6.0 DOSE ASSESSMENT

The offsite environmental surveillance system, operated around the Nevada Test Site (NTS) by the U.S. Environmental Protection Agency's (EPA's) Radiation and Indoor Environments National Laboratory in Las Vegas (R&IE-LV), measured no radiation exposures attributable to recent NTS operations. However, using onsite emission measurements, estimates provided by U.S. Department of Energy (DOE) and calculated resuspension data as input to the EPA's Clean Air Package 1988 (CAP88)-PC model, a potential effective dose equivalent (EDE) to the maximally exposed individual (MEI) was calculated to be 0.11 mrem (1.1×10^{-3} mSv) to a hypothetical resident of Springdale, Nevada, located 58 km (36 mi) west-northwest of Control Point 1 (CP-1) on the NTS. The calculated population dose (collective EDE) to the approximately 32,210 residents living within 80 km (50 mi) from each of the NTS airborne emission sources was 0.34 person-rem (3.4×10^{-3} person-Sv). Monitoring network data indicated a 1996 exposure to the MEI of 144 mrem (1.44 mSv) from normal background radiation. The calculated dose to this individual from worldwide distributions of radioactivity as measured from surveillance networks was 0.023 mrem (2.3×10^{-4} mSv). These maximum dose estimates, excluding background, are less than 1 percent of the most restrictive standard.

6.1 ESTIMATED DOSE FROM NTS ACTIVITIES

The potential EDE to the offsite population due to NTS activities is estimated annually. Two methods are used to estimate the EDE to residents in the offsite area in order to determine the community potentially most impacted by airborne releases of radioactivity from the NTS. In the first method, effluent release estimates, based on monitoring data or calculated resuspension of deposited radioactivity, and meteorological data are used as inputs to EPA's CAP88-PC model which then produces estimated EDEs. The second method entails using data from the Offsite Radiological Safety Program (ORSP) with documented assumptions and conversion factors to calculate the committed effective dose equivalent (CEDE). The latter method provides an estimate of the EDE to a hypothetical individual continuously present outdoors at the location of interest that includes both NTS emissions and worldwide fallout. In addition, a collective EDE is calculated by the first method for the total offsite population residing within 80 km (50 mi) of each of the NTS emission sources. Background radiation measurements are used to provide a comparison with the calculated EDEs. In the absence of detectable releases of radiation from the NTS, the Pressurized Ion Chamber (PIC) network provides a measurement of background gamma radiation in the offsite area.

There are four sources of possible radiation exposure to the population of Nevada, some of which were monitored by EPA's offsite monitoring networks during 1996. These were:

- Background radiation due to natural sources such as cosmic radiation, radioactivity in soil, and ^{7}Be in air.

- Worldwide distributions of man-made radioactivity, such as ^{90}Sr in milk and plutonium in soil.

- Operational releases of radioactivity from the NTS, including those from drill-back and purging activities when they occur.

- Radioactivity that was accumulated in migratory game animals during their residence on the NTS.

Operational releases and calculated sources of radioactive emissions from the NTS are used as input data for CAP88-PC to provide estimates of exposures to offsite populations. The other three sources of exposure listed above are discussed below.

ESTIMATED DOSE USING REPORTED NTS EMISSIONS

Onsite source emission measurements, as provided by DOE, are listed in Chapter 5, Table 5.1, and include tritium, radioactive noble gases, and plutonium. These are estimates of releases made at the point of origin. Meteorological data collected by the Air Resources Laboratory Special Operations and Research Division (ARL/SORD) were used to construct wind roses and stability arrays for the following areas: Mercury, Area 12, Area 20, Yucca Flat, and the Radioactive Waste Management Site (RWMS) in Area 5. A calculation of estimated dose from NTS effluents was performed using EPA's CAP88-PC model (EPA 1992). The results of the model indicated that the hypothetical individual with the maximum calculated dose from airborne NTS radioactivity would reside at Springdale, Nevada, 58 km (36 mi) west-northwest of CP-1. The maximum dose to that individual could have been 0.11 mrem (1.1×10^{-3} mSv). For comparison, data from the PIC monitoring network indicated a 1996 dose of 144 mrem (1.44 mSv) from background gamma radiation occurring in that area. The population living within a radius of 80 km (50 mi) from the airborne sources on the NTS was estimated to be 32,210 individuals, based on 1995 population data. The collective population dose within 80 km (50 mi) from each of these sources was calculated to be 0.34 person-rem (3.4×10^{-3} person-Sv). Activity concentrations in air that would cause these calculated doses are much higher than actually detected by the offsite monitoring network. For example, 0.107 mrem of the calculated EDE to the MEI is due to plutonium. The annual average plutonium concentration in air that would cause this EDE is 4.1×10^{-17} µCi/mL. This is about 20 times the annual average plutonium in air measured in Goldfield, Nevada, (nearest community) of 0.19×10^{-17} µCi/mL (Chapter 5, Table 5.22). Table 6.1 summarizes the annual contributions to the EDEs due to 1996 NTS operations as calculated by use of CAP88-PC and the radionuclides listed in Chapter 5, Table 5.1.

Input data for the CAP88-PC model included meteorological data from ARL/SORD and effluent release data calculated from monitoring results and from resuspension estimates. These release data are known to be estimates and the meteorological data are mesoscale; e.g., representative of an area approximately 40 km (25 mi) or less around the point of collection. However, these data are considered sufficient for model input, primarily because the model itself is not designed for complex terrain such as that on and around the NTS. Errors introduced by the use of the effluent and meteorological data are small compared to the errors inherent in the model. The model results are considered over-estimates of the dose to offsite residents. This has been confirmed by comparison with the offsite monitoring results.

ESTIMATED DOSE USING MONITORING NETWORK DATA

Potential CEDEs to individuals may be estimated from the concentrations of radioactivity, as measured by the EPA monitoring networks during 1996. Actual results obtained in analysis are used; the majority of which are less than the reported

minimum detectable concentration (MDC). No krypton or tritium in air data were collected offsite, so the onsite krypton for this year, and an average value for previous year's offsite tritium were used. No vegetable or animal samples were collected in 1996, so calculations for these intakes are not done.

Data quality objectives (DQOs) for precision and accuracy are, by necessity, less stringent for values near the MDC, so confidence intervals around the input data are broad. The concentrations of radioactivity detected by the monitoring networks and used in the calculation of potential CEDEs are shown in Table 6.2.

The concentrations given in Table 6.2 are expressed in terms of activity per unit volume. These concentrations are converted to a dose by using the assumptions and dose conversion factors described below. The dose conversion factors assume continuous presence at a fixed location and no loss of radioactivity in storage or handling of ingested materials.

- Adult respiration rate = 8400 m^3/yr (ICRP 1975)

- Milk intake (average for 20 and 40 yr old) = 110 L/yr (ICRP 1975)

- Water consumption = 2 L/day (ICRP 1975)

The EDE conversion factors are derived from Federal Guidance Report No. 11 (EPA 1988). Those used here are:

- ^{3}H:
  6.4×10^{-8} mrem/pCi (ingestion or inhalation)

- ^{7}Be:
  2.6×10^{-7} mrem/pCi (inhalation)

- ^{90}Sr:
  1.4×10^{-4} mrem/pCi (ingestion)

- ^{85}Kr:
  1.5×10^{-5} mrem/yr per pCi/m^3 (submersion)

- $^{238,239+240}Pu$:
  3.7×10^{-4} mrem/pCi (ingestion, $f_1=10^{-4}$)
  3.1×10^{-1} mrem/pCi (inhalation, Class Y)

The algorithm for the internal dose calculation is:

- (concentration) x (intake in volume [mass]/unit time) x (CEDE conversion factors) = CEDE

As an example calculation, the following is the result of breathing a concentration of tritium in air of 0.2 pCi/m^3:

- (2×10^{-1} pCi/m^3) x (8400 m^3/yr) x (6.4×10^{-8} mrem/pCi) = 1.1×10^{-4} mrem/yr

However, in calculating the inhalation CEDE from ^{3}H, the value must be increased by 50 percent to account for skin absorption (ICRP 1979). The total dose in one year, therefore, is $1.1 \times 10^{-4} \times 1.5 = 1.6 \times 10^{-4}$ mrem/yr. Dose calculations from ORSP data are summarized in Table 6.2.

The individual CEDEs, from the various pathways, added together give a total of 0.015 mrem/yr. Total EDEs can be calculated based on different combinations of data. If the interest was in just one area, for example, the concentrations from those stations closest to that area could be substituted into the equations used herein.

In 1996, because of budget cuts and the standby status of nuclear device testing, samples of game animals and garden vegetables were not collected. Also, the noble gas and tritium sampling network was discontinued in the offsite locations, and the air sampling network was reduced. In order to calculate an EDE for a resident of Springdale, Nevada, using the MEI from the CAP88-PC operation, it is necessary to make some assumptions. The NTS average krypton-85 concentration is representative of

statewide levels so it can be used. Also, tritium in air does not change much from year to year so previous data for that can be used. Finally, Goldfield, Nevada, has the nearest air sampler to Springdale, Nevada, so its plutonium concentration is used to calculate the EDE.

6.2 DOSE (EDE) FROM BACKGROUND RADIATION

In addition to external radiation exposure due to cosmic rays and gamma radiation from naturally occurring radionuclides in soil (e.g., ^{40}K, U, and Th and their progeny), there is a contribution from ^{7}Be that is formed in the atmosphere by cosmic ray interactions with oxygen and nitrogen. The annual average ^{7}Be concentration measured by the offsite surveillance network was 0.24 pCi/m^3. With a dose conversion factor for inhalation of 2.6×10^{-7} mrem/pCi, and a breathing volume of 8,400 m^3/yr, this equates to a dose of 5.2×10^{-4} mrem as calculated in Table 6.2. This is a negligible quantity when compared with the PIC network measurements that vary from 73 to 156 mR/year, depending on location.

6.3 SUMMARY

The offsite environmental surveillance system operated around the NTS by EPA's R&IE-LV detected no radiological exposures that could be attributed to recent NTS operations, but a calculated EDE of 0.015 mrem can be obtained, if certain assumptions are made, as shown in Table 6.2. Calculation with the CAP88-PC model, using estimated or calculated effluents from the NTS during 1996, resulted in a maximum dose of 0.11 mrem (1.1×10^{-3} mSv) to a hypothetical resident of Springdale, Nevada, 14 km (9 mi) west of the NTS boundary. Based on monitoring network data, this dose is calculated to be 0.005 mrem. This latter EDE is about 5 percent of the dose obtained from CAP88-PC calculation. This maximum dose estimate is less than 1 percent of the International Commission on Radiological Protection (ICRP) recommendation that an annual EDE for the general public not exceed 100 mrem/yr (ICRP 1985). The calculated population dose (collective EDE) to the approximately 32,210 residents living within 80 km (50 mi) of each of the NTS airborne emission sources was 0.34 person-rem (3.4×10^{-3} person-Sv). Background radiation yielded a CEDE of 3,064 person-rem (30.6 person-Sv).

Data from the PIC gamma monitoring indicated a 1996 dose of 144 mrem from background gamma radiation measured in the Springdale area. The CEDE calculated from the monitoring networks or the model, as discussed above, is a negligible amount by comparison. The uncertainty (2σ) for the PIC measurement at the 144 mrem exposure level is approximately 5 percent. Extrapolating to the calculated annual exposure at Springdale, Nevada, yields a total uncertainty of approximately 7 mrem which is greater than either of the calculated EDEs. Because the estimated dose from NTS activities is less than 1 mrem (the lowest level for which DQOs are defined, as given in Chapter 10), no conclusions can be made regarding the achieved data quality as compared to the DQOs for this insignificant dose.

Table 6.1 Summary of Effective Dose Equivalents from NTS Operations - 1996

	Maximum EDE at NTS Boundary[a]	Maximum EDE to an Individual[b]	Collective EDE to Population within 80 km of the NTS Sources
Dose	0.12 mrem (1.2×10^{-3} mSv)	0.11 mrem (1.1×10^{-3} mSv)	0.34 person-rem (3.4×10^{-3} person-Sv)
Location	Site boundary 40 km WNW of NTS CP-1	Springdale, NV 58 km WNW of NTS CP-1	32,210 people within 80 km of NTS Sources
NESHAP[c] Standard	10 mrem per yr (0.1 mSv per yr)	10 mrem per yr (0.1 mSv per yr)	-----
Percentage of NESHAP	1.2	1.1	-----
Background	144 mrem (1.44 mSv)	144 mrem (1.44 mSv)	3064 person-rem (30.6 person-Sv)
Percentage of Background	0.08	0.08	0.011

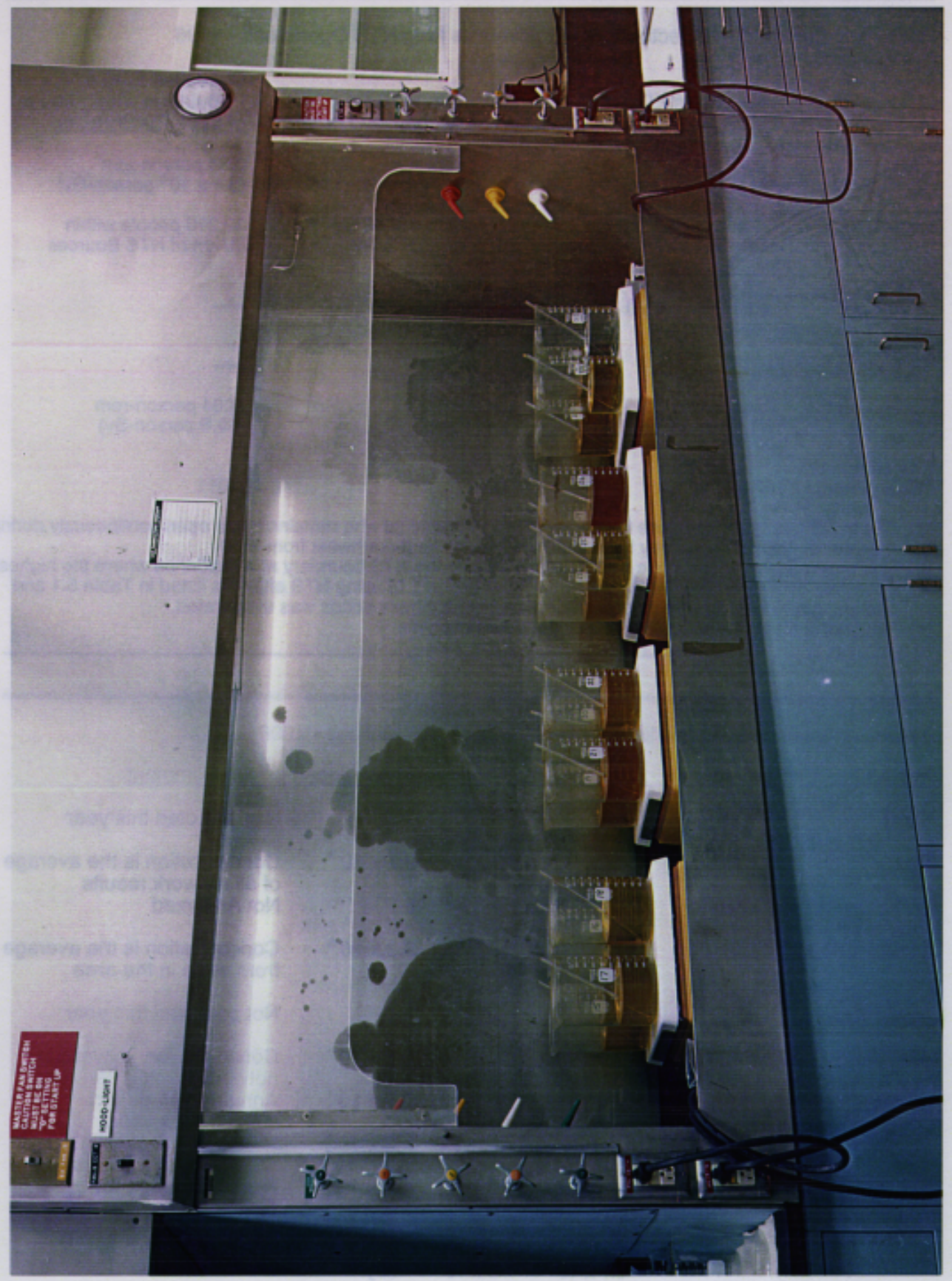
(a) The maximum boundary dose is to a hypothetical individual who remains in the open continuously during the year at the NTS boundary located 40 km (25 mi) west-northwest from CP-1.
(b) The maximum individual dose is to a person outside the NTS boundary at a residence where the highest dose-rate occurs as calculated by CAP88-PC (Version 1.0) using NTS effluents listed in Table 5.1 and assuming all tritiated water input to the Area 12 containment ponds was evaporated.
(c) National Emission Standards for Hazardous Air Pollutants.

Table 6.2 Monitoring Networks Data Used in Dose Calculations - 1996

Medium	Radionuclide	Concentration	Mrem\Year	Comment
Meat				Not collected this year
Milk	^{90}Sr	0.63 [a] (0.023)	9.7×10^{-3}	Concentration is the average of all network results
	^{3}H	0	0	Not Analyzed
Drinking Water	^{3}H	0.71 [a] (0.026)	3.3×10^{-5}	Concentration is the average from wells in the area
Vegetables				Not collected this year
Air	^{3}H	0.2 [b] (0.007)	1.6×10^{-4}	Concentration is average network result (1994 data)
	^{7}Be	0.24 [b] (0.010)	5.2×10^{-4}	Annual average for Goldfield, Nevada
	^{85}Kr	25.2 [b] (0.93)	3.8×10^{-4}	NTS network average
	$^{239+240}Pu$	1.7×10^{-6} [b] (6.3×10^{-8})	4.4×10^{-3}	Annual average for Goldfield, Nevada

TOTAL (Air = 5.5×10^{-3}, Liquids = 9.7×10^{-3}) = 1.5×10^{-2} mrem/yr

(a) Units are pCi/L and Bq/L.
(b) Units are pCi/m^3 and Bq/m^3.



Analyzing Bioassay Samples at Building 650 Laboratory