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# 3

# Affected Environment

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# 3. AFFECTED ENVIRONMENT

To analyze potential environmental impacts that could result from the implementation of the Proposed Action, the U.S. Department of Energy (DOE) has compiled extensive information about the environments that could be affected. The Department used this information to establish the baseline against which it measured potential impacts (see Chapter 4). Chapter 3 describes (1) environmental conditions that will exist at and in the region of the proposed repository site at Yucca Mountain after the conclusion of site characterization activities (Section 3.1); (2) environmental conditions along the proposed transportation corridors in Nevada that DOE could use to ship spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site (Section 3.2); and (3) environmental conditions at the 72 commercial and 5 DOE sites in the United States that manage spent nuclear fuel and high-level radioactive waste (Section 3.3).

DOE obtained baseline environmental information from many sources. These sources included reports and studies sponsored by DOE, other Federal agencies (for example, the U.S. Geological Survey), and the State of Nevada and affected units of local government. (Affected units of local government include county governments near the potential repository site and along potential transportation routes within Nevada.)

DOE received reports from the State of Nevada and affected units of local government during the EIS scoping process, informally from local government personnel, and formally during ongoing interactions between DOE and State and local governments. The subjects of these reports include socioeconomics, cultural resources, hydrology, transportation planning and emergency response, and resource supply. DOE evaluated these reports and, where appropriate, they are discussed in individual resource area sections of the EIS.

## 3.1 Affected Environment at the Yucca Mountain Repository Site at the Conclusion of Site Characterization Activities

To define the existing environment at and in the region of the proposed repository, DOE has compiled environmental baseline information for 13 subject areas. This environment includes the manmade structures and physical disturbances from DOE-sponsored site selection studies (1977 to 1988) and site characterization studies (1989 to 2001) to determine the suitability of the site for a repository. This chapter and supporting documents, called *environmental baseline files*, contain baseline information for:

- *Land use and ownership:* Land-use practices and land ownership information in the Yucca Mountain region (Section 3.1.1)

- *Air quality and climate:* The quality of the air in the Yucca Mountain region and the area's climatic conditions (temperature, precipitation, etc.) (Section 3.1.2)

- *Geology:* The geologic characteristics of the Yucca Mountain region both at and below the ground surface, the frequency and severity of seismic activity, volcanism, and mineral and energy resources (Section 3.1.3)

- *Hydrology:* Surface-water and groundwater features in the Yucca Mountain region and the quality of the water (Section 3.1.4)

- *Biological resources and soils:* Plants and animals that live in the Yucca Mountain region, the occurrence of special status species and wetlands, and the kinds and quality of soils in the region (Section 3.1.5)

- *Cultural resources:* Historic and archaeological resources in the Yucca Mountain region, the importance those resources hold, and for whom (Section 3.1.6)

- *Socioeconomic environment:* The labor market, population, housing, community services, and transportation services in the Yucca Mountain region (Section 3.1.7)

- *Occupational and public health and safety:* The levels of radiation that occur naturally in the Yucca Mountain air, soil, animals, and water; radiation dose estimates for Yucca Mountain workers from background radiation; radiation exposure, dispersion, and accumulation in air and water for the Nevada Test Site area from past nuclear testing and current operations; and public radiation dose estimates from background radiation (Section 3.1.8)

- *Noise:* Noise sources and levels of noise that commonly occur in the Yucca Mountain region during the day and at night, and the applicability of Nevada standards for noise in the region (Section 3.1.9)

- *Aesthetics:* The visual resources of the Yucca Mountain region in terms of land formations, vegetation, and color, and the occurrence of unique natural views in the region (Section 3.1.10)

- *Utilities, energy, and materials:* The amount of water available for the Yucca Mountain region, water-use practices, water sources, the demand for water at different times of the year, the amounts of power supplied to the region, the means by which power is supplied, and the availability of natural gas and propane (Section 3.1.11)

- *Waste and hazardous materials:* Ongoing solid and hazardous waste and wastewater management practices at Yucca Mountain, the kinds of waste generated by current activities at the site, the means by which DOE disposes of its waste, and DOE recycling practices (Section 3.1.12)

- *Environmental justice:* The locations of low-income and minority populations in the Yucca Mountain region and the income levels among low-income populations (Section 3.1.13)

DOE evaluated the existing environments in regions of influence for each of the 13 subject areas. Table 3-1 defines these regions, which are specific to the subject areas in which DOE could reasonably expect to predict potentially large impacts related to the proposed repository. Human health risks from exposure to airborne contaminant emissions were assessed for an area within approximately 80 kilometers (50 miles), and economic effects, such as job and income growth, were evaluated in a three-county socioeconomic region.

In the past, the vicinity around Yucca Mountain has been the subject of a number of studies in support of mineral and energy resource exploration, nuclear weapons testing, and other DOE activities at the Nevada Test Site. From 1977 to 1988, the Yucca Mountain Project performed studies to assist in the site selection process for a repository. These studies, which involved the development of roads, drill holes, trenches, and seismic stations, along with non-Yucca Mountain activities, disturbed about 2.5 square kilometers (620 acres) of land in the vicinity of Yucca Mountain (DOE 1998h, page 1). Yucca Mountain site characterization activities began in 1989 and will continue until 2001. These activities include surface excavations, excavations of exploration shafts, subsurface excavations and borings, and testing to evaluate the suitability of Yucca Mountain as the site for a repository. By 2001, these activities

**Table 3-1.** Regions of influence for the proposed Yucca Mountain Repository.

| Subject area | Region of influence |
|---|---|
| Land use and ownership | Land around site of proposed repository that DOE would disturb and over which DOE would need to obtain control; analyzed land withdrawal area is 600 square kilometers[a] (Section 3.1.1). |
| Air and climate | An approximate 80-kilometer[b] radius around Yucca Mountain, and at boundaries of controlled lands surrounding Yucca Mountain (Section 3.1.2). |
| Geology | The regional geologic setting and the specific geology of Yucca Mountain (Section 3.1.3). |
| Hydrology | *Surface water:* construction areas that would be susceptible to erosion, areas affected by permanent changes in flow, and areas downstream of the repository that would be affected by eroded soil or potential spills of contaminants. |
| | *Groundwater:* aquifers that would underlie areas of construction and operation, aquifers that could be sources of water for construction, and aquifers downstream of the repository that repository use or long-term releases from the repository could affect (Section 3.1.4). |
| Biological resources and soils | Area that contains all potential surface disturbances resulting from the Proposed Action (described in Chapter 2) plus some additional area to evaluate local animal populations; roughly equivalent to the analyzed land withdrawal area of about 600 square kilometers (Section 3.1.5). |
| Cultural resources | Land areas that repository activities would disturb (described in Chapter 2) and areas in the analyzed land withdrawal area where impacts could occur (Section 3.1.6). |
| Socioeconomic environment | Three Nevada counties (Clark, Lincoln, and Nye) in which repository activities could influence local economies and populations (Section 3.1.7). |
| Occupational and public health and safety | An approximate 80-kilometer radius around Yucca Mountain and at the approximate boundary of analyzed land withdrawal area (Section 3.1.8). |
| Noise | Existing residences in the Yucca Mountain region and at the approximate edge of the analyzed land withdrawal area (Section 3.1.9). |
| Aesthetics | Approximate boundary of analyzed land withdrawal area (Section 3.1.10). |
| Utilities, energy, and materials | Public and private resources on which DOE would draw to support the Proposed Action (for example, private utilities, cement suppliers) (Section 3.1.11). |
| Waste and hazardous materials | On- and offsite areas, including landfills and hazardous and radioactive waste processing and disposal sites, in which DOE would dispose of site-generated repository waste (Section 3.1.12). |
| Environmental justice | Varies with the different subject areas. The environmental justice regions of influence will correspond to those of the specific subject areas, as defined in this table (Section 3.1.13). |

a. 600 square kilometers = about 150,000 acres or 230 square miles.
b. 80 kilometers = about 50 miles.

will have disturbed about an additional 1.5 square kilometers (370 acres) in the vicinity of Yucca Mountain (TRW 1999a, Table 6-2). Reclamation activities have started and will continue to occur as sites are released from further study.

The existing environment at Yucca Mountain includes the Exploratory Studies Facility, which includes the tunnel (drift), the North and South Portal pads and supporting structures, an excavated rock storage area, a topsoil storage area, borrow pits, boreholes, trenches, roads, and supporting facilities and disturbances for site characterization activities. Table 3-2 lists existing facilities, structures, equipment, and disturbances at Yucca Mountain and at the central support site in Area 25 of the Nevada Test Site. Area 25 was used in the early 1960s by the Atomic Energy Commission (a DOE predecessor agency) and the National Aeronautics and Space Administration as part of a program to develop nuclear reactors for use in the Nation's space program. The former Nuclear Rocket Development Station administrative areas complex in Area 25 has become the Yucca Mountain Site Characterization Central Support Site.

**Table 3-2.** Existing facilities, structures, and disturbances at Yucca Mountain.[a]

| Yucca Mountain | Area 25 Central Support Site |
|---|---|
| Exploratory Studies Facility (North Portal pad and supporting structures) | Field Operations Center |
| Exploratory Studies Facility (South Portal pad) | Hydrologic research facility |
| Cross drift[b] | Sample management facility and warehouse |
| Concrete batch plant and precast yard | Radiological studies facility |
| Fill borrow pits (3) and screening plants | Meteorology/air quality studies facility |
| Subdock equipment storage facility | Project accumulation area for hazardous waste |
| Equipment/supplies laydown yard | Gas station |
| Hydrocarbon management facility | Maintenance facility |
| Boxcar equipment and supplies yard | U.S. Geological Survey technical warehouse |
| Water wells J-12 and J-13 | Tunnel rescue facility |
| Excavated rock storage pile | Sewage lagoon operated by the Nevada Test Site |
| Topsoil storage pile | |
| Explosives storage magazines (2) | |
| Water booster pump and distribution system | |
| Boreholes (about 300) | |
| Trenches and test pits (about 200) | |
| Busted Butte geologic test drift | |
| Fran Ridge heated-block test facility | |
| Water infiltration test sites | |
| Meteorological monitoring towers | |
| Air quality monitoring sites | |
| Radiological monitoring sites | |
| Ecological study plots | |
| Reclamation study plots | |
| Septic system | |
| Roads | |

a. Source: Modified from DOE (1998i, all).
b. Drift is a mining term for a horizontal tunnel.

### 3.1.1 LAND USE AND OWNERSHIP

The region of influence for land use and ownership includes the lands that surround the site of the proposed repository over which DOE would have to obtain permanent control to operate the repository. The Department has compiled land-use and ownership information for this region. Most of the land in the region is managed by agencies of the Federal Government. Sections 3.1.1.1 and 3.1.1.2 discuss land use and ownership for the region of influence and for a larger area around Yucca Mountain. Section 3.1.1.3

describes the analyzed land withdrawal area for the repository. Section 3.1.1.4 discusses Native American views about the ownership of the land around Yucca Mountain. TRW (1999f, all) is the basis of the information in this section unless otherwise noted.

### 3.1.1.1 Regional Land Use and Ownership

The Federal Government manages more than 85 percent of the land in Nevada (about 240,000 square kilometers or 93,000 square miles). Most of this land is under the control of the Bureau of Land Management (which is part of the U.S. Department of the Interior), the U.S. Department of Defense, and DOE. The remainder of the Federally managed land is primarily under the jurisdiction of the Forest Service, which is part of the U.S. Department of Agriculture, with smaller areas under the control of the National Park Service and the Bureau of Reclamation, both of which are parts of the Department of the Interior. About 42,000 square kilometers (16,000 square miles) are under State, local, or private ownership, and about 5,000 square kilometers (2,000 square miles) are Native American lands. Table 3-3 summarizes Nevada land holdings and the controlling authority. Figure 3-1 shows ownership and use of lands around the site of the proposed repository.

**Table 3-3.** Nevada land areas and controlling authorities (square kilometers).[a,b]

| Authority | Area |
|---|---|
| State, local, county, or private | 42,000 |
| Bureau of Land Management | 190,000 |
| Department of Defense | 13,000 |
| Department of Energy | 3,500 |
| Other Federal authorities | 31,000 |
| Native American tribes | 5,000 |

a. Source: TRW (1999f, page 1).
b. To convert square kilometers to square miles, multiply by 0.3861.

The Nevada Test Site, which is a DOE facility, covers about 3,500 square kilometers (1,400 square miles). The Atomic Energy Commission, a DOE predecessor agency, established the Nevada Test Site in the 1950s to test nuclear devices. More information on current and future uses of the Nevada Test Site is available in the *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DOE 1996f, all). The U.S. Air Force operates the Nellis Air Force Range, which covers about 13,000 square kilometers (5,000 square miles) and is one of the largest and most active military training ranges in the United States. More information on current and future uses of the Nellis Air Force Range is available in the *Renewal of the Nellis Air Force Range Land Withdrawal Legislative Environmental Impact Statement* (USAF 1999, all).

The region has special-use areas, which generally are excluded from development that would require terrain alterations unless such alterations would benefit wildlife or public recreation. The Fish and Wildlife Service of the U.S. Department of the Interior manages the Desert National Wildlife Refuge and the Ash Meadows National Wildlife Range, which are about 50 kilometers (30 miles) east and 39 kilometers (24 miles) south of Yucca Mountain, respectively (Figure 3-1). These areas provide habitat for a number of resident and migratory animal species in relatively undisturbed natural ecosystems. The National Park Service manages Death Valley National Park, which is in California approximately 35 kilometers (22 miles) southwest of Yucca Mountain. The small enclave of Devils Hole Protective Withdrawal in Nevada south of Ash Meadows is also administered by the National Park Service (Figure 3-1).

There is virtually no State-owned land immediately adjacent to the repository site. There are scattered tracts of private land in and near the Towns of Beatty, Amargosa Valley, and Indian Springs in Nevada. There are also larger private tracts in the agricultural areas of the Las Vegas Valley, near Pahrump, and in the Amargosa Desert south of the Town of Amargosa Valley. The closest year-round housing is at Lathrop Wells in the Amargosa Valley, about 22 kilometers (14 miles) south of the site. There is

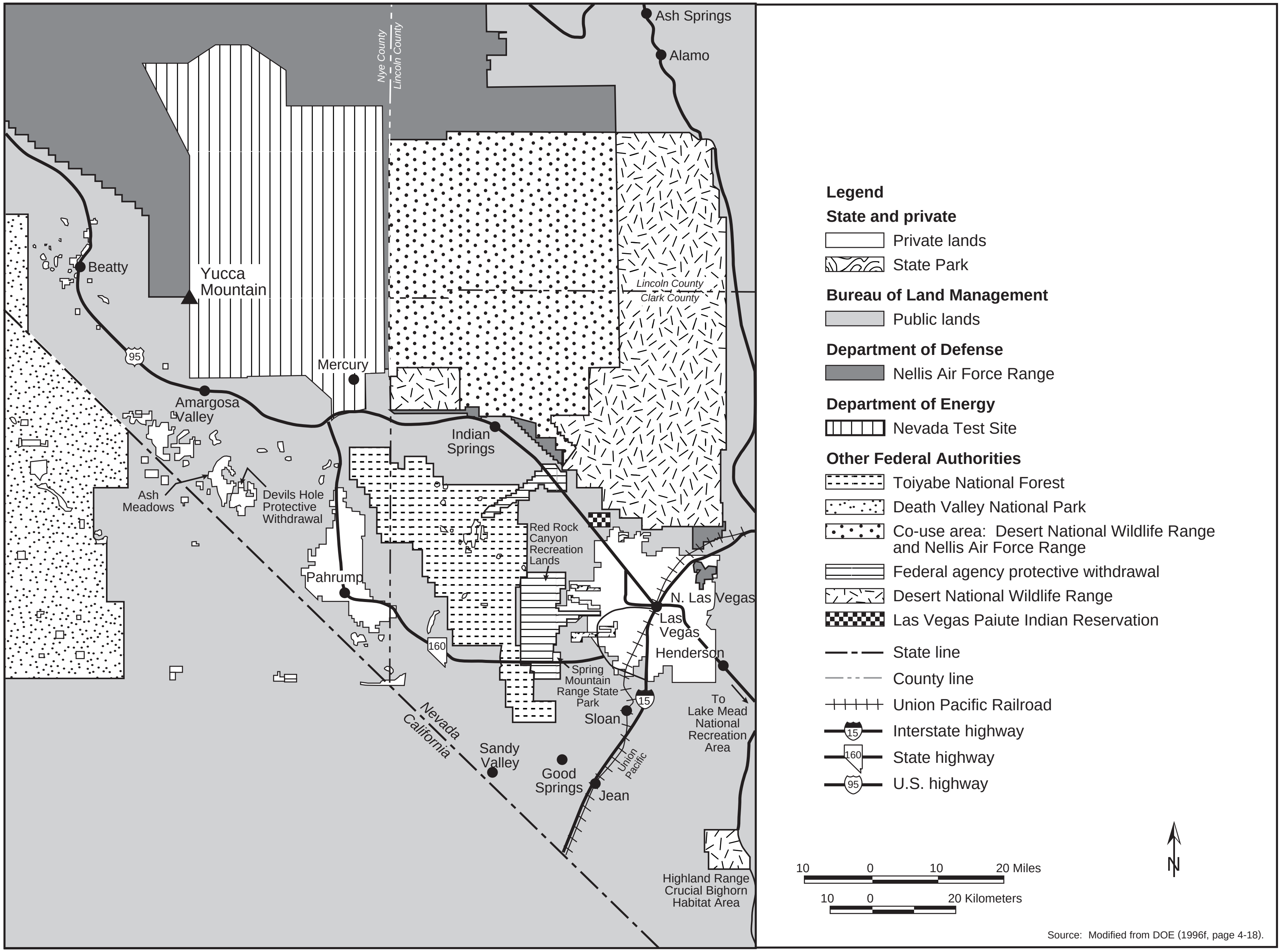



**Figure 3-1.** Land use and ownership in the Yucca Mountain region.

farming—primarily grasses and legumes—for hay and dairy operations about 30 kilometers (19 miles) south of the proposed repository in the Town of Amargosa Valley (Figure 3-1).

#### 3.1.1.2 Current Land Use and Ownership at Yucca Mountain

DOE has established land-use agreements to support its site characterization activities at Yucca Mountain. The Yucca Mountain Site Characterization Zone (Figure 3-2) includes DOE, Bureau of Land Management, and Air Force lands.

The Bureau of Land Management granted DOE a right-of-way reservation (N-47748) for Yucca Mountain site characterization activities (BLM 1988, all). This reservation comprises 210 square kilometers (81 square miles). The land in this reservation is open to public use, with the exception of about 20 square kilometers (8 square miles) near the site of the proposed repository that were withdrawn in 1990 from the mining and mineral leasing laws to protect the physical integrity of the repository rock (P.L. Order 6802, "Withdrawal of Public Land to Maintain the Physical Integrity of the Repository Rock"). The lands in this reservation not withdrawn from the mining and mineral leasing laws contain a number of unpatented mining claims (lode and placer). In addition, there is one patented mining claim in the reservation. Patented Mining Claim No. 27-83-0002 covers 0.8 square kilometer (0.3 square mile) to mine volcanic cinders used as a raw material in the manufacture of cinderblocks.

The Bureau of Land Management manages surface resources on the Nellis Air Force Range. In 1994, the Bureau granted DOE a right-of-way reservation (N-48602) to use about 75 square kilometers (29 square miles) of Nellis land for Yucca Mountain site characterization activities (BLM 1994a, all). This land, which is closed to public access and use, has been studied extensively. Many of the exploratory facilities are on Nellis land.

The Yucca Mountain Site Characterization Office and the DOE Nevada Operations Office have a management agreement that allows the use of about 230 square kilometers (90 square miles) of Nevada Test Site land for site characterization activities.

#### 3.1.1.3 Potential Repository Land Withdrawal

Nuclear Regulatory Commission licensing conditions for a monitored geologic repository (10 CFR Part 60) include a requirement that DOE have either ownership or permanent control of the lands for which it is seeking a repository license. As noted, portions of the lands being used for site characterization that would be required for the repository are controlled by the Bureau of Land Management, the Air Force, and the DOE Nevada Operations Office. Because all of these lands are not under permanent DOE control, a land withdrawal would be required.

The procedure for land withdrawal is the method by which the Federal Government places exclusive control over land it owns with a particular agency for a particular purpose. Only Congress has the power to withdraw Federal lands permanently for the exclusive purposes of specific agencies. Congress can authorize and direct a permanent withdrawal of lands such as those required for the proposed repository at Yucca Mountain. The extent and conditions of the withdrawal would be determined by Congress. The extent of a land withdrawal area is important to the analysis and understanding of the impacts of the Proposed Action. For example, the magnitude of impacts to a member of the public from an accident at an operating repository would be determined in part by the proximity of the land withdrawal boundary to the repository operations areas. As a consequence, DOE used a land withdrawal area as the basis for analysis in this EIS.

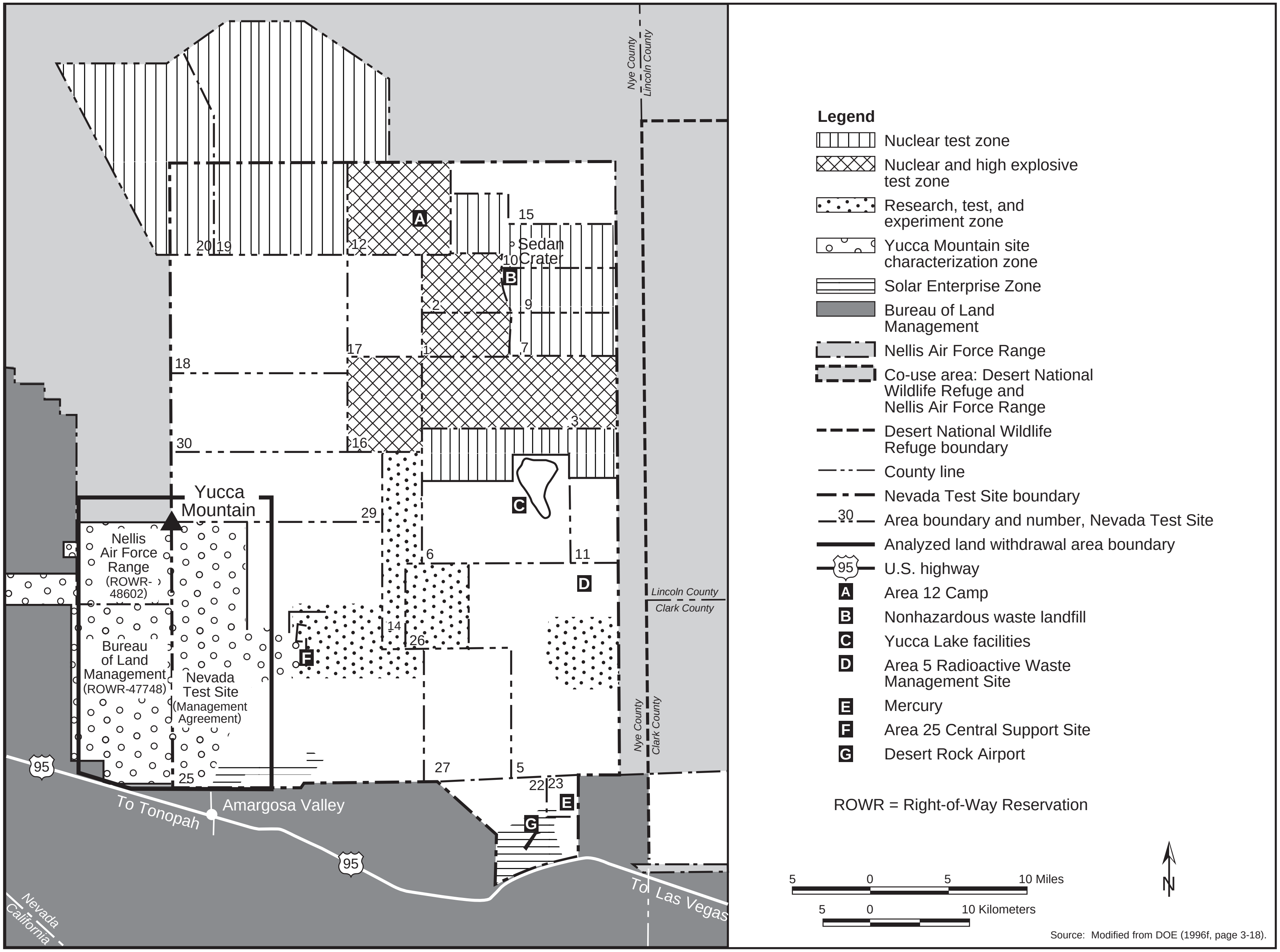



**Figure 3-2.** Land use and ownership in the analyzed land withdrawal area and vicinity.

Figure 3-2 shows the land withdrawal area analyzed in this EIS that encompasses the current right-of-way reservations for site characterization. This area includes about 600 square kilometers (150,000 acres) of land. The land in this area is currently under the control of the Air Force, DOE, and the Bureau of Land Management (Table 3-4).

**Table 3-4.** Current land ownership and public accessibility to the analyzed land withdrawal area.[a,b]

| Agency | Area (square kilometers)[c] | Current accessibility |
|---|---|---|
| DOE (Nevada Test Site) | 300 | No public access |
| U.S. Air Force (Nellis Air Force Range) | 97 | No public access |
| Bureau of Land Management (public land) | 200 | Public access |
| Private land (one patented mining claim) | 1 | No public access |

a. Source: DOE (1998j, all).
b. A description of the area by township, range, and section is available from DOE, Las Vegas, Nevada.
c. To convert square kilometers to square miles, multiply by 0.3861.

Most of the land controlled by the Bureau of Land Management in the analyzed land withdrawal area is associated with the current right-of-way reservation (N-47748) for Yucca Mountain site characterization activities. This land is open to public use, with the exception of about 20 square kilometers (8 square miles) near the site of the proposed repository that are withdrawn from the mining and mineral leasing laws except for an existing patented mining claim. That claim (No. 27-83-0002) covers 0.8 square kilometer (0.3 square mile) to mine volcanic cinders (a raw material used in the manufacture of cinderblocks). The lands open to public use also contain a number of unpatented mining claims (lode and placer). Off-road vehicle use is permitted in these lands. There is a designated utility corridor in the southern portion of these lands.

More detailed descriptions of the land under the control of the Bureau of Land Management in the region of Yucca Mountain are available in the *Proposed Las Vegas Resource Management Plan and Final Environmental Impact Statement* (BLM 1998, all).

### 3.1.1.4 Native American Treaty Issue

One Native American ethnic group with cultural and historic ties to the Yucca Mountain region is the Western Shoshone. A special concern of the Western Shoshone people is the Ruby Valley Treaty of 1863. The Western Shoshone people maintain that the treaty gives them rights to 97,000 square kilometers (24 million acres) in Nevada, including the Yucca Mountain region (Western Shoshone v. United States 1997, all). The legal battle over the land began in 1946 when the Indian Claims Commission Act gave tribes the right to sue the Federal Government for unkept treaty promises. If a tribe were to win a claim against the Government, the Act specifies that the tribe could receive only a monetary award and not land or other remunerations.

The Western Shoshone people filed a claim in the early 1950s alleging that the Government had taken their land. The Indian Claims Commission found that Western Shoshone title to the Nevada lands had gradually extinguished and set a monetary award as payment for the land. In 1977, the Commission granted a final award to the Western Shoshone people, who dispute the Commission findings and have not accepted the monetary award for the lands in question. They maintain that no payment has been made (the U.S. Treasury is holding these monies in an interest-bearing account) and that Yucca Mountain is on Western Shoshone land. A 1985 U.S. Supreme Court decision (United States v. Dann 1985, all) ruled that even though the money has not been distributed, the United States has met its obligations with the Commission’s final award and, as a consequence, the aboriginal title of the land had been extinguished.

### 3.1.2 AIR QUALITY AND CLIMATE

The region of influence for air quality is an area within a radius of about 80 kilometers (50 miles) around the site of the proposed repository and at the boundaries of controlled lands around Yucca Mountain. This region encompasses portions of Clark and Nye Counties in Nevada and a portion of Inyo County, California. To determine the air quality and climate for the Yucca Mountain region, DOE site characterization activities have included the monitoring of air quality and meteorological conditions. The Department has monitored the air for gaseous criteria pollutants (carbon monoxide, nitrogen dioxide, ozone, and sulfur dioxide) and for particulate matter. This section describes the existing air quality and climate at the proposed repository site and in the surrounding region. Sections 3.1.2.1 and 3.1.2.2 describe the air quality and climate, respectively. Unless otherwise noted, the *Environmental Baseline File for Meteorology and Air Quality* (TRW 1999g, all) is the basis for the information provided in this section.

#### 3.1.2.1 Air Quality

Air quality is determined by measuring concentrations of certain pollutants in the atmosphere. The U.S. Environmental Protection Agency designates an area as being *in attainment* for a particular pollutant if ambient concentrations of that pollutant are below National Ambient Air Quality Standards (Table 3-5).

**Table 3-5.** National and Nevada ambient air quality standards.[a]

| Pollutant | Primary and Secondary NAAQS,[b] except as noted: Period | Concentration | Highest measured Yucca Mountain concentration[c] | Nevada standards[d] |
|---|---|---|---|---|
| Sulfur dioxide | Annual[e] | 0.03 part per million | 0.002 | Same |
| | 24-hour[f] | 0.14 part per million | 0.002 | |
| Sulfur dioxide (secondary) | 3-hour[f] | 0.5 part per million | 0.002 | |
| $PM_{10}$[g] | Annual[h] | 50 micrograms per cubic meter | 12 | Same |
| | 24-hour[i] | 150 micrograms per cubic meter | 67 | |
| $PM_{2.5}$[j] | Annual[h] | 15 micrograms per cubic meter | N/A[k] | None |
| | 24-hour[l] | 65 micrograms per cubic meter | N/A | |
| Carbon monoxide | 8-hour[f] | 9 parts per million | 0.2 | Same[m] |
| | 1-hour[f] | 35 parts per million | 0.2 | Same |
| Nitrogen dioxide | Annual[e] | 0.053 part per million | 0.002 | Same |
| Ozone | 1-hour[n] | 0.12 part per million | 0.1 | Same |
| | 8-hour[o] | 0.08 part per million | N/A | None |

a. Sources: 40 CFR 50.4 through 50.11; Nevada Administrative Code 445B.391.
b. NAAQS = National Ambient Air Quality Standard.
c. Units correspond to the units listed in the concentration column.
d. Nevada Administrative Code 445B.391.
e. Average not to be exceeded in the period shown.
f. Average not to be exceeded more than once in a calendar year.
g. $PM_{10}$ = particulate matter with a diameter less than 10 micrometers (0.0004 inch). If and until the revised State Implementation Plan is approved 40 CFR 50.6 applies; then 40 CFR 50.7 would apply.
h. Expected annual arithmetic mean should be less than value shown.
i. Number of days per calendar year exceeding this value should be less than 1. Under 40 CFR 50.7, 99th-percentile value should be less than value shown.
j. $PM_{2.5}$ = particulate matter with a diameter less than 2.5 micrometers (0.0001 inch). Standard has not been implemented.
k. N/A = not available; no monitoring data has been collected since the new standard was implemented.
l. 98th-percentile value should be less than value shown.
m. The Nevada ambient air quality standard for carbon monoxide is 9 parts per million at less than 1,500 meters (4,900 feet) above mean sea level and 6 parts per million at or above 1,500 meters; Nevada Administrative Code 445B.31.
n. This standard was replaced in 1998 by 40 CFR 50.10 for all air quality regions of interest.
o. Standard implemented in 1998. Three-year average of the fourth-highest monitored daily maximum 8-hour average concentration.

(Ambient air is that part of the atmosphere outside buildings to which the general public has access.) The Environmental Protection Agency established the national standards, as directed by the Clean Air Act, to define levels of air quality that are necessary, with an adequate margin of safety, to protect the public health (primary standards) and the public welfare (secondary standards). The standards specify the maximum pollutant concentrations and frequencies of occurrence for specific averaging periods.

Areas in violation of one or more of these standards are called *nonattainment areas*. If there are not enough air quality data to determine the status of attainment of a remote or sparsely populated area, the area is listed as *unclassified*. For regulatory purposes, unclassified areas are considered to be in attainment.

The quality of the air at the site of the proposed repository and the surrounding parts of the Nevada Test Site, Nellis Air Force Range, and southern Nye County is unclassified because there are limited air quality data (40 CFR 81.329). Data collected at the site indicate the air quality is within applicable standards. Portions of Clark County in the air quality region of influence are in attainment with the National Ambient Air Quality Standards. Inyo County, California, is in attainment with national and California ambient air quality standards for carbon monoxide, nitrogen dioxide, and sulfur dioxide. It is in attainment with the national $PM_{10}$ standard, but in nonattainment with the more restrictive California standard (CEPA 1998, pages H6 to H35).

Air quality in attainment areas is controlled under the Prevention of Significant Deterioration program of the Clean Air Act, with the goal of preventing significant deterioration of existing air quality. Under the Prevention of Significant Deterioration provisions, Congress established a land classification scheme for areas of the country with air quality better than the National Ambient Air Quality Standards. Class I allows very little deterioration of air quality; Class II allows moderate deterioration; and Class III allows more deterioration; but in all cases the pollution concentrations shall not violate any of the National Ambient Air Quality Standards. Congress designated certain areas as mandatory Class I, which precludes redesignation to a less restrictive class, to acknowledge the value of maintaining these areas in relatively pristine condition. Congress also protected other nationally important lands by originally designating them as Class II and restricting redesignation to Class I only.

All other areas were initially classified as Class II, and can be redesignated as either Class I or Class III. In the region of influence, all areas are designated as Class II. There are no Class I areas, although one area, the Death Valley National Park, is a national monument and a protected Class II area that could be redesignated as Class I (EPA 1999a, all; EPA 1999b, all). It is about 35 kilometers (22 miles) southwest of Yucca Mountain.

The construction and operation of a facility in an attainment area could be subject to the requirements of the Prevention of Significant Deterioration program if the facility received a classification as a major source of air pollutants. At present, the proposed repository site and the Nevada Test Site have no sources subject to those requirements (DOE 1996f, page 4-146).

As part of Yucca Mountain site characterization, DOE obtained an air quality operating permit from the State of Nevada (NDCNR 1996, all). The permit places specific operating conditions on various systems that DOE uses during site characterization activities. These conditions include limiting the emission of criteria pollutants, defining the number of hours a day and a year a system is allowed to operate, and determining the testing, monitoring, and recordkeeping required for the system.

In 1989, DOE began monitoring particulate matter at the site of the proposed repository as part of site characterization activities and later as part of the Nevada Air Quality operating permit requirements. Concentration levels of inhalable particles smaller than 10 micrometers in diameter have been well below applicable National Ambient Air Quality Standards, with annual average concentrations 20 to 25 percent of the standard (see Table 3-5).

In 1997, the Environmental Protection Agency issued National Ambient Air Quality Standards for ozone and particulate matter. The new standard for particulate matter (40 CFR 50.7) includes fine particles in the respirable range with diameters smaller than 2.5 micrometers (see Table 3-5). The implementation of this new standard applies to all areas, but initial monitoring will focus on urban areas because (1) this pollutant comes primarily from combustion (auto exhaust, etc.) rather than fugitive dust sources (windblown dust, etc.) and (2) the first priority for monitoring programs is the assessment of densely populated areas.

From October 1991 through September 1995, DOE monitored the site of the proposed repository for gaseous criteria pollutants (carbon monoxide, nitrogen dioxide, ozone, and sulfur dioxide) as part of site characterization. The concentration levels of each pollutant were well below the applicable National Ambient Air Quality Standards (see Table 3-5). In fact, concentrations of carbon monoxide and sulfur dioxide were not detectable during the entire monitoring period. Nitrogen dioxide was detected occasionally at concentrations of a few parts per billion (around 0.002 part per million) by volume, probably from nearby vehicle exhausts, about 4 percent of the applicable annual average standard (see Table 3-5). Ozone was the only criteria pollutant routinely detected, although these concentrations were barely detectable (0.081 to 0.096 part per million) and ranged from 67 to 80 percent of the 1-hour regulatory standard. The source of the ozone has not been determined, but could be urban areas in southern California. In 1998, the Environmental Protection Agency revoked the 1-hour ozone standard for all counties in the United States with no current measured violations, including all of Nevada and the region around Yucca Mountain, and replaced it with a new 8-hour ozone standard. Nonattainment areas for the new ozone standard will be designated in 2000.

#### 3.1.2.2 Climate

The Yucca Mountain region has a relatively arid climate, with annual precipitation totals ranging between approximately 10 and 25 centimeters (4 and 10 inches) per year (DOE 1998a, Volume 1, page 2-29). Precipitation at a given location depends on nearby topographic features. The winter season is mild, with some periods of below freezing temperatures. Occasional periods of persistent rain have produced more than 5 centimeters (2 inches) of rainfall in daily periods. The summer season is typically hot and dry, with occasional periods of monsoon thunderstorms producing locally large amounts of rain. Storms can produce more than 2.5 centimeters (1 inch) of rain in a matter of hours.

Mean nighttime and daytime air temperatures typically range from 22°C to 34°C (72°F to 93°F) in the summer and from 2°C to 10.5°C (34°F to 51°F) in the winter (TRW 1997a, pages A-1 to A-16). Temperature extremes range from -15°C to 45°C (5°F to 113°F). On average, the daily range in temperature change is about 10°C (18°F). Higher elevations are cooler, though the coldest areas can be in canyons and washes to which heavy cold air flows at night. Relative humidity levels range from about 10 percent on summer afternoons to about 50 percent on winter mornings and to near 100 percent during precipitation events.

In the valleys, airflow is channeled by local topography, particularly at night during stable conditions (TRW 1997a, pages 4-13 to 4-16). With the exception of the nearby confining terrain, which includes washes and small canyons on the east side of Yucca Mountain, local wind patterns have a strong daily cycle of daytime winds from the south and nighttime winds from the north. Confined areas also have daily cycles, but the wind directions are along terrain axes, typically upslope in the daytime and downslope at night. Wind direction can also vary with height. As shown in Figure 3-3, the winds at a height of 60 meters (200 feet) show a strong north-south flow up and down the valley. The winds at

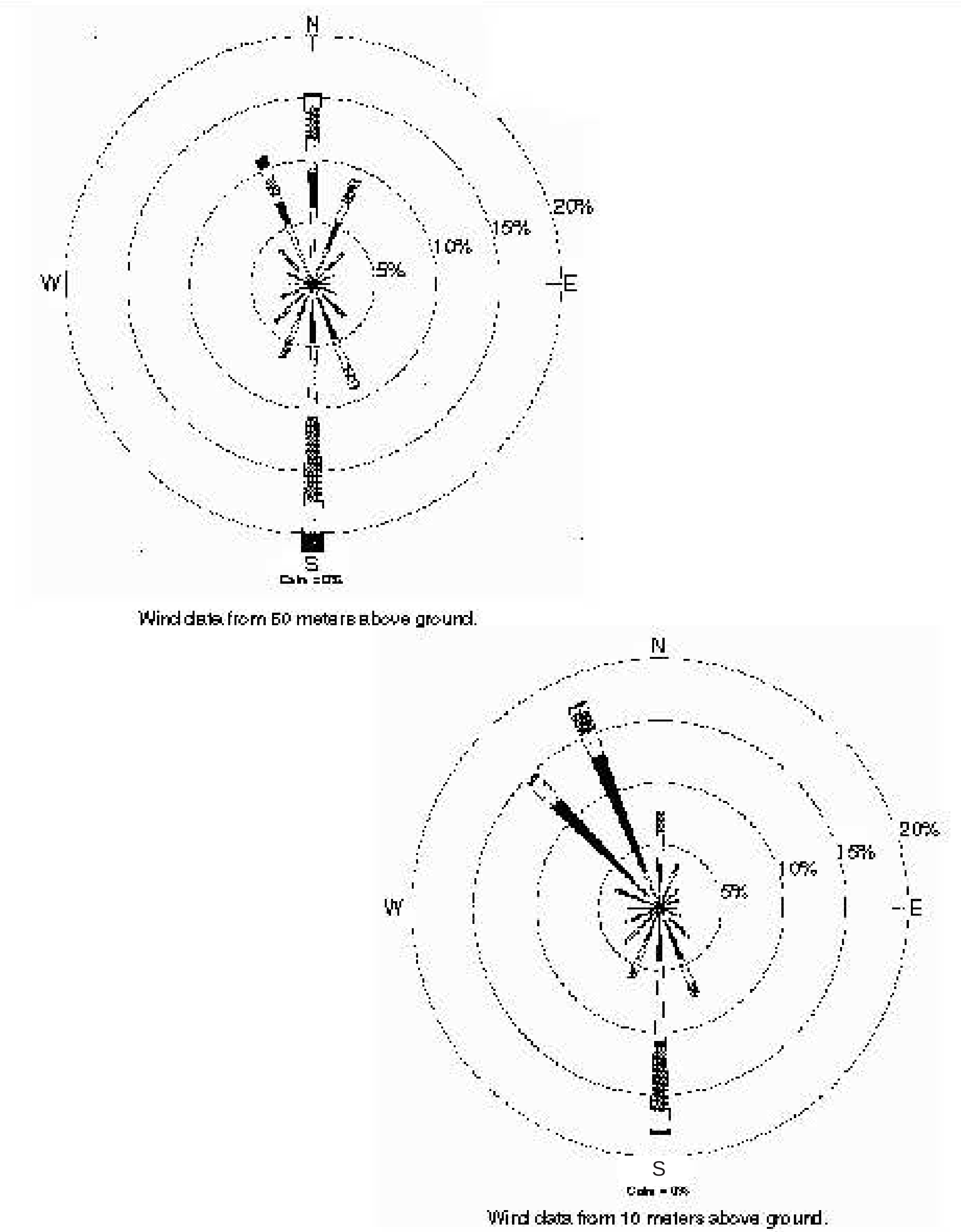



**Figure 3-3.** Wind rose plots for 10 and 60 meters (33 and 200 feet) above ground in the proposed repository facilities vicinity.

10 meters (33 feet) show a strong southerly flow, but at night the wind pattern reflects more of the drainage flow downslope from Yucca Mountain. Hourly average wind speeds are usually greater than 1.8 meters a second (4 miles an hour), indicating few calm periods. Over the entire monitoring network, the average wind speed ranges from 2.5 to 4.4 meters a second (5.6 to 9.8 miles an hour); the fastest 1-minute wind speeds range from 19 to 33 meters a second (42 to 74 miles an hour); and the peak gusts range from 26 to 38 meters a second (59 to 86 miles an hour). The highest wind speeds typically occur on exposed ridges.

Severe weather can occur in the region, usually in the form of summer thunderstorms. These storms can generate an abundant amount of lightning, strong winds, and heavy and rapid precipitation. Tornadoes can occur, though they are not a substantial threat in the region; four have been recorded within 240 kilometers (150 miles) of the site of the proposed repository during the past 53 years, and one occurred in 1987 in Amargosa Valley about 50 kilometers (30 miles) south of the site (TRW 1997a, page 4-26).

### 3.1.3 GEOLOGY

DOE has studied the existing physiographic setting (characteristic landforms), stratigraphy (rock strata), and geologic structure (structural features resulting from rock deformations) at Yucca Mountain and in the surrounding region. These studies have yielded detailed information about the surface and subsurface features in the region. This section describes the baseline conditions of the region's geology. DOE investigated seismicity (earthquake activity) in the Yucca Mountain region; the investigations focused on understanding the Quaternary history of movement on faults in the region and the historic record of earthquake activity. The Department also investigated volcanoes in the Yucca Mountain region to assess the potential for volcanism to result in adverse effects to a repository. In addition, DOE considered the possibility that there might be minerals and energy resources at or near the site of the proposed repository. Unless otherwise referenced, the information in this section is from the *Geology/Hydrology Environmental Baseline File* (TRW 1999h, all), the *Yucca Mountain Site Description* (TRW 1998a, all), or the *Viability Assessment of a Repository at Yucca Mountain* (DOE 1998a, all).

#### 3.1.3.1 Physiography (Characteristic Landforms)

Yucca Mountain is in the southern part of the Great Basin subprovince of the Basin and Range Physiographic Province (Figure 3-4), a region characterized by generally north-trending, linear mountain ranges separated by intervening valleys (basins). The Great Basin encompasses nearly all of Nevada plus parts of Utah, Idaho, Oregon, and California. Mountain ranges of the Great Basin, including Yucca Mountain, are mostly tilted, fault-bounded crustal blocks that are as much as 80 kilometers (50 miles) long and 8 to 24 kilometers (5 to 15 miles) wide. Ranges typically rise from 300 to 1,500 meters (1,000 to 4,900 feet) above the adjacent valley floors and occupy 40 to 50 percent of the total land area.

Valleys between the mountain ranges are filled with alluvial sediments (deposits of sand, mud, and other such materials formed by flowing water) from the adjacent ranges. Most valleys are called *closed basins* because they lack a drainage outlet. Water and sediment from adjacent ranges become trapped and move to the lowest part of such valleys to form a *playa*, a flat area that is largely vegetation-free owing to high salinity, which results from evaporation of the water. Valleys with drainage outlets have intermittent stream channels that carry eroded sediment to lower drainage areas.

The present landscape, distinguished by the broad series of elongated mountain ranges alternating with parallel valleys, is the result of past episodes of faulting that elevated the ranges above the adjacent valleys. Section 3.1.3.2 addresses such faulting. Yucca Mountain is an irregularly shaped volcanic upland, 6 to 10 kilometers (4 to 6 miles) wide and 40 kilometers (25 miles) long. This mountain is part of

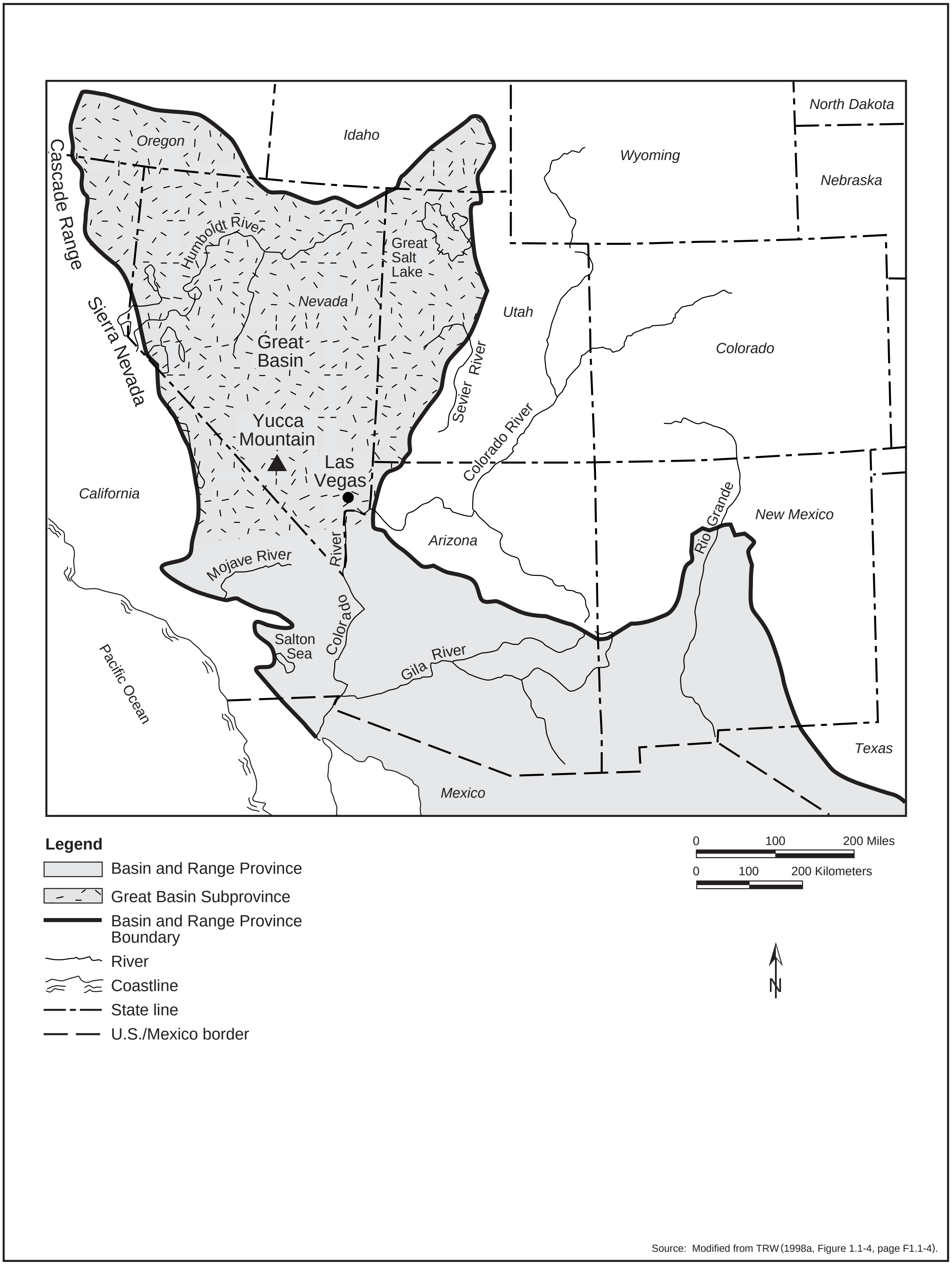



**Figure 3-4.** Basin and Range Physiographic Province and Great Basin Subprovince.

a volcanic plateau formed between about 14 million and 11.5 million years ago (Sawyer et al. 1994, page 1304) known as the Southwestern Nevada volcanic field. Although Yucca Mountain is a product of both volcanic activity and faulting, the region exhibits evidence of a complex history of deformation associated with past interactions of crustal segments (plates) (TRW 1998a, page 3.2-1). Geologic relations indicate that many of the current features and the landscape in the Yucca Mountain region formed between 12.7 million and 11.7 million years ago (TRW 1998a, page 3.4-2). Remnants of the Timber Mountain caldera (one of the centers of the southwestern Nevada volcanic field from which most of the volcanic rocks on the surface of Yucca Mountain were erupted) and other calderas are north of Yucca Mountain (see Figure 3-5).

> **CALDERA**
>
> A volcanic crater that has a diameter many times that of the vent. It is formed by collapse of the central part of a volcano or by explosions of extraordinary violence. The erupted materials are commonly spread over great distances beyond the caldera. Volcanic debris that erupted from the Timber Mountain and other calderas north of Yucca Mountain formed the southwestern Nevada volcanic field of which the volcanic rocks at Yucca Mountain are a part.

Almost without exception, west-facing slopes at Yucca Mountain are steep and east-facing slopes are gentle, which expresses the underlying geologic structure (see Section 3.1.3.2). Small valleys eroded in the mountain are narrow, V-shaped drainages that flatten and broaden near the mountain base. The crest of Yucca Mountain is between 1,400 meters (4,600 feet) and 1,500 meters (4,900 feet) above sea level. The bottoms of the adjacent valleys are approximately 600 meters (2,000 feet) lower.

Yucca Mountain is bordered on the north by Pinnacles Ridge and Beatty Wash, on the west by Crater Flat, on the south by the Amargosa Valley, and on the east by the Calico Hills and by Jackass Flats, which contains Fortymile Wash (Figure 3-6). Beatty Wash is one of the largest tributaries of the Amargosa River (see Section 3.1.4.1) and drains the region north and west of Pinnacles Ridge, including the northern end of Yucca Mountain.

Crater Flat (Figure 3-6) is an oval-shaped valley between Yucca Mountain and Bare Mountain. It contains four prominent volcanic cinder cones and related lava flows that rise above the valley floor. Crater Flat drains to the Amargosa River through a gap in the southern end of the basin.

Jackass Flats is an oval-shaped valley east of Yucca Mountain bordered by Yucca, Shoshone, Skull, and Little Skull Mountains (Figure 3-6). It drains southward to the Amargosa River. Fortymile Wash is the most prominent drainage through Jackass Flats to the Amargosa River.

### *Site Stratigraphy and Lithology*

The exposed stratigraphic section at Yucca Mountain is dominated by mid-Tertiary volcanic ash-flow and ash-fall deposits with minor lava flows and reworked materials. These deposits originated in the calderas shown in Figure 3-5. Regionally, the thick series of volcanic rocks that form Yucca Mountain overlies Paleozoic sedimentary rocks that are largely of marine origin. The volcanic rocks, in turn, are covered in many areas by a variety of late Tertiary and Quaternary surficial deposits. The stratigraphic section is summarized in Table 3-6, which depicts rock assemblages according to the geologic age during which they were deposited. The stratigraphic sequence of the Yucca Mountain area consists, from oldest to youngest, of Pre-Cenozoic sedimentary and metasedimentary (sedimentary rocks that have been altered by metamorphism), mid-Tertiary siliceous (rich in silica) volcanic rocks, Tertiary to Quaternary basalts, and late Tertiary to late Quaternary surficial deposits.

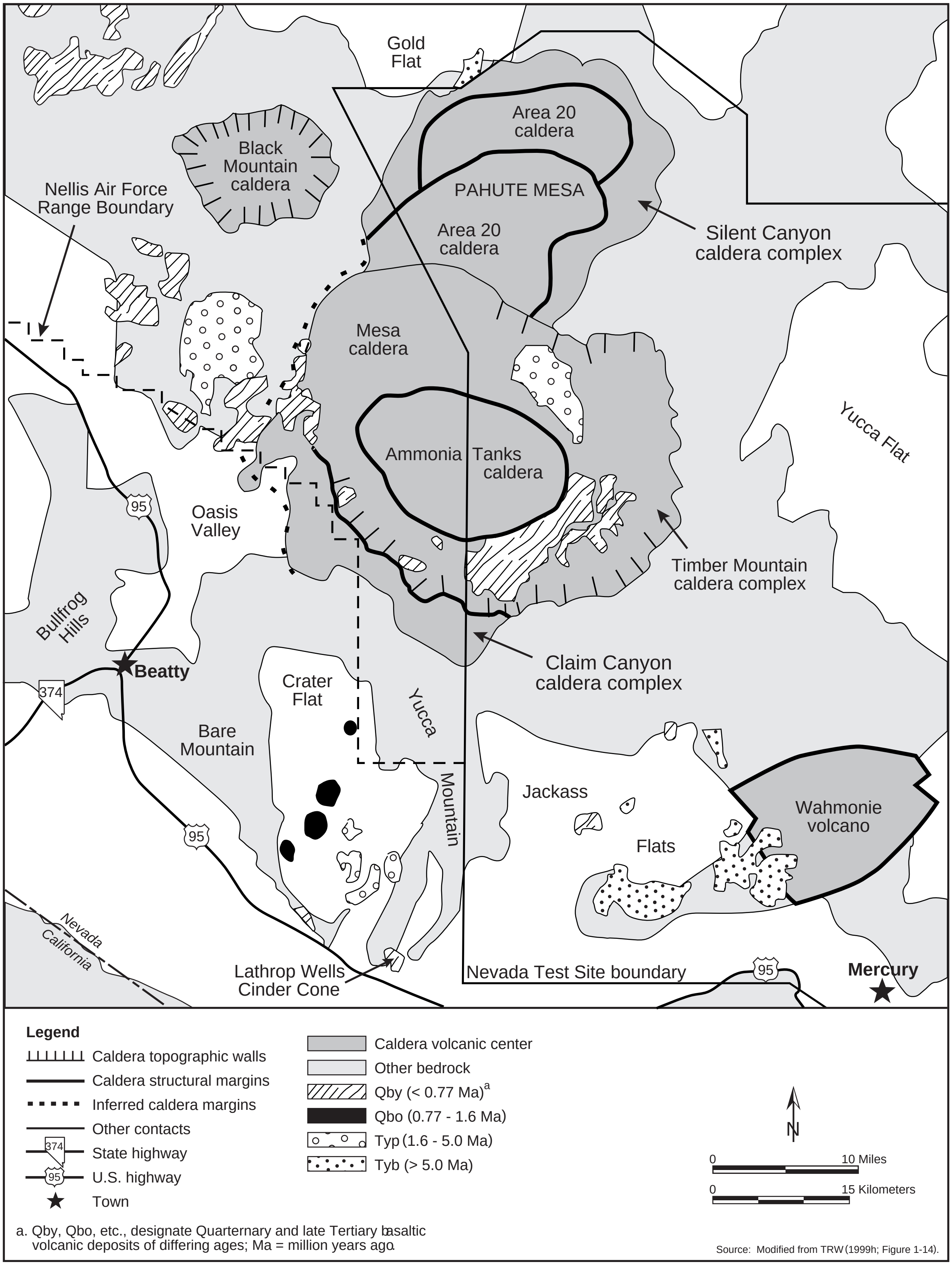



**Figure 3-5.** Calderas of the southwest Nevada volcanic field in the Yucca Mountain vicinity.

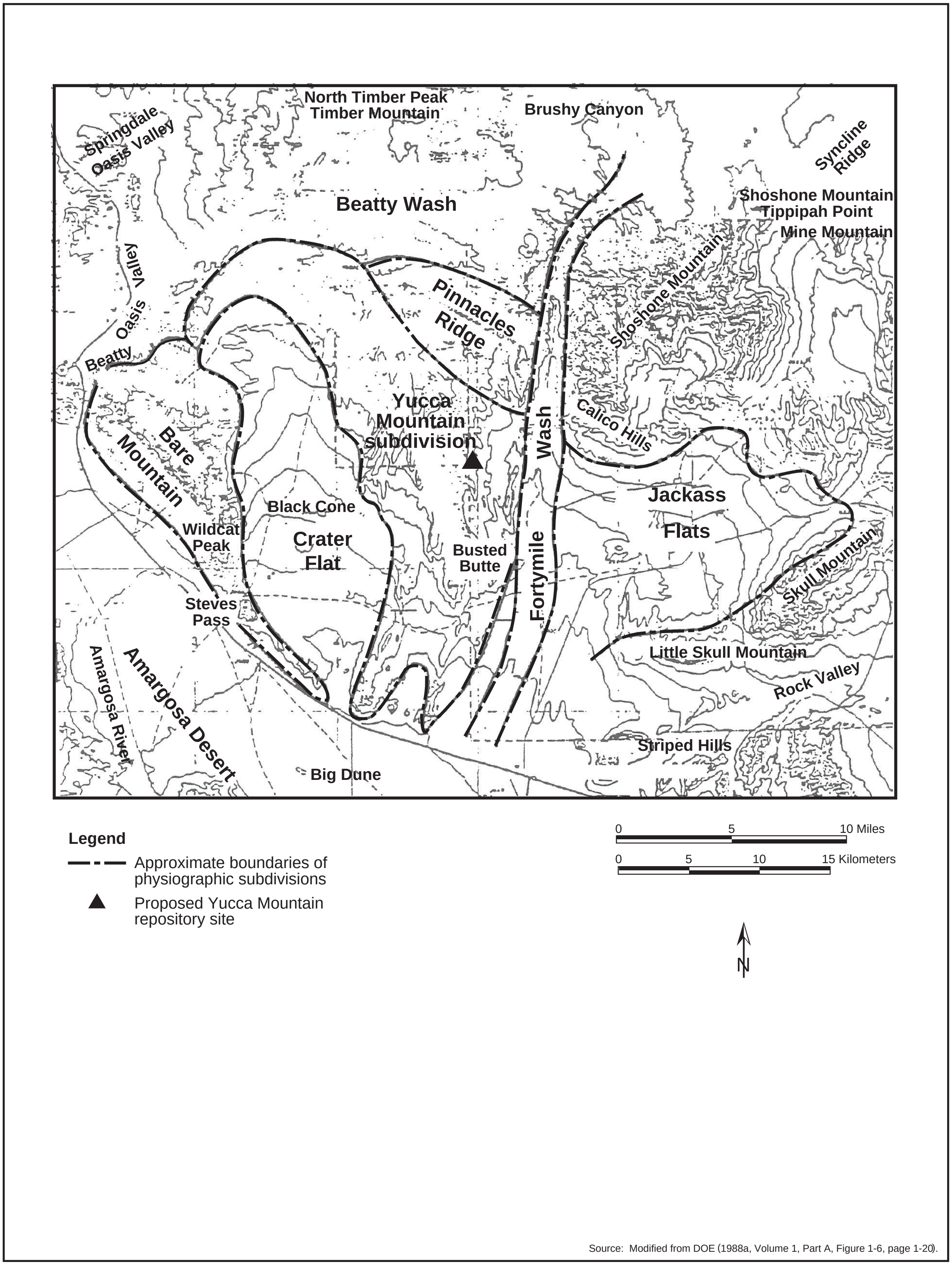



**Figure 3-6.** Physiographic subdivisions in the Yucca Mountain vicinity.

**Table 3-6.** Highly generalized stratigraphy summary for the Yucca Mountain region.[a]

| Geologic age designation | Major rock types (lithologies) |
|---|---|
| *Cenozoic Era* | |
| Quaternary Period (< 1.6 Ma)[b] | Alluvium; basalt |
| Tertiary Period (< 65 - 1.6 Ma) | Silicic ash-flow tuffs; minor basalts. Predominantly volcanic rocks of the southwestern Nevada volcanic field (includes Topopah Spring Tuff, host rock for the potential repository). Table 3-7 lists major volcanic formations at Yucca Mountain. |
| *Mesozoic Era* (240 - 65 Ma) | No rocks of this age found in Yucca Mountain region. |
| *Paleozoic Era* (570 - 240 Ma) | Three major lithologic groups (lithosomes) predominate: a lower (older) carbonate (limestone, dolomite) lithosome deposited during the Cambrian through Devonian Periods (see Figure 3-15), a middle fine-grained clastic lithosome (shale, sandstone) formed during the Mississippian Period, and an upper (younger) carbonate lithosome formed during the Pennsylvanian and Permian Periods. |
| *Precambrian Era* (> 570 Ma) | Quartzite, conglomerates, shale, limestone, and dolomite that overlie older igneous and metamorphic rocks that form the crystalline "basement." |

a. Source: Adapted from TRW (1999h, Section 1.2, pages 1-8 to 1-15).
b. Ma = approximate years ago in millions.

Only Tertiary and younger rocks are exposed at Yucca Mountain. Parts of the older (Pre-Cenozoic) rock assemblages described in Table 3-6 are exposed at Bare Mountain (Figure 3-6) about 15 kilometers (9 miles) west of Yucca Mountain and at other localities scattered around the region. Many of these older rocks are widespread in the Great Basin where their cumulative thickness is thousands of feet. Detailed information about their characteristics is lacking at Yucca Mountain because only one borehole, about 2 kilometers (1.2 miles) east of Yucca Mountain, has penetrated these rocks. Paleozoic carbonate rocks were penetrated in this borehole at a depth of about 1,250 meters (4,100 feet) (Carr et al. 1986, page 5-5). Paleozoic carbonate rocks form important aquifers in southern Nevada (Winograd and Thordarson 1975, all).

Table 3-7 lists the principal mid-Tertiary volcanic stratigraphic units mapped at the surface, encountered in boreholes, and examined in the Exploratory Studies Facility that have been a major focus of site characterization investigations. The proposed repository and access to it would be entirely in the Paintbrush Group, so investigations have focused particularly on the formations in that stratigraphic unit. Detailed descriptions of the volcanic stratigraphic units are in the Yucca Mountain Project Stratigraphic Compendium (DOE 1996g, all). The following paragraphs provide a general summary based on the *Yucca Mountain Site Description* (TRW 1998a, pages 3.5-1 to 3.5-28).

The bulk of the volcanic sequence consists of tuffs. Volcanic rocks known as ash-flow tuff (or pyroclastic flow deposits) form when a hot mixture of volcanic gas and ash violently erupts and flows. As the ash settles, it is subjected to various degrees of compaction and fusion depending on temperature and pressure conditions. If the temperature is high enough, glass and pumice fragments are compressed and fused to produce welded tuff (a hard, brick-like rock with very little open pore space in the rock matrix). Nonwelded tuffs, compacted and consolidated at lower temperatures, are less dense and brittle and generally have greater porosity. Ash-fall tuffs are formed from ash that cooled before settling on the ground surface, and bedded tuffs are composed of ash that has been reworked by stream action. All of these are found in the volcanic assemblage at Yucca Mountain.

In general, characterization of the various volcanic units is based on changes in depositional features, the development of zones of welding and devitrification (crystallization of glassy material), and the

**Table 3-7.** Tertiary volcanic rock sequence at Yucca Mountain.[a]

| Name | Age millions of years) | Thickness (meters)[b] | Characteristics |
|---|---|---|---|
| *Timber Mountain Group* | | | |
| • Ammonia Tanks Tuff | 11.5 | 215 | Welded to nonweld rhyolite tuff; exposed in southern Crater Flat. |
| • Rainier Mesa Tuff | 11.6 | < 30 - 40 | Nonwelded to moderately welded vitric to devitrified tuff exposed locally along downthrown sides of large normal faults. |
| *Post-Tiva Canyon, pre-Rainier Mesa Tuffs* | 12.5 | 0 - 61 | Pyroclastic flows and fallout tephra deposits in subsurface along east flank of Yucca Mountain. |
| *Paintbrush Group* | | | Four formations (below) interlayered locally with lava flows and reworked volcanic deposits. |
| • Tiva Canyon Tuff | 12.7 | < 50 - 175 | Crystal-rich to crystal-poor densely welded rhyolite tuff that forms most rock at surface of Yucca Mountain. |
| • Yucca Mountain Tuff | --[c] | 0 - 45 | Mostly nonwelded tuff but is partially to densely welded where it thickens to north and west. |
| • Pah Canyon Tuff | -- | 0 - 70 | Northward-thickening nonwelded to moderately welded tuff with pumice fragments. |
| • Topopah Spring Tuff | 12.8 | Maximum: 380 | Rhyolite tuff divided into upper crystal-rich member and lower crystal-poor member. Each member contains variations in lithophysal content, zones of crystallization, and fracture density. Glassy unit (vitrophyre) present at the base. Proposed host for repository. |
| *Calico Hills Formation* | 12.9 | 15 - 460 | Northward-thickening series of pyroclastic flows, fallout deposits, lavas, and basal sandstone; abundant zeolites except where entire formation is vitric in southwest part of central block of Yucca Mountain. |
| *Crater Flat Group* | | | Pyroclastic flows and interbedded tuffs of rhyolitic composition distinguished by abundance of quartz and biotite. |
| • Prow Pass Tuff | 13.1 | 60 - 228 | Sequence of variably welded pyroclastic deposits. |
| • Bullfrog Tuff | 13.3 | 76 - 275 | Partially welded, zeolytic upper and lower parts separated by a central densely welded tuff. |
| • Tram Tuff | 13.5 | 60 - 396 | Lower lithic-rich unit overlain by upper lithic-poor unit. |
| • Lithic Ridge Tuff | 14.0 | 185 - 304 | Southward thickening wedge of welded and nonwelded pyroclastic flows and interbedded tuff extensively altered to clays and zeolites. |
| *Pre-Lithic Ridge* | +14.0 | 180 - 345+ | Mostly altered pyroclastic flows, lavas, and bedded tuff of rhyolitic composition. |

a. Modified from TRW (1999h, pages 1-16 to 1-28).
b. To convert meters to feet, multiply by 3.208.
c. -- = no absolute dates.

development of alteration products in some rocks. Mineral and chemical composition and properties such as density and porosity also have been used in distinguishing some units. Most of the formations listed in Table 3-7 contain phenocrysts (mineral grains distinctly larger than the surrounding rock matrix) and lithic clasts (rock fragments), have some part that is at least partially welded, and typically have some part that has devitrified during cooling of the deposit. In addition, the vitric (glassy) parts of many formations have been partly altered to clay and zeolite minerals, and all the rocks have developed various amounts of fractures, some of which contain secondary mineral fillings.

Lithophysal cavities are prominent features in some units, notably in the Tiva Canyon and Topopah Spring Tuffs, where they range from 1 to 50 centimeters (0.4 to 20 inches) in diameter and are a basis for the further subdivision of these formations. Lithophysal cavities are voids resulting from vapors trapped in densely welded parts of the formations. Lithophysal zones contain fewer fractures compared to nonlithophysal zones.

Although welded tuffs dominate the volcanic sequence, bedded tuffs are present in the Paintbrush Group and in some older parts of the sequence. Joints and fractures are common in the welded tuffs, producing much greater bulk permeabilities than those of the nonwelded and bedded tuffs. This is an important distinction with regard to investigation of hydrologic conditions.

Some parts of the volcanic formations contain secondary mineral products created by alteration of the original materials after their original deposition and consolidation. Some alteration has resulted from reactions with groundwater, and the types of new mineral substances found can differ based on occurrence below or above the water table. Alteration products such as clay minerals and zeolites occur in several parts of the volcanic sequence; in some places, in-filling with zeolites has reduced the porosity and thus affected hydrologic properties. In most of the formations, contacts between vitric and devitrified layers are commonly marked by an interval containing clay or zeolite alteration minerals. A notable example is the interval, as much as several meters thick, where glassy rock at the base of the Topopah Spring Tuff (the basal vitrophyre) is in contact with the overlying nonlithophysal zone; this interval of alteration occurs in most boreholes in the vicinity of the proposed site. Subtle differences in geochemical conditions are believed to have given rise locally over short distances to some unusual zeolites. One in particular is the fibrous zeolite erionite, which is a potential human health hazard (see Section 3.1.8). Data from rock samples show that in the potential repository horizon erionite, if it occurs, is either in the altered zone immediately above the Topopah Spring lower vitrophyre or in the moderately welded zone underlying this vitrophyre. It has also been identified in the lower Tiva Canyon Tuff (DOE 1998a, Volume 1, page 2-25).

Figure 3-7 is a geologic map that shows the surficial distribution of Tertiary volcanic units and younger surficial deposits in the vicinity of the proposed site. Figure 3-8 is a vertical cross-section through the southern part of this area that shows the subsurface expression of the mapped units, including structural aspects (east-dipping rock units and predominantly west-dipping normal faults). Volcanic rocks younger than the Tertiary units occur locally at and in the Yucca Mountain vicinity but are of limited extent (Figure 3-5). They represent such relatively quiet, nonexplosive eruptions of basaltic materials as lava flows and cinder cones. Examples include the lava flows that cap Skull and Little Skull Mountains at the south and southeast margins of Jackass Flats, a basalt ridge that forms the southern boundary of Crater Flat, and a basaltic dike dated at 10 million years that intrudes in the northern part of the Solitario Canyon fault, which bounds the west flank of Yucca Mountain. A north-trending series of cinder cones and lava flows on the southeast side of Crater Flat has been dated at 3.7 million years, and in the center of Crater Flat a series of four northeast-trending cinder cones (Qbo in Figure 3-5) has been dated at about 1 million years. The youngest basaltic center is the Lathrop Wells center, which is a single cone estimated to be 75,000 years old.

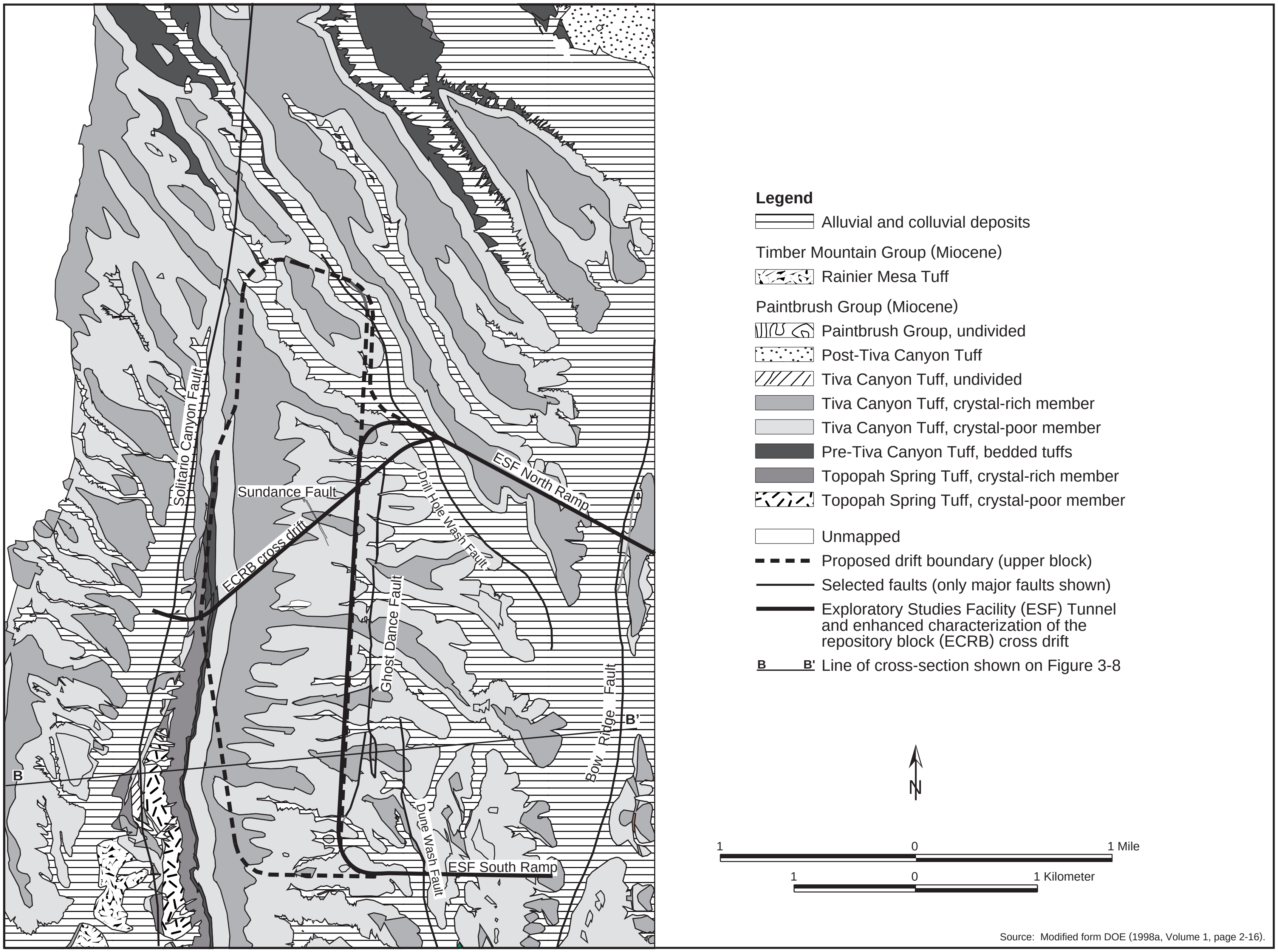
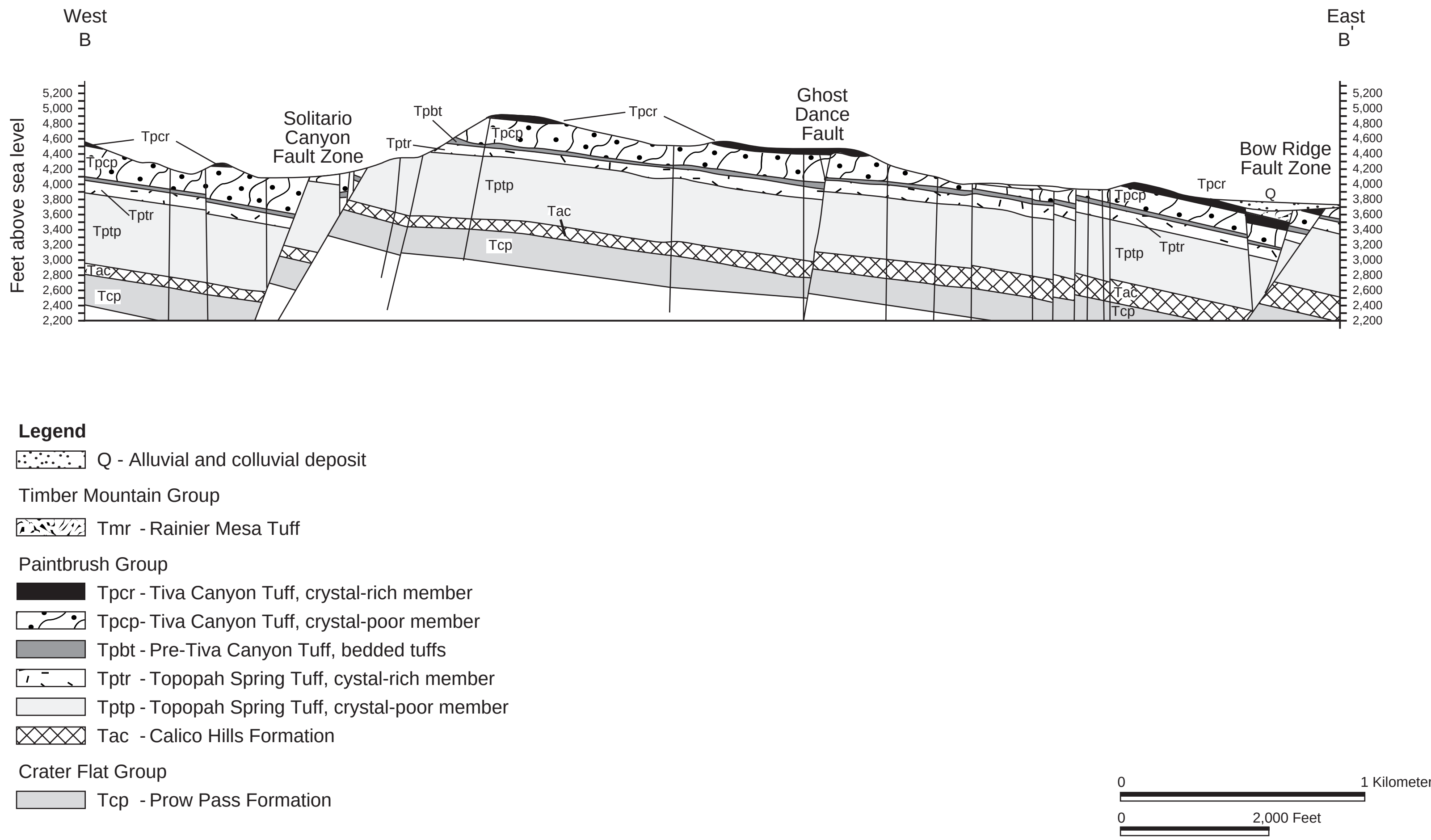



**Figure 3-7.** General bedrock geology of the proposed repository Central Block Area.




Note: Line of cross-section indicated on Figure 3-7. Faults consistent with Figure 3-10.

Source: Modified from DOE (1998a, Volume 1, page 2-17).

**Figure 3-8.** Simplified geologic cross-section of Yucca Mountain, west to east.

The youngest stratigraphic units at Yucca Mountain are the predominantly unconsolidated surficial deposits of late Tertiary and Quaternary age. They are shown in Figure 3-7 as alluvium (material such as sand, silt, or clay deposited on land by water) and colluvium (loose earth material that has accumulated at the base of a hill through the action of gravity) but have been classified in more detail as stream (alluvial) deposits, hillslope (colluvial) deposits, spring deposits, and windblown (eolian) deposits (TRW 1998a, pages 3.4-1 to 3.4-33). Most Quaternary units exposed at the surface were deposited during the last 100,000 years (DOE 1998a, Volume 1, page 2-26). The bulk of these consist of alluvium deposited by intermittent streams that transported rock debris from hillslopes to adjacent washes and valleys.

### *Selection of Repository Host Rock*

Selection of the Topopah Spring tuff as the repository host rock was based on several considerations, which include (1) depth below the ground surface sufficient to protect nuclear waste from exposure to the environment, (2) extent and characteristics of the host rock, (3) location of faults that could adversely affect the stability of underground openings or act as pathways for water flow that could eventually lead to radionuclide release, and (4) location of groundwater in relation to the proposed repository (TRW 1993, pages 5-99 to 5-101).

DOE selected the middle to lower portion of the Topopah Spring tuff as the potential repository horizon. The rock is strongly welded with variable fracture density and void space; experience gained from the excavation of the Exploratory Studies Facility shows the capability to construct stable openings in this rock. Thermal and mechanical properties of this section of rock should enable it to accommodate the range of temperatures anticipated (thermal properties will not be affected greatly by construction and operation, as compared to postemplacement), and the identified repository volume is between major faults. Finally, the selected repository horizon is well above the present groundwater table. Based on geologic evidence the water table under Yucca Mountain has not been more than about 100 meters (330 feet) higher than its present level in the past several hundred thousand years; at such levels the water table would still be about 100 to 200 meters (330 to 660 feet) below the selected repository horizon (DOE 1998a, Volume 1, page 2-24). Section 3.1.4 discusses the water table level further.

### *Potential for Volcanism at the Yucca Mountain Site*

DOE has performed extensive investigations to determine the ages and nature of the volcanic episodes that produced the rocks described above (see Chapter 5). The rocks that form the southwestern Nevada volcanic field, characterized by large-volume silicic ash flows (including the host rock for the proposed repository), were erupted during a period of intense tectonic activity associated with active geologic faulting (Sawyer et al. 1994, all). The volcanism that produced these ash flows is complete and, based on the geology of similar volcanic systems in the Great Basin, no additional large-volume silicic activity is likely.

Basaltic volcanism in the Yucca Mountain region began about 11 million years ago as silicic eruptions waned and continued as recently as about 75,000 years ago (TRW 1998a, pages 3.2-18 and 3.2-19). Basaltic volcanic events were much smaller in magnitude and less explosive than the events that produced the ash flows mentioned above. Typical products are the small volcanoes or cinder cones and associated lava flows in Crater Flat (about 1 million years old) and the Lathrop Wells volcano (possibly as young as 75,000 years).

Differing views on the likelihood of volcanism near Yucca Mountain result from uncertainties in the hazard assessment. To address these uncertainties, DOE has performed analyses, conducted extensive volcanic hazard assessments, considered alternative interpretations of the geologic data, and consulted with recognized experts, representing other Federal agencies (for example, the U.S. Geological Survey), national laboratories, and universities (for example, the University of Nevada and Stanford University). A panel of 10 scientists with expertise in volcanism reviewed the extensive information on volcanic activity in the Yucca Mountain vicinity and assessed the likelihood that future volcanic activity could occur at or in the vicinity of the repository.

The probability of basaltic lava intruding into the repository is expressed as the annual probability that a volcanic event would disrupt (intersect) a repository, given that a volcanic event would occur during the period of concern. In 1995 and 1996, DOE convened the panel of recognized experts representing other Federal agencies (for example, the U.S. Geological Survey, national laboratories) and universities (for example, the University of Nevada and Stanford University) to assess uncertainties associated with the data and models used to evaluate the potential for disruption of the potential Yucca Mountain Repository by a volcanic intrusion (dike) (Geomatrix and TRW 1996, all). The panel estimated the probability of a dike disrupting the repository during the first 10,000 years after closure to be 1 chance in 7,000.

#### 3.1.3.2 Geologic Structure

Geologic structures (folds, faults, etc.) are features that result from deformation to rocks after their original formation. The present-day geologic structure of the Great Basin, including the Yucca Mountain region, is the cumulative product of multiple episodes of deformation caused by both compression and extension (stretching) of the Earth’s crust.

Major crustal compression occurred in the Great Basin between about 350 million and 50 million years ago, which resulted in older rocks being thrust over younger rocks for great distances (for example, thrust faults) to produce mountains. During the last 15 million years, crustal extension has resulted in the pattern of elongated mountain ranges and intervening basins. Crustal extension has resulted in vertical, lateral, and oblique movements (Figure 3-9). By about 11.5 million years ago the present mountains and valleys were well developed (Scott and Bonk 1984, all; Day et al. 1996, all).

Figure 3-7 shows the bedrock geology at the Yucca Mountain site and Figure 3-8 shows geologic structure. Figure 3-10 shows the surface traces of faults and their characteristic northerly alignment.

The crustal extension during the last 15 million years fractured the crust along the generally north-trending normal faults. Some of the crustal blocks were downdropped and tilted by movement along their bounding faults (called block-bounding faults). The estimated total displacement along the major north-trending block-bounding faults during the last 12 million years ranges from less than 100 meters (330 feet) to as much as 600 meters (2,000 feet).

The total estimated displacement along the most active north-trending block-bounding faults in the Yucca Mountain region during the past 1.6 million years is less than 50 meters (165 feet) (Simonds et al. 1995, all). During the last 730,000 years the total displacement of north-trending block bounding faults has been as much as 6 meters (20 feet). However, during the past 128,000 years the typical total displacement has been about 1 to 2.5 meters (about 3.3 to 8 feet).

Table 3-8 lists the characteristics of the faults that are important to an understanding of seismic hazards to the potential repository. The Solitario Canyon fault along the west side of Yucca Mountain is the major block-bounding fault. The proposed repository has been configured so that there would be no block-bounding faults in the emplacement zone.

Between the major north-trending, block-bounding faults are many subsidiary northwest-trending faults with smaller displacements (Scott and Bonk 1984, all). There is no clear evidence that displacements have occurred along these subsidiary faults during the last 1.6 million years (Simonds et al. 1995, all). One short northwest-trending subsidiary fault, called the Sundance fault, transects the potential repository area (Figure 3-10). In addition, there is one intrablock fault, called the Ghost Dance fault, in the area of

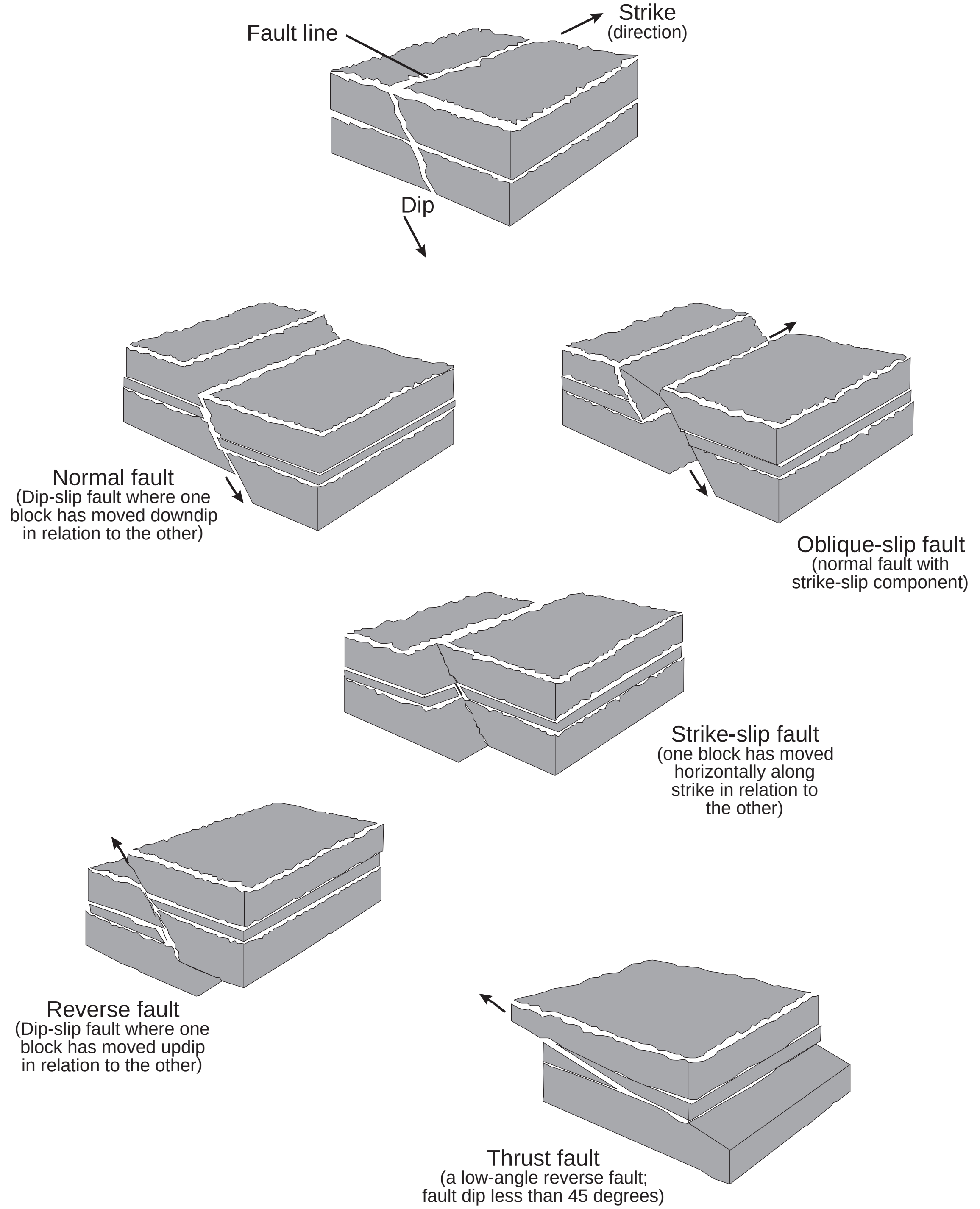



**Figure 3-9.** Types of geologic faults.

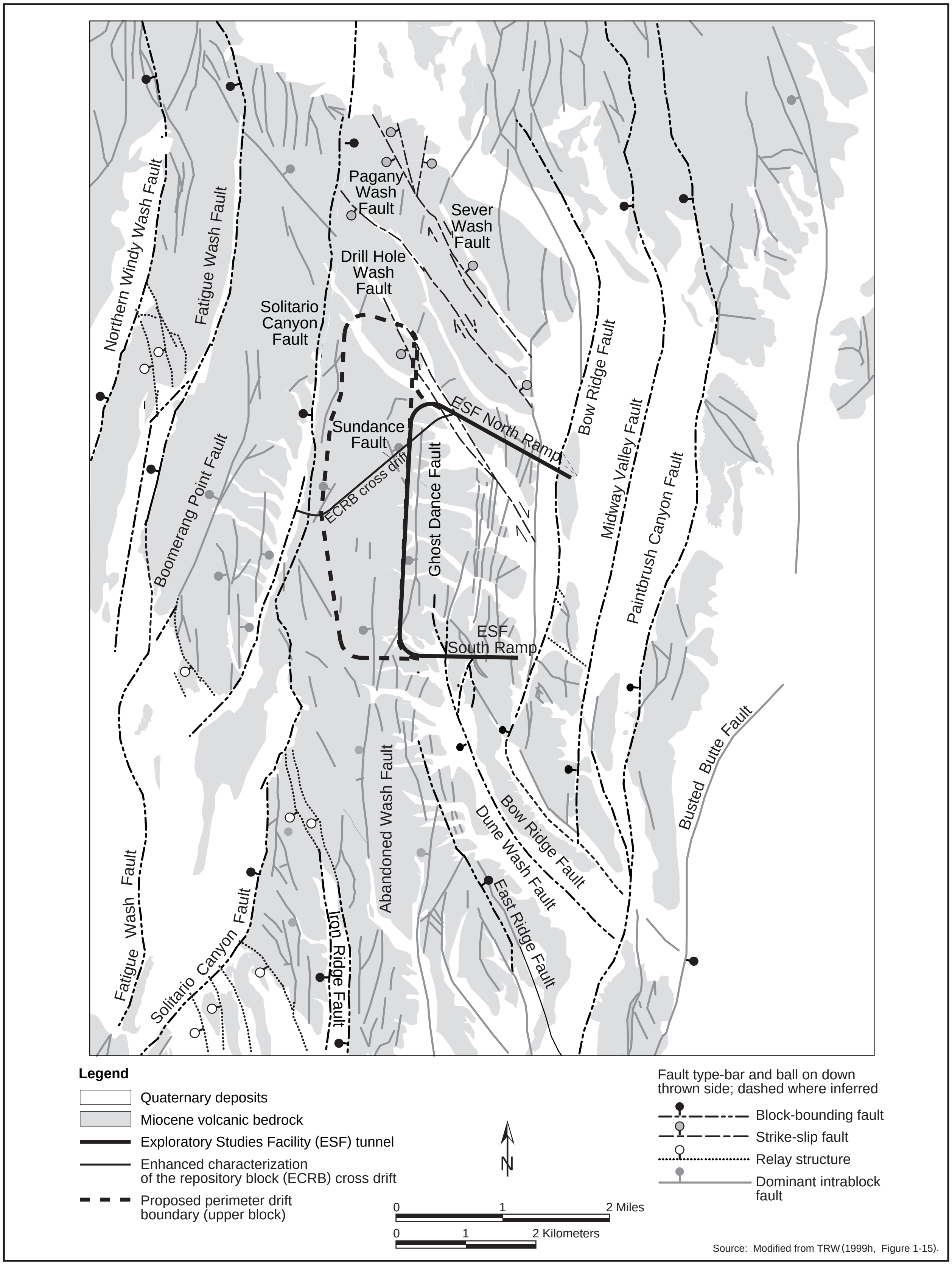



**Figure 3-10.** Mapped faults at Yucca Mountain and in the Yucca Mountain vicinity.

**Table 3-8.** Characteristics of major faults at Yucca Mountain.[a]

| Fault | Surface features | Evidence of late Quaternary displacement | Quaternary displacement (past 1.6 million years) | Total displacement; type of movement | Fault length (kilometers)[b] and dip |
|---|---|---|---|---|---|
| Windy Wash fault[c] | East-facing fault-line scarps in alluvium; bedrock-alluvium fault contacts; merges with Fatigue Wash fault. | Two trenches show multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium. | 1 meter[d] in late Quaternary; < 0.1 meter during past 10,000 years. | Increases southward to 500 meters; dip-slip, west side down. | 3 - 25; 61° west. |
| Fatigue Wash fault[c] | Bedrock and alluvial scarps; fault-line scarps, lineaments in alluvium; merges with Fatigue Wash fault. | One trench shows multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium. | 2.2 meters in late Quaternary. | 72 meters; oblique left-lateral, west side down. | 9.5 - 17; 71° west. |
| Solitario Canyon fault[c] | Prominent fault-line scarp; discontinuous fault traces; subtle scarps in alluvium; merges with Stagecoach Road fault. | Nine trenches show multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium. | 1.7 - 2.5 meters in late Quaternary. | Increases southward from 61 meters to > 500 meters; oblique left-lateral, down on east at north end, down on west at south end. | 12.5 - > 21; 68° to 71° west. |
| Ghost Dance fault zone[e] | Bedrock fault in zone of subparallel minor faults and breccia zones. | None | None | Increases southward from 0 - 30 meters; dip-slip, west side down. | 3 - 9; ~vertical. |
| Bow Ridge fault[c] | Fault-line scarp along bedrock/alluvium contact; subtle lineaments; may merge with Paintbrush Canyon fault. | Five trenches show multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium. | 0.5 - 1.3 meters in late Quaternary. | 125 meters; oblique left-lateral, west side down. | 0.8 - 107; 75° west. |
| Midway Valley fault[c] | None, fault located on basis of geophysical evidence. | None | None | 40 - 60 meters; dip-slip, west side down. | 1 - 8 ; west[f] |
| Paintbrush Canyon fault[c] | Bedrock and alluvial faults, scarps, and lineaments; possibly merges with Stagecoach Road fault. | Four trenches and exposures at Busted Butte show multiple ruptures; basalt ash in fault plane; fractures in alluvium. | 1.7 - 2.7 meters (4.6 - 6.3 meters at Busted Butte in last 730,000 years). | 250 - 300 meters; dip-slip and oblique left-lateral, west side down. | 10 - > 26; 75° west. |
| Northwest-trending faults[g] | Bedrock faults with local scarps; most located by drilling and geophysical surveys. | None, with the exception of one trench across Pagany Wash fault showing possible Quaternary displacement. | None (see column to left). | 40 meters right-lateral, 5 - 10 meters vertical. | 2 - 8 per fault; > 70° south. |

a. Source: Modified from TRW (1999h, Table 1-2, pages 1-40 and 1-41).
b. To convert kilometers to miles, multiply by 0.62137.
c. Block-bounding fault.
d. To convert meters to feet, multiply by 3.2808.
e. Intrablock fault.
f. The dip and direction of this fault are uncertain.
g. Subsidiary faults (to be verified).

the proposed repository. The Ghost Dance fault has a near-vertical dip from the surface to the depth of the repository (TRW 1998a, page 3.6-24). This fault crosses the Exploratory Studies Facility tunnel. There is no evidence of Quaternary movement along the Ghost Dance fault (Table 3-8).

DOE identified and described alternative tectonic models to explain the current geologic structure resulting from past tectonic processes and deformation events that have affected the Yucca Mountain site. These models are described in the *Yucca Mountain Site Description* (TRW 1998a, Section 3.3), and were considered by the experts in the Probabilistic Seismic Hazard Analysis (USGS 1998, all) discussed below. Computer models provide a means of integrating data on volcanism, deposition, and fault movement, and include a representation of the existing geologic structures and the processes that operate at depth. Tectonic models provide a basis for evaluating the processes and events that could occur in the future and potentially affect the performance of a repository. The DOE hazard assessments used models that are supported by data.

### 3.1.3.3 Modern Seismic Activity

DOE has monitored seismic activity at the Nevada Test Site since 1978. The epicenters of many earthquakes that the Southern Great Basin Seismic Network has located within 20 kilometers (12 miles) of Yucca Mountain do not correlate with mapped surface traces of Quaternary faults. This lack of correlation is a common feature of earthquakes, particularly those of smaller magnitude, in the Great Basin and elsewhere. Earthquakes in the Yucca Mountain region have focal depths (the point of origin of an earthquake below the ground surface) ranging from near-surface to about 15 kilometers (9 miles). The earthquake focal mechanisms are strike-slip to normal oblique-slip along moderately to steeply dipping fault surfaces. These focal mechanisms indicate the nature of the fault planes on which the earthquakes occur, as shown in Figure 3-9.

The largest recorded historic earthquake within 50 kilometers (30 miles) of Yucca Mountain was the Little Skull Mountain earthquake in 1992, which had a Richter magnitude of 5.6. This seismic event occurred about 20 kilometers (12 miles) southeast of Yucca Mountain, about a day after the magnitude 7.3 earthquake at Landers, California, 300 kilometers (190 miles) south-southeast of Yucca Mountain. The Little Skull Mountain event caused no damage at Yucca Mountain, although some damage occurred at the Field Office Center in Jackass Flats about 5 kilometers (3 miles) north of the epicenter.

#### *Seismic Hazard*

DOE based the design ground motion and fault displacement that could be associated with future earthquakes at Yucca Mountain on the record of historic earthquakes in the Great Basin, evaluation of prehistoric earthquakes based on investigations (trenching and detailed mapping) of the faults at Yucca Mountain, and observation of ground motions associated with modern earthquakes using the Southern Great Basin Seismic Network.

Experts have evaluated site data and other relevant information (including differing models) to assess where and how often future earthquakes will occur, how large they will be, how much offset will occur at the Earth's surface, and how ground motion will diminish as a function of distance. Two panels of scientific experts conducted the Probabilistic Seismic Hazard Analysis (USGS 1998, all); one panel characterized sources of future earthquakes and their potential for surface fault displacement and the second addressed ground motion for the Yucca Mountain region. The results of this analysis are hazard curves that show the ground motions and potential fault displacements plotted with annual frequency of being exceeded. These are used to determine the design-basis ground motions and to assess the postclosure performance of the site.

The expert assessments indicate that geologic fault displacement hazard is generally low. For locations not on a major block-bounding fault, displacements greater than 0.1 centimeter (0.04 inch) will be exceeded an average of less than once in 100,000 years, whereas the mean displacements that are likely to be exceeded on the block-bounding Bow Ridge and Solitario Canyon faults are 7.8 and 32 centimeters (3.1 and 13 inches), respectively. Mitigating potential fault displacement effects would involve avoiding faults in laying out repository facilities.

Ground motion studies have investigated the level of shaking produced at Yucca Mountain by both local and regional earthquakes, and have estimated expected ground motion from hypothetical earthquakes. These predictions of probable ground motion amplitudes and frequencies support preliminary design requirements (the Exploratory Studies Facility), and future studies will provide additional site-specific information on soil and rock properties that will enable refinement of preliminary results and facilitate design analyses to mitigate seismic risk to a potential repository (DOE 1998a, Volume 1, pages 2-86 and 2-87).

The seismic design basis for the repository specifies that structures, systems, and components important to safety should be able to withstand the horizontal motion from an earthquake with a return frequency of once in 10,000 years (annual probability of occurrence of 0.0001) (Kappes 1998, page VII-3). A recent comprehensive evaluation of the seismic hazards associated with the site of the proposed repository (USGS 1998, Figure 7-4) concluded that a 0.0001-per-year earthquake would produce peak horizontal accelerations at a reference rock site at Yucca Mountain of about 0.53*g* (mean value). DOE needs to complete additional investigations of ground motion site effects before it can produce the final seismic design basis for the surface facilities.

A recent study published in *Science* magazine (Wernicke et al. 1998, all) claims that the crustal strain rates in the Yucca Mountain area are at least an order of magnitude higher than would be predicted from the Quaternary volcanic and tectonic history of the area. If higher strain rates are present, the potential volcanic and seismic hazards would be underestimated on the basis of the long-term geologic record.

As part of the Yucca Mountain site characterization activities, DOE established a 13-station, 50-kilometer (30-mile), geodetic array, centered on Yucca Mountain, and conducted surveys in 1983, 1984, and 1993. As interpreted by Savage et al. (1994, all), the surveys indicated no large strain accumulation and thus do not support the claims in Wernicke et al. (1998, all). The Yucca Mountain array was resurveyed in 1998 (Savage, Svarc, and Prescott 1998, all). After correction for deformation associated with the Little Skull Mountain earthquake, the data continue to indicate a strain rate about an order of magnitude lower than that reported by Wernicke et al. (1998, all).

DOE is continuing to monitor crustal strain in the Yucca Mountain region to determine if it can confirm the results of Wernicke et al. (1998, all). Through the University of Nevada, DOE is supporting continued monitoring by Dr. Wernicke. If the higher crustal strain rates are confirmed, DOE will reassess the volcanic and seismic hazard at Yucca Mountain.

### 3.1.3.4 Mineral and Energy Resources

The southern Great Basin contains valuable or potentially valuable mineral and energy resources, including deposits with past or current production of gold, silver, mercury, base metals, and uranium. The proximity of known deposits and the identification of similar geologic features at Yucca Mountain have led some investigators to propose that the analyzed Yucca Mountain land withdrawal area (see Figure 3-2) could have the potential for mineral resources (Weiss, Noble, and Larson 1996, page 5-26).

DOE site investigations included evaluation of the potential for mineral and energy resources in the analyzed withdrawal area because the presence of such resources could lead to exploration and inadvertent human intrusion (see Chapter 5). The *Yucca Mountain Site Description* (TRW 1998a, Section 3.11) describes results of investigations that address relevant natural resources. Site characterization investigators identified no economic deposits of base or precious metals, industrial rocks or minerals, and energy resources, based on present use, extraction technology, and economic value of the resources. DOE believes the potential for economically useful mineral or energy resources in the analyzed Yucca Mountain withdrawal area is low.

### 3.1.4 HYDROLOGY

This section describes the current hydrologic conditions in the Yucca Mountain region in terms of surface-water and groundwater system characteristics. Unless otherwise specified, the primary references for this section are the *Environmental Baseline File for Water Resources* (TRW 1999i, all) and the *Geology/Hydrology Environmental Baseline File* (TRW 1999h, all). Section 3.1.4.1 describes surface-water conditions, and Section 3.1.4.2 describes groundwater conditions.

The hydrologic system in the Yucca Mountain region is characterized and influenced by a very dry climate, limited surface water [annual average precipitation of about 10 to 25 centimeters (4 to 10 inches) (Section 3.1.2.2), potential evaporation of almost 170 centimeters (66 inches) per year (DOE 1998a, Volume 1, page 2-29)], and deep aquifers. Important characteristics of the hydrologic system include drainages and streambeds, streams, springs, and playa lakes. In addition, water quantity and quality are important characteristics. Yucca Mountain is in the Alkali Flat-Furnace Creek Ranch sub-basin of the larger Death Valley Regional Groundwater Flow System. Death Valley is a terminal hydrologic basin; surface water and groundwater cannot leave except by evapotranspiration (Luckey et al. 1996, page 30). Important characteristics of the groundwater system include recharge zones (areas where water infiltrates from the surface and reaches the saturated zone), discharge points (locations where groundwater reaches the surface), unsaturated zones (the portion of the groundwater system above the water table), saturated zones (the portion of the groundwater system below the water table), and aquifers (water-bearing layers of rock that provide water in usable quantities). In combination, these characteristics define the quantity and quality of the available groundwater. This section also describes groundwater use as part of the system.

**EVAPOTRANSPIRATION**

*Evapotranspiration* is the loss of water by evaporation from the soil and other surfaces, including evaporation of moisture emitted or transpired from plants.

#### 3.1.4.1 Surface Water

##### 3.1.4.1.1 *Regional Surface Drainage*

Yucca Mountain is in the southern Great Basin, which generally lacks permanent streams and other surface-water bodies. The Amargosa River system drains Yucca Mountain and the surrounding areas (Figure 3-11). Although referred to as a river, the Amargosa and its tributaries (the washes that drain to it) are dry along most of their lengths most of the time. Exceptions include short stretches where groundwater discharges to the channel near Beatty, Nevada, south of Tecopa, California, and in southern Death Valley, California (TRW 1998a, page 5.1-4). The river drains an area of about 8,000 square kilometers (3,100 square miles) by the time it reaches Tecopa (Bostic et al. 1997, pages 103 and 112), and its course extends roughly 90 kilometers (56 miles) farther before it ends in the Badwater Basin in Death Valley, which is more than 80 meters (260 feet) below sea level. The nearest surface-water impoundments are Peterson Reservoir, Crystal Reservoir, Lower Crystal Marsh, and Horseshoe

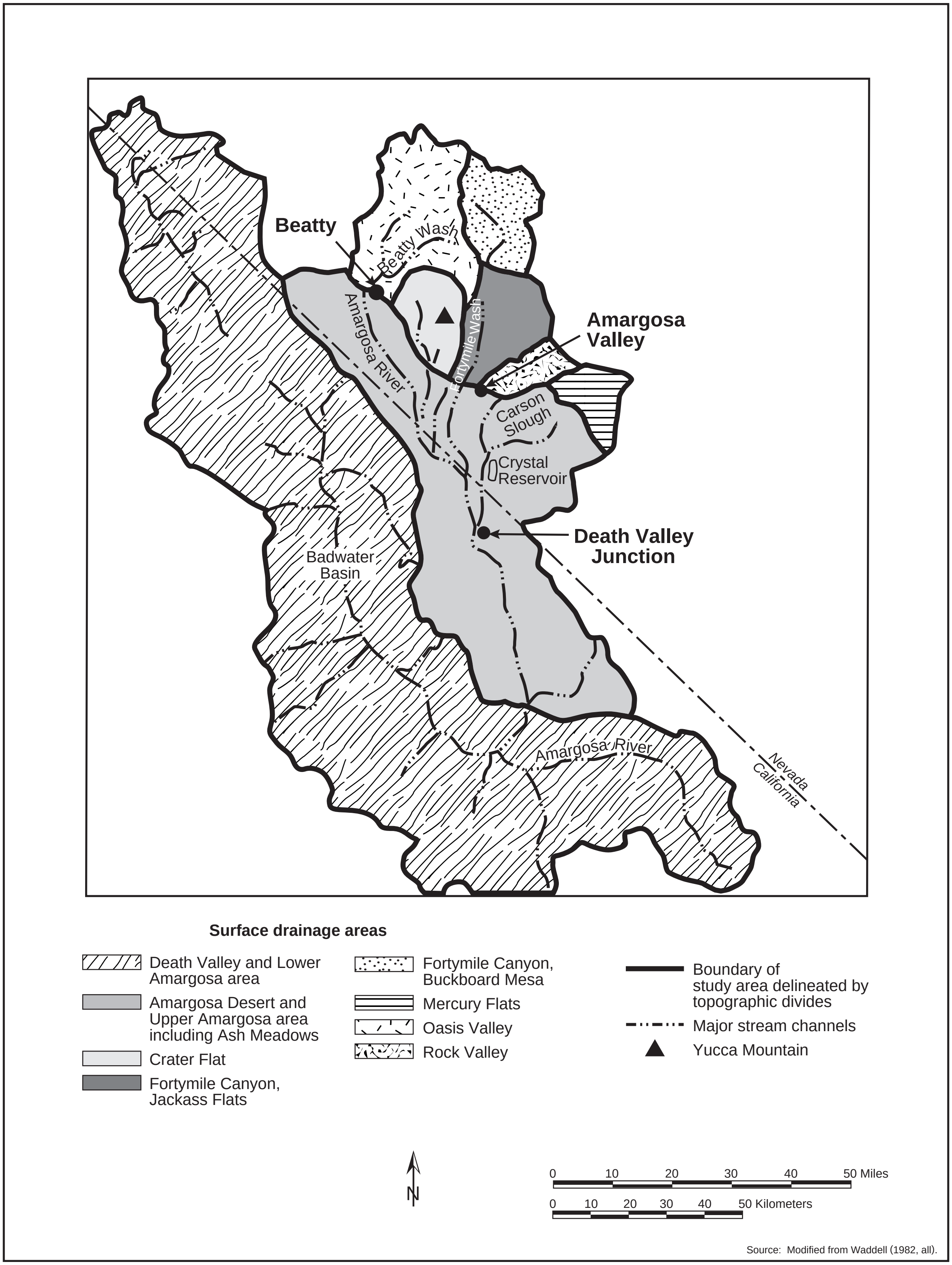



**Figure 3-11.** Surface areas drained by the Amargosa River and its tributaries.

Reservoir. The largest of these is Crystal Reservoir, a manmade impoundment at Ash Meadows, which captures the discharge from several springs in the area and has a capacity of 1.8 million cubic meters (1,500 acre-feet). Crystal Reservoir and other smaller pools in Ash Meadows drain to the Amargosa River through Carson Slough (TRW 1998a, page 5.1-4).

#### 3.1.4.1.2 *Yucca Mountain Surface Drainage*

*Occurrence.* No perennial streams, natural bodies of water, or naturally occurring wetlands occur at Yucca Mountain or in the analyzed land withdrawal area. Fortymile Wash, a major wash that flows to the Amargosa River, drains the eastern side of Yucca Mountain (Figure 3-12). The primary washes draining to Fortymile Wash at Yucca Mountain include Yucca Wash to the north; Drill Hole Wash, which, together with its tributary, Midway Valley Wash, drains most of the repository site; and Busted Butte (Dune) Wash to the south. The western side of Yucca Mountain is drained through Solitario Canyon Wash and Crater Flat, both of which eventually drain to the Amargosa River. In this area, most of the water from summer storms is lost relatively quickly to evapotranspiration unless a storm is intense enough to produce runoff or subsequent storms occur before the water is lost. Thunderstorms in the area can be local and intense, creating runoff in one wash while an adjacent wash receives little or no rain. Evapotranspiration is lower during the winter, when water from precipitation or melting snow has a better chance to result in stream flow.

*Flood Potential.* Although flow in most washes is rare, the area is subject to flash flooding from intense summer thunderstorms or sustained winter precipitation. When it occurs, intense flooding can include mud and debris flows in addition to water runoff (Blanton 1992, page 2). Table 3-9 lists peak discharges for estimated floods along the main washes at Yucca Mountain, including an estimate for a regional maximum flood. In addition to the flood estimates listed in the table, DOE used another estimating method, the *probable maximum flood* methodology [based on American National Standards Institute and American Nuclear Society Standards for Nuclear Facilities (ANS 1992, all)] to generate another maximum flood value for washes adjacent to the existing facilities and operations at the North and South Portals (Blanton 1992, all; Bullard 1992, all). The flood value this method generates, which includes a bulking factor to account for mud and debris, is the most severe reasonably possible for the location under evaluation and is larger than the regional maximum flood listed in Table 3-9. DOE used the probable maximum flood values to predict the areal extent of flooding and to determine if facilities and operations are at risk of flood damage.

> **PREDICTED FLOODS**
>
> **100-year flood:** The magnitude of peak discharge at any point on a river or drainage channel that can be expected to occur or be exceeded, on average, once in 100 years.
>
> **500-year flood:** The magnitude of peak discharge at any point on a river or drainage channel that can be expected to occur or be exceeded, on average, once in 500 years.
>
> **Regional maximum flood:** The magnitude of a peak discharge based on data from extreme floods, in this case, occurring elsewhere in Nevada and in nearby states.
>
> **Probable maximum flood:** The hypothetical peak discharge considered to be the most severe reasonably possible based on a probable maximum precipitation and other factors favorable for runoff.

Figure 3-12 shows the extent of estimated floods calculated for the proposed repository before the construction of the Exploratory Studies Facility. It shows the area that the estimated 100- and 500-year floods would inundate as well as the inundation area for the most conservative (highest) of the estimated maximum floods. As indicated on the figure, the partial or discontinuous inundation areas in Midway

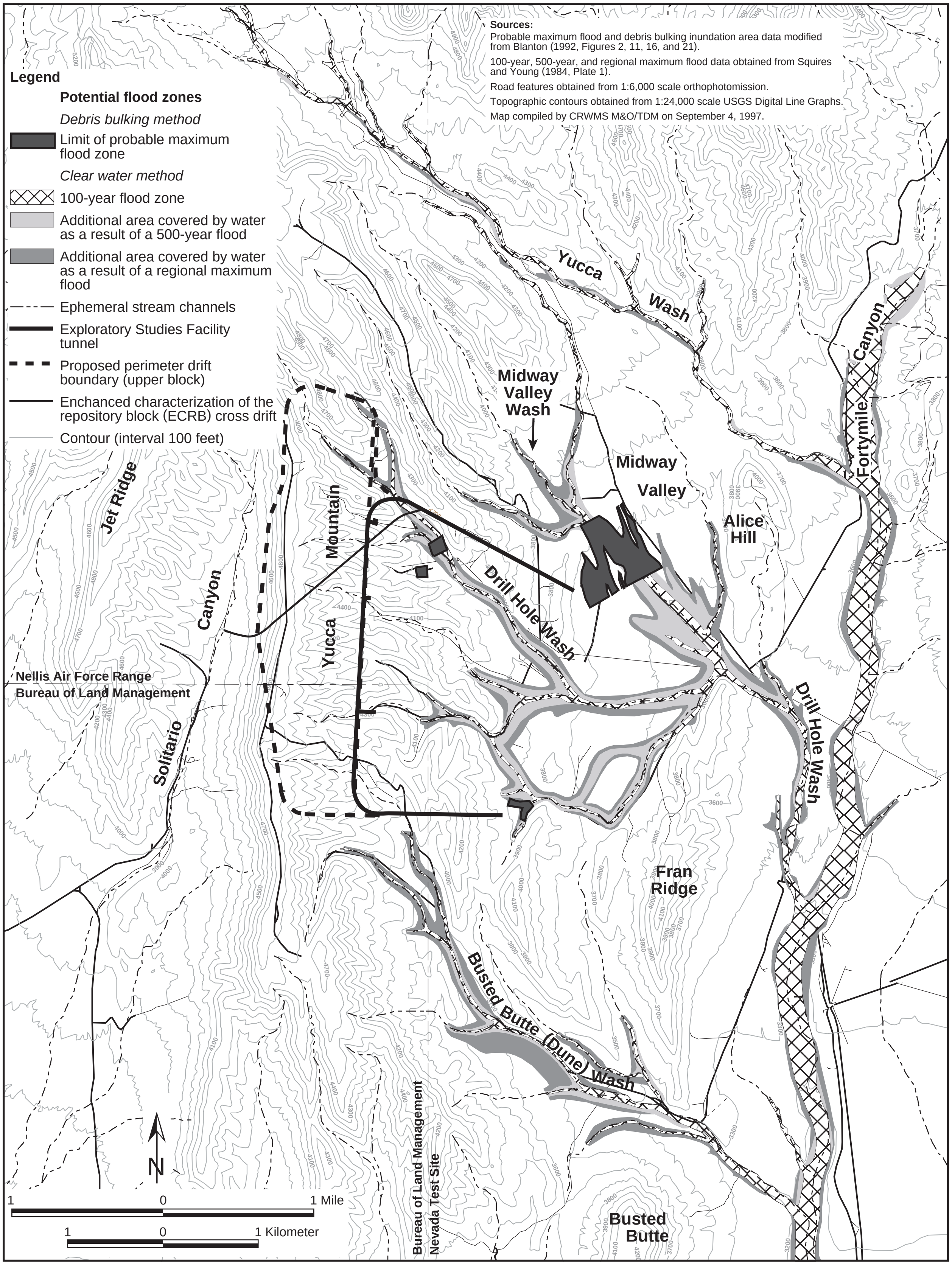



**Figure 3-12.** Site topography and potential flood areas.

**Table 3-9.** Estimated peak discharges along washes at Yucca Mountain.[a]

| Name | Drainage area (square kilometers)[b] | Peak discharge 100-year flood (cubic meters per second)[c] | Peak discharge 500-year flood (cubic meters per second) | Regional maximum flood (cubic meters per second) |
|---|---|---|---|---|
| Fortymile Wash | 810 | 340 | 1,600 | 15,000 |
| Busted Butte (Dune) Wash | 17 | 40 | 180 | 1,200 |
| Drill Hole Wash[d] | 40 | 65 | 280 | 2,400 |
| Yucca Wash | 43 | 68 | 310 | 2,600 |

a. Source: TRW (1999h, page 2-4).
b. To convert square kilometers to square miles, multiply by 0.3861.
c. To convert cubic meters to cubic feet, multiply by 35.314.
d. Includes Midway Valley and Coyote Washes as tributaries—North and South Portal Areas.

Valley Wash and the upper reaches of Drill Hole Wash are based on the probable maximum flood values derived in accordance with guidelines of the American National Standards Institute and American Nuclear Society; for other areas, the most extensive flood zones are based on the regional maximum flood levels listed in Table 3-9. The figure also shows that all floods along Fortymile Wash and Yucca Wash would remain within existing stream channels.

Along Busted Butte (Dune) and Drill Hole Washes, the 500-year flood would exceed stream channels at several places, and the probable maximum flood would inundate broad areas in Midway Valley Wash near the North Portal. In no case, however, would flood levels reach either the North or South Portal opening to the subsurface facilities, which would be at either end of the Exploratory Studies Facility tunnel shown in the figure.

The U.S. Geological Survey (Thomas, Hjalmarson, and Waltemeyer 1997, all) recently published a revised methodology for calculating peak flood discharges in the southwestern United States. A preliminary evaluation indicates that the methodology, if appropriate for use, could result in estimates for 100-year floods that are larger than those listed in Table 3-8 and shown in Figure 3-12. However, the new methodology affects only the 100-year flood estimate, so discharge numbers and expanded inundation lines resulting from its use would be within the bounds set by the 500-year flood.

DOE has prepared a floodplain assessment for the Proposed Action in accordance with the requirements of 10 CFR Part 1022. Appendix L contains the floodplain assessment.

*Surface-Water Quality.* Samples of stream waters in the Yucca Mountain region have been collected and analyzed for their general chemical characteristics. Because surface-water flows are rare and in immediate response to storms, data from sampling events are sparse. Results of the surface-water sample analyses (Table 3-10) bear some resemblance to those from groundwater samples, as discussed in Section 3.1.4.2.2, because both contain bicarbonate as a principal

**Table 3-10.** Chemistry of surface water in the Yucca Mountain region.[a]

| Chemical[b] | Range of chemical composition |
|---|---|
| pH | 6.2 - 8.7 |
| Total dissolved solids (milligrams per liter) | 45.0 - 122 |
| Calcium (milligrams per liter) | 5.3 - 28.0 |
| Magnesium (milligrams per liter) | 0.2 - 4.0 |
| Potassium (milligrams per liter) | 3.0 - 11.0 |
| Sodium (milligrams per liter) | 2.4 - 46.0 |
| Bicarbonate (milligrams per liter) | 32.0 - 340.0 |
| Chloride (milligrams per liter) | 1.3 - 13.0 |
| Sulfate (milligrams per liter) | 2.8 - 26.0 |
| Silica (milligrams per liter) | 4.5 - 48.0 |

a. Source: TRW (1998a, Table 6.2-5a); TRW (1999h, page 2-8).
b. Based on samples from 15 different surface-water locations (12 involve a single sampling event, 2 involve two sampling events, and 1 involves three sampling events) collected from 1984 to 1995. One milligram per liter is equivalent to one part per million.

component. However, in general, the groundwaters have a higher mineral content, suggesting more interaction between rock and water.

### 3.1.4.2 Groundwater

This section discusses groundwater, first on a regional basis and then in the Yucca Mountain vicinity. Many studies have been conducted on the groundwater system under and surrounding Yucca Mountain. These studies provide a firm basis of understanding of the hydrology of the region. However, because groundwater systems are complex and difficult to study, there are differences of opinion among experts related to interpreting available data and describing certain aspects of the Yucca Mountain groundwater system. Therefore, this section also discusses the various views on the groundwater system under Yucca Mountain, where viewpoints differ.

#### 3.1.4.2.1 *Regional Groundwater*

The groundwater flow system of the Death Valley region is very complex, involving many aquifers and confining units. Over distance, these layers vary in their characteristics or even their presence. In some areas confining units allow considerable movement between aquifers; in other areas confining units are sufficiently impermeable to support artesian conditions (where water in a lower aquifer is under pressure in relation to an overlying confining unit; when intersected by a well, the water will rise up the borehole).

In general, the principal water-bearing units of the Death Valley groundwater basin are grouped in three types of saturated hydrogeologic units: basin-fill alluvium (or alluvial aquifer), volcanic aquifers, and carbonate aquifers (TRW 1998a, pages 5.2-4 to 5.2-9). An alluvial aquifer is in a permeable body of sand, silt, gravel, or other detrital material deposited primarily by running water. Volcanic and carbonate aquifers are in permeable units of igneous (of volcanic origin) and carbonate (limestone or dolomite) rock, respectively. The mountainous area that makes up the north portion of the Death Valley hydrologic basin that includes the Yucca Mountain region is often underlain by volcanic rocks and associated volcanic aquifers. The basin areas to the south and southeast of Yucca Mountain contain alluvial aquifers, including those beneath the Amargosa Desert. Carbonate aquifers are regionally extensive and generally occur at large depths below volcanic aquifers or alluvial aquifers (TRW 1998a, page 5.2-8). The discussion of groundwater at Yucca Mountain describes the position of the various aquifers and confining units in relation to each other and to stratigraphic units.

**HYDROGEOLOGIC TERMS**

**Permeability:** Describes the ease or difficulty with which water passes through a given material. Permeable materials allow fluids to pass through readily, while less permeable materials inhibit the flow of fluids.

**Aquifer:** A permeable water-bearing unit of rock or sediment that yields water in a usable quantity to a well or spring.

**Confining unit (or aquitard):** A rock or sediment unit of relatively low permeability that retards the movement of water in or out of adjacent aquifers.

**Inflow:** Sources of water flow into a groundwater system such as surface infiltration (recharge) or contributions from other aquifers.

The alluvial aquifers below the Amargosa Desert receive underflow (groundwater movement from one area to another) from sub-basins to the north as well as from sub-basin areas to the east and, therefore, contain a mixture of water from several different aquifers. For example, the volcanic aquifers beneath Yucca Mountain are believed to provide inflow to the alluvial aquifers beneath the Amargosa Desert. In addition, the springs in the Ash Meadows area are fed in part by the carbonate aquifers (Winograd and Thordarson 1975, page C53) and what is not discharged through the springs flows into groundwater moving through the alluvial aquifers at the southeast end of the Amargosa Desert and then discharges at Alkali Flat (Franklin Lake Playa) or continues as groundwater into Death Valley. There is also evidence that indicates a carbonate aquifer might be present below the volcanic sequence, extending from eastern Yucca Mountain south into the Amargosa Desert (Luckey et al. 1996, pages 32 and 40).

*Basins.* The Death Valley regional groundwater flow system, or basin, covers about 41,000 square kilometers (16,000 square miles) (Harrill, Gates, and Thomas 1988, sheet 1 of 2). Straddling the Nevada-California border, this flow system includes several prominent valleys (Amargosa Desert, Pahrump Valley, and Death Valley) and their separating mountain ranges and extends north to the Kawich Valley, encompassing all of the Nevada Test Site. The major recharge areas are mountains in the east and north portions of the basin. The discharge points are primarily to the south and include the southernmost discharge points in Death Valley and intermediate points such as Ash Meadows in the Amargosa Desert and Alkali Flat. Therefore, flow is primarily to the west or south.

Hydrologic investigations of the Death Valley region date back to the early 1900s, with early work performed primarily by the U.S. Geological Survey (D'Agnese et al. 1997, page 4). More recently, studies by both the U.S. Geological Survey and the State of Nevada have included efforts to collect and compile water-level data from regional wells (TRW 1998a, pages 5.2-17 to 5.2-21). DOE has collected groundwater-level data from wells at Yucca Mountain and in neighboring areas on a routine basis since 1983, and has used the levels to which water rises in these wells—called the *potentiometric surface*—to map the slope of the groundwater surface and to determine the direction of flow. Based on these and other data, groundwater in aquifers below Yucca Mountain and in the surrounding region flows generally south toward discharge areas in the Amargosa Desert and Death Valley (Figure 3-13). The area around Yucca Mountain is in the central portion of the regional groundwater basin, and this portion has three sub-basins: (1) Ash Meadows, (2) Alkali Flat-Furnace Creek Ranch, and (3) Pahute Mesa-Oasis Valley (Rush 1970, pages 10 and 11; Waddell 1982, pages 13 to 20; Luckey et al. 1996, pages 28-30; and D'Agnese et al. 1997, page 65). The aquifers below Yucca Mountain have been included in the Alkali Flat-Furnace Creek Ranch sub-basin because of evidence that the groundwater discharges mainly at Alkali Flat (Franklin Lake Playa) and potentially to the Furnace Creek Wash area of Death Valley.

The Ash Meadows sub-basin is the easternmost of the three sub-basins that make up the Central Death Valley subregion. It underlies eastern portions of the Nevada Test Site (Yucca Flat, Frenchman Flat, Mercury Valley, Rock Valley), parts of Shoshone Mountain, Rainier Mesa to the north, and the Ash Meadows area of the Amargosa Desert in the south. Inflow is principally from the Spring Mountains, Pahranagat Range, Sheep Range, and Pahranagat Valley in the eastern portion of the sub-basin (D'Agnese et al. 1997, pages 67 and 68). Outflow is basically in the form of discharge to the surface and underflow to the lower portion of the Alkali Flat-Furnace Creek Ranch sub-basin. The primary discharge point for this sub-basin is Ash Meadows, where springs occur in a line along a major fault. Estimates of discharge at Ash Meadows range from 21 million to 37 million cubic meters (17,000 to 30,000 acre-feet) per year (Walker and Eakin 1963, page 24; D'Agnese et al. 1997, page 46).

The Pahute Mesa-Oasis Valley sub-basin includes the western portion of Pahute Mesa, Gold Flat, and Oasis Valley. Recharge comes primarily from the north at Black Mountain, Quartz Mountain, and Pahute Mesa, and along the Amargosa River and its tributaries. Subsurface outflow is into the Amargosa Desert

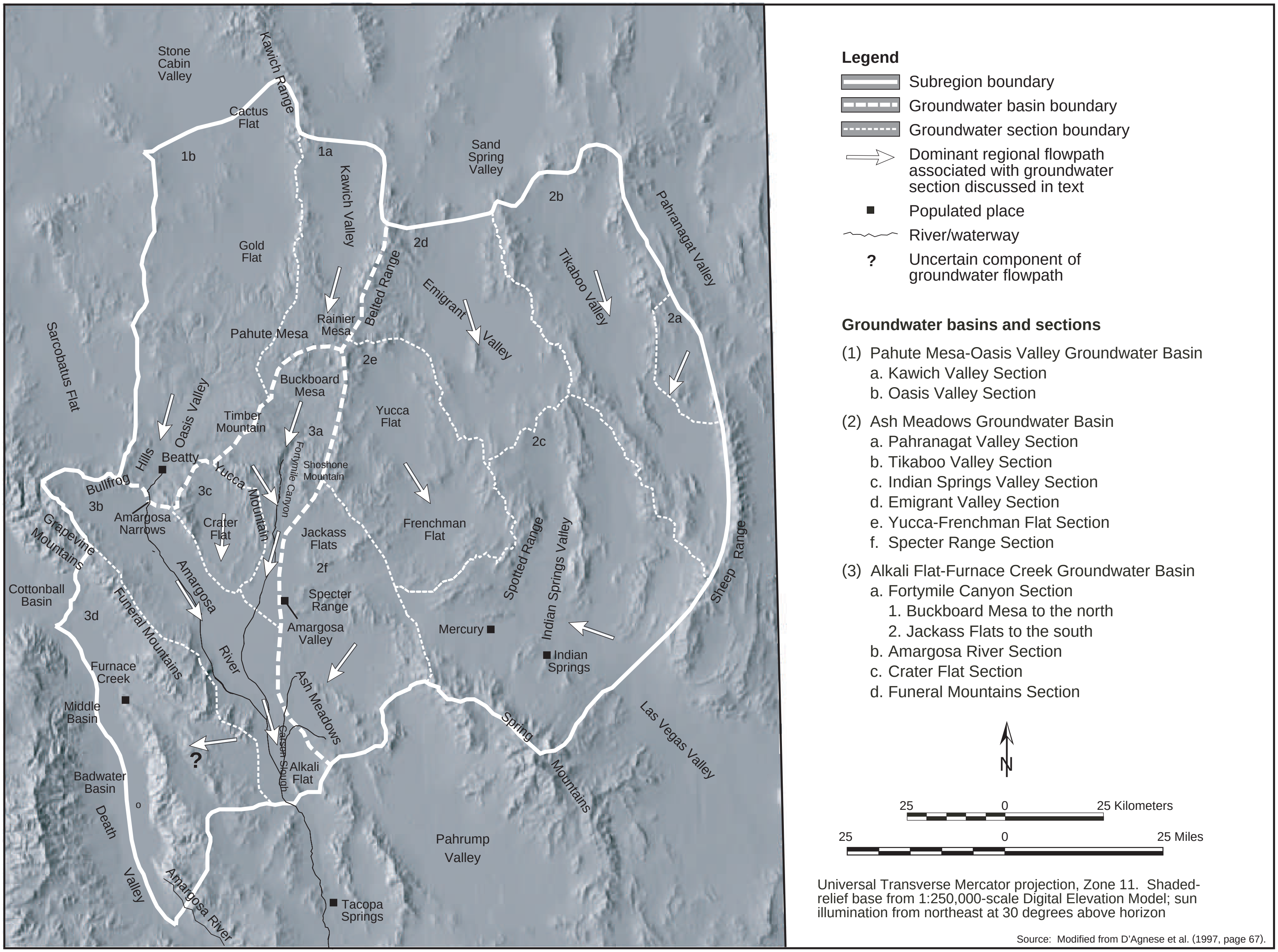



**Figure 3-13.** Groundwater basins and sections of the Central Death Valley subregion.

of the Alkali Flat-Furnace Creek Ranch sub-basin, and has been estimated at about 0.49 million cubic meters (400 acre-feet) per year (Malmberg and Eakin 1962, page 26).

The Alkali Flat-Furnace Creek Ranch sub-basin is bordered on the northwest by the Pahute Mesa-Oasis Valley sub-basin and on the east by the Ash Meadows sub-basin. This sub-basin includes portions of the Nevada Test Site (parts of Rainier Mesa, Pahute Mesa, and Buckboard Mesa to the north, Shoshone Mountain, Yucca Mountain, and Jackass Flats in the southern half), Crater Flat in the west, and part of Death Valley and the central part of the Amargosa Desert in the south (D'Agnese et al. 1997, pages 67 to 69).

In the immediate vicinity of Yucca Mountain, sources of recharge to the groundwater include Fortymile Wash and precipitation that infiltrates the surface. However, these local sources are not among the primary sources of recharge in the region that makes up the Alkali Flat-Furnace Creek Ranch sub-basin. The primary sources of surface recharge in this region are infiltration on Pahute Mesa, Timber Mountain, and Shoshone Mountain to the north, and the Grapevine and Funeral Mountains to the south (D'Agnese et al. 1997, page 68). One numerical model of infiltration for Yucca Mountain used energy- and water-balance calculations to obtain an average infiltration rate of 6.5 millimeters (0.3 inch) a year over the potential repository area for the current climate. This represents about 4 percent of an average annual precipitation rate of about 170 millimeters (7 inches) at Yucca Mountain. In comparison, areas such as Pahute Mesa, Timber Mountain, and Shoshone Mountain receive more precipitation (DOE 1997e, Plate 1) and have higher estimated percentages of precipitation infiltrating deep into the ground and eventually becoming recharge to the aquifer.

Water infiltrating at Yucca Mountain and becoming recharge to the groundwater would join with water in the Jackass Flats hydrographic area. From there the general direction of groundwater flow is to the Amargosa Desert basin and then Death Valley. There have been many estimates of the amount of groundwater moving along this path. One study (NDCNR 1971, page 50) that is still used extensively by the State of Nevada in its groundwater planning efforts estimated annual groundwater movement of 10 million cubic meters (8,100 acre-feet) from the Jackass Flats basin to the Amargosa Desert basin and 23.4 million cubic meters (19,000 acre-feet) from the Amargosa Desert basin to Death Valley. DOE studies indicate that the quantity of water that might move through a repository area of 10 square kilometers (2,500 acres) under the low thermal load, assuming 6.5 millimeters (0.3 inch) of infiltration per year, would be about 0.3 percent of the estimated 23.4 million cubic meters (19,000 acre-feet) that moves from the Amargosa Desert to Death Valley on an annual basis.

As water in the Alkali Flat-Furnace Creek Ranch sub-basin moves south through the Amargosa Desert, eastern portions of the flow are joined by underflow from the Ash Meadows sub-basin (DOE 1998a, Volume 1, pages 2-56 to 2-58). The line of springs formed by discharge from the Ash Meadows sub-basin provides much of the boundary between the two sub-basins. In this area there is a marked decline [about 37 meters (120 feet)] in water table elevation between Ash Meadows and the Amargosa Desert area to the west and south (Dudley and Larson 1976, page 23). This elevation decline indicates that the potential groundwater flow is from Ash Meadows toward the Alkali Flat-Furnace Creek Ranch sub-basin, rather than the opposite. The primary groundwater discharge point for this sub-basin is Alkali Flat (Franklin Lake Playa) as indicated by the potentiometric surface (or slope) of the groundwater and hydrochemical data. A small portion could move toward discharge points in the Furnace Creek area of Death Valley.

Different researchers have speculated that the general flow boundaries of the three sub-basins in the Central Death Valley groundwater basin are in slightly different locations (D'Agnese et al. 1997, page 59). Some studies [for example, Waddell (1982, page 15)] have placed the Kawich Valley area in the Alkali Flat-Furnace Creek Ranch sub-basin rather than in the Pahute Mesa-Oasis Valley sub-basin as shown in Figure 3-13. This uncertainty in general flow boundaries is a reflection of the complex groundwater flow systems in the Death Valley region. The differing interpretations of the sub-basin boundaries do not, however, disagree on the relative location of the aquifers below Yucca Mountain, which are consistently placed in the central Alkali Flat-Furnace Creek Ranch sub-basin.

*Use.* Table 3-11 summarizes groundwater use in the Yucca Mountain region. The hydrographic areas listed in the table are basically a finer division of the basins and sub-basins discussed above; their locations are consistent with the hydrographic areas shown in Figure 3-13. DOE has been using small amounts of Jackass Flats hydrographic area groundwater for Nevada Test Site operations, and Yucca Mountain activities have contributed to water use from this source. Most water use in the Alkali Flat-Furnace Creek sub-basin, however, occurs south of Yucca Mountain, from the Amargosa Desert alluvial aquifer. Between 1985 and 1992, water use in the Amargosa Desert from this aquifer averaged 8.1 million cubic meters (6,600 acre-feet) a year for agriculture, mining, livestock, and domestic purposes. As Table 3-11 indicates, water use averaged about 17.5 million cubic meters (14,000 acre-feet) a year from 1995 through 1997. As listed in Table 3-11, groundwater in the Amargosa Desert is heavily appropriated—at much higher levels than is actually withdrawn. The Ash Meadows area of the Amargosa Desert has restrictions on groundwater withdrawal as a result of a U.S. Supreme Court decision (Cappaert v. United States 1976, all) to protect the water level in Devils Hole.

**Table 3-11.** Perennial yield and water use in the Yucca Mountain region.

| Hydrographic area[a] | Perennial yield[b,c] (acre-feet per year)[d] | Current appropriations[e,c] (acre-feet per year) | Average annual withdrawals 1995-1997 (acre-feet) | Chief uses |
|---|---|---|---|---|
| Jackass Flats (Area 227a) | 880[f] - 4,000 | 500[g] | 340[h] | Nevada Test Site programs and site characterization of Yucca Mountain. Minor amounts of water are also discharged for tests at Yucca Mountain. |
| Crater Flat (Area 229) | 220 - 1,000 | 1,200[i] | 140[j] | Mining, site characterization of Yucca Mountain |
| Amargosa Desert (Area 230) | 24,000 - 34,000 | 27,000 | 14,000[j] | Agriculture, mining, livestock, municipal, wildlife habitat |
| Oasis Valley (Area 228) | 1,000 - 2,000 | 1,700 | N/A[k] | Agriculture, municipal |

a. A specific area in which the State of Nevada allocates and manages the groundwater resources. See Figure 3-17.
b. An estimate of the quantity of groundwater that can be withdrawn annually from a basin without depleting the reservoir.
c. Sources: Thiel (1997, pages 5-12); perennial yield values only, DOE (1996f, pages 4-117 and 4-118).
d. An acre-foot is a commonly used hydrologic measurement of water volume equal to the amount of water that would cover an acre of ground to a depth of 1 foot. To convert acre-feet to cubic meters, multiply by 1,233.49; to convert to gallons, multiply acre-feet by 325,851.
e. The amount of water that the State of Nevada authorizes for use; the amount used might be much less. These appropriations do not cover Federal Reserve Water Rights held by the Nevada Test Site or Air Force.
f. The low estimate for perennial yield from Jackass Flats breaks the quantity down further into 300 acre-feet for the eastern third of the area and 580 acre-feet for the western two-thirds.
g. Area 227a appropriations include about 370 acre-feet for Yucca Mountain characterization activities.
h. Source of Area 227a withdrawals: Bauer et al. (1996, page 702) and Bostic et al. (1997, page 592) for withdrawals from wells J-12 and J-13 at the Nevada Test Site.
i. Area 229 appropriations include temporary mining rights and 61 acre-feet for Yucca Mountain characterization activities.
j. Sources of Area 229 and 230 withdrawals: La Camera, Westenburg, and Locke (1996, page 74) and La Camera and Locke (1997, page 77).
k. N/A = not available.

Table 3-11 lists water volumes (perennial yield, appropriations, and withdrawals) in acre-feet. This unit of volume is common in hydrology and water resource planning. This EIS describes water volumes in both metric (cubic meters) and English (acre-feet) units.

*Groundwater Quality.* The U.S. Geological Survey has accumulated and evaluated almost 90 years of groundwater data for the Yucca Mountain region and, in more recent years, has periodically collected and analyzed groundwater quality samples. A recent sampling effort (Covay 1997, all) looked for a wide range of inorganic and organic constituents, as well as general water quality properties. This effort collected samples from five groundwater sources in the Amargosa Desert region and three from the immediate vicinity of Yucca Mountain (as discussed in Section 3.1.4.2.2). The regional sampling locations included two wells in the central Amargosa Desert, one well in the Ash Meadows area, and two springs along the border between the Alkali Flat-Furnace Creek Ranch sub-basin and the Ash Meadows sub-basin.

**ENVIRONMENTAL PROTECTION AGENCY DRINKING WATER QUALITY STANDARDS**

**Primary standards** are health-based and enforceable for all public drinking water supply systems (including the existing system at the site of the proposed repository).

**Secondary standards** control substances that primarily affect aesthetic qualities (such as taste, odor, and color). They are not Federally enforceable and, if exceeded, would generally not cause health problems.

The U.S. Geological Survey effort compared the regional groundwater quality measurements to the primary and secondary drinking water standards established by the Environmental Protection Agency [EPA 1993, all; see also the Safe Drinking Water Act, as amended, 42 USC 300(f) *et seq.*]. Though drinking water standards are for public water supply systems, it is common to compare results from groundwater sampling and analysis to these standards for an indication of groundwater quality. The findings indicated that the five groundwater sources met primary drinking water standards, but that a few sources exceeded secondary and proposed standards. Specifically, four of the wells exceeded a proposed standard for radon (Section 3.1.8.2 discusses the natural occurrence of radon in the Yucca Mountain region) and one of those four exceeded secondary standards for sulfate and total dissolved solids and a proposed standard for uranium. Overall, however, regional groundwater quality is generally good and consistent with the State of Nevada description that most groundwater aquifers in the State are suitable, or marginally suitable, for most uses (NDWP 1999a, all). Additional water quality data for wells on the Nevada Test Site are available in the *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DOE 1996f, pages 4-124 to 4-126). Section 3.1.4.2.2 discusses radiological parameters, including results from regional sample locations.

### 3.1.4.2.2 *Groundwater at Yucca Mountain*

Groundwater at Yucca Mountain occurs in an unsaturated zone and a saturated zone. This section describes these zones and the characteristics of the groundwater in them.

#### Unsaturated Zone

*Water Occurrence.* The unsaturated zone at Yucca Mountain extends down from the crest of the mountain 500 to 750 meters (about 1,600 to 2,500 feet) to the water table (the upper surface of the saturated zone). The primary emplacement area (the upper block) of the proposed repository would be in the unsaturated zone, between about 175 and 365 meters (570 and 1,200 feet) above the present water table. The excavation of the Exploratory Studies Facility encountered very limited quantities of water, and no dripping water or water in sufficient quantities to collect. Some moist areas were observed during excavations through the Paintbrush nonwelded tuff (Figure 3-14) (Peters 1999, all). Boreholes in the

**SUBSURFACE FORMATIONS CONTAINING WATER**

**Unsaturated zone:** The zone of soil or rock between the land surface and the *water table*.

**Saturated zone:** The region below the *water table* where rock pores and *fractures* are completely saturated with *groundwater*.

**Perched water bodies:** Saturated lenses (thin layers of water) surrounded by unsaturated conditions.

unsaturated zone identified water in the rock matrix, along faults and other fractures, and in isolated saturated zones of perched water (Figure 3-14). The water found in the pores of the rock matrix is chemically different from water found in fractures, perched water, or water in the saturated zone. Perched water in Yucca Mountain occurs where fractured rock overlies rock of low permeability such as unfractured rock, and upslope from faults where permeable or fractured rock lies against less permeable rock and fault fill material. Perched water bodies occur approximately 100 to 200 meters (330 to 660 feet) below the proposed repository horizon (TRW 1998a, page 5.3-236) near the base of the Topopah Spring welded tuff unit (Figure 3-14). Water flow along fractures probably is responsible for recharging the perched water bodies. The apparent age of the perched water based on carbon-14 dating indicates this recharge occurred during the past 6,000 years. Although there are limitations in the use of carbon-14 dating on water (such as knowing the initial activity of carbon-14, estimating sources of losses or gains, and adjusting for postnuclear age contributions), the general conclusion is that the perched water is much too recent to indicate large contributions from pore water in the rock matrix. To learn how recently recharge might have occurred, these dating efforts also looked for the presence of tritium, which would indicate contributions from water affected by atmospheric nuclear weapons tests (after 1952). The results indicate that if tritium has reached the perched water bodies, it is in quantities too small for reliable detection.

*Hydrologic Properties of Rock.* The unsaturated zone at Yucca Mountain consists of small areas of alluvium (clay, mud, sand, silt, gravel, and other detrital matter deposited by running water) and colluvium (unconsolidated slope deposits) at the surface underlain by volcanic rocks, mainly fragmented materials called tuffs that have varying degrees of welding. The hydrologic properties of tuffs vary widely. Some layers of tuff are welded and have low matrix porosities, but many contain fractures that allow water to flow more quickly than through the rock. Other layers, such as nonwelded and bedded tuff, have high matrix porosities but few fractures. Some layers have many small hollow bubble-like structures (called lithophysae) that tend to reduce water flow in the unsaturated zone.

**TYPES OF TUFF**

**Welded tuff** results when the volcanic ash is hot enough to melt together and is further compressed by the weight of overlying materials.

**Non-welded tuff** results when volcanic ash cools in the air sufficiently that it does not melt together, yet later becomes rock through compression.

Rock units defined by a set of hydrologic properties do not necessarily correspond to rock units defined by geologic properties and characteristics. For geologic studies, rocks are generally divided on the basis of characteristics that reflect the rock origin and manner of deposition. Hydrogeologic units, on the other hand, reflect the manner in which water moves through the rock. A stratigraphic unit and a hydrogeologic unit commonly do not represent the same layer of rock. For example, a single stratigraphic unit (such as tuff flow) might have been generated by an igneous or volcanic flow. Because of different cooling rates at different depths, a single volcanic flow unit might have layers with different degrees of welding that cause water to move at different rates. The result of this example is a single stratigraphic.

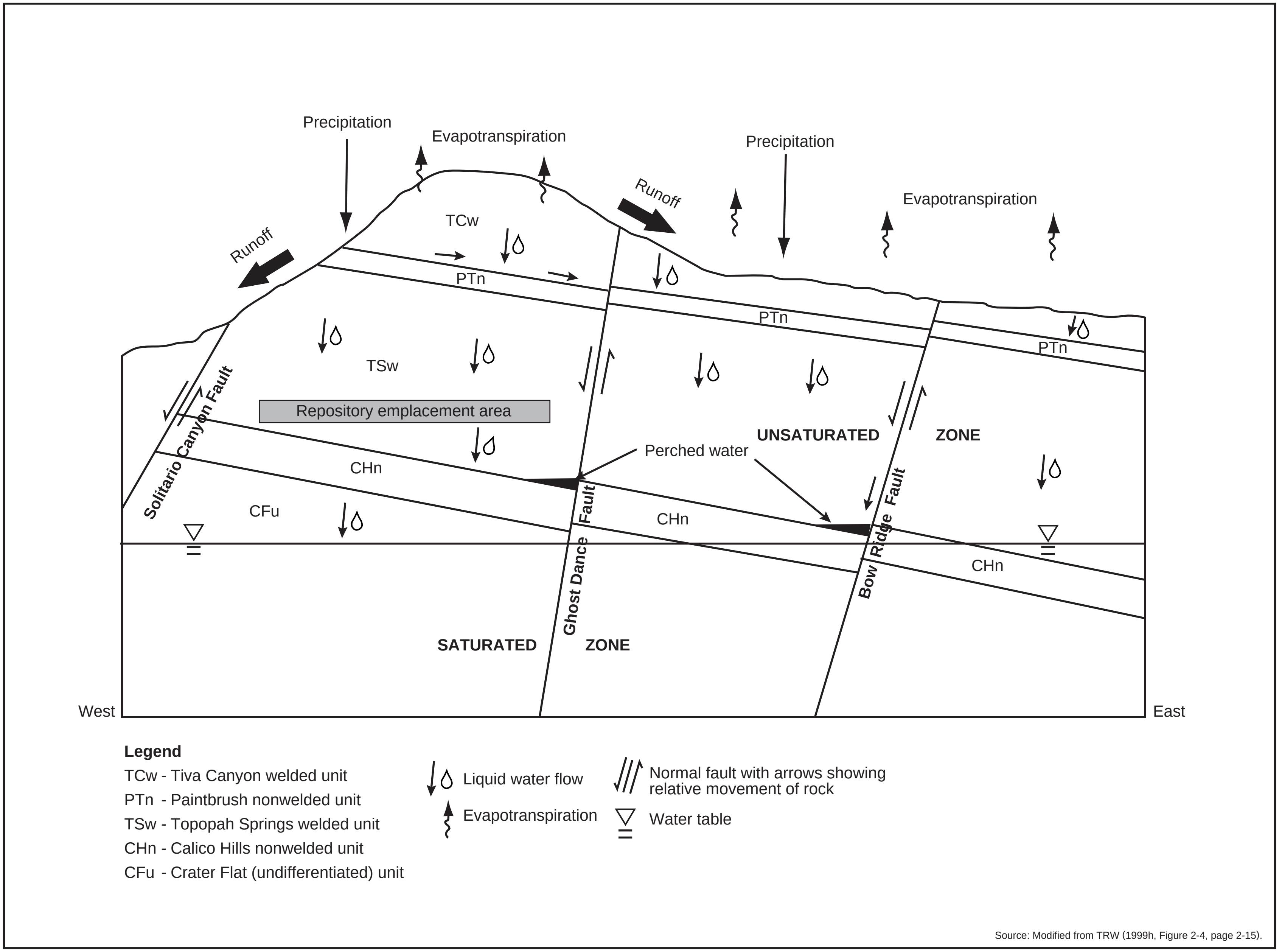



**Figure 3-14.** Conceptual model of water flow at Yucca Mountain.

unit that includes more than one hydrogeologic unit. Further, because the physical processes of water movement are very different under unsaturated conditions than under saturated conditions, the hydrogeologic units defined in the unsaturated zone can differ from those defined when the same rock sequence is saturated. Figure 3-15 shows the relationship between the stratigraphic units discussed in Section 3.1.3 and the hydrogeologic units discussed in this section, including the aquifers and confining units that make up the area's groundwater system. Table 3-12 lists the hydrogeologic units in the unsaturated zone at Yucca Mountain.

**Table 3-12.** Hydrogeologic units in the unsaturated zone at Yucca Mountain.[a]

| Unit and characteristics[b] | Thickness (meters)[c] |
|---|---|
| *Quaternary alluvium/colluvium*<br>Unconsolidated stream deposits beneath valleys and loose slump deposits beneath slopes; porosity and permeability medium to high. | 0 - 30 |
| *Tiva Canyon welded unit (TCw)*<br>Mainly pyroclastic flow tuffs; porosity typically 10 to 30 percent; saturation commonly 50 to 80 percent. | 0 - 150 |
| *Paintbrush nonwelded unit (PTn)*<br>Includes the Yucca Mountain and Pah Canyon Tuffs and uppermost part of the welded Topopah Spring Tuff; porosity generally high, 30 to 60 percent; matrix saturation, 30 to 60 percent. | 20 - 100 |
| *Topopah Spring welded unit (TSw)*<br>Mainly devitrified ash flow tuff; porosity generally low, less than 20 percent, but up to 40 percent in glassy zones; matrix saturation generally greater than 40 percent, commonly greater than 80 percent. | 290 - 360 |
| *Calico Hills nonwelded unit (CHn)*<br>Made up of four subunits, the lower three of which contain zeolites; the unit also includes Prow Pass Tuff (pyroclastic flow) of the Crater Flat Group; porosity variable, 10 to 40 percent; matrix saturation 20 to 90 percent, commonly near 100 percent in zeolitic zones. | 100 - 400 |
| *Crater Flat undifferentiated unit (CFu)*<br>Consists of welded Bullfrog Tuff (stratigraphically above) and nonwelded Tram Tuff (stratigraphically below); is below water table in much of the area, but is unsaturated beneath western part of Yucca Mountain; Bullfrog Tuff has low porosity, less than 20 percent, and high matrix saturation, close to 100 percent; Tram Tuff has porosity 20 to 40 percent; and high matrix saturation. | 0 - 200 |

a. Source: TRW (1999h, pages 2-12 and 2-13).
b. Letters in parentheses are used in Figures 3-14 and 3-15.
c. To convert meters to feet, multiply by 3.2808.

*Water Source and Movement.* When precipitation falls on Yucca Mountain, part leaves as runoff, part evaporates, and part infiltrates the ground. Some of the water that infiltrates the ground eventually evaporates in the arid climate or passes to plants; the remainder percolates into the ground as infiltration. Some of the infiltration remains at shallow levels, some eventually rises to the surface as vapor, and some (called *net infiltration*) moves deeper into the unsaturated zone. The estimated net infiltration for the current climate is 4.5 millimeters (0.2 inch) per year in a study area of about 230 square kilometers (89 square miles) that includes Yucca Mountain and 6.5 millimeters (0.3 inch) per year in the potential repository area (Flint, Hevesi, and Flint 1996, page 91). These are estimates of average net infiltration for fairly large surface areas. Because of the arid climate, the sporadic nature of storms, and the variation in topography, the actual amount of annual infiltration varies widely from year to year and across the area. Net infiltration varies over segments of the larger areas based, in part, on the amount of unconsolidated material present. The estimated net infiltration ranges from zero where alluvium is more than 6 meters (20 feet) thick to 8 centimeters (3 inches) and more where thin alluvium overlies highly permeable bedrock. On a year-to-year basis, the average net infiltration can range from 0 to 2 centimeters (0.8 inch).

| Era | Geologic Age | Stratigraphic unit | Approximate range of thickness (meters) | Hydrogelogic units: Unsaturated | Hydrogelogic units: Saturated | Comments |
|---|---|---|---|---|---|---|
| Cenozoic Era | Quaternary and Tertiary Periods | Alluvium, colluvium, eolian deposits, spring deposits, basalt lavas, lacustrine deposits, playa deposits | 0-30 | QAL, alluvium | QTa, Valley-fill aquifer; QTc, valley-fill confining unit | QAL restricted to stream channels on Yucca Mountain; QTa occurs mainly in Amargosa Desert; major water-supply source |
| | Tertiary Period | Timber Mountain Group Rainier Mesa Tuff | | | | Minor erosional remnants at Yucca Mountain |
| | | Paintbrush Group Tiva Canyon Tuff | 0-150 | TCw Tiva canyon welded unit | | Mainly densely welded; caprock on Yucca Mountain; not known in saturated zone at or near Yucca Mountain |
| | | (bedded tuff)<br>Yucca Mountain Tuff<br>Pah Canyon Tuff | 20-100 | PTn Paintbrush nonwelded unit | | Includes bedded and nonwelded tuffs between basal part of Tiva Canyon Tuff and upper part of Topopah Spring Tuff. |
| | | Topopah Spring Tuff<br>(vitrophyre and non-welded tuffs at base) | 290-360 | TSw Topopah Spring welded unit | uva, Upper volcanic | About 300 meters of densely welded tuff in unsaturated zone; host rock for repository; in saturated zone where downfaulted to east, south, and west of site |
| | | Calico Hills Formation | 100-400 | CHn Calico Hills nonwelded unit | uvc, Upper volcanic confining unit | Mainly nonwelded tuff, with thin rhyolite lavas in northern site area; varies from vitric in southwest site area to zeolitic where near or below water table |
| | | Crater Flat Group Prow Pass Tuff<br>Bullfrog Tuff<br>Tram Tuff | 0-200 | CFu Crater Flat undifferentiated unit | mva Middle volcanic aquifer units | Small occurrence in unsaturated zone; widespread in saturated zone; variably welded ash-flow tuffs and rhyolite lavas; commonly zeolitized; most permeable zones are fracture-controlled |
| | | Unnamed flow breccia Lithic Ridge Tuff | 1,000-2,000 | | mvc, Middle volcanic confining unit | Nonwelded tuff, pervasively zeolitized |
| | | Volcanics of Big Dome | | | lva, Lower volcanic aquifer | Lava flows and welded tuff; not known at Yucca Mountain |
| | (Lower Tertiary?) | Older volcanics | | | lvc, Lower volcanic confining unit | Nonwelded tuff, pervasively zeolitized; tuffaceous sediments in lower part |
| Paleozoic Era | Permian/ Pennsylvanian Periods | Bird Spring Formation Tippipah Limestone | 1,000 ± | | uca, Upper carbonate aquifer | Limited distribution in saturated zone north and east of Yucca Mountain |
| | Mississipian/ Devonian Periods | Eleana Formation<br>(Chainman Shale) | 2,500 ± | | ecu, Eleana confining unit | Argillite (mudstone) and siltstone; occurrence inferred beneath volcanics of northern Yucca Mountain |
| | Devonian Silurian Ordovician Cambrian Periods | Devils Gate Limestone, Nevada Formation, Ely Springs Dolomite, Eureka Quartzite, Pogonip Group, Nopah Formation, Dunderberg Shale, Bonanza King Formation, Upper Carrara Formation | 7,500 ± | | lca, Lower carbonate aquifer | Mainly limestone and dolomite with relatively thin shales and quartzites; major regional aquifer, more than 5 kilometers (3.1 miles) thick |
| | | Lower Carrara Formation | | | zcu, Precambrian confining unit | Dolomite, shale |
| Proterozoic | (Upper Precambrian) | Proterozoic rocks | | | | Quartzite, slate, marble; fractures commonly healed by mineralization |

Source: Modified from TRW (1999h, Figure 2-3, pages 2-10 and 2-11).

**Figure 3-15.** Correlation of generalized stratigraphy with unsaturated and saturated hydrogeologic units in the Yucca Mountain vicinity.

Groundwater movement in the unsaturated zone at Yucca Mountain occurs in the pore space (matrix) of rock units and along faults and fractures of rock units. Water movement through the pore space of rock units is a relatively slow (or stagnant) process compared with flow through faults and fractures. Water movement through faults and fractures is believed to be episodic in nature (occurring at discrete times related to periods of high surface infiltration), is capable of traveling rapidly through rock units, and is the likely source of perched water in the unsaturated zone.

The characteristics of groundwater movement through specific rock units differ based on their hydrogeologic properties. Water that infiltrates into the Tiva Canyon welded unit can often be transported as deep as the underlying Paintbrush nonwelded unit. Due to its high porosity and low fracture density, the Paintbrush unit tends to slow the downward velocity of water flow dramatically in relation to highly fractured units such as the Tiva Canyon unit. However, isotopic (chlorine-36) analysis has identified isolated pathways that provide relatively rapid water movement through the Paintbrush nonwelded unit to the top of the underlying Topopah Springs welded unit where, due to increased fracturing, it has the potential to travel quickly through the unit.

**CHLORINE-36 STUDIES**

These studies use the fact that a very small portion of chlorine in the atmosphere consists of the radioactive isotope chlorine-36. The production of chlorine-36 (caused in part by interactions between argon molecules and high-energy protons and neutrons in the atmosphere) is sufficiently balanced with the rate of its removal as atmospheric fallout that the ratio of chlorine-36 to stable chlorine (chlorine-35) at any given location remains fairly constant in atmospheric salts deposited on land, such as that dissolved in rainwater. Once chlorine is isolated from the surface environment (as when dissolved in water percolating down through the soil and subsurface rocks), subsequent changes in the chlorine-36-to-total-chlorine ratio can be attributed to decay of the chlorine-36 (Levy et al. 1997, page 2) (that is, if the residence times are long enough in relation to the 301,000-year half-life of this radionuclide). Measuring the chlorine-36-to-total-chlorine ratio in underground water or in residues it leaves behind, and knowing what the ratio was at the time of recharge provides a means of estimating the age of the water. In reality, slight variations over time in the atmospheric ratio and the potential for some minor production of chlorine-36 in the subsurface has made the use of this technique for water dating difficult, and its use is still under investigation. However, the atmospheric ratio of chlorine-36 to total chlorine has increased by orders of magnitude as a result of above-ground nuclear testing during the past 50 years. As a consequence, the technique has been very successful in tracing underground water or water residues that originated at the surface within the past 50 years, with the so-called *bomb-pulse signal* indicating very young water.

DOE has used the ratio of chlorine-36 (a naturally occurring isotope) to total chlorine to determine where and when moisture has moved in the unsaturated zone at Yucca Mountain. High enough chlorine-36 ratios indicate waters exposed to very small amounts of fallout associated with above-ground nuclear weapons testing (called bomb-pulse water). The methodology used in these studies is complicated and is still under investigation; however, findings thus far have been valuable in reaching certain conclusions.

Chlorine-36 analyses at Yucca Mountain have identified locations where water has moved fairly rapidly (in several decades) from the surface to the depth of the proposed repository and also where it has moved very slowly (thousands to tens of thousands of years). The chlorine-36 studies included one study that collected 247 rock samples along the 8-kilometer (5-mile) Exploratory Studies Facility tunnel. About 70 percent of the samples were from areas thought to be more likely to show evidence of rapid water movement [that is, areas of broken rock such as faults, fractures, or breccia zones (areas where rock composed of fragments of older rocks melded together)].

Most of the samples (87 percent) had ratios that were ambiguous in that they fell within the range over which the chlorine-36-to-total-chlorine ratio has varied over the last 50,000 years or more. Results of these samples indicate that the groundwater travel times from the surface to the repository depth in most areas probably are thousands to tens of thousands of years. This is because there is little evidence for measurable radioactive decay of the chlorine-36 signal in the subsurface. However, a few samples indicated ratios low enough to suggest the possible presence of zones of relatively old or stagnant water (TRW 1998a, page 5.3-176). Further, the data indicate that, away from fault zones, travel times to the repository horizon correlate with the thickness of the overlying nonwelded Paintbrush unit. The shortest travel times (less than 10,000 years) occur in the southern part of the Exploratory Studies Facility where the unit is thinnest.

About 13 percent of the samples (31 samples) had high enough chlorine-36-to-total-chlorine ratios to indicate the water originated from precipitation occurring in the past 50 years (that is, nuclear age precipitation) (TRW 1998a, page 5.3-176). Locations where bomb-pulse water occurred were correlated with the physical conditions in the mountain and on the surface that could lead to, or otherwise affect, the findings. The conclusion to date of these ongoing studies is that relatively fast transport of water through the mountain is controlled by the following factors (Fabryka-Martin et al. 1998, page 3-2):

- The presence of a continuous fracture path from the surface: The limiting factor is a fracture or fault cutting the Paintbrush nonwelded bedded tuffs (PTn) hydrogeologic unit (this prominent unit is above the repository horizon; see Figure 3-14 and Table 3-12). Fracture pathways are normally available in the welded portions of the overlying Tiva Canyon and underlying Topopah Spring units. This is consistent with hydrologic modeling of percolation through this nonwelded bedded tuff, which indicates that there must be fracture pathways due to faulting or other disturbances for water to travel through this unit in 50 years or less. Section 3.1.3 discusses fault locations inside Yucca Mountain.

- The magnitude of surface infiltration: There must be enough infiltration to sustain a small component of flow along the connected fracture pathway.

- The residence time of water in the soil cover: This time must be less than 50 years; to achieve this, the depth of the soil overlying the fracture pathway must be less than an estimated 3 meters (10 feet).

Water percolating to the depth of the repository and beyond is affected not only by fractures but also by the nature of the hydrogeologic units it encounters. Pressure testing in boreholes indicates that fractures in the Topopah Spring tuff (the rock unit in which DOE would build the repository) are very permeable and extensively interconnected. Below the repository level, low-permeability zeolite zones impede the vertical flow of water near the Topopah Spring welded unit and its contact with the underlying Calico Hills nonwelded unit, forming perched water bodies. The primary source of the perched water is water traveling down along faults and fractures. In the dipping or sloped strata beneath Yucca Mountain, perched water bodies require vertical impediments such as fault zones where less permeable rock and fault-gouge material block the lateral flow of water (Figure 3-14). If these conditions do not exist at the fault zone, the fault can provide a downward pathway. Even in cases where fault zones are barriers to lateral water flow, they can be very permeable to gas and moisture flow along the fault plane and permit the rapid vertical flow of water from the land surface to great depth. Studies of heat flux above and below the perched water zone appear to indicate more water percolation above the perched water than below. This is consistent with the concept that some of the water moves laterally on top of the zeolite zone before it resumes its downward course to the saturated zone.

*Unsaturated Zone Groundwater Quality.* DOE has analyzed water from the unsaturated zone, both pore water from the rock matrix and perched water, to obtain information on the mechanisms of recharge and the amount of connection between the two. The preceding sections discuss some of the relevant findings.

Table 3-13 summarizes the chemical composition of perched and pore water samples from the vicinity of Yucca Mountain.

**Table 3-13.** Water chemistry of perched and pore water samples in the vicinity of Yucca Mountain.[a]

| | Ranges of chemical composition | |
|---|---|---|
| Constituent | Perched | Pore |
| pH | 7.6 - 8.7 | 7.7 - 8.4 |
| Total dissolved solids (milligrams per liter) | 140 - 330 | 320 - 360 |
| Calcium (milligrams per liter) | 2.9 - 45 | 1.1 - 62 |
| Magnesium (milligrams per liter) | 0 - 4.1 | 0 - 4.5 |
| Potassium (milligrams per liter) | 1.7 - 10 | N/A[b] |
| Sodium (milligrams per liter) | 34 - 98 | 49 - 140 |
| Bicarbonate (milligrams per liter) | 110 - 220 | 170 - 230 |
| Chloride (milligrams per liter) | 4.1 - 16 | 26 - 90 |
| Bromide (milligrams per liter) | 0 - 0.41 | 0 |
| Nitrate (milligrams per liter) | 0 - 34 | 11 - 17 |
| Sulfate (milligrams per liter) | 4 - 220 | 14 - 45 |

a. Source: Striffler et al. (1996, Table 2).
b. N/A = not available.

The smaller concentrations of dissolved minerals, particularly chloride, in perched water in comparison to those in pore water is a primary indicator of differences between the two. This difference in dissolved mineral concentrations indicates that the two types of water do not interact to a large extent and that the perched water reached its current depth with little interaction with rock. This, in turn, provides strong evidence that flow through faults and fractures is the primary source of the perched water.

## Saturated Zone

*Water Occurrence.* The saturated zone at Yucca Mountain has three aquifers and two confining units. The aquifers are commonly referred to as the upper volcanic aquifer, the lower volcanic aquifer, and the lower carbonate aquifer. The interlayered aquitards (low permeability units that retard water movement) that separate the aquifers are called the upper volcanic confining unit and the lower volcanic confining unit (see Figure 3-15). The upper volcanic aquifer is composed of the Topopah Spring welded tuff, which occurs in the unsaturated zone near the repository but is present beneath the water table to the east and south of the proposed repository. The upper volcanic confining unit includes the Calico Hills nonwelded unit and the uppermost unstructured end of the Prow Pass tuff where they are saturated. The lower volcanic aquifer includes most of the Crater Flat Group, and the lower volcanic confining unit includes the lowermost Crater Flat Group and deeper tuff, lavas, and flow breccias. An upper carbonate aquifer, though regionally important, is not known to occur beneath Yucca Mountain. (The lower volcanic aquifer discussed here corresponds to the middle volcanic aquifer shown in Figure 3-15. The lower volcanic aquifer in Figure 3-15 has not been identified in the area of the proposed repository.)

South of the proposed repository site, downstream in the groundwater flow path from Yucca Mountain, the Tertiary volcanic rocks (and the volcanic aquifers) pinch out and groundwater moves into the valley-fill sediments of the Amargosa Desert (TRW 1998a, page 5.3-7). In the Amargosa Desert south of Yucca Mountain, the most important source of water is an aquifer formed by valley-fill deposits.

The lower carbonate aquifer is more than 1,250 meters (4,100 feet) below the proposed repository horizon. This aquifer, which consists of lower Paleozoic carbonate rocks (limestone and dolomite) that have been extensively fractured during many periods of mountain building (see Section 3.1.3), forms a regionally extensive aquifer system through which large amounts of groundwater flow. Evidence indicates that water in the lower carbonate aquifer is at least as old as most of the water in the volcanic aquifers (with apparent ages in the range of 10,000 to 20,000 years) and, similarly, was recharged during a wetter and cooler climate. Some of the limited carbonate aquifer sample results indicate older water ages (30,000 years and greater), but use of carbon-14 dating on this water has an additional limitation due to the probable contribution of "dead carbon" (nonradioactive) dissolved from the carbonate rock. Limited data show that the level to which water rises in a well that penetrates the lower carbonate aquifer is about 20 meters (66 feet) higher than the water levels in the overlying volcanic aquifers. This indicates that, in the vicinity of Yucca Mountain, water from the lower carbonate aquifer is pushing up against a confining layer with more force than the water in the upper aquifers is pushing down. This suggests that water in the volcanic aquifers does not flow down into the lower carbonate aquifer at Yucca Mountain because it would be moving against a higher upward pressure and that, if mixing occurs, it would be from carbonate to volcanic and not the reverse.

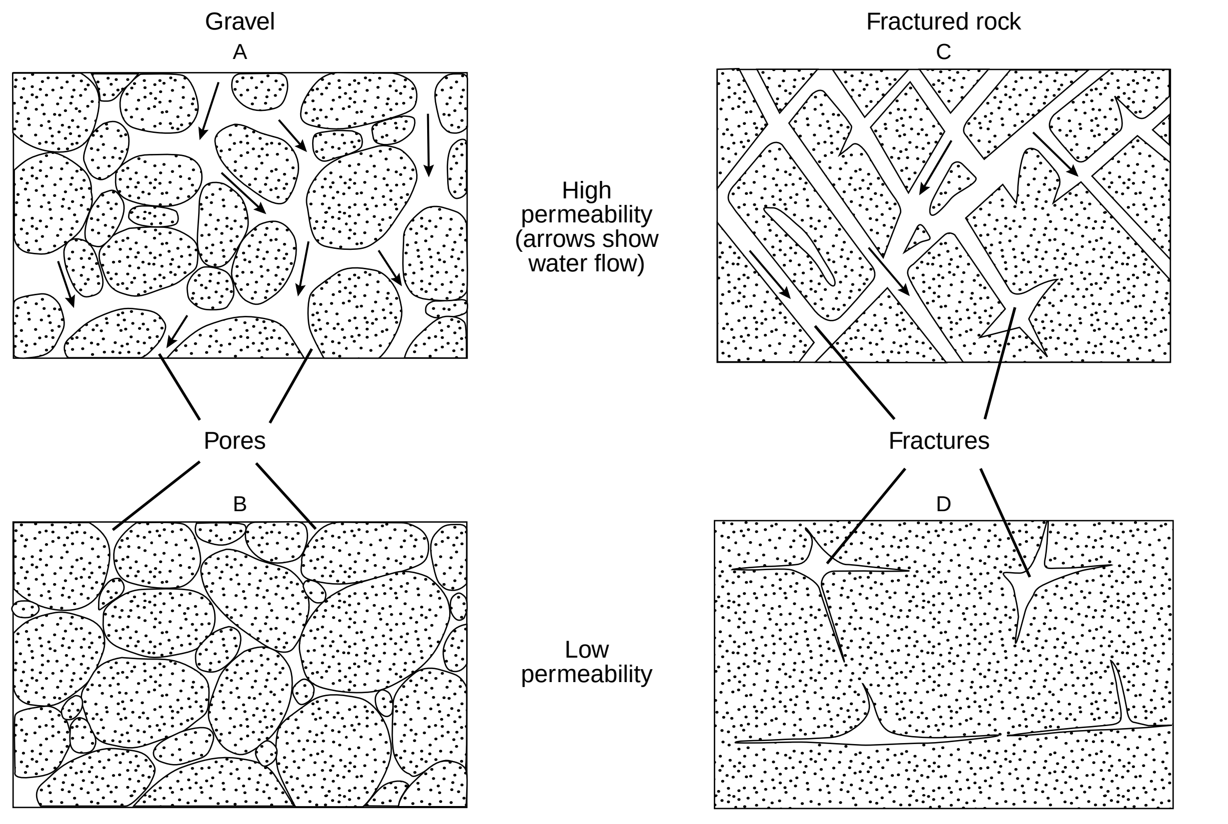
Paleoclimatic (referring to the climate during a former period of geologic time) studies have identified six wetter and cooler periods in the southern Great Basin during late Pleistocene time. These periods occurred 10,000 to 50,000 years ago; 60,000 to 70,000 years ago; 120,000 to 170,000 years ago; 220,000 to 260,000 years ago; 330,000 to 400,000 years ago; and 430,000 to 470,000 years ago. They represent the sequencing of glacial (cooler and wetter) to interglacial (warmer and drier) and back to glacial climates (TRW 1998a, page 4.2-24). During the wetter periods, the elevation of the saturated zone was as much as about 100 meters (330 feet) higher than it is today. The repository would be above this historic maximum elevation (see Section 2.1). Calcite veins and opal were deposited along fractures during the wetter periods. The calcite and opal coatings have been dated by the uranium series method; the calcites have also been dated by the carbon-14 method. The youngest vein deposits are 16,000 years old. The *Yucca Mountain Site Description* (TRW 1998a, pages 4.2-1 to 4.2-41) provides additional information, including supporting evidence, on the timing, magnitude, and character of past climate changes in the Yucca Mountain region.

Several investigators have suggested that the water table in the vicinity of Yucca Mountain has risen dramatically higher than 100 meters (330 feet) above the current level, even reaching the land surface in the past (Szymanski 1989, all). If such an event occurred, it would affect the performance of the proposed repository. These concerns originated in the early- to mid-1980s when surface excavations performed as part of site investigations exposed vein-like deposits of calcium carbonate and opaline silica (TRW 1998a, page 3.4-20). Szymanski (1989, all) hypothesized that the carbonate and silica were deposited by hydrothermal fluids, driven to the surface by pressurization of groundwater by earthquakes (a mechanism called *seismic pumping*) or by thermal processes that occurred in the Yucca Mountain vicinity. A number of investigators and groups, including a National Academy of Science panel specifically designated to look at the issue (National Research Council 1992, all), have examined the model on which this position is based and have rejected its important aspects (Luckey et al. 1996, pages 76-77). The National Research Council panel concluded that the evidence cited as proof of groundwater upwelling in Yucca Mountain and in its vicinity could not reasonably be attributed to that process. In addition, the panel stated its position that the proposed mechanism for upwelling water was inadequate to raise the water table more than a few tens of meters (DOE 1998a, Volume 1, page 2-26). Finally, the panel concluded that the carbonate-rich depositions in fractures were formed from surface water from precipitation and surface processes (TRW 1998a, page 3.4-29).

Another alternative interpretation of past groundwater levels at Yucca Mountain occurs in Dublyansky (1998, all). This study involved the examination of tiny pockets of water (known as *fluid inclusions*) trapped in the carbonate-opal veinlets deposited in rock fractures at Yucca Mountain. According to the report, an analysis of samples collected from the Exploratory Studies Facility includes evidence of trace quantities of hydrocarbons and evidence that the fluid inclusions were formed at elevated temperatures. These findings, and others, are used to support the report's conclusion that the carbonate-opal veinlets were caused by warm upwelling water and not by the percolation of surface water. DOE, given the opportunity to review a preliminary version of the report, arranged for review by a group of independent experts, including U.S. Geological Survey personnel and a university expert. This review group did not concur with the conclusion in the report by Dublyansky (1998, all), which now contains an appendix with the DOE-arranged review comments and the author's responses. Although DOE has disagreed with some of the central scientific conclusions presented in this report, both parties have agreed that additional research is needed to resolve the issues. DOE and the State of Nevada are continuing to evaluate these and other alternative conceptual models and data interpretations.

*Hydrologic Properties of Rock.* This section discusses the hydrologic properties of rock in the saturated zone, and specifically the aquifers and confining units at Yucca Mountain. As discussed above, these properties depend in part on whether the rocks are saturated. In general, the amount and speed at which water flows through an aquifer depend chiefly on the transmissivity and effective porosity of the rock. *Transmissivity* is a measure of how much water an aquifer can transfer and is equal to the average hydraulic conductivity of the aquifer multiplied by the thickness of the aquifer that is saturated. *Porosity* is the ratio of the rock's void (open) space to its total volume; *effective porosity* is the ratio of interconnected void space to total volume.

Figure 3-16 shows the types of conditions that might exist in gravel and rock aquifers that would make them more or less permeable to water movement. The empty spaces between gravel fragments or in the rock fractures represent the porosity. Although not necessarily representative of conditions at Yucca Mountain, the figure shows that the manner in which void spaces are interconnected, more than their size




A. Gravel with interconnected pore space having relatively high permeability.
B. Gravel with limited interconnected pore space having relatively low permeability.
C. Rock with interconnected fractures having relatively high permeability.
D. Rock with few interconnected fractures having relatively low permeability.

Source: Modified from USGS (1993, page 2).

**Figure 3-16.** Aquifer porosity and effects on permeability.

or quantity, determines how water can move through the material. At Yucca Mountain, conditions are often such that the rock with the highest porosity is also the rock with the fewest fractures. Because the void spaces are not interconnected very well, such a high-porosity rock has low transmissivity. Because a large portion of the groundwater flow at Yucca Mountain is probably along fractures, representative transmissivity values are difficult to measure. Measurements can vary greatly depending on the nature of the fractures that happen to be intercepted by the borehole and the location in the borehole at which measurements are made. This is reflected in the wide range of transmissivity values listed in Table 3-14, which also lists the characteristics, thicknesses, apparent hydraulic conductivities, and porosities of the three aquifers and two confining units beneath Yucca Mountain. For the lower carbonate aquifer, the table lists a single transmissivity value because there was only a single test for that unit. Similarly, only one apparent hydraulic conductivity value, which is a measure of the aquifer's capacity to transport water, is provided for the lower carbonate aquifer unit because it is based on tests in a single well at Yucca Mountain. However, the value is an average of measurements taken from that well. This and the other hydraulic conductivity values are called *apparent* because they are all based on single-borehole tests. Such measurements, which are believed to represent conditions at a limited distance around the well, could vary greatly depending on whether there are water-bearing fractures in the well zone being tested. When such fractures are present, hydraulic properties measured in a single-borehole test probably reflect conditions only in isolated locations rather than in the overall rock matrix in the test zone.

**Table 3-14.** Aquifers and confining units in the saturated zone at Yucca Mountain.

| Unit | Typical thickness (meters)[a,b,c] | Transmissivity (square meters per day)[d,e] | Apparent hydraulic conductivity (meters per year)[e] | Porosity[f,g] (ratio) |
|---|---|---|---|---|
| *Upper volcanic aquifer*<br>Densely welded and densely fractured part of Topopah Spring Tuff | 300 | 120 - 1,600 | 47 - 6,900 | 0.036 - 0.16 |
| *Upper volcanic confining unit*<br>Basal vitrophyre of Topopah Spring Tuff, Calico Hills Formation Tuff, and uppermost nonwelded part of Prow Pass Tuff | 90 - 330 | 2.0 - 26 | 7.3 - 95 | 0.17 - 0.35 (Calico Hills) |
| *Lower volcanic aquifer*<br>Most of Prow Pass Tuff and underlying Bullfrog and Tram Tuffs of Crater Flat Group | 370 - 700 | 1.1 - 3,200 | < 1.4 - 4,700 | 0.26 - 0.33 (Prow Pass Tuff)<br>0.12 - 0.26 (Bullfrog Tuff) |
| *Lower volcanic confining unit*<br>Bedded tuffs, lava flows, and flow breccia beneath Tram Tuff | 370 - > 750 | 0.003 - 23 | 0.002 - 40.2 | N/A[h] |
| *Lower carbonate aquifer*<br>Cambrian through Devonian limestone and dolomite | N/A | 120 | 69 | N/A |

a. Source: Luckey et al. (1996, Table 2 and Figure 7).
b. To convert meters to feet, multiply by 3.2808.
c. Typical thickness ranges for the upper volcanic confining unit, the lower volcanic aquifer, and the lower volcanic confining unit are based on measurements from 13 boreholes. With respect to the lower volcanic confining unit, only one penetrated and showed a unit thickness of about 370 meters (1,200 feet); of the others, about 750 meters (2,500 feet) was the deepest penetration without passing through. Water was detected in the rock unit that elsewhere makes up the upper volcanic aquifer unit in only one of the 13 boreholes. (Beneath the center of Yucca Mountain, the upper volcanic aquifer is above the saturated zone.) The typical thickness shown here for this unit is based on Figure 7 from Luckey et al. (1996, Figure 7).
d. To convert square meters to square feet, multiply by 10.764.
e. Source: TRW (1998a, Tables 5.3-35 and 5.3-36).
f. Source: TRW (1999h, Table 2-2, page 2-40).
g. Ranges are for means of several hydrogeological subunits.
h. N/A = not available.

*Water Source and Movement.* Section 3.1.4.2.1 describes the direction of water movement (Figure 3-13), the nature of the rock through which it moves, and where local recharges to and discharges from the aquifer might occur.

When undisturbed by pumping, groundwater levels at Yucca Mountain have been very stable, with long-term measurements generally varying less than 0.1 meter (0.3 foot) since 1983. These small variations are probably due to changes in barometric pressure and Earth tides. In addition, short-term fluctuations in groundwater elevations also have been attributed to apparent recharge events and earthquakes. Water levels in wells have fluctuated by as much as 2.2 meters (7 feet) in response to earthquake events, but the fluctuations are typically of short duration with water levels returning to the pre-earthquake conditions within minutes to a few hours. An exception to this occurred in response to earthquakes in the summer of 1992, when water levels in specific wells at Yucca Mountain fluctuated over several months. At the northern end of Yucca Mountain, the apparent potentiometric surface slopes steeply southward, dropping almost 300 meters (980 feet) in a horizontal distance of 2.5 kilometers (1.6 miles). Experts reviewing the data have suggested several credible reasons for this steep gradient, including that it results from an undetected geological feature with low permeability, that it is caused by groundwater draining to deep aquifers, or that it is a perched water table being encountered in this area (Geomatrix and TRW 1998, pages 3-5 and 3-6). However, there are no obvious geologic reasons for the steep gradient, and it is still under investigation.

The north-trending Solitario Canyon fault, on the west side of Yucca Mountain, apparently impedes the eastward flow of groundwater in the saturated zone. West of the fault, the water table slopes moderately about 20 meters (66 feet) in 0.4 kilometer (0.25 mile), while east of the fault the water table slopes very gently. West of the Solitario Canyon fault groundwater probably flows southward either along the fault or beneath Crater Flat.

The gentle southeastward groundwater gradient east of the Solitario Canyon fault underlies the proposed repository horizon and extends beneath Fortymile Wash and probably farther east into Jackass Flats. This gentle gradient might indicate that the rocks through which the water flows are highly transmissive, that only small amounts of groundwater flow through this part of the system, or a combination of both. This gentle southeastward gradient is a local condition in the regional southward flow of the groundwater.

In an opposing viewpoint about the stability of groundwater levels at Yucca Mountain, Davies and Archambeau (1997, pages 33 and 34) suggests that a moderate magnitude earthquake at the site could cause a southward displacement of the large hydraulic gradient to the north of the proposed repository, resulting in a water table rise of about 150 meters (490 feet) at the site. In addition, that report proposed that a severe earthquake could cause a rise of about 240 meters (790 feet) in the water table, flooding the repository. As part of its study of groundwater flow in the saturated zone, DOE elicited expert opinions on various issues from a panel of five experts in the fields of groundwater occurrence and flow. Among the issues put to the panel were those raised by Davies and Archambeau (1997, all). The panel reviewed the Davies and Archambeau paper and received briefings by project personnel and outside specialists. The consensus of the panel was that a rise of the groundwater to the level of the proposed repository was essentially improbable and that changes to the water table associated with earthquakes would be neither large nor long-lived (Geomatrix and TRW 1998, page 3-14).

*Inflow to Volcanic Aquifers at Yucca Mountain.* There are four potential sources of inflow to the volcanic aquifers in the vicinity of Yucca Mountain: (1) lateral flow from volcanic aquifers north of Yucca Mountain, (2) recharge along Fortymile Wash from occasional stream flow, (3) precipitation at Yucca Mountain, and (4) upward flow from the underlying carbonate aquifer. The actual and relative amounts of inflow from each source are not known.

North of Yucca Mountain, the potentiometric surface rises steeply toward probable recharge areas on Pahute Mesa (Figure 3-13) and Rainier Mesa. Chemical data indicate that some recharge to the groundwater has occurred everywhere in the Yucca Mountain vicinity during the past 10,000 years, but that most recharge occurred between 10,000 and 20,000 years ago (based on apparent carbon-14 ages) during a wetter climate. From west to east across Yucca Mountain, the age of water in the saturated zone decreases from about 19,000 years to 9,100 years (Benson and McKinley 1985, page 4).

The estimated annual recharge along the 150-kilometer (93-mile) length of Fortymile Wash averages about 4.22 million cubic meters (3,400 acre-feet). Much of the recharge occurs during and after heavy precipitation when water flows in the wash. On rare occasions, Fortymile Wash carries water to Jackass Flats and into the Amargosa Desert. After several periods of flow in Fortymile Wash during 1992 and 1993, water levels in nearby wells rose substantially. Earlier studies found that shallow water in some wells was younger than water deeper in the wells, indicating that recharge was occurring. Paleoclimatic evidence suggests that a perennial stream might have existed in Fortymile Wash 25,000 to 50,000 years ago, and that substantial recharge might have occurred as recently as 15,000 years ago.

Recharge to the saturated zone below Yucca Mountain from precipitation is probably small in comparison to inflow from volcanic aquifers to the north or recharge along Fortymile Wash (see the unsaturated zone discussion). An average net infiltration of 4.5 millimeters (0.2 inch) over a 220-square-kilometer (85-square-mile) vicinity around Yucca Mountain would produce a quantity of recharge less than one quarter of the estimated annual recharge along Fortymile Wash.

Monitoring well data collected during the site characterization effort have shown that the potentiometric surface of the carbonate aquifer (that is, the level to which water rises in wells tapping this aquifer), at least in the immediate vicinity of Yucca Mountain, is higher than the water level in the overlying volcanic aquifer. Based on this and other considerations, studies suggest that, provided structural pathways exist, the lower carbonate aquifer might provide upward flow to the volcanic aquifer beneath the proposed level of the repository and farther south. The amount of inflow, if it occurs, is not known.

*Outflow from Volcanic Aquifers at and Near Yucca Mountain.* Pathways by which water might leave the volcanic aquifers in the Yucca Mountain vicinity include (1) downgradient movement into other volcanic aquifers and alluvium in the Amargosa Desert, (2) downward movement into the carbonate aquifer (though evidence indicates that this does not occur), and (3) upward movement into the unsaturated zone. In addition, water is pumped from wells for a variety of uses, as described in Section 3.1.4.2.1. With the exception of well withdrawals, the actual and relative amounts of outflow from each source are not known.

The regional slope of the potentiometric surface indicates that much of the groundwater flowing southward beneath Yucca Mountain discharges about 80 kilometers (50 miles) to the south at Alkali Flat (Franklin Lake Playa) and in Death Valley. Death Valley, more than 80 meters (260 feet) below sea level, is the final sink for surface water and groundwater in the Death Valley groundwater basin (Figure 3-13); as such, water leaves only by evapotranspiration. Therefore, the pathway for groundwater beneath Yucca Mountain, as indicated by the potentiometric surface, is southerly where it traverses portions of the volcanic aquifers before encountering the basin-fill alluvium and carbonate rock that underlie the Amargosa Valley.

Outflow from the volcanic aquifers into the underlying carbonate aquifer might occur, but direct evidence for this does not exist. Studies suggest that the steeply sloping potentiometric surface at the north end of Yucca Mountain could be explained by a large outflow from the volcanic aquifers to the carbonate aquifer. However, in the vicinity of Yucca Mountain, data available on the potentiometric head of the carbonate aquifer indicate that the opposite condition (that is, outflow from the carbonate aquifer up to the volcanic aquifer) is more likely.

The third possible pathway of outflow from the volcanic aquifer (that is, upward movement to the unsaturated zone), if present, has not been quantified. However, consistent with the above discussion of net infiltration, DOE believes that there is a net downward movement of water in the unsaturated zone in the vicinity of Yucca Mountain.

*Use.* Two wells, J-12 and J-13 (shown in Figure 3-17), are part of the water system for site characterization activities at Yucca Mountain. These are the nearest production wells to Yucca Mountain and they support water needs for Area 25 of the Nevada Test Site and for Exploratory Studies Facility activities. Both of these wells withdraw groundwater from the Jackass Flats hydrographic area, as listed in Table 3-11. Groundwater has also been pumped from the Jackass Flats area from various boreholes for hydraulic testing, and most recently from the C-well complex, which consists of three separate wells grouped in an area just east of the South Portal Operations Area (Luckey et al. 1996, Figure 17). In addition, water has been pumped occasionally from borehole USW VH-1 (also designated CF-2) in support of Yucca Mountain characterization activities. But the volume pumped from this well, which is in the Crater Flat hydrographic area, is small (Luckey et al. 1996, page 70).

The Yucca Mountain Site Characterization Project has received water appropriation permits (Numbers 57373, 57374, 57375, and 57376) from the State of Nevada for wells J-12, J-13, VH-1 (also known as F-2), and the C-Well complex (Numbers 58827, 58828, and 58829), and a Potable Water Supply permit (NY-0867-12NCNT) for the distribution system. The permits allow a maximum pumping rate of about 0.028 cubic meter (1 cubic foot) a second, with a maximum yearly withdrawal of about 530,000 cubic meters (430 acre-feet). The permit limits apply to site characterization water use. Table 3-15 lists historic and projected water use from wells J-12 and J-13 from 1992 to 2005 for the Exploratory Studies Facility and Concrete Batch Plant, and from the C-Wells, which is pumped and then reinjected as part of aquifer testing. It also lists the total amount of water pumped from wells J-12 and J-13 for both Yucca Mountain and the Nevada Test Site. The difference between the quantities pumped from wells J-12 and J-13 for Yucca Mountain activities and the total withdrawals from these wells represents the quantities used for Nevada Test Site activities in the area. The water-use projections in Table 3-15 are through the end of site characterization activities; Section 4.1.3 discusses water demand projections for the proposed repository.

The U.S. Geological Survey, in support of Yucca Mountain characterization efforts and in compliance with the State permits, has kept records of the amount of water pumped from the J-12 and J-13 wells and of measured water elevation levels in those and other wells in their immediate area since 1992 (La Camera and Locke 1997, pages 1 and 2). One of the objectives of keeping these records is to detect and document changes in groundwater resources during the Yucca Mountain investigations. Therefore, the Survey effort included the collection of historic water elevation data to establish a baseline. Results from these efforts have been documented in annual reports. The report for 1997 (La Camera, Locke, and Munson 1999, all) includes a summary of 1996 results and detailed results for 1997. Table 3-16 summarizes the changes observed in median groundwater elevations in seven wells in Jackass Flats. The second column of the table identifies the historic or baseline elevation for each well against which the annual median values are being compared. In addition, the table lists the average deviation of measured water levels during the period from which the baseline was generated.

The elevation changes listed in Table 3-16 are different from the short-term fluctuations described above that are a response to changes in barometric pressure and Earth tides. The differences in comparison of annual median values should indicate water level trends, if there are any. The data show that a decline in

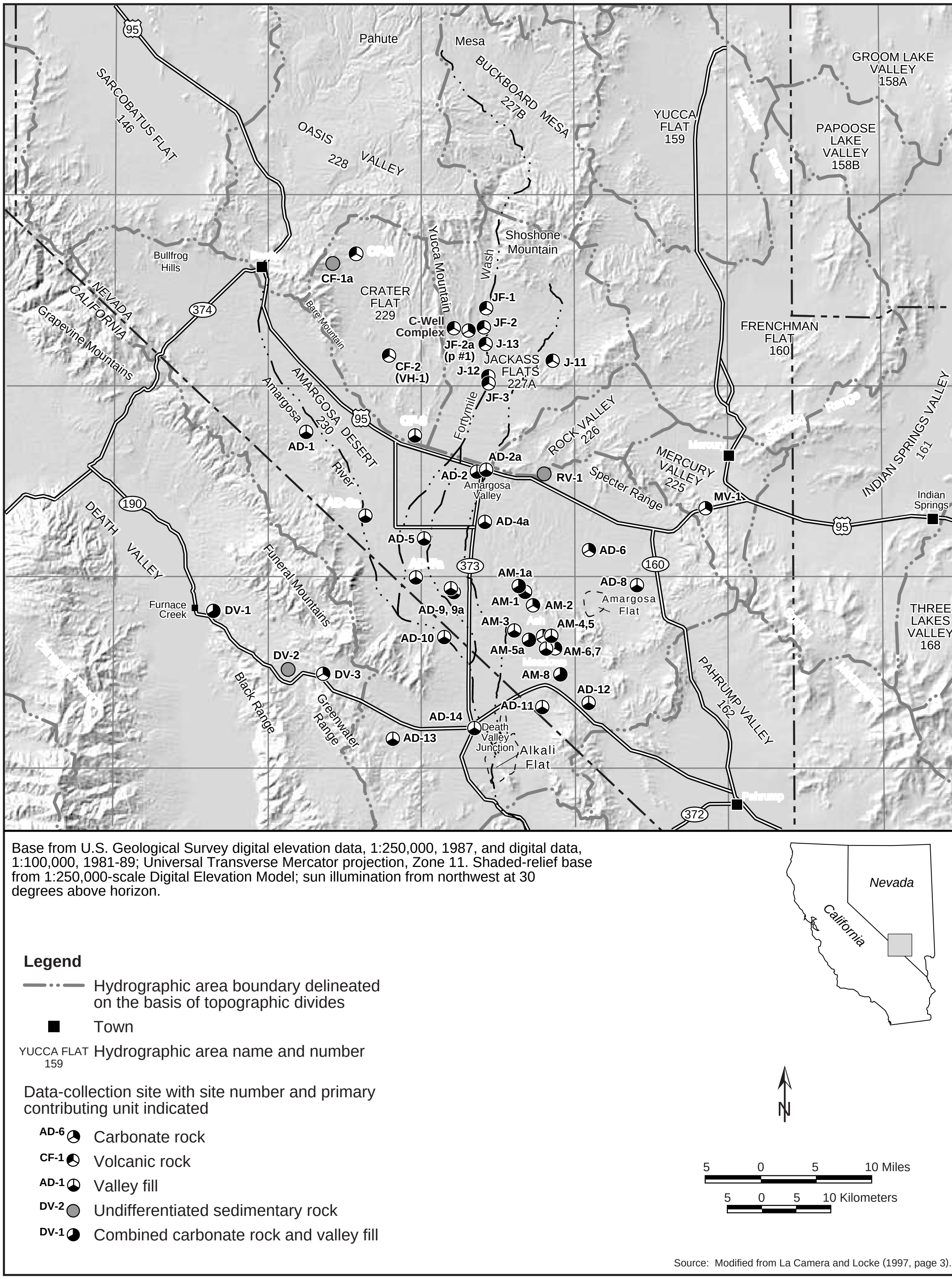



**Figure 3-17.** Selected groundwater data-collection sites in the Yucca Mountain region.

**Table 3-15.** Water withdrawals (acre-feet)[a] from wells in the Yucca Mountain vicinity.

| Year | J-12 and J-13 Yucca Mountain characterization[b] | J-12 and J-13 total withdrawals[c] | C-wells[b] |
|---|---|---|---|
| 1992 | 18 | 120 | 0 |
| 1993 | 80 | 210 | 0 |
| 1994 | 75 | 280 | 0 |
| 1995 | 94 | 260 | 19 |
| 1996 | 66 | 220 | 180 |
| 1997 | 63 | 150 | 190 |
| 1998 | 63[d] | N/A[e] | 190[f] |
| 1999 | 63 | N/A | N/A |
| 2005 | 63 | N/A | N/A |

a. To convert acre-feet to cubic meters, multiply by 1233.49.
b. Source: TRW (1999j, page 4).
c. Source: Clary et al. (1995, page 660); Bauer et al. (1996, page 702); Bostic et al. (1997, page 592); Bonner et al. (1998, page 606); La Camera, Locke, and Munson (1999, all); withdrawals for 1992 and 1993 were estimated from figures in La Camera and Locke (1997, page 51).
d. Assumed to remain constant from 1997 through 2005.
e. N/A = not available.
f. Assumed to remain constant from 1997 to 1998.

**Table 3-16.** Differences between annual median elevations and baseline median elevations.[a]

| | Baseline elevations | | Difference (in centimeters[b]) baseline | | | | | |
|---|---|---|---|---|---|---|---|---|
| Well | Median (meters[c] above sea level) | Average deviation about the median (centimeters) | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
| JF-1 | 729.23 | ± 6 | –3 | 0 | –6 | 0 | –6 | –3 |
| JF-2 | 729.11 | ± 9 | +3 | 0 | +3 | +9 | 0 | –3 |
| JF-2a[d] | 752.43 | ± 12 | 0 | +6 | +12 | +15 | +21 | +27 |
| J-13 | 728.47 | ± 6 | –3 | –3 | –9 | –6 | –12 | –12 |
| J-11 | 732.19 | ± 3 | 0 | 0 | +3 | +6 | +6 | +12 |
| J-12 | 727.95 | ± 3 | 0 | 0 | –3 | –3 | –9 | –9 |
| JF-3 | 727.95 | ± 3 | N/A[e] | N/A | –6 | –6 | –9 | –9 |

a. Source: La Camera, Locke, and Munson (1999, Table 10).
b. To convert centimeters to inches, multiply by 0.3937.
c. To convert meters to feet, multiply by 3.2808.
d. Well JF-2a is also known as UE-25 p#1, or P-1.
e. N/A = not available.

groundwater elevation has been seen in some, but not all, of the local wells. Specifically, the data show the following:

- Two wells, JF-1 and JF-2, stayed within the band of elevations characteristic of the baseline data.

- Two wells, JF-2a (also known as UE-25 p#1, or P-1) and J-11, indicated elevation increases of 15 and 9 centimeters (about 5.9 and 3.5 inches), respectively, above the band of elevations characteristic of the baseline data (and even higher above the median of the baseline data as listed in the table).

- Three wells, J-13, J-12, and JF-3, each indicated an elevation decrease of 6 centimeters (about 2.4 inches) below the band of elevations characteristic of the baseline data (and even further below the median of the baseline data as listed in the table).

In its discussion of groundwater levels, the U.S. Geological Survey (La Camera and Locke 1997, page 22) indicated that monitoring of water levels in the seven wells should continue to see if additional decreases occur and if they can be correlated to periods of withdrawal. In regard to overall groundwater levels in the Jackass Flats area, the data do not appear to show any definitive trend in elevation change, either up or down. However, the three wells showing a water decline are either being pumped (J-12 and J-13) or, in the case of JF-3, are close to a production well. Five of these wells (see Figure 3-17) are in or very close to Fortymile Wash and the two wells (JF-2a and J-11) that are farthest from the wash are those wells that have shown a water level increase.

**Table 3-17.** Water chemistry of volcanic and carbonate aquifers at Yucca Mountain (milligrams per liter).[a]

| | Chemical composition | |
|---|---|---|
| Chemical constituent | Volcanic aquifers[b] | Lower carbonate aquifer[c] |
| Calcium | 1 - 20 | 100 |
| Magnesium | 0.01 - 2 | 39 |
| Potassium | 1 - 5 | 12 |
| Sodium | 38 - 100 | 150 |
| Bicarbonate | 110 - 280 | 570 |
| Chloride | 5 - 10 | 28 |
| Sulfate | 40 - 57 | 160 |
| Silica | 40 - 57 | 41 |

a. Source: TRW (1999h, pages 2-43 to 2-44).
b. Based on samples from 12 wells.
c. Based on samples from one well.

*Saturated Zone Groundwater Quality.* Groundwater quality for the aquifers beneath Yucca Mountain was addressed by the Geological Survey sampling and analysis effort described above for regional groundwater quality. This effort included the collection and analysis of samples from three wells in the Jackass Flats area (including J-12 and J-13); the results indicated that the concentrations of dissolved substances in local groundwater were below the numerical criteria of the primary drinking water standards set by the Environmental Protection Agency for public drinking water systems (Covay 1997, all). However, samples from each of the wells exceeded the secondary standard for fluoride, as was a proposed standard for radon. Both of these constituents occur naturally in the rock through which the groundwater flows. Overall, local groundwater quality is generally good.

Investigations of the chemical and mineral composition of groundwater at Yucca Mountain have provided an indication of the differences between the aquifers beneath the site. The chemical composition of groundwater depends on the chemistry of the recharge water and the chemistry of the rocks through which the water travels. Water in the volcanic aquifers and confining units at Yucca Mountain has a relatively dilute sodium-potassium-bicarbonate composition that probably results from the dissolution of volcanic tuff (Table 3-17). The chemistry of water from the lower carbonate aquifer is very different (a generally more concentrated calcium-magnesium-bicarbonate composition), which would be expected from water traveling through and dissolving carbonate rock (Table 3-17).

As part of the Yucca Mountain project, well and spring monitoring activities performed during 1997 aided the establishment of a baseline for radioactivity in groundwater near the site of the proposed repository (TRW 1998b, all). The quarterly sampling included six wells and two springs that were selected to ensure that at least two were representative of each of the three general aquifers (carbonate, volcanic, and alluvial) in the region. Samples were analyzed for gross alpha, gross beta, total uranium, and concentrations of selected beta and gamma-emitting radionuclides. Table 3-18 lists the results from this monitoring as average values from the quarterly sampling events for each well or spring. The table lists the location of each well or spring, including the data collection site designations shown on Figure 3-17, the contributing aquifer, and a comparison, if applicable, to Maximum Contaminant Levels established by the Environmental Protection Agency for water supplied by public drinking water systems. As indicated in the table, the sites sampled include locations outside the Alkali Flat-Furnace Creek sub-basin in which Yucca Mountain is located. The Cherry Patch location is in the Ash Meadows sub-basin and Crystal Pool and Fairbanks Spring are on the border between the two sub-basins, but are fed by flow

**Table 3-18.** Results of 1997 groundwater sampling and analysis for radioactivity.[a]

| Site name and location description[b] | Contributing aquifer | Average combined radium-226 and -228 (picocuries per liter) | Average gross alpha (picocuries per liter) | Average total uranium[c] (micrograms per liter) | Average gross beta (picocuries per liter) |
|---|---|---|---|---|---|
| J-12 Fortymile Wash, SE of Yucca Mtn. | Volcanic | 0.18±0.31 | BDL[d] | 0.52±0.05 | 6.23±0.86 |
| J-13 Fortymile Wash, SE of Yucca Mtn. | Volcanic | 0.45±0.36 | BDL | 0.51±0.04 | 5.84±0.85 |
| C-3 (C-well complex) By South Portal, SE of Yucca Mtn. | Volcanic | 0.58±0.36 | 1.34±1.05 | 1.04±0.09 | 3.59±0.76 |
| Crystal Pool (Spring) (AM-5a) Ash Meadows | Carbonate/ alluvial[e] | 0.93±0.20 | BDL | 2.64±0.23 | 14.0±1.28 |
| Fairbanks Spring (AM-1a) Ash Meadows | Carbonate/ alluvial | 0.80±0.36 | BDL | 2.23±0.19 | 11.1±1.17 |
| Nevada Department of Transportation Well (AD-2a) Amargosa Valley | Alluvial | 0.32±0.33 | BDL | 2.55±0.22 | 5.95±0.93 |
| Gilgans South Well (AD-9a) Amargosa Desert | Alluvial | 0.19±0.31 | BDL | 0.63 ± 0.05 | 9.14±0.97 |
| Cherry Patch Well (AD-8) NE of Ash Meadows | Alluvial | 0.22±0.33 | 9.19±4.35 | 13.1 ± 1.16 | 18.7±1.65 |
| *Drinking water Maximum Contaminant Levels*[f] | | 5 | 15 | NA[g] | NA |

a. Source: TRW (1998b, pages 12 to 21).
b. Figure 3-18 shows the locations of the wells.
c. To convert total uranium concentrations in micrograms per liter to picocuries per liter, multiply by 0.68 (TRW 1998b, page 15).
d. BDL = below detection limit.
e. Alluvium is identified as valley fill in TRW (1999h, pages 1-7 and 1-8).
f. Drinking water Maximum Contaminant Levels are set by the Environmental Protection Agency in 40 CFR Part 141.
g. NA = not applicable.

through Ash Meadows. The location variety supports area comparisons as well as comparisons between the different contributing aquifers.

Table 3-18 indicates that Maximum Contaminant Levels for combined radium-226 and radium-228 and for gross alpha were not exceeded by the average values from any of the sampling sites or by the maximum values reported for those parameters (TRW 1998b, pages 12 to 21). The samples were analyzed for other beta- or gamma-emitting radionuclides, specifically tritium, carbon-14, chlorine-36, nickel-59, strontium-89, strontium-90, technetium-99, iodine-129, and cesium-137. The table does not list the results for these parameters because they are below minimum detectable activity (TRW 1998b, page 13). As a conservative measure, however, DOE used the values reported by the laboratory to calculate dose contributions (TRW 1998b, Appendix F). Water from each sampling location was shown to have exposure values well below the 4-millirem-per-year total body (or any internal organ) dose limit set as the Maximum Contaminant Level for beta- or gamma-emitting radionuclides.

There is no indication that DOE activities at the Nevada Test Site have contaminated the groundwater beneath Yucca Mountain. This is consistent with studies performed on the Nevada Test Site. Nimz and Thompson (1992, all) documented about a dozen instances in which radionuclides have migrated into the groundwater from areas of nuclear weapons testing at the Nevada Test Site in 40 years. The maximum distance of tritium migration is believed to be several kilometers; less mobile radioactive constituents, which include a wide variety of isotopes (DOE 1996f, pages 4-126 to 4-129), have migrated no more than about 500 meters (1,600 feet). There has, however, been recent evidence of plutonium migration from one below-groundwater test at Pahute Mesa. Groundwater monitoring results indicate plutonium has migrated at least 1.3 kilometers (0.8 mile) from this site in 28 years and is apparently associated with the movement of very small particles called colloids (Kersting et al. 1999, page 56). None of the nuclear testing occurred in Area 25 where the Yucca Mountain Repository facilities would be. However, the flow of groundwater from areas on Pahute and Buckboard Mesas where DOE conducted 81 and 2 nuclear tests, respectively, could be to the south toward Yucca Mountain. The distance is about 40 kilometers (25 miles) to Pahute Mesa and about 30 kilometers (19 miles) to Buckboard Mesa (Figure 3-17). Because of these distances, there is no reason to believe that radionuclides from nuclear tests could migrate as far as Yucca Mountain during the active life of the repository. Chapter 8 discusses the potential for long-term migrations of radionuclides to result in cumulative radiation from nuclear testing contamination eventually migrating through the groundwater system under the repository.

## 3.1.5 BIOLOGICAL RESOURCES AND SOILS

DOE used available information and studies on plants and animals at the site of the proposed repository and the surrounding region to identify baseline conditions for biological resources. This information included land cover types, vegetation associations, and the distribution and abundance of plant and animal species in the region of influence (the analyzed land withdrawal area) and in the broader region. The plants and animals in the Yucca Mountain region are typical of species in the Mojave and Great Basin Deserts.

DOE has surveyed the region for naturally occurring wetlands and has studied soil characteristics (thicknesses, water-holding capacity, texture, and erosion hazard) in the region. This section summarizes this information and describes existing soil conditions in relation to potential contaminants. Unless otherwise noted, this information is from the *Environmental Baseline File for Biological Resources* (TRW 1999k, all) or the *Environmental Baseline File for Soils* (TRW 1999l, all).

The State of Nevada (NWPO 1997, all) has expressed the opposing view that there was no systematic, interdisciplinary, environmental program before investigations began in 1982 to characterize the unique and fragile desert environment at Yucca Mountain before potential irreversible alterations (Lemons and Malone 1989, pages 435 to 441). However, after site investigations started and impacts might have occurred, DOE began studies of sensitive species, archaeology, airborne particulates, and groundwater (Lemons and Malone 1989, pages 435 to 441), and established an environmental baseline from these data for use in the preparation of the EIS (Malone 1989, pages 77 to 95). Many of the studies conducted to establish the baseline and evaluate impacts, particularly those on plants and animals (Malone 1995, pages 271 to 284), did not use an integrated ecosystem approach and, therefore, are of little value for evaluating impacts of the repository.

Studies initiated after the start of site investigations are suitable for establishing the baseline needed for this EIS. The purpose of studies of the impacts of site characterization activities on plants and animals was not to evaluate potential impacts from a repository, but rather to focus on the appropriate level of ecological organization for the types of impacts that occurred during characterization activities. DOE used the results of those studies in the EIS analysis to understand and predict possible impacts from similar activities during repository construction and operation (for example, habitat destruction).

### 3.1.5.1 Biological Resources

#### 3.1.5.1.1 *Vegetation*

Broad categories of land cover types (based primarily on predominant vegetation) have been identified and mapped across the State of Nevada (Utah State University 1996, GAP Data) and at the site of the proposed Yucca Mountain Repository (TRW 1998c, page 9). Land cover types typical of the Mojave and

Great Basin Deserts occur in the analyzed land withdrawal area; they include creosote-bursage (56 percent), blackbrush (14 percent), hopsage (13 percent), Mojave mixed scrub (10 percent), salt desert scrub (4 percent), sagebrush (3 percent), and pinyon-juniper (much less than 1 percent) (Figure 3-18). None of the more than 210 plant species known to occur in the analyzed land withdrawal area is endemic to the area; that is, they all occur in other places.

Plant species typical of the Mojave Desert dominate the vegetation at low elevations in the analyzed land withdrawal area. Low-elevation valleys, alluvial fans, and large washes are dominated by white bursage (*Ambrosia dumosa*), creosotebush (*Larrea tridentata*), Nevada jointfir (*Ephedra nevadensis*), littleleaf ratany (*Krameria erecta*), and pale wolfberry (*Lycium pallidum*). Low-elevation hillsides are dominated by similar species, with the addition of shadscale (*Atriplex confertifolia*), California buckwheat (*Eriogonum fasciculatum*), and spiny hopsage (*Grayia spinosa*).

At higher elevations, generally at the northern end of the analyzed land withdrawal area, species typical of the Great Basin Desert are dominant. Ridge tops and slopes are dominated by blackbrush (*Coleogyne ramosissima*), heathgoldenrod (*Ericameria teretifolius*), Nevada jointfir, broom snakeweed (*Gutierrezia sarothrae*), green ephedra (*Ephedra viridis*), and California buckwheat. On some steep north-facing slopes, big sagebrush (*Artemisia tridentata*) is predominant.

#### 3.1.5.1.2 *Wildlife*

Wildlife at Yucca Mountain is dominated by species associated with the Mojave Desert, with some species from the Great Basin Desert at higher elevations.

The 36 species of mammals that have been observed in the analyzed Yucca Mountain land withdrawal area include 17 species of rodents, seven species of bats, three species of rabbits and hares, and nine species of large mammals such as coyote *(Canis latrans)*, mule deer *(Odocoileus hemionus)*, and burros (*Equus asinus*). The most abundant species are long-tailed pocket mice *(Chaetodipus formosus*) and Merriam’s kangaroo rats (*Dipodomys merriami*).

The 27 species of reptiles include 12 species of lizards, 14 species of snakes, and the desert tortoise (*Gopherus agassizii*). The most abundant lizard is the side-blotched lizard (*Uta stansburiana*), while the western whiptail (*Cnemidophorus tigris*) is common. The most abundant snakes are the coachwhip (*Masticophis flagellum*) and the long-nosed snake (*Rhinocheilus lecontei*). No amphibians have been found at Yucca Mountain.

There have been no formal attempts to quantify the birds present at Yucca Mountain, but at least 120 species have been sighted in or near the analyzed land withdrawal area, including 14 species that nest there. Transient and resident species have been recorded including species typical of the desert, migrating water birds and warblers, and raptors. Black-throated sparrows (*Amphispiza bilineata*) are the most common resident birds and mourning doves (*Zenaida macroura*) are seasonally common.

Researchers have collected invertebrates from 18 orders and 53 families at Yucca Mountain. Members of the insect orders Lepidoptera (butterflies and moths), Hymenoptera (bees, wasps, and ants), and Coleoptera (beetles) were the most numerous of those collected.

Several game species and furbearers (see Nevada Administrative Code 503.125) have been observed in the analyzed land withdrawal area, including (1) three species of game birds—Gambel’s quail (*Callipepla gambelii*), chukar (*Alectoris chukar*), and mourning doves, (2) mule deer (*Odocoileus*

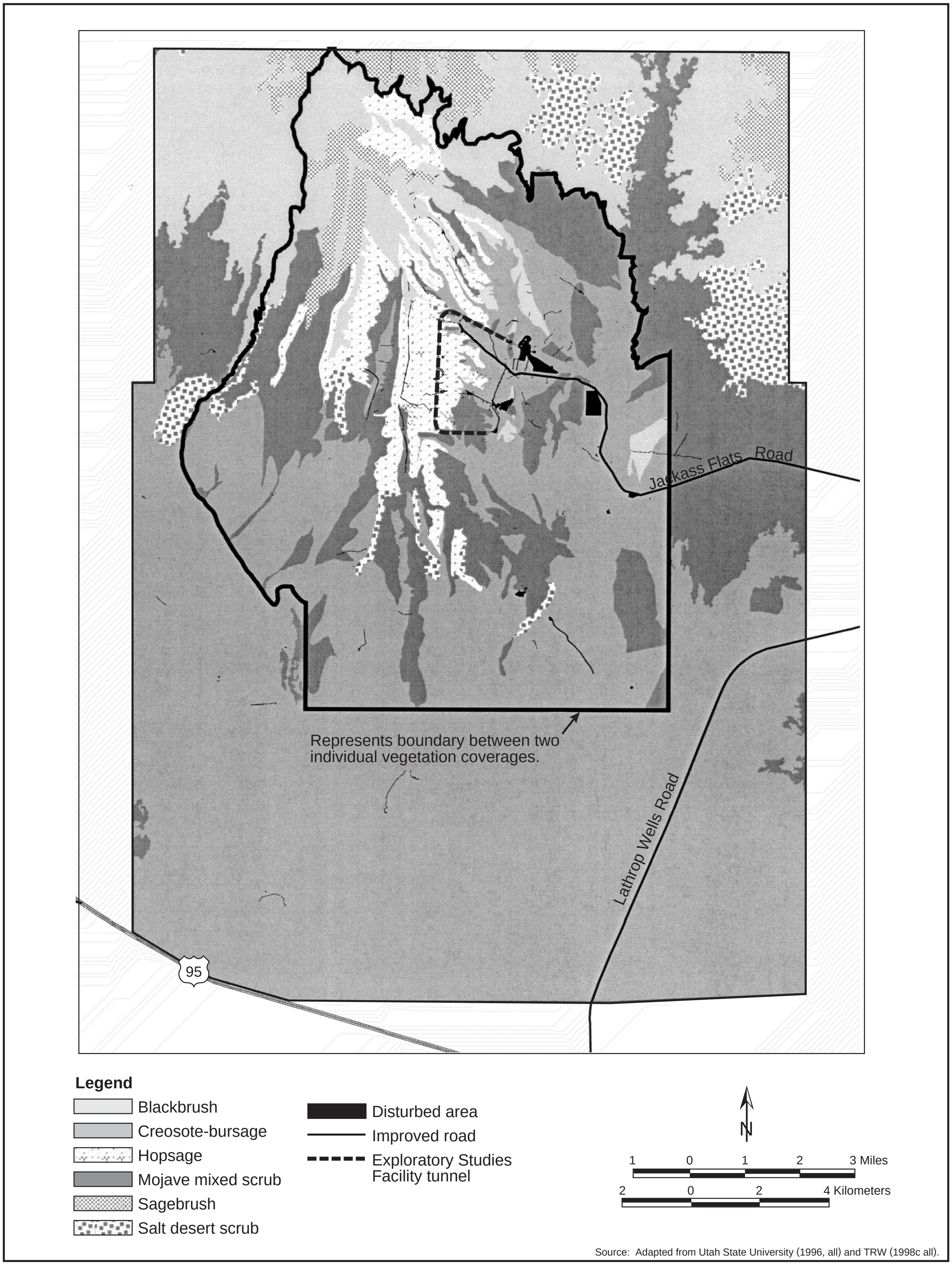



**Figure 3-18.** Vegetation types in the analyzed land withdrawal area.

*hemionus*), and (3) three species of furbearers—kit foxes (*Vulpes velox*), mountain lions (*Puma concolor*), and bobcats (*Lynx rufus*).

### 3.1.5.1.3 *Special Status Species*

**SPECIAL STATUS SPECIES**

An **endangered species** is classified under the Endangered Species Act as being in danger of extinction throughout all or a significant part of its range.

A **threatened species** is classified under the Endangered Species Act as likely to become an endangered species in the foreseeable future.

**Candidate species** are species for which the Fish and Wildlife Service has enough substantive information on biological status and threats to support proposals to list them as threatened or endangered under the Endangered Species Act. Listing is anticipated but has been precluded temporarily by other listing activities.

The State of Nevada has also designated special status species as endangered, threatened, protected, and sensitive. Species with these classifications are protected under Nevada Administrative Code Chapter 503.

Bureau of Land Management **sensitive species** include species designated by the Bureau's State Director in addition to those listed, proposed, or candidates under the Endangered Species Act or listed by the State of Nevada as endangered or otherwise protected.

No plant species listed as threatened or endangered or that are proposed or candidates for listing under the Endangered Species Act occur in the analyzed land withdrawal area. No plant species classified as sensitive by the Bureau of Land Management are known to occur in the analyzed land withdrawal area. Several species of cacti and yucca, all of which are protected by the State of Nevada from commercial collection, are scattered throughout the region, including the analyzed land withdrawal area.

One animal species that occurs at Yucca Mountain, the desert tortoise, is listed as threatened under the Endangered Species Act. Yucca Mountain is at the northern edge of the range of the desert tortoise (Rautenstrauch, Brown, and Goodwin 1994, page 11), and the abundance of tortoises at Yucca Mountain is low or very low in comparison to other portions of its range. Aspects of the ecology of the desert tortoise population at Yucca Mountain have been studied extensively (TRW 1999k, all).

Individual threatened bald eagles (*Haliaeetus leucocephalus)* or endangered peregrine falcons (*Falco peregrinus)* occasionally migrate through the region; these species have been seen once each at the Nevada Test Site. Both species are rare in the region and have not been seen at Yucca Mountain. The State of Nevada has classified both birds as endangered.

No other Federally listed threatened or endangered species or candidates for listing under the Endangered Species Act occur at Yucca Mountain.

Five species classified as sensitive by the Bureau of Land Management occur at Yucca Mountain. Two species of bats—the long-legged myotis (*Myotis volans*) and the fringed myotis (*M. thysanodes*)—have been observed near the site. Three other species, the western chuckwalla (*Sauromalus obesus*), burrowing owl (*Speotyto cunicularia*), and Giuliani's dune scarab beetle (*Pseudocotalpa giulianii*), occur in the analyzed land withdrawal area. The chuckwalla, one of the largest lizards in Nevada, is locally common and widely distributed in rocky habitats throughout the analyzed land withdrawal area and the surrounding region. The seldom-seen burrowing owl generally occurs in valley bottoms and is known to be a year-round resident at the Nevada Test Site. Giuliani's dune scarab beetle has been found near the cinder cones north of U.S. Highway 95 at the south end of Crater Flat.

Ash Meadows is about 39 kilometers (24 miles) south of Yucca Mountain. Although Ash Meadows is outside the region of influence for biological resources, it contains a number of special status species that an evaluation of regional biological resources should consider. Of the eight endemic plant species at Ash Meadows, one is listed as endangered (Amargosa alkali plant, *Nitrophila mohavensis*) and six are listed as threatened (Spring-loving centaury, *Centaurium namophilum*; Ash Meadows milkvetch, *Astragalus phoenix*; Ash Meadows naked stem sunray, *Enceliopsis nudicaulis* var. *corrugata*; Kings Mousetail, *Ivesia kingii* var. *eremica*; Ash Meadows gumweed, *Grindelia fraximopratensis*; and Ash Meadows blazing star, *Mentzelia leucophylla*) (50 *FR* 20777, May 20, 1985). Four endemic fish species occur in the springs and pools. The Fish and Wildlife Service and the State of Nevada list these species—the Ash Meadows Amargosa speckled dace (*Rhinichthys osculus nevadensis*), Ash Meadows Amargosa pupfish (*Cyprinodon nevadensis mionectes*), Devils Hole pupfish (*C. diabolis*), and Warm Springs Amargosa pupfish (*C. nevadensis pectoralis*)—as endangered. The springs also provide habitat for a number of endemic riffle beetles, springsnails, and other invertebrates, including the threatened Ash Meadows naucorid bug (*Ambrysus amargosus*).

#### 3.1.5.1.4 *Wetlands*

There are no naturally occurring jurisdictional wetlands (wetlands that are regulated under Section 404 of the Clean Water Act) at Yucca Mountain. Four manmade ponds in the Yucca Mountain region have riparian vegetation. Fortymile Wash and some of its tributaries might be classified as waters of the United States as defined by the Clean Water Act. Jurisdictional wetlands associated with Ash Meadows are outside the region of influence for the Proposed Action.

### 3.1.5.2 Soils

Researchers have conducted a soil survey centered on Midway Valley (the location of the proposed North Portal facilities) and the ridges to the west (Resource Concepts 1989, all), and a more general soil survey of the entire Yucca Mountain region (DOE 1997f, all). The survey that centered on Midway Valley identified 17 soil series and seven map units (Table 3-19) at Yucca Mountain (Resource Concepts 1989, all); none of these series is classified as prime farmland. Based on a wetlands assessment at the Nevada Test Site (Hansen et al. 1997, all), there are no hydric soils at Yucca Mountain. Yucca Mountain soils are derived from underlying volcanic rocks and mixed alluvium dominated by volcanic material, and in general have low water-holding capacities.

**SOIL TERMS**

**Prime farmland:** Land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops, and is available for these uses (urban areas are not included). It has the soil quality, growing season, and moisture supply needed for the economic production of sustained high yields of crops when treated and managed (including water management) according to acceptable farming methods (Farmland Protection Policy Act of 1981, 7 CFR 7.658).

**Piedmont:** Land lying along or near the foot of a mountain. For example, a fan piedmont is a fan-shaped landform between the mountain and the basin floor.

**Table 3-19.** Soil mapping units at Yucca Mountain.[a]

| Map unit | Percent | Geographic setting | Soil characteristics |
|---|---|---|---|
| Upspring-Zalda | 11 | Mountain tops and ridges. Soils occur on smooth, gently sloping ridge tops and shoulders and on nearly flat mesa tops. Rhyolite and tuffs are parent materials for both soil types. | Typically shallow (10 - 51 cm[b]) to bedrock, or to thin duripan[c] over bedrock. They are well to excessively drained, have low available water-holding capacity, medium to rapid runoff potential, and slight erosion hazard. |
| Gabbvally-Downeyville-Talus | 8 | North-facing mountain sideslopes. Talus is stone-sized rock occurring randomly throughout unit in long, narrow, vertically oriented accumulations. | Shallow (10 - 36 cm) to bedrock. Permeability is moderate to moderately rapid. They have moderate to rapid runoff potential, are well drained, and have low available water-holding capacity and moderate erosion hazard. |
| Upspring-Zalda-Longjim | 27 | Mountain sideslopes. Soils occur on south-, east-, and west-facing slopes, and on moderately sloping alluvial deposits below sideslopes. | Shallow (10 - 51 cm) to bedrock or to thin duripan over bedrock. They are well to excessively drained and have moderately rapid to rapid permeability and runoff potential, very low available water-holding capacity, and slight erosion hazard. |
| Skelon-Aymate | 22 | Alluvial fan remnants. Soils occur on gently to strongly sloping summits and upper sideslopes. | Moderately deep (51 - 102 cm) to indurated[d] duripan or petrocalcic[e] layer with low to very low available water-holding capacity, moderately rapid permeability, slow runoff potential, and slight erosion hazard. |
| Strozi variant-Yermo-Bullfor | 7 | Alluvial fan remnants. Soils occur on gently to moderately sloping alluvial fan remnants and stream terraces adjacent to large drainages. | Moderately deep (51 - 102 cm) to deep (102 cm). They are well drained and have rapid permeability, very low available water-holding capacity, slow runoff potential, and slight erosion hazard. |
| Jonnic variant-Strozi-Arizo | 12 | Dissected alluvial fan remnants. Soils occur on fan summits, moderately sloping fan sideslopes, and inset fans. They are formed in alluvium from mixed volcanic sources. | Moderately deep (36 - 43 cm) to deep (more than 102 cm), sometimes over strongly cemented duripan. They have slow or rapid permeability, slow or moderate runoff potential, very low available water-holding capacity, and slight erosion hazard. |
| Yermo-Arizo-Pinez | 13 | Inset fans and low alluvial sideslopes in mountain canyons; and drainages between fan remnants. Soils occur on moderately to strongly sloping inset fans near drainages, adjacent to lower fan remnants, and below foothills. | Deep (more than 102 cm), sometimes over indurated duripan. They are well drained and have very low available water holding-capacity, moderately slow to rapid permeability, slow to medium runoff potential, and slight erosion hazard. |

a. Source: TRW (1999l, pages 3 and 4).
b. To convert centimeters (cm) to inches, multiply by 0.3937.
c. Duripan: A subsurface layer cemented by silica, usually containing other accessory cements.
d. Indurated: Hardened, as in a subsurface layer that has become hardened.
e. Petrocalcic: A subsurface layer in which calcium carbonate or other carbonates have accumulated to the extent that the layer is cemented or indurated.

The shallow soils on ridge tops at Yucca Mountain often consist of a thin *hardpan* (hardened or cemented soil layer) on top of bedrock and range from *well drained* to *excessively drained,* which means that water drains readily to very rapidly. The soil has a topsoil layer typically less than 15 centimeters (6 inches) thick and, in some instances, a subsoil layer 5 to 30 centimeters (2 to 12 inches) thick. Soil textures range from gravelly to cobbly, loamy sands to sandy loams. Soils are calcareous (high in calcium carbonate), with lime coatings on the undersides of rocks in the subsoil layer. The soils are moderately to strongly alkaline, with a pH ranging from 8.0 to 8.6. Rock fragments ranging in size from gravel to cobbles dominate 45 to 65 percent of the ground surface.

Soils on fan piedmonts and in steep, narrow canyons are relatively deep and are *well drained* (water is drained readily, but not rapidly). These soils developed from residues of volcanic parent material, with a component of calcareous eolian sand. Soils formed from the volcanic parent material generally range from *moderately shallow* [50 to 75 centimeters (20 to 30 inches)] to *moderately deep* [75 to 100 centimeters (30 to 40 inches)] over a thin hardpan on top of bedrock. The topsoil layers are generally less than 25 centimeters (10 inches) thick, with a subsoil layer thickness of 25 to 50 centimeters (10 to 20 inches). The mixed soils, containing residues from volcanic parent material and calcareous eolian sand, are often *deep* [100 to 150 centimeters (40 to 60 inches)] or moderately deep, having a well-cemented hardpan. The topsoil layers are less than 15 centimeters (6 inches) thick, with the layer of soil parent material as deep as 150 centimeters (60 inches). Soil textures are gravelly, sandy loams with 35 to 70 percent rock fragments. Soils are generally calcareous and moderately to strongly alkaline.

Soils on alluvial fans and in stream channels are *very deep* [greater than 150 centimeters (60 inches)] and range from well drained to excessively drained. The topsoil layers are generally less than 20 centimeters (8 inches) thick, with the layer of soil parent material as deep as 150 centimeters. Soil textures are very gravelly, with fine sands to sandy loams and abundant rock fragments. The soils are calcareous and moderately alkaline.

The Yucca Mountain site characterization project has sampled and analyzed surface soils for radiological constituents. In addition, records of spills or releases of nonradioactive materials have been maintained to meet regulatory requirements and to provide a baseline for the Proposed Action. A recent summary of existing radiological conditions in soils is based on 98 surface samples collected within 16 kilometers (10 miles) of the Exploratory Studies Facility. The results of that analysis, when compared to other parts of the world, indicate average levels of the naturally occurring radionuclide uranium-238 series decay products and above-average levels of the naturally occurring radionuclides potassium-40 and thorium-232 series decay products. The higher-than-average radionuclide values might be due to the origin of the soil at the site from tuffaceous igneous rocks. The studies also detected concentrations of the manmade radionuclides strontium-90, cesium-137, and plutonium-239 from worldwide nuclear weapons testing.

### 3.1.6 CULTURAL RESOURCES

Cultural resources include any prehistoric or historic district, site, building, structure, or object resulting from or modified by human activity. Cultural resources could also include potential traditional cultural properties. Under Federal regulation, cultural resources designated as historic properties warrant consideration with regard to potential adverse impacts resulting from proposed Federal actions. A cultural resource is an historic property if its

**CULTURAL RESOURCES**

**Archaeological site:** The location of a past event, a prehistoric or historic occupation or activity, or a building or structure, whether standing, ruined, or vanished, where the location itself maintains archaeological value.

**Traditional cultural property:** A property associated with the cultural practices or beliefs of a living community that are (1) rooted in that community's history, and (2) important in maintaining the cultural identity of the community.

attributes make it eligible for listing or it is formally listed on the *National Register of Historic Places*. For this analysis, DOE has evaluated the importance of historic and archaeological resources according to National Register eligibility criteria.

Cultural resources at Yucca Mountain include archaeological resources that are prehistoric or historic, and other resources important to Native American tribes and organizations, such as potential traditional cultural properties. DOE has collected information on the various types of archaeological sites, detailing their purposes and the kinds of artifacts typically present. DOE also has focused on Native American interests in the region's cultural resources. Section 3.1.6.2 summarizes these issues in discussions of Native American views of the affected environment.

Unless otherwise indicated, the information in this section is derived from either the summary of past archaeological projects at Yucca Mountain (TRW 1999m, all) or from *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (AIWS 1998, all).

### 3.1.6.1 Archaeological and Historic Resources

Site characterization efforts have led to a number of archaeological investigations at Yucca Mountain over the past two decades, including an archaeological field survey of a 44-square-kilometer (about 11,000-acre) parcel that proposed repository activities probably would affect. The field survey was followed by limited test excavations at 29 sites to determine their scientific importance and to develop management strategies for the protection of archaeological resources. Additional archaeological surveys have been conducted along nearby Midway Valley and Yucca Wash and in lower Fortymile Canyon just east of the Yucca Mountain site.

Concurrent with these investigations, DOE directed archaeological surveys and data-recovery projects before beginning planned ground-disturbing activities specific to the Yucca Mountain Project. Limited data-recovery efforts at 18 archaeological sites support a model for a local cultural sequence that includes a pattern of linear-shaped sites along major drainages dating as far back as 7,000 years, and a shift to a more dispersed pattern of sites about 1,500 years ago. A site monitoring program designed to examine human and natural impacts to cultural resources through time began in 1991 and is continuing at Yucca Mountain.

Decades of cultural resource investigations at Yucca Mountain and at the Nevada Test Site have revealed archaeological features and artifacts. Based on archaeological site file searches at the Desert Research Institute in Las Vegas and Reno and at the Harry Reid Center at the University of Nevada, Las Vegas, approximately 826 archaeological sites have been discovered in the analyzed land withdrawal area. Most of the known archaeological sites are small scatters of lithic (stone) artifacts, usually comprised of fewer than 50 artifacts with few formal tools and no temporally or culturally diagnostic artifacts in the inventory. None of the sites has been listed on the *National Register of Historic Places,* but 150 are potentially eligible for nomination (see Table 3-20). Several reports describe the specific procedures used to study and protect these cultural sites (Buck and Powers 1995, all; DOE 1992a, all). DOE (1988b, all) describes how the Department meets its responsibilities under Section 106 of the National Historic Preservation Act and the American Indian

**Table 3-20.** Sites in the Yucca Mountain region potentially eligible for the *National Register of Historic Places.*

| Type | Number |
|---|---|
| Temporary camps | 43 |
| Extractive localities | 14 |
| Processing localities | 9 |
| Localities | 77 |
| Caches | 2 |
| Stations | 1 |
| Historic sites | 4 |
| **Total** | **150** |

Religious Freedom Act, and interactions with the Advisory Council on Historic Preservation and the Nevada State Historic Preservation Officer.

This EIS separates archaeological sites into two broad groups, prehistoric and historic, separated by the first contact between Native Americans and Euroamericans; in the Great Basin, this contact occurred in the early 1800s. The oldest prehistoric sites in southern Nevada are about 11,000 years old. These sites include one or more of the following features: temporary campsites, rock art, scattered lithic artifacts, quarries, plant-processing remains, hunting blinds, and rock alignments. The sites are categorized as temporary camps, extractive localities, processing localities, localities, caches, and stations. Historic sites include mining sites, ranching sites, transportation and communication sites, and some Cold War facilities. The following paragraphs define eligible types of sites at Yucca Mountain in each group (Table 3-20).

*Temporary Camps.* When occupied by a group of people, a temporary camp was a hub of activity for raw materials processing, implement manufacturing, and maintenance and general living activities. Camp artifacts typically include debris and discards from the making of stone tools, projectile points, bifacial stone tools, cores, milling stones, pottery, specialized tools, hearths, shelters, structures, and art. The nature and diversity of artifacts and features are the basis for designating a site as a temporary camp.

*Extractive Localities.* These were sites for specific extractive or resource-procurement tasks. They probably were occupied for short periods and for such limited activities as toolstone quarrying, hunting, and seed gathering. A single locality can contain isolated artifacts or large quantities of artifacts that reflect specific activities. In comparison to temporary camps, extractive localities have a low diversity of artifacts. Extractive locality artifacts include isolated projectile points or bifacial stone tools where hunting occurred, toolstone quarries with thousands of flakes, diffuse scatters of lithic flakes where plant materials were gathered, hunting blinds, and *tinajas* or water-catchment basins.

*Processing Localities.* Specific resource-processing tasks occurred at processing localities. These localities probably were occupied only for short periods and for limited activities such as butchering, milling, and roasting. A single site can contain an isolated artifact or large quantities of artifacts that reflect specific activities. Like extractive localities, processing localities have a low diversity of artifacts. Examples of processing localities include stone tool manufacturing stations, milling stations for processing food, diffuse scatters containing stone tools for processing meat and hides, hearths, and roasting pits.

*Localities.* This category includes sites that might have been either extractive or processing localities but for which there is not enough information to determine if such activities occurred.

*Caches.* Caches are temporary places for storing resources or artifacts. They include sealed rock shelters, rock piles, rock rings without evidence of habitation, rock alignments, brush piles held in place by rocks, and storage pits. A cache can also be an association of similar artifacts such as heat-treated bifacial stone tools, projectile points, and snares, or such resources as toolstone blanks and firewood in or on a natural feature such as at the base of a tree, in a rock shelter, or in a mountain saddle. Caches are distinguished from localities as places for storing resources, rather than as places of procurement or processing.

*Stations.* Stations are sites where groups gathered to exchange information about such things as game movement, routes of travel, and ritual activities. Examples of stations are rock cairns marking routes of travel, isolated petroglyphs and pictographs, geoglyphs, and observation points and overlooks.

*Historic Sites.* Historic sites are contemporaneous with or postdate the introduction of European influences in the region. Historic archaeological sites are few in number in the project area, usually represented by a small scatter of artifacts (cans and bottles). These short-term activities were related to mining, ranching, and transportation.

### 3.1.6.2 Native American Interests

#### 3.1.6.2.1 *Yucca Mountain Project Native American Interaction Program*

In 1987, DOE initiated the Native American Interaction Program to consult and interact with tribes and organizations on the characterization of the Yucca Mountain site and the possible construction and operation of a repository. These tribes and organizations—Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone people from Arizona, California, Nevada, and Utah—have cultural and historic ties to the Yucca Mountain area.

The Native American Interaction Program concentrates on the protection of cultural resources at Yucca Mountain and promotes a government-to-government relationship with the tribes and organizations. Its purpose is to help DOE comply with various Federal laws and regulations, including the American Indian Religious Freedom Act, the Archaeological Resources Protection Act, the National Historic Preservation Act, the Native American Graves Protection and Repatriation Act, DOE Order 1230.2 (*American Indian and Tribal Government Policy*), and Executive Orders 13007 (*Indian Sacred Sites*) and 13084 (*Consultation and Coordination with Indian Tribal Governments*). These regulations mandate the protection of archaeological sites and cultural items and require agencies to include Native Americans and Federally recognized tribes in discussions and interactions on major Federal actions.

Initial studies identified three tribal groups—Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone—whose cultural heritage includes the Yucca Mountain region (Stoffle 1987, page 5-13). Additional ethnographic efforts eventually identified 17 tribes and organizations involved in the Yucca Mountain Project Native American and cultural resource studies. Figure 3-19 shows the traditional boundaries and locations of the 17 tribes and organizations.

Of the 17 tribal groups, 15 are Federally recognized tribes. The Pahrump Paiute Indian Tribe, which consists of a group of Southern Paiutes living in Pahrump, Nevada, has applied for Federal tribal recognition but to date has not received it. In addition, the Las Vegas Indian Center is not a Federally recognized tribe, but DOE included it in the Native American Interaction Program because it represents the urban Native American population of Las Vegas and Clark County, Nevada (Stoffle et al. 1990, page 7).

The 17 tribes and organizations have formed the Consolidated Group of Tribes and Organizations, which consists of officially appointed tribal representatives who are responsible for presenting their respective tribal concerns and perspectives to DOE. The primary focus of this group has been the protection of cultural resources and environmental restoration at Yucca Mountain. Members of the group have participated in many ethnographic interviews and have provided DOE valuable insights into Native American cultural and religious values and beliefs. These interactions have produced several reports that record the regional history of Native American people and the interpretation of Native American cultural resources in the Yucca Mountain region (Stoffle, Evans, and Harshbarger 1989, pages 30 to 74; Stoffle et al. 1990, pages 11 to 25; Stoffle, Olmsted, and Evans 1990, pages 23 to 49). In addition, tribal representatives have identified and discussed traditional and current uses of plants in the area (Stoffle et al. 1989, pages 22 to 139).

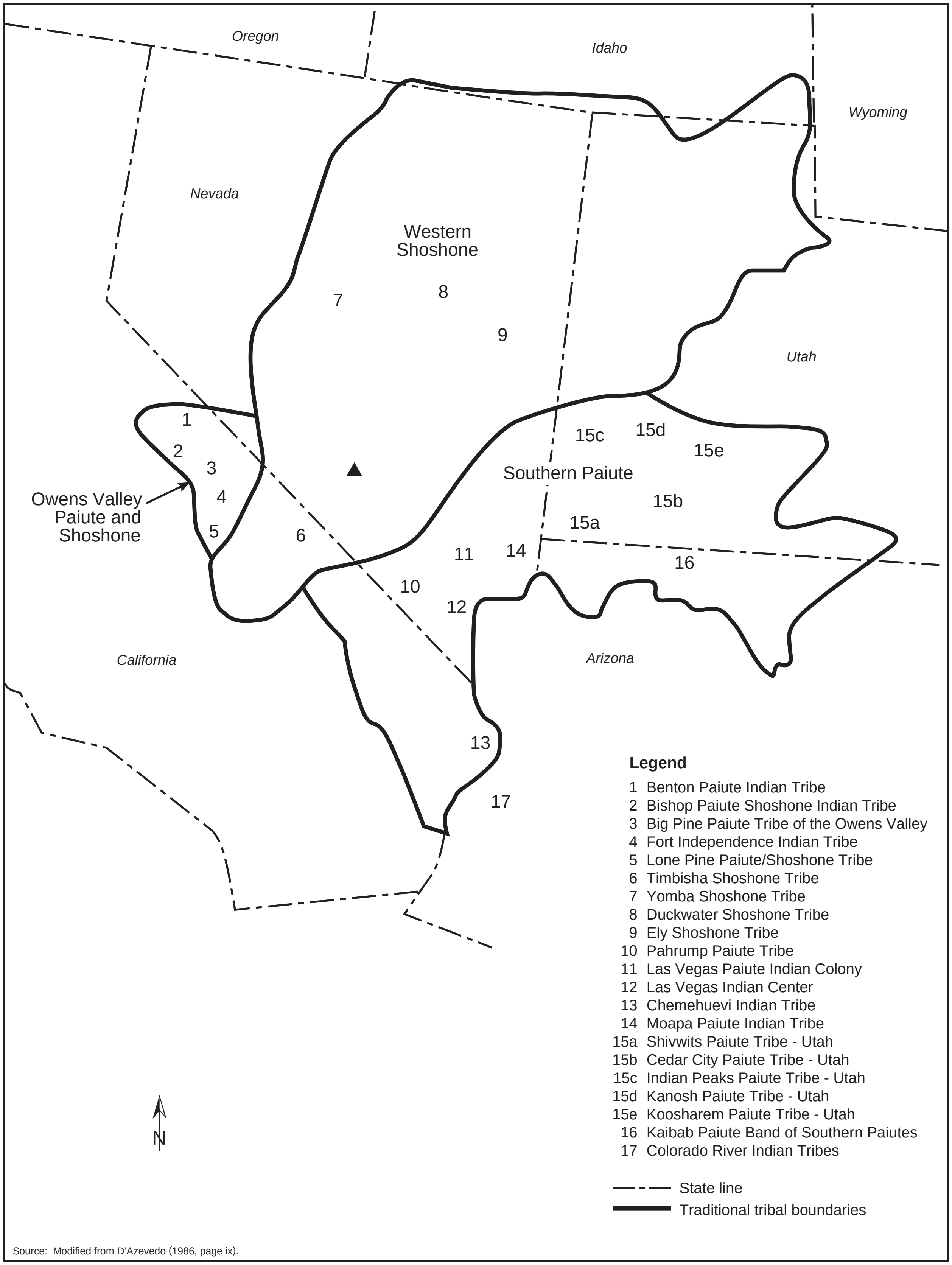



**Figure 3-19.** Traditional boundaries and locations of tribes in the Yucca Mountain region.

#### 3.1.6.2.2 *Native American Views of Affected Environment*

During the EIS scoping process, DOE visited many tribes to encourage their participation. Members of the Consolidated Group of Tribes and Organizations designated individuals who represented the three tribal groups (Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone) to document their viewpoints on the Yucca Mountain area. This group, the American Indian Writers Subgroup, prepared a resource document that provides Native American perspectives on the repository (AIWS 1998, all). This report also describes the relationship between Native American people and DOE and discusses impacts of the Proposed Action while recommending impact mitigation approaches for reducing potential impacts to Native American resources and other heritage values in the Yucca Mountain region. In addition to the general and specific cultural resources issues, which are summarized in the following paragraphs, the report covers other critical topics, including concerns for occupational and public health and safety, environmental justice and equity issues, and social and economic issues. The report also provides recommendations for the conduct of appropriate consultation procedures for the repository and associated activities, and requests Native American participation in development of project resource management approaches to enable the incorporation of accumulated centuries of ethnic knowledge in long-term cultural resource protection strategies.

Native American people believe that they have inhabited their traditional homelands since the beginning of time. Archaeological surveys have found evidence that Native American people used the immediate vicinity of Yucca Mountain on a temporary or seasonal basis (Stoffle et al. 1990, page 29). Native Americans emphasize that a lack of abundant artifacts and archaeological remains does not mean that their people did not use a site or that the land is not an integral part of their cultural ecosystem. Native Americans assign meanings to places involved with their creation as a people, religious stories, burials, and important secular events. The traditional stories of the Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone peoples identify such places, including the Yucca Mountain area. Native Americans believe that cultural resources are not limited to the remains of native ancestors but include all natural resources and geologic formations in the region, such as plants and animals and natural landforms that mark important locations for keeping their historic memory alive and for teaching their children about their culture. Equally important are the water resources and minerals in the Yucca Mountain region. Native Americans used traditional quarry sites to make tools, stone artifacts, and ceremonial objects; many of these sites are *power places* associated with traditional healing ceremonies. Despite the current physical separation of tribes from Yucca Mountain and neighboring lands, Native Americans continue to value and recognize the meaningful role of these lands in their culture and continued survival. Many areas in the Yucca Mountain region are important to them. Fortymile Canyon was an important crossroad where a number of traditional trails from such distant places as Owens Valley, Death Valley, and the Avawtz Mountain came together. Oasis Valley was an important area for trade and ceremonies. Native Americans believe that Prow Pass was an important ceremonial site and, because of this religious importance, have recommended that DOE conduct no studies in this area. Other areas are important based on the abundance of artifacts, traditional-use plants and animals, rock art, and possible burial sites.

According to Native American people, the Yucca Mountain area is part of the holy lands of the Western Shoshone, Southern Paiute, and Owens Valley Paiute and Shoshone peoples. Native Americans generally do not concur with the conclusions of archaeological investigators that their ancestors were highly mobile groups of aboriginal hunter-gatherers who occupied the Yucca Mountain area before Euroamericans began using the area for prospecting, surveying, and ranching. They believe that these conclusions overlook traditional accounts of farming that occurred before European contact. Yucca Mountain and nearby lands were central in the lives of the Western Shoshone, Southern Paiute, and Owens Valley Paiute and Shoshone peoples, who shared them for religious ceremonies, resource uses, and social events. Native Americans value the cultural resources in these areas, viewing them in a holistic manner. They believe that the water, animals, plants, air, geology, and artifacts are interrelated and dependent on each other for existence.

### 3.1.7 SOCIOECONOMICS

To define the existing conditions for the socioeconomic environment in the Yucca Mountain region, DOE determined the current economic and demographic status in a well-defined region (called the *region of influence*) near the site of the proposed repository. DOE based its definition of the socioeconomic region of influence on the distribution of the residences of current employees of the Department and its contractors who work on the Yucca Mountain Project or at the Nevada Test Site. The region of influence, therefore, consists of the counties where about 90 percent of the DOE workforce lives. The Department used the residential distribution, which reflects existing commuting patterns, to estimate the future distribution of direct workers associated with the Proposed Action and the No-Action Alternative. Unless otherwise noted, the *Yucca Mountain Site Characterization Project Environmental Baseline File for Socioeconomics* (TRW 1999n, all) is the basis for the information in this section.

DOE received numerous reports from affected units of local government providing socioeconomic baseline environmental information. The reports contain information that characterizes the existing community environment, provides assessments of economic development, or includes basic economic and demographic trends. DOE reviewed these reports and determined that the information provided was consistent with the information used in this EIS.

The socioeconomic region of influence for the Proposed Action consists of Clark, Lincoln, and Nye Counties in southern Nevada (Figure 3-20). Clark County contains the City of Las Vegas and its suburbs. Based on a count of respondents to a 1994 survey, an estimated 79 percent of Yucca Mountain Project and Nevada Test Site onsite employees live in Clark County (Table 3-21). The region of influence includes Lincoln County because of the possibility that DOE could build and operate an intermodal transfer station there.

**Table 3-21.** Distribution of Yucca Mountain Project and Nevada Test Site onsite employees (survey respondents) by place of residence.[a]

| Place of residence | Onsite workers | Percent of total |
|---|---|---|
| Clark County | 1,268 | 79 |
| Lincoln County | 5 | 0.3 |
| Nye County | 310 | 19 |
| **Total region of influence** | **1,583** | **98** |
| Outside region of influence | 31 | 2 |
| ***Total respondents*** | ***1,614*** | ***100.0*** |

a. Source: TRW (1994a, all).

#### 3.1.7.1 Population

DOE used the Regional Economic Models, Inc. (REMI) model to estimate baseline socioeconomic conditions at the conclusion of site characterization (Treyz, Rickman, and Shao 1992, all).

Southern Nevada has been and continues to be one of the fastest-growing areas in the country. During the 1980s, the population of the region of influence had an average annual growth rate of 4.8 percent, adding more than 29,000 people annually and reaching 780,000 residents in 1990. In comparison to the State of Nevada, which had a average annual growth rate of 4 percent between 1980 and 1990, the United States had a growth rate of less than 1 percent during the same period (Bureau of the Census 1999, all). This trend has increased during the 1990s. From 1990 to 1997, the region of influence had an annual growth rate of 5.5 percent, averaging 51,000 new residents annually. In 1997, the population of the region increased 5.4 percent and added 57,000 new residents, bringing the estimated population to about 1.14 million. Led by Clark County, Nevada is the fastest growing state in the country. From 1990 to 1997, Nevada had an annual growth rate of 4.5 percent compared to the 1-percent annual growth rate of the United States.

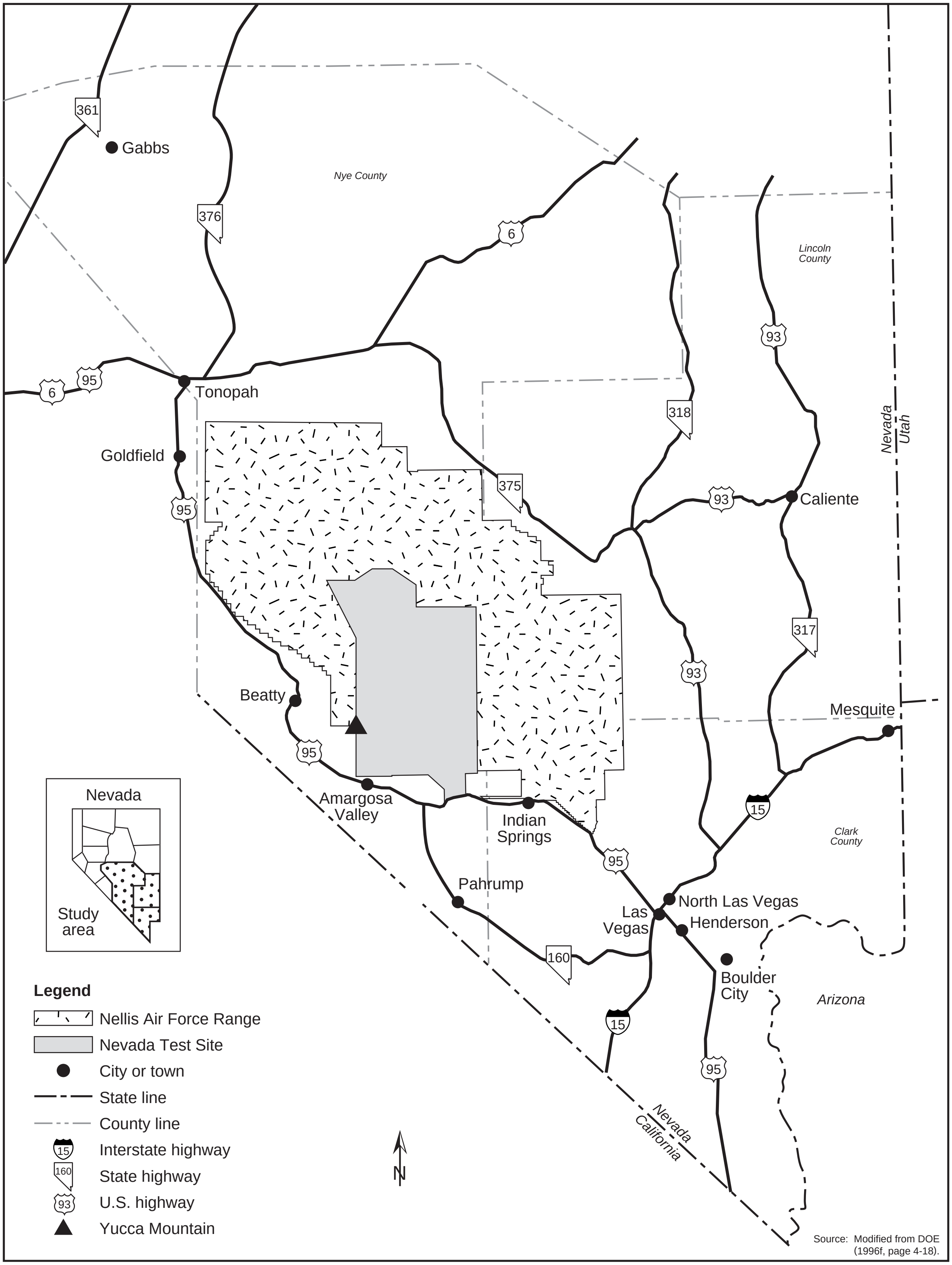



**Figure 3-20.** Socioeconomic region of influence.

Las Vegas and the immediate surrounding area dominate the Clark County population. The Las Vegas economy is driven by the growth of the hotel and gaming industry. As the popularity of gaming grew in the 1970s and 1980s, Las Vegas evolved as one of the country's major tourism and convention destinations. In 1997, Las Vegas hosted 30.5 million visitors, contributing $25 billion to the local economy (LVCVA 1999, all). The tourism trend is expected to continue well into the next century. The relatively inexpensive land, Sunbelt climate, and favorable business conditions have also contributed to commercial and residential growth.

Another factor influencing strong growth is the number of retirees moving to communities in the region of influence. The pleasant climate, abundance of recreational opportunities, and Nevada's favorable tax structure have attracted retirees from across the United States.

Nye County, which has been the site of booms and busts due to fluctuating mining activity and the recent decline of Nevada Test Site employment, is home to approximately 19 percent of the Yucca Mountain Project workforce (Table 3-21). Pahrump, in southern Nye County, is experiencing growth caused primarily by inmigrating retirees.

In 1997, Nye County had about 26,000 residents, and it has experienced a 3.7-percent annual growth rate in the 1990s. The 1997 population in Lincoln County was about 4,200, up from about 3,800 in 1990. Although the annual growth rate of the region of influence is likely to slow, the population should increase 2 to 4 percent a year in the next decade. Clark County should lead the population growth in the foreseeable future in the region of influence.

The region of influence includes a number of incorporated cities as well as unincorporated towns (Table 3-22). The largest city in Clark County is Las Vegas, followed by Henderson. In 1997, Las Vegas had a population of about 430,000 compared to Henderson, which had about 150,000 residents. Nye County has one incorporated city, but the largest community is unincorporated Pahrump, which had an estimated population of about 19,000 in 1997. Lincoln County also has only one incorporated city, Caliente, which is the largest community. In 1997, Caliente had a population of about 1,100.

**Table 3-22.** Population of incorporated cities and selected unincorporated towns, 1991 to 1997.[a,b]

| Jurisdiction | 1991 | 1995 | 1997 |
|---|---|---|---|
| *Clark County* | | | |
| Boulder City | 13,000 | 14,000 | 14,000 |
| Henderson | 77,000 | 120,000 | 150,000 |
| Indian Springs[c] | N/A[d] | N/A | 1,200 |
| Las Vegas | 290,000 | 370,000 | 430,000 |
| Mesquite | 2,100 | 5,100 | 9,300 |
| North Las Vegas | 51,000 | 78,000 | 93,000 |
| *Nye County* | | | |
| Amargosa Valley[c] | N/A | N/A | 990 |
| Beatty[c] | N/A | N/A | 1,600 |
| Gabbs | 680 | 360 | 400 |
| Pahrump[c] | N/A | N/A | 19,000 |
| Tonopah[c] | N/A | N/A | 2,800 |
| *Lincoln County* | | | |
| Caliente | 1,100 | 1,200 | 1,100 |

a. Source: TRW (1999n, all).
b. Population numbers have been rounded to two significant figures.
c. Selected unincorporated towns.
d. N/A = not available.

### 3.1.7.2 Employment

Of the three counties that comprise the region of influence, Clark County has by far the largest economy; in 1995, the estimated employment was about 620,000. This constituted 98 percent of the regional employment and about 64 percent of the State employment. During the same year Nye County had an employment of about 11,000, and the Lincoln County employment was about 2,100. Clark County should continue to outpace the growth of the other counties in the region.

Between 1980 and 1990, Clark County added an average of 19,000 jobs a year (Table 3-23). Since 1990 that pace has increased to more than 30,000 new jobs a year with an average annual growth rate of 6.1 percent. Total employment increased 35 percent between 1990 and 1995, adding about 160,000 jobs. By 2000, Clark County is expected to have an employment of about 860,000, continuing to create over 2,000 new jobs a month. The services employment sector is the largest in Clark County, representing 46 percent of the employment in 1995.

**Table 3-23.** Clark County employment by sector, 1980 to 2000.[a,b]

| Sector | 1980 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| *Private sector (totals)* | *230,000* | *410,000* | *560,000* | *780,000* |
| Agriculture, forestry, and fisheries | 1,300 | 3,900 | 6,200 | 9,000 |
| Mining | 590 | 820 | 1,200 | 1,300 |
| Construction | 16,000 | 41,000 | 53,000 | 79,000 |
| Manufacturing | 7,300 | 12,000 | 18,000 | 20,000 |
| Transportation and public utilities | 14,000 | 21,000 | 29,000 | 37,000 |
| Wholesale trade | 6,500 | 14,000 | 19,000 | 24,000 |
| Retail trade | 44,000 | 72,000 | 98,000 | 130,000 |
| Finance, insurance, and real estate | 20,000 | 32,000 | 44,000 | 55,000 |
| Services | 120,000 | 210,000 | 290,000 | 420,000 |
| *Government (totals)* | *38,000* | *51,000* | *62,000* | *79,000* |
| Federal Government - civilian | 4,800 | 6,900 | 7,800 | 7,700 |
| Federal Government - military | 11,000 | 11,000 | 9,500 | 10,000 |
| State and local government | 22,000 | 33,000 | 45,000 | 11,000 |
| *Farm* | *420* | *400* | *300* | *310* |
| ***Totals*** | ***268,420*** | ***460,000*** | ***620,000*** | ***859,310*** |

a. Sources: 1980, 1990, and 1995: TRW (1999n, all); 2000: estimated.
b. Employment numbers have been rounded to two significant figures.

Although Nye County's employment increased between 1980 and 1990, it declined to about 11,000 in 1995, a decrease of 15 percent (Table 3-24). The services sector represented the largest in the Nye County economy. In 1995, services comprised 47 percent of the employment. Projections indicate that employment will decline to about 10,000 by 2000. Lincoln County employment also declined between 1990 and 1995 after growth during the 1980s (Table 3-25). In 1995, Lincoln County had a employment of about 2,100, a decline of 13 percent from 1990. As in Clark and Nye Counties, services represented the largest sector of the Lincoln County economy. In 1995, services comprised 39 percent of the employment.

Las Vegas, in Clark County, has one of the fastest growing economies in the country. The rapid growth of the Las Vegas area is driven by the gaming and tourism industry. For each hotel room constructed, an employment multiplier effect creates an estimated 2.5 direct and indirect jobs. About 14,000 hotel rooms were added between 1996 and 1998. Five new major resorts under construction with completion dates between Spring 1998 and Spring 2000 will add about 14,000 hotel rooms (*Las Vegas Sun* 1998, all). Despite an inventory of more than 100,000 rooms, hotels consistently operate at 90 percent occupancy, reaching to 97 percent on weekends.

**Table 3-24.** Nye County employment by sector, 1980 to 2000.[a,b]

| Sector | 1980 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| *Private sector (totals)* | *6,900* | *12,000* | *9,600* | *11,000* |
| Agriculture, forestry, and fisheries | 50 | 70 | 110 | 120 |
| Mining | 1,100 | 2,000 | 1,400 | 1,000 |
| Construction | 410 | 390 | 560 | 1,000 |
| Manufacturing | 88 | 160 | 250 | 290 |
| Transportation and public utilities | [210] | [280] | 280 | 380 |
| Wholesale trade | 25 | 49 | 100 | 150 |
| Retail trade | 530 | 960 | 1,200 | 1,800 |
| Finance, insurance, and real estate | [360] | [290] | 450 | 490 |
| Services | 4,100 | 7,700 | 5,200 | 5,500 |
| *Government (totals)* | *770* | *1,200* | *1,500* | 1,700 |
| Federal Government - civilian | 130 | 200 | 200 | *200* |
| Federal Government - military | 100 | 77 | 53 | 79 |
| State and local government | 540 | 930 | 1,200 | 1,400 |
| *Farm* | *220* | *260* | *210* | 210 |
| ***Totals*** | ***7,890*** | ***13,360*** | ***11,310*** | ***12,910*** |

a. Sources: 1980, 1990, and 1995: TRW (1999n, all), except estimates in [brackets] appear wherever data suppression by TRW (1999n) was indicated by zeros; 2000: estimated.

b. Employment numbers have been rounded to two significant figures.

**Table 3-25.** Lincoln County employment by sector, 1980 to 2000.[a,b]

| Sector | 1980 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| *Private sector (totals)* | *1,300* | *1,712* | *1,380* | *1,558* |
| Agriculture, forestry, and fisheries | [4] | [30] | 22 | 24 |
| Mining | 310 | 30 | 18 | 14 |
| Construction | 75 | 47 | 44 | 24 |
| Manufacturing | 12 | [10] | 10 | 37 |
| Transportation and public utilities | 96 | 88 | 62 | 62 |
| Wholesale trade | 12 | 10 | [17] | 41 |
| Retail trade | 310 | 250 | [270] | 386 |
| Finance, insurance, and real estate | 51 | 47 | 68 | 74 |
| Services | 380 | [1,200] | [869] | 846 |
| *Government (totals)* | *400* | *537* | *607* | *573* |
| Federal Government - civilian | 25 | 45 | 39 | 34 |
| Federal Government - military | 12 | 12 | *8* | 9 |
| State and local government | 360 | 480 | 560 | 530 |
| *Farm* | *160* | *180* | *150* | *149* |
| ***Totals*** | ***1,860*** | ***2,429*** | ***2,137*** | ***2,280*** |

a. Sources: 1980, 1990, and 1995: TRW (1999n, all), except estimates in [brackets] appear wherever data suppression by TRW (1999n) was indicated by zeros; 2000: estimated.

b. Individual employment numbers have been rounded to two significant figures.

Because of the thousands of new jobs added to the economy each month, the Las Vegas area has a low unemployment rate. In 1997, Clark and Nye Counties had unemployment rates below the Nevada and national rates at 4.0 percent and 3.9 percent, respectively. The planned closing of the Bullfrog Mine in Nye County will increase unemployment. In 1997, the Bullfrog Mine employed approximately 290 workers; however, it will probably close in 2000 (Meyers 1998, all). Lincoln County had an unemployment rate above the national average at 7.8 percent (Reel 1998, all). The State of Nevada had an unemployment rate of 4.1 percent and the United States had a rate of 4.9 percent (NDETR 1999, all). Onsite employment levels at the Exploratory Studies Facility remained relatively constant between 1995 and 1997, and are not likely to fluctuate substantially through the end of site characterization activities.

In 1997, an average of about 1,600 workers (140 on the site and 1,460 off the site) worked on the Yucca Mountain Project. Most offsite workers are in the Las Vegas area (TRW 1998d, all). The employment projection for 2000 reflects expected changes due to new hotel construction, closure of the Bullfrog Mine, and Yucca Mountain Project employment.

### 3.1.7.3 Payments Equal to Taxes

Another issue of interest is the DOE Payments-Equal-To-Taxes Program. Section 116(c)(3)(A) of the Nuclear Waste Policy Act of 1982, as amended, requires the Secretary of Energy to "…grant to the State of Nevada and any affected unit of local government an amount each fiscal year equal to the amount such State or affected unit of local government, respectively, would receive if authorized to tax site characterization activities…." The Yucca Mountain Site Characterization Office is responsible for implementing and administering this program for the Yucca Mountain Project. DOE acquired data from the project organizations that purchase or acquire property for use in Nevada, have employees in Nevada, or use property in Nevada. These organizations include Federal agencies, national laboratories, and private firms. Not all of them have a Federal exemption, so they pay the appropriate taxes. The purchases (sales and use tax), employees (business tax), and property (property or possessory use taxes) of the Yucca Mountain Project organizations that exercise a Federal exemption are subject to the Payments-Equal-To-Taxes Program (NLCB 1996, all).

The estimated sales and use taxes, property taxes, and Nevada business taxes Yucca Mountain Project organizations paid from May 1986 through June 1996 have been totaled. These organizations paid sales or use taxes of $2.25 million for purchases consumed in Clark County and $3.8 million in Nye County, paid property or possessory taxes of about $110,000 in Clark County and $37,355 in Nye County, and paid Nevada business taxes of about $460,000 (NLCB 1996, all).

The Payments-Equal-To-Taxes for sales or use taxes from May 1986 through June 1996 was about $1.68 million for purchases consumed in Clark County and $240,000 in Nye County. For property taxes it was about $200,000 in Clark County, $14.8 million in Nye County, $8,000 in Lincoln County, $3,700 in Esmeralda County, and $24,000 in Inyo County. For Nevada business taxes, about $95,000 has been paid.

### 3.1.7.4 Housing

Spurred by the rapid population growth and soaring employment opportunities, the residential housing market is strong and steady in the Las Vegas area. From 1992 to 1996, annual sales of new homes exceeded 16,000 units. In 1996, a record 19,000 units were sold. More than 400 residential developers sell properties in the Las Vegas area, leading to a highly competitive market. The competition has kept price increases to the rate of inflation. Eighty-five percent of the new homes sold were priced between $100,000 and $190,000. The average home sold for about $131,000 in 1996. Large master-planned communities are common, and average about 30 percent of the total home sales. Steady employment and population growth should continue to spur demand for housing. Sustained growth will depend on further development of large-scale resort and gaming projects.

The housing stock of Clark County in 1990 was about 320,000 units, which consisted of about 150,000 single-family units, 130,000 multifamily units, and 33,000 mobile homes or other accommodations. About 290,000 of these units were occupied, resulting in 2.5 persons per household (Bureau of the Census 1998, all). Assuming that the persons per household and occupancy rate remain the same, the expected number of households in Clark County in 2000 is about 570,000.

The housing stock of Nye County in 1990 was about 8,100 units, which consisted of about 2,300 single-family units, 560 multifamily units, and 5,200 mobile homes or other accommodations. About 6,700 of these units were occupied, resulting in 2.5 persons per household (Bureau of the Census 1998, all). Assuming that the persons per household and occupancy rate remain the same, the expected number of households in Nye County in 2000 is about 12,000.

The housing stock of Lincoln County in 1990 was about 1,800 units, which consisted of about 1,000 single-family units, 160 multifamily units, and 600 mobile homes or other accommodations. About 1,300 of these units were occupied, resulting in 2.6 persons per household (Bureau of the Census 1998, all). Assuming that the persons per household and occupancy rate remain the same, the expected number of households in Lincoln County in 2000 is about 1,800.

Because most population and employment growth in the region of influence will occur in Clark County, most housing growth also will occur there. The only other area in the region likely to see large growth is Pahrump in southern Nye County. Housing changes in Lincoln County probably will be minimal in the foreseeable future.

### 3.1.7.5 Public Services

*Education.* In the 1996-1997 school year, the region of influence contained about 180 elementary and middle schools, 34 high schools, 13 alternative schools, and 4 special education schools. The average pupil-teacher ratio was about 21-to-1 for elementary schools and 19-to-1 for secondary schools (Clark County 1997a, all; NDE 1997, page 4). In 1997, the national pupil-teacher ratio was about 19-to-1 for elementary schools and 15-to-1 for secondary schools (USDE 1999, all). Clark County has the tenth-largest school district in the country; during the 1996-1997 school year, Clark County had about 210 schools and nearly 180,000 students (Table 3-26). During the same period, Nye County had 16 schools and fewer than 5,000 students, and Lincoln County had nine schools and about 1,000 students (Clark County 1997a, all; TRW 1999n, all; NDE 1997, page 4).

Because Clark County is experiencing rapid growth, voters have passed three bond issues totaling $1.85 billion dollars since 1988 to renovate existing schools and build new schools. The most recent was a $643 million bond in 1996. Eleven new schools—six elementary, three middle, and two high schools—were scheduled to open during the 1997-1998 school year (Clark County 1998, all). Nye County was scheduled to seek approval in a 1998 bond issue to build a new middle and elementary school over the next few years (Harge 1997, page 18).

**Table 3-26.** Enrollment by school district and grade level.[a,b]

| District | Actual 1996-1997[c] | Projected 2000-2001[d] |
|---|---|---|
| *Clark County*[e] | | |
| Prekindergarten | 1,000 | 1,300 |
| Kindergarten | 15,000 | 19,000 |
| Elementary (grades 1-6) | 90,000 | 110,000 |
| Secondary (grades 7-12) | 73,000 | 91,000 |
| **District totals** | **179,000** | **221,300** |
| *Nye County*[f] | | |
| Prekindergarten | 43 | 44 |
| Kindergarten | 310 | 380 |
| Elementary (grades 1-6) | 2,300 | 2,400 |
| Secondary (grades 7-12) | 2,200 | 2,300 |
| **District totals** | **4,853** | **5,124** |
| *Lincoln County*[g] | | |
| Prekindergarten | 22 | 20 |
| Kindergarten | 57 | 51 |
| Elementary (grades 1-6) | 400 | 360 |
| Secondary (grades 7-12) | 630 | 570 |
| **District totals** | **1,109** | **1,001** |

a. Figures include ungraded students who are enrolled in school for special education and students who cannot be assigned to a grade because of the nature of their condition; Prekindergarten refers to 3- and 4-year-old minors receiving special education.
b. Enrollment numbers have been rounded to two significant figures.
c. Enrollments for the 1996-1997 school year are as of the end of the first school month.
d. Projected enrollment for the 2000-2001 school year is based on the ratio of actual 1996-1997 figures to the 1996 population estimate multiplied by the 2000 population forecast.
e. Source: Clark County (1997a, all).
f. Source: NDE (1997, page 4).
g. Source: TRW (1999n, all).

*Health Care.* Health care services in the region of influence are concentrated in Clark County, particularly in the Las Vegas area. In 1995, Clark County had seven hospitals and four specialized care facilities. Although Nye County has one hospital in Tonopah, most people in the southern part of the county use local clinics or go to hospitals in Las Vegas. Lincoln County has one hospital in Caliente (Rodefer et al. 1996, all). Table 3-27 lists hospital use in the region of influence.

**Table 3-27.** Hospital use by county in the region of influence.[a,b]

| County | 1990 | 1995 | 2000 |
|---|---|---|---|
| *Clark* | | | |
| Population | 750,000 | 1,000,000 | 1,310,000 |
| Average number of beds | 2,000 | 2,100 | 2,900[c] |
| Beds per 1,000 residents | 2.6 | 2.2 | 2.2[d] |
| Patient-days | 490,000 | 530,000 | 700,000[e] |
| *Nye* | | | |
| Population | 18,000 | 24,000 | 26,000 |
| Average number of beds | 21 | 21 | 22[c] |
| Beds per 1,000 residents | 1.2 | 0.86 | 0.86[d] |
| Patient-days | 1,800 | 1,900 | 2,000[e] |
| *Lincoln* | | | |
| Population | 3,800 | 3,900 | 3,400 |
| Average number of beds | 5 | 4 | 4[c] |
| Beds per 1,000 residents | 1.3 | 1.0 | 1.0[d] |
| Patient-days | 520 | 360 | 310[e] |

a. Source: Rodefer et al. (1996, pages 214 to 216).
b. All numbers have been rounded to two or three significant figures.
c. Calculated assuming number of beds per 1,000 residents remained constant.
d. Held constant at 1995 levels.
e. 2000 patient-days calculated by multiplying 2000 population by 1995 ratio of patient-days to population.

Medical services are available at the Nevada Test Site for Exploratory Studies Facility personnel; these services include two paramedics and an ambulance in Area 25. Backup services are on call from other Test Site locations. In addition, the Nevada Test Site provides medical services for Yucca Mountain Project workers at a clinic in Mercury, which has no overnight capability. When patients need urgent care, the Yucca Mountain Project relies on the helicopter "Flight for Life" and "Air Life" operations from Las Vegas. In emergencies, Area 25 can call on Nellis Air Force Base or Nye County for help.

*Law Enforcement.* The Las Vegas Metropolitan Police Department is responsible for law enforcement in Clark County with the exceptions of the Cities of North Las Vegas, Henderson, Boulder City, and Mesquite, which have their own police departments. The Las Vegas police department is the largest law enforcement agency in Nevada; in 1996, it had about 1,200 employees, a ratio of about 1.2 employees per 1,000 residents. In 1996, the Nye County Sheriff Department had 110 employees, a ratio of 4.4 employees per 1,000 residents, and Lincoln County had 14 sheriff department employees, a ratio of 3.7 employees per 1,000 residents. In comparison, the national officer-to-population ratio is 2.4 officers per 1,000 residents, (FBI 1996, pages 1 to 3). Assuming that the number of employees per 1,000 residents remains the same, the expected law enforcement staffing in 2000 will be about 1,600 in Clark County, 120 in Nye County, and 15 in Lincoln County.

*Fire Protection and Emergency Management.* A combination of fire departments provides protection in the region of influence; these include the Clark County, Las Vegas, and North Las Vegas fire departments and several other city, county, and military departments. In 1992, Clark County had about 1,100 paid, 420 volunteer, and 80 seasonal or inmate firefighters, a ratio of 1.9 firefighters per 1,000 residents. In 1992, Nye County had 150 paid and 330 volunteer firefighters, a ratio of about 25 firefighters per 1,000 residents, and Lincoln County had 73 volunteer firefighters, a ratio of about 19 firefighters per 1,000 residents. The national average is 4.1 firefighters (full and volunteer) per 1,000 residents.

## 3.1.8 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY

The public health and safety region of influence consists of the number of persons residing within an 80-kilometer (50-mile) radius of the repository site at the end of site characterization. The estimated population in 2000 is about 28,000. The region of influence encompasses communities in Nye and Clark Counties in Nevada, as well as Inyo County in California (Figure 3-21). Potentially affected workers include those at the repository site and at nearby Nevada Test Site facilities. This section describes the existing radiation environment and the baseline cancer incidence in the region of influence. Unless otherwise noted, the *Environmental Baseline File for Human Health* (TRW 1999o, all) is the basis of the information in this section.

Section 3.1.8.1 describes the various radiation sources that make up the radiation environment. Section 3.1.8.2 describes the existing radiation environment in the Yucca Mountain region. Section 3.1.8.3 describes the health-related mineral issues encountered during site characterization activities. Section 3.1.8.4 describes the worker industrial safety experienced from site characterization activities.

### 3.1.8.1 Radiation Sources in the Environment

There are ambient levels of radiation at and around the site of the proposed repository just as there are around the world. All people are inevitably exposed to the three sources of ionizing radiation: those of *natural* origin unaffected by human activities, those of natural origin but affected by human activities (called *enhanced natural* sources), and *manmade* sources. Natural sources include cosmic radiation from space, *terrestrial* radiation from natural radioactive sources in the ground (radon, for example), radiation from radionuclides naturally present in the body, and inhaled and ingested radionuclides of natural origin. Enhanced natural sources include those that can increase exposure as a result of human actions, deliberate or otherwise. For example, air travel, especially at very high altitudes, increases exposure to cosmic radiation, and tunneling through rock (as at Yucca Mountain) increases worker exposure to naturally occurring sources. A variety of exposures result from manmade materials and devices such as radiopharmaceuticals and X-rays in medicine, and consumer products such as some smoke detectors. Exposures can also result from episodic events, such as uncontained nuclear weapons tests.

External background radiation comes from two sources of approximately equal magnitude: cosmic radiation from space and terrestrial gamma radiation from radionuclides in the environment, mainly from the Earth itself. In the case of cosmic radiation, charged particles (primarily protons from extraterrestrial sources) have sufficiently high energies to generate secondary particles that have direct and indirect ionizing properties. The three main contributors to the terrestrial gamma radiation field are potassium-40 and the members of the thorium and uranium decay series. Most terrestrial gamma radiation comes from the top 20 centimeters (8 inches) of soil, with a small contribution from airborne radon decay products.

*Cosmogenic* radionuclides are produced by interactions of cosmic particles with certain atoms in the atmosphere or in the Earth. There are four cosmogenic radionuclides of interest for internal doses: tritium (hydrogen-3), beryllium-7, carbon-14, and sodium-22. With the exception of beryllium-7, all are isotopes of important elements in the human body. The dose rates from natural cosmic, cosmogenic, and terrestrial radiation vary throughout the world depending on such factors as altitude and geology. Natural background radiation is the largest contributor to the average radiation dose to individuals and is the most variable component of background radiation. Table 3-28 lists estimated radiation doses from natural sources to individuals in the region of influence and other locations.

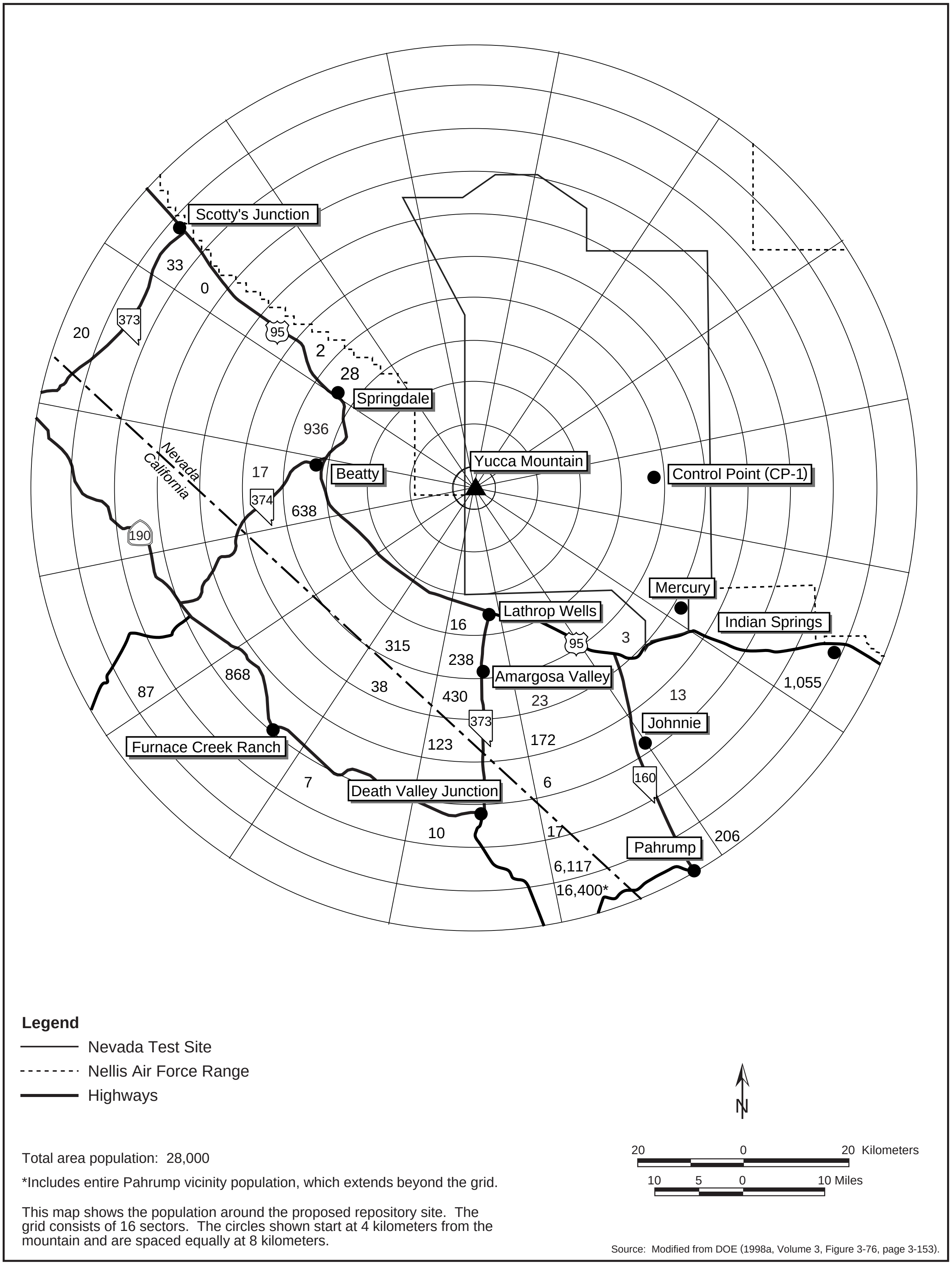



**Figure 3-21.** Population distribution within 80 kilometers (50 miles) of the proposed repository site, year 2000 estimate.

**Table 3-28.** Radiation exposure from natural sources (millirem per year).[a]

| Source | Annual dose (effective dose equivalent) | | | | | |
|---|---|---|---|---|---|---|
| | U.S. average | Aiken[b] | Oak Ridge[c] | Las Vegas | Region of influence: Amargosa Valley | Region of influence: Beatty |
| Cosmic and cosmogenic | 28 | 33 | 29 | (d) | 40 | (d) |
| Terrestrial | 28 | 43 | 38 | 89 | 56 | 150 |
| Radon in homes (inhaled)[e] | 200 | 200 | 200 | 200 | 200 | 200 |
| In body | 40 | 40 | 40 | 40 | 40 | 40 |
| **Totals**[f] | **300** | **320** | **310** | **330** | **340** | **390** |

a. Sources: Bechtel (1998, page 4-31); DOE (1995e, pages 4-211 and 4-394); NCRP (1987, Section 2).
b. Aiken, South Carolina, is the location of the DOE Savannah River Site.
c. Oak Ridge, Tennessee, is the location of the DOE Oak Ridge National Laboratory.
d. Included in the terrestrial source.
e. Value for radon is an average for the United States.
f. Totals might differ from sums due to rounding.

The effect of radiation on people depends on the kind of radiation exposure (alpha and beta particles, and X-rays and gamma rays), the total amount of tissue exposed to radiation, and the duration of the exposure. The amount of radiant energy imparted to tissue from exposure to ionizing radiation is referred to as *absorbed dose*. The sum of the absorbed dose to each tissue, when multiplied by certain quality and weighting factors that take into account radiation quality and different sensitivities of the various tissues, is referred to as *effective dose equivalent* and is measured in rem. The Code of Federal Regulations contains further discussion of DOE radiation protection standards and methods of dose assessment (10 CFR Part 835).

An individual can be exposed to radiation from outside or inside the body because radioactive materials can enter the body by ingestion or inhalation. External dose is different from internal dose in that it is delivered only during the actual time of exposure. An internal dose, however, continues to be delivered as long as the radioactive source is in the body (although both radioactive decay and elimination of the radionuclide by ordinary metabolic processes decrease the dose rate with the passage of time).

**TERMS USED IN RADIATION DOSE ASSESSMENT**

**Curie:** A unit of radioactivity equal to 37 billion disintegrations per second; also a quantity of any nuclide or mixture of nuclides having 1 curie of radioactivity.

**Picocurie per liter:** A unit of measure describing the amount of radioactivity in a liter of a given substance (for example, air or water). A picocurie is one one-trillionth of a curie.

**Roentgen:** A unit of measure of X-ray or gamma-ray radiation exposure described in terms of the amount of energy transferred to a unit mass of air. One roentgen corresponds to the absorption of 87.7 ergs (about $6.5 \times 10^{-6}$ foot-pound) per gram of air.

**Rem:** The dose of an ionizing radiation that will cause the same biological effect as 1 roentgen of X-ray or gamma ray exposure (rem means Roentgen Equivalent in Man).

Radiation can cause a variety of adverse health effects in people. A large dose of radiation can cause prompt death. At low doses, the most important adverse health effect for depicting the consequences of environmental and occupational radiation exposures (which are typically low doses) is the potential inducement of cancers that can lead to death in later years. This effect is referred to as *latent cancer* *fatalities* because the cancer can take years to develop and for death to occur, and might never actually be the cause of death.

The collective dose to an exposed population is calculated by summing the estimated doses received by each member of the exposed population. This is referred to as a *population dose*. The total population dose received by the exposed population is measured in person-rem. For example, if 1,000 people each received a dose of 0.001 rem, the population dose would be 1.0 person-rem (1,000 persons multiplied by 0.001 rem equals 1.0 person-rem). The same population dose (1.0 person-rem) would result if 500 people each received a dose of 0.002 rem (500 persons multiplied by 0.002 rem equals 1 person-rem).

The factor used in this EIS to relate a dose to its potential effect is 0.0004 latent cancer fatality per person-rem for workers and 0.0005 latent cancer fatality per person-rem for individuals among the general population (NCRP 1993a, page 3). The latter factor is slightly higher because some individuals in the public, such as infants, might be more sensitive to radiation than workers. These risk factors have been endorsed by the International Commission on Radiological Protection, Environmental Protection Agency, Nuclear Regulatory Commission, and National Council on Radiation Protection and Measurements. The factors apply if the dose to an individual is less than 20 rem and the dose rate is less than 10 rem per hour. At doses greater than 20 rem, the factors used to relate radiation doses to latent cancer fatalities are doubled. At much higher doses, prompt effects, rather than latent cancer fatalities, might be the primary concern.

These concepts can be used to estimate the effects of exposing a population to radiation. For example, if 100,000 people were each exposed only to background radiation (0.3 rem per year), 15 latent cancer fatalities could occur as a result of 1 year of exposure (100,000 persons multiplied by 0.3 rem per year multiplied by 0.0005 latent cancer fatality per person-rem equals 15 latent cancer fatalities per year).

Calculations of the number of latent cancer fatalities associated with radiation exposure do not normally yield whole numbers and, especially in environmental applications, can yield numbers less than 1.0. For example, if 100,000 people were each exposed to a total dose of only 1 millirem (0.001 rem), the population dose would be 100 person-rem, and the corresponding estimated number of latent cancer fatalities would be 0.05 (100,000 persons multiplied by 0.001 rem multiplied by 0.0005 latent cancer fatality per person-rem equals 0.05 latent cancer fatality).

The *average* number of deaths that would result if the same exposure situation were applied to many different groups of 100,000 people is 0.05. In most groups, nobody (zero people) would incur a latent cancer fatality from the 1-millirem dose each member would have received. In a small fraction of the groups, 1 latent fatal cancer would result; in exceptionally few groups, 2 or more latent fatal cancers would occur. The average number of deaths over all the groups would be 0.05 latent fatal cancer (just as the average of 0, 0, 0, and 1 divided by 4 is 0.25). The most likely outcome is no latent cancer fatalities in these different groups.

The same concepts apply to estimating the effects of radiation exposure on a single individual. Consider the effects, for example, of exposure to background radiation over a lifetime. The "number of latent cancer fatalities" corresponding to a single individual's exposure to 0.3 rem a year over a (presumed) 70-year lifetime is:

$$\begin{aligned}\text{Latent cancer fatality} &= 1 \text{ person} \times 0.3 \text{ rem per year} \times 70 \text{ years} \\ &\quad \times 0.0005 \text{ latent cancer fatality per person-rem} \\ &= 0.011 \text{ latent cancer fatality.}\end{aligned}$$

Again, this should be interpreted in a statistical sense; that is, the estimated effect of background radiation exposure on the exposed individual would produce a 1.1-percent chance that the individual would incur a latent fatal cancer. The baseline Nevada cancer fatality rate in a population of 100,000 is about 185 deaths per year (ACS 1998, page 6), resulting in a baseline rate of about 50 cancer deaths per year in the region of influence.

#### 3.1.8.2 Radiation Environment in the Yucca Mountain Region

Ambient radiation levels from cosmic and terrestrial sources at Yucca Mountain are higher than the U.S. average. The higher elevation at Yucca Mountain results in higher levels of cosmic radiation due to less shielding by the atmosphere. The U.S. average for cosmic, cosmogenic, and terrestrial radiation exposures is 56 millirem per year (Table 3-28). The exposures at the Yucca Mountain ridge and Yucca Mountain surface facilities are about 160 and 150 millirem per year, respectively. Moreover, there are higher amounts of naturally occurring radionuclides in the soil and parent rock of this region than in some other regions of the United States, which also results in higher radiation doses.

The Yucca Mountain Project and the DOE Nevada Operations Office (in conjunction with the Environmental Protection Agency) conduct environmental surveillances around the Nevada Test Site. This monitoring has identified no radioactivity attributable to current operations at the Test Site. It did detect trace amounts of manmade radionuclides from worldwide nuclear testing in milk, game, and foods and in soil. Even though the monitoring has not detected ongoing releases to the environment related to the Test Site, DOE has made quantitative estimates of offsite doses from releases from past weapons testing activities at the Nevada Test Site (Bechtel 1998, page 7-5). Sources of ongoing releases at the Nevada Test Site include water containment ponds and contaminated soil resuspension. The estimated maximum annual radiation dose to a hypothetical individual in Springdale, Nevada [approximately 16 kilometers (10 miles) north of Beatty on U.S. 95], from airborne radioactivity is 0.09 millirem. The estimated maximum annual radiation dose for a hypothetical individual at the Nevada Test Site boundary is 0.12 millirem. These doses, which are about 1 percent of the 10-millirem-per-year dose limit that the Environmental Protection Agency established for a member of the public from emissions to the air from manmade sources (40 CFR Part 61), are conservative because data from offsite surveillance do not support doses of this magnitude.

Workers in the Exploratory Studies Facility can inhale naturally occurring radon-222 (a radioactive noble gas that is a decay product of naturally occurring uranium in rock) and its radioactive decay products. Radon concentration measurements during working hours, at a location representative of repository conditions, ranged from about 0.22 to 72 picocuries per liter, with a median concentration of about 6.5 picocuries per liter (TRW 1999o, page 12). The median annual dose to involved workers from inhalation of radon and decay products underground was estimated to be about 60 millirem. Appendix F contains additional information on the estimated underground external dose to involved workers from radon.

Workers in the Exploratory Studies Facility are also exposed to external gamma radiation from radon decay products and other naturally occurring radionuclides. Ambient radiation monitoring in this facility indicated a dose rate from background sources of radionuclides in the drift walls of about 40 millirem per year, which is about the same as the cosmic and cosmogenic components from background radiation on the surface in the Amargosa Valley region (see Table 3-28).

Naturally occurring radon-222 and decay products are released from the Exploratory Studies Facility in the exhaust ventilation air. The estimated annual release of radon and decay products is about 80 curies. The estimated annual dose to an individual 20 kilometers (12 miles) south of the repository is about 0.1 millirem. The estimated annual dose to the population within 80 kilometers (50 miles) is about

0.6 person-rem. These doses are small percentages of the dose from natural sources shown in Table 3-28. Appendix G contains additional information on the estimated releases of radon from the repository.

#### 3.1.8.3 Health-Related Mineral Issues Identified During Site Characterization

Certain minerals known to present a potential risk to worker health are present in the volcanic rocks at Yucca Mountain (DOE 1998a, Volume 1, pages 2-24 and 2-25). The risks are generally related to potential exposures caused by inhalation of airborne particulates (dust). Some of the minerals represent a hazard commonly associated with underground construction, whereas others are rare and less well known.

Crystalline silica (silicon dioxide) comes in several forms—among them quartz, tridymite, and cristobalite. Inhaling silica dust causes a disease called *silicosis* that damages an area of the lungs called the air sac (alveoli) (EPA 1996a, all). The presence of silica dust in the alveoli causes a defensive reaction that results in the formation of scar tissue in the lungs. This scar tissue can reduce overall lung capacity.

DOE typically performs evaluations of exposure to crystalline silica at Yucca Mountain for cristobalite that encompass potential impacts from exposure to other forms of crystalline silica. The repository host rock has a cristobalite content ranging from 18 to 28 percent (TRW 1999b, page 4-81). The American Conference of Governmental Industrial Hygienists has established Threshold Limit Values for various forms of crystalline silica (ACGIH 1999, page 61). These limits are based on an 8-hour day and 40-hour week and, therefore, could be exceeded for a short period—as long as the average time spent by a worker is below the limit. The Threshold Limit Values for respirable cristobalite dust and quartz dust are 0.05 and 0.1 milligram per cubic meter, respectively. In addition, crystalline silica has been listed by the World Health Organization as a carcinogen (IARC 1997, page 41).

Normal underground mechanical excavation produces dust when the rock is broken loose from the face. Dust is also generated when the broken rock is transferred to railcars or conveyors, or a storage pile. Dust can also be generated by wind erosion of excavated rock storage piles. Excavation activities during site characterization have caused exceedances of crystalline silica Threshold Limit Values at specific work locations. Workers at these locations were required to wear respirators. DOE will use the experience gained during Experimental Studies Facility activities to design engineering controls to minimize future exposures.

Erionite is an uncommon zeolite mineral that the International Agency for Research on Cancer recognized as a human carcinogen in 1987; at Yucca Mountain, it occurs primarily in the basal vitrophyre of the Topopah Spring tuff and in isolated zones of the Tiva Canyon tuff (see Section 3.1.3). Even at low doses erionite is believed to be a potent carcinogen capable of causing mesothelioma, a form of lung cancer. As a result of its apparent carcinogenicity, erionite could pose a risk if encountered in quantity during underground construction, even with standard modern construction practices. Because erionite appears to be absent or rare at the proposed repository depth and location, most repository operations should not be affected. However, repository workers would take precautions (for example, dust suppression, air filters, personal protective gear) during construction when penetrating horizons in which erionite could occur, such as in the basal vitrophyre of the Topopah Spring tuff.

A number of other minerals present at Yucca Mountain might have associated health risks if prolonged exposures occur; however, there is no evidence suggesting a link to cancer. Therefore, the International Agency for Research on Cancer has ranked these substances not classifiable (IARC 1997, all). Some of the minerals identified and considered in establishing health and safety practices for potential repository operations include the zeolite group minerals mordenite (which is fibrous and similar in some respects to erionite), clinoptilolite, heulandite, and phillipsite. Because there is no known risk associated with the other zeolite minerals, and because they occur primarily in nonwelded units below the repository horizon, they probably do not represent a large risk. The measures implemented to mitigate risk from silica (for example, dust suppression, air filters, personal protective gear) should also protect workers from exposure to other minerals.

#### 3.1.8.4 Industrial Health and Safety Impacts During Construction of the Exploratory Studies Facility

During Yucca Mountain site characterization activities, health and safety impacts to workers have resulted from common industrial hazards (such as tripping and falling). The categories of worker impacts include total recordable incidents, lost workdays, and fatalities. Recordable incidents or cases are occupational injuries or occupation-related illnesses that result in (1) a fatality, regardless of the time between the injury or the onset of the illness and death, (2) lost workday cases (nonfatal), and (3) incidents that result in the transfer of a worker to another job, termination of employment, medical treatment, loss of consciousness, or restriction of motion during work activities.

Site characterization activities at Yucca Mountain have had no involved worker fatalities. DOE has compiled statistics for the other types of health and safety impacts in accordance with the regulations of the Occupational Safety and Health Administration (29 CFR Part 1904) (see Appendix F, Table F.2-3). These statistics cover the 30-month period from the fourth quarter of 1994 through the first quarter of 1997. DOE selected this period because there was high onsite work activity in which the tunnel-boring machine was in operation in the Exploratory Studies Facility. DOE expects this condition to be characteristic of the types of activities that would occur during the construction of the surface facilities and the development of the emplacement drifts. Table 3-29 lists the industrial health and safety loss statistics for industry, general construction, general mining, and the Yucca Mountain site.

**Table 3-29.** Comparison of health and safety statistics for mining activities from the Bureau of Labor Statistics to those for Yucca Mountain during excavation of the Exploratory Studies Facility.[a]

| Statistic | Total industry[b] | General construction[b] | General mining[b] | Yucca Mountain experience from DOE CAIRS data base, involved workers[c] |
|---|---|---|---|---|
| Total recordable cases rate | 7.1 | 9.5 | 5.9 | 6.8 |
| Lost workday cases rate | 3.3 | 4.4 | 3.7 | 4.8 |
| Lost workdays rate | Not available | Not available | Not available | 100 |

a. Statistics based on 100 full-time equivalent work years or 200,000 worker hours.
b. Source: BLS (1998, all).
c. Source: Appendix F, Table F.2-3.

### 3.1.9 NOISE

Noise comes from either natural or manmade sources. DOE has evaluated existing noise conditions in the Yucca Mountain region and has compiled the detected ranges of noise levels at different locations under differing conditions.

#### 3.1.9.1 Noise Sources and Levels

Yucca Mountain is in a quiet desert environment where natural phenomena such as wind, rain, and wildlife account for most background noise. The acoustic environment is typical of other desert environments where average day-night sound-level values range from 22 decibels on calm days to 38 decibels on windy days (Brattstrom and Bondello 1983, page 170).

**NOISE MEASUREMENT**

**What are *sound* and *noise*?**

When an object vibrates it possesses energy, some of which transfers to the air, causing the air molecules to vibrate. The disturbance in the air travels to the eardrum, causing it to vibrate at the same frequency. The ear and brain translate the vibration of the eardrum to what we call *sound*. *Noise* is simply unwanted sound.

**How is sound measured?**

The human ear responds to sound pressures over an extremely wide range of values. The range of sounds people normally experience extends from low to high pressures by a factor of 1 million. Accordingly, scientists have devised a special scale to measure sound. The term decibel (abbreviated dB), borrowed from electrical engineering, is the unit commonly used.

Another common sound measurement is the A-weighted sound level, denoted as dBA. The A-weighting accounts for the fact that the human ear responds more effectively to some pitches than others. Higher pitches receive less weighting than lower ones. Most of the sound levels provided in this EIS are A-weighted; however, some are in decibels due to lack of information on the frequency spectrum of the sound. The scale to the right provides common references to sound on the A-weighted sound-level scale.

Source: Modified from DOE (1999g, page 3-39).

**TYPICAL A-WEIGHTED SOUND LEVELS**

| | DECIBELS | |
|---|---|---|
| | 140 | |
| 50-horsepower siren (33 meters)[a] | | |
| | 130 | |
| Jet takeoff (66 meters) | | |
| | 120 | Diesel motors |
| Riveting machine[b] | | |
| | 110 | |
| Cut-off saw<br>Pneumatic peen hammer[b] | | |
| | 100 | Outdoor public address system loudspeakers |
| Rock drill (16 meters)<br>Textile weaving plant[b] | | |
| Subway train (6.6 meters) | 90 | |
| Dump truck (16 meters)<br>Pneumatic drill (16 meters) | | Ventilation fans |
| | 80 | |
| Freight train (33 meters)<br>Vacuum cleaner (3.3 meters) | | Inside sports car (24 meters per second)[c] |
| Speech (0.33 meters) | 70 | |
| Passenger auto (16 meters) | | Near freeway (auto traffic) |
| | 60 | Large store |
| Large transformer (66 meters) | | Accounting office |
| | 50 | Private business office<br>Light traffic (33 meters)<br>Average residence |
| | 40 | |
| Soft whisper (13 centimeters) | | |
| | 30 | Studio (speech) |
| | 20 | Quiet |
| | 10 | |
| Threshold of hearing (youths) | 0 | |

a. To convert meters to feet, multiply by 3.2808.
b. Operator's position.
c. 24 meters per second = about 50 miles per hour.
d. 13 centimeters = about 5 inches.

Manmade noise occurs periodically in the area as vehicles travel to and from Yucca Mountain, from site characterization activities at the operations areas, and from occasional low-flying military jets. Sound-level measurements recorded in May 1997 at areas adjacent to and at the Yucca Mountain operations areas were consistent with noise levels associated with industrial operations [sound levels from 44 to 72 decibels (A-weighted)] (Brown-Buntin 1997, pages 4-6). Table 3-30 lists estimated sound-level values for Yucca Mountain, nearby communities and cities, and other environments.

### 3.1.9.2 Regulatory Standards

With the exception of prohibiting nuisance noise, neither the State of Nevada nor local governments have established numerical noise standards. Nevertheless, many Federal agencies use average day-night sound

**Table 3-30.** Estimated sound levels in southern Nevada environments.[a]

| Environment | Sound level[b] (decibels) |
|---|---|
| Calm day at Yucca Mountain | 22 |
| Windy day at Yucca Mountain | 38 |
| Rural communities (Panaca, Hadley, Rachel, Alamo, Jean, Goodsprings, Sandy) | 40 - 47 |
| Small towns or rural communities along busy highways (Beatty, Indian Springs, Pahrump, Lathrop Wells, Caliente, Tonopah, Goldfield, Mercury) and at the intersection of proposed transportation routes to Yucca Mountain | 45 - 55 |
| Suburban parts of Las Vegas | 52 - 60 |
| Urban parts of Las Vegas | 56 - 66 |
| Dense urban parts of Las Vegas with heavy traffic | 64 - 74 |
| Under flight path at McCarran International Airport (0.8 to 1.6 kilometers[c] from runway) | 78 - 88 |

a. Source: modified from EPA (1974, page 14); Brattstrom and Bondello (1983, page 170).
b. Day-night average sound level.
c. About 0.5 to 1 mile.

levels as guidelines for land-use compatibility and to assess the impacts of noise on people. Many agencies, including the Environmental Protection Agency, recognize an average day-night sound level of 55 decibels (A-weighted) as an outdoor goal for protecting public health and welfare in residential areas (EPA 1974, page 3). This noise level, which has been established by scientific consensus, is not a regulatory criterion in Nevada, and could protect against activity interference and annoyance. As required, DOE monitors noise levels in worker areas, and a hearing protection program has been in place during site characterization. Hearing protection is used as a supplement to engineering controls, which are the primary method of noise suppression.

## 3.1.10 AESTHETICS

Visual resources include the natural and manmade physical features that give a particular landscape its character and value as an environmental factor. Sections 3.1.3 and 3.1.5 describe the geologic and biological settings, respectively, at Yucca Mountain.

The region surrounding Yucca Mountain consists of unpopulated to sparsely populated desert and rural lands. Because Yucca Mountain is on the Nevada Test Site and Nellis Air Force Range with restricted public access, public visibility is limited to portions of U.S. Highway 95 near Amargosa Valley.

The Bureau of Land Management uses four visual resource classes in the management of public lands (BLM 1986, all). Classes I and II are the most valued, Class III is moderately valued, and Class IV is of least value. Visual resources fall into one of these classes based on a combination of three factors: (1) scenic quality, (2) visual sensitivity, and (3) distance from travel routes or observation points (BLM 1986, all). There are three scenic quality classes in the Visual Resource Management system. Class A includes areas that combine the most outstanding characteristics of each physical feature category. Class B includes areas in which there is a combination of some outstanding and some fairly common characteristics. Class C includes areas in which the characteristics are fairly common to the region. A visual sensitivity rating for an area is based on the number and types of users, public interest in the area, and adjacent land uses.

The Bureau of Land Management has not assigned a Visual Resource Management class to Yucca Mountain because the Nevada Test Site is not under the Bureau's jurisdiction. However, using the Bureau's method of determining scenic quality, DOE has evaluated the visual resources of the Yucca Mountain region from two observation points—one at Lathrop Wells on U.S. 95 and the other on the Nevada Test Site at a location that provides a clear view of the proposed repository site (TRW 1999p, all).

**BUREAU OF LAND MANAGEMENT VISUAL RESOURCE MANAGEMENT CLASS OBJECTIVES (used in the management of public lands)**

| | |
|---|---|
| Class I | The objective of this class is to preserve the existing character of the landscape. This class provides for natural ecological changes; however, it does not preclude very limited management activity. The level of change to the characteristic landscape should be very low and must not attract attention. |
| Class II | The objective of this class is to retain the existing character of the landscape. The level of change to the characteristic landscape should be low. Management activities may be seen, but should not attract the attention of the casual observer. Any changes must repeat the basic elements of form, line, color, and texture found in the predominant natural features of the characteristic landscape. |
| Class III | The objective of this class is to partially retain the existing character of the landscape. The level of change to the characteristic landscape should be moderate. Management activities may attract attention but should not dominate the view of the casual observer. Changes should repeat the basic elements found in the predominant natural features of the characteristic landscape. |
| Class IV | The objective of this class is to provide for management activities that require major modification of the existing character of the landscape. The level of change to the characteristic landscape can be high. These management activities may dominate the view and be the major focus of viewer attention. However, every attempt should be made to minimize the impact of these activities through careful location, minimal disturbance, and repeating the basic elements. |

The visual assessment at both these locations concluded that the scenic quality classification of Yucca Mountain is C.

### 3.1.11 UTILITIES, ENERGY, AND SITE SERVICES

DOE research into the current consumer demand for utilities and energy in the Yucca Mountain region has yielded information on water and power sources, use, and supply systems. The research included water treatment capabilities. The region of influence for potential impacts to utility and energy supplies consists of Clark, Lincoln, and Nye Counties in Nevada. Sections 3.1.11.1 and 3.1.11.2 contain information on current water and energy suppliers and consumer use. Unless otherwise noted, the *Yucca Mountain Site Characterization Project Environmental Baseline File for Utilities, Energy, and Site Services* (TRW 1999j, all) is the basis of the information in this section.

#### 3.1.11.1 Utilities

Water and sewer utilities in the region could be affected by the Proposed Action as a result of project-related increases in population and the associated increases in water demand and sewage production. DOE anticipates that the predominant project-related increase in population would occur in Clark County, with a smaller increase in Nye County (see Section 3.1.7).

*Water.* The Southern Nevada Water Authority supplies water to five communities in Clark County: Boulder City, Henderson, Las Vegas (including parts of unincorporated Clark County), Nellis Air Force Base, and North Las Vegas. Eighty-five percent of the water supplied to the Las Vegas Valley comes from the Colorado River through Lake Mead; the remaining 15 percent comes from groundwater (Las Vegas Valley Hydrographic Area; SNWA 1997, page 2). To meet growing water demands, the Water Authority is upgrading current facilities and installing new facilities, such as a second raw water intake at Lake Mead, a second water treatment facility, and additional pipelines and pumping stations.

In southern Nye County, where the repository would be, groundwater is the only source of water. In August 1996, a water supply and demand evaluation for southern Nye County, including Beatty, Amargosa Desert, and Pahrump, was performed (Buqo 1996, all). In Beatty (Oasis Valley Hydrographic Area), the local water utility will have difficulty meeting future water demands due not to a high growth rate but to falling well yields and poor water quality in some wells. Existing pumping capacity is not adequate to meet projected peak demands between 1997 and 2000, and one or more additional wells will be needed. In Amargosa Desert (Amargosa Desert Hydrographic Area), the current committed amount of groundwater appropriations (permits and certificates) is larger than the lower estimate of perennial yield for the applicable groundwater. However, historic pumping amounts have never been higher than the estimates of yield. In Pahrump (Pahrump Valley Hydrographic Area), the total groundwater pumped from the basin in 1995 was almost 30 million cubic meters (24,000 acre-feet). This is about 25 percent higher than the upper end of estimates of the basin's perennial yield, which range from 15 million cubic meters [12,000 acre-feet (NDWP 1992, page 7)] to 23 million cubic meters [19,000 acre-feet (Buqo 1996, page 17)]. Much of Pahrump's water consumption results from about 7,000 domestic water supply wells. Drilling continues at a rate of about two wells a year (Buqo 1999, page 34). Alternatives to address long-term water supply issues in Pahrump Valley include optimizing the locations of new wells, reducing per capita consumption, developing the carbonate aquifer, and importing water from other groundwater basins. Overall groundwater withdrawals in Nye County totaled about 93 million cubic meters (75,000 acre-feet) in 1995. The predominant use of this water was agriculture, accounting for 80 percent of the total; domestic use was responsible for only 7 percent of the total withdrawal (Horton 1997, Table 1).

*Sewer.* Wastewater treatment needs in the Las Vegas Valley are supported by three major wastewater treatment facilities: one operated by the City of Las Vegas (which also serves the City of North Las Vegas); one operated by the City of Henderson; and one operated by the Clark County Sanitation District. The County Sanitation District includes all the unincorporated areas in Clark County, and it provides services to several outlying communities including Blue Diamond, Laughlin, Overton, and Searchlight (Clark County 1999, all). However, its primary service area is the portion of the Las Vegas Valley south and east of the City of Las Vegas and extending to Henderson. There might be other small wastewater treatment units serving parts of Clark County outside the populous area of the Las Vegas Valley, but septic tank and drainage field systems provide the primary means of wastewater treatment in these outlying areas, particularly for private residences.

Southern Nye County does not have a metropolitan area or a sanitation district comparable to Clark County, and communities in this area rely primarily on individual dwelling or small communal wastewater treatment systems. For example, Pahrump has no community-wide wastewater treatment system. Several wastewater treatment units serve parts of the town, such as the dairy and the jail, but most households have septic tank and drainage field systems. This is likely to be typical of the small communities in southern Nye County.

### 3.1.11.2 Energy

*Electric Power.* Three different power distributors—Nevada Power Company, Valley Electric Association, Inc., and Lincoln County Power District No. 1—supply electric power in the region of influence.

Nevada Power Company supplies electricity to southern Nevada in a corridor from southern Clark County, including Las Vegas, North Las Vegas, Henderson, and Laughlin, to the Nevada Test Site in Nye County. In 1996, the power sources were 50 percent company-generated (38 percent coal, 12 percent natural gas), 4 percent Hoover Dam hydroelectric, and 46 percent purchased power. In 1996, Nevada Power Company sold 13.7 million megawatt-hours to its 490,000 customers, with average annual sales per residential customer of about 13,000 kilowatt-hours. In 1996, the peak load was the highest ever at about 3,300 megawatts with a generating capacity and firm purchases of about 3,900 megawatts. Nevada Power Company has an annual customer growth rate of 7.2 percent. To keep pace with demands for electricity, each year Nevada Power must build more substations and transmission and distribution facilities; in 1996, it invested about $180 million in such equipment (NPC 1997, all).

The Valley Electric Association is a nonprofit cooperative that distributes power to southern Nye County, including Pahrump Valley, Amargosa Valley, Beatty, and the Nevada Test Site. The Western Area Power Administration allocates Valley Electric a portion of the lower cost hydroelectric power from the Colorado River dams. The private power market supplies the supplemental power necessary to meet the needs of the members. Since 1995, the amount of power available in the marketplace has been abundant. The amount of energy that Valley Electric sells annually to its members almost tripled in the 11 years from 1985 through 1995. In 1995, Valley Electric sold about 300 million kilowatt-hours to its 8,600 members (McCauley 1997, pages 54 and 55). To meet the power demands of its members, Valley Electric has built a new 230-kilovolt transmission line from Las Vegas to Pahrump and plans to install three new substations in Pahrump.

At present, two commercial utility companies own transmission lines that supply electricity to the Nevada Test Site (Figure 3-22). The electric power for the Yucca Mountain Project in Area 25 comes through the Nevada Test Site power grid. The Test Site buys power at 138 kilovolts at the Mercury Switch Station and at the Jackass Flats Substation. The 138-kilovolt system at the Test Site has nine substations, one switching center, and one tap station, which are connected by approximately 210 kilometers (130 miles) of transmission line. A 138-kilovolt line owned by Nevada Power Company connects the Mercury Switch Station to the Jackass Flats substation, which reduces the power and transmits it to the Field Operations Center and nearby buildings in Area 25 that support the Yucca Mountain Project. A Valley Electric Association 138-kilovolt line also provides power to the Jackass Flats Substation. From the Jackass Flats substation, a 138-kilovolt line feeds the Canyon Substation in Area 25, which provides power to the Exploratory Studies Facility. The Canyon Substation reduces the voltage from 138 to 69 kilovolts, with a capacity of 10 megawatts, and transmits it to the Yucca Mountain substation at the Exploratory Studies Facility.

The capacity of the Nevada Test Site grid is 72 megawatts. Since 1990, the historic monthly peak use was about 18,000 megawatt-hours in January 1992, with a peak load of about 37 megawatts (Thurman 1997, page 1).

Table 3-31 lists the combined historic and projected electricity use for the Exploratory Studies Facility and the Field Operations Center for 1995 through 2000. The Exploratory Studies Facility consumed about 70 percent of the listed amounts (Thurman 1997, all). Annual power use and peak demand at the Exploratory Studies Facility would probably decline and stabilize at a lower level than the 1997 use rates because site activity would decline until

**Table 3-31.** Electric power use for the Exploratory Studies Facility and Field Operations Center.[a,b]

| | Power use | |
|---|---|---|
| Fiscal Year | Consumption (megawatt-hours) | Peak (megawatts) |
| 1995 | 9,800 | 3.5 |
| 1996 | 19,000 | 4.9 |
| 1997 | 23,000 | 5.3 |
| 1998[c] | 21,000 | 4.2 |
| 1999[c] | 17,000 | 4.2 |
| 2000[c] | 8,700 | 4.2 |

a. Source: TRW (1998a, Table 2, page 8).
b. Before 1995, Yucca Mountain Project power was not metered separately.
c. Projected.

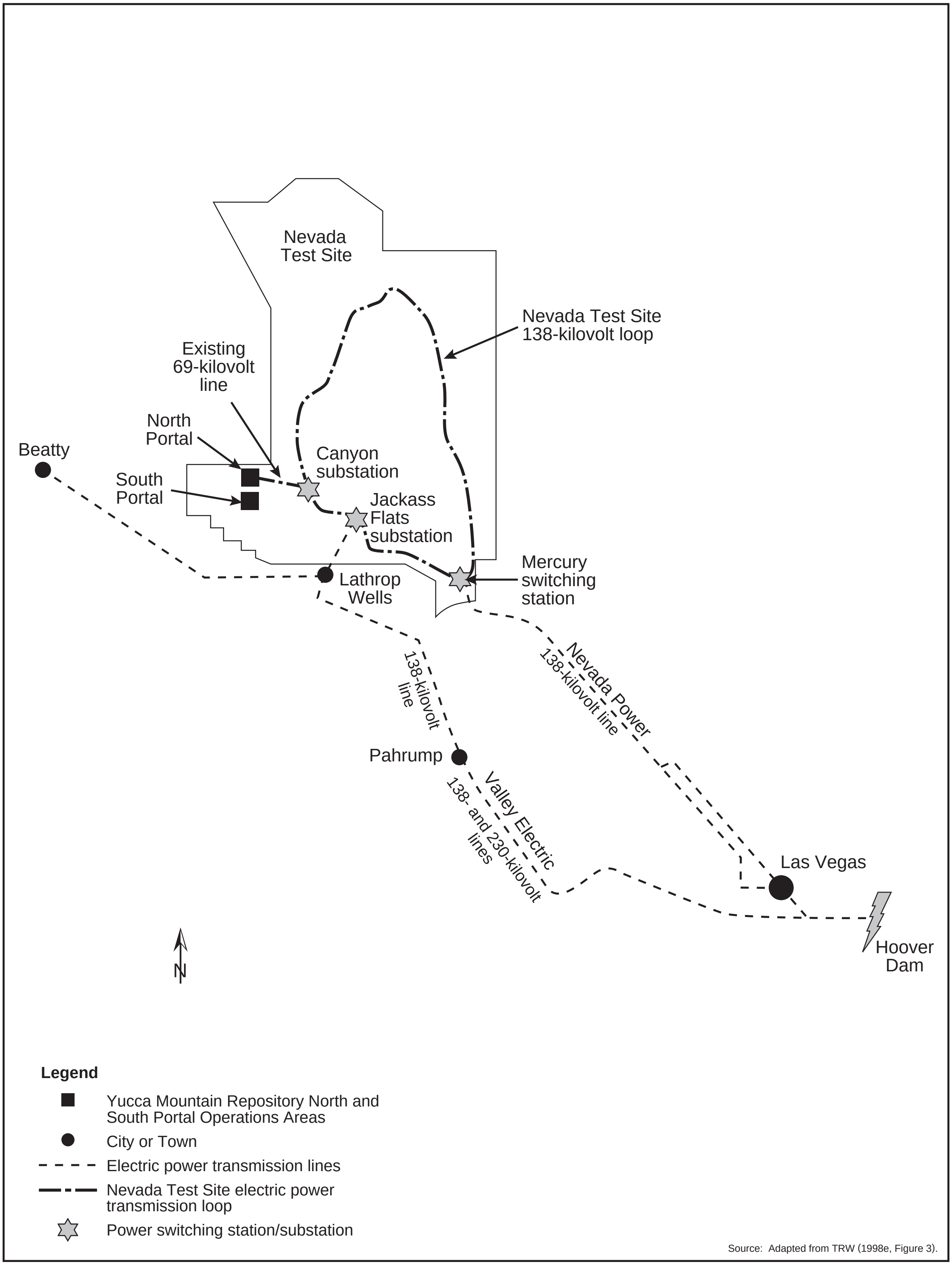



**Figure 3-22.** Existing Nevada Test Site electric power supply.

repository construction began in 2005. Historically, from 1995 through 1997 Exploratory Studies Facility use has accounted for about 15 percent to 20 percent of the electric power used by all of the Nevada Test Site (TRW 1998a, Table 2, page 8).

*Fossil Fuel.* The fossil fuels that DOE has used at the Exploratory Studies Facility are heating oil, propane, diesel, gasoline, and kerosene. Natural gas, coal, and jet fuel have not been used. In 1996, site activities consumed about 1.02 million liters (270,000 gallons) of heating oil and diesel fuel and about 65,000 liters (17,000 gallons) of propane; in 1997, they consumed slightly less than 1 million liters (264,000 gallons) of heating oil and diesel fuels. The amounts of gasoline and kerosene used at the Exploratory Studies Facility were very small in those years. Fossil-fuel supplies are delivered to the Nevada Test Site and the Exploratory Studies Facility by truck from readily available supplies in southern Nevada.

#### 3.1.11.3 Site Services

DOE has established an existing support infrastructure to provide emergency services to the Exploratory Studies Facility. The Yucca Mountain Project *Emergency Management Plan* (DOE 1998k, all) describes emergency planning, preparedness, and response. The project cooperates with the Nevada Test Site in such areas as training and emergency drills and exercises to provide full emergency preparedness capability to the site. In addition, the project trains and maintains an underground rescue team. The Nevada Test Site security program is responsible for project security, with enforcement provided by a contractor following direction from DOE. The Nye County Sheriff's Department provides law enforcement and officers for Yucca Mountain site patrol. Nevada Test Site personnel and equipment support fire protection and medical services. Medical services are provided through the Nevada Test Site by two paramedics and an ambulance stationed in Area 25 with backup from other Test Site locations. The Yucca Mountain staff uses a medical clinic with outpatient capability at Mercury. Urgent medical transport is provided by the "Flight for Life" and "Air Life" programs from Las Vegas. Nellis Air Force Base and Nye County also provide emergency support.

### 3.1.12 WASTE AND HAZARDOUS MATERIALS

The Yucca Mountain Site Characterization Project developed its waste management systems to handle the waste and recyclable material generated by its activities. This material includes nonhazardous solid waste; construction debris; hazardous waste; recyclables such as lead-acid batteries, used oil, metals, paper, and cardboard (Harris 1997, Page 6); sanitary sewage; and wastewater. It does not include low-level radioactive or mixed wastes. DOE uses landfills to dispose of solid waste and construction debris; accumulates and consolidates hazardous waste, then transports it off the site for treatment and disposal; treats and reuses wastewater; and treats and disposes of sanitary waste. In most categories of waste, especially solid waste, some types of material can be recycled or reused. DOE has processes in place to ensure that it collects the material and recycles it as appropriate.

#### 3.1.12.1 Solid Waste

DOE disposes of Yucca Mountain Site Characterization Project solid waste and construction debris in landfills in Areas 23 and 9, respectively, on the Nevada Test Site. The Area 23 landfill has a capacity of 450,000 cubic meters (16 million cubic feet) (DOE 1996f, page 4-37) and a 100-year estimated life (DOE 1995f, page 9). The Area 9 landfill, which is in Crater U-10C, is an open circular pit with steep, almost vertical sides formed as a result of an underground nuclear test. The Area 9 landfill has a disposal capacity of 990,000 cubic meters (35 million cubic feet) (DOE 1996f, page 4-37) and an estimated 70-year operational life (DOE 1995f, page 8). The environmental impact statement for the Nevada Test Site describes these landfills (DOE 1996f, page 4-37). DOE disposes of Yucca Mountain Site

Characterization Project oil-contaminated debris from maintenance activities at the industrial landfill at Apex, Nevada, using an environmental company for transport and disposal. The Apex facility is a multilined landfill with on- and offsite monitoring in compliance with State of Nevada requirements (Harris 1997, page 4).

DOE recycles as many materials as feasible from its site characterization activities. The *Waste Minimization and Pollution Prevention Awareness Plan, Approved* (DOE 1997h, all) governs recycling and other waste minimization activities. At present, a Nevada Test Site contractor collects paper, cardboard, and scrap metal and recycles it. For such recyclables as oils, solvents, coolants, lead-acid batteries, and oil-contaminated soils, the Yucca Mountain Site Characterization Project contracts directly with recycling services (Harris 1997, pages 1 to 3).

#### 3.1.12.2 Hazardous Waste

The Yucca Mountain Site Characterization Project is a small-quantity [less than 1,000 kilograms (2,200 pounds) a month] generator of hazardous waste. DOE accumulates hazardous wastes near their generation sources, consolidates them at a central location at the Yucca Mountain site (Harris 1997, page 5), and ships them off the site for treatment and disposal. The hazardous waste accumulation areas are managed in accordance with Federal and State regulations. The waste is treated and disposed of off the site at a permitted treatment, storage, and disposal facility under contract to the Nevada Test Site (Harris 1997, page 5).

#### 3.1.12.3 Wastewater

DOE uses a septic system to treat and dispose of sanitary sewage at the Yucca Mountain site (TRW 1998f, page 15). The system design can handle a daily flow of about 76,000 liters (20,000 gallons) (TRW 1998g, page 64).

At present, wastewater from tunneling operations and water from secondary containment (following rains) is processed through an oil-water separator, and the treated water is used for dust suppression in accordance with a State of Nevada permit (Harris 1997, page 2). The oil is recycled with the other used oil generated by the project.

#### 3.1.12.4 Existing Low-Level Radioactive Waste Disposal Capacity

The Nevada Test Site accepts low-level radioactive waste for disposal from approved generator sites. It has an estimated disposal capacity of 3.1 million cubic meters (110 million cubic feet). DOE estimates that a total of approximately 670,000 cubic meters (23.7 million cubic feet) of low-level radioactive waste will be disposed of at the Test Site through 2070 (DOE 1998l, page 2-23), not including repository-generated waste.

Commercial spent nuclear fuel generators and contractor-operated transportation facilities such as an intermodal transfer station would dispose of low-level radioactive waste in commercial facilities. Commercial disposal capacity for a broad range of low-level radioactive wastes is available at two licensed facilities, and three more disposal facilities are under license review (NRC 1997a, U.S. Low-Level Radioactive Waste Disposal Section).

#### 3.1.12.5 Materials Management

DOE has programs and procedures in place to procure and manage hazardous and nonhazardous chemicals and materials (DOE 1996h, all). By using these programs, the Department is able to minimize the number and quantities of hazardous chemicals and materials stored at the Yucca Mountain site and maintain appropriate storage facilities.

The chemical and material inventory report (Dixon 1999, pages 4, 4a, and 5) for the Nevada State Fire Marshal's office lists 33 hazardous chemicals and materials. The Yucca Mountain Project holds many of these in small quantities, and it stores sulfuric acid in larger quantities [above the threshold planning quantity of about 450 kilograms (1,000 pounds) that requires emergency planning]. Most of the sulfuric acid is in lead-acid batteries (Dixon 1999, all). In addition, the Yucca Mountain Site Characterization Project stores the following hazardous chemicals in large amounts [exceeding 4,500 kilograms (10,000 pounds)]: propane, gasoline, cement, and lubricating and hydraulic oils. The project does not store highly toxic substances in quantities higher than the State of Nevada reporting thresholds (Dixon 1999, page 1).

## 3.1.13 ENVIRONMENTAL JUSTICE

**ENVIRONMENTAL JUSTICE TERMS**

**Minority:** Hispanic, Black, Asian/Pacific Islander, American Indian/Eskimo, Aleut, and other non-white person.

**Low income:** Below the poverty level as defined by the Bureau of the Census.

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, directs each Federal agency "to make achieving environmental justice a part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations." In a memorandum that accompanies the Executive Order, President Clinton directs that "...environmental effects, including human health, economic and social effects, of Federal actions, including effects on minority communities and low-income communities, [be analyzed] when such analysis is required by the National Environmental Policy Act."

DOE has identified the minority and low-income communities in the Yucca Mountain region of influence, which consists of Clark, Lincoln, and Nye Counties in southern Nevada. Unless otherwise noted, the *Environmental Baseline File for Environmental Justice* (TRW 1999q, all) is the basis for information in this section.

To identify minority and low-income communities in the region of influence, DOE analyzed Bureau of the Census population designations called *block groups*. DOE pinpointed block groups where the percentage of minority or low-income residents is meaningfully greater than average. For environmental justice purposes, the pinpointed block groups are minority or low-income communities. This EIS considers whether activities at Yucca Mountain could cause disproportionately high and adverse human health or environmental effects to those communities.

### 3.1.13.1 State of Nevada

Minority persons comprised 21 percent of the population in Nevada in the 1990 census (Bureau of the Census 1992a, Tables P8 and P12). As defined by the Nuclear Regulatory Commission (NRC 1995, all), a minority population is present in a community when the percentage of minority persons in the area exceeds the percentage of minority persons in the state or region affected by a project by 10 percent or more (that is, 31 percent or more minority persons in a community). This analysis identifies communities at the Bureau of the Census block group level. The following discussion uses data from the 1990 census. Figure 3-23 shows block groups in which 31 percent or more of the population consists of minority persons.

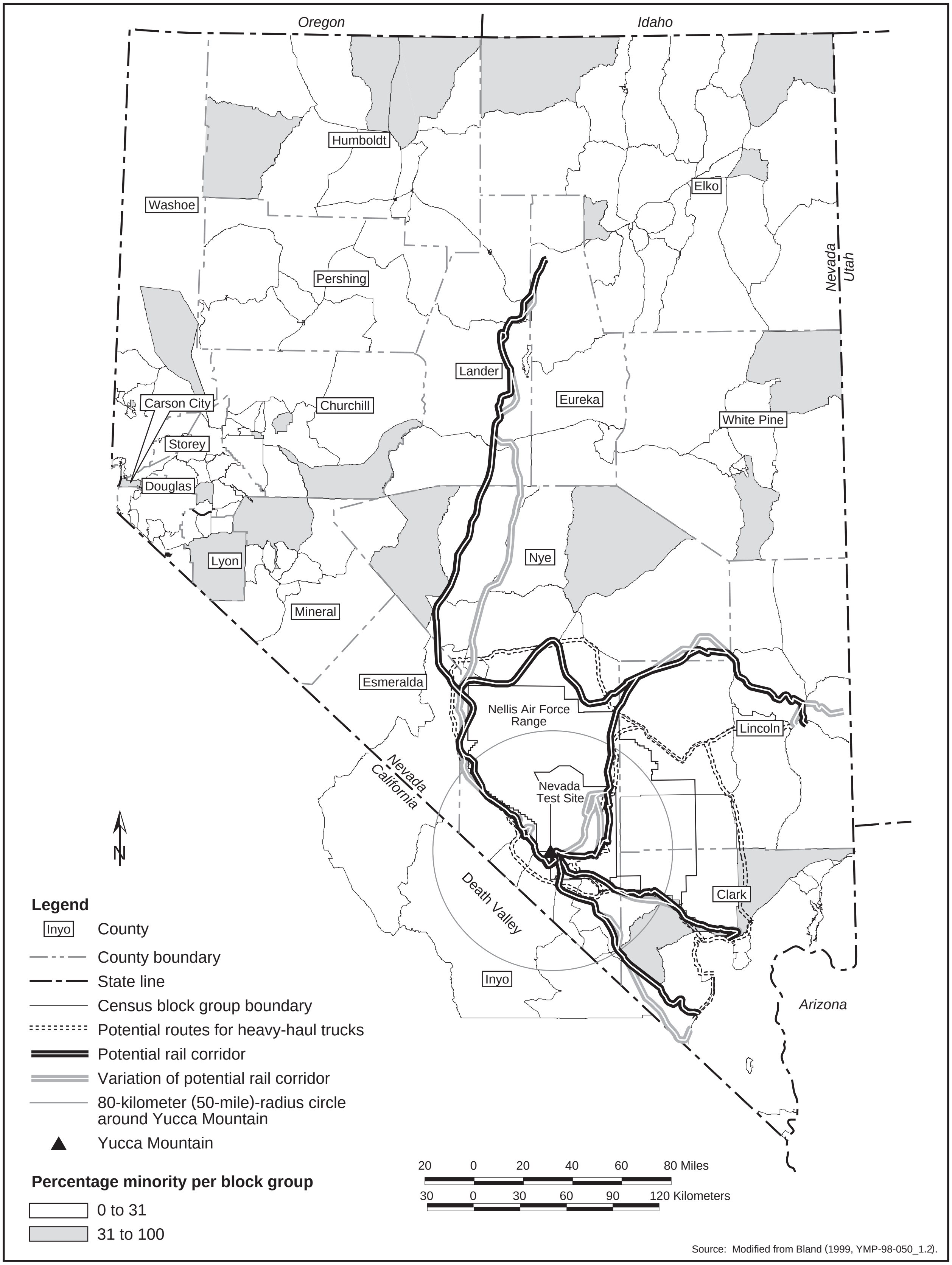



**Figure 3-23.** Minority communities in Nevada.

The 1990 census characterized about 10 percent of the people in Nevada as living in poverty (Bureau of the Census 1992a, Table P117). The Bureau of the Census characterizes persons in poverty as those whose income is less than a statistical poverty threshold, which is based on family size and the ages of its members. In the 1990 census the threshold for a family of four was a 1989 income of $12,674 (Bureau of the Census 1995, Section 14). In this environmental impact statement, low-income communities are those in which the percentage of persons in poverty equals or exceeds 20 percent as reported by the Bureau of the Census. Figure 3-24 shows low-income communities.

### 3.1.13.2 Clark County

In 1990, the minority population of Clark County was about 180,000 persons, or 25 percent of the total population (Bureau of the Census 1992b, Tables P8 and P12). A total of 6,800 residents, or 11 percent of the Clark County population, was characterized as living in poverty (Bureau of the Census 1992b, Table P117) Forty-three of Clark County's 325 block groups had both minority populations greater than the 31-percent threshold necessary for identification as minority communities and populations that exceeded the 20-percent low-income community threshold. Thirty-five more block groups had minority populations greater than the 31-percent threshold. An additional 12 block groups had low-income populations greater than the 20-percent threshold. In all, the process identified 90 block groups in Clark County for environmental justice study.

### 3.1.13.3 Lincoln County

In 1990, the Lincoln County minority population consisted of about 370 persons, or 10 percent of the population (Bureau of the Census 1992c, Tables P8 and P12). Five hundred persons, or 14 percent of the population, were characterized as living in poverty (Bureau of the Census 1992c, Table P117). No block groups exceeded the 31-percent threshold for identification as a minority community. One of the block groups in Lincoln County exceeded the threshold for identification as a low-income community.

### 3.1.13.4 Nye County

In 1990, the Nye County minority population was about 2,200 persons, or 12 percent of the population (Bureau of the Census 1992d, Tables P8 and P12). There were 2,000 persons, or 11 percent of the population, characterized as living in poverty (Bureau of the Census 1992d, Table P117). Two block groups had populations that exceeded the thresholds for both minority and low-income populations. Three more of the 25 block groups in Nye County exceeded the threshold for identification as low-income communities.

### 3.1.13.5 Inyo County, California

One block group with a low-income population located in the area of the Stewart Valley in Inyo County, California, lies partly within the 80-kilometer (50-mile) air quality region of influence for the repository (Figure 3-21). DOE performed additional review and concluded that low-income persons living in the block group would be likely to live outside the 80-kilometer region of influence for the repository.

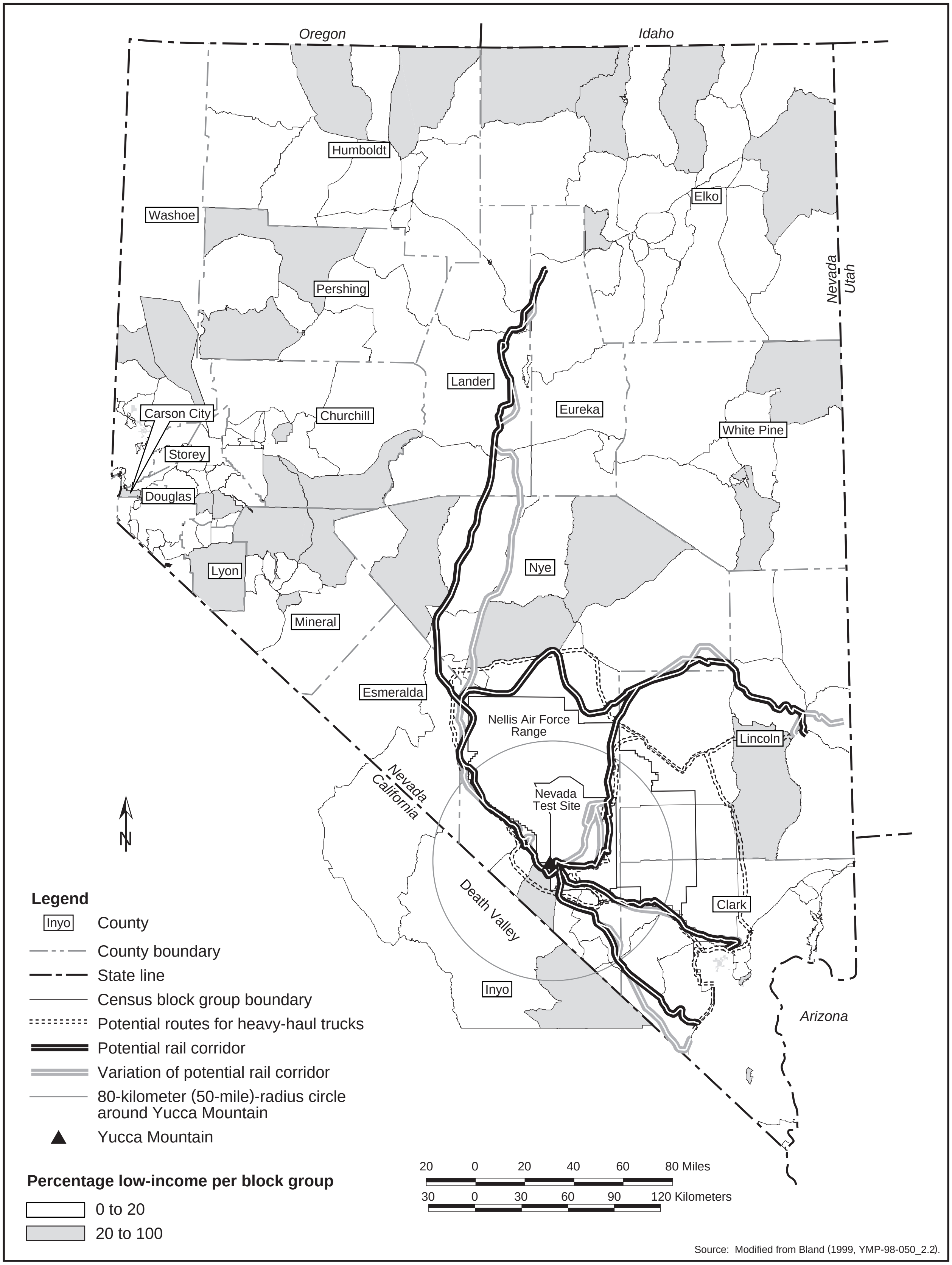



**Figure 3-24.** Low-income communities in Nevada.

# 3.2 Affected Environment Related to Transportation

This section describes the existing (or baseline) environmental conditions along the potential transportation corridors to the Yucca Mountain site. Section 3.2.1 discusses the existing national transportation infrastructure that DOE would use to ship spent nuclear fuel and high-level radioactive waste to Nevada.

Section 3.2.2 describes the existing environmental conditions along the proposed transportation corridors and routes in Nevada.

## 3.2.1 NATIONAL TRANSPORTATION

The loading and shipping of spent nuclear fuel and high-level radioactive waste would occur at 72 commercial and 5 DOE sites in 37 states. The Department's efforts to transport these materials to the Yucca Mountain site could use trains, legal-weight trucks, heavy-haul trucks, and barges; the trains and trucks would travel on the Nation's railroads and highways. Barges and heavy-haul trucks would be used for short-distance transport of spent nuclear fuel from storage sites to nearby railheads. (Heavy-haul trucks could also be used for Nevada transportation, as discussed in Section 3.2.2.2.)

The national transportation of spent nuclear fuel and high-level radioactive waste would use existing highways and railroads and would represent a small fraction of the existing national highway and railroad traffic [0.006 percent of truck miles per year or 0.007 percent of railcar miles per year (BTS 1998, page 5)]. Because no new land acquisition and construction would be required to accommodate these shipments, this EIS focuses on potential impacts to human health and safety and the potential for accidents along the shipment routes.

The region of influence for public health and safety along existing transportation routes is 800 meters (0.5 mile) from the centerline of the transportation rights-of-way and from the boundary of railyards for incident-free (nonaccident) conditions. The region of influence extends to 80 kilometers (50 miles) to address potential human health and safety impacts from accident scenarios.

### 3.2.1.1 Highway Transportation

Highway (legal-weight truck) transportation of spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site would use local highways near the commercial and DOE sites and near Yucca Mountain, Interstate Highways, Interstate bypasses around metropolitan areas, and preferred routes designated by state routing agencies where applicable. DOE used the HIGHWAY computer program (Johnson et al. 1993a, all) to derive highway routes for shipping spent nuclear fuel and high-level radioactive waste. This model considered population densities along the routes, and selected existing highway routes between the commercial and DOE sites and the proposed repository in accordance with U.S. Department of Transportation routing constraints. Population density distributions were calculated along the routes to support human health risk consequences.

Appendix J describes the routes used for analysis in this EIS. Final transportation mode and routing decisions will be made on a site-specific basis during the transportation planning process, following a decision to build a repository at Yucca Mountain.

### 3.2.1.2 Rail Transportation

In most cases, rail transportation of spent nuclear fuel and high-level radioactive waste would originate on track operated by shortline rail carriers that provide service to the commercial and DOE sites. At railyards near the sites, shipments in general freight service would switch from trains and tracks operated by the shortline rail carriers to trains and tracks operated by national mainline railroads. Figure 2-29 in Chapter 2 is a map of mainline track for the major U.S. railroads that DOE could use for shipments to Nevada. This interlocking network has about 290,000 kilometers (180,000 miles) of track that link the major population centers and industrial, agricultural, and energy and mineral resources of the Nation (AAR 1996, all). With the exception of shortline regional railroads that serve the commercial and DOE sites, DOE anticipates that cross-country shipments would move on mainline railroads.

Rail transportation routing of spent nuclear fuel and high-level radioactive waste shipments is not regulated by the U.S. Department of Transportation. The routes used in this EIS were derived from the INTERLINE computer program (Johnson et al. 1993b, all). The selection of these routes was based on current routing activities using existing routes. Appendix J describes the rail routes used in this EIS analysis.

#### 3.2.1.3 Barge and Heavy-Haul Truck Transportation

Commercial sites that do not have direct rail service could ship spent nuclear fuel on heavy-haul trucks or barges to nearby railheads. Heavy-haul trucks would use local highways to carry the spent nuclear fuel to a nearby railhead for transfer to railcars for transport to Nevada. Barge shipments would use navigable waterways accessible from the nuclear plant site. These shipments would travel on the waterways to nearby railheads for transfer to railcars for transport to Nevada. Appendix J describes the heavy-haul truck and barge routes used in this EIS analysis.

### 3.2.2 NEVADA TRANSPORTATION

Shipments of spent nuclear fuel and high-level radioactive waste arriving in Nevada would be transported to the Yucca Mountain site by legal-weight truck, rail, or heavy-haul truck. The discussion of national transportation modes and routes in Section 3.2.1 addresses the affected environment for legal-weight truck transport from commercial and DOE facilities to the Yucca Mountain site, including travel in Nevada. This section addresses the affected environment in Nevada for candidate rail corridors, heavy-haul truck routes, and potential locations for an intermodal transfer station that DOE could use for transporting spent nuclear fuel and high-level radioactive waste and that would require new construction.

Legal-weight truck shipments in Nevada would use existing highways and would be a very small fraction of the total traffic [less than 0.5 percent of commercial vehicle traffic on U.S. Highway 95 in southern Nevada (NDOT 1997, page 9; Cerocke 1998, page 1). Because no new land acquisition and construction would be required to accommodate legal-weight trucks, this EIS focuses on potential impacts to human health and safety and the potential for accidents along the shipment routes from legal-weight truck shipments. Appendix J contains baseline environmental information related to human health and safety and the impacts from accident scenarios.

To allow large-capacity rail cask shipments to the repository, DOE is considering the construction of a new branch rail line or the establishment of heavy-haul truck shipment capability. Sections 3.2.2.1 and 3.2.2.2 describe the existing (or baseline) environment for each of the candidate rail corridors and heavy-haul truck routes and for potential locations for an intermodal transfer station.

#### 3.2.2.1 Environmental Baseline for Potential Nevada Rail Corridors

This section discusses the environmental characteristics of land areas that could be affected by the construction and operation of a rail line to transport spent nuclear fuel and high-level radioactive waste to the proposed repository. It describes the environmental conditions in five alternative rail corridors—Caliente, Carlin, Caliente-Chalk Mountain, Jean, and Valley Modified. Chapter 2, Section 2.1.3.2, describes these corridors in more detail. Figures 6-10 through 6-15 in Chapter 6 show detailed maps for these corridors.

To define the existing (or baseline) environment along the five proposed rail corridors; DOE has compiled environmental information for each of the following subject areas:

- *Land use and ownership:* The condition of the land, current land-use practices, and land ownership information (Section 3.2.2.1.1)
- *Air quality and climate:* The quality of the air and the climate (Section 3.2.2.1.2)
- *Hydrology:* The characteristics of surface water and groundwater (Section 3.2.2.1.3)
- *Biological resources:* Important biological resources (Section 3.2.2.1.4)
- *Cultural resources:* Important cultural resources (Section 3.2.2.1.5)
- *Socioeconomic environments:* The existing socioeconomic environments (Section 3.2.2.1.6)
- *Noise:* The existing noise environments (Section 3.2.2.1.7)
- *Aesthetics:* The existing visual environments (Section 3.2.2.1.8)
- *Utilities, energy, and materials:* Existing supplies of utilities, energy, and materials (Section 3.2.2.1.9)
- *Environmental justice:* The locations of low-income and minority populations (Section 3.2.2.1.10)

The INTERLINE computer program (Johnson et al. 1993b, all) provided population distributions for differing population zones (urban, rural, suburban) along the alternative rail corridors. This approach is consistent with the national transportation analysis (see Chapter 6 for more detail).

DOE expects waste quantities generated by rail line construction and operation to be minor in comparison to those from repository construction and operation. As such, no discussion of existing waste disposal infrastructure along the routes is provided.

DOE evaluated the potential impacts of the implementing alternatives in regions of influence for each of the subject areas listed above. Table 3-32 defines these regions, which are specific to the subject areas, in which DOE could reasonably expect to predict potentially large impacts related to rail line construction and operation. The following sections describe the various environmental baselines for the rail implementing alternatives.

#### 3.2.2.1.1 *Land Use and Ownership*

Table 3-33 summarizes the estimated land commitment and current ownership or control of the land in each rail corridor. Public lands in and near the corridors are used for a variety of activities including grazing, mining, and recreation. All public land in the Caliente, Carlin, Jean, and Valley Modified corridors is open to mining and mineral leasing laws and offroad vehicle use, with restrictions in some areas (BLM 1979, all; BLM 1994b, all; BLM 1999a, all).

*Caliente.* Most of the lands associated with the Caliente corridor (88 percent) are public lands managed by the Ely, Battle Mountain, and Las Vegas offices of the Bureau of Land Management. Detailed

**Table 3-32.** Regions of influence for rail implementing alternatives.

| Subject area | Region of influence |
|---|---|
| Land use and ownership | Land areas that would be disturbed or whose ownership or use would change as a result of construction and use of branch rail line |
| Air quality and climate | The Las Vegas Valley for implementing alternatives where constructing and operating a branch rail line could contribute to the level of carbon monoxide and $PM_{10}$ already in nonattainment of standards, and the atmosphere in the vicinity of sources of criteria pollutants that would be emitted during branch rail line construction and operations |
| Hydrology | *Surface water:* areas near where construction would take place that would be susceptible to erosion, areas affected by permanent changes in flow, and areas downstream of construction that could be affected by eroded soil or potential spills of construction contaminants |
| | *Groundwater:* aquifers that would underlie areas of construction and operations and aquifers that might be used to obtain water for construction |
| Biological resources | Habitat, including jurisdictional wetlands and riparian areas inside the 400-meter-wide[a] corridors; habitat, including jurisdictional wetlands outside the corridor that could be disturbed by rail line construction and operations; habitat, including jurisdictional wetlands, and riparian areas that could be affected by permanent changes in surface-water flows; migratory ranges of big game animals that could be affected by the presence of a branch rail line |
| Cultural resources | Lands inside the 400-meter-wide rail corridors |
| Socioeconomic environments | Clark, Lincoln, Nye and other counties that a potential branch rail line would traverse |
| Public health and safety | 800 meters[b] on each side of the rail line for incident-free transportation, 80-kilometer[c] radius for potential impacts from accident scenarios |
| Noise | Inhabited commercial and residential areas where noise from rail line construction and operations could be a concern |
| Aesthetics | The landscapes along the potential rail corridors with aesthetic qualities that could be affected by construction and operations |
| Utilities, energy, and materials | Local, regional, and national supply infrastructure that would be required to support rail line construction and operations |
| Environmental justice | Varies with the individual resource area |

a. 400 meters = 0.25 mile.
b. 800 meters = 0.5 mile.
c. To convert kilometers to miles, multiply by 0.62137.

**Table 3-33.** Land ownership for the candidate rail corridors.[a]

| | Land in corridor | | | | | |
|---|---|---|---|---|---|---|
| | | Ownership or control (percent)[d] | | | | |
| Corridor | Totals ($km^2$)[b,c] | BLM | USAF | DOE | Private | Other |
| Caliente | 200 | 88 | 9 | 2 | < 1 | 0 |
| Carlin | 210 | 85 | 9 | 2 | 3 | 0 |
| Caliente-Chalk Mountain | 140 | 57 | 16 | 27 | < 1 | 0 |
| Jean | 72 | 83 | 0 | 12 | 5 | 0 |
| Valley Modified | 64 | 50 | 14 | 33 | 0 | 3 |

a. Source: (TRW 1999d, all).
b. To convert square kilometers ($km^2$) to acres, multiply by 247.1.
c. Totals might differ from sums due to rounding.
d. Bureau of Land Management (BLM) property is public land administered by the Bureau; U.S. Air Force property is the Nellis Air Force Range; DOE property is the Nevada Test Site; and the single Other designation is the Desert National Wildlife Refuge managed by the Fish and Wildlife Service.

information on land use is available in the *Proposed Tonopah Resource Management Plan and Final Environmental Impact Statement* (BLM 1994b, all), the *Department of the Interior Final Environmental Impact Statement Proposed Domestic Livestock Grazing Management Program for the Caliente Area* (BLM 1979, all), the *Draft Caliente Management Framework Plan Amendment and Environmental Impact Statement for the Management of Desert Tortoise Habitat* (BLM 1999a, all), and the *Proposed Las Vegas Resource Management Plan and Final Environmental Impact Statement* (BLM 1998, all).

The U.S. Air Force uses about 9 percent of the lands associated with the Caliente corridor. The corridor crosses the western boundary of the Nellis Air Force Range near Scotty's Junction. Detailed information on current and future uses of the Nellis Air Force Range is available in the *Renewal of the Nellis Air Force Range Land Withdrawal Department of the Air Force Legislative Environmental Impact Statement* (USAF 1999, all).

DOE uses about 2 percent of the lands associated with the Caliente corridor. The corridor enters the Nevada Test Site south of Beatty. Detailed information on current and future uses of the Nevada Test Site is available in the *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DOE 1996f, all).

Less than 1 percent of the land associated with the Caliente corridor is private. The corridor crosses private land near Caliente.

*Carlin.* Most of the lands associated with the Carlin corridor (about 85 percent) are public lands managed by the Battle Mountain and Las Vegas offices of the Bureau of Land Management. Detailed information on land use is available in the *Draft Management Plan and Environmental Impact Statement for the Shoshone-Eureka Resource Area, Nevada* (BLM 1983, all), the *Proposed Tonopah Resource Management Plan and Final Environmental Impact Statement* (BLM 1994b, all), and the *Proposed Las Vegas Resource Management Plan and Final Environmental Impact Statement* (BLM 1998, all).

The U.S. Air Force uses about 9 percent of the lands associated with the Carlin corridor. The combined Carlin/Caliente corridor crosses into the western portion of the Nellis Air Force Range near Scotty's Junction. Detailed information on current and future uses of the Nellis Air Force Range is available in USAF (1999, all).

DOE uses about 2 percent of the lands associated with the Carlin corridor. The combined Carlin/Caliente corridor enters the Nevada Test Site south of Beatty. Detailed information on current and future uses of the Nevada Test Site is available in DOE (1996f, all).

About 3 percent of the land associated with the Carlin corridor is private. The corridor crosses private roads in the northern part of the route, from Beowawe through Crescent Valley.

*Caliente-Chalk Mountain.* Most of the lands associated with the Caliente-Chalk Mountain corridor (about 57 percent) are public lands managed by the Ely office of the Bureau of Land Management. Detailed information on land use is available in BLM (1979, all) and BLM (1999a, all).

The U.S. Air Force uses about 16 percent of the lands associated with the Caliente-Chalk Mountain corridor. The corridor enters the Nellis Air Force Range west of Rachel, Nevada, and travels south through the range. Detailed information on current and future uses of the Nellis Air Force Range is available in USAF (1999, all).

DOE uses about 27 percent of the lands associated with the Caliente-Chalk Mountain corridor. The corridor crosses the northern border of the Nevada Test Site and travels to the Yucca Mountain site. Detailed information on current and future uses of the Nevada Test Site is available in DOE (1996f, all).

Less than 1 percent of the lands associated with the Caliente-Chalk Mountain corridor is private. The combined Caliente and Caliente-Chalk Mountain corridor crosses private lands near Caliente.

*Jean.* Most of the lands associated with the Jean corridor (about 83 percent) are public lands managed by the Las Vegas office of the Bureau of Land Management. Detailed information on land use is available in BLM (1998, all).

DOE uses about 12 percent of the lands associated with the Jean corridor. The corridor enters the Nevada Test Site near the Amargosa Valley traveling north to the Yucca Mountain site. Detailed information on current and future uses of the Nevada Test Site is available in DOE (1996f, all).

About 5 percent of the land associated with the Jean corridor is private. The corridor crosses private lands in the Pahrump Valley.

*Valley Modified.* Half of the lands associated with the Valley Modified corridor are public lands managed by the Las Vegas office of the Bureau of Land Management. Detailed information on land use is available in BLM (1998, all).

The U.S. Air Force uses about 14 percent of the lands associated with the Valley Modified corridor. The corridor crosses Nellis Air Force Base northeast of Las Vegas and the Nellis Air Force Range near Indian Springs. Detailed information on current and future uses of the Nellis Air Force Range is available in USAF (1999, all).

DOE uses about 33 percent of the lands associated with the Valley Modified corridor. The corridor enters the Nevada Test Site near Mercury, traveling northwest to the Yucca Mountain site. Detailed information on current and future uses of the Nevada Test Site is available in DOE (1996f, all).

The Fish and Wildlife Service manages about 3 percent of the lands associated with the Valley Modified corridor as part of the Desert National Wildlife Refuge, which was established in 1936 for the protection and preservation of desert bighorn sheep. Portions of this refuge overlap the Nellis Air Force Range and are controlled jointly by the Air Force and the Fish and Wildlife Service. Use and public access to the joint-use area of the Desert National Wildlife Refuge and Nellis Air Force Range are restricted by a memorandum of understanding (USAF 1999, Appendix C).

#### 3.2.2.1.2 *Air Quality and Climate*

This section contains information on the existing air quality in areas through which the candidate rail corridors pass. It also provides background on the general climate in those areas.

*Air Quality.* The Caliente, Carlin, Caliente-Chalk Mountain, and Jean corridors pass through rural parts of Nevada that are either unclassifiable or in attainment for criteria pollutants (EPA 1999c, all). There are no State air-quality monitoring stations in these corridors (NDCNR 1999, pages A1-1 through A1-9).

The Valley-Modified rail corridor crosses central Clark County at the north end of the Las Vegas Valley and continues in a northwest direction toward the Nevada Test Site. The air quality in the part of the corridor that passes through the Las Vegas Valley and extends part of the way to Indian Springs is in nonattainment for particulate matter with a diameter of less than 10 micrometers ($PM_{10}$). Clark County adopted a plan for demonstrating $PM_{10}$ attainment (Clark County 1997b, all) that includes a request to the Environmental Protection Agency to extend the year for attainment demonstration from 2001 to 2006. The plan includes proposals to reduce emissions of particulate matter from a variety of sources. The Las Vegas Valley is also a nonattainment area for carbon monoxide.

*Climate.* There are two general climate descriptions for the five rail corridors: one for the three corridors that approach the Yucca Mountain site from the north and one for the two corridors that approach the site from the south or southeast. The Caliente, Carlin, and Caliente-Chalk Mountain corridors approach from the north and cross a number of mountain ranges and valleys with elevations well above 1,500 meters (4,900 feet). Although much of Nevada is arid, in central Nye County the annual precipitation exceeds 20 centimeters (8 inches), and the annual snowfall exceeds 25 centimeters (10 inches); annual precipitation exceeds 40 centimeters (16 inches) in some mountainous areas, and snowfall exceeds 100 centimeters (40 inches) (Houghton, Sakamoto, and Gifford 1975, pages 45, 49, and 52). Occasional brief periods of intense rainfall at rates exceeding 5 centimeters (2 inches) an hour can occur in the summer.

The Jean and Valley Modified corridors approach the Yucca Mountain site from the south where precipitation is generally between 10 and 20 centimeters (4 and 8 inches) per year and snowfall is rare. Occasional brief periods of intense rainfall at rates exceeding 5 centimeters (2 inches) an hour can occur in the summer (Houghton, Sakamoto, and Gifford 1975, pages 45, 49, and 52).

### 3.2.2.1.3 *Hydrology*

This EIS discusses hydrologic conditions in terms of surface water and groundwater.

**3.2.2.1.3.1 Surface Water.** Researchers studied the alternative rail corridors for their proximity to sensitive environmental resources, including surface waters and riparian lands (TRW 1999k, Appendixes E, F, G, H, and I). The goal in planning the corridors was to avoid springs and riparian lands by 400 meters (1,300 feet) if possible. Table 3-34 summarizes potential surface-water-related resources along the candidate corridors. It lists resources within the 400-meter corridor or within a 1-kilometer (0.6-mile) region of influence along the corridor.

Potential hydrologic hazards along the rail corridors include flash floods and debris flow. All corridors have potential flash flooding concerns. DOE would design and build a rail line that would be able to withstand a 100-year flood event safely.

**3.2.2.1.3.2 Groundwater.** Groundwater basins that the candidate rail corridors cross represent part of the potentially affected environment. As described for groundwater in the immediate region of Yucca Mountain (Section 3.1.4.2.1), the State of Nevada has been divided into groundwater basins and sub-basins. The sub-basins are called hydrographic areas. A map of these areas (Bauer et al. 1996, page 543) was overlain with a drawing of the proposed rail corridors to produce a reasonable approximation of the areas that would be crossed by each corridor. Table 3-35 lists results of this effort. The table also lists estimates of the perennial yield for each hydrographic area crossed and if the area is a State Designated Groundwater Basin [a hydrographic area in which the permitted water rights approach or exceed the estimated perennial yield and the water resources are depleted or require additional administration, including a State declaration of preferred uses (municipal and industrial, domestic supply, agriculture, etc.)] (NDWP 1999b, Region 14). These are the areas where additional water demand would be most likely to produce an adverse effect on local groundwater resources. The table indicates that none of the corridors would completely avoid Designated Groundwater Basins. However, the Caliente-Chalk Mountain corridor would cross only two Designated Basins, one at Panaca Valley near the start of the corridor and one at Penoyer Valley where the Caliente and Caliente-Chalk Mountain corridors split.

**Table 3-34.** Surface-water-related resources along candidate rail corridors.[a]

| Rail corridor | Distance from corridor (kilometers)[b] | Feature |
|---|---|---|
| *Caliente* | | |
| Caliente to Meadow Valley | 0.5 | Springs – two unnamed springs, in Meadow Valley north of Caliente |
| | Within | Riparian area/stream – corridor crosses and is adjacent to stream and riparian area in Meadow Valley Wash |
| Meadow Valley to Sand Spring Valley | 1.0 | Spring – Bennett Spring, 3.2 kilometers southeast of Bennett Pass |
| | 0.05 - 2.6 | Springs – group of five springs (Deadman, Coal, Black Rock, Hamilton, and one unnamed) east of White River |
| | Within | Riparian/river – corridor parallels (and crosses) the White River for about 25 kilometers. August 1997 survey found river to be mostly underground with ephemeral washes above ground. |
| | 0.8 | Spring – McCutchen Spring, north of Worthington Mountains |
| Sand Spring Valley to Mud Lake | 0.02 | Spring – Black Spring, south of Warm Springs |
| Mud Lake to Yucca Mountain | Within - 2.5 | Springs – numerous springs and seeps along Amargosa River in Oasis Valley |
| | Within | Riparian area – designated area east of Oasis Valley, flowing into Amargosa Valley |
| | 0.3 - 1.3 | Springs – group of 13 unnamed springs in Oasis Valley north of Beatty |
| | Within - 0.3 | Riparian area/stream – Amargosa River, with persistent water and extensive wet meadows near springs and seeps |
| *Carlin* | | |
| Beowawe to Austin | 0.5 | Spring – Tub Spring, northeast of Red Mountain |
| | 0.8 | Spring – Red Mountain Spring, east of Red Mountain |
| | 0.9 | Spring – Summit Spring, west of corridor and south of Red Mountain |
| | 0.4 | Spring – Dry Canyon Spring, west of Hot Springs Point |
| | 0.8 | Spring – unnamed spring on eastern slope of Toiyabe Range, southwest of Hot Springs Point |
| | 1.0 | Riparian area – intermittent riparian area associated with Rosebush Creek, in western Grass Valley, north of Mount Callaghan |
| | Within | Riparian/creek – corridor crosses Skull Creek, portions of which have been designated riparian areas |
| | Within | Riparian/creek – corridor crosses intermittent Ox Corral Creek; portions designated as riparian habitat. An August 1997 survey found creek dry with no riparian vegetation present |
| | 0.1 | Spring – Rye Patch Spring, at north entrance of Rye Patch Canyon, west of Bates Mountain |
| | Within | Riparian area – corridor crosses and parallels riparian area in Rye Patch Canyon |
| | 0.7 | Spring – Bullrush Spring, east of Rye Patch Canyon |
| Austin to Mud Lake | 0.8 | Springs – group of 35 unnamed springs, about 25 kilometers north of Round Mountain on east side of Big Smokey Valley |
| | 0.6 | Riparian area – marsh area formed from group of 35 springs |
| | 0.6 | Spring – Mustang Spring, south of Seyler Reservoir |
| | 0.3 | Riparian/reservoir – Seyler Reservoir, west of Manhattan |
| Mud Lake to Yucca Mountain | | See Caliente corridor |
| *Caliente-Chalk Mountain* | | |
| Caliente to Meadow Valley | | See Caliente corridor |
| Meadow Valley to Sand Spring Valley | | See Caliente corridor |
| Sand Spring Valley to Yucca Mountain | 1.0 | Spring – Reitman's Seep, in eastern Yucca Flat, east of BJ Wye |
| | 0.8 | Spring – Cane Spring, on north side of Skull Mountain on Nevada Test Site |
| *Jean* | | None identified |
| *Valley Modified* | | None identified |

a. Source: TRW (1999k, Appendixes E, F, G, H, and I).
b. To convert kilometers to miles, multiply by 0.62137.

**Table 3-35.** Hydrographic areas (groundwater basins) crossed by candidate rail corridors.

| Rail corridor | Hydrographic area[a] No. | Hydrographic area[a] Name | Perennial yield (acre-feet)[b,c,d] | Designated Groundwater Basin[e,f] |
|---|---|---|---|---|
| *Caliente* | | | | |
| Caliente to Sand Spring Valley | 204 | Clover Valley | 1,000 | No |
| | 203 | Panaca Valley | 9,000 | Yes |
| | 181 | Dry Lake Valley | 2,500 | No |
| | 208 | Pahroc Valley | 21,000 | No |
| | 171 | Coal Valley | 6,000 | No |
| | 172 | Garden Valley | 6,000 | No |
| Sand Spring Valley to Mud Lake | 170 | Penoyer Valley (Sand Spring Valley) | 4,000 | Yes |
| | 173A | Railroad Valley, southern part | 2,800 | No |
| | 156 | Hot Creek | 5,500 | No |
| | 149 | Stone Cabin Valley | 2,000 | Yes |
| | 141 | Ralston Valley | 6,000 | Yes |
| Mud Lake to Yucca Mountain | 142 | Alkali Spring Valley | 3,000 | No |
| | 145 | Stonewall Flat | 100 | No |
| | 144 | Lida Valley | 350 | No |
| | 146 | Sarcobatus Flat | 3,000 | Yes |
| | 228 | Oasis Valley | 1,000 | Yes |
| | 229 | Crater Flat | 220 | No |
| | 227A | Fortymile Canyon and Jackass Flats | 880[g] | No |
| *Carlin* | | | | |
| Beowawe to Austin | 54 | Crescent Valley | 16,000 | Yes |
| | 138 | Grass Valley | 13,000 | No |
| Austin to Mud Lake – Via Big Valley | 137B | Big Smokey Valley, northern part | 65,000 | Yes |
| | 137A | Big Smokey Valley and Tonopah Flat | 6,000 | Yes |
| Mud Lake to Yucca Mountain | 142 to 227A | See Caliente corridor | | |
| *Caliente-Chalk Mountain* | | | | |
| Caliente to Sand Spring Valley | 204 to 170 | See Caliente corridor | | |
| Sand Spring Valley to Yucca Mountain | 158A | Emigrant Valley and Groom Lake Valley | 2,800 | No |
| | 159 | Yucca Flat | 350 | No |
| | 160 | Frenchman Flat | 16,000 | No |
| | 227A | Fortymile Canyon and Jackass Flats | 880[g] | No |
| *Jean* | | | | |
| Jean to Yucca Mountain | 165 | Jean Lake Valley | 50 | Yes |
| | 164A | Ivanpah Valley, northern part | 700 | Yes |
| | 163 | Mesquite Valley (Sandy Valley) | 2,200 | Yes |
| | 162 | Pahrump Valley | 12,000 | Yes |
| | 230 | Amargosa Desert | 24,000 | Yes |
| | 227A | Fortymile Canyon and Jackass Flats | 880[g] | No |
| *Valley Modified* | | | | |
| Dike Siding (north of Las Vegas) to Yucca Mountain | 212 | Las Vegas Valley | 25,000 | Yes |
| | 211 | Three Lakes Valley, southern part | 5,000 | Yes |
| | 161 | Indian Springs Valley | 500 | Yes |
| | 225 | Mercury Valley | 250 | Yes |
| | 226 | Rock Valley | 30 | No |
| | 227A | Fortymile Canyon and Jackass Flats | 880[g] | No |

a. Source: Bauer et al. (1996, pages 542 and 543 with corridor map overlay).

b. Source: NDWP (1998, Regions 4, 10, 13, and 14), except hydrographic areas 225 through 230 for which the source is Thiel (1997, pages 6 to 12). The Nevada Division of Water Planning identifies a perennial yield of only 24,000 acre-feet (30 million cubic meters) for the combined area of hydrographic areas 225 through 230 (NDWP 1998, 1999b, hydrographic area 225; NDWP (1999b, hydrographic area 230).

c. Perennial yield is the estimated quantity of groundwater that can be withdrawn annually from a basin without depleting the reservoir.

d. To convert acre-feet to cubic meters, multiply by 1,233.49.

e. Source: NDWP (1999b, Regions 4, 10, 13, and 14).

f. "Yes" indicates the State of Nevada considers the area a Designated Groundwater Basin where permitted water rights approach or exceed the estimated perennial yield and the water resources are being depleted or require additional administration, including a State declaration of preferred uses (municipal and industrial, domestic supply, agriculture, etc.). Designated Groundwater Basins are also referred to as Administered Groundwater Basins.

g. The perennial yield value shown for Area 227A is the lowest estimated value presented in Thiel (1997, page 8) and is further broken down into 370,000 cubic meters (300 acre-feet) for the eastern third of the area and 715,000 cubic meters (580 acre-feet) for the western two-thirds.

There are a number of published estimates of perennial yield for many of the hydrographic areas in Nevada, and they often differ from one another by large amounts. This is the reason for listing a range of perennial yield values in Table 3-10 for the hydrographic areas in the Yucca Mountain region. For simplicity, the perennial yield values listed in Table 3-35 generally come from a single source (NDWP 1998, Regions 4, 10, 13, and 14) and, therefore, do not show a range of values for each area. The hydrographic areas in the Yucca Mountain region (that is, areas 225 through 230) are the exception to perennial yield values from the single source. The perennial yield values for these areas are from Thiel (1997, pages 6 to 12), which compiles estimates from several sources. The table lists the lowest values in that document.

The perennial yield value shown for Area 227A is the lowest estimated value presented in Thiel (1997, page 8) and is further divided into 300 acre-feet (370,000 cubic meters) for the eastern third of the area and 580 acre-feet (715,000 cubic meters) for the western two-thirds.

#### 3.2.2.1.4 *Biological Resources*

The following sections describe biological resources along each of the candidate rail corridors. These environments include habitat types and springs and riparian areas located in a 400-meter (1,300-foot)-wide corridor along each route. Springs and riparian areas are important because they provide habitat for large numbers of plants, animals, and insects. Unless otherwise noted, this information is from the *Environmental Baseline File for Biological Resources* (TRW 1999k, all).

*Caliente.* From the beginning of the corridor at Caliente to Mud Lake, the Caliente rail corridor crosses Meadow, Dry Lake, Coal, Garden, Sand Spring, Railroad, Reveille, Stone Cabin, and Ralston Valleys. From Mud Lake, the corridor crosses Stonewall and Sarcobatus flats, the upper portion of the Amargosa River, the lower portion of Beatty Wash, and Crater and Jackass Flats. The valleys and flats along the corridor range in elevation from 900 to 1,900 meters (3,000 to 6,200 feet). The corridor also crosses several mountain ranges including the Highland, Seaman, Golden Gate, Worthington, and Kawich mountain ranges at elevations ranging from 1,400 to 1,900 meters (4,600 to 6,200 feet). The Caliente rail corridor is in the southern Great Basin from its beginning at Caliente to near Beatty Wash. The land cover types along this portion of the corridor include salt desert scrub (60 percent) and sagebrush (33 percent). South of Beatty Wash, the corridor crosses into the Mojave Desert. Predominant land cover types from Beatty Wash to Yucca Mountain include creosote-bursage (59 percent), Mojave mixed scrub (22 percent), and salt desert scrub (19 percent) (TRW 1999k, page 3-22).

The only resident threatened or endangered species in the Caliente rail corridor is the desert tortoise, which occurs only along the southern end of the corridor from about Beatty Wash to Yucca Mountain (Bury and Germano 1994, pages 57 to 72). This area is not critical habitat for desert tortoises (50 CFR 17.95) and their abundance in this area is low in relation to other areas in the range of the species in Nevada (Karl 1981, pages 76 to 92; Rautenstrauch and O'Farrell 1998, pages 407 to 411). The only other threatened or endangered species near the corridor is the Federally threatened (State of Nevada protected, Nevada Administrative Code 503.067) Railroad Valley springfish (*Crenichthys nevadae*), which occurs in Warm Springs about 3 kilometers (1.9 miles) north of the corridor in Hot Creek Valley (FWS 1996, all).

Four other species classified as sensitive by the Bureau of Land Management occur in the corridor (NNHP 1997, all). Unnamed subspecies of the Meadow Valley Wash speckled dace (*Rhinichthys osculus* ssp.) and Meadow Valley Wash desert sucker (*Catostomus clarki* ssp. 2) have been found in Meadow Valley Wash north of Caliente. In the Beatty area, the Nevada sanddune beardtongue (*Penstemon arenarius*) has been found on sandy soils 10 kilometers (6 miles) north of Springdale. A number of bats classified as sensitive by the BLM also may occur along the corridor and the southern end of the corridor is in the range of the chuckwalla (*Sauromalus obesis*).

The Caliente rail corridor crosses several areas designated as game habitat (BLM 1979, pages 2-27 through 2-36; BLM 1994b, Maps 9 through 13). A bighorn sheep (*Ovis canadensis*) winter forage area is in the Cedar Range, approximately 13 kilometers (8 miles) west of Crestline, and the corridor also crosses bighorn sheep habitat west of Goldfield near Stonewall Mountain. Mule deer also use the winter forage area in the Cedar Range, and the corridor crosses mule deer use areas in or near the Chief Mountains, Delamar Mountains, Reveille Range, Kawich Range/Quinn Canyon, Stonewall Mountain, and west of the Worthington Mountains. The corridor crosses pronghorn antelope (*Antilocapra americana*) habitat in the Sand Spring, Railroad, Reveille, and Stone Cabin Valleys, and from Mud Lake to Stonewall Mountain. Meadow Valley Wash north of Caliente is classified as habitat for waterfowl.

At least six springs or groups of springs and three streams or riparian areas are within 0.4 kilometer (0.25 mile) of the corridor (TRW 1999k, page 3-23). These might be wetlands or other waters of the United States, as defined in the Clean Water Act, although no formal wetlands delineation has been conducted along the corridor. Black Spring is near the corridor at the north end of the Kawich Range and an unnamed spring is near the corridor at the north end of the North Pahroc Range. An unnamed spring is 0.3 kilometer (0.2 mile) east of the corridor between Mud Lake and Yucca Mountain west of Willow Spring. A series of springs is in the corridor near the Amargosa River in Oasis Valley. The corridor crosses the Meadow Valley Wash south of Panaca. The corridor also crosses the White River between U.S. 93 and Sand Spring Valley and parallels the river for approximately 25 kilometers (16 miles). An August 1997 survey of that portion of the river found it was mostly dry with some standing water in stock waterholes. The corridor crosses the Amargosa River in the north end of the Oasis Valley, in an area designated as a riparian area by the Bureau of Land Management (BLM 1994b, Maps 14 and 15). The corridor also crosses a number of ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act.

The Caliente rail corridor also crosses eight Bureau of Land Management-designated wild horse or wild horse and burro herd management areas (BLM 1979, pages 2-26 through 2-35; BLM 1994b, Maps 18 and 19). From U.S. Highway 93 to Sand Spring Valley, the corridor passes through a herd management area in the Chief Range. From Sand Spring Valley to Mud Lake, the corridor crosses the Saulsbury, Reveille, and Stone Cabin herd management areas, and from Mud Lake to Yucca Mountain the route crosses the Goldfield, Stonewall, and Bullfrog herd management areas.

*Carlin.* The Carlin rail corridor crosses Crescent and Grass Valleys, then passes through Big Smokey Valley to Mud Lake. From Mud Lake, the corridor crosses Stonewall and Sarcobatus Flats, the upper portion of the Amargosa River, the lower portion of Beatty Wash, and Crater and Jackass Flats. Elevations along the route range from 900 to 2,200 meters (3,000 to 7,200 feet).

The Carlin rail corridor is in the Great Basin from its start in Beowawe to near Beatty Wash. Land cover types along this portion of the corridor are dominated by salt desert scrub (57 percent), sagebrush (28 percent), and greasewood (7 percent). At Beatty Wash, the corridor crosses into the Mojave Desert. Predominant land cover types from Beatty Wash to Yucca Mountain include creosote-bursage (59 percent), Mojave mixed scrub (22 percent), and salt desert scrub (19 percent) (TRW 1999k, page 3-24).

The only resident threatened or endangered species in the Carlin rail corridor is the desert tortoise, which occurs only along the southern end of the corridor from about Beatty Wash to Yucca Mountain (Bury and Germano 1994, pages 57 to 72). This area is not critical habitat for desert tortoises (50 CFR 17.95) and their abundance in the region is low (Karl 1981, pages 76 to 92; Rautenstrauch and O'Farrell 1998, pages 407 to 411).

Three other species classified as sensitive by the Bureau of Land Management or as protected by Nevada occur along the Carlin rail corridor. A ferruginous hawk (*Buteo regalis*) (also classified as protected by Nevada) nesting area is east of Mount Callaghan. The San Antonio pocket gopher (*Thomomys umbrinus curtatus*) has been found in Big Smokey Valley northwest of the San Antonio Mountains. The Nevada sand dune beardtongue has been found in sandy soils 10 kilometers (6 miles) north of Springdale (NNHP 1997, all). A number of bats classified as sensitive by the Bureau of Land Management might occur along the corridor, and the southern end of the corridor is in the range of the chuckwalla.

The Carlin rail corridor crosses several areas designated as game habitat by the Bureau of Land Management (BLM 1983, Map 3-1; BLM 1994b, Maps 9 to 13; TRW 1999k, page 3-25). The corridor crosses an area designated as sage grouse (*Centrocercus urophasianus*) habitat in western Grass Valley and another at the southeast end of Rye Patch Canyon. The corridor enters pronghorn antelope habitat north of U.S. Highway 50 near Rye Patch Canyon, north of Toquima Range near Hickison summit, along most of Big Smokey Valley, and from Mud Lake to Stonewall Mountain. The corridor crosses mule deer habitat on the west side of Grass Valley, in the Simpson Park Range, and at Stonewall Mountain. The corridor crosses bighorn sheep habitat east of Goldfield and at Stonewall Mountain.

Three springs, seven riparian areas, and one reservoir are within 0.4 kilometer (0.25 mile) of the Carlin corridor (TRW 1999k, page 3-25). These areas might be wetlands or other waters of the United States, as defined by the Clean Water Act, although no formal wetlands delineation has been conducted along the corridor. Rye Patch Spring is on the edge of the corridor at the south end of the Simpson Park Mountains. An unnamed spring is 0.3 kilometer (0.2 mile) east of the corridor between Mud Lake and Yucca Mountain, west of Willow Spring. A series of springs is in the corridor near the Amargosa River in Oasis Valley. Seyler Reservoir is 0.2 kilometer (0.1 mile) from the corridor in the south end of Big Smokey Valley. Five of the riparian areas (Skull, Steiner, and Ox Corral creeks, and Water and Rye Patch canyons) are along the section of the route between Beowawe and Austin at the south end of Grass Valley. Two of these (Steiner and Ox Corral creeks, both at the south end of Grass Valley) are ephemeral and have little or no riparian vegetation where the route crosses them. The corridor crosses the Amargosa River in the north end of the Oasis Valley, in an area designated as a riparian area by the Bureau of Land Management. This corridor also crosses a number of ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act.

The corridor crosses two wild horse or wild horse and burro herd management areas between Beowawe and Austin (Mount Callaghan and Bald Mountain), one in Big Smokey Valley (Hickison) and three between Mud Lake and Yucca Mountain (Goldfield, Stonewall, and Bullfrog) (BLM 1983, Map 2-4; BLM 1994b, Maps 18 and 19).

*Caliente-Chalk Mountain.* The Caliente-Chalk Mountain rail corridor begins near Caliente and is identical to the Caliente rail corridor from Caliente to Sand Spring Valley, crossing Meadow, Dry Lake, Coal, and Garden Valleys at elevations ranging from 1,400 to 1,600 meters (4,600 to 5,200 feet). This portion of the corridor also crosses the Highland, Seaman, Golden Gate, and Worthington mountain ranges at elevations of 1,500 to 1,800 meters (4,900 to 5,900 feet). After splitting from the Caliente rail corridor, the Caliente-Chalk Mountain rail corridor proceeds south through Sand Spring and Emigrant Valleys, over Groom Pass, and through Yucca and Jackass Flats to Yucca Mountain. The elevation along this portion of the route ranges from approximately 1,100 to 1,700 meters (3,600 to 5,600 feet).

Predominant land cover types between Caliente and Sand Spring Valley include sagebrush (50 percent) and salt desert scrub (47 percent). The vegetation along the route from Sand Spring Valley to Yucca Flat is typical of the southern portion of the Great Basin. From Yucca Flat to Yucca Mountain, the corridor passes through a zone of transition between the Mojave and Great Basin deserts. The predominant land cover types from Sand Spring Valley to the Yucca Mountain site are blackbrush (50 percent), salt desert scrub (31 percent), and sagebrush (9 percent).

The only resident threatened or endangered species in the Caliente-Chalk Mountain rail corridor is the desert tortoise, which occurs on the Nevada Test Site south of Yucca Flat. This area is not critical habitat for desert tortoises (50 CFR 17.95) and their abundance is low (Rautenstrauch and O'Farrell 1998, pages 407 to 411).

Seven species classified as sensitive by the Bureau of Land Management have been found in the corridor (NNHP 1997, all). Unnamed subspecies of the Meadow Valley Wash speckled dace and Meadow Valley Wash desert sucker have been found in Meadow Valley Wash. Ripley's springparsley (*Cymopterus ripleyi* var. *saniculoides*) has been reported between Sand Spring Valley and Yucca Mountain in Yucca Flat. The largeflower suncup (*Camissonia megalantha*) has been found in the corridor at three locations in Yucca Flat. Beatley's scorpionweed (*Phacelia beatleyae*) also has been reported at two locations in Yucca Flat. The long-legged myotis (*Myotis volans*, a bat) has been found in Jackass Flats and other bats classified as sensitive by the Bureau of Land Management also may occur near the corridor. Chuckwalla may occur in suitable habitat on the Nevada Test Site.

The Caliente-Chalk Mountain rail corridor crosses several areas designated as game habitat by the Bureau of Land Management (BLM 1979, pages 2-26 through 2-35; BLM 1994b, Maps 9, 10, 11). A bighorn sheep winter forage area is in the Cedar Range, approximately 13 kilometers (8 miles) west of Crestline. Mule deer also use the winter forage area in the Cedar Range, and the corridor crosses mule deer use areas in or near the Chief, Delamar, Worthington, and Quinn Canyon mountains. The corridor crosses pronghorn habitat in Sand Spring and Emigrant Valleys. Areas within 0.4 kilometer (0.25 mile) of springs, seeps, and livestock watering developments in Meadow Valley are classified as crucial areas for quail and portions of the area are classified as habitat for waterfowl.

Three springs and two streams occur within 0.4 kilometer (0.25 mile) of the corridor. These areas might be classified as wetlands or other waters of the United States (TRW 1999k, page 3-27), as defined in the Clean Water Act, although no formal wetlands delineation has been conducted. An unnamed spring is near the corridor at the north end of the North Pahroc Range. The corridor crosses Meadow Valley Wash south of Panaca. The corridor crosses the White River between U.S. 93 and Sand Spring Valley and parallels the river for approximately 25 kilometers (16 miles). An August 1997 survey of that portion of the river found it was mostly dry with some standing water in stock waterholes. This corridor also crosses a number of ephemeral streams or washes that might be classified as waters of the United States.

The Caliente-Chalk Mountain rail corridor passes through two wild horse or wild horse and burro herd management areas (BLM 1979, pages 2-42 and 2-43; BLM 1994b, Maps 18 and 19) in the Cedar Mountains south of Panaca and in the Chief Range west of Panaca.

*Jean.* The Jean rail corridor starts in Ivanpah Valley north of Jean and proceeds west of Wilson Pass to the Pahrump Valley. The corridor continues to the Yucca Mountain site through Pahrump Valley and across the Amargosa Desert and Jackass Flats. This corridor is in the Mojave Desert, with elevations ranging from about 850 to 1,500 meters (2,800 to 4,900 feet).

The predominant land cover types in the corridor are creosote-bursage (59 percent), Mojave mixed scrub (21 percent), and blackbrush (18 percent) (TRW 1999k, page 3-28).

The only resident threatened or endangered species in the Jean rail corridor is the desert tortoise. The entire corridor is in the range of this species (Bury and Germano 1994, pages 57 to 72). Along most of the corridor, especially the western portions from Pahrump to Yucca Mountain, the abundance of desert tortoises is low (Karl 1980, pages 75 to 87; Rautenstrauch and O'Farrell 1998, pages 407 to 411). However, some areas crossed by the corridor in Ivanpah, Goodsprings, Mesquite, and Pahrump Valleys have a higher abundance of tortoises (BLM 1992, Map 3-13). The corridor does not cross areas classified as critical habitat for desert tortoises (50 CFR 17.95).

One location of each of two subspecies of the pinto beardtongue (*Penstemon bicolor bicolor* and *P.b. roseus)*, which is classified as sensitive by the Bureau of Land Management, is in the first 5 kilometers (3 miles) of the corridor near Jean (NNHP 1997, all). No other Bureau of Land Management sensitive species have been documented in the corridor, although chuckwalla, gila monsters (*Heloderma suspectus cinctum*), and a number of bat species classified as sensitive probably occur there in suitable habitat.

The Jean rail corridor crosses several areas the Bureau of Land Management designates as game habitat (BLM 1998, Maps 3-7, 3-8, and 3-9). The corridor crosses four areas designated as quail/chukar or quail habitat: at the intersection of State Highway 161, northeast of Goodsprings, south of Potosi Spring, and east of Pahrump. An additional quail habitat area is on the route from the town of Johnnie to Yucca Mountain. Designated mule deer habitat occurs in three places along the corridor: on the southern half of Potosi Mountain, northwest of Goodsprings, and south of the intersection with State Highway 161. Bighorn sheep winter areas occur south of the intersection of the corridor with State Highway 161. Bighorn sheep habitat is in the Wilson Pass area and to the north on Potosi Mountain. The corridor also crosses a potential bighorn sheep migration corridor from winter range in the Devils Hole Hills to historic but currently unoccupied habitat at the west end of the Spring Mountains.

There are no springs, perennial streams, or riparian areas within 0.4 kilometer (0.25 mile) of this corridor. The corridor crosses a number of ephemeral washes that might be classified as waters of the United States under Section 404 of the Clean Water Act.

There are three wild horse and burro herd management areas in the corridor (BLM 1998, Map 2-1). The Red Rock herd management area is southeast of the Spring Mountains and the Wheeler Pass and Johnnie herd management areas are west of the Spring Mountains.

*Valley Modified.* The Valley Modified rail corridor begins in the northeastern corner of the Las Vegas Valley, crosses the northern edge of the valley south of the Las Vegas Range, and continues northwest toward Indian Springs. The route continues across the southern portion of Three Lakes and Indian Springs Valleys to the Nevada Test Site and passes through Mercury Valley, Rock Valley, and Jackass Flats to the Yucca Mountain site. The corridor ranges in elevation from approximately 700 to 1,100 meters (2,300 to 3,600 feet).

This route is in the Mojave Desert and the predominant land cover types are creosote-bursage (79 percent) and Mojave mixed scrub (16 percent; TRW 1999k, page 3-29).

The only resident threatened or endangered species in the Valley Modified rail corridor is the desert tortoise. The entire corridor is in the range of this species (Bury and Germano 1994, pages 57 to 72). In general, the abundance of tortoises along this corridor through Las Vegas Valley, Indian Springs Valley, and the Nevada Test Site is low (BLM 1992, Map 3-13; Rautenstrauch and O'Farrell 1998, pages 407 to 411). This corridor does not cross areas classified as critical habitat for desert tortoises (50 CFR 17.95). The razorback sucker (*Xyrauchen texanus*), classified as threatened under the Endangered Species Act and as protected under Nevada Administrative Code, has been introduced into ponds at Floyd Lamb State Park, 4.2 kilometers (2.6 miles) south of the corridor (TRW 1999k, page 3-29). Refuge populations of the Pahrump poolfish (*Empetrichthys latos latos*), classified as endangered under the Endangered Species Act and Nevada Administrative Code, has been introduced into ponds in Floyd Lamb State Park and into the outflow of Corn Creek Springs, 4.5 kilometers (2.8 miles) northeast of the corridor (NNHP 1997, all; TRW 1999k, page 3-29).

Two other species classified as sensitive by the Bureau of Land Management occur in the corridor. Three populations of Parish's scorpionweed (*Phacelia parishii*) and a population of Ripley's springparsley have been reported on the Nevada Test Site in Rock Valley. No other Bureau of Land Management sensitive species have been documented in the corridor, although chuckwalla, gila monsters, and a number of bat species probably occur there in suitable habitat.

There are no herd management areas, Areas of Critical Environmental Concern, or designated game habitat in the Valley Modified rail corridor (TRW 1999k, page 3-29; BLM 1998, Maps 3-7, 3-8, and 3-9). No springs or riparian areas occur within 0.4 kilometer (0.25 mile) of this rail corridor. This corridor crosses a number of ephemeral streams or washes that might be classified as waters of the United States under Section 404 of the Clean Water Act.

#### 3.2.2.1.5 *Cultural Resources*

The baseline environmental conditions presented in this section focus on the archaeological and historic resources associated with the candidate rail corridors. This section also discusses Native American interests in relation to two of the corridors. Unless otherwise noted, this information is from the *Environmental Baseline File for Archaeological Resources* (TRW 1999m, all). In addition, information from the *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (AIWS 1998, all) was used.

*Archaeological and Historic Resources.* Archaeological data from the five rail corridors, including a 0.2-kilometer (0.1-mile)-wide buffer zone on either side of each corridor, are very limited. Based on a records search at the Desert Research Institute in Las Vegas and Reno, and at the Harry Reid Center at the University of Nevada, Las Vegas, archaeological surveys have been conducted in less than 1 percent of the total areas for the Caliente, Jean, and Valley Modified corridors, less than 3 percent of the total area for the Carlin corridor, and less than 5 percent of the total area for the Caliente-Chalk Mountain corridor. Although it is possible to identify areas in a corridor that are most likely to contain cultural resources based on such factors as general land forms and proximity to water, these predictions are highly uncertain and, therefore, are not included in this EIS.

Records indicate that a number of archaeological sites have been identified along the corridors and that some of these sites are recorded as potentially eligible for nomination to the *National Register of Historic Places*. Table 3-36 summarizes this information. The table also lists potentially eligible sites by type. For conservatism, this group includes sites not yet evaluated for eligibility. The sites recorded but not included in the potentially eligible group represent sites that had no recommendations about eligibility to the National Register.

DOE is implementing the stipulations and forms of a Programmatic Agreement (DOE 1988b, all) with the Advisory Council on Historic Preservation to address DOE's responsibilities under Sections 106 and 110 of the National Historical Preservation Act and the Council's implementing regulations. Although not a formal signatory to the Agreement, the Nevada State Historic Preservation Officer has the right at any time, upon request, to participate in monitoring DOE compliance with the Programmatic Agreement. In addition, DOE provides annual reports to the Advisory Council on Historic Preservation and the Nevada State Historic Preservation Officer describing the activities conducted by DOE each year to implement the stipulations of the Programmatic Agreement. This report includes a description of DOE coordinations and consultations with Federal and State agencies and Native American tribes concerning historic and culturally significant properties at Yucca Mountain.

**Table 3-36.** Number of archaeological sites along candidate rail corridors.

| Category[a] | Caliente | Carlin | Caliente-Chalk Mountain | Jean | Valley Modified |
|---|---|---|---|---|---|
| *Potentially eligible for nomination* | | | | | |
| Temporary camps | --[b] | -- | 3 | -- | -- |
| Extractive localities | -- | -- | 3 | -- | -- |
| Processing localities | -- | -- | -- | -- | -- |
| Localities | -- | 1 | 16 | -- | -- |
| Caches | -- | -- | -- | -- | -- |
| Stations | -- | -- | -- | -- | -- |
| Historic sites | -- | -- | 3 | -- | -- |
| Unknown type | 7 | 20 | 3 | -- | 7 |
| ***Total potentially eligible*** | ***7*** | ***21*** | ***28*** | ***0*** | ***7*** |
| *Not evaluated* | 29 | 26 | 6 | 2 | 4 |
| ***Recorded sites (approximate total)*** | ***97*** | ***110*** | ***100*** | ***6*** | ***19*** |

a. Section 3.1.6 contains the definitions of site types for potentially eligible for nomination sites (temporary camps, extractive localities, etc.).
b. -- = none identified.

DOE will continue to seek input from the Nevada State Historic Preservation Officer and the Advisory Council on Historic Preservation, and will interact appropriately to meet the reporting and other stipulations of the Programmatic Agreement.

There is some additional information available for the Carlin corridor. The northern part of this corridor is not well known archaeologically. The central part has been the subject of important archaeological and ethnographic investigations. Elston (1986, all) summarizes the region's prehistory. Archaeological research in Monitor Valley at the Gatecliff Shelter established important chronological data for this part of the Great Basin. In addition, there have been studies of settlement patterns in the Upper Reese River Valley west of the Carlin rail corridor.

Thomas, Pendleton, and Cappannari (1986, all) summarizes ethnographic studies in this region. The Big Smokey Valley, which the Carlin corridor crosses, was part of several ethnographic studies of the Western Shoshone. A part of the Pony Express route crosses the northern end of the Carlin rail corridor.

*Native American Interests.* Through the American Indian Writers Subgroup of the Consolidated Group of Tribes and Organizations, Native Americans have noted that, while transportation issues are of extreme interest to them, at present they cannot provide specific comments on any of the Nevada transportation project alternatives (AIWS 1998, pages 4-4 to 4-6) due to the absence of systematic ethnographic studies for any of the proposed project areas.

General concerns for potential transportation-related impacts raised by Native Americans include the following:

- Radioactive and hazardous waste transportation could have an adverse impact along rail or highway routes near existing or planned Native American communities, people, businesses, and resources.

- All of the proposed routes being considered pass through the traditional holy lands of the Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone peoples.

- Many of these routes correspond or are adjacent to ancient pathways and complex trail systems known to and used by Native American peoples.

- The Consolidated Group of Tribes and Organizations is aware of important culturally sensitive areas, traditional use areas, sacred sites, and other important resources that fall in the proposed transportation project areas, and will present this information when appropriate in the development of the Nevada transportation system.

These general concerns apply to the proposed rail corridors discussed in this section, and the proposed heavy-haul route alternatives and intermodal transfer station locations discussed in Section 3.2.2.2.5.

Native Americans live in the vicinity of two of the candidate rail corridors:

- *Jean.* The Pahrump Paiute Tribe is a non-Federally recognized tribe without a land base. The tribe consists of about 100 Southern Paiute people living in the Pahrump area (see Section 3.1.6.2). Individual members of the tribe live as close as 5 kilometers (3 miles) from the Jean corridor.

- *Valley Modified.* The Las Vegas Paiute Colony is a Federally recognized tribe consisting of about 100 people living on two separate tribal parcels in southern Nevada. One parcel near downtown Las Vegas consists of about 73,000 square meters (18 acres) of land with 21 homes and various businesses. This parcel is about 11 kilometers (7 miles) from the route of the Valley Modified rail corridor. The other parcel is in the northwest part of the Las Vegas Valley along U.S. 95. It consists of 16 million square meters (4,000 acres) with 12 homes and various business enterprises. This parcel is about 1.6 kilometers (1 mile) from the Valley Modified rail corridor.

### 3.2.2.1.6 *Socioeconomics*

Section 3.1.7 describes the socioeconomic backgrounds of the three counties (Clark, Lincoln, and Nye) most involved in the corridors. The Carlin corridor includes other counties— Esmeralda, Eureka, and Lander—in addition to Nye County. This section contains baseline socioeconomic information for Eureka, Esmeralda, and Lander Counties.

Socioeconomic effects from the construction of a rail line would be small and, for the most part, short-term. Therefore, the socioeconomic information for Esmeralda, Eureka, and Lander Counties is less detailed than the information for the counties in the repository site region of influence in Section 3.1.7.

*Employment.* Section 3.1.7.2 contains employment and economic information on Clark, Nye, and Lincoln Counties. Portions of the potential Carlin rail route pass through Esmeralda, Eureka, and Lander Counties. In 1994, Esmeralda, Eureka, and Lander Counties had average labor forces of about 670, 840, and 3,000, respectively, and average unemployment rates of 7.7, 9.5, and 10 percent (Bureau of the Census 1998, all). During the same year, the per capita income of Esmeralda, Eureka, and Lander Counties was about $33,000, $27,000, and $20,000, respectively (NDETR 1999, all). All three of these counties are small in economic terms and have chronically high unemployment.

*Population.* Section 3.1.7.1 contains population data on Clark, Lincoln, and Nye Counties. This section provides population background for the other counties potentially affected by the Carlin rail corridor (Esmeralda, Eureka, and Lander).

The population of Esmeralda County is 100 percent rural. The 1990 Census population for the county was about 1,300 persons. The two block groups that comprise the county had densities of 0.3 and 0.4 person per square mile. The Esmeralda County population projection for 2000 is about 1,400 (NSDO 1998, Esmeralda).

The population of Eureka County is 100 percent rural. The 1990 Census population of the county was about 1,500. Density at the block group level ranged from 0 to 5.3 persons per square mile. The projected population of Eureka County for 2000 is about 2,100 (NSDO 1998, Eureka).

The population of Lander County is 56 percent urban and 44 percent rural, with the urban population concentrated entirely in Battle Mountain. The 1990 Census population of the county was about 6,300 persons. The projected population of Lander County for 2000 is about 7,700 (NSDO 1998, Lander).

*Housing.* Section 3.1.7.4 contains housing data on Clark, Lincoln, and Nye Counties. Esmeralda, Eureka, and Lander Counties are rural areas. The housing stock of Esmeralda County in 1990 was about 1,000 units, of which about 590 were occupied (Bureau of the Census 1998, Esmeralda). The housing stock of Eureka County in 1990 was about 820 units, of which about 620 were occupied (Bureau of the Census 1998, Eureka). The housing stock of Lander County in 1990 was about 2,600 housing units, of which about 2,200 were occupied (Bureau of the Census 1998, Lander).

*Economy.* Section 3.1.7.2 contains employment and economic information on Clark, Lincoln, and Nye Counties. For the Esmeralda, Eureka, and Lander portions of the Carlin corridor. Esmeralda, Eureka, Lander, and Nye are very small counties in economic terms. Esmeralda County is particularly small, smaller even than Lincoln County in earnings and employment. Like Lincoln County, Esmeralda and Lander have lower per capita incomes than other Nevada counties and chronically high unemployment.

*Public Services.* Section 3.1.7.5 contains information on public services in Clark, Lincoln, and Nye Counties. Esmeralda, Eureka, and Lander Counties are rural areas. Public services (for example, hospitals, libraries, community centers) are available in small communities in the counties (for example, Battle Mountain, Ely, Eureka). Community water and sewer services are available in small communities; wells and septic tanks serve outlying areas.

### 3.2.2.1.7 *Noise*

Most of the proposed rail corridors pass through unpopulated desert with average day-night background sound levels of 22 to 38 A-weighted decibels (dBA). (A-weighted decibels are explained in Section 3.1.9.1.) However, each candidate corridor passes near small rural communities (see Figures 6-10 through 6-15). Noise levels in rural communities usually range from 40 to 55 dBA. DOE used computerized mapping programs to examine proposed transportation corridors for the presence and proximity to routes that could be designated for the transfer of nuclear material to the Yucca Mountain site. The process involved the examination of computerized maps at very high detail to determine the extent of road grids in communities and major road intersections. The analysis estimated the distance from the proposed rail corridor and the community to determine if the community was in the region of influence for rail transportation.

*Caliente.* Most of the Caliente corridor passes through undeveloped Bureau of Land Management land where background noise levels range from 22 to 38 dBA (Table 3-30), influenced primarily by wind. Noise levels of 40 to 55 dBA are present in the rural communities along the corridor including Goldfield, Panaca, and Caliente (Table 3-30).

*Carlin.* The Carlin rail corridor, from its origin at Beowawe to its terminus at Yucca Mountain, including the Monitor Valley option and other options south of Tonopah, traverses mostly unpopulated desert. The only town within 1.6 kilometers (1 mile) of the corridor is Hadley at the southern end of Big Smokey Valley (Monitor Valley option). Noise levels of 40 to 55 dBA are present in rural communities near the corridor, including Goldfield, Tonopah, Austin, and smaller communities between Tonopah and Battle

Mountain (Table 3-30). Occasional noise from military aircraft overflights occurs near the Nellis Air Force Range.

*Caliente-Chalk Mountain.* Almost half of the 345-kilometer (214-mile) Caliente-Chalk Mountain corridor is on Nellis Air Force Range or Nevada Test Site land; the remainder is on Bureau of Land Management land. Noise levels of 40 to 55 dBA are present in rural communities along the corridor including Panaca and Caliente (Table 3-30). Occasional noise from military aircraft overflights occurs near and in the Nellis Air Force Range.

*Jean.* The Jean rail corridor, with the Stateline option, passes through Bureau of Land Management land and a small section of private land. A large portion of this proposed corridor passes through unpopulated desert. Noise levels of 40 to 55 dBA are present in small communities along the corridor including Amargosa Valley, Goodsprings, Pahrump, and Jean (Table 3-30). Occasional noise from military aircraft overflights occurs near and in the Nellis Air Force Range.

*Valley Modified.* The Valley Modified rail corridor, and its various options, begins in the northeast end of the Las Vegas Valley, travels west across Nellis Air Force Base and the southern end of the Desert National Wildlife Range, and then closely parallels U.S. 95 to the vicinity of Mercury. Noise levels along stretches of unpopulated desert should range from 22 to 38 dBA, which are typical for a desert environment during calm and windy days (Brown-Buntin 1997, page 7). The corridor would pass 3 kilometers (2 miles) north of Floyd R. Lamb State Park and less than 5 kilometers (3 miles) south of Corn Creek Station, which is part of the Desert National Wildlife Range managed by the Fish and Wildlife Service. Noise levels at the state park and at Corn Creek would probably be only slightly higher than those in an unpopulated desert environment. Noise levels in the northern Las Vegas Valley can be as high as 60 dBA (Table 3-30). Noise levels in Indian Springs and Mercury probably range from 45 to 55 dBA (Table 3-30). Occasional noise from military aircraft overflights occurs near and in the Nellis Air Force Range.

#### 3.2.2.1.8 *Aesthetics*

To assist in the management of public lands under its control, the Bureau of Land Management established land management guidelines based on the visual resources of an area. Visual resources include the natural and manmade physical features that give a particular landscape its character and value as an environmental factor. There are four visual resource classes. Classes I and II are the more highly valued. Class III is moderately valued, and Class IV is of least value. The majority of land in the potential rail corridors is under the jurisdiction of the Bureau of Land Management. The following paragraphs contain aesthetic baseline information for each of the rail corridors. Section 3.1.10 contains more information on the Bureau of Land Management visual resource classes and scenic quality classes. Unless otherwise noted, this information is from the *Environmental Baseline File: Aesthetics* (TRW 1999p, all).

*Caliente.* Section 3.2.2.1.4 describes the environmental setting along the Caliente corridor. The corridor passes through the Caliente, Schell, Tonopah, and Las Vegas Bureau of Land Management resource areas. The corridor crosses mostly Class IV lands, crosses Class III land near Caliente, and crosses or skirts the edges of Class II lands near Caliente and in the Seaman, Reveille and Kawich ranges, the Golden Gate Hills, and the Worthington Mountains. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-25).

*Carlin.* Section 3.2.2.1.4 describes the environmental setting of the Carlin corridor. The corridor passes through four Bureau of Land Management resource areas (Elko, Shoshone-Eureka, Tonopah, and Las

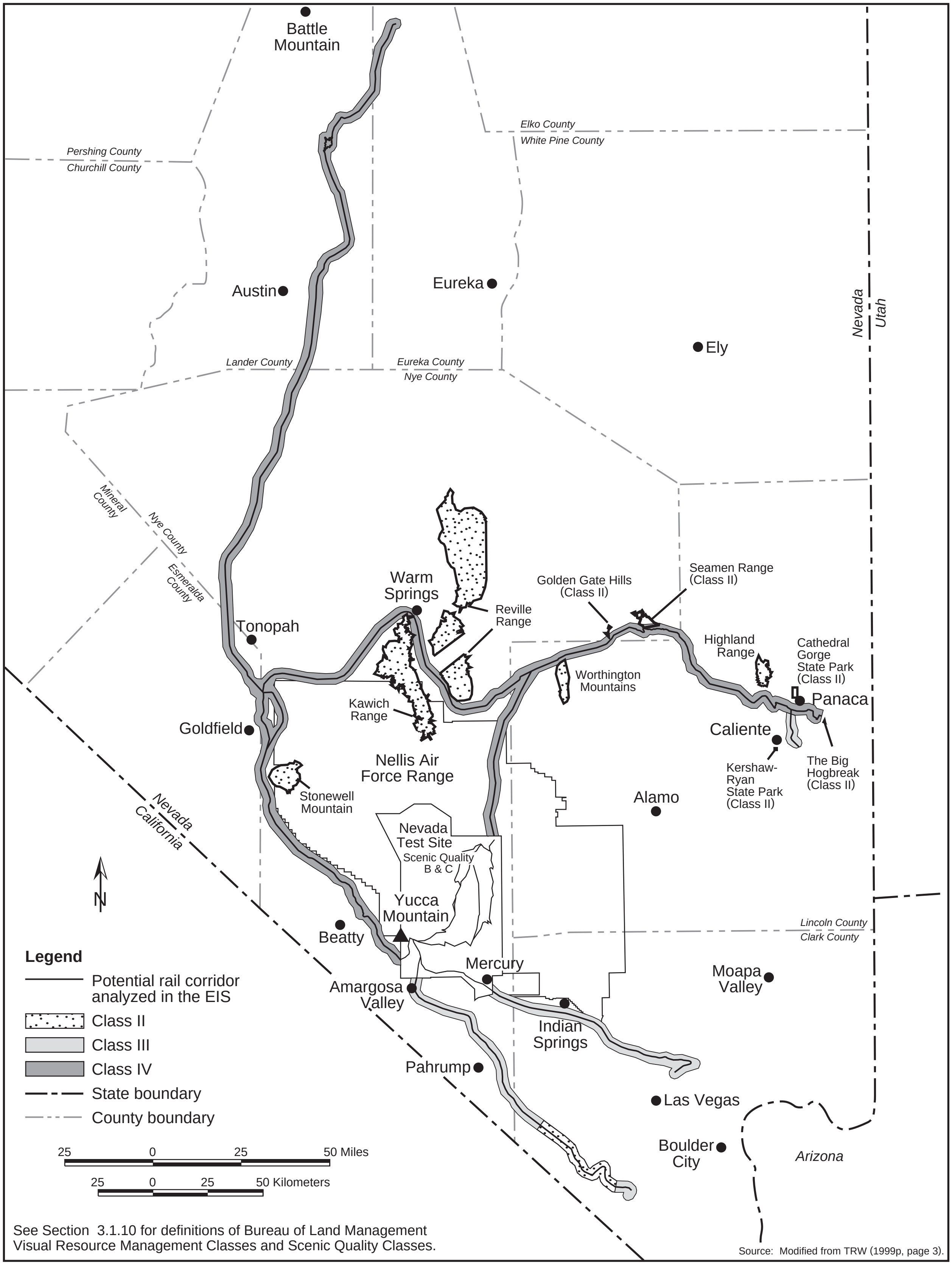



**Figure 3-25.** Visual Resource Management classes along the potential rail corridors.

Vegas). The route is on Class IV land from its beginning to the Nevada Test Site border. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-25).

*Caliente-Chalk Mountain.* Section 3.2.2.1.4 describes the environmental setting of the Caliente-Chalk mountain corridor. The corridor passes through the Caliente and Schell Bureau of Land Management resource areas. The route begins on Class III land east of Caliente, and crosses mostly Class IV land to the border of the Nevada Test Site (Figure 3-25). On the Nevada Test Site the corridor passes through lands with scenic quality Class B or C.

*Jean.* Section 3.2.2.1.4 describes the environmental setting of the Jean corridor. The corridor crosses the Las Vegas and the Northern and Eastern Mojave Bureau of Land Management resource areas. The Wilson Pass alternate passes through Class II land in Goodsprings Valley, but the rest of the route and west of the Stateline Pass secondary corridor cross Class III land. Approximately 10 kilometers (6 miles) of the route crosses lands in California; that area does not have Visual Resource Management class ratings. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-25).

*Valley Modified.* Section 3.2.2.1.4 describes the environmental setting of the Valley Modified corridor. The corridor crosses the Las Vegas Bureau of Land Management resource area. The entire route to the boundary of the Nevada Test Site crosses Class III land. Lands on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-25).

#### 3.2.2.1.9 *Utilities, Energy, and Materials*

All five primary rail corridors pass through typically remote Nevada countryside but are within the southern Nevada supply chain for the commodities required during construction and operation. Electric power, which would be available to a limited extent at nearby communities or other locations near power lines, probably would not be needed.

#### 3.2.2.1.10 *Environmental Justice*

The five candidate rail corridors would not appreciably affect counties other than those through which they pass. Section 3.1.13 contains information on the minority and low-income communities in the three counties most involved in the corridors (Clark, Lincoln, and Nye). The Carlin corridor is the only route that passes through other counties (Esmeralda, Eureka, and Lander, in addition to Nye). This section contains baseline information on minority and low-income communities in Esmeralda, Eureka, and Lander Counties. Unless otherwise noted, the *Environmental Baseline File for Environmental Justice* (TRW 1999q, all) is the basis for the information in this section.

In 1990, the minority population (White Hispanic, Black, Asian/Pacific Islander, American Indian/ Eskimo/Aleut, and Other) of Esmeralda County was about 210, or 15 percent of the population. No block group in the county exceeded the threshold for identification as a minority community (Bureau of the Census 1992e, Tables P8 and P12). In 1990, there were about 210 persons living in poverty, or 15 percent of the population. No block group in Esmeralda County exceeded the threshold for identification as a low-income community (Bureau of the Census 1992e, Table P117). (Section 3.1.13 defines minority and low-income communities.)

In 1990, the minority population of Eureka County was about 170 persons, or 11 percent. No block group in the county exceeded the threshold for identification as a minority community (Bureau of the Census 1992f, Tables P8 and P12). In 1990, there were about 160 persons living in poverty, or 10 percent of the population. No block group in Eureka County exceeded the threshold for identification as a low-income community (Bureau of the Census 1992f, Table P117).

In 1990, the minority population of Lander County was about 1,100 persons, or 17 percent. No block group in the county exceeded the threshold for identification as a minority community (Bureau of the Census 1992g, Tables P8 and P12). In 1990, there were about 670 persons living in poverty, or 11 percent of the population. No block group in Lander County exceeded the threshold for identification as a low-income community (Bureau of the Census 1992g, Table P117).

Tables 3-37 and 3-38 list by county the number of census block groups with high minority and low-income populations, respectively, that the rail corridors pass through or near. Table 3-39 lists the number of census block groups with high minority populations, high low-income populations, or both that each rail corridor could affect. More than 300 block groups in the City of Las Vegas have either low-income or minority populations. However, the rail corridors do not intersect any of these block groups.

Ninety block groups in the City of Las Vegas have low-income or minority populations or both. However, the rail corridors do not intersect any of these block groups.

**Table 3-37.** High minority population census block groups near or crossed by rail corridors.

| County | Crosses | Near |
|---|---|---|
| Eureka | 0 | 0 |
| Lander | 0 | 0 |
| Nye | 0 | 1[a] |
| Esmeralda | 0 | 0 |
| Clark[b] | 2 | 2 |
| Lincoln | 0 | 0 |

a. This block group is also a high low-income population block group included in Table 3-39.
b. Outside Las Vegas.

**Table 3-38.** High low-income population census block groups near or crossed by rail corridors.

| County | Crosses | Near |
|---|---|---|
| Eureka | 0 | 0 |
| Lander | 0 | 0 |
| Nye | 2 | 3[a] |
| Esmeralda | 0 | 0 |
| Clark[b] | 0 | 0 |
| Lincoln | 0 | 0 |

a. One block group is also a high minority population block group included in Table 3-39.
b. Outside Las Vegas.

**Table 3-39.** High minority and high low-income population census block groups near or crossed by rail corridors.

| Corridor | Minority | Low-income | Minority and low-income |
|---|---|---|---|
| Caliente | 0 | 2 near, 3 crossed[a] | 0 |
| Carlin | 0 | 2 crossed[a] | 1 near[a] |
| Caliente-Chalk Mountain | 0 | 0 | 0 |
| Jean | 0 | 1 near[a] | 0 |
| Valley Modified | 2 crossed[b] | 0 | 0 |

a. In Nye County.
b. In Clark County outside Las Vegas.

### 3.2.2.2 Heavy-Haul Truck Route and Intermodal Transfer Station Environmental Baseline

This section discusses the environmental characteristics of counties and land areas that could be affected by the construction and operation of an intermodal transfer station and the operation of heavy-haul trucks carrying spent nuclear fuel and high-level radioactive waste to the Yucca Mountain Repository on Nevada highways. The discussion describes existing environmental conditions in the candidate areas where an intermodal transfer station could be located along Nevada highway routes that could be used for the heavy-haul truck transportation of casks containing spent nuclear fuel and high-level radioactive waste. The candidate locations for an intermodal transfer station are near the communities of Caliente, Sloan, and Jean, and northeast of Las Vegas near Dry Lake on the Union Pacific Railroad Valley siding. These locations can be grouped into three general sites near existing rail lines and highways: near Caliente

(Caliente), southeast of Las Vegas (Sloan/Jean), and northeast of Las Vegas (Apex/Dry Lake). DOE is considering more than one site for the station in each general area.

The heavy-haul trucks would use existing highways that would be upgraded as necessary to accommodate such vehicles. There are five potential heavy-haul routes. Three of these routes (Caliente, Caliente-Chalk Mountain, and Caliente-Las Vegas) are associated with the Caliente intermodal transfer station site. The Sloan/Jean and Apex/Dry Lake intermodal transfer station sites are associated with one candidate route each.

To define the existing (or baseline) environment associated with the three candidate intermodal transfer station locations and along the five candidate heavy-haul truck routes, DOE has compiled environmental information for each of the following subject areas.

- *Land use and ownership:* The condition of the land, current land-use practices, and land ownership information (Section 3.2.2.2.1)
- *Air quality and climate:* The quality of the air and climate (Section 3.2.2.2.2)
- *Hydrology:* The characteristics of surface water and groundwater (Section 3.2.2.2.3)
- *Biological resources:* Important biological resources (Section 3.2.2.2.4)
- *Cultural resources:* Important cultural resources (Section 3.2.2.2.5)
- *Socioeconomic environments:* The existing socioeconomic environments (Section 3.2.2.2.6)
- *Noise:* The existing noise environments (Section 3.2.2.2.7)
- *Aesthetics:* The existing visual environments (Section 3.2.2.2.8)
- *Utilities, energy, and materials:* Existing supplies of utilities, energy, and materials (Section 3.2.2.2.9)
- *Environmental justice:* The locations of low-income and minority populations (Section 3.2.2.2.10)
- *Existing traffic on potential routes for heavy-haul trucks:* Existing traffic in terms of level of service (on the five alternative heavy-haul routes for trucks) (Section 3.2.2.2.11)

The HIGHWAY computer program (Johnson et al. 1993a, all) provided population distributions for the different population zones (urban, rural, and suburban) along the alternative highway routes for heavy-haul trucks. This approach, which Chapter 6 and Appendix J describe in detail, is consistent with the national transportation analysis. DOE expects the waste quantities generated by intermodal transfer station construction to be small in comparison to those from repository construction and operation. Therefore, this discussion does not include existing waste disposal infrastructure along the routes.

DOE evaluated potential impacts of the implementing alternatives in the region of influence for each of the following subject areas. Table 3-40 defines these regions, which are specific to the subject areas in which DOE could reasonably expect to predict potentially large impacts related to heavy-haul infrastructure construction and operations.

**Table 3-40.** Regions of influence for heavy-haul implementing alternatives.

| Subject area | Region of influence |
|---|---|
| Land use and ownership | Land areas that would be disturbed or for which ownership or use would change as a result of construction and use of an intermodal transfer station and associated highway route |
| Air quality and climate | The Las Vegas Valley for implementing alternatives in which the construction and operation of an intermodal transfer station and associated heavy-haul route could contribute to the level of carbon monoxide and $PM_{10}$ already in nonattainment of standards, and the atmosphere in the vicinity of sources of criteria pollutants that would be emitted during construction and operations |
| Hydrology | *Surface water:* areas where construction would take place that would be susceptible to erosion, areas affected by permanent changes in flow, and areas downstream of construction that would be affected by eroded soil or potential spills of construction contaminants |
| | *Groundwater:* aquifers that would underlie areas of construction and operations and that could be used to obtain water for construction |
| Biological resources | Habitat, including jurisdictional wetlands, that could be disturbed by construction and operation of an intermodal transfer station and associated heavy-haul route; habitat, including jurisdictional wetlands, and riparian areas that could be affected by permanent changes in surface-water flow |
| Cultural resources | Land areas that would be disturbed by the construction and operation of an intermodal transfer station and associated heavy-haul route |
| Socioeconomic environments | Clark, Lincoln, Nye, and other counties that a route for heavy-haul vehicles could traverse |
| Occupational and public health and safety | 800 meters[a] on each side of the route for heavy-haul vehicles for incident-free transportation, 80-kilometer[b] radius for potential impacts from accidents |
| Noise | Inhabited commercial and residential areas where noise from the construction and operation of an intermodal transfer station and associated routes for heavy-haul vehicles could be a concern |
| Aesthetics | The landscapes along potential routes for heavy-haul vehicles and at potential locations for intermodal transfer station where aesthetic quality could be affected by construction and operation |
| Utilities energy, and materials | Local, regional, and national supply infrastructure that would be required to support construction and operation of an intermodal transfer station and associated route for heavy-haul vehicles |
| Environmental justice | Varies with the individual resource area |

a. 800 meters = 0.5 mile.
b. 80 kilometers = 50 miles.

*Caliente.* DOE has identified two locations for an intermodal transfer station southwest of the City of Caliente. Table 3-41 lists the ownership of the land involved. Both sites would use a local road to provide access to U.S. 93, the starting point for all three of the heavy-haul routes associated with this intermodal transfer station. Both parcels being considered are in the Rainbow Canyon section of Meadow Valley Wash. This canyon is used for a variety of recreational purposes and is the route of the Union Pacific railroad. Kershaw-Ryan State Park is across Meadow Valley Wash about 0.4 kilometer (0.25 mile) east of the station sites (DOE 1998j, all). The northern parcel includes a wastewater treatment plant.

#### 3.2.2.2.1 *Land Use and Ownership*

This section describes existing land use and ownership for the candidate intermodal transfer station locations and for the candidate heavy-haul routes. Table 3-41 summarizes the estimated land commitment for each site at the three candidate locations. The following paragraphs describe the candidate intermodal transfer station sites.

**Table 3-41.** Estimated land commitment areas for candidate intermodal transfer station sites (square kilometers).[a,b]

| | Commitment | | |
|---|---|---|---|
| | | Percentage current ownership or control[c] | |
| Potential location | Total area | BLM | City of Caliente[d] |
| *Caliente* | | | |
| North Site | 0.5 | | 100 |
| South Site | 0.25 | | 100 |
| *Sloan/Jean* | | | |
| North Site | 3.3 | 100 | |
| Middle Site | 3.1 | 100 | |
| South Site | 1 | 100 | |
| *Apex/Dry Lake* | | | |
| North Site | 3.5 | 100 | |
| South Site | 1 | 100 | |

a. Source: TRW (1999d, all).
b. To convert square kilometers to acres, multiply by 247.1.
c. Bureau of Land Management property is public land administered by the Bureau.
d. "City of Caliente" designates patented land owned by the city. A small undesignated portion of both Caliente sites is Bureau of Land Management land.

*Sloan/Jean.* DOE has identified three possible parcels in the area of Sloan and Jean for potential use as the location of an intermodal transfer station. Each provides adequate land area adjacent to the Union Pacific mainline and has access to existing roadways. Figure 2-29 in Chapter 2 shows these sites. The Bureau of Land Management controls all lands associated with these parcels through its Las Vegas Field Office. Detailed information on land use is available in the *Proposed Las Vegas Resource Management Plan and Environmental Impact Statement* (BLM 1998, all).

*Apex/Dry Lake.* DOE has identified two land parcels near the intersection of U.S. 93 and Interstate 15 at the Apex and Dry Lake areas northeast of Las Vegas for the possible location of an intermodal transfer station. Both provide adequate land area close to the Union Pacific mainline and have access to existing roadways. The Bureau of Land Management controls all lands associated with these parcels through its Las Vegas Field Office. Detailed information on land use is available in BLM (1998, all). The Moapa Indian Reservation is about 5 kilometers (3 miles) north of the proposed station site. The Dry Lake solar enterprise zone is almost 5 kilometers west of the site (DOE 1996f, page 4-227). The Apex industrial complex is about 16 kilometers (10 miles) to the southwest. Tenants at the complex include Kerr-McGee Chemical Corporation, Chemstar Inc., and Georgia Pacific Corporation. Silver State Disposal operates a waste landfill and waste-processing facilities east of I-15 about 5 kilometers south of the southernmost site.

*Routes for Heavy-Haul Trucks.* The five possible routes that heavy-haul trucks could use in Nevada—Caliente, Caliente-Las Vegas, Caliente-Chalk Mountain, Sloan/Jean, and Apex/Dry Lake—have existing highways in established rights-of-way. The routes use combinations of highways that, after improvement, heavy-haul trucks could use to travel from an intermodal transfer station at a mainline railroad to the repository.

#### 3.2.2.2.2 *Air Quality and Climate*

This section summarizes existing air quality and climate conditions for each of the candidate intermodal transfer station sites and the five candidate heavy-haul routes.

*Air Quality.* Both the Caliente and Apex/Dry Lake sites are in areas that are either unclassified or in attainment for criteria pollutants (Fosmire 1999, all). The northern portion of the Sloan/Jean site is in the Las Vegas nonattainment area (Fosmire 1999 all; EPA 1999c, all). There are no State of Nevada air quality monitoring stations at or near either the Caliente or Apex/Dry Lake site (NDCNR 1999, pages A1-1 through A1-9). Clark County operates a particulate matter ($PM_{10}$) monitoring station at Jean.

The Caliente and Caliente-Chalk Mountain heavy-haul routes both pass through rural parts of Nevada. These areas are either unclassifiable or in attainment for criteria pollutants. The air quality in these areas is good. There are no State of Nevada air quality monitoring stations along these routes (NDCNR 1999, pages A1-1 through A1-9). These statements are also true for the Caliente-Las Vegas, Sloan/Jean, and Apex/Dry Lake routes before they enter and after they leave the Las Vegas Valley.

The air quality in the segments of the Caliente-Las Vegas, Sloan/Jean, and Apex/Dry Lake routes that pass through the Las Vegas Valley and extend part of the way to Indian Springs is in serious nonattainment for particulate matter ($PM_{10}$) (EPA 1999c, Region 9 $PM_{10}$ Nonattainment Areas). Clark County adopted a plan for demonstrating $PM_{10}$ attainment (Clark County 1997b, all) that includes a request to the Environmental Protection Agency to extend the year for attainment demonstration from 2001 to 2006. The plan includes proposals to reduce emissions of particulate matter from a variety of sources. In addition, the Las Vegas Valley is in serious nonattainment for carbon monoxide. Efforts are being made to bring the area into attainment status.

*Climate.* This section describes the climate affecting the candidate intermodal transfer station sites and heavy-haul routes.

The community of Caliente and the site of the proposed intermodal transfer station are in Meadow Valley Wash, a relatively narrow canyon that trends to the northeast. Small canyons enter Meadow Valley Wash from the east and west. The diurnal cycle of up-canyon winds during the daytime and down-canyon winds at night minimizes periods of calm conditions. The community of Caliente is about 1,300 meters (4,300 feet) above sea level. Average annual precipitation is about 22 centimeters (9.0 inches); average snowfall is about 35 centimeters (14 inches) (TRW 1997a, page A-14). The maximum single-day precipitation record is 5.4 centimeters (2.1 inches). Occasional brief periods of intense rainfall at rates exceeding 5 centimeters (2 inches) an hour can occur in the summertime. The mean maximum July temperature is 35ºC (95ºF), and the mean minimum January temperature is –8.2ºC (18ºF) (TRW 1997a, page A-14).

The climate at the Sloan/Jean and Apex/Dry Lake station sites is similar to Las Vegas (TRW 1997a, Section 4.1; Houghton, Sakamoto, and Gifford 1975, pages 45, 49, and 52). Precipitation in Las Vegas averages between 10 and 20 centimeters (4 and 8 inches) a year and snowfall is rare. Occasional brief periods of intense rainfall, at rates exceeding 5 centimeters (2 inches) an hour, can occur in the summertime. The maximum recorded daily precipitation is 6.6 centimeters (2.6 inches). The mean maximum July temperature is 40ºC (104ºF), and the mean minimum January temperature is 0.9ºC (33ºF).

The Caliente and Caliente-Chalk Mountain heavy-haul routes, and to a lesser extent the Caliente-Las Vegas route, cross mountain ranges and valleys with elevations well above 1,500 meters (4,900 feet). Although much of Nevada is arid, in central Nevada the annual precipitation exceeds 20 centimeters (8 inches), and the annual snowfall exceeds 25 centimeters (10 inches) in central White Pine and Nye Counties; annual precipitation exceeds 40 centimeters (16 inches) in some mountainous areas, and snowfall exceeds 100 centimeters (40 inches) (Houghton, Sakamoto, and Gifford 1975, pages 45, 49, and 52). The southern portion of the Caliente-Las Vegas route, through Clark County, is at low elevations where precipitation averages between 10 and 20 centimeters (4 and 8 inches) a year and snowfall is rare (Houghton, Sakamoto, and Gifford 1975, pages 45, 49, and 52). Along all three of these routes, occasional brief periods of intense rainfall at rates exceeding 5 centimeters (2 inches) an hour can occur in the summertime.

The Sloan/Jean and Apex/Dry Lake heavy-haul routes are at low elevations where precipitation averages between 10 and 20 centimeters (4 and 8 inches) a year and snowfall is rare (Houghton, Sakamoto, and Gifford 1975, pages 45, 49, and 52). However, occasional brief periods of intense rainfall, at rates exceeding 5 centimeters (2 inches) an hour, can occur in the summertime.

#### 3.2.2.2.3 *Hydrology*

This section describes hydrologic conditions in terms of surface water and groundwater near the candidate intermodal transfer stations and along the candidate heavy-haul shipment routes.

**3.2.2.2.3.1 Surface Water.** DOE studied each of the candidate intermodal transfer station sites and associated highway routes for their proximity to sensitive environmental resources (TRW 1999k, Appendixes J, K, L, M, N, and O), including surface waters and riparian lands. Table 3-42 summarizes potential surface-water-related resources within a 1-kilometer (0.6-mile) region of influence from the station sites and highway routes that heavy-haul trucks would use. The table lists surface-water-related resources associated with the Caliente intermodal transfer station site and with each of the potential routes starting at that site. No surface-water-related resources were identified in the region of influence for either the Sloan/Jean or Apex/Dry Lake station site, and none were identified along the associated routes.

***Intermodal Transfer Station Locations***

*Caliente.* Flood Insurance Rate Maps published by the Federal Emergency Management Agency address the area in Meadow Valley Wash south of Caliente where the two proposed sites for the Caliente intermodal transfer stations are located. The maps (FEMA 1988a, all; FEMA 1988b, all) show two areas on the west side of the Union Pacific rail tracks that match up with the proposed sites. Both areas are outside the inundation boundary of the 100-year flood, but within the boundary of the 500-year flood.

*Sloan/Jean.* Based on Flood Insurance Rate Maps, the southernmost site proposed for the Jean intermodal transfer station (on the west site of the Union Pacific rail tracks) would be in the same general area as a 100-year flood inundation zone. The flood map (FEMA 1995a, all) shows three separate washes or drainage areas that originate in the area northwest of the intersection of State Route 161 (or State Route 53 on the map) and I-15. From their origins, the washes drain to the southeast, beneath I-15, and join a southwest drainage that parallels the rail tracks until it reaches the Roach Lake area to the south. The southern Jean intermodal transfer station site is in the area where the first southeast-draining channel curves around into a southwest-draining channel. The 100-year flood inundation areas appear to be about 150 meters (500 feet) wide for these drainage channels.

The northern site proposed for the Jean intermodal transfer station is on the east side of the tracks in an area where the map shows no inundation lines (FEMA 1995a, all). In fact, the map identifies this area with a Zone X designation, indicating it is outside the 500-year floodplain.

According to the Federal Emergency Management Agency Map Index for Clark County, Nevada, and Incorporated Areas (FEMA 1995b, all), the northernmost site for this area, the Sloan intermodal transfer station site, is in an area (Panel 32003C2925 D) with no printed map. The Map Index further describes these unprinted areas as Zone X, indicating they are outside the 500-year floodplain.

*Apex/Dry Lake.* Based on the Flood Insurance Rate Map for the area of the Apex/Dry Lake intermodal transfer station sites (FEMA 1995c, all), both proposed locations are outside any 100-year flood zone. The nearest flood zone identified on the map is for the Dry Lake area west of the sites. At its closest, the inundation area approaches to within about 300 meters (1,000 feet) of I-15, but the intermodal transfer station site would be on the other side (east side) of I-15. The northern site would appear to be at least

**Table 3-42.** Surface-water-related resources at potential intermodal transfer station sites and along candidate routes for heavy-haul trucks.[a]

| Station or route | Distance from station or route (kilometers)[b] | Feature |
|---|---|---|
| *Caliente station* | 0.5 | Spring – unnamed spring, southwest of Caliente and northwest of station site |
| | 0.2 | Riparian/stream – perennial stream and riparian habitat along Meadow Valley Wash |
| *Caliente route* | | |
| Caliente to Crystal Springs | 0.3 | Spring – unnamed, west of Caliente |
| | 0.5 | Spring – unnamed, in Newman Canyon |
| | 0.8 | Spring – unnamed, in Newman Canyon |
| Crystal Springs to Rachel | 0.01 - 0.07 | Spring – Crystal Springs, group of thermal springs near Town of Crystal Springs, flows along road |
| Rachel to Yucca Mountain (via Tonopah) | 0.2 | Springs – Twin Springs, 15 kilometers east of Warm Springs |
| | Within - 0.2 | Springs – Warm Springs, group of thermal springs near town of Warm Springs, outflow crosses the route |
| | 0.4 | Spring – Fivemile Spring in Stone Cabin Valley |
| | 1.0 | Spring – Rabbit Spring, west of Goldfield |
| | 0.1 | Spring – unnamed, in upper Oasis Valley, northwest of Beatty |
| | 0.3 | Spring – unnamed, in upper Oasis Valley |
| | 0.4 | Spring – unnamed, in upper Oasis Valley, northwest of Beatty |
| | 0.4 | Spring – unnamed, east of U.S. 95 in upper Oasis Valley |
| | 0.4 | Spring – Fleur-de-lis Spring at Springdale |
| | 0.1 | Spring – unnamed, east of U.S. 95 in upper Oasis Valley |
| | 0.1 | Spring – unnamed, east of U.S. 95 north of Beatty |
| | 0.9 | Spring – unnamed, east of U.S. 95, north of Beatty |
| | 0.9 | Spring – Gross Spring, east of U.S. 95, north of Beatty |
| | Within | River – Amargosa River, parallels U.S. 95 for about 23 kilometers near Beatty |
| | 0.2 - 0.3 | Springs – group of thermal springs on east border of U.S. 95, north of Beatty |
| | 0.3 | Spring – Well Spring, west of U.S. 95, north of Beatty |
| | 0.4 | Spring – Ute Spring, north of Beatty |
| | 0.6 | Spring – unnamed, west of U.S. 95, north of Beatty |
| | 0.3 | Spring – Revert Spring in Beatty |
| | 0.3 | Spring – unnamed, east of U.S. 95, south of Beatty |
| *Caliente-Chalk Mountain route* | | |
| Caliente to Crystal Springs | 0.3 | Spring – unnamed, west of Caliente |
| | 0.4 | Spring – unnamed, in Newman Canyon |
| | 0.8 | Spring – unnamed, in Newman Canyon |
| Crystal Springs to Rachel | 0.01 - 0.07 | Spring – Crystal Springs, group of thermal springs near Town of Crystal Springs, flows along road |
| Rachel to Yucca Mountain (via Nellis Air Force Range and Nevada Test Site) | 0.9 | Spring – Cane Spring, north of Skull Mountain on Nevada Test Site |
| *Caliente-Las Vegas route* | | |
| Caliente to Crystal Springs | 0.3 | Spring – unnamed, west of Caliente |
| | 0.4 | Spring – unnamed, in Newman Canyon |
| | 0.8 | Spring – unnamed, in Newman Canyon |
| Crystal Springs to I-15 (via U.S. 93) | 0.7 | Spring – Pedretti Seeps, 3.5 kilometers southeast of Crystal Springs |
| | 0.7 | Spring – unnamed, west of route, just south of Pedretti Seeps |
| | 0.8 | Spring – Deacon Spring, 5 kilometers southeast of State Highway 375 |
| | 1.0 | Spring – Brownie Spring, 5 kilometers southeast of State Highway 375 |
| | 0.1 | Spring – Ash Springs, 7 kilometers southeast of State Highway 375, flows under road |
| | 0.7 | Spring – Grove Spring, 1.5 kilometers north of Upper Pahranagat Valley |
| | 0.1 | Lakes – route parallels Upper and Lower Pahranagat lakes and associated inundated areas (marshes) for about 15 kilometers |
| | 0.1 | Spring – unnamed, 0.2 kilometers west of U.S. 93 and Maynard Lake |
| | 0.1 | Lake – Maynard Lake, route borders for about 1 kilometer |
| | 0.8 | Spring – Coyote Springs, 21.5 kilometers north of junction with State Route 168 |
| U.S. 93/I-15 junction to U.S. 95 (via the proposed northern beltway) | | None |
| U.S. 95 to Yucca Mountain | | None |
| *Sloan/Jean station* | | None identified |
| *Sloan/Jean route* | | None identified |
| *Apex/Dry Lake station* | | None identified |
| *Apex/Dry Lake route* | | None identified |

a. Source: TRW (1999k, Appendixes J, K, L, M, N, and O).
b. To convert kilometers to miles, multiply by 0.62137.

300 meters from the inundation zone. Both areas are in Zone X (determined to be outside the 500-year floodplain).

### *Highway Routes for Heavy-Haul Trucks*

Potential hydrologic hazards along a heavy-haul route include flash flooding and debris flow. All routes have potential flash flooding concerns. However, because of the required road upgrades, the robustness of the vehicle and shipping cask, and the en route safeguards (for example, escorts), flash flooding or standing water is not expected to be a serious threat to heavy-haul shipments.

**3.2.2.2.3.2 Groundwater.** As discussed in relation to the potential rail corridors, all of Nevada has been divided into groundwater basins and sub-basins, with these latter, smaller divisions termed hydrographic areas. The water resource planning and management information generated by the State of Nevada for these hydrographic areas provides the basis for groundwater information presented for both intermodal transfer station locations and the candidate highway routes that would be used by heavy-haul trucks. The following paragraphs provide an overview of the groundwater conditions at these sites and along the associated routes. Water demand at an intermodal transfer station would be small for both construction and operations. Water needs during operations would consist primarily of the needs of the personnel that staff the station. Water needs for construction and operations would be met by trucking water to the site, installing a well, or possibly by connection to a local water distribution system. This demand would be unlikely to cause noticeable change in water consumption rates for the area. Consequently, no baseline water-use information is provided.

### *Intermodal Transfer Station Locations*

*Caliente.* The two sites southwest of Caliente being considered for the intermodal transfer station are close to one another and are located in Nevada’s Colorado River Basin (designated Hydrographic Region 13). This hydrographic region covers about 32,000 square kilometers (12,000 square miles) and parts of four counties (NDWP 1999b, Region 13). The Colorado River Basin is further divided into 27 hydrographic areas including Lower Meadow Valley Wash (Area 205), where the Caliente sites are located. This area has been assigned a “Designated Groundwater Basin” status, which means that its permitted water rights approach or exceed the estimated perennial yield and its water resources are being depleted or require additional administration. The additional administration normally includes a State declaration of preferred uses (municipal and industrial, domestic supply, agriculture, etc.) for the groundwater from this area.

*Sloan/Jean.* The Jean sites being considered for the intermodal transfer station are in Nevada’s Central Hydrographic Region (also designated Region No. 10). This is the largest hydrographic region in Nevada, encompassing about 120,000 square kilometers (46,000 square miles) and parts of 13 counties (NDWP 1999b, Region 10). The Central Region has 90 hydrographic areas and sub-areas, including Ivanpah Valley/Northern Part (Area 164A), where the Jean sites are located. This area has also been assigned a Designated Groundwater Basin status. The depth to groundwater in the vicinity of the candidate Jean sites is approximately 150 meters (490 feet) (Thomas, Welch, and Dettinger 1996, Plate 1).

The site near Sloan being considered for the intermodal transfer station is in Nevada’s Colorado River Basin (Hydrographic Region 13), as described for the Caliente sites. The Sloan site is in the hydrographic area designated Las Vegas Valley (Area 212). This area has also been assigned a Designated Groundwater Basin status. The depth to groundwater at Sloan is approximately 240 meters (790 feet) (Thomas, Welch, and Dettinger 1996, Plate 1).

*Apex/Dry Lake.* The two sites near Apex/Dry Lake being considered for the intermodal transfer station are close to one another and are in Nevada’s Colorado River Basin, as described for the Caliente sites.

The Apex/Dry Lake sites are in the hydrographic area designated Garnet Valley (Area 216). The estimated perennial yield for the groundwater in this area is only 490,000 cubic meters (400 acre-feet), but it is not a Designated Groundwater Basin. The depth to groundwater at Apex/Dry Lake is about 60 meters (200 feet) (Thomas, Welch, and Dettinger 1996, Plate 1).

### Highway Routes for Heavy-Haul Trucks

The highway routes in Nevada that heavy-haul trucks could use cross through several hydrographic regions and a greater number of hydrographic areas. To identify groundwater that could potentially be affected, a map of these hydrographic areas (Bauer et al. 1996, page 543) was overlain with a drawing of the proposed highway routes to get a reasonable approximation of the areas that would be crossed. The results of this effort are listed in Table 3-43. This table also lists estimates of the perennial yield for each of the hydrographic areas crossed and if the area is a Designated Groundwater Basin. Basins with this designation are the areas where additional water demand would be most likely to adversely affect local groundwater resources. None of the candidate routes would totally avoid Designated Groundwater Basins. However, the Caliente-Chalk Mountain route would cross only two designated basins: one in the Lower Meadow Valley Wash at the beginning of the route and one at Penoyer Valley where the Caliente and Caliente-Chalk Mountain routes split.

There are a number of published estimates of perennial yield for many of the hydrographic areas in Nevada, and they often differ from one another by large amounts. This is the reason for listing a range of perennial yield values in Table 3-11. For simplicity, the perennial yield values listed in Table 3-43 generally come from a single source (NDWP 1998, Regions 10, 13, and 14) and, therefore, are not ranges of values. The hydrographic areas in the vicinity of Yucca Mountain (that is, Areas 225 through 230) are the exception to perennial yield values coming from the single source. The perennial yield values for these areas come from Thiel (1997, pages 6 to 12), which compiles estimates from several sources. The table lists the lowest values presented in that document.

## 3.2.2.2.4 *Biological Resources*

The existing biological environments described in this section includes the areas inside the boundaries of the intermodal transfer station sites and within 100 meters (about 330 feet) of the centerline of the heavy-haul routes. It also includes springs within 400 meters (0.25 mile) of the intermodal transfer sites and the routes. The section discusses environmental settings and important biological resources for each candidate station and associated heavy-haul routes. Unless otherwise noted, this information is from the *Environmental Baseline File for Biological Resources* (TRW 1999k, all).

### Caliente Intermodal Transfer Station

The 0.7-square kilometer (170-acre) area DOE is considering for the Caliente intermodal transfer station is about 1 kilometer (0.6 mile) southwest of Caliente and less than 500 meters (1,600 feet) west of Meadow Valley Wash. This area is at an elevation of about 1,200 meters (3,900 feet). The land cover types at this site are primarily agricultural—pasture, 88 percent, and salt desert scrub, 12 percent.

No species classified as Federally threatened or endangered, as State protected, or as sensitive by the Bureau of Land Management occur in the proposed location of the Caliente intermodal transfer station. However, two species classified as sensitive by Bureau of Land Management, the Meadow Valley Wash speckled dace and the Meadow Valley Wash desert sucker (*Catostomus clarki* ssp.), occur in the adjacent Meadow Valley Wash (NNHP 1997, all). Nevada also classifies the Meadow Valley Wash desert sucker as sensitive.

**Table 3-43.** Hydrographic areas (groundwater basins) crossed by candidate routes for heavy-haul trucks.[a]

| Route | Hydrographic area | | Perennial yield[b,c] (acre-feet)[d] | Designated groundwater basin[e,f] |
|---|---|---|---|---|
| | Number | Name | | |
| *Caliente* | | | | |
| Caliente to Crystal Springs (near Hiko) | 203 | Panaca Valley | 9,000 | Yes |
| | 181 | Dry Lake Valley | 2,500 | No |
| | 182 | Delamar Valley | 3,000 | No |
| Crystal Springs to Rachel | 209 | Pahranagat Valley | 25,000 | No |
| | 169A | Tikaboo Valley, Northern Part | 1,300 | No |
| Rachel to Yucca Mountain (via Tonopah) | 170 | Penoyer Valley (Sand Spring Valley) | 4,000 | Yes |
| | 173A | Railroad Valley, Southern Part | 2,800 | No |
| | 173B | Railroad Valley, Northern Part | 75,000 | No |
| | 156 | Hot Creek | 5,500 | No |
| | 149 | Stone Cabin Valley | 2,000 | Yes |
| | 141 | Ralston Valley | 6,000 | Yes |
| | 137A | Tonopah Flat | 6,000 | Yes |
| | 142 | Alkali Spring Valley | 3,000 | No |
| | 144 | Lida Valley | 350 | No |
| | 146 | Sarcobatus Flat | 3,000 | Yes |
| | 228 | Oasis Valley | 1,000 | Yes |
| | 230 | Amargosa Valley | 24,000 | Yes |
| | 229 | Crater Flat | 220 | No |
| | 227A | Fortymile Canyon and Jackass Flats | 880[g] | No |
| *Caliente-Chalk Mountain* | | | | |
| Caliente to Crystal Springs (near Hiko) | 203 to 209 | See Caliente Route | | |
| Crystal Springs to Rachel | 209 to 170 | See Caliente Route | | |
| Rachel to Yucca Mountain (via Nellis Air Force Range and Nevada Test Site) | 170 | | | |
| | 158A | Emigrant Valley and Groom Lake Valley | 2,800 | No |
| | 159 | Yucca Flat | 350 | No |
| | 160 | Frenchman Flat | 16,000 | No |
| | 227A | Fortymile Canyon and Jackass Flats | 880[g] | No |
| *Caliente-Las Vegas* | | | | |
| Caliente to Crystal Springs (near Hiko) | 203 to 209 | See Caliente Route | | |
| Crystal Springs (near Hiko) to U.S. 93/I-15 junction at Dry Lake | 209 | | | |
| | 210 | Coyote Springs Valley | 18,000 | Yes |
| | 217 | Hidden Valley | 200 | No |
| U.S. 93/I-15 junction at Dry Lake to U.S. 95 junction | 216 | Garnet Valley | 400 | No |
| U.S. 95 junction to Yucca Mountain | 212 | Las Vegas Valley | 25,000 | Yes |
| | 211 | Three Lakes Valley, Southern Part | 5,000 | Yes |
| | 161 | Indian Springs Valley | 500 | Yes |
| | 225 | Mercury Valley | 250 | No |
| | 226 | Rock Valley | 30 | No |
| | 227A | Fortymile Canyon and Jackass Flats | 880[g] | No |
| *Sloan/Jean*[h] | | | | |
| Jean to U.S. 95 junction | 164A | Ivanpah Valley, Northern Part | 700 | Yes |
| | 165 | Jean Lake Valley | 50 | Yes |
| U.S. 95 junction to Yucca Mountain | 212 to 227A | See Caliente-Las Vegas route | | |
| *Apex/Dry Lake* | | | | |
| U.S. 93/I-15 junction at Dry Lake to U.S. 95 junction | 216 to 212 | See Caliente-Las Vegas route | | |
| U.S. 95 junction to Yucca Mountain | 212 to 227A | See Caliente-Las Vegas route | | |

a. Source: Bauer et al. (1996, pages 542 and 543 with route map overlay).
b. Perennial yield is the estimated quantity of groundwater that can be withdrawn annually from a basin without depleting the reservoir.
c. Source: NDWP (1998, Regions 10, 13, and 14); for Hydrographic Areas 225 through 230 the source is Thiel (1997, pages 6 to 12). The Nevada Division of Water Planning identifies a perennial yield of only 24,000 acre-feet for the combined area of hydrographic areas 225 through 230 (NDWP 1998, all; NDWP 1999a, page 9).
d. To convert acre-feet to cubic meters, multiply by 1,233.49.
e. "Yes" indicates that the State of Nevada considers the area a Designated Groundwater Basin where permitted water rights approach or exceed the estimated perennial yield, and the water resources are being depleted or require additional administration, including a State declaration of preferred uses (municipal and industrial, domestic supply, agriculture, etc.). Designated Groundwater Basins are also referred to as Administered Groundwater Basins.
f. Source: NDWP (1999b, Regions 10, 13, and 14).
g. The perennial yield value shown for Area 227A is the lowest estimated value in Thiel (1997, page 8), and is accompanied by the additional qualification: 370,000 cubic meters (300 acre-feet) for the eastern third of the area and 720,000 cubic meters (580 acre-feet) for the western two-thirds.
h. The hydrographic areas listed for the Sloan/Jean Route are based on the intermodal transfer station located at Jean. For the Sloan location, the route would begin with Hydrographic Area 212, then proceed as shown.

There is no designated game habitat in this area, but the adjacent Meadow Valley Wash is classified as important habitat for Gambel's quail (BLM 1979, pages 2-34 and 2-35).

There are no springs at the proposed station location, but moist areas in the proposed station location might be wetlands (TRW 1999k, pages 3-35 and 3-36). The adjacent perennial stream and riparian habitat along Meadow Valley Wash also might be classified as a wetlands or other waters of the United States, although there has been no formal wetlands delineation.

*Caliente Route.* This route passes through the southern Great Basin Desert from the beginning of the route in Caliente to near Beatty. From south of Beatty to Yucca Mountain, the route passes through the Mojave Desert. The predominant land cover types along the entire route are salt desert scrub (49 percent), sagebrush (14 percent), and creosote-bursage (13 percent).

Three threatened or endangered species occur within 100 meters (about 330 feet) of the Caliente heavy-haul route. The Hiko White River springfish (*Crenicthys baileyi grandis*, Federally endangered) occurs in Crystal Springs (FWS 1998, page 16), which is about 75 meters (250 feet) south of State Route 375 near the intersection with U.S. 93. The springs and outflow, which come within about 10 meters (33 feet) of State Route 375, are critical habitat for the Hiko White River springfish (50 CFR 17.95). A population of the Railroad Valley springfish (*Crenicthys nevadae*, Federal threatened) has been introduced into Warm Springs, the outflow of which crosses U.S. Highway 6 (FWS 1996, page 20). The southern part of the route, along U.S. 95 from Beatty to Yucca Mountain, is within the range of the desert tortoise (Bury and Germano 1994, pages 57 to 72). This area is not classified as critical habitat for desert tortoises (50 CFR 17.95), and the relative number of tortoises in this area is low (Karl 1981, pages 76 to 92; Rautenstrauch and O'Farrell 1998, pages 407 to 411).

Six species classified as sensitive by the Bureau of Land Management have been documented within 100 meters (about 330 feet) of the route (NNHP 1997, all). The Pahranagat speckled dace (*Rhinichthys osculus velfier*) occurs in Crystal Springs. The Railroad Valley tui chub (*Gila bicolor* ssp 7) (also classified as sensitive by Nevada) occurs in Twin Spring Slough along State Route 375. The Amargosa toad (*Bufo nelsoni*) and the Oasis Valley speckled dace (*Rhinichthys osculus* ssp 1) (both also classified as protected by Nevada) occur in the Amargosa River and elsewhere in the Oasis Valley. Two bats, the Townsend's big-eared bat (*Corynorhinus townsendii*) and fringed myotis (*Myotis thysanodes*), have been documented near the southern end of the route, and other bats classified as sensitive by the Bureau of Land Management might occur near the route. The chuckwalla lizard (*Sauromalus obesus*) also might occur in suitable habitat along the southern end of the route.

This route crosses eight areas designated as game habitat (BLM 1979, pages 2-27 to 2-36; BLM 1994b, Maps 9, 10, 12, and 13). Portions of Meadow Valley Wash are designated important habitat for Gambel's quail (*Callipepla gambelii*) and waterfowl. The route crosses mule deer habitat in Newman Canyon, in the Pahroc Range, in the Pahranagat Range, and northwest of the Groom Range. It also crosses bighorn sheep habitat in the Pahranagat Range, and pronghorn habitat northwest of the Groom Range and from west of Sand Spring Valley through Railroad, Stone Cabin, and Ralston Valleys.

Nineteen springs or riparian areas within 0.4 kilometer (0.25 mile) of the route might be considered wetlands or other waters of the United States under Section 404 of the Clean Water Act, although no formal wetlands delineation has been conducted. The route is adjacent to Meadow Valley Wash at the proposed location of the intermodal transfer station. There is an unnamed spring near U.S. 93 west of Caliente. Crystal Spring and its outflow are about 10 meters (33 feet) from State Route 375, which also passes within 250 meters (820 feet) of Twin and Warm Springs and crosses their outflows. Fivemile Spring is about 0.4 kilometer from U.S. 6 in Stone Cabin Valley. U.S. 95 passes within 0.4 kilometer of 12 springs or groups of springs in the Oasis Valley and along the Amargosa River, and crosses the

Amargosa River at Beatty. This route also crosses a number of ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act.

The route also borders the Bureau of Land Management Oasis Valley Area of Critical Environmental Concern, which is designed to protect riparian areas and sensitive species in Oasis Valley south of Springdale (TRW 1999k, page 3-32).

*Caliente-Chalk Mountain Route.* From Caliente to Crystal Springs, this heavy-haul route crosses the Burnt Spring Range, Dry Lake Valley, Sixmile Flat, and the north end of the South Pahroc Range at elevations from 1,200 to 1,900 meters (3,900 to 6,200 feet). From Crystal Springs to Rachel the route crosses Hancock Summit and Tikaboo Valley at elevations ranging from about 1,300 to 1,700 meters (4,300 to 5,600 feet). From Rachel to Yucca Mountain the route passes through Sand Spring and Emigrant Valleys, and Yucca Flat, Frenchman Flat, and Jackass Flats, at elevations from 1,700 to 1,900 meters (5,600 to 6,200 feet). Along the entire route, the predominant land cover types are salt desert scrub (37 percent), blackbrush (16 percent), sagebrush (11 percent), and creosote-bursage (10 percent).

Two resident threatened or endangered species occur within 100 meters (about 330 feet) of the Caliente-Chalk Mountain heavy-haul route. The Hiko White River springfish (*Crenichthys baileyi grandis*, Federally endangered) occurs in Crystal Springs (FWS 1998, page 16). The springs and outflow, which come within about 10 meters (33 feet) of State Route 375, are critical habitat for the Hiko White River springfish (50 CFR 17.95). The part of the route from the northern end of Frenchman Flat to Yucca Mountain is within the range of the desert tortoise (Rautenstrauch, Brown, and Goodwin 1994, all). This area is not classified as critical habitat for desert tortoises (50 CFR 17.95), and the relative abundance of tortoises in this area is low (Rautenstrauch and O'Farrell 1998, pages 407 to 411).

Three species classified as sensitive by the Bureau of Land Management occur within 100 meters (about 330 feet) of this route (NNHP 1997, all). The Pahranagat speckled dace occurs in Crystal Springs, Ripley's springparsley (*Cymopterus ripleyi* var. *saniculoides*) occurs in a number of locations in Yucca Flat on the Nevada Test Site, and the fringed myotis has been observed in Fortymile Wash on the Nevada Test Site. A number of bats classified as sensitive by the Bureau of Land Management might occur along the route and the southern end of the route is within the range of the chuckwalla.

This route crosses six areas designated as game habitat (BLM 1979, pages 2-27 to 2-36; BLM 1994b, Maps 9, 10, 12, and 13). Meadow Valley Wash is designated important habitat for Gambel's quail and waterfowl. The route crosses mule deer habitat in four areas: west of Caliente, near Pahroc Summit Pass, in the Pahranagat Range, and in the Groom Range. It also crosses bighorn sheep habitat in the Pahranagat Range.

Three springs or riparian areas within 0.4 kilometer (0.25 mile) of the route might be wetlands or other waters of the United States under Section 404 of the Clean Water Act, including Meadow Valley Wash, an unnamed spring near U.S. 93 west of Caliente, and Crystal Springs and its outflow. No formal wetlands delineation has been conducted along this route. This route also crosses a number of ephemeral streams or washes that might be classified as waters of the United States under Section 404 of the Clean Water Act.

*Caliente-Las Vegas Route.* From Caliente to Crystal Springs, this candidate route crosses the Burnt Spring Range, Dry Lake Valley, Sixmile Flat, and the north end of the South Pahroc Range at elevations from 1,200 to 1,900 meters (3,900 to 6,200 feet). From Crystal Springs to Las Vegas, the route parallels the White River through Pahranagat Valley, and then through Coyote Springs, Hidden, Dry Lake, Las Vegas, Mercury, and Rock Valleys, and crosses Jackass Flats to Yucca Mountain. Elevations along the section from Crystal Springs to Yucca Mountain range from 610 to 1,200 meters (2,000 to 3,900 feet). Along the route the predominant land cover types are creosote-bursage (62 percent) and Mojave mixed scrub (16 percent).

Three resident threatened or endangered species occur within 100 meters (about 330 feet) of the Caliente-Las Vegas heavy-haul route. The section of the route from about Alamo to Yucca Mountain is within the range of the threatened desert tortoise (Bury and Germano 1994, pages 57 to 72). An approximately 100-kilometer (60-mile) section of U.S. 93 from Maynard Lake south to a point approximately 6 kilometers (4 miles) north of I-15 is critical habitat for the desert tortoise (50 CFR 17.95). The relative abundance of desert tortoises along the remainder of the route through Las Vegas Valley, Indian Springs Valley, and the Nevada Test Site is low (BLM 1992, Map 3-13; Rautenstrauch and O'Farrell 1998, pages 407 to 411). The White River springfish (*Crenichthys baileyi baileyi*, Federally endangered and Nevada protected) has been found in Ash Springs, less than 100 meters from U.S. 93 in northern Pahranagat Valley (FWS 1998, pages 12 to 14). The route crosses the outflow of Ash Springs, which is designated critical habitat for the White River springfish (50 CFR 17.95). The Pahranagat roundtail chub (*Gila robusta jordani*, Federally endangered and Nevada protected) occurs in Ash Springs, the outflow, and throughout Pahranagat Creek, but now is restricted to an approximately 3.5-kilometer (2.2-mile) length of Pahranagat Creek and approximately 2.5 kilometers (1.6 mile) of irrigation ditch in the area (FWS 1998, pages 11 to 12).

Nine other species classified as sensitive by the Bureau of Land Management have been documented within 100 meters (about 330 feet) of the route (NNHP 1997, all). The Pahranagat speckled dace occurs in Ash Springs. The Pahranagat pebblesnail (*Fluminicola merriami*), Pahranagat naucorid (*Pelocoris shoshone shoshone*), and the grated tryonia (*Tryonia clathrata*) occur in Ash Springs, and the Pahranagat Valley montane vole (*Microtus montanus fucosus*) has been observed near the route in Pahranagat National Wildlife Refuge. In addition, pinto beardtongue (*Penstemon bicolor bicolor* and *P. b. roseus*) occurs along U.S. 93 north of I-15, Ripley's springparsley and Parish's scorpionweed (*Phacelia parishii*) occur adjacent to Jackass Flats Road in eastern Rock Valley, and the fringed myotis has been observed in Fortymile Wash on the Nevada Test Site. A number of other bats classified as sensitive by the Bureau of Land Management occur along the route and most of the route south from Pahranagat Valley is within the range of the chuckwalla and gila monster (*Heloderma suspectus*).

Seven springs, streams, or lakes less than 0.4 kilometer (0.25 mile) from the route might be classified as wetlands under Section 404 of the Clean Water Act, including Meadow Valley Wash, Ash Springs and its outflow, unnamed springs on U.S. 93 west of Caliente and near Maynard Lake, Upper and Lower Pahranagat lakes and their associated marshes, and Maynard Lake. This route also crosses a number of ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act.

The route crosses eight areas designated as game habitat (BLM 1979, pages 2-26 to 2-35; BLM 1998, Maps 3-7 to 3-9). Meadow Valley Wash and much of Pahranagat Valley are designated as habitat for Gambel's quail and waterfowl, and areas along U.S. 93 north of I-15 are designated as quail habitat. U.S. 93 crosses mule deer habitat west of Caliente and around Maynard Lake, two bighorn sheep migration routes, and crucial bighorn sheep habitat north of the U.S. 93 and I-15 junction.

#### *Sloan/Jean Station and Route*

The area that DOE is considering for the Sloan/Jean intermodal transfer station is in Ivanpah Valley. DOE is considering three sites in this valley: southwest of Sloan [3.2 square kilometers (800 acres)], northeast of Jean [3 square kilometers (750 acres)], and east of Jean [1 square kilometer (250 acres)]. These sites are at an elevation of about 910 meters (3,000 feet) and have vegetation typical of the Mojave Desert. The predominant land cover type is creosote-bursage (97 percent). Elevations along the associated Sloan/Jean heavy-haul route range from about 700 to 1,100 meters (2,300 to 3,600 feet). Predominant land cover types along the route include creosote-bursage (78 percent), Mojave mixed scrub (12 percent), and urban development (9 percent).

The three sites that DOE is considering for the Sloan/Jean intermodal transfer station are in the range of the threatened desert tortoise. The abundance of tortoises generally is moderate to high in Ivanpah Valley in relation to other areas in Nevada (Karl 1980, pages 75 to 87; BLM 1992, Map 3-13). This area is not critical habitat for desert tortoises (50 CFR 17.95).

One species classified by the Bureau of Land Management as sensitive, and by the State of Nevada as protected, occurs in the candidate Sloan/Jean station sites (NNHP 1997, all). The pinto beardtongue (*Penstemon bicolor* ssp. *roseus)* has been observed on the site southwest of Sloan and on the site east of Jean. There are no important game habitats (BLM 1998, Maps 2-1, 3-7, 3-8, and 3-9) and no springs, riparian areas, or other potential wetlands within 0.4 kilometer (0.25 mile) of these sites (TRW 1999k, page 3-36).

The only resident threatened or endangered species along the Sloan/Jean heavy-haul route is the desert tortoise. The entire route is within the range of the desert tortoise (Bury and Germano 1994, pages 57 to 72). The abundance of tortoises along the first part of the route in Ivanpah Valley is moderate to high in relation to other areas in Nevada (BLM 1992, Map 3-13). The abundance of tortoises along the remainder of the route through Las Vegas Valley, Indian Springs Valley, and the Nevada Test Site generally is low to very low (BLM 1992, Map 3-13; Rautenstrauch and O'Farrell 1998, pages 407 to 411). This route does not cross areas classified as critical habitat for desert tortoises (50 CFR 17.95).

Four species classified as sensitive by the Bureau of Land Management have been documented within 100 meters (about 330 feet) of this route (NNHP 1997, all). The pinto beardtongue (*Penstemon bicolor bicolor* and *P. b. roseus*) occurs in the Las Vegas Valley. Ripley's springparsley and Parish's scorpionweed occur adjacent to Jackass Flats Road in eastern Rock Valley on the Nevada Test Site, and the fringed myotis has been observed near the Yucca Mountain in Fortymile Wash. A number of other bats classified as sensitive by the Bureau of Land Management might occur along the route, and the route is within the range of the chuckwalla and gila monster.

The route crosses ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act. The route does not cross designated game habitats (BLM 1998, Maps 3-7 to 3-9) and there are no springs, riparian areas, or other potential wetlands within 0.4 kilometer (0.25 mile).

### *Apex/Dry Lake Station and Route*

The area that DOE is considering for the Apex/Dry Lake intermodal transfer station is northeast of Las Vegas in Dry Lake Valley. The Department is considering three sites in this area, two to the west of I-15 [0.18 and 3.6 square kilometers (45 and 890 acres)] and one east of the Interstate [0.95 square kilometer (240 acres)]. The elevation of these sites is about 610 meters (2,000 feet). This area is in the Mojave Desert and the predominant land cover type is creosote-bursage (100 percent). The associated route starts at the station area and crosses Las Vegas, Mercury, and Rock Valleys and Jackass Flats to Yucca Mountain at elevations ranging from 700 to 1,100 meters (2,300 to 3,600 feet). Predominant land cover types along this route are creosote-bursage (77 percent) and Mojave mixed scrub (16 percent).

The only resident threatened or endangered species along the Apex/Dry lake heavy-haul route is the desert tortoise. The entire route passes through desert tortoise habitat (Bury and Germano 1994, pages 57 to 72), and the relative abundance of tortoises along this route through the Las Vegas Valley, Indian Springs Valley, and the Nevada Test Site generally is low (BLM 1992, Map 3-13; Rautenstrauch and

O'Farrell 1998, pages 407 to 411). This route does not cross areas classified as critical habitat for desert tortoises (50 CFR 17.95).

Three species classified as sensitive by the Bureau of Land Management have been documented within 100 meters (about 330 feet) of this route (NNHP 1997, all). Ripley's springparsley and Parish's scorpionweed occur adjacent to Jackass Flats Road on the Nevada Test Site in eastern Rock Valley, and the fringed myotis has been observed near Yucca Mountain in Fortymile Wash. A number of other bats classified as sensitive by the Bureau of Land Management might occur along the route, and the route is within the range of the chuckwalla and gila monster.

The route crosses ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act. The route does not cross designated game habitat (BLM 1998, Maps 3-7 to 3-9). There are no springs, riparian areas, or other potential wetlands within 0.4 kilometer (0.25 mile) of the intermodal transfer station area or the route.

#### 3.2.2.2.5 *Cultural Resources*

The description of environmental conditions in this section focuses on archaeological and historic resources associated with the candidate intermodal transfer station areas and the associated heavy-haul routes. In addition, this section discusses Native American interests in relation to several of the heavy-haul truck routes. Unless otherwise noted, the *Environmental Baseline File for Archaeological Resources* (TRW 1999m, all) is the basis for the information in this section.

*Archaeological and Historic Resources.* Archaeological data from the candidate intermodal transfer station sites are very limited. Based on a records search at the Desert Research Institute in Las Vegas and Reno and at the Harry Reid Center at the University of Nevada, Las Vegas, four, seven, and two archaeological sites have been recorded at the Caliente, Sloan/Jean, and Apex/Dry Lake sites, respectively. These sites have not been evaluated with regard to their potential eligibility for listing in the *National Register of Historic Places.*

There is some relevant information about the candidate Caliente intermodal transfer location. Various cultural groups have occupied the Caliente/Meadow Valley Wash area for at least the past 11,000 years (Fowler et al. 1973, all; Fowler and Madsen 1986, all). Previously recorded prehistoric archaeological resources in the region include scattered lithic artifacts, rock shelters, temporary camps, and rock art (Kautz and Oothoudt 1992, all). Historic archaeological resources in the region typically consist of remains of late nineteenth- and early twentieth-century activities such as mining and ranching. The Caliente Railroad Depot is listed in the *National Register of Historic Places.*

In general, there are little or no current data for the presence of cultural resource sites in the existing road rights-of-way; with the exception of one route, field inventories have not been conducted. A few archaeological surveys have been conducted along or near the Caliente-Chalk Mountain heavy-haul route. An archival search of a 0.2-kilometer (0.1-mile)-wide corridor along this route identified five archaeological sites. Two of these sites are not considered eligible for inclusion on the National Register; the other three have not been evaluated.

*Native American Interests.* Section 3.2.2.1.5 discusses general Native American concerns about transportation routes.

The Moapa Paiute Indian Tribe is a Federally recognized tribe of about 290 Southern Paiute people. The tribe's reservation near the town of Moapa on I-15 and the Union Pacific Railroad's mainline contains homes and business enterprises. The reservation is about 6 kilometers (4 miles) east of the Caliente-Las

Vegas heavy-haul route and about 5 kilometers (3 miles) north of the Apex/Dry Lake station site (AIWS 1998, Chapter 4).

The Las Vegas Paiute Colony is a Federally recognized tribe of about 100 people living on two separate tribal parcels in southern Nevada (AIWS 1998, Chapter 4). One parcel near downtown Las Vegas consists of 73,000 square meters (18 acres) of land with 21 homes and various business enterprises. This parcel is about 11 kilometers (7 miles) from an overlapping portion of the Caliente-Las Vegas, Sloan/Jean, and Apex/Dry Lake heavy-haul routes (northern Las Vegas beltway for the Las Vegas and Apex/Dry Lake routes, and western Las Vegas beltway for the Sloan/Jean route). The other parcel is in the northwest part of the Las Vegas Valley along U.S. 95. It consists of 16.2 square kilometers (4,000 acres) with 12 homes and various business enterprises. An overlapping portion of the Caliente-Las Vegas, Sloan/Jean, and Apex/Dry Lake heavy-haul routes goes through a 1.6-kilometer (1-mile) corner of this parcel.

#### 3.2.2.2.6 *Socioeconomics*

The candidate heavy-haul intermodal transfer station sites and routes would not appreciably affect counties other than those in which the facilities were located. Section 3.1.7 contains socioeconomic background information on the three counties (Clark, Lincoln, and Nye) most involved in the heavy-haul routes. The Caliente heavy-haul route is the only route involving a county outside the region of influence; it passes through Esmeralda County in addition to Lincoln and Nye Counties. Section 3.2.2.1.6 contains socioeconomic information for Esmeralda County.

#### 3.2.2.2.7 *Noise*

Most of the proposed routes pass through unpopulated desert with background noise levels of 22 to 38 dBA. All routes pass through small rural communities (see Figures 6-10 through 6-15). Noise levels in rural communities usually range from 40 to 55 dBA (Table 3-30). Traffic noise along highways generally ranges from 5 to 15 dBA above natural background levels (EPA 1974, page D.5). Roadside noise levels are highly dependent on the volume of traffic, the road surface, composition of the traffic (trucks, automobiles, motorcycles, etc.), and vehicle speed. Measurements taken 90 meters (300 feet) from the centerline of U.S. 95 just outside the Nevada Test Site ranged from 45 to 55 dBA (Brown-Buntin 1997, pages 8 and 9). Less traveled rural highways would have lower 1-hour noise levels, possibly as low as 33 dBA at 90 meters (300 feet) from the centerline. Communities potentially affected by the candidate intermodal transfer stations and associated heavy-haul routes were identified by examining the proposed route of each corridor and estimating if construction or heavy-haul vehicle noise could affect area communities. Occasional noise from passing military aircraft occurs near and in the Nellis Air Force Range.

##### Caliente Station

DOE is considering two parcels of land in Meadow Valley Wash several miles south of Caliente for the intermodal transfer station. A water treatment plant adjacent to the larger parcel could contribute to background noise levels. The other parcel of land has no buildings. Estimated noise levels range from 22 to 45 dBA depending on traffic volume (based on Table 3-30).

*Caliente Route.* The Caliente heavy-haul route goes from Caliente to the Yucca Mountain site, passing through or near the towns of Caliente, Tonopah, Goldfield, Beatty, Hiko, Rachel, Warm Springs, and Amargosa Valley. Estimated noise levels in these communities range from 40 to 55 dBA (based on Table 3-30). This longest route travels on existing highways through predominantly Bureau of Land Management land.

*Caliente-Chalk Mountain Route.* The Caliente-Chalk Mountain heavy-haul route would use existing paved roads to a point in western Lincoln County where it would turn south through the Nellis Air Force Range and the Nevada Test Site. Caliente and Rachel are the only towns through which the heavy-haul route would pass. Estimated noise levels in these communities would range from 45 to 55 dBA (based on Table 3-30).

*Caliente-Las Vegas Route.* The Caliente-Las Vegas heavy-haul route follows U.S. 93 from Caliente to I-15, then into Las Vegas primarily on Bureau of Land Management land. The section of the route on the planned Northern Beltway to U.S. 95 would have the highest noise levels, biased toward the 55-dBA level. Traffic noise levels along U.S. 95 would range from 45 to 55 dBA (Brown-Buntin 1997, pages 8 and 9). Estimated noise levels in Caliente, Alamo, Indian Springs, and Mercury range from 40 to 55 dBA (based on Table 3-30).

**Sloan/Jean Station**

DOE is considering three parcels of land in the Sloan/Jean area. Some residences, a quarry, and a concrete plant are next to the northernmost site. The eastern parcel is along I-15 adjacent to several commercial enterprises. The third parcel is in the community of Jean and is close to two large casinos. Estimated noise levels in these areas, which are greater than levels encountered in unpopulated desert areas, range from 40 to 55 dBA (based on Table 3-30).

*Sloan/Jean Route.* The Sloan/Jean heavy-haul route would use existing paved roads from the intermodal transfer station to the Yucca Mountain site, and would pass through a number of small towns and the western and northern portions of the Las Vegas Valley. Existing noise levels in the Las Vegas Valley probably range from 52 to 74 dBA; estimated noise levels in Indian Springs and Mercury range from 40 to 55 dBA (based on Table 3-30).

**Apex/Dry Lake Station**

The candidate location for the Apex/Dry Lake intermodal transfer station is in an unpopulated part of Dry Lake Valley. Existing noise levels are probably somewhat higher than typical levels for a desert environment because of vehicles that travel along I-15 in this area. Depending on local meteorological conditions, noise from the Apex industrial site and passing trains would add to the existing acoustic environment at this site. The northern boundary of one possible location for an intermodal transfer station in the Apex/Dry Lake area is about 3 kilometers (2 miles) south of the Moapa Indian Reservation.

*Apex/Dry Lake Route.* The Apex/Dry Lake heavy-haul route would use existing paved roads from the intermodal transfer station to the Yucca Mountain site. It would pass through a number of small communities and the north end of the Las Vegas Valley. Existing noise levels in Indian Springs and Mercury probably range from 40 to 55 dBA (Table 3-30). Estimated noise levels in the Las Vegas Valley range from 52 to 74 dBA (based on Table 3-30).

### 3.2.2.2.8 *Aesthetics*

This section describes the existing aesthetic qualities associated with each of the intermodal transfer station sites and associated heavy-haul routes. Section 3.1.10 provides additional description of Bureau of Land Management visual resource classes and scenic quality classes. Unless otherwise noted, this information is from the *Environmental Baseline File: Aesthetics* (TRW 1999p, all).

**Caliente Station**

The proposed location for the Caliente facility is southeast of Caliente, on the western edge of Meadow Valley Wash. This area is in the Caliente Bureau of Land Management resource area and is classified Class III (Figure 3-26).

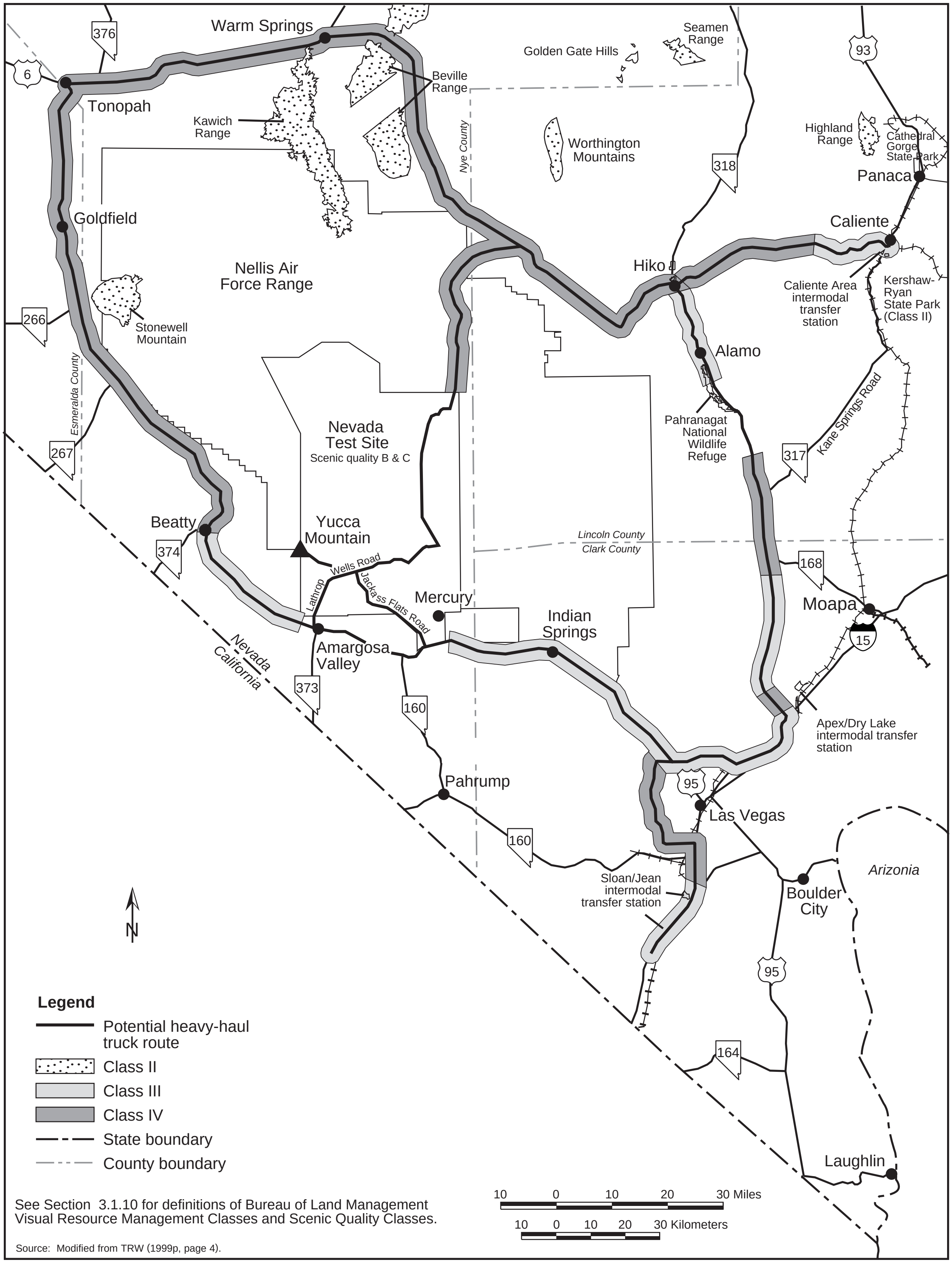



**Figure 3-26.** Visual Resource Management classes along the potential routes for heavy-haul trucks.

*Caliente Route.* Section 3.2.2.2.4 describes the environmental setting along the Caliente route. The route passes through the Caliente, Schell, Tonopah, and Las Vegas Bureau of Land Management resource areas. From Caliente to the south end of the Burnt Springs Range the route passes through Class III land, and then through Class IV land to Rachel. From Rachel to Tonopah the route crosses Class III land except portions of the Reveille and Kawich Ranges near Warm Springs, which are Class II areas. From Tonopah to Beatty, the route crosses Class IV land, then Class III land from Beatty to the Nevada Test Site boundary. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or Class C (Figure 3-26).

*Caliente-Chalk Mountain Route.* Section 3.2.2.2.4 describes the environmental setting along the route. The route passes through the Caliente and Schell Bureau of Land Management resource areas. From Caliente to the south end of Burnt Springs Range, the route passes through Class III land. From the Burnt Springs Range west through Crystal Springs to Rachel, the route passes through Class IV land. The route from Rachel south crosses Class III and VI land to the Nevada Test Site boundary. Lands crossed on the Nevada Test Site are rated Class B or Class C (Figure 3-26).

*Caliente-Las Vegas Route.* Section 3.2.2.2.4 describes the environmental setting along the Caliente-Las Vegas route. The route passes through the Caliente, Schell, and Las Vegas Bureau of Land Management resource areas. From Caliente to Crystal Springs the route crosses Class III and Class IV land. From Crystal Springs south to the Pahranagat National Wildlife Refuge, the route crosses Class III land. The refuge is rated Class II. The route from the south end of the refuge to I-15 crosses Class III and IV land. The remainder of the route along I-15, the Northern Beltway, and U.S. 95 passes through Class III land. Lands crossed on the Nevada Test Site are rated Class B or Class C (Figure 3-26).

#### Sloan/Jean Station and Route

Section 3.2.2.2.4 describes the environmental setting for the Sloan/Jean intermodal transfer station and associated route. The potential location for the Sloan/Jean intermodal transfer station has three parcels located some distance apart, two near Jean and one near Sloan. All portions of these parcels are in the Las Vegas Bureau of Land Management resource area and are designated as Class III lands. From Jean to Sloan the route travels through Class III lands. From Sloan along the Las Vegas Beltway to U.S. 95 is designated as Class IV lands. The portion of the route to the Nevada Test Site is through Class III lands. The remainder of the route on the Nevada Test Site is classified as scenic quality Class B and C (Figure 3-26).

#### Apex/Dry Lake Station and Route

Section 3.2.2.2.4 describes the environmental setting for the Apex/Dry Lake intermodal transfer station and route. Most of the land in the potential intermodal transfer areas is classified as Class IV lands. A small portion of the southern section of land is designated as Class III lands. The entire route passes through Class III lands from the Apex/Dry Lake siding (and the location of the intermodal transfer station) to the Nevada Test Site boundary. On the Nevada Test Site the route to the repository passes through lands with a scenic quality designated as Class B and C (Figure 3-26).

### 3.2.2.2.9 *Utilities, Energy, and Materials*

The implementation of the heavy-haul approach for transporting spent nuclear fuel and high-level waste to the repository would involve the construction and operation of an intermodal transfer station and upgrades of existing highways. The scope of the utilities, energy, and materials analysis includes consumption of electric power, fossil fuel, and construction materials such as concrete and steel to support these activities. The sites studied for the intermodal transfer station (Caliente, Sloan/Jean, and Apex/Dry Lake) are in areas with at least some light industrial activity or other activity that requires electric power. The sites would, therefore, have access to light industrial levels of electric power. The sites under consideration would also have access to the regional supply capability to provide fossil fuel and construction materials. Heavy-haul route upgrades would also use the southern Nevada regional supply system to provide materials for highway upgrades.

#### 3.2.2.2.10 *Environmental Justice*

The candidate location for the Caliente intermodal transfer station is in Lincoln County and the associated heavy-haul routes go through Lincoln, Nye, and Esmeralda Counties for the Caliente route; Lincoln and Nye Counties for the Caliente-Chalk Mountain route; and Lincoln, Clark, and Nye Counties for the Caliente-Las Vegas route. Section 3.1.13 discusses minority and low-income populations in Clark, Lincoln, and Nye Counties; Section 3.2.2.1.10 discusses minority and low-income populations in Esmeralda County. Unless otherwise noted, the *Environmental Baseline File for Environmental Justice* (TRW 1999q, all) is the basis for the information in this section.

The candidate locations for both the Sloan/Jean and Apex/Dry Lake intermodal transfer stations are in Clark County; the associated heavy-haul routes both go through Clark and Nye Counties. Section 3.1.13 discusses minority and low-income populations in Clark and Nye Counties.

None of the proposed intermodal transfer station sites is in a census block group with high minority or low-income populations, though a facility in the Caliente area would be near a block group with a low-income population and a facility in the Apex/Dry Lake area would be near the Moapa Indian Reservation, a block group with a high minority population.

Ninety block groups in the City of Las Vegas have low-income or minority populations or both. However, the block groups are not near any of the possible sites for an intermodal transfer station. Tables 3-44 and 3-45 list by county the number of census block groups with high minority or low-income populations, respectively, near or through which the heavy-haul routes would pass. Table 3-46 lists the number of census block groups with high minority populations, high low-income populations, or both that each heavy-haul route could encounter.

**Table 3-44.** High minority population census block groups near or crossed by candidate routes for heavy-haul trucks.

| County | Crosses | Near |
|---|---|---|
| Eureka | No route | No route |
| Lander | No route | No route |
| Nye | 0 | 0 |
| Esmeralda | 0 | 0 |
| Clark[a] | 2 | 0 |
| Lincoln | 0 | 0 |

a. Outside Las Vegas.

**Table 3-45.** High low-income population census block groups near or crossed by candidate routes for heavy-haul trucks.

| County | Crosses | Near |
|---|---|---|
| Eureka | No route | No route |
| Lander | No route | No route |
| Nye | 2 | 1 |
| Esmeralda | 0 | 0 |
| Clark[a] | 0 | 0 |
| Lincoln | 1 | 0 |

a. Outside Las Vegas.

**Table 3-46.** High minority and high low-income population census block groups near or crossed by candidate routes for heavy-haul trucks.

| Route | Minority | Low-income | Minority and low-income |
|---|---|---|---|
| Caliente | 0 | 1[a] | 0 |
| Caliente-Chalk Mountain | 0 | 0 | 0 |
| Caliente-Las Vegas | 2[b] | 0 | 0 |
| Apex/Dry Lake | 2[b] | 0 | 0 |
| Sloan/Jean | 1 | 0 | 0 |

a. Route passes near a low-income block groups in Nye County.
b. Route crosses two minority block groups in Clark County.

The transportation routes would not intersect any of the 90 block groups in the City of Las Vegas with low-income or minority populations or both.

#### 3.2.2.2.11 *Existing Traffic on Candidate Routes for Heavy-Haul Trucks*

The description of the affected transportation environment characterizes routes in terms of traffic volume and roadway capability (DOE 1998m, pages 3-1 to 3-14). The potential for congestion and other problems on a roadway is expressed in terms of levels of service. The level of service scale ranges from A to F, as follows:

A Indicates free-flow conditions.

B Indicates free-flow, but the presence of other vehicles begins to be noticeable. Average travel speeds are somewhat lower than level of service A.

C Indicates a range in which the influence of traffic density on flow becomes marked. The ability to maneuver in the traffic stream and to select an operating speed is clearly affected by the presence of other vehicles.

D Indicates conditions in which speed and the ability to maneuver are severely restricted due to traffic congestion.

E Indicates full capacity; a disruption, no matter how minor, causes backups to form.

F Indicates breakdown of flow or stop-and-go traffic.

Each level is defined by a range of volume-to-capacity ratios. Level of service A, B, or C is considered good operating conditions in which minor or tolerable delays of service are experienced by motorists. Level of service D represents below average conditions. Level of service E corresponds to the maximum capacity of the roadway. Level of service F indicates a heavily congested or overburdened capacity. Roads outside the Las Vegas metropolitan area are generally level of service A or B; roads inside the Las Vegas metropolitan area are generally level of service E or F. Table 3-47 lists current levels of service on potential heavy-haul routes (excluding the planned Las Vegas Beltway).

**Table 3-47.** Existing levels of service along candidate routes for heavy-haul trucks.[a]

| Route segment | Level of service |
|---|---|
| Caliente | |
| U.S. 93 to U.S. 6/U.S. 95 interchange | A |
| U.S. 95/U.S. 6 to Tonopah city limit | C |
| U.S. 95 (to Mercury, Nevada) | B |
| *Caliente-Chalk Mountain* | |
| Caliente to Rachel | A |
| Cost of route on U.S. Government facility | N/A |
| *Caliente-Las Vegas* | |
| U.S. 93 (between I-15 and Caliente) | A |
| I-15 (to Craig interchange) | A |
| I-15 (in Las Vegas) | E or F[b] |
| U.S. 95 (in Las Vegas) | E or F[b] |
| U.S. 95 (Las Vegas to Mercury) | B |
| *Sloan/Jean* | |
| I-15 (to and in Las Vegas) | C, F[b] |
| U.S. 95 (in Las Vegas) | C, F[b] |
| U.S. 95 (Las Vegas to Mercury) | B |
| *Apex/Dry Lake* | |
| I-15 (to Craig interchange | A |
| I-15 (in Las Vegas) | E and F[b] |
| U.S. 95 (in Las Vegas) | E and F[b] |
| U.S. 95 (Las Vegas to Mercury) | B |

a. Source: DOE (1998m, pages 3-1 to 3-14).
b. Does not consider the Las Vegas Beltway.

## 3.3 Affected Environment at Commercial and DOE Sites

The No-Action Alternative analyzes the impacts of not constructing and operating a monitored geologic repository at Yucca Mountain. It assumes that the spent nuclear fuel and high- level radioactive waste would remain at commercial and DOE sites throughout the United States. For this alternative, this section describes the affected environment that reflect the average or mean conditions of the sites. The affected environment includes spent nuclear fuel and high-level radioactive waste inventories, climatic parameters, groundwater flowrates, downstream surface-water users, and downstream surface-water flowrates. In all cases, DOE used data from actual sites to develop the hypothetical sites.

To develop the hypothetical sites (see Appendix K for more information), DOE divided the 77 sites among five regions (Figure 3-27). Climate varies considerably across the United States. The radionuclide release rates would depend primarily on the interaction of climate and materials. DOE analyzed these release rates for a hypothetical site in each region that was a mathematical representation of the actual sites in that region. The development process for the hypothetical site used weighted values for material inventories, climate, and groundwater flow information from each actual site to ensure that the results of the analyses of the hypothetical site were comparable to the results for each actual site, if analyzed independently. Similarly, the process constructed downstream populations of water users and river flow for the hypothetical sites from population and river flow data for actual sites, so they reflect the populations downstream of actual storage facilities and the actual amount of water those populations use.

### 3.3.1 CLIMATIC FACTORS AND MATERIAL

DOE assumed that a single hypothetical site in each region would store all the spent nuclear fuel and high-level radioactive waste in each region. Such a site does not exist, but DOE used it for this analysis. To ensure that the calculated results of the regional analyses reflected the appropriate inventory, facility and material degradation, and radionuclide transport, DOE developed the spent nuclear fuel and high-level radioactive waste inventories, engineered barriers, and environmental parameters for the hypothetical site from data from the actual sites in that region. Weighting criteria accounted for the different amounts and types of spent nuclear fuel and high-level radioactive waste at each site, so the results of the analyses of the hypothetical site were representative of the sum of the results if DOE had modeled each actual site independently. If there are no storage areas in a particular part of a region, DOE did not analyze the environmental parameters of that part (for example, there are no storage facilities in the Upper Peninsula of Michigan, so the analysis for Region 3 did not include environmental parameters from cities in the Upper Peninsula). In addition, if the storage area would not affect drinking water (for example, groundwater near the Calvert Cliffs Nuclear Generating Plant outcrops to the Chesapeake Bay), the regional hypothetical storage facility did not include their fuel inventories.

The following climate parameters are important to material degradation times and rates of release:

- Precipitation rate (amount of precipitation per year)
- Rain days (percent of days with measurable precipitation)
- Wet days (percent of year that included rain days and days when the relative humidity was greater than 85 percent)
- Temperature
- Precipitation chemistry (pH, chloride anions, and sulfate anions)

Table 3-48 lists the regional values for each parameter. Appendix K contains more information on the selection and analysis of these parameters.

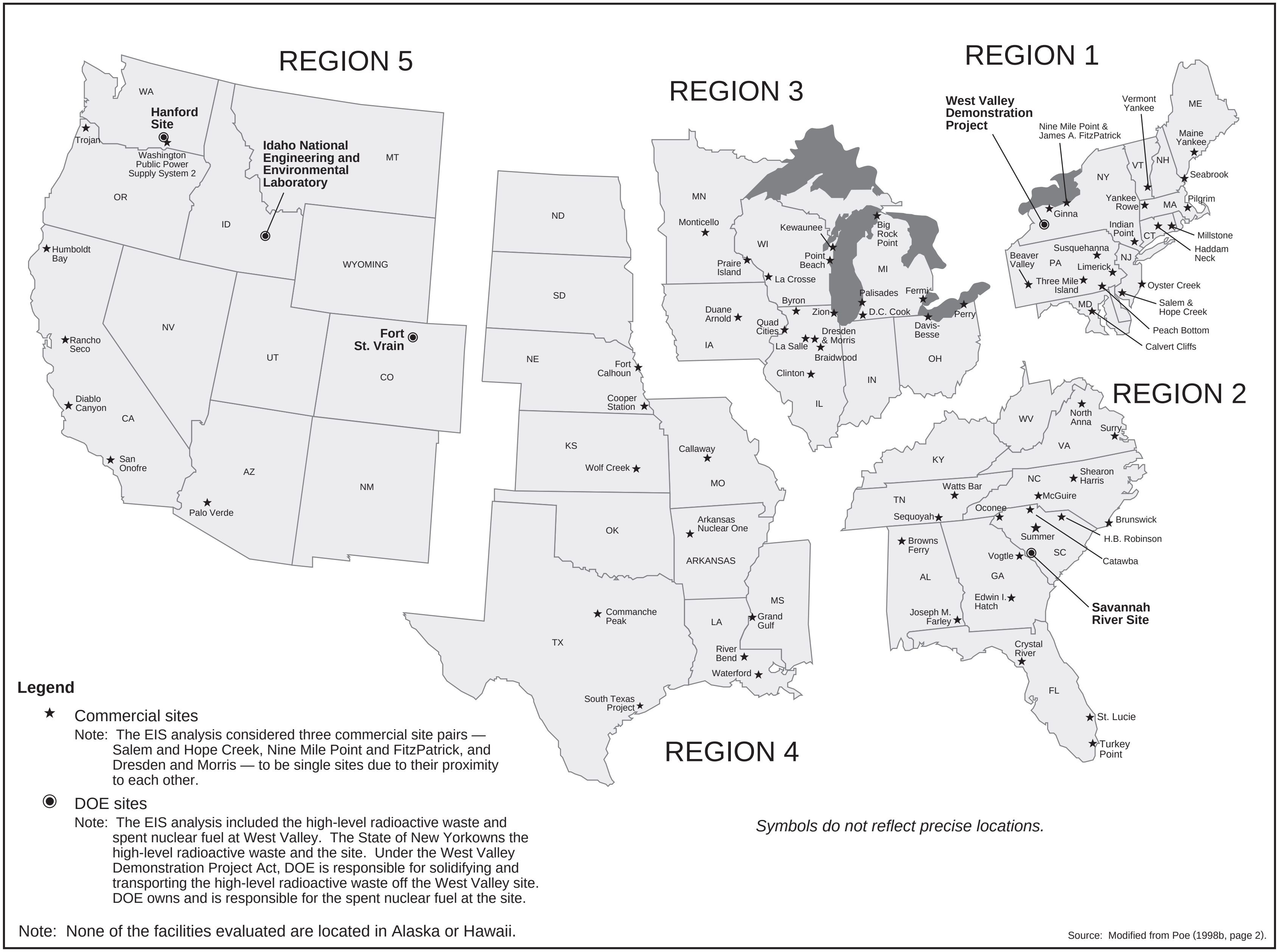



**Figure 3-27.** Commerical and DOE sites in each No-Action Alternative analysis region.

**Table 3-48.** Regional environmental parameters.

| Region | Precipitation rate (centimeters per year)[a] | Percent rain days (per year) | Percent wet days (per year) | pH | Precipitation chemistry: Chloride anions (weight percent) | Precipitation chemistry: Sulfate anions (weight percent) | Average temperature (°C)[b] |
|---|---|---|---|---|---|---|---|
| 1 | 110 | 30 | 31 | 4.4 | $6.9\times10^{-5}$ | $1.5\times10^{-4}$ | 11 |
| 2 | 130 | 29 | 54 | 4.7 | $3.9\times10^{-5}$ | $9.0\times10^{-5}$ | 17 |
| 3 | 80 | 33 | 42 | 4.7 | $1.6\times10^{-5}$ | $2.4\times10^{-4}$ | 10 |
| 4 | 110 | 31 | 49 | 4.6 | $3.5\times10^{-5}$ | $1.1\times10^{-4}$ | 17 |
| 5 | 30 | 24 | 24 | 5.3 | $2.1\times10^{-5}$ | $2.5\times10^{-5}$ | 13 |

a. To convert centimeters to inches, multiply by 0.3937.
b. To convert degrees Centigrade to degrees Fahrenheit, add 17.78 and then multiply by 1.8.

### 3.3.2 GROUNDWATER PARAMETERS

Most of the radioactivity and metals from degraded material would seep into the groundwater and flow with it to surface outcrops to rivers or streams. Therefore, the analysis had to account for the groundwater characteristics at each site, including the time it takes the water to move through the unsaturated zone and the aquifer. The analysis assumed that the storage facilities would be 490 meters (1,600 feet) up the groundwater gradient from the hypothetical reactor and used this assumption to calculate the time it would take contaminants to reach surface water. Table 3-49 lists the ranges of groundwater flow times in each region. Appendix K contains more information on the sources of groundwater data.

**Table 3-49.** Ranges of flow time (years) for groundwater and contaminants in the unsaturated and saturated zones in each region.

| Region | Contaminant $K_d$[a] (milliliters per gram) | Unsaturated zone: Water flow time | Unsaturated zone: Contaminant flow time | Saturated zone: Groundwater flow time | Saturated zone: Contaminant flow time | Total contaminant flow time |
|---|---|---|---|---|---|---|
| 1 | 0[b] - 100 | 0.7 - 4.4 | 0.4 - 2,100 | 0.3 - 56 | 10 - 5,000 | 10 - 6,000 |
| 2 | 10 - 250 | 0.6 - 10 | 35 - 5,000 | 3.3 - 250 | 11 - 310,000 | 460 - 310,000 |
| 3 | 10 - 250 | 0.5 - 14 | 32 - 1,500 | 1.3 - 410 | 9 - 44,000 | 65 - 45,000 |
| 4 | 10 - 100 | 0.2 - 7.1 | 110 - 2,300 | 3.9 - 960 | 300 - 520,000 | 460 - 520,000 |
| 5 | 0 - 10 | 0.9 - 73 | 14 - 4,700 | 1.7 - 170 | 0 - 25,000 | 200 - 26,000 |

a. $K_d$ = equilibrium adsorption coefficient.
b. The $K_d$ would be 0 if there was no soil at the site.

### 3.3.3 AFFECTED WATERWAYS

Most of the estimated population dose for the No-Action Alternative would be a result of drinking contaminated surface water. The first step in determining the population dose was to identify the waterways that receive groundwater from beneath existing storage facilities (Figure 3-28) and the number of public drinking water systems that draw water from the potentially contaminated waterways (Table 3-50). DOE calculated the river flow past each population center (Section 3.3.4) along each river, and used this number in the calculation to determine dose to the population.

**Table 3-50.** Public drinking water systems and the populations that use them in the five regions.[a]

| Region | Drinking water systems | Population |
|---|---|---|
| 1 | 85 | 10,000,000 |
| 2 | 150 | 5,600,000 |
| 3 | 150 | 12,000,000 |
| 4 | 95 | 600,000 |
| 5 | 6 | 2,800,000 |
| **Totals** | **486** | **31,000,000** |

a. Sources: Based on current information and the 1990 census.


**Figure 3-28.** Major waterways near commercial and DOE sites.

### 3.3.4 AFFECTED POPULATIONS

After identifying the affected waterways, DOE identified the populations that get their drinking water from those waterways. The total population using the river was expressed as number of people per cubic foot per second. If a river system traverses more than one region (for example, the Mississippi drains three regions), weighting criteria accounted for materials received from storage facilities upstream of the region that would flow past several downstream population centers, as necessary. Table 3-50 lists the number of people using the public drinking water systems potentially affected by the degradation of radioactive materials.