RISK-BASED DECISION PROCESS FOR ACCELERATED CLOSURE OF A NUCLEAR WEAPONS FACILITY

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ABSTRACT

Nearly 40 years of nuclear weapons production at the Rocky Flats Environmental Technology Site (RFETS or Site) resulted in contamination of soil and underground systems and structures with hazardous substances, including plutonium, uranium and hazardous waste constituents. The Site was placed on the National Priority List in 1989. There are more than 370 Individual Hazardous Substance Sites (IHSSs) at RFETS. Accelerated cleanup and closure of RFETS is being achieved through implementation and refinement of a regulatory framework that fosters programmatic and technical innovations: 1) extensive use of “accelerated actions” to remediate IHSSs, 2) development of a risk-based screening process that triggers and helps define the scope of accelerated actions consistent with the final remedial action objectives for the Site, 3) use of field instrumentation for real time data collection, 4) a data management system that renders near real time field data assessment, and 5) a regulatory agency consultative process to facilitate timely decisions. This paper presents the process and interim results for these aspects of the accelerated closure program applied to Environmental Restoration activities at the Site.

Accelerated Action Program

In 1996, DOE, EPA, and the Colorado Department of Health and Environment (CDPHE) (the Parties) executed the Rocky Flats Cleanup Agreement (RFCA). RFCA provides the regulatory approach and framework for the remediation of hazardous substance releases at the Site. In order to expedite remediation and maximize early risk reduction at RFETS, RFCA provides the framework for extensive use of accelerated actions to remove, stabilize, and/or contain IHSSs. A main feature of this framework is the reliance on a consultative process to streamline planning and reviews while achieving compliance with RCRA and CERCLA. Furthermore, RFCA requires the Parties to work together and fully involve the community in the decision making process for cleanup and closure of the Site.

Risk-Based Screening Process

As established in RFCA, RFETS is to be remediated to protect reasonably foreseeable land and water uses. In 1996, the foreseeable land use was open space and limited industrial. The Rocky Flats Wildlife Refuge Act of 2001 establishes Rocky Flats, upon cleanup and closure in accordance with RFCA, Colorado’s seventh national wildlife refuge. The Act provides that the Site will remain in federal ownership in perpetuity, and that jurisdiction of the Site will be transferred to the Interior Department to be maintained and protected as a refuge. This event coincided with discussions between the RFCA Parties and the community concerning the reevaluation of RFCA action levels for radionuclides in surface soils, i.e., the “interim cleanup levels” established in 1996. Since it is currently believed that the reevaluation will result in an agreement to lower the radionuclide surface soil action levels, this will result in removal of additional radionuclide surface contamination from the Site. In 1996, RFCA subsurface soil action levels merely adopted surface soil action levels as interim cleanup levels because a subsurface conceptual model for exposure pathways was not determined. These factors have resulted in development of a new risk-based screening process for assessing the need for, or extent of, accelerated actions for subsurface soil at IHSSs. The screening process compares contaminant concentrations in environmental media to Action Levels that are based on protection of a wildlife refuge worker surface user and ecological receptors for a wildlife refuge.

Instrumentation for IHSS Characterization

In order to facilitate data turnaround, the field program emphasizes use of an onsite laboratory and field portable instruments that generate real time data. Examples of instruments used on Site include gas chromatographs/mass spectrometers (GC/MS)), x-ray fluorescence (XRF) spectrometers, and high purity germanium (HPGe) gamma spectrometers. The on-site laboratory is equipped with a sufficient number of instruments to accomplish the analyses with only a few hour turnaround time. Off-site laboratories are used to provide additional validation of data generated by on-site instrumentation. Because turnaround times for receipt of data using off-site laboratories is typically very long (several days to weeks), special contracts have been established with the off-site laboratories for rapid analysis and data reduction.

Remedial Action Decision Management System

In order to shorten the time to render remedial decisions, data from on-site and off-site laboratories as well as field portable instruments are uploaded into the Remedial Action Decision Management System (RADMS). RADMS is an analytical database system that incorporates a Geographic Information System (GIS). RADMS tracks the collection of data, automatically verifies and validates the data, and graphically portrays the extent of contamination above Action Levels at a site using
standard geostatistical techniques that account for the spatial variability of data. The process is intended to provide the decision-makers with rapid, yet accurate, information regarding the proposed accelerated action.

Regulatory Agency Involvement
RADMS is populated with all previous environmental analytical data that was determined to meet quality criteria for use in evaluating IHSS contamination profiles. This is used to plan accelerated actions and to facilitate consultation to develop a notification of an accelerated action at a particular IHSS for regulatory approval. The regulatory agencies participate in a consultative manner in the day-to-day characterization and remediation process. Offices and computers are provided onsite for the regulatory personnel, and these personnel are active participants in the review and evaluation of field data. This team approach allows the regulatory personnel to actively review sampling activities and characterization results, and participate “real time” in the remedial decision process for an accelerated action.

INTRODUCTION
The Rocky Flats Environmental Technology Site (RFETS or the Site) is a Department of Energy (DOE) nuclear weapons facility undergoing closure. The Site was placed on the CERCLA National Priorities List in 1989. It is an industrial complex with process facilities, soils, and groundwater contaminated with radioactive and hazardous constituents. These facilities and contaminated media must be cleaned-up and the waste generated must be disposed to achieve closure of the Site. In 1996, the Department of Energy (DOE), Environmental Protection Agency (EPA), and the Colorado Department of Public Health and Environment (CDPHE) executed RFCA which is the Federal Facility Compliance Agreement and Consent Order negotiated pursuant to CERCLA, RCRA, and the Colorado Hazardous Waste Act (CHWA). RFCA provides the regulatory framework for completing CERCLA remediation and RCRA corrective actions to achieve Site closure.

Cleanup and closure of RFETS is being achieved through use of: 1) accelerated actions to remediate IHSSs, 2) a risk-based screening process that triggers and helps define the scope of accelerated actions consistent with the final remedial action objectives for the Site, 3) field instrumentation for real time data collection, 4) a data management system that renders near real time field data assessment, and 5) a regulatory agency consultative process that permits timely decisions.

ACCELERATED ACTION PROGRAM
RFCA provides the regulatory framework for DOE’s response obligations under CERCLA and corrective action obligations under RCRA/CHWA. RFCA adopts an accelerated action approach to Site cleanup, as described in RFCA paragraph 79: “To expedite remedial work and maximize early risk reduction at the Site, the Parties intend to make extensive use of accelerated actions to remove, stabilize, and/or contain Individual Hazardous Substance Sites (IHSSs)”.

During the accelerated action process, personnel from DOE; its contractor, Kaiser-Hill Company, L.L.C. (K-H); CDPHE; and EPA use the RFCA consultative process for accelerated action decisions, ensures that remediation does not pose unacceptable risks to workers or the public, and provides documentation for RCRA/CHWA closure of IHSSs that are also hazardous waste units.

In order to streamline the planning and implementation of accelerated actions, the Environmental Restoration (ER) RFCA Standard Operating Protocol (RSOP) for Routine Soil Remediation (ER RSOP) was prepared to serve as a single decision document for accelerated actions involving routine soil and debris remediation at Individual Hazardous Substance Sites (IHSSs). The following routine actions are described in the RSOP:

- Excavation of soil contaminated above Action Levels (ALs) (see below) and associated debris, and off-site disposal with or without off-site treatment; and
- Excavation of soil contaminated above ALs and associated debris, on-site thermal desorption treatment of VOC-contaminated soil, and on-site backfilling or off-site disposal.

The ER RSOP defines a process for implementing soil and associated debris remediation that, protects human health and the environment, meets RFCA cleanup goals, minimizes generation of waste, favors offsite disposal of radioactive waste, and is cost effective. The ER RSOP also coordinates remediation with the decommissioning schedule for buildings and Site infrastructure, uses the RFCA consultative process for accelerated action decisions, ensures that remediation does not pose unacceptable risks to workers or the public, and provides documentation for RCRA/CHWA closure of IHSSs that are also hazardous waste units.
RISK-BASED SCREENING PROCESS

The risk-based soil screening process involves the application of two screens; one for surface soil, and the other for subsurface soil. The Contaminants of Concern (COC) concentrations in surface and subsurface soil are compared to ALs that are based on protection of human and ecological receptors. The results of the evaluation allow determination of an appropriate accelerated action.

Action Levels

In order to provide guidance on the need for, or extent of, accelerated actions, ALs for ground water, and soils, and ALs and standards for surface water are established by RFCA and are contained in RFCA Attachment 5, “Action Levels and Standards Framework for Surface Water, Ground Water, and Soils” (ALF). These ALs, when exceeded, trigger an evaluation, accelerated action, and/or management action. ALs are risk based and are developed based on a reasonably anticipated future land use, an appropriate human exposure scenario for the land use, and a defined human health risk (carcinogenic and non-carcinogenic).

Under CERCLA policy, cleanup levels are to be consistent with the final reasonable anticipated future land use. On December 28, 2001, President Bush signed the Fiscal Year 2002 Defense Authorization, which included the Rocky Flats Wildlife Refuge Act that designated RFETS Colorado’s seventh national wildlife refuge. The designation will be effective upon achieving cleanup and closure, at which time the jurisdiction over the portions of the Site that DOE does not need to retain to implement the final CERCLA remedy will be transferred to the Interior Department to be maintained and protected as a wildlife refuge. Accordingly, ALs are based on protection of both human and ecological receptors for a wildlife refuge.

For protection of human health, surface soil ALs have been established based on direct contact of the wildlife refuge worker with the soil. The wildlife refuge worker surface soil exposure scenario consists of the following pathways:

♦ Ingestion of surface soil,

♦ Inhalation of dust or volatiles

♦ External radiation exposure from radionuclides, and

♦ Dermal contact for nonradionuclides.

ALs are based on an excess lifetime cancer risk of $1 \times 10^{-5}$ and a Hazard Quotient (HQ) of 1.0 to a wildlife refuge worker. The reasonably anticipated future use as a wildlife refuge is a surface land use, such that the dominant exposure pathway is to surface and near surface soil contamination. [At the Site, there is no useable groundwater, and while some groundwater is expressed into surface water on-Site, groundwater does not migrate off-Site. Thus, the exposure pathway to contaminants in groundwater is via surface water.]

Although ALs are not final remediation goals, ALs were set at a $1 \times 10^{-5}$ target risk because this target risk will result in completed accelerated actions consistent with CERCLA remedy threshold criteria of overall protection of human health and the environment and compliance with ARARs. Upon completion of all accelerated actions, it is expected that the final Comprehensive Risk Assessment (CRA) for the Site will show that residual risk from soil contamination to be less than $1 \times 10^{-6}$ for the following reasons:

♦ The final Site risks will be based on exposure units that are much larger than individual IHSSs, and thus encompass low contaminated or uncontaminated soil. Therefore, the actual risks posed by surface soil to humans from direct contact (another pathway) in an exposure unit will be significantly lower than the risks posed by the IHSSs.

♦ Generally IHSSs do not have all COCs present at concentrations above the ALs.

♦ Most areas at the Site with the potential to have subsurface contamination that could impact groundwater (and thus surface water) have incomplete pathways because of the groundwater barrier/remediation systems that are in place today.
Ecological-based ALs were developed for small mammals, ground-feeding birds, terrestrial invertebrates, and avian predators. The ALs are based on Lowest-Observed-Adverse-Effects Level (LOAEL) end points. The ecological-based surface soil ALs are the lowest AL calculated for each of the four selected wildlife receptors; Preble’s meadow jumping mouse (fossorial (burrowing) small mammal), mourning dove (small ground-feeding bird), terrestrial invertebrate (multiple species), and American kestrel (avian predator).

**Definition of Surface and Subsurface Soil**

In ALF, accelerated action decisions are dependent on the types and depths of soil contamination that are present, but there is no delineation of surface and subsurface soil action levels. The accelerated action decision policies are presented below in the discussion of the soil screens for protection of human health.

**Soil Contamination at or Near the Surface**

For contamination found in surface soil, COC concentrations are compared with the soil ALs. If COC concentrations are below the ALs, no further action is required for protection of human health. If the COC concentrations exceed the ALs, the need for an accelerated action is evaluated, and implemented as appropriate. The following remediation policies are applicable to this screen:

1. Non-radionuclide contamination that occurs in the upper 6 inches of soil at concentrations exceeding the surface soil ALs will be remediated to a depth of 6 inches to achieve the ALs. Non-radionuclide contamination that occurs at greater depths is evaluated in the Soil Risk Screen.

2. Radionuclide contamination that occurs between the surface and a depth of 3 feet at concentrations exceeding the surface soil ALs will be remediated to achieve the ALs unless, through the consultative process with the regulatory agencies, it is determined that such remediation is not practical. Radionuclide contamination that occurs at greater depths is evaluated in the Soil Risk Screen.

**Soil Risk Screen**

There are several mechanisms where a human receptor residing at the surface can be exposed to contamination originating in subsurface soil; 1) the subsurface soil becomes exposed at the surface because of a landslide; 2) the soil is brought to the surface by a burrowing animal; and 3) the contamination migrates through the subsurface to surface water, with subsequent exposure by the worker to the surface water. These mechanisms are the primary basis for the Soil Risk Screen (Figure 1) as applied to subsurface soil. Six screens are applied during the evaluation:

1. Screen 1 is a conservative pre-screen to determine if additional human health protection screening (Screens 2 – 4) is required for subsurface soil. It is conservative because COC concentrations in subsurface soil are compared with surface soil ALs. If COC concentrations are below the surface soil ALs, no further action is required for protection of human health. If the COC concentrations exceed the ALs, further screening (Screens 2 – 4) is required.

2. As mentioned, subsurface soil can become exposed at the surface because of a landslide. Accordingly, Screen 2 evaluates the likelihood of a landslide occurring at the IHSS. If a landslide is likely, then the surface soil ALs are directly applicable to subsurface soil (as applied in Screen 1) because subsurface soil can become exposed at the surface. Numerous landslide deposits have been mapped by the USGS along the sides of stream drainages at RFETS. These mapped slides and adjacent, similar geomorphic areas were delineated as areas of high landslide potential for application of Screen 2. If contamination exceeds the ALs in the subsurface in an area of high landslide potential, the need for an accelerated action is evaluated, and implemented as appropriate.

3. Screen 3 is a comparison of plutonium and americium concentrations in the subsurface at depths of 3 to 6 feet to subsurface soil ALs. The subsurface soil ALs are based on the concept that subsurface soil in this depth range can be brought to the surface in small amounts by a burrowing animal. If plutonium and americium contamination exceeds the ALs in the depth interval of 3 to 6 feet, the need for an accelerated action is evaluated, and implemented as appropriate. The subsurface soil ALs are an adjustment to the surface soil ALs based on the following considerations:
human exposure to the small area of subsurface soil that has been brought to the surface (i.e., the prairie dog mound) is a fraction of the exposure to the surrounding surface soil [application of an Area Factor (AF)], and

the possibility exists that, at the depth where contamination is found, the area of contamination may be less than the area disturbed by the prairie dog, i.e., the subsurface soil that is brought to the surface from a specific depth is a mixture of contaminated and non-contaminated soil from that depth (application of a Dilution Factor (DF)).

The application of the dilution factor introduces the area of subsurface contamination ($A_{sc}$) as a variable in determining the subsurface ALs. In effect, a factor is applied to the surface soil ALs to arrive at the subsurface soil ALs for a given area of subsurface soil contamination. The resulting factors are shown below.

<table>
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<th>$A_{sc}$ (m$^2$)</th>
<th>Factor</th>
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<tr>
<td>24</td>
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</tr>
<tr>
<td>48</td>
<td>100</td>
</tr>
<tr>
<td>80</td>
<td>60</td>
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</table>

As can be seen, as the area of subsurface plutonium and americium contamination increases, the factor decreases. The factor range of 60 to 200 and the associated areas are used to calculate subsurface soil plutonium and americium ALs that will trigger an evaluation and an accelerated action determination.

4. Screen 4 is a prescreen to simply identify if there is a hydraulically downgradient groundwater collection system that would capture contamination emanating from this IHSS into groundwater, and subsequently into surface water. If there is not (or will not be) a downgradient groundwater collection system, the IHSS is further evaluated for accelerated action.

5. With Screen 5, COC concentrations in surface soil are compared with the soil ALs that protective of ecological receptors. If COC concentrations are below the ALs, no further action is required for protection of human health. If the COC concentrations exceed the ALs, an accelerated action implemented unless the COCs do not pose an unacceptable hazard considering the target species and the exposure unit for the species, and the location, areal extent, and concentration of the COCs.

6. Screen 6 is used to identify if there is potential for contamination in soil at the IHSS to migrate to surface water and exceed the surface water standard at a Point of Compliance. If such a potential exists, the IHSS is flagged for further evaluation. Otherwise no further accelerated action is required.

It should be noted that contamination that occurs deeper than 6 feet or is otherwise beneath subsurface structures such as basements, sumps, vaults, pits, etc. will be evaluated on a Site-wide basis for potential impacts to ecological receptors and surface water quality. Remedial action will be taken as appropriate based on the Site-wide evaluations.

REAL-TIME CHARACTERIZATION OF IHSSs

The characterization of IHSSs is performed by dedicated field crews using an on-site laboratory and portable instrumentation to achieve real-time or near real-time data turnaround. Instrument sensitivities are sufficient to reliably detect contamination above ALs, i.e., minimize to the extent possible the production of data that represent false negatives in terms of need for accelerated action (or further accelerated action). On-site laboratory instrumentation includes x-ray fluorescence (XRF) spectrometers for metal analyses, gas chromatograph/mass spectrometers (GC/MSs) for organic analyses, and gamma spectrometers using high purity germanium detectors (HPGe) for radionuclide analyses. The on-site laboratory instrumentation is in full compliance with SW-846 analytical methods and other methods appropriate to radiochemical analysis. They are in sufficient numbers to accomplish the authorized work to achieve a maximum data turn around time (TAT) of 24 hours after sample collection. The main field instrument used is the in-situ HPGe gamma spectrometer.

REMEDIAL ACTION DECISION MANAGEMENT SYSTEM

In order to shorten the time to render remedial decisions, data from the onsite laboratory and field portable instruments is uploaded into the Remedial Action Decision Management System (RADMS). RADMS is the “engine” that drives the streamlined characterization and remediation strategy. The system is the key link between the characterization and
remediation phases of the cleanup effort as well as the information management tool for closeout reporting and day-to-day interface with the regulatory agencies. RADMS is a networked geo-database system that relates all data to geographic locations. It consists of the following integrated modules:

- **Geo-spatial.** This module is used to develop the sample planning documents for which regulatory agency approval is required prior to initiation of field work.
- **Field Data Collection.** This large, complex module supports sample collection, shipping and tracking as well as exchange of data with the RFETS’ Analytical Services Division (ASD).
- **Verification and Validation (V&V).** This module validates all analytical data prior to use for decision making. The module is complex and computation intensive. It is currently undergoing beta testing.
- **Data Quality Objectives (DQO).** This module incorporates all of the data requirements and processes agreed to by the regulatory agencies relative to the quality of the ER sampling data and the methods for determining whether contaminant concentrations merit remedial action. The module is currently incorporating extensive Data Quality Assessment (DQA) methodologies for performing multiple statistical analyses to determine data adequacy.
- **Risk Analysis.** This module performs two complex functions. The first is risk screening to determine if an IHSS cleanup will result in a cleanup level that is acceptable under the Site’s cleanup agreement. This function is complete. The second function is to support performance of the CRA to be performed after completion of all accelerated remedial actions. The module will analyze approximately 5 million analytical records and will be in operation by the end of FY03.

RADMS supports accelerated actions by providing valid and statistically-interpreted data so the right decisions can be made by DOE and the regulatory agencies. RADMS is accessible to DOE and the regulatory agencies onsite. This facilitates characterization and remediation decisions that are made through the consultative process.

**REGULATORY AGENCY INVOLVEMENT**

Accelerated actions have three phases: planning; implementation; and closeout. Each phase provides the opportunity for interaction between the regulatory agencies. Each phase has one or more RFCA decision points and additional checks and balances through which CDPHE and EPA fulfill their regulatory oversight obligations. Decision points and additional checks and balances are briefly described below.

**Planning**

The sampling plans that govern IHSS characterizations contain an Addendum element. The Addendum accommodates the Site’s obligation to administratively disposition every IHSS, PAC and UBC site. It acts as a tracking vehicle and contains the target sites, site maps, site-specific potential COCs, existing qualified sampling data, starting-point sampling locations, and sampling methodology. The Addendum is prepared in consultation with the agencies and is subject to their approval. The first agency checkpoint in the process is approval of the Sampling and Analysis Plan (SAP) Addendum.

The second agency checkpoint in the process is the submittal of the notification letter. The intent to take an accelerated action is provided through a notification letter issued by DOE to the regulatory agencies. The Lead Regulatory Agency (LRA) has 14 calendar days to approve the notification letter.

**Implementation**

After approval of the Notification letter, the regulatory agencies remain informed about sampling activities and results. Data are immediately translated into remediation maps to guide remediation crews using RADMS. Concurrence is reached on remediation maps through the consultative process within a day or two after characterization. Concurrence on when remediation is finished is through the consultative process and documented through electronic mail.

**Closeout**

The purpose of closeout is to document the accelerated action activities. The Closeout Report summarizes characterization data, the action taken, demarcation of excavation, confirmation sampling results, remediation waste volume and disposition, any changes in remediation approach and the rationale behind the change, stewardship recommendations, and the demarcation of residual contamination left in place at an IHSS. The Closeout Report is a RFCA decision document and the vehicle by which the regulatory agencies approve completion of the accelerated action.
ACCELERATED ACTION PROGRAM RESULTS
The accelerated action program has proven to be a success at RFETS. As shown in Table 1, since the signing of RFCA, remediation has been completed or a no further action (NFA) determination has been proposed at 201 of the 370 contaminant-release sites at RFETS. Of the 201 sites, 150 are considered closed by the regulatory agencies, i.e., the remedial activity that was implemented or the NFA determination was deemed acceptable.

<table>
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<td>UBCs</td>
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<td>Plumes</td>
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<tr>
<td>Totals</td>
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<td>166</td>
<td>144</td>
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</table>

IHSS – Individual Hazardous Substance Site
PAC – Potential Area of Concern
UBC – Under Building Contamination

CONCLUSION
The overriding goal for DOE is to achieve final closure of RFETS so that it offers long-term protection of public health and the environment. This is being achieved through implementation of accelerated actions that are safe to workers and the public, and that are consistent with the final remedy for the Site. The Accelerated Action Program is an integrated approach that has provided clear, consistent direction for accelerated actions through upfront resolution of a number of interrelated issues critical to achieving cleanup and closure of RFETS.
Figure 1: Soil Risk Screen

ACRONYMS
COC - contaminant of concern
IHSS - Individual Hazardous Substance Site
AOC - Area of Concern
OU - Operable Unit
POC - Point of Compliance