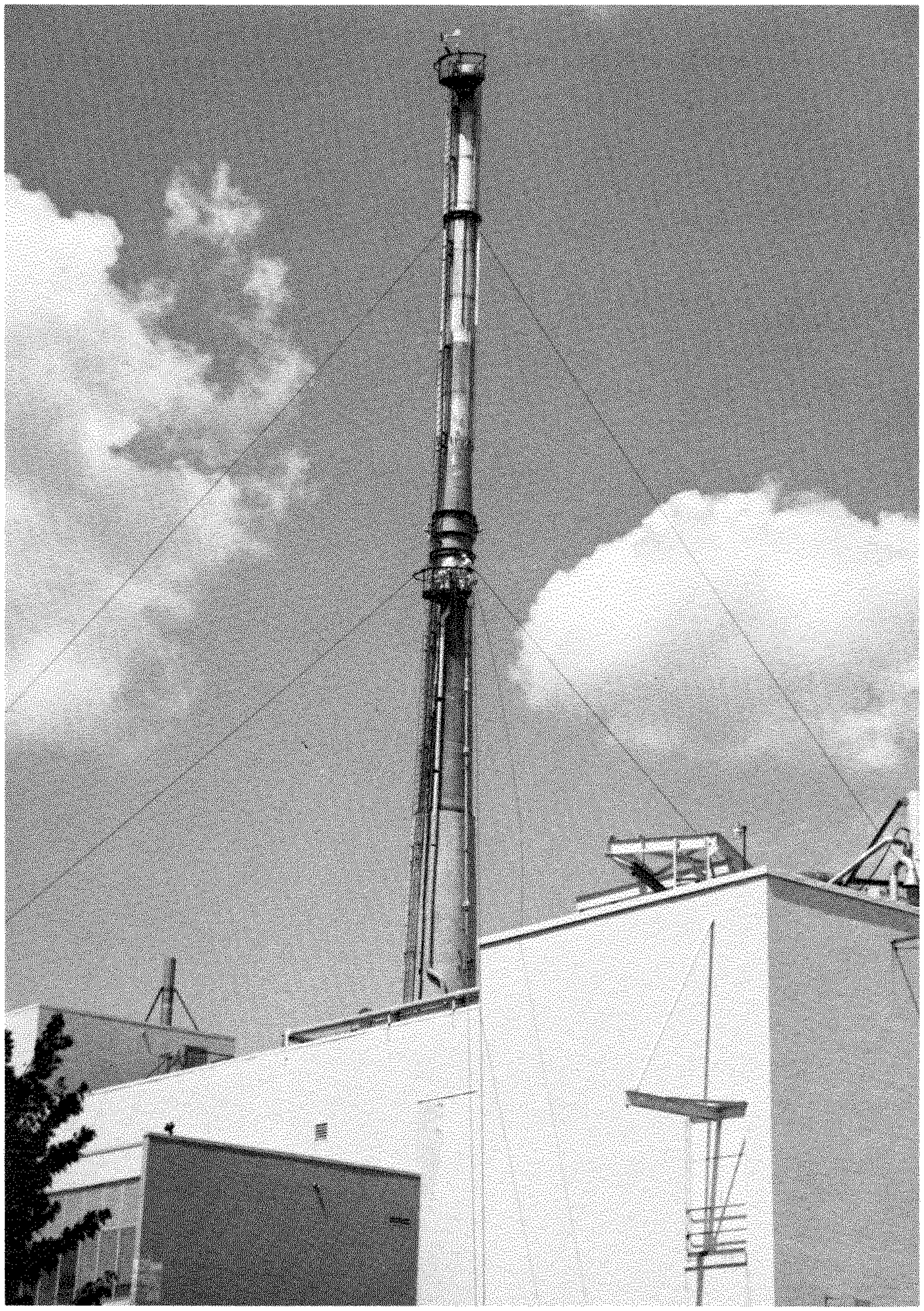

The West Valley Demonstration Project Main Plant Ventilation Stack

Radiological Dose Assessment

Each year the potential radiological dose to the public from the West Valley Demonstration Project is assessed in order to ensure that no individual could possibly have received an exposure exceeding the limits established by the regulatory agencies. The results of these conservative dose calculations demonstrate that the hypothetical maximum dose to an off-site resident is well below permissible standards and is consistent with the "as low as reasonably achievable" philosophy of radiation protection.

Dose Estimates

This chapter describes the methods used to estimate the dose to the public from radionuclides emitted from the Project through air and water discharges during 1991. The dose estimates, based on concentrations of radionuclides measured in air and water collected from monitored on-site effluent points throughout 1991 are compared to the radiation standards established by the Department of Energy (DOE) and the Environmental Protection Agency (EPA) for protection of the public. The radiation doses reported for 1991 are also compared to the doses reported in previous years.

Computer Modeling

Because of the difficulty of measuring the small amounts of radionuclides emitted from the site beyond those that occur naturally in the environment, computer codes were used to model the environmental dispersion of the radionuclides emitted from on-site monitored ventilation stacks and liquid discharge points and to calculate the effective dose equivalent (EDE) to the maximally exposed off-site individual and the collective effective dose equivalent (CEDE) to the population.These models have been approved by the Department of Energy and the Environmental Protection Agency to demonstrate compliance with radiation standards.

Radiological dose is evaluated for the three major exposure pathways: external irradiation, inhalation, and ingestion of local food products. The dose contributions from each radionuclide and pathway combination are then summed to obtain the reported dose estimates.

Sources of Radiation Energy and Radiation Exposure

Radionuclides

Atoms that emit radiation are called radionuclides. Radionuclides are unstable isotopes (variations of an element) that have the same number of protons and electrons as any other isotope of the element but different numbers of neutrons, resulting in different atomic masses. For example, the element hydrogen has two stable isotopes, H-1 and H-2 (deuterium), and one radioactive isotope, H-3 (tritium). The numbers following the element's symbol identify the atomic mass — the numbers of protons and neutrons — in the nucleus.

Once a radioactive atom decays by emitting radiation, the resulting daughter atom may itself be radioactive or stable. Each radioactive isotope has a unique half-life that represents the time it takes for 50% of the atoms to decay. Strontium-90 and cesium-137 have half-lives of about thirty years, while plutonium-239 has a half-life of 24,000 years.

Radiation Dose

The energy released from a radionuclide is eventually deposited in matter encountered along the path of radiation, resulting in a radiation dose to the absorbing material. The absorbing material can be either inanimate matter or living tissue.

While most of the radiation dose affecting the general public is background radiation, manmade sources of radiation may also contribute to the radiation dose to individual members of the public. Such sources can include diagnostic and therapeutic x-rays, nuclear medicine, fallout from atmospheric nuclear weapons tests, effluents from nuclear fuel cycle facilities, and consumer products such as smoke detectors and cigarettes.

The West Valley Demonstration Project is part of the nuclear fuel cycle. The radionuclides present at the site are left over from the recycling of commercial nuclear fuel during the 1960s and early 1970s. A very small fraction of these radionuclides is released off-site annually through ventilation systems and liquid discharges. An even smaller fraction actually contributes to the radiation dose to the surrounding population.

Health Effects of Low Levels of Radiation

The concept of dose equivalent (DE) was developed by the radiation protection community to allow a rough comparison of doses from different types of radiation.

The primary effect of low levels of radiation in an exposed individual appears to be an increased risk of cancer. Radionuclides entering the body through air, water, or food are usually distributed unevenly in different organs of the body. For example, isotopes of iodine concentrate in the thyroid gland. Strontium, plutonium, and americium isotopes concentrate in the skeleton. Uranium and plutonium isotopes, when inhaled, remain in the lungs for a long time. Some radionuclides such as tritium, carbon-14, or cesium-137 will be distributed uniformly throughout the body. Depending on the radionuclide, some organs may receive quite different doses. Moreover, at the same dose levels certain organs (such as the breast) are more prone to developing a fatal cancer than other organs (such as the thyroid).

Dose Estimation Methodology

The International Commission on Radiological Protection (ICRP) found a way to account for this difference in radionuclide distribution and organ sensitivity. In Publications 26 (1977) and 30 (1979), the Commission developed an organ-weighted (weighting factor) average dose methodology to limit permissible worker exposures following intakes of radionuclides. This weighting factor — a ratio of the risk from a dose to a specific organ or tissue to the total risk when the whole body is uniformly irradiated — represents the relative sensitivity of a particular organ to develop a fatal effect. For example, to determine the weighting factor following a uniform irradiation, the risk factor of death from cancer of a specific organ is divided by the total risk of dying from cancer. Organ-weighted dose equivalents are then summed to obtain an effective dose equivalent (EDE).

Units of Measurement

The U.S. unit of measurement for dose equivalent is the rem. The international unit of measurement of dose equivalent is the sievert (Sv), which is equal to 100 rem. The millirem (mrem) and millisievert (mSv) are used more frequently to report the low dose equivalents encountered in environmental exposures.

The National Council on Radiation Protection and Measurements (NCRP) Report 93 (1987) estimates that the average annual effective dose equivalent (EDE) received by an individual living in the U.S. is about 360 mrem (3.6 mSv) from both natural and manmade sources of radiation (Fig. 4-1). This number is based on the collective EDE, defined as the total EDE received by a population (expressed in units of person-Sv or person-rem). The average individual EDE is obtained by dividing the collective EDE by the population.

Risk Estimate

The Committee on Biological Effects of Ionizing Radiations (BEIR V) has estimated that the increased risk of dying from cancer from a single acute dose of 10 rem (0.1 Sv) is about 0.8% of the background risk of cancer. According to the BEIR Committee, chronic exposure,

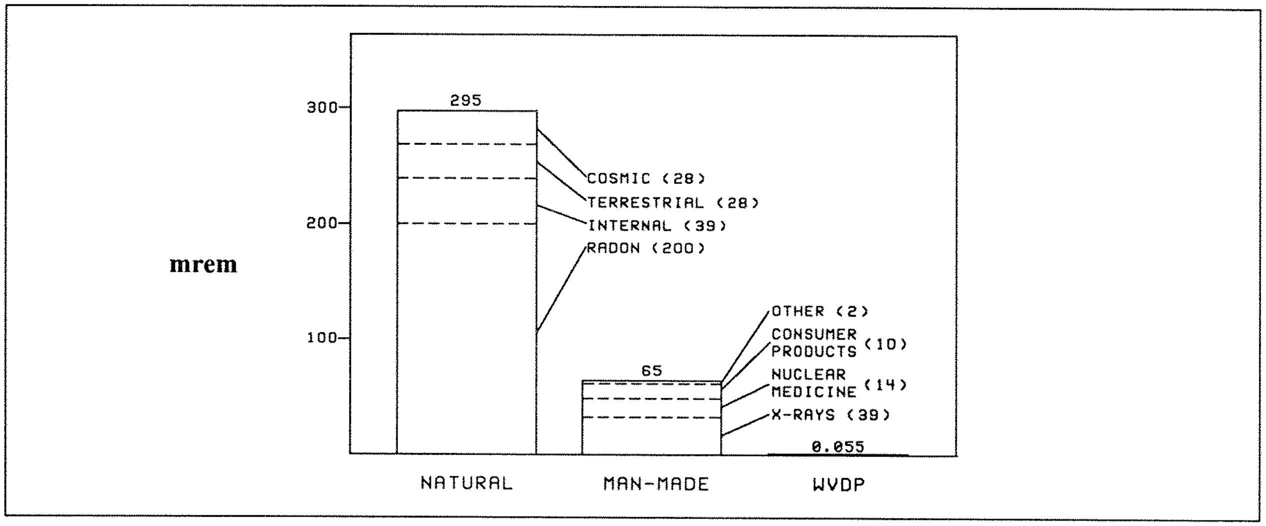

FIGURE 4-1. COMPARISON OF ANNUAL RADIATION DOSE (MREM) TO AN AVERAGE MEMBER OF THE UNITED STATES POPULATION (NCRP 1987) WITH THE MAXIMUM DOSE TO AN OFF-SITE RESIDENT FROM 1991 WVDP EFFLUENTS.

i.e., accumulation of the same dose over long periods of time, might, compared to acute exposure, reduce the risk by a factor of two or more.

The BEIR Committee has stressed that the health effects of very low levels of radiation are not clear, and any use of risk estimates at these levels is subject to great uncertainty (BEIR 1990). As will be shown in the following sections, the estimated maximum EDE received by a member of the public from Project activities during 1991 is many orders of magnitude lower than the exposures considered in the BEIR report.

Estimated Radiological Dose from Airborne Effluents

Sources of Radioactivity from the WVDP

As reported in Chapter 2, *Environmental Monitoring*, five stacks were monitored for radioactive air emissions during 1991. The activity that was released to the atmosphere from these stacks is listed in Tables C-2.1 through C-2.11 in *Appendix C-2*.

The main plant stack, which vents to the atmosphere at a height of 63 meters (208 ft), is considered an elevated release; all other releases are considered ground level (10 m) releases.

Meteorological Data

Wind data collected from the on-site meteorological tower during 1991 were used as input to the dose assessment codes. Data collected at the 60-meter and 10-meter heights were used in combination with elevated and ground level effluent release data, respectively.

Applicable Standards

Airborne emission of radionuclides are regulated by the EPA under the Clean Air Act. Department of Energy facilities are subject to 40 CFR 61, subpart H, National Emission Standards for Hazardous Air Pollutants (NESHAPs) Radionuclides. The applicable standard for radionuclides released during 1991 is 10 mrem (0.10 mSv) EDE for any member of the public.

Maximum Dose to an Off-Site Resident

Based on the airborne radioactivity released from the site during 1991 and using CAP88-PC, a person living in the vicinity of the WVDP was estimated to receive an EDE of 4.9×10^{-4} mrem (4.9×10^{-6} mSv). This hypothetical maximally exposed individual was assumed to reside continuously about 1.9 kilometers north-northwest of the site and to eat only locally produced foods. Approximately 80% of the dose from airborne emissions in 1991 was contributed by iodine-129. Americium-241 and isotopes of plutonium made up much of the remainder.

The dose reported above is 0.005% of the 10 mrem (0.10 mSv) standard and can be compared to about one minute of the annual background radiation received by an average member of the U.S. population.

Collective Dose to the Population

The CAP88-PC version of AIRDOS-EPA was used to estimate the collective effective dose equivalent (CEDE) to the population. According to census projections for 1991, an estimated 1.7 million people reside within 80 kilometers (50 mi) of the WVDP. This population received an estimated 4.7×10^{-3} person-rem (4.7×10^{-5} person-Sv) collective EDE from radioactive airborne effluents released from the WVDP during 1991. The resulting average EDE per individual is 2.8×10^{-6} mrem (2.8×10^{-8} mSv).

There are no standards limiting the collective EDE to the population. However, the calculated average individual EDE is 110 million times lower than the 300 mrem (3 mSv) that an average member of the U.S. population receives in one year from natural background radiation (equivalent to an exposure of less than one second of background radiation).

Estimated Radiological Dose from Liquid Effluents

Sources of Radioactivity from the WVDP

Six batch releases of liquid radioactive effluents were monitored during 1991. The radioactivity that was discharged in these effluents is listed in *Appendix C-1*, Table C-1.1.

Applicable Standards

Currently there are no EPA standards establishing limits on the radiation dose to members of the public from liquid effluents except as applied in 40 CFR 141 and 40 CFR 143, Drinking Water Guidelines (USEPA 1984b,c). The potable water wells sampled for radionuclides are upgradient of the West Valley Demonstration Project and are not considered a realistic pathway in the dose assessment. Since Cattaraugus Creek is not designated as a drinking water supply, the estimated radiation dose was compared with the limits stated in DOE Order 5400.5.

Dose Assessment Methodology

The computer code LADTAP II (Simpson and McGill 1980) was used to calculate the EDE to the maximally exposed off-site individual and the collective EDE to the population from routine releases

and dispersion of these effluents. Since the effluents eventually reach Cattaraugus Creek, which is not used as a source of drinking water, the local exposure pathway calculated by the code is from the consumption of 21 kilograms (46 lb) of fish caught in the creek. Population dose estimates assume that the radionuclides are further diluted in Lake Erie before reaching municipal drinking water supplies. A detailed description of LADTAP II is given in *Radiological Parameters for Assessment of WVDP Activities* (Faillace and Prowse 1990).

Maximum Dose to an Off-Site Individual

Based on the radioactivity in effluents released from the WVDP during 1991, an off-site individual was estimated to receive a maximum EDE of 5.5×10^{-2} mrem (5.5×10^{-4} mSv). Approximately 98% of this dose is from cesium-137. This dose is about 5,400 times lower than the 300 mrem (3 mSv) that an average member of the U.S. population receives in one year from natural background radiation (equivalent to an exposure of two hours of background radiation).

Collective Dose to the Population

As a result of radioactivity released in liquid effluents from the WVDP during 1991, the population living within 80 kilometers (50 mi) of the site received a collective EDE of 1.1×10^{-2} person-rem (1.1×10^{-4} person-Sv). This estimate is based on a population of 1.7 million living within the 80-kilometer radius. The resulting average EDE per individual is 6.5×10^{-6} mrem (6.5×10^{-8} mSv), or approximately 46 million times lower than the 300 mrem (3 mSv) that an average person receives in one year from natural background radiation (equivalent to an exposure of less than one second of background radiation).

Estimated Radiological Dose from All Pathways

The potential dose to the public from both airborne and liquid effluents released from the Project during 1991 is the sum of the individual dose contributions. The maximum EDE from all pathways to a nearby resident was 5.5×10^{-2} mrem (5.5×10^{-4} mSv).

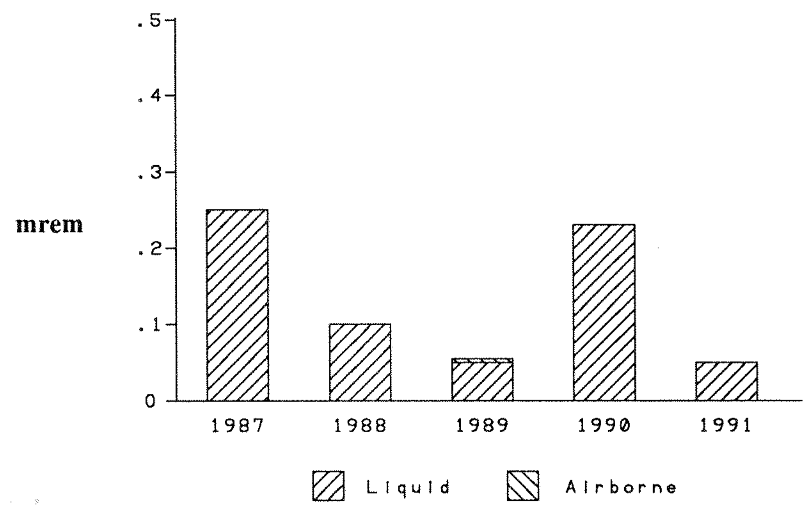

FIGURE 4-2.. MAXIMUM DOSE EQUIVALENT (MREM) FROM LIQUID AND AIRBORNE EFFLUENTS TO AN INDIVIDUAL RESIDING NEAR THE WVDP.

This dose is 0.05% of the 100 mrem (1 mSv) annual limit in DOE Order 5400.5. The total collective EDE to the population within 80 kilometers (50 mi) of the site was 1.6×10^{-2} person-rem (1.6×10^{-4} person-Sv), with an average EDE of 9.4×10^{-6} mrem (9.4×10^{-8} mSv) per individual.

Table 4-1 summarizes the dose contributions from all pathways and compares the individual doses to the applicable standards.

Figure 4-2 shows the trend in dose to the maximally exposed individual over the last five years. The estimated dose for 1991 is lower than the dose reported in 1990.

Figure 4-3 shows the trend in collective dose to the population. The estimated collective dose for 1991 is lower than the dose reported in 1990.

Estimated Radiological Dose from Local Food Consumption

In addition to dose estimates based on dispersion modeling, the maximum CEDE to a nearby resident from consumption of locally produced food can also be estimated. Because the estimated doses using the computer models already incorporate the food pathway, the doses from food consumption should not be added to doses reported in previous sections but should serve as an additional means of measuring the effect of Project operations.

Near-site and control samples of fish, milk, beef, venison, fruit, and vegetables were collected and analyzed for various radionuclides, including tritium, potassium-40, cobalt-60, strontium-90, iodine-129, cesium-134, and cesium-137. The measured radionuclide concentrations reported in *Appendix C-3*, Tables C-3.1 through C-3.4 are the basis for these dose estimates.

When statistically significant differences were found between near-site and background sample concentrations, the excess near-site sample concentration was used as a basis for the dose estimate. Most of the measured radionuclides were found to be under the minimum detectable concentration. When this was the case for both near-site and control samples, the concentrations in both were assumed to be at background levels.

The EDE to nearby residents from the consumption of foods with radionuclide concentrations above background concentration was estimated. The potential dose was calculated by multiplying the excess concentration by the maximum adult annual consumption rate for each food and the ingestion unit dose factor for the measured radionuclide. The consumption rates are based on site-specific data and recommendations in *NRC Regulatory Guide* 1.109 for terrestrial food chain dose assessments (USNRC 1977). The internal dose conversion factors

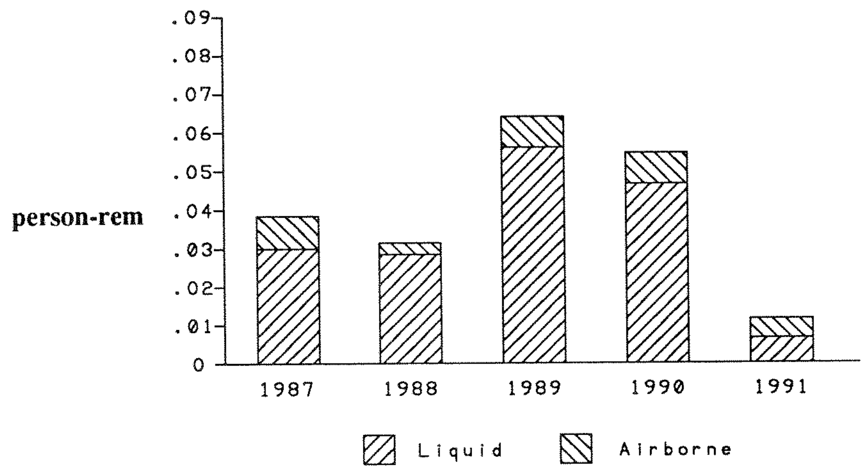

FIGURE 4-3. COLLECTIVE DOSE EQUIVALENT (PERSON-REM) FROM LIQUID AND AIRBORNE EFFLUENTS TO THE POPULATION RESIDING WITHIN 80 KM OF THE WEST VALLEY DEMONSTRATION PROJECT.

were obtained from *Internal Dose Conversion Factors for Calculation of Dose to the Public* (U.S. Department of Energy 1988).

The results of the dose estimates for each food type are reported in the following sections. The four-year trend in total EDE from consumption of all the sampled food products is plotted in Figure 4 - 4. All of the calculated doses are well below both the EPA and DOE limits discussed in the previous sections.

Milk

Milk samples were collected from various nearby dairy farms throughout 1991. Control samples were collected from farms 25-30 kilometers (15-20 mi) to the south and north of the WVDP. Milk samples were measured for tritium, strontium-90, iodine-129, cesium-134, and cesium-137. Only cesium-137 was found above minimum detectable concentration levels in near-site samples. To obtain a conservative estimate, the average background concentration was subtracted from the near-site sample from one location with the highest reported concentrations. Based on an annual consumption rate of 310 liters (327 qts), the maximum collective EDE (CEDE) from drinking this milk was estimated to be 2.7×10^{-2} mrem (2.7×10^{-4} mSv).

Beef

Near-site and control samples of locally raised beef were collected in mid- and late 1991. These samples were measured for strontium-90, cesium-134, cesium-137, and potassium-40 concentrations. (Potassium-40 provides a built-in calibration spike from a natural isotope of potassium not released in Project effluents.) Only cesium-134 was detected above the minimum detectable concentration level in the maximum near-site sample, with the highest excess concentration reported during late 1991. Based on an annual consumption rate of 110 kilograms (242 lbs), the maximum CEDE from eating this meat was estimated to be 1.8×10^{-1} mrem (1.8×10^{-3} mSv).

Venison

Meat samples from three near-site and three control deer were collected in the last months of 1991. These samples were measured for strontium-90, cesium-134, cesium-137, and potassium-40 concentrations. Only cesium-134 was detected above minimum detectable concentration levels. Based on an annual consumption rate of 45 kilograms (99.1 lbs), the maximum CEDE from eating this meat was estimated to be 9.7×10^{-3} mrem (9.7×10^{-5} mSv).

Produce (Beans, Apples, and Corn)

Near-site and control samples of beans, apples, and corn were collected in 1991. These samples were measured for tritium, strontium-90, potassium-40, cobalt-60, and cesium-137 concentrations. Only strontium-90 in beans was detected above the minimum detectable concentration level. Based on an annual consumption rate of 52 kilograms (115 lbs), which is one-tenth of the maximum

TABLE 4 - 1

SUMMARY OF DOSE ASSESSMENT FROM 1991 WEST VALLEY DEMONSTRATION PROJECT EFFLUENTS

	Maximum Dose to an Individual [1]	**Maximum Dose to the Population** [2]
Effective Dose Equivalent from Airborne Emissions [3]	4.9E-04 mrem (4.9E-06 mSv)	4.7E-03 person-rem (4.7E-05 person-Sv)
(percent of EPA standard)	(4.9E-03%)	NA
EPA Radiation Protection Standard [4]	10 mrem	NA
Effective Dose Equivalent from Liquid Effluents [5]	5.5E-02 mrem (5.5E-04 mSv)	1.1E-02 person-rem (1.1E-04 person-Sv)
Effective Dose Equivalent from all Releases	5.5E-02 mrem (5.5E-04 mSv)	1.6E-02 person-rem (1.6E-04 person-Sv)
(percent of DOE standard)	(0.06%)	NA
(percent of background)	(0.02%)	(3.1E-06%)
DOE Radiation Protection Standard [6]	100 mrem	NA
Background Effective Dose Equivalent [7]	300 mrem (3 mSv)	510,000 person-rem (5100 person-Sv)

[1] *Maximally exposed individual at a residence 1.9 km NNW from the main plant.*

[2] *Population of 1.7 million within 80 km of the site.*

[3] *Calculated using AIRDOS-EPA (CAP88-PC for individual and population).*

[4] *Airborne emissions only.*

[5] *Calculated using methodology described in WVDP-065, Rev.2 (10/5/90).*

[6] *Applies to combined doses from both airborne and liquid effluents.*

[7] *U.S. average (NRCP 1987).*

Note: In scientific notation 4.9E-04 = $4.9x10^{-4}$

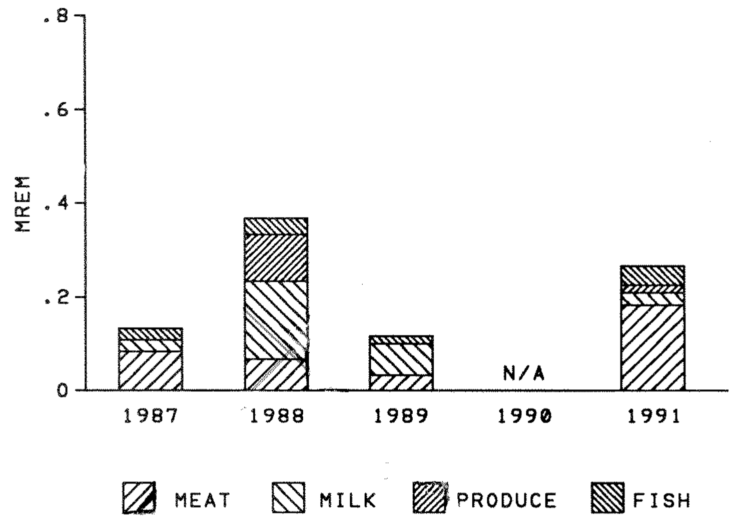

FIGURE 4-4. MAXIMUM COMMITTED EFFECTIVE DOSE EQUIVALENT (MREM) TO AN INDIVIDUAL FROM CONSUMPTION OF FOODS PRODUCED NEAR THE WEST VALLEY DEMONSTRATION PROJECT.

annual consumption rate of 520 kilograms (1150 lbs) for all produce, the maximum CEDE from eating these beans was estimated to be 1.3×10^{-2} mrem (1.3×10^{-4} mSv).

Fish

Fish were caught in the second and third quarters of 1991 in Cattaraugus Creek upstream (control samples) and downstream of the site (above and below the Springville dam). Samples of fish flesh were measured for strontium-90, cesium-134, and cesium-137 concentrations. Only strontium-90 was detected above minimum detectable concentration levels, with the highest excess concentration reported in fish caught upstream of the Springville dam. Based on an annual consumption rate of 21 kilograms (46 lbs), the maximum CEDE from eating this fish was estimated to be 3.5×10^{-2} mrem (3.5×10^{-4} mSv).

Conclusions

Based on dose assessment, the West Valley Demonstration Project during 1991 was in compliance with all applicable EPA standards and DOE Orders. The effective dose equivalent to members of the public estimated from effluent dispersion models and radionuclide concentrations in food samples was below the dose limits, indicating no measurable effects on the public's health.