
USEFUL INFORMATION

This section provides background information that may be useful to the reader in understanding and interpreting the results presented in this Annual Site Environmental Report (ASER). First, it presents brief summaries of concepts pertaining to radiation and radioactivity, including:

- radioactive decay;
- types of ionizing radiation;
- measurement of radioactivity;
- measurement of dose;
- background radiation; and
- potential health effects of radiation.

It describes how data are presented in the ASER, and presents tables of unit prefixes, units of measure, and conversion factors. It discusses limits applicable to air emissions and water effluents, and describes (and presents a table of) the dose-based DOE derived concentration guides (DCGs). It includes a discussion of CAP88-PC, the computer code used to evaluate compliance with the air dose standard. It also presents discussions of 1) water quality classifications, standards, and limits for ambient water; 2) potable water standards; 3) soil and sediment guidelines; and 4) evaluation of monitoring data with respect to limits.

Radiation and Radioactivity

Radioactivity is a property of atoms with unstable nuclei. The unstable nuclei spontaneously decay by emitting radiation in the form of energy (such as gamma rays) or particles (such as alpha and beta particles) (see inset on following page). If the emitted energy or particle has enough energy to break a chemical bond or to knock an electron loose from another atom, a charged particle (an "ion") may be created. This radiation is known as "ionizing radiation."

As used in this ASER, the term "radiation" refers only to ionizing radiation and does not include nonioniz-

ing forms of radiation such as visible light, radio waves, microwaves, infrared light, or ultraviolet light.

Radioactive Decay

An atom is the smallest particle of an element. It cannot be broken down by chemical means. An atom consists of a central core (the *nucleus*), composed of positively charged particles (*protons*) and particles with no charge (*neutrons*), surrounded by negatively charged particles (*electrons*) that revolve in orbits in the region surrounding the nucleus. The protons and neutrons are much more massive than the electrons, therefore most of an atom's mass is in the nucleus.

An element is defined by the number of protons in its nucleus, its atomic number. For example, the atomic number of hydrogen is one (one proton), the atomic number of strontium is 38 (38 protons), and the atomic number of cesium is 55 (55 protons).

The mass number of an atom, its *atomic weight*, is equal to the total number of protons and neutrons in its nucleus. For example, although an atom of hydrogen will always have one proton in its nucleus, the number of neutrons may vary. Hydrogen atoms with zero, one, or two neutrons will have atomic weights of one, two, or three, respectively. These atoms are known as *isotopes* (or *nuclides*) of the element hydrogen. Elements may have many isotopes. For instance, the elements strontium and cesium have more than 30 isotopes each.

Isotopes may be stable or unstable. An atom from an unstable isotope will spontaneously change to another atom. The process by which this change occurs, that is, the spontaneous emission from the nucleus of alpha or beta particles, often accompanied by gamma radiation, is known as *radioactive decay*. Depending upon the type of radioactive decay, an atom may be transformed to another isotope of the same element or, if the number of protons in the

Note: Much of the background information in this section was taken from The Handbook of Health Physics and Radiological Health (Shleien, 1998), from the Environmental Protection Agency website (www.epa.gov/radiation/understand), and from The Health Physics Society website (<http://hps.org/publicinformation>).

Some Types of Ionizing Radiation

Alpha Particles. An alpha particle is a fragment of a much larger nucleus. It consists of two protons and two neutrons (similar to the nucleus of a helium atom) and is positively charged. Compared to beta particles, alpha particles are relatively large and heavy and do not travel very far when ejected by a decaying nucleus. Therefore, alpha radiation is easily stopped by a few centimeters of air or a thin layer of material, such as paper or skin. However, if radioactive material is ingested or inhaled, the alpha particles released inside the body can damage soft internal tissues because their energy can be absorbed by tissue cells in the immediate vicinity of the decay. An example of an alpha-emitting radionuclide is the uranium isotope with an atomic weight of 232 (uranium-232). Uranium-232 was in the high-level waste (HLW) mixture at the West Valley Demonstration Project (WVDP) as a result of a thorium-based nuclear fuel reprocessing campaign conducted by Nuclear Fuel Services, Inc. Uranium-232 has been detected in liquid waste streams.

Beta Particles. A beta particle is an electron emitted during the breakdown of a neutron in a radioactive nucleus. Compared to alpha particles, beta particles are smaller, have less of a charge, travel at a higher speed (close to the speed of light), and can be stopped by wood or a thin sheet of aluminum. If released inside the body, beta particles do much less damage than an equal number of alpha particles because beta particles deposit energy in tissue cells over a larger volume than alpha particles. Strontium-90, a fission product found in the liquids associated with the HLW, is an example of a beta-emitting radionuclide.

Gamma Rays. Gamma rays are high-energy “packets” of electromagnetic radiation, called photons, that are emitted from the nucleus. Gamma rays are similar to x-rays, but are generally more energetic. If an alpha or beta particle released by a decaying nucleus does not carry off all the energy generated by the nuclear disintegration, the excess energy may be emitted as gamma rays. If the released energy is high, a very penetrating gamma ray is produced that can be effectively reduced only by shielding consisting of several inches of a dense material, such as lead, or of water or concrete several feet thick. Although large amounts of gamma radiation are dangerous, gamma rays are also used in lifesaving medical procedures. An example of a gamma-emitting radionuclide is barium-137m, a short-lived daughter product of cesium-137. Both barium-137m and its precursor, cesium-137, are major constituents of the WVDP HLW.

nucleus has changed, to an isotope of another element.

Isotopes (nuclides) that undergo radioactive decay are called *radioactive* and are known as *radioisotopes* or *radionuclides*. Radionuclides are customarily referred to by their atomic weights. For instance, the radionuclides of hydrogen, strontium, and cesium measured at the WVDP are hydrogen-3 (also known as tritium), strontium-90, and cesium-137. For some radionuclides, such as cesium-137, a short-lived intermediate is formed that decays by gamma emission. This intermediate radionuclide may be designated by the letter “m” (for metastable) following the atomic weight. For cesium-137, the intermediate radionuclide is barium-137m, with a half-life of less than three minutes.

The process of radioactive decay will continue until only a stable, nonradioactive isotope remains. Depending on the radionuclide, this process can take

anywhere from less than a second to billions of years. The time required for half of the radioactivity to decay is called the radionuclide’s *half-life*. Each radionuclide has a unique half-life. The half-life of hydrogen-3 is slightly more than 12 years, both strontium-90 and cesium-137 have half-lives of approximately 30 years, and plutonium-239 has a half-life of more than 24,000 years.

Knowledge of radionuclide half-lives is often used to estimate past and future inventories of radioactive material. For example, a 1.0 millicurie source of cesium-137 in 2006 would have measured 2.0 millicuries in 1976 and will be 0.5 millicuries in 2036. For a list of half-lives of radionuclides applicable to the WVDP, see Table UI-4.

Measurement of Radioactivity

As they decay, radionuclides emit one or more types of radiation at characteristic energies that can be measured and used to identify the radionuclide. Detection instruments measure the quantity of radiation emitted over a specified time. From this measurement, the number of decay events (nuclear transformations) over a fixed time can be calculated.

Radioactivity is measured in units of curies (Ci) or becquerels (Bq). One Ci (based on the rate of decay of one gram of radium-226) is defined as the "quantity of any radionuclide that undergoes an average transformation rate of 37 billion transformations per second." In the International System of Units (SI), one Bq is equal to one transformation per second. In this ASER, radioactivity is customarily expressed in units of Ci followed by the equivalent SI unit in parentheses, as follows: 1 Ci (3.7E+10 Bq).

In this report, measurements of radioactivity in a defined volume of an environmental media, such as air or water, are presented in units of concentration. Since levels of radioactivity in the environment are typically very low, concentrations may be expressed in microcuries per milliliter, with SI units (becquerels per liter) in parentheses, as follows: 1.00E-06 μ Ci/mL (3.7E+01 Bq/L). (One microcurie is equal to one millionth of a curie.)

Measurement of Dose

The amount of energy absorbed by a material that receives radiation is measured in rads. A rad is 100 ergs of radiation energy absorbed per gram of material. (An erg is the approximate amount of energy necessary to lift a mosquito one-sixteenth of an inch.) "Dose" is a means of expressing the amount of energy absorbed, taking into account the effects of different kinds of radiation.

Alpha, beta, and gamma radiation affect the body to different degrees. Each type of radiation is given a quality factor that indicates the extent of human cell damage it can cause compared with equal amounts of other ionizing radiation energy. Alpha particles cause 20 times as much damage to internal tissues as x-rays, so alpha radiation has a quality factor of 20, compared to gamma rays, x-rays, or beta particles, each of which have a quality factor of one.

The unit of dose measurement to humans is the *rem*. The number of rem is equal to the number of rads

multiplied by the quality factor for each type of radiation. In the SI system, dose is expressed in sieverts. One sievert (Sv) equals 100 rem. This ASER expresses dose in standard units, followed by equivalent SI units in parentheses, as follows: 1 mrem (0.01 Sv).

Background Radiation

Background radiation is always present, and everyone is constantly exposed to low levels of such radiation from both naturally occurring and man-made sources. In the United States the average total annual exposure to low-level background radiation is estimated to be about 360 millirem (mrem) or 3.6 millisieverts (mSv). Most of this radiation, approximately 295 mrem (2.95 mSv), comes from natural sources. The rest comes from medical procedures, consumer products, and other man-made sources (National Council on Radiation Protection and Measurements Report 93, 1987). (See Figure 3-1 in Chapter 3.)

Background radiation includes cosmic rays; the decay of natural elements, such as potassium, uranium, thorium, and radon; and radiation from sources such as chemical fertilizers, smoke detectors, and cigarettes. Actual doses vary depending on such factors as geographic location, building ventilation, and personal health and habits.

Potential Health Effects of Radiation

The three primary pathways by which people may be exposed to radiation are (1) direct exposure, (2) inhalation, and (3) ingestion. Exposure from radiation may be from a source outside the body (external exposure) or from radioactive particles that have been taken in by breathing or eating and have become lodged inside the body (internal exposure). Radionuclides that are taken in are not distributed in the same way throughout the body. Radionuclides of strontium, plutonium, and americium concentrate in the skeleton, while radioisotopes of iodine concentrate in the thyroid. Radionuclides such as hydrogen-3 (tritium), carbon-14, or cesium-137, however, will be distributed uniformly throughout the body.

Living tissue in the human body can be damaged by ionizing radiation. The severity of the damage depends upon several factors, among them the amount of exposure (low or high), the duration of the exposure (long-term [*chronic*] or short-term [*acute*]), the type of radiation (alpha, beta, and gamma radiations of various energies), and the sensitivity of the hu-

man (or organ) receiving the radiation. The human body has mechanisms that repair damage from exposure to radiation, however, repair processes are not always successful.

Biological effects of exposure to radiation may be either somatic or genetic. *Somatic* effects are limited to the exposed individual. For example, a sufficiently high exposure could cause clouding of the lens of the eye or a decrease in the number of white blood cells. *Genetic* effects may show up in future generations. Radiation could damage chromosomes, causing them to break or join incorrectly with other chromosomes. Radiation-produced genetic defects and mutations in the offspring of an exposed parent, while not positively identified in humans, have been observed in some animal studies.

Assessing the biological damage from low-level radiation is difficult because other factors can cause the same symptoms as radiation exposure. Moreover, the body is able to repair damage caused by low-level radiation. Epidemiological studies have not demonstrated adverse health effects in individuals exposed to small doses (less than 10 rem) over a period of years. (For comparison, note that average background radiation in the United States is about 0.36 rem/year, and estimated annual dose from activities at the WVDP in 2007 was about 0.000067 rem/year [0.067 mrem/year].)

The effect most often associated with exposure to relatively high levels of radiation appears to be an increased risk of cancer. However, scientists have not been able to demonstrate with certainty that exposure to low-level radiation causes an increase in injurious biological effects, nor have they been able to determine if there is a level of radiation exposure below which there are no adverse biological effects.

Data Reporting

In the text of this ASER, radiological units (e.g., rem, rad, curie) are presented first, followed by the International System of Units (SI) equivalent in parentheses. Nonradiological measurements are presented in English units, followed by the metric unit equivalent in parentheses. See Tables UI-1, UI-2, and UI-3 for a summary of unit prefixes, units of measurement, and basic conversion factors used in this ASER.

Where results are very large or very small, scientific notation is used. Numbers greater than 10 are expressed with a positive exponent. To convert the num-

ber to its decimal form, the decimal point must be moved to the right by the number of places equal to the exponent. For example, 1.0E+06 would be expressed as 1,000,000 (one million). Numbers smaller than 1 are expressed with a negative exponent. For example, 1.0E-06 would be expressed as 0.000001 (one millionth).

TABLE UI-1
Unit Prefixes Used in This ASER

Multiplication factor		Prefix	Symbol
Scientific notation	Decimal form		
1.0E+06	1000000	mega	M
1.0E+03	1000	kilo	k
1.0E-02	0.01	centi	c
1.0E-03	0.001	milli	m
1.0E-06	0.000001	micro	μ
1.0E-09	0.000000001	nano	n
1.0E-12	0.000000000001	pico	p

Radiological data are reported as a result plus or minus (\pm) an associated uncertainty, customarily the 95% confidence interval. The uncertainty is in part due to the random nature of radioactive decay. Generally, the relative uncertainty in a measurement increases as the amount of radioactivity being sampled decreases. For this reason, low-level environmental analyses for radioactivity are especially prone to significant uncertainty in comparison with the result. Radiological data are presented in the following manner:

Example: $1.04 \pm 0.54 \text{ E-}09$

Where: 1.04 = the result
 ± 0.54 = plus or minus the associated uncertainty
 E-09 = times 10 raised to the power -09

A result is considered "positive" if the result is larger than the associated uncertainty (i.e., the constituent was detected). Nonradiological data are not reported with an associated uncertainty.

In general, the detection limit is the minimum amount of a constituent that can be detected, or distinguished from background, by an instrument or a measurement technique. If a result is preceded by the symbol "<" (i.e., <5 ppm), the constituent was not measurable below the detection limit (in this example, 5 ppm).

TABLE UI-2
Units of Measure Used in This ASER

Type	Measurement	Symbol	Type	Measurement	Symbol
Length	meter	m	Dose	rad (absorbed dose)	rad
	centimeter	cm		rem (dose equivalent)	rem
	kilometer	km		millirem	mrem
	inch	in		sievert	Sv
	foot	ft		millisievert	mSv
	mile	mi		gray	Gy
Volume	gallon	gal	Exposure	roentgen	R
	liter	L		milliroentgen	mR
	milliliter	mL		microroentgen	μR
	cubic meter	m ³	Concentration	parts per million	ppm
cubic feet	ft ³	parts per billion		ppb	
Area	acre	ac		parts per trillion	ppt
	hectare	ha		milligrams per L (ppm)	mg/L
	square meter	m ²		micrograms per L (ppb)	μg/L
	square foot	ft ²		nanograms per L (ppt)	ng/L
Temperature	degrees Fahrenheit	°F	milligrams per kg (ppm)	mg/kg	
	degrees Celsius	°C	micrograms per g (ppm)	μg/g	
Mass	gram	g	micrograms per mL (ppm)	μg/mL	
	kilogram	kg	milliliters per mL	mL/L	
	milligram	mg	microcuries per mL	μCi/mL	
	microgram	μg	picocuries per L	pCi/L	
	nanogram	ng	microcuries per g	μCi/g	
	pound	lb	Becquerels per L	Bq/L	
	tonne (metric ton)	t	nephelometric turbidity units	NTU	
	ton, short	T	standard units (pH)	SU	
	Radioactivity	curie	Ci	Flow rate	gallons per day
millicurie		mCi	million gallons per day		mgd
microcurie		μCi	cubic feet per minute		cfm
nanocurie		nCi	liters per minute		lpm
picocurie		pCi	meters per second		m/sec
becquerel		Bq			

TABLE UI-3
Conversion Factors Used in This ASER

To convert from	to	Multiply by
miles	kilometers	1.609344
feet	meters	0.3048
inches	centimeters	2.54
acres	hectares	0.4046873
pounds	kilograms	0.45359237
gallons	liters	3.785412
curies	becquerels	3.7E+10
rad	gray	0.01
rem	sievert	0.01

Note: To convert from the units in column two to the units in column one, divide by the conversion factor.

The number of significant digits reported depends on the precision of the measurement technique. Integer counts are reported without rounding. Calculated values are customarily reported to three significant figures. Dose estimates are usually reported to two significant figures.

Limits Applicable to Environmental Media

Dose Standards. The two dose standards against which releases at the West Valley Demonstration Project (WVDP) are assessed are those established by the Environmental Protection Agency (EPA) for air emissions and that established by the U.S. Department of Energy (DOE) regarding all exposure modes from DOE activities.

Radiological air emissions other than radon from DOE facilities are regulated by the EPA under the National Emission Standards for Hazardous Air Pollutants (NESHAP) regulation (40 Code of Federal Regulation [CFR] 61, Subpart H), which establishes a

standard of 10 mrem/year effective dose equivalent to any member of the public. See "CAP88-PC Computer Code" in inset.

DOE Order 5400.5 sets the DOE primary standard of 100 mrem/year effective dose equivalent to members of the public considering all exposure modes from DOE activities. (Currently there are no EPA standards establishing limits on the radiation dose to members of the public from liquid effluents.)

Note that the EPA establishes a drinking water limit of 4-mrem/year (0.04-mSv/year) (40 CFR Parts 141 and 143, Drinking Water Guidelines). Corollary limits for community water supplies are set by the New York State Department of Health (NYSDOH) in the New York State Sanitary Code (Title 10 of the Official Compilation of Codes, Rules, and Regulations of the State of New York [NYCRR] 5-152). These limits are not applicable at the WVDP because no drinking water sources are affected by the WVDP.

CAP88-PC Computer Code

The WVDP Annual Site Environmental Report (ASER) summarizes the airborne radioactivity released (see Appendix C^{en}) and the effect from those releases (Chapter 3). The computer code Clean Air Act Assessment Package-1988 for personal computers (CAP88-PC), Version 2.0, approved in October 1999, is used to perform radiation dose and risk calculations from WVDP airborne releases.

Version 3.0 of CAP88-PC (Trinity Engineering Associates, Inc., March 2006, with updates in November 2006, and March, October, and December of 2007) was approved by the EPA for use in February 2006 to demonstrate compliance with the 10-mrem/year NESHAP standard. Version 3.0 incorporates updated scientific methods to calculate radiation dose and risk. Version 3.0 also considers age and gender factors not considered in Version 2.0. Both versions use weighting factors that consider the sensitivity of various human organs to radiation. The models also calculate how long radioactive material will remain in a particular organ or system. Together, these factors are used to calculate dose and risk. Version 2.0 uses seven different organs and Version 3.0 uses 23. The risk of getting cancer from radiation exposure is calculated for 15 sites in Version 3.0 versus 10 in Version 2.0.

Upon initial and follow-up evaluation of code releases through December 2007, issues were encountered in running this new software code. At this juncture, the EPA accepts the use of any of the three approved versions of CAP88 for compliance purposes. After final evaluation (post-revision) at the WVDP, this updated (Version 3.0) code, or an appropriate approved alternative, will be used in the future at the WVDP, as recommended in the Federal Register notice.

The net effect is that dose and risk estimates summarized in the ASER from using CAP88-PC Version 2.0 and Version 3.0 are slightly different, even if the radioactivity released from WVDP and meteorology both remain constant. However, test calculations with both versions have resulted in estimated doses far below the compliance limit.

Derived Concentration Guides. A derived concentration guide (DCG) is defined as the concentration of a radionuclide in air or water that, under conditions of continuous exposure by one exposure mode (i.e., ingestion of water, immersion in air, or inhalation) for one year, would result in an effective dose equivalent of 100 mrem (1 mSv) to a "reference man" (DOE Order 5400.5). DCGs are applicable only at locations where members of the public could be exposed to air or water containing contaminants. DCGs for radionuclides measured at the WVDP are listed in Table UI-4. At the WVDP, DCGs are used as a screening tool for evaluating liquid effluents and airborne emissions. (DCGs are not used to estimate dose.)

State Pollutant Discharge Elimination System (SPDES) Permit Requirements. The site's SPDES permit defines points where sampling must be conducted, sampling frequency, the type of samples to be collected, constituents for which samples must be analyzed, and the limits applicable to these constituents. Results are reported monthly to the New York State Department of Environmental Conservation in a Discharge Monitoring Report. Requirements of the current permit are summarized in Appendix B-1⁶⁰.

Water Quality Classifications, Standards, and Limits for Ambient Water. The objective of the Clean Water Act of 1972 (CWA) is to restore and maintain the integrity of the nation's waters and ensure that, wherever attainable, waters be made useful for fishing and swimming. To achieve this goal, New York State is delegated with authority under Sections 118, 303, and 510 of the CWA to (1) classify and designate the best uses for receiving waters, such as streams and rivers, within its jurisdiction, and (2) establish and assign water quality standards — goals for achieving the designated best uses for these classified waters.

In addition to achieving CWA goals for fishing and swimming, New York has further classified its jurisdictional waters and established ambient water standards, guidelines, and maximum contaminant levels (MCLs) to achieve objectives under the Safe Drinking Water Act for drinking water. These standards serve as the basis for periodic evaluation of the integrity of the receiving waters and identification of needed controls.

The definitions for best usage classification of New York's jurisdictional waters and the water quality standard goals for these classifications are provided in Title 6 of the Official Compilation of Codes, Rules,

and Regulations of the State of New York (6 NYCRR) Parts 701–704. Mapping of the Cattaraugus Creek drainage basin and assignment of best usage designations and classification to each receiving water segment within this drainage basin are described in 6 NYCRR Part 838.

According to these regulations, Franks Creek, Quarry Creek, and segments of Buttermilk Creek under the influence of water effluents from the WVDP are identified as Class "C" receiving waters with a minimum designated best usage for fishing with conditions suitable for fish propagation and survival.

Cattaraugus Creek, in the immediate downstream vicinity of the Western New York Nuclear Service Center (WNYNSC), is identified as a Class "B" receiving water with best designated usages for swimming and fishing. All fresh (nonsaline) groundwaters within New York are assigned a "GA" classification with a designated best usage as a potable water supply source.

Refer to Appendix B⁶⁰ for a summary of the water quality standards, guidelines, and MCLs assigned to these water classifications for those constituents that are included in the WVDP environmental monitoring program for ambient water.

Potable Water Standards. Standards for drinking water are established by the EPA and by NYSDOH. These standards are expressed as MCLs or maximum contaminant level goals. See Appendix B⁶⁰ for a summary of these levels.

Soil and Sediment Concentration Guidelines. The Nuclear Regulatory Commission (NRC) and the EPA, in a 2002 memorandum of understanding pertaining to decommissioning and decontamination of contaminated sites, agreed upon concentrations of residual radioactivity in soil that would trigger consultation between the two agencies. Consultation "trigger" levels for radioactive contamination in both residential and industrial soil are listed in Appendix F⁶⁰ for nuclides applicable to the WVDP.

In 2006, the NRC, in a decommissioning guidance document (NUREG-1757, Vol. 2, 2006), provided concentration screening values for common radionuclides in soil that could result in a dose of 25 mrem/year. For summary tables of screening levels for radionuclides of interest at the WVDP, see Appendix F⁶⁰.

In 1999, NYSDEC issued updated guidance for screening contaminated aquatic sediments. This guidance

includes sediment quality criteria correlated to the severity of environmental impact. These criteria, which are derived from National Oceanic and Atmospheric Administration (Long and Morgan, 1990) and 1992 Ministry of Ontario "Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario" (Persaud et al., 1992), are presented in Appendix F⁶⁰.

Contaminants in soil are potential sources for contamination of groundwater, ambient air, and plants and animals. Appendix F⁶⁰ includes a summary of

screening criteria from NYSDEC and 6 NYCRR. Criteria include background concentration ranges for eastern United States soil.

Evaluation of Monitoring Data with Respect to Limits

Monitoring data for calendar year 2007 were evaluated against the limits presented in Table UI-4, and Appendices B⁶⁰ and F⁶⁰. Those locations with results exceeding the limits are listed in Chapter 2, Table 2-4.

TABLE UI-4
U.S. Department of Energy Derived Concentration Guides (DCGs)^a for Inhaled Air or Ingested Water (μCi/mL)

Radionuclide	Half-life (years) ^b	DCG in Air	DCG in Water
Gross Alpha (as Am-241) ^c	NA	2E-14	3E-08
Gross Beta (as Sr-90) ^c	NA	9E-12	1E-06
Tritium (H-3)	1.23E+01	1E-07	2E-03
Carbon-14 (C-14)	5.70E+03	6E-09	7E-05
Potassium-40 (K-40)	1.25E+09	9E-10	7E-06
Cobalt-60 (Co-60)	5.27E+00	8E-11	5E-06
Strontium-90 (Sr-90)	2.89E+01	9E-12	1E-06
Technetium-99 (Tc-99)	2.11E+05	2E-09	1E-04
Iodine-129 (I-129)	1.57E+07	7E-11	5E-07
Cesium-137 (Cs-137)	3.00E+01	4E-10	3E-06
Europium-154 (Eu-154)	8.59E+00	5E-11	2E-05
Uranium-232 (U-232)	6.89E+01	2E-14	1E-07
Uranium-233 (U-233)	1.59E+05	9E-14	5E-07
Uranium-234 (U-234)	2.46E+05	9E-14	5E-07
Uranium-235 (U-235)	7.04E+08	1E-13	6E-07
Uranium-236 (U-236)	2.34E+07	1E-13	5E-07
Uranium-238 (U-238)	4.47E+09	1E-13	6E-07
Plutonium-238 (Pu-238)	8.77E+01	3E-14	4E-08
Plutonium-239 (Pu-239)	2.41E+04	2E-14	3E-08
Plutonium-240 (Pu-240)	6.56E+03	2E-14	3E-08
Americium-241 (Am-241)	4.32E+02	2E-14	3E-08

^a DCGs are established in DOE Order 5400.5 and are defined as the concentration of a radionuclide that, under conditions of continuous exposure for one year by one exposure mode, would result in an effective dose equivalent of 100 mrem (1 mSv).

^b Nuclear Wallet Cards. April 2005. National Nuclear Data Center. Brookhaven National Laboratory. Upton, New York.

^c Because there are no DCGs for gross alpha and gross beta concentrations, the DCGs for the most restrictive alpha and beta emitters at the WVDP (americium-241 and strontium-90, respectively) are used as a conservative basis for comparison at locations for which there are no radionuclide-specific data, in which case a more appropriate DCG may be applied.