ECF-HANFORD-18-0015
Revision 0

CALCULATION OF RADIOLOGICAL DOSE BASED ON CALENDAR YEAR 2017 ATOMIC ENERGY ACT GROUNDWATER MONITORING AT HANFORD

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

P.O. Box 1600
Richland, Washington 99352

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APPROVED
By Mary P. Curry at 3:15 pm, Aug 21, 2018

Release Approval | Date

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Printed in the United States of America

ENVIRONMENTAL CALCULATION COVER PAGE

Section 1: Completed by the Responsible Manager

Project: AEA Groundwater Monitoring

Date:

Calculation Title & Description: Calculation of Radiological Dose Based on Calendar Year 2017 Atomic Energy Act Groundwater Monitoring at Hanford

RELEASE / ISSUE

DATE: Aug 21, 2018 HANFORD RELEASE

Section 2: Completed by Preparer

Calculation No.: ECF-HANFORD-18-0015 **Revision No.:** 0

Revision History

Revision No.	Description	Date	Affected Pages ADD ROW
0	Initial Release		All
			☒

Section 3: Completed by the Responsible Manager

Document Control:

Is the document intended to be controlled within the Document Management Control System (DMCS)? ☒ Yes ☐ No

Does document contain scientific and technical information intended for public use? ☒ Yes ☐ No

Does document contain controlled-use information? ☐ Yes ☒ No

Section 4: Document Review & Approval

	Name /Position	Signature	Date
Preparer:	L Scantlebury/Staff Hydrogeologist SSPA		6/12/2018
Checker:	EE Frohling/Geologist		6/10/18
Senior Reviewer:	CW Miller/Project Scientist		19Jul18
Responsible Manager:	WR Faught		7/26/18

Section 5: Applicable if calculation is a risk assessment or uses an environmental model

PRIOR TO INITIATING MODELING:

Required training for modelers completed:

	Name /Position	Signature	Date
Integration Lead			

Safety Software Approved:

	Name /Position	Signature	Date
Integration Lead			

CALCULATION APPROVED:

	Name /Position	Signature	Date
Risk/Modeling Integration Manager:			

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Appendices

These appendices are located on attached USB card

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Terms

AEA	*Atomic Energy Act of 1954*
CHPRC	CH2M HILL Plateau Remediation Company
DCS	derived concentration standard
DOE	U.S. Department of Energy
ECF	environmental calculation file
EPA	U.S. Environmental Protection Agency
GWIA	groundwater interest area
HEIS	Hanford Environmental Information System
MCL	maximum contaminant level
MDA	minimum detectable activity
MDL	Method detection limit
SDWA	*Safe Drinking Water Act of 1974*
TED	total effective dose

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1 Purpose

This environmental calculation file (ECF) describes the methodology, input data, and calculations used for developing screening estimates of radiological doses resulting from hypothetical exposure of the public to radiologically contaminated groundwater encountered at the U.S. Department of Energy's (DOE's) Hanford Site in Washington State. This analysis was performed in support of the DOE, Richland Operations Office's assessment of environmental monitoring needs conducted in accordance with DOE O 458.1, *Radiation Protection of the Public and the Environment*, and with DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*. This calculation provides assessment of both the hypothetical dose due to consumption of water in the context of the 100 mrem/yr dose limit according to DOE's Orders as well as comparison of the measured values to the drinking water beta/gamma-emitter dose, alpha-emitter activity concentration, and uranium mass concentration maximum contaminant levels (MCLs) established under the *Safe Drinking Water Act of 1974* (SDWA).

2 Background

The *Atomic Energy Act of 1954* (AEA) was promulgated to ensure the proper management of radioactive materials. Through the AEA, DOE regulates the control of radioactive materials under its authority. Accordingly, DOE promulgated a series of regulations and directives (DOE Orders) to protect human health and the environment from potential risks associated with radioactive materials. Sections of the AEA authorize DOE to establish radiation protection standards for itself and its contractors through DOE Orders and contractor requirement documents.

Requirements for groundwater monitoring associated with environmental surveillance under the AEA are implemented through DOE O 458.1; DOE O 436.1, *Departmental Sustainability*; and DOE O 435.1, *Radioactive Waste Management* (primarily applied in DOE M 435.1-1, *Radioactive Waste Management Manual*). These DOE Orders and their associated manuals, standards, guidance, and contractor requirement documents implement AEA requirements across the DOE complex and include groundwater monitoring to detect, characterize, and respond to releases of radionuclides. DOE has not relinquished this responsibility under Ecology et al., 1989, *Hanford Federal Facility Agreement and Consent Order*; rather, DOE conducts activities in accordance with both sets of requirements.

In 2016, DOE implemented a new AEA monitoring plan (DOE/RL-2015-56, *Hanford Atomic Energy Act Sitewide Groundwater Monitoring Plan*). This calculation evaluates measured conditions against both the 100 mrem/yr DOE protection standard and the drinking water standards because the DOE Orders require that the department meet the drinking water standards for any drinking water supplied on the site. Although groundwater is not routinely used for drinking water supply at most locations at the Hanford Site, the comparison to the drinking water standards is performed for information.

3 Methodology

Groundwater radioisotope concentrations from analysis of groundwater samples collected from existing monitoring locations (i.e., wells and aquifer tubes) at the Hanford Site were used as the concentration basis for this analysis. Measurements included both activity concentrations for specific isotopes and mass concentrations for total uranium. The assessment required conversion of some measurements into specified units and uranium measurements were required to be converted from mass to activity, and vice versa. For the screening exercise, the maximum and minimum concentrations of the nuclides of interest were selected from each monitoring well during calendar year 2017. All samples that were collected in 2017 were included. Samples were separated on a per-well, per-sampling-event basis for identification of maximum and minimum results and subsequent comparison to selected metrics.

Dose estimates were calculated using two separate bases:

- The derived concentration standards (DCSs), published in DOE STD-1196-2011, *Derived Concentration Technical Standard*.
- The single-nuclide MCL-equivalent derived concentrations for beta and photon emitters, published by the U.S. Environmental Protection Agency (EPA) under the National Primary Drinking Water Standards of the SDWA, and specifically under 65 FR 76708, "Radionuclide Rule."

Concentration-based metrics were applied using the following bases:

- The total alpha-emitter MCL under the National Primary Drinking Water Standards, and specifically under 65 FR 76708.
- The uranium mass concentration MCL under the National Primary Drinking Water Standards, and specifically under 65 FR 76708.

The data consisted of analytical measurements for the groundwater constituents in Table 1.

Table 1. Groundwater Constituents Included in Analysis

Americium-241	Carbon-14	Cesium-134,-137	Chlorine-36
Cobalt-60	Iodine-129	Neptunium-237	Plutonium isotopes
Radium isotopes	Selenium-79	Strontium-90	Technetium-99
Thorium isotopes	Tritium	Uranium isotopes	Uranium metal
Gross Alpha	Gross Beta	Total Beta Radiostrontium	

To estimate the DCS-based total effective dose (TED) and the beta/gamma-emitter MCL dose, alpha activity concentration MCL, and uranium mass concentration, the following data manipulation steps were performed on the input data:

1. Replaced non-detect sample reported values with their corresponding method detection limit (MDL) or minimum detectable activity (MDA), where available. Chapter 5 describes additional logic applied to determine whether non-detect values should be used in calculating the cumulative doses.
2. As appropriate, uranium mass concentration values were converted to isotopic activity concentrations, assuming the isotopic distribution of natural uranium.
3. Converted uranium isotopic activity concentrations to uranium mass concentration, as appropriate.
4. Adjusted gross alpha measurements by deducting uranium and radon activity concentrations.
5. Converted individual isotopic activity concentrations to effective dose units.
6. Calculated DCS-based TED (by sum-of-fractions), total alpha activity concentration, total beta/gamma-emitter MCL dose (by sum-of-fractions), and uranium mass concentration for each sample.
7. Compared estimated minimum and maximum dose and/or concentration values to applicable water standards.

The standard metrics selected for comparison of measured values in this calculation are shown in Table 2.

Table 2. Applicable Radioisotope Metrics and Limits for Groundwater Assessment

Metric	Value	Units	Reference
Total Effective Dose Equivalent	100	mrem/yr	DOE O 458.1
Total Effective Dose Equivalent	5	mrem/yr	DOE-HDBK-1216-2015
Total Alpha Emitters	15	pCi/L	DOE O 458.1/SDWA
Radium-226/Radium-228	5	pCi/L	DOE O 458.1/SDWA
Cumulative Beta/Photon-emitter dose	4	mrem/yr	DOE O 458.1/SDWA
Uranium mass concentration	30	µg/L	DOE O 458.1/SDWA

Note: Complete reference citations are listed in Chapter 7.

3.1 Conversion from Uranium Mass Concentration to Isotopic Activity Concentration

Uranium values reported in mass concentration (µg/L) were converted to activity concentration (pCi/L) assuming a typical isotopic distribution in natural uranium and the corresponding isotopic specific activities, as shown in Table 3.

Table 3. Cumulative Specific Activity of Natural Uranium

Isotope	Assumed Mass Content of Natural U (wt. %)	Isotope Specific Activity (Bq/g)	Isotope Fraction	Isotope Activity in Natural U (Bq Isotope/g Uranium)	Isotope Activity Contribution in Natural U (%)
U-238	99.000%	1.234E+04	0.99	12,216.600	45.947
U-235	0.700%	7.995E+04	0.007	559.650	2.105
U-234	0.006%	2.302E+08	0.00006	13,812.000	51.948
Cumulative Specific Activity of Natural U (Bq/g)				26,588.250	

Where:

- **Assumed Mass Content of Natural Uranium** values were obtained from Hawley et al., 1987, *Hawley's Condensed Chemical Dictionary*.
- **Isotope Specific Activity** values were obtained from the Firestone et al., 1995, *Table of Isotopes Eighth Edition*.
- **Isotope Fraction** is the decimal representation of *assumed mass content of natural uranium.*
- **Isotope Activity in Natural Uranium** is the *isotope specific activity* multiplied by the *isotope fraction.*
- **Cumulative Specific Activity of Natural Uranium** is the total (summed) isotope activity in natural uranium for all isotopes.
- **Isotope Activity Contribution in Natural Uranium** is the percentage activity contribution of each isotope in the cumulative specific activity of natural uranium.

For ease of use in calculations where total uranium is reported in units of µg, and isotopic activity concentrations are reported in pCi, the cumulative specific activity is expressed in units of pCi/µg using the following conversion:

$$26588.25\ \frac{Bq}{g} \times \frac{1\ Ci}{3.70 \times 10^{10} Bq} \times \frac{1 \times 10^{12}\ pCi}{1\ Ci} \times \frac{1\ g}{1 \times 10^{6}\ \mu g} = 7.19 \times 10^{-1}\ pCi/\mu g$$

In multiplying by the above value, samples reported in uranium mass concentration (µg/L) could be converted to uranium activity concentration (pCi/L). To further determine the individual uranium isotope activity concentrations, the total uranium activity concentration can be multiplied by the individual isotope activity contribution shown in the right-hand column of Table 3.

3.2 Calculating Well Dose

The cumulative dose for each sample was calculated by converting the maximum activity concentration for each well and constituent into its equivalent in the effective dose units of mrem/year, using two different bases. The AEA basis dose was calculated using conversion factors from the DCS values published by DOE in DOE STD-1196-2011, excerpted in Table 4.

Table 4. DOE Derived Concentration Standards

Constituent	µCi/mL per 100 mrem/yr	Conversion to pCi/L per 100 mrem/yr
Americium-241	1.70E-07	1.70E+02
Antimony-125	2.70E-05	2.70E+04
Carbon-14	6.20E-05	6.20E+04
Cesium-134	2.10E-06	2.10E+03
Cesium-137	3.00E-06	3.00E+03
Chlorine-36	3.20E-05	3.20E+04
Cobalt-60	7.20E-06	7.20E+03
Europium-152	2.30E-05	2.30E+04
Europium-154	1.50E-05	1.50E+04
Europium-155	8.70E-05	8.70E+04
Iodine-129	3.30E-07	3.30E+02
Neptunium-237	3.20E-07	3.20E+02
Plutonium-238	1.50E-07	1.50E+02
Plutonium-239/240[a]	N/A	1.40E+02
Plutonium-239	1.40E-07	1.40E+02
Plutonium-240	1.40E-07	1.40E+02
Plutonium-241	7.60E-06	7.60E+03
Potassium-40	4.80E-06	4.80E+03

Table 4. DOE Derived Concentration Standards

Constituent	µCi/mL per 100 mrem/yr	Conversion to pCi/L per 100 mrem/yr
Radium-226	8.70E-08	8.70E+01
Radium-228	2.50E-08	2.50E+01
Selenium-79	8.50E-06	8.50E+03
Strontium-90	1.10E-06	1.10E+03
Technetium-99	4.40E-05	4.40E+04
Thorium-228	3.40E-07	3.40E+02
Thorium-230	1.60E-07	1.60E+02
Thorium-232	1.40E-07	1.40E+02
Tritium	1.90E-03	1.90E+06
Uranium-233/234[b]	N/A	6.70E+02
Uranium-233	6.60E-07	6.60E+02
Uranium-234	6.80E-07	6.80E+02
Uranium-235	7.20E-07	7.20E+02
Uranium-236	7.20E-07	7.20E+02
Uranium-238	7.50E-07	7.50E+02

Note: DOE Derived Concentration Standards (taken from DOE-STD-1196-2011, *Derived Concentration Technical Standard*.

a. The DCS for Pu-239 = DCS for Pu-240 = 140 pCi/L. This value is also used for measurements reported as Pu-239/240.

b. Uranium-233/234 DCS calculated as the average value of the DCS for U-233 and U-234 and is used as the DCS for measurements reported as U-233/234 when individual U-233 and U-234 isotopic activity concentrations are not reported.

DCS = derived concentration standard

DOE = U.S. Department of Energy

The beta/photon emitter-MCL basis dose was calculated using conversion factors published by EPA under the National Primary Drinking Water Standards, specifically 65 FR 76708 (Table 5).

Table 5. MCL-Equivalent Beta and Photon Emitters Derived Concentrations from EPA 816-F-00-002

Constituent	pCi/L per 4 mrem/yr
Americium-241	N/A[a]
Antimony-125	300
Carbon-14	2000
Cesium-134	80
Cesium-137	200

Table 5. MCL-Equivalent Beta and Photon Emitters Derived Concentrations from EPA 816-F-00-002

Constituent	pCi/L per 4 mrem/yr
Chlorine-36	700
Cobalt-60	100
Europium-152	200
Europium-154	60
Europium-155	600
Iodine-129	1
Plutonium-239	N/A[a]
Plutonium-239/240	N/A[a]
Plutonium-241	300
Selenium-79	N/A[b]
Strontium-90	8
Technetium-99	900
Tritium	20000
Uranium	N/A[c]
Uranium-233/234	N/A[c]
Uranium-234	N/A[c]
Uranium-235	N/A[c]
Uranium-236	N/A[c]
Uranium-238	N/A[c]

EPA 816-F-00-002, *Implementation Guidance for Radionuclides, Office of Ground Water and Drinking Water*.

a. Americium-241, plutonium-239 and plutonium-240 are alpha emitters and are not regulated under the beta/photon emitter dose MCL.

b. Selenium-79 is not one of the selected isotopes regulated under the beta/photon emitter dose MCL.

c. Uranium and uranium isotopes are not regulated under the beta/photon emitter dose MCL.

MCL = maximum contaminant level

N/A = not available

The dose concentration relationships presented in Table 4 and Table 5 were used to calculate the mrem/year doses for the constituents in each sample using the following relationships:

$$TED\ DCS\ \left(\frac{mrem}{year}\right) = \left(\ Concentration\ \left(\frac{pCi}{L}\right) \times 100\right) / (DCS\ Dose\ Conversion\ (\frac{pCi}{L} per\ 100\ \frac{mrem}{year})$$

$$Dose\ MCL\ \left(\frac{mrem}{year}\right) = \left(Max. Concentration\ \left(\frac{pCi}{L}\right) \times 4\right) / (MCL\ derived\ concentration\ (\frac{pCi}{L} per\ 4\ \frac{mrem}{year})$$

By summing the doses for each constituent for each sample, a sample cumulative dose can be calculated. For the TED DCS calculation, at first the maximum cumulative uranium dose is calculated from (a) the individual isotope and (b) the combined isotope (U-233/234). Therefore, for each sample, the maximum of two different uranium isotopic measurement combinations is selected:

- U-233/234 + U-235 + U-238
- U-234 + U-235 + U-238

This maximum cumulative uranium dose is added to the cumulative dose of the non-uranium constituents to comprise the TED DCS.

It should be noted that for values calculated using isotopic uranium concentrations, the use of the activity concentration to mass concentration ratio results in an estimated, not measured, concentration.

To calculate an alpha activity concentration for comparison to the alpha MCL for each sample, the cumulative activity was summed over only the radionuclides that emit majority alpha, excluding uranium and radon (if present).

Table 2 presents the dose bases for comparison of groundwater measurements to the DCSs and to the drinking water standards.

4 Input and Assumptions

Groundwater chemistry data were queried from the Hanford Environmental Information System (HEIS) database, which is maintained by CH2M HILL Plateau Remediation Company (CHPRC). The HEIS database contains one table (HEIS_ADM_PNLGW_STD_RESULT_MV), which contains information on groundwater samples, including laboratory and review data qualifiers, sample medium, sample collection purpose, analytical method, and reporting limits.

It was assumed all data not indicated as having been rejected, particularly the maximum concentrations used in this analysis, were accurate and valid measurements. For the dose-based comparisons, the derived doses from each isotope measured during a single sampling event at each monitoring location were summed to calculate the cumulative dose estimate for each location.

5 Calculation

Dose estimate calculations were performed in Microsoft® Excel® workbook "ECF-HANFORD-18-0015_Calculations.xslx", which is included as Appendix A of this ECF. Chemistry data were queried from HEIS on March 1, 2018, by Elyse Frohling. The query results were then imported into the workbook "ECF-HANFORD-18-0015_Calculations.xslx" on the worksheet "Raw Data".
The calculation steps discussed in Chapter 3 were organized in separate worksheets. Following is the list of the calculation steps and corresponding worksheets:

1. Replaced non-detect sample reported values with their corresponding detection limit, or minimum detectable activity, where available (Worksheet "Corrected Data").
2. Removed constituents that were not detected in any sample event in 2017.
3. Removed constituents that were not detected in any sample event for a specific well for 2017.

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4. Removed “R” qualified (i.e., rejected) data where encountered (Worksheet “Corrected Data”).
5. Removed specified values based on input and further review from project scientists (Worksheets “Corrected Data” and “Exclusions List”).
6. Converted uranium mass concentration values to activity concentration (Worksheet “Corrected Data”)
7. Found the concentrations for each sample-date pair (i.e., duplicates) for each constituent (Worksheets “Pivot,” “Pivot Numbers”).
8. Converted activity concentrations to effective dose units (conversion factors in worksheet “DCS-MCL”).
9. Calculated TED DCS, total alpha activity concentration, net alpha activity concentration, total dose MCL, and uranium mass concentration for each sample (Worksheets “Dose DCS,” “Beta MCL,” “Alpha Dose”, “Uranium GW”).
    a. TED DCS for each sample was calculated as the sum of the dose contributions from the following isotopes, measured in mrem/yr: americium-241, antimony-125, carbon-14, cesium-134, cesium-137, chlorine-36, cobalt-60, europium-152, europium-154, europium-155, iodine-129, neptunium-237, plutonium-238, plutonium-239/240, plutonium-241, potassium-40, radium-226, radium-228, selenium-79, strontium-90, technetium-99, thorium-228, thorium-230, thorium-232, tritium, and uranium isotopes.
    b. Alpha activity concentration was calculated as the sum of the following isotopes, measured in pCi/L: americium-241, neptunium-237, plutonium-238, plutonium-239/240, radium-226, radium-228, thorium-228, thorium-230, and thorium-232.
    c. Net alpha activity concentration was calculated as the sum of cumulative uranium activity plus radon activity subtracted from the gross alpha measurement (no radon activity concentration measurements were recorded). The derived net alpha activity concentration is subsequently compared to the alpha emitters MCL value of 15 pCi/L.
    d. Dose MCL was calculated as the sum of the dose contributions from the following isotopes, measured in mrem/yr: antimony-125, carbon-14, cesium-134, cesium-137, chlorine-36, cobalt-60, europium-152, europium-154, europium-155, iodine-129, plutonium-241, strontium-90, technetium-99, and tritium.
    e. Cumulative uranium mass concentration was calculated as the greatest of measured total uranium mass concentration, or the derived mass concentration based on uranium isotope activity concentrations (i.e., U-233/234 + U-235 + U-238, or U-234 + U-235 + U-238) divided by 0.719 pCi/L per µg/L.
10. Where multiple sample events occurred at a well the estimated minimum and maximum doses for each sampling event at that well were compared to drinking water standards (Worksheet “MinMaxbyWell”) to find those exceeding the standard. The minimum and maximum doses for a single location were reported to indicate locations that were in exceedance in multiple sampling events.
    a. The minimum and maximum TED DCS for each well was compared to 100 mrem/year DOE human health protection target.

b. The minimum and maximum alpha activity concentration was compared to 15 pCi/L alpha emitter MCL.
c. The minimum and maximum net alpha activity concentration was compared to 15 pCi/L alpha emitter MCL.
d. The minimum and maximum dose MCL was compared to 4 mrem/year beta/photon emitter MCL.
e. The minimum and maximum cumulative uranium mass concentration was compared to 30 µg/L uranium MCL.

In order to improve and document the data correction and reduction process a data filtering script was developed. This filtering script was written in python programming language by Leland Scantlebury of S.S. Papadopulos and Associates, Inc. This script was applied for steps 1 through 5. The filtering script is attached in Appendix B. No calculations were performed in the use of this python script. In step 1, for samples flagged as non-detects (flag "U" in "LAB_QUALIFIER" field of HEIS query), the standard reported value was replaced by the associated MDA for radionuclides, except for uranium mass concentrations. For non-detect uranium mass concentrations the MDL replaced the standard reported value, presented in the data set as the reported MDL value with a "U" laboratory qualifier, indicating that the analyte was not detected above the detection limit. Column "sspaValue" in ECF-HANFORD-18-0015 represents the substituted MDA and MDL values.

For steps 2 and 3, in calculating the dose MCL, several constituents were removed from the calculation because there were no recorded detections of the constituent at a location in calendar year 2017. To prevent non-detects from being the cause of exceedance, the following were omitted from the cumulative sum: antimony-125, cesium-134, chlorine-36, europium-152, europium-154, europium-155, and neptunium-237. To further prevent excess conservatism in the calculation, MDA or MDL values for individual locations were removed if that sampling location had no detected value of the constituent during 2017. Where MDA or MDL values replaced the standard reported value the magnitude of the MDA and MDL was assessed against the associated standard for that radionuclide. In 12 sampling events the MDA was greater than the associated drinking water standard for iodine-129. For 11 of these events the standard value reported was greater than the 1 pCi/L MCL for I-129 and the MDA. At well 299-E33-341 the reported non-detect iodine-129 value was 0.571 pCi/L and the MDA was 1.21 pCi/L. When considering the upper bound of the error (0.63) the concentration would be within 1% of the MDA. For non-detect values where the MDA is greater than the standard the data may be inconclusive for determination in exceedance of standards; however, in this instance the upper bounds of the error is within 1% of the MDA and was not excluded from the data calculations. Multiple sampling events for europium-154 had MDA values that exceeded the MCL derived concentration; however, no values for europium-154 were included in calculations because all reported values were non-detects or excluded from the dataset.

For step 4, any samples flagged as rejected (flag "R" in "Review_QUALIFIER" field of HEIS query) were removed. In step 5, after all filtering steps were completed a final review of the filtered data set was performed. Based on this review some analytes were flagged for further review and excluded from the data set. Other values were excluded based on sample representativeness of the aquifer, relative percent difference calculations, assessment of the MDA, historical trend analysis, laboratory errors, and total analytical error. A complete list of sampling events and analytes excluded during this review and the reasoning for exclusion is given in worksheet "Exclusions List".

Worksheet "MinMaxbyWell" summarizes the minimum and maximum cumulative TED, beta/photon drinking water dose, alpha emitter activity concentration, net alpha activity concentration, and uranium mass concentration that exceeded the drinking water standard for each well. The sheet is divided into three vertical sections:

- The first section contains the minimum and maximum value of the cumulative calculations of a location for each standard.
- The middle section contains a series of Boolean (true/false) columns to determine if a well has exceeded the corresponding dose standard. Wells were sorted by groundwater interest area (GWIA), using the field "GW_AREA_OF_INTEREST," as defined in HEIS. The column "Has Exceedance" indicates whether any of the standards have been exceeded for a well.
- The third section is like the first section; however, only values that exceeded the aforementioned standards are displayed.

Some wells in HEIS do not have a GWIA currently assigned. These wells were identified in the "GW_AREA_OF_INTEREST" field as blank cells. These wells were identified with a "0" in the MinMaxbyWell worksheet GWIA.

6 Results

The result of these calculations was a compilation of which wells exhibited conditions that exceeded one or more of the standards compiled in Table 2. A total count of how many wells exceeded each of these standards is presented in Table 6. The total number of wells in the analysis was 1,081. From those wells, 8,263 samples were collected in 2017 and used in this calculation.

Table 6. Total Number of Locations with Samples Exceeding Standards

Metric	Number of Locations Exceeding
Cumulative TED ≥5 mrem/yr	309
Cumulative TED ≥100 mrem/yr	22
Cumulative Drinking Water Dose (beta/photon) ≥4 mrem/yr	324
Cumulative Alpha-Emitter Activity Concentration ≥15 pCi/L	0
Net Alpha Activity Concentration ≥15 pCi/L	7
Cumulative Uranium Mass Concentration ≥30 µg/L	79

A full list of locations in exceedance is presented in table 7. These calculations will be used to support the DOE/RL-2017-66, *Hanford Site Groundwater Monitoring Report for 2017*.

Table 7. Locations in Exceedance of Drinking Water Standards

Monitoring Location/Well Name	Cumulative TED ≥ 100 mrem/Year	Cumulative Drinking Water Dose (beta/photon) ≥ 4 mrem/Year	Net Alpha Activity ≥ 15 pCi/L	Cumulative Uranium Mass ≥ 30µg/L
06-M		4.39		
103mArray-US25				73.80
199-B3-1		16.30		
199-B3-46		14.41		

Table 7. Locations in Exceedance of Drinking Water Standards

Monitoring Location/Well Name	Cumulative TED ≥ 100 mrem/Year	Cumulative Drinking Water Dose (beta/photon) ≥ 4 mrem/Year	Net Alpha Activity ≥ 15 pCi/L	Cumulative Uranium Mass ≥ 30µg/L
199-B3-47		8.83		
199-B3-52		23.53		
199-B4-4		8.02		
199-B5-2		10.03		
199-D5-132		13.90		
199-D5-142		6.30		
199-F5-1		7.90		
199-F5-55		60.00		
199-F5-56		22.95		
199-H1-49				54.40
199-H3-11		7.20		
199-H3-28				142.00
199-H3-6		5.35		
199-H4-11		4.81		
199-H4-13		11.55		
199-H4-45		4.15		
199-H4-63		7.05		
199-H4-83		12.90		
199-H4-84				127.00
199-H4-88				55.20
199-K-106A		59.28		
199-K-107A		16.20		
199-K-111A		31.00		
199-K-132		6.53		
199-K-139		10.50		
199-K-141		42.97		
199-K-161		5.05		
199-K-185		12.34		

Table 7. Locations in Exceedance of Drinking Water Standards

Monitoring Location/Well Name	Cumulative TED ≥ 100 mrem/Year	Cumulative Drinking Water Dose (beta/photon) ≥ 4 mrem/Year	Net Alpha Activity ≥ 15 pCi/L	Cumulative Uranium Mass ≥ 30µg/L
199-K-189		7.40		
199-K-19		6.73		
199-K-20		8.60		
199-K-200		83.43		
199-K-201		7.90		
199-K-202		15.92		
199-K-203		4.15		
199-K-204		53.20		
199-K-207		69.00		
199-K-21		9.69		
199-K-221		28.40		
199-K-222	1426.70	7820.97	77.92	34.90
199-K-227	203.28	764.16		
199-K-34		20.27	18.24	
199-N-103A		459.75		
199-N-105A	207.76	1141.84		
199-N-106A	211.35	1161.68		
199-N-122	101.91	560.34		
199-N-123		81.43		
199-N-14	125.90	691.70		
199-N-146		251.77		
199-N-147		119.00		
199-N-173		10.64		
199-N-183		40.44		
199-N-184	145.66	797.09		
199-N-186		218.16		
199-N-187	1291.56	7102.46		
199-N-188	293.81	1615.68		

Table 7. Locations in Exceedance of Drinking Water Standards

Monitoring Location/Well Name	Cumulative TED ≥ 100 mrem/Year	Cumulative Drinking Water Dose (beta/photon) ≥ 4 mrem/Year	Net Alpha Activity ≥ 15 pCi/L	Cumulative Uranium Mass ≥ 30µg/L
199-N-19		6.11		
199-N-2	148.39	815.80		
199-N-201		5.05		
199-N-229		31.05		
199-N-248		8.10		
199-N-268		525.00		
199-N-269	169.09	930.00		
199-N-27		92.84		
199-N-28		14.94		
199-N-280		432.00		
199-N-281	261.82	1440.00		
199-N-297	109.09	600.00		
199-N-298	130.91	720.00		
199-N-3		432.37		
199-N-315		361.50		
199-N-316		43.25		
199-N-332		188.50		
199-N-34		27.10		
199-N-347		4.28		
199-N-348		31.72		
199-N-349		49.30		
199-N-350		40.55		
199-N-351		219.56		
199-N-352		434.13		
199-N-353		28.04		
199-N-354		7.75		
199-N-355		339.00		
199-N-356		216.41		

Table 7. Locations in Exceedance of Drinking Water Standards

Monitoring Location/Well Name	Cumulative TED ≥ 100 mrem/Year	Cumulative Drinking Water Dose (beta/photon) ≥ 4 mrem/Year	Net Alpha Activity ≥ 15 pCi/L	Cumulative Uranium Mass ≥ 30µg/L
199-N-357	153.91	846.03		
199-N-358		185.00		
199-N-359		132.73		
199-N-360		347.88		
199-N-361		68.50		
199-N-362		188.50		
199-N-363		178.03		
199-N-364		128.12		
199-N-365		103.08		
199-N-366		96.81		
199-N-367		4.33		
199-N-374		77.05		
199-N-377		17.26		
199-N-57		5.53		
199-N-67	945.97	5201.80	60.07	
199-N-75	220.40	1211.52		
199-N-76		113.37		
199-N-81		237.83		
299-E16-2		4.68		
299-E17-1		73.88	15.3	
299-E17-12		4.38		
299-E17-13		5.42		
299-E17-14		99.19		
299-E17-15		41.90		
299-E17-16		21.67		
299-E17-17		9.62		
299-E17-18		5.30		
299-E17-19		77.19		

Table 7. Locations in Exceedance of Drinking Water Standards

Monitoring Location/Well Name	Cumulative TED ≥ 100 mrem/Year	Cumulative Drinking Water Dose (beta/photon) ≥ 4 mrem/Year	Net Alpha Activity ≥ 15 pCi/L	Cumulative Uranium Mass ≥ 30µg/L
299-E17-23		10.26		
299-E17-25		11.56		
299-E17-26		11.59		
299-E24-16		49.77		
299-E24-20		34.28		
299-E24-22		33.95		
299-E24-25		11.27		
299-E24-33		37.55		
299-E24-5		10.16		
299-E25-11		14.76		
299-E25-17		15.25		
299-E25-18		18.07		
299-E25-19		18.09		
299-E25-2		23.64		
299-E25-20		35.88		
299-E25-22		18.60		
299-E25-237		22.19		
299-E25-26		9.21		
299-E25-28		16.83		
299-E25-29P		15.28		
299-E25-29Q		7.51		
299-E25-3		21.93		
299-E25-32P		16.48		
299-E25-34		16.80		
299-E25-35		22.88		
299-E25-36		18.26		63.00
299-E25-37		11.12		
299-E25-39		13.60		

Table 7. Locations in Exceedance of Drinking Water Standards

Monitoring Location/Well Name	Cumulative TED ≥ 100 mrem/Year	Cumulative Drinking Water Dose (beta/photon) ≥ 4 mrem/Year	Net Alpha Activity ≥ 15 pCi/L	Cumulative Uranium Mass ≥ 30µg/L
299-E25-40		25.66		
299-E25-41		34.96		
299-E25-42		19.24		
299-E25-43		40.08		
299-E25-44		10.20		
299-E25-47		11.40		
299-E25-6		21.46		
299-E25-93		26.81		
299-E25-94		25.46		
299-E26-13		43.60		
299-E26-4		28.34		
299-E27-10		5.44		
299-E27-12		27.26		
299-E27-13		55.92		
299-E27-14		59.36		
299-E27-15		18.83		
299-E27-155		33.95		
299-E27-16		6.00		
299-E27-19		6.18		
299-E27-21		129.78		
299-E27-22		38.74		
299-E27-23		69.22		
299-E27-24		40.37		
299-E27-25		18.80		
299-E27-26		20.93		
299-E27-7		37.41		
299-E27-8		6.40		
299-E27-9		6.44		

Table 7. Locations in Exceedance of Drinking Water Standards

Monitoring Location/Well Name	Cumulative TED ≥ 100 mrem/Year	Cumulative Drinking Water Dose (beta/photon) ≥ 4 mrem/Year	Net Alpha Activity ≥ 15 pCi/L	Cumulative Uranium Mass ≥ 30µg/L
299-E28-1		7.91		
299-E28-23		230.44	17.02	
299-E28-24		320.50		56.00
299-E28-31		11.22		
299-E28-32		6.98		
299-E28-4		6.34		
299-E28-5		12.12		
299-E28-6				43.20
299-E28-7		157.22		
299-E29-54				54.80
299-E32-10		15.11		
299-E32-8		7.77		
299-E32-9		11.82		
299-E33-12		4.49		
299-E33-14		54.70		
299-E33-15		102.08		
299-E33-16		182.23		79.00
299-E33-17		147.08		
299-E33-1A		30.98		
299-E33-20	151.42	48.06		1325.91
299-E33-268		47.58		61.20
299-E33-28		7.00		
299-E33-29		4.35		
299-E33-3		46.25		
299-E33-31		42.49		78.40
299-E33-32		14.72		
299-E33-33		14.04		
299-E33-337		92.58		116.00

Table 7. Locations in Exceedance of Drinking Water Standards

Monitoring Location/Well Name	Cumulative TED ≥ 100 mrem/Year	Cumulative Drinking Water Dose (beta/photon) ≥ 4 mrem/Year	Net Alpha Activity ≥ 15 pCi/L	Cumulative Uranium Mass ≥ 30µg/L
299-E33-338		15.66		41.50
299-E33-339		10.99		
299-E33-34		20.38		
299-E33-341		33.44		
299-E33-342		98.91		
299-E33-343		10.17		150.00
299-E33-345		32.72		819.00
299-E33-35		13.29		
299-E33-350	15040.32	214.27		147272.20
299-E33-351	3699.99	186.73		36473.63
299-E33-36		24.61		
299-E33-360		48.88		2970.00
299-E33-361		8.80		
299-E33-38		38.31		41.70
299-E33-39		63.01		
299-E33-41		17.73		34.00
299-E33-42		10.76		31.00
299-E33-44		136.50		113.00
299-E33-47		113.94		91.20
299-E33-48		15.51		54.30
299-E33-49		7.12		
299-E33-7		33.85		
299-E34-8		8.70		
299-E34-9		28.19		
299-W11-40		49.33		
299-W11-47		46.47		
299-W11-50		6.01		
299-W11-90		6.70		

Table 7. Locations in Exceedance of Drinking Water Standards

Monitoring Location/Well Name	Cumulative TED ≥ 100 mrem/Year	Cumulative Drinking Water Dose (beta/photon) ≥ 4 mrem/Year	Net Alpha Activity ≥ 15 pCi/L	Cumulative Uranium Mass ≥ 30µg/L
299-W11-96		7.03		
299-W14-11		44.07		
299-W14-13		47.74		
299-W14-20		4.80		
299-W18-260		9.87		
299-W19-101				82.95
299-W19-113		10.43		169.00
299-W19-114		5.78		
299-W19-115		20.28		510.00
299-W19-116		12.19		
299-W19-12		10.44		
299-W19-123		11.73		69.00
299-W19-36	543.61	41.96		5139.15
299-W19-39				37.70
299-W19-42		5.38		
299-W19-43				119.00
299-W19-45		60.89		
299-W19-47		10.67		
299-W19-48				35.25
299-W21-3		101.70		
299-W22-10		24.73		
299-W22-113		9.44		
299-W22-114		22.16		
299-W22-115		22.19		
299-W22-116		49.78		
299-W22-24P		20.44		
299-W22-81		6.18		
299-W22-82		11.30		

Table 7. Locations in Exceedance of Drinking Water Standards

Monitoring Location/Well Name	Cumulative TED ≥ 100 mrem/Year	Cumulative Drinking Water Dose (beta/photon) ≥ 4 mrem/Year	Net Alpha Activity ≥ 15 pCi/L	Cumulative Uranium Mass ≥ 30µg/L
299-W22-83		13.82		
299-W22-85		17.32		
299-W22-86		8.26		
299-W22-88		4.24		
299-W22-91		19.51		
299-W22-92		9.24		
299-W22-93		8.98		
299-W22-96		12.44		
299-W23-19		62.79		
299-W23-4		12.63		33.00
299-W6-15		9.37		
399-1-1				44.00
399-1-105				102.00
399-1-118				116.00
399-1-129				8450.00
399-1-139				90.70
399-1-158				94.00
399-1-159				71.20
399-1-162				45.80
399-1-16A				54.80
399-1-17A				177.00
399-1-23				82.20
399-1-55				437.00
399-1-62				1260.00
399-1-63				59.90
399-1-67				123.00
399-1-7				54.10
399-2-1				59.30

Table 7. Locations in Exceedance of Drinking Water Standards

Monitoring Location/Well Name	Cumulative TED ≥ 100 mrem/Year	Cumulative Drinking Water Dose (beta/photon) ≥ 4 mrem/Year	Net Alpha Activity ≥ 15 pCi/L	Cumulative Uranium Mass ≥ 30µg/L
399-2-2				81.00
399-3-1				69.04
399-3-10				146.00
399-3-12				65.80
399-3-33				69.30
399-3-37				36.80
399-3-38				36.10
399-3-6				56.10
399-3-9				120.00
399-4-1				31.80
399-4-10				68.00
399-4-14				39.80
399-4-7				46.00
399-4-9				87.70
399-6-3			28.59	194.00
399-8-1				65.79
399-8-5A				60.50
499-S0-7		4.72		
699-13-0A		8.60		
699-13-1E		16.38		
699-13-2D		35.60		
699-13-3A		114.00		
699-2-3		4.09		
699-26-38			16.60	
699-30-73				147.00
699-31-68		4.26		
699-32-22A		34.60		
699-32-72A		7.58		

Table 7. Locations in Exceedance of Drinking Water Standards

Monitoring Location/Well Name	Cumulative TED ≥ 100 mrem/Year	Cumulative Drinking Water Dose (beta/photon) ≥ 4 mrem/Year	Net Alpha Activity ≥ 15 pCi/L	Cumulative Uranium Mass ≥ 30µg/L
699-35-66A		24.81		
699-36-61A		10.72		
699-36-63B		25.00		
699-36-66B		57.09		
699-36-70A		55.35		
699-37-47A		18.32		
699-37-66		16.96		
699-37-E4		7.68		
699-38-61		12.34		
699-38-70C		5.97		
699-40-1		6.24		
699-41-1A		8.38		
699-41-23		18.64		
699-41-42		12.58		
699-42-42B		8.92		
699-43-3		9.27		
699-43-41F		18.38		
699-43-41G		4.40		
699-43-45		37.33		
699-45-42		11.31		
699-46-21B		4.96		
699-46-4		4.48		
699-48-77C		9.08		
699-48-77D		12.06		
699-49-57A		14.94		
699-50-56		5.71		
699-50-59		9.00		
699-53-47B		140.00		

Table 7. Locations in Exceedance of Drinking Water Standards

Monitoring Location/Well Name	Cumulative TED ≥ 100 mrem/Year	Cumulative Drinking Water Dose (beta/photon) ≥ 4 mrem/Year	Net Alpha Activity ≥ 15 pCi/L	Cumulative Uranium Mass ≥ 30µg/L
699-53-48A		42.45		
699-53-55B		10.19		
699-53-55C		8.93		
699-54-49		68.50		
699-55-55		7.00		
699-55-57		6.72		
699-57-59		11.52		
699-59-58		4.37		
699-S31-E10A				32.40
699-S31-E10C				34.50
699-S31-E10D				34.20
86-M		4.89		
APT1		349.50		
APT5		90.50		
AT-3-1-M				38.20
AT-3-2-M				81.40
AT-3-5-S				71.40
AT-B-3-S		6.67		
C6230		9.15		
C6324		6.00		
C6347				175.00
C6350				42.20
C6353		5.05		
C7725		8.76		
C7881		36.20		
C7934		161.40		
C7935		168.10		
C7936		39.61		

Table 7. Locations in Exceedance of Drinking Water Standards

Monitoring Location/Well Name	Cumulative TED ≥ 100 mrem/Year	Cumulative Drinking Water Dose (beta/photon) ≥ 4 mrem/Year	Net Alpha Activity ≥ 15 pCi/L	Cumulative Uranium Mass ≥ 30µg/L
C9587		96.50		
C9589		29.50		
C9590		25.10		
N116mArray-10A		57.00		
N116mArray-11A		385.00		
N116mArray-2A		12.90		
N116mArray-3A		101.00		
N116mArray-4A		104.50		
N116mArray-6A		91.50		
N116mArray-9A		114.00		
NVP2-116.0	217.27	1195.00		

Blank cells indicate no exceedance for that well at that standard.

TED = total effective dose

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Appendix A

Calculations

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Appendix B

Filtering Script

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