ORRES. CONTROL
NCOMING LTR NO.

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DATE

ACTION

DIST.	LTR	ENC
ERMAN, H.S.		
ERNIVAL, G.J.		
OPP, R.D.		
ORDOVA, R.C.		
AVIS, J.G.		
ERRERA, D.W.		
RANZ, W.A.		
ANNI, B.J.		
ALY, T.J.		
EDAHL, T.G.		
LSIG, J.G.		
UTCHINS, N.M.		
ELL, R.E.		
RBY, W.A.		
ESTER, A.W.		
RHAFFEY, J.N.		
NN, H.P.		
RX, G.E.		
KENNA, F.G.		
ORGAN, R.V.		
ZUTO, V.M.		
TTER, G.L.		
NDLIN, N.B.		
TTERWHITE, D.G		
CHUBERT, A.L.		
TLOCK, G.H.		
GER, S.G.	X	X
LLIVAN, M.T.		
ANSON, E.R.		
KINSON, R.B.		
SON, J.M.		
Jenkins J	X	
Roberts RX		

RRES CONTROL	x	x
MN RECORD/080	X	3
TS/T130G		

Reviewed for Addressee
Corres. Control RFP

4/94 Cm
DATE BY

Ref Ltr. #

DE ORDER # 54841

F-46522 (Rev. 01/94)

1A700

Department of Energy

ROCKY FLATS OFFICE
P.O. BOX 928
GOLDEN, COLORADO 80402-0928

MAR 30 1994

94-DOE-03457

Mr. Martin Hestmark
U. S. Environmental Protection Agency, Region VIII
ATTN: Rocky Flats Project Manager, 8HWM-RI
999 18th Street, Suite 500, 8WM-C
Denver, Colorado 80202-2405

0110023642

Mr. Gary Baughman
Hazardous Waste Facilities Unit Leader
Colorado Department of Health
4300 Cherry Creek Drive South
Denver, Colorado 80222-1530

Gentlemen:

Please find enclosed two (2) copies of the final document entitled "Guide for Conducting Statistical Comparisons of RFI/RI Data and Background Data At the Rocky Flats Plant". This document was prepared in response to: (1) the U.S. Environmental Protection Agency, Region VIII, (EPA) letter to the U.S. Department of Energy, Rocky Flats Office (DOE/RFO) dated May 20, 1993; and the August 12, 1993 EPA/Colorado Department of Health (CDH) Stop Work letter to DOE/RFO. In addition, please find enclosed responses to EPA comments dated September 21 and October 25, 1993 and CDH comments dated September 13 and October 13, 1993. These comments, along with the discussion from the September 29, 1993 meeting between EPA, CDH and DOE/RFO are reflected in the final methodology.

The enclosed statistical methodology will be used for comparing Resource Conservation and Recovery Act Facility Investigation/Remedial Investigation (RFI/RI) data and background data for Operable Units (OUs) 3 and up at the Rocky Flats Plant. As stated in the EPA May 20, 1993 letter, both OUs 1 and 2 are exempt from this methodology.

Any questions or concerns regarding this letter and enclosure should be addressed to Bruce Thatcher of my staff at 966-3532.

Sincerely,

for Jessie R. Roberson

Jessie Roberson
Acting Assistant Manager for
Environmental Restoration

Enclosure

APR 1994
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OU03-A-002597

cc w/Enclosure:
A. Rampertaap, EM-453
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S. Slaten, ER, RFO
S. Olinger, AMESH, RFO
G. Hill, ESH, RFO
S. Stiger, EG&G
R. Gilbert, PNL
B. Ramsey, SMS

cc w/o Enclosure:
M. Silverman, OOM, RFO
L. Smith, OOM, RFO
B. Thatcher, ER, RFO
J. Hopkins, EG&G
R. Roberts, EG&G

Guide for Conducting Statistical Comparisons of RFI/RI Data and Background Data At the Rocky Flats Plant

General

This document is intended to provide guidelines for OU-to-background comparisons of data, and to explicitly discuss approaches to the issue of determining OU-specific contamination. The OU-to-background comparison will be applied for inorganics and radionuclides. In addition, the comparison may occasionally be performed for organics on a limited, case-by-case basis, subject to EPA and CDH approval.

It is important to establish a common approach leading to a common list of possible contaminants for each OU. To this end, Figure 1, **GENERAL APPROACH TO DETERMINING "CONTAMINANTS"** was developed. In this general technique, a "Tool-Box" approach is employed to arrive at one common list of contaminants for each OU (or subdivision), for all functional aspects of the RFI/RI and CMS/FS.

As indicated, several disciplines such as the Human Health or Ecological Risk Assessors and Regulatory specialists may pare the list of contaminants to "Contaminants of Concern" (COCs) based on factors germane to their application (e.g., toxicity).

The text below follows Figure 2, **FLOWCHART FOR COMPARING OU DATA TO BACKGROUND.**

Start

Determine Background and OU Target Populations

Appropriate geographical, geological, and temporal data sets will be defined for comparison. This is essentially a matching exercise so that Site (OU) data sets are comparable to background sets. Consideration will be given to issues such as:

Geologic materials
Hydrostratigraphic unit
Temporal comparability
Sample size for statistical tests
Confidence in geo/hydrologic regime determination

The background data sets will be taken from the 1993 Background Geochemistry Characterization Report (EG&G, September, 1993), except for surficial soils. Rock Creek surficial soil samples were used as background for OUs 1 and 2, and will be used until the FY94 surficial soil sampling data is available. Surficial soils are scheduled to be sampled in FY94 to supplement the Rock Creek data and the FY94 samples will be used subsequently as background surficial soil data. The following media have defined backgrounds: groundwater (Rocky Flats Alluvium, valley fill alluvium, colluvium, weathered sandstone, and unweathered Arapahoe/Laramie formation rocks), surface water (Rock Creek and Woman Creek), seeps, stream sediments (Rock Creek and Woman Creek), seep sediments, and soils (Rocky Flats Alluvium, colluvium, surficial, weathered claystone, and weathered Arapahoe, Laramie sandstone). Site media will be cross-referenced to one or more background media.

Set DQOs

DQOs are established to define data needs for each of the RFI/RI tasks, coordinate that collection activities support those needs, and ensure the quality and quantity of resultant data. Three stages are used in the development of DQOs:

Identify Decision Types:

Identify and involve data users,
Evaluate available data,
Develop a conceptual model of the study site, and
Specify RFI/RI objectives, and anticipate the decisions necessary to achieve the objectives.

Identify Data Uses and Needs:

Identify data uses,
Identify data types,
Identify data-quality needs,
Identify data-quantity needs,
Evaluate sampling and analysis options, and
Review data precision, accuracy, representativeness, completeness, and comparability (PARCC).

Design Data Collection Program:

Assemble data-collection components, and
Develop data-collection documentation.

Data Collection and Validation

Under current IAG schedule conditions, analytical data may not be 100% "validated" when the background comparisons are made in each draft report. However, non-validated data will be used only for draft RFI/RIs. Final RFI/RI reports will use only data that have undergone

validation. Data that have been rejected will not be used. The potential impacts of using non-validated data will be discussed on a case-by-case basis in the final reports.

Data Presentation

A "preliminary" exploratory data appraisal will be performed to obtain a "feel" for the data. This will involve techniques and identification of issues such as:

Gross summary statistics
Spatial arrays
Temporal plots
Sampling strategy comparability evaluation
Affected media matrix
Hit ratios
Non-detect rates
Detection limit/quantitation limit issues
Extent of data qualifications "J", "B", etc.
Histograms/boxplots/other visuals
DQO adequacy/completeness assessment

This step will help guide the need for, and evaluate the appropriateness and applicability of further analysis, evaluate assumptions, and ascertain the impacts and limitations in light of the actual data as collected. Information generated during the exploratory data appraisal will be used in evaluating the appropriateness of the scope of the formal RFI/RI proposal. Results will be informationally discussed in a meeting with EPA, CDH, and DOE/RFO.

Several data-presentation techniques were identified by Dr. Gilbert as appropriate for different conditions. To perform them all for all compounds in a standard full suite is not necessary when it is clear from a preliminary review that the vast majority of data points for some compounds are entirely or almost entirely non-detects.

Accordingly, we have refined the methodology as follows:

Box plots will be used when the percentage of non-detects is 50% or less.

Histograms will also be used when the percentage of non-detects is 50% or less. Bars in the histogram will be shaded to indicate the percentage of detects and non-detects within each bar interval.

Probability plots, ordered listings, and other graphics will be used as appropriate.

As indicated by the OU1 process, visual presentation of the data is important. Interpretable graphics will be produced to the extent that they facilitate analysis. In general, graphics will be a central feature of analysis.

BACKGROUND COMPARISON METHODOLOGY TOOL BOX APPROACH

Employing: Bounding-Benchmark Comparison (Hot Measurement), Inferential Statistics, and Professional Judgement

General

The tool-box approach employs a bounding-benchmark comparison, inferential statistics, and professional judgement. This approach was forwarded in the OU1 comment-resolution process, endorsed by Dr. Gilbert, and is widely applied in the hazardous waste industry and environmental business across America. It employs a "weight-of-evidence" framework wherein all three aspects are factored into the determination of what is a Site (OU) contaminant. Statisticians will be used to verify that the methods used are correct.

Bounding-Benchmark Comparison ("Hot-Measurement Test" Component)

- A hot-measurement test will be performed that will compare each analyte concentration to an upper-limit value for that analyte.

- The upper-limit value will be the value at which there is a 99% probability that 99% of the background distribution will be below this value ($UTL_{99/99}$). If the $UTL_{99/99}$ cannot be calculated or reasonably estimated, then background values from technical literature and professional judgement will be used. The resulting geochemical interpretation of data will be subject to Agency review and approval.

- The $UTL_{99/99}$ is required instead of a toxicity-based value because a single list of potential contaminants must be used by many disciplines (Human Health, Ecological, Regulatory, etc.,) to ensure consistency across the RFI/RI and CMS/FS Reports. The subjective nature of what is "hot", as well as toxicity and ARAR considerations, will be dealt with by the specialists who determine COC's specific to their discipline.

- In addition to ensuring that high concentrations do not get overlooked, the $UTL_{99/99}$ is an important tool for identifying locations of suspected elevated concentration in the "nature and extent" section.

Background Comparison Using Inferential Statistical Methods

Based on Dr. Gilbert's work, the following inferential statistical tests will be used to compare background data sets to data sets compiled at the Operable Units (OUs). These data sets will be compiled and compared by analyte, and by the correct background data set (i.e., colluvium, alluvium, alluvium + colluvium, surface soils, etc. [See Determine Background and OU Target Populations]).

It should be noted that Dr. Gilbert's recommendations establish a framework that emphasizes using the most appropriate test available. Thus professional judgement will be necessary both in application of inferential tests, as well as their interpretation. Additionally, within the framework of a battery of tests drawn from a "tool box" of methods, it is requested that EPA and CDH remain open to consultation on the use of other tests as appropriate.

The results of all tests (hot-measurement, inferential) will then be evaluated in light of professional judgement. This process is depicted on Figure 3, **BACKGROUND COMPARISONS METHODOLOGY.**

If hot-measurement or inferential statistical tests show that the concentration of a given analyte in the OU data set is not greater than the concentration in the background data set, and if considerations in the professional-judgement arena do not override, then the analyte is considered not to be a contaminant.

If either the hot-measurement test or at least one inferential statistical test shows that the concentration of a given analyte in the OU data set may be greater than the concentration in the background data set, then professional judgement (using temporal and spatial analysis, as well as pattern-recognition concepts) is again applied to see if the analyte concentrations in the two data sets are actually different.

After the hot-measurement test and prior to the use of inferential statistical testing, the issue of non-detects must be dealt with for all tests except the Gehan test, which can be applied with non-detects present. For all other tests, non-detects should be replaced with a value of 0.5 times the applicable reported detection limit, following EPA guidance (Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance, July 1992), but realizing the performance of simple substitution decreases with an increasing proportion of non-detects.

The handling of non-detects, and the presence of multiple detection limits in the RFEDS data base, requires the use of good professional judgement along with the general guidance offered here. The use of graphical displays of data will assist in the handling of high-value non-detects.

Detection limits will be discussed in the RI report.

Gehan Test or Nonparametric ANOVA Test

- The Gehan test is a nonparametric test and can be used when multiple detection limits are present. The Gehan test will be applied without replacing non-detects. These are the principal favorable attributes of the Gehan test.

- Standard nonparametric ANOVA tests (Wilcoxon Rank Sum and Kruskal-Wallis) are widely used in environmental assessment, and are discussed in EPA guidance (Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance, July 1992). These tests require replacement of non-detect values, either by simple substitution or maximum-likelihood methods.

- For the Gehan or nonparametric ANOVA test, a p-value will be generated and p-values that are equal to or less than 0.05 will normally be considered indicative of a significant difference from background. Statements of the test and null hypotheses will be given, in both statistical and narrative terms.

Quantile Test

- The quantile test is also a nonparametric test and can be considered as a rapid screening test.

- Due to limitations in the quantile test, the test will only be used if the largest 20% of the combined background and site data are detects.

- A p-value will be generated and p-values that are equal to or less than 0.05 will indicate a significant difference from background. Statements of the test and null hypotheses will be given, in both statistical and narrative terms.

Slippage Test

- The slippage test is a nonparametric test and can be considered as a rapid screening test.

- Due to limitations in the slippage test, the test will possibly not be used if the largest background value is a non-detect. If the largest background value is a non-detect, then professional judgement will be applied to determine whether or not the slippage test is applicable. For example, if the second largest background value is a detect and is similar in value to the largest background value, it could be used in place of the largest value (although the replacement must be taken into account when interpreting the test results).

- A p-value will be generated and p-values that are equal to or less than 0.05 will indicate a significant difference from background. Statements of the test and null hypotheses will be given, in both statistical and narrative terms.

T-Test

- The t-test is a parametric test and is very commonly used when testing the difference between means of two data sets.

- Due to limitations in the t-test, the test will be applied in cases where both background and OU data are normally distributed and contain at least 20 data points, and less than 20% of the background and OU data are classified as non-detects.

- A p-value will be generated and p-values that are equal to or less than 0.05 will indicate a significant difference from background. Statements of the test and null hypotheses will be given, in both statistical and narrative terms.

Professional Judgement

The following general guidelines will be used individually and collectively, in conjunction with the above comparison and statistical "tools" to ascertain if a reported analytical detection(s) constitutes contamination at the OU. When professional judgement is applied, documented and defensible evidence will be furnished, and DOE will bear the "burden of proof".

- **Spatial distribution** of analytes above background are or are not indicative of contamination due to waste-related activities at the OU. Spatial plots, interpreted in a source-to-receptor conceptual model, in addition to compound-specific mobility considerations, generally assist in interpretation of inconclusive results.

- **Temporal distribution** of analyte concentrations at a station indicates the "high" value(s) is(are) outlier(s). Time-series plots at wells or surface-water locations can generally be used to link apparently insignificant **outlier** reports to seasonal or hydrological phenomena, and vice versa.

- Other associated analytes are determined not to be contaminants in the sample or at the station. Then this may be added to cumulative evidence ("burden of proof") that the analyte in question is not a potential contaminant of concern. **Pattern-recognition concepts** are useful in identifying anomalies as well as confirming "fingerprint" associations.

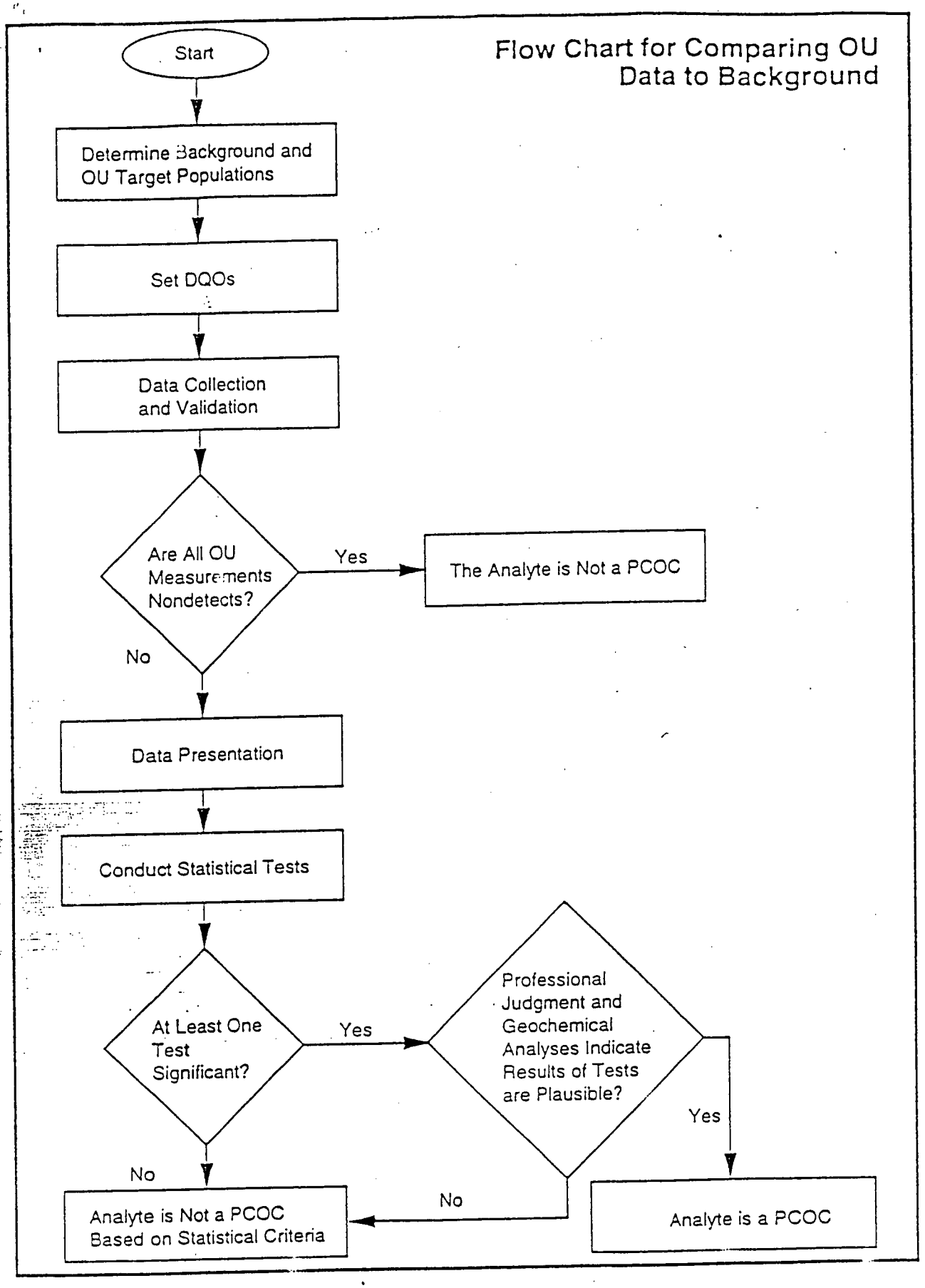

Figure 1
Flow Chart for Comparing
OU Data to Background

GENERAL APPROACH TO DETERMINING "CONTAMINANTS"

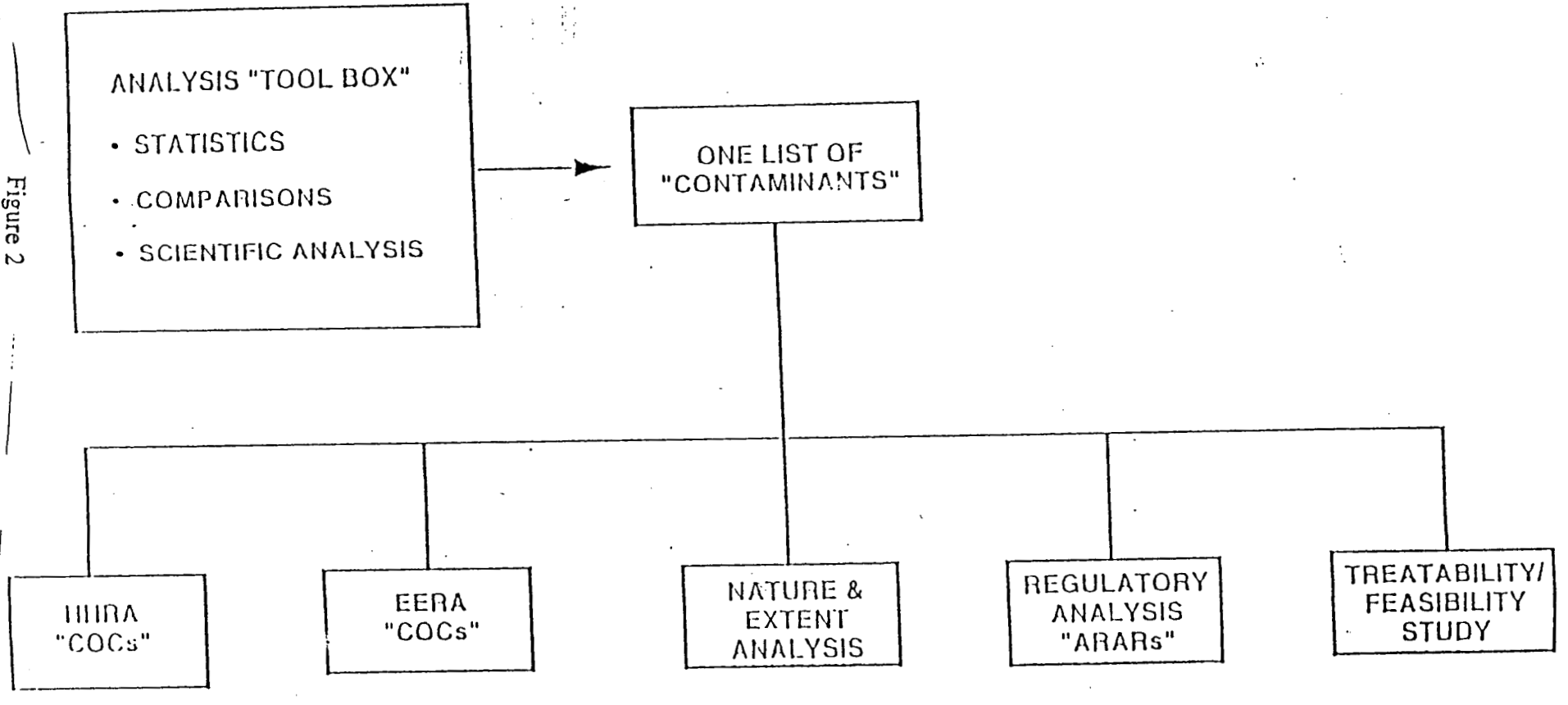

Figure 2
General Approach To Determining "Contaminants"

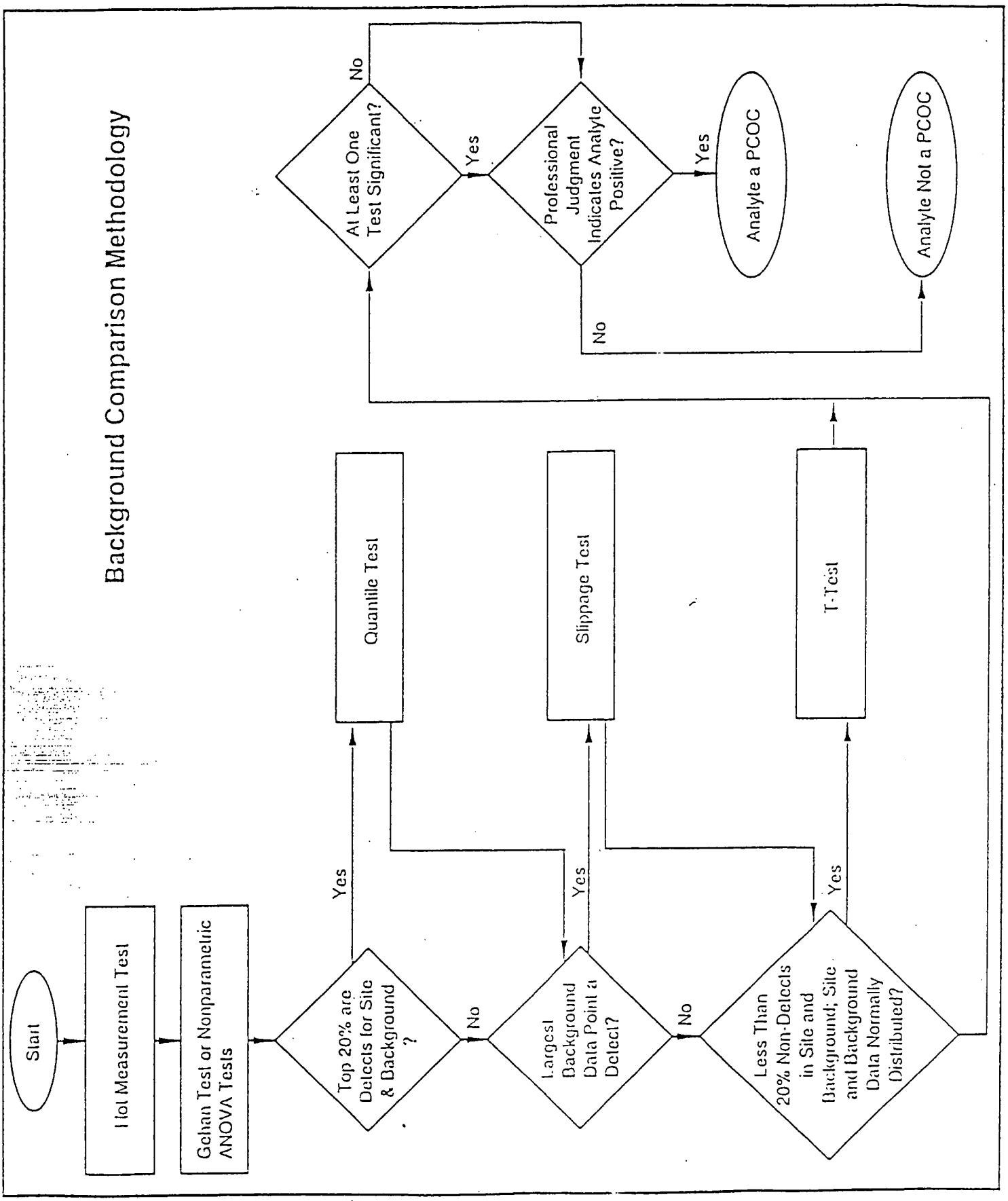

Figure 3
Background Comparison Methodology

Table C-1. Groundwater UTLs by geologic unit for dissolved metals.

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER, DISSOLVED METALS

ANALYTE	GEOLOGIC UNIT	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	COL	35	71.43	59.18	49.50	224.21	UG/L
ANTIMONY	COL	33	33.33	14.84	9.50	46.92	UG/L
BARIUM	COL	34	79.41	77.05	39.03	207.99	UG/L
CADMIUM	COL	34	23.53	1.97	1.67	7.57	UG/L
CALCIUM	COL	35	100.00	96,314.29	34,355.90	210,868.89	UG/L
CHROMIUM	COL	32	28.12	5.87	5.93	26.03	UG/L
COPPER	COL	33	36.36	5.08	4.20	19.27	UG/L
IRON	COL	34	61.76	46.38	79.70	313.70	UG/L
LITHIUM	COL	34	88.24	122.77	84.53	406.30	UG/L
MAGNESIUM	COL	34	100.00	20,479.41	10,610.71	56,070.91	UG/L
MANGANESE	COL	35	74.29	32.10	38.69	161.12	UG/L
MOLYBDENUM	COL	33	42.42	19.35	32.15	127.67	UG/L
POTASSIUM	COL	33	84.85	2,086.36	1,903.98	8,513.03	UG/L
SELENIUM	COL	32	62.50	17.40	42.89	163.12	UG/L
SILVER	COL	31	25.81	3.22	2.81	12.84	UG/L
SODIUM	COL	35	100.00	98,454.29	64,522.31	313,594.26	UG/L
STRONTIUM	COL	34	97.06	701.88	374.80	1,959.08	UG/L
TIN	COL	31	41.94	44.01	62.59	258.16	UG/L
VANADIUM	COL	32	65.62	8.17	7.85	34.84	UG/L
ZINC	COL	35	74.29	11.30	10.64	46.78	UG/L
ALUMINUM	RFA	104	75.00	68.23	125.93	361.64	UG/L
ANTIMONY	RFA	113	49.56	18.37	12.98	48.61	UG/L
BARIUM	RFA	114	83.33	72.32	24.50	129.39	UG/L
CADMIUM	RFA	107	22.43	1.66	1.13	4.29	UG/L
CALCIUM	RFA	113	100.00	37,655.53	18,707.96	81,245.08	UG/L
CHROMIUM	RFA	113	41.59	4.86	3.33	12.63	UG/L
COPPER	RFA	112	43.75	4.79	4.13	14.40	UG/L
IRON	RFA	113	76.99	70.28	157.23	436.62	UG/L
LEAD	RFA	111	24.32	1.40	3.01	8.41	UG/L
LITHIUM	RFA	109	68.81	12.68	17.36	53.12	UG/L
MAGNESIUM	RFA	112	91.96	4,266.21	1,369.27	7,456.60	UG/L
MANGANESE	RFA	114	52.63	6.17	15.04	41.21	UG/L
MOLYBDENUM	RFA	106	35.85	19.37	34.13	98.88	UG/L
NICKEL	RFA	106	36.79	7.66	7.65	25.49	UG/L
POTASSIUM	RFA	110	79.09	925.94	705.81	2,570.48	UG/L
SILVER	RFA	105	28.57	2.73	1.88	7.11	UG/L
SODIUM	RFA	112	98.21	7,602.21	1,740.42	11,557.40	UG/L
STRONTIUM	RFA	112	86.61	132.73	91.06	344.89	UG/L
THALLIUM	RFA	92	21.74	1.68	1.64	5.50	UG/L
TIN	RFA	100	41.00	29.72	34.02	108.98	UG/L
VANADIUM	RFA	111	62.16	8.36	9.95	31.54	UG/L
ZINC	RFA	113	79.65	15.69	19.83	61.88	UG/L

Table C-2. Groundwater UTLs by geologic unit for total metals.

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER, TOTAL METALS

ANALYTE	GEOLOGIC UNIT	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	COL	19	100.00	745.11	789.02	3,816.32	UG/L
ANTIMONY	COL	20	30.00	17.74	9.52	54.22	UG/L
ARSENIC	COL	20	40.00	1.93	1.65	8.24	UG/L
BARIUM	COL	20	85.00	90.87	86.40	345.29	UG/L
CADMIUM	COL	20	25.00	1.97	1.74	8.64	UG/L
CALCIUM	COL	20	100.00	99,540.00	37,654.79	243,816.53	UG/L
CHROMIUM	COL	18	22.22	4.59	4.36	21.88	UG/L
COPPER	COL	20	65.00	9.29	11.81	54.54	UG/L
IRON	COL	19	100.00	865.11	679.22	3,308.92	UG/L
LEAD	COL	18	38.89	2.28	4.27	19.18	UG/L
LITHIUM	COL	20	85.00	117.94	86.49	449.35	UG/L
MAGNESIUM	COL	20	100.00	21,320.00	11,477.51	65,296.75	UG/L
MANGANESE	COL	20	95.00	57.46	126.39	541.73	UG/L
MOLYBDENUM	COL	20	40.00	23.88	39.19	174.05	UG/L
NICKEL	COL	18	33.33	7.25	6.31	32.26	UG/L
POTASSIUM	COL	20	75.00	2,013.25	1,893.58	9,268.62	UG/L
SELENIUM	COL	18	66.67	15.04	47.11	201.61	UG/L
SILICON	COL	12	100.00	8,600.75	2,462.31	20,008.64	UG/L
SODIUM	COL	20	100.00	101,010.00	68,738.74	364,386.48	UG/L
STRONTIUM	COL	20	100.00	705.85	379.49	2,159.90	UG/L
THALLIUM	COL	20	35.00	1.68	1.76	8.43	UG/L
TIN	COL	20	40.00	35.35	34.62	167.99	UG/L
VANADIUM	COL	20	75.00	16.82	27.37	121.70	UG/L
ZINC	COL	20	95.00	31.55	36.14	170.01	UG/L
ALUMINUM	RFA	66	93.94	3,844.45	5,057.31	19,223.71	UG/L
ANTIMONY	RFA	63	42.86	21.40	15.61	68.88	UG/L
ARSENIC	RFA	61	27.87	2.07	1.76	7.43	UG/L
BARIUM	RFA	66	78.79	96.13	36.76	207.92	UG/L
CALCIUM	RFA	67	100.00	38,690.30	17,954.04	93,288.54	UG/L
CESIUM	RFA	65	23.08	150.64	202.63	766.84	UG/L
CHROMIUM	RFA	64	56.25	8.21	7.49	30.99	UG/L
COBALT	RFA	66	21.21	8.46	10.30	39.78	UG/L
COPPER	RFA	66	77.27	12.25	13.56	53.48	UG/L
IRON	RFA	66	98.48	4,262.08	5,950.89	22,389.15	UG/L
LEAD	RFA	63	71.43	3.64	3.95	1[illegible].54	UG/L
LITHIUM	RFA	67	76.12	17.15	19.09	75.19	UG/L
MAGNESIUM	RFA	67	95.52	5,050.67	2,112.67	11,475.30	UG/L
MANGANESE	RFA	66	90.91	90.09	113.99	436.73	UG/L
MOLYBDENUM	RFA	63	33.82	24.80	40.38	147.60	UG/L
NICKEL	RFA	66	40.91	13.25	11.32	47.69	UG/L
POTASSIUM	RFA	68	76.47	1,578.46	1,190.52	5,198.84	UG/L
SILICON	RFA	37	100.00	19,033.92	11,446.15	56,777.23	UG/L
SODIUM	RFA	67	97.01	7,797.16	1,995.38	13,865.12	UG/L
STRONTIUM	RFA	64	78.12	125.27	39.20	244.47	UG/L
TIN	RFA	68	32.35	34.01	36.65	145.45	UG/L
VANADIUM	RFA	66	78.79	14.87	11.21	48.97	UG/L
ZINC	RFA	67	8[illegible]6	40.26	67.22	244.69	UG/L

Table C-2 (cont').

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER, TOTAL METALS (CONT')

ANALYTE	GEOLOGIC UNIT	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	VFA	43	97.67	2,560.55	3,909.13	14,893.86	UG/L
ANTIMONY	VFA	41	31.71	16.54	9.86	47.64	UG/L
ARSENIC	VFA	41	31.71	1.70	1.57	6.65	UG/L
BARIUM	VFA	43	83.72	112.77	30.98	210.51	UG/L
CADMIUM	VFA	43	25.58	1.79	1.78	7.39	UG/L
CALCIUM	VFA	43	100.00	60,361.72	30,137.58	155,445.78	UG/L
CESIUM	VFA	40	30.00	142.06	184.65	741.90	UG/L
CHROMIUM	VFA	42	50.00	6.96	6.89	28.69	UG/L
COBALT	VFA	43	20.93	6.73	8.52	33.83	UG/L
COPPER	VFA	43	81.40	10.43	12.48	49.80	UG/L
IRON	VFA	43	100.00	2,732.59	4,[illegible]79.64	17,181.35	UG/L
LEAD	VFA	40	77.50	3.39	3.26	13.97	UG/L
LITHIUM	VFA	43	81.40	22.51	18.95	82.29	UG/L
MAGNESIUM	VFA	43	97.67	12,865.24	6,410.62	33,090.74	UG/L
MANGANESE	VFA	43	95.35	92.38	104.18	421.07	UG/L
MERCURY	VFA	43	23.26	0.12	0.04	0.26	UG/L
MOLYBDENUM	VFA	43	27.91	18.90	36.26	133.29	UG/L
NICKEL	VFA	43	44.19	8.41	7.05	30.65	UG/L
POTASSIUM	VFA	43	81.40	1,785.13	913.58	4,667.48	UG/L
SELENIUM	VFA	42	42.86	3.42	7.97	28.55	UG/L
SILICON	VFA	23	100.00	15,831.46	11,777.33	59,186.01	UG/L
SODIUM	VFA	43	100.00	32,929.90	16,184.58	83,992.25	UG/L
STRONTIUM	VFA	43	95.35	374.14	206.92	1,025.97	UG/L
THALLIUM	VFA	43	27.91	1.47	1.59	6.49	UG/L
TIN	VFA	42	38.10	31.89	32.57	134.65	UG/L
VANADIUM	VFA	43	79.07	12.20	10.56	45.52	UG/L
ZINC	VFA	43	100.00	39.93	28.56	130.03	UG/L
ALUMINUM	WCS	19	89.47	1,326.18	2,630.79	11,566.37	UG/L
ANTIMONY	WCS	17	47.06	19.09	10.53	61.58	UG/L
BARIUM	WCS	19	84.21	113.17	66.05	370.27	UG/L
CALCIUM	WCS	19	100.00	53,731.58	13,527.83	106,387.86	UG/L
CESIUM	WCS	20	35.00	188.32	215.25	1,013.07	UG/L
CHROMIUM	WCS	19	36.84	5.40	4.02	21.06	UG/L
COPPER	WCS	19	57.89	7.15	4.34	24.03	UG/L
IRON	WCS	19	89.47	1,690.19	3,323.94	14,628.42	UG/L
LEAD	WCS	19	73.68	2.68	2.62	12.89	UG/L
LITHIUM	WCS	19	73.68	29.12	15.94	91.18	UG/L
MAGNESIUM	WCS	19	100.00	11,527.89	3,792.95	25,291.71	UG/L
MANGANESE	WCS	19	68.42	37.44	56.99	259.28	UG/L
MOLYBDENUM	WCS	19	42.11	33.49	44.45	206.49	UG/L
POTASSIUM	WCS	19	73.68	1,858.95	500.67	3,807.76	UG/L
SELENIUM	WCS	18	50.00	9.10	19.03	84.48	UG/L
SILICON	WCS	10	100.00	10,474.00	5,966.37	40,745.70	UG/L
SODIUM	WCS	19	100.00	27,557.89	9,531.60	64,659.09	UG/L
STRONTIUM	WCS	19	100.00	390.47	150.51	976.33	UG/L
THALLIUM	WCS	18	27.78	1.95	1.96	9.71	UG/L
TIN	WCS	19	31.58	36.28	39.56	190.26	UG/L
VANADIUM	WCS	19	68.42	10.57	9.20	46.39	UG/L
ZINC	WCS	19	84.21	25.91	17.93	95.69	UG/L

Table C-2 (cont').

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER, TOTAL METALS (CONT)

ANALYTE	GEOLOGIC UNIT	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	KAR	37	91.89	1,791.87	2,773.43	10,937.17	UG/L
ANTIMONY	KAR	35	31.43	15.62	10.40	50.28	UG/L
ARSENIC	KAR	35	54.29	2.76	2.02	9.51	UG/L
BARIUM	KAR	36	86.11	113.95	51.97	286.27	UG/L
CALCIUM	KAR	37	100.00	36,382.43	23,881.47	115,130.79	UG/L
CESIUM	KAR	35	25.71	131.59	175.16	715.62	UG/L
CHROMIUM	KAR	36	38.89	5.25	4.61	20.54	UG/L
COPPER	KAR	36	61.11	11.99	21.82	84.34	UG/L
IRON	KAR	37	94.59	2,239.92	3,697.44	14,432.11	UG/L
LEAD	KAR	36	61.11	3.82	4.29	18.06	UG/L
LITHIUM	KAR	37	86.49	40.69	29.29	137.26	UG/L
MAGNESIUM	KAR	37	94.59	6,679.46	5,030.81	23,268.40	UG/L
MANGANESE	KAR	37	86.49	61.87	125.21	474.75	UG/L
MERCURY	KAR	37	27.03	0.13	0.05	0.28	UG/L
MOLYBDENUM	KAR	36	47.22	18.59	33.45	129.48	UG/L
NICKEL	KAR	35	34.29	8.70	7.25	32.89	UG/L
POTASSIUM	KAR	37	89.19	2,846.38	1,725.69	8,536.77	UG/L
SELENIUM	KAR	36	33.33	1.19	0.63	3.27	UG/L
SILICON	KAR	20	100.00	9,427.50	6,631.12	34,835.00	UG/L
SODIUM	KAR	37	100.00	139,228.38	134,404.33	582,422.16	UG/L
STRONTIUM	KAR	37	97.30	399.78	312.58	1,430.50	UG/L
THALLIUM	KAR	36	27.78	1.40	1.50	6.36	UG/L
TIN	KAR	37	29.73	27.46	31.18	130.28	UG/L
VANADIUM	KAR	36	69.44	10.43	11.26	47.75	UG/L
ZINC	KAR	36	97.22	52.45	51.31	222.56	UG/L

Table C-3. Groundwater UTLs by geologic unit for dissolved radionuclides.

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER, DISSOLVED RADIONUCLIDES

ANALYTE	GEOLOGIC UNIT	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	UTL 99 / 99	UNITS
CESIUM-137	COL	2	100.00	0.36	0.42	78.73	pCi/L
GROSS ALPHA	COL	30	100.00	41.31	78.79	312.85	pCi/L
GROSS BETA	COL	27	100.00	17.51	29.87	123.04	pCi/L
RADIUM-226	COL	15	100.00	0.21	0.10	0.64	pCi/L
STRONTIUM-89,90	COL	23	100.00	0.25	0.24	1.13	pCi/L
TRITIUM	COL	31	100.00	76.12	109.42	450.48	pCi/L
URANIUM-233,234	COL	30	100.00	31.82	56.44	226.34	pCi/L
URANIUM-235	COL	30	100.00	0.86	1.39	5.63	pCi/L
URANIUM-238	COL	24	100.00	26.70	42.13	180.03	pCi/L
CESIUM-137	RFA	15	100.00	0.27	0.29	1.48	pCi/L
GROSS ALPHA	RFA	82	100.00	0.59	0.80	3.02	pCi/L
GROSS BETA	RFA	76	100.00	1.66	1.52	6.28	pCi/L
RADIUM-226	RFA	2	100.00	0.17	0.04	7.91	pCi/L
RADIUM-228	RFA	2	100.00	2.20	0.42	8[illegible].95	pCi/L
STRONTIUM-89,90	RFA	81	100.00	0.27	0.23	0.98	pCi/L
TRITIUM	RFA	63	100.00	163.03	223.01	841.20	pCi/L
URANIUM-233,234	RFA	7[illegible]	100.00	0.23	0.21	0.88	pCi/L
URANIUM-235	RFA	78	100.00	0.03	0.07	0.23	pCi/L
URANIUM-238	RFA	69	100.00	0.14	0.14	0.56	pCi/L
CESIUM-137	VFA	17	100.00	0.58	0.71	3.43	pCi/L
GROSS ALPHA	VFA	60	100.00	2.93	3.17	12.94	pCi/L
GROSS BETA	VFA	55	100.00	3.20	1.69	8.54	pCi/L
RADIUM-226	VFA	13	100.00	0.31	0.11	0.81	pCi/L
RADIUM-228	VFA	4	100.00	2.08	0.62	9.76	pCi/L
STRONTIUM-89,90	VFA	59	100.00	0.49	0.38	1.68	pCi/L
TRITIUM	VFA	42	100.00	115.00	137.64	549.26	pCi/L
URANIUM-233,234	VFA	60	100.00	2.05	2.77	10.80	pCi/L
URANIUM-235	VFA	60	100.00	0.08	0.12	0.47	pCi/L
URANIUM-238	VFA	49	100.00	1.66	2.30	8.92	pCi/L
CESIUM-137	WCS	4	100.00	0.32	0.20	2.86	pCi/L
GROSS ALPHA	WCS	41	100.00	7.70	5.95	26.47	pCi/L
GROSS BETA	WCS	38	100.00	4.85	3.22	15.41	pCi/L
RADIUM-226	WCS	6	100.00	0.32	0.06	0.78	pCi/L
STRONTIUM-89,90	WCS	17	100.00	0.24	0.24	1.21	pCi/L
TRITIUM	WCS	29	100.00	[illegible]3.42	118.54	388.30	pCi/L
URANIUM-233,234	WCS	39	100.00	8.59	21.06	77.33	pCi/L
URANIUM-235	WCS	39	100.00	0.20	0.51	1.88	pCi/L
URANIUM-238	WCS	35	100.00	3.54	3.19	14.17	pCi/L
CESIUM-137	KAR	4	100.00	0.22	0.30	3.92	pCi/L
GROSS ALPHA	KAR	60	100.00	3.13	6.24	22.81	pCi/L
GROSS BETA	KAR	54	100.00	3.23	2.84	12.19	pCi/L
RADIUM-226	KAR	2	100.00	1.72	1.78	331.75	pCi/L
STRONTIUM-89,90	KAR	42	100.00	0.47	1.19	4.21	pCi/L
TRITIUM	KAR	49	100.00	56.88	135.94	485.77	pCi/L
URANIUM-233,234	KAR	57	100.00	1.64	2.85	10.63	pCi/L
URANIUM-235	KAR	57	100.00	0.03	0.06	0.23	pCi/L
URANIUM-238	KAR	54	100.00	0.77	1.53	5.58	pCi/L

Table C-4. Groundwater UTLs by geologic unit for total radionuclides.

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER, TOTAL RADIONUCLIDES

ANALYTE	GEOLOGIC UNIT	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	UTL 99 / 99	UNITS
AMERICIUM-241	COL	25	100.00	0.00	0.00	0.01	pCi/L
CESIUM-137	COL	23	100.00	0.18	0.35	1.49	pCi/L
GROSS ALPHA	COL	6	100.00	150.35	142.75	1,197.38	pCi/L
GROSS BETA	COL	6	100.00	81.55	85.25	706.79	pCi/L
PLUTONIUM-239,240	COL	26	100.00	0.01	0.01	0.04	pCi/L
STRONTIUM-89,90	COL	7	100.00	0.26	0.11	0.95	pCi/L
TRITIUM	COL	17	100.00	201.15	193.39	981.82	pCi/L
URANIUM-233,234	COL	8	100.00	58.74	66.80	446.99	pCi/L
URANIUM-235	COL	8	100.00	2.14	2.39	16.03	pCi/L
URANIUM-238	COL	6	100.00	36.04	46.48	376.92	pCi/L
AMERICIUM-241	RFA	82	100.00	0.01	0.01	0.03	pCi/L
CESIUM-137	RFA	75	100.00	0.08	0.33	1.09	pCi/L
GROSS ALPHA	RFA	5	100.00	1.89	1.28	13.30	pCi/L
GROSS BETA	RFA	5	100.00	2.25	1.48	15.45	pCi/L
PLUTONIUM-238	RFA	7	100.00	0.00	0.00	0.01	pCi/L
PLUTONIUM-239,240	RFA	85	100.00	0.00	0.00	0.01	pCi/L
STRONTIUM-89,90	RFA	13	100.00	0.11	0.21	1.04	pCi/L
TRITIUM	RFA	21	100.00	226.72	307.18	1,386.83	pCi/L
URANIUM-233,234	RFA	12	100.00	0.48	0.45	2.58	pCi/L
URANIUM-235	RFA	12	100.00	0.12	0.20	1.05	pCi/L
URANIUM-238	RFA	11	100.00	0.40	0.50	2.83	pCi/L
AMERICIUM-241	VFA	56	100.00	0.01	0.01	0.05	pCi/L
CESIUM-137	VFA	44	100.00	0.10	0.30	1.05	pCi/L
GROSS ALPHA	VFA	7	100.00	3.66	2.06	16.84	pCi/L
GROSS BETA	VFA	7	100.00	4.54	2.83	22.56	pCi/L
PLUTONIUM-238	VFA	6	100.00	0.01	0.01	0.09	pCi/L
PLUTONIUM-239,240	VFA	62	100.00	0.01	0.04	0.12	pCi/L
STRONTIUM-89,90	VFA	8	100.00	0.43	0.37	2.56	pCi/L
TRITIUM	VFA	27	100.00	142.96	180.32	779.97	pCi/L
URANIUM-233,234	VFA	7	100.00	1.58	1.00	8.01	pCi/L
URANIUM-235	VFA	7	100.00	0.10	0.10	0.75	pCi/L
URANIUM-238	VFA	2	100.00	1.23	1.20	223.18	pCi/L

Table C-4 (cont').

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER, TOTAL RADIONUCLIDES (CONT')

ANALYTE	GEOLOGIC UNIT	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	UTL 99 / 99	UNITS
AMERICIUM-241	WCS	20	100.00	0.01	0.01	0.07	pCi/L
CESIUM-137	WCS	14	100.00	0.28	0.36	1.86	pCi/L
GROSS ALPHA	WCS	5	100.00	12.65	12.46	124.04	pCi/L
GROSS BETA	WCS	5	100.00	8.27	5.11	53.95	pCi/L
PLUTONIUM-239,240	WCS	21	100.00	0.00	0.00	0.02	pCi/L
RADIUM-226	WCS	4	100.00	0.36	0.15	2.19	pCi/L
STRONTIUM-89,90	WCS	4	100.00	0.05	0.26	3.25	pCi/L
TRITIUM	WCS	19	100.00	2,128.76	8,937.88	36,918.91	pCi/L
URANIUM-233,234	WCS	8	100.00	7.49	6.30	44.13	pCi/L
URANIUM-235	WCS	8	100.00	0.28	0.26	1.81	pCi/L
URANIUM-238	WCS	3	100.00	5.11	4.96	123.65	pCi/L
AMERICIUM-241	KAR	43	100.00	0.01	0.02	0.07	pCi/L
CESIUM-137	KAR	39	100.00	0.00	0.29	0.95	pCi/L
GROSS ALPHA	KAR	6	100.00	11.08	16.63	133.08	pCi/L
GROSS BETA	KAR	6	100.00	12.01	13.45	110.67	pCi/L
PLUTONIUM-238	KAR	5	100.00	0.01	0.01	0.14	pCi/L
PLUTONIUM-239,240	KAR	48	100.00	0.00	0.01	0.02	pCi/L
RADIUM-226	KAR	3	100.00	0.59	0.45	11.30	pCi/L
STRONTIUM-89,90	KAR	4	100.00	0.10	0.26	3.34	pCi/L
TRITIUM	KAR	16	100.00	62.93	367.23	1,577.10	pCi/L
URANIUM-233,234	KAR	4	100.00	0.77	0.57	7.79	pCi/L
URANIUM-235	KAR	4	100.00	0.03	0.02	0.27	pCi/L
URANIUM-238	KAR	2	100.00	0.35	0.26	48.13	pCi/L

Table C-5. Groundwater UTLs by geologic unit for water-quality parameters.

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER, WATER-QUALITY PARAMETERS

ANALYTE	GEOLOGIC UNIT	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
BICARBONATE	COL	52	100.00	393,871.94	175,851.17	948,682.39	UG/L
CHLORIDE	COL	42	100.00	18,114.29	10,104.20	49,993.05	UG/L
FLUORIDE	COL	51	100.00	1,053.73	536.87	2,747.56	UG/L
NITRATE/NITRITE	COL	56	64.29	1,683.75	3,700.64	13,359.28	UG/L
ORTHOPHOSPHATE	COL	27	48.15	11.93	7.48	38.34	UG/L
PHOSPHORUS	COL	10	40.00	30.50	29.86	181.98	UG/L
SILICA	COL	44	100.00	12,037.35	6,549.60	32,701.34	UG/L
SULFATE	COL	48	100.00	215,566.67	264,980.47	1,051,580.04	UG/L
TOTAL DISSOLVED SOLIDS	COL	52	100.00	687,230.77	409,401.70	1,978,893.12	UG/L
TOTAL SUSPENDED SOLIDS	COL	52	67.31	18,038.46	24,207.00	94,411.55	UG/L
BICARBONATE	RFA	114	100.00	114,859.08	56,766.87	247,125.88	UG/L
CHLORIDE	RFA	95	91.58	8,707.47	13,538.26	40,251.63	UG/L
FLUORIDE	RFA	108	96.30	306.39	90.85	518.06	UG/L
NITRATE/NITRITE	RFA	115	97.39	1,448.26	765.26	3,231.31	UG/L
NITRITE	RFA	23	43.48	33.13	53.44	229.87	UG/L
ORTHOPHOSPHATE	RFA	81	56.79	14.44	12.92	53.73	UG/L
PHOSPHORUS	RFA	22	68.18	44.27	49.43	228.50	UG/L
SILICA	RFA	105	100.00	15,873.61	8,274.40	35,152.97	UG/L
SULFATE	RFA	103	99.03	22,384.47	19,440.47	67,680.75	UG/L
TOTAL DISSOLVED SOLIDS	RFA	115	100.00	189,817.39	94,386.90	409,738.87	UG/L
TOTAL SUSPENDED SOLIDS	RFA	111	66.49	182,684.68	334,207.01	961,387.02	UG/L
BICARBONATE	VFA	78	100.00	242,462.09	116,731.17	597,441.57	UG/L
CHLORIDE	VFA	67	97.01	16,061.19	12,727.88	54,766.69	UG/L
CYANIDE	VFA	21	28.57	9.39	5.70	30.92	UG/L
FLUORIDE	VFA	76	97.37	505.27	186.31	1,071.82	UG/L
NITRATE/NITRITE	VFA	72	65.28	202.08	257.28	984.46	UG/L
NITRITE	VFA	12	25.00	19.17	15.05	88.90	UG/L
ORTHOPHOSPHATE	VFA	54	55.56	17.82	27.04	103.13	UG/L
PHOSPHORUS	VFA	15	46.67	44.67	42.49	224.10	UG/L
SILICA	VFA	76	100.00	15,164.53	8,599.63	41,315.99	UG/L
SULFATE	VFA	69	100.00	54,486.96	74,995.26	282,547.55	UG/L
TOTAL DISSOLVED SOLIDS	VFA	76	100.00	334,744.54	167,754.49	844,885.94	UG/L
TOTAL SUSPENDED SOLIDS	VFA	72	88.89	90,727.64	141,259.37	520,297.38	UG/L

Table C-5 (cont').

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER, WATER-QUALITY PARAMETERS (CONT')

ANALYTE	GEOLOGIC UNIT	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
BICARBONATE	WCS	67	100.00	255,472.87	134,489.69	664,456.02	UG/L
CHLORIDE	WCS	53	83.02	9,094.34	11,230.61	44,526.93	UG/L
CYANIDE	WCS	7	28.57	10.00	7.07	55.34	UG/L
FLUORIDE	WCS	65	98.46	893.69	595.09	2,703.37	UG/L
NITRATE/NITRITE	WCS	62	87.10	715.40	1,067.15	3,960.61	UG/L
NITRITE	WCS	11	63.64	28.82	27.52	161.71	UG/L
ORTHOPHOSPHATE	WCS	29	44.83	14.48	11.52	54.50	UG/L
PHOSPHORUS	WCS	9	66.67	28.89	31.30	197.58	UG/L
SILICA	WCS	49	100.00	10,404.94	6,489.24	30,878.48	UG/L
SULFATE	WCS	58	100.00	131,008.62	241,197.17	891,985.69	UG/L
TOTAL DISSOLVED SOLIDS	WCS	67	100.00	405,940.30	375,873.93	1,548,972.91	UG/L
TOTAL SUSPENDED SOLIDS	WCS	66	69.70	187,939.39	787,142.93	2,581,641.05	UG/L
ALKALINITY AS CACO3	KAR	3	100.00	305,166.67	160,234.46	4,134,059.44	UG/L
BICARBONATE	KAR	93	100.00	233,546.17	102,980.99	473,491.87	UG/L
CARBONATE	KAR	92	28.26	3,318.77	4,245.24	13,210.17	UG/L
CHLORIDE	KAR	79	96.20	100,205.95	128,066.02	489,654.73	UG/L
FLUORIDE	KAR	92	97.83	949.35	465.34	2,033.58	UG/L
NITRATE/NITRITE	KAR	90	78.89	861.22	945.96	3,737.87	UG/L
NITRITE	KAR	16	56.25	190.62	295.19	1,407.78	UG/L
ORTHOPHOSPHATE	KAR	54	61.11	18.46	10.16	50.52	UG/L
PHOSPHORUS	KAR	14	64.29	173.57	264.99	1,322.89	UG/L
SILICA	KAR	83	100.00	8,077.25	5,808.92	25,742.17	UG/L
SULFATE	KAR	82	95.12	123,943.90	250,872.10	886,845.95	UG/L
TOTAL DISSOLVED SOLIDS	KAR	94	100.00	545,138.30	445,290.59	1,582,665.38	UG/L
TOTAL SOLIDS	KAR	5	80.00	318,240.00	356,657.98	3,506,414.55	UG/L
TOTAL SUSPENDED SOLIDS	KAR	88	77.27	403,085.23	727,972.80	2,616,850.51	UG/L

Table C-6. Groundwater UTLs by flow-system for dissolved metals.

UPPER TOLERANCE LIMITS BY FLOW-SYSTEM

GROUNDWATER, DISSOLVED METALS

ANALYTE	FLOW-SYSTEM	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	LOWER	66	78.79	48.81	44.02	182.67	UG/L
ANTIMONY	LOWER	63	44.44	15.50	9.17	43.37	UG/L
ARSENIC	LOWER	59	49.15	2.41	1.70	7.77	UG/L
BARIUM	LOWER	66	86.36	84.18	21.79	150.44	UG/L
CADMIUM	LOWER	62	22.58	1.76	1.33	5.80	UG/L
CALCIUM	LOWER	67	100.00	34,535.82	23,552.79	106,159.84	UG/L
CESIUM	LOWER	54	29.63	160.88	179.94	728.59	UG/L
CHROMIUM	LOWER	65	26.15	3.97	3.15	13.55	UG/L
COPPER	LOWER	65	27.69	4.17	3.83	15.82	UG/L
IRON	LOWER	67	79.10	33.67	35.32	141.06	UG/L
LEAD	LOWER	64	20.31	1.80	5.27	17.83	UG/L
LITHIUM	LOWER	66	81.82	38.53	27.84	123.21	UG/L
MAGNESIUM	LOWER	67	97.01	6,072.16	4,067.56	18,441.63	UG/L
MANGANESE	LOWER	67	71.64	9.29	7.24	31.31	UG/L
MOLYBDENUM	LOWER	64	53.13	16.86	27.01	99.00	UG/L
NICKEL	LOWER	65	23.08	5.81	6.26	24.86	UG/L
PHOSPHORUS	LOWER	4	100.00	174.75	85.65	1,235.68	UG/L
POTASSIUM	LOWER	67	89.55	2,731.18	1,612.39	7,634.46	UG/L
SELENIUM	LOWER	54	25.63	1.34	1.09	4.78	UG/L
SILVER	LOWER	59	28.81	2.69	2.01	9.03	UG/L
SODIUM	LOWER	67	100.00	142,012.69	135,521.56	554,133.75	UG/L
STRONTIUM	LOWER	66	100.00	383.02	294.27	1,277.90	UG/L
THALLIUM	LOWER	56	21.43	1.72	1.87	7.62	UG/L
TIN	LOWER	65	40.00	23.07	25.30	100.01	UG/L
VANADIUM	LOWER	65	56.92	6.71	7.60	29.81	UG/L
ZINC	LOWER	67	83.58	10.96	10.20	41.99	UG/L
ALUMINUM	UPPER	246	77.64	59.52	87.29	262.91	UG/L
ANTIMONY	UPPER	248	48.39	17.34	11.10	43.20	UG/L
BARIUM	UPPER	256	83.59	83.42	34.56	153.94	UG/L
CADMIUM	UPPER	240	22.08	1.73	1.25	4.66	UG/L
CALCIUM	UPPER	256	100.00	55,414.55	32,564.11	131,288.91	UG/L
CESIUM	UPPER	211	21.33	202.20	285.69	867.87	UG/L
CHROMIUM	UPPER	250	36.00	4.84	3.80	13.69	UG/L
COPPER	UPPER	248	39.11	5.01	4.42	15.32	UG/L
CYANIDE	UPPER	3	33.33	5.83	3.82	97.09	UG/L
IRON	UPPER	255	76.47	56.26	113.44	320.57	UG/L
LEAD	UPPER	251	23.90	1.59	4.71	12.57	UG/L
LITHIUM	UPPER	250	75.20	33.95	54.30	160.47	UG/L
MAGNESIUM	UPPER	253	95.65	10,038.28	8,309.40	29,399.19	UG/L
MANGANESE	UPPER	255	60.78	27.47	67.43	184.57	UG/L
MOLYBDENUM	UPPER	241	37.34	19.64	33.94	98.73	UG/L
NICKEL	UPPER	236	32.63	7.01	7.18	23.73	UG/L
PHOSPHORUS	UPPER	8	100.00	167.00	52.43	471.74	UG/L
POTASSIUM	UPPER	252	81.75	1,371.50	1,069.01	3,862.30	UG/L
SELENIUM	UPPER	219	31.96	5.58	19.07	50.02	UG/L
SILVER	UPPER	235	28.51	2.84	2.12	7.79	UG/L
SODIUM	UPPER	254	99.21	32,012.98	43,667.67	133,758.65	UG/L
STRONTIUM	UPPER	252	92.86	323.60	303.58	1,030.95	UG/L
THALLIUM	UPPER	212	22.17	1.64	1.63	5.44	UG/L
TIN	UPPER	235	42.98	30.96	37.34	117.96	UG/L
VANADIUM	UPPER	249	64.66	7.92	8.73	28.26	UG/L
ZINC	UPPER	256	80.47	14.03	17.87	55.56	UG/L

Table C-7. Groundwater UTLs by flow-system for total metals.

UPPER TOLERANCE LIMITS BY FLOW-SYSTEM

GROUNDWATER, TOTAL METALS

ANALYTE	FLOW-SYSTEM	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	LOWER	37	91.89	1,791.87	2,773.43	10,937.17	UG/L
ANTIMONY	LOWER	35	31.43	15.62	10.40	50.28	UG/L
ARSENIC	LOWER	35	54.29	2.76	2.02	9.51	UG/L
BARIUM	LOWER	36	86.11	113.95	51.97	286.27	UG/L
CALCIUM	LOWER	37	100.00	36,382.43	23,881.47	115,130.79	UG/L
CESIUM	LOWER	35	25.71	131.59	175.16	715.62	UG/L
CHROMIUM	LOWER	36	38.89	5.25	4.61	20.54	UG/L
COPPER	LOWER	36	61.11	11.99	21.82	84.34	UG/L
IRON	LOWER	37	94.59	2,239.92	3,697.44	14,432.11	UG/L
LEAD	LOWER	36	61.11	3.82	4.29	18.06	UG/L
LITHIUM	LOWER	37	86.49	40.69	29.29	137.26	UG/L
MAGNESIUM	LOWER	37	94.59	6,679.46	5,030.81	23,268.40	UG/L
MANGANESE	LOWER	37	86.49	61.87	125.21	474.75	UG/L
MERCURY	LOWER	37	27.03	0.13	0.05	0.28	UG/L
MOLYBDENUM	LOWER	36	47.22	18.59	33.45	129.48	UG/L
NICKEL	LOWER	35	34.29	8.70	7.25	32.89	UG/L
POTASSIUM	LOWER	37	89.19	2,846.38	1,725.69	8,536.77	UG/L
SELENIUM	LOWER	36	33.33	1.19	0.63	3.27	UG/L
SILICON	LOWER	20	100.00	9,427.50	6,631.12	34,835.00	UG/L
SODIUM	LOWER	37	100.00	139,228.38	134,404.33	582,422.16	UG/L
STRONTIUM	LOWER	37	97.30	399.78	312.58	1,430.50	UG/L
THALLIUM	LOWER	36	27.78	1.40	1.50	6.36	UG/L
TIN	LOWER	37	29.73	27.46	31.18	130.28	UG/L
VANADIUM	LOWER	36	69.44	10.43	11.26	47.75	UG/L
ZINC	LOWER	36	97.22	52.45	51.31	222.56	UG/L
ALUMINUM	UPPER	147	95.24	2,742.80	4,248.73	12,642.33	UG/L
ANTIMONY	UPPER	141	38.30	19.19	12.85	49.14	UG/L
ARSENIC	UPPER	138	28.26	1.95	1.71	5.93	UG/L
BARIUM	UPPER	148	81.76	102.44	45.37	208.14	UG/L
CALCIUM	UPPER	149	100.00	55,030.23	31,667.78	128,816.15	UG/L
CESIUM	UPPER	142	24.65	154.42	198.79	617.60	UG/L
CHROMIUM	UPPER	143	47.55	7.01	6.68	22.58	UG/L
COPPER	UPPER	148	74.32	10.67	12.21	39.12	UG/L
IRON	UPPER	147	97.96	3,017.34	4,994.50	14,654.53	UG/L
LEAD	UPPER	140	69.29	3.26	3.64	11.75	UG/L
LITHIUM	UPPER	149	78.52	33.75	48.76	147.37	UG/L
MAGNESIUM	UPPER	149	97.32	10,315.64	7,956.43	28,854.11	UG/L
MANGANESE	UPPER	148	89.86	79.59	108.18	331.64	UG/L
MERCURY	UPPER	148	20.27	0.12	0.04	0.22	UG/L
MOLYBDENUM	UPPER	150	34.00	24.09	39.47	116.04	UG/L
NICKEL	UPPER	145	37.24	10.58	9.49	32.68	UG/L
POTASSIUM	UPPER	150	77.33	1,731.21	1,176.59	4,472.65	UG/L
SELENIUM	UPPER	144	30.56	4.57	18.64	47.99	UG/L
SILICON	UPPER	2	100.00	15,564.97	10,797.33	48,395.65	UG/L
SODIUM	UPPER	149	98.66	30,081.85	40,019.71	123,327.78	UG/L
STRONTIUM	UPPER	146	89.04	312.61	271.09	944.25	UG/L
THALLIUM	UPPER	146	23.97	1.67	1.76	5.77	UG/L
TIN	UPPER	149	34.90	33.88	35.33	116.20	UG/L
VANADIUM	UPPER	148	77.03	13.81	14.09	46.64	UG/L
ZINC	UPPER	149	91.95	37.16	49.80	153.21	UG/L

Table C-8. Groundwater UTLs by flow-system for dissolved radionuclides.

UPPER TOLERANCE LIMITS BY FLOW-SYSTEM

GROUNDWATER, DISSOLVED RADIONUCLIDES

ANALYTE	FLOW-SYSTEM	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	UTL 99 / 99	UNITS
CESIUM-137	LOWER	4	100.00	0.22	0.30	3.92	pCi/L
GROSS ALPHA	LOWER	60	100.00	3.13	6.24	22.81	pCi/L
GROSS BETA	LOWER	54	100.00	3.23	2.84	12.19	pCi/L
RADIUM-226	LOWER	2	100.00	1.72	1.78	331.75	pCi/L
STRONTIUM-89,90	LOWER	42	100.00	0.47	1.19	4.21	pCi/L
TRITIUM	LOWER	49	100.00	56.88	135.94	485.77	pCi/L
URANIUM-233,234	LOWER	57	100.00	1.64	2.85	10.63	pCi/L
URANIUM-235	LOWER	57	100.00	0.03	0.06	0.23	pCi/L
URANIUM-238	LOWER	54	100.00	0.77	1.53	5.58	pCi/L
AMERICIUM-241	UPPER	2	100.00	0.01	0.01	2.11	pCi/L
CESIUM-137	UPPER	38	100.00	0.42	0.53	2.14	pCi/L
GROSS ALPHA	UPPER	213	100.00	8.35	32.32	93.86	pCi/L
GROSS BETA	UPPER	196	100.00	4.89	12.23	37.25	pCi/L
RADIUM-226	UPPER	36	100.00	0.26	0.11	0.63	pCi/L
RADIUM-228	UPPER	6	100.00	2.12	0.52	5.94	pCi/L
STRONTIUM-89,90	UPPER	180	100.00	0.34	0.31	1.05	pCi/L
TRITIUM	UPPER	165	100.00	101.70	180.30	578.79	pCi/L
URANIUM-233,234	UPPER	207	100.00	6.91	25.44	74.22	pCi/L
URANIUM-235	UPPER	207	100.00	0.20	0.64	1.88	pCi/L
URANIUM-238	UPPER	177	100.00	4.83	17.67	51.60	pCi/L

Table C-9. Groundwater UTLs by flow-system for total radionuclides.

GROUNDWATER

TOTAL RADIONUCLIDES

ANALYTE	FLOW-SYSTEM	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	UTL 99 / 99	
AMERICIUM-241	LOWER	43	100.00	0.01	0.02	0.07	pCi/L
CESIUM-137	LOWER	39	100.00	0.00	0.29	0.96	pCi/L
GROSS ALPHA	LOWER	6	100.00	11.08	16.63	133.08	pCi/L
GROSS BETA	LOWER	6	100.00	12.01	13.45	110.67	pCi/L
PLUTONIUM-238	LOWER	5	100.00	0.01	0.01	0.14	pCi/L
PLUTONIUM-239,240	LOWER	48	100.00	0.00	0.01	0.02	pCi/L
RADIUM-226	LOWER	3	100.00	0.59	0.45	11.30	pCi/L
STRONTIUM-89,90	LOWER	4	100.00	0.10	0.26	3.34	pCi/L
TRITIUM	LOWER	16	100.00	62.93	367.23	1,577.10	pCi/L
URANIUM-233,234	LOWER	4	100.00	0.77	0.57	7.79	pCi/L
URANIUM-235	LOWER	4	100.00	0.03	0.02	0.27	pCi/L
URANIUM-238	LOWER	2	100.00	0.35	0.26	48.13	pCi/L
AMERICIUM-241	UPPER	183	100.00	0.01	0.01	0.03	pCi/L
CESIUM-137	UPPER	156	100.00	0.12	0.33	1.00	pCi/L
GROSS ALPHA	UPPER	23	100.00	43.50	94.28	390.58	pCi/L
GROSS BETA	UPPER	23	100.00	24.95	53.34	221.31	pCi/L
PLUTONIUM-238	UPPER	15	100.00	0.00	0.01	0.03	pCi/L
PLUTONIUM-239,240	UPPER	194	100.00	0.00	0.02	0.06	pCi/L
RADIUM-226	UPPER	6	100.00	0.36	0.13	1.29	pCi/L
STRONTIUM-89,90	UPPER	32	100.00	0.22	0.28	1.15	pCi/L
TRITIUM	UPPER	84	100.00	624.85	4,246.75	13,539.22	pCi/L
URANIUM-233,234	UPPER	35	100.00	15.62	36.75	144.83	pCi/L
URANIUM-235	UPPER	35	100.00	0.62	1.38	5.23	pCi/L
URANIUM-238	UPPER	22	100.00	10.84	27.73	114.17	pCi/L

Table C-10. Groundwater UTLs by flow-system for water-quality parameters.

UPPER TOLERANCE LIMITS BY FLOW-SYSTEM

GROUNDWATER, WATER-QUALITY PARAMETERS

ANALYTE	FLOW-SYSTEM	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALKALINITY AS CACO3	LOWER	3	100.00	305,166.67	160,234.46	4,134,059.44	UG/L
BICARBONATE	LOWER	93	100.00	233,546.17	102,980.99	473,491.87	UG/L
CARBONATE	LOWER	92	28.26	3,318.77	4,245.24	13,210.17	UG/L
CHLORIDE	LOWER	79	96.20	100,205.95	128,066.02	489,654.73	UG/L
FLUORIDE	LOWER	92	97.83	949.35	465.34	2,033.58	UG/L
NITRATE/NITRITE	LOWER	90	78.89	861.22	945.96	3,737.87	UG/L
NITRITE	LOWER	16	56.25	190.62	295.19	1,407.78	UG/L
ORTHOPHOSPHATE	LOWER	54	61.11	18.46	10.16	50.52	UG/L
PHOSPHORUS	LOWER	14	64.29	173.57	264.99	1,322.89	UG/L
SILICA	LOWER	83	100.00	8,077.25	5,808.92	25,742.17	UG/L
SULFATE	LOWER	82	95.12	123,943.90	250,872.10	886,845.95	UG/L
TOTAL DISSOLVED SOLIDS	LOWER	94	100.00	545,138.30	445,290.59	1,582,665.38	UG/L
TOTAL SOLIDS	LOWER	5	80.00	318,240.00	356,657.98	3,506,414.55	UG/L
TOTAL SUSPENDED SOLIDS	LOWER	88	77.27	403,085.23	727,972.80	2,616,850.51	UG/L
ALKALINITY AS CACO3	UPPER	3	100.00	156,900.00	158,643.41	3,947,773.53	UG/L
BICARBONATE	UPPER	311	100.00	223,807.08	151,717.58	577,309.04	UG/L
CHLORIDE	UPPER	257	92.61	12,241.67	12,930.51	42,369.76	UG/L
FLUORIDE	UPPER	300	97.67	611.07	472.04	1,710.92	UG/L
NITRATE/NITRITE	UPPER	305	81.64	1,048.34	1,807.86	5,260.65	UG/L
NITRITE	UPPER	54	37.04	27.94	38.25	148.61	UG/L
ORTHOPHOSPHATE	UPPER	191	53.40	15.05	17.47	55.76	UG/L
PH	UPPER	3	100.00	7.17	0.46	18.20	UG/L
PHOSPHORUS	UPPER	56	57.14	39.45	41.60	170.70	UG/L
SILICA	UPPER	274	100.00	14,082.92	8,075.96	32,899.91	UG/L
SULFATE	UPPER	278	99.64	86,370.14	174,613.96	493,220.67	UG/L
TOTAL DISSOLVED SOLIDS	UPPER	310	100.00	355,495.44	312,010.29	1,082,479.41	UG/L
TOTAL SOLIDS	UPPER	4	75.00	24,025.00	36,789.98	479,752.89	UG/L
TOTAL SUSPENDED SOLIDS	UPPER	301	80.07	133,396.64	429,323.86	1,133,721.25	UG/L

Table C-11. Geologic material UTLs by geologic unit for total metals.

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GEOLOGIC MATERIALS, TOTAL METALS

ANALYTE	GEOLOGIC UNIT	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	COL	28	100.00	10,541.43	4,945.95	27,861.88	MG/KG
ARSENIC	COL	28	85.71	3.57	1.74	9.65	MG/KG
BARIUM	COL	28	100.00	133.20	94.05	462.57	MG/KG
BERYLLIUM	COL	28	96.43	5.47	5.47	24.62	MG/KG
CADMIUM	COL	26	57.69	0.86	0.42	2.35	MG/KG
CALCIUM	COL	28	100.00	9,082.14	6,368.14	31,386.50	MG/KG
CESIUM	COL	24	75.00	206.24	56.68	413.26	MG/KG
CHROMIUM	COL	28	100.00	13.79	5.86	34.31	MG/KG
COBALT	COL	28	25.00	6.11	3.87	19.66	MG/KG
COPPER	COL	28	96.43	14.67	5.48	33.87	MG/KG
IRON	COL	28	100.00	15,028.07	6,715.26	38,544.51	MG/KG
LEAD	COL	28	100.00	16.23	4.62	32.40	MG/KG
LITHIUM	COL	28	28.57	8.52	7.56	34.99	MG/KG
MAGNESIUM	COL	28	78.57	2,987.32	1,577.90	8,513.05	MG/KG
MANGANESE	COL	28	100.00	191.87	160.26	753.10	MG/KG
MERCURY	COL	27	22.22	0.18	0.20	0.88	MG/KG
NICKEL	COL	28	92.86	16.97	8.28	45.97	MG/KG
POTASSIUM	COL	28	35.71	979.61	721.36	3,505.78	MG/KG
SELENIUM	COL	27	22.22	0.85	0.65	3.15	MG/KG
SILVER	COL	19	42.11	5.85	9.46	42.68	MG/KG
STRONTIUM	COL	28	85.71	55.92	27.04	150.63	MG/KG
TIN	COL	23	26.09	87.36	147.51	630.37	MG/KG
VANADIUM	COL	28	100.00	30.31	12.23	73.15	MG/KG
ZINC	COL	28	100.00	56.13	21.92	132.87	MG/KG
ALUMINUM	RFA	62	100.00	13,565.95	13,657.25	55,097.66	MG/KG
ARSENIC	RFA	62	69.35	4.15	5.70	21.48	MG/KG
BARIUM	RFA	62	83.87	84.46	100.14	388.97	MG/KG
BERYLLIUM	RFA	62	87.10	4.65	4.66	18.83	MG/KG
CADMIUM	RFA	46	47.83	0.84	0.48	2.36	MG/KG
CALCIUM	RFA	62	82.26	6,676.41	19,969.15	67,402.61	MG/KG
CESIUM	RFA	62	75.81	242.09	337.12	1,267.28	MG/KG
CHROMIUM	RFA	62	100.00	22.08	30.15	113.77	MG/KG
COBALT	RFA	62	35.48	8.[illegible]5	13.16	48.79	MG/KG
COPPER	RFA	62	87.10	11.68	15.59	59.10	MG/KG
IRON	RFA	62	100.00	14,347.10	16,125.79	63,388.67	MG/KG
LEAD	RFA	62	100.00	9.05	7.07	30.54	MG/KG
LITHIUM	RFA	62	59.68	14.33	12.85	53.41	MG/KG
MAGNESIUM	RFA	62	58.06	2,482.38	4,093.78	14,931.58	MG/KG
MANGANESE	RFA	62	100.00	235.92	417.44	1,505.36	MG/KG
MERCURY	RFA	54	42.59	0.29	0.80	2.81	MG/KG
NICKEL	RFA	59	88.14	23.35	25.45	103.63	MG/KG
POTASSIUM	RFA	61	27.87	1,545.33	3,036.93	10,780.63	MG/KG
SILVER	RFA	55	30.91	2.48	5.55	19.99	MG/KG
STRONTIUM	RFA	62	30.65	77.93	87.02	342.55	MG/KG
VANADIUM	RFA	62	95.77	32.03	34.96	138.33	MG/KG
ZINC	RFA	61	93.44	29.97	61.25	216.23	MG/KG

Table C-11 (cont').

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GEOLOGIC MATERIALS, TOTAL METALS (CONT')

ANALYTE	GEOLOGIC UNIT	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	WCS	8	100.00	14,181.25	5,023.23	43,375.23	MG/KG
ARSENIC	WCS	9	77.78	2.94	1.55	11.27	MG/KG
BARIUM	WCS	9	88.89	64.81	26.27	206.40	MG/KG
BERYLLIUM	WCS	9	100.00	3.57	1.09	9.45	MG/KG
CADMIUM	WCS	9	22.22	0.63	0.27	[illegible].06	MG/KG
CALCIUM	WCS	9	66.67	2,213.33	1,356.05	9,5[illegible]0.93	MG/KG
CESIUM	WCS	9	100.00	214.89	5.99	247.16	MG/KG
CHROMIUM	WCS	9	100.00	20.70	5.93	52.65	MG/KG
COPPER	WCS	9	100.00	12.14	5.91	43.99	MG/KG
IRON	WCS	9	100.00	14,282.22	4,066.80	36,177.70	MG/KG
LEAD	WCS	9	100.00	6.68	3.15	23.66	MG/KG
MAGNESIUM	WCS	9	55.56	2,033.89	1,253.36	8,788.12	MG/KG
MANGANESE	WCS	9	100.00	171.88	99.17	706.30	MG/KG
NICKEL	WCS	9	100.00	15.31	6.87	52.31	MG/KG
SELENIUM	WCS	9	66.67	1.95	1.25	8.71	MG/KG
SILVER	WCS	9	100.00	24.29	6.94	61.68	MG/KG
TIN	WCS	9	100.00	278.00	85.04	628.52	MG/KG
VANADIUM	WCS	9	100.00	31.42	11.01	90.76	MG/KG
ZINC	WCS	9	100.00	23.62	8.30	68.34	MG/KG
ALUMINUM	KAR	21	100.00	7,482.60	2,681.30	17,608.83	MG/KG
ARSENIC	KAR	21	66.67	3.72	3.26	16.05	MG/KG
BARIUM	KAR	21	95.24	99.40	55.10	307.51	MG/KG
BERYLLIUM	KAR	21	100.00	3.35	3.16	15.29	MG/KG
CADMIUM	KAR	19	57.89	0.83	0.37	2.28	MG/KG
CALCIUM	KAR	21	100.00	5,477.14	1,831.78	12,395.06	MG/KG
CESIUM	KAR	16	93.75	223.62	31.26	352.50	MG/KG
CHROMIUM	KAR	21	100.00	8.91	2.98	20.18	MG/KG
COBALT	KAR	21	23.81	6.74	7.20	33.94	MG/KG
COPPER	KAR	20	100.00	15.76	5.93	38.48	MG/KG
IRON	KAR	20	100.00	12,96[illegible].25	8,753.38	46,502.32	MG/KG
LEAD	KAR	21	100.00	18.91	6.19	42.29	MG/KG
LITHIUM	KAR	21	28.57	7.17	8.39	38.84	MG/KG
MAGNESIUM	KAR	21	66.67	2,053.71	1,213.43	6,636.37	MG/KG
MANGANESE	KAR	21	100.00	171.90	183.74	865.82	MG/KG
MERCURY	KAR	21	33.33	0.23	0.24	1.13	MG/KG
NICKEL	KAR	19	84.21	18.78	13.39	70.90	MG/KG
SELENIUM	KAR	19	31.58	0.90	1.01	4.85	MG/KG
SILVER	KAR	16	25.00	3.72	6.22	29.37	MG/KG
STRONTIUM	KAR	21	90.48	69.50	30.95	186.40	MG/KG
VANADIUM	KAR	20	90.00	20.70	8.76	54.25	MG/KG
ZINC	KAR	21	100.00	60.24	19.22	132.82	MG/KG

Table C-12. Geologic material UTLs by geologic unit for total radionuclides.

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GEOLOGIC MATERIALS, TOTAL RADIONUCLIDES

ANALYTE	GEOLOGY	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	UTL 99 / 99	UNITS
CESIUM-137	COL	28	100.00	0.01	0.04	0.17	pCi/g
GROSS ALPHA	COL	28	100.00	31.95	8.90	63.10	pCi/g
GROSS BETA	COL	28	100.00	27.00	3.52	39.32	pCi/g
PLUTONIUM-239,240	COL	28	100.00	0.01	0.01	0.03	pCi/g
RADIUM-226	COL	21	100.00	1.07	0.18	1.77	pCi/g
RADIUM-228	COL	21	100.00	1.57	0.29	2.65	pCi/g
STRONTIUM-89,90	COL	28	100.00	-0.01	0.36	1.24	pCi/g
TRITIUM	COL	28	100.00	62.14	106.16	433.90	pCi/g
URANIUM, TOTAL	COL	28	100.00	1.86	0.73	4.41	pCi/g
URANIUM-233,234	COL	28	100.00	1.14	1.58	6.66	pCi/g
URANIUM-235	COL	28	100.00	0.04	0.06	0.24	pCi/g
URANIUM-238	COL	28	100.00	0.94	0.34	2.15	pCi/g
AMERICIUM-241	RFA	28	100.00	-0.00	0.01	0.02	pCi/g
CESIUM-137	RFA	62	100.00	0.01	0.04	0.14	pCi/g
GROSS ALPHA	RFA	62	100.00	22.32	8.18	47.21	pCi/g
GROSS BETA	RFA	62	100.00	24.10	6.75	44.62	pCi/g
PLUTONIUM-239,240	RFA	62	100.00	0.00	0.01	0.02	pCi/g
RADIUM-226	RFA	58	100.00	0.63	0.10	0.96	pCi/g
RADIUM-228	RFA	58	100.00	1.34	0.31	2.32	pCi/g
STRONTIUM-89,90	RFA	62	100.00	0.03	0.35	1.[illegible]	pCi/g
TRITIUM	RFA	62	100.00	172.90	122.68	545.96	pCi/g
URANIUM, TOTAL	RFA	62	100.00	1.29	0.81	3.76	pCi/g
URANIUM-233,234	RFA	62	100.00	0.64	0.46	2.04	pCi/g
URANIUM-235	RFA	62	100.00	0.01	0.03	0.11	pCi/g
URANIUM-238	RFA	62	100.00	0.64	0.38	1.79	pCi/g
CESIUM-137	WCS	9	100.00	0.01	0.03	0.19	pCi/g
GROSS ALPHA	WCS	9	100.00	20.89	5.88	52.59	pCi/g
GROSS BETA	WCS	9	100.00	21.89	5.53	51.70	pCi/g
PLUTONIUM-239,240	WCS	9	100.00	0.01	0.01	0.07	pCi/g
RADIUM-226	WCS	4	100.00	0.68	0.15	2.53	pCi/g
RADIUM-228	WCS	4	100.00	1.42	0.29	4.98	pCi/g
STRONTIUM-89,90	WCS	9	100.00	0.17	0.44	2.56	pCi/g
TRITIUM	WCS	9	100.00	174.44	114.47	791.30	pCi/g
URANIUM, TOTAL	WCS	9	100.00	1.36	0.21	2.50	pCi/g
URANIUM-233,234	WCS	9	100.00	0.60	0.12	1.26	pCi/g
URANIUM-235	WCS	9	100.00	0.02	0.07	0.38	pCi/g
URANIUM-238	WCS	9	100.00	0.73	0.12	1.39	pCi/g
CESIUM-137	KAR	21	100.00	0.00	0.00	0.00	pCi/g
GROSS ALPHA	KAR	21	100.00	29.98	8.42	61.78	pCi/g
GROSS BETA	KAR	21	100.00	25.76	3.85	40.29	pCi/g
PLUTONIUM-239,240	KAR	21	100.00	0.00	0.01	0.03	pCi/g
RADIUM-226	KAR	14	100.00	1.09	0.12	1.63	pCi/g
RADIUM-228	KAR	14	100.00	1.30	0.19	2.14	pCi/g
STRONTIUM-89,90	KAR	21	100.00	-0.11	0.36	1.24	pCi/g
TRITIUM	KAR	21	100.00	65.95	122.69	529.32	pCi/g
URANIUM, TOTAL	KAR	21	100.00	1.96	0.64	4.40	pCi/g
URANIUM-233,234	KAR	21	100.00	0.96	0.39	2.42	pCi/g
URANIUM-235	KAR	21	100.00	0.04	0.08	0.35	pCi/g
URANIUM-238	KAR	21	100.00	0.98	0.25	1.92	pCi/g

Table C-13. Geologic material UTLs by geologic unit for total "water-quality" parameters.

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GEOLOGIC MATERIALS, TOTAL "WATER-QUALITY" PARAMETERS

ANALYTE	GEOLOGY	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	UTL 99 / 99	UNITS
PH	COL	28	100.00	8.26	0.45	5 / 10	PH UNITS
SULFIDE	COL	27	18.52	1.87	1.39	6.36	MG/KG
PH	RFA	60	100.00	7.97	0.77	5 / 10.4	PH UNITS
SULFIDE	RFA	53	32.08	2.27	3.02	30,082.97	MG/KG
NITRATE/NITRITE	WCS	9	33.33	1.08	0.62	4.44	MG/KG
PH	WCS	9	100.00	7.41	0.18	5 / 9	PH UNITS
SULFIDE	WCS	9	22.22	3.00	1.84	6.00	MG/KG
PH	KAR	21	100.00	8.43	0.87	5 / 11.7	PH UNITS

Table C-14. Geologic material UTLs by flow-system for total metals.

UPPER TOLERANCE LIMITS BY FLOW-SYSTEM

GEOLOGIC MATERIALS, TOTAL METALS

ANALYTE	FLOW-SYSTEM	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	LOWER	21	100.00	7,482.60	2,681.30	17,608.83	MG/KG
ARSENIC	LOWER	21	66.67	3.72	3.26	16.05	MG/KG
BARIUM	LOWER	21	95.24	99.40	55.10	307.51	MG/KG
BERYLLIUM	LOWER	21	100.00	3.35	3.16	15.29	MG/KG
CADMIUM	LOWER	19	57.89	0.83	0.37	2.28	MG/KG
CALCIUM	LOWER	21	100.00	5,477.14	1,831.78	12,395.06	MG/KG
CESIUM	LOWER	16	93.75	223.62	31.26	352.50	MG/KG
CHROMIUM	LOWER	21	100.00	8.91	2.98	20.18	MG/KG
COBALT	LOWER	21	23.81	6.74	7.20	33.94	MG/KG
COPPER	LOWER	20	100.00	15.76	5.93	38.48	MG/KG
IRON	LOWER	20	100.00	12,963.25	8,753.38	46,502.32	MG/KG
LEAD	LOWER	21	100.00	18.91	6.19	42.29	MG/KG
LITHIUM	LOWER	21	28.57	7.17	8.39	38.84	MG/KG
MAGNESIUM	LOWER	21	66.67	2,053.71	1,213.43	6,636.37	MG/KG
MANGANESE	LOWER	21	100.00	171.90	183.74	865.82	MG/KG
MERCURY	LOWER	21	33.33	0.23	0.24	1.13	MG/KG
NICKEL	LOWER	19	84.21	18.78	13.39	70.90	MG/KG
SELENIUM	LOWER	19	31.58	0.90	1.01	4.85	MG/KG
SILVER	LOWER	16	25.00	3.72	6.22	29.37	MG/KG
STRONTIUM	LOWER	21	90.48	69.50	30.95	186.40	MG/KG
VANADIUM	LOWER	20	90.00	20.70	8.76	54.25	MG/KG
ZINC	LOWER	21	100.00	60.24	19.22	132.82	MG/KG
ALUMINUM	UPPER	98	100.00	12,752.03	11,310.57	39,105.66	MG/KG
ARSENIC	UPPER	99	74.75	3.88	4.63	14.66	MG/KG
BARIUM	UPPER	99	88.89	95.46	95.46	321.20	MG/KG
BERYLLIUM	UPPER	99	90.91	4.78	4.71	15.75	MG/KG
CADMIUM	UPPER	81	48.15	0.82	0.44	2.17	MG/KG
CALCIUM	UPPER	99	85.86	6,951.09	16,215.59	44,733.41	MG/KG
CESIUM	UPPER	95	77.89	230.46	273.51	867.74	MG/KG
CHROMIUM	UPPER	99	100.00	19.61	24.33	76.30	MG/KG
COBALT	UPPER	99	30.30	7.50	10.77	32.60	MG/KG
COPPER	UPPER	99	90.91	12.57	12.82	42.43	MG/KG
IRON	UPPER	99	100.00	14,531.98	13,257.27	45,421.42	MG/KG
LEAD	UPPER	99	100.00	10.87	7.05	27.29	MG/KG
LITHIUM	UPPER	99	45.45	11.76	11.45	38.45	MG/KG
MAGNESIUM	UPPER	99	63.64	2,584.42	3,365.51	10,426.06	MG/KG
MANGANESE	UPPER	99	100.00	217.64	341.96	1,014.41	MG/KG
MERCURY	UPPER	86	33.72	0.24	0.64	2.20	MG/KG
NICKEL	UPPER	96	90.62	20.73	20.74	69.05	MG/KG
POTASSIUM	UPPER	98	28.57	1,311.57	2,442.62	7,002.88	MG/KG
SELENIUM	UPPER	82	25.61	1.22	1.79	6.68	MG/KG
SILVER	UPPER	83	40.96	5.62	9.46	34.39	MG/KG
STRONTIUM	UPPER	99	43.43	65.62	72.88	235.42	MG/KG
TIN	UPPER	92	22.83	61.75	112.28	323.37	MG/KG
VANADIUM	UPPER	99	97.98	31.49	28.50	97.89	MG/KG
ZINC	UPPER	98	95.92	36.86	51.12	155.97	MG/KG

Table C-15. Geologic material UTLs by flow-system for total radionuclides.

UPPER TOLERANCE LIMITS BY FLOW-SYSTEM

GEOLOGIC MATERIALS, TOTAL RADIONUCLIDES

ANALYTE	FLOW-SYSTEM	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	UTL 99 / 99	UNITS
CESIUM-137	LOWER	21	100.00	0.00	0.00	0.00	pCi/g
GROSS ALPHA	LOWER	21	100.00	29.98	8.42	51.78	pCi/g
GROSS BETA	LOWER	21	100.00	25.76	3.85	40.29	pCi/g
PLUTONIUM-239,240	LOWER	21	100.00	0.00	0.01	0.03	pCi/g
RADIUM-226	LOWER	14	100.00	1.09	0.12	1.63	pCi/g
RADIUM-228	LOWER	14	100.00	1.30	0.19	2.14	pCi/g
STRONTIUM-89,90	LOWER	21	100.00	-0.11	0.36	1.24	pCi/g
TRITIUM	LOWER	21	100.00	65.95	122.69	529.32	pCi/g
URANIUM, TOTAL	LOWER	21	100.00	1.96	0.64	4.40	pCi/g
URANIUM-233,234	LOWER	21	100.00	0.96	0.39	2.42	pCi/g
URANIUM-235	LOWER	21	100.00	0.04	0.08	0.35	pCi/g
URANIUM-238	LOWER	21	100.00	0.98	0.25	1.92	pCi/g
AMERICIUM-241	UPPER	28	100.00	-0.00	0.01	0.02	pCi/g
CESIUM-137	UPPER	99	100.00	0.01	0.04	0.11	pCi/g
GROSS ALPHA	UPPER	99	100.00	24.91	9.28	49.48	pCi/g
GROSS BETA	UPPER	99	100.00	24.72	6.06	40.75	pCi/g
PLUTONIUM-239,240	UPPER	99	100.00	0.00	0.01	0.02	pCi/g
RADIUM-226	UPPER	83	100.00	0.75	0.23	1.45	pCi/g
RADIUM-228	UPPER	83	100.00	1.40	0.32	2.37	pCi/g
STRONTIUM-89,90	UPPER	99	100.00	0.03	0.36	0.98	pCi/g
TRITIUM	UPPER	99	100.00	141.72	125.75	477.09	pCi/g
URANIUM, TOTAL	UPPER	99	100.00	1.46	0.79	3.55	pCi/g
URANIUM-233,234	UPPER	99	100.00	0.78	0.93	3.25	pCi/g
URANIUM-235	UPPER	99	100.00	0.02	0.05	0.14	pCi/g
URANIUM-238	UPPER	99	100.00	0.73	0.38	1.73	pCi/g

Table C-16. Geologic material UTLs by flow-system for total "water-quality" parameters.

UPPER TOLERANCE LIMITS BY FLOW-SYSTEM

TOTAL "WATER-QUALITY" PARAMETERS

ANALYTE	FLOW-SYSTEM	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	UTL 99 / 99	UNITS
PH	LOWER	21	100.00	8.43	0.87	11.73	PH UNIT
PH	UPPER	97	100.00	8.00	0.69	9.61	PH UNIT
SULFIDE	UPPER	88	27.27	2.22	2.52	9.88	MG/KG

Table C-17. Stream water UTLs for dissolved metals.

UPPER TOLERANCE LIMITS (SITE-WIDE) STREAM WATER, DISSOLVED METALS						
ANALYTE	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	134	41.79	89.80	165.40	475.18	UG/L
ANTIMONY	92	29.35	18.01	17.68	59.20	UG/L
BARIUM	145	57.24	45.17	35.44	127.74	UG/L
CALCIUM	154	93.51	23,621.75	11,474.97	50,358.44	UG/L
COPPER	125	37.60	5.90	4.97	17.48	UG/L
IRON	153	68.63	144.92	178.41	560.62	UG/L
LEAD	113	27.43	1.33	1.63	5.14	UG/L
LITHIUM	119	33.61	15.71	20.58	63.66	UG/L
MAGNESIUM	150	76.67	4,735.82	2,173.67	9,800.47	UG/L
MANGANESE	149	71.14	28.02	47.73	139.22	UG/L
PHOSPHORUS	6	100.00	194.83	124.91	1,111.00	UG/L
POTASSIUM	126	51.59	1,427.16	926.51	3,585.92	UG/L
SELENIUM	85	25.88	2.24	3.63	13.26	UG/L
SODIUM	153	94.12	16,603.04	7,508.05	34,096.80	UG/L
STRONTIUM	139	69.06	241.81	313.57	972.43	UG/L
TIN	99	21.21	28.52	23.40	83.05	UG/L
ZINC	139	58.99	13.59	18.14	55.86	UG/L

Table C-18. Stream water UTLs for total metals.

UPPER TOLERANCE LIMITS (SITE-WIDE) STREAM WATER, TOTAL METALS						
ANALYTE	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	139	78.42	747.63	1,349.84	3,892.76	UG/L
ARSENIC	110	27.27	1.73	1.76	5.84	UG/L
BARIUM	131	68.70	58.84	34.02	138.11	UG/L
CALCIUM	153	94.77	23,601.21	11,100.19	49,464.66	UG/L
COPPER	121	41.32	5.59	4.87	16.95	UG/L
IRON	157	89.81	1,247.08	2,866.81	7,926.75	UG/L
LEAD	131	35.88	1.88	2.35	7.36	UG/L
LITHIUM	126	41.27	11.77	17.42	52.35	UG/L
MAGNESIUM	146	81.51	4,901.94	2,107.61	9,812.55	UG/L
MANGANESE	151	78.81	84.76	343.57	885.29	UG/L
PHOSPHORUS	6	83.33	186.25	138.68	1,203.40	UG/L
POTASSIUM	128	57.03	1,569.97	1,071.73	4,167.09	UG/L
SELENIUM	120	21.67	1.55	2.05	6.33	UG/L
SILICON	67	100.00	6,076.23	3,377.17	16,346.19	UG/L
SODIUM	155	92.90	16,060.41	7,620.96	33,817.24	UG/L
STRONTIUM	125	63.70	171.63	179.61	590.13	UG/L
TIN	118	20.34	20.18	20.13	67.07	UG/L
VANADIUM	120	27.50	6.97	9.36	28.76	UG/L
ZINC	151	67.55	31.91	61.69	175.64	UG/L

Table C-19. Stream water UTLs for dissolved radionuclides.

UPPER TOLERANCE LIMITS (SITE-WIDE)

STREAM WATER, DISSOLVED RADIONUCLIDES

ANALYTE	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
AMERICIUM-241	34	100.00	0.07	0.13	0.50	pCi/L
CESIUM-134	3	100.00	2.27	0.10	4.67	pCi/L
CESIUM-137	10	100.00	0.82	1.22	6.99	pCi/L
GROSS ALPHA	61	100.00	1.81	8.85	28.71	pCi/L
GROSS BETA	61	100.00	4.89	6.78	25.30	pCi/L
GROSS GAMMA	24	100.00	0.70	0.25	1.63	pCi/L
PLUTONIUM-236	4	100.00	0.00	0.01	0.07	pCi/L
PLUTONIUM-238	4	100.00	0.01	0.01	0.07	pCi/L
PLUTONIUM-239,240	36	100.00	0.12	0.20	0.79	pCi/L
RADIUM-226	3	100.00	0.19	0.21	5.23	pCi/L
RADIUM-228	2	100.00	1.05	0.49	92.93	pCi/L
STRONTIUM-89,90	87	100.00	0.73	0.55	2.42	pCi/L
TRITIUM	56	100.00	185.58	416.00	1,498.07	pCi/L
URANIUM, TOTAL	6	100.00	0.72	0.48	4.27	pCi/L
URANIUM-233,234	56	100.00	0.92	4.21	14.20	pCi/L
URANIUM-235	56	100.00	0.14	0.20	0.78	pCi/L
URANIUM-238	56	100.00	0.71	3.24	10.93	pCi/L

Table C-20. Stream water UTLs for total radionuclides.

UPPER TOLERANCE LIMITS (SITE-WIDE)

STREAM WATER, TOTAL RADIONUCLIDES

ANALYTE	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
AMERICIUM-241	106	100.00	0.00	0.01	0.02	pCi/g
CESIUM-134	8	100.00	1.53	1.29	9.04	pCi/g
CESIUM-137	93	100.00	0.23	0.60	1.63	pCi/g
GROSS ALPHA	88	100.00	2.96	8.25	28.06	pCi/g
GROSS BETA	84	100.00	5.49	8.17	30.35	pCi/g
PLUTONIUM-236	12	100.00	-0.00	0.00	0.01	pCi/g
PLUTONIUM-238	12	100.00	-0.00	0.01	0.03	pCi/g
PLUTONIUM-239,240	105	100.00	0.00	0.01	0.02	pCi/g
RADIUM-226	4	100.00	1.07	1.25	16.56	pCi/g
STRONTIUM-89,90	75	100.00	0.92	1.30	4.88	pCi/g
TRITIUM	73	100.00	75.71	209.22	711.94	pCi/g
URANIUM, TOTAL	17	100.00	0.59	0.52	2.59	pCi/g
URANIUM-233,234	79	100.00	0.49	0.55	2.16	pCi/g
URANIUM-235	75	100.00	0.05	0.07	0.28	pCi/g
URANIUM-238	55	100.00	0.36	0.43	1.73	pCi/g

Table C-21. Stream water UTLs for water-quality parameters.

UPPER TOLERANCE LIMITS (SITE-WIDE)

STREAM WATER, WATER-QUALITY PARAMETERS

ANALYTE	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
BICARBONATE	154	100.00	97,571.20	40,237.29	191,324.08	UG/L
CARBONATE	154	24.03	2,999.74	1,937.53	7,514.19	UG/L
CBOD5	10	100.00	7,635.00	3,912.66	27,486.77	UG/L
CHLORIDE	151	92.05	16,833.01	15,608.95	53,201.88	UG/L
CYANIDE	129	31.01	2,221.93	5,220.92	14,386.67	UG/L
DISSOLVED ORGANIC CARBON	35	100.00	6,102.57	3,267.38	16,997.16	UG/L
FLUORIDE	100	98.00	338.41	107.90	589.81	UG/L
NITRATE/NITRITE	153	56.86	324.55	438.84	1,347.05	UG/L
NITRITE	85	22.35	13.98	14.74	58.81	UG/L
OIL AND GREASE	105	33.33	4,024.29	3,756.06	12,775.89	UG/L
PH	51	98.04	7.34	0.63	9.32	PH UNITS
PHOSPHORUS	102	35.29	43.68	55.07	171.98	UG/L
SILICA	95	97.89	11,128.11	7,265.36	28,056.40	UG/L
SULFATE	151	98.01	18,782.45	8,174.66	37,829.40	UG/L
TOTAL DISSOLVED SOLIDS	151	100.00	170,119.21	56,721.65	302,260.65	UG/L
TOTAL ORGANIC CARBON	49	100.00	7,466.94	4,621.53	22,047.87	UG/L
TOTAL SUSPENDED SOLIDS	159	59.75	18,877.99	45,772.72	125,528.42	UG/L

Table C-22. Seep/spring water UTLs for dissolved metals.

UPPER TOLERANCE LIMITS (SITE-WIDE)

SEEP / SPRING WATER, DISSOLVED METALS

ANALYTE	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	43	25.58	42.77	30.04	137.54	UG/L
ANTIMONY	30	30.00	25.89	28.49	124.08	UG/L
BARIUM	47	44.68	71.95	42.39	205.69	UG/L
CALCIUM	50	98.00	50,222.00	34,498.38	159,064.39	UG/L
COPPER	41	24.39	6.01	5.51	23.40	UG/L
IRON	49	69.39	1,927.00	4,082.76	14,808.10	UG/L
LEAD	42	21.43	1.08	0.86	3.81	UG/L
LITHIUM	43	32.56	29.46	20.72	94.84	UG/L
MAGNESIUM	47	72.34	7,002.07	5,198.40	23,403.02	UG/L
MANGANESE	44	86.36	127.57	185.52	712.90	UG/L
MERCURY	22	22.73	0.18	0.26	1.16	UG/L
MOLYBDENUM	34	20.59	33.81	21.07	104.49	UG/L
POTASSIUM	39	41.03	1,389.94	1,640.62	6,745.06	UG/L
SODIUM	50	98.00	12,297.00	5,585.54	29,919.38	UG/L
STRONTIUM	45	77.78	481.40	401.87	1,749.29	UG/L
ZINC	48	45.65	15.68	21.13	82.33	UG/L

Table C-23. Seep/spring water UTLs for total metals.

UPPER TOLERANCE LIMITS (SITE-WIDE)

SEEP / SPRING WATER, TOTAL METALS

ANALYTE	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	48	83.33	18,115.18	47,149.24	166,871.02	UG/L
ANTIMONY	34	32.35	46.68	108.89	411.91	UG/L
ARSENIC	44	59.09	69.77	192.06	675.73	UG/L
BARIUM	44	75.00	913.39	1,692.11	6,252.00	UG/L
BERYLLIUM	38	34.21	2.81	3.37	13.86	UG/L
CADMIUM	33	30.30	9.08	17.25	67.29	UG/L
CALCIUM	53	90.57	94,329.72	128,636.27	500,177.15	UG/L
CESIUM	33	24.24	419.98	449.37	1,936.79	UG/L
CHROMIUM	40	40.00	23.69	49.27	183.74	UG/L
COBALT	35	34.29	43.39	90.97	346.73	UG/L
COPPER	44	52.27	43.89	99.94	359.20	UG/L
CYANIDE	5	40.00	5.95	7.48	72.83	UG/L
IRON	51	88.24	175,074.71	518,671.63	1,811,483.71	UG/L
LEAD	45	66.67	91.14	207.26	745.05	UG/L
LITHIUM	35	48.57	29.43	26.57	118.02	UG/L
MAGNESIUM	50	80.00	10,370.60	7,644.36	34,488.56	UG/L
MANGANESE	51	80.39	1,798.04	5,027.04	17,658.34	UG/L
MOLYBDENUM	33	27.27	33.46	39.12	155.51	UG/L
NICKEL	35	37.14	50.68	116.39	438.78	UG/L
POTASSIUM	41	48.78	3,386.23	3,069.81	13,071.50	UG/L
SELENIUM	36	38.89	3.31	3.72	15.64	UG/L
SILICON	11	100.00	8,408.18	3,027.84	23,029.71	UG/L
SILVER	32	31.25	10.05	23.69	97.35	UG/L
SODIUM	53	88.68	12,005.80	5,016.89	27,834.09	UG/L
STRONTIUM	42	61.90	506.16	476.35	2,009.06	UG/L
TIN	35	37.14	94.03	190.89	730.54	UG/L
VANADIUM	41	51.22	117.09	280.76	1,002.88	UG/L
ZINC	50	82.00	195.22	431.42	1,556.36	UG/L

Table C-24. Seep/spring water UTLs for dissolved radionuclides.

UPPER TOLERANCE LIMITS (SITE-WIDE) SEEP / SPRING WATER, DISSOLVED RADIONUCLIDES						
ANALYTE	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
AMERICIUM-241	8	100.00	0.13	0.28	1.76	pCi/L
CESIUM-137	3	100.00	-0.27	0.21	4.71	pCi/L
GROSS ALPHA	13	100.00	2.78	5.21	26.09	pCi/L
GROSS BETA	14	100.00	5.94	10.09	49.69	pCi/L
GROSS GAMMA	5	100.00	1.09	1.25	12.27	pCi/L
PLUTONIUM-239,240	8	100.00	0.10	0.16	1.02	pCi/L
RADIUM-226	2	100.00	0.99	1.30	242.36	pCi/L
STRONTIUM-89,90	20	100.00	0.52	0.39	2.01	pCi/L
TRITIUM	13	100.00	301.25	298.70	1,637.06	pCi/L
URANIUM, TOTAL	3	100.00	1.90	2.43	59.89	pCi/L
URANIUM-233,234	13	100.00	0.91	0.73	4.19	pCi/L
URANIUM-235	12	100.00	0.12	0.13	0.72	pCi/L
URANIUM-238	13	100.00	0.60	0.54	3.03	pCi/L

Table C-25. Seep/spring water UTLs for total radionuclides.

UPPER TOLERANCE LIMITS (SITE-WIDE) SEEP / SPRING WATER, TOTAL RADIONUCLIDES						
ANALYTE	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
AMERICIUM-241	37	100.00	0.01	0.02	0.08	pCi/L
CESIUM-137	37	100.00	0.58	1.99	7.16	pCi/L
GROSS ALPHA	36	100.00	42.52	89.77	340.13	pCi/L
GROSS BETA	10	100.00	2.15	1.50	9.74	pCi/L
PLUTONIUM-239,240	33	100.00	0.21	0.78	2.85	pCi/L
RADIUM-226	12	100.00	7.72	9.10	49.88	pCi/L
RADIUM-228	5	100.00	16.38	14.11	142.53	pCi/L
STRONTIUM-89,90	32	100.00	0.32	0.38	1.61	pCi/L
TRITIUM	31	100.00	-87.72	1,275.95	4,277.76	pCi/L
URANIUM, TOTAL	9	100.00	0.85	0.63	4.23	pCi/L
URANIUM-233,234	33	100.00	0.64	1.29	4.99	pCi/L
URANIUM-235	32	100.00	0.02	0.08	0.31	pCi/L
URANIUM-238	28	100.00	0.64	1.21	4.89	pCi/L

Table C-26. Seep/spring water UTLs for water-quality parameters.

UPPER TOLERANCE LIMITS (SITE-WIDE)						
SEEP / SPRING WATER, WATER-QUALITY PARAMETERS						
ANALYTE	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
BICARBONATE	60	100.00	321,643.17	574,858.46	2,135,321.61	UG/L
CARBONATE	55	43.64	4,495.68	4,965.08	20,160.52	UG/L
CHLORIDE	53	90.57	12,523.58	17,061.93	66,353.96	UG/L
CYANIDE	46	26.09	7.11	7.00	29.21	UG/L
DISSOLVED ORGANIC CARBON	5	100.00	5,000.00	2,236.07	24,988.27	UG/L
FLUORIDE	18	100.00	552.22	264.88	1,601.23	UG/L
NITRATE/NITRITE	53	60.38	945.19	2,118.91	7,630.34	UG/L
OIL AND GREASE	24	37.50	2,448.13	1,934.86	9,490.08	UG/L
PH	35	100.00	7.22	0.43	8.64	PH UNITS
PHOSPHORUS	18	61.11	354.94	804.15	3,539.67	UG/L
SILICA	17	100.00	17,025.45	8,569.50	51,617.95	UG/L
SULFATE	53	96.23	46,962.26	87,305.62	322,411.50	UG/L
TOTAL DISSOLVED SOLIDS	53	100.00	263,867.92	174,307.09	813,806.81	UG/L
TOTAL ORGANIC CARBON	7	100.00	9,014.29	3,184.56	29,433.51	UG/L
TOTAL SUSPENDED SOLIDS	54	87.04	2,712,305.56	7,791,125.40	27,293,306.20	UG/L

Table C-27. Stream sediment UTLs for total metals.

UPPER TOLERANCE LIMITS (SITE-WIDE)

STREAM SEDIMENTS, TOTAL METALS

ANALYTE	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	59	100.00	5,887.61	4,912.73	21,387.27	MG/KG
ANTIMONY	52	44.23	4.55	4.16	17.68	MG/KG
ARSENIC	59	69.49	2.24	2.50	10.13	MG/KG
BARIUM	57	84.21	74.47	56.85	253.82	MG/KG
BERYLLIUM	57	63.16	0.93	3.40	11.65	MG/KG
CADMIUM	51	39.22	0.72	0.58	2.55	MG/KG
CALCIUM	59	81.36	3,554.57	4,719.98	18,446.12	MG/KG
CESIUM	56	62.50	101.77	107.96	442.39	MG/KG
CHROMIUM	59	84.75	8.25	7.49	31.88	MG/KG
COBALT	59	76.27	5.16	3.57	16.43	MG/KG
COPPER	59	83.05	10.81	8.23	36.78	MG/KG
IRON	59	100.00	8,852.63	6,263.19	28,612.98	MG/KG
LEAD	59	100.00	22.02	36.79	138.09	MG/KG
LITHIUM	57	91.23	10.01	9.83	41.01	MG/KG
MAGNESIUM	59	79.66	1,404.18	1,253.37	5,358.56	MG/KG
MANGANESE	59	100.00	229.52	214.85	907.35	MG/KG
MERCURY	49	48.98	0.12	0.11	0.46	MG/KG
MOLYBDENUM	58	53.45	5.48	8.33	31.75	MG/KG
NICKEL	57	75.44	7.01	5.44	24.16	MG/KG
POTASSIUM	58	70.69	812.50	743.98	3,159.74	MG/KG
SELENIUM	58	43.10	0.45	0.55	2.18	MG/KG
SILICON	19	100.00	331.53	362.31	1,741.79	MG/KG
SILVER	54	33.33	0.86	0.71	3.11	MG/KG
SODIUM	59	79.66	161.47	136.80	593.09	MG/KG
STRONTIUM	58	89.66	45.62	77.91	291.42	MG/KG
THALLIUM	50	24.00	0.34	0.24	1.10	MG/KG
TIN	54	53.70	9.69	9.79	40.57	MG/KG
VANADIUM	57	91.23	18.15	14.34	63.39	MG/KG
ZINC	58	98.28	44.44	29.98	139.04	MG/KG

Table C-28. Stream sediment UTLs for total radionuclides.

UPPER TOLERANCE LIMITS (SITE-WIDE) STREAM SEDIMENTS, TOTAL RADIONUCLIDES						
ANALYTE	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
AMERICIUM-241	37	100.00	0.17	0.48	1.77	pCi/g
CESIUM-137	35	100.00	0.26	0.38	1.54	pCi/g
GROSS ALPHA	45	100.00	22.98	20.46	87.54	pCi/g
GROSS BETA	43	100.00	35.35	9.98	66.83	pCi/g
PLUTONIUM-238	5	100.00	0.00	0.00	0.00	pCi/g
PLUTONIUM-239,240	45	100.00	0.54	1.61	5.62	pCi/g
RADIUM-226	21	100.00	0.85	0.36	2.12	pCi/g
RADIUM-228	20	100.00	1.70	0.74	4.55	pCi/g
STRONTIUM-89,90	43	100.00	0.21	0.27	1.07	pCi/g
TRITIUM	42	100.00	194.30	265.07	1,030.59	pCi/g
URANIUM, TOTAL	6	100.00	1.48	0.69	6.57	pCi/g
URANIUM-233,234	47	100.00	1.68	1.15	5.29	pCi/g
URANIUM-235	49	100.00	0.06	0.05	0.21	pCi/g
URANIUM-238	36	100.00	1.40	1.03	4.82	pCi/g

Table C-29. Stream sediment UTLs for total "water-quality" parameters.

UPPER TOLERANCE LIMITS (SITE-WIDE) STREAM SEDIMENTS, TOTAL "WATER-QUALITY" PARAMETERS						
ANALYTE	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALKALINITY AS CACO3	28	92.86	1,970.44	5,102.72	19,839.86	MG/KG
BICARBONATE AS CACO3	4	100.00	1,041.25	1,449.27	18,993.76	MG/KG
NITRATE/NITRITE	52	71.15	7.76	15.67	57.19	MG/KG
NITRITE	12	83.33	0.34	0.19	1.21	MG/KG
PH	51	100.00	7.26	0.66	9.34	PH UNITS
TOTAL ALKALINITY	6	100.00	4,470.00	8,116.00	63,997.31	MG/KG

Table C-30. Seep/spring sediment UTLs for total metals.

UPPER TOLERANCE LIMITS (SITE-WIDE)

SEEP / SPRING SEDIMENTS, TOTAL METALS

ANALYTE	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	20	100.00	10,354.30	5,010.71	29,553.14	MG/KG
ANTIMONY	18	44.44	8.81	8.14	41.04	MG/KG
ARSENIC	20	90.00	12.55	14.23	67.25	MG/KG
BARIUM	20	95.00	204.61	155.62	800.88	MG/KG
BERYLLIUM	16	81.25	1.13	0.92	4.94	MG/KG
CADMIUM	16	43.75	1.65	1.66	8.52	MG/KG
CALCIUM	20	100.00	19,407.50	16,059.56	80,940.62	MG/KG
CESIUM	17	52.94	260.47	200.55	1,070.01	MG/KG
CHROMIUM	18	94.44	10.98	5.27	31.87	MG/KG
COBALT	19	84.21	8.47	5.48	29.81	MG/KG
COPPER	18	94.44	18.74	10.68	61.04	MG/KG
IRON	18	100.00	20,763.89	22,673.64	110,559.63	MG/KG
LEAD	18	100.00	36.37	22.64	126.03	MG/KG
LITHIUM	18	88.89	19.79	20.12	99.49	MG/KG
MAGNESIUM	20	80.00	2,249.30	1,152.86	6,666.56	MG/KG
MANGANESE	19	100.00	261.63	273.79	1,327.33	MG/KG
MERCURY	15	33.33	0.23	0.31	1.55	MG/KG
MOLYBDENUM	19	57.89	15.77	19.74	92.59	MG/KG
NICKEL	17	88.24	12.99	7.51	43.31	MG/KG
POTASSIUM	18	61.11	1,050.72	616.83	3,493.61	MG/KG
SELENIUM	19	68.42	1.25	0.98	5.07	MG/KG
SILICON	10	100.00	1,698.70	2,117.17	12,440.63	MG/KG
SILVER	15	46.67	2.15	1.98	10.49	MG/KG
SODIUM	20	60.00	251.62	294.04	1,378.24	MG/KG
STRONTIUM	20	90.00	113.70	92.03	466.32	MG/KG
THALLIUM	13	30.77	1.42	2.44	12.33	MG/KG
TIN	19	57.89	22.18	18.75	95.16	MG/KG
VANADIUM	19	100.00	27.63	14.21	82.96	MG/KG
ZINC	20	100.00	56.13	22.67	143.00	MG/KG

Table C-31. Seep/spring sediment UTLs for total radionuclides.

UPPER TOLERANCE LIMITS (SITE-WIDE)						
SEEP / SPRING SEDIMENTS, TOTAL RADIONUCLIDES						
ANALYTE	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
AMERICIUM-241	14	100.00	0.13	0.31	1.46	pCi/g
CESIUM-137	13	100.00	0.81	0.60	3.51	pCi/g
GROSS ALPHA	15	100.00	19.71	14.00	78.83	pCi/g
GROSS BETA	14	100.00	23.73	5.08	45.76	pCi/g
PLUTONIUM-238	3	100.00	0.00	0.00	0.01	pCi/g
PLUTONIUM-239,240	16	100.00	0.61	1.71	7.68	pCi/g
RADIUM-226	9	100.00	0.71	0.24	1.97	pCi/g
RADIUM-228	9	100.00	1.18	0.32	2.88	pCi/g
STRONTIUM-89,90	14	100.00	0.35	0.52	2.63	pCi/g
TRITIUM	13	100.00	198.54	127.73	769.75	pCi/g
URANIUM, TOTAL	3	100.00	1.87	0.59	15.87	pCi/g
URANIUM-233,234	16	100.00	0.82	0.38	2.39	pCi/g
URANIUM-235	17	100.00	0.04	0.05	0.25	pCi/g
URANIUM-238	14	100.00	0.73	0.41	2.52	pCi/g

Table C-32. Seep/spring sediment UTLs for total "water-quality" parameters.

UPPER TOLERANCE LIMITS (SITE-WIDE)						
SEEP / SPRING SEDIMENTS, "WATER-QUALITY" PARAMETERS						
ANALYTE	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALKALINITY AS CACO3	8	100.00	14,192.25	27,343.99	173,110.00	MG/KG
NITRATE/NITRITE	17	52.94	4.14	3.90	19.89	MG/KG
NITRITE	3	100.00	1.33	1.53	37.91	MG/KG
PH	18	100.00	7.24	0.56	9.47	PH UNITS
TOTAL ALKALINITY	4	75.00	750.25	1,499.83	19,329.11	MG/KG

SURFICIAL SOILS FROM ROCK CREEK

TOTAL METALS

Analyte	MEAN	STD DEV	N	TOL FACT	99 / 99 UTL	UNITS
Aluminum	12992.9	2251.53	18	3.9604	21909.85	MG/KG
Antimony	10.525	1.724	18	3.9604	17.35	MG/KG
Arsenic	5.817	1.818	18	3.9604	13.02	MG/KG
Barium	195.2	84.63	18	3.9604	530.37	MG/KG
Beryllium	0.983	0.256	18	3.9604	2.00	MG/KG
Cadmium	1.048	0.362	17	4.0367	2.51	MG/KG
Calcium	5068.1	2220.5	18	3.9604	13862.17	MG/KG
Cesium	61.43	61.43	18	3.9604	304.72	MG/KG
Chromium	15.207	2.798	19	3.8924	26.10	MG/KG
Cobalt	7.781	4.305	18	3.9604	24.83	MG/KG
Copper	12.964	3.629	18	3.9604	27.34	MG/KG
Iron	15381.7	3226.62	18	3.9604	28160.41	MG/KG
Lead	37.535	6.024	18	3.9604	61.39	MG/KG
Lithium	10.98	2.273	18	3.9604	19.98	MG/KG
Magnesium	2853.3	1049.95	18	3.9604	7011.52	MG/KG
Manganese	443.67	457.01	18	3.9604	2253.61	MG/KG
Mercury	0.09256	0.0306	18	3.9604	0.21	MG/KG
Molybdenum	3.31997	1.59652	18	3.9604	9.64	MG/KG
Nickel	12.578	3.588	18	3.9604	26.79	MG/KG
Potassium	2977.9	575.47	18	3.9604	5256.99	MG/KG
Selenium	0.4785	0.1468	18	3.9604	1.06	MG/KG
Silicon	780.99	700.452	18	3.9604	3555.05	MG/KG
Silver	1.726	0.693	18	3.9604	4.47	MG/KG
Sodium	175.14	75.031	18	3.9604	472.29	MG/KG
Strontium	35.331	13.811	18	3.9604	90.03	MG/KG
Thallium	0.3773	0.1204	18	3.9604	0.85	MG/KG
Tin	38.346	9.2105	18	3.9604	74.82	MG/KG
Vanadium	31.603	6.049	18	3.9604	55.56	MG/KG
Zinc	55.824	7.795	18	3.9604	86.70	MG/KG

SURFICIAL SOILS FROM ROCK CREEK

TOTAL RADIONUCLIDES

Analyte	MEAN	STD DEV	N	TOL FACT	99 / 99 UTL	UNITS
Americium-241	0.01854	0.0092	15	4.2224	0.05	PCI/G
Cesium-137	1.41	0.4897	12	4.633	3.68	PCI/G
Gross alpha	19.825	4.916	10	5.0737	44.77	PCI/G
Gross beta	32.031	5.599	19	3.8924	54.21	PCI/G
Plutonium-239,240	0.05523	0.02023	16	3.9604	0.14	PCI/G
Radium-226	0.94538	0.12813	10	5.0737	1.60	PCI/G
Radium-228	2.1767	0.5309	10	5.0737	4.87	PCI/G
Strontium-89,90	0.61833	0.29768	9	5.3889	2.22	PCI/G
Uranium-233,234	1.14497	0.15557	16	4.1233	1.79	PCI/G
Uranium-235	0.05263	0.03271	16	4.1233	0.19	PCI/G
Uranium-238	1.18301	0.16799	16	4.1233	1.96	PCI/G

Where "TOL FACT" is the tolerance factor for the 99/99 UTL, and "STD DEV" is the standard deviation for sample size, N. The 99/99 UTL is calculated as (TOL FACT * STD DEV) + MEAN. Metals are 89-percent validated, and radionuclides are 64-percent validated in this table.

RESPONSES TO EPA LETTER 8HWM-FF - STATISTICAL COMPARISONS TO BACKGROUND AT ROCKY FLATS DATED SEPTEMBER 21, 1993:

GENERAL COMMENTS

1. Overall, the report is outstanding. It succinctly outlines a comprehensive paradigm for the background analysis of inorganic chemicals at RFP. It is obvious that the multitiered approach, incorporating specific data quality objectives, presentation and graphic analysis, and a series of six statistical tests has been well thought-out and all possible scenarios considered and problems anticipated. It directly addresses the predominant contentious and divisive issue, the proper application of the upper tolerance limit (UTL) approach that has been advanced by DOE.

On a purely technical level, the approach is well-balanced. However, the report appears to be overly concerned with Type I or false positive errors and not as concerned with Type II or false negative errors. From a risk assessment standpoint, a Type I error can be easily managed if it is unknowingly included in the risk assessment since the analysis can be revisited and professional judgement applied if the risk associated with the chemical in question becomes unacceptable. In contrast, a Type II error cannot be so easily managed. If a Type II error is made, the chemical will be incorrectly eliminated early in the COC selection process and will not be further considered. Although it is desirable to minimize or eliminate both types of errors from the analysis, from a public health perspective it is preferable to make a Type I error. Chemicals included in the risk assessment from a Type I error will not automatically be remediated. EPA recommends that for risk assessment, sampling design should specify the probability of a Type I error as 20% and the probability of a Type II error as 10% or less. This is an important item to reach consensus on between EPA, CDH, and DOE.

> **Clarification.** It is necessary to reach a compromise between acceptable Type I error rates, acceptable Type II error rates, and cost. Each OU should have addressed these issues in the OU-specific workplan approved by DOE and the Agencies. The corresponding background data are now a matter of historical record, as this sampling program was terminated after four years of data collection. At the September 29, 1993 meeting, all parties agreed to the Type I error rates incorporated into the current plan, which is 5% for the Gehan, quantile, slippage, t-test, and Wilcoxon Rank Sum tests, with the Type II error rate left unspecified. However, it should be noted that the actual Type II error rate has been reduced, and the Type I error rate has been increased, because of the battery of tests. The UTL test will increase the Type I error rate and reduce the Type II error rate as well.

2. One additional problem that is not addressed in Dr. Gilbert's report, perhaps because it was outside the scope of work, involves data aggregation. This is a fundamental issue that has yet to receive the proper amount of focused attention. Without an established methodology for aggregating data within different environmental media, the time and effort expended in executing the sophisticated statistical approach presented in this report will be misspent. Although the report touches on some aspects of this broad problem, it does not directly discuss the issue.

Therefore, EPA, CDH, and DOE need to address it.

Clarification. Data aggregation is another topic, being addressed by DOE/RFO, CDH, and EPA separately from this forum, which deals strictly with site-to-background comparison.

3. If the agencies can agree that the above concerns will be addressed, the background analysis approached developed by Dr. Gilbert provides a well-balanced methodology that will, if implemented properly, lead to a robust background analysis. This objective, scientific approach will result in verifiable conclusions, expedite the review and comment period, and prevent an overreliance on professional judgement.

No response necessary.

SPECIFIC COMMENTS

1. Page 2. Seventh Bullet. It is suggested that the same field sampling and laboratory procedures be used for both background and site data. The statement should be extended to include data aggregation. Past review of RFP data from operable units showed inconsistencies in the methodology used to aggregate data. Problems encountered at this phase will be magnified at later stages of the background analysis.

Concur. The same field sampling and laboratory procedures were used for both background and site data.

Clarification. Data aggregation is another topic, being addressed by DOE/RFO, CDH, and EPA separately from this forum, which deals strictly with site-to-background comparison.

2. Page 4, Task 1, Observation 1, Third Bullet. This statement suggests that background analysis should be the initial state in selecting COCs. This is consistent with the COC selection methodology developed for Rocky Flats by DOE, EPA, and CDH. However, in order to manage DOE's effort in background comparisons, we point out that it is not necessary to carry all chemicals through an elaborate, time consuming statistical analysis if they can be eliminated as essential nutrients or as infrequently detected chemicals. It may be more cost-effective and expeditious to simply eliminate chemicals on the basis of these two preliminary criteria than to conduct a background analysis only to eliminate them later based on the background analysis. We suggest that DOE consider this in the development of a plan to implement Dr. Gilbert's approach.

Clarification. Essential nutrients have not been eliminated from the protocol in the statistical methodology. This comment was withdrawn by EPA at the September 29, 1993 meeting.

3. Page 5, Task 1, Observation 4, Second Bullet. This statement expresses concern about measurements that are less than the contract required detection limits (CRQL) but above instrument detection limits (IDL). According to Risk Assessment Guidance for Superfund,

Human Health Evaluation Manual, Volume I, Part A, these measurements should be "J" coded and interpreted as estimated values. They should not be viewed as non-detected chemicals. If they are currently classified as non-detect chemicals in the RFP background geochemical report, the entire validation process currently in place should be reevaluated.

Clarification. There has been confusion over the detection limits and their application. A qualifier of "J" indicates that the reported value is between the instrument detection limits and the contract required detection limits. A non-detect has a reported value of a detection limit, not the detected value, and conveys less information than a "J".

4. Page 9, Paragraphs 3 and 4. The essence of this discussion is that a hot measurement (HM) concentration should serve as a "safety net" that can prevent "hot spots" from passing unnoticed in a risk assessment. It should be noted that this need has been previously recognized and was addressed in the original flow chart devised during the summer 1992 meetings involving EPA, DOE, and CDH. At that time, it was agreed that a risk-based concentration (RBC) would effectively serve as the "hot measurement." Although a UTL has some utility in identifying hot spots, there is no need to conduct a lengthy analysis if the highest detected concentrations do not exceed a predetermined RBC and pose an unacceptable human health risks. Thus, it is possible to have measurements above the UTL but below an RBC in which case there would be little reason to consider the chemical further.

Clarification. The Guide for Conducting Statistical Comparisons of RFI/RI Data and Background Data at the Rocky Flats Plant (called The Guide subsequently) addresses statistical determination of the presence or absence of analytes, and does not address human health effects. For each OU, additional tests will determine if the analyte concentrations present are below regulatory (ARARs) and/or human health effect (PRGs) levels, but that is external to the statistical discussion at hand.

5. Page 10, Third and Fourth Bullet. This statement refers to lowering the potential for a Type I, false positive error to using a 99 percent UTL on the 99 percentile. However, this concern is not properly balanced against the potential for a Type II error. A false negative could have profound consequences on the risk assessment and subsequent remedy selected for the site.

Do not concur. If the 95% UTL were used, then a very high percentage of data points would be considered pCoCs, because theoretically, even a background population will have 5% of readings above the UTL. A site, even if its concentration levels are slightly above background, may have considerably more than 5% of its readings above the $UTL_{95/95}$. Any analytes that show a false negative on this test will still be considered pCoCs if they test positive on any of the other statistical tests.

6. Page 11, Second Paragraph. This paragraph suggests that data quality objectives (DQOs) be established at the design stage of the studies. Although this is a relevant comment in the context of planning a background analysis, the background and most of the OU planning and sampling has already been completed. Thus, this comment is appropriate in theory but there is little chance for implementation. Revitalized effort should be directed to establishing DQOs where they were not previously established, and analyzing whether the sampling efforts

completed to date have succeeded in meeting these DQOs. DOE, EPA, and CDH will need to look at options for correcting the situation if the DQOs have not been met.

Concur. The draft RIs for each OU have a section for reviewing data quality. Each OU manager bears the responsibility for ensuring that DQOs are met for his or her OU. This issue will be dealt with independently from the statistical methodology, as was agreed to by EPA, CDH, and DOE at the September 29, 1993 meeting.

7. Task 4. Flow Chart for Comparing OU Data to Background. With a minor exception, this flow chart adequately describes the framework for a background analysis. The exception is an inadequate description of appropriate conditions under which particular statistical tests should applied.

Explicit guidelines for the application of specific statistical tests under well-defined conditions should be presented to circumvent future misunderstandings: It would be highly useful for EPA, DOE, and CDH to agree to a predetermined paradigm in which all possible circumstances and conditions have been anticipated and the appropriate statistical tests identified. Knowing in advance what particular test will be applied under what circumstances will prevent protracted discussions and possible disagreements.

Concur. The Background Comparison Methodology chart shows the specific tests and gives the conditions under which they are or are not applicable. In addition, The Guide's text states which tests will be conducted, under what circumstances.

IMPLEMENTATION ISSUES

1. EPA, DOE, and CDH must reach consensus on procedures for defining non-detects.

   Concur. The Guide states that non-detects will be considered to be one-half of the reported detection limit, in accordance with EPA guidance.

2. EPA, DOE, and CDH must reach consensus on what hot measurement value should be used.

   Concur. Our methodology uses a value of $UTL_{99/99}$.

3. EPA, DOE, and CDH must establish data quality objectives which address acceptable power and confidence levels, required detection limits, and anticipated data aggregation.

   Clarification. The draft RIs for each OU have a section for reviewing data quality. Each OU manager bears the responsibility for ensuring that DQOs are met for his or her OU. This issue will be dealt with independently from the statistical methodology, as was agreed to by EPA, CDH, and DOE at the September 29, 1993 meeting.

4. EPA, DOE, and CDH must revisit the assumptions which Dr. Gilbert lists on page two of his cover letter. Are these assumptions valid? What are the consequences if the assumptions are violated? Can this be handled in an uncertainty analysis?

   Clarification. All of the assumptions listed, except for the last four, are difficult to quantify and are thus not "valid" or "invalid". These last four are now answered individually.

   The same field-sampling techniques are used for background and site, so this assumption is valid.

   Measurements are not always validated by third-party subcontractors before the draft RFI/RI statistical testing has been completed, so this assumption is not valid. When the data validation results have been obtained, the data are reanalyzed, and the final RFI/RI contains no rejected data.

   Background data were checked for outliers, per EPA comments upon the 1992 Background Geochemical Report, and extreme outliers were excluded from statistical analysis in the 1993 Background Geochemical Report, so this assumption is not entirely valid. However, OU data outliers are not typically deleted, although data from the OUs are checked for "geochemical reasonableness", and any unusual results are discussed in the ensuing reports.

   The instrument detection limits are not always reported in the data bases, so this assumption is not completely valid. However, the costs of recovering this information would be considerable.

5. EPA, DOE, and CDH must reach consensus on a paradigm for implementation. The issues to be worked out include:

a. The appropriate background data sets by analyte, medium, and location.

Concur. The section of The Guide entitled "Determine Background and OU Target Populations" addresses how this will be done.

b. How to deal with clearly non-random (e.g., spatial) patterns.

Concur. The Guide states in the Professional Judgement section that spatial patterns are subject to professional judgement, which is then subject to EPA and CDH review.

c. Measurement errors and multiple non-detects.

Concur. Measurement errors are an inevitable part of physical data. Efforts are taken throughout the data-collection process to minimize errors. When non-detect replacement is necessary (i.e., for t-tests or UTL tests), non-detects are dealt with by replacing the data value with ½ of the reported detection limit.

d. Structure for the formal statistical tests.

Concur. The Guide furnishes this structure.

e. Data aggregation for comparison in the statistical tests.

Clarification. Data aggregation is another topic, being addressed by CDH and EPA separately from this forum, which deals strictly with site-to-background comparison.

RESPONSES TO CDH LETTER - STATISTICAL METHODS FOR THE COMPARISON OF REMEDIAL INVESTIGATION DATA TO BACKGROUND DATA AT ROCKY FLATS PLANT, DATED SEPTEMBER 13, 1991

1. The Division would like to emphasize the importance of effective graphical presentation of data to enhance the understanding and interpretation of the statistical tests. The Division believes that the development of effective graphical procedures to display and interpret both site and background data is essential to the usefulness of the methodology and should not be overlooked or down-played. The Division requests that specific graphical techniques be developed and included in the "statistical strawman" methodology.

Concur. The Guide specifically addresses graphical techniques.

2. The Division does not recommend the use of a risk based hot measurement comparison value in the hot measurement comparison. The use of risk based decisions is not appropriate in the context of comparisons to background.

Concur. The hot-measurement comparison value is not risk-based.

3. As noted in Dr. Gilbert's report, the proper treatment of non-detects and multiple detection limits is critical to the implementation of his recommendations. Both of these issues occur frequently in Rocky Flats data sets. Therefore, the Division recommends that DOE emphasize specific protocol for proper treatment of non-detects and multiple detection limits in the "strawman" methodology.

Concur. The Guide states that non-detects will be dealt with by replacing the data value with ½ of the reported detection limit.

4. The Division agrees with Dr. Gilbert that professional judgement is necessary in evaluating the results of statistical tests. However, it is not the Division's intention that professional judgement be a substitute for an inadequate site investigation or as a tool to dismiss dubious data. The scope of appropriate professional judgement and limitations on its application should be outlined in the "strawman" methodology. Guidelines and criteria for making decision based on professional judgement should also be identified.

Concur. The Guide restricts professional judgement to several specific areas.

Response to EPA: Hestmark letter 8HWM-FF received 10/25/93

1. To determine the appropriate background and operable unit populations for comparison, we understand that some matching of the two populations is done by geologists and chemists. Data for an analyte in a non-background area are grouped according to a combination of background classes which represent independent background populations. A table that cross references the operable unit populations and the background populations will be provided.

Concur. The strawman has been changed to require tables that cross-reference OU media to background media.

2. A more explicit statement of the null hypothesis that is being tested will be included. In addition, a fixed p value of 0.05 will be used for each of the inferential statistical tests as written in the strawman proposal. There was some inconsistency in what was written in the proposal and what was stated in the meeting regarding the p value. A fixed value of 0.05 is what we will accept.

Concur. The strawman states that p values must be less than or equal to 0.05 to demonstrate a significant difference from background. Footnote 3 on page 5 of the strawman, which was not clear on this point, has been deleted.

3. All references to comparison of background and operable unit populations for organics will be removed. Background comparisons apply to inorganics and radionuclides only.

Do not concur. Although background comparisons for organics are not commonly used, there are instances when it may be applicable, in which wide-ranging organic contamination is due to non-site-specific anthropogenic sources. We want to retain the option of performing background comparisons for these organics, when geochemists or geologists determine that it is applicable to do so. In these instances, we will retain the burden of proof, and the applicability of the comparison will be subject to EPA and CDH approval.

The strawman has been rewritten to state that background comparisons for organics will be done on a limited, case-by-case basis, subject to EPA and CDH approval.

4. The use of professional judgement in interpreting the results of the graphical displays and statistical analyses will be limited to consideration of spatial distribution, temporal distribution, and pattern recognition concepts. The strawman proposal included five additional criteria. These will be deleted in the final implementation document.

Concur. The five criteria (intermedia interactions and geochemical processes, not an expected contaminant, blank data, regional background range, and influence of field activities) have been deleted. .

5. The non-background population is defined as the entire operable unit remedial investigation set. The data aggregation for the purpose of background comparison will be done within the area defined by the operable unit boundaries.

Concur. Analysis will be done on an OU-wide basis.

6. The attached flowchart, "Background Comparison Methodology", distributed at the meeting will be clarified. It is EPA's understanding that all the data sets will undergo the hot measurement test and the battery of inferential statistical tests (Gehan, Quantile, Slippage, and T-Test) provided the data satisfies the conditions stated in the strawman and on the flowchart. If any one of these tests, including the hot measurement test, shows significance, the analyte will be further considered, using professional judgement, as a contaminant of concern. The flowchart would benefit from the addition of decision blocks after each test indicating the next step if significance is demonstrated or not.

Clarification. The chart "Background Comparison Methodology" attached to EPA's memo is not the same as that distributed at the September 29, 1993 meeting and contained within the strawman proposal. The difference is that nonparametric ANOVA tests are given as options to the Gehan test in the chart within the strawman proposal. Because the Gehan method is not standard and will therefore incur practical liabilities (e.g., the method has not been adequately tested and verified, preliminary usage shows it to require excessive man-hours, and subcontractors will need to be instructed in its use), we want to retain the option of performing standard nonparametric ANOVA testing, using the Wilcoxon or Kruskal-Wallis tests, instead of the Gehan test.

Additional clarification. The suggested decision blocks are not necessary. All tests will be performed, if applicable, regardless of whether other tests demonstrate significance.

Concur with the need to redo the flowchart. This has been done.

6. (continued) We also have some specific questions that need to be addressed in the final document:

a. What happens to data which is carried through the slippage test but does not qualify for the t-test?

Clarification. The data that do not qualify for the t-test will be routed to the "At Least One Test Significant?" block. The flowchart has been revised to show this.

b. What is the basis for the 20% detect value as the criteria for the Quantile test? How does this criteria relate to the criteria for applying this test as stated in Dr. Gilbert's report on page 20?

Clarification. Dr. Gilbert's method proposed looking up tabulated values for n and r parameters. The quantile test could be correctly applied only if the largest n values were all detects. Our statisticians have stated that, typically, this restriction equates to the

largest 20% or less of the combined sample sizes being detects, and recommend using a flat 20% to simplify application.

c. What is the basis for the criteria of N>20 value for background and operable unit data?

Clarification. Our statisticians derived this value from application of the Central Limit Theorem for a two sample problem. If both samples have N=20, then there will be 38 total degrees of freedom, which will permit assumptions about the distribution.

7. EG&G's claim that these impacts [of implementing Dr. Gilbert's recommendations] could range from $30,000 up to $120,000 per operable unit is not supported by the information provided. In fact, it appears that there is some evidence that implementation will not negatively impact costs or schedules.

Do not concur. Because the Gilbert method requires additional work, there will be cost and/or schedule impacts.

In addition to the impacts mentioned above, cost impacts may result if the Gehan method is used. For OU11, approximately 200 hours were required to perform the Gehan test, when less than 40 hours would have been sufficient to perform standard ANOVA testing. However, the majority of these costs appear to be one-time costs such as coding development. Subsequent testing on the same OU indicate that the cost impacts may be as little as 30 hours for a small data set.

Response to CDH letter "DOE Proposed Methodology for Statistical Comparison of Remedial Investigation Data at the Rocky Flats Plant" from G. Baughman to R. Schassburger, dated 10/13/93

1. To minimize any potential future misunderstandings of this agreement, the Division feels that it is critical for the Agencies to develop a formal guidance/policy document institutionalizing the agreement. The Strawman document was written for the purpose of facilitating agreement among the Agencies. However, the end users of this document will be the operable unit managers and sub-contractors preparing and reviewing RFI/RI reports. The majority of these people were not involved in the development of this methodology. It is critical to the future of this agreement that final documentation of this agreement be developed to clearly and concisely guide future end users in the implementation of this methodology. This formal guidance should be completed in parallel with the implementation of the agreement.

Concur. When the strawman has been completed and accepted by all concerned parties, it will then be rewritten as a procedure for statistical comparison of OU data to background.

2. The Division recommends that the title of this document be revised to more accurately reflect its content and intent, that being methodology and guidelines for the comparison of site data to background data. The Division proposes the title, "Guide for Conducting Statistical Comparisons of RFI/RI Data and Background Data at the Rocky Flats Plant," for consideration.

Concur. The CDH's proposed title is an improvement to the current title, and has been adopted.

3. One of the central themes of Dr. Gilbert's recommendations was the need for statisticians to be involved throughout the entire process. However, statistician involvement is not discussed in the methodology. The division requests that the role of the statistician in implementation of this methodology be clarified in this document.

Concur. Statisticians will be employed to verify that the methods used are correct. The strawman has been rewritten to incorporate this.

4. The Division does not believe that references to specific DOE sub-contractors are appropriate in this document. The Division recommends DOE review all references to sub-contractors and, where appropriate, modify the reference to more accurately reflect DOE's role and responsibilities.

Concur. References to DOE subcontractors have been eliminated.

5. This section (Determine Background and OU Target Populations) outlines the steps for matching site and background populations. However, it is unclear exactly how the matching will be implemented. The Division recommends that the rationale for combining media/geology groupings for testing be detailed in this section. For example, any criteria for minimum group size necessary for statistical testing should be specified. The Division further recommends adding a table or diagram depicting the general rationale for grouping data by media and geology.

Concur. The strawman states that the OU will match one or more of several specified background media. In addition, the strawman has been changed to require that a cross-reference be performed between the site and one or more background media.

6. As discussed during the September 29th meeting, and emphasized by Dr. Gilbert, it is critical to statistical hypothesis testing that the hypothesis to be tested is explicitly defined and clearly stated. The Division recommends a statement of the test and null hypotheses, in both "english" (narrative qualitative description) and statistical terms, be added to this section of the methodology so there is no misunderstanding of what is being tested. This statement should also address confidence and power requirements for the tests.

Concur. The strawman has been modified to require statistical and prose statements of the null and alternative hypotheses.

7. The Division does not agree with the blanket statement at the beginning of this discussion, "Under current IAG schedule conditions, analytical data will not be 'validated' when the background comparisons will be made in each draft report." This claim is not substantiated by the schedules submitted by DOE in the approved OU work plans and is in direct contradiction to Dr. Gilbert's Task 5 recommendations. Dr. Gilbert states that, "These data quality evaluations are conducted prior to descriptive graphical analyses and formal statistical tests." In finalizing this methodology, the Division recommends that DOE follow Dr. Gilbert's recommendations for data validation <u>before</u> formal graphical presentation and statistical testing. The need for variance from this approach will be considered by the Division on an OU specific basis.

Do not concur. Under the present system of data validation, the non-validated data are used only for the draft RFI/RI. The final RFI/RI is based solely upon validated data. The lag time between receiving data from the laboratory, and validated data from the independent subcontractor can exceed one month. Waiting for 100% validation may impact schedules, but will probably not change the results in the final RFI/RI. The potential impacts of using non-validated data at each OU will be discussed on a case-by-case basis.

8. The Division recommends DOE add a discussion of detection limits to this section of the methodology. In the past there has been confusion as to what detection limits are being reported and used (instrument detection limits vs contract limits vs reporting limits). Part of this confusion may be because detection limits have not been formal discussed. This section should state what detection limits are to be used in statistical testing and how they are

determined from the RFEDS data set.

Concur. The strawman addresses detection limits, and it specifies how determinations are made on how to handle non-detects.

9. The Division recommends that this section (Preliminary Exploratory Data Appraisal) be moved to the Data Presentation section.

Concur. This section has been moved to the Data Presentation section.

10. The Division interprets this section as describing the informal data analysis conducted during RFI/RI preparation and not normally included in the formal RFI/RI report. The Division recommends adding language to indicate that this informal data analysis will be made available and reviewed with the regulators in evaluating the appropriateness of the scope of the formal RFI/RI proposal.

Clarification. We have added language to this section to clarify that this informal data analysis will be informally discussed with CDH, EPA, and DOE/RFO. However, this will not constitute a formal deliverable.

11. The Division does not agree with DOE's recommendations that box plots are applicable only when there are no non-detects. The problem of estimating percentiles for data sets with multiple non-detects was not resolved by Dr. Gilbert. The Division recommends that when a reasonably small percentage of non-detects are present, percentiles be estimated using Maximum Likelihood Estimation (MLE) techniques in constructing box plots.

Concur. We will provide box plots unless the percentage of non-detects exceeds 50%. The 50% figure is chosen for consistency with the 1993 Background Geochemical Characterization Report (September 30, 1993).

12. The Division does not agree with DOE's suggestion that histograms are not useful for small or highly censored data sets, such as inorganics. As stated by Dr. Gilbert, such histograms are not likely to be useful in visually assessing whether the data sets are better modeled by a normal or lognormal distribution. However, they may still be useful to visually compare the spread, central tendency, and skewness of the two data sets to look for differences that may be important.

Concur. We will provide histograms unless the percentage of non-detects exceeds 50%. Bars in the histogram will be shaded to indicate the percentage of detects and non-detects within each bar interval.

13. The Division recommends that a discussion be added to this section of the methodology to address what to do when a UTL 99/99 can not be reasonably estimated or is unknown (ie small or highly censored background data set).

Concur. We have modified the strawman to state that professional judgement, and use of

geochemical background data from the literature, will be used. The result will be a geochemical interpretation of data, subject to agency review and approval.

14. The reference in Footnote 2 to OU 1 is not appropriate and should be removed. The inferential tests conducted at OU 1 were the result of a compromise agreement, are not precedent setting for other OUs and are not the tests being proposed in this document. However, as stated in this note, limited professional judgement as presented later in this document may be applicable.

Concur. This footnote has been deleted.

15. This discussion (Footnote 3) should be moved to the DQOs or statistical test definition section of the document.

Clarification. This footnote has been deleted. We intend to use a p value of 0.05, and the footnote made that intent unclear.

16. The Division does not agree with the limitations DOE has placed upon the Slippage Test. The slippage test can be applied to data sets when the largest background point is a non-detect. If the largest background data point is a non-detect then logic must be applied to determine if the slippage test is applicable, but the test should not be categorically eliminated.

Concur. We have rewritten the strawman to state that, if the largest background data point is a non-detect, we will apply judgement to investigate whether or not the slippage test is applicable.

17. The Division recommends limiting the use of professional judgement to the first three criteria; spatial distribution, temporal distribution, and pattern recognition. In addition, it is recommended that the introduction to this section include acknowledgement that in applying professional judgement, the "burden of proof" lies solely on DOE. Professional judgement will only be considered by the Division on a limited basis where well documented and defensible evidence is presented.

Concur. We have eliminated the last five criteria from the strawman, and acknowledged that we will bear the burden of proof.

18. To make the process more efficient the task of eliminating non-detected analytes should be completed prior to data presentation. The flow chart should be modified to reflect this change.

Concur. We have changed the flowchart. CDH's comment improved the process.

19. This flow chart is confusing and difficult to follow due to the many multiple and undefined branches. To minimize the potential for misunderstanding this chart must either be clarified or deleted.

Concur. The flowchart is too important to delete. It has been clarified. Lines denoting the flow of information have been deleted, keeping only the lines denoting flow of control, in accordance with common flowcharting techniques. Decision blocks have been transformed into diamond shapes. Alternative "No" paths have been added for the blocks labeled "No Non-Detect Present...OU Data Normally Distributed?", and "At Least One Test Significant?" Finally, the block representing the conditions which must be met prior to performing the t-test has been changed to reflect the conditions given in the text.