RCRA Facility Investigation – Remedial Investigation/ Corrective Measures Study – Feasibility Study Report for the Rocky Flats Environmental Technology Site

Section 7.0
Summary and Conclusions of the Comprehensive Risk Assessment

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7.0 SUMMARY AND CONCLUSIONS OF THE COMPREHENSIVE RISK ASSESSMENT

Sections 3.0 through 6.0 present the nature and extent of contamination by medium after completion of Rocky Flats Cleanup Agreement (RFCA) accelerated actions. Each nature and extent of contamination evaluation identified analytes of interest (AOIs). The purpose of identifying AOIs is to focus the nature and extent evaluation on constituents that have been detected at concentrations that may contribute to the risk to future receptors and show overall spatial and temporal trends of those constituents on a sitewide basis. A subset of the Remedial Investigation (RI) data set was used to complete a Comprehensive Risk Assessment (CRA)[1] to evaluate various exposure scenarios and potential adverse impacts to human health and the environment that may exist from contaminated environmental media associated with residual contamination.

This section summarizes the CRA for the Rocky Flats Environmental Technology Site (RFETS or site). The details of the CRA are found in Appendix A of this RI/Feasibility Study (FS) Report. The CRA was conducted in accordance with the regulatory agency-approved CRA Work Plan and Methodology (CRA Methodology) (DOE 2005).

The CRA consists of two parts: a Human Health Risk Assessment (HHRA) and an Ecological Risk Assessment (ERA). The CRA was designed to provide information to decision makers to help determine the final remedy that is adequately protective of human health and the environment.

Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the U.S. Environmental Protection Agency (EPA) considers environmental concentrations corresponding to a 10^{-6} to 10^{-4} cancer risk range and a total noncancer hazard index (HI) less than or equal to 1 to be adequately protective of human health (NCP 1990 and EPA 1989, respectively).

The Colorado Department of Public Health and Environment (CDPHE) defines acceptable human health risk as a lifetime excess cancer risk less than 1×10^{-6} from exposure to carcinogenic compounds and/or a hazard quotient (HQ) less than 1.0 for noncarcinogenic compounds (CDPHE 1994). State regulations also require that residual radioactivity be evaluated against annual dose criteria. These regulations establish a 25-millirem (mrem) annual dose limit for human receptors under use restrictions. If institutional controls restricting use were to fail, residual radioactivity must be less than 100 millirems per year (mrem/yr) to the appropriate human receptor. The results of the required dose assessment are described in Section 10.0.

The overall risk management goal identified for use in the ERA, as stated in the CRA Methodology, is the following:

[1] Data processing rules for the CRA data set are described in Appendix A, Volume 2, Attachment 2 of the CRA. Depth intervals for soil data used in the CRA are based on the Site Conceptual Model (SCM) and potential exposure of human and ecological receptors.

> *Site conditions due to residual contamination should not represent significant risk of adverse ecological effects to receptors from exposure to site-related residual contamination.*

The ERA was designed and implemented to determine whether site conditions meet the defined goal.

7.1 Purpose and Format of the Comprehensive Risk Assessment

Both the HHRA and ERA consist of the following four basic steps and are intended to answer the corresponding questions:

1. Identification of Contaminants of Concern (COCs) for the HHRA and Identification of Ecological Contaminants of Potential Concern (ECOPCs) for the ERA – What contaminants exist at the site and which of these contaminants are present at concentrations that may impact humans or ecological receptors?

2. Exposure Assessment – How could humans or ecological receptors be exposed to these contaminants?

3. Toxicity Assessment –What are the potential effects of the contaminants on human health or ecological receptors?

4. Risk Characterization – What are potential risks to human and ecological receptors based on potential exposures at the site and the toxicity of the contaminants that are present?

The CRA consists of a total of 15 volumes, as follows:

- Executive Summary (Volume 1);
- Comprehensive Risk Assessment Methodology and Data Description (Volume 2);
- Risk Assessment for West Area Exposure Unit (Volume 3);
- Risk Assessment for Rock Creek Drainage Exposure Unit (Volume 4);
- Risk Assessment for Inter-Drainage Exposure Unit (Volume 5);
- Risk Assessment for No Name Gulch Drainage Exposure Unit (Volume 6);
- Risk Assessment for Upper Walnut Drainage Exposure Unit (Volume 7);
- Risk Assessment for Lower Walnut Drainage Exposure Unit (Volume 8);
- Risk Assessment for Wind Blown Area Exposure Unit (Volume 9);
- Risk Assessment for Upper Woman Drainage Exposure Unit (Volume 10);

- Risk Assessment for Lower Woman Drainage Exposure Unit (Volume 11);
- Risk Assessment for Southwest Buffer Zone Area Exposure Unit (Volume 12);
- Risk Assessment for Southeast Buffer Zone Area Exposure Unit (Volume 13);
- Risk Assessment for Industrial Area Exposure Unit (Volume 14); and
- Risk Assessment for Wide-Ranging Ecological Receptors and Aquatic Species (Volumes 15A and 15B).

7.2 Description of Exposure Units and Aquatic Exposure Units

For purposes of the CRA, RFETS was divided into 12 Exposure Units (EUs) (Volumes 3 through 14) for assessing potential risks for human and terrestrial ecological receptors and 7 Aquatic EUs (AEUs) (Volume 15B) for assessing potential risks for aquatic ecological receptors.[2] The EUs and AEUs are shown on Figure 7.1 and Figure 7.2, respectively. In addition, a sitewide analysis was conducted for wide-ranging terrestrial receptors (Volume 15A).

The EUs were designated based on known sources and potential contaminant release patterns to collectively assess areas with similar types of potential contamination. Other criteria used in distinguishing the EUs included separate watersheds, similar topography and vegetation, and expected land use. The resulting units also represent “functional areas,” meaning they all fall within a size range where future on-site workers would likely spend their time. Table 7.1 presents a summary of the EU characteristics.

The AEUs represent a framework for evaluating population risks to aquatic receptors from exposure to surface water and sediment within aquatic systems at RFETS. The basis for these AEUs is that they represent separate drainages or the upper and lower portions of a large single drainage.

7.3 Results of the Data Quality and Adequacy Evaluations

The data used in the CRA are the result of implementation of regulatory agency-approved Sampling and Analysis Plans (SAPs) and SAP Addenda that were prepared to characterize background and site conditions for soil, sediment, groundwater, and surface water for the years 1991 through 2005. Data Quality Assessments (DQAs) were prepared for the sitewide data set (Appendix A, Volume 2, Attachment 2), for each EU (Attachment 2 in Volumes 3 through 14) and each AEU (Attachment 2 in Volumes 15B1

[2] CDPHE guidance requires evaluation of contaminant concentrations on a Solid Waste Management Unit or release site basis. As discussed in Section 1.2.3, this was implemented at RFETS on an Individual Hazardous Substance Site (IHSS)-by-IHSS basis during the accelerated action process. As noted in Section 1.4.3, by addressing cumulative impacts from multiple release sites, the CRA EU unit approach complements, but does not supplant, the Colorado Hazardous Waste Act (CHWA) emphasis on individual release sites. Because the parties had anticipated using institutional controls consistent with the anticipated future use of the site, CDPHE determined that a post-remediation analysis of residual risk on a release site basis was not necessary.

and 15B2). Data quality was assessed using a standard precision, accuracy, representativeness, completeness, and comparability (PARCC) parameter analysis (EPA 2000). Field and laboratory quality control (QC) sample data were also reviewed. Based on the DQAs, it was determined that the CRA data meet the data quality objectives (DQOs) and are of adequate quality for the CRA.

Sufficient samples must also be collected in each medium to adequately estimate the long-term average exposure of receptors to contaminants in an EU. Through the consultative process used to develop the CRA Methodology, the RFCA Parties identified specific data adequacy guidelines in order to evaluate the adequacy of the data. The guidelines pertain to 1) the number of samples 2) spatial representativeness and 3) temporal representativeness. The evaluation of data adequacy was performed for each EU and AEU unit with respect to these guidelines. There are some uncertainties associated with the CRA data set for some EUs/AEUs for purposes of the ERA, and these details are provided in Section 2 and Attachment 3 of Volume 2 of Appendix A of the RI/FS Report as well as the individual EU/AEU volumes (Volumes 3 through 15B of Appendix A of the RI/FS Report). Overall, it was concluded that the data are adequate for the purposes of the CRA.

7.4 Overview of Site Data

In accordance with the CRA Methodology, only data collected on or after June 28, 1991, were used in the CRA. Specifically, only data from June 1991 to September 1, 2005, are used in the CRA because these data meet the approved analytical quality assurance (QA)/QC programs established by the Interagency Agreement (IAG) and RFCA. For the CRA, analytical data for samples collected over this time frame constitute a reasonably representative data set for use in calculating concentration estimates for the CRA. For subsurface soil and subsurface sediment, only samples from a depth of up to 8 feet (ft) below ground surface (bgs) were used in the CRA.[3] This was done because it is not anticipated that workers or burrowing animals will dig to depths deeper than 8 ft bgs.

Data used to make accelerated action decisions included field screening methods (gamma spectroscopy and x-ray fluorescence). These data were appropriate for an accelerated action decision because, in accordance with approved SAPs (for example, the Industrial Area [IA] and Buffer Zone [BZ] SAP), field screening methods were approved as a conservative method to determine when to take an accelerated action. However, these data are inappropriate for decision making in the RI/FS, because field screening QC elements do not meet specific RI/FS QA/QC requirements (EPA 1988), and therefore, these data are not used in the CRA.

The sampling data used for the HHRA (that is, used for evaluating direct contact pathways including incidental ingestion, inhalation, dermal contact, and external radiation that were evaluated on an EU basis) and ERA for each EU are as follows:

[3] Subsurface soil samples are often collected over a large depth interval. All samples with a starting depth less than or equal to 8 ft bgs and an ending depth greater than 0.5 ft bgs were included, even if the ending depth was greater than 8 ft.

- Combined surface soil/surface sediment data (HHRA);
- Combined subsurface soil/subsurface sediment data (HHRA);
- Surface soil data (ERA); and
- Subsurface soil data (ERA).

For the HHRA, the surface soil and surface sediment data were combined into one medium because both are surficial media and exposure patterns are assumed to be similar. For the same reason, the subsurface soil and subsurface sediment data were also combined for the HHRA.

Sitewide evaluations in the HHRA (that is, evaluations for exposure pathways including ingestion of surface water and exposure to volatile organic compounds (VOCs) in indoor air that were performed on a sitewide basis) were performed using the following data:

- Groundwater data (indoor air pathway);
- Subsurface soil/subsurface sediment data (indoor air pathway); and
- Surface water data.

For the AEUs (ERA) the following data were used:

- Sediment data; and
- Surface water data.

7.5 Human Health Risk Assessment

7.5.1 Selection of Human Health Contaminants of Concern

In the first step of the HHRA, COCs are identified. This is the hazard assessment portion of the HHRA, in which chemical concentrations in each EU are evaluated to assess whether a quantitative assessment of risks needs to be conducted.

The human health COC selection process (that is, for the direct contact exposure pathways described above that are evaluated on an EU basis) is illustrated on Figure 7.3, and the human health COCs selected for each EU are listed in Table 7.2. On Figure 7.3, chemicals entering the COC selection process, which include all chemicals that were detected at the site, are called potential contaminants of concern (PCOCs). Only those chemicals that are retained for the risk assessment are called COCs.

Based on this process, COCs were identified for surface soil/surface sediment, but not for subsurface soil/subsurface sediment at the site. COCs were identified for 5 of the 12 EUs including the No Name Gulch Drainage EU (NNEU), Upper Walnut Drainage EU (UWNEU), Wind Blown Area EU (WBEU), Upper Woman Drainage EU (UWOEU), and Industrial Area EU (IAEU). The COCs for RFETS include arsenic, vanadium, benzo(a)pyrene, dioxin, and plutonium 239/240, as shown in Table 7.2.

7.5.2 Human Health Exposure Assessment

An exposure assessment is conducted to evaluate the ways by which people might be exposed to the COCs at a site (that is, the exposure pathways) and estimate the amount and duration of the exposure. People may be exposed to chemicals by breathing, touching, or consuming (in some cases incidentally) contaminated air, soil, water, or food. The quantity of chemicals that people take in is affected by the land use of the site and the associated activities. Therefore, land use and expected activities are important considerations in risk assessments. Anticipated site uses and exposures are described below.

Overview of Potential Exposures

The Site Conceptual Model (SCM) provides an overview of potential human exposures at RFETS. It describes what kind of human populations may be present, through which environmental media humans may be exposed, and through which pathways exposure may occur. The SCM is illustrated on Figure 7.4 and is described in the following sections.

The future land use for RFETS is a wildlife refuge and, therefore, human populations who may be present include wildlife refuge worker (WRW) and wildlife refuge visitor (WRV) receptors. Workers may staff a visitor center, monitor and maintain the trail system, and track the on-site wildlife populations. Visitors may hike, bike, and bird watch at RFETS. WRW receptors are assumed to be adults, while WRV receptors will likely include both adults and children.

Workers and visitors could theoretically contact contaminants in surface soil, subsurface soil, sediment, surface water, and groundwater. All exposure pathways included in the SCM are identified as complete (meaning that exposure through the pathway is at least theoretically possible). In addition, the pathways are identified as either significant or insignificant. Insignificant pathways are those that are associated with such low exposure that there will be negligible risk even if exposure occurs. The significant pathways were evaluated on an EU basis and risk calculations are only performed for significant pathways in the individual EU volumes (Volumes 3 through 14 of Appendix A of the RI/FS Report). However, pathways considered to be insignificant are evaluated to ensure that the pathways are appropriately identified as such.

The following exposure pathways are identified as potentially complete and significant in the SCM:

- Incidental ingestion of surface soil/surface sediment;
- Inhalation of dust released from surface soil/surface sediment;
- Dermal exposure to surface soil/surface sediment;

- External irradiation exposure from surface soil/surface sediment;
- Incidental ingestion of subsurface soil/subsurface sediment;
- Inhalation of particulates released from subsurface soil/subsurface sediment;
- Dermal exposure to subsurface soil/subsurface sediment; and
- External irradiation exposure from subsurface soil/subsurface sediment.

These pathways are quantitatively characterized for an EU if COCs are identified. As described above, COCs were identified for surface soil/surface sediment in 5 of the 12 EUs. However, COCs were not identified for subsurface soil/subsurface sediment in any EU. Therefore, quantitative risk characterization for subsurface soil/subsurface sediment was not performed.

The following exposure pathways are identified as insignificant in the SCM:

- Incidental ingestion of and dermal contact with surface water;
- Inhalation of volatiles released from subsurface soil/subsurface sediment or from groundwater to indoor air; and
- Ingestion of deer and/or grazing animals.

The following section presents the results of the analyses that were conducted to confirm that these pathways were correctly identified as insignificant.

Evaluation of Surface Water, Indoor Air, and Ingestion of Deer and Grazing Animal Pathways

The exposure pathways (that is, incidental ingestion of and dermal contact with surface water, inhalation of volatiles released from subsurface soil/subsurface sediment or from groundwater to indoor air, and ingestion of deer and/or grazing animals) that were identified as insignificant in the CRA Methodology were evaluated on a sitewide basis, as discussed below. Analyses were conducted to confirm that these pathways were correctly identified as insignificant. Additional detail for these analyses is presented in Appendix A, Volume 2, Attachment 4 of the RI/FS Report.

<u>Surface Water Pathway</u>

The WRW and WRV may contact surface water while working or recreating on the site near streams or seeps. In areas where chemicals have been detected in surface water, people who contact surface water may be exposed to these chemicals. However, because the chemical concentrations in surface water are generally low and any contact with surface water is expected to be infrequent and of short duration, the surface water exposure pathway is not considered significant.

The surface water exposure pathway was evaluated by comparing the maximum detected concentrations (MDCs) of analytes in surface water[4] to preliminary remediation goals (PRGs) for surface water that were developed for the CRA Methodology.[5] The surface water PRGs are based on the WRW receptor and include exposure by the incidental ingestion route only. Dermal exposure was not included in the PRG calculations because it is generally assumed that incidental ingestion is the primary exposure route for receptors for surface water. For the analytes with an MDC greater than the PRG, a Tier 1 exposure point concentration (EPC) was calculated (see Section 7.5.2.3 for a description of Tier 1 EPCs).

Exceedances of surface water PRGs occurred within three EUs: the IAEU, UWNEU, and UWOEU. For analytes with concentrations that exceeded the PRG, the frequency of exceedances was less than 2 percent for any given analyte and EU, and exceedances were no more than six times the PRG. In most cases, these exceedances occurred prior to 2000, and more recent sampling (that is, post-2000) has confirmed that concentrations are well below the PRGs. Only arsenic, nitrate, and uranium-233/234 in the IAEU, and tetrachloroethene and trichloroethene in the UWNEU have MDCs from the most recent sampling events greater than the PRGs. None of these analytes have Tier 1 EPC results for recent samples that exceed the PRGs. Therefore, based on results of this evaluation, human exposure to these analytes in surface water is not a significant pathway.

<u>Indoor Air Inhalation Pathway</u>

Volatile chemicals have been detected in the subsurface in some sampling locations on site. If a building is erected over these sampling locations in the future, the volatile chemicals may migrate through the building foundation indoors and be subsequently inhaled by people. The indoor air inhalation pathway is not considered significant for most areas of the site.

The evaluation for the indoor air inhalation pathway was performed by comparing the MDCs of VOCs in subsurface soil/subsurface sediment and groundwater to PRGs for indoor air. The PRGs were developed in the CRA Methodology using the Johnson and Ettinger Indoor Air Model which has been endorsed by EPA (EPA 2000). This model estimates migration of volatile compounds in the subsurface into air inside a building. Assuming that these compounds are then inhaled by people, the model is used to develop acceptable concentrations for chemicals in the subsurface. Site-specific exposure assumptions for WRW receptors at RFETS were used in the model.

The MDCs of volatile compounds in subsurface soil/subsurface sediment and groundwater were compared to the PRGs, and maps were created showing all locations where maximum concentrations (that is, maximum concentrations measured at a groundwater well or in a soil boring) exceeded the PRGs (Figure 7.5 and Figure 7.6).

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[4] The surface water data set includes samples from streams and seeps.

[5] Surface water PRGs developed for the CRA Methodology are not the standards specified in the Colorado Water Quality Control Regulations, which are the applicable or relevant and appropriate requirements (ARARs) for surface water. This surface water evaluation for the CRA using PRGs is to determine whether surface water contamination may pose a significant risk to the WRW.

Most of the locations with volatilization PRG exceedances are within or near the IAEU. In these locations, the indoor air inhalation pathway is potentially significant if buildings were constructed there. In locations where there are no exceedances of the volatilization PRGs, the indoor air inhalation pathway is assumed to be insignificant. The results of this evaluation will be further evaluated in the Corrective Measures Study (CMS) – FS.

Ingestion of Deer and Grazing Animals Pathway

The Rocky Flats National Wildlife Refuge Final Comprehensive Conservation Plan (CCP) and Environmental Impact Statement (EIS) includes a limited public hunting program at the site. The program is described as a controlled youth and/or disabled person's deer and/or elk hunting program occurring a few weekends a year. However, the program may be extended to include a wider human population in the future. Use of livestock for weed control on the site is also a possible future consideration. For these reasons, ingestion of meat from animals on the site is a possibility, and the significance of this exposure pathway is further evaluated.

The evaluation was conducted by comparing the potential risks from the meat ingestion pathway to the total potential risk for Rocky Flats visitors. Because any contaminants in deer and livestock would be associated with surface soil (through incidental ingestion of soil during feeding and ingestion of contaminated plants), the risk from the meat ingestion pathway is compared to that for other surface soil exposure pathways.

The meat ingestion pathway was evaluated for radionuclides only. Risks were calculated using the Residual Radioactivity (RESRAD) computer model with sitewide radionuclide concentrations. Because this analysis was conducted before completion of the accelerated actions, some of the data did not reflect conditions that would exist after the cleanup (that is, lower contaminant concentrations). The existing data set, therefore, was modified by reducing all reported radionuclide concentrations above the action levels (ALs) for soil to the ALs. The upper confidence limit (UCL) concentrations were then calculated using the modified data set. Risks were estimated assuming that one individual consumes venison taken from Rocky Flats every year for 30 years. Based on the limited hunting proposed at Rocky Flats in the future, this is likely an overestimation. In addition, the evaluation of venison consumption is a conservative estimate of consumption of meat from other livestock that may graze on the site.

The results from RESRAD indicate that the individual risks by this exposure pathway and the total risks are lower than EPA's acceptable risk range of 1×10^{-4} to 1×10^{-6}. In addition, the relative contribution of venison consumption to the total risk from soil exposure is low (less than 10 percent in all cases) and, consequently, the meat consumption pathway may be considered insignificant relative to the other soil exposure pathways.

This conclusion was supported by the results of another risk assessment for the deer ingestion pathway that was conducted by the U.S. Fish and Wildlife Service (USFWS). The risk levels presented by USFWS for deer muscle and liver consumption range from 2×10^{-9} to 7×10^{-8} for a 1-year exposure duration. These risks are highly conservative because they are based on detected radionuclide concentrations only, without consideration for the large percentage of nondetections. Moreover, according to USFWS (Todd and Sattelberg 2004), the risk levels associated with the deer tissue samples were developed using extremely conservative assumptions (that is, one individual consumes the liver and muscle tissue from one entire deer every year) and, therefore, calculations likely overestimate the risk associated with deer tissue consumption.

Exposure Point Concentrations

EPCs are calculated for the COCs identified in surface soil/surface sediment. EPCs are an estimate of COC concentrations to which people may be exposed. Two types of concentration estimates are used to evaluate exposure at RFETS: Tier 1 and Tier 2.

It is usually assumed that the best estimate for the EPC is the average concentration for an area. Because there is some uncertainty in having measured the average concentration accurately, a value higher than the calculated average is used in risk assessments. This value is the UCL on the average or mean concentration within an area. The 95 percent UCL is defined as the value that equals or exceeds the true mean with 95 percent confidence. This is the Tier 1 concentration.

If most of the data for an EU have been collected in areas associated with historic releases, and few data points are available for the nonimpacted areas, the Tier 1 EPC is likely to overestimate the concentration for the EU as a whole. Therefore, a second approach is used for the Tier 2 EPCs that equally weighs the data for different subareas of an EU. In this approach, averages are first calculated for 30-acre subareas of an EU. These averages are then combined to calculate an EU-wide average. Due to the uncertainty in having accurately characterized the average, a UCL is again calculated using the 30-acre subarea averages; this UCL is the Tier 2 EPC. In areas where the data are evenly spaced throughout the EU, there are only minor differences between the Tier 1 and Tier 2 EPCs.

Risks for COCs in surface soil and surface sediment are calculated using both Tier 1 and Tier 2 EPCs. The Tier 1 and Tier 2 EPCs used in the risk calculations are provided in Attachment 4 of the individual EU volumes.

Exposure Assumptions

Exposure assumptions are factors that describe how exposure is assumed to occur. Exposure assumptions describe, for example, how long exposure will occur (exposure duration), how often (exposure frequency), and how much air will be inhaled for every hour spent on the site (inhalation rate). Risk assessments typically use values that are intended to be protective of humans (that is, that overestimate rather than underestimate potential exposures). Most assumptions used to evaluate WRW and WRV receptors follow EPA guidelines. In addition, several site-specific assumptions were developed based on the input from the RFCA Parties and other interested parties. Overall, the exposure assumptions and estimates represent the maximum amount of exposure that the WRW and WRV receptors can reasonably be expected to come into contact with, per

EPA guidelines. All exposure assumptions are documented in the regulatory agency-approved CRA Methodology.

Exposure assumptions for the WRW and WRV receptors, including the site-specific parameters, are provided in Table 7.3 and Table 7.4, respectively, for radionuclides, and Table 7.5 and Table 7.6, respectively, for other chemical analytes. These and other exposure assumptions were combined with the EPCs to calculate estimates of exposure.

7.5.3 Human Health Toxicity Assessment

A toxicity assessment is an estimate of how much of a chemical it would take to cause adverse human health effects. Chemicals may cause cancer and a variety of noncancer effects, such as skin rashes, damage to organs, asthma and other respiratory disorders, and nervous system problems. Different chemicals have different potencies, and these are reflected in the toxicity criteria that are used in HHRAs.

Toxicity criteria for the COCs are shown in Table 7.7. These toxicity criteria were used in the risk calculations for the COCs. In addition, the toxicity criteria for these and other analytes were used for the calculation of PRGs; the toxicity criteria for analytes that were not identified as COCs are presented in the CRA Methodology. The toxicity criteria used in the CRA and the PRG calculations have been developed by EPA and other regulatory agencies following a review of all available data for each chemical. Two types of toxicity criteria are used: cancer slope factors (CSFs) and reference doses (RfDs). The former are used to estimate cancer risks, while the latter are used to estimate noncancer health effects. Because one of the COCs for one EU is a radionuclide, a radionuclide dose is also estimated using a computer code that was designed to estimate radiation doses from RESRAD.

7.5.4 Human Health Risk Characterization

In the risk characterization, the estimated exposures are combined with the toxicity criteria to calculate risks. For example, cancer risks are calculated by multiplying the exposure estimate for a COC by the CSF, as illustrated by the following equation:

$$\text{Cancer Risk (unitless)} = \text{Dose Estimate (milligrams per kilogram (mg/kg) - day)} \times \text{CSF (mg/kg - day)}^{-1}$$

For this equation, an EPC is factored together with exposure duration, exposure frequency, body weight, intake rate, and averaging time to produce the dose estimate. The estimated cancer risk represents a probability of a person developing cancer. EPA considers 1 in 1,000,000 to 1 in 10,000 to be the acceptable risk range, where the acceptable risk for each site is determined based on site-specific conditions (In the reports for this site and the results presented in Table 7.7, a 1-in-1,000,000 risk is written as 1E-06 or 1 x 10^{-6}).

Noncancer health effects are calculated by dividing the exposure estimate by the noncancer toxicity criterion (RfD). The ratio between the two levels is called a hazard quotient (HQ), and an HQ less than 1 indicates that people are unlikely to have adverse health effects. An HQ is based on a single contaminant while a HI is based on the summation of HQs of multiple contaminants.

For RFETS, risks are estimated for exposure to surface soil/surface sediment by workers and visitors in five EUs where COCs were identified, including the IAEU, UWOEU, NNEU, WBEU, and UWNEU. No COCs were identified for subsurface soil/subsurface sediment and, therefore, a quantitative risk characterization for this medium is not necessary. Cancer risks, noncancer risks, and radionuclide doses are estimated for surface soil/surface sediment.

A summary of cancer and noncancer risks and dose estimates for future WRW and WRV receptors at RFETS is presented in Table 7.8. Risks were calculated for five EUs for which COCs were identified. The cancer risk estimates for the five EUs were at the lower end of EPA's 1 x 10^{-6} to 1 x 10^{-4} risk range (that is, less than 1 x 10^{-5}). The noncancer health effect estimates (HIs) were all below 1, indicating noncancer health effects are unlikely.

Radiological dose estimates have been developed using RESRAD, which can be programmed to evaluate all applicable exposure pathways at a site. The dose estimate for plutonium for the WRW is 0.3 mrem/yr and for the WRV child it is 0.2 mrem/yr. These dose estimates are well below the acceptable annual radiation dose of 25 mrem specified in the Colorado Standards for Protection Against Radiation (CDPHE 2005).

Background cancer risks and noncancer health effects from naturally occurring metals at RFETS were calculated on a sitewide basis. All detected metals for which toxicity criteria are available were included in this evaluation. Background cancer risks for WRW and WRV receptors are approximately 2 x 10^{-6} and HIs are 0.3 for the WRW and 0.1 for the WRV. These estimates are similar to the results for the 5 EUs where COCs were identified and risks and noncancer hazards were quantitatively evaluated.

7.5.5 Human Health Uncertainty Discussion

Risk assessments are designed to be protective of human health and, as such, employ conservative EPC estimates, exposure assumptions, and toxicity criteria. Using the UCL rather than the average concentration, even when the site has been well characterized, helps ensure that the EPC is protective of human health. The exposure assumptions are expected to overestimate typical exposures at a site. For example, it is highly unlikely that an individual would ingest 100 milligrams of soil every day when working or recreating at the site or that soil would come in contact with a large percentage of his or her body. In addition, there are safety factors built into the toxicity criteria. Depending on the amount of uncertainty in the data, scientists may apply uncertainty factors of 100 to 10,000 to the toxicity criteria.

Some uncertainties are associated with the data sets used for the HHRA (for example, elevated detection limits for some analytes and limited special coverage for some analyte groups within some EUs). However, the data are considered adequate for risk assessment and risk management decision making.

There are also uncertainties associated with the lack of PRGs for some analytes and there is a potential for underestimation of cumulative risks because these analytes are not evaluated in the HHRA. However, the inorganic and organic analytes that do not have PRGs are not usually included in HHRAs because they are not expected to result in significant human health impacts. PRGs are available for all individual radionuclides.

Because, in general, many conservative assumptions are combined, it is expected that the calculated risk for RFETS is protective of any potential future exposures for WRW and WRV receptors.

7.6 Ecological Risk Assessment

Two types of ecological receptors were evaluated as part of the ERA: terrestrial and aquatic. The terrestrial ecological analysis was conducted for the same EUs as defined for the HHRA (Figure 7.1). A sitewide analysis was also conducted for wide-ranging terrestrial receptors that may range over the entire site (that is, coyotes and deer). The aquatic ecological analysis was conducted on a watershed-specific basis using the AEUs shown on Figure 7.2.

An overview of the key issues and findings of the ERA is provided below.

7.6.1 Ecological Site Conceptual Model

The ecological SCM for RFETS reflects the most representative ecological receptors for the site, based on the future land use as a wildlife refuge, and identifies the potential pathways by which ecological receptors may be exposed to ECOPCs (Figure 7.7). These identified pathways become the focus of the ERA.

The SCM identifies pathways that are potentially complete as well as potentially significant pathways for exposure of the ecological receptor groups. Some of the pathways (inhalation and dermal contact with surface water for terrestrial fauna) were designated in the CRA Methodology as potentially complete but insignificant, and are therefore not quantitatively evaluated.

7.6.2 Ecological Risk Management Goals and Endpoints

Development of overall site management goals, assessment endpoints, and measurement endpoints is an important part of ERAs. Site management goals define the assessment endpoints or ecological values that are to be protected at a site. Assessment endpoints are the explicit description of the ecological values to be protected as a result of management actions at a site, while measurement endpoints are the data and analysis tools that are used to evaluate the assessment endpoints.

The overall risk management goal identified for use in this ERA is:

> *Site conditions due to residual contamination should not represent significant risk of adverse ecological effects to receptors from exposure to site-related residual contamination.*

Significant risk of adverse ecological effects implies toxicity that reduces survivorship or reproductive capability and thereby threatens populations or communities of wildlife at RFETS. For species that have additional regulatory protection due to their rare or threatened status, such as Preble's meadow jumping mouse (PMJM), significant adverse effects can occur even if individuals are affected. Therefore, the assessment for the PMJM addresses the potential for individual mice to be adversely affected by contact with ECOPCs. For other species with stable or healthy populations, the assessment focused on population-level effects, where some individuals may suffer adverse effects however the effects are not ecologically meaningful because the overall site population is not significantly affected.

For non-PMJM receptors, including aquatic organisms, the risk management goal and endpoints are:

- **Goal –** Prevent adverse effects on populations due to lethal, mutagenic, reproductive, systemic, or general toxic effects of contact with ECOPCs from the site.

- **Assessment endpoints –** Survival, growth, and reproduction adequate to sustain receptor populations at the site.

- **Measurement endpoints –** Comparison of total intake measures calculated from receptor-specific ingestion models, ECOPCs from abiotic data (soil and surface water), and food items to toxicity reference values (TRVs) or comparison of ECOPC concentrations to reference concentrations.

The receptors evaluated as assessment endpoints for the site are listed in Table 7.9. These receptors were identified based on ecological functional groups, and representative species were then identified to focus the analysis.

For PMJM, the overall risk management goal and endpoints are:

- **Goal –** Prevent adverse effects on individual PMJM due to lethal, mutagenic, reproductive, systemic, or general toxic effects of contact with ECOPCs from the site.

- **Assessment endpoints –** Survival, growth, and reproduction of individual PMJM at the site.

- **Measurement endpoints –** Comparison of total intake measures calculated from PMJM-specific ingestion models, ECOPCs from abiotic data (soil and surface water), and food items to TRVs.

If an ECOPC presents a significant risk of adverse ecological effects, the ECOPC is considered an ecological contaminant of concern (ECOC), and the FS would address achieving the risk management goal for the ERA.

7.6.3 Identification of Ecological Contaminants of Potential Concern

Identification of ECOPCs to be evaluated in detail in the risk characterization portion of the CRA was based on a comparison of site media concentrations (surface soil, subsurface soil, sediment, and surface water) to ecological screening levels (ESLs) for representative ecological receptor groups. ESLs for wildlife were based primarily on potential ingestion of ecological contaminants of interest (ECOIs) in abiotic media, forage, and prey, and the transfer of ECOIs among these media. ESLs for aquatic receptors were based upon concentrations protective of the aquatic community as a whole based on the total exposure from either sediment or surface water. Figure 7.8 depicts the process used to identify ECOPCs for the ERA.

Because of the presence of the special-status PMJM receptor that requires a different level of protection than the other receptors, the ECOPC identification process consists of two parallel evaluations, one for PMJM and one for non-PMJM receptors. Two different data sets were used in these evaluations, one including all data for an EU, and one including only sampling locations within PMJM habitat. A summary of the ECOPCs identified for each EU is presented in Table 7.10. For the AEUs, the ECOPCs for surface water and sediment are presented in Table 7.11 and Table 7.12, respectively.

7.6.4 Ecological Exposure Assessment

Exposure results from contact between a receptor and ECOPCs in an environmental medium. For exposure to occur a release must have occurred and a receptor must have a point of potential contact with that medium. The potential for receptor contact and identification of exposure routes are shown on the SCM (Figure 7.7).

The exposure assessment describes the relationships and equations used to estimate how much of a given chemical in a given medium is taken up by the receptor via a given exposure route. Two basic exposure models are used in the CRA: the concentration-based model (used for aquatic receptors, terrestrial plants, and invertebrates) and a dosage-based model (used for wildlife receptors). The concentration-based exposure model is a simple method where the EPC is representative of the total exposure to that receptor. The exposure-based model used for avian and mammalian receptors is based on estimated exposure to contaminants through multiple pathways including the ingestion of soils, food items (plant, invertebrate, and bird/mammal tissue), and surface water.

Receptor-Specific Exposure Assessment

Exposure to ecological receptors was estimated for representative species of functional groups based on taxonomy, habitat, and feeding behavior (Table 7.9). For wildlife receptors, exposure was calculated in the form of a daily rate of intake for each ECOPC/receptor pair. For aquatic receptors, terrestrial plants, and invertebrates, exposure was estimated using estimates of media concentrations.

Exposures to terrestrial ecological receptors were calculated on an EU-by-EU basis. Wide-ranging species that generally utilize areas larger than the EUs (that is, coyote and mule deer) were also addressed separately using sitewide data (Appendix A, Volume 15A). As described previously, the EUs are reasonable aggregations of common source areas, hydrological systems, and habitat for assessing ecological risk. Only the PMJM receptor was evaluated on a sub-EU basis due to its status as a protected species and the individual level of protection afforded to it under the assessment endpoints. PMJM receptors were evaluated using functional habitat patches (Figure 7.9). The habitat patches were designed to represent realistic home ranges for individual PMJM or sub-populations of PMJM.

Exposure to aquatic receptors was calculated on a watershed-specific basis, but also considered smaller, but important, habitat areas such as ponds within each AEU.

Exposure Point Concentrations

EPCs were estimated using Tier 1 and Tier 2 values, as described previously for the HHRA. The EPC used for the small-home-range receptors is the 95 percent UCL of the 90th percentile (upper tolerance limit [UTL]), or the MDC in the event that the UTL is greater than the MDC. The EPC for large-home-range receptors is the UCL of the mean, or the MDC in the event that the UCL is greater than the MDC. For the PMJM, the Tier 1 UCLs for the habitat patches were used to evaluate risks. For the aquatic receptors, Tier 1 UTLs were used as the EPCs for sediment and surface water. The EPCs (that is, UCLs and UTLs) are conservative estimates of average exposure for the various receptors.

7.6.5 Ecological Toxicity Assessment

Calculated intakes (birds and mammals) or exposure concentrations were then compared to the toxicological properties of each ECOPC. For wildlife receptors, laboratory-based toxicity benchmarks are termed TRVs and consist of several basic types. The no-observed-adverse-effect-level (NOAEL) TRVs are intake rates or soil concentrations below which no ecologically significant effects are expected. The NOAEL TRVs were used to calculate the NOAEL ESLs employed in screening steps of the ECOPC identification process to eliminate chemicals that have no potential to cause risk to the representative receptors. The lowest-observed-adverse-effects-level (LOAEL) TRV is a concentration above which the potential for some ecologically significant adverse effect could be present. Threshold TRVs represent the hypothetical dose at which the response in a group of exposed organisms may first begin to be significantly greater than in unexposed receptors and are calculated as the geometric mean of the NOAEL and LOAEL. Threshold TRVs were calculated based on specific data quality rules for use in the ECOPC identification process for a small subset of ECOIs in the CRA Methodology. TRVs for ECOPCs in each EU were obtained from the CRA Methodology.

For concentration-based exposure models, the no observed effect concentration (NOEC) is analogous to the NOAEL TRV, but represents a concentration in an environmental medium below which no effects are expected. Lowest observed effect concentrations (LOECs) are analogous to the LOAEL TRVs representing a concentration in an environmental medium above which the potential for some ecologically significant adverse effect could be present. The LOECs were not previously presented in the CRA

Methodology; however, LOECs that represented the same requirements for LOAEL TRVs as outlined in the CRA Methodology have since been selected.

7.6.6 Ecological Risk Characterization

The risk characterization process defines a range of potential risks to receptors from the ECOPCs. Characterization of risk focuses on the overall results for each assessment endpoint. The overall risk is then summarized for each receptor group and level of biological organization (that is, individual or population level of protection), as appropriate for the assessment endpoints. When interpreting the results of the risk characterization to all receptors (except the PMJM), it is important to consider that the assessment endpoint to non-PMJM receptors is based on the sustainability of exposed populations, and risks to some individuals in a population may be acceptable if the population is expected to remain healthy and stable. For the PMJM, the interpretation of the HQ results is based on potential risks to individuals rather than populations.

The risk characterization provided for each EU and AEU has two main components: the risk estimation and the risk description. The risk estimation summarizes results of the analysis, identifying the receptors and ECOPCs and a range of potential risks as well as the locations/EUs/AEUs where risk may be present. The risk description then provides context for the analysis, including uncertainties related to each ECOPC and an interpretation of overall results.

Risk Estimation

The risk estimation summarizes results of the analysis, identifying the receptors and ECOPCs and a range of potential risks and the EUs/AEUs where risk may be present. HQs are the major tool used in the risk estimations for each EU and AEU. The HQ is a ratio of the estimated exposure concentration to the TRV where:

$$\boxed{HQ = Exposure/TRV}$$

In general, if the NOAEL-based HQ is less than 1, no adverse effects are predicted. If the LOAEL-based HQ is less than 1 but the NOAEL-based HQ is above 1, some adverse effects are possible; however, it is expected that the magnitude and frequency of the effects will usually be low (assuming the magnitude and severity of the response at the LOAEL are not large and the endpoint of the LOAEL accurately reflects the assessment endpoints for that receptor). If the LOAEL-based HQ is greater than or equal to 1, the risk of an adverse effect is of potential concern, with the probability and/or severity of effect tending to increase as the value of the HQ increases.

For the EUs, HQs were calculated for each ECOPC/receptor pair based on the exposures estimated and TRVs described above. The NOAEL and NOEC TRVs, along with default screening-level exposure assumptions, are first used to calculate HQs. However, these no-effects HQs are typically considered as screening-level results and tend to overestimate risks for the site. EPA risk assessment guidance (1997) recommends a tiered approach to evaluation, and following the first tier of evaluation “the risk assessor should review the assumptions used (e.g., 100 percent bioavailability) against values reported in the literature (e.g., only up to 60 percent for a particular contaminant), and consider how the HQs would change if more realistic conservative assumptions were used instead." Accordingly, LOAEL and threshold TRVs are also used in this evaluation to calculate HQs. Where LOAEL HQs greater than 1 are calculated using default exposure assumptions, and the uncertainty analysis indicates that alternative bioaccumulation factors (BAFs) (median values) and/or additional TRVs would be beneficial to reduce uncertainty and conservatism, refined HQs are calculated.

HQs for the AEUs were calculated using the chronic ESLs and acute criteria for surface water and NOECs and LOECs for sediment.

ECOPC-Specific Uncertainty Discussion

Uncertainty in the risk estimation is a major consideration when describing risks. The risk characterization process uses environmental data to estimate intake and toxicity through the use of models and professional judgment. While steps are taken to minimize this uncertainty, no ERA is without considerable levels of uncertainty.

For each ECOPC discussed in the risk estimation, a discussion of the uncertainties related to the toxicological properties of the TRVs selected is presented. Additionally, because very little food tissue data were available for use, the uncertainties related to the estimation of ECOPC concentrations in prey tissues were also provided for each ECOPC. If high levels of uncertainty were found for a specific ECOPC in terms of the TRVs or BAFs, alternative TRVs or BAFs were used in a refined analysis along with the rationale for their selection.

Risk Description

The risk description provides context for the analysis, including uncertainties related to each ECOPC and an interpretation of overall results. The risk description incorporates results of the risk estimates along with the uncertainties associated with the risk estimations, refined HQ calculations, and other lines of evidence to evaluate potential chemical effects on ecological receptors at RFETS following accelerated actions. Information considered in the risk description includes receptor groups potentially affected, type of TRV exceeded (for example, NOAEL versus LOAEL), relation of EU or AEU concentrations to other criteria such as EPA ecological soil screening levels (EcoSSLs), and whether refined HQs, and risk are above background conditions. In addition, other site-specific and regional factors are considered, such as the use of a given ECOPC within the EU or AEU related to historical RFETS activities, comparison of ECOPC concentrations within each EU or AEU to the rest of RFETS as they relate to background, and/or comparison to regional background concentrations.

As discussed above, if a NOAEL-based HQ is less than 1, no adverse effects are predicted. If the LOAEL-based HQ is less than 1 but the NOAEL-based HQ is above 1, some adverse effects are possible, but it is expected that the magnitude and frequency of the effects will usually be low. If the LOAEL-based HQ is greater than or equal to 1, the risk of an adverse effect is potentially significant, with the probability and/or severity of effect tending to increase as the value of the HQ increases.

The conclusions drawn in the ERA considered results from the default HQ calculations, chemical-specific uncertainty evaluations, HQs calculated using additional BAFs and TRVs in a refined analysis, background risk and ecosystem health data in making the final risk estimation.

7.6.7 General Ecological Uncertainty Analysis

Quantitative evaluation of ecological risks is limited by uncertainties regarding the assumptions used to predict risk and the data available for quantifying risk. These limitations are usually addressed by making estimates based on the data available or by making assumptions based on professional judgment when data are limited. Because of these assumptions and estimates, the results of the risk calculations themselves are uncertain, and it is important for risk managers and the public to view the results of the risk assessment with this in mind. The general uncertainties related to the ERA are provided in Appendix A, Volume 2 of the RI/FS Report. Those specific to each ERA are summarized in the EU- or AEU-specific volume of the CRA.

7.6.8 Ecological Background Risk Analysis

As part of the uncertainty analysis, risks to the receptors evaluated in the ERA were also evaluated based on concentrations to which they could be exposed in background areas. Background risks were calculated for surface soil, surface water, and sediment.

The BAFs, receptor parameters, and TRVs are for the default scenario provided in the CRA Methodology. HQs were calculated using both the NOAEL and LOAEL TRVs. Where they were provided in the CRA Methodology, threshold TRVs were also used to calculate background risks. The EPCs used for the background risk analysis were the UCL and UTL of background surface soil concentrations.

LOAEL HQs were calculated using the appropriate EPCs for metals in background surface soil. HQs are greater than 1 for at least one receptor for cadmium, chromium, lead, nickel, vanadium, and zinc. LOAEL HQs greater than 1 using background EPCs were calculated for three receptors for chromium and nickel. Background HQs were also calculated for surface water and sediment for the AEUs using UTLs as EPCs. HQs were calculated using chronic ESLs and acute criteria for surface water and NOECs and LOECs for sediment. Background risks were taken into consideration in the risk-based conclusions for each ECOPC/receptor pair for the EUs, and for surface water and sediment ECOPCs for the AEUs .

7.7 Results

This section presents an overview of the methods and approaches used in the CRA for RFETS. The overall results of the CRA are summarized below.

7.7.1 Human Health Risk Assessment

A human health risk assessment was conducted separately for each of the 12 EUs identified for RFETS. The HHRA consisted of a data evaluation, COC selection step, exposure assessment, toxicity assessment, and risk characterization. Exposure and toxicity assessments and the risk characterization were only performed if COCs were identified for at least one medium in an EU.

COCs were identified for surface soil/surface sediment, but not for subsurface soil/subsurface sediment. Five of the 12 EUs have COCs in surface soil/surface sediment, as follows:

- NNEU (vanadium);
- UWNEU (benzo[a]pyrene);
- WBEU (arsenic and plutonium-239/240);
- UWOEU (benzo[a]pyrene and dioxins); and
- IAEU (arsenic and benzo[a]pyrene).

The COCs were quantitatively evaluated for the WRW and WRV receptors. Cancer risks, noncancer health effects estimates and total annual radiation doses were calculated and presented in Table 7.8. Risk calculations were performed using both Tier 1 and Tier 2 EPCs. The cancer risk estimates for the five EUs were at the lower end of EPA's 1 x 10^{-6} to-1 x 10^{-4} risk range (that is, less than 1 x 10^{-5}). The noncancer health effects estimates (HIs) were all below 1, indicating noncancer health effects are unlikely. Dose estimates were less than 1 mrem/yr. For the seven EUs that do not have COCs, risks are expected to be similar to risks associated with background conditions.

Background cancer risk and noncancer health effects from naturally occurring metals at RFETS were calculated on a sitewide basis. All detected metals for which toxicity criteria are available were included in this evaluation. The background cancer risk for the WRW and WRV is approximately 2 x 10^{-6} and HIs are 0.3 for the WRW and 0.1 for the WRV.

No Name Gulch Drainage EU

Noncancer health effects are estimated for vanadium in the NNEU. The noncancer health effects estimates (HIs) were all below 1, indicating noncancer health effects are unlikely for WRW and WRV receptors at RFETS.

Upper Walnut Drainage EU

The cancer risk estimates for the UWNEU are from exposure to benzo(a)pyrene (1 x 10^{-6}). Although identified as a COC in the UWNEU, benzo(a)pyrene has not been directly associated with any historical source areas at the site, but could be associated with traffic, pavement degradation, or pavement operations.

Wind Blown Area EU

The cancer risk estimates for the WBEU are estimated for exposure to plutonium (2 x 10^{-6}) and arsenic (2 x 10^{-6}). Arsenic concentrations in this EU are also similar to background concentrations. The Tier 1 dose estimate for plutonium for the WRW is 0.3 mrem/yr and for the WRV child it is 0.2 mrem/yr. These dose estimates are well below the acceptable annual radiation dose of 25 mrem specified in the Colorado Standards for Protection Against Radiation.

Noncancer health effects are estimated for arsenic in the WBEU. The noncancer health effects estimates (HIs) were all below 1, indicating noncancer health effects are unlikely for WRW and WRV receptors at RFETS.

Upper Woman Drainage EU

The cancer risk estimates for the WRW in the UWOEU are estimated for exposure to benzo(a)pyrene (7 x 10^{-6}) and to dioxins (2 x 10^{-6}). It is important to note that the benzo(a)pyrene samples that were used in the risk estimate for the UWOEU are located in an area that is now several feet below the Original Landfill cover. As part of the uncertainty analysis for the HHRA, the EPC for benzo(a)pyrene was recalculated using only samples from the UWOEU that are located outside the landfill cover. This EPC is less than the PRG thus benzo(a)pyrene would not be identified as a COC for the portion of the UWOEU that is outside the landfill cover. Accordingly, risks associated with exposure to benzo(a)pyrene in the areas of the EU outside the landfill cover are less than 1 x 10^{-6}.

In addition, the soil containing dioxins in the UWOEU is located approximately 20 ft bgs where exposure is not anticipated. Because the dioxin samples in this EU were confirmation samples collected after an accelerated action, the samples were classified as surface soil and included in the risk assessment.

Even without taking into account the depth of contamination in the UWOEU, the site is still considered protective of human health because the cancer risk falls within the acceptable range of 1 x 10^{-6} to 1 x 10^{-4} cancer risks for dioxins and benzo(a)pyrene.

Industrial Area (IA) EU

The cancer risk estimates for the IAEU are from exposure to arsenic (2 x 10^{-6}) and benzo(a)pyrene (1 x 10^{-6}). Arsenic concentrations in this EU are similar to background concentrations. Although identified as a COC in the IAEU, benzo(a)pyrene has not been directly associated with any historical source areas at the site, but could be associated with traffic, pavement degradation, or pavement operations.

Noncancer health effects are estimated for arsenic in the IAEU. The noncancer health effects estimates (HIs) were all below 1, indicating noncancer health effects are unlikely for WRW and WRV receptors at RFETS.

7.7.2 Ecological Risk Assessment

An ERA for terrestrial receptors was conducted separately for each of the 12 EUs identified for RFETS. In addition, an ERA for aquatic receptors was conducted for each of the seven AEUs. The ERA risk conclusions are summarized in Table 7.13. The ERA consisted of a data evaluation, ECOPC identification step, exposure assessment, toxicity assessment, and risk characterization. Exposure and toxicity assessments and the risk characterization were only performed if ECOPCs were identified for at least one medium in an EU or AEU.

Of the 12 EUs that were evaluated for potential risk to terrestrial ecological receptors, 8 EUs had ECOPCs identified for surface soil during risk characterization for non-PMJM receptors. PMJM receptors were evaluated for eight EUs; of these EUs, five had surface soil ECOPCs for the PMJM receptor (Table 7.10). The three EUs that did not have any ECOPCs identified for either non-PMJM or PMJM receptors (West Area EU [WAEU], Southeast Buffer Zone EU [SEEU] Area, and Southwest Buffer Zone EU [SWEU] Area) are part of the BZ of RFETS. No radionuclides were identified as ECOPCs for PMJM or non-PMJM receptors in any medium within any EU. No ECOPCs were identified for subsurface soil for any of the EUs.

The HQs for the ECOPC/receptor pairs in the EUs indicate the potential for adverse effects to PMJM and non-PMJM receptors range from low to moderate in the EUs where ECOPCs were identified. Results of the uncertainty analysis and background risk calculations were also considered in order to characterize the full range of potential risk and define the uncertainties and conservatism inherent in the HQ models. No significant risks were identified for any receptor in any EU, and no high levels of uncertainty were identified for the EU data sets. Therefore, no ECOCs were identified for any of the EUs or for wide-ranging receptors evaluated in Volume 15A.

As part of the characterization of risk, the ERA also considered the results of ecological monitoring studies that have been conducted since 1991. The purpose of this long-term program was to monitor specific habitats to provide a sitewide database from which to monitor trends in the wildlife populations at RFETS. Although a comprehensive compilation of monitoring results has not been presented, the annual reports of the monitoring program provide localized information and insights on the general health of the Rocky Flats ecosystem. Data collected on wildlife abundance and diversity indicate wildlife species richness remains high at RFETS. Overall, low risk to survival, growth, and reproduction is predicted for the ecological receptors evaluated at RFETS. These data appear to support conclusions that there are no significant risks to receptor populations at RFETS.

Of the seven AEUs that were evaluated for potential risk to aquatic ecological receptors, five AEUs had ECOPCs identified for surface water and sediment (Table 7.11 and Table 7.12, respectively). The two AEUs that did not have ECOPCs identified are the Rock Creek AEU (RC AEU) and Southeast AEU (SE AEU), both located in the BZ of RFETS. The ECOPCs were evaluated in the risk characterization using multiple lines of evidence including an HQ assessment using chemical data and review of drainage-specific conclusions from previous studies for ECOPCs. As discussed for each AEU, the previous studies included tissue analyses, aquatic population studies, toxicity bioassays, waterfowl and wading bird exposure studies, and contaminant loading analyses.

The AEU assessments indicate there are no continuing, significant risks to aquatic life from residual ECOPCs due to RFETS-related operations. Overall, the aquatic communities in the AEUs are limited by natural environmental conditions (that is, low flows and poor habitat) characteristic of this area along the Colorado Front Range. No additional significant risks above what would be expected to be encountered in the natural environment in the vicinity of the AEUs are predicted for the aquatic life receptors evaluated in the ERA.

While significant risks from exposure to ECOPCs in surface water and sediment are not expected, further monitoring is recommended. Ecological data on species diversity and richness suggest that an ecosystem is present in these AEUs that does not exhibit signs of chemical stress but is limited by habitat quality and hydrology.

The overall conclusions from the ERA indicate site conditions due to residual contamination do not represent significant risk of adverse ecological effects to receptors from exposure to site-related residual contamination and; therefore, no ECOCs were identified.

7.8 Risk Management Decisions and Conclusions of the Comprehensive Risk Assessment

The overall risk management decisions and conclusions of the CRA are summarized below.

7.8.1 Human Health Risk Assessment

All COCs identified in Section 7.7.1 are evaluated in Section 8.0, Contaminant Fate and Transport. However, from a risk management perspective, only one COC, plutonium-239/240 in the WBEU, requires further evaluation in the FS (Sections 10.0 and 11.0). The cancer risk estimated for the WBEU for exposure to plutonium-239/240 is 2×10^{-6}. The Tier 1 dose estimate for plutonium-239/240 for the WRW is 0.3 mrem/yr and for the WRV child it is 0.2 mrem/yr. While RFETS is protective of human health based on the low risk presented by this COC, the FS will evaluate removal of surface soil to reduce the residual plutonium-239/240 contamination to below the 1×10^{-6} WRW risk target concentration.

The indoor air pathway was evaluated on a sitewide basis. Volatile chemicals have been detected in the subsurface in some subsurface soil and groundwater sampling locations of the site at concentrations greater than volatilization PRGs (Figure 7.5 and Figure 7.6, respectively). In these locations, the indoor air inhalation pathway is potentially significant if buildings were constructed there. In locations where there are no exceedances of the volatilization PRGs, the indoor air inhalation pathway is assumed to be insignificant. The results of this evaluation will be further evaluated in the FS.

7.8.2 Ecological Risk Assessment

Based on the results of the ERA for terrestrial receptors, no ECOCs were identified for soil at RFETS. In addition, the ERA for aquatic receptors did not identify any ECOCs for surface water or sediment. The overall conclusions from the ERA indicate that site conditions due to residual contamination do not represent significant risk of adverse ecological effects to receptors from exposure to site-related residual contamination. However, additional surface water, sediment, and ecological monitoring is included in the FS to address uncertainties identified in the ERA.

7.9 References

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TABLES

Table 7.1
Summary of EU Characteristics

EU	Number of Acres	Topography	Predominant Vegetation Type	Number of PMJM Habitat Patches[a]	Number of Historical IHSSs/PACs and UBCs[a]	Topographic and Hydrologic Location Relative to the IA
West Area	468	Upland	Xeric tallgrass prairie	3	1	Upgradient
Rock Creek Drainage	735	Drainage	Mesic mixed grassland and xeric tallgrass prairie	10	0	Upgradient
Inter-Drainage	596	Upland	Xeric tallgrass prairie	3	7	Upgradient
No Name Gulch Drainage	425	Drainage	Mesic mixed grassland, xeric tallgrass prairie, and disturbed reclaimed areas	2	21	Upgradient
Upper Walnut Drainage	403	Drainage	Mesic mixed and reclaimed grassland	5	25	Downgradient
Lower Walnut Drainage	390	Drainage	Mesic mixed grassland	3	1	Downgradient
Wind Blown Area	715	Upland	Mesic mixed grassland and xeric tallgrass prairie	1	46	Downgradient
Upper Woman Drainage	524	Drainage	Mesic mixed grassland and xeric tallgrass prairie	3	23	Crossgradient
Lower Woman Drainage	448	Drainage	Reclaimed and mesic mixed grasslands	7	6	Downgradient
Southwest Buffer Zone Area	476	Upland	Xeric tallgrass prairie and mesic mixed grasslands	3	1	Upgradient
Southeast Buffer Zone Area	579	Upland	Reclaimed and mesic mixed grasslands	3	1	Upgradient
Industrial Area	428	Upland	Disturbed	0	285	N/A

[a] Some IHSSs and PACs extend into more than one EU. Where this is the case, they are counted in each of the EUs in which they occur.
IHSS = Individual Hazardous Substance Site
PAC = Potential Area of Concern
UBC = Under Building Contamination

Table 7.2
Summary of Human Health COCs

Medium	COC	Exposure Unit[a]				
		No Name Gulch Drainage (Volume 6)	Upper Walnut Drainage (Volume 7)	Wind Blown Area (Volume 9)	Upper Woman Drainage (Volume 10)	Industrial Area (Volume 14)
Surface Soil/Surface Sediment[b]	**Inorganics**					
	Arsenic			X		X
	Vanadium	X				
	Organics					
	Benzo(a)pyrene		X		X	X
	2,3,7,8-TCDD TEQ				X	
	Radionuclides					
	Plutonium-239/240			X		

[a] No COCs were identified for any of the other EUs that are not listed here.
[b] No COCs were identified for any other media.

Table 7.3
Radionuclide Exposure Factors Used in Surface Soil/Surface Sediment Intake Calculations for the WRW

Exposure Route/Exposure Factor	Abbreviation	Value	Units	Source
Ingestion				
RI = Cs x IRwss x EFwss x EDw x CF_1				
Radionuclide Intake	RI	radionuclide-specific	pCi	calculated
Radionuclide concentration in soil	Cs	radionuclide-specific	pCi/g	Tier 1 or 2 EPC
Ingestion Rate of soil/sediment	IRwss	100	mg/day	EPA et al. 2002
Exposure Frequency	EFwss	230	days/year	EPA et al. 2002
Exposure Duration	EDw	18.7	yr	EPA et al. 2002
Conversion factor	CF_1	0.001	g/mg	1 g = 1000 mg
Outdoor Inhalation of Suspended Particulates				
RI = Cs x IRawss x EFwss x EDw x ETwss x ETFo x MLF x CF_2				
Radionuclide Intake	RI	radionuclide-specific	pCi	calculated
Radionuclide concentration in soil	Cs	radionuclide-specific	pCi/g	Tier 1 or 2 EPC
Inhalation Rate	Irawss	1.3	m^3/hr	EPA et al. 2002
Exposure Frequency	EFwss	230	days/year	EPA et al. 2002
Exposure Duration	EDw	18.7	yr	EPA et al. 2002
Exposure Time	ETwss	8	hr/day	EPA et al. 2002
Exposure Time Fraction, outdoor	ETFo	0.5	--	EPA et al. 2002
Mass loading, (PM 10) for inhalation[a]	MLF	6.70E-08	kg/m^3	EPA et al. 2002
Conversion factor	CF_2	1000	g/kg	1000 g = 1 kg
Indoor Inhalation of Suspended Particulates				
RI = Cs x IRawss x EFwss x EDw x ETwss x ETFi x DFi x MLF x CF_2				
Radionuclide Intake	RI	radionuclide-specific	pCi	calculated
Chemical concentration in soil	Cs	radionuclide-specific	pCi/g	Tier 1 or 2 EPC
Inhalation Rate	Irawss	1.3	m^3/hr	EPA et al. 2002
Exposure Frequency	EFwss	230	days/year	EPA et al. 2002
Exposure Duration	EDw	18.7	yr	EPA et al. 2002
Exposure Time	ETwss	8	hr/day	EPA et al. 2002
Exposure Time Fraction, indoor	ETFi	0.5	--	EPA et al. 2002
Dilution Factor, indoor inhalation	DFi	0.7	--	EPA et al. 2002
Mass Loading, (PM 10) for inhalation	MLF	6.70E-08	kg/m^3	EPA et al. 2002[a]
Conversion factor	CF_2	1000	g/kg	1000 g = 1 kg
Outdoor External Radiation Exposure				
RE = Cs x Te_A x Te_Do x EDw x ACF x GSFo				
Radionuclide Exposure	RE	radionuclide-specific	(pCi-yr)/g	calculated
Radionuclide concentration in soil	Cs	radionuclide-specific	pCi/g	Tier 1 or 2 EPC
Gamma exposure factor (annual) surface soil	Te_A	0.630	--	EFwss / 365 day/yr
Gamma exposure factor (daily) outdoor	Te_Do	0.167	--	ETwss x ETFo / 24 hr/day
Exposure Duration	EDw	18.7	yr	EPA et al. 2002
Area Correction Factor	ACF	0.9	--	EPA et al. 2002
Gamma Shielding Factor (1-SE) outdoor	GSFo	1	--	EPA et al. 2002

Exposure Route/Exposure Factor	Abbreviation	Value	Units	Source
Indoor External Radiation Exposure				
RE = Cs x Te_A x Te_Di x EDw x ACF x GSFi				
Radionuclide Exposure	RE	radionuclide-specific	(pCi-yr)/g	calculated
Radionuclide concentration in soil	Cs	radionuclide-specific	pCi/g	EPC
Gamma exposure factor (annual) surface soil	Te_A	0.630	--	EFwss / 365 day/yr
Gamma exposure factor (daily) outdoor	Te_Di	0.167	--	ETwss x ETFi / 24 hr/day
Exposure Duration	EDw	18.7	yr	EPA et al. 2002
Area Correction Factor	ACF	0.9	--	EPA et al. 2002
Gamma Shielding Factor (1-SE) outdoor	GSFi	0.4	--	EPA et al. 2002

[a] The mass loading value is the 95th percentile of the estimated mass loading distribution estimated in the RSALs Task 3 Report (EPA et al. 2002).

Table 7.4
Radionuclide Exposure Factors Used in Surface Soil/Surface Sediment Intake Calculations for the WRV

Exposure Route/Exposure Factor	Abbreviation	Value	Units	Source
Ingestion				
RI = Cs x IRagevss_r x EFvss x (EDav + EDcv) x CF_1				
Radionuclide Intake	RI	chemical-specific	pCi	calculated
Radionuclide concentration in soil	Cs	chemical-specific	pCi/g	Tier 1 or 2 EPC
Age-adjusted Soil Ingestion Rate for radionuclides	IRagevss_r	60	mg/day	EPA et al. 2002
Exposure Frequency	EFvss	100	days/year	EPA et al. 2002[a]
Exposure Duration - adult	EDav	24	yr	EPA et al. 2002
Exposure Duration - child	EDcv	6	yr	EPA et al. 2002
Conversion factor	CF_1	0.001	g/mg	1 g = 1000 mg
Outdoor Inhalation of Suspended Particulates				
RI = Cs x IRa_agevss_r x EFvss x (EDav + EDcv) x ETvss x MLF x CF_2				
Radionuclide Intake	RI	chemical-specific	pCi	calculated
Radionuclide concentration in soil	Cs	chemical-specific	pCi/g	EPC
Age-averaged Inhalation Rate for radionuclides	IRa_agevss_r	2.2	m^3/hr	Tier 1 or 2 EPC
Exposure Frequency	EFvss	100	days/year	EPA et al. 2002[a]
Exposure Duration - adult	EDav	24	yr	EPA et al. 2002
Exposure Duration - child	EDcv	6	yr	EPA et al. 2002
Exposure Time	ETvss	2.5	hr/day	EPA et al. 2002[b]
Mass loading, (PM 10) for inhalation	MLF	6.70E-08	kg/m^3	EPA et al. 2002[c]
Conversion factor	CF_2	1000	g/kg	1000 g = 1 kg
Outdoor External Radiation Exposure				
RE = Cs x Te_Av x Te_Dv x (EDav + EDcv) x ACF x GSFo				
Radionuclide Exposure	RE	chemical-specific	(pCi-yr)/g	calculated
Radionuclide concentration in soil	Cs	chemical-specific	pCi/g	EPC
Gamma exposure factor (annual) surface soil	Te_Av	0.274	--	EFv / 365 day/yr
Gamma exposure factor (daily) outdoor	Te_Dv	0.104	--	ETv / 24 hr/day
Exposure Duration - adult	EDav	24	yr	EPA et al. 2002
Exposure Duration - child	EDcv	6	yr	EPA et al. 2002
Area Correction Factor	ACF	0.9	--	EPA et al. 2002
Gamma Shielding Factor (1-SE) outdoor	GSFo	1	--	EPA et al. 2002

[a] Value is 95th percentile of visitation frequency for open space users (Jefferson County 1996).

[b] Value is 50th percentile of time spent for open space users (Jefferson County 1996).

[c] The mass loading value is the 95th percentile of the estimated mass loading distribution estimated in the RSALs Task 3 Report (EPA et al. 2002).

Table 7.5
Chemical Exposure Factors Used in Surface Soil/Surface Sediment Intake Calculations for the WRW

Exposure Route/Exposure Factor	Abbreviation	Value	Unit	Source
Ingestion				
CI = (Cs x IRwss x EFwss x EDw x CF_3) / (BW x [ATc_wss or ATn_wss][b])				
Chemical Intake	CI	chemical-specific	mg/kg-day	calculated
Chemical Concentration in Soil	Cs	chemical-specific	mg/kg	Tier 1 or 2 EPC
Ingestion Rate of Soil/Sediment	IRwss	100	mg/day	EPA et al. 2002
Exposure Frequency	EFwss	230	days/year	EPA et al. 2002
Exposure Duration	EDw	18.7	yr	EPA et al. 2002
Conversion Factor	CF_3	1.00E-06	kg/mg	1 kg = 1.0E6 mg
Adult Body Weight	BW	70	kg	EPA 1991
Averaging Time-Carcinogenic	ATc_wss	25,550	day	calculated
Averaging Time-Noncarcinogenic	ATnc_wss	6,826	day	calculated
Outdoor Inhalation of Suspended Particulates				
CI = (Cs x IRawss x EFwss x EDw x ETwss x ETFo x MLF) / (BW x [ATc_wss or ATn_wss][b])				
Chemical Intake	CI	chemical-specific	mg/kg-day	calculated
Chemical Concentration in Soil	Cs	chemical-specific	mg/kg	Tier 1 or 2 EPC
Inhalation Rate	IRawss	1.3	m^3/hr	EPA et al. 2002
Exposure Frequency	EFwss	230	days/year	EPA et al. 2002
Exposure Duration	EDw	18.7	yr	EPA et al. 2002
Exposure Time	ETwss	8	hr/day	EPA et al. 2002
Exposure Time Fraction, outdoor	ETFo	0.5	--	EPA et al. 2002
Mass Loading, (PM 10) for inhalation[a]	MLF	6.70E-08	kg/m^3	EPA et al. 2002
Adult Body Weight	BW	70	kg	EPA 1991
Averaging Time-Carcinogenic	ATc_wss	25,550	day	calculated
Averaging Time-Noncarcinogenic	ATnc_wss	6,826	day	calculated
Indoor Inhalation of Suspended Particulates				
CI = (Cs x IRawss x EFwss x EDw x ETwss x ETFi x DFi x MLF) / (BW x [ATc_wss or ATn_wss][b])				
Chemical Intake	CI	chemical-specific	mg/kg-day	calculated
Chemical Concentration in Soil	Cs	chemical-specific	mg/kg	Tier 1 or 2 EPC
Inhalation Rate	IRawss	1.3	m^3/hr	EPA et al. 2002
Exposure Frequency	EFwss	230	days/year	EPA et al. 2002
Exposure Duration	EDw	18.7	yr	EPA et al. 2002

Table 7.5
Chemical Exposure Factors Used in Surface Soil/Surface Sediment Intake Calculations for the WRW

Exposure Route/Exposure Factor	Abbreviation	Value	Unit	Source
Exposure Time	ETwss	8	hr/day	EPA et al. 2002
Exposure Time Fraction, indoor	ETFi	0.5	--	EPA et al. 2002
Dilution Factor, indoor inhalation	DFi	0.7	--	EPA et al. 2002
Mass Loading, (PM 10) for inhalation[a]	MLF	6.70E-08	kg/m^3	EPA et al. 2002
Adult Body Weight	BW	70	kg/m3	EPA 1991
Averaging Time-Carcinogenic	ATc_wss	25,550	day	calculated
Averaging Time-Noncarcinogenic	ATnc_wss	6,826	day	calculated
Dermal Contact				
CI = (Cs x SAw x AFw x EFwss x EDw x ABS x EVw x CF_3) / (BW x [Atc_wss or Atn_wss][b])				
Chemical Intake	CI	chemical-specific	mg/kg-day	calculated
Chemical Concentration in Soil	Cs	chemical-specific	mg/kg	Tier 1 or 2 EPC
Skin Surface Area[c]	SAw	3300	cm^2	EPA 2001
Skin-Soil Adherence Factor	AFw	0.117	mg/cm^2-event	EPA 2001
Exposure Frequency	EFwss	230	days/year	EPA et al. 2002
Exposure Duration	EDw	18.7	yr	EPA et al. 2002
Conversion Factor	CF_3	1.00E-06	kg/mg	1 kg = 1.0E6 mg
Absorption Fraction	ABS	chemical-specific		EPA 2001[c]
Event Frequency	EVw	1	events/day	EPA 2001
Adult Body Weight	BW	70	kg	EPA 1991
Averaging Time-Carcinogenic	ATc_wss	25,550	day	calculated
Averaging Time-Noncarcinogenic	ATnc_wss	6,826	day	calculated

[a] The mass loading value is the 95th percentile of the estimated mass loading distribution estimated in the RSALs Task 3 Report (EPA et al. 2002).
[b] Carcinogenic or noncarcinogenic averaging times (Atc and Atnc, respectively) are used in equations, depending on whether carcinogenic or noncarcinogenic intakes are being calculated.
[c] The skin surface area value is the EPA default for commercial/industrial exposures and is the average of the 50th percentile for men and women > 18 years old wearing a short-sleeved shirt, long pants, and shoes. The value was recommended by CDPHE for use in the WRW PRGs.

Table 7.6
Chemical Exposure Factors Used in Surface Soil/Surface Sediment Intake Calculations for the WRV

Exposure Route/Exposure Factor	Abbreviation	Value	Units	Source
Ingestion				
CI = (Cs x IRagevss x EFvss x CF_3) / [Atc_vss or Atnc][a] **where, IRageav = ((IRvss x EDav) / BW) + ((IRcvss x EDcv) / BWc)**				
Chemical Intake	CI	chemical-specific	mg/kg-day	calculated
Chemical Concentration in Soil	Cs	chemical-specific	mg/kg	Tier 1 or 2 EPC
Age-Adjusted Soil Ingestion Rate for Chemicals	IRagevss	57	mg-yr/kg-day	calculated
Exposure Frequency	EFvss	100	days/year	EPA et al. 2002[b]
Exposure Duration - adult	EDav	24	yr	EPA et al. 2002
Exposure Duration - child	EDcv	6	yr	EPA et al. 2002
Conversion Factor	CF_3	1.00E-06	kg/mg	1 kg = 1.0E6 mg
Soil Ingestion Rate - adult	IRvss	50	mg/day	EPA et al. 2002
Soil Ingestion Rate - child	IRcvss	100	mg/day	EPA et al. 2002
Adult Body Weight	BW	70	kg	EPA 1991
Child Body Weight	BWc	15	kg	EPA 1991
Averaging Time-Carcinogenic	ATc_vss	25,550	day	calculated
Averaging Time-Noncarcinogenic	ATn_vss	8,760	day	calculated
Averaging Time-Noncarcinogenic (child)	ATn_c_vss	2,190	day	calculated
Averaging Time-Noncarcinogenic (child+adult)	ATnc	10,950	day	calculated
Outdoor Inhalation of Suspended Particulates				
CI = (Cs x IRa_agevss x EFvss x MLF) / [Atc_vss or Atnc][a] **where, IRa_agevss = (((Ira_vss x EDav) / BW) + ((IRa_cvss x EDcv) / BWc)) x ET**				
Chemical Intake	NRI	chemical-specific	mg/kg-day	calculated
Chemical Concentration in Soil	Cs	chemical-specific	mg/kg	EPC
Age-averaged Inhalation Rate for Chemicals	IRa_agevss	3.7	m^3-yr/kg-day	EPA et al. 2002[b]
Exposure Frequency	EFvss	100	days/year	EPA et al. 2002[b]
Mass loading, (PM 10) for inhalation	MLF	6.70E-08	kg/m^3	EPA et al. 2002
Exposure Duration - adult	EDav	24	yr	EPA et al. 2002
Exposure Duration - child	EDcv	6	yr	EPA et al. 2002
Adult Body Weight	BW	70	kg	EPA 1991
Child Body Weight	BWc	15	kg	EPA 1991
Air Inhalation Rate - adult	IRavss	2.4	m^3/hr	EPA et al. 2002
Air Inhalation Rate - child	IRa_cvss	1.6	m^3/hr	EPA et al. 2002
Exposure Time	Etvss	2.5	hr/day	EPA et al. 2002[b]
Averaging Time-Carcinogenic	ATc_vss	25,550	day	calculated
Averaging Time-Noncarcinogenic	ATn_vss	8,760	day	calculated
Averaging Time-Noncarcinogenic (child)	ATn_c_vss	2,190	day	calculated
Averaging Time-Noncarcinogenic (child+adult)	ATnc	10,950	day	calculated
Dermal Contact				
CI = (Cs x SFSagav x EFvss x ABS x EVv x CF_3) /[ATc_vss or ATnc][a]				

Table 7.6
Chemical Exposure Factors Used in Surface Soil/Surface Sediment Intake Calculations for the WRV

Exposure Route/Exposure Factor	Abbreviation	Value	Units	Source
where, SFSagav = ((SAav x AFav xEDav) / BW) + ((SAcv x AFcv x EDcv) / BWc)				
Chemical Intake	CI	chemical-specific	mg/kg-day	calculated
Chemical concentration in soil	Cs	chemical-specific	mg/kg	Tier 1 or 2 EPC
Exposure Frequency	EFvss	100	days/year	EPA et al. 2002[b]
Exposure Duration - adult	EDav	24	yr	EPA et al. 2002
Exposure Duration - child	EDcv	6	yr	EPA et al. 2002
Adult skin-soil adherence factor	AFav	0.07	mg/cm^2-event	EPA 2001b[c]
Child skin-soil adherence factor	AFcv	0.2	mg/cm^2-event	EPA 2001b[d]
Adult skin surface area (exposed)	SAav	5700	cm^2	EPA 2001b[e]
Child skin surface area (exposed)	SAcv	2800	cm^2	EPA 2001b[f]
Age-averaged surface area/adherence factor	SFSagav	361	mg-yr/kg-event	EPA 2001b
Absorption Fraction	ABS	chemical-specific	[--]	EPA 2001b
Event frequency	EVv	1.00	events/day	EPA 2001
Conversion Factor	CF_3	0.000001	kg/mg	1 kg = 1.0E6 mg
Adult Body Weight	Bw	70	kg	EPA 1991
Child Body Weight	BWc	15	kg	EPA 1991
Averaging Time-Carcinogenic	ATc_vss	25,550	day	calculated
Averaging Time-Noncarcinogenic	ATn_vss	8,760	day	calculated
Averaging Time-Noncarcinogenic (child)	ATn_c_vss	2,190	day	calculated
Averaging Time-Noncarcinogenic (child+adult)	ATnc	10,950	day	calculated

[a] Carcinogenic or noncarcinogenic averaging times (Atc and Atnc, respectively) are used in the equations, depending on whether carcinogenic or noncarcinogenic intakes are being calculated.
[b] Value is the 50th percentile of time spent for open space users (Jefferson County 1996).
[c] The adult skin-soil adherence factor is the EPA residential default and the 50th percentile for gardeners. This is the value recommended by CDPHE for use in the WRW PRGs.
[d] The child skin-soil adherence factor is the EPA residential default and the 95th percentile for children playing in wet soil. This is the value recommended by CDPHE for use in the open space user PRGs.
[e] The adult skin-surface area value is the EPA default for residential exposures and the average of the 50th percentile for males and females > 18 years old wearing short-sleeved shirts, shorts, and shoes. The value was recommended by CDPHE for use in the WRW PRGs.
[f] The child skin-surface area value is the EPA default for residential exposures and the average of the 50th percentiles for males and females from <1 to <6 years old wearing short-sleeved shirts, shorts, and no shoes. The value was recommended by CDPHE for use in the WRW PRGs.

Table 7.7
Toxicity Criteria

COC	Cancer Slope Factor for Non-Radionuclide Chemicals[a]		Cancer Slope Factor for Radionuclides[a]	Inhalation Slope Factor (Risk/pCi)	External Slope Factor (Risk/yr/pCi/g)	Reference Doses for Noncarcinogens[b]	
	Oral/Ingestion Slope Factor $(mg/kg\text{-}day)^{-1}$	Inhalation Slope Factor $(mg/kg\text{-}day)^{-1}$	Soil Ingestion Oral Slope Factor (Risk/pCi)			Oral RfD (mg/kg-day)	Inhalation RfD (mg/kg-day)
Inorganics							
Arsenic	1.50E+00	1.51E+01	N/A	N/A	N/A	3.00E-04	n/a
Vanadium	N/A	N/A	N/A	N/A	N/A	1.00E-03	n/a
Organics							
Benzo(a)pyrene	7.30E+00	3.10E+00	N/A	N/A	N/A	n/a	n/a
2,3,7,8-TCDD	1.50E+05	1.50E+05	N/A	N/A	N/A	n/a	n/a
Radionuclides							
Plutonium-239	N/A	N/A	2.76E-10	3.33E-08	2.00E-10	n/a	n/a
Plutonium-240	N/A	N/A	2.77E-10	3.33E-08	6.98E-11	n/a	n/a

N/A = Not applicable; the chemical does not fall within this group.
n/a = Toxicity criterion for evaluating noncancer health effects of this chemical is not available.
mg/kg = milligrams per kilogram.
pCi = Picocuries.
pCi/g = Picocuries per gram.
RfD = Reference dose.
[a] Because the exposure estimate is multiplied by the slope factor to arrive at a risk, a larger slope factor indicates a greater carcinogenic potency.
[b] The exposure estimate is divided by the reference dose; therefore, the smaller the reference dose, the greater the toxicity.

Table 7.8
Summary of Human Health Risk Estimates[a]

EU	Surface Soil/Surface Sediment COC	WRW						WRV					
		Excess Lifetime Cancer Risk		Noncancer Hazard Quotient		Annual Dose Rate[b]		Excess Lifetime Cancer Risk		Noncancer Hazard Quotient		Annual Dose Rate[b]	
		Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2
No Name Gulch Drainage (Volume 6)	Vanadium	NC	NC	0.1	0.05	N/A	N/A	NC	NC	0.01	0.03	N/A	N/A
Upper Walnut Drainage (Volume 7)	Benzo(a)pyrene	1E-06	1E-06	NC	NC	N/A	N/A	2E-06	1E-06	NC	NC	N/A	N/A
Wind Blown Area (Volume 9)	Arsenic	2E-06	2E-06	0.02	0.01	N/A	N/A	2E-06	1E-06	0.01	0.008	N/A	N/A
	Plutonium-239/240	2E-06	9E-07	NC	NC	3E-01	2E-01	1E-06	6E-07	NC	NC	2E-01[c]	1E-01[c]
Upper Woman Drainage (Volume 10)	2,3,7,8-TCDD TEQ	2E-06	2.E-06	NC	NC	N/A	N/A	2E-06	2E-06	NC	NC	N/A	N/A
	Benzo(a)pyrene	6E-06	2.E-06	NC	NC	N/A	N/A	7E-06	2E-06	NC	NC	N/A	N/A
Industrial Area	Arsenic	2E-06	2.E-06	0.01	0.02	N/A	N/A	2E-06	2E-06	0.01	0.009	N/A	N/A
(Volume 14)	Benzo(a)pyrene	1E-06	2.E-06	NC	NC	N/A	N/A	1E-06	2E-06	NC	NC	N/A	N/A

TEQ = Toxicity equivalence.
TCDD = Tetrachlorodibenzo-p-dioxin.
NC = Not calculated. Appropriate toxicity criteria are not available.
N/A = This health effect is not applicable for the chemical.
COC = Contaminant of concern.
[a] Includes only EUs and media for which COCs have been identified.
[b] Annual dose rate is in millirems (mrem) per year.
[c] Child annual dose rate. Adult annual dose rate: Tier 1 = 7E-02; Tier 2 = 4E-02.

Table 7.9
Summary of Ecological Receptors of Concern and Exposure Pathways Evaluated in the CRA

Representative Feeding Guild	Selected Receptor of Concern	Relative Home Range Size	Exposure Pathways Evaluated Quantitatively
Raptors	American Kestrel	Small	Ingestion of surface soil, surface water, small mammals, and terrestrial invertebrates
Carnivorous Mammals	Coyote - Carnivore	Large	Ingestion of surface soil, surface water, and small mammals
Omnivorous Mammals	Coyote - Generalist	Large	Ingestion of surface soil, surface water, small mammals, and terrestrial invertebrates
Insectivorous Mammals	Coyote - Insectivore	Large	Ingestion of surface soil, surface water, and terrestrial invertebrates
Herbivorous Small Mammals	Deer Mouse - Herbivore	Small	Ingestion of surface soil, surface water, and terrestrial plants
Insectivorous Small Mammals	Deer Mouse - Insectivore	Small	Ingestion of surface soil, surface water, and terrestrial invertebrates
Herbivorous Birds	Mourning Dove - Herbivore	Small	Ingestion of surface soil, surface water, and terrestrial plants
Insectivorous Birds	Mourning Dove - Insectivore	Small	Ingestion of surface soil, surface water, and terrestrial invertebrates
Herbivorous Large Mammals	Mule Deer	Large	Ingestion of surface soil, surface water, and terrestrial plants
T&E Species	PMJM	Small	Ingestion of surface soil, surface water, terrestrial plants, and terrestrial invertebrates
Herbivorous Burrowing Mammals	Prairie Dog	Small	Ingestion of subsurface soil, surface water, and terrestrial plants
Terrestrial Invertebrates	Terrestrial Invertebrates	Small	Direct contact with surface soil
Terrestrial Plants	Terrestrial Plants	Small	Direct contact with surface soil
Aquatic Life	General aquatic life, including amphibians and benthic macroinvertebrates	N/A	Direct contact with surface water and sediment

Table 7.10
Summary of Terrestrial ECOPCs

	Non-PMJM ECOPCs	PMJM ECOPCs	Burrowing Receptor
West Area EU (Volume 3)	None	Not Evaluated	None
Rock Creek Drainage EU (Volume 4)	None	Manganese	None
		Tin	
Inter-Drainage EU (Volume 5)	Antimony	None	None
	Lead		
No Name Gulch EU (Volume 6)	Antimony	Nickel	None
	Barium	Vanadium	
	Copper	Zinc	
	Mercury		
	Molybdenum		
	Nickel		
	Tin		
	Bis(2-ethylhexyl)phthalate		
	Di-n-butylphthalate		
	PCB (total)		
Upper Walnut Creek Drainage EU (Volume 7)	Antimony	Antimony	None
	Copper	Nickel	
	Molybdenum	Tin	
	Nickel	Vanadium	
	Silver	Zinc	
	Tin		
	Vanadium		
	Zinc		
	Bis(2-ethylhexyl)phthalate		
	Di-n-butylphthalate		
	PCB (total)		
Lower Walnut Creek Drainage (Volume 8)	4,4'-DDT	None	None
Wind Blown Area EU (Volume 9)	Chromium	Not Evaluated	None
	Manganese		
	Nickel		
	Silver		
	Thallium		
	Tin		
	Bis(2-ethylhexyl)phthalate		

Table 7.10
Summary of Terrestrial ECOPCs

	Non-PMJM ECOPCs	PMJM ECOPCs	Burrowing Receptor
	Endrin		
	PCB (total)		
Upper Woman Creek EU (Volume 10)	Antimony	Antimony	None
	Copper	Cadmium	
	Manganese	Chromium	
	Nickel	Copper	
	Silver	Manganese	
	Tin	Mercury	
	Uranium	Nickel	
	Bis(2-ethylhexyl)phthalate	Tin	
	Di-n-butylphthalate	Vanadium	
	Dioxin	Zinc	
	PCB (total)	PCB (total)	
Lower Woman Creek EU (Volume 11)	Chromium	Chromium	None
	Copper	Manganese	
	Manganese	Nickel	
	Nickel	Selenium	
	Thallium	Tin	
	Tin	Vanadium	
	Vanadium	Zinc	
Southwest Buffer Zone EU Area (Volume 12)	None	None	None
Southeast Buffer Zone EU Area (Volume 13)	None	Not Evaluated	None
Industrial Area Exposure Unit (Volume 14)	Antimony	Not Evaluated	None
	Chromium		
	Copper		
	Molybdenum		
	Tin		
	Bis(2-ethylhexyl)phthalate		
	Di-n-butylphthalate		
	Dioxin		
	PCB (total)		
Sitewide EU (Volume 15A)	Nickel	Not Evaluated	Not Evaluated
	Dioxin		

Table 7.11
Surface Water ECOPCs in the AEUs

ECOPC	No Name	Rock Creek	McKay Ditch	Southeast	North Walnut	South Walnut	Woman Creek
Inorganics							
Aluminum (T)			x		x	x	x
Ammonia (un-ionized)	x				x	x	x
Barium (T)	x						
Cadmium (D)			x		x	x	x
Cyanide (T)					x	x	
Iron (T)			x		x		
Lead (D)	x						
Selenium (D)	x						
Silver (D)	x				x	x	x
Vanadium (T)					x		
Zinc (D)	x		x				
Organics							
Bis(2-ethylhexyl)phthalate	x						
Di-n-butylphthalate	x						
4,4'-DDT						x	
Aroclor-1254					x		
Phenol	x						
Phenanthrene	x						
Radium-228					x		
Total ECOPCs	**10**	**0**	**4**	**0**	**9**	**6**	**4**

T = Total metal.
D = Dissolved metal.
The ECOPC selection was conducted on the MDC, either dissolved or total.
x = ECOPC

Table 7.12
Sediment ECOPCs in the AEUs

ECOPC	No Name	Rock Creek	McKay Ditch	Southeast	North Walnut	South Walnut	Woman Creek
Inorganics							
Aluminum	x		x		x	x	x
Antimony					x	x	x
Arsenic							
Barium	x				x	x	x
Cadmium					x	x	x
Chromium			x				
Copper					x	x	x
Fluoride			x		x	x	x
Iron	x				x		x
Lead	x				x	x	x
Manganese					x		
Mercury					x		x
Nickel			x		x		x
Selenium			x		x		x
Silver					x	x	x
Zinc					x	x	x
Organics							
2-Methylnaphthalene					x		
4-Methylphenol							x
4,4-DDT					x		
Acenaphthene					x	x	x
Anthracene					x	x	x
Aroclor-1254					x	x	x
Aroclor-1260						x	
Atrazine					x		
Benzo(a)anthracene	x				x	x	x
Benzo(a)pyrene	x				x	x	x
Benzo(g,h,i)perylene	x				x	x	x

Table 7.12
Sediment ECOPCs in the AEUs

ECOPC	No Name	Rock Creek	McKay Ditch	Southeast	North Walnut	South Walnut	Woman Creek
Benzo(k)fluoranthene					x	x	x
Bromomethane						x	
Carbazole					x	x	
Chrysene	x				x	x	x
Dibenz(a,h)anthracene					x	x	
Fluoranthene					x	x	x
Fluorene					x	x	
Heptachlor							x
Indeno(1,2,3-cd)pyrene	x				x	x	x
Naphthalene					x		
Pentachlorophenol							
Phenanthrene	x				x	x	x
Pyrene	x				x	x	x
Total PAHs	x		x		x	x	x
Total PCBs					x	x	x
Total ECOPCs	**12**	**0**	**6**	**0**	**35**	**28**	**29**

x = ECOPC

Table 7.13
Summary of Ecological Risk Conclusions

EUs	Non-PMJM Receptor	PMJM Receptor	Burrowing Receptor
West Area EU (Volume 3)	No ECOPCs. No risk is predicted.	PMJM habitat evaluated with RCEU and IDEU.	No ECOPCs. No risk is predicted.
Rock Creek Drainage EU (Volume 4)	No ECOPCs. No risk is predicted.	Risk from all ECOPCs is low.	No ECOPCs. No risk is predicted.
Inter-Drainage EU (Volume 5)	Risk from all ECOPCs is low to moderate.	No ECOPCs. No risk is predicted.	No ECOPCs. No risk is predicted.
No Name Gulch EU (Volume 6)	Risk from all ECOPCs is low to moderate.	Risk from all ECOPCs is low.	No ECOPCs. No risk is predicted.
Upper Walnut Creek Drainage EU (Volume 7)	Risk from all ECOPCs is low to moderate.	Risk from all ECOPCs is low.	No ECOPCs. No risk is predicted.
Lower Walnut Creek Drainage (Volume 8)	Risk is low from the ECOPC.	No ECOPCs. No risk is predicted.	No ECOPCs. No risk is predicted.
Wind Blown Area EU (Volume 9)	Risk from all ECOPCs is low.	PMJM habitat evaluated with UWNEU and LWOEU	No ECOPCs. No risk is predicted.
Upper Woman Creek EU (Volume 10)	Risk from all ECOPCs is low to moderate.	Risk from all ECOPCs is low.	No ECOPCs. No risk is predicted.
Lower Woman Creek EU (Volume 11)	Risk from all ECOPCs is low.	Risk from all ECOPCs is low.	No ECOPCs. No risk is predicted.
Southwest Buffer Zone Area EU (Volume 12)	No ECOPCs. No risk is predicted.	No ECOPCs. No risk is predicted.	No ECOPCs. No risk is predicted.
Southeast Buffer Zone EU Area (Volume 13)	No ECOPCs. No risk is predicted.	PMJM habitat evaluated with LWOEU and SWEU.	No ECOPCs. No risk is predicted.
Industrial Area Exposure Unit (Volume 14)	Risk from all ECOPCs is low to moderate.	PMJM habitat evaluated with UWNEU.	No ECOPCs. No risk is predicted.
Sitewide EU (Volume 15A)	Risk from all ECOPCs is low.	Not applicable.	Not applicable.
AEUs	**Surface Water**	**Sediment**	
Sitewide Aquatic ERA (Volume 15B)			
No Name Gulch AEU	Risk from all ECOPCs is low to moderate.	Risk from all ECOPCs is low.	
McKay Ditch AEU	Risk from all ECOPCs is low to moderate.	Risk from all ECOPCs is low.	
Rock Creek AEU	No ECOPCs. No risk is predicted.	No ECOPCs. No risk is predicted.	
Southeast AEU	No ECOPCs. No risk is predicted.	No ECOPCs. No risk is predicted.	
North Walnut AEU	Risk from all ECOPCs is low to moderate.	Risk from all ECOPCs is low to moderate.	
South Walnut AEU	Risk from all ECOPCs is low to moderate.	Risk from all ECOPCs is low to moderate.	
Woman Creek AEU	Risk from all ECOPCs is low.	Risk from all ECOPCs is low.	

Note: The level of uncertainty associated with the risk conclusions may range from low to high. The specific uncertainties for each EU and AEU are presented in Volumes 3 through 15 of Appendix A of the RI/FS Report.

FIGURES

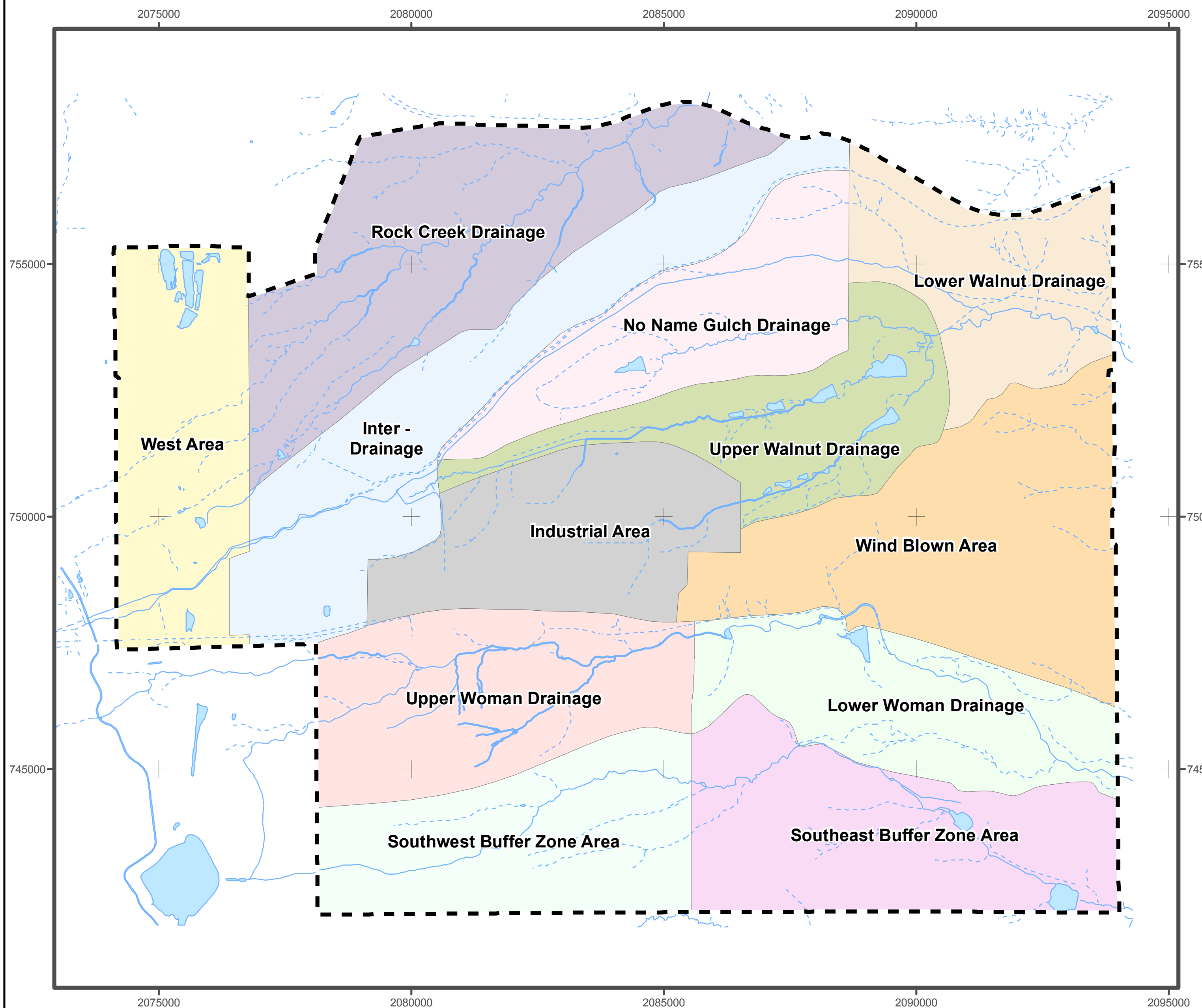

Figure 7.1
Rocky Flats Environmental
Technology Site
Exposure Units

KEY

Exposure unit boundary
Pond
Site boundary
Perennial stream
Intermittent stream
Ephemeral stream

N
W E
S

0 1,500 3,000 Feet

Scale 1:36,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

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Rocky Flats Environmental
Technology Site

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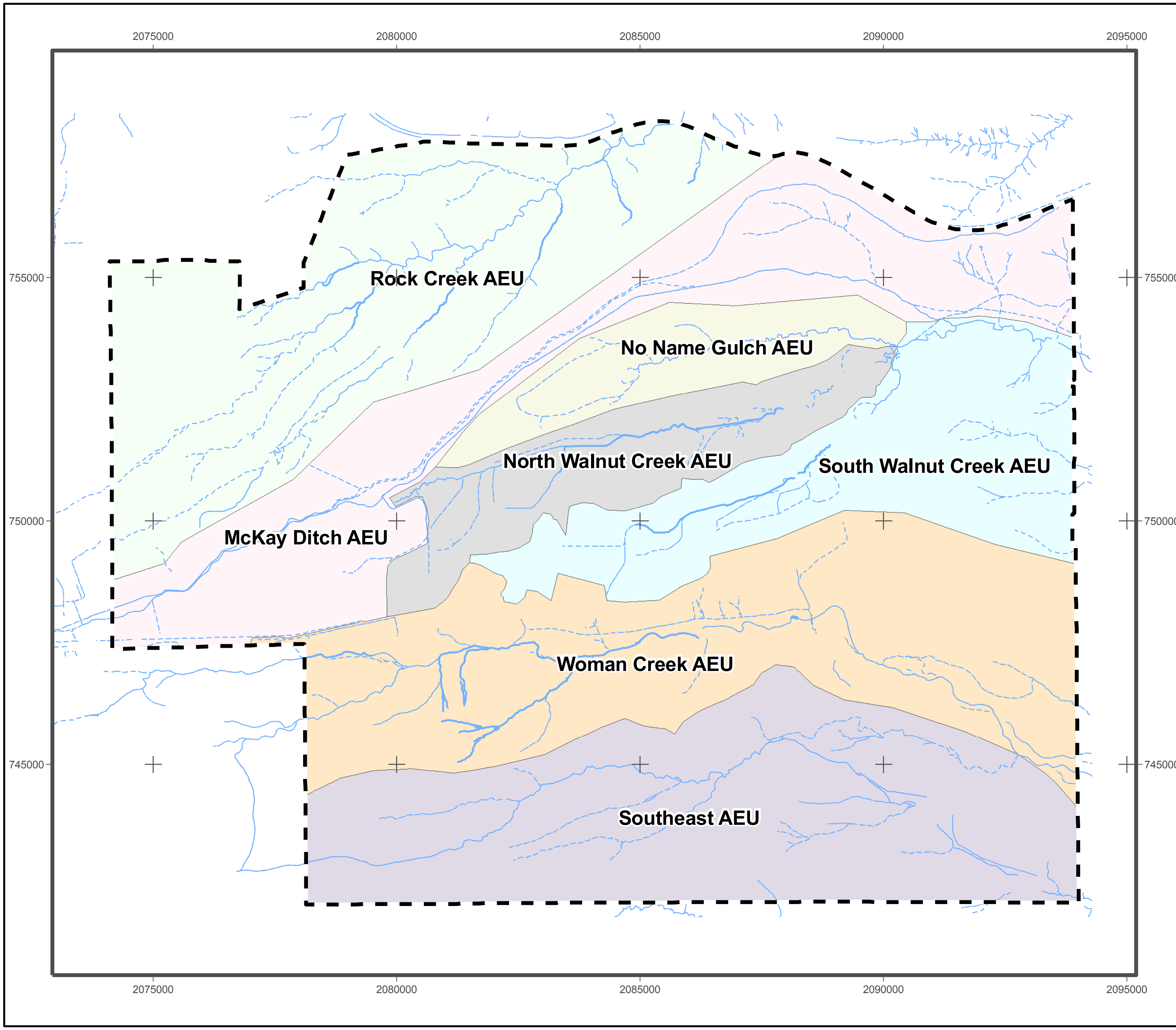

Figure 7.2
Rocky Flats Environmental
Technology Site
Aquatic Exposure Units

KEY

Aquatic exposure unit boundary
Pond
Site boundary
Perennial stream
Intermittent stream
Ephemeral stream

N
W E
S

0 1,500 3,000 Feet

Scale 1:36,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental
Technology Site

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Figure 7.3 Human Health CRA COC Selection Process

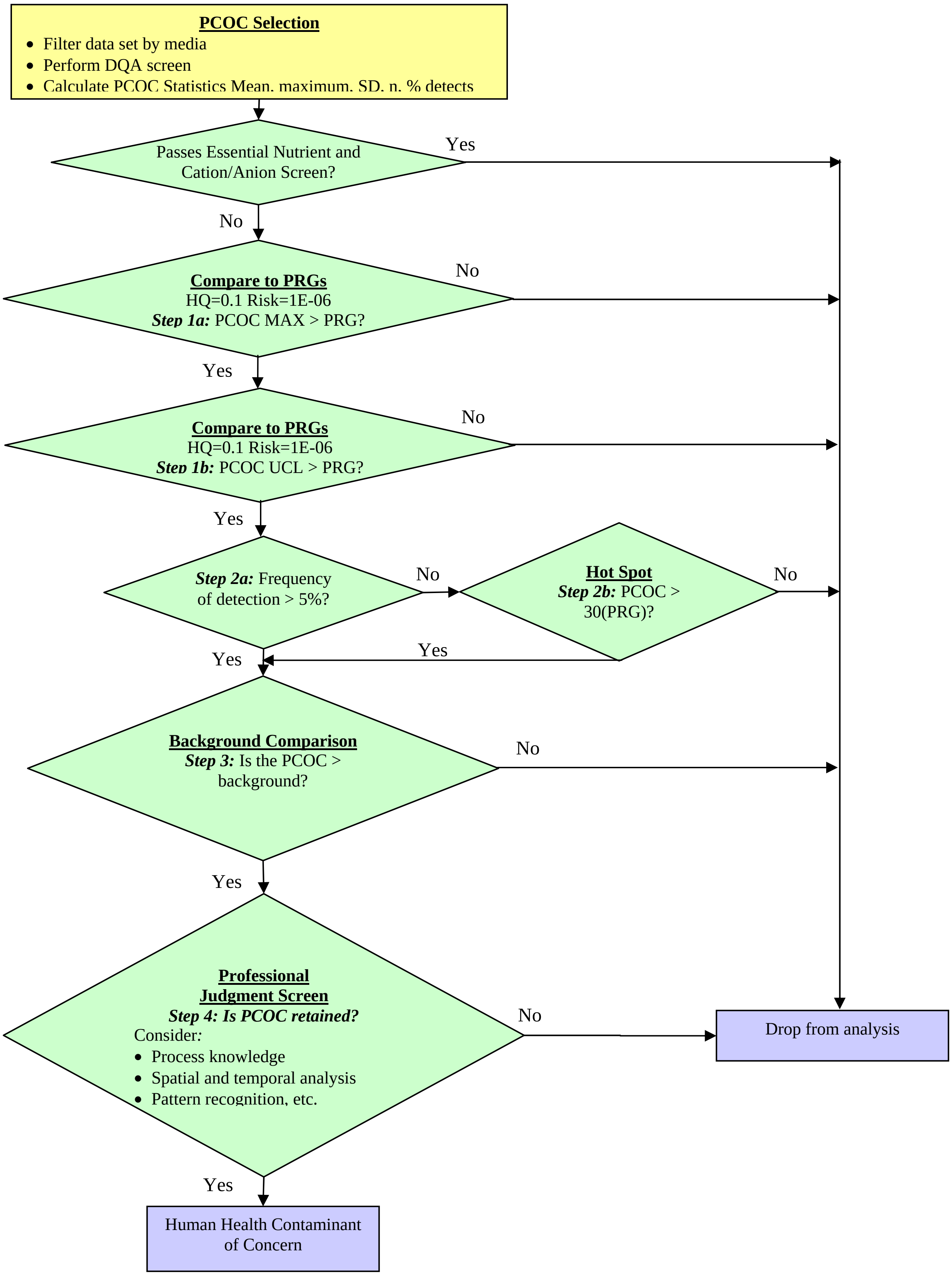

Figure 7.4 Human Health Site Conceptual Model

Primary Source	Primary Release Mechanism	Affected Media	Secondary Release Mechanism	Affected Media	Wildlife Refuge Worker Exposure Pathways	Wildlife Refuge Visitor Exposure Pathways
Surface Soil, Subsurface Soil, Sediment, and Building Rubble	Stormwater Runoff	Surface Water Streams/Seeps	Direct Contact		Oral (I) Dermal (I)	Oral (I) Dermal (I)
			Biotic Uptake	Fish	Oral (IC)	Oral (IC)
			Ingestion	Deer/Grazing Animals	Oral (IC)	Oral (I)
	Infiltration Percolation	UHSU Groundwater	Percolation	LHSU Groundwater	Oral (IC) Dermal (IC)	Oral (IC) Dermal (IC)
			Domestic Use		Oral (IC) Dermal (IC)	Oral (IC) Dermal (IC)
			Surface Water		Oral (I) Dermal (I)	Oral (I) Dermal (I)
	Volatilization	Groundwater Subsurface Soil	Volatilization	Indoor Air	Inhalation (I)	Inhalation (IC)
				Outdoor Air	Inhalation (I)	Inhalation (I)
		Surface Water	Volatilization	Outdoor Air	Inhalation (I)	Inhalation (I)
	Resuspension	Airborne Particulates		Indoor Air	Inhalation (S)	Inhalation (IC)
				Outdoor Air	Inhalation (S)	Inhalation (S)
			Deposition	Deer/Grazing Animals	Oral (IC)	Oral (I)
	Plant Uptake	Vegetation	Ingestion	Deer/Grazing Animals	Oral (IC)	Oral (I)
	Direct Contact	Surface Soil (0 to 0.5 foot)[a]			Oral (S) Dermal (S[b])	Oral (S) Dermal (S[c])
		Subsurface Soil (0.5 to 8 feet)			Oral (S) Dermal (S[b])	Oral (IC) Dermal (IC)
		Subsurface Soil (Below 8 feet)			Oral (IC) Dermal (IC)	Oral (IC) Dermal (IC)
		Sediment[a]			Oral (S) Dermal (S[b])	Oral (S[b]) Dermal (S[b])
		Building Rubble			Oral (IC) Dermal (IC)	Oral (IC) Dermal (IC)
	Radioactive Decay	Surface Soil			External Irradiation (S)	External Irradiation (S)
		Subsurface Soil			External Irradiation (I)	External Irradiation (I)
		Sediment			External Irradiation (S)	External Irradiation (I)
		Building Rubble			External Irradiation (I)	External Irradiation (I)

a. Surface soil and sediments to a depth of 0.5 foot will be combined for the exposure assessment.

b. Dermal exposures will be assessed for organic COCs only.
UHSU - upper hydrostratigraphic unit
LHSU – lower hydrostratigraphic unit

Key to Exposure Pathways:
S – Significant
I – Insignificant
IC – Incomplete

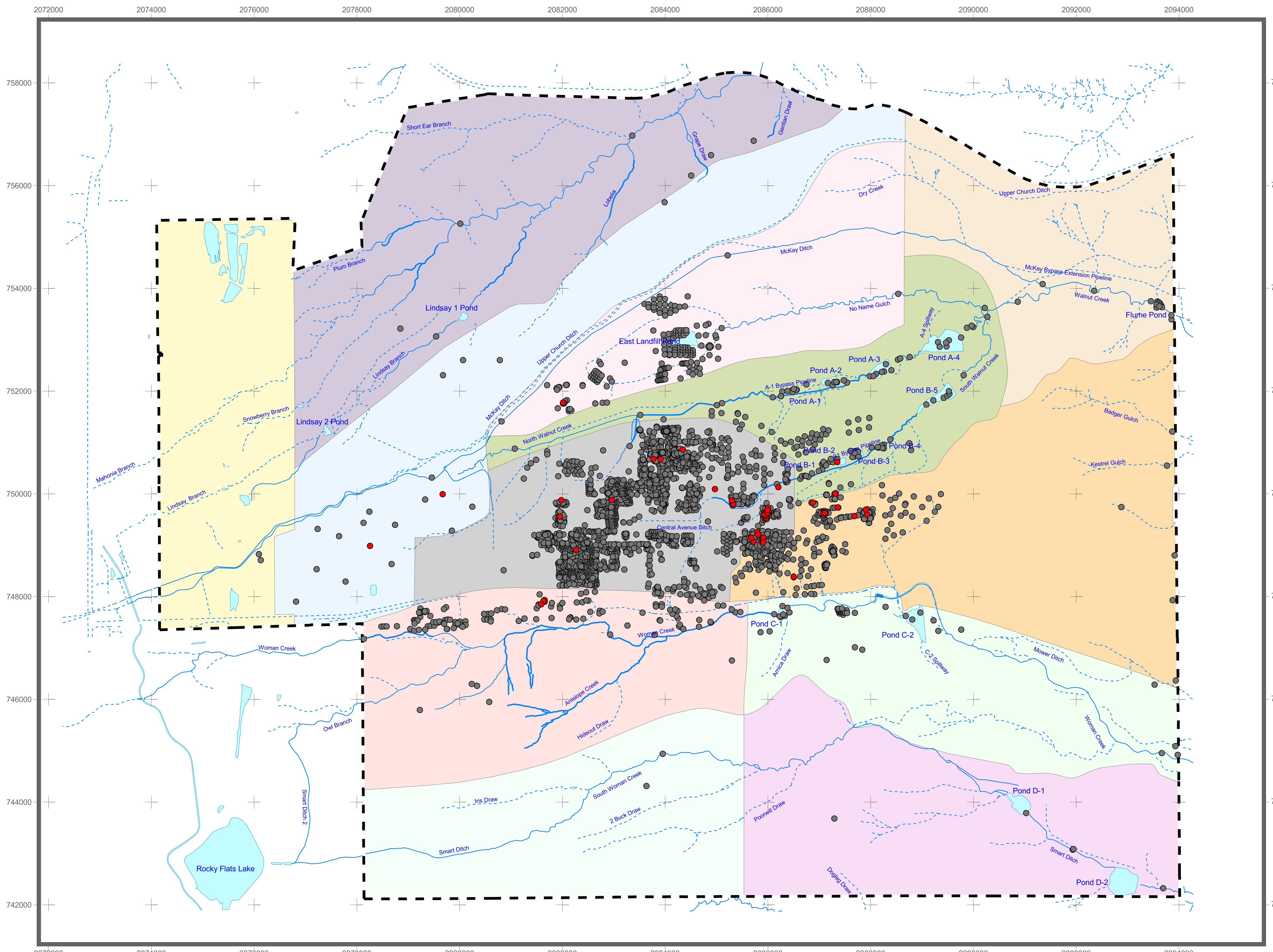

Figure 7.5

Subsurface Soil Sampling Locations Where Volatilization PRGs Were Exceeded

KEY

- Exceeded volatilization PRGs
- Did not exceed volatilization PRGs

A location is classified as a PRG exceedance if any analyte was detected at a concentration exceeding its PRG since June 28, 1991.

Standard Map Features

- Site boundary
- Pond
- Perennial stream
- Intermittent stream
- Ephemeral stream

Exposure Units

- Industrial Area
- Inter-Drainage
- Lower Walnut Drainage
- Lower Woman Drainage
- No Name Gulch Drainage
- Rock Creek Drainage
- Southeast Buffer Zone Area
- Southwest Buffer Zone Area
- Upper Walnut Drainage
- Upper Woman Drainage
- West Area
- Wind Blown Area

N
W E
S

0 1000 2000 Feet

Scale 1:24,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

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Technology Site

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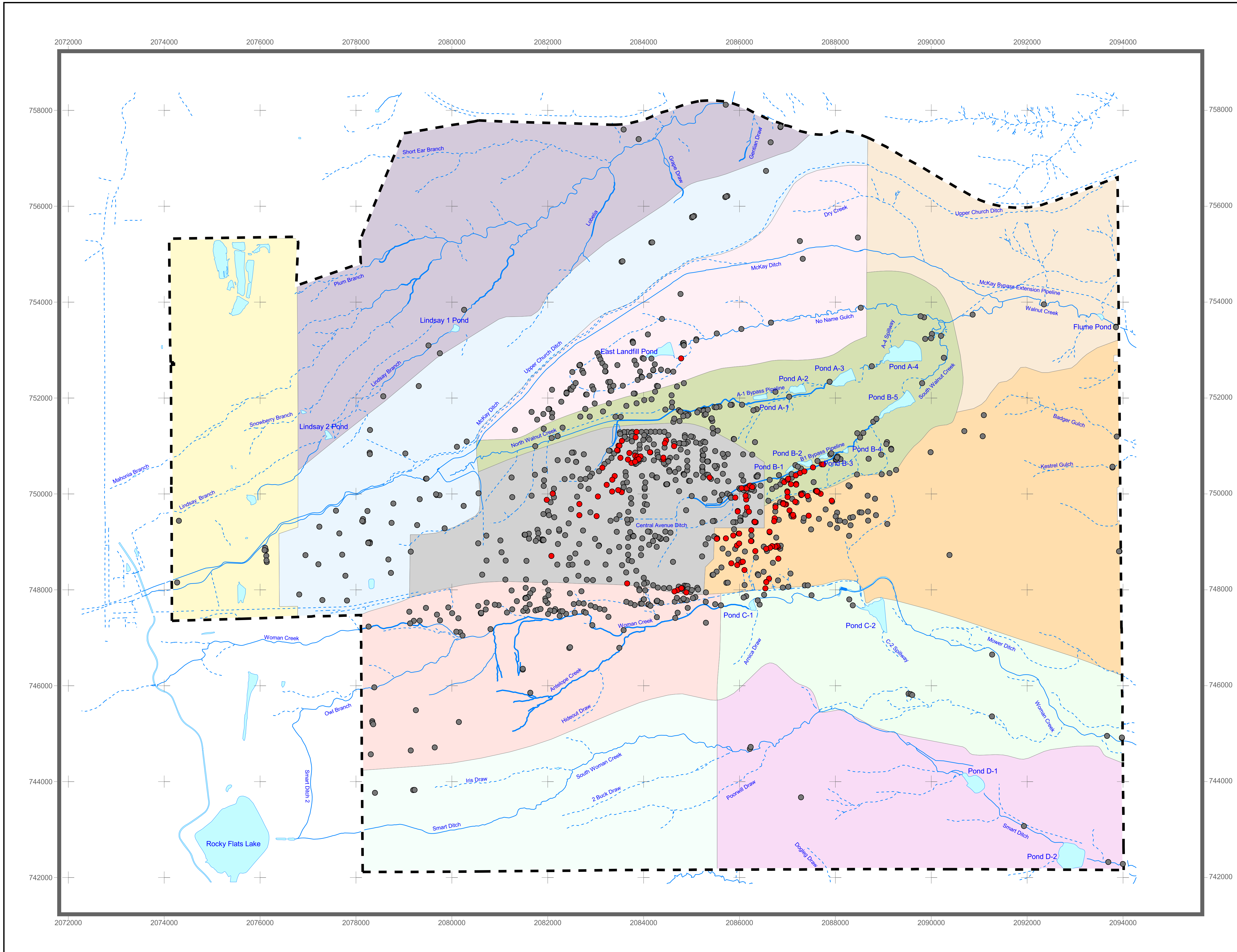

Figure 7.6

Groundwater Sampling Locations Where Volatilization PRGs Were Exceeded

KEY

- Exceeded volatilization PRGs
- Did not exceed volatilization PRGs

A location is classified as a PRG exceedance if any analyte was detected at a concentration exceeding its PRG since June 28, 1991.

Standard Map Features

- Site boundary
- Pond
- Perennial stream
- Intermittent stream
- Ephemeral stream

Exposure Units

- Industrial Area
- Inter-Drainage
- Lower Walnut Drainage
- Lower Woman Drainage
- No Name Gulch Drainage
- Rock Creek Drainage
- Southeast Buffer Zone Area
- Southwest Buffer Zone Area
- Upper Walnut Drainage
- Upper Woman Drainage
- West Area
- Wind Blown Area

N E S W

0 1000 2000 Feet

Scale 1:24,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

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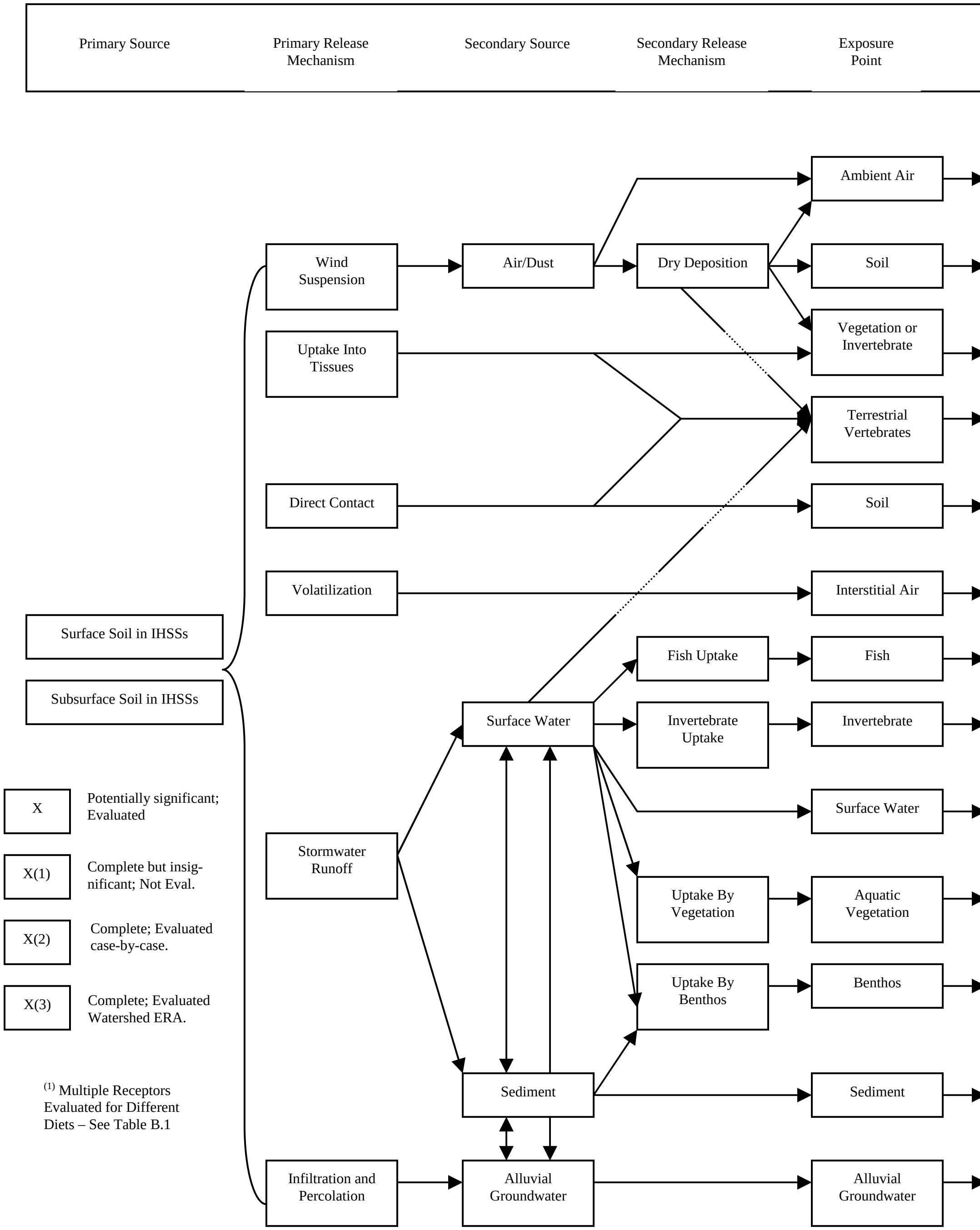
Figure 7.7 Ecological Site Conceptual Model



Exposure Point	Exposure Route	Terrestrial Birds			Terrestrial Mammals					Community	
		Passeriformes[1]	Raptor	Waterfowl	PMJM	Burrowing Herbivore	Ungulate	Small Rodents[1]	Carnivore[1]	Plants and Invertebrates	Aquatic Community
Ambient Air	Inhalation	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)		
Soil	Ingestion	X	X		X	X	X	X	X		
Soil	Direct Contact	X(1)	X(1)		X(1)	X(1)	X(1)	X(1)	X(1)	X	
Vegetation or Invertebrate	Ingestion	X	X		X	X	X	X	X		
Terrestrial Vertebrates	Ingestion		X						X		
Soil	Ingestion	X	X		X	X	X	X	X		
Soil	Direct Contact	X(1)	X(1)		X(1)	X(1)	X(1)	X(1)	X(1)	X	
Interstitial Air	Inhalation	X(1)	X(1)	X(1)	X(1)	X(2)	X(1)	X(1)	X(1)		
Fish	Ingestion			X(3)							
Invertebrate	Ingestion			X(3)							
Surface Water	Ingestion	X	X	X(3)	X	X	X	X	X		
Surface Water	Direct Contact	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)		X
Aquatic Vegetation	Ingestion			X(3)							
Benthos	Ingestion			X(3)							
Sediment	Ingestion			X(3)							
Sediment	Direct Contact	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)		X
Alluvial Groundwater	Direct Contact									X(1)	

Figure 7.8 ECOPC Identification Process

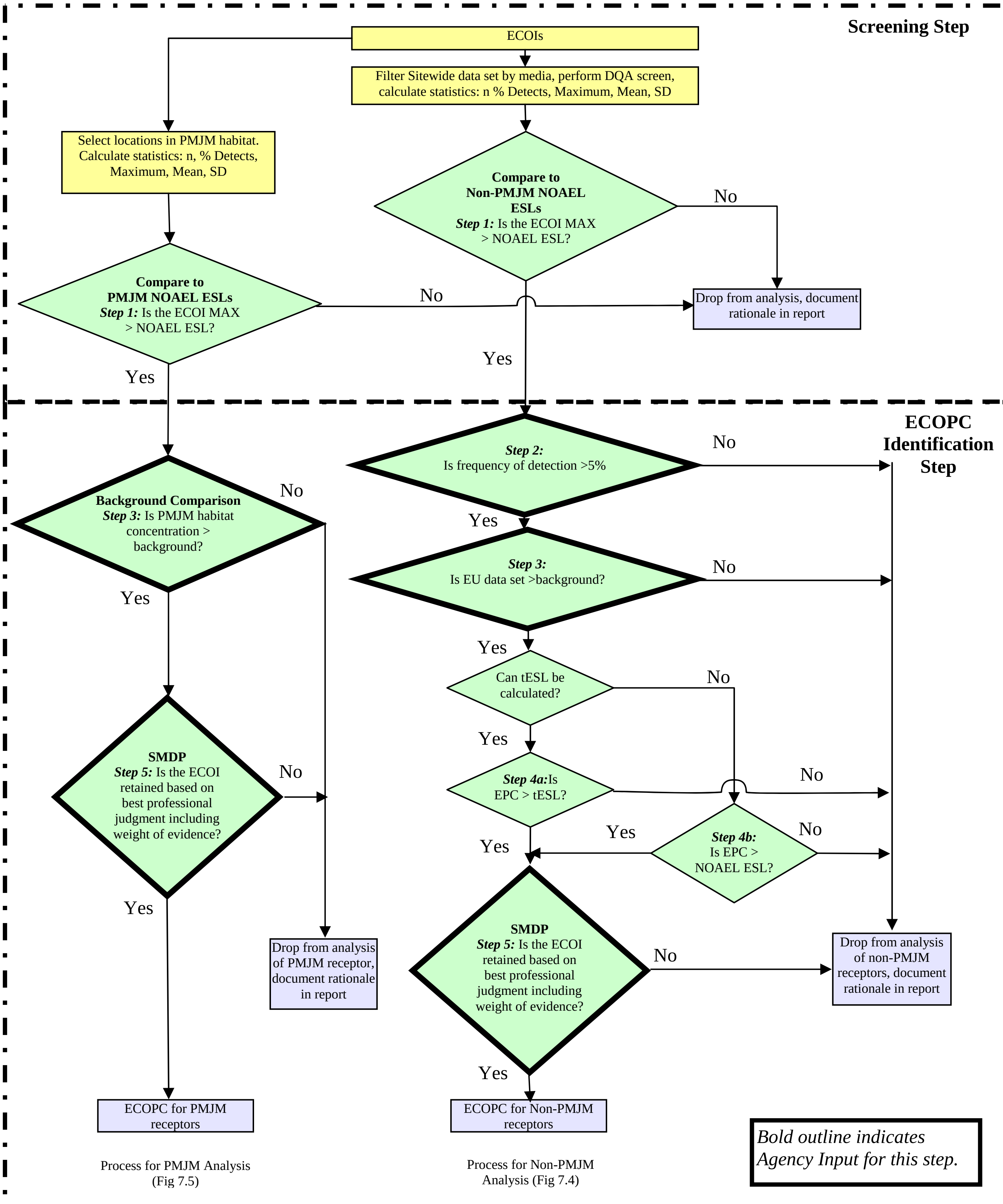
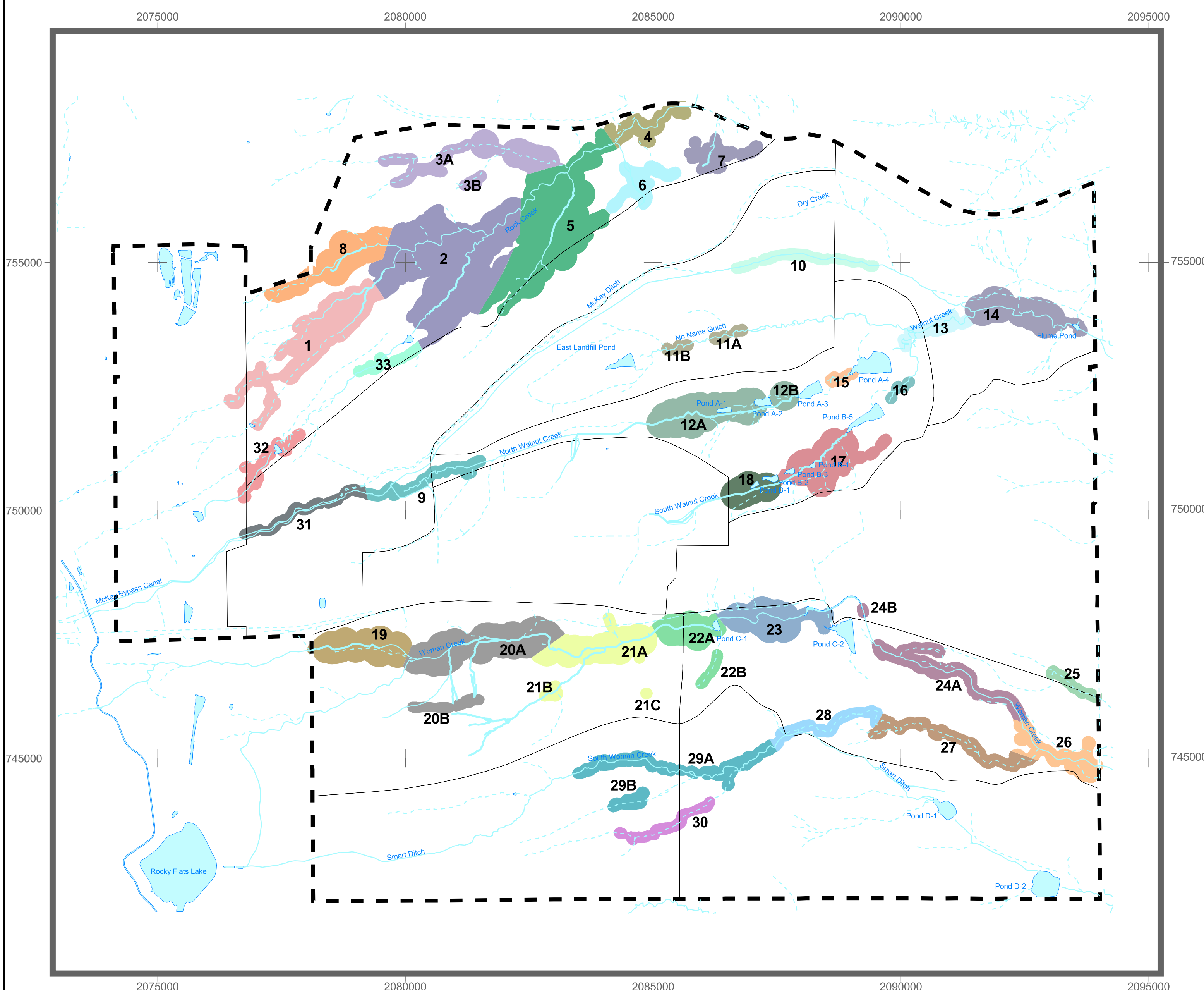


Figure 7.9

Preble's Meadow Jumping Mouse Functional Habitat Patches



KEY

PMJM habitat patch

1 PMJM habitat patch ID

Standard Map Features

Exposure unit boundary

Pond

Site boundary

Perennial stream

Intermittent stream

Ephemeral stream

N E S W

0 1500 3000 Feet

Scale 1:36000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

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Table 7.1
Summary of EU Characteristics

Table 7.2
Summary of Human Health COCs

Table 7.3
Radionuclide Exposure Factors Used in Surface Soil/Surface Sediment Intake Calculations for the WRW

Table 7.4
Radionuclide Exposure Factors Used in Surface Soil/Surface Sediment Intake Calculations for the WRV

Table 7.5
Chemical Exposure Factors Used in Surface Soil/Surface Sediment Intake Calculations for the WRW

Table 7.6
Chemical Exposure Factors Used in Surface Soil/Surface Sediment Intake Calculations for the WRV

Table 7.7
Toxicity Criteria

Table 7.8
Summary of Human Health Risk Estimates

Table 7.9
Summary of Ecological Receptors of Concern and Exposure Pathways Evaluated in the CRA

Table 7.10
Summary of Terrestrial ECOPCS

Table 7.11
Surface Water ECOPCs in the AEUs

Table 7.12
Sediment ECOPCs in the AEUs

Table 7.13
Summary of Ecological Risk Conclusions

Figure 7.1
Rocky Flats Environmental Technology Site Exposure Units

Figure 7.2
Rocky Flats Environmental Technology Site Aquatic Exposure Units

Figure 7.3
Human Health CRA COC Selection Process

Figure 7.4
Human Health Site Conceptual Model

Figure 7.5
Subsurface Soil Sampling Locations Where Volatilization PRGs Were Exceeded

Figure 7.6
Groundwater Sampling Locations Where Volatilization PRGs Were Exceeded

Figure 7.7
Ecological Site Conceptual Model

Figure 7.8
ECOPC Identification Process

Figure 7.9
Preble's Meadow Jumping Mouse Functional Habitat Patches