells are located between the NTS boundary and the Oasis Valley discharge area[36] and 12 more wells are located in Oasis Valley.[37] For perspective, Figure 7 shows 76 locations where data was collected and used in the Stoller-Navarro (2006) model.[38][39] This map is important because it shows the locations of several key wells near Beatty labeled 70, 71, 73, and 76 for wells number ER-OV-5, ER-OV-2, ER-OV-3a, and ER-OV-4a, respectively.[40] Figure 8 shows hydrogeologic domains such as the Detached Volcanics Domain where ER-OV-5 is located but does not display these other wells. We will consider wells ER-OV-5 and ER-OV-4a in the next paragraph.

The underground water environment of Western Pahute Mesa is described as a fracture-flow environment.[41] Many scientists have studied the geologic, hydrologic, chemical, and physical (porosity and permeability) characteristics of the NTS and region. Based on models and sparse data collected, multiple reports and papers predict a southerly and southwesterly flow of groundwater.[42] Estimated flow velocity for groundwater in the area are “1 to 80 m [per] yr[].”[43] Figure 9[44] illustrates some of these predicted southward flow paths, some of which would flow into Oasis Valley. Note that this figure is based upon work where a higher weight is placed on well ER-OV-4a (weight = 0.77) while a much lower weight is placed on well ER-OV-5 (weight =1 x 10^{-3}). It is unclear whether these weights are based upon an assumption or a result of the Pahute Mesa Model. What is clear, however, is that the model shows predicted flow paths going through ER-OV-4a but not ER-OV-5. These results appear to show different predictions for Oasis Valley and Beatty.[45]

(b) What are some of the issues that individuals in nearby communities are concerned about?

Nearby communities are concerned that the FFACO process to identify boundaries for contaminants may miss potential groundwater flow paths in such an environment. They refer to statements by scientists such as "...we do not plume chase" as an example of scientific disregard for their health and well being. Further, they report skepticism with models that appear to be based on a presumption that there are boundaries to groundwater flow near communities given such a complex fracture-flow environment. Finally, residents in nearby communities express concern about federal budget cuts, as there is a perception that the EM programs at the NTS are a low priority for the entire DOE complex. Overall, citizens in the communities of Oasis Valley, Beatty and Amargosa Valley express support for more real data and less modeling.[48] If modeling must be used, then validation of those models must be provided using data from wells located between residents and the contaminant sources.

(c) Can plutonium migrate in groundwater?

Kersting et al. (1999)[49] report evidence, primarily from well number 1 in the ER-20-5 well cluster, that plutonium[50] from the 1968 Benham test migrated[51] 1.3 kilometers (km) to the south. Note that the sampling point of well number 1 is considerably higher than the depth of burial for the Benham test and is the shallowest of the two wells that were extensively sampled. This result is unexpected because it showed that plutonium, a relatively insoluble radionuclide,[52] was transported away from the immediate vicinity of an underground test cavity. In this case, the plutonium not only traveled horizontally but was detected in two aquifers separated 300 meters vertically.[53] Their findings suggest that "models that either predict limited transport or do not allow for colloid-facilitated transport may thus significantly underestimate the extent of radionuclide migration."[54] In their discussion, the authors consider the possibility that the Benham test, later tests, or pumping of groundwater might have transported the radionuclides. However, they state that this is "highly unlikely." Instead they report that plutonium may have been carried "through fractures a few hundred meters and subsequently transported by groundwater."[55] It is important to note that the authors also state "that [less than] 1% of the observed [plutonium] is in the dissolved fraction of the groundwater."[56] Hence, whatever the transport mechanism, the plutonium migrated as a colloid and not as a dissolved salt in the groundwater. Finally, from an environmental contamination point-of-view, it is important to note that Kersting et al. (1999) qualify their findings by pointing out that the Plutonium measured at ER-20-5 is "a small fraction of the total Plutonium associated with the Benham nuclear test."[57]

(d) What uncertainties exist in this area?

While the area has been studied by many scientists, uncertainties remain with respect to the hydrologic character of the Thirsty Canyon Structure (Fault or Lineament), the Timber Mountain Bench, and the Silent Canyon Caldera. It is not known whether these geologic formations are barriers or conduits for groundwater flows.

Given the unexpected findings by Kersting et al. (1999), a variety of uncertainties, the proximity to nearby communities, and concern by potential receptors that the models appear to presume Beatty and other nearby communities will not be affected by groundwater contamination while Oasis Valley might be affected,[59] we focused our well-site evaluation to the area between the southwestern edge of the Pahute Mesa on the NTS, and nearby communities.

III. APPROACH

The CAB UGTA committee is composed of individuals from multiple disciplines. In order to identify potential sites for wells, our committee obtained information from multiple sources including: stakeholders, scientists (DOE, government contractors, State of Nevada, UGTA peer review group, UGTA Technical Working Group (TWG), and others), reports, academic books and peer-reviewed journal articles. See Appendix I. for a summary of papers and reports.[60] Our goal was to focus on the geological, hydrological, chemical and radiological uncertainties identified in the previous section and identify potential well sites that might reduce some of these uncertainties.

After extensive reviews and meetings over a period of five years,[61] our committee initially provided DOE with three recommended well locations. DOE provided our committee with a map that identifies the nearby communities, existing wells, and our recommended wells shown in Figure 10. We include two additional aerial photographs called Figures 11 and 12 provided by DOE that illustrate the CAB recommendation sites with respect to accessibility. Technical experts working on the UGTA project reviewed the CAB recommendations and provided helpful comments and suggestions.

IV. WELL RECOMMENDATIONS[62]

As stated in the CAB (2005) letter, see Appendix II, three locations for wells were identified as CAB 1, 2, and 3. See Figures 10, 11, and 12 for a map and two photographs of the area with well locations, respectively. With respect to CAB 1, we recommend installing a well down gradient of well ER–20–5 # 1. We recommend CAB 2 be located down gradient of the first well in the transition area between the Silent Canyon caldera and the possible barrier, the Timber Mountain bench area to obtain more information about the bench structure, i.e. groundwater barrier or conduit. Finally, with respect to CAB 3, we are interested in a third well at the junction of the potential barrier structure (the “bench”) and a major fault, the Thirsty Canyon Structure identified by geophysics as a possible fast path into Oasis Valley.[63] On further analysis of the site accessibility, we have withdrawn a specific location for now because of the difficulty of physical access. However a third well in this area is still important to complete a system to enhance our understanding of the groundwater flow direction.

These wells could show us how much farther radionuclides have been transported beyond ER-20-5#1, the general direction of groundwater flow in that area, and may also add to our understanding of the hydrologic characteristics of the bench; i.e. whether it is a barrier or conduit to groundwater flow.

V. DISCUSSION

There are several issues to discuss with respect to our well recommendations. First, many people on the CAB UGTA committee worked on this for over six years through multiple CAB members, multiple technical advisers, multiple public meetings, and personnel changes at DOE. In spite of all of these changes, the level of overall openness and cooperation remained strong throughout the process. The committee was provided with a great deal of support including maps, the latest reports, data, and access to the groundwater modeling team. We were also provided the exact coordinates of the wells and springs used in the latest model published by Stoller-Navarro (2006).

Second, there is a timing issue to consider with respect to this paper. We refer to the Stoller-Navarro (2006) report throughout this document. Although this report was published after the CAB (2005) letter, key presentations and maps presented to the CAB were incorporated in this later report.

Finally, we acknowledge and appreciate the different perspectives provided by the UGTA TWG in their comments to and discussions with committee members. We recognize the tradeoffs between expenditures on sophisticated models and additional data collection through wells. Our recommendation for multiple wells is approximately $18 million,[64] almost a quarter of an annual budget for the NTS EM program and we acknowledge that there are risks to workers associated with drilling at least one well potentially contaminated with radionuclides. We base these recommendations on the following: the current model covers approximately 1,042 square miles and is based upon less than 180 data points with sparse data coverage in the areas between Western Pahute Mesa and Oasis Valley; there is evidence that plutonium did move 1.3 kilometers south over a 30-year period; and finally, there is a need for additional information in areas with sparse coverage to support or reject hypotheses that water flows south rather than west and that wells such as ER-OV-4a appear to serve as a western-most point of potential contaminant flows. If a case is to be made that there are scientifically defensible boundaries for contaminant flows, hard data is critical to this effort to either support or reject this hypothesis.

VI. CONCLUSION

This paper attempts to resolve some of the concerns of down-stream residents about the potential migration of contaminated groundwater to their wells and/or springs. We report what is and is not known about the underground environment down gradient of Western Pahute Mesa, the Thirsty Canyon Lineament and Timber Mountain Bench. Based on what is not known, we identified three locations to site wells and collect data. Upon further examination we now stand by two of these recommendations and recommend, for future research, that a third well be identified in place of the withdrawn recommendation. The authors hope to have stimulated interest in addressing uncertainties and concerns for nearby residents. Our analyses, however simplistic, support adding wells to both provide scientists with additional groundwater data and protect the domestic water supply of nearby residents.

VII. REFERENCES:

Acronyms and Abbreviations

ASME	American Society of Mechanical Engineers
BN	Bechtel Nevada
CAB	Community Advisory Board for Nevada Test Site Programs
CAI	Corrective Action Investigation
CAIP	Corrective Action Investigation Plan
CAU	Corrective Action Unit
DOE	U.S. Department of Energy
DoD	U.S. Department of Defense
DRI	Desert Research Institute
FFACO	Federal Facility Agreement and Consent Order
HFM	Hydrostratigraphic Framework Model
LANL	Los Alamos National Laboratory
NDEP	State of Nevada, Division of Environmental Protection
NTS	Nevada Test Site
NNSA	U.S. Department of Energy National Nuclear Security Administration
NSO EM	U.S. Department of Energy Nevada Site Office Environmental Management
SNJV	Stoller-Navarro Joint Venture

TWG	Technical Work Group
UGTA	Underground Test Area
UNLV	University of Nevada, Las Vegas
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator

Sources

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VIII. ENDNOTES AND REFERENCES

[1] Community Advisory Board (2005).

[2] We began our study by considering the entire NTS. Given the relative proximity of residents in the Beatty and Oasis Valley regions, the committee chose to narrow its focus on Pahute Mesa.

[3] The Federal Facility Agreement and Consent Order, (FFACO) March 15, 1996, is an agreement between the State of Nevada Department of Conservation and Natural Resources, Division of Environmental Protection (NDEP), the U.S. Department of Energy (DOE), and the U.S. Department of Defense (DoD). It was last accessed at http://ndep.nv.gov/boff/agree.htm.

[4] U.S. Department of Energy (2007; p. 2). According to the DOE, this public involvement plan will be "incorporated into the FFACO as appendix V."

[5] This group is called the Underground Test Area Technical Working Group (UGTA TWG).

[6] American Society of Mechanical Engineers (ASME) (2001) at pp. 135 - 137. According to ASME, the corrective action strategy contains several phases, regional modeling and CAU-specific modeling in order to determine contaminant boundaries. For a definition of corrective action investigation, see FFACO, 1996, at p. 8 "IV.14."Corrective Action Investigation" (CAI) shall mean an investigation conducted by DOE and/or DoD to gather data sufficient to characterize the nature, extent, and rate of migration or potential rate of migration from releases or discharges of pollutants or contaminants and/or potential releases or discharges from corrective action units identified at the facilities."

[7] ASME (2001; p.19). The Pahute Mesa is split into two Corrective Action Units (CAUs) called the Western Pahute Mesa CAU which consists of 18 nuclear tests and the Central Pahute Mesa CAU which consists of 64 nuclear tests.

[8] According to Bowen et al. (2001; p. 21, Table V) the total radionuclide inventory for Pahute Mesa is 8.01 E+07 Curies (area 19 + area 20 =1.9 E+07 + 6.09 E+07). For perspective, this is approximately 61 percent of the total radionuclide inventory (1.32E+08 total Curies) for the entire NTS. For additional perspective, the total radionuclide inventory for Western Pahute Mesa alone is 6.09E+07 Curies which is approximately 46 percent, the total for the entire NTS.

[9] The half life of plutonium-239 is 24,100 years according to the DOE (2000; p. 12).

[10] According to ASME (2001, p. 130) the estimated total cost of cleanup is $1.3 to 2.5 billion dollars.

[11] According to the DOE (2003) "the total costs of this 141-year effort is projected at $2.2 billion, which includes 100 years of monitoring." According to another source ASME (2001, p. 127) the cost of the modeling/monitoring approach is an estimated $240 million for 50 years.

[12] Consider excerpts from Gertz's letter to Claire, DOE (2002) describing the DOE strategy for well locations. "The UGTA Project utilizes the flow paths from existing models for determining well locations and will continue to utilize them in executing the strategy. NNSA/NV recognizes that the Pahute Mesa area is of high importance and has focused a considerable amount of effort in this area. Of the 40 new wells that the UGTA Project has drilled, 28 have been drilled in the Pahute Mesa/Oasis Valley area. The UGTA Project is evaluating all of the data collected and developing a model of this area to better determine the optimum locations to collect new data, if needed."

[13] See ASME (1999, pp. 135 – 137) for a description of the first phase on regional modeling and figure 42, process flow diagram for the underground test area CAUs. This was part of the early phase of the FFACO and Corrective Action Investigation Plan (CAIP) (1999) to eventually plan and build a monitoring network of wells.

[14] For a definition of model see National Research Council (2000; p. 5, footnote 5) "A conceptual model is a description of the subsurface as estimated from knowledge of the known site geology and hydrology and the physical, chemical and biological processes that govern contaminant behavior." See p. 50 for a definition of "Validate – Verify conceptual models and the performance of remediation processes or strategies."

[15] ASME (2001; p. 181) "For example, as modeling proceeds with consideration of both 'discrete' and 'distributed' uncertainties, additional data will be needed to increase confidence. The data needed may include evidence (e.g., seismic profiling) or monitoring at either existing or new wells to discriminate between alternative hydrogeologic models and hydrologic properties of the subsurface. During questioning, it was learned that interactions between data acquisition and modeling are in fact taking place and will continue to take place. However, no information was given that suggested plans for interactions between modeling and early verification of modeling predictions."

[16] ASME (2001; p. 188).

[17] ASME (2001; p. 189).

[19] National Research Council (2000, p. 113).

[21] Letter from Gertz to Claire, DOE (2002) states "As you can see in the responses above, NNSA/NV is and will continue executing the UGTA strategy in accordance with your comments and the peer review recommendations. I continue to offer the CAB, in conjunction with their technical adviser, the opportunity to select a location for a sentinel/transition well. My staff will be happy to discuss this with you and assist the CAB in this endeavor."

[22] For a summary of the committee processes, see Nevada Test Site Community Advisory Board, Stakeholder Summation Recommendations to Address Groundwater Concerns at the Nevada Test Site, September 2007.

[23] Kersting et al. (1999).

[24] Laczniak et al. (1996).

[25] Mankinen et al. (2003). “Figure 16… ..inferred position of the Thirsty Canyon fault zone (wavy pattern, queried where uncertain….)…and major springs in the Oasis Valley discharge area. Solid circle, water well; symbols, wells with radioactive contamination. Contour interval 100 m.”

[26] McCord et al. (2006). We use several figures from this report. They are figure 1 at p. 83 on pdf file, Figure 1-1: Location of the Pahute Mesa Corrective Action Units. Figure 6 at p. 86 on pdf file, Figure 1-2 Map Showing Location of the Pahute Mesa Model Area; Figure 7 at p. 90 on pdf file, Figure 1-4: Geophysically Inferred Geologic Features of the Pahute Mesa Area; Figure 5 at p. 884 on pdf file, Figure C. 4-1, Location of Boreholes Used in Study; Figure 8 at p.5-24, on p. 253 on pdf file, Figure 5-6 Map Showing Hydrogeologic Domains in the Pahute Mesa/Oasis Valley Model Area; and Figure 9 at p. 7-9, Figure 7-6: Locations of Flow Model Calibration Wells (black circles), Geochemical Target Wells (blue circles), and Pathlines for Forward SPTR Particles Originating in Open Screened Intervals of Wells in Model Domain.

[27] Fridrich (2007) is the source for our figures 4, 4a, and 4b.

[28] ASME (2001) p. 19.

[29] Calculation by authors where we use estimates provided in Bowen et al. 2001, p. 22 where radionuclide inventory (Curies) at Western Pahute Mesa / radionuclide inventory (Curies) for Nevada Test Site = 6.086 E +07 / 1.32 E +08 = .46 or 46 percent.

[30] According to Mankinen et al. (2003) at pdf p. 37 “The Thirsty Canyon fault zone, for example, seems to represent a series of coalesced ring-fracture systems along an older Basin and Range fault. Among the many, potentially important features characterized, the Thirsty Canyon fault zone provides one of the most direct routes for groundwater flowing from the northwestern part of the Nevada Test Site to reach inhabited areas to the southwest and warrants special attention for monitoring efforts. Continued definition of major structural features will help refine sub-basin boundaries and contribute to developing a better conceptual understanding of groundwater flow in the study area.”

[31] McCord et al. (2006; p. 2-3) provide a summary of the UGTA Regional Model reports and describe the model which was used to set boundary conditions (see p. 3-20).

[32] See McCord et al. (2006).

[33] McCord et al. (2006; p. ES-8) where they report 2,700 square kilometers and the Universal Transverse Mercator (UTM) for each of the maps are x (horizontal or easting) values of 519,125 m to 569,000 m and y (vertical or northing) values of 4,085,000 m to 4,138,000 m.

[34] See calibration targets of head and flow in McCord et al. (2006, p. ES-17 and p. 5-36, Table 5-6) where 191 represents the total number of data points from well head, spring head, oasis valley discharge, and boundary flow.

[35] See McCord et al. (2006; Section 5, p. 5-8). They use "four types of information, or targets" which are "hydraulic head from wells, estimated spring head in and near Oasis Valley, Oasis Valley discharge derived from Laczniak et al. (2001) and Edge flows estimated from regional model analysis presented in the Pahute Mesa hydrologic data document (SNJV, 2004[.])" to calibrate their flow model multiple times. In the Base Hydrostratigraphic Framework Model (HFM) using no depth decay and no anistropy assumptions they report using 152, 28, 7, and 4 observations, respectively to validate their model which checks out with the number reported under model limitations of 191 calibration targets.

[36] See McCord et al. (2006; p. Table F.1-1), these wells are the ER-EC wells.

[37] See McCord et al. (2006; Table C. 6-1) where it shows the model used 12 wells in Oasis Valley. However, several of these wells are essentially on top of each other meaning only seven wells appear on a map.

[38] Figure 5 is a copy of McCord et al. (2006; p. C-10) map identifying the location of each site which they describe as boreholes.

[39] In technical reports there are references to holes, boreholes and wells. For example, in Laczniak et al. (1996; pp. 30 – 32), the title for their table 5 is "Water levels, underground tests, and associated test and hole parameters used to determine general position of test relative to the water table." They include both sites of atomic tests and wells under a column entitled hole name.

[40] See McCord et al (2006). Figure 7 at p. 884 on pdf file, Figure C. 4-1, Location of Boreholes Used in Study; Figure 8 at p.5-24, on p. 253 on pdf file, Figure 5-6 Map Showing Hydrogeologic Domains in the Pahute Mesa/Oasis Valley Model Area.

[41] Fenelon (2000; p. 4).

[42] See Koonce et al. (2006) and McCord et al. (2004).

[43] See Kersting et al. (2006; p. 56, paragraph 3) where they refer to Blankennagel and Weir (1973) for these flow velocities.

[44] See McCord et al. (2006; p. 7-9) Figure 7-6: Locations of Flow Model Calibration Wells (black circles), Geochemical Target Wells (blue circles), and Pathlines for Forward SPTR Particles Originating in Open Screened Intervals of Wells in Model Domain.

[45] For more details see McCord et al. (2006; pp. 5-10 to 5-15 or pdf pp. 239 – 244) Table 5-2 where wells between Western Pahute Mesa and communities of Oasis Valley and Beatty appear to receive low calibration weights for the model relative to wells to the west of these wells. Wells such as ER-20-5 received a weight of 0.72 which was last sampled on 5/14/96 and the Beatty well which was last sampled on 10/26/1962 received a weight of 1 x 10^{-3} while the Beatty Wash Terrace Well that was last sampled on 9/27/2001 received a weight of 0.2. ER-OV5 which was last sampled on 9/13/01 which appears to be due north of Beatty received a weight of 1 x 10^{-3} while ER-OV-4a which was last sampled on 9/13/01 received a weight of 0.77. In the McCord et al, Stoller-Navarro 2006 report, Figure 7 – 6 appears to show that well number ER-OV-4a is an inflection point where the flow switches from a southwestern flow to a southern flow.

[48] In support of citizens request for more data, consider the scientific method summarized by Millard and Neerchal (2001; pp. 13 – 14). The steps are “(1) form a hypothesis…”; “(2) [p]erform an experiment…”; “(3) [r]ecord and analyze the results of the experiment.”; and “(4) [r]evise the hypothesis based on the results. Repeat steps 2 to 4.” On p. 17 they introduce the concept of type I and type II errors, which refer to as a false positive rate and false negative rate, respectively. (One can argue the hypothesis scientists wish to support, in this case a contaminant boundary or no movement of contaminants toward Oasis Valley should bear the burden of proof. The data requirements to reject the null, traditional statistics versus spatial statistics require consideration.)

[49] Kersting et al. (1999).

[50] Kersting et al.(1999) report an isotopic ratio of $^{240}Pu/^{239}Pu$.

[51] Kersting et al.(1999) use the word migration in their title and the verb to migrate throughout their paper. There is an issue that Kersting et al.(1999) discuss at the end of their paper whether the radionuclides traveled as a result of the test itself or whether it is due to the hydrogeology of the area. They state it is highly unlikely that it was a test that caused the radionuclides to travel 1.3 km. Some committee members disagree with this discussion point.

[52] Kersting et al. (1999; p. 56, paragraph 1) "It has been argued that plutonium introduced into the subsurface environment is relatively immobile owing to its low solubility in groundwater [.] and strong sorption onto rocks [.]. Nonetheless, colloid-facilitated transport of radionuclides has

been implicated in field observations [.] [.], but unequivocal evidence of subsurface transport is lacking [.]. Moreover, colloid filtration models predict transport over a limited distance resulting in a discrepancy between observed and modeled behavior[.]."

[53] Kersting et al. (1999; p. 59, paragraph 2).

[54] Kersting et al. (1999; p. 56, abstract, last sentence).

[55] Kersting et al. (1999; p. 59, paragraph 2).

[56] Kersting et al.(1999; p. 59, paragraph 1).

[57] Kersting et al. (1999; p. 59, first paragraph, last sentence).

[59] McCord et al. (2006; p. ES-17, 6) report "….it is almost certain that flow in the intrusive confining units is very slow, if not nil, which has no effect on the shallower part of the flow system."

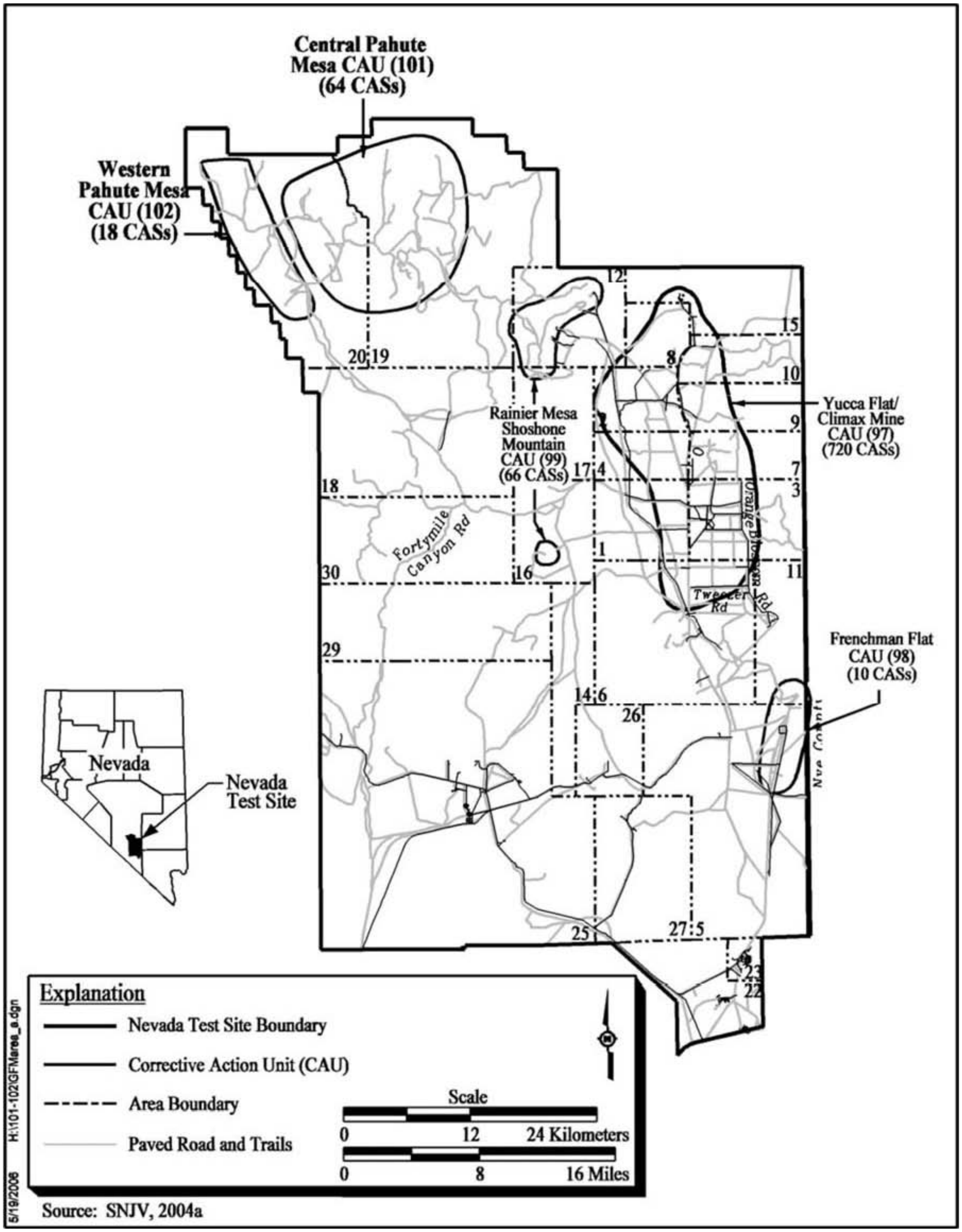
[60] See Appendix I, Table A-1: Summary of References. This reference is an excel spreadsheet of scientific papers, reports, and books the committee has either studied or was given as a reference during presentations and meetings.

[61] This subcommittee of the NTS CAB has been meeting since 1999.

[62] These recommendations appear in a letter from Phillips to Mellington, February 9, 2005. An earlier version of this paper provided details on the wells on pp. 28 – 32.

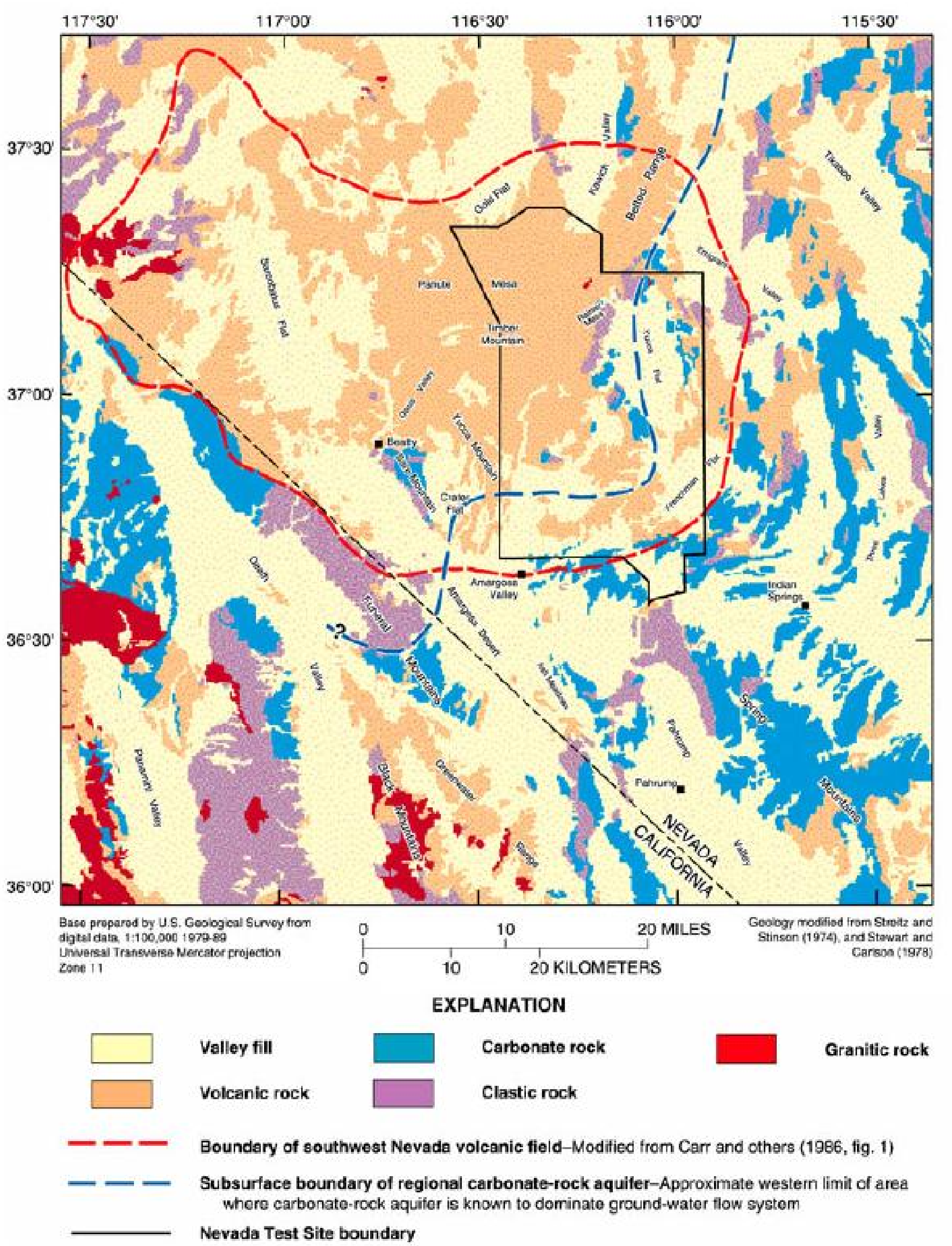
[63] See Edward A. Mankinen, Hildenbrand, Fridrich, McKee, and Schenkel, Geophysical Setting of the Pahute Mesa-Oasis Valley Region Southern Nevada, Nevada Bureau of Mines and Geology, Report 50, 2003. [64] This estimate of $18 million is based on a personal communication from Kelly Snyder, DOE NSO EM Public Accountability Specialist, and Bill Willborn, DOE NSO EM UGTA Federal Subproject Director, on October, 2006 where the average cost for drilling is $5.726 million (this includes road, pad and drilling depth of 5,000 feet). Well development, testing and sampling averages $711,000. Average total cost for a hot well is $6.437 million.

Figure 1: Location of the Pahute Mesa Corrective Action Units



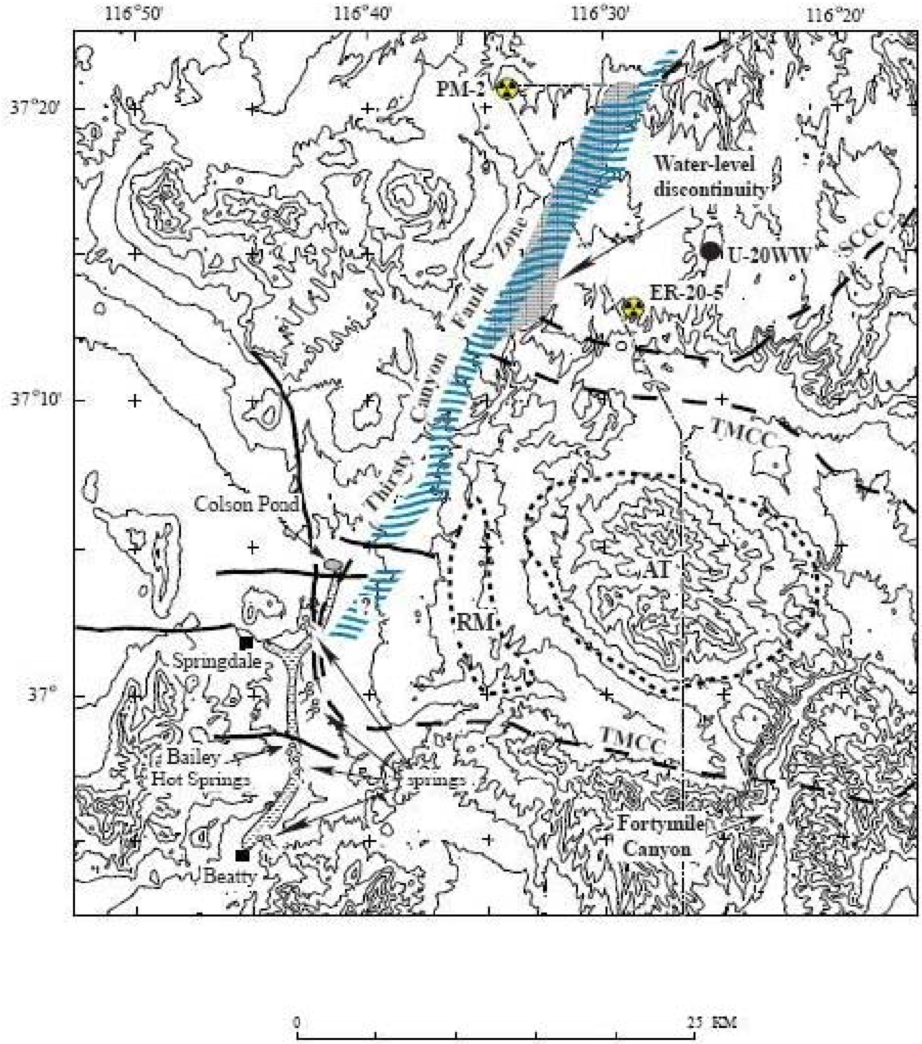
Source: Stoller-Navarro (2006) Groundwater Flow Model of CAUs 101 and 102: Central and Western Pahute Mesa, Nye County, Nevada, Figure 1-1 Location of the Pahute Mesa Corrective Action Units, p. 1-2.

Figure 2: Surface distribution of rocks in and near Nevada Test Site



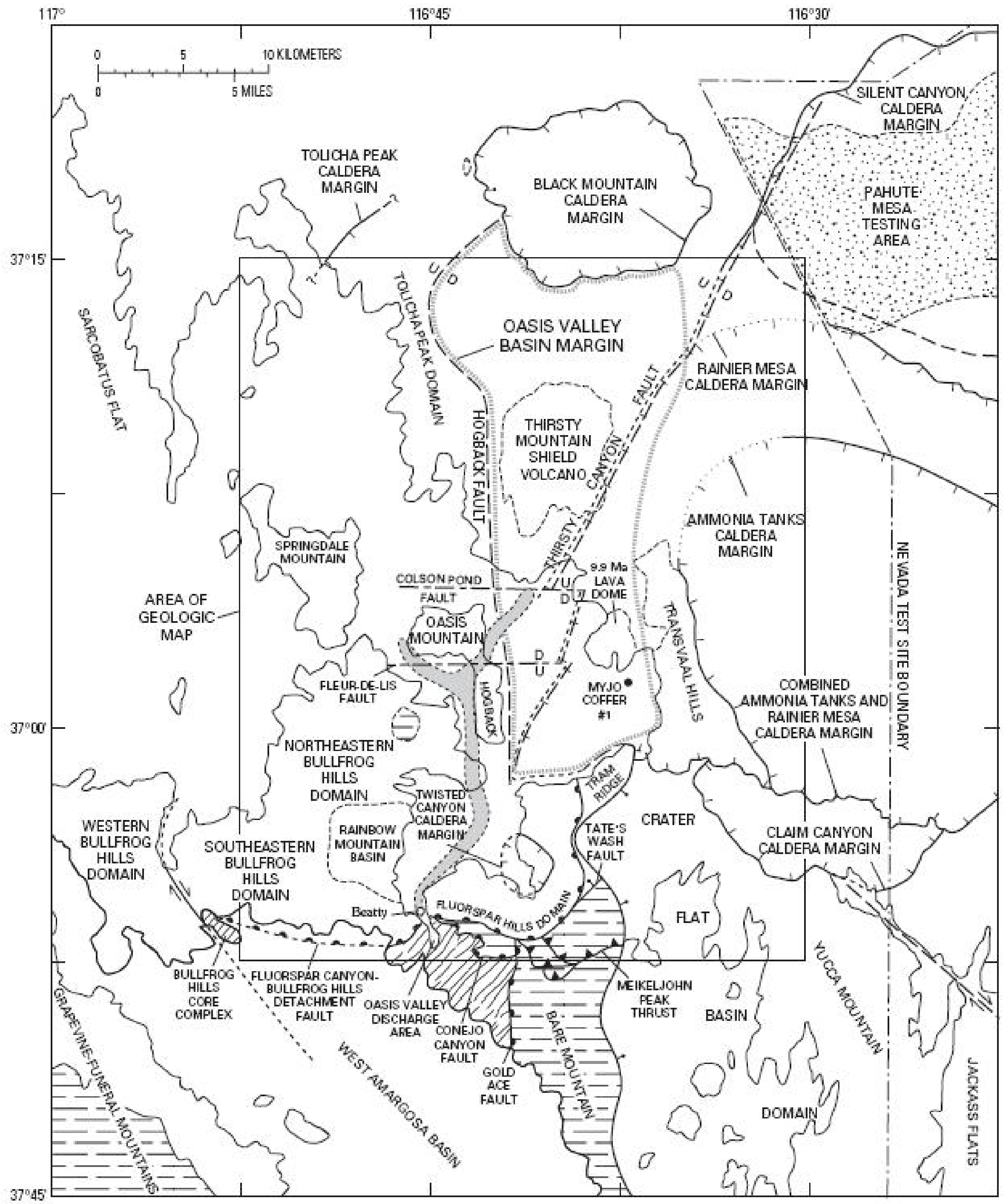
Source: Randell J. Laczniak, James C. Cole, David A. Sawyer, and Douglas A. Trudeau.(1996) Summary of Hydrogeologic Controls on Ground-Water Flow at the Nevada Test Site, Nye County, Nevada, U.S. Geological Survey, Water-Resources Investigations Report 96-4109, prepared in cooperation with the Office of Environmental Restoration and Waste Management, U.S. Department of Energy Nevada Operations Office, under Interagency Agreement DE-A108 91NV11040 last downloaded from website http://pubs.usgs.gov/wri/wri964109/report.htm#HDR0 on August 12, 2007.

Figure 3: Map showing major features expressed by geophysical data.



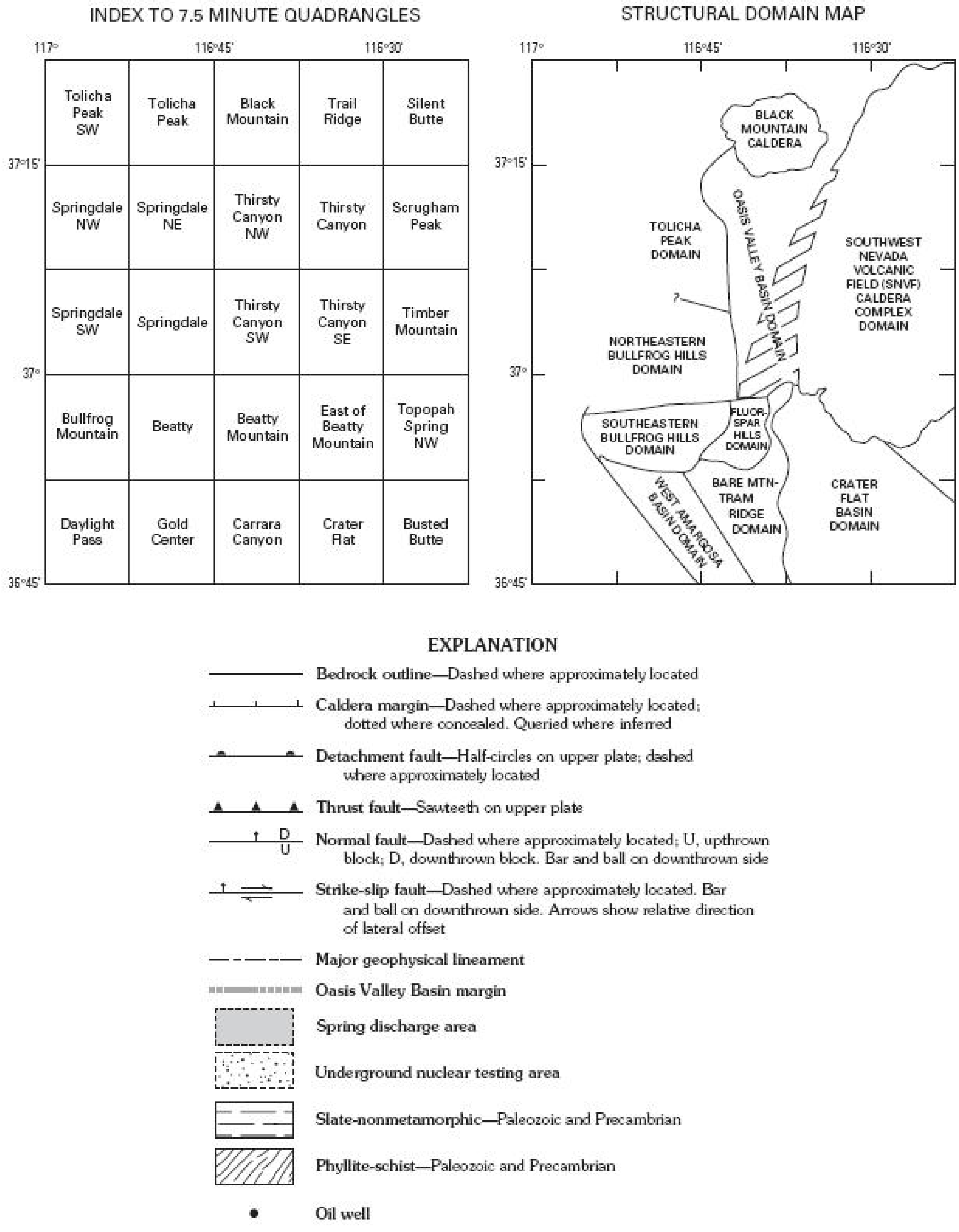
Source: Edward A. Mankinen, Hildenbrand, Fridrich, McKee, and Schenkel, (2003) Geophysical Setting of the Pahute Mesa-Oasis Valley Region Southern Nevada, Nevada Bureau of Mines and Geology, Report 50. “Figure 16… ..inferred position of the Thirsty Canyon fault zone (wavy pattern, queried where uncertain….)…and major springs in the Oasis Valley discharge area. Solid circle, water well; symbols, wells with radioactive contamination. Contour interval 100 m.”

Figure 4: Index map of the Oasis Valley basin and vicinity showing the Pahute Mesa testing area, Oasis Valley spring-discharge area, caldera outlines and selected faults.



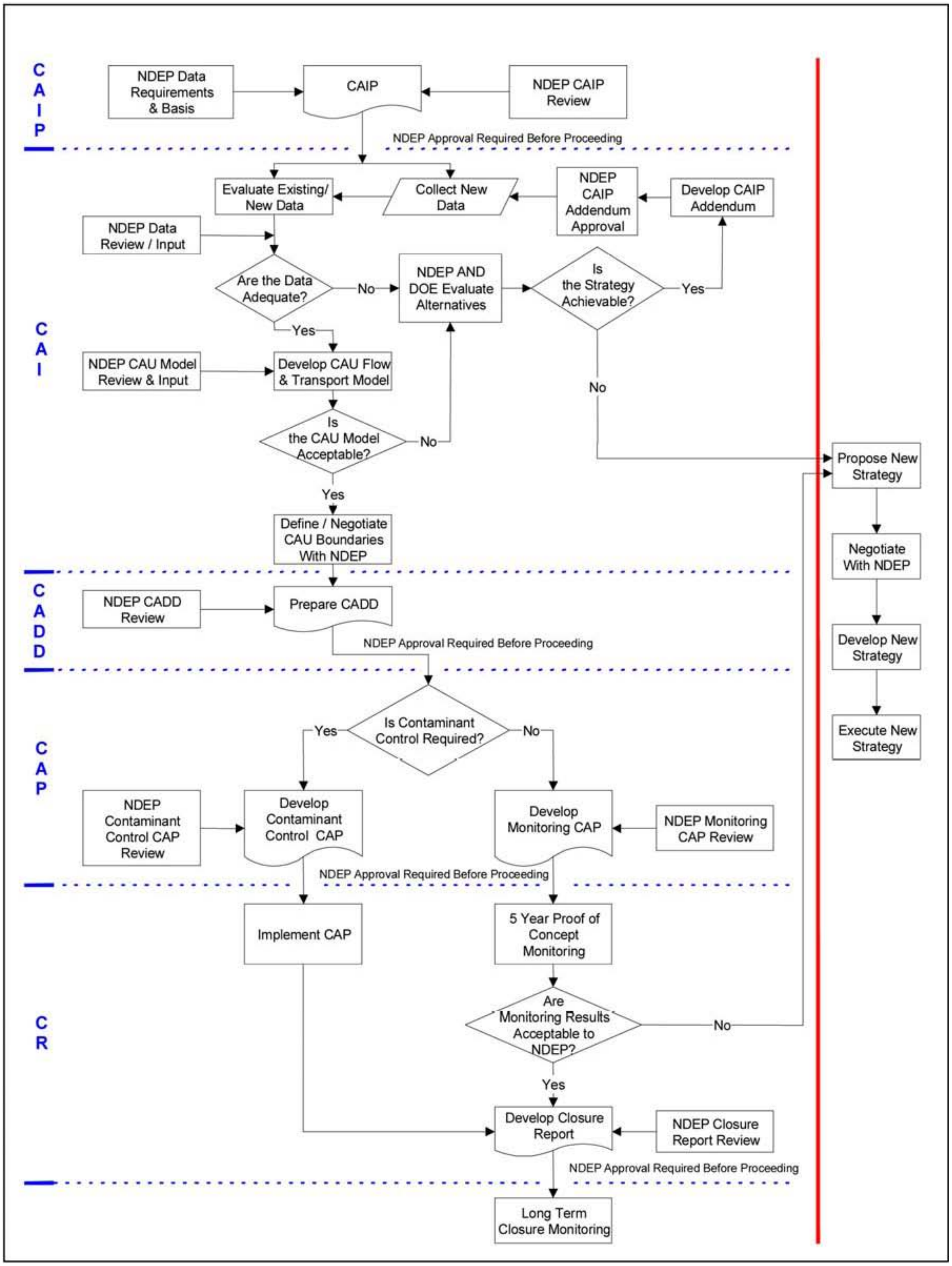
Source: Fridrich, C.J., Minor, S.A., Slate, J.L., and Ryder, P.L., 2007, Geologic map of Oasis Valley spring-discharge area and vicinity, Nye County, Nevada: U.S. Geological Survey Scientific Investigations Map 2957, 25 p., scale 1:50,000 last downloaded on August 12, 2007 from http://pubs.usgs.gov/sim/2007/2957/.

Figures 4a and 4b: 25 quandrangles of Figure 4 and a structural domain map of the area.



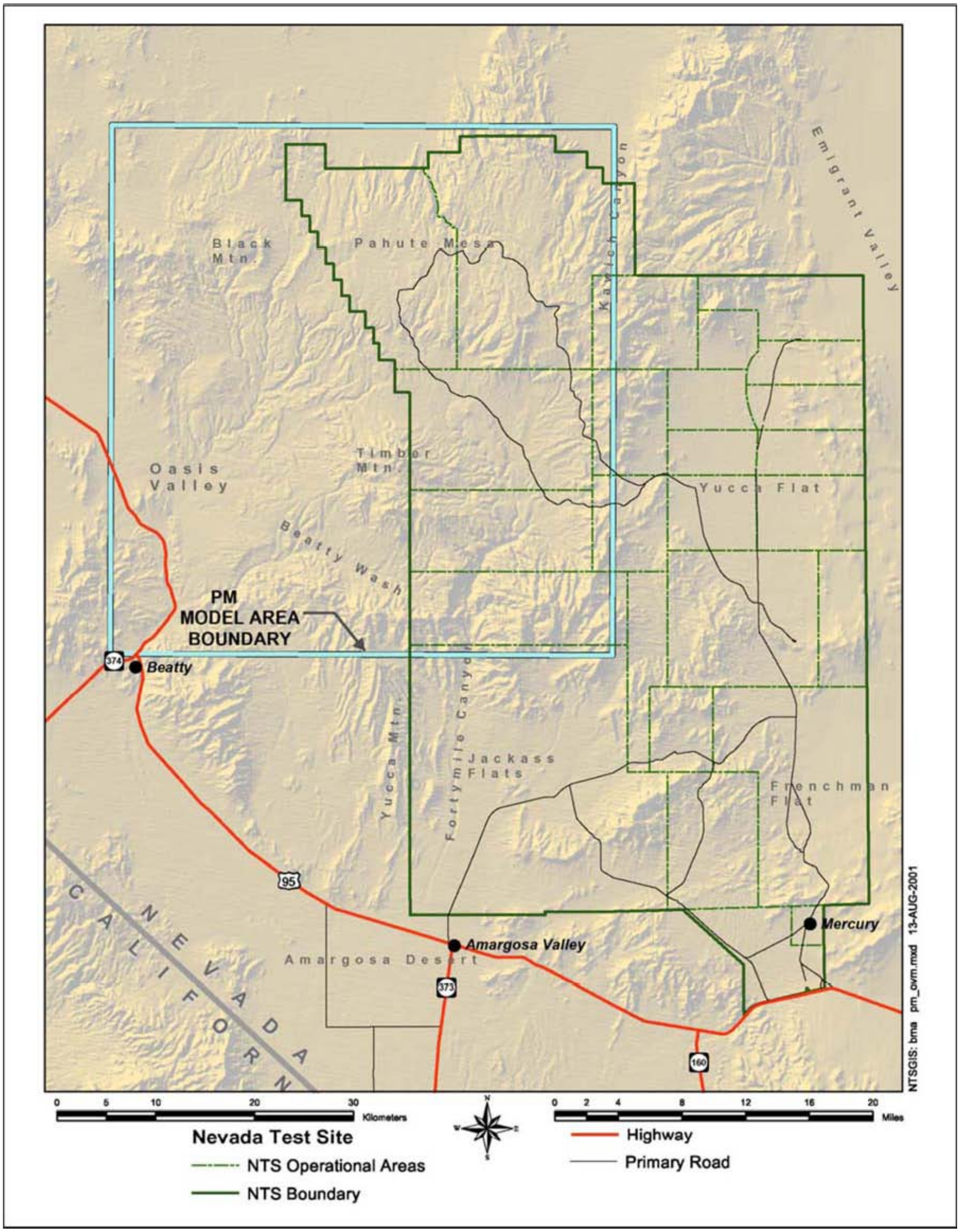
Source: Fridrich, C.J., Minor, S.A., Slate, J.L., and Ryder, P.L., 2007, Geologic map of Oasis Valley spring-discharge area and vicinity, Nye County, Nevada: U.S. Geological Survey Scientific Investigations Map 2957, 25 p., scale 1:50,000 last downloaded on August 12, 2007 from http://pubs.usgs.gov/sim/2007/2957/.

Figure 5: Flow Diagram for the Underground Test Area Corrective Action Units.



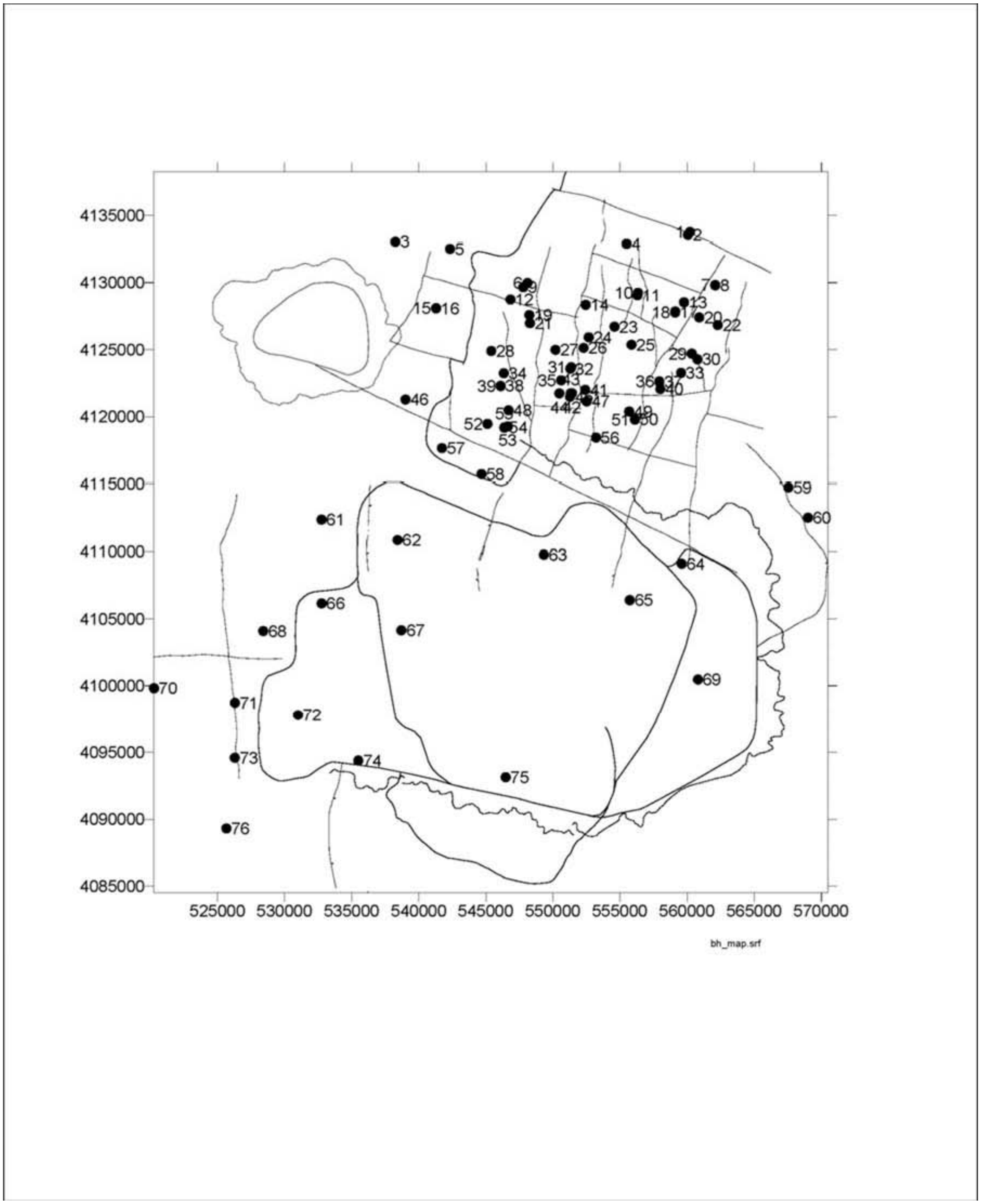
Source: Department of Energy, 2007.

Figure 6: Map Showing Location of the Pahute Mesa Model Area



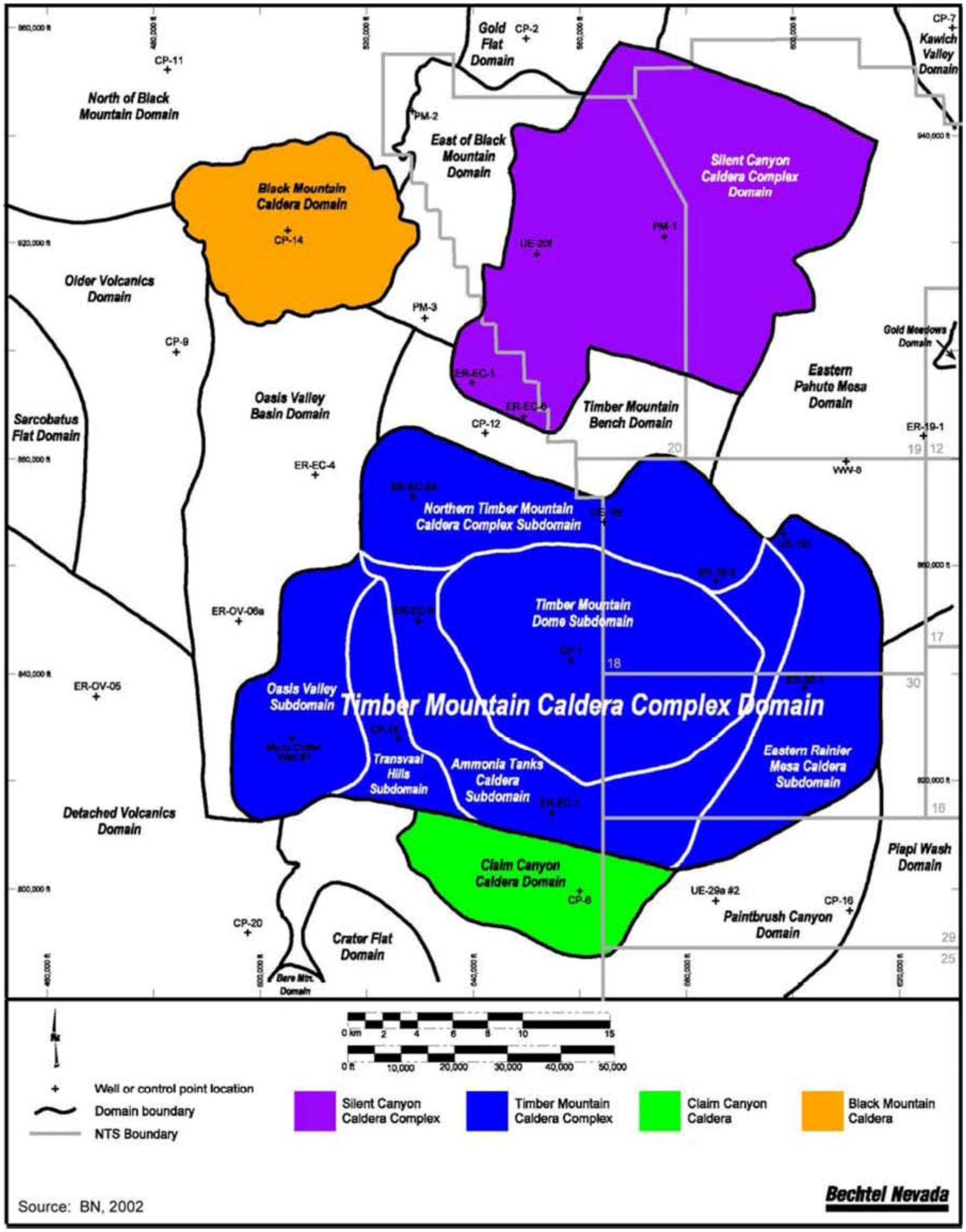
Source: Stoller-Navarro (2006) Groundwater Flow Model of CAUs 101 and 102: Central and Western Pahute Mesa, Nye County, Nevada, Figure 1-1 Location of the Pahute Mesa Corrective Action Units, p. 1-5.

Figure 7: Location of Boreholes used in Stoller-Navarro (2006)



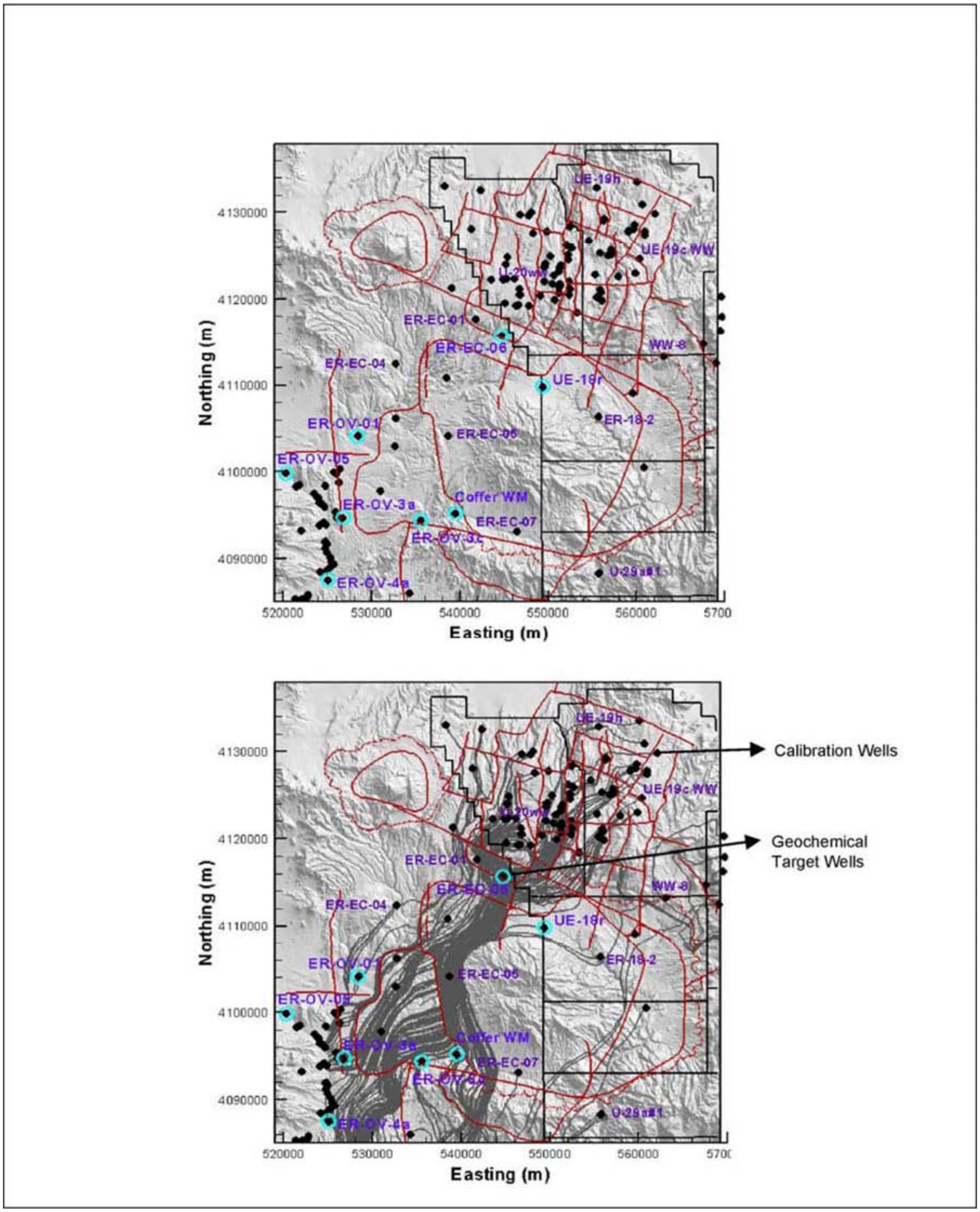
Source: Stoller-Navarro (2006) Groundwater Flow Model of CAUs 101 and 102: Central and Western Pahute Mesa, Nye County, Nevada, Figure C.4-1 Location of Boreholes Used in Study, Appendix C, p. C-10.

Figure 8: Map Showing Hydrogeologic Domains in the Pahute Mesa and Oasis Valley Model Area



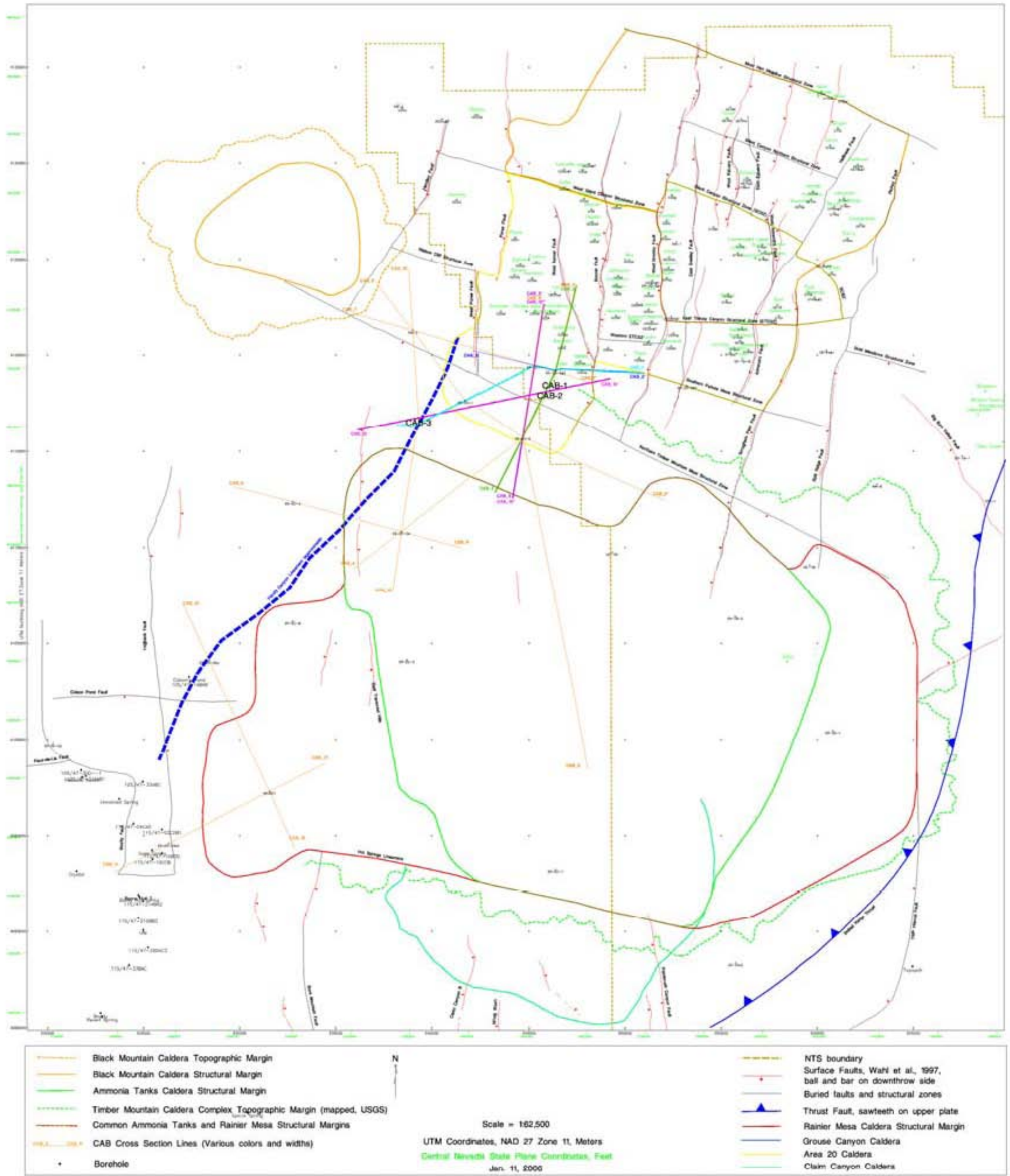
Source: Stoller-Navarro (2006) Groundwater Flow Model of CAUs 101 and 102: Central and Western Pahute Mesa, Nye County, Nevada, Figure 5-6 Map Showing Hydrogeologic Domains in the Pahute Mesa/Oasis Valley Model Area, p. 5-24.

Figure 9: Locations of Boreholes and Predicted Flow Paths



Source: Stoller-Navarro (2006) Groundwater Flow Model of CAUs 101 and 102: Central and Western Pahute Mesa, Nye County, Nevada, Figure 7-6, Locations of Flow Model Calibration Wells (black circles), Geochemical Target Wells (blue circles), and Pathlines for Forward SPTR Particles Originating in Open Screened Intervals of Wells in Model Domain, p. 7-9.

Figure 10: Map of the Pahute Mesa Area including NTS CAB well recommendations 1, 2, and 3



Source: Stoller-Navarro (2006) Source: U.S. DOE (2006) Source: U.S. DOE (2006)

Figure 11: Photograph of Area around NTS CAB Well Recommendations 1 and 2

Source: U.S. DOE (2006)

Figure 12: Photograph of Area around NTS CAB Well Recommendation Number 3

Source: U.S. DOE (2006)