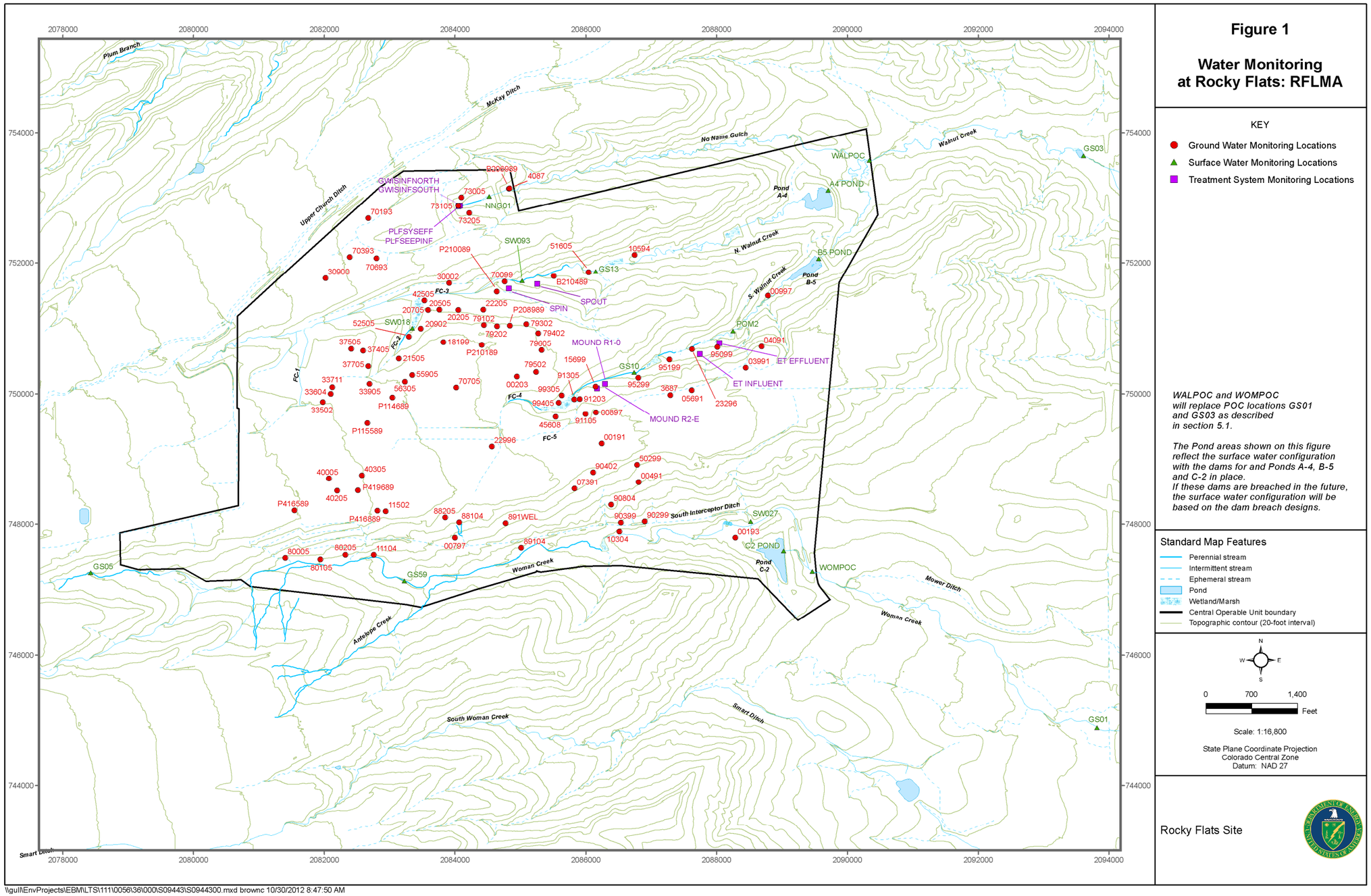

Figure 1

Water Monitoring at Rocky Flats: RFLMA

KEY

- Ground Water Monitoring Locations
- Surface Water Monitoring Locations
- Treatment System Monitoring Locations

WALPOC and WOMPOC will replace POC locations GS01 and GS03 as described in section 5.1.

The Pond areas shown on this figure reflect the surface water configuration with the dams for and Ponds A-4, B-5 and C-2 in place. If these dams are breached in the future, the surface water configuration will be based on the dam breach designs.

Standard Map Features

- Perennial stream
- Intermittent stream
- Ephemeral stream
- Pond
- Wetland/Marsh
- Central Operable Unit boundary
- Topographic contour (20-foot interval)

N W E S

0 700 1,400 Feet

Scale: 1:16,800

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

Rocky Flats Site

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Figure 1. Water Monitoring at Rocky Flats

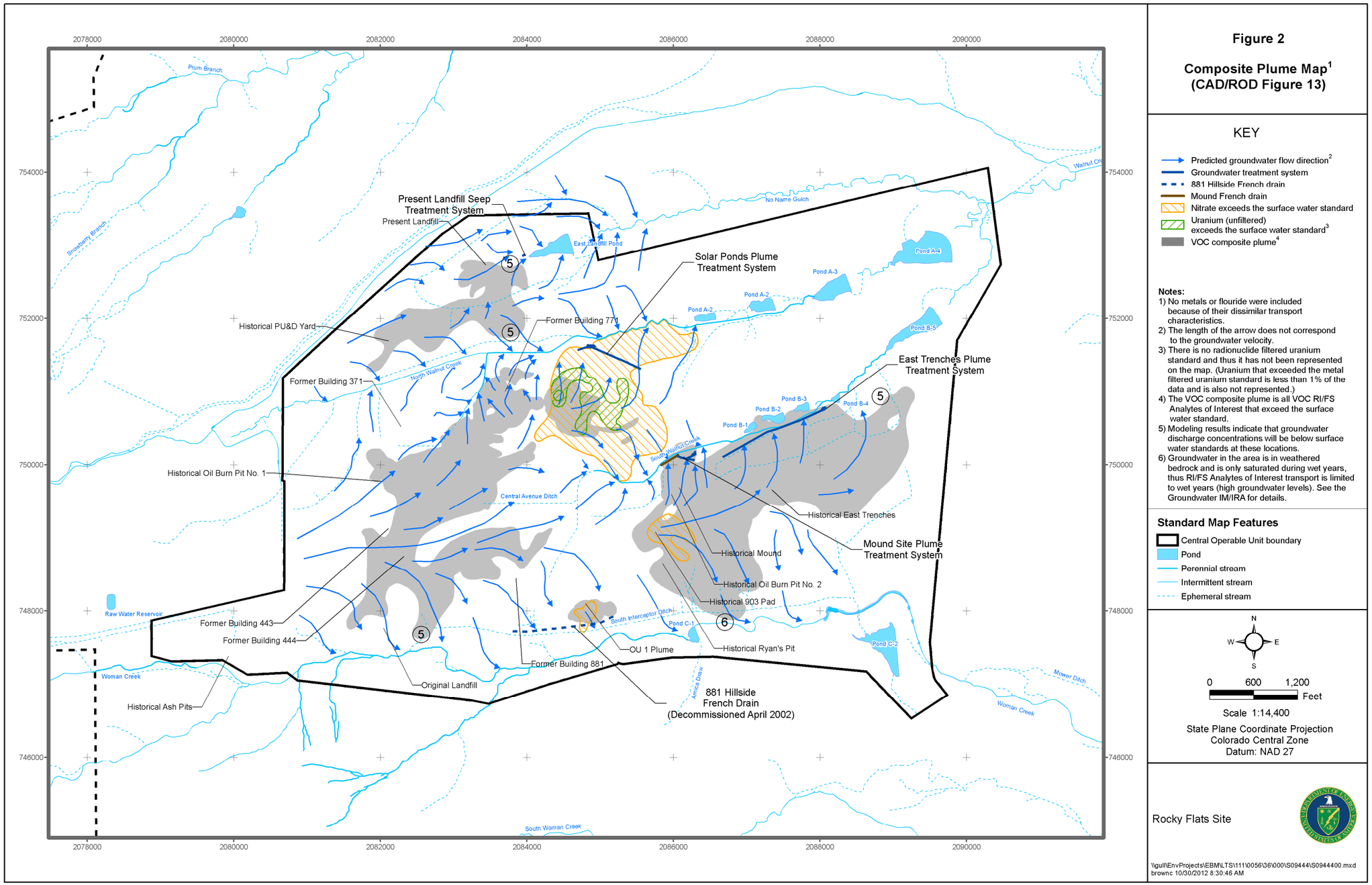

Figure 2

Composite Plume Map[1] (CAD/ROD Figure 13)

KEY

- Predicted groundwater flow direction[2]
- Groundwater treatment system
- 881 Hillside French drain
- Mound French drain
- Nitrate exceeds the surface water standard
- Uranium (unfiltered) exceeds the surface water standard[3]
- VOC composite plume[4]

Notes:

1) No metals or flouride were included because of their dissimilar transport characteristics.
2) The length of the arrow does not correspond to the groundwater velocity.
3) There is no radionuclide filtered uranium standard and thus it has not been represented on the map. (Uranium that exceeded the metal filtered uranium standard is less than 1% of the data and is also not represented.)
4) The VOC composite plume is all VOC RI/FS Analytes of Interest that exceed the surface water standard.
5) Modeling results indicate that groundwater discharge concentrations will be below surface water standards at these locations.
6) Groundwater in the area is in weathered bedrock and is only saturated during wet years, thus RI/FS Analytes of Interest transport is limited to wet years (high groundwater levels). See the Groundwater IM/IRA for details.

Standard Map Features

- Central Operable Unit boundary
- Pond
- Perennial stream
- Intermittent stream
- Ephemeral stream

N
W E
S

0 600 1,200 Feet

Scale 1:14,400

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

Rocky Flats Site

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Figure 2. Composite Plume Map

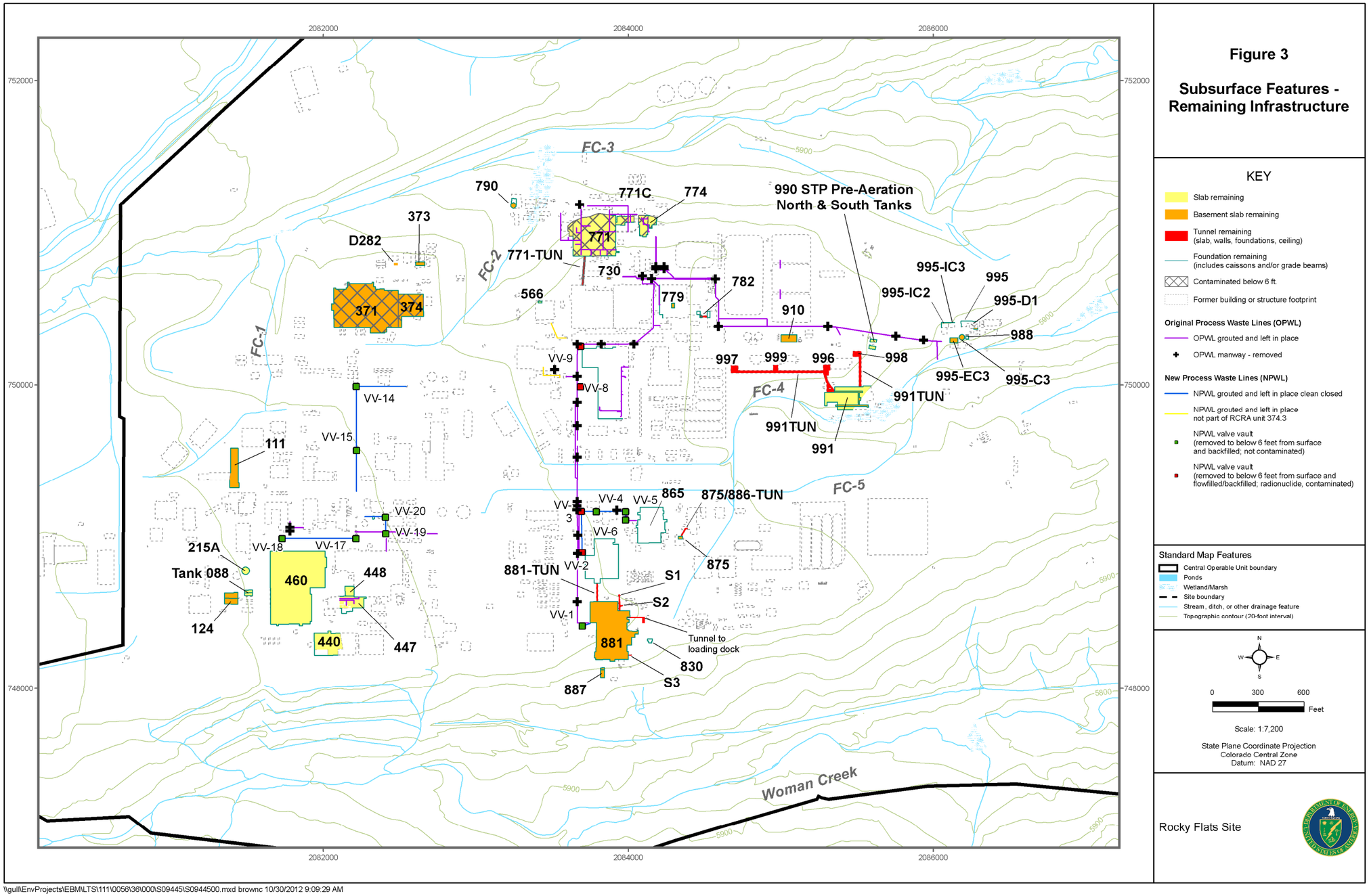

Figure 3

Subsurface Features - Remaining Infrastructure

KEY

- Slab remaining
- Basement slab remaining
- Tunnel remaining (slab, walls, foundations, ceiling)
- Foundation remaining (includes caissons and/or grade beams)
- Contaminated below 6 ft
- Former building or structure footprint

Original Process Waste Lines (OPWL)

- OPWL grouted and left in place
- OPWL manway - removed

New Process Waste Lines (NPWL)

- NPWL grouted and left in place clean closed
- NPWL grouted and left in place not part of RCRA unit 374.3
- NPWL valve vault (removed to below 6 feet from surface and backfilled; not contaminated)
- NPWL valve vault (removed to below 6 feet from surface and flowfilled/backfilled; radionuclide, contaminated)

Standard Map Features

- Central Operable Unit boundary
- Ponds
- Wetland/Marsh
- Site boundary
- Stream, ditch, or other drainage feature
- Topographic contour (20-foot interval)

N W E S

0 300 600 Feet

Scale: 1:7,200

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

Rocky Flats Site

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Figure 3. Subsurface Features—Remaining Infrastructure

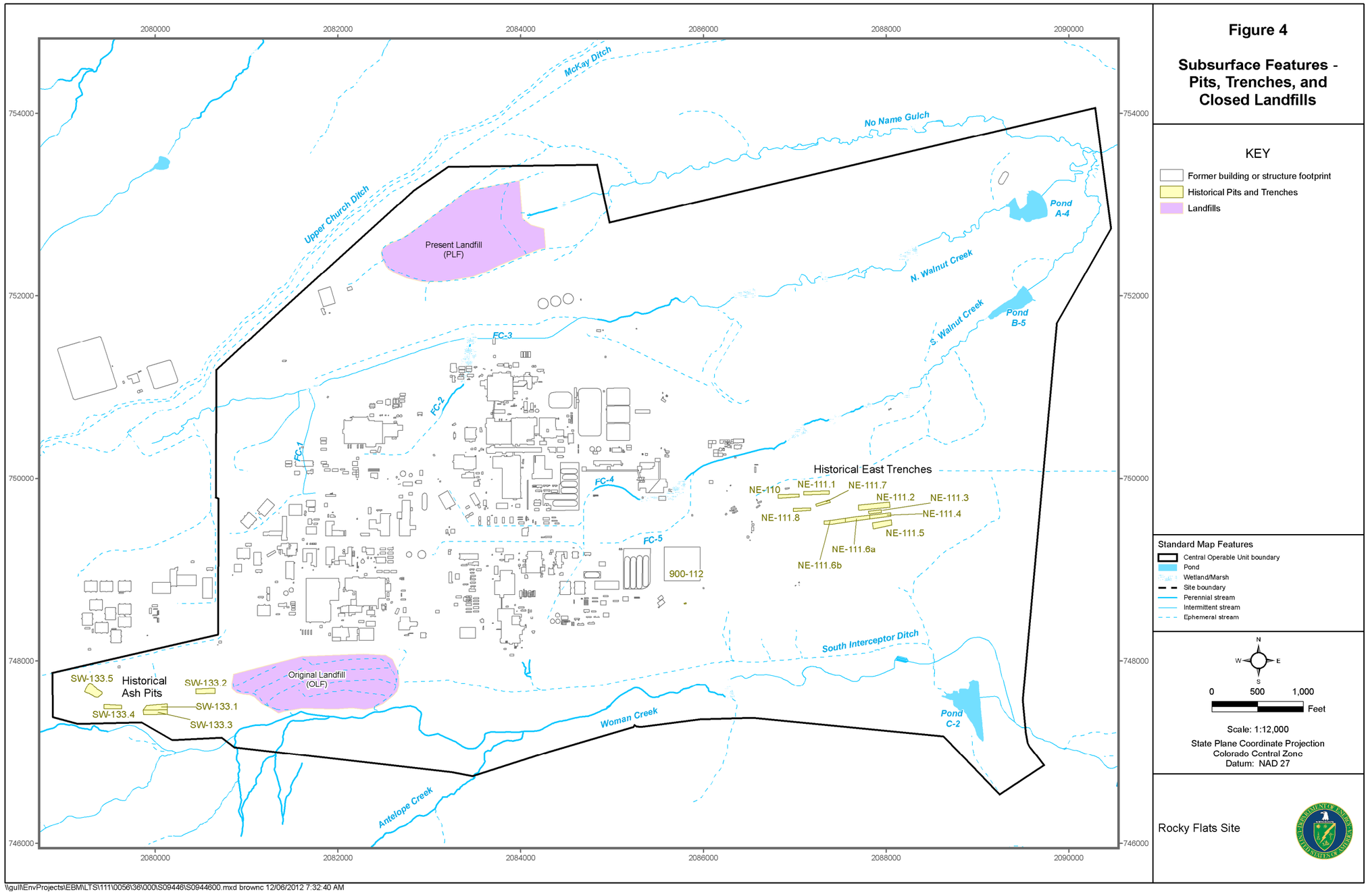


Figure 4

Subsurface Features - Pits, Trenches, and Closed Landfills

KEY

- Former building or structure footprint
- Historical Pits and Trenches
- Landfills

Standard Map Features

- Central Operable Unit boundary
- Pond
- Wetland/Marsh
- Site boundary
- Perennial stream
- Intermittent stream
- Ephemeral stream

N
W E
S

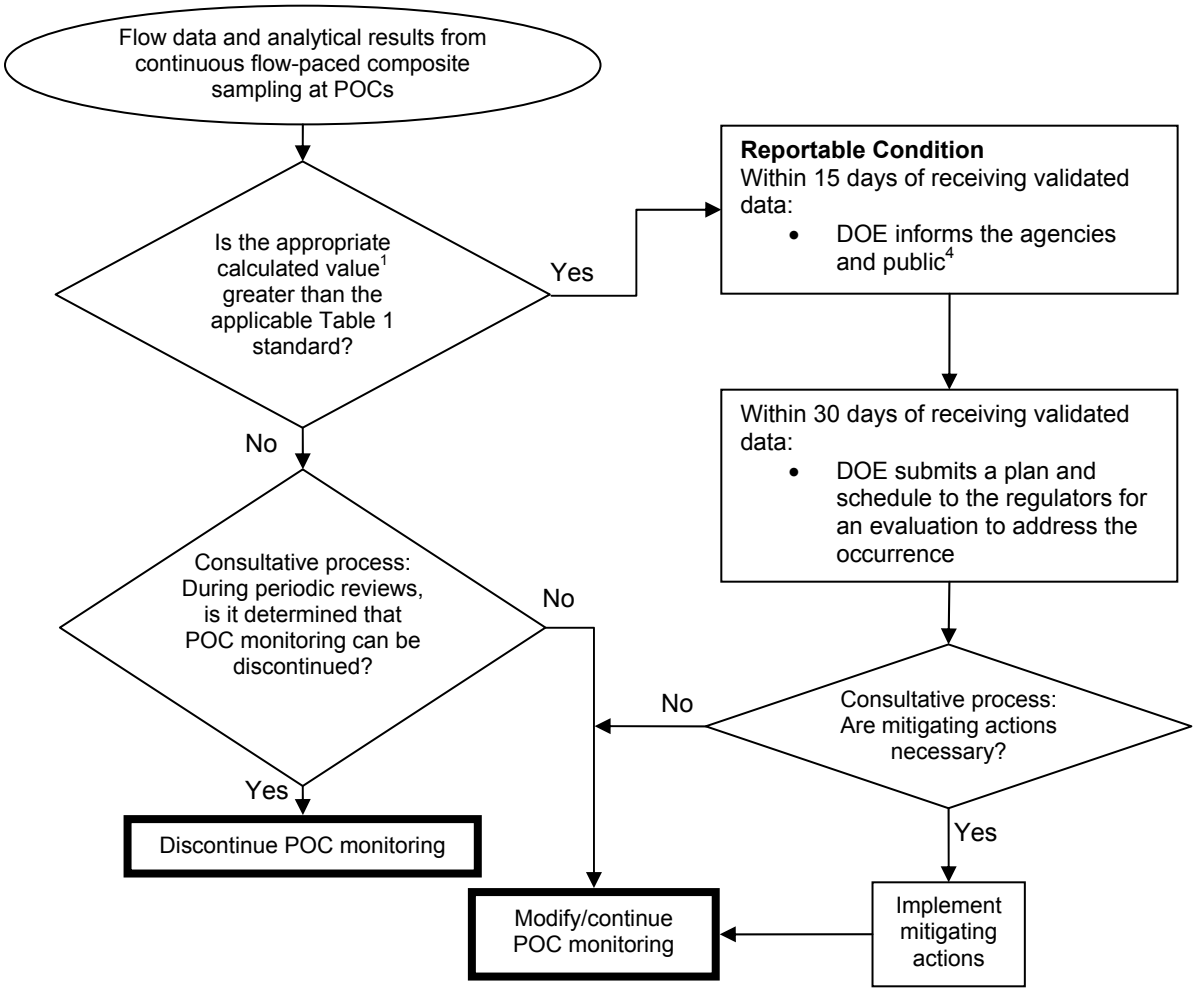
0 500 1,000
Feet

Scale: 1:12,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

Rocky Flats Site

Figure 4. Subsurface Features—Pits, Trenches, and Closed Landfills



Notes: see Fig. 1 and Tables 1 and 2 for locations, standards, and sampling criteria.

[1]Calculated values for determining Reportable Condition and exceedances of remedy performance standards at POCs.

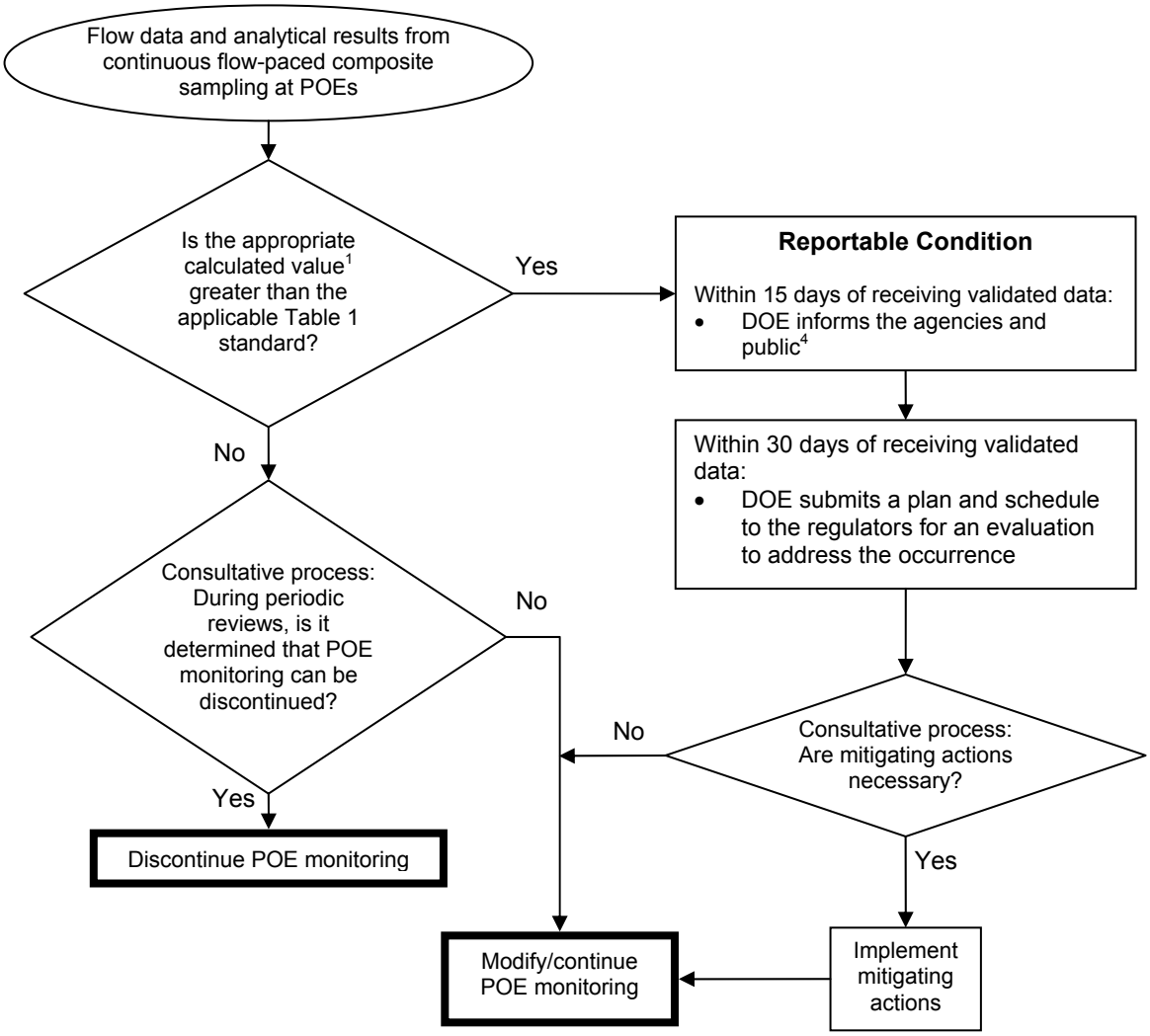
- Reportable conditions (according to Section 6.0):
  - **plutonium, americium, uranium, nitrate** → 30-day average[2]
- Reportable Conditions and evaluation of compliance with remedy performance standards in Table 1:
  - **plutonium, americium, uranium, nitrate** → 12-month rolling average[3] for POCs inside COU; 30-day average for GS01 and GS03.

[2] The 30-day average for a particular day is calculated as a volume-weighted average of a "window" of time containing the previous 30 days with measurable flow. Each day has its own discharge volume (measured with a flow meter) and activity/concentration (from the sample carboy in place at the end of that day). Therefore, there are 365 30-day moving averages for a location that flows all year. At locations that have intermittent flows, 30-day averages are reported as averages of the previous 30 days of greater than zero flow. For days where no analytical result is available, either due to failed laboratory analysis or non-sufficient quantity (NSQ) for analysis, no 30-day average is reported.

[3] The 12-month rolling average for the last day of a particular month is calculated as a volume-weighted average of a "window" of time containing the previous 12 months. Each 12-month "window" includes daily discharge volumes (measured with a flow meter) and daily activities/concentrations (from the sample carboy in place at the end of that day). Therefore, there are twelve 12-month rolling averages for a given calendar year. Days with no flow or no analytical result, either due to failed laboratory analysis or NSQ for analysis, are not included in the average. When no flow has occurred in the previous 12 months, no 12-month rolling average is reported.

[4] Agencies: EPA, CDPHE, and USFWS
Public: Cities of Broomfield, Northglenn, Thornton, and Westminster; Rocky Flats Stewardship Council (RFSC)

Figure 5. Points of Compliance



Notes: see Fig. 1 and Tables 1 and 2 for locations, standards, and sampling criteria.

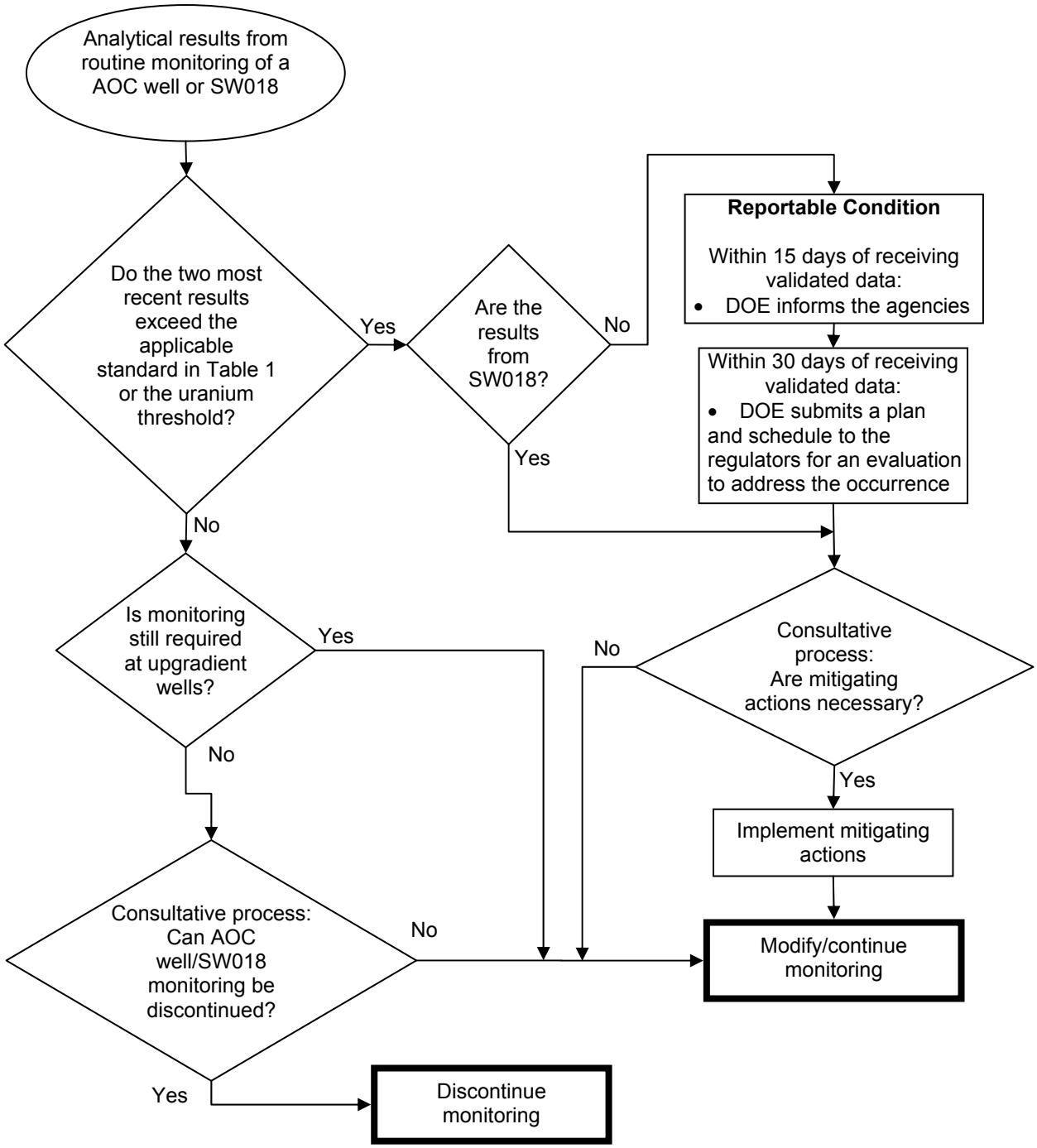
[1] Calculated Values by analytes (see Table 2 for reference)
- plutonium, americium, uranium → 12-month rolling average[2]
- dissolved Cd and Ag, total Be and Cr → 85th percentile of 30-day averages[3] for previous calendar year

[2] The 12-month rolling average for the last day of a particular month is calculated as a volume-weighted average of a "window" of time containing the previous 12 months. Each 12-month "window" includes daily discharge volumes (measured with a flow meter) and daily activities/concentrations (from the sample carboy in place at the end of that day). Therefore, there are twelve 12-month rolling averages for a given calendar year. Days with no flow or no analytical result, either due to failed laboratory analysis or NSQ for analysis, are not included in the average. When no flow has occurred in the previous 12 months, no 12-month rolling average is reported.

[3] The 30-day average for a particular day is calculated as a volume-weighted average of a "window" of time containing the previous 30 days with measurable flow. Each day has its own discharge volume (measured with a flow meter) and activity/concentration (from the sample carboy in place at the end of that day). Therefore, there are 365 30 day moving averages for a location that flows all year. At locations that have intermittent flows, 30-day averages are reported as averages of the previous 30 days of greater than zero flow. For days where no analytical result is available, either due to failed laboratory analysis or NSQ for analysis, no 30-day average is reported.

[4] Agencies: EPA, CDPHE, and USFWS
Public: Cities of Broomfield, Northglenn, Thornton, and Westminster; Rocky Flats Stewardship Council (RFSC)

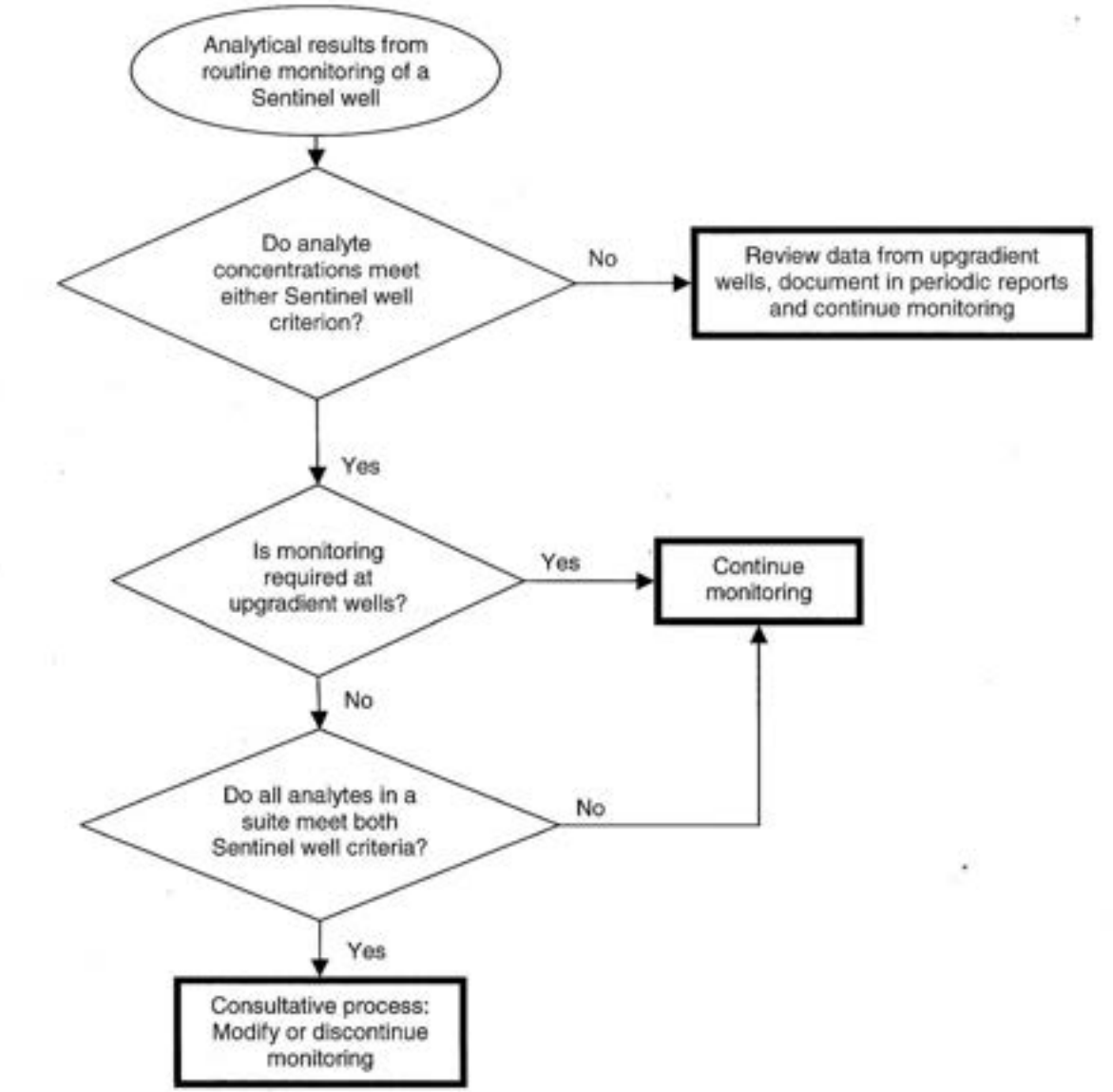
Figure 6. Points of Evaluation



Notes: see Fig. 1 and Tables 1 and 2 for locations, standards, and sampling criteria.

- AOC wells and location SW018 are sampled twice each year; see Table 2.
- Decisions related to uranium in groundwater are based upon a 120 ug/L threshold for AOC wells (basis: a grand mean of results from Site-wide high-resolution uranium analyses performed in the late 1990s through mid-2000s), rather than the standard in Table 1.

Figure 7. Area of Concern Wells and SW018



Notes: see Fig. 1 and Tables 1 and 2 for locations, standards, and sampling criteria.

- Sentinel wells are sampled twice each year; see Table 2.
- Decisions related to uranium are based upon a 120 ug/L threshold for AOC wells (basis: a grand mean of results from Site-wide high-resolution uranium analyses performed in the late 1990s through mid-2000s), rather than the standard in Table 1.

Sentinel Well Criteria

1. The 85th percentile concentration of an analyte *is less than or equal to* the corresponding concentration in Table 1 or, for uranium, the 85th percentile concentration does not exceed 2x120 ug/L or the highest calendar year 2005 concentration, whichever is higher.
2. Analyte concentrations exhibit an indeterminate or statistically-significant *decreasing* trend at the 95% confidence level.

Figure 8. Sentinel Wells

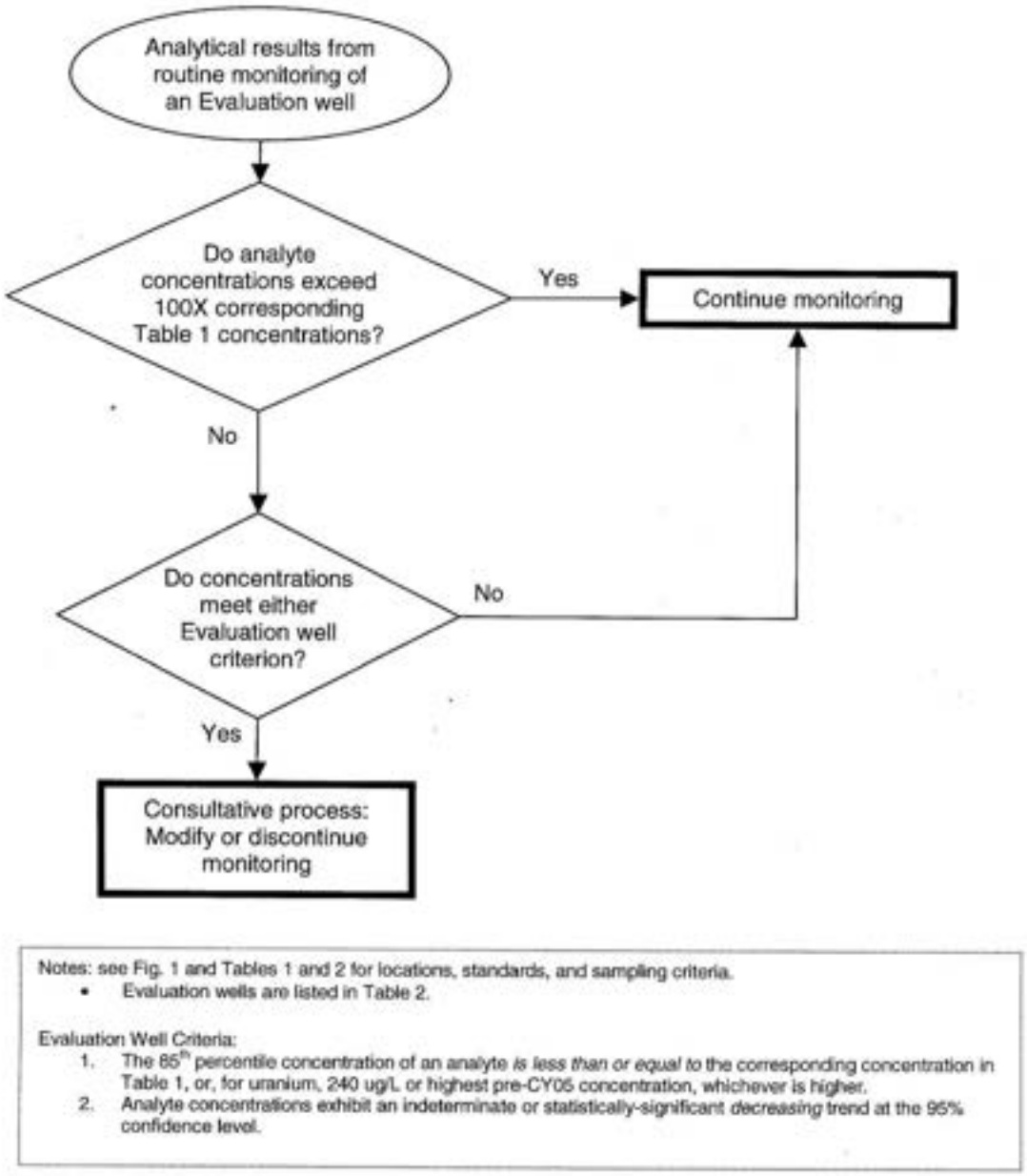


Figure 9. Evaluation Wells

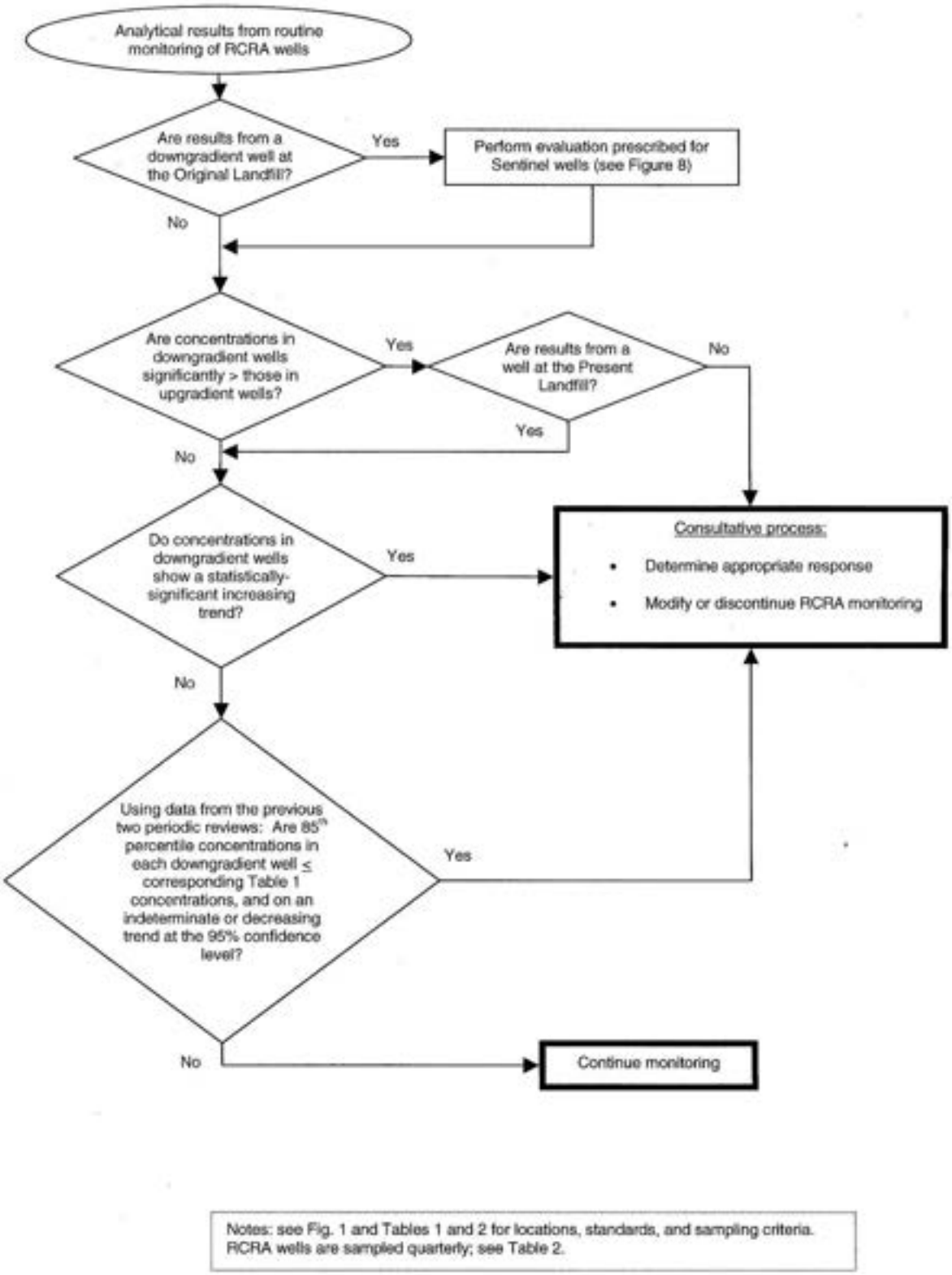


Figure 10. RCRA Wells

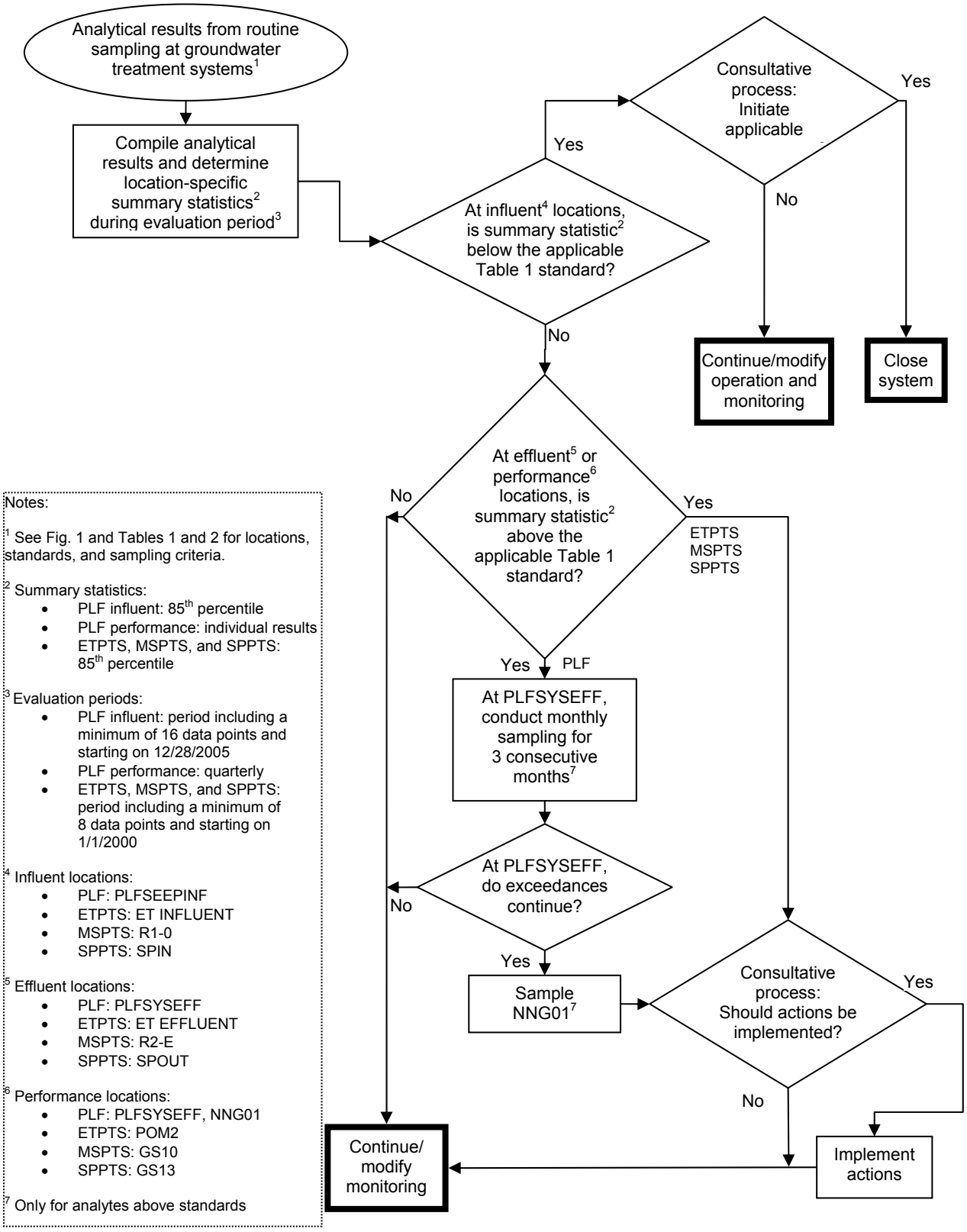


Figure 11. Groundwater Treatment Systems

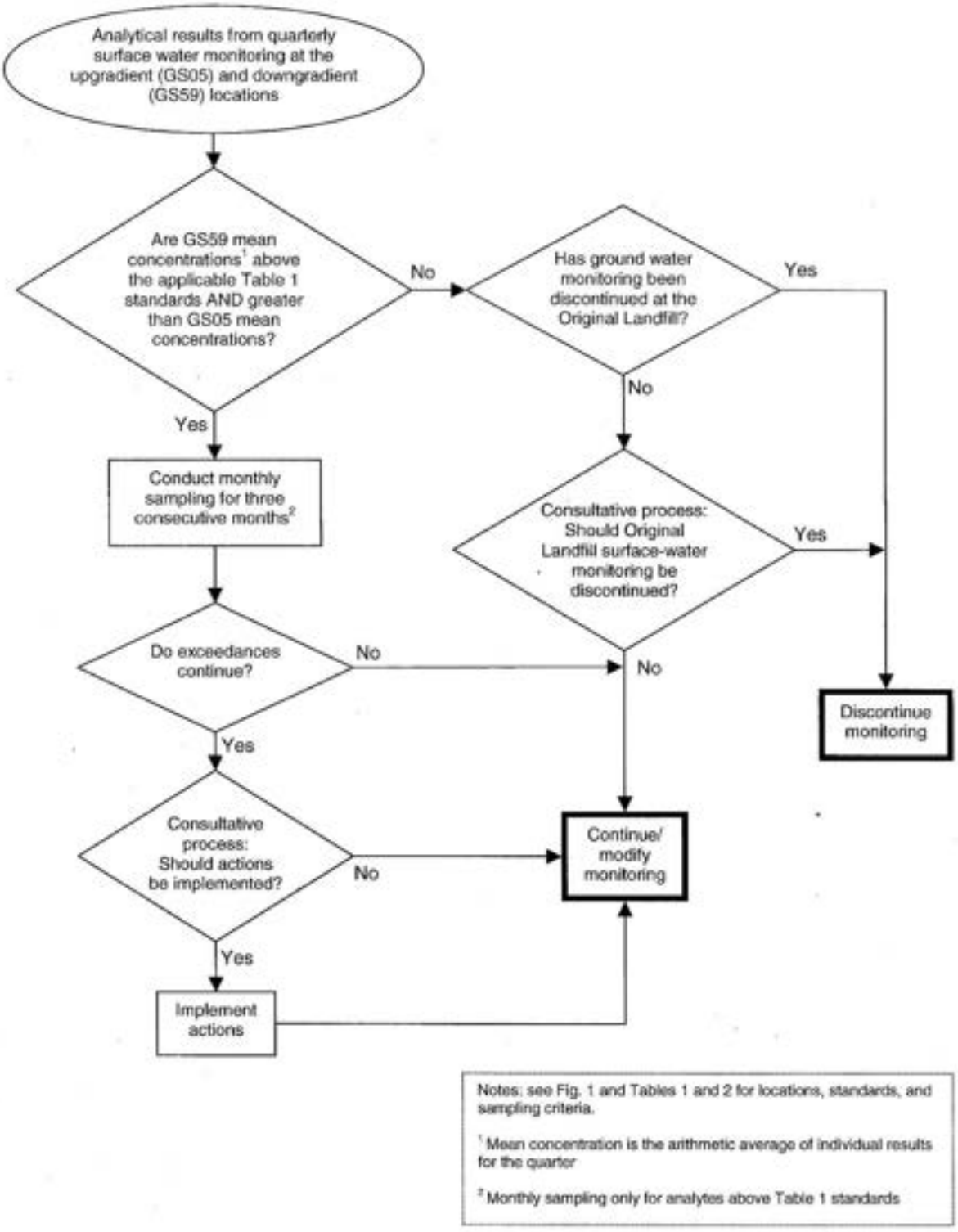


Figure 12. Original Landfill Surface Water

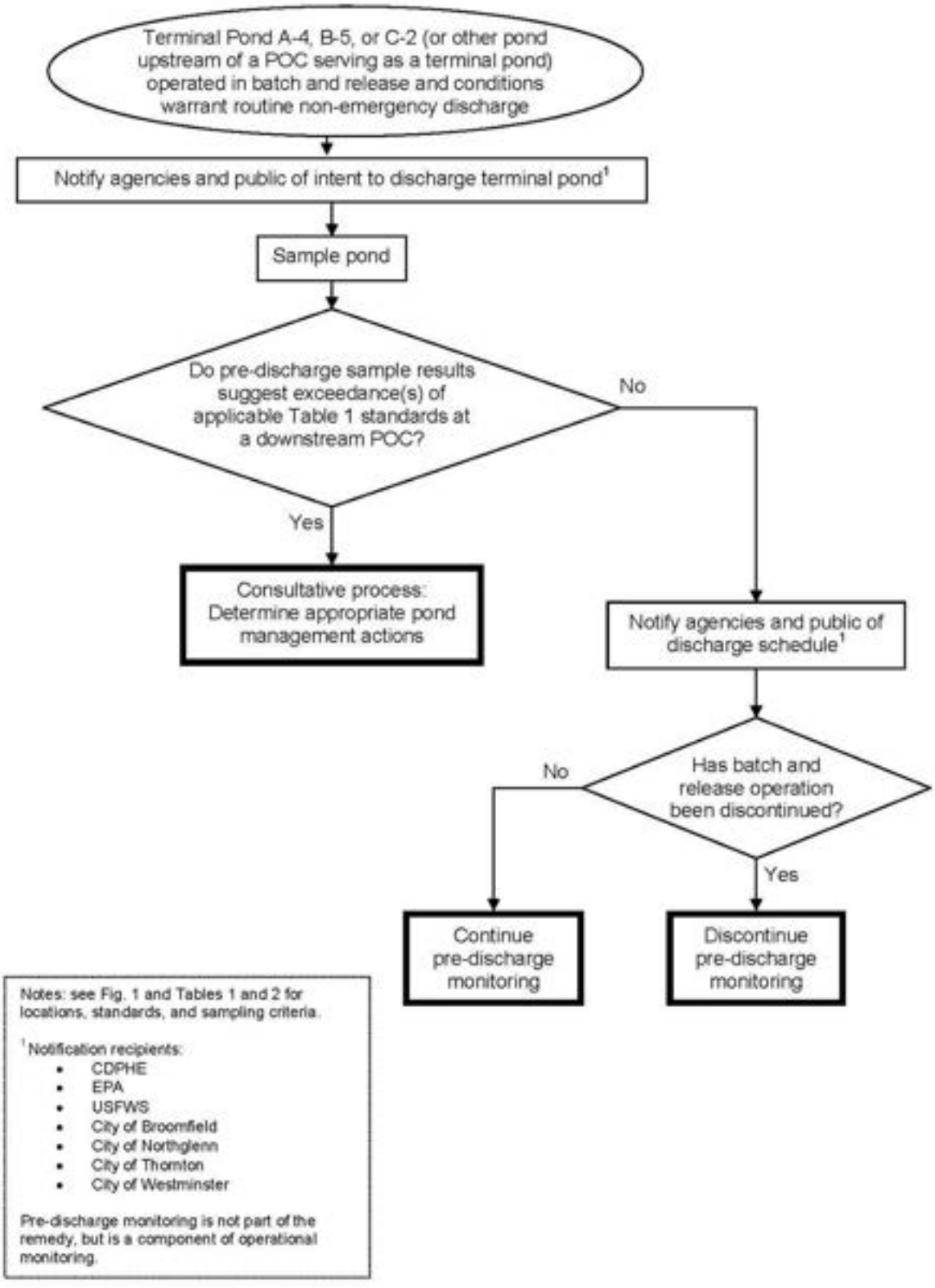


Figure 13. Pre-discharge Pond Sampling

Appendix C

Risk Assessment Review for COU, POU, and OU3

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C1.0 Introduction

This appendix presents the methodology for reviewing and evaluating changes to chemical and radiological risk assessment parameters that took effect during this five-year review (FYR) period and details the results of the risk evaluation. The methodology used for this evaluation is based on the methodology used for the comprehensive risk assessment (CRA) completed in 2006. The CRA included human health and ecological risk assessments for the Central Operable Unit (COU) and the Peripheral Operable Unit (POU); a separate risk assessment was completed for Operable Unit 3 (OU3) (DOE 1996). A summary of the CRA may be found in the Third FYR Report (DOE 2012), and the complete CRA is found as an appendix to the Remedial Investigation/Feasibility Study (RI/FS) Report (DOE 2006).

In accordance with Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) guidance, this FYR must provide an evaluation of changes to risk assessment factors to determine if these changes impact the risks presented by residual contamination left within the COU. The conclusions of this evaluation are then used to determine if the remedy remains protective.

Although this FYR risk evaluation is limited to risks posed by residual contamination within the COU, a separate review of the impacts of changes to risk assessment factors was conducted for the POU and OU3. The purpose of this separate review was to determine if the unlimited use/unrestricted exposure (UU/UE) designation is still valid at both OUs. The POU and OU3 were both deleted from the National Priorities List (NPL) in 2007 because they posed no significant threat to public health or the environment (Volume 72 *Federal Register* p. 29276 [72 FR 29276]).

C2.0 Central Operable Unit

In the RI/FS Report (DOE 2006), the nature and extent of residual contamination in soil and sediment were evaluated after completion of the Rocky Flats Cleanup Agreement accelerated actions. Each nature and extent of contamination evaluation identified analytes of interest (AOIs). AOIs are chemicals that have been detected at concentrations that may contribute to the risk to future receptors. The evaluation studied the extent of contaminants within the COU and POU and evaluated which chemicals remained after the completed accelerated actions. The soil AOIs identified in the RI/FS Report are presented in Table C-1.

In 2006, a comprehensive risk assessment was completed for the COU and POU to quantify the risk of residual contamination remaining after accelerated cleanup actions (DOE 2006). The CRA was conducted in accordance with the *Final Comprehensive Risk Assessment Work Plan and Methodology* (DOE 2005), approved by the U.S. Environmental Protection Agency (EPA) and the Colorado Department of Public Health and Environment (CDPHE). Calculations and conclusions in the CRA were based on post-remediation data; that is, data collected after the completion of all Rocky Flats Cleanup Agreement accelerated actions. To facilitate the CRA, the lands comprising the COU and POU were divided into the 12 exposure units (EUs) shown in Figure C-1. The basic methodology for conducting human health risk assessments, as described in the *Risk Assessment Guidance for Superfund* (EPA 1989), has not changed since the CRA was completed.

Table C-1. Soil Analytes of Interest Identified in the Remedial Investigation/Feasibility Study Report

Surface Soil (0–0.5 feet)	Subsurface Soil (0.5–8 feet)	Subsurface Soil (>8 feet)
Radionuclides		
Americium-241 Plutonium-239/240 Uranium-233/234 Uranium-235 Uranium-238	Americium-241 Plutonium-239/240 Uranium-235 Uranium-238	Plutonium-239/240
Metals		
Aluminum Arsenic Chromium (total) Vanadium	Chromium (total) Lead	
Volatile Organic Compounds (VOCs)		
	Tetrachloroethene	1,1,2,2-Tetrachloroethane Carbon tetrachloride Chloroform Methylene chloride Tetrachloroethene Trichloroethene
Semivolatile Organic Compounds (SVOCs)		
Benzo[*a*]pyrene Dibenz[*a,h*]anthracene	Benzo[*a*]pyrene	Benzo[*a*]pyrene
Polychlorinated Biphenyls (PCBs)		
Aroclor-1254 Aroclor-1260 2,3,7,8-TCDD		Aroclor-1260

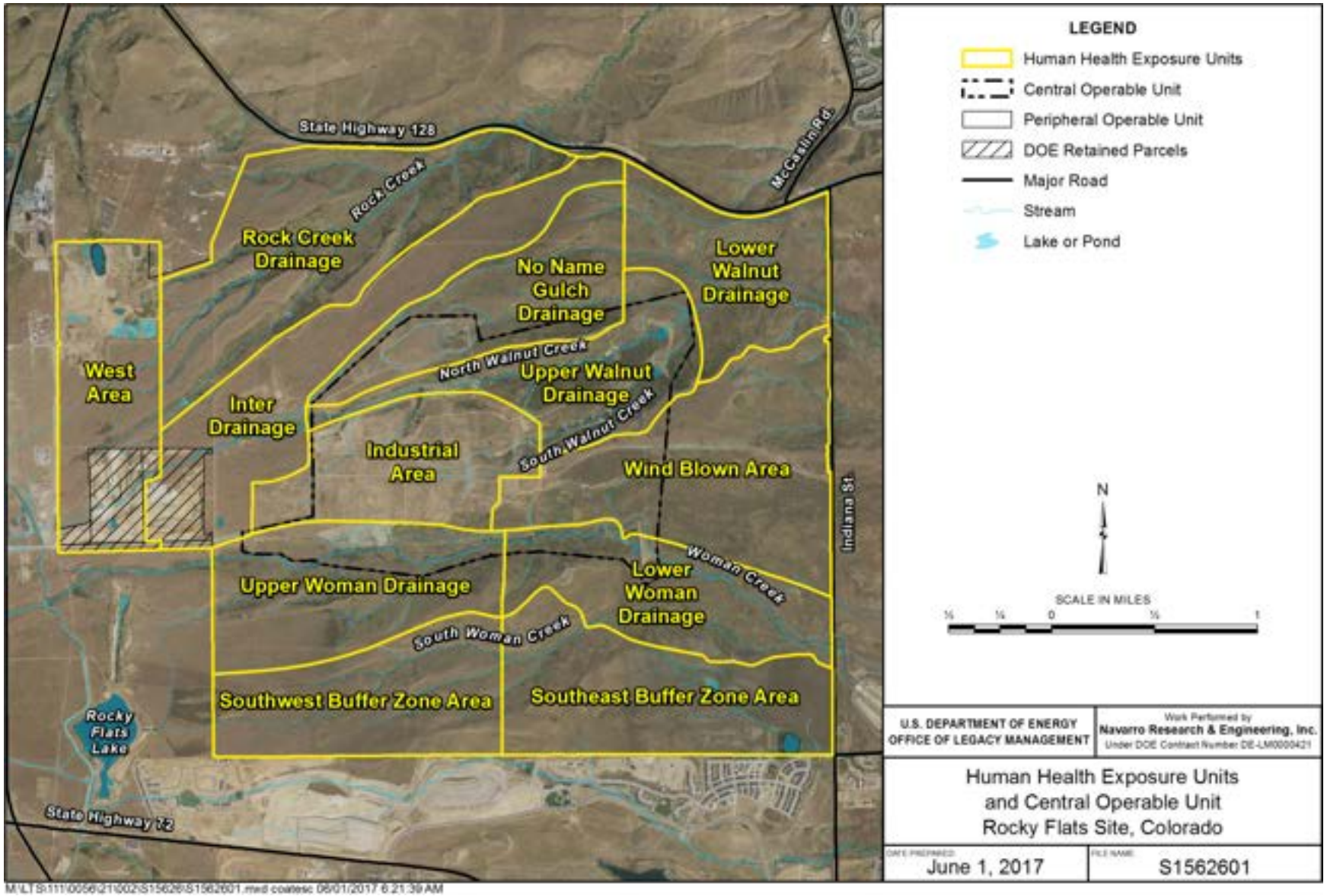

Figure C-1. Human Health EUs and COU Boundary

C2.1 Risk Definitions

This section presents the definitions of key risk terms used throughout this appendix.

95 percent upper confidence limit (95UCL): The statistical upper bound estimate of the mean for a set of samples and a conservative measure of the average concentration. As a general rule, EPA recommends use of the 95UCL as the exposure point concentration for soils at a site (EPA 2002).

Cancer risk: The added probability of an individual or population of developing cancer during a lifetime as a result of exposure to site contaminants. The acceptable risk range for CERCLA sites is an added risk of less than 1 in 1,000,000 (1×10^{-6}) to a maximum of 1 in 10,000 (1×10^{-4}).

Dose conversion factor (DCF): The dose to the human body associated with an exposure to a radionuclide (usually presented in millirem per picocurie [mrem/pCi] or millirem per year [mrem/year]/picocurie per gram [pCi/g]).

Hazard quotient (HQ): The ratio of the exposure level of a single substance to an acceptable noncarcinogenic toxicity value (e.g., reference dose). If multiple substances are present, hazard quotients are summed in a hazard index. For CERCLA sites, the maximum acceptable hazard index is 1.0.

Maximum detected concentration (MDC): Maximum concentration detected in any soil sample for a given constituent and exposure unit.

Slope factor: An estimate of the risk of developing cancer associated with exposure to a carcinogenic or potentially carcinogenic substance (i.e., risk per dose).

C2.2 CRA Review Methodology

As one of the initial steps in the comprehensive risk assessment process (Figure C-2), residual concentrations of constituents in soil for each EU were compared to preliminary remediation goals (PRGs) developed for a wildlife refuge worker (WRW). The PRGs represent concentrations for individual chemicals that would equate to a carcinogenic risk of 1×10^{-6} or a noncarcinogenic HQ of 0.1 based on the exposure assumptions for the WRW. The 2006 CRA used a HQ value of 0.1 as an initial, conservative screening level; a HQ value greater than 1.0 indicates an exposure that exceeds a reference dose. The PRGs were developed using toxicity data that were current at the time of the CRA and were developed for exposures to both surface and subsurface soils. PRGs for subsurface soils are higher than those for surface soils, as it was assumed that the exposure frequency would be much lower (20 compared to 230 days per year). The MDC for each detected constituent at each EU was compared to its respective PRG. If the MDC was less than the PRG, the constituent was eliminated from further consideration. If the MDC exceeded the PRG, the 95UCL of the mean for that constituent was compared to the PRG. If the 95UCL was less than the PRG, the constituent was eliminated from further consideration. If the 95UCL exceeded the PRG, the constituent was further evaluated based on frequency of detection, comparison to background concentrations, and professional judgement. Constituents passing through these remaining screening criteria were identified as contaminants of concern (COCs) for each EU (Table C-2) and were further evaluated in the CRA. (Note that the analytes

of interest screening process and CRA EU-specific COC screening process were somewhat different and produced different results.) In the 2006 CRA, COCs were only identified for surface soils. All constituents in subsurface soils were eliminated by the 95UCL screen and no quantitative risks were calculated.

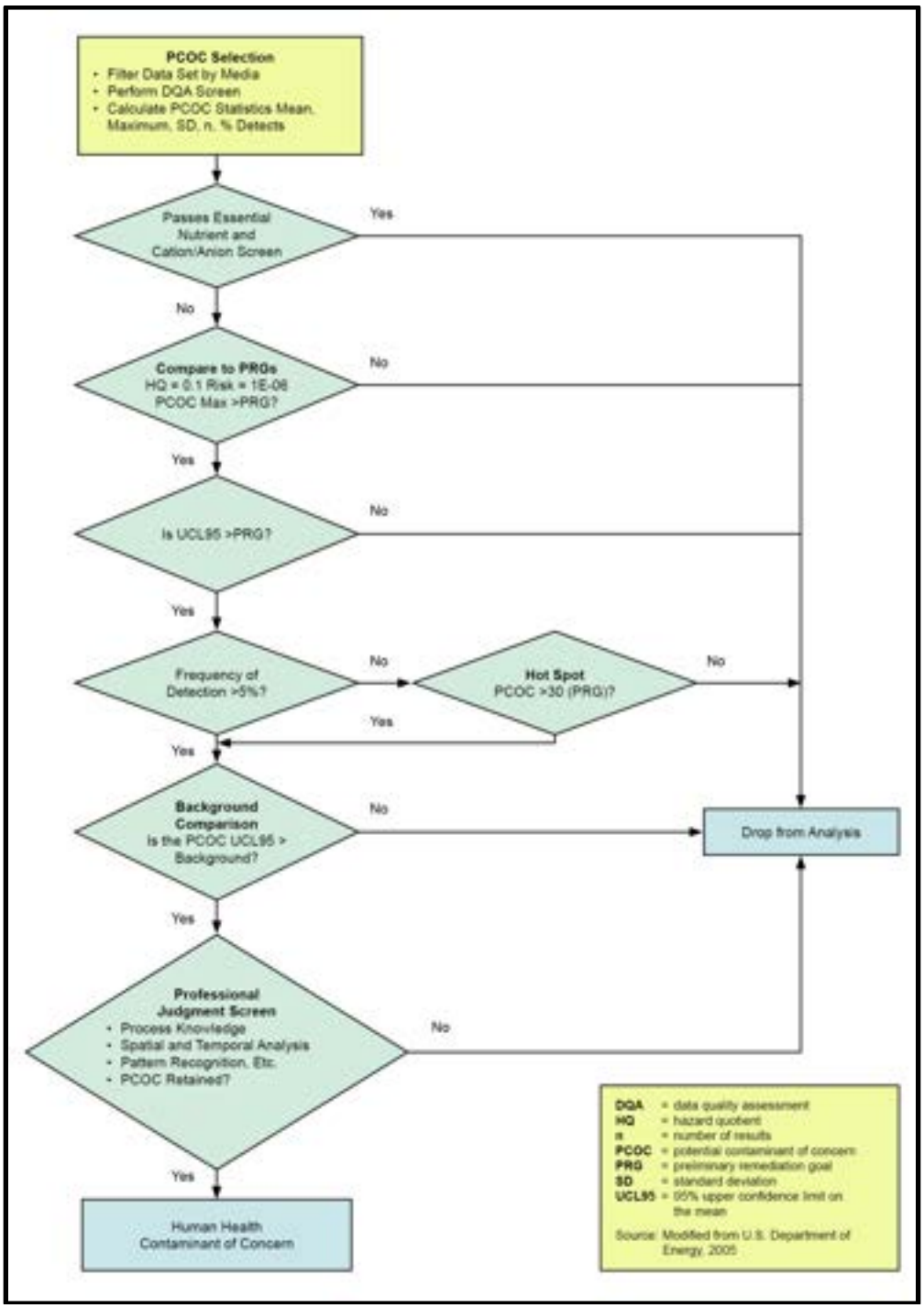

Figure C-2. CRA Constituent Review Process

Table C-2. Surface Soil COCs Identified for Each EU in the CRA

Constituent	Exposure Unit											
	Industrial Area EU	Upper Woman Drainage EU	Wind Blown EU	No Name Gulch EU	Upper Walnut Drainage EU	Lower Woman Drainage EU	Rock Creek EU	Lower Walnut Drainage EU	Inter Drainage EU	West Area EU	Southwest Buffer Zone Area EU	Southeast Buffer Zone Area EU
Part of COU	●	●	●	●	●	●						
Part of POU	●	●	●	●	●	●	●	●	●	●	●	●
Arsenic	X	-	X	-	-	-	-	-	-	-	-	-
Vanadium	-	-	-	X	-	-	-	-	-	-	-	-
2,3,7,8-TCDD	-	X	-	-	-	-	-	-	-	-	-	-
Benzo[*a*]pyrene	X	X	-	-	X	-	-	-	-	-	-	-
Plutonium-239/240	-	-	X	-	-	-	-	-	-	-	-	-

Abbreviations:
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
X = constituent was designated a COC in the 2006 CRA
- = constituent was not designated a COC in the 2006 CRA

C2.3 FYR Risk Evaluation

The following sections discuss the review methodology and results from this FYR risk evaluation for the COU. The sections have been separated into chemical and radionuclide constituents because the methodologies for these evaluations were slightly different.

C2.3.1 Chemical Constituent Review Methodology

Because the first two steps of the COC screening process in the CRA relied on a comparison of residual soil concentrations with the WRW PRGs, any subsequent changes to exposure assumptions or toxicity values used to calculate the PRGs could change the outcome of the screening process. For this FYR risk evaluation, a methodology similar to that described above for the CRA was applied to determine the impact of changes to risk assessment parameters for surface soils. Figure C-3 presents the screening methodology. In lieu of recalculating over 200 site-specific PRGs for a WRW, this FYR risk evaluation utilized the EPA regional screening levels (RSLs) for industrial soil as a proxy for revised WRW PRGs (EPA 2016a). The RSLs incorporate current toxicity data and methodologies for the same exposure pathways of concern for the WRW. The default exposure assumptions for the industrial soil scenario are very similar to those used for the WRW for surface soils. Table C-3 compares the key assumptions used in RSL and site-specific PRG calculations. Where exposure factors are not the same, those used by EPA tend to be more conservative (i.e., assume a greater degree of exposure). Therefore, it was determined that the EPA industrial soil RSLs were an acceptable screening tool to represent updated surface soil WRW PRGs (referred to as "updated WRW RSLs" for the remainder of this appendix).

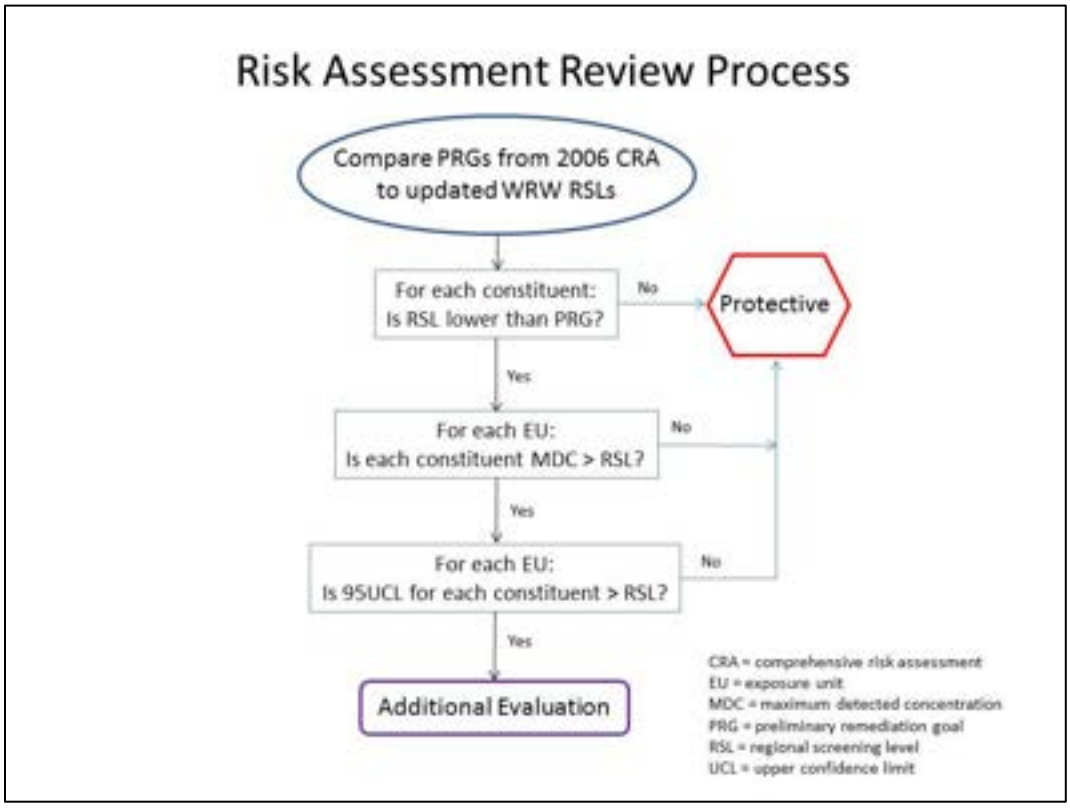

Figure C-3. FYR Risk Assessment Review Process

Table C-3. Comparison of Key Exposure Assumptions for RSLs and PRGs

Exposure Factor (units)	EPA RSL Default Value	WRW PRG Assumption
Frequency of exposure (days/year)	250	Surface soils, 230 Subsurface soils, 20
Exposure duration (years)	25	18.7
Exposure time (hours/day)	8	8
Soil ingestion rate (milligrams/day)	100	100
Adult body weight (kilograms)	80	70
Skin surface area (square centimeters)	3527	3300

The complete list of surface soil PRGs developed for the comprehensive risk assessment was compared to the updated WRW RSLs list (EPA 2016a). Of the more than 200 original PRGs that were evaluated, slightly more than half of the PRGs were higher than (i.e., greater than) the updated RSLs. This means that some COCs could have been eliminated during the original CRA screening process that would have been retained based on more current data. The vast majority of the lower RSL values were for organic chemicals of which many are volatile organic compounds (VOCs). EPA has recently finalized guidance on vapor intrusion (EPA 2015) and as a result has updated information on many VOCs included in the RSL tables. Additionally, the EPA approach to evaluating risks for the inhalation pathway was finalized in 2009. The methodology used in the CRA reflects older guidance for estimating exposures for this pathway. It is likely that a combination of these factors explain why such a large number of the PRGs are

higher than current RSLs. Decreases for most constituents were within an order of magnitude, but RSLs for a few constituents are several orders of magnitude lower than PRGs (e.g., cyclohexane).

Where PRGs were lower than current RSLs, it was assumed that results of the original screening process are still valid for non-COCs. Statistical data for COCs were screened against the higher RSLs to determine if they would still be considered COCs based on the updated values. Where RSLs were lower than PRGs, a rescreening of the EU statistical data was also performed. EPA RSLs were compared to data presented in the CRA for each EU. The analytical data (MDCs and 95UCL values) used in this FYR are the same data used in the 2006 comprehensive risk assessment; no new data were collected to support this FYR. The MDCs and 95UCLs used in the surface soil screening were compared to the RSLs. If 95UCL data were not already tabulated, a 95UCL was calculated from statistical data provided in the CRA. If MDCs or 95UCLs were lower than the current RSLs, constituents were eliminated from further consideration. All other constituents were retained for further evaluation. Table C-4 presents the results of the chemical screening process by EU; Table C-5 summarizes the screening process by constituent.

Table C-4. Surface Soil Chemical Constituent Screening Results by EU

Constituent	Industrial Area EU	Upper Woman Drainage EU	Wind Blown EU	No Name Gulch EU	Upper Walnut Drainage EU	Lower Woman Drainage EU	Rock Creek EU	Lower Walnut Drainage EU	Inter Drainage EU	West Area EU	Southwest Buffer Zone Area EU	Southeast Buffer Zone Area EU
Arsenic[a]	X	-	X	-	-	-	-	-	-	-	-	-
Vanadium[a]	-	-	-	X	-	-	-	-	-	-	-	-
2,3,7,8-TCDD	-	X	-	-	-	-	-	-	-	-	-	-
Aroclor-1254	X	X	X	X	-	-	-	-	-	-	-	-
Aroclor-1260	X	-	-	-	-	-	-	-	-	-	-	-
Benzo[*a*]pyrene[b]	X	X	-	-	-	-	-	-	-	-	-	-
Cobalt	X	-	-	-	-	-	-	-	-	-	-	-
Lead and compounds	-	-	-	X	-	-	-	-	-	-	-	-
Mercury (elemental)	X	-	-	-	-	-	-	-	-	-	-	-
Naphthalene	-	X	-	-	-	-	-	-	-	-	-	-
N-Nitroso-di-*n*-propylamine	-	-	X	-	-	-	-	-	-	-	-	-
Uranium (soluble salts)[c]	X	X	-	-	-	-	-	-	-	-	-	-

Notes:

[a] Arsenic and vanadium were included in this table because these constituents were identified as COCs in the CRA and their 95UCL exceeds their PRG.

[b] Screening values for benzo[*a*]pyrene and other PAHs were from EPA's PRG calculator and based on EPA's January 2017 report on benzo[*a*]pyrene. These screening levels are higher than those contained in EPA's current RSLs.

[c] The revised risk-based screening level for uranium was calculated using the oral reference dose recommended in EPA's December 2016 memorandum (EPA 2016b). This screening level is lower than that contained in EPA's current RSLs.

Abbreviations:

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
X = constituent MDC > WRW RSL
- = constituent MDC or 95UCL < WRW RSL
Shaded boxes indicate 95UCL > WRW RSL

Table C-5. Surface Soil Chemical Constituent FYR Screening Results by Constituent

All Constituents with PRGs[a]	Constituents Where EPA RSL < PRG[b]	Constituents Where EPA RSL < PRG (any EU)[c]	Constituents Where MDC > EPA RSL (any EU)[d]
Acenaphthene			
Acenapthylene			
Acetone	x	x	
Acrolein	x		
Acrylonitrile	x		
Alachlor			
Aldicarb			
Aldicarb sulfone			
Aldicarb sulfoxide			
Aldrin			
Aluminum			
Ammonia			
Anthracene			
Antimony (metallic)			
Aroclor 1016			
Aroclor 1221	x		
Aroclor 1232	x		
Aroclor 1242	x	x	
Aroclor 1248	x	x	
Aroclor 1254	x	x	x
Aroclor 1260	x	x	x
Arsenic, inorganic	x		
Atrazine	x		
Barium	x		
Benzene	x	x	
Benzidine	x		
Benz[*a*]anthracene			
Benzo[*a*]pyrene[e]			x
Benzo[*b*]fluoranthene			
Benzo[*g,h,i*]perylene			
Benzo[*k*]fluoranthene			
Benzoic acid			
Benzyl alcohol	x	x	
Beryllium and compounds			
Bis(2-chloroethyl)ether	x		
Bis(2-chloro-1-methylethyl)ether			
Bis(2-ethylhexyl)phthalate	x	x	
Boron and borates only			
Bromodichloromethane	x	x	

Table C-5. Surface Soil Chemical Constituent FYR Screening Results by Constituent (continued)

All Constituents with PRGs[a]	Constituents Where EPA RSL < PRG[b]	Constituents Where EPA RSL < PRG (any EU)[c]	Constituents Where MDC > EPA RSL (any EU)[d]
Bromoform	x		
Bromomethane	x	x	
2-Butanone (methyl ethyl ketone)	x	x	
Butyl benzyl phthalate	x	x	
Cadmium (diet)			
Carbazole			
Carbofuran			
Carbon disulfide	x	x	
Carbon tetrachloride	x	x	
Chlordane-alpha			
Chlordane-beta			
Chlordane-gamma	x		
4-Chloroaniline	x		
Chlorobenzene	x	x	
Ethyl chloride (chloroethane)			
Chloroform	x	x	
Chloromethane (methyl chloride)	x	x	
4-Chloro-3-methylphenol (Cresol, *p*-chloro-*m*-)			
2-Chloronaphthalene (beta-)	x		
2-Chlorophenol			
Chlorpyrifos	x		
Chromium(III), insoluble salts			
Chromium(VI)	x	x	x
Chrysene			
Cobalt	x	x	x
Copper			
Cyanide (CN^-)	x		
Cyclohexane	x		
DDD	x	x	
DDE, *p,p*'-	x	x	
DDT	x	x	
Dalapon			
Demeton			
Dibenz[*a,h*]anthracene			
Dibenzofuran		x	
Dibromochloromethane	x		
1,2-Dibromo-3-chloropropane	x		
Dibutyl phthalate			
Dicamba			

Table C-5. Surface Soil Chemical Constituent FYR Screening Results by Constituent (continued)

All Constituents with PRGs[a]	Constituents Where EPA RSL < PRG[b]	Constituents Where EPA RSL < PRG (any EU)[c]	Constituents Where MDC > EPA RSL (any EU)[d]
1,2-Dichlorobenzene	x		
1,3-Dichlorobenzene			
1,4-Dichlorobenzene			
3,3'-Dichlorobenzidine	x		
Dichlorodifluoromethane	x		
1,1-Dichloroethane	x		
1,2-Dichloroethane	x		
1,1-Dichloroethylene			
1,2-Dichloroethene(total)			
2,4-Dichlorophenol			
2,4-Dichlorophenoxy acetic acid			
4-(2,4-Dichlorophenoxy)butyric acid			
1,2-Dichloropropane	x	x	
1,3-Dichloropropane			
cis-1,3-Dichloropropene			
trans-1,3-Dichloropropene			
Dieldrin	x	x	
Diethyl ether (ethyl ether)			
Di(2-ethylhexyl)adipate	x		
Diethyl phthalate			
Dimethoate	x		
2,4-Dimethylphenol	x	x	
Dimethylphthalate	x	x	
4,6-Dinitro-*o*-cresol	x		
2,4-Dinitrophenol	x	x	
2,4-Dinitrotoluene	x		
2,6-Dinitrotoluene	x		
di-N-Octyl phthalate	x	x	
Dinoseb			
1,4-Dioxane	x		
2,3,7,8-TCDD	x	x	x
1,2-Diphenylhydrazine	x		
Diquat			
Endosulfan I			
Endosulfan II			
Endosulfan sulfate			
Endosulfan (technical)			
Endrin			
Endrin aldehyde			
Endrin ketone			

Table C-5. Surface Soil Chemical Constituent FYR Screening Results by Constituent (continued)

All Constituents with PRGs[a]	Constituents Where EPA RSL < PRG[b]	Constituents Where EPA RSL < PRG (any EU)[c]	Constituents Where MDC > EPA RSL (any EU)[d]
Ethyl acetate	x		
Ethylbenzene	x	x	
Ethylene dibromide (1,2-dibromoethane)			
Fluoranthene			
Fluorene	x	x	
Fluorine (soluble fluoride)			
Glyphosate			
Guthion (azinphos-methyl)			
Heptachlor	x		
Heptachlor epoxide			
Hexachlorobenzene	x	x	
Hexachlorobutadiene	x	x	
Hexachlorocyclohexane, alpha-	x		
Hexachlorocyclohexane, beta-	x		
Hexachlorocyclohexane, gamma- (Lindane)	x		
Hexachlorocyclohexane, delta-			
Hexachlorocyclohexane, technical	x		
Hexachlorocyclopentadiene	x		
Hexachlorodibenzo-*p*-dioxin	x		
HxCDD, 1,2,3,6,7,8-	x		
HxCDD, 1,2,3,7,8,9-	x		
Hexachloroethane	x		
Indeno[1,2,3-*cd*]pyrene			
Iron			
Isobutyl alcohol			
Isophorone	x	x	
Isopropylbenzene (cumene)			
Lead and compounds	x	x	x
Lithium	x	x	
Manganese (diet)			
Mercury (elemental)	x	x	x
Methoxychlor			
MCPA			
MCPP			
Methylene chloride			
Methyl methacrylate	x		
2-Methylnaphthalene	x	x	
Methyl isobutyl ketone (4-methyl-2-pentanone)	x	x	
2-Methylphenol (cresol, *o*-)			

Table C-5. Surface Soil Chemical Constituent FYR Screening Results by Constituent (continued)

All Constituents with PRGs[a]	Constituents Where EPA RSL < PRG[b]	Constituents Where EPA RSL < PRG (any EU)[c]	Constituents Where MDC > EPA RSL (any EU)[d]
4-Methylphenol (cresol, *p*-)			
Methyl *tert*-butyl ether (MTBE)	x		
Mirex	x		
Molybdenum			
Naphthalene	x	x	x
Nickel soluble salts			
Nitrate			
Nitrite			
2-Nitroaniline			
4-Nitroaniline	x		
Nitrobenzene	x		
4-Nitrophenol			
Nitroso-di-N-butylamine, N-	x		
Nitrosodiethylamine, N-	x		
Nitrosodimethylamine, N-	x		
Nitrosodiphenylamine, N-	x		
Nitroso-di-*n*-propylamine, N-	x	x	x
Nitrosopyrrolidine, N-	x		
p-Nitrotoluene	x		
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)			
Oxamyl			
Parathion			
Pentachlorobenzene			
Pentachlorophenol	x	x	
Phenanthrene			
Phenol			
Picloram			
Pyrene			
Selenium			
Silver			
Simazine	x		
Strontium, stable			
Styrene	x	x	
Sulfide			
1,2,4,5-Tetrachlorobenzene			
1,1,1,2-Tetrachloroethane	x		
1,1,2,2-Tetrachloroethane	x	x	
Tetrachloroethylene			
2,3,4,6-Tetrachlorophenol			

Table C-5. Surface Soil Chemical Constituent FYR Screening Results by Constituent (continued)

All Constituents with PRGs[a]	Constituents Where EPA RSL < PRG[b]	Constituents Where EPA RSL < PRG (any EU)[c]	Constituents Where MDC > EPA RSL (any EU)[d]
Thallium (soluble salts)	x	x	
Tin			
Titanium			
Toluene			
Toxaphene	x		
1,2,4-Trichlorobenzene	x	x	
1,1,1-Trichloroethane	x	x	
1,1,2-Trichloroethane	x		
Trichloroethylene			
Trichlorofluoromethane			
2,4,5-Trichlorophenol			
2,4,6-Trichlorophenol	x	x	
2,4,5-Trichlorophenoxypropionic acid			
1,2,3-Trichloropropane	x	x	
1,1,2-Trichloro-1,2,2-trifluoroethane	x	x	
2,4,6-Trinitrotoluene			
Uranium (soluble salts)[f]	x	x	x
Vanadium and compounds			
Vinyl acetate	x		
Vinyl chloride	x		
Xylene, *p*-	x		
Xylene, *m*-	x		
Xylene, *o*-	x		
Xylenes	x	x	
Zinc and compounds			

Notes:
[a] This column lists all constituents for which WRW PRGs were developed (DOE 2005).
[b] This column lists all constituents where the May 2016 EPA RSLs were lower than the WRW PRGs.
[c] This column includes all constituents that were detected and carried through the original CRA screening process for any EU.
[d] This column contains all constituents with an MDC that exceeded an EPA RSL. Note that arsenic and vanadium are not carried past the first column in this table because the EPA RSLs are greater than the WRW PRGs and rescreening is not required.
[e] Even though the current RSL for benzo[*a*]pyrene is higher than the PRG, it was carried through the screening process to determine if it would still be considered a COC based on current data.
[f] The revised risk-based screening level for uranium was calculated using the oral reference dose recommended in EPA's December 2016 memorandum (EPA 2016). This screening level is lower than that contained in EPA's current RSLs.

No COCs were identified in the CRA for subsurface soils. Because the reevaluation of surface soil data discussed above verified that the CRA process correctly identified the COCs, rescreening of all PRGs against subsurface soil data is not warranted. A more targeted approach was taken in this FYR by focusing on constituents that were most likely to be present in subsurface soils. An abbreviated PRG list was used for subsurface soil screening based on the

results of the surface soil screening process. This included all constituents for which any surface soil MDC exceeded the surface soil PRG (constituents listed in Table C-4 and last column in Table C-5); tetrachloroethene was also added to this list as it was identified as a subsurface analyte of interest in the RI/FS (Table C-1). The constituents evaluated along with screening results are listed in Table C-6. Original subsurface soil PRGs were 11.5 times higher than surface soil PRGs because of the lower frequency of exposure (20 versus 230 days) (DOE 2005). Therefore, the current WRW RSLs were multiplied by 11.5 to obtain current estimates of subsurface WRW PRGs. The screening with this smaller set of PRGs proceeded in the same manner as the surface soil FYR evaluation described above.

Table C-6. Subsurface Soil Chemical Constituent Screening Results by EU

Constituent	Industrial Area EU	Upper Woman Drainage EU	Wind Blown EU	No Name Gulch EU	Upper Walnut Drainage EU	Lower Woman Drainage EU	Rock Creek EU	Lower Walnut Drainage EU	Inter Drainage EU	West Area EU	Southwest Buffer Zone Area EU	Southeast Buffer Zone Area EU
2,3,7,8-TCDD	-	-	-	-	-	-	-	-	-	-	-	-
Aroclor-1254	X	-	-	-	-	-	-	-	-	-	-	-
Aroclor-1260	-	-	-	-	-	-	-	-	-	-	-	-
Arsenic	X	-	-	-	-	-	-	-	-	-	-	-
Benzo[*a*]pyrene	X	X	-	-	-	-	-	-	-	-	-	-
Cobalt	-	X	-	-	-	-	-	-	-	-	-	-
Lead and compounds	-	-	-	-	-	-	-	-	-	-	-	-
Mercury (elemental)	-	-	-	-	-	-	-	-	-	-	-	-
Naphthalene	X	-	-	-	-	-	-	-	-	-	-	-
N-Nitroso-di-*n*-propylamine	-	-	-	-	-	-	-	-	-	-	-	-
Tetrachloroethene	-	-	-	-	-	-	-	-	-	-	-	-
Vanadium	-	-	-	-	-	-	-	-	-	-	-	-
Uranium (soluble salts)	X	-	-	-	-	-	-	-	-	-	-	-

Note:
Arsenic and vanadium were included in this table because these constituents were identified as COCs in the CRA and their 95UCL exceeds their WRW PRG.

Abbreviations:
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
- = MDC < EPA RSL
X = MDC > EPA RSL

C2.3.2 Chemical Constituent Evaluation Results

Surface Soils. As was the case in the original comprehensive risk assessment screening process, nearly all constituents were eliminated in this FYR risk evaluation based on the MDC comparison screen. Very few constituents were retained by the RSL screen that were not also retained by the PRG screen (see Table C-5). Among these is uranium, for which EPA has

recently recommended a much lower toxicity value (EPA 2016b). Most constituents passing the RSL screen were subsequently eliminated based on the 95UCL comparison or following additional evaluation (e.g., frequency of detection <5%). Of the constituents evaluated in this FYR evaluation screening process, only three constituents passed through the 95UCL screen. These are summarized in Table C-7.

Table C-7. Chemical Constituents and EUs where 95UCL Exceeds Current Screening Level

	Exposure Unit											
Constituent	**Industrial Area EU**	**Upper Woman Drainage EU**	**Wind Blown EU**	**No Name Gulch EU**	**Upper Walnut Drainage EU**	**Lower Woman Drainage EU**	**Rock Creek EU**	**Lower Walnut Drainage EU**	**Inter Drainage EU**	**West Area EU**	**Southwest Buffer Zone Area EU**	**Southeast Buffer Zone Area EU**
Arsenic	X	-	X	-	-	-	-	-	-	-	-	-
Vanadium	-	-	-		-	-	-	-	-	-	-	-
2,3,7,8-TCDD		X	-	-	-	-	-	-	-	-	-	-
Benzo[*a*]pyrene		X	-			-	-	-	-	-	-	-

Note:
Shaded boxes differ from the CRA results.

Abbreviations:
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
- = constituent not considered a COC in CRA.
X = constituent would be considered a COC based on CRA screening methodology

As in the original comprehensive risk assessment, dioxin was identified as a COC for the Upper Woman Drainage EU and benzo[*a*]pyrene as a COC for the Upper Woman Drainage EU. Based on recently revised toxicity data (EPA 2017), benzo[*a*]pyrene would no longer be considered a COC for the Industrial Area EU or the Upper Walnut Drainage EU, with concentrations below the current RSL based on EPA's PRG calculator. The rescreening process also confirmed that arsenic is still considered a COC for the Industrial Area EU and Wind Blown EU based on current RSL concentrations; estimated risk levels associated with residual arsenic would be similar to that in the CRA. The arsenic 95UCL for all the other EUs also exceeded the PRG (and the current RSL), but arsenic was eliminated as a COC for those EUs in the CRA based on subsequent screens. On the basis of the current vanadium RSL, vanadium would not be a COC. The vanadium PRG is based on a lower toxicity value than is currently being used by EPA; however, vanadium is still undergoing study and this value could change in the future. For the most part, the rescreening process confirmed the results of the CRA for surface soils.

Subsurface Soils. The MDCs for a number of constituents exceeded the updated WRW RSLs. However, all constituents dropped out based on the 95UCL screen, and the reevaluation confirmed that there are no subsurface COCs.

The vapor intrusion pathway was identified in the CRA as a potentially complete pathway for VOCs in subsurface soils, including those at depths greater than 8 feet. Most of the AOIs identified for subsurface soils in the RI/FS Report are VOCs (Table C-1). EPA has finalized

guidance for evaluating the vapor intrusion pathway (EPA 2015) and provided guidance for evaluating this pathway in five-year reviews (EPA 2012b). Updated toxicity data are also available for some VOCs that are identified as AOIs at subsurface depths greater than 8 feet (e.g., tetrachloroethene and trichloroethene). However, institutional controls are in place at the COU that eliminate the vapor intrusion pathway by prohibiting the construction of habitable structures. Remedial action objectives (RAOs) and cleanup goals remain valid and are not affected by updated guidance and toxicity data as long as institutional controls remain in place.

In addition to the toxicity values discussed above, EPA is reviewing the toxicity of arsenic. Preliminary results of the arsenic study suggest that current methods of estimating risks from arsenic due to soil ingestion likely overestimate actual risks. Therefore, results will not affect the protectiveness of the remedy.

C2.3.3 Radiological Constituent Review Methodology

As various scientific radiological organizations and communities (e.g., Center for Radiation Protection Knowledge, International Commission on Radiological Protection [ICRP], and EPA Federal Guidance Reports [FGRs]) gain greater knowledge of the effects of ionizing radiation on humans, changes are made to their supporting and guidance documents that are then used in radiological risk and dose calculation tools, such as the online EPA PRG calculator and the RESRAD dose model.

The current EPA online PRG calculator was used in this FYR radiological risk review to determine if the risks from radionuclides to the WRW in the COU remain within the CERCLA acceptable risk range (i.e., 1×10^{-4} to 1×10^{-6}). The online PRG calculator incorporates the numerous changes to toxicity factors that have occurred since 2006, including revisions specific to Pu and U. In September 2014, a significant revision was adopted that follows EPA recommendations concerning the use of exposure parameters from the EPA *Exposure Factors Handbook* (EPA 2011). New slope factors for radionuclides have been programmed into the calculator that were derived following Federal Guidance Reports 12 and 13 using the updated isotope list from ICRP107. Examples of some of the slope factors used in the CRA (2006) compared to those found in the current EPA PRG calculator (2017) are shown in Table C-8.

To perform the FYR radiological risk review, the input parameters used in the 2006 CRA for the WRW were entered into the current online EPA PRG calculator to obtain updated PRG values that correspond to risk levels within the EPA acceptable risk range (1×10^{-4} to 1×10^{-6}). These updated PRG values were then compared to the WRW PRG values from the 2006 CRA. For completeness, this FYR considered $^{239/240}$Pu (the only radionuclide COC identified in the 2006 CRA), ^{241}Am, ^{234}U, ^{235}U, and ^{238}U. The Am and U isotopes represent the other primary radionuclides associated with RFP historical operations.

The determination of risk level in the Corrective Action Document/Record of Decision (CAD/ROD) was based on a comparison of measured concentrations to target risk levels calculated in the CRA for WRW and Wildlife Refuge Visitor (WRV) scenarios (DOE 2006). The methodology used for this FYR review does not require input of site-specific analytical data because PRGs represent concentrations based on a target risk level rather than a calculated risk due to measured concentrations. As such, no new soil analytical data were collected for this FYR risk review. Changes in PRG values (from 2006 to 2017) are the result of changes made to the

calculator and how it functions (e.g., formulas used in the calculation process have been modified/updated), the scientific data that the calculator uses to compute risk (e.g., isotopic cancer slope factors or DCFs), or a combination of both.

Table C-8.Comparison of Slope Factors for Various Pathways

Isotope	1994[a]	2006	2017
	Adult Ingestion		
^{241}Am	2.40×10^{-10}	9.1×10^{-11}	9.1×10^{-11}
^{239}Pu	2.30×10^{-10}	1.21×10^{-10}	1.21×10^{-10}
^{234}U	1.60×10^{-11}	5.11×10^{-11}	5.11×10^{-11}
^{235}U	1.60×10^{-11}	4.92×10^{-11}	4.92×10^{-11}
^{238}U	1.60×10^{-11}	4.66×10^{-11}	4.66×10^{-11}
	Adult Inhalation		
^{241}Am	3.20×10^{-8}	2.81×10^{-8}	3.77×10^{-8}
^{239}Pu	3.80×10^{-8}	3.33×10^{-8}	5.55×10^{-8}
^{234}U	2.60×10^{-8}	1.14×10^{-8}	2.78×10^{-8}
^{235}U	2.50×10^{-8}	1.01×10^{-8}	2.50×10^{-8}
^{238}U	2.40×10^{-8}	9.32×10^{-9}	2.36×10^{-8}
	Adult External Exposure		
^{241}Am	4.90×10^{-9}	2.76×10^{-8}	2.77×10^{-8}
^{239}Pu	1.70×10^{-11}	2.00×10^{-10}	2.09×10^{-10}
^{234}U	3.00×10^{-11}	2.52×10^{-10}	2.53×10^{-10}
^{235}U	2.40×10^{-7}	5.18×10^{-7}	5.51×10^{-7}
^{238}U	2.10×10^{-11}	4.99×10^{-11}	1.24×10^{-10}

Note:
[a] DOE 1994.

C2.3.4 Radionuclide Constituent Evaluation Results

Table C-9 contains the PRG comparison results for the WRW in the COU. As shown in the table, the 2017 PRGs calculated for ^{241}Am and ^{235}U at the 1×10^{-6} risk level are less conservative (i.e., larger) than the PRGs calculated in 2006 at the same risk level. The 2017 PRGs calculated for ^{239}Pu, ^{240}Pu, ^{234}U, and ^{238}U are slightly more conservative (i.e., smaller) than the PRGs calculated in 2006 at the 1×10^{-6} risk level. The largest decrease in PRGs for any radionuclide is ^{238}U, which decreased from 29.3 to 22.9 pCi/g, a difference of 6.4 pCi/g. The decrease in calculated PRGs from 2006 for ^{239}Pu, ^{240}Pu, ^{234}U, and ^{238}U is most likely attributed to the revision of the Pu and U slope factors adopted by EPA since 2006 (see Table C-8). Although the calculated risk associated with these four radionuclides increased slightly, the risk remains on the lower end (i.e., more protective) of the risk range, between 1×10^{-5} and 1×10^{-6}. In summary, the calculated risk to a WRW in the COU remains within the acceptable risk range considered by EPA to be protective of human health and therefore, the remedy in the COU remains protective.

Table C-9. PRG Comparison for WRW[a]

Isotope	2006 CRA PRG[b] (pCi/g)	2017 PRG (pCi/g)		
Risk Level	**1×10^{-6}**	**1×10^{-4}**	**1×10^{-5}**	**1×10^{-6}**
^{241}Am	7.7	1150.0	115.0	11.5
^{239}Pu	9.8	929.0	92.9	9.3
^{240}Pu	9.8	931.0	93.1	9.3
^{234}U	25.3	2000.0	200.0	20.0
^{235}U	1.1	454.0	45.4	4.5
^{238}U	29.3	2290.0	229.0	22.9

Notes:
[a] The calculated risk to a WRV in the COU is less than the calculated risk to a WRW, primarily due to the difference in exposure frequency. The WRW scenario exposure frequency is 230 days/year; the WRV scenario exposure frequency for an adult is 250 hours/year.
[b] DOE 2005. Values have been rounded to the first decimal place.

C2.3.5 Radiological Dose Assessment Review

In addition to human health risk calculations performed in the comprehensive risk assessment, a radiation dose assessment for exposure to residual radionuclide contamination in surface soil and subsurface soil was also completed. The purpose of the dose assessment was to demonstrate compliance with the annual dose limits in Colorado Radiation Control Regulations (Volume 6 *Code of Colorado Regulations* Regulation 1007-1, Part 4 [6 CCR 1007-1, Part 4]), which were identified as Applicable Relevant and Appropriate Requirements (ARARs) in the CAD/ROD (DOE 2006). For radiological sites that do not allow for unrestricted use, as is the case for the COU, Colorado regulations require that institutional controls be in place that reasonably ensure that the total effective dose equivalent from residual radioactivity at the site does not exceed 25 mrem/year (6 CCR 1007-4.61.2).

RESRAD-ONSITE is a pathway analysis computer code that calculates radiation doses and cancer risks to a critical population group and can be used to derive cleanup criteria for radioactively contaminated soils. Since 2002, eight revisions have been made to RESRAD-ONSITE (RESRAD). In 2014, RESRAD was revised to allow dose conversion factor database and software capability for ICRP107. In 2016, RESRAD was revised to provide options to choose between the ICRP38 radionuclide decay database and the ICRP107 radionuclide decay database; ICRP38 supports the use of either ICRP26/30- or ICRP60/72-based dose coefficients, and ICRP107 supports the use of ICRP60-based dose coefficients from DCFPAK 3.02. A comparison of the RESRAD version 6.3 dose results to the RESRAD version 7.2 dose results indicates little change in total dose (see Table C-12).

Changes to ICRP Versions. Within the RESRAD-ONSITE computer code (Revision 7.2, July 20, 2017), both DCFs and slope factors are used. For the verification calculations performed in 2017, the program was first set to use ICRP38 for radionuclide transformations. This configuration defaults to ICRP72 (selectable from adult to infant) for the internal dose library, ICRP60 for the external dose library, and FGR13 morbidity risk factors (Figure C-4). The ICRP38 configuration best approximates the older 2006 (Revision 6.3) version of the calculator

that was used in 2006, as ICRP38 was replaced by ICRP107 in 2008 in the software program. Then the calculator was set to use ICRP107 for radionuclide transformations. This configuration defaults to U.S. Department of Energy (DOE) STD-1196-2001 Reference Person (selectable from adult to infant) for the internal dose library, DCFPAK 3.02 for the external dose library, and DCFPAK 3.02 morbidity risk factors (Figure C-5). The *Oak Ridge National Laboratory, Calculation of Slope Factors and Dose Coefficients, September 2014* (https://epa-prgs.ornl.gov/radionuclides/SlopesandDosesFinal.pdf) provides detailed information regarding the development of the risk factors and dose coefficients used in the current RESRAD-ONSITE software program. Both the ICRP38 and ICRP107 versions of the RESRAD-ONSITE calculator were run (using the 2006 data), to provide an understanding of the revisions to the RESRAD-ONSITE calculator, based on the results of the calculator runs.

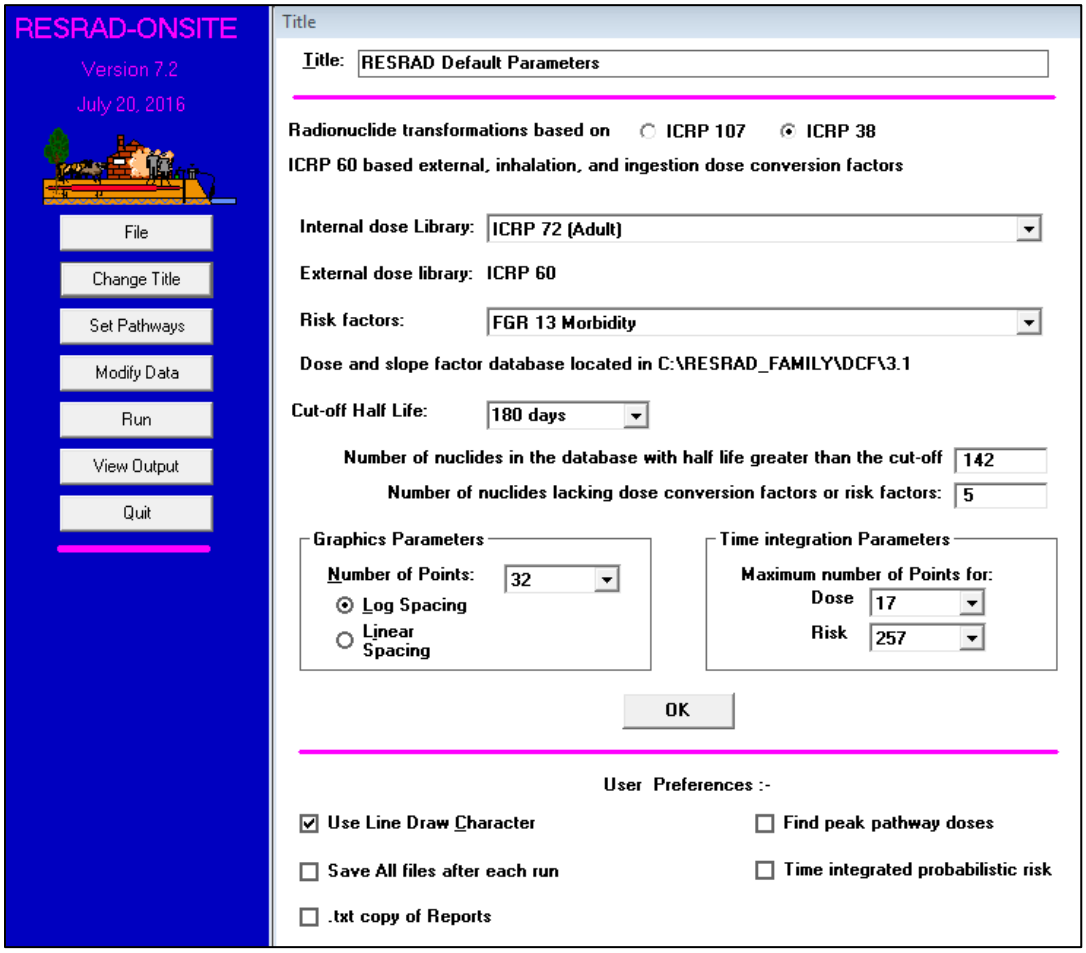

Figure C-4. RESRAD-ONSITE Title Screen, ICRP 38

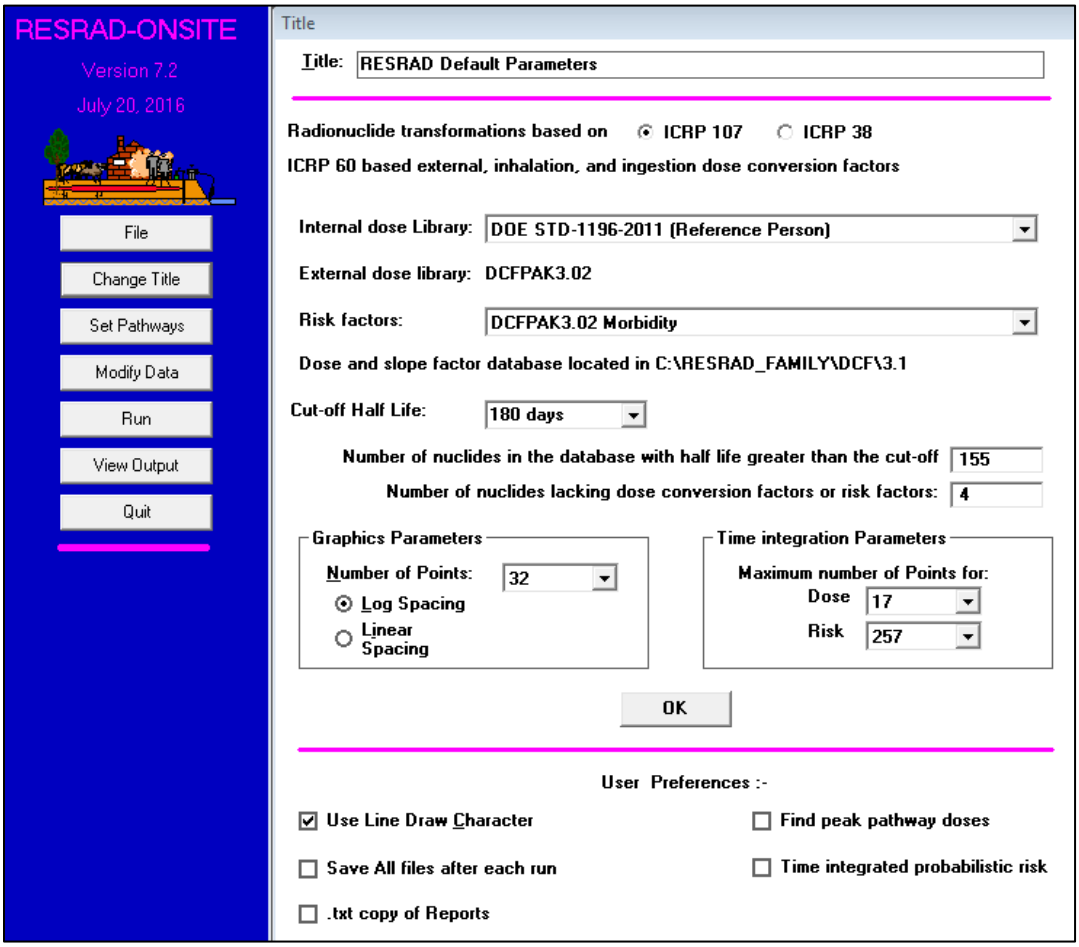

Figure C-5. RESRAD-ONSITE Title Screen, ICRP 107

Changes to Dose Conversion Factors. RESRAD-ONSITE dose conversion factors were evaluated for changes between the 2006 and 2017 software program (versions 6.3 and 7.2 and ICRP38 and ICRP107, respectively). Only the key isotopes (those input in the calculator for the modeling runs performed in both 2006 and 2017, ^{241}Am, ^{239}Pu, ^{234}U, ^{235}U, and ^{238}U) were evaluated, as progeny isotope DCF values would likely follow suit of the parent isotope.

As shown in Tables C-10 and C-11, most DCF values for the inhalation and ingestion pathways changed between the 2006 and 2017 calculator versions for the parent and progeny isotopes. Shaded cells in the tables are the key isotopes (^{239}Pu, ^{241}Am) that were input into the calculators. Nonshaded table cells are isotopes that are introduced by the RESRAD-ONSITE calculator as a result of progeny ingrowth during the 1000-year evaluation time period. While those added isotopes add little value to the comparison aspect of the review, they represent the various DCFs for the radionuclides that in-grow over the 1000-year evaluation time period.

Table C-10. RESRAD Dose Conversion Factors (2006 and 2017, Am and Pu, Adult)

DCFs for Inhalation (mrem/pCi)					
Menu Code	**Isotope[a]**	**2006 ICRP72 Value**	**2017 ICRP38 Value**	**2017 ICRP107 Value**	**Parameter Name**
B-1	^{227}Ac+D	6.724×10^{0}	2.104×10^{0}	6.714×10^{-1}	DCF2(1)
	^{241}Am	1.600×10^{-1}	3.552×10^{-1}	3.630×10^{-1}	DCF2(2)
	^{237}Np+D	5.400×10^{-1}	1.850×10^{-1}	1.869×10^{-1}	DCF2(3)
	^{231}Pa	1.280×10^{0}	5.180×10^{-1}	8.769×10^{-1}	DCF2(4)
	^{239}Pu	1.900×10^{-1}	4.440×10^{-1}	4.477×10^{-1}	DCF2(5)
	^{229}Th+D	2.169×10^{0}	9.481×10^{-1}	9.865×10^{-1}	DCF2(6)
	^{233}U	1.350×10^{-1}	3.552×10^{-2}	3.811×10^{-2}	DCF2(7)
	^{235}U+D	1.100×10^{-2}	3.145×10^{-2}	3.378×10^{-2}	DCF2(8)
DCFs for Ingestion (mrem/pCi)					
Menu Code	**Isotope[a]**	**2006 ICRP72 Value**	**2017 ICRP38 Value**	**2017 ICRP107 Value**	**Parameter Name**
D-1	^{227}Ac+D	1.480×10^{-2}	4.473×10^{-3}	2.308×10^{-3}	DCF3(1)
	^{241}Am	7.400×10^{-4}	7.400×10^{-4}	8.806×10^{-4}	DCF3(2)
	^{237}Np+D	4.444×10^{-3}	4.102×10^{-4}	4.674×10^{-4}	DCF3(3)
	^{231}Pa	1.060×10^{-2}	2.627×10^{-3}	2.068×10^{-3}	DCF3(4)
	^{239}Pu	9.300×10^{-4}	9.250×10^{-4}	1.066×10^{-3}	DCF3(5)
	^{229}Th+D	4.027×10^{-3}	2.269×10^{-3}	3.329×10^{-3}	DCF3(6)
	^{233}U	2.890×10^{-4}	1.887×10^{-4}	2.227×10^{-4}	DCF3(7)
	^{235}U+D	1.713×10^{-4}	1.752×10^{-4}	2.048×10^{-4}	DCF3(8)

Note:
[a] Nonshaded table cells are isotopes that are introduced by the RESRAD-ONSITE calculator as a result of progeny ingrowth during the 1000-year evaluation time period.

Abbreviation:
+D = includes daughters (i.e., progeny)

Table C-11. RESRAD Dose Conversion Factors (2006 and 2017, U, Adult)

DCFs for Inhalation (mrem/pCi)					
Menu Code	**Isotope[a]**	**2006 ICRP72 Value**	**2017 ICRP38 Value**	**2017 ICRP107 Value**	**Parameter Name**
B-1	^{227}Ac+D	6.724×10^{0}	2.104×10^{0}	6.714×10^{-1}	DCF2(1)
	^{231}Pa	1.280×10^{0}	5.180×10^{-1}	8.769×10^{-1}	DCF2(2)
	^{210}Pb+D	2.320×10^{-2}	3.697×10^{-2}	4.017×10^{-2}	DCF2(3)
	^{226}Ra+D	8.594×10^{-3}	3.526×10^{-2}	3.823×10^{-2}	DCF2(4)
	^{230}Th	3.260×10^{-1}	3.700×10^{-1}	3.848×10^{-1}	DCF2(5)
	^{234}U	1.300×10^{-2}	3.478×10^{-2}	3.737×10^{-2}	DCF2(6)
	^{235}U+D	1.100×10^{-2}	3.145×10^{-2}	3.378×10^{-2}	DCF2(7)
	^{238}U	1.060×10^{-2}	2.960×10^{-2}	3.212×10^{-2}	DCF2(8)
	^{238}U+D	1.063×10^{-2}	2.963×10^{-2}	3.215×10^{-2}	DCF2(9)
DCFs for Ingestion (mrem/pCi)					
Menu Code	**Isotope[a]**	**2006 ICRP72 Value**	**2017 ICRP38 Value**	**2017 ICRP107 Value**	**Parameter Name**
D-1	^{227}Ac+D	1.480×10^{-2}	4.473×10^{-3}	2.308×10^{-3}	DCF3(1)
	^{231}Pa	1.060×10^{-2}	2.627×10^{-3}	2.068×10^{-3}	DCF3(2)
	^{210}Pb+D	7.276×10^{-3}	6.998×10^{-3}	1.026×10^{-2}	DCF3(3)
	^{226}Ra+D	1.321×10^{-3}	1.037×10^{-3}	1.677×10^{-3}	DCF3(4)
	^{230}Th	5.480×10^{-4}	7.770×10^{-4}	9.361×10^{-4}	DCF3(5)
	^{234}U	1.800×10^{-4}	1.813×10^{-4}	2.150×10^{-4}	DCF3(6)
	^{235}U+D	1.713×10^{-4}	1.752×10^{-4}	2.048×10^{-4}	DCF3(7)
	^{238}U	1.700×10^{-4}	1.665×10^{-4}	1.939×10^{-4}	DCF3(8)
	^{238}U+D	1.837×10^{-4}	1.791×10^{-4}	2.112×10^{-4}	DCF3(9)

Note:
[a] Nonshaded table cells are isotopes that are introduced by the RESRAD-ONSITE calculator as a result of progeny ingrowth during the 1000-year evaluation time period.

Abbreviation:
+D = includes daughters

Notes

For information not available/provided in the 2006 RESRAD result data sheets, 2017 RESRAD-ONSITE calculator default values were used.

For Child Surface Soil Am and Pu, Solar Ponds Revision 7.2, the RESRAD-ONSITE internal dose library allows for the selection of an age range of the child's age (unlike 2006) for use in a given scenario (five nonadult choices of age). "Age 1" was used as the scenario input for the 2017 recalculation. The "Age" input section is very sensitive to the calculation result, so results varied significantly (11.5–0.778 mrem) as age selection was varied. The "older" ages (10 and 15) result in relatively smaller doses at time zero (the time of the largest dose to the individual). The 2006 Child scenarios reviewed identified "child" as the selection, and not "infant." The reviewer followed suit and elected not to use the "infant" option for the Age input selection.

C2.3.6 Dose Assessment Review Results

The dose assessment completed in 2006 used version 6.3 of the RESRAD computer code to calculate radiation doses to a scenario-driven critical population within the COU. The input parameters used in 2006 were entered into the most recent version of RESRAD (version 7.2) to calculate dose. The results of these 2006 calculations were compared to the current version of RESRAD (version 7.2) results, allowing the reviewer the ability to compare past RESRAD calculation results to current results. This comparison can then be used to better understand if changes in the results are occurring, and if occurring, to what magnitude. Note that a new dose was not calculated for the COU in this evaluation. No new sample data were collected to support this fourth FYR dose evaluation. Instead, the same input parameters and analytical data values used in 2006 were entered into the most recent RESRAD version to determine the relative impact of changes to the computer code.

To understand the relatively minor impact to dose resulting from the numerous changes to input parameters and the computer model that have occurred since 2006, a range of exposure scenarios and associated analytical data evaluated in the 2006 RESRAD (version 6.3) dose assessment was entered into the current RESRAD model (version 7.2). Four existing 2006 scenarios were selected to review and recalculate total dose: (1) resident adult exposure to ^{239}Pu and Am in subsurface soil in the Ash Pits East area, (2) resident child exposure to ^{239}Pu and Am in surface soil at the Solar Evaporation Ponds, (3) WRW exposure to U in subsurface soil at the Wind Blown area, and (4) WRW exposure to ^{239}Pu and Am in surface soil at the Wind Blown area. This semirandom selection of scenarios was slightly bias-based to include a mix of radionuclides (^{241}Am, ^{239}Pu, ^{234}U, ^{235}U, and ^{238}U), both adult and child scenarios, and three different locations with surface and subsurface impacts/potential impacts in different OUs (COU and POU). Table C-12 presents the 2006 RESRAD scenario calculation results for the four scenarios, the 2017 RESRAD-ONSITE scenario calculation results using ICRP38, and the 2017 RESRAD-ONSITE results using ICRP107.

A comparison of the RESRAD version 6.3 dose results to the RESRAD version 7.2 dose results indicates little change in total dose (Table C-12). Each of the 2006 scenarios evaluated yielded similar results, suggesting that the changes in total dose for all scenarios and locations evaluated in 2006 would be negligible using the current RESRAD model version. This simply means that the changes to RESRAD since 2006 have not resulted in major impacts to dose calculated by the model. That is, the dose calculated using RESRAD version 6.3 is nearly the same as the dose calculated using RESRAD version 7.2, given the same site-specific input parameters used in 2006. Therefore, because the dose assessment from 2006 indicated that the lands within the COU are in compliance with the dose criteria ARAR from the CAD/ROD with a total dose much less than 25 mrem/year, a recalculation of dose using the most updated version of RESRAD yields the same results, and the ARAR would still be met. As a result, this FYR dose assessment evaluation shows that the dose criteria ARAR continues to be met and supports the conclusion that the remedy in the COU remains protective.

Table C-12. RESRAD Scenario Calculation Results (2006 and 2017)

RESRAD Scenario Identification	Maximum Total Dose (mrem/year)
2006 Resident Adult Subsurface Soil Am and Pu Ash Pits East	8.918×10^{-4}
2017 Resident Adult Subsurface Soil Am and Pu Ash Pits East (ICRP38)	8.986×10^{-4}
2017 Resident Adult Subsurface Soil Am and Pu Ash Pits East (ICRP107)	9.893×10^{-4}
2006 Resident Child Surface Soil Am and Pu Solar Ponds	1.499×10^{0}
2017 Resident Child Surface Soil Am and Pu Solar Ponds (ICRP38)	1.351×10^{0}
2017 Resident Child Surface Soil Am and Pu Solar Ponds (ICRP107)	1.361×10^{0}
2006 WRW Subsurface Wind Blown U	8.499×10^{-3}
2017 WRW Subsurface Wind Blown U (ICRP38)	8.682×10^{-3}
2017 WRW Subsurface Wind Blown U (ICRP107)	9.259×10^{-3}
2006 WRW Surface Wind Blown Am/Pu	4.159×10^{-1}
2017 WRW Surface Wind Blown Am/Pu (ICRP38)	5.075×10^{-1}
2017 WRW Surface Wind Blown Am/Pu (ICRP107)	5.602×10^{-1}

C3.0 POU

The chemical and radiological risks associated with the POU were evaluated as part of the 2006 comprehensive risk assessment (DOE 2006). A radiological dose assessment using the RESRAD computer code was also completed. The POU and OU3 (discussed in Section C4.0) were determined to be suitable for UU/UE and were deleted from the NPL in 2007 (72 FR 29276). Because conditions at these two OUs were determined to meet the criteria for UU/UE, a FYR of these OUs is not required. However, the continued applicability of UU/UE for these OUs was reviewed in light of potential changes to toxicity factors and other risk-related information since the original UU/UE determinations were made. The conclusions from these reviews are discussed in this section for the POU and in Section C4.0 for OU3.

C3.1 Chemical Constituents Evaluation

The chemical review of the UU/UE criteria for the POU utilized a similar approach as the COU chemical risk evaluation. The rural resident soil action levels calculated in 2002 were compared to the EPA 2016 residential RSL table values (most recent values available). All 2016 RSLs that were lower than the 2002 values (i.e., were more conservative) were retained for comparison against residual POU surface soil concentrations from the 2006 CRA dataset (Table C-13). All residual surface soil concentrations correspond to levels within or below the CERCLA acceptable risk range (1×10^{-4} to 1×10^{-6}) based on the updated residential RSLs. It is therefore confirmed that the POU is still suitable for UU/UE.

Table C-13. 2016 Residential RSLs and POU Surface Soil Concentrations

Constituent	2016 Residential RSLs (µg/kg)		Range of Concentrations Detected in POU Surface Soils (µg/kg)
Risk Level	1×10^{-4}	1×10^{-6}	
2,6-Dinitrotoluene	36,000	360	170–550
Benzo[*a*]anthracene	16,000	160	170–550
Benzo[*a*]pyrene	1600	16	170–1000
Benzo[*b*]fluoranthene	16,000	160	170–550
Bis(2-chloroethyl)ether	23,000	230	170–550
Bis(2-chloroisopropyl)ether	8600	86	170–550
Dibenz[*a,h*]anthracene	1600	16	170–550
Hexachlorobenzene	21,000	210	170–550
Indeno[1,2,3-*cd*]pyrene	16,000	160	170–550
N-Nitroso-di-*n*-propylamine	7800	78	170–550
Aroclor-1254	3,800[a]	120[a]	80–260
Pentachlorophenol	100,000	1000	850–2650

Note:
[a] Upper screening level based on HQ = 1.

Abbreviation:
µg/kg = micrograms per kilogram

C3.2 Radiological Constituents Evaluation

The radiological review of the UU/UE criteria for the POU utilized the same approach as the COU radiological risk evaluation. The EPA online PRG calculator was used to generate 2017 PRGs for the POU based on the residential scenario referenced in the 2006 CAD/ROD. These PRGs were then compared to the rural resident PRGs calculated in 2002. As with each of the risk reviews completed for this FYR report, no new soil analytical data were collected. The site-specific input parameters for the POU risk review were taken from the 2002 Radionuclide Soil Action Levels report (DOE, EPA, and CDPHE 2002) and are presented in Figure C-6. It was necessary to use the input parameters from this report because, unlike the 2006 CRA, the 2002 report included evaluation of a rural resident scenario, which is appropriate for the UU/UE evaluation.

Figure C-6. 2002 Site-Specific Input Values

Table C-14 presents the results of the POU UU/UE review. Although the only COCs identified in the POU were $^{239/240}$Pu and ^{241}Am, the U isotopes were included to be consistent with the COU and OU3 reviews. As shown in the table, the 2017 PRGs for ^{241}Am, ^{239}Pu, ^{234}U, and ^{238}U at a risk level of 1×10^{-6} are lower than those calculated in 2002 at the same risk level. The changes in the PRGs for ^{239}Pu are significant across the risk range (1×10^{-4} to 1×10^{-6}), which indicates that the calculated risk associated with ^{239}Pu for the rural resident has increased since 2002. To provide perspective, the MDC of ^{239}Pu in the POU in 2006 was approximately 20 pCi/g (DOE, EPA, and CDPHE 2006). This equates to a risk between 1×10^{-4} and 1×10^{-5} when compared to the 2017 PRG values. While this risk is closer to the higher end of the risk range (i.e., less protective), it is still within the CERCLA acceptable risk range considered by EPA to be protective of human health. Based on this FYR radiological review, the POU continues to meet the criteria for UU/UE.

A comparison of 2017 PRGs for the COU (Table C-9) and the POU (Table C-14) shows that the calculated PRGs decreased from the original PRGs for ^{239}Pu, ^{234}U, and ^{238}U in both the WRW and rural resident scenarios. The PRGs for ^{241}Am and ^{235}U increased from the original PRGs using the WRW scenario in the COU and decreased from the original PRGs using the rural resident scenario in the POU. The decreases in the PRGs are attributed to the revision of slope factors for Pu and U that were adopted by EPA over the years since the original PRGs were calculated. In addition, differences in the exposure pathways inherent to the WRW and rural resident scenarios also impact the PRG calculations. For example, the WRW scenario does not include exposure pathways for the ingestion of vegetables, whereas the rural resident scenario does include this pathway. Thus, because the rural resident is potentially exposed to site

contaminants through more pathways than the WRW, the PRG value to protect the resident must be lower than the PRG value to protect the WRW at the same risk level (i.e., 1×10^{-6}).

Table C-14. PRGs for POU Rural Resident Exposure Scenario[a]

Isotope	2002[b] (pCi/g)			2017 (using ICRP 107) (pCi/g)		
Risk Level	**1×10^{-4}**	**1×10^{-5}**	**1×10^{-6}**	**1×10^{-4}**	**1×10^{-5}**	**1×10^{-6}**
^{241}Am	70.0	7.0	1.0	53.5	5.4	0.5
^{239}Pu	128.0	13.0	1.0	43.5	4.4	0.4
^{240}Pu	Not available[c]			43.6	4.4	0.4
^{234}U	36.0	4.0	0.4	12.3	1.2	0.1
^{235}U	11.0	1.0	0.1	11.4	1.1	0.1
^{238}U	40.0	4.0	0.4	13.6	1.4	0.1

Notes:
[a] The rural resident exposure scenario is more conservative than the WRW and WRV exposure scenarios applicable to the COU.
[b] DOE, EPA, and CDPHE 2002. Values have been rounded to the first decimal place.
[c] The source document for the 2002 PRGs only included a PRG for ^{239}Pu; a PRG for ^{240}Pu was not included in the source document.

C4.0 OU3

A Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI) report and baseline risk assessment (BRA) were completed for OU3 in June 1996 (DOE 1996). This report identified the COCs in OU3 as $^{239/240}$Pu and ^{241}Am in surface soils and $^{239/240}$Pu in surface sediments within the Great Western Reservoir. Although COCs were only identified for surface soil and sediment in OU3, the Facility Investigation/Remedial Investigation gathered and considered a substantial amount of surface water, groundwater, and air data. The baseline risk assessment included evaluation of residential and recreational exposure scenarios and concluded that conditions in OU3 were within the acceptable risk range for protection of human health. The CAD/ROD for OU3 was published in June 1997 and selected no action as the remedy (DOE, EPA, and CDPHE 1997).

C4.1 Radiological Constituents Review Methodology and Results

The 2017 PRGs calculated for the POU rural resident in Table C-14 were compared to the PRGs originally calculated for OU3 in 1994. The same 2017 PRGs used for the FYR risk review of the POU were used for the OU3 comparison because these PRGs were calculated using the most up-to-date input parameters for a residential scenario. As with the COU and POU risk reviews, no new data were collected for the FYR risk review for OU3. Figures C-7 and C-8 present the equations used to calculate the original 1994 PRGs and 2017 PRGs for exposure to soil using a residential scenario. As evidenced in these figures, there have been several changes to input parameters and equations since 1994.

$$PPRG_1 = \frac{TR \times AT \times 365\ days/year}{EF \times \left[(SFi \times IRa \times ED \times \frac{1}{BW} \times \frac{1}{PEF}) + (SFo \times 10^{-6}\ kg/mg \times IF) \right]}$$

where:

Variable	Explanation (Units)	Default Value
$PPRG_1$	Risk-based PPRG for surface soil based on residential use (mg/kg)	-
TR	target excess lifetime cancer risk (unitless)	10^{-6}
AT	averaging time (years)	70 years
EF	exposure frequency (days/year)	350 days/year
SFi	inhalation cancer slope factor $(mg/kg\text{-}day)^{-1}$	COC-Specific
IRa	daily inhalation rate (m^3/day)	20 m^3/day
ED	exposure duration (years)	30 years
BW	adult body weight (kg)	70 kg
PEF	particulate emission factor (m^3/kg)	4.63×10^9 m^3/kg
SFo	oral cancer slope factor $(mg/kg\text{-}day)^{-1}$	COC-Specific
IF	age-adjusted soil ingestion factor (mg-yr/kg-day)	114 mg-yr/kg-day

Figure C-7. 1994 Equation for Resident Soil PRG

Resident Soil (Default Input Values Shown)

- incidental ingestion of soil

$$PRG_{res\text{-}soil\text{-}ing}(pCi/g) = \frac{TR \times t_{res}(year) \times \lambda\left(\frac{1}{year}\right)}{\left(1-e^{-\lambda t_{res}}\right) \times SF_s\left(\frac{risk}{pCi}\right) \times IFS_{res\text{-}adj}(1{,}120{,}000\ mg) \times \left(\frac{g}{1000\ mg}\right)}$$

where:

$$IFS_{res\text{-}adj}(1{,}120{,}000\ mg) = \left(\left(EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}c}(6\ years) \times IRS_{res\text{-}c}\left(\frac{200\ mg}{day}\right)\right) + \left(EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}a}(20\ years) \times IRS_{res\text{-}a}\left(\frac{100\ mg}{day}\right)\right)\right)$$

- inhalation of particulates emitted from soil

$$PRG_{res\text{-}soil\text{-}inh}(pCi/g) = \frac{TR \times t_{res}(year) \times \lambda\left(\frac{1}{year}\right)}{\left(1-e^{-\lambda t_{res}}\right) \times SF_i\left(\frac{risk}{pCi}\right) \times IFA_{res\text{-}adj}\left(161{,}000\ m^3\right) \times \frac{1}{PEF\left(\frac{m^3}{kg}\right)} \times \left(\frac{1000\ g}{kg}\right)}$$

where:

$$IFA_{res\text{-}adj}\left(161{,}000\ m^3\right) = \left(\left(EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}c}(6\ years) \times ET_{res\text{-}c}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times IRA_{res\text{-}c}\left(\frac{10\ m^3}{day}\right)\right) + \left(EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}a}(20\ years) \times ET_{res\text{-}a}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times IRA_{res\text{-}a}\left(\frac{20\ m^3}{day}\right)\right)\right)$$

- external exposure to ionizing radiation

$$PRG_{res\text{-}soil\text{-}ext}(pCi/g) = \frac{TR \times t_{res}(year) \times \lambda\left(\frac{1}{year}\right)}{\left(1-e^{-\lambda t_{res}}\right) \times SF_{ext\text{-}sv}\left(\frac{risk/year}{pCi/g}\right) \times EF_{res}\left(\frac{350\ days}{year}\right) \times \left(\frac{1\ year}{365\ days}\right) \times ED_{res}(26\ years) \times ACF_{ext\text{-}sv} \times \left[\left(ET_{res\text{-}o}\left(\frac{1.752\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times GSF_{o\text{-}ext\text{-}sv}(1.0)\right) + \left(ET_{res\text{-}i}\left(\frac{16.416\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times GSF_i(0.4) \times GSF_b(1.0)\right)\right]}$$

Figure C-8. 2017 Equations for Resident Soil PRGs

- consumption of fruits and vegetables back-calculated to soil

$$PRG_{res\text{-}soil\text{-}produce\text{-}ing\text{-}tot}\,(pCi/g) = \frac{1}{\left(\sum_{i=1}^{n} \frac{1}{PRG_{res\text{-}soil\text{-}produce\text{-}ing}\,(pCi/g)_i}\right)}$$

where:

n = total number of produce items included

and:

$$PRG_{res\text{-}soil\text{-}produce\text{-}ing}\,(pCi/g) = \frac{PRG_{res\text{-}produce\text{-}ing}\,(pCi/g)}{\left(R_{upv} + R_{es}\right)} \times \left(\frac{t_{res}\,(year) \times \lambda\left(\frac{1}{year}\right)}{\left(1 - e^{-\lambda t_{res}}\right)}\right)$$

where:

$$R_{upv} = Bv_{wet} \;;\; R_{es} = MLF_{produce}$$

- consumption of fruits and vegetables.

$$PRG_{res\text{-}produce\text{-}ing}\,(pCi/g) = \frac{TR}{SF_f\left(\frac{risk}{pCi}\right) \times IF_{res\text{-}adj}\,(g) \times CF_{res\text{-}produce}\,(1)}$$

where:

$$IF_{res\text{-}adj}\,(g) = \left(\left(EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}c}\,(6\ years) \times IR_{res\text{-}c}\left(\frac{g}{day}\right)\right) + \left(EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}a}\,(20\ years) \times IR_{res\text{-}a}\left(\frac{g}{day}\right)\right)\right)$$

- total

$$PRG_{res\text{-}soil\text{-}tot}\,(pCi/g) = \frac{1}{\frac{1}{PRG_{res\text{-}soil\text{-}ing}} + \frac{1}{PRG_{res\text{-}soil\text{-}inh}} + \frac{1}{PRG_{res\text{-}soil\text{-}ext}} + \frac{1}{PRG_{res\text{-}soil\text{-}produce\text{-}ing\text{-}tot}}}$$

Figure C-8. 2017 Equations for Resident Soil PRGs (continued)

Table C-15 presents the OU3 PRGs calculated in 1994 and the 2017 PRGs. As shown in the table, the calculated 2017 PRGs at the 1×10^{-6} risk level for ^{241}Am, ^{239}Pu, ^{240}Pu, ^{234}U, and ^{238}U are much smaller than those calculated in 1994 at the same risk level. This is due to the numerous changes to input parameters (e.g., slope factors) and risk assessment equations that have been adopted by EPA since 1994. The comparison of slope factor changes from 1994 to 2017 is shown in Table C-8. The most significant differences between the 1994 and 2017 PRGs are for ^{234}U and ^{238}U. As stated in the 1996 RFI/RI for OU3, U isotopes were not considered to be above background concentrations and were not identified as COCs. However, to provide perspective, the maximum concentration of ^{234}U and ^{238}U identified at OU3 was in subsurface soil (DOE 1996). Uranium-234 was detected at 2.02 pCi/g, and ^{238}U was detected at 2.15 pCi/g,

which are both within the EPA acceptable risk range, as shown in Table C-15. As stated in the 1996 CAD/ROD, the only COCs identified for OU3 were ^{239}Pu, ^{240}Pu, and ^{241}Am (DOE, EPA, and CDPHE 1997). The highest surface soil level for $^{239/240}$Pu was 6.47 pCi/g and for ^{241}Am was 0.52 pCi/g (DOE, EPA, and CDPHE 1997). A comparison of these data with the 2017 PRGs calculated for the rural resident demonstrates that the highest Pu and Am levels measured at OU3 fall within the acceptable risk range considered by EPA to be protective of human health (Table C-15). As such, OU3 continues to meet the conditions for UU/UE.

Table C-15. PRGs for OU3 Residential Exposure Scenario

Isotope	1994[a] (pCi/g)	2017 (using ICRP107) (pCi/g)		
Risk Level	**1×10^{-6}**	**1×10^{-4}**	**1×10^{-5}**	**1×10^{-6}**
^{241}Am	2.4	53.5	5.4	0.5
^{239}Pu	3.4	43.5	4.4	0.4
^{240}Pu	3.4	43.6	4.4	0.4
^{234}U	45.3	12.3	1.2	0.1
^{235}U	0.2	11.4	1.1	0.1
^{238}U	46.0	13.6	1.4	0.1

Note:
[a] DOE 1994. Values have been rounded to the first decimal place.

C5.0 References

72 FR 29276. "Notice of Partial Deletion of the Rocky Flats Plant from the National Priorities List," *Federal Register*, May 25, 2007, accessed at https://www.federalregister.gov/-hazardous-substances-pollution-contingency-plan-national-priorities-list.

DOE (U.S. Department of Energy), 1994. *Programmatic Risk-Based Preliminary Remediation Goals*, U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado, October.

DOE (U.S. Department of Energy), 1996. *Resource Conservation and Recovery Act Facility Investigation/Remedial Investigation Report, Operable Unit 3 (Offsite Areas)*, RF/ER-96-0029.UN, June.

DOE (U.S. Department of Energy), 2005. *Final Comprehensive Risk Assessment Work Plan and Methodology*, Revision 1, prepared by the Kaiser-Hill Co. LLC for the U.S. Department of Energy, September.

DOE (U.S. Department of Energy), 2006. *RCRA Facility Investigation – Remedial Investigation/Corrective Measures Study – Feasibility Study Report for the Rocky Flats Environmental Technology Site,* Appendix A—Comprehensive Risk Assessment, Volume 14 of 15, Industrial Area Exposure Unit, June.

DOE, EPA, and CDPHE (U.S. Department of Energy, U.S. Environmental Protection Agency, and Colorado Department of Public Health and Environment), 1997. *Corrective Action Decision/Record of Decision, Operable Unit 3, the Offsite Areas, Rocky Flats Environmental Technology Site, Golden, Colorado*, April.

DOE, EPA, and CDPHE (U.S. Department of Energy, U.S. Environmental Protection Agency, and Colorado Department of Public Health and Environment), 2002. *Task 3 Report and Appendices: Calculation of Surface Radionuclide Soil Action Levels for Plutonium, Americium, and Uranium*, September.

DOE, EPA, and CDPHE (U.S. Department of Energy, U.S. Environmental Protection Agency, and Colorado Department of Public Health and Environment), 2006. *Corrective Action Decision/Record of Decision for Rocky Flats Plant (USDOE) Peripheral Operable Unit and Central Operable Unit*, *Jefferson and Boulder Counties, Colorado*, September.

DOE, EPA, and CDPHE (U.S. Department of Energy, U.S. Environmental Protection Agency, and Colorado Department of Public Health and Environment), 2012. *Third Five-Year Review Report for the Rocky Flats Site, Jefferson and Boulder Counties, Colorado*, LMS/RFS/S07693, Office of Legacy Management, July.

EPA (U.S. Environmental Protection Agency), 1989. *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A)*, Interim Final, EPA/540/1-89-002, December.

EPA (U.S. Environmental Protection Agency), 2002. *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites,* OSWER 9285.6-10, December.

EPA (U.S. Environmental Protection Agency), 2011. *Exposure Factors Handbook*, 2011 ed., (Final), EPA/600/R-09/052F, Washington, D.C.

EPA (U.S. Environmental Protection Agency), 2012a. *Compilation and Review of Data of Relative Bioavailability of Arsenic in Soil*, OSWER 9200.1-113, December.

EPA (U.S. Environmental Protection Agency), 2012b. *Assessing Protectiveness at Sites for Vapor Intrusion, Supplement to the "Comprehensive Five-Year Review Guidance*," OSWER Directive 9200.2-84, December 3.

EPA (U.S. Environmental Protection Agency), 2015. *OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air*, OSWER Publication 9200.2-154, June.

EPA (U.S. Environmental Protection Agency), 2016a. Regional Screening Level Tables, May 2016, at https://www.epa.gov/risk/regional-screening-levels-rsls, May, last accessed November 23.

EPA (U.S. Environmental Protection Agency), 2016b. Considering a Noncancer Oral Reference Dose for Uranium for Superfund Human Health Risk Assessments; Memorandum from Dana Stalcup, Director, to Superfund National Policy Managers, Regions 1–10; December 21.

EPA (U.S. Environmental Protection Agency), 2017. "Toxicological Review of Benzo[a]pyrene" [CASRN 50-32-8], EPA/635/R-17/003Fa, January.

RESRAD version 7.2, Argonne National Laboratory, Environmental Sciences Division, accessed at https://web.evs.anl.gov/resrad/ on February 22, 2017.

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