Planning and Implementing RCRA/CERCLA Closure and Post-Closure Care When Wastes Remain Onsite

Background: This Information Bulletin is primarily intended for personnel with project management responsibilities for Department of Energy (DOE) environmental restoration or waste management projects conducted pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or the Resource Conservation and Recovery Act (RCRA). It describes issues faced at CERCLA sites and RCRA facilities/units undergoing closure and post-closure care ***when wastes will remain onsite or groundwater is contaminated***, and discusses techniques for addressing these issues effectively. [Note: this Information Bulletin does not discuss closure when no wastes remain onsite (i.e., clean closure under RCRA, or cases resulting in unrestricted land use under CERCLA or RCRA corrective action).]

Post-closure care is required when hazards remain onsite (e.g., contaminants remain above risk-based or other regulatory levels) and "barriers" are in place to prevent exposure of humans and ecological receptors to these hazards. In this Information Bulletin, the term "barrier" is defined broadly to include any administrative or engineered device in place to prevent unacceptable exposures to hazards (e.g., covers, fencing, land use restrictions, pumping and treating of groundwater to prevent migration of contaminants). Specifically, this Information Bulletin describes how four principles, consistent with and based on the Principles of Environmental Restoration (as outlined in **Highlight 1**), may be used as a framework for effectively complying with regulations and addressing issues associated with closure and post-closure care.

Statutes: Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended.
Resource Conservation and Recovery Act (RCRA) as amended.

Regulations: National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 *CFR* Part 300
40 *CFR* 264/265, Subpart G

References:

1. "Delay of Closure for RCRA Hazardous Waste Management Facilities," EH-231-021/0993, September 1993. Available at the EH-41 website: http://tis.eh.doe.gov/oepa/guidance/rcra/delay.pdf.
2. "Expediting Cleanup through a Core Team Approach," DOE/EH-413-9911/0999 (September 1999).
3. "Expediting Cleanup through Early Identification of Likely Response Actions," DOE/EH-413-9902, May 1999. Available at the EH-41 website: http://tis.eh.doe.gov/oepa/guidance/cercla/earlyid.pdf.
4. "Expediting Cleanup through Problem Identification and Definition," DOE/EH-413-9904, May 1999. Available at the EH-41 website: http://tis.eh.doe.gov/oepa/guidance/cercla/prob_id.pdf.
5. "Site Conceptual Exposure Model (SCEM) Builder." Available at the EH-41 website: http://tis-nt.eh.doe.gov/oepa/programs/scem.cfm
6. "Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites," OSWER Directive # 9200.4-17, *62 FR 64588-64589*, December 8, 1997.
7. "Uncertainty Management: Expediting Cleanup Through Contingency Planning," DOE/EH/(CERCLA)-002, February 1997. Available at the EH-41 website: http://tis.eh.doe.gov/oepa/guidance/cercla/7combine.pdf.
8. "RCRA Closure and Post-Closure Plans," EH-231-009/1291, December 1991. Available at the EH-41 website: http://tis.eh.doe.gov/oepa/guidance/rcra/pcplans.pdf.

Introduction

Closure and post-closure care activities include:

1. Terminating waste management operations or active remediation of past releases, and

2. Planning and implementing management of wastes that remain in place in a "unit.[1]"

There are specific requirements under both RCRA and CERCLA for conducting closure and post-closure care when wastes remain onsite.[2] These activities include those needed to obtain agreement from site regulators that a CERCLA or RCRA project is complete. Also included are activities necessary to implement surveillance, monitoring, and maintenance of any barriers that are part of a remedy. Examples of the types of administrative activities required by statute or regulation under CERCLA and RCRA include:

1. For **CERCLA** projects, the statute and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) define a process for deletion of sites from the NPL, detail how to conduct 5-year reviews to ensure protectiveness of the remedy when wastes remain in place, and require project managers to document completion of a removal operation.[3]

2. For **RCRA corrective action** projects, the owner/operator must document completion of corrective measures and submit a request for a permit modification leading to post-closure care.[4]

Highlight 1: The History of the Principles of Environmental Restoration

The Principles of Environmental Restoration are the distilled lessons learned from years of practical field experience implementing environmental response programs under RCRA and CERCLA. These principles emerged based on the collective experience of project managers working on both public and private lead sites since the inception of these environmental programs in the United States. This wealth of experience, combined with the analysis of site approaches where responses have been successful, lead to the development of four principles of environmental restoration. Together, these principles form a framework that fosters communication and leads to project streamlining.

The four principles of Environmental Restoration are:

1. Building an effective core team is essential. *For more information, refer to DOE/EH-413-9911/0999 (September 1999)*

2. Clear, concise, and accurate problem identification and definition are critical. *For more information, refer to DOE/EH-413-9904 (May 1999).*

3. Early identification of likely response actions is possible, prudent, and necessary. *For more information, refer to DOE/EH-413-9902 (May 1999).*

4. Uncertainties are inherent and will always need to be managed. *For more information, refer to DOE/EH/(CERCLA)-002 (February 1997).*

3. For **closure of RCRA regulated units**, the owner/operator must submit a survey plat that indicates where hazards remain to the authority with jurisdiction over local land use. The owner/operator must also document the plans for post-closure care, which generally must

[1] The term 'unit,' as used in this document, refers to any distinct areas of a site where remediation or waste management is conducted or evaluated. A unit may be a single area (e.g., RCRA regulated unit, landfill, groundwater remediation project) or a number of smaller projects grouped together (e.g., CERCLA operable unit, entire NPL site).
[2] RCRA closure/post-closure care requirements are found in 40 CFR 264/265, Subpart G. CERCLA requirements are found in 40 CFR 300.
[3] See 40 CFR 300.425(e), 40 CFR 300.430(f)(4)(ii), and 40 CFR 300.165, respectively
[4] Per 40 CFR 264.110 - 264.120 (Subpart G)

continue for at least 30 years after the date of closure.[5]

In addition to an administrative component of remedy completion, closure, and post-closure, RCRA and CERCLA regulations establish performance-based approaches that must be met (e.g., develop a monitoring program to ensure that actions protect human health and the environment). What is lacking in the regulations, however, is a detailed framework to help project managers make the technical decisions needed to meet these performance measures. ***This Information Bulletin outlines considerations, consistent with the principles of environmental restoration, which provide this framework.***

Overview of major statutory and regulatory requirements related to closure and post-closure care

The key steps leading to RCRA and CERCLA closure and the specific scope of this Information Bulletin are depicted in **Figure 1**. On the next page, **Figure 2** describes the major regulatory requirements under which remedy completion, closure, and post-closure is typically conducted when wastes are left in place or groundwater is contaminated. However, as seen in Figure 2, the general requirements and technical objectives of these projects are primarily performance-based, regardless of the regulatory framework under which the work is executed. For example, to reach construction completion under CERCLA, project managers must demonstrate that the implemented remedy is "functioning properly" and "performing as designed."[6] To reach project closure under RCRA, regulators must agree that a remedy has achieved its project performance objectives and that owners/operators have taken and will continue to take "all steps to prevent threats to human health and the environment."[7] In all cases, when hazards remain onsite, project managers must develop monitoring and maintenance plans to ensure continued protection.

Performance-based objectives have the advantage of providing project managers flexibility in the technical approaches they can use. This flexibility also allows project managers to remediate in the most efficient and effective manner possible. To achieve performance-based objectives effectively, however, project managers must consider a number of critical issues, including:

- **Inherent uncertainties in actual site conditions.** When wastes remain in place, uncertainties about the actual site conditions nearly always remain following remediation. These uncertainties may include questions regarding the nature, amount, and behavior of the waste materials left in place. For example, project managers may question whether predictions about the future fate and transport of waste left in place in a disposal area are accurate. Consequently, project managers should consider what deviations from expected site conditions and waste characteristics are likely. Furthermore, if a remedy does not work or does not continue to work in a satisfactory manner following implementation, a different remedial approach may need to be evaluated (i.e., a contingent remedy).

- **Potential for future exposure.** When wastes remain in place, there is always a potential that future activities will lead to unplanned exposures to human and environmental receptors. Even if site conditions remain as expected (e.g., wastes remain in disposal units), exposure pathways that have been eliminated by means of an engineered or administrative barrier may be reopened (e.g., if animals burrow through cap). In some cases new, unplanned-for exposure pathways may be established (e.g., if different land uses than assumed occur).

- **Continued community awareness and involvement.** Both RCRA and CERCLA regulations require continued communication with the local community during closure and post-closure activities, particularly where different land reuse scenarios are possible. In

[5] Per 40 CFR 264.117(a)(1) and 40 CFR 264.117 (a) (2) (i) & (ii)
[6] Per 40 CFR 300.435(f)(2)
[7] Per 40 CFR 264.113(a)(2)

Figure 1. Timeline of Stages Leading to Closeout of RCRA and CERCLA Environmental Projects

Typical RCRA/CERCLA Remediation

Phase:	*Discovery (PA/SI or RFA)*	*Investigation and Alternative Evaluation (RI/FS and RFI/CMS)*	*Remedy Selection Implementation (ROD/RDI and SOB/CMI)*	*Project Closeout and Long-term Care*
Focus:	Identify releases potentially requiring response	Gather sufficient data to define problems, evaluate responses, and manage uncertainties that will arise during implementation	Define completion objectives before implementation begins and manage uncertainties as they arise during action.	Define and implement technical requirements to meet NCP close-out conditions, define objectives to measure success of long-term care, conduct 5-year reviews and delete from NPL, identify and manage uncertainties that
Primary OEPA References:		•RI/FS Guidance[1] •Phased Approach Guidance[2] •Principles Factsheets[3, 4, 5, 6]	•Multiple guidance documents. Refer to: http://tis.eh.doe.gov/oepa/ •Also refer to the Principles of Environmental Restoration II: Design and Implementation training	•This Information Bulletin

Typical RCRA Regulated Units:

Phase:	*Planning*	*Operation of Unit*	*Closure and Post-Closure Care*
Focus:	Obtain permits and/or establish procedures for operation to meet Federal / State hazardous waste requirements	Comply with permit and other regulatory requirements; develop plan detailing how closure of operations will occur.	Define and implement technical aspects of RCRA closure requirements, obtain post-closure permit, define objectives to measure success of long-term care, manage uncertainties that remain.
Primary OEPA References:	•RCRA Permitting Guide for Hazardous and Radioactive Mixed Waste Management Facilities[7]	•Multiple guidance documents. Refer to: http://tis.eh.doe.gov/oepa/	•This Information Bulletin

1. http://tis.eh.doe.gov/oepa/guidance/cercla/ri_fs/allri_fs.pdf
2. http://tis.eh.doe.gov/oepa/guidance/cercla/phased/phased.pdf
3. http://tis.eh.doe.gov/oepa/guidance/cercla/prob_id.pdf
4. http://tis.eh.doe.gov/oepa/guidance/cercla/earlyid.pdf
5. DOE-EH-413-9911/0999 (September 1999)
6. http://tis.eh.doe.gov/oepa/guidance/cercla/7combine.pdf
7. http://tis.eh.doe.gov/oepa/guidance/rcra/permit_a.pdf

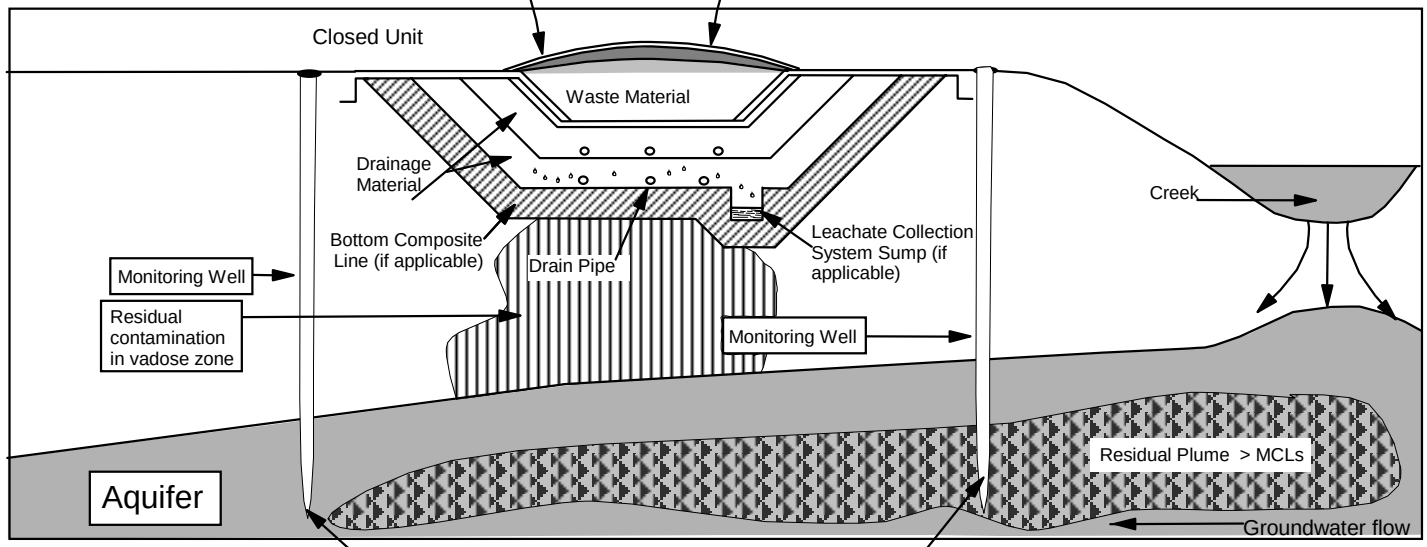
Figure 2. Typical Regulatory Requirements for Closure of Hazardous, Mixed, and Remediation Units with Waste in Place*

TYPICAL COVER DESIGN CRITERIA

Cover the landfill or cell with a final cover designed and constructed to:
- Provide long-term minimization of migration of liquids through the closed landfill.
- Function with minimum maintenance.
- Promote drainage and minimize erosion or abrasion of the cover.
- Accommodate settling and subsidence so that the cover's integrity is maintained.
- Have a permeability less than or equal to the permeability of any bottom liner system or natural soils present

TYPICAL UNIT POST CLOSURE REQUIREMENTS

Owner/Operator must:
- Maintain the integrity and effectiveness of the final cover (e.g. make repairs to correct effects of settling, subsidence, erosion, or other events).
- Continue to operate leachate collection and removal system until the leachate is no longer detected.
- Maintain and monitor the leak detection system.
- Prevent run-on and run-off from eroding or otherwise damaging the final cover.
- Protect and maintain surveyed benchmarks used in complying with surveying and record-keeping regulations.



TYPICAL PERFORMANCE REQUIREMENTS (40 CFR § 264.111)

Owner Operator must:
- Minimize the need for further maintenance.
- Control, minimize, or eliminate to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated run-off, or hazardous waste decomposition products to the ground or surface waters or the atmosphere.

TYPICAL MONITORING REQUIREMENTS

Owner Operator must:
- Maintain and monitor the groundwater monitoring system.

GROUNDWATER PLUME CONTROL

Owner Operator must:
- Control and maintain plume to prevent exposure and movement beyond points of compliance.
- Maintain compliance with regulatory standards.

*Typical requirements for regulated units and as ARARs or applicable requirements to CERCLA and RCRA corrective actions.

addition to meeting the regulatory requirements, ensuring community awareness of remaining hazards and encouraging community involvement are often crucial to maintaining the protection of human health and the environment in the long-term.

- **Transfer of information.** During closure, a project manager must identify what information should be transferred to the regulators and other stakeholders to ensure continuation of effective project closeout. Project managers must also identify methods that work best to transfer that information.

By considering the following four principles, a project manager will have a more effective framework for evaluating and addressing each of these issues associated with the closure / post-closure phase of RCRA and CERCLA projects.

Planning and Implementing Effective Project Closeout[8]

Four principles, consistent with and based on the principles of environmental restoration, provide a framework for planning and implementing effective project closeout activities:

1. Define baseline conditions that exist at start of project closure and post-closure activities.

2. Early identification of monitoring needs is possible, prudent, and necessary to detect any significant changes to the baseline conditions.

3. Uncertainties are inherent during closure and post-closure care, and must be managed.

4. Early, open communication and involved decision-making by stakeholders is essential.

These principles are not a prescriptive recipe for success; rather, they are fundamental considerations for thinking about issues associated with closure.

Principle 1. Define baseline conditions that exist at start of project closure and post-closure activities. *Clear definition of the baseline conditions of the unit at the time of remedy completion and unit closure is essential to ensure effective protection of human health and the environment in the long-term.*

Perhaps the single most important activity a project manager can do to ensure effective protection of human health and the environment into the future is to clearly document the baseline conditions when an environmental project is completed. The baseline conditions are the elements of the legally agreed-upon or mandated "protective" scenario required by the regulations. Under any regulatory framework, this "protective" scenario is defined by four components:

- **Waste characteristics** (e.g., contaminant types, concentrations of contaminants left in place);

- **Unit characteristics** (e.g., media containing contamination, distance to groundwater, possible transport mechanisms for contaminants, exposure pathways to receptors);

- **Barriers in place** (e.g., design and requirements to maintain a multi-level cap, pump-and-treat system to restrict plume migration, fence enclosing unit); and

- **Other key assumptions/restrictions to maintain protectiveness** (e.g., restricted land-use, groundwater use restrictions, zoning restrictions).

Together, these four components describe the status of the known hazards that remain in a unit and how protection of human health and the environment has been achieved and will be maintained. If changes to these baseline conditions

[8] The term "closeout" encompasses all of those activities associated with terminating waste management operations or active remediation of past releases, and planning and implementing management of wastes that remain in place in a unit. Closeout includes remedy completion, closure and post-closure care.

occur, protection of human health and the environment may not continue to be maintained. A project manager ensures that future caretakers of the unit understand the details of the "protective" scenario by documenting the baseline conditions of a unit at completion.

One method for documenting the baseline conditions is to develop a Post-Closure Conceptual Site Model. This tool visually summarizes the remaining potential hazards, potential exposure pathways, and how pathways are blocked. In most cases, the framework of the Post-Closure Conceptual Site Model already exists because sites typically create conceptual site models during the remedial investigation and remedy selection phases of remediation. Existing conceptual site models can easily be modified to reflect the changes that occurred during remedial action. In addition to the Post-Closure Conceptual Site Model, creation of a matrix that summarizes assumed conditions and other restrictions is often beneficial. This matrix further defines the waste and unit characteristics, and barriers in place. The matrix also elaborates on the other restrictions that are required to maintain protectiveness. **Figure 3** provides an example of a Post-Closure Conceptual Site Model with a matrix of baseline conditions.

Principle 2. Early identification of monitoring needs is possible, prudent, and necessary to detect any significant changes to the baseline conditions. *When hazards will remain onsite, monitoring establishes that baseline conditions are being maintained. Early identification of these monitoring needs is prudent. Identification of when, if ever, the level of these monitoring efforts can be reduced or need to evolve is also critical.* (See **Highlight 2** for examples of different methods to monitor the performance of a remedy.)

After documenting the assumed baseline conditions of a unit, a project manager must next define how any major changes in these conditions will be identified. These management requirements translate into monitoring needs.

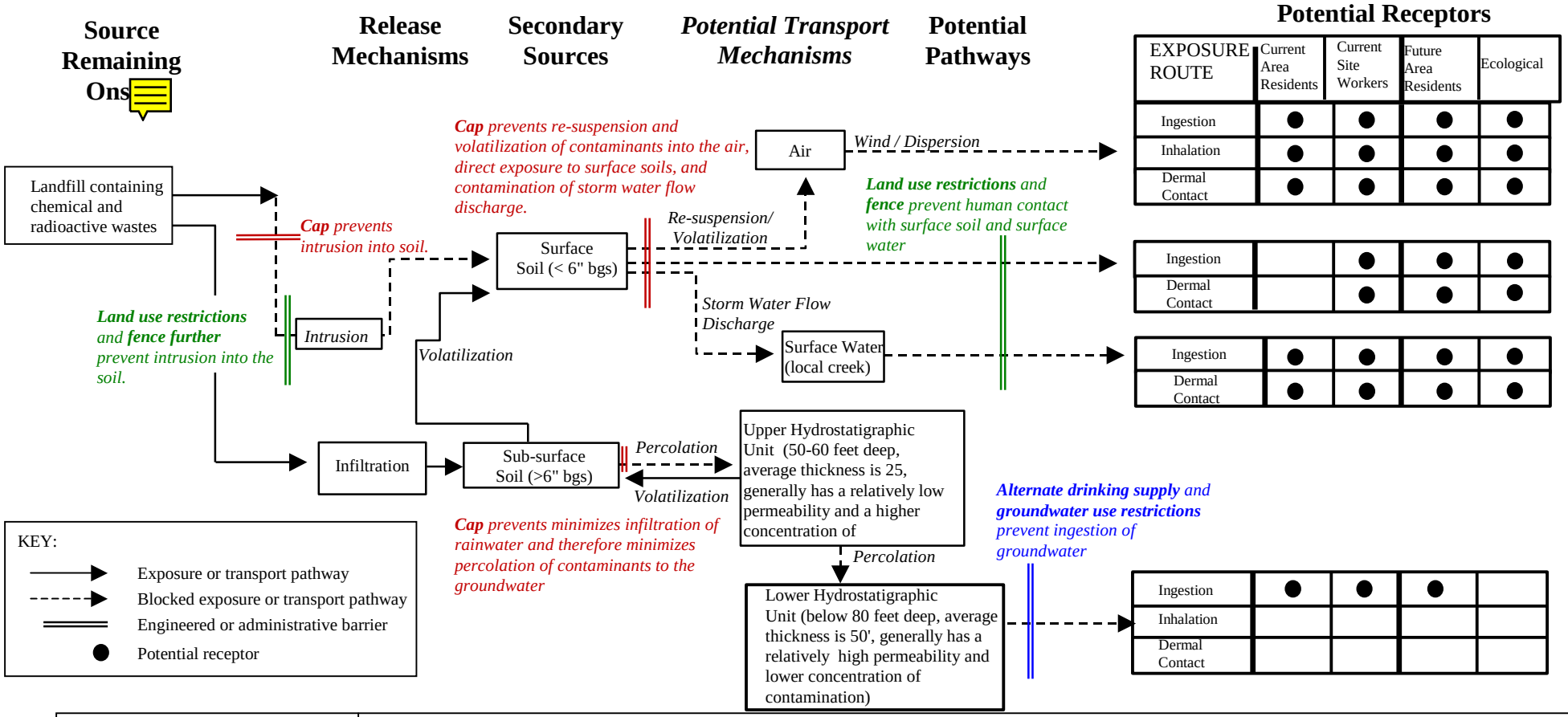
Some monitoring needs will be driven by closure

Highlight 2. Examples illustrating different ways to monitor performance of a remedy.

At a closed RCRA regulated landfill unit, a project manager is often able to monitor the performance of a cap through direct observation. For example, the project manager may determine that the expected condition of the unit is that the cap will prevent infiltration of water and, therefore, minimize formation of leachate. The assumed conditions are that if any leachate is produced, it will be in such small quantities that the collection system's capacity will not be exceeded. However, a reasonable deviation to this expected condition is that leachate will form faster than the system can collect and treat it. Because the unit has a leachate collection sump, the project manager can directly monitor how much leachate is produced. If monitoring indicates that leachate is forming faster than expected, the project manager can devise a method for addressing this unexpected condition (e.g., expand the capacity of the treatment system, modify the cap).

At a unit where waste has been capped in place, and no engineered liner or leachate collection system exist, the project manager must implement a different method for monitoring performance of the cap. In this case, the assumed conditions may be that the cap will minimize infiltration of contaminants into the groundwater that in the past resulted in concentrations above maximum contaminant levels (MCLs). Because the project manager cannot directly observe how much leachate is generated, the performance of the remedy may be monitored by installing wells at the boundary of the unit. Monitoring of these wells will provide indications that the cap is functioning properly (e.g., may demonstrate a trend of decreasing contaminant concentrations). In addition, the wells should be designed to provide conclusive evidence if the cap has failed and the groundwater is contaminated (e.g., detection of contaminants at levels above MCLs) so that the project manager has time to address this unexpected condition before unacceptable exposures occur.

Figure 3. Example Post-Closure Conceptual Site Model and Matrix of Baseline Conditions



Components of the Protective Scenario	Description
Waste Characteristics	One landfill containing wastes remains onsite. Contaminants in the landfill include: Ra-226, Sr-90 Cr, NO, $CHCL_3$, DCE, Toluene, H^3, C^{14}, and DCA. The estimated volume of material is approximately 420,000 cubic yards; a minimum of 1,000 curies was disposed of in the landfill, based on historical information and knowledge of materials disposed of in this area.
Unit Characteristics	The landfill is approximately 50-60 feet above the upper hydrostatigraphic unit (HSU) and approximately 80 feet above the lower HSU of the groundwater aquifer. The contaminants detected in the upper HSU include: $CHCl_3$, DCA, Cr, NO_3, DCE, Toluene, H^3, and C^{14}. The contaminants detected in the lower HSU include: Cr, NO, $CHCl_3$, DCE, Toluene, H^3, C^{14}, and DCA.
Barriers in Place	One single-layer cap with a design life of 30 years covers the landfill. There is a covenant that restricts land use in two ways: 1) There is to be no digging in the landfill area, and 2) There shall be no agricultural or residential use of groundwater; pumping groundwater from wells is prohibited.
Other Key Assumptions to Maintain Protectiveness	Land use will remain industrial. Monitored natural attenuation will demonstrate that contaminants in the groundwater are below MCLs in 20 years. Remaining contaminants in landfill area will not continue to leach to the groundwater. An alternate drinking supply is provided to local residents.

and post-closure regulations. Other monitoring activities need to be implemented as a necessary best management practice for ensuring protection of human health and the environment. Regardless of the specific reasons a project manager chooses to implement monitoring, there will be a continuing need to evaluate the performance of engineered and administrative barriers when hazards remain onsite. For example, there is always a chance that an engineered barrier will not perform as intended (e.g., the design of a barrier fails to contain contaminants). There is also a chance that a functioning barrier will be breached (e.g., burrowing animals damage the structural integrity of a cap). Hence, exposure to remaining hazards at a site might occur under if:

1. Engineered barriers fail,

2. Engineered or administrative barriers are breached, or

3. Actual site conditions are or become different than those assumed.

Consequently, monitoring should be designed to detect if any of these non-protective conditions may exist or could develop.

Under some circumstances, a project manager may directly observe whether a remedy is functioning properly (e.g., determine whether a cap has minimized infiltration of water through a closed RCRA unit by measuring the amount of leachate generated through routine monitoring of a leachate collection system). This type of monitoring allows a project manager to gain definitive evidence of whether a remedy is successful (e.g., by demonstrating that expected quantities of leachate are being produced). Direct observation can also indicate when a remedy has failed (e.g., a sudden increase in the amount of leachate generated could indicate a breach in cap integrity). However, direct observation can only be employed if a project manager is able to identify parameters or conditions that can be observed as direct measures of success or progress.

Not all aspects of response actions are amenable to direct observations. For instance, many containment in-place or in-situ technologies must be monitored through use of discrete monitoring points (i.e., wells). These discrete monitoring points may provide positive evidence of whether a remedy has failed (e.g., concentrations of contaminants in the groundwater increase above a pre-determined threshold level). Monitoring a remedy's performance from discrete points can also provide indicators of success (e.g., demonstrate that contaminants above the threshold level have not yet been detected, demonstrate a trend of decreasing concentrations of contaminants). However, this type of monitoring frequently cannot provide conclusive evidence that the remedy is functioning properly. Instead, monitoring of discrete points indicates trends, which, in turn, project managers and regulators must interpret to determine if a remedy is functioning properly.

It is important to note that certain remedies may require specific monitoring approaches to be employed. For example, if monitored natural attenuation is selected as the remedy, a substantial monitoring approach is required, as defined in the *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites; Directive 9200.4-17P, April 21, 1999.*[9]

Decision rules for reducing monitoring and maintenance

Another crucial aspect of devising an effective monitoring approach is identifying when monitoring and maintenance activities need to be changed or can be reduced. As in all other stages of environmental restoration, only those data should be collected that are necessary for project managers and regulators to make sound technical and engineering decisions.

Data from monitoring can be used as the basis for evaluating attainment of the end remediation

[9]This directive is available on the internet at: http://www.epa.gov/swerust1/directiv/d9200417.htm

objective or compliance with regulatory or permit requirements. For example, a remediation strategy for a groundwater plume containing tritium may be a combination of pumping (to control plume migration) and natural attenuation. Once monitoring demonstrates that tritium has decayed to below its MCL, plume migration measures can be stopped.

During the remedy completion and closure phases, project managers should evaluate what additional action will be needed to protect human health and the environment if site conditions change or if remedies fail. Long-term care activities should require a level of effort commensurate with the hazards that remain onsite and the potential risks they pose. Similarly, monitoring should be commensurate with the level of uncertainty at a site. As certainty in site conditions increases, the level of effort associated with monitoring can often decrease.

Decision rules are a tool for defining criteria or boundaries for decreasing monitoring requirements. Because the project manager likely will not be the individual responsible for long-term care of a unit, it is crucial that these criteria be precisely defined during project closeout.

Highlight 3: Example of a Decision Rule

IF a contaminant X is not detected in any of the groundwater monitoring wells above EPA's MCLs for 12 consecutive quarterly monitoring efforts, ***THEN*** remove constituent X from the list of analytes of concern and do not continue monitoring for this constituent.

It is important to note that regulators must approve the use of certain decision rules, as is the case in the above example. Once decision-makers agree on a decision rule, generally the technical staff may execute the decision without subsequent approvals as long as all criteria have been met.

Principle 3. Uncertainties are inherent during closure and post-closure care, and must be managed: *If hazards remain onsite, project- and programmatic-level uncertainties are inherent and will need to be managed.*

When wastes remain in place, there are inherent uncertainties that project managers should identify and manage to ensure that protective conditions are maintained. For example, there are often uncertainties in baseline conditions, whether existing monitoring is adequate, whether remedies will continue to function as planned, and whether key assumptions about potential receptors will remain valid in the future.

When construction of a remedy is complete, one potential uncertainty is whether regulatory objectives have been met or if progress is being made towards meeting those objectives. If there is no question that the response is complete (e.g., all contaminated soil was located and removed), there should be no need for monitoring or contingencies. However, some remedies (e.g., capping or other engineered barriers) do not provide such definitive results. In many cases, questions remain as to whether all contamination has been located and mitigated.

In addition to project-specific, technical uncertainties, a number of programmatic uncertainties may need to be evaluated:

- Will the assumed land-uses remain as anticipated?
- Will future uses of the site create new exposure pathways?
- Will deed restrictions and other administrative controls remain in place in the long-term?
- How long will engineered barriers retain their structural integrity?

The Post-Closure Conceptual Site Model, discussed as a tool useful for implementing the first principle, also may be the basis for evaluating remaining uncertainties. To evaluate uncertainties

using this tool, a project manager should consider the following:

- What are the uncertain factors associated with the baseline conditions (i.e., what potential deviations from expected conditions are likely to occur)? Note that these uncertain factors may be technical or administrative in nature.

- What is the likelihood that deviations from expected conditions will occur?

- What are the potential impacts that these deviations will have on protection of human health and the environment?

- What timeframe would be necessary to respond to encountering an unexpected condition?

By considering these factors, the project manager can assess the significance of an uncertainty. The most significant uncertainties are those that have:

1. A high probability of occurrence,

2. A highly undesirable impact, and

3. Minimal time to respond before an unacceptable exposure to human or environmental receptors occurs.

Project managers may determine that contingency plans should be developed to manage significant uncertainties (e.g., plan to provide local residents with an alternate drinking water supply if contaminants spread to the groundwater aquifer). By gaining upfront agreement from site regulators on contingency plans, the project manager can act without delay if an identified deviation from expected conditions is encountered.

As noted above, project managers may develop contingencies as a means of managing uncertainties. In addition, a monitoring system must be devised to alert decision-makers when these contingencies must be implemented. Decision-makers should identify thresholds that, if crossed, signal that the contingency must be implemented. Responsibility must be assigned to conduct the monitoring and to evaluate the results. *(The next section contains a discussion of the parties responsible for implementing stewardship activities.)*

The uncertainty matrix is a tool designed to assist project managers in assessing and managing post-closure uncertainties. By organizing information regarding uncertainties into a matrix, project managers may facilitate a determination of what type(s) of management strategies are appropriate. **Figure 4** provides an example of an uncertainty matrix.

Refer to *Uncertainty Management: Expediting Cleanup Through Contingency Planning,* DOE/EH/(CERCLA)- 002 (February 1997) and *Expediting Cleanup through Problem Identification and Definition,* DOE/EH-413-9904 (May 1999).[10]

Principle 4. Early and open communication and involved decision-making by stakeholders are essential: *Early and open communication and involved decision-making are necessary for addressing issues and reaching a state of closure. Identifying the appropriate decision-makers and building a post-closure core team are also essential to ensuring protection of human health and the environment in the long-term.*

The last principle relates to the importance of maintaining open and frequent communication, both among decision-makers at a site and with other stakeholders during and after closeout occurs. All of the other principles are more effectively implemented using involved decision-making.

Under RCRA and CERCLA, DOE advocates formation of a core team. This team is responsible for agreeing that a project is complete and that protection of human health and the environment has been obtained. The core team traditionally

[10] These documents are available on the EH-41 website at: http://tis.eh.doe.gov/oepa/guidance/cercla/7combine.pdf and http://tis.eh.doe.gov/oepa/guidance/cercla/prob_id.pdf respectively.

Figure 4. Example Uncertainty Matrix

Expected Condition	Reasonable Deviation	Probability of Occurrence	Time to Respond	Impact	Monitoring Plan	Contingency Plan
Cap prevents intrusion into surface soils and re-suspension / volatilization of contaminants into the air	Burrowing animals or plant roots will breach cap integrity	High. Operations of other landfills indicate that over time this is a common intrusion scenario.	Short. If the air exposure pathway is reestablished, transport of contaminants could occur quickly.	1. High. Radioactive contaminants may be re-suspended on particles and dispersed from the site, posing an unacceptable risk to human health and potentially posing an unacceptable risk to ecological receptors. 2. Low. VOCs will likely no longer present a problem due to rapid volatilization.	Site inspection every 3 months to ensure integrity of cap. *Note:* Maintenance activities will include plant removal from cap area.	If signs of burrowing animals or root intrusion are detected, an additional foot of soil cover will be placed on top of the cap.
	Humans will dig in the area of the landfill, breaching integrity of the cap.	Low. Additional controls (i.e., land use restrictions and a fence) are in place to prevent human intrusion.	Short. If the air exposure pathway is reestablished, transport of contaminants could occur quickly.	Same as above. In addition, intrusion into the soil would likely result in dermal contact with radioactive contaminants, posing an unacceptable risk to human health.	Site inspection will include evaluation of fence integrity and implementation of land use controls. *Note:* Maintenance activities will include fence repairs.	Reevaluation of remedy will be conducted if humans breach the integrity of the cap and land use controls are not functional.

Figure 4. Example Uncertainty Matrix (Continued)

Expected Condition	Reasonable Deviation	Probability of Occurrence	Time to Respond	Impact	Monitoring Plan	Contingency Plan
Contaminants in the groundwater will naturally attenuate to levels below MCLs within a 20-year timeframe.	Contaminants do not attenuate naturally to levels below MCLs within the required timeframe.	Low. Based on modeling of site conditions, contaminant characteristics, and the general trend established by existing monitoring data, MCLs will be attained within a 20-year timeframe.	Long. Monitoring data will indicate if the current trend in contaminant reduction changes. Based on these data, the site manager will have advance warning if end objectives will not be met in 20 years.	1. High. If groundwater remediation goals cannot be reached in the 20-year period, unit regulators will require a different remediation approach, which would be quite costly. 2. Low. No risk to human health would result from additional contamination of the groundwater because land use restrictions and an alternate drinking supply prevent ingestion.	Wells at the area boundary will be sampled every 3 months to ensure that natural attenuation is reducing the concentration of contaminants in the groundwater.	If, after 3 years, data do not indicate that contaminant concentrations will be below MCLs in the required timeframe, the remedy will be re-evaluated.

consists of those parties with decision-making authority at a site. For CERCLA and RCRA corrective action sites, there are generally three agencies with this decision-making power: DOE, EPA, and the host state. Often, for RCRA regulated units, only the state as the permitting authority must certify completion of closure. Members of a core team ideally act as co-project managers, evaluating technical data and determining the best approach forward. Even though regulators are members of the core team, they still retain their enforcement/oversight role throughout the process.

Refer to *Expediting Cleanup through a Core Team Approach*, DOE/EH-413-9911/0999 (September 1999).

As a site prepares for long-term care, the traditional core team will finish its formal duties and a new team should be formed to oversee project closure and post-closure care. This team will be responsible for making decisions about long-term care and should include (at a minimum):

1. The party responsible for enforcement of closeout activities.

2. The party responsible for monitoring, maintenance, and implementation of other closeout activities, as well as any needed contingencies. In some cases the individuals responsible for implementation of these closeout activities will also be responsible for conducting long-term stewardship activities at the site. However, if different parties will be responsible for long-term stewardship activities, it is beneficial to include these individuals on the team as well.

3. Any local government or other appropriate officials, if zoning restrictions or other land-use restrictions are components of the implemented remedy.

This team will have decision-making authority for the site in the years following closeout. At a minimum, the post-closure core team will:

- Determine if monitoring data indicate that contingency plans should be implemented;

- Determine when additional remedial action is complete if contingency actions are necessary;

- Evaluate how changes in land-use affect the protectiveness of the remedy;

- Evaluate data from site inspections to determine if engineered and administrative controls are functioning properly and what actions are needed if they are not;

- Communicate with the community any changes in site conditions; and

- Determine when monitoring and maintenance activities can be reduced.

Ideally, the post-closure team should be formed prior to completion of closure activities. An informal transfer of information between the remediation-phase core team and the post-closure team could be a valuable supplement to the closeout documentation. This type of exchange benefits those members responsible for ensuring continued protection of human health and the environment.

Questions of policy or questions requiring policy decisions will not be dealt with in EH-413 Information Bulletins unless that policy has already been established through appropriate documentation. Please refer any questions concerning the subject matter covered in this Information Bulletin to Jerry Coalgate, RCRA/CERCLA Division (EH-413), (202) 586-6075. *To obtain a copy of this document, please access the EH-41 website (http://tis-nt.eh.doe.gov/oepa).*