APPENDIX I

DEMOGRAPHY AND ECOSYSTEMS

APPENDIX 1
DEMOGRAPHY AND ECOSYSTEMS

The following sections present information about the demography and ecosystems of the Yucca Mountain area.

Land Use

The environment in and around Yucca Mountain is characterized by desert valley and Great Basin mountain terrain and topography. Its climate, flora, and fauna are typical of the southern Great Basin deserts. Access is restricted to the Yucca Mountain area due to its remoteness and its proximity to the Nevada Test Site (NTS) and adjacent U.S. Air Force lands. The predominant non-government land use surrounding Yucca Mountain is open range for livestock grazing, with scattered mining, farming, and recreational areas.

Figure I-1 delineates the variety of land uses within 180 miles (300 km) of the NTS and Yucca Mountain areas. The area southeast of Yucca Mountain (shown on the southwest border of the NTS) is relatively uniform, since the Mojave Desert ecosystem comprises most of this part of Nevada and California. The area directly south is the Amargosa Valley, which has limited, but locally intensive, farming and ranching activity. In the relatively barren area north of Yucca Mountain, the major agricultural activity is the grazing of cattle and sheep.

Population

Yucca Mountain is located in Nye County, NV. As shown in Figure I-2, eight counties in Nevada and one county in California border Nye County. The county population levels shown in this figure are from the 1990 census. Population estimates for Nye County and its communities were updated in 1994; these updated estimates will be used in the remainder of this section. Excluding Clark County, which is the major population center in Nevada (about one million persons), the population density of counties adjacent to Yucca Mountain is about 0.7 people per square mile (0.4 per square km)(NYE93d).

For comparison, the population density of the 48 contiguous states is 70.3 persons per square mile (27 per square km). The average population density of Nevada is 10.9 persons per square mile, or 3.1 per square km. The only region in Nye County with a density greater than three people per mile is in the extreme southern portion, in and around the community of Pahrump, which is 60 miles west of Las Vegas (NYE93d).

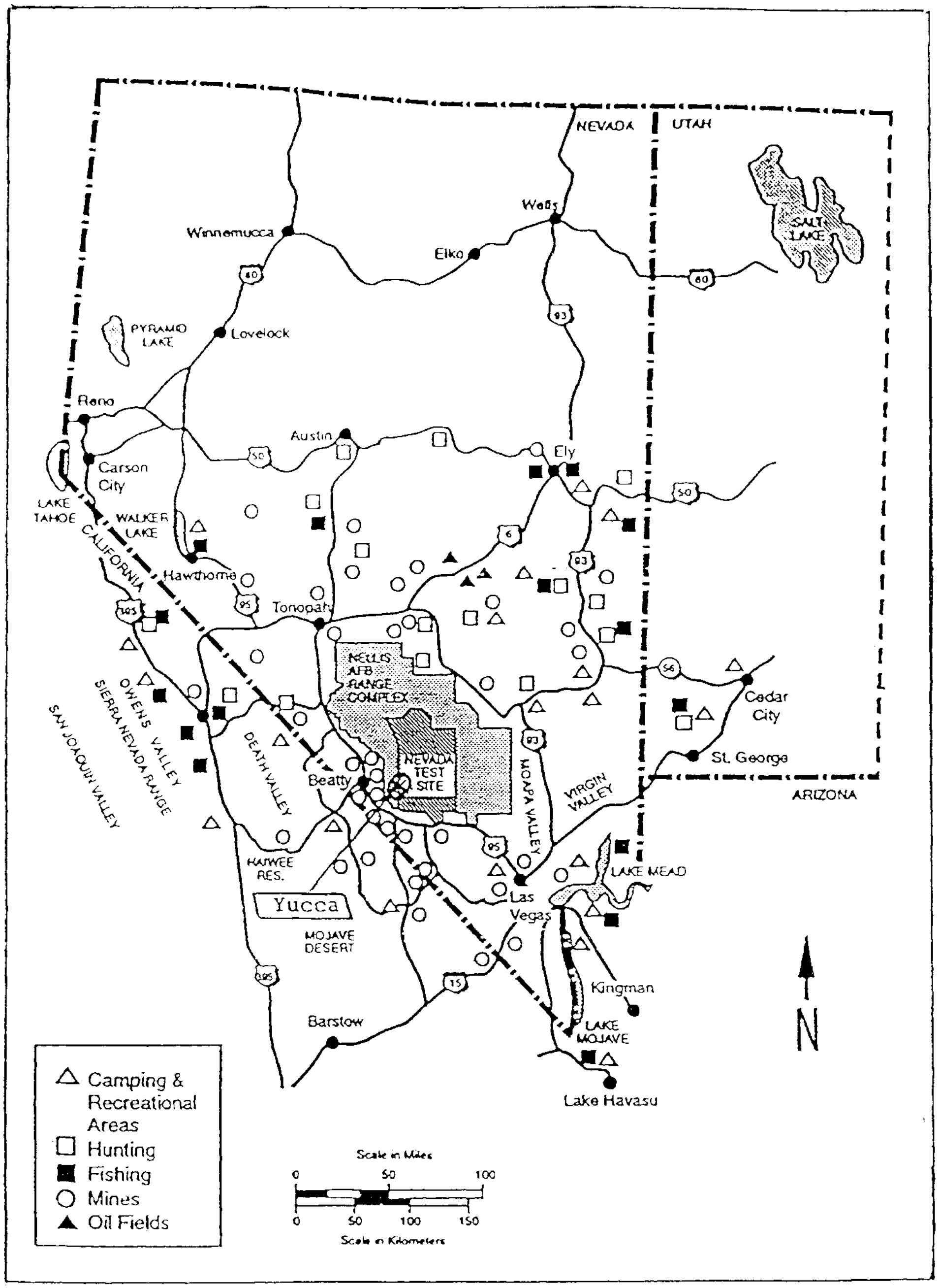

Figure I-1. General Land Use Within 180 Miles (300 km) of the Nevada Test Site (NYE93a)

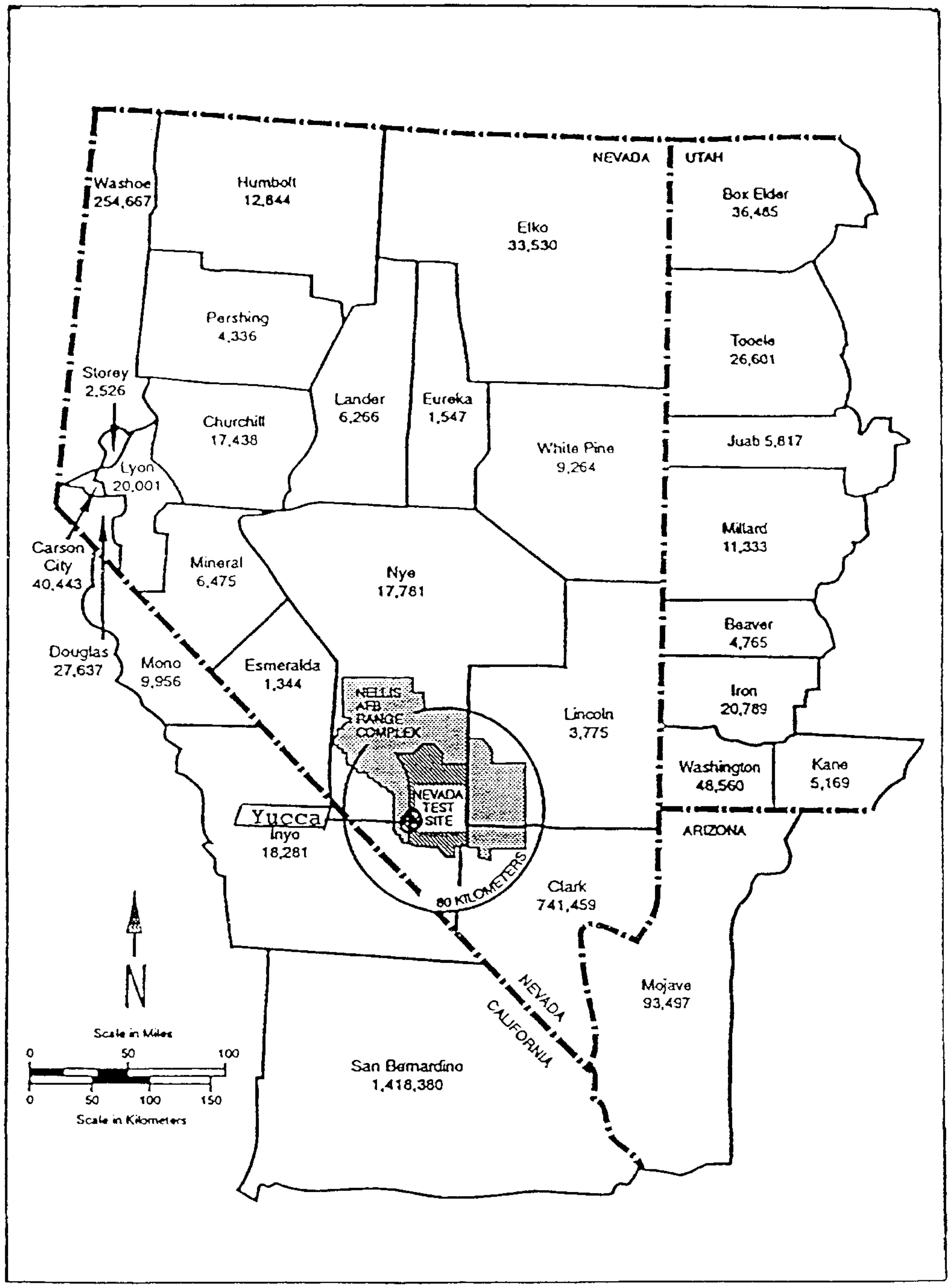

Figure I-2. Population of Arizona, California, Nevada, and Utah Counties Near the Nevada Test Site (NYE93a)

The primary area of interest (based on DOE95a) is within an 80-km radius of Yucca Mountain, shown approximately in Figure I-2. This region also includes several small communities that are not shown here, but are generally located southeast to west of the site. The largest of these communities, Pahrump, is a growing rural community with a 1994 estimated population of 10,892. Pahrump is located about 80 km southeast of Yucca Mountain. Other communities in the immediate area include: Beatty (25 km west) and Amargosa Valley (20 km south) in Nye County, Nevada; Indian Springs (70 km east) in Clark County, Nevada; and Death Valley Junction in Inyo County, California (55 km south). Also contained in this area are portions of Death Valley National Park (DVNP). The socioeconomic characteristics of the Nevada communities are summarized in Table I-1 and in NYE94.

The Mojave Desert of California, which includes DVNP, lies along the southwest border of Nevada. Population within the park ranges from a minimum of 200 residents in the summer to 5,000 tourists per day in winter (excluding major holidays, when as many as 30,000 can be present). The largest populated area in the region is Ridgecrest, California (160 km southwest), with a population of 28,000. The Owens Valley, beginning 50 km west of Death Valley, contains many small towns, the largest of which is Bishop, California, with a 1990 population of 3,475. As shown in Figure I-2, the area of southwestern Utah, due east from Yucca Mountain, is more developed than the adjacent parts of Nevada, based on population levels. St. George (200 km east) is the largest community, with a 1990 population of 28,500. The extreme northwestern part of Arizona (Mojave County) is mostly range land except for the portion containing Lake Meade and other small communities along the Colorado River.

Employment

The NTS, which is adjacent to Yucca Mountain, accounts for a high concentration of employment in southern Nye County, although approximately 80 percent of the employees reside in Clark County (M&O94). During the week, an average of approximately 140 persons reside in NTS group quarters at Mercury. In December 1994, NTS employment was reported to be 3,000, down significantly from more than 5,000 workers in the mid-1980s. At the same time, the employment at Yucca Mountain increased substantially from 281 workers (65.8 FTEs) in January 1988 (M&O90) to 540 (371.9 FTEs) in December 1994 (M&O95). Table I-1 shows establishments in the Nye County communities by Standard Industrial Classification (SIC) Groups and demonstrates potential employment concentrations in the region.

Table I-1. Summary of Socioeconomic Characteristics Compiled by Community for the First Quarter of 1994 (DOE95a)

Socioeconomic Characteristics	**Pahrump**	**Beatty**	**Amargosa Valley**	**Indian Springs**
Square Miles	298	692.5	499	18
Acreage (1)	190,720	443,200	319,360	11,520
Total Occupied Housing Units:	4,879	788	352	492
Single Family (2)	4,692	719	344	492
Multi Family	187	69	8	
Group Quarters (3)	2	4		
Total Estimated Population:	10,892	1,947	909	1,200
Single Family (2)	10,463	1,747	888	1,200
Multi Family	417	168	21	
Group Quarters (3)	12	32		
Establishments by Standard Industrial Classification Group:	660	134	60	37
Ag/For/Fishing (4)	20	6	7	
Mining/Construction	98	15	6	
Manufacturing	21	2	1	
TCEGSS (5)	42	8	7	2
Wholesale & Retail Trade	178	29	15	5
FIRE (6)	67	17		7
Services	209	47	20	13
Government	25	10	4	10

* Tax boundaries specified by the Nye County Board of Commissioners are used to delineate the boundaries for Pahrump, Beatty, and Amargosa Valley. For Indian Springs, the legal description specified by the Clark County Commissioners for the unincorporated town is used.

Please note: Community boundaries encompass many whole, as well as some partial, cells. Therefore, information within this table is not directly comparable to the information presented in this Appendix. For Pahrump, the information included in this table is for the entire community both inside and outside of the RadMP grid.

(1) Acreages for the communities in Nye County were supplied by the Nye County Assessor's Office, and are the best estimate of the actual acreages encompassed within the taxation boundaries (Nye County Assessor's Office, 1988).

(2) This category was refined to include all single-family dwellings and mobile homes, due to the new method of data collection. Units housing persons visiting or residing in the area on a "short-term" temporary basis, such as in RV parks, are not included.

(3) This category includes the group quarters in Pahrump and the employee housing in Beatty, reported as the number of facilities in the housing section (not included in total) and number of residents in the population section (included in total and not used to calculate the PPH).

(4) Agriculture/Forestry/Fishing.

(5) TCEGSS refers to Transportation, Communications, Electric, Gas, and Sanitary Services.

(6) FIRE refers to Finance, Insurance, Real Estate.

Agriculture

Within the 80 km radius around Yucca Mountain, agricultural activity appears to be holding steady, with increases in alfalfa being offset by decreases in acreage planted in barley and oats. Farmers in the Amargosa Valley primarily grow sod/turf, alfalfa, barley, oats, and relatively small amounts of fruits. The area west of Pahrump grows primarily alfalfa. The majority of livestock in the region consists of bee colonies in Pahrump (honey production); catfish farming in Amargosa Valley; dairy cows in Pahrump and Amargosa that produce milk shipped to southern California; pigs raised for commercial consumption locally; and range cattle. Recent openings of new dairies in Amargosa have generated additional demand for locally produced feed for dairy cows.

Mining and Construction

Within the 80-km radius, the areas west and south of Yucca Mountain near the communities of Beatty, Amargosa Valley, and Pahrump contain 12 mining and open pit operations and 71 construction and drilling operations. The activities associated with these businesses include mining, sand and gravel operations, construction, drilling, and landfills. Other active mines and oil and gas wells are widely dispersed throughout the state.

Ecosystems

As described in previous sections, the diverse topography, geology, and climates of the southern Nevada desert create a complex variety of plant life. Vegetation ranges from sparse desert scrub in the lowest valleys to well-developed woodland on highlands above 2,000 meters (m). Only sheer cliffs and playa floors are devoid of plants. Even the apparently barren hills of the Amargosa Desert support widely spaced shrubs and succulents.

Table I-2 shows plant types and associations found in the regions in and around Yucca Mountain. As described in the table, plant associations classified as Great Basin conifer woodlands are distinguished by dominance of single-needle pinyon pine and Utah juniper. In south-central Nevada, these pygmy conifer communities are restricted to elevations above 1,800 meters. Dominant plant taxa in Great Basin desert scrub communities are flowering plants such as shadscale. These desert scrub associations usually occur below the tree line, but above Mojave Desert vegetation. The plant species typical of lower elevation Mojave desert scrub vegetation, like creosote bush and white bursage, have their center of distribution south of Yucca Mountain. Exceptions include plants dominated by species endemic to the northern Mojave, such as box thorn and greasewood. The vegetation classifications at Yucca Mountain are dominated by representatives of Mojave desert scrub. However, many Mojave desert scrub species are at the northern limits of their distribution in southwest Nevada, and most are restricted to elevations below 1,800 m.

Table I-2. Principal Plant-Community Types and Examples of Representative Plant Associations on Rock Slopes (SPA85)

Representative Plant Association	Distribution and Common Associates
Great Basin Conifer Woodland	
Pinus monophylla-Quercus gambelii-Juniperus osteosperma	Volcanic highlands in the northern test site, generally at elevations above 1,950 meters (such as the eastern Pahute Mesa and Timber Mountain). Associates include Artemisia tridentata Symphoricarpos longiflorus, Purshia tridentata, and Lupinus argenteus.
Pinus monophylla-Artemisia tridenta-Juniperus osteosperma	Highlands at elevations above 1,770 meters; restricted to xeric habitats at elevations above 2,100 meters. Common associates include Artemisia nova, Cowania mexicana, Haplopappus nanus, and Brickellia microphylla.
Great Basin Desertscrub	
Atriplex canescens-mixed scrub	The flanks of hills and rocky mesas, usually of volcanic substrate. Elevations from about 1,500 to 2,000 m.
Atriplex confertifolia-mixed scrub	Limestone and dolomite slopes at elevations from about 850 to 1,700 m. Common associates are usually: Mojave Desert shrubs such as Amphipappus fremintii; Ephedra torreyana; Larrea divaricata; and Gutierrezia microcephala.
Mojave Desertscrub	
Lepidium fremontii-mixed scrub	On the talus slopes and ridges of calcareous mountains at elevations from about 1,050 to 1,700 meters. Associates include a diverse complement to upper elevation Mojave desertscrub species, such as Coleogyne ramosissma, Ephedra torreyana, Buddleja utahensis, and Lycium andersonii.
Gutierrezia microcephala-mixed scrub	Talus slopes, cliff bases, and ridges generally at elevations below 1,400 meters on calcareous substrates. Common associates include Larrea divaricata, Ambrosia dumosa, Ephedra spp., Amphipappus fremontii, and Lycium pallidum.
Ambrosia dumosa-Larrea divaricata	On talus slopes, ridges, and mesas generally at elevations below 1,200 m. Normally occurring with lower-elevation Mojave Desert species, such as Peucephyllum schottii, Eucnide urens, Gutierrezia microcephala, and Echinocactus polycephalus. Atriplex confertifolia is common at some sites.

According to the U.S. Fish and Wildlife Service (USF99, 64 FR 46542), Southern Nye County (south of Tonopah), like most of the state, hosts a number of threatened and endangered species, as shown in Table I-3. According to the Nye/Esmeralda Economic Development Authority, however, only two of these have affected growth and development (NYE93b).

Table I-3. Threatened and Endangered Species in Southern Nye County (NYE93b)

Common Name	Scientific Name
ENDANGERED	
Southwestern Willow Flycatcher	Empidonax traillii extimus
Devil's Hole pupfish	Cyprinodon diabolis
Ash Meadows Amargosa pupfish	Cyprinodon nevadensis mionectes
Warm Springs pupfish	Cyprinodon nevadensis pectoralis
Ash Meadows speckled dace	Rhinichthys osculus nevadensis
Ash Meadows speckled pupfish	Cyprinodon nevadensis mionectes
Amargosa niterwort	Nitrophila mohavensis
THREATENED	
Bald Eagle	Haliaeetus leucocephalus
Desert tortoise	Gopherus agassizii
Ash Meadows naucorid	Ambrysus amargosus
Ash Meadows milkvetch	Astragalus phoenix
Spring-loving centaury	Centaurium namophilum
Ash Meadows sunray	Enceliopsis nudicaulis var. corrugata
Ash Meadows gumplant	Grindelia fraxino-pratensis
Ash Meadows ivesia	Ivesia eremica
Ash Meadows blazing star	Mentzelia leucophylla

The Devil's Hole Pupfish has limited development in the Ash Meadows area of Amargosa Valley. Protection of the Pupfish and several other threatened and endangered species resulted in the creation of the Ash Meadows National Wildlife Refuge. Thus, casual use of this region is restricted to existing roads, trails, and washes. The ground water level is protected in spring flows in Ash Meadows, which is managed by the Fish and Wildlife Habitat Management Program of the Bureau of Land Management.

Also, like much of southern Nevada, certain areas in Pahrump and Amargosa Valley have been classified as desert tortoise habitat. Land within this classification requires a biological assessment before it can be developed. If necessary, the U.S. Fish and Wildlife Service may require a second environmental assessment and a site-specific habitat conservation plan.

Sources of Human Radiation Exposure

All members of the public are exposed to ionizing radiation from a variety of sources. Exposure to some sources is not only inevitable, but life-long; exposure to other sources may be episodic and influenced by numerous factors. For convenience, sources of public exposures are commonly categorized as: (1) natural origin and unperturbed by human activities; (2) natural origin but affected by human activities (termed enhanced natural sources); and (3) man-made sources. Natural radiation and naturally-occurring radioactivity in the environment are by far the major sources of human radiation exposure. Consequently, these sources have been extensively studied and are commonly compared with various man-made sources of ionizing radiation.

Natural sources include cosmic radiation from outer space; terrestrial radiation from radionuclides in soil, rocks, and other materials; and radionuclides within our bodies. Each of these natural sources has specific characteristics that cause variations in individual exposures, which are influenced by geographic location, dietary habits, lifestyles, and other factors.

Enhanced natural sources include those for which human exposures have increased due to deliberate or inadvertent behavior. For example, extensive air travel may significantly increase exposure to cosmic radiation. Similarly, tailings from phosphate mining, when used for construction fill, can increase terrestrial exposure. Another example involves the combustion of fossil fuels (coal, oil, natural gas) by industry and electric utilities, which results in the localized release of naturally-occurring radionuclides in stack gases released into the air. Even indoor exposure to radon might be considered "enhanced," because air concentrations of radon and radon daughters are significantly affected by the design, construction, and use of a home or building.

In addition to natural sources, most individuals are also exposed to radiation from numerous man-made sources, materials, and devices. The largest category among man-made sources is classified as medical and refers to a variety of diagnostic and therapeutic procedures (e.g., x-rays, fluoroscopic examinations, CAT-scans, radioactive pharmaceuticals and implants, and exposure to teletherapy units). The public is also exposed to a variety of consumer products, such as televisions and smoke detectors, nuclear weapons production and testing, and nuclear power and the associated fuel cycle.

The scientific literature abounds with information on public exposure to natural and man-made radiation sources. Among the most comprehensive reports are those issued by EPA (EPA72a, EPA77) and several prominent scientific committees, including the United Nations Scientific Committee on the Effects of Atomic Radiation (UNS88, UNS93, UNS94), the Committee on the Biological Effects of Ionizing Radiation of the National Academy of Sciences (NAS80, NAS88, NAS90), and the National Council on Radiation Protection and Measurements (NCR87a, NCR87b, NCR89).

This section summarizes average exposures received by the general public in the United States, as well as estimates of exposures to individuals currently residing in the vicinity of Yucca Mountain.

Natural Radiation Sources and Exposures

Cosmic Radiation

Cosmic radiation refers to primary energetic particles originating from the sun and from outside the solar system, as well as to secondary radiation generated by their interaction with the earth's atmosphere. In the absence of the earth's atmosphere, the biosphere’s dose of cosmic radiation would be about 1,000 times greater than current levels. The intensity of cosmic radiation is also affected by the earth's geomagnetic field, which varies with latitude, and by the sun's activity, which follows a cycle of about 11 years. However, at ground level, variations in cosmic radiation intensity within the continental United States, due to the geomagnetic field effect, are less than two percent (CAR69); the 11-year variations due to solar activity are less than 10 percent of the mean level (ERD77).

At sea level, the average cosmic-ray annual dose equivalent is about 26 mrem. This annual dose rate essentially doubles with each 2,000 meter increase in altitude in the lower atmosphere. Accordingly, inhabitants of Denver at 1,600 meters and Leadville, Colorado, at 3,200 meters have estimated annual external exposures from cosmic radiation of 50 mrem and 125 mrem, respectively (NCR87b). Considering the distribution of altitudes for the U.S. population, an average annual cosmic-ray dose of 27 mrem is generally assumed. However, the dose to a specific individual is affected by the amount of time spent outdoors and the shielding provided by indoor environments.

The cosmic-ray exposure rates in aircraft are considerably higher. At normal commercial jet aircraft altitudes of about 11-12 kilometers (km), average dose rates of 0.5 mrem/hour have been estimated (NAS86). A single transcontinental flight from New York to Los Angeles would be expected to result in an average dose of 2 to 3 mrem, so crew members working ordinary schedules on high-altitude, long-distance routes would likely receive average doses in excess of 500 mrem per year (BAR95). Solar flares, although infrequent, can yield dose rates in excess of 1,000 mrem/hour at these altitudes (UNS82).

Naturally-Occurring Radionuclides

Several dozen naturally-occurring radionuclides exist with half-lives on the same order of magnitude as the estimated age of the earth (about 4.5 billion years). These include potassium-40, rubidium-87, and radionuclides belonging to the decay chain series of uranium-238, uranium-235, and thorium-232 (such as radium). These naturally-occurring radionuclides contribute to exposure that is both external and internal to the body.

External Terrestrial Radiation

Potassium-40 and several decay-chain members in each of the uranium and thorium series emit penetrating gamma radiation. These radionuclides exist in low, but varying, concentrations in virtually all types of rocks and soil. Since many building products, such as cut stone, brick, cement, and gypsum are derived from natural stone, they also contribute to external radiation. For most individuals, external exposure received indoors to radionuclides derived from the terrestrial environment is nearly equivalent to that received outdoors (Table I-4).

Table I-4. Comparison of External Indoor to Outdoor Radiation Dose

Building Materials (exterior walls)	**Percent of Outdoor Terrestrial Radiation**
1. Mostly Woodframe (single homes)	70 - 82
2. Brick (apartment building)	96
3. Stone (apartments & houses)	80 - 100
4. Steel and Concrete (office building)	87 - 106

Source: EPA72b

Two distinct major regions of the United States differ in average terrestrial dose rates by a factor of about two (EPA72b). A lower dose rate of 16 mrem/year corresponds to the Atlantic and Gulf Coastal Plain; the remaining major portion of the country (referred to as Non-Coastal Plain) yields average dose rates of about 30 mrem/year (Figure I-3). The Denver area showed average terrestrial dose rates of 63 mrem/year. (It is assumed that other areas on the eastern slopes of the Rocky Mountains would show similar levels.) It should be further noted that for each average value cited above, the range in values between the 10th and 90th percentile differed by at least a factor of two.

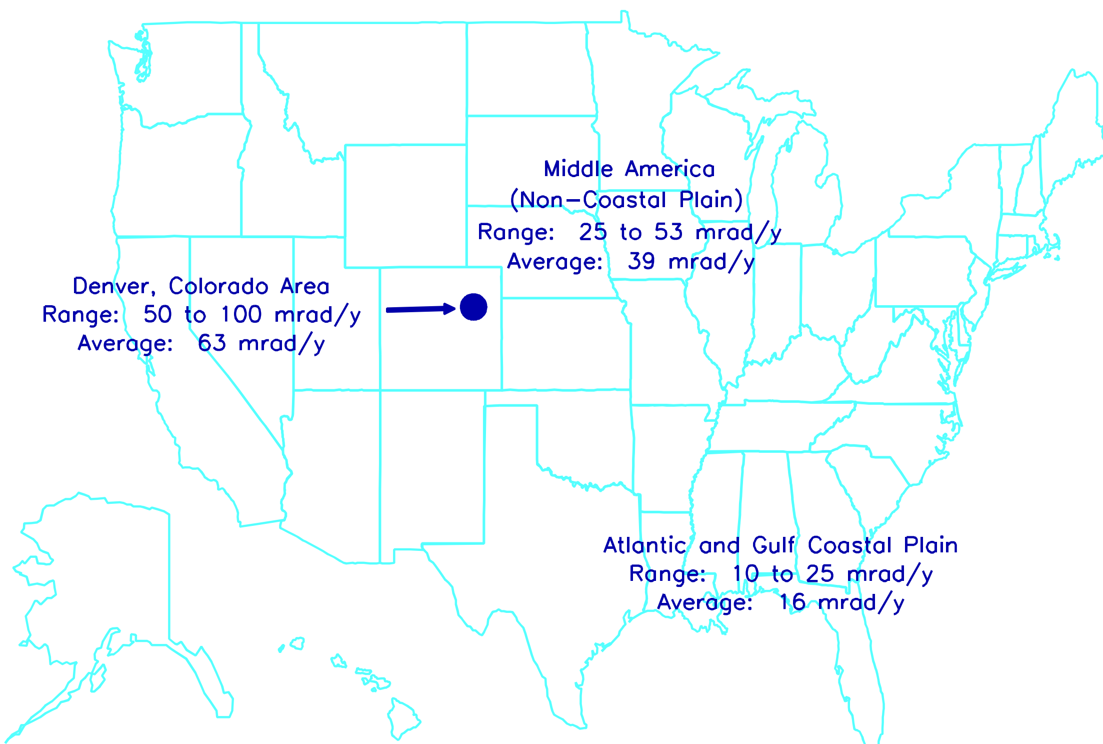

Figure I-3. Terrestrial Dose Rates in the United States

Radionuclides in the Body

Naturally occurring radionuclides in rocks and soil also give rise to internal radiation exposure because they are present in drinking water and foods that are consumed by humans. Upon ingestion, their distribution in the body is complex and is governed by their chemical properties and the physiological regulatory mechanisms of the body. For example, radioactive potassium-40 exists in a fixed ratio to its non-radioactive form of potassium. Potassium is an essential dietary element to most living systems, and it is distributed nearly uniformly in lean soft tissue. The concentrations of other radionuclides associated with the decay chains of uranium and thorium are potentially highly variable. For humans, internal exposure to these naturally-occurring radionuclides is not only determined by dietary composition, but also by the total quantities of foods consumed and the geographic location/origin of the food products. Maximum body burdens would, therefore, be expected for individuals who consume foods (and water): (1) that are derived from areas of high terrestrial background radioactivity; (2) that are higher in radionuclide content than foods of normal diets; and (3) in large quantities.

Internal Doses. Reports of unusual exposure in the United States are contained in the literature. High exposures have been documented for Eskimo and select Indian tribes whose diet includes reindeer caribou, moose, elk, and deer that subsist largely on lichen during winter months. Here the lichen-animal-human food chain leads to high concentrations of natural Pb-210 and Po-210 (as well as Cs-137 from fallout) in the diet (HOL66, ECK86, MAT75).

In general, however, there are insufficient data at this time to define the extent of variability of internal exposures among individuals. Factors cited above that would potentially yield significant differences in exposure are largely eliminated by a food distribution system that is nationwide and offers a wide range of foods.

Dose estimates from internally-deposited naturally-occurring radionuclides are principally based on limited post-mortem measurements of the nuclide content of various organs. Estimates of average doses to specific tissues of the body are given in Table I-5. By multiplying annual tissue doses by their corresponding weighting factors, it is estimated that the average individual in the United States receives an internal dose of 39 mrem per year from naturally occurring radionuclides.

Table I-5. Average Annual Dose from Internal Exposure to Naturally Occurring Radionuclides

Tissue	Tissue Dose (mrem)	Tissue Weighting Factor	Effective Dose Equivalents (mrem)
Lung	33	0.12	4
Gonads	36	0.25	9
Bone Surfaces	100	0.03	3
Bone Marrow	50	0.12	6
Other Tissues	35	0.48	17
Total Body		1.00	39

Inhaled Radionuclides

Except for radon and its short-lived decay products, the inhalation pathway yields doses that are small relative to the ingestion pathway. For this reason, reference to inhaled radionuclides is limited to gaseous radon and its solid radioactive daughter products. This group of radionuclides belongs to the uranium-238 and thorium-232 decay chain series and is, therefore, present in all soils and rocks, as previously discussed.

As a gas, radon is able to diffuse through soil pore spaces and escape into surrounding media. In outdoor air, radon quickly diffuses and results in relatively small exposures. Significant exposures, however, result when radon gas enters homes and other buildings where it is contained for periods of time that allow the buildup of its solid (i.e., non-gaseous) radioactive daughters. When inhaled, particulate radon daughters deposit onto the mucous layer of the airways and emit energetic alpha particles, imparting substantial doses to cells that line the upper respiratory tract and lungs.

Estimates of Radon Doses. The magnitude of human exposure to radon and radon daughters is not only influenced by the amount of radon formed in the soil, but also by numerous other factors affecting its migration and movement through soil, rate of entry into a home or building, and containment and daughter buildup in indoor air. For example, factors affecting exposure include soil porosity and moisture content, the design of the structure, and building operating variables related to heating, air conditioning, and ventilation.

A large number of localized survey data exist for indoor radon or decay-product concentrations. However, most of these measurements have been made in single-family houses, and little data exist for high rise apartments, commercial and industrial buildings, and other structures in which various population subgroups spend significant amounts of time.

Further complicating estimates of average exposure and the distribution of individual exposures is the fact that existing data exhibit very large variations. For example, clusters of unusually high indoor radon concentrations have been found in parts of northeastern Pennsylvania, New Jersey, and southeastern New York. This area, known as the Reading Prong, is characterized by soil concentrations of uranium series radionuclides that are about 100 times greater than the national average.

Best estimates suggest an average indoor radon concentration of about 1.25 pCi/L, which yields an average individual dose (i.e., effective dose equivalent) of about 200 mrem per year (NCR87a, NCR87b).

<u>Summary of Natural Background Exposures</u>

Table I-6 summarizes the average individual exposures in the United States to natural background radiation. On average, cosmic radiation, external terrestrial gamma radiation, and radionuclides within the body contribute nearly equally, yielding a total dose of about 100 mrem per year. However, this is only about one-half of the annual inhalation exposure resulting from indoor radon and its decay products, estimated to be 200 mrem. It is important to note, however, that the dose resulting from exposure to indoor radon has a very large amount of variability, with a significant number of people experiencing doses that are several times that of the average value.

Table I-6. Estimated Average Annual Dose* To Members of the Public in the United States from Natural Background Radiation

Source	**Dose* (mrem/yr)**
Cosmic	28
Terrestrial	28
In the Body	39
Inhaled (Radon)	200
Rounded Total	300

* All doses are expressed as effective dose equivalents.

Public Exposures to Artificial and Other Sources of Radiation

Members of the public are also exposed to a variety of radiation sources categorized as "artificial," i.e., those that involve human technological activities. Among artificial sources, the largest exposures involve medical x-rays and radioactive pharmaceuticals used for diagnostic purposes or the treatment of various diseases. There are also a number of consumer products that contain radioactivity or emit radiation.

It is estimated that on average, artificial sources contribute an annual dose of 60 mrem. An important aspect of human exposure to most of these sources is that the exposure is: (1) episodic; (2) voluntary; or (3) has an associated benefit to the individual or society at large.

Medical Sources

Radiation has broad application in the diagnosis and treatment of various diseases that affect humans and is widely employed by physicians, dentists, podiatrists, chiropractors, and other health-care professionals. Diagnostic radiation principally involves x-rays, fluoroscopic examinations, and specialized medical imaging procedures such as computerized tomography and scans involving radiopharmaceuticals. Therapeutic uses of radiation, such as cancer therapy, involve similar sources of radiation but deliver larger individual doses.

Table I-7 provides summary data on medical radiation exposures in the United States (NCR89). It is estimated that on average, medical radiation contributes an annual dose of about 54 mrem to individuals living in the United States. While such an average value is an important and useful statistic, it must be pointed out that the distribution of medical exposures among individuals is highly variable.

Consumer Products

Many commercial and consumer products either emit radiation or contain radioactive materials. In 1977, the NCRP issued a comprehensive report, NCRP Report No. 56 (NCR77), that estimated population exposures from consumer products. Because of revised Federal regulations and newly introduced technologies, the NCRP updated its earlier estimates in a revised report issued in 1987 (NCR87c). Scaling the population estimates contained in the 1987 report to the current U.S. population of 260 million, it is estimated that the average annual exposure in the United States to consumer products is in the range of six to 13 mrem.

Table I-7. Estimated Total Number and Frequencies of Diagnostic Procedures in the United States and Associated Radiation Doses

Group	Total No. of Exams	No. of Exams per 1,000 Population	Range of Doses per Exam (mrem)[1]	Avg. Dose Per Exam (mrem)[1]	Avg. Annual Dose to a Member of the Public (mrem/yr)[1]
Diagnostic X-Rays[2]	181,000,000	1,230	6 > 400	50	40
• Physicians/Osteopaths	164,000,000	724	---	---	---
• Chiropractors	9,800,000	43	---	---	---
• Podiatrists	5,900,000	23	---	---	---
• Dentists	101,000,000	440	---	---	---
Radiopharmaceuticals[3]	7,400,000	32	150-1,200	430	14
Total					54

[1] Doses are expressed in effective dose equivalents.
[2] Data reflect procedures performed in 1980.
[3] Data reflect procedures performed in 1982.

This estimate does not include the contribution of tobacco, which contains Po-210. The deposition of Po-210 on the bronchial epithelium of smokers is estimated to result in a localized tissue dose of 16 rem/year, which corresponds to an effective dose equivalent of 1,300 mrem/year. Current data compiled by the American Cancer Society identified 26 percent of persons aged 18 and over as smokers (ACS95). Therefore, the average annual dose to adults from tobacco is estimated to be 340 mrem.

Thus, radiation exposure from the use of tobacco not only represents the greatest contributor to the effective dose equivalent of all consumer products, but also exceeds the average combined contributions from indoor radon and all other natural sources of radiation.

Miscellaneous Sources of Public Exposures

Nominal exposure to members of the public may also result from past and ongoing activities related to nuclear power generation and associated fuel cycle facilities, other NRC-licensed facilities (e.g., radiopharmaceutical manufacturers, hospitals, research facilities), DOE facilities associated with nuclear weapons, and the transportation of radioactive materials. For all but transportation, exposure results primarily from airborne releases.
Public dose estimates for these source categories rely on computer models. The discrete nature of these facilities/sources suggests that public exposures are highly variable and primarily affect

near-field residents. Doses as high as 50 mrem/year, for example, have been assigned to near-field residents of the Oak Ridge Reservation (NCR87c). The total estimated population dose of 16,000 person-rem from all such sources yields an average annual dose of about 0.6 mrem to individuals in the near-field. Since the exposed near-field population represents only about 10 percent of the total U.S. population, these miscellaneous sources are thought to contribute about 0.06 mrem/year on average to members of the total population.

Between 1945 and 1962, atmospheric tests conducted by the United States involved nuclear weapons with an explosive yield of about 140 megatons of TNT equivalence, which represents about 27 percent of the world's total, estimated to be 510 megatons (UNS82). The radiation dose commitment from fallout has changed significantly over the years due to natural decay and depletion/removal mechanisms from environmental media which limit further biological uptake. The current dose rate to members of the general public is estimated to be one mrem per year (NCR87b), derived largely from residual radionuclides contained in our bodies.

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