Appendix A
Helpful Information

The following information is provided to assist the reader in understanding this report. Definitions of technical terms can be found in Appendix C.

Scientific Notation

Scientific notation is used in this report to express very large or very small numbers. For example, the number 1 billion could be written as 1,000,000,000 or, by using scientific or "E" notation, written as 1×10^9 or 1.0E+09. Translating from scientific notation to a more traditional number requires moving the decimal point either left or right from its current location. If the value given is 2.0×10^3 (or 2.0E+03), the decimal point should be moved three places to the **right** so that the number would then read 2,000. If the value given is 2.0×10^{-5} (or 2.0E-05), the decimal point should be moved five places to the **left** so that the result would be 0.00002.

Units of Measure

The primary units of measure used in this report are metric. Table A.1 summarizes and defines the terms and corresponding symbols (metric and non-metric). A conversion table is also provided in Table A.2.

Table A.1. Names and Symbols for Units of Measure

Symbol	Name	Symbol	Name
Temperature		**Length**	
°C	degree Celsius	cm	centimeter (1×10^{-2} m)
°F	degree Fahrenheit	ft	foot
Time		in.	inch
d	day	km	kilometer (1×10^3 m)
h	hour	m	meter
min	minute	mi	mile
s	second	mm	millimeter (1×10^{-3} m)
yr	year	μm	micrometer (1×10^{-6} m)
Rate		**Area**	
cfs (or ft³/s)	cubic foot per second	ha	hectare (1×10^4 m²)
gpm	gallon per minute	km²	square kilometer
mph	mile per hour	mi²	square mile
Volume		ft²	square foot
cm³	cubic centimeter	**Mass**	
ft³	cubic foot	g	gram
gal	gallon	kg	kilogram (1×10^3 g)
L	liter	mg	milligram (1×10^{-3} g)
m³	cubic meter	μg	microgram (1×10^{-6} g)
mL	milliliter (1×10^{-3} L)	ng	nanogram (1×10^{-9} g)
yd³	cubic yard	lb	pound
Concentration		wt%	weight percent
ppb	parts per billion		
ppm	parts per million		
ppmv	parts per million by volume		

			Table A.2. Conversion Table			

Multiply	By	To Obtain		Multiply	By	To Obtain
in.	2.54	cm		cm	0.394	in.
ft	0.305	m		m	3.28	ft
mi	1.61	km		km	0.621	mi
lb	0.454	kg		kg	2.205	lb
gal	3.785	L		L	0.2642	gal
ft^2	0.093	m^2		m^2	10.76	ft^2
acre	0.405	ha		ha	2.47	acres
mi^2	2.59	km^2		km^2	0.386	mi^2
ft^3	0.0283	m^3		m^3	35.31	ft^3
yd^3	0.7646	m^3		m^3	1.308	yd^3
nCi	0.001	pCi		pCi	1,000	nCi
pCi/L	10^{-9}	μCi/mL		μCi/mL	10^9	pCi/L
pCi/m^3	10^{-12}	Ci/m^3		Ci/m^3	10^{12}	pCi/m^3
pCi/m^3	10^{-15}	mCi/cm^3		mCi/cm^3	10^{15}	pCi/m^3
mCi/km^2	1.0	nCi/m^2		nCi/m^2	1.0	mCi/km^2
Bq	2.7×10^{-11}	Ci		Ci	3.7×10^{10}	Bq
Bq	27	pCi		pCi	0.037	Bq
Gy	100	rad		rad	0.01	Gy
Sv	100	rem		rem	0.01	Sv
ppb	0.001	ppm		ppm	1,000	ppb
°F	(°F -32) ÷ 9/5	°C		°C	(°C x 9/5) + 32	°F
g	0.035	oz		oz	28.349	g
metric ton	1.1	ton		ton	0.9078	metric ton

Radioactivity Units

Much of this report deals with levels of radioactivity in various environmental media. Radioactivity in this report is usually discussed in units of **curies (Ci)**, with units of **becquerels (Bq)** in parenthesis (Table A.3). The curie is the basic unit used to describe the amount of radioactivity present, and activities are generally expressed in terms of curies per mass or volume (e.g., picocuries per liter). One curie is equivalent to 37 billion disintegrations per second or is a quantity of any radionuclide that decays at the rate of 37 billion disintegrations per second. Conversely, one becquerel is equivalent to one disintegration per second. Nuclear disintegrations produce spontaneous emissions of alpha or beta particles, gamma radiation, or combinations of these. Table A.4 includes selected conversions from curies to becquerels.

	Table A.3. Names and Symbols for Units of Radioactivity

Symbol	Name
Ci	curie
cpm	counts per minute
mCi	millicurie (1×10^{-3} Ci)
μCi	microcurie (1×10^{-6} Ci)
nCi	nanocurie (1×10^{-9} Ci)
pCi	picocurie (1×10^{-12} Ci)
aCi	attocurie (1×10^{-18} Ci)
Bq	becquerel (2.7×10^{-11} Ci)
kBq	kilobecquerel (1×10^{3} Bq)
MBq	megabecquerel (1×10^{6} Bq)
GBq	gigabecquerel (1×10^{9} Bq)
TBq	terabecquerel (1×10^{12} Bq)

Radiological Dose Units

The amount of ionizing radiation energy absorbed by a living organism is expressed in terms of radiological dose. Radiological dose in this report is usually written in terms of effective dose equivalent and reported numerically in units of **millirems (mrem)**, with the metric units **millisieverts (mSv)** following in parenthesis or footnoted (Table A.5). Millirem (millisievert) is a term that relates ionizing radiation and biological effect or risk (to humans). A dose of 0.01 millirem (1 millisievert) has a biological effect similar to

Table A.4. Conversions for Radiological Dose Units									
pCi	nCi	nCi	µCi	µCi	mCi	mCi	Ci	Ci	kCi
27	1	27	1	27	1	27	1	27	1
1	37	1	37	1	37	1	37	1	37
Bq	Bq	kBq	kBq	MBq	MBq	GBq	GBq	TBq	TBq

New unit of quantity = Becquerel (Bq) (formerly curie [Ci]) (1 Ci = 3.7×10^{10} dps).
1 Becquerel = 1 disintegration/sec (dps).

Table A.5. Names and Symbols for Units of Radiation Dose or Exposure

Symbol	**Name**
mrad	millirad (1×10^{-3} rad)
mrem	millirem (1×10^{-3} rem)
Sv	sievert (100 rem)
mSv	millisievert (1×10^{-3} Sv)
µSv	microsievert (1×10^{-6} Sv)
R	roentgen
mR	milliroentgen (1×10^{-3} R)
µR	microroentgen (1×10^{-6} R)
Gy	gray (100 rad)

from exposure to naturally produced radiation of ~3 millirems (300 millisieverts). Medical and dental x-rays and air travel add to this total. (See Section 5.7 for a more in-depth discussion of risk comparisons.) Table A.6 includes selected conversions from rems to sieverts.

Also used in this report is the metric unit **rad**, with the corresponding unit **Gray (Gy)** in parenthesis or footnoted. The rad (Gray) is a measure of the energy absorbed by any material, whereas a rem relates to both the amount of radiation energy absorbed by humans and its consequence. The Gray can be converted to rad by multiplying by 100. The conversions in Table A.6 can also be used to convert Grays to rads.

A **roentgen** is a measure of radiation exposure with no SI equivalent. In the metric system, it is expressed in terms of energy per unit mass over time (e.g., watts [W] per kilogram). For conversion purposes, one micro-roentgen per hour ((R/h) is equal to 2.109 picowatts per kilogram (pW/kg).

Additional information on radiation and dose terminology can be found in Appendix C. A list of the radionuclides discussed in this report, their symbols, and their half-lives are included in Table A.7.

the dose received from an approximate 1-day exposure to natural background radiation. An acute (short-term) dose of 1,000 to 4,000 millirems (100,000 to 400,000 millisieverts) can cause radiation sickness in humans. An acute dose of 4,000 to 5,000 millirems (400,000 to 500,000 millisieverts), if left untreated, results in death ~50% of the time. Exposure to lower amounts of radiation (10 millirems [1,000 millisieverts] or less) produces no immediate observable effects, but long-term (delayed) effects are possible. The average person in the United States receives an annual dose

Table A.6. Conversions for Radioactivity Units								
µSv	µSv	µSv	µSv	µSv	mSv	mSv	mSv	Sv
0.01	0.1	1	10	100	1	10	100	1
1	10	100	1	10	100	1	10	100
µrem	µrem	µrem	mrem	mrem	mrem	rem	rem	rem

Unit of absorbed dose – Gray (Gy) (formerly rad).
Unit of dose equivalent – Sievert (Sv) (formerly rem).
Table also converts Gy to rad.

Symbol	Radionuclide	Half-Life	Symbol	Radionuclide	Half-Life
^{3}H	tritium	12.35 yr	^{137m}Ba	barium-137m	2.552 min
^{7}Be	beryllium-7	53.44 d	^{152}Eu	europium-152	13.3 yr
^{14}C	carbon-14	5,730 yr	^{154}Eu	europium-154	8.8 yr
^{40}K	potassium-40	1.3×10^8 yr	^{155}Eu	europium-155	5 yr
^{51}Cr	chromium-51	27.7 d	^{212}Pb	lead-212	10.6 h
^{54}Mn	manganese-54	312.7 d	^{220}Rn	radon-220	56 s
^{55}Fe	iron-55	2.7 yr	^{222}Rn	radon-222	3.8 d
^{59}Fe	iron-59	44.63 d	^{232}Th	thorium-232	1.4×10^{10} yr
^{59}Ni	nickel-59	75,000 yr	U or uranium[b]	uranium total	--[c]
^{60}Co	cobalt-60	5.3 yr	^{233}U	uranium-233	1.59×10^5 yr
^{63}Ni	nickel-63	100.1 yr	^{234}U	uranium-234	2.4×10^5 yr
^{65}Zn	zinc-65	243.9 d	^{235}U	uranium-235	7×10^8 yr
^{85}Kr	krypton-85	10.7 yr	^{237}Np	neptunium-237	2.14×10^6 yr
^{90}Sr	strontium-90	29.1 yr	^{238}U	uranium-238	4.5×10^9 yr
^{90}Y	yttrium-90	64.1 h	^{238}Pu	plutonium-238	87.7 yr
^{95}Zr	zirconium-95	63.98 d	^{239}Pu	plutonium-239	2.4×10^4 yr
^{99}Tc	technetium-99	2.1×10^5 yr	^{240}Pu	plutonium-240	6.5×10^3 yr
^{103}Ru	ruthenium-103	39.3 d	^{241}Pu	plutonium-241	14.4 yr
^{106}Ru	ruthenium-106	368.2 d	^{242}Pu	plutonium-242	3.76×10^5 yr
^{113}Sn	tin-113	115 d	^{241}Am	americium-241	432.2 yr
^{125}Sb	antimony-125	2.8 yr	^{243}Am	americium-243	7,380 yr
^{129}I	iodine-129	1.6×10^7 yr	^{243}Cm	curium-243	28.5 yr
^{131}I	iodine-131	8 d	^{244}Cm	curium-244	18.11 yr
^{134}Cs	cesium-134	2.1 yr	^{245}Cm	curium-245	8,500 yr
^{137}Cs	cesium-137	30 yr			

(a) From Shleien 1992.
(b) Total uranium may also be indicated by U-natural (U-nat) or U-mass.
(c) Natural uranium is a mixture dominated by ^{238}U, thus the half-life is approximately 4.5×10^9 years.

Chemical and Elemental Nomenclature

The chemical contaminants discussed in this report are listed in Table A.8 along with their chemical (or elemental) names and their corresponding symbols.

Understanding the Data Tables

Some degree of variability, or uncertainty, is associated with all analytical measurements. This uncertainty is the consequence of a series of minor, often unintentional or unavoidable, inaccuracies related to collecting and analyzing the samples. These inaccuracies could include errors associated with reading or recording the result, handling or processing the sample, calibrating the counting instrument, and numerical rounding. With radionuclides, inaccuracies can also result from the randomness of radioactive decay. In this report, the uncertainties used include standard deviation, total propagated analytical uncertainty, and standard error of the mean. If the reported concentration of a given constituent is smaller than its associated uncertainty (e.g., 40 ± 200), the sample may not contain that constituent. Such low-concentration values are considered to be below detection, meaning the concentration of the constituent in the sample is so low that it is undetected by the method and/or instrument.

Standard Deviation

The standard deviation (SD) of sample data relates to the variation around the mean of a set of individual

Table A.8. Elemental and Chemical Constituent Nomenclature

Symbol	Constituent	Symbol	Constituent
Ag	silver	Hg	mercury
Al	aluminum	K	potassium
As	arsenic	LiF	lithium fluoride
B	boron	Mg	magnesium
Ba	barium	Mn	manganese
Be	beryllium	Mo	molybdenum
Br	bromine	NH_3	ammonia
C	carbon	NH_4^+	ammonium
Ca	calcium	N	nitrogen
CaF_2	calcium fluoride	Na	sodium
CCl_4	carbon tetrachloride	Ni	nickel
Cd	cadmium	NO_2^-	nitrite
$CHCl_3$	trichloromethane	NO_3^-	nitrate
Cl^-	chloride	Pb	lead
CN^-	cyanide	PO_4^{-3}	phosphate
Cr^{+6}	chromium (species)	P	phosphorus
Cr	chromium (total)	Sb	antimony
CO_3^{-2}	carbonate	Se	selenium
Co	cobalt	Si	silicon
Cu	copper	Sr	strontium
F^-	fluoride	SO_4^{-2}	sulfate
Fe	iron	Ti	titanium
HCO_3^-	bicarbonate	Tl	thallium
		V	vanadium

sample results. If differences in analytical results occur among samples, then two times the standard deviation (or ±2 SD) implies that 95% of the time, a re-count or re-analysis of the same sample would give a value somewhere between the mean result minus the standard deviation and the mean result plus the standard deviation. Analytical results that are close together will have a smaller deviation than the deviation for results that are spread farther apart.

Total Propagated Analytical Uncertainty

For samples that are prepared or manipulated in the laboratory prior to counting (counting the rate of radioactive emissions from a sample), the total propagated analytical uncertainty includes both the counting uncertainty and the uncertainty associated with sample preparation and chemical separations. For samples that are not manipulated in the laboratory before counting, the total propagated analytical uncertainty only accounts for the uncertainty associated with counting the sample. The uncertainty associated with samples that are analyzed but not counted includes only the analytical process uncertainty. In this situation, the total propagated analytical uncertainty is assumed to be the nominal detection limit.

Standard Error of the Mean

Just as individual values are accompanied by counting uncertainties, mean values (averages) are accompanied by ±2 times the standard error of the calculated mean (or ±2 SEM). If the data fluctuate randomly, then two times the standard error of the mean is a measure of the uncertainty in the estimated mean of the data from this randomness. If trends or periodic (e.g., seasonal) fluctuations are present, then two times the standard error of the mean is primarily a measure of the variability in the trends and fluctuations about the mean of the data. As with other uncertainties, two times the standard error of the mean implies that ~95% of the time the next calculated mean will fall somewhere between the reported value minus the standard error and the reported value plus the standard error.

Median, Maximum, and Minimum Values

Median (or sometimes mean), maximum, and minimum values are reported in some sections of this report. A median value is the middle value when all the values are arranged in order of increasing or decreasing magnitude. For example, the median value in the series of

numbers - 1, 2, 3, 3, 4, 5, 5, 5, 6 is 4. The maximum value would be 6 and the minimum value would be 1. Median, maximum, and minimum values are reported when there are too few analytical results to accurately determine the mean with a ± statistical uncertainty or when the data do not follow a bell-shape (i.e., normal) distribution. Figure A.1 provides a graphical representation of median (or sometimes mean), maximum, and minimum values. The upper line is the maximum value, the center dot is the median (or mean) value, and the lower line is the minimum value.

Negative Concentrations

There is always a small amount of natural radiation in the environment. The instruments used in the laboratory to measure radioactivity in Hanford Site environmental media are sensitive enough to measure the natural, or background, radiation along with any contaminant radiation in a sample. To obtain a true measure of the contaminant level in a sample, the natural, or background, radiation level must be subtracted from the total amount of radioactivity measured by an instrument. Because of the randomness of radioactive emissions and the very low activities of some contaminants, it is possible to obtain a background measurement that is larger than the actual contaminant measurement. When the larger background measurement is subtracted from the smaller contaminant measurement, a negative result is generated. The negative results are reported because they are essential when conducting statistical evaluations of the data.

Understanding Graphic Information

Graphs are useful when comparing numbers collected at several locations or at one location over time. Graphs make it easy to visualize differences in data where they exist. However, while graphs may make it easy to evaluate data, they also may lead the reader to incorrect conclusions if they are not interpreted correctly. Careful consideration should be given to the scale (linear or logarithmic), concentration units, and type of uncertainty used.

Some of the data graphed in this report are plotted using logarithmic, or compressed, scales. Logarithmic scales are useful when plotting two or more numbers that differ greatly in size. For example, a sample with a concentration of 5 grams per liter would get lost at the bottom of the graph if plotted on a linear scale with a sample having a concentration of 1,000 grams per liter (Figure A.2). A logarithmic plot of these same two numbers allows the reader to see both data points clearly (Figure A.3).

The mean (average) and median (defined earlier) values graphed in this report have vertical lines extending above and below the data point. When used with a mean value, these lines (called error bars) indicate the amount of uncertainty (standard deviation, total propagated analytical uncertainty, or two standard error of the mean) in the reported result. The error bars in this report represent a 95% chance that the mean is between the upper and lower ends of the error bar and a 5% chance that the true mean is either lower or higher than
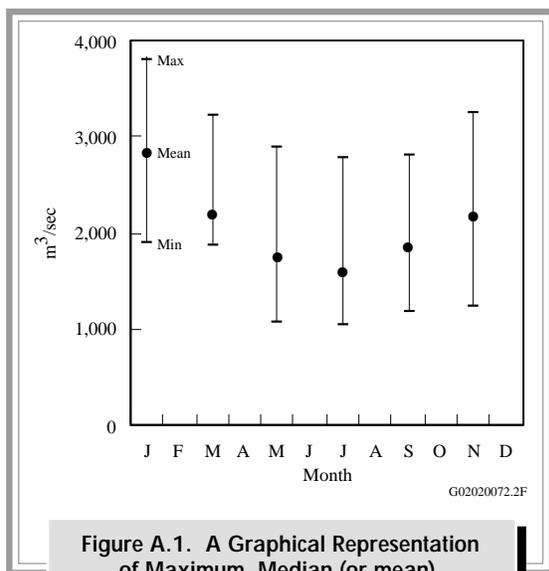

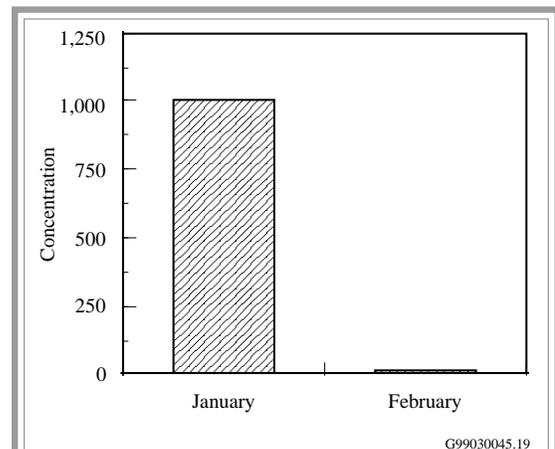Figure A.1. A Graphical Representation of Maximum, Median (or mean), and Minimum Values

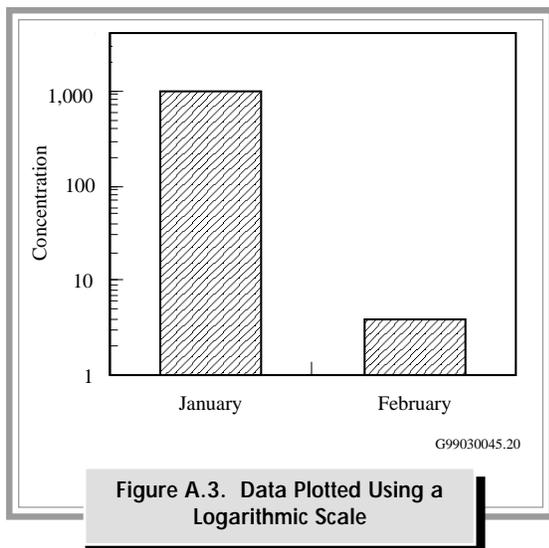Figure A.2. Data Plotted Using a Linear Scale
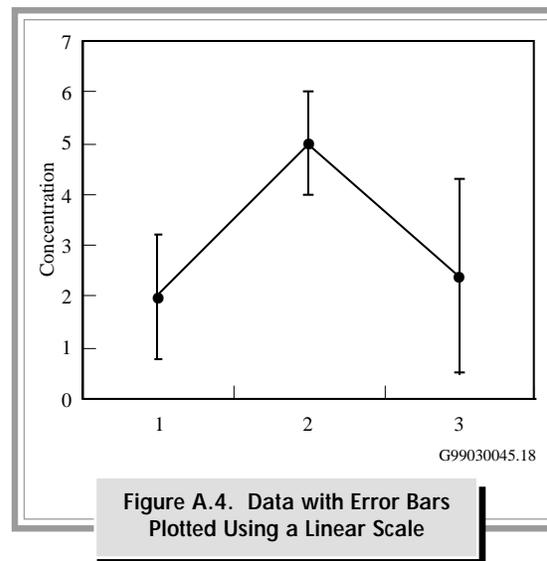
Figure A.3. Data Plotted Using a Logarithmic Scale

Figure A.4. Data with Error Bars Plotted Using a Linear Scale

the error bar.[a] For example, in Figure A.4, the first plotted mean is 2.0 ± 1.1, so there is a 95% chance that the true mean is between 0.9 and 3.1, a 2.5% chance that it is less than 0.9, and a 2.5% chance that it is greater than 3.1. Error bars are computed statistically, employing all of the information used to generate the mean value. These bars provide a quick, visual indication that one mean may be statistically similar to or different from another mean. If the error bars of two or more means overlap, as is the case with means 1 and 3 and

means 2 and 3, the means may be statistically similar. If the error bars do not overlap (means 1 and 2), the means may be statistically different. Means that appear to be very different visually (means 2 and 3) may actually be quite similar when compared statistically.

When vertical lines are used with median values, the lower end of each bar represents the minimum concentration measured; the upper end of each bar represents the maximum concentration measured.

Greater Than (>) or Less Than (<) Symbols

Greater than (>) or less than (<) symbols are used to indicate that the actual value may either be larger than the number given or smaller than the number given. For example, >0.09 would indicate that the actual value is greater than 0.09. An inequality symbol

pointed in the opposite direction (<0.09) would indicate that the number is less than the value presented. An inequality symbol used with an underscore ($\leq$ or $\geq$) indicates that the actual value is less than or equal to or greater than or equal to the number given, respectively.

Reference

Shleien, B. 1992. *The Health Physics and Radiological Health Handbook, Revised Edition.* Scinta, Inc., Silver Spring, Maryland.

(a) Assuming a normal statistical distribution of the data.