DRAFT FINAL

Performance-Based Management

Remedial Objectives Assessment

Using the Statutory Tests of Performance to Develop Achievable Response-Action Completion Strategies

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SUMMARY

This guide was issued by the Air Force Center for Environmental Excellence (AFCEE) to support environmental project teams responsible for implementing the Defense Environmental Restoration Program (DERP). It reflects the Air Force's continuing commitment to demonstrate protectiveness and to meet necessary, feasible, and reasonable environmental cleanup obligations in the most effective and efficient manner possible. This Remedial Objectives Assessment guide is designed to help environmental project teams assess, document, and improve the protectiveness of implemented response decisions to achieve response complete in a reasonable time frame as part of the Performance-Based Management (PBM) initiative. This guide reviews how to assess remedial objectives by taking advantage of the flexibility inherent in the DERP Guidance and the iterative nature of cleanup programs under the Comprehensive Environmental Restoration, Compensation, and Liability Act (CERCLA), as amended. Improving scientific and technical knowledge should be integrated into the various tests of performance provided by the environmental statutes, to demonstrate protectiveness while improving the rate of response-complete determinations.

A remedial objectives assessment uses current knowledge of the site and science to iteratively:

- Define the environmental problem by updating the conceptual site model (CSM) in order to validate or refine the protectiveness requirements and options
- Use the statutory-provided tests of performance to update applicable or relevant and appropriate requirement (ARAR) selection in order to ensure the necessity, feasibility, and reasonableness of the remedial action objectives
- Use comparative benefit/cost analysis techniques to ensure implementation of the most effective and efficient means to achieve protectiveness and realistic completion goals in a reasonable time frame without waste of national resources.

Project teams are encouraged to take full advantage of innovations in environmental and performance data collection and evaluation techniques to improve CSMs, validate response-action decisions, optimize remedy performance, and expedite effective and efficient completion of environmental response actions.

BASIS FOR ISSUANCE

This Remedial Objectives Assessment guide has been issued by the Air Force Center for Environmental Excellence (AFCEE) to emphasize the need to incorporate evolving scientific and technical information on response-action requirements and remedy performance into realistic decisions from which protectiveness can be documented and completed in a reasonable time frame. This guide has been prepared to support ongoing efforts to evaluate and report on program execution, performance metrics, and fiscal requirements. This guide supplements and clarifies specific information provided in Department of Defense (DoD) Directive 4715.1, *Environmental Security*, February 24, 1996; DoD Instruction 4715.7, *Environmental Restoration Program*, April 22, 1996; and the *Management Guidance for the Defense Environmental Restoration Program,* September 28, 2001.

The Air Force has issued this guide as part of a self-auditing initiative to identify optimization opportunities throughout its environmental restoration program by assessing response-action performance in accordance with the Government Performance and Results Act of 1993. This guide was developed as part of the Air Force's ongoing commitment to provide strategic environmental management direction, consistent with the tenets of an Environmental Management System as described by Instruction for Standard Operations (ISO) 14001. It is intended to help environmental project teams assess and document remedy protectiveness by taking advantage of the flexibility inherent in the DERP and its governing regulations, in order to achieve response complete in a reasonable time frame. This performance- focus can be applied at any stage of an environmental program, from site assessment, risk analysis, and decision planning (i.e., selection of response-action objectives and the means to achieve those objectives), through response-action implementation, operation, and optimization.

This guide will help environmental project teams 1) perform the various tests of performance recognized in the environmental statutes governing federal cleanup programs; 2) communicate clearly with involved stakeholders about the trade-offs inherent in any decision; and 3) use the iterative nature of the CERCLA cleanup program to improve response completion rates. Resource balancing and decision consequences (trade-offs) are considered as part of the iterative analyses of applicable or relevant and appropriate requirements (ARARs) and periodic evaluations of the performance of different remedial components.

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ACRONYMS AND ABBREVIATIONS

§	Section of regulation or statute
ACL	Alternate concentration limit
AFCEE	Air Force Center for Environmental Excellence
AFI	Air Force Instruction
AR	Administrative record
ARAR	Applicable or relevant and appropriate requirement
BACT	Best available control technology
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CSM	Conceptual site model
CTC	Cost to complete
D&D	NRC Residual Radiation Computer Program
DCA	Decision consequence analysis
DCGL	Derived Concentration Guideline Level
DERP	Defense Environmental Restoration Program
DLA	Defense Logistics Agency
DNAPL	Dense, non-aqueous-phase liquid
DoD	U.S. Department of Defense
DOE	Department of Energy
DPG	Defense planning goal
DQO	Data quality objective
EMS	Environmental management system
EPA	Environmental Protection Agency
ERPIMS	Environmental Respiration Program Information Management System
ESD	Explanation of significant differences
ETD	Extraction, treatment, and disposal/discharge
FS	Feasibility Study
FSS	Final Status Survey
GPRA	Government Performance and Results Act of 1993
ISO	International Standards Organization
KWH	Kilowatt-hour
LTM	Long-term monitoring
LUC/IC	Land use control/institutional control
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goal
MNA	Monitored natural attenuation
NCP	National Oil and Hazardous Substances Contingency Plan
NEPA	National Environmental Policy Act of 1969
NFAR	No Further Action Required
NORM	Naturally Occurring Radioactive Material
NRC	Nuclear Regulatory Commission
O&M	Operations and maintenance
OA	Objectives assessment

OSWER	U.S. EPA's Office of Solid Waste and Emergency Response
PBC	Performance-based cleanup
PBM	Performance-Based Management
POE	Point-of-exposure
POU	Point-of-use
PRB	Permeable reactive barrier
PRP	Potentially responsible party
RAO	Remedial action objective
RA-O	Remedial action operations
RBC	Results based cleanup
RC	Response complete
RCRA	Resource Conservation and Recovery Act
RESRAD	DOE Residual Radiation Computer Program
RI	Remedial Investigation
ROD	Record of Decision
RPO	Remedial Process Optimization
RSE	Remedial Systems Evaluation
RSSI	Radiological Site Survey and Investigation
SARA	Superfund Amendments and Reauthorization Act of 1986
SDWA	Safe Drinking Water Act
STC	Schedule to complete
SVE	Soil-vapor extraction
TBC	To-be-considered
USCA	United States Code Anotated
ZVI	Zero-valent iron

1.0 INTRODUCTION

The ultimate goal of an environmental response action is to protect human health and the environment. The ultimate performance goal of the Defense Environmental Restoration Program (DERP) is to complete those response actions that are necessary, feasible, and reasonable to protect human health and the environment in a reasonable time frame. A response action is not complete until reliable and sustainable protection is ensured (Comprehensive Environmental Response, Compensation and Liability Act [CERCLA], as amended by the Superfund Amendments and Reauthorization Act [SARA])[1]. While completion of required actions to ensure protectiveness is the end goal, demonstrating progress toward achieving protectiveness has been challenging. To better meet this challenge, the Air Force encourages its environmental project teams to take a fresh look at their response-action decisions by taking full advantage of the iterative performance assessment and course-correction opportunities provided by CERCLA.

> **Response action**–the cleanup activities undertaken to fulfill the response-action decision requirements in the decision document.
>
> **Response-action decision**–the course of action to meet environmental cleanup obligations at a site as documented in a decision document.
>
> **Remedial action objective (RAO)**–the cleanup objectives that define success in an environmental cleanup and lead to response complete and site closure.

The technical knowledge base available to make response-action decisions has expanded dramatically over the past two decades. The experience gained through years of implementing cleanup programs may now be used to reassess the necessity, feasibility and reasonableness of certain response strategies, with the intent of documenting sustainable, reliable protectiveness so that the rate at which response actions are completed improves.

The Air Force Center for Environmental Excellence (AFCEE) prepared this guide to Remedial Objectives Assessment (OA) as part of the Performance-Based Management (PBM) initiative to proactively assess, document, and enhance performance of remedial decisions at Air Force installations, according to the requirements of CERCLA, the Government Performance and Results Act of 1993 (GPRA), and the tenets outlined in Instruction for Standard Operations (ISO) 14001. This guide will help environmental project teams to:

- Incorporate the growing body of knowledge about the site, remediation technologies, and environmental sciences to assess the necessity, feasibility, and reasonableness of response-action decisions
- Use a probabilistic decision model to define or refine response-action decisions in order to facilitate implementation and completion of "smarter/faster" decisions.
- Develop and present the site-specific evidence required to justify and leverage regulatory flexibility regarding final RAOs and effective and efficient means to achieve them.

[1]See CERCLA §104[c][6]

This document describes the remedial objectives assessment process in the context of the PBM initiative. The document is organized as follows:

- Section 1 presents an overview of remedial objectives assessments and describes where they fit in the PBM initiative
- Section 2 discusses testing RAOs for necessity, feasibility, and reasonableness
- Section 3 describes tailored cleanup expectations from ARAR evaluations
- Section 4 discusses comparing remedial strategies using benefit/cost ratios
- Section 5 discusses procedures for negotiating changes in RAOs, where necessary

Regulatory-related terms, used to describe the selection of RAOs and the methods used to conduct an objectives assessment, are defined is side bars where first used in the text and also listed in the Glossary in Appendix D.

1.1 PERFORMANCE-BASED MANAGEMENT INITIATIVE

The Air Force PBM initiative for environmental remediation programs provides a framework for initiating environmental cleanup actions and optimizing the cleanup actions as they progress. The PBM approach consists of eight components for the management of environmental remediation programs, as shown in Figure 1.

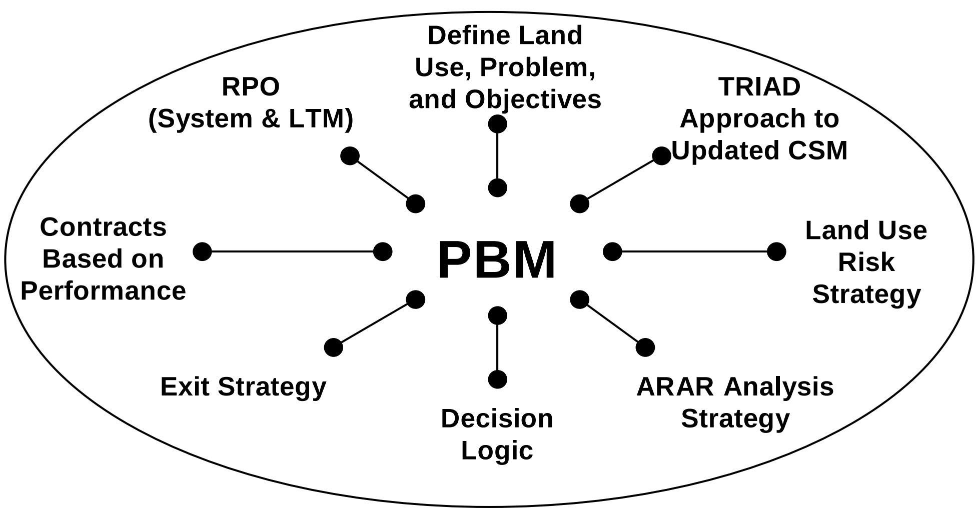

Figure 1. Performance-Based Management (PBM) Components

PBM originated based on the requirements of federal and state regulatory programs. Over time, the Air Force recognized that many of the cleanup actions were not performing as originally expected and began to develop guidance for optimization of cleanup actions. The first was the Long-Term Monitoring Optimization Guide, released by the AFCEE in October 1997. Optimization of treatment system equipment was addressed the following year by a joint Army, Navy, Air Force effort that resulted in the Remedial Systems Evaluation (RSE) guidelines and optimization checklists that are available from the Army Corps of Engineers.[2] The RSE approach looks at the performance and maintenance of individual pieces of remediation equipment (e.g., does a pump's performance meet the manufacturer's specification and is it adequately maintained). The Air Force's Remedial Process Optimization (RPO) initiative (draft RPO Handbook released in 2000 and revised final version in 2001 [AFCEE and DLA, 2001]) took a broader view of remediation program optimization by addressing the performance of the selected remedial technology (e.g., is the technology removing contaminant mass as expected). RPO considers whether the technology can be optimized or whether a change of technology would be appropriate at this point in the remediation progresses. Finally, this guide further broadens optimization by assessing the RAOs that form the basis of the cleanup effort. In essence, this remedial OA addresses the question "are we headed toward the appropriate goal?"

1.1.1 Components of PBM

The component steps and decision logic of the PBM approach are shown in Figure 2. New projects begin with initial project definition, remedy selection and installation, and operational parameter selection. These three steps originated from the requirements specified by CERCLA and other environmental regulations. Air Force guidance now recommends that these three project development steps include all of the components shown in Figure 3.

For many existing cleanup programs, where the PBM approach might not have been used in the past, PBM can still be implemented after the remedy has been installed and put into operation (see "Start PBM for an Existing Project" in Figure 2). Periodic performance reviews, performed to update and optimize the remedy, are required by environmental regulations (e.g., five-year reviews), by the DERP, and by Air Force Instruction (AFI) 32-7020. If the final cleanup goals have not been attained, an OA should be done before, or in conjunction, with an RPO review to verify that the program objectives are necessary and feasible.

It should be noted that while the OA should be done in conjunction with the RPO review, it is separate from the RPO initiative. Unlike RPO, much of the thought process of an OA is also applicable to selection of applicable or relevant and appropriate requirements (ARARs) and RAOs during the development of a new remediation program (see Figure 3).

1.1.2 Remedial Objectives Assessment

The purpose of an OA is to determine whether the current RAOs (for a site, a program, or an installation) were appropriate and are still appropriate given the current knowledge of the site(s) and the capabilities of the technologies selected, and to manage uncertainty in the remediation process. The test of appropriateness is based upon the three tests of necessity, feasibility, and reasonableness that are provided by CERCLA, as amended by SARA.

The component steps for conducting an OA include the following:

- Update the problem statement and the conceptual site model (CSM)
- Review the RAOs, document the basis of the decision, and negotiate RAO changes if necessary

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[2] RSE guidelines and checklist documents are available from the USACE Web site at http://www.environmental.usace.army.mil/guide/rsechk/rsechk.html .

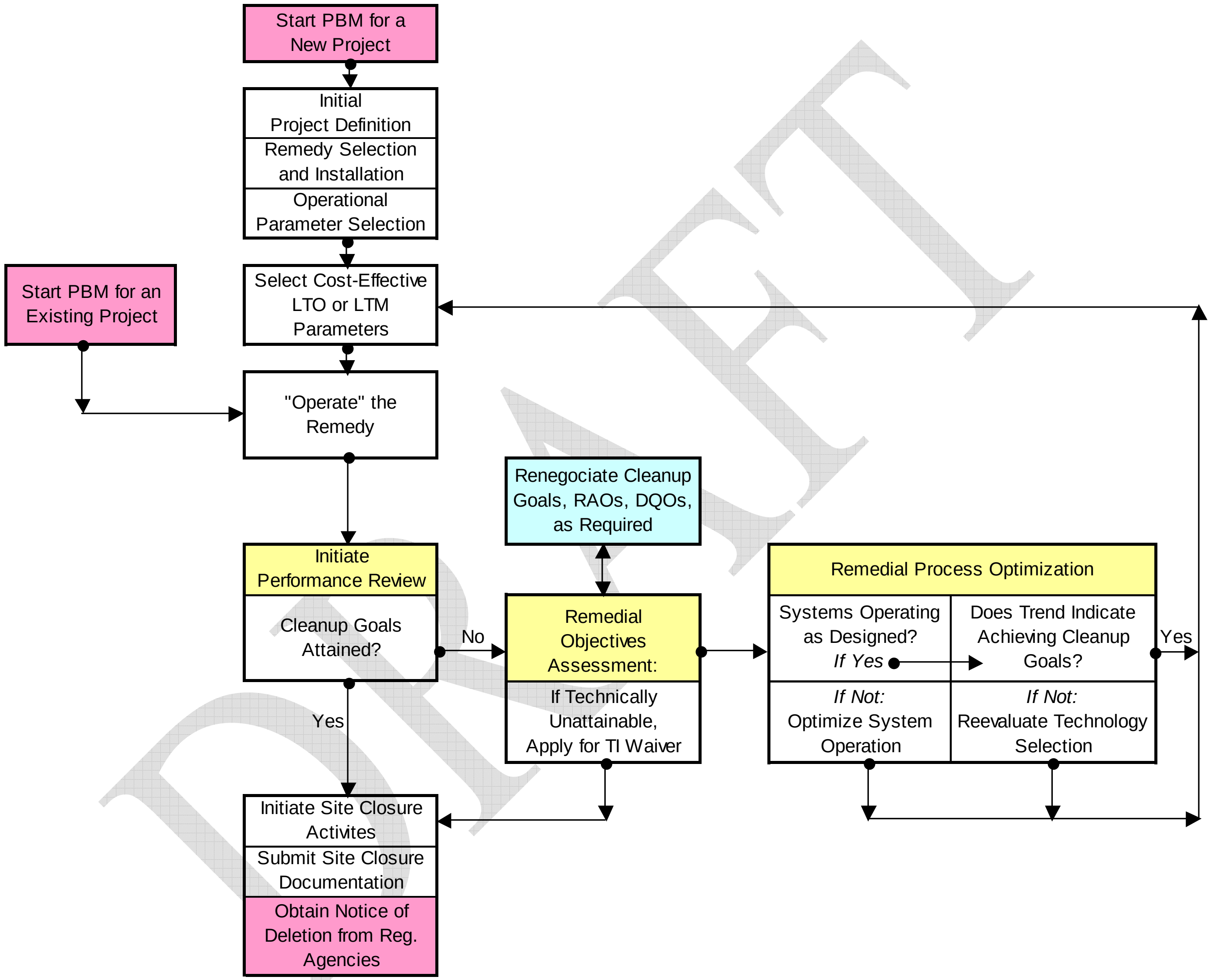


Figure 2. Performance-Based Management Program Decision Logic

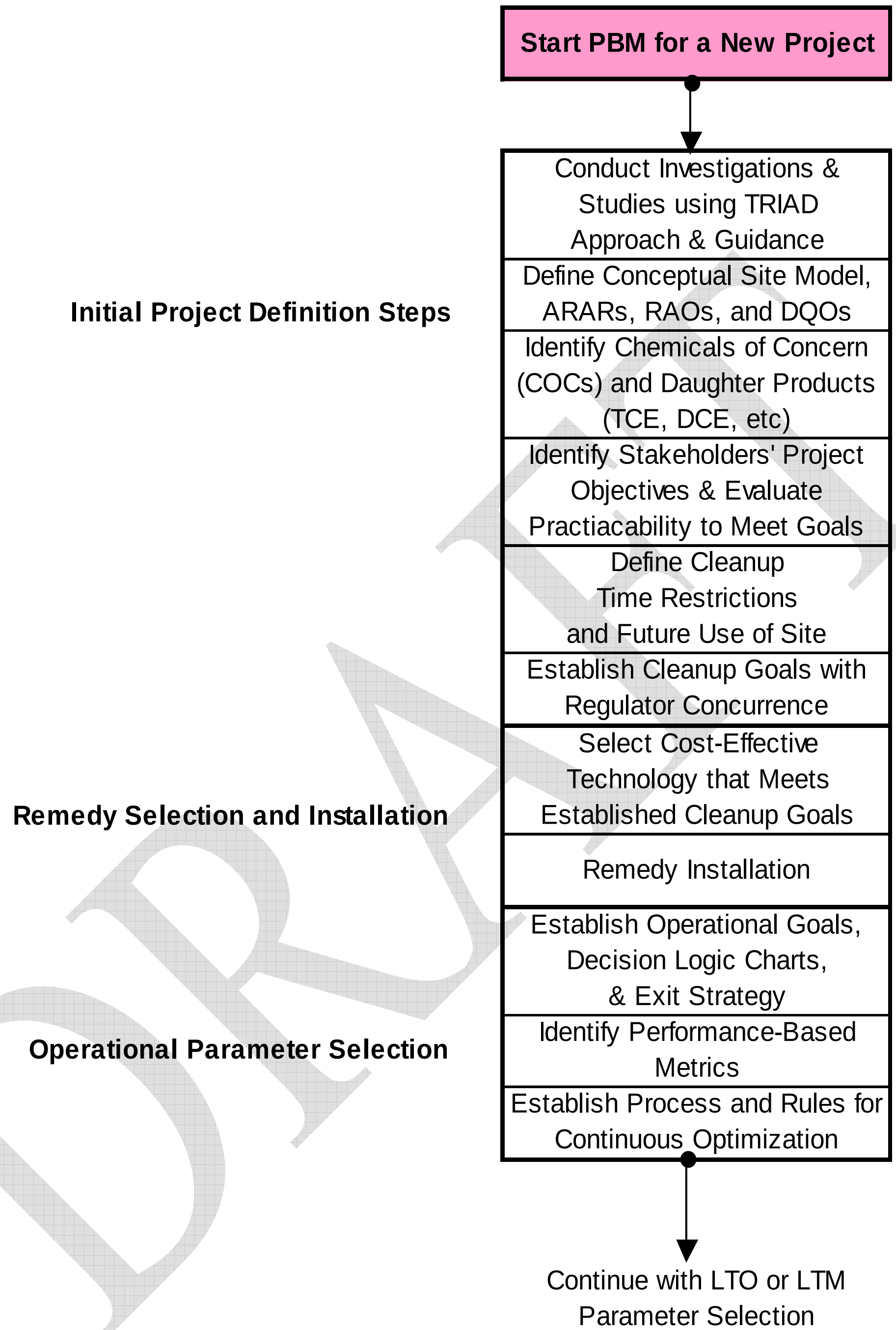


Figure 3. PBM Project Development Steps

- Establish metrics to measure progress
- Document an exit strategy to terminate remedial action and implement site closure (see Exit Strategy sidebar).

Exit Strategy

Restoration programs based on optimized, performance-based, remedial and monitoring processes have a high probability of success. However, the measure of "success" must be defined in terms of stakeholder-approved, performance-based metrics. A completion plan using decision logic should be prepared stating how cleanup goals will be measured to demonstrate their attainment. The completion plans should be updated whenever new information is available. Knowledge of the selected or imposed cleanup goals and the expected time of completion, however, is not sufficient to ensure restoration success. The larger purpose of the completion plan is to identify all requirements that must be met, as measured through stakeholder approved performance-based metrics, to complete the restoration program. The completion plan in essence is an Exit Strategy.

Ideally, an exit strategy should address the stakeholders concerns, meet all applicable regulations, identify all performance metrics, assess costs/risks/future use/benefits of the remedial actions and identify requirements to terminate remedial action operation (RA-O) and long-term monitoring (LTM) activities. If delisting or deleting from a permit is applicable, the Exit Strategy should describe the milestone(s) that will trigger initiation of delisting deletion procedures, and define the schedule.

1.1.3 Staffing an OA Review

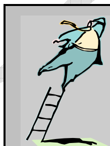
The environmental project team conducting an OA should include the appropriate technical disciplines such as a risk assessor, a regulatory specialist, and individuals familiar with the remedial technologies operating at the site(s). Since the staff qualifications for conducting an OA are similar to those of an RPO team, the same people might be selected to perform both reviews. The OA is an assessment of the current objectives and the basis for their selection, and it should be made clear to installation personnel that the OA is not an audit of their performance. Instead, the OA team should be protrayed as consultants to the installation staff.

Installation environmental staff may provide valuable "corporate knowledge" of how and why the existing RAOs were selected and insight to the performance of the existing remedial systems. Therefore, the appropriate installation staff should be invited to participate as part of the environmental project team conducting the OA.

1.2 THE NEED FOR OBJECTIVES ASSESSMENTS

For most in-place remedial actions, site conditions (e.g., contaminant concentrations) have changed since the remedy was installed, and more is known about environmental conditions at the site and about the performance of the remedial technology selected. Using this expanded knowledge, the remedial objectives assessment determines whether the response-action decision's performance objectives (the RAOs) are still valid and whether the objectives are the ones that would be selected today.

RAOs describe the site conditions that are necessary, feasible, and reasonable to achieve in a reasonable time frame to ensure protectiveness. By definition, human health and the environment are not reliably protected from potential harm due to exposure to site-related contamination until the RAOs are achieved. The Air Force, as decision authority, is obligated to continue response actions until human health and the environment are protected as required by the response-action decision. Protection and completion of the response-action obligations are measured by attainment of the narrative (qualitative) and numeric (quantitative) RAOs.



Routinely **check the objectives** of the response-action decision—to verify necessity, feasibility, and reasonableness.

It is a waste of resources, however, to pursue compliance with RAOs that are not necessary to ensure reliable protectiveness. Similarly, the pursuit of RAOs that result in a greater risk to human health or the environment than the risk posed by current conditions is contrary to the intent of statutory and program mandates. It is also a waste of resources to implement infeasible or unreasonable means to secure sustainable, reliable protectiveness. Finally, in accordance with CERCLA and all state environmental cleanup laws, the RAOs must be achievable in a reasonable time frame to ensure that the decision results in timely, reliable protection. Timeliness in achieving protectiveness is a relative term, but is assumed in this guide to be a period of approximately 10–12 years or less.

Knowledge about what realistically can be accomplished to provide protection, and "smarter and faster" ways to provide that protection, improves each year. Decisions made 5, 10, or 15 years ago do not reflect that improving knowledge base. Emerging exposure concerns (e.g., chemical vapor migration) and previously non-addressed chemicals of potential concern (e.g., perchlorate) are but two examples of how an evolving knowledge base might affect the basis and scope of earlier decisions. Improving our understanding of the necessity, feasibility, and reasonableness of response-action strategies might impact the effectiveness and efficiency with which response complete (RC) status is achieved. It is anticipated that incorporating evolving information about site conditions and remedy performance might substantially improve response-action decisions.

Given that a remedial action decision consists of both performance objectives (RAOs) and the means used to achieve those performance objectives (the remedial components), the need to focus first on the performance objectives during remedy selection and optimization becomes apparent. The remedial objectives drive the selection of the means used to achieve those objectives. Consequently, the performance objectives are the foundation of the planning and implementation process. Refinement of the performance objectives may lead to refinement of the means used to achieve those objectives. Conversely, consistent underperformance of the means should trigger reassessment of the basis for (i.e., the necessity, feasibility, and reasonableness of) the objectives. The performance objectives for all Air Force projects completed under the DERP should be systematically and iteratively evaluated for necessity, feasibility, and reasonableness to ensure timely completion of response-action obligations.

1.3 CLEANUP STANDARDS

Every response-action decision is defined by the level or standard of control selected as necessary to provide reliable protectiveness. Thus, the development of all potential performance objectives, or RAOs, begins with a site-specific risk assessment to define risk-based cleanup levels. In 1986 Congress amended CERCLA by adding Section 121(d) of SARA, which requires substantive compliance with federal and state ARARs for on-site response actions. Congress added ARARs to the CERCLA risk-based framework to incorporate proscriptive location- and contaminant-specific considerations that might need to be addressed by response decisions. This approach was intended to integrate different environmental requirements to promote the overall protectiveness of decisions, both during implementation and following completion.

> **Substantive**–essential; real or actual; permanent

The SARA amendments intended ARARs to serve as decision guideposts to ensure safe hazardous-substance management practices during response-action implementation and to establish appropriate cleanup, emissions, and discharge limits to offset adverse effects of the response actions themselves. ARARs basically are a means of verifying comprehensive protectiveness because pertinent standards can be used to validate the site-specific risk assessment and address other measures of protectiveness that typically are not addressed in the risk assessment (e.g., natural resource damage limitations, management of sensitive environments, and performance engineering stipulations).

Efforts to comply with the substantive performance requirements of ARARs, however, should not limit the flexibility inherent in the risk-based CERCLA program (EPA, 1998). Rather, the risk assessment is the foundation of remedy selection, and ARARs are intended to define the scope of the response actions that are necessary, feasible, and reasonable to ensure protectiveness at a specific site in a reasonable time frame. The ARAR identification, evaluation, and selection process often controls the remedy selection and implementation process, and could control the time and cost required to demonstrate protectiveness (i.e., attain RAOs). Therefore, the Air Force must complete a thorough, site-specific ARAR analysis to ensure that the response decision incorporates only RAOs that meet each of the following requirements:

- The performance commitments are **necessary** to achieve and document sustainable, reliable protectiveness and prevent further damage to the environment
- The means to achieve protectiveness is **feasible** in a reasonable time frame, as indicated by site conditions, treatability data, and general remedy performance data
- The means to achieve protectiveness within the time frame is **reasonable**, as indicated by a site-specific benefit/cost evaluation.

1.4 STATUTORY TESTS OF PERFORMANCE

The RAOs establish the compliance requirements for the response action that were judged to meet three statutory tests of performance (i.e., **necessary** to provide the required protection,

feasible to achieve with available remedy technologies in a reasonable time frame, and **reasonable** by providing protectiveness without undue cost or consumption of resources)[3] at the time the response-action was selected. Response-action decisions should be periodically subjected to a focused performance assessment, incorporating current knowledge about site-specific conditions and remedy performance, to determine whether the RAOs still meet all three tests of performance.

Evaluations conducted as part of the Remedial Process Optimization (RPO) initiative have shown that knowledge gathered at a site during remedial operation and monitoring often does not support the selected RAOs as necessary, feasible, and reasonable performance goals for publicly funded actions designed to provide reliable protection in a reasonable (e.g., 10-year) time frame. Consequently, environmental project teams should be aware of the importance of realistic RAOs, and particularly watchful for the following types of decisions:

- Response-action decisions driven by toxicity data or exposure assumptions that are the subject of considerable scientific debate
- Response-action decisions driven by attempts to achieve a level of control *in situ* based on maximum contaminant levels (MCLs) or maximum contaminant level goals (MCLGs) for all impacted environmental media, particularly groundwater, with no clear and defensible demonstration of site-specific relevancy and appropriateness or practicality
- Response-action decisions derived using best-available-control-technology (BACT) strategies, where the performance means are "presumptively" established regardless of long-term uncertainties, contaminant source persistence, long-term maintenance costs, the potential for future remedial action costs should the remedy fail, and the potential threat to human health and the environment associated with extensive engineered containment and treatment activities (e.g., landfill containment, groundwater extraction and treatment, *in situ* thermal treatment of soils and groundwater).

The Air Force expects this level of evaluation to be completed as part of both remedy selection and ongoing remedy evaluation and optimization efforts to ensure implementation of practical, effective, and cost-efficient responses, as required by statutory mandates. Environmental project teams should apply performance tests to help routinely validate or improve response-action decisions during periodic performance evaluations, particularly for those types of decisions as listed above.

1.5 INTEGRATING LESSONS LEARNED: THE ROLE OF PROBABILISTIC PLANS

Environmental project teams should use a probabilistic decision model to help achieve and document protectiveness. Planning and decision documents should define specific metrics and ranges of acceptable performance for remedial actions, and should identify contingency actions to be taken if the performance metrics fall outside acceptable ranges.

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[3]CERCLA §121[d][4]

In the first phase of decision-making, the environmental problem is framed so that remedy alternatives can be identified and evaluated, as shown in Figure 4. This framing phase is typically completed as part of the CSM development, and serves as a statement of the environmental problem that may warrant action.

The next phase of decision-making is deterministic analysis where the values and preferences of the stakeholders are identified, and a decision/consequence model is used to illustrate the expected consequences of choosing different alternatives. The use of deterministic analysis techniques is well-grounded in the response-action selection process. The nine evaluation criteria developed by the EPA represent the values and preferences that should be considered when developing response decisions. The evaluation of different response-action alternatives against these evaluation criteria represents one form of decision/consequence model.

Probabilistic–the doctrine that certainty is impossible and that probability suffices to govern practice.

Sufficient performance data are now available to take the next evolutionary step in environmental decision-making, and project teams are encouraged to move beyond deterministic planning to probabilistic analysis. A probabilistic decision model allows the environmental project team to plan for various probable outcomes of the remedial action by identifying performance metrics and decision criteria that will trigger implementation of an appropriate contingency alternative should the originally selected response action fail to perform as expected. By doing so, the project team may be better prepared to address unplanned, but not unexpected, outcomes of response-action decisions (e.g., failure to achieve established RAOs—and therefore document protectiveness—in a reasonable time frame).

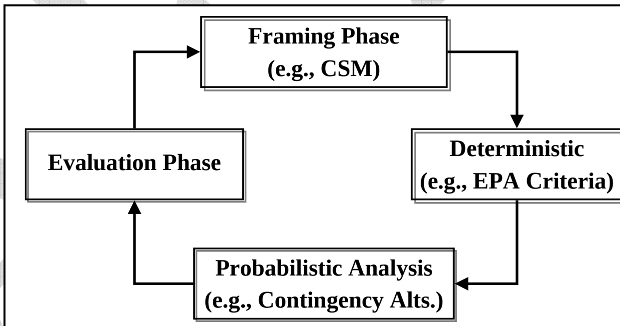


Figure 4. Evolutionary Phases of Decision-Making

A probabilistic response-action decision may be represented as a decision tree. Decision trees are constructed to describe "if–then–else" actions (i.e., if "X" happens then do "A," or else do "B") that result from different probable outcomes. Decision trees provide for contingencies of varying remedial performance as part of the initial remedial decision. For example, if an implemented response-action decision is not performing as expected (i.e., if the hypothesis of successful performance in a reasonable time frame is rejected), an alternative course of action is defined "upfront" to ensure protection. Probabilistic planning may be compared to hypothesis testing according to the scientific method, where successful performance of the remedial action initially implemented is comparable to proving the null hypothesis being tested. Disproving the null hypothesis results in an alternate hypothesis (i.e., refinement of the response decision).

Probabilistic plans are much easier to evaluate and implement through time than deterministic plans because the specific performance metrics and decision criteria are clearly articulated, and improving site and technical information can be used to revise the decision. The more comprehensive the initial decision tree, the less likely the need to reframe the decision to address unexpected outcomes.

1.6 OBJECTIVES ASSESSMENTS AND RPO

This guide is intended to complement the Air Force RPO initiative by further clarifying certain concepts and approaches introduced in the RPO Handbook (AFCEE and DLA, 2001). OA focuses on optimization of the *basis* of response-action decisions in order to document substantive protectiveness, so that projects can transition into verification of protectiveness. To capitalize on the institutionalization of RPO, as supported in Section 20 of Department of Defense's (DoD) *Management Guidance for the DERP*, OA builds upon the concepts of RPO with the added dimension of "optimizing" the RAOs using the statutory tests of performance (DoD, 2001).

The Air Force adheres to the relative-risk prioritization policy established within the implementing guidance for the DERP, but challenging environmental problems still remain to be addressed (e.g., groundwater contamination, landfills and other persistent sources, and emerging issues). It is recognized that legally allowed and mandated efforts to optimize the performance of response-action decisions require an iterative and integrated assessment of legal requirements in the context of expanding scientific and technological information. Thus, legal response obligations must be justified in the context of the expanding scientific and technical knowledge base, particularly at the most complex sites, where demonstrable progress toward protectiveness (as defined by current RAOs) may be below expectations.

This guide is consistent with the "plan-do-check-correct" approach that is fundamental to all performance-focused management efforts (e.g., environmental management systems [EMSs] compliant with the general requirements of ISO 14001). It is expected that environmental project teams will use the concepts in this guide to systematically focus response-action planning and implementation activities on intended outcomes (i.e., results) and the information to document progress toward that outcome (i.e., performance metrics). Environmental project teams are encouraged to conduct a response-action performance evaluation each year, in anticipation of the budget planning process, as a way to emphasize response-action performance and progress toward achieving protectiveness and RC.

2.0 TESTING FOR NECESSITY, FEASIBILITY, AND REASONABLENESS

Periodic performance evaluations—which are mandated by law for certain situations (e.g., CERCLA 5-year reviews)—provide the opportunity to analyze evolving site characterization and remedy performance data.[4] These analyses are intended to verify the basis of, and need for, the response action including the degree of cleanup required to protect human health and the environment. At the same time, these periodic performance evaluations also represent an opportunity to iteratively refine the RAOs, and the means used to achieve those RAOs, that were believed to be necessary, feasible, and reasonable to complete when the decision was first made.

The response-action planning and implementation process often is incorrectly considered to be linear, which means that the process would be based on a deterministic decision model (i.e., the first answer is the only "right" answer). However, the response-action decision process was designed to allow meaningful incorporation of evolving knowledge. Thus, newly acquired information should be used to improve the performance (protectiveness) of the decision through time. Information developed throughout the response-action planning and implementation process should be used to verify that the basis, nature, and scope of the decision continue to be justifiable (i.e., necessary, feasible, and reasonable), and that the proposed or implemented decision continues to be the most effective and efficient way to protect human health and the environment.

Evolving knowledge should be systematically and continuously subjected to the statutory tests of performance to guide efforts to implement and improve complex closure decisions. Environmental project teams are encouraged to use the statutory tests of performance to identify defensible, measurable decision criteria that will be used to document protectiveness in a reasonable time frame. These principles should also be applied when evaluating and reporting on project and program performance, and when preparing cost to complete (CTC) and schedule to complete (STC) estimates for known response-action obligations.

2.1 INFORMATION NEEDS

The statutory tests of performance require a well-articulated CSM, a site-specific risk assessment, performance data for proposed or implemented response technologies and strategies, estimated and realized cost information, and a summary of the assumptions or expectations driving the degree of cleanup and the ARAR identification process (e.g., land and resource use plans, practical and enforceable exposure controls, STC estimates).

Most of the technical and legal information required by the statutory tests of performance can be located in the Administrative Record (AR) for any response-action decision. Considerable time and money are typically expended in collecting data relevant to the selection, design, and implementation of any response action. This information may be stored in large databases, such as the Environmental Restoration Program Information Management System (ERPIMS), or in project files, and form a foundation for the assumptions used to design the performance objectives as documented in the Record of Decision (ROD) or an equivalent decision document.

[4]CERCLA §121[c]

The performance objectives are defined by both narrative and numeric RAOs. The environmental project team is encouraged to critically evaluate the AR for completeness, with particular attention paid to the ROD and the CSM, before subjecting the proposed or in-progress decision to the statutory tests of performance.

2.1.1 Updating the CSM

The CSM should represent the current understanding of the physicochemical problems to be addressed by the response action. Information on the characteristics and mechanisms of initial release, the potential for receptor exposure, and the influence of natural processes that control the movement and fate of chemicals in the environment form the basis of decisions about what needs to be done, what can be done, and how best to do it.

The CSM should provide the following:

- A detailed description of the site and its setting that is used to form hypotheses about the release and ultimate fate of contamination at the site
- Sources of site contamination, potential chemicals of concern, and the affected media (soil, groundwater, surface water, structures) affected
- How contaminants may be migrating from the sources, and the media and pathways through which migration and exposure of potential human or environmental receptors could occur (including possible air releases)
- A framework for conducting the cleanup action that takes into account the future use of the site
- The basis for site-specific procedures for sample collection and analysis
- A reliable estimate of any site conditions that might lead to unacceptable risks and warrant further study.

Environmental project teams are encouraged to update the CSM based on the most recent environmental monitoring and remedy performance data. Monitoring data collected during response-action implementation can provide valuable information about what processes are effectively influencing the movement and fate of site-related chemicals in impacted environmental media. The CSM should be sufficiently well developed to allow the team to determine <u>why</u> site conditions are as observed, and <u>what</u> feasibly could be done to influence those site conditions. Site conditions that define the nature and extent of feasible RAOs, or limit the performance of different cleanup strategies, should be identified to the extent possible. Remaining sources of uncertainty in the CSM also should be identified, and their potential impact on the success of the remedial decision should be assessed. Additional data collection to address identified data needs may be warranted at some sites. In such cases, dynamic and cost-effective data-collection strategies, such as the EPA's Triad approach (see sidebar on the Triad approach), should be used (EPA, 2001).

Type and Condition of Source Waste

Chlorinated solvents are an example of contaminants that present particular challenges in finding feasible technologies for cleanup. The presence of chlorinated solvents in groundwater indicates that the chlorinated solvent was released in non-aqueous form at some point in the past. Chlorinated solvents may be present as dense, nonaqueous-phase liquids (DNAPLs), which are often overlooked in the CSM. DNAPLs tend to find their way to underground locations that may

The Triad Approach

The Triad approach focuses on the management of decision uncertainty by incorporating: 1) systematic project planning, 2) dynamic work plan strategies, and 3) the use of real-time measurement technologies to accelerate site investigation and improve the cleanup process.

Systematic Project Planning

Systematic planning is a common-sense approach to help ensure that the level of information gathered will facilitate the decision-making process required to reach site cleanup objectives. An important component of systematic planning is to identify decision end-points and estimate acceptable levels of uncertainty for the decisions that need to be made at a site. Factors and variables that might impact the design and execution of project activities are identified so that cost-effective strategies to manage those factors can be developed. The project team anticipates and addresses issues that may adversely impact the project such as budget, schedule, staff and material resources, as well as regulatory and programmatic requirements before initiating field activities.

Dynamic Work Plan Strategies

A dynamic work plan strategy is one where decisions are made and the work plans guiding sampling and analysis are adjusted in response to data generated while the field crew is still on site.

A key element is the development of decision logic to guide the teams while in the field. Decision trees and real-time uncertainty management practices are used to reach critical decision points in as few mobilizations as possible. Field activities are sequenced to minimize crew sizes and allow for data collection and processing time, while not slowing overall project progress. This logic is reviewed and approved by the regulator and others who will use the data before initiating field activities.

Real Time Measurements

Real-time measurements are those that are produced within a rapid time frame so that real-time decision-making can occur in real-time. This encompasses on-site analytical tools, such as test kits and field instrumentation, and also includes rapid turnaround of results from a fixed laboratory that may use either definitive or screening methods.

Field analytical tools include analytical methods and equipment that can be applied either at the sample collection site or at a nearby laboratory capable of generating results on a quick or slightly accelerated rate. Screening analyses provide vital input by estimating the variability in contaminated matrices and indicating when one or more distinct populations (e.g., “clean” vs. “hotspots”) are present. The role of more rigorous, traditional fixed laboratory methods is to provide analyte-specific data with low detection limits, low bias, and better precision for samples of known representativeness when higher analytical rigor is needed for risk assessment or establishing regulatory compliance.

be both difficult to locate and infeasible to remove. DNAPL is difficult to characterize directly from field samples and measurements, so indirect indicators usually are used to estimate its potential occurrence. These indirect indicators can be useful for estimating the nature and extent of the DNAPL release, but the specific location(s) of the DNAPL source(s) usually elude detection and characterization.

Except in rare cases—typically those where relatively low-mass releases have occurred—the presence of a persistent source (e.g., DNAPL) indicates that compliance with stringent RAOs at all points within an impacted aquifer will be infeasible. Complete engineered removal of all forms of DNAPL from the subsurface is frequently not possible with today's technology. This means that cleanup time frames for these types of sites might extend into centuries. Consequently, most sites contaminated with chlorinated solvents, for which long-term performance objectives for *in situ* resources have been defined using drinking-water standards, have an extremely low probability of being able to document protectiveness or achieving RC status in a reasonable time frame. These sites should almost always be addressed using a tailored response-action decision, based on an ARAR analysis and performance objectives that incorporate the test of feasibility.

Metals in groundwater can present a similar problem. Metals often are mobilized in the presence of other chemicals, such as chlorinated solvents or petroleum products. Even undifferentiated organics, such as organic carbon found at inactive construction and debris landfills, can result in mobilization of metals in the groundwater. Although the geochemical basis for this mobilization is beyond the scope of this guide, it is important to realize that the movement and fate of some contaminants may be closely related to other anthropogenic physicochemical conditions and soil properties. If the anthropogenic conditions that control metals release (e.g., a DNAPL release) are infeasible to address by specific means, then the resultant metals release that results from stimulating natural processes will be equally infeasible to address in a reasonable time frame. Care should be taken to ensure that the updated CSM fully reflects the current understanding of the physical, chemical, and biological processes that control contaminant movement and fate.

Landfills are another general category of waste source. Most landfill closure strategies are built around a BACT response-action decision strategy. That is, most landfills are addressed using a combination of containment and isolation techniques. Because no treatment is pursued, the time frame required to achieve protectiveness, and complete the response action, should be defined by the time period required to validate reliable performance of the BACT. However, the required monitoring period may extend long into the future.

Controls on Contaminant Fate

Many early CSMs did not completely address the natural processes controlling the movement and fate of chemicals in the environment. Although physical processes such as advection, dispersion, and volatilization were often acknowledged in the CSM, limited information on chemical and biological processes *in situ* was included. Consideration of this information is important because the chemical and biological processes may be responsible for limiting contaminant migration over time, and for eventually stabilizing (containing) and reducing (treating) contaminant mass *in situ*, in some cases at rates that exceeded the mass reduction through the selected engineered remedy.

The rate at which these natural attenuation processes affect stability and mass is site specific. In some cases, these natural attenuation processes might even interfere with the performance of the response action (e.g., contaminant adsorption on soil versus removal via groundwater extraction). Yet natural attenuation processes also may afford the most reliable and sustainable form of control to contain and eventually remove chemicals *in situ*. Natural attenuation processes may define the short- and long-term performance potential of any response-action and thus are master controls on the feasibility of different RAOs and the means to achieve those RAOs in a reasonable time frame. Therefore, efforts to refine the performance objectives of the response action should be based on a technically credible explanation of natural attenuation potential, both in the short and long term.

Whenever possible, the environmental project team should adopt a facility-wide performance evaluation strategy rather than a project-specific performance evaluation approach. Doing so will better unify the response-action decisions made for different areas of the facility. Facility-wide evaluations will also help reintegrate decisions that may have been segmented to support initial framing and deterministic analysis efforts. A comprehensive, facility-wide CSM will lead to an integrated and comprehensive protectiveness determination. This is necessary because, in most instances, a determination that protectiveness has been achieved and response is complete ultimately will need to be made at the facility level.

2.2 SUMMARIZE THE CURRENT DECISION

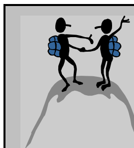
Statory test–an evaluation specifically provided in a regulation.

Before the response-action decision can be evaluated using the statutory tests of performance, the environmental project team will need to prepare a brief description of the current decision. This description should specifically include the following elements:

- Basis for the response (e.g., sources, nature, and extent of contamination; affected media; risk assessment results; current and future land use; completed exposure pathways; and targeted contaminants)
- Estimated cost to construct the remedy including management costs for non-engineered responses (typically available in predecision and/or decision documents)
- Construction-complete information including schedule and cost (note that cost information should be the sum of all funds spent and obligated to implement the response action, including management costs)
- Expected period of operation (e.g., expected removal rates over time)
- System improvements planned and installed including the basis, nature, and cost of these modifications
- Monitoring requirements of the response action (e.g., included as part of normal operation and maintenance [O&M]) and in surrounding affected media
- Related compliance requirements (e.g., decisions about the need for and scope of water and air treatment or discharge permits)
- Balance sheet of energy and utility consumption and the pollution generated by the remedial action.

In addition, the environmental project team is encouraged to develop a narrative description of how the proposed or implemented remedy integrates into the facility-wide cleanup effort, including the following information:

- Synopsis of the site-specific cleanup and exit strategy (i.e., how will implementing the response action facilitate achieving RC at both the site and facility level?)
- Summary of decisions made to date (i.e., a status report on formal documented decisions relevant to both the site and the facility)
- Summary of pending decisions (e.g., outstanding data needs, formal remedial decisions)
- Synopsis of other facility remedy components (e.g., land-use-controls/institutional controls [LUC/ICs]).



> Make sure everyone understands **where** you are going and **why-** so that everyone can help you get there as fast as possible!

Next, the environmental project team should develop a description of the performance objectives (i.e., the intended outcome) of the implemented response action. Short-term performance objectives generally can be classified as operational design objectives. These performance objectives define how the response action is expected to perform in order to satisfy the final performance objective—protection of human health and the environment. Short-term objectives are defined by action-specific ARARs and the means used to pursue the long-term objective. Long-term remedy objectives are the narrative and numeric RAOs that are to be achieved in order to document sustainable, reliable protection and completion of response-action obligations (i.e., the completion criteria).

It is imperative that the environmental project team carefully evaluate the predecision and decision documents in the AR to construct a complete summary of performance objectives. These requirements represent the full nature and scope of the formal commitments proposed or made by the DoD in terms of response-action obligations, and define the extent of substantive compliance requirements and environmental liabilities to be addressed under the DERP. These requirements also illustrate the current expectations of stakeholders with respect to the nature and degree of responses that are necessary, feasible, and reasonable to complete in a reasonable time frame.

2.3 TESTS OF NECESSITY: EXPOSURE POTENTIAL AND POINTS OF COMPLIANCE

Performance decision criteria related to the ***necessity*** of any response action are set forth in two statutory tests of performance.[5], [6] Environmental project teams should verify that the proposed or implemented response-action decision is **necessary** to provide the degree of protection required by the risk assessment and ARARs. The project team should verify that protective cleanup standards are applicable or relevant and appropriate to achieve at the established points of compliance. The point of compliance should be based on realistic exposure assumptions, the

[5]CERCLA §121[d][4]

[6]40 Code of Federal Regulations [CFR] 300.430[f][1][ii][B]

latest toxicity and fate information, and point-of-compliance stipulations within the ARARs under consideration.

The response action should also be **consistent** with other proposed or implemented response actions required to provide protection. The project team should verify that the performance objectives, and means used to achieve those performance objectives, are internally consistent for each decision across the facility and account for current and future real-property management plans and enforceable resource use controls.

2.3.1 Measuring Protection

The most important performance objective for any response-action decision implemented under the DERP is protectiveness**.** Yet, the criteria used to evaluate response actions often center on costs incurred or avoided, STC, or various operational measurements (e.g., pounds of targeted contaminant removed from soil or groundwater). Measuring and communicating progress toward the protection of human health and the environment requires that protection-related performance criteria be clearly identified as part of the decision process.

Developing and stating a definition of "protectiveness" that can be presented and understood by the stakeholders is a crucial step in the tests of necessity. Protectiveness is a general concept that can be expressed by different metrics. The following protectiveness metrics are appropriate for most sites:

- Short-term protection—the ability to prevent unacceptable exposure or continuing environmental releases into the environment immediately and during response
- Long-term protection—the effectiveness of the response at reliably controlling exposure or recovering chemical mass from the environment
- Permanence—the ability to <u>sustain</u> reliable protection forever
- Time—the time required to demonstrate protectiveness and compliance with necessary legal response obligations
- Stakeholder acceptance—the perceived expectations, such as preference for treatment over containment/control.

The metrics of protectiveness should be articulated as part of the basis for taking action because this information is crucial to documenting initial performance expectations. Environmental project teams should carefully consider what information is available to help demonstrate that the protectiveness criteria have been met. Project teams should also consider whether the available information indicates, or suggests, that an alternative standard of control (or alternative RAO) would provide appropriate protection.

Know what you are measuring and why! Metrics should be:

► Goal driven
► Appropriate and objective
► Measuring results, not activity
► Tracking trends
► Understandable to all
► Within the span of control

Most RODs stipulate that "protectiveness" will be measured using indirect (i.e., calculated or predictive) metrics, such as numeric standards developed as part of different regulations (e.g., MCLs established under the Safe Drinking Water Act [SDWA]). If indirect metrics are used, careful attention must be given to where performance is measured and verify that the point of exposure is the necessary point of compliance.

Such an approach might shift the emphasis away from complete *in situ* restoration using some relevant but indirect metric of protection (e.g., restoration of an entire aquifer to MCLs) to technically achievable containment and treatment strategies that provide immediate point-of-exposure protection. This approach is legally allowable by the statutory tests of performance as long as substantial evidence is available to demonstrate that an equivalent level of protection can be provided by an alternative standard of control (i.e., an alternative RAO).

2.3.2 Exposure Potential and Controls

The *necessity* of a response action is directly linked to the potential exposure of a receptor. Response actions are only necessary to address conditions that pose a substantial or unacceptable risk—via a *completed* exposure pathway—to human health and/or the environment. Thus, assumptions about exposure are at the heart of the response-action decision process. The potential for exposure is considered for both the near term (current) and the long term (future).

Exposure pathways define how a particular receptor could come into contact with a chemical contaminant in the environment. In an exposure pathways analysis, the CSM uses chemical transport and fate information, along with assumptions about land uses and how receptors behave, to identify ways in which those receptors could come into contact with different environmental media. In the absence of direct measurements, many assumptions must be made to estimate potential exposure pathway completion. Receptor exposure pathways under current conditions do not require as many assumptions as those to be considered under future conditions. Because assumptions about what will happen in the long term require some form of prediction about unknown conditions, exposure assumptions really should be expressed in terms of their probability of occurrence. Such an approach to exposure pathway analysis transforms human and ecological risk assessments from **deterministic** (i.e., there is one "right" answer) to **probabilistic** (i.e., there are a number of possible "right" answers). Expressions of probability help stakeholders understand that there is a choice to be made with regard to how we best manage potential risk.

> All cleanup decisions should be risk-based, by definition, because the **controlling standard** of performance **is protection** of human health and the environment.

Estimates of how future exposure potential might occur are often conservative and reflect an assumption that human behavior cannot be reliably controlled in the long term. In fact, the entire remediation industry is built upon the assumption that engineered strategies to control contaminant behavior in the environment are more effective and cost-efficient than controls designed to limit human behavior. This is one of the initial assumptions underlying many response-action decisions that could be objectively verified or refined using years of engineering performance and cost data. An example of this is the assumption that generally has been made about drinking water that the most effective way to protect human health from contaminants in groundwater is to remove the contaminants *in situ* so that the groundwater anywhere in the aquifer could be safely used for drinking without any further treatment. A corollary of this assumption is that the groundwater will be totally accessible in the future to the installation of a drinking water well anywhere in the aquifer. In reality, access to groundwater resources currently is controlled through a series of requirements ranging from well installation permits to wellhead withdrawal and treatment access rights. Water quality is typically monitored during well installation, and depending upon its quality, additional treatment may be required before use. Such treatment is a legally required form of exposure control.

As long as the impacted resources are stabilized, either naturally or through engineered containment methods, these forms of *ex situ* exposure control could serve to protect future receptors from exposure just as they do today. As long as the extent of the contamination is known and contained, this type of exposure control would accomplish protection of human health. In these cases, RC would be demonstrated by achieving reliable and sustainable exposure control (e.g., enforceable resource restrictions and/or point-of-compliance treatment). Natural reductions in contaminant concentrations through time, as a result of natural attenuation or withdrawal and treatment for beneficial use, will occur with the result that eventually the exposure controls may not be necessary. The point is that RC status—which is attained when reliable protection has been achieved—is not tied to that eventuality, and thus the projects could transition into verification monitoring only.

Yet these forms of exposure control—which are used to provide current protection—are rarely recognized as an option for future exposure control. Environmental project teams should revisit the assumptions related to the statutory tests of necessity to validate or refine the assumptions related to engineering capability versus exposure control reliability. One of the key questions to ask during such assessments is: if exposure control responses are providing the necessary degree of protection today, why are exposure control responses insufficient to provide the necessary degree of protection tomorrow?

Anti-degradation Laws

Some state environmental laws have attempted to define natural resources as potential receptors to indicate that no exposure (i.e., degradation) is desirable. These state anti-degradation laws generally are designed to require waste control/containment activities, so that additional resources are not degraded. However, these anti-degradation laws typically do not apply to releases that occurred before the law went into effect.

2.3.3 Points of Compliance

The point at which the necessary standards of "protectiveness" must be achieved is the point of compliance. The point of compliance should be the point of exposure. Assumptions about reasonable points of compliance are inherent in the tests of necessity.

The best examples of how important the defined points of compliance are to the nature and scope of final RAOs are the National Primary and Secondary Drinking Water Standards in the SDWA.[7] Drinking-water standards often are incorrectly identified as legally applicable requirements at CERCLA sites. For CERCLA actions, MCLs are legally applicable only when response actions impact public water systems that have at least 15 service connections or serve at least 25 year-round residents. If these assumptions are not valid, the relevance of the standard is subject to question, and an alternative standard of "protectiveness" (or alternative RAO) could be justified using the tests of necessity.

[7] 40 CFR 141

However, some states have codified the Federal SDWA standards into their state cleanup or groundwater protection programs as general "health-based criteria." This action represents an effort to apply the level of control or treatment requirements afforded to potable public water supplies to all potential sources of potable water (e.g., groundwater). Performance objectives that are defined by state reinterpretations of federal drinking-water protection criteria (i.e., changing the point of compliance inherent in the definition of the federal standard) could be tested for necessity, feasibility, and reasonableness, particularly where those interpretations may drive use of federal funds. Evaluation of the relevance and appropriateness of identified ARARs is at the discretion of the Air Force as the lead decision agency (EPA, 1998).

2.4 TEST OF FEASIBILITY: EXPECTED INFLUENCE ON NATURAL PROCESSES

The test of feasibility should be used to guide the compilation of site-specific technical evidence that is relevant to understanding what kind of past damage can feasibly be addressed in a reasonable time frame using currently available means. An objective is feasible when it can be achieved in a reasonable time frame using currently available response-action technologies. Recognizing and documenting the significant limitations of currently available technologies is the basis of the test of feasibility. The statutory test of feasibility is recognized as part of the technical impracticability waiver provision.[8], [9] The test of feasibility applies to both the performance objective and the response action. However, necessary protection should not be sacrificed as a result of a finding of infeasibility. The test of feasibility involves documenting the effectiveness and efficiency of different response actions at influencing post-release natural environmental processes.

2.4.1 Effectiveness of the Means

The effectiveness and efficiency of the means used to achieve the performance objectives should be routinely evaluated. A growing body of remedy performance data is available to improve response-action decisions and to create a workable definition of success. The knowledge base was incomplete when the cleanup program began, and what could and could not be done in a reasonable time frame (e.g., 10 years) to achieve reliable protectiveness was unclear.

The type of information required for this evaluation is described in the *Remedial Process Optimization Handbook* (AFCEE and DLA, 2001), so only a brief summary of the issues to consider is presented here. Environmental project teams should consult the RPO Handbook, and other appropriate references, for additional details on how to check the performance of their selected response. This information is critical for developing performance-focused closure plans for future use.

Technology-Specific Lessons Learned

> Remember that each remedy is a piece of the RC puzzle—they all must fit together correctly!

A large body of knowledge about the short- and long-term performance of different remedial technologies is available. Project teams should not feel that their knowledge about remedy

[8]CERCLA §121[d][4]

[9]40 CFR 300.430[f][1][ii][B]

performance need be confined to their experience at a particular site. Results from field-scale applications are potentially relevant at all sites with similar conditions.

This is the very approach that EPA and state regulators have taken to enforce consistency in the response-action decision process. If the decision process currently implemented results in approaches that cannot achieve protectiveness in a reasonable time frame, the decision itself must be revised. Project teams should use the growing body of knowledge about the real limitations on remedy performance observed at other sites to help construct a workable definition of success. Environmental project teams are expected to use any information relevant to the general and/or site-specific performance of the response technology or strategy to estimate the effectiveness of the selected approach at achieving the RAOs in a reasonable time frame.

Site-Specific Effectiveness Evaluations

Effectiveness evaluations can best be completed by direct comparison of actual performance data to established performance criteria. Illustrations such as charts, graphs, and overlay maps are useful tools for evaluating these data. When evaluating the treatability or treatment performance of any response technology or strategy, the trend-analysis charts should show at least the following:

- Changes in indicator contaminant concentrations over time at several key monitoring locations (e.g., Figure 5)
- The original (or baseline) mass of contaminants, the total mass removed to date as a result of the response action, and the residual mass to be addressed by ongoing response actions
- Changes, if any, in response performance through time (e.g., rate of groundwater extraction *vs*. time)
- Costs incurred to date (annual and total) compared to the progress made toward the final numeric RAOs.

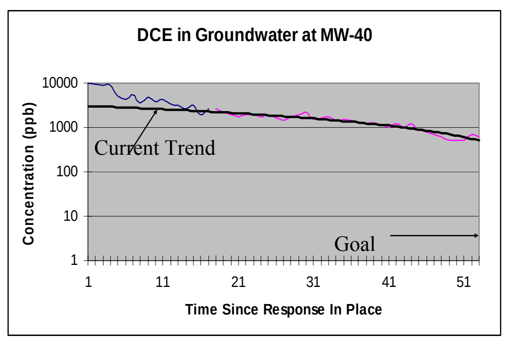


Figure 5. Temporal Chemical Data

The cost presentation should summarize how much the realized benefit has cost and the expected benefit/cost trend, assuming no significant changes in performance through time. These graphs are intended to help illustrate the past, present, and potential future performance of the response action in achieving timely completion of RAOs.

The goal of this kind of evaluation is to use temporal trend data to project long-term performance potential. Near-term effectiveness improvements should be consistent with modifications required to document protectiveness and improve the rate of completing required response obligations. For example, optimization efforts should first determine whether the in-place response action is making measurable progress toward its intended objectives. To do this, the project team should extrapolate the temporal trend data over time to illustrate the rate of progress toward the targeted performance goal that can be achieved with the current response approach (Figure 5). If this extrapolation indicates that the proposed or implemented response-action cannot be completed in a reasonable time frame based on the current rate of performance, the project team will need to identify what corrective actions might be warranted to facilitate completion, and why those actions are both required and consistent with satisfying the overall objective of the DERP.

Using Contingency Waivers

In the absence of remedy performance data (e.g., early in the response-action decision process), environmental project teams are encouraged to consider the use of "contingency waivers" to incorporate an iterative test for feasibility into ARAR-based decisions. When explicitly included in decision documents, contingency waivers provide a way to document the intent to execute a probabilistic site completion strategy (see Office of Solid Waste and Emergency Response [OSWER] Directive 9234.2-01/FS-A). The use of contingency waivers is one method of ensuring flexibility in the decision process by reserving the right to reexamine any element of the response decision in light of improving future knowledge, and to waive compliance with those elements that no longer satisfy the tests of performance through time. Such an approach allows improving site knowledge about the feasibility of achieving certain objectives to be incorporated, as necessary, into the completion plan for the site.

Contingency Waivers

When sufficient information is available at the time of ROD signature indicating the possibility that an ARAR waiver may be invoked at a site (e.g., the RI/FS indicates that it may be technically impracticable to attain non-zero MCLGs or MCLs in the groundwater based upon final determinations of the size and scope of the contaminated plume), the lead agency may consider including a contingency waiver in the ROD. RODs with contingency waivers should provide a detailed and objective level or situation at which the waiver would be triggered. In addition, the ROD should specify that the contingency is "reserved to be decided at a later date," so that if the contingency is invoked, the resulting documentation becomes part of the AR (see National Contingency Plan [NCP] section 300.824(a)(1), 55FR at 8861).

The decision to invoke the contingency should be documented in a fact sheet which is placed in the AR file. The region may also decide to issue a public notice (e.g., in a major local newspaper of general circulation) that the contingency has been invoked. An explanation of significant differences (ESD) is not required to invoke a contingency specifically contemplated in the ROD. (See Guide to Developing Superfund No Action, Interim Action, and Contingency Remedy RODS, Publication 9355.3-02/FS-3, April 1991, for a general discussion of contingent remedies.)

From: OSWER Directive 9234.2-01/FS-A

For example, if the CSM was not particularly well developed at the time a decision was put into place, the performance of various response-action technologies over time could not be reliably predicted. The Decision Document could articulate the assumptions about performance and expected outcome that were made to select the decision, and also clarify what conditions would suggest that those assumptions were invalid.

Contingency waivers represent probabilistic decision planning in that the possibility of an unexpected outcome is recognized, and efficient alternative outcomes are identified as part of the formal decision. The project team should formalize contingency planning by specifying the decision criteria (triggers) to be used to invoke an ARAR waiver on the basis of technical impracticability should the selected response action fail to perform as expected.

2.5 TEST OF REASONABLENESS: MAXIMIZING BENEFITS AND MANAGING COSTS

The final three statutory tests of performance provide for the test of reasonableness:[10],[11]

- Greater risk to human health and the environment
- Fund balancing
- Inconsistent application of a state standard.

The tests of reasonableness are based on assessing the relative benefits received as a function of the full costs (risks), and on consistency of application. The reasonableness of different choices that are not risk-driven will depend on the ratio of benefits to cost.

2.5.1 Greater Risk Test

Assessing the potential for greater risks to human health and the environment as part of an assessment of response-action decision performance is a concept that is not often applied within the federal cleanup program. Response actions are planned to provide necessary protection, and ARARs are a means to ensure protection during response actions. The possibility of greater, unanticipated negative impact on human health or the environment typically is not addressed in response-action decisions.

The project team is encouraged to assess both the monetary and nonmonetary costs, or additional risks, to be incurred by taking action. This test of reasonableness is designed to check that targeted performance objectives or means to achieve those objectives actually result in a net benefit (i.e., high benefit/cost ratio). This test of reasonableness focuses on resource balancing to ensure that the targeted "protectiveness" is not achieved at the expense of another important environmental value (e.g., recovery of water resources at the expense of air quality). Section 4 of this guide illustrates how to use comparative benefit/cost ratios to establish performance objectives and emphasize effective/efficient remedial components.

Economic valuation techniques can be used to compare the full costs associated with different response-action decisions. However, attempts to place dollar values on protection plans (e.g., human life, clean water) may result in stakeholder confusion and controversy to such an extent that it interferes with the decision process itself. Therefore, the use of simple qualitative ranking techniques is recommended as a way to compare the benefits and costs of any decision, and to communicate the expected benefit/cost outcome to involved stakeholders. This approach is similar to the CERCLA remedy evaluation approach promoted by the EPA (EPA, 1989a, 1997, and 1999).

Costs (or risks) to be incurred by any response-action strategy can be expressed as direct costs, indirect costs, and transactional costs. Direct costs are the easiest costs to identify and have often been the only costs recorded in the decision planning process. Direct costs include capital costs,

[10] CERCLA §121[d][4]

[11] 40 CFR 300.430[f][1][ii][B]

O&M costs required during response action implementation, and monitoring costs incurred during implementation and following completion to verify protectiveness.

Indirect costs require a more complete decision consequence analysis (see sidebar on remedial action generated risk and pollution in Section 2.5.3). Loss of environmental resources as a result of taking a specific action must be considered. The assessment team should consider at least five major classes of indirect costs:

- Long-term costs incurred by using power to pursue protection, because such actions result in a reduction in overall available energy sources and increase power-related pollution (e.g., mining and drilling activities, greenhouse gas emissions)
- Environmental costs incurred by generating secondary or tertiary waste streams produced as a result of phase-transfer of contaminants (e.g., air discharges, acid rain, landfill requirements)
- Costs associated with resource consumption or loss (e.g., need to provide for in-kind replacement or compensation for a damaged natural resource, need to dispose of treated material with no immediate beneficial use, forests damaged by acid rain)
- Stakeholder perception costs associated with different expectations and values (e.g., effort and time required to improve the knowledge base and improve consensus, perceived impact on an agency's reputation as a result of negative press coverage)
- Other indirect costs (e.g., real or perceived risks to other programs as a result of a certain action, real or perceived loss in value of impacted resource, litigation costs).

Many of the indirect costs may be directly proportional to the degree to which stakeholders believe that it is necessary, feasible, or reasonable to achieve "restoration" of impacted environmental resources in a reasonable time frame. Decisions focused on restoration frequently have high indirect costs and may represent a low benefit/cost ratio.

> **Restoration**–the cleanup objective of restoring the environmental resources to their condition before the release of contamination.

Transactional costs of any decision often are not fully recognized in the CERCLA response-action planning process. Transactional costs are directly related to the level of complexity required to:

- Assess and monitor performance of any specific remedial technology/approach
- Fulfill administrative compliance reporting requirements or other agency-specific performance monitoring requirements (e.g., verifying current CTC estimates).

These kinds of costs are a necessary element of verifying protectiveness, and often represent long-term commitments to ensure protectiveness.

In general, the nature and scope of engineered controls will drive the nature and scope of transactional costs to be incurred. Transactional costs associated with administrative/legal controls may involve programs administered by various other government agencies (e.g., state groundwater well permitting programs).

Understanding the full costs (or risks) associated with a specific decision is an important check on the "protectiveness" of certain ARARs, remedial technologies, and strategies. Each response decision should be evaluated to determine that it will not result in more risk (costs) than benefits. Compiling this information will help validate (or revalidate) the RAOs that must be achieved to document "protectiveness."

2.5.2 Fund-Balancing Test

The second test of reasonableness is embodied in the fund-balancing waiver. For Superfund-led sites, an ARAR may be waived and replaced with an alternative performance objective if compliance would be costly relative to the degree of protection or risk reduction likely to be attained and if the expenditure would jeopardize implementation of remedial actions at other sites. This waiver currently is not available to lead Federal agencies other than the EPA (per statutory language restricting its use to Fund-financed projects only).

However, the fund-balancing statutory test is important in terms of evaluating how best to satisfy response commitments involving significant project costs that are driven by attempts to comply with similar performance objectives or cleanup expectations. Such information feeds into ongoing efforts to update DERP expectations.

2.5.3 Inconsistent Application of a State Requirement Test

The third statutory waiver related to the test of reasonableness is based on the inconsistent application of state requirements. A state ARAR can be waived if evidence exists that the requirement has not been applied to other sites (under CERCLA or any other regulatory program) or has been applied inconsistently. This waiver is intended to prevent unjustified or unreasonable state restrictions from being imposed at CERCLA sites. Use of this statutory waiver may complicate future regulatory coordination efforts and create public acceptance issues. However, this type of statutory performance test might be considered during negotiations as one of the lines of evidence of the "reasonableness" of certain decisions.

Remedial Action Generated Risk and Pollution

The O&M of a cleanup remedy may result in substantial costs and indirect risks. The electrical power, required for the operation of many treatment processes, has both a direct cost and indirect costs to the environment. For example, the electrical power for a one-horsepower motor operating continuously will incur a direct cost of approximately $1.33 per day or $485.23 per year (at the 2003 average retail cost for electricity 0f $0.0742/KWH).[1]

Indirect costs of electrical usage include the use of nonrenewable natural resources and the environmental pollution produced in the generation of the electricity. The generation of electricity to power a one-horsepower motor operating continuously will result in the emission of approximately 9,106 pounds of carbon dioxide, 39.5 pounds of sulfur dioxide, and 19.4 pounds of nitrogen oxides into the atmosphere[2]. Additionally, there may be potential risks of local pollution at the site due to construction equipment operation, wind-blown dust, stormwater runoff, or spills resulting from the remedial action and the risk of accidents and injury to the site workers.

The following is an example comparing the environmental risk and pollution that might result from each of five alternative remedies for the cleanup of a 6,000 Kg spill of total petroleum hydrocarbon (TPH). The original risk is assumed to be 1 x 10^{-3}.

Remedial Action	Cost ($ Mil)	Time to RC (Yr)	Risk after RC	RA Risk	Energy Consumption	Pollution Due to Energy Consumption [2]	Contaminants Removed
No Action	0	100 +	10^{-4}	0	0	0	~ 4,000 Kg
Dig & Haul (D&H)	$1	50	10^{-4}	10^{-3}	5,000 Gal Diesel	60 ton CO_2 880 lb. NO_x 36.4lb. SO_2	~ 4,000 Kg
Pump & Treat (P&T)	$8	75	10^{-6}	10^{-5}	$3*10^6$ KWH	2,089 ton CO_2 4.44 ton NO_x 9.06 ton SO_2	~ 5,000 Kg
D&H + P&T	$9	47	10^{-7}	10^{-3}	$3*10^6$ KWH + 5,000 Gal. Diesel	2,149 ton CO_2 4.88 ton NO_x 9.08 ton SO_2	~ 5,500 Kg
Enhanced MNA	$0.9	53	10^{-7}	10^{-5}	$3*10^3$ KWH + 500 Gal. Diesel	8.09 ton CO_2 96.9 lb. NO_x 21.8 lb. SO_2	~ 5,500 Kg

KWH = kilowatt-hour

[1] Average of January–August 2003 retail electricity costs, Energy Information Administration, December 2003 Monthly Energy Review.

[2] Based on average emissions for U.S. power plants in 2000, Environmental Protection Agency eGRID Highlights.

3.0 TAILORED CLEANUP EXPECTATIONS FROM ARAR EVALUATIONS

To ensure that response actions are tailored (i.e., site-specific), environmental project teams should periodically evaluate whether compliance with identified ARARs would lead to response actions that are necessary, feasible, and reasonable to protect human health and the environment. This kind of focused performance assessment hinges on providing substantial evidence to justify that protectiveness can be achieved and documented by either complying with the level of control specified by the ARARs (e.g., cleanup standards), or complying with an alternative level of control. An alternate level of control might include an alternative point of compliance to that suggested by an identified ARAR, or in other ways reflect site-specific conditions or knowledge relevant to the cleanup program.

The importance of the ARAR evaluation process has not been clearly described, even in various EPA guidance documents (e.g., EPA, 1989a, 1991, 1998). Although guidance on how to <u>identify</u> potential ARARs is available, little information has been developed on how to <u>evaluate and select</u> ARARs to establish achievable RAOs. The absence of this kind of guidance has led environmental project teams to incorrectly conclude that identification of ARARs requires compliance.

> **Stipulate**–to require, as a condition for an agreement

Data compiled to support response-action decision selection and periodic performance review are critical to evaluating whether specific ARARs stipulate the necessary, feasible, and reasonable level of protectiveness to be used as substantive compliance and completion criteria. Much of the substantive evidence required to defend an alternative standard or level of control, as provided in CERCLA[12] and most state environmental cleanup laws, may not have been readily available early in the cleanup program. This is particularly true with regard to the tests of feasibility and reasonableness. However, the knowledge base has expanded dramatically, and this evolving information may be directly relevant to updating the ARAR analyses.

The following subsections summarize the general steps that could be taken to apply the statutory tests of performance to establish the need to comply with or waive ARARs selected for a given site.

3.1 STEP 1: IDENTIFY THE BASIS

As a first step, the project team should review the existing remedial objectives and identify the ARARs that drove the original decision selecting the objective. Documentation explaining the historical basis for identifying and selecting each ARAR should be reviewed to understand the original decision process. During this review the environmental project team should also consider whether there are other ARARs not previously identified that should now be considered, based on current knowledge of the site.

[12]CERCLA §121(d)(4)

The DoD typically solicits regulatory agency input with regard to candidate (potential) ARARs during the response-action planning process. This input should be documented in the AR. This regulatory agency input was the beginning of the ARAR analysis and selection effort. However, periodic performance evaluations at many facilities (e.g., RPO evaluations and five-year review reports) have shown that site-specific information relevant to the necessity, feasibility, and reasonableness of ARARs suggested by the regulatory agencies is often missing or not presented clearly in the AR. Also, emerging technical information relevant to the statutory tests of performance is often not clearly linked to assumptions made during the planning and implementation process. Therefore, environmental project teams should use the ARARs that form the basis of existing RAOs as a guide for identifying the data needed to determine the legal applicability or the relevance and appropriateness of those ARARs.

The information gained from this review documents why the existing ARARs were originally selected (i.e., the basis for selection). The following steps examine whether the original decision was appropriate then, and considers whether that decision is still appropriate given the current knowledge of site conditions.

3.2 STEP 2: LEGAL DETERMINATION OF APPLICABILITY

The next step is to define or verify legal applicability. A pertinent standard may be either "applicable" or "relevant *and* appropriate," but not both. In order to be legally applicable, the standard must be promulgated under Federal or state law. The term "promulgated" means that the standard is in a law or regulation that is legally enforceable (i.e., the issuing agency has the legislative power to issue such rules). Guidance and advisories are not considered "promulgated" because they are not legally enforceable (i.e., they are interpretive "rules" or policy statements).

A pertinent standard is applicable only if it directly and fully addresses the situation at the site. To be applicable, all jurisdictional elements also must apply. The question of applicability is a legal one, so the environmental project team should seek legal counsel if necessary.

As an example, the National Primary and Secondary Drinking Water Standards (i.e., MCLs) are promulgated standards that are legally enforceable for the circumstances for which they were issued. These Federal MCLs are intended to regulate specific chemicals in public water supply systems that have at least 15 service connections or serve at least 25 year-round residents. This means that the Federal MCLs define the allowable concentration in public drinking water supplies at the tap following any necessary treatment. These standards were not designed to address the circumstances at most CERCLA sites, or to define necessary, feasible, and reasonable cleanup standards for *in situ* resources. Federal MCLs usually are not legally applicable for response-action decisions for *in situ* groundwater resources. These standards should be evaluated for relevancy and appropriateness.

In many cases, however, states have adopted the Federal MCLs as part of their groundwater cleanup and antidegradation requirements. These state standards may be legally applicable. State antidegradation laws typically cannot be used to require cleanup to the aquifer's original quality prior to contamination because these laws are prospective and are intended to prevent *further* degradation of groundwater quality. However, antidegradation statutes may be applicable to state waters that are currently unaffected by site contaminants, but that may in the future be threatened by migrating contamination.

State cleanup laws could stipulate targeted cleanup standards for groundwater, which should match the anticipated beneficial uses of that water. Most state cleanup laws clearly recognize the potential impracticality of meeting those standards (e.g., by inclusion of specific waiver provisions or use of the clause "as practicable"). An initial or continuing decision to pursue compliance with these applicable standards should be supported by substantial evidence of the necessity (e.g., beneficial use determination), feasibility (e.g., demonstrated evidence of likelihood to achieve the stipulated degree of cleanup in a reasonable time frame, given the capabilities and measurable effectiveness of current remedial technologies), and reasonableness (e.g., benefit/cost analysis considering resource replacement or point-of-exposure treatment costs).

3.3 STEP 3: JUDGMENT OF RELEVANCE AND APPROPRIATENESS

A requirement that is not legally applicable may be relevant and appropriate if it addresses problems or pertains to circumstances that are sufficiently similar to those encountered at the specific site (relevant) and are well-suited (appropriate) for application at the specific site.[13] Note that a requirement can be relevant but not appropriate. For instance, federal regulations[14] establish procedures for asbestos emission control and waste management during demolition of equipment or buildings containing friable asbestos material. This regulation may be noted as relevant to response-action decisions regarding residual asbestos in soil impacted by past demolition activities, but may not be determined to be appropriate for application because such standards are not well suited to the specific conditions.

Only those requirements that are both relevant and appropriate need be considered in the ARAR evaluation process (EPA, 1998). The Air Force, as lead Federal agency, is afforded significant flexibility and discretion in these determinations because they typically are made using best professional judgment. And, unlike legally applicable standards, the lead Federal agency can determine that only a portion of a promulgated standard is relevant and appropriate (i.e., compliance with all substantive provisions of a pertinent standard may not be required).

Environmental project teams are encouraged to carefully and routinely evaluate both general and site-specific technical information pertinent to potentially relevant and appropriate requirements. Conclusions regarding the necessity, feasibility, and reasonableness (i.e., the appropriateness) of these types of ARARs will drive efforts to achieve and document protectiveness and achieve RC.

3.4 STEP 4: TO-BE-CONSIDERED ELEMENTS

In addition to ARARs, to-be-considered (TBC) elements or guidelines may be used in conjunction with ARARs to define the necessary, feasible, and reasonable RAOs and/or means to achieve those RAOs. TBCs are not promulgated, and therefore are a category of potentially pertinent requirements, criteria, or limitations distinct from ARARs. For instance, the EPA has noted that statements regarding expectations for the Federal response-action program (e.g., efforts to return usable groundwater to its beneficial uses, wherever practicable, within a time

[13] NCP §300.5

[14] 40 CFR §§61.147 and 61.152

frame that is reasonable given the particular circumstances of the site[15]) are not “binding requirements,” which may mean that such policy interpretations are TBCs.

The Air Force anticipates that TBCs might be used to clarify response-action obligations if such guidelines are required to ensure protection at points of potential exposure that may exist under reasonable assumptions (e.g., *CERCLA Compliance with Other Laws Manual* [EPA, 1989a]). Thus, existing RAOs should have spatially defined points of compliance specified for any TBCs. Any existing RAO that was built upon a TBC should be accompanied by an explicit explanation of why that “criterion” was necessary, feasible, and reasonable to provide reliable protection of human health and the environment.

3.5 STEP 5: TEST STANDARDS FOR NECESSITY, FEASIBILITY, AND REASONABLENESS

Once candidate ARARs have been confirmed to be either applicable or relevant and appropriate, the level or standard of control specified by the ARAR should be rigorously evaluated using the tests of necessity, feasibility, and reasonableness based on the best available information. This level of evaluation should have been completed and clearly documented in the AR.

The ARAR evaluation process should be supported by a site-specific risk assessment to define risk-based cleanup concentrations. If an updated site-specific risk assessment indicates that an equivalent standard of protection can be achieved with a different standard or level of control than an existing ARAR, such risk assessments are sufficient evidence to determine that compliance with the ARAR is unnecessary to meet the performance objectives of Federal and state laws and regulations.

Recognizing the very real limitations of certain types of response-action technologies and strategies is a key step in evaluating ARARs for practicality (feasibility and reasonableness). The national cleanup programs are built upon the aggressive but realistic use of treatment methods. Performance assessments regarding the practicality of certain ARARs should be clearly linked to performance data for the response technologies. Note that a determination of impracticability and invoking any of the “impracticability waivers” does not mean that protectiveness cannot be achieved. For example, the impracticability of reducing contaminant concentrations in an entire aquifer to a specific cleanup standard would shift the focus of response actions to a more realistic point of compliance to achieve the desired protection. In this case, wellhead treatment may achieve protection at the point of compliance without subjecting an entire aquifer to an infeasible standard.

To test for reasonableness, environmental project teams should consider the use of simple comparative benefit/cost ratios when undertaking thorough analyses of the practicality of complying with candidate ARARS (see Section 4.0 of this guide). The use of such methods is consistent with certain provisions of Federal and state response laws, including the National Environmental Policy Act of 1969 (NEPA) and natural resource damage assessment programs.

The principal test of reasonableness is specifically designed to determine whether compliance with a candidate ARAR could result in greater risk to human health or the environment than would compliance with an alternative standard of control (see Section 2.5.1). For example,

[15]§300.430[a][1][iii][F]

efforts to aggressively contain low-risk groundwater that is discharging into nearby surface water by implementing high-volume extraction and treatment could impact the hydrology and uses of that surface water body. Similarly, installation of an engineered cover that requires destruction of existing habitat and negatively impacts groundwater quality characteristics by eliminating surface recharge may present a greater risk to the environment than would an alternative standard of control. Such responses would be classic examples of the cure being worse than the illness. This information may be used to identify unreasonable ARARs, and, if necessary, justify waiver of an ARAR.

3.6 STEP 6: COMMUNICATE THE DECISION BASIS

When the ARAR assessment is finished, the project team should document the findings specifically addressing:

- What ARARs were evaluated
- The original basis for selection
- The validity of the original selection
- Whether the ARAR is still appropriate, considering current knowledge of site conditions.
- Recommendations for any changes to existing ARARs and RAOs.

This document will be used in future Objectives Assessments as a summary of the present understanding of the site conditions and the Air Force's environmental obligations. If changes to existing ARARs or RAOs are recommended, this summary will be part of the documentation used to support the negotiations with regulators discussed in Section 5 of this guide.

4.0 STRATEGY COMPARISONS USING BENEFIT/COST RATIOS

Response-action completion strategies always are focused on results (i.e., protection of human health and the environment). Every decision results in an outcome or consequence. This is why the CERCLA response-action planning process is based on a formal decision/ consequence analysis (DCA). The goal of effective decision-making is to maximize the benefits and minimize the costs of any selected course of action. Thus, the selection of any specific completion strategy requires a comparison of the costs to be incurred by that action against the expected benefits. The response planning process is intended to identify feasible and reasonable approaches to achieving necessary protectiveness (benefits) in a reasonable time frame, as cost-efficiently as practicable.

All anticipated benefits and costs must be accounted for throughout the response-action planning and implementation process to ensure that any response-action completion plan continues to maximize real benefits achieved for minimal cost. This type of strategic planning process, which includes a clearly-stated benefit/cost analysis, is required by the GPRA, DoD's Strategic Plan, the DERP, and all major environmental laws (e.g., CERCLA).

This section briefly reviews how to use simple benefit/cost ratios to develop easy-to-follow response-action completion plans that clarify performance expectations, so that such information can be used to evaluate progress toward achieving those commitments. This ratio also provides a rational comparison of alternatives even in cases where there may be zero benefits (e.g., some cases of the No Action alternative) yet costs are still involved (e.g., administrative costs). This information will also be necessary to focus future optimization efforts by providing the framework to incorporate lessons learned about remedy performance and costs.

4.1 ESTIMATING THE BENEFITS OF A DECISION

Response-action completion strategies, which are first developed in the predecision documents and established in the ROD, are an educated guess on how best to achieve necessary protection in a reasonable time frame. Thus, the ultimate benefit of any response-action strategy is protectiveness of human health and the environment.

Many pre-decision planning documents and RODs have not clearly summarized the site-specific assessment of potential benefits that are expected as a result of selecting a specific response action. The metrics of protectiveness should be clearly stated as part of the basis for taking action because this information is crucial for documenting initial performance expectations. This same information should be used to conduct periodic performance evaluations to track progress toward complying with the initial performance expectations over time. Failure to achieve the targeted level of benefits (i.e., protectiveness) in a reasonable time frame should prompt adjustments to improve performance and the selection of results-based contingency actions.

Although the absolute value of a particular benefit that results from implementing a response action may be difficult to quantify, the relative value of the benefit may be readily apparent. For example, enforcement of LUC/ICs at a contaminated site may result in the immediate attainment of complete protection of human health and the environment within the enforcement area. This result represents the greatest level of protectiveness (hence, the greatest benefit) available. On the other hand, a response that results in “No Action” will provide no protection (thus, no benefit) at the same site. Other possible responses could attain relative protectiveness that might be characterized as “low degree” or “intermediate degree” of protection (corresponding to low benefit and intermediate benefit) for those responses. Consequently, an array of potential response actions can be developed and ranked according to the total relative benefit that each provides.

Appendix A presents an example of one method of clarifying the relative value of the benefit achieved by different response-action strategies. In order to specify the value-added by different remedial components, the project team should first identify the potential benefits that are expected by different elements of the response-action decisions.

For example, ranking matrices can be used to evaluate the relative benefits associated with various soil and groundwater response strategies. The matrices assign relative values for each of five potential response-action benefits (short-term protection, long-term protection, permanence, time required, and acceptance) to potential response-action components for contaminated soil and groundwater (see examples in Table A1 and Table A3). The relative benefit assigned to a particular response-action component is based on the level of performance qualitatively anticipated for that component under most general circumstances.

The objective of this exercise is to prepare a clear assessment of the relative benefit achieved by proposed, in-progress, and completed response actions as a means of validating whether protectiveness has been achieved, and if not, developing strategic plans to increase the protectiveness afforded by the decision. If, however, protectiveness has been achieved and can be documented, the objective can be simplified to documenting RC (i.e., protectiveness achieved), and beginning to evaluate cost-efficient ways to verify that reliable protectiveness is being sustained by the decision.

4.2 ESTIMATING THE COSTS OF A DECISION

As discussed in Section 2.5.1, costs to be incurred by any response-action strategy can be expressed as direct costs, indirect costs, and transactional costs. Unfortunately, the actual direct and indirect monetary costs of response implementation often are difficult to develop. Other “costs,” including loss of beneficial use of a resource as a consequence of remedy implementation (e.g., groundwater removed from the subsurface using an extraction system is no longer available for use) and risks associated with remedy implementation (e.g., potential worker exposure during a removal action) are extremely difficult to quantify (see also the sidebar on remedial action generated risk and pollution following Section 2.5.3). It is not necessary, however, to place dollar values on direct, indirect, or transactional costs (or risks) in order to compare them qualitatively.

As with benefits, the relative costs of different response-action technologies/strategies can be assigned a simple ranking value. For example, in Appendix A the direct costs associated with aggressive engineered treatment systems can be expected to be relatively higher than the direct costs incurred by engineered containment systems. The direct costs of this technology may be ranked higher than other strategies. However, when indirect and transactional costs—which include potential impacts on other resources (see Section 2.5.1)—are considered, the total costs of different remedial technologies and approaches may change.

Ranking matrices can be used to assign relative values for direct, indirect, and transaction costs to potential response-action components for contaminated soil and groundwater (Appendix A). The relative cost assigned to a particular response-action component is based qualitatively on the costs anticipated for implementation of that component under most general circumstances, and ranges from 0 (no cost) to 3 (greatest cost) in this example. Note that the relative importance of various factors can be weighted by using larger or smaller ranges for the qualitative factors (e.g., use a range of 0 to 5 for high importance factors and a range of 0 to 1 or 2 for low importance factors) as shown in Table 1.

Table 1. Parameter Ranges for Factor Weighting

Importance of Factor	Range of Values	0	1	2	3	4	5
Very Low	0–1	None	Some				
Low	0–2	None	Low	High			
Average	0–3	None	Low	Average	High		
High	0–4	None	Very Low	Low	High	Very High	
Very High	0–5	None	Very Low	Low	Average	High	Very High

In the past, most predecision planning documents or RODs did not clearly present a site-specific assessment of the potential total costs expected to be incurred as a result of selecting a specific response action. The costs of pursuing protectiveness should be presented as part of the basis for taking action because this information is crucial to documenting initial performance expectations. Similarly, this information is critical to conducting periodic performance evaluations and making determinations about the long-term cost-effectiveness of different technologies and approaches.

4.3 BENEFIT/COST ANALYSES

The relative benefits and costs of different response action decisions are proportional to the relative effectiveness of different technologies in terms of providing the necessary protectiveness. For example, in many cases, "restoration" objectives have defined the compliance commitments made by the Air Force, as the lead Federal decision agency. These performance objectives, however, may not be necessary to ensure protectiveness at the current point of exposure. Rather, "restoration" objectives frequently represent a desire to "recover" degraded environmental resources to prerelease conditions.

Additionally, "restoration" objectives may not be achievable given the demonstrated effectiveness of current remedial technologies. For example, experience with pump-and-treat systems has shown that the rate of mass removal typically declines over time and may approach some concentration limit without ever achieving the regulated concentration limit. As a consequence, impracticable compliance commitments may be made, which means that protectiveness—as defined by the RAOs stipulated in the decision documents—cannot be achieved or documented in a reasonable time frame. The relative benefits achieved by the expended costs often cannot be justified in these situations.

An example of a graphical benefit/cost comparison for a hypothetical response decision focused on achieving restoration as the final performance requirement for protectiveness is shown in Figure 6. Note that the degree of protectiveness does not depend on the effectiveness of mass-recovery techniques or *in situ* restoration methods. Rather, protectiveness is provided through time at the point of exposure via engineered and/or administrative/legal controls. In order to document protectiveness, therefore, the decision needs to recognize the benefits realized by the administrative/legal controls. The benefit of pursuing a restoration RAO is that it limits the long-term need for *ex situ* controls. However, the benefits of a restoration RAO may be offset by the costs (impracticability) of available remedial technologies. Continued pursuit of restoration as the final RAO might lead to noncompliance with that RAO for many years, and delay achieving RC.

As discussed earlier, simple ranking methods can comparatively evaluate the relative benefits and costs of alternate decisions. A benefit/cost analysis begins with compiling the relative benefits and costs associated with particular response actions. All specific components of the decision should be included (RAOs and remedial techniques). For example, a removal action to address soil in a contaminant source area may combine excavation and *e -situ* treatment or disposal of soil with legal or administrative controls to prevent public access to the source area before or during implementation of the response action.

The relative benefits and relative costs of the response-action components are combined to yield a total relative benefit and total relative cost for the complete response action. Relative benefits and relative costs are combined according to the following procedure:

- Benefits are regarded as nonadditive—that is, combining a component having the least relative benefit with a component having an intermediate relative benefit will not produce a response action having more than an intermediate relative benefit. Accordingly, the largest relative benefit provided by any component of the complete response approach is identified for each of the benefit factors (shaded cells in the example Table A5), and the values for each of the benefit factors are summed to produce the "Total Relative Benefit" for the complete response action.
- Costs are regarded as additive—that is, certain identifiable costs are associated with each component of a response action, and these costs are cumulative as the response is developed and implemented. Accordingly, all costs for each component of the response approach are identified for each cost type (shaded cells in the example Table A6), and these are summed to produce the "Total Relative Cost" for the complete response action.

After relative total benefits and relative total costs have been estimated for one or more complete response actions, these values can be used to generate a benefit/cost ratio for each potential response action. Benefit/cost ratios generated for several potential response actions at a particular site then can be ranked and used to evaluate the relative applicability of each potential response action in successfully addressing conditions at the site. Various combinations of response-action components can also be tested using this procedure, to develop response approaches that provide the greatest relative benefit at a site, while reducing the incremental relative costs necessary to achieve that benefit.

This procedure was developed as a screening-level evaluation tool and is based on professional judgment and industry-wide operating experience extending through a period of approximately 30 years. The greatest advantage of the procedure derives from its ability to combine both objective and subjective factors associated with performance evaluation criteria, into a single numerical score, which allows alternatives to be simultaneously ranked according to how well they satisfy all performance criteria for a decision. Moreover, the approach is readily adaptable to changing response-action technologies or approaches, and to site-specific conditions, making it a useful tool for iterative performance assessments. For example, it is possible that improvements in a particular technology (e.g., *in situ* oxidation) might result in improved performance of the technology while reducing overall cost of application. In such circumstances, the relative benefits and relative costs in the matrices could be adjusted to better reflect technology-specific or site-specific information.

4.4 STATING THE BASIS FOR BENEFITS AND COSTS

Straightforward (and therefore easy to explain) benefit/cost ratios should be used to clarify and justify the basis of any decision. Benefit/cost ratios can be used to clarify the feasibility and reasonableness of achieving certain RAOs at different compliance points (e.g., restoration RAOs throughout the impacted environmental medium within a reasonable time frame). Note that the necessity of taking action to prevent unacceptable exposure at reasonable points of exposure is established by credible risk assessment techniques. Often, however, development of the RAOs is based on unreasonable assumptions about potential exposure (e.g., all impacted groundwater will be a source of untreated drinking water) or on unreasonable expectations regarding the feasibility of achieving certain objectives (e.g., restoration by current remedial technologies can be achieved in a reasonable time frame).

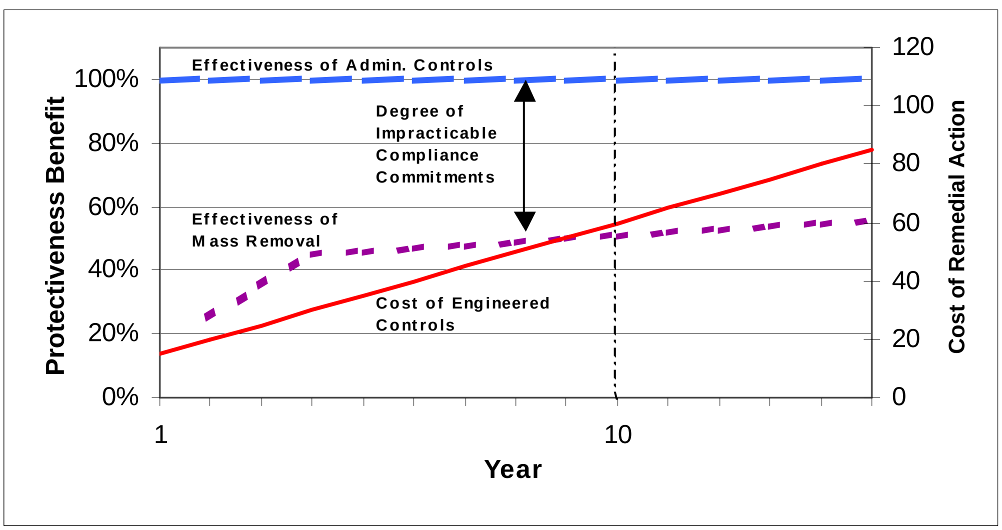


Figure 6. Relative Benefits and Costs of Protectiveness Based on Restoration Objective

Most response decisions include some form of engineering or administrative/ legal controls that provide for immediate and effective protection (Figure 6). Those controls will remain in place as long as they are required to maintain and verify protectiveness. Often, the duration through which those controls are necessary is defined by the feasibility of restoration (i.e., until mass removal has been achieved to a degree such that no controls or restrictions are required). Benefit/cost ratios can be used to evaluate the degree to which various responses may achieve spatial and temporal RAOs that afford equivalent levels of protection (benefits), together with associated relative costs. Thus, a site- and response-specific benefit/cost ratio can be developed to assist in selection of ARARs and/or the derivation of protective alternate concentration limits (ACLs), as well as support the selection and optimization of the means to achieve the RAOs. This analysis can be used to clarify how all the metrics of protectiveness are, or will be, satisfied by the current or proposed response-action decision.

For example, current site conditions may be protective in the short term, provided that adequate engineering and administrative/legal controls are in place to prevent unacceptable human exposures or further environmental degradation. In this case, the protectiveness metrics that can be initially satisfied by short-term RAOs include short-term protection, reasonable time, and stakeholder acceptance. The relative benefit achieved by attaining these RAOs depends upon interrupting potential exposure pathways and containing/controlling waste. Thus, long-term RAOs must satisfy only the protectiveness metrics of long-term protection and permanence. Both of these metrics hinge on the definition of “reliable.”

The common perception of what constitutes reliable protectiveness appears to be derived from the statutory preference for permanent, treatment-based remedies. As a consequence, long-term RAOs are based on the perceived need to achieve resource restoration in order to demonstrate reliable protectiveness. While this is a desirable goal, practical experience with currently available remedial technologies in certain site conditions calls into question the feasibility and reasonableness of achieving such “reliability” in any reasonable time frame. Until restoration is achieved, all metrics of protectiveness are satisfied by other means (e.g., administrative/legal controls, engineering controls at the point of exposure). Thus, the benefit/cost ratio of attaining “restoration” RAOs is defined by the full costs incurred to achieve that degree of reliability (i.e., the full cost to reach RC).

Benefit/cost ratios also can be used to clarify the relative costs associated with different means of providing equivalent levels of protectiveness, and the relative benefits provided and relative costs incurred can be evaluated for various response components to help identify appropriate responses.

4.5 BUILDING BALANCED AND FLEXIBLE RESPONSE DECISIONS

Response-action planning often is viewed as a deterministic process, where there is a single path to a single “successful” solution. Deterministic planning does not address the possibility that the planned or implemented actions may not produce the outcomes anticipated or expected. Efforts to minimize costs have focused on adopting a precision approach to ensuring successful completion of response-action obligations. This means that planning efforts do not explicitly account for uncertainty and the possibility of failure (e.g., failure to document protectiveness, failure to maintain a high benefit/cost ratio).

In order to deal with the uncertainty associated with evolving scientific knowledge and technological capabilities, the response decision could be presented in the form of a probabilistic rather than a deterministic plan. The possibility for optimization, improvement, and/or replacement thus becomes an integral part of the decision, so that any decision can be improved as knowledge about site conditions, contaminant toxicity, and remedy performance improves.

A probabilistic response decision is designed to address the potential for various possible outcomes of an action and present suitable contingency responses. A probabilistic response decision can be used to clearly specify performance decision criteria, including measurable attributes of any element of the decision that would trigger implementation of an optimization evaluation.

A probabilistic completion plan, or exit strategy, is characterized by the use of decision trees. Decision trees are constructed to describe "if–then–else" actions (i.e., if "X" happens, do "A," or else do "B") to clearly describe the basis and justifiable scope of performance improvements. Decision trees map all options and potential consequences in a manner that is easy to understand and explain to stakeholders. The decision tree illustrates the basis of the decision and the criteria used by the project team to define performance and nonperformance. Although the statutory tests of performance limit the general scope of information that should be considered in site-specific performance criteria, the metrics and triggers selected to guide decision making efforts are highly site specific.

Probabilistic planning does not lead to RAOs that are less stringent than required to provide the level of protection desired by all stakeholders. Rather, environmental project teams should lead stakeholders through the logic required to make better decisions over time as their knowledge improves. Decision-analysis techniques, such as decision trees, are useful tools that can be used to help structure complex decisions and make use of improving knowledge about whether the initial decisions were "right" or "wrong" to improve the decision over time. The intended outcome of this kind of planning is to use lessons learned to develop achievable RAOs.

For example, if the rate of removal of contaminant from an aquifer by a treatment system is greater than predicted, the CTC and STC estimates may need to be modified as a result of practical experience. Conversely, if the rate of removal is less than predicted, the performance objectives (i.e., the RAOs and ARARs) of the decision should be reassessed in the context of evolving knowledge for necessity, feasibility, and reasonableness. Changes in the performance objectives could drive changes in the means used to achieve those performance objectives in a reasonable (e.g., 10-year) time frame. Figure 7 is a site-specific example of a response-action completion strategy that includes self-executing performance decision criteria.

If sufficient site-specific data are available to justify an alternative level or standard of control, the probabilistic plan can be used to communicate the basis for refining the ARAR analyses and resultant RAOs. Any recommended changes to the means used to efficiently achieve those RAOs can also be presented, particularly as such changes may be relevant to the statutory tests of feasibility and reasonableness.

4.6 INCENTIVIZING PERFORMANCE

Environmental project teams are encouraged to clearly articulate the metrics used to evaluate performance of response decisions through time. Project teams may wish to use this information to establish results-based or performance-based cleanup (RBC or PBC) contracts to inspire and reward creative solutions and measurable performance. These kinds of cleanup contracts are built on clear performance objectives and decision criteria (e.g., specified benefit/cost ranges) incorporated into a well-articulated completion plan.

RBC or PBC is a unique contracting mechanism that is designed to contractually define results so that performance can be easily measured. PBC is quite straightforward in principle, and more challenging in practice. PBC provides incentives for contractors to perform by providing full payment, and possibly a bonus, upon meeting or exceeding the standards of performance. In turn, falling below the standard of performance can lead either to payments being withheld until the standard is met, or payments being decreased because of poor performance. PBC is designed to shift the focus of management away from staffing and activity and toward creative solutions that bring measurable results, which should increase accountability and accomplishments.

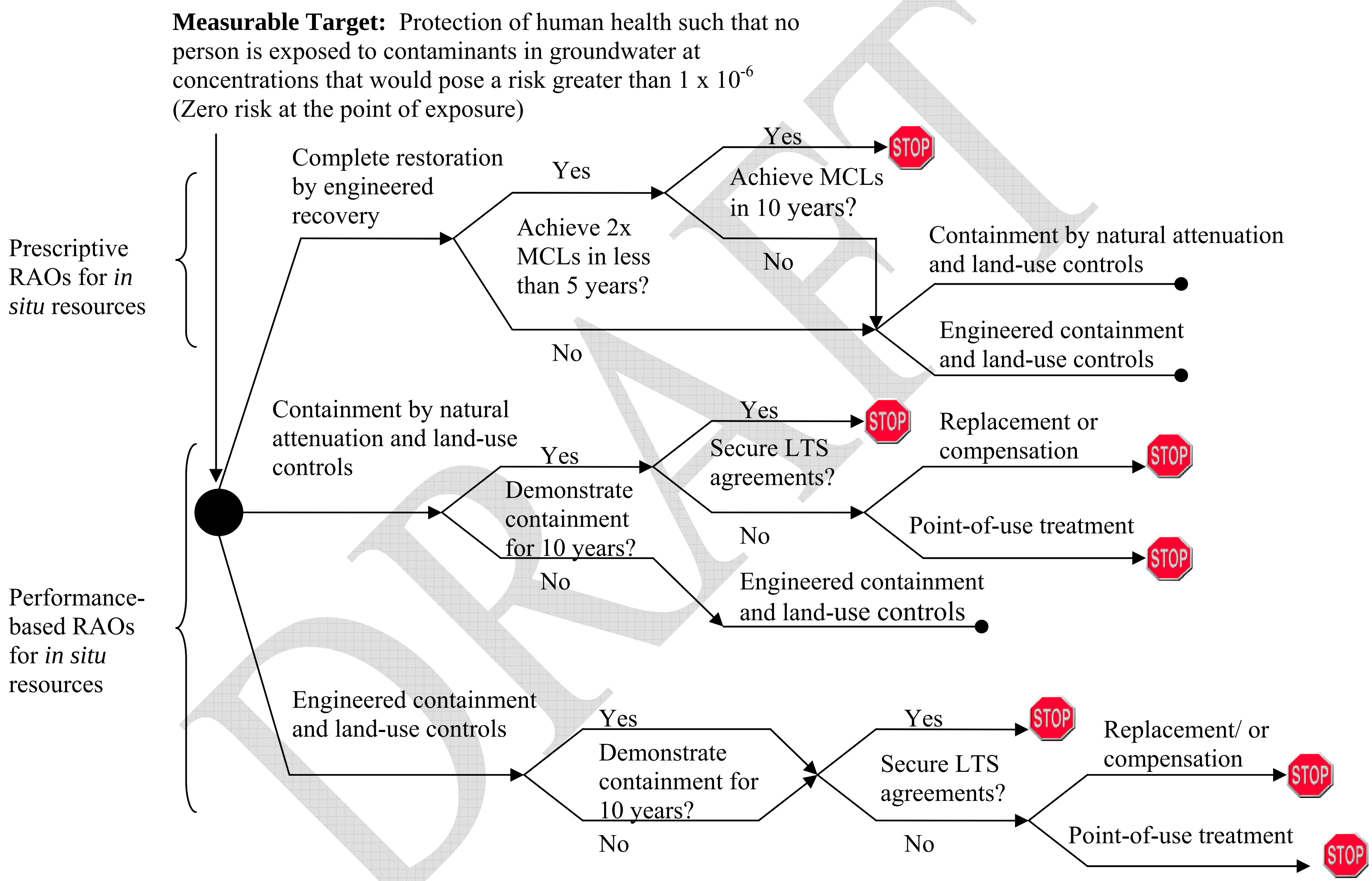


Figure 7. Example Decision Tree With Uncertainty Management Strategies

5.0 NEGOTIATING CHANGES IN OBJECTIVES

After a ROD is signed, new information might be received or generated that could affect the implementation of the remedy selected in the ROD, or could prompt a reassessment of that remedy. If the new information indicates that changing the remedial objective presented in the original ROD would improve the protectiveness of the implemented response decision or help achieve completion of the response objective in a more reasonable time frame, then the environmental project team should determine what the magnitude of the change would mean to the scope, performance, and cost of the remedial action. Depending on the extent or scope of the modification being considered, negotiation with the lead regulatory agency may be necessary. If negotiations are necessary, the project team should consult a team of technical, legal, and public relations experts to help achieve the desired goals.

5.1 POST-ROD DECISION CONSIDERATIONS

Section 117(c) of CERCLA provides that if a remedial action, enforcement action, or settlement "differs in any significant respects" from a previously signed ROD, EPA "shall publish an explanation of the significant differences and the reasons such changes were made." The EPA guidance details this requirement, creating three categories of remedy changes, each with more extensive public participation requirements for more substantial changes (EPA, 1989). The project team should evaluate site data and new information to determine if the change to the remedy should be classified as nonsignificant, significant, or fundamental and how the scope, performance, and cost will be impacted as set out in the NCP.[16] The criteria for this decision are as follows:

- **Scope**—Does the change alter the scope of the remedy (e.g., type of treatment or containment technology, the physical area of the response, remediation goals to be achieved, type and volume of wastes to be addressed)?
- **Performance**—Would the change alter the performance (e.g., treatment levels to be attained, long-term reliability of the remedy)?
- **Cost**—Are there significant changes in costs from estimates in the ROD, taking into account the recognized uncertainties associated with the hazardous waste engineering process selected?

Based on this evaluation, and depending on the extent or scope of modification being considered, the project team must determine the category of change involved (i.e., nonsignificant or minor, significant, or fundamental), present information to the lead agency defining the change, and ultimately negotiate the post-ROD change decision.

Nonsignificant Changes

Nonsignificant or minor changes usually arise during design and construction, when modifications are made to the functional specifications of the remedy to address issues such as performance optimization, new technical information, support agency/community concerns and/or cost minimization (e.g., value engineering process). Such changes may affect things such as the type or cost of materials, equipment, facilities, services, and supplies used to implement

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[16]NCP, 300.435(c)(2)

the remedy. These changes can include soil treatment volume changes, disposal location changes, or groundwater monitoring frequency changes. The change will not have a significant impact on the scope, performance, or cost of the remedy.

Examples of nonsignificant or minor changes are as follows:

- **Small Increase in Volume:** Remedial design testing shows that the volume of soil requiring treatment is 75,000 cubic yards rather than the 60,000 estimated in the ROD, but the estimated cost of the overall remedy will only increase by a small percentage.
- **Small Change in Disposal Location:** During remedial design, it is discovered that it is not feasible to construct the on-site landfill (which is part of the selected remedy) in the location specified in the ROD. However, another similar location at the site is suitable for a landfill, and this location is chosen.
- **Change in Frequency of Groundwater Monitoring:** The selected remedy calls for long-term pump and treat of contaminated groundwater with monitoring on a quarterly basis. After a period of time, a determination is made that no significant change in data quality or monitoring effectiveness will occur if monitoring contaminant levels in the groundwater is less frequent. Groundwater monitoring is changed to semiannual sampling.

Significant Changes

Significant changes generally involve a change in a remedy component that does not fundamentally alter the overall cleanup approach. These can include disposal location, contingency remedies, and new ARAR promulgation.

Examples of significant changes are as follows:

- **Large Increase in Volume/Cost Increase:** Sampling during the remedial design phase indicates the need to significantly increase the volume of contaminated waste material to be incinerated in order to meet selected cleanup levels, thereby substantially increasing the estimated cost of the remedy.
- **Major Change in Disposal Location:** It is determined that it is not feasible to construct an on-site landfill for treated waste in accordance with the remedy selected in the ROD. The treated wastes must be sent to an off-site landfill. Although the overall management approach for the treated waste (landfill disposal) will remain the same, the costs and implementation time will increase significantly.
- **Contingency Remedy:** As part of an active groundwater pump and treat system, contaminant concentrations decrease to an asymptotic level, which is close to attainment of the cleanup level. Investigation shows that adding wells to pump and treat groundwater will not improve the performance of the remedy in attaining the cleanup level. The ROD included contingency language that the pump and treat remedy would continue operating until contaminant levels were reduced by at least 90 persent. At such time, monitored natural attenuation would be relied upon to attain the cleanup levels specified in the ROD. A decision is made to implement the contingency, thus changing the remedy from pump and treat to monitored natural

attenuation. This represents a significant change in achieving cleanup levels at the site.

- **New ARAR Promulgated (Impacts on Cleanup Levels and Other Parameters):** Based on new scientific evidence, it is determined that the attainment of a newly promulgated requirement is necessary, because an existing ARAR is no longer protective. Although this new requirement will significantly change the remedy (i.e., cleanup level, timing, volume, or cost), it will not fundamentally alter the remedy specified in the ROD and it will not impact the level of protection (i.e., risk reduction) that the remedy will provide.
- **Land Use:** During remedial design, the local zoning board decides to change the current land use from residential to commercial. Although this new requirement will significantly change features of the remedy, it will not fundamentally alter the remedy specified in the ROD (i.e., the selected technology will not change).
- **Institutional Controls:** A five-year review determines that additional institutional control measures which differ significantly from those in the ROD are necessary to be protective (e.g., need for an easement to replace a deed notice).
- **Change in ARARs:** A five-year review determines that a cleanup level is not consistent with an updated state cleanup standard, and thus is not protective and needs to be modified. This change will not cause a fundamental change in the volume of waste to be remediated.

Fundamental Changes

A fundamental change is one that results in a reconsideration of the overall waste management approach selected in the original ROD. Fundamental changes involve appreciable change or changes in the scope, performance, and/or cost, or might be a number of significant changes that together have the effect of a fundamental change.

Examples of fundamental changes are as follows:

- **Change Primary Treatment Method:** Testing during remedial design shows the *in situ* soil-washing remedy selected in the ROD to be infeasible. A decision is made to fundamentally change the remedy to excavation and thermal treatment of the waste.
- **Change Primary Treatment Method with Cost Increase:** Additional information obtained during remedial design testing demonstrates that the selected remedy for groundwater, monitored natural attenuation, will not meet cleanup levels that had originally been predicted in the remedial investigation (RI) or feasibility study (FS). The decision is made to fundamentally change the remedy from monitored natural attenuation to pump and treat. The estimated cost of the cleanup increases significantly.
- **Change Primary Treatment Method with Cost Decrease:** Pump and treat is the selected remedy for groundwater. Prior to constructing the pump and treat system, groundwater data indicate that contaminant concentrations are decreasing due to natural processes. Modeling indicates that monitored natural attenuation will achieve cleanup levels in a time frame comparable to pump and treat at substantially less cost.
- **Technical Impracticability or Other Waivers:** While implementing an active pump and treat remedy, the presence of DNAPL is discovered. A determination is made to invoke a Technical Impracticability Waiver of the ARAR because treatment

of the DNAPL zone is impracticable from an engineering perspective. Rather than treat the source material (DNAPL), a decision is made to implement a containment approach (i.e., slurry wall) for the DNAPL zone, with pump and treat continuing outside of the containment zone. As a result, the scope, performance, and cost of the original remedy are fundamentally changed.

5.2 DOCUMENTING POST-ROD CHANGES

The type of documentation required for a post-ROD change depends on the nature of the change. Changes that significantly or fundamentally affect the remedy selected in the ROD will require more explanation and/or more opportunity for public comment than those that do not.[17]

5.3 NEGOTIATING CHANGES

Once the decision is made to negotiate a change in the ROD and the type of change(s) and impact(s) determined, the change(s) must be presented and negotiated with the lead regulatory agency. Effective negotiating requires significant internal preparation. While the need for preparation is a matter of common sense, the potentially responsible parties (PRPs) often embark on sensitive negotiations without being fully prepared. The result is generally adverse to the PRP's interest. The PRP must fully identify all salient issues and thoroughly map out strategies and negotiating positions before contacting the regulatory agency.

Changes to cleanup initiatives should be viewed as a business problem that cannot be approached haphazardly. It is essential to assemble a team of technical, legal, and public relations experts early in the process in order to achieve the desired goals. Early formation of the team is important because these individuals can provide strategy, intelligence, and an analysis of current and proposed policy and political developments that can help during the negotiation process. Assessing current attitudes and sensitivities among lead agency staff, organizations, and sectors will assist the project team in understanding the likely reaction of the regulatory bodies even before the information is presented. Proper timing and presentation of substantive issues will create an atmosphere in which the PRP advises the agency about the actions it intends to take and seeks the agency's approval, rather than allowing the agency to dictate those actions. Given the scope of most agencies' responsibilities and authorities, there is a limit to how deferential the agency is likely to be. Therefore, it is essential to exert enough control over the presentation/negotiation process to achieve a reasonable settlement.

The most critical measure a PRP can take in negotiating a post-ROD change is to submit a well-thought-out technical proposal to the agency, regardless of what actions the agency is demanding. This document ensures control over the technical design of the changes and becomes the basis for further discussion. The bottom line for a PRP is to agree on a remediation program that is protective and protectively and economically feasible to carry out. To that end, preparing a budget may be an appropriate prenegotiation step. For the regulatory agencies, the bottom line is generally a remediation program that complies with all pertinent laws, regulations, and policies.

[17]More information about documenting Post Record of Decision Changes at http://www.epa.gov/superfund/resources/remedy/rods/index.htm .

6.0 REFERENCES

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APPENDIX A: RELATIVE BENEFIT/COST EXAMPLE

The following hypothetical example is presented to illustrate the concepts described in Section 4 of the guidance. The site is assumed to have volatile contaminants present in the vadose zone soil and the site conditions are such that the following four response actions are considered to be feasible and reasonable means to provide protectiveness:

- Excavation and *ex situ* treatment or disposal of contaminated soil, with legal/ administrative controls
- Soil vapor extraction (SVE) of contaminants from the vadose zone, with legal/ administrative controls
- Isolation/containment of contaminants, with legal/ administrative controls
- *In situ* thermal treatment of contaminants, with legal/administrative controls.

In addition to these active approaches, the No Action option is also considered, as required by the National Oil and Hazardous Substances Contingency Plan (NCP).

The relative benefits and relative costs associated with each potential response action for the site can be estimated using the ranking procedures outlined previously. Selection of the No Action approach produces no relative benefits at the site, even though this approach is not without costs. As a consequence of the resulting zero relative benefit, implementation of the No Action approach would produce the lowest benefit/cost ratio (value of 0.00) of any of the potential responses considered. Selecting any one of the first three potential response actions listed above would produce a relatively high level of total relative benefits (13 for each approach), indicating that implementation of any of these three approaches would provide an equivalent level of protection at the site.

However, the relative costs associated with each of these three approaches vary somewhat, so that the benefit/cost ratios for the three approaches are different. In the situation under consideration, the approach that includes excavation and *ex situ* treatment or disposal of contaminated soil appears to provide the greatest relative benefit (reliable protectiveness) for the lowest relative incremental cost (i.e., this approach has the highest benefit/cost ratio), and probably should be selected for implementation. The last remedy considered—*in situ* thermal treatment of contaminated soil, with legal/administrative controls—apparently provides a lower total relative benefit at the highest relative cost of any of the approaches considered.

Few approaches involving engineered controls alone are fully protective prior to complete implementation. The long-term protectiveness of any engineered control is not ensured until remedial action objectives (RAOs) have been achieved. On the other hand, imposition of legal or administrative controls is regarded as the most effective means of achieving immediate and effective protection in the short term, and through the duration of response implementation (long-term protection). This is reflected in the benefits-ranking matrices (Tables A1 and A3), which assign a value of 3 (greatest benefit) to the benefits resulting from short-term and long-term protectiveness associated with legal/ administrative controls. Therefore, all response approaches considered in this hypothetical example include some form of administrative/legal controls.

The relative effects associated with imposition of administrative/legal controls also can be examined using the hypothetical example above. Selection of *in situ* thermal treatment of contaminated soil, with no legal/administrative controls in place would produce a total relative benefit of 3—the lowest for any approach at the site except No Action (Table A7). Although some cost savings would result from not providing legal/administrative controls, failure to implement controls of this nature would produce a total benefit/cost ratio less than one-half that produced by the same engineered approach with legal/administrative controls in place. This result suggests that neglecting legal/administrative controls is an example of false economy, and that implemented response actions should generally include some element of legal/administrative controls.

This benefit/cost analysis approach can be tailored to address site-specific, contaminant-specific, and location-specific considerations. For example, the benefits resulting from implementation of a particular response action may vary depending upon location relative to a contaminant source. Thus, a range of benefit/cost ratios may be estimated for responses applied at a number of different potential exposure points at a particular site. This would enable a manager to identify the best location(s) for implementing a particular approach.

Table A1. Relative Benefits Resulting from Potential Response-Action Components to Address Contaminated Soil

Potential Response-Action Component	**Benefits[a]**				
	Short-Term Protection[b]	**Long-Term Protection[c]**	**Permanence[d]**	**Time Required[e f]**	**Acceptance[g]**
No Action[h]	0	0	0	0	0
Legal/Administrative Controls	3	3	3	1	1
Engineering Controls					
Excavation and *Ex-Situ* Treatment/Disposal	0	3	3	1	3
SVE[i/]	0	2	2	1	3
Bioventing	0	2	2	1	3
In-Situ Oxidation	0	1	1	0	2
In-Situ Thermal Treatment[j/]	0	1	1	0	1
Stabilization/Solidification	0	0	0	0	1
Enhanced Soil Flushing[k/]	0	1	1	0	1
Isolation/Containment[l/]	0	0	0	0	2
POE[m/] Treatment	3	3	3	0	1

[a] Benefits presented in relative terms, as follows: 0 = no benefit; 1 = least benefit; 2 = intermediate benefit; 3 = greatest benefit.
[b] Protection of human health and the environment from unacceptable exposure or continuing releases of contaminants achieved during implementation of response action.
[c] Protection of human health and the environment from unacceptable exposure or continuing releases of contaminants achieved during operation of response action (i.e., from implementation until remedial action objectives have been achieved).
[d] Ability to sustain reliable, long-term protection of human health and the environment from unacceptable exposure or continuing releases of contaminants.
[e] Time required to demonstrate protectiveness and achievement of remedial action objectives necessary for protection.
[f] Benefits assigned as follows: 1 = time less than or equal to 10 years; 0 = time greater than 10 years.
[g] Perceived acceptability of the response action to stakeholders.
[h] Consideration of the "No Action" alternative is required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).
[i] SVE = soil vapor extraction.
[j] May include such technologies as resistive heating, steam flushing, or thermal enhancements to SVE.
[k] May include such technologies as surfactant flushing or co-solvent flushing/extraction.
[l] May include such technologies as covering, capping, or lined waste-management unit.
[m] POE = point-of-exposure.

Table A2. Relative Costs Associated with Potential Response-Action Components to Address Contaminated Soil

Potential Response-Action Component	Associated Costs[a]									
	Direct Costs			Indirect Costs					Transaction Costs	
	Capital	O&M[b]	Monitoring	Long-Term Power[c]	Waste Stream[d]	Long-Term Resource Consumption or Loss[e]	Acceptance[f]	Other[g]	Compliance Requirements[h]	Performance Assessment[i]
No Action[j]	0	0	0	0	0	3	3	0	0	0
Legal/Administrative Controls	1	0	1	0	0	3	2[k/]	2	2	1
Engineering Controls										
Excavation and *Ex-Situ* Treatment/Disposal	3	0	0	0	3	0	0	3	2	1
SVE[l]	2	2	2	2	2	1	0	3	3	3
Bioventing	1	1	1	1	1	2	1	2	2	2
In Situ Oxidation	2	0	2	0	1	2	1	2	2	2
In Situ Thermal Treatment[m]	3	3	3	3	2	2	2	3	3	3
Stabilization/Solidification	2	0	1	0	1	3	2	2	1	2
Enhanced Soil Flushing[n]	3	3	2	1	2	2	2	2	2	3
Isolation/Containment[o]	3	1	1	0	1	3	1	3	3	2
POE[p] Treatment	1	1	1	1	1	0	2	2	1	1

[a] Costs presented in relative terms, as follows: 0 = no cost; 1 = least cost; 2 = intermediate cost; 3 = greatest cost.
[b] O&M = operations and maintenance.
[c] Costs associated with power consumption due to operation of the response action over the long term.
[d] Costs associated with managing or disposing of waste products, including sampling waste, generated by response action.
[e] Costs associated with consumption or loss of beneficial use of a resource due to application of the response action (e.g., habitat loss or degradation).
[f] Costs associated with perceived acceptability of the response action to stakeholders.
[g] "Other" indirect costs may include risks resulting from installation or operation of the response action, opportunity costs, financing costs, aesthetic costs, litigation, or other intangibles.
[h] Costs associated with compliance with regulatory requirements not directly associated with remedial action objectives (e.g., permitting).
[i] Costs associated with periodic review of performance of the response action.
[j] Consideration of the "No Action" alternative is required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).
[k] Depends upon the length of time control is required.
[l] SVE = soil-vapor extraction.
[m] May include such technologies as resistive heating, steam flushing, or thermal enhancements to SVE.
[n] May include such technologies as surfactant flushing or co-solvent flushing/extraction.
[o] May include such technologies as covering, capping, or lined waste-management unit.
[p] POE = point-of-exposure.

Table A3. Relative Benefits Resulting from Potential Response-Action Components to Address Contaminated Groundwater

Potential Response-Action Component	Benefits[a]				
	Short-Term Protection[b]	Long-Term Protection[c]	Permanence[d]	Time Required[e f]	Acceptance[g]
No Action[h]	0	0	0	0	0
Legal/Administrative Controls	3	3	1	0	1
Engineering Controls					
Groundwater ETD[i]	0	1	1	0	3
Air Sparging	0	1	1	0	3
In-Situ Oxidation	0	1	1	1	2
PRB[j]	0	1	2	0	1
ZVI[k] Injection		1	1	1	1
Nutrient Amendment	0	1	2	1	2
MNA[l]	0	1	3	0	1
POU[m] Treatment	3	3	3	0	2
Vapor Exposure Control	0	1	2	0	2

[a] Benefits presented in relative terms, as follows: 0 = no benefit; 1 = least benefit; 2 = intermediate benefit; 3 = greatest benefit.
[b] Protection of human health and the environment from unacceptable exposure or continuing releases of contaminants achieved during implementation of response action.
[c] Protection of human health and the environment from unacceptable exposure or continuing releases of contaminants achieved during operation of response action (i.e., from implementation until remedial action objectives have been achieved).
[d] Ability to sustain reliable, long-term protection of human health and the environment from unacceptable exposure or continuing releases of contaminants.
[e] Time required to demonstrate protectiveness and achievement of remedial action objectives necessary for protection.
[f] Benefits assigned as follows: 1 = time less than or equal to 10 years; 0 = time greater than 10 years.
[g] Perceived acceptability of the response action to stakeholders.
[h] Consideration of the "No Action" alternative is required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).
[i] ETD = extraction, treatment, and disposal/discharge.
[j] PRB = permeable reactive barrier.
[k] ZVI = zero-valent iron.
[l] MNA = monitored natural attenuation.
[m] POU = point-of-use.

Table A4. Relative Costs Associated with Potential Groundwater Response-Action Components

Potential Response-Action Component	**Associated Costs[a]**									
	Direct Costs			Indirect Costs					Transaction Costs	
	Capital	**O&M[b]**	**Monitoring**	**Long-Term Power[c]**	**Waste Stream[d]**	**Long-Term Resource Consumption or Loss[e]**	**Acceptance[f]**	**Other[g]**	**Compliance Requirements[h]**	**Performance Assessment[i]**
No Action[j]	0	0	0	0	0	3	3	0	0	0
Legal/Admin. Controls	1	0	1	0	0	3	2[k/]	2	2	1
Engineering Controls										
Groundwater ETD[l]	3	3	3	3	3	3	0	3		3
Air Sparging	3	2	3	2	2	2	0	3	2	3
In-Situ Oxidation	2	0	2	0	1	2	1	2	2	2
PRB[m]	3	1	2	0	1	3	2	1	1	2
ZVI[n] Injection	2	0	2	0	1	2	2	1	2	2
Nutrient Amendment	2	0	2	0	1	2	1	1	2	2
MNA[o]	1	0	2	0	1	3	2	1	1	1
POU[p] Treatment	1	1	2	1	1	0	2	2	1	1
Vapor Exposure Control	1	1	2	1	1	0	1	2	1	2

[a] Costs presented in relative terms, as follows: 0 = no cost; 1 = least cost; 2 = intermediate cost; 3 = greatest cost.
[b] O&M = operations and maintenance.
[c] Costs associated with power consumption due to operation of the response action over the long term.
[d] Costs associated with managing or disposing of waste products, including sampling waste, generated by response action.
[e] Costs associated with consumption or loss of beneficial use of a resource due to application of the response action (e.g., habitat loss or degradation).
[f] Costs associated with perceived acceptability of the response action.
[g] "Other" indirect costs may include risks resulting from installation or operation of the response action, opportunity costs, financing costs, aesthetic costs, litigation, or other intangibles.
[h] Costs associated with compliance with regulatory requirements not directly associated with remedial action objectives (e.g., permitting).
[i] Costs associated with periodic review of performance of the response action.
[j] Consideration of the "No Action" alternative is required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).
[k] Depends on the length of time control is required.
[l] ETD = extraction, treatment, and disposal/discharge.
[m] PRB = permeable reactive barrier.
[n] ZVI = zero-valent iron.
[o] MNA = monitored natural attenuation.
[p] POU = point-of-use.

Table A5. Example Total Relative Benefits Resulting from Potential Response Action to Address Contaminated Soil

Potential Response-Action Component	**Benefits[a]**					
	Short-Term Protection[b]	**Long-Term Protection[c]**	**Permanence[d]**	**Time Required[e f]**	**Acceptance[g]**	**Total Relative Benefit[h] for Complete Response Action**
Legal/Administrative Controls	3[i/]	3	3	1	1	Not Applicable
In-Situ Oxidation	0	1	1	0	2	
Complete Response Action						
In-Situ Oxidation with Legal/Administrative Controls	3	3	3	1	2	12

[a] Relative benefits of each of the components of the potential response action assigned on the basis of Table A1. Benefits presented in relative terms, as follows: 0 = no benefit; 1 = least benefit; 2 = intermediate benefit; 3 = greatest benefit.
[b] Protection of human health and the environment from unacceptable exposure or continuing releases of contaminants achieved during implementation of response action.
[c] Protection of human health and the environment from unacceptable exposure or continuing releases of contaminants achieved during operation of response action (i.e., from implementation until remedial action objectives have been achieved).
[d] Ability to sustain reliable, long-term protection of human health and the environment from unacceptable exposure or continuing releases of contaminants.
[e] Time required to demonstrate protectiveness and achievement of remedial action objectives necessary for protection.
[f] Benefits assigned as follows: 1 = time less than or equal to 10 years; 0 = time greater than 10 years.
[g] Perceived acceptability of the response action to stakeholders.
[h] Total relative benefit resulting from implementation of the response action is the sum of the relative benefits for each of the five relative-benefit factors.
[i] Shaded cell indicates that the relative benefit of the indicated response-action component is used as the value of the relative benefit of that factor for the response action.

Table A6. Example Total Relative Costs Associated with Potential Response Action to Address Contaminated Soil

Potential Response-Action Component	**Associated Costs[a]**										
	Direct Costs			**Indirect Costs**					Transaction Costs		**Total Relative Cost[j] for Complete Response Action**
	Capital	**O&M[b]**	**Monitoring**	**Long-Term Power[c]**	**Waste Stream[d]**	**Long-Term Resource Consumption or Loss[e]**	**Acceptance[f]**	**Other[g]**	**Compliance Requirements[h]**	**Performance Assessment[i]**	
Legal/Administrative Controls	1[k]	0	1	0	0	3	2	2	2	1	Not Applicable
Excavation and *Ex Situ* Treatment/ Disposal	3	0	0	0	3	0	0	3	2	1	
Complete Response Action											
Excavation and *Ex Situ* Treatment/ Disposal with Legal/ Administrative Controls	4	0	1	0	3	3	2	5	4	2	24

[a] Relative costs of each of the components of the potential response action assigned on the basis of Table 2. Costs presented in relative terms, as follow: 0 = no cost; 1 = least cost; 2 = intermediate cost; 3 = greatest cost.
[b] O&M = operations and maintenance.
[c] Costs associated with power consumption due to operation of the response action over the long term.
[d] Costs associated with managing or disposing of waste products, including sampling waste, generated by response action.
[e] Costs associated with consumption or loss of beneficial use of a resource due to application of the response action (e.g., habitat loss or degradation).
[f] Costs associated with perceived acceptability of the response action to stakeholders.
[g] "Other" indirect costs may include risks resulting from installation or operation of the response action, opportunity costs, financing costs, aesthetic costs, litigation, or other intangibles.
[h] Costs associated with compliance with regulatory requirements not directly associated with remedial action objectives (e.g., permitting).
[i] Costs associated with periodic review of performance of the response action.
[j] The total relative cost resulting from implementation of a particular response action is the sum of all of the relative cost factors of each component of the potential response action.
[k] Shaded cell indicates that the relative cost of the indicated response-action component is used in the sum to calculate the value of the relative cost of that factor for the response action.

Table A7. Example Relative Benefit/Cost Evaluation of Potential Response Actions to Address Contaminated Soil

Potential Response Action	Benefit	Cost	
	Relative Benefit[a]	Relative Cost[b]	Benefit/Cost Ratio[c]
No Action	0	6	0/6 (= 0.00)
Excavation and *Ex Situ* Treatment/Disposal with Legal/Administrative Controls	13	24	13/24 (= 0.54)
SVE[l/] with Legal/Administrative Controls	13	32	13/32 (= 0.41)
In-Situ Thermal Treatment (No Legal/Administrative Controls)	3	27	3/27 (= 0.11)
In-Situ Thermal Treatment with Legal/Administrative Controls	11	39	11/39 (= 0.28)
Isolation/Containment with Legal/Administrative Controls	13	30	13/30 (= 0.43)

[a] Relative benefits of each of the components of a potential response action assigned on the basis of Table A1. As each of the five relative-benefits factors is considered, the greatest value of that factor occurring in any component of a particular response action is used as the value of the relative benefit of that factor for the response action (refer to Table A5); and the total relative benefit resulting from implementation of that response action is the sum of the relative benefits for each of the five relative-benefit factors.

[b] Relative costs of each of the components of a potential response action assigned on the basis of Table A2. The total relative cost resulting from implementation of a particular response action is the sum of all of the relative cost factors of each component of the potential response action (refer to Table A6).

[c] Benefit/cost ratio for a particular response action is the ratio of the total relative benefit anticipated to result from implementation of the response action, and the total relative cost associated with implementation. The preferred response action is that which provides the greatest relative benefit for the least relative cost (i.e., has the highest benefit/cost ratio).

[d] SVE = soil vapor extraction.

Table A8. Example Relative Benefit/Cost Evaluation of Potential Response Actions to Address Contaminated Groundwater

Potential Response Action	Benefit	Cost	
	Relative Benefit[a]	**Relative Cost**[b]	**Benefit/Cost Ratio**[c]
No Action	0	6	0/6 (= 0.00)
Groundwater ETD[d] with Legal/Administrative Controls	10	39	10/39 (= 0.26)
PRB[e] with Legal/Administrative Controls	9	28	9/28 (= 0.32)
MNA[f] (no Legal/Administrative Controls)	5	12	8/12 (= 0.42)
MNA with Legal/Administrative Controls	10	24	10/24 (= 0.42)
POU[g] Treatment with Legal/Administrative Controls	11	24	11/24 (= 0.46)

[a] Relative benefits of each of the components of a potential response action are assigned on the basis of Table A3. As each of the five relative-benefits factors is considered, the greatest value of that factor occurring in any component of a particular response action is used as the value of the relative benefit of that factor for the response action (refer to Table A5); and the total relative benefit resulting from implementation of that response action is the sum of the relative benefits for each of the five relative-benefit factors.
[b] Relative costs of each of the components of a potential response action are assigned on the basis of Table A4. The total relative cost resulting from implementation of a particular response action is the sum of all of the relative cost factors of each component of the potential response action (refer to Table A6).
[c] Benefit/cost ratio for a particular response action is the ratio of the total relative benefit anticipated to result from implementation of the response action, and the total relative cost associated with implementation. The preferred response action is that which provides the greatest relative benefit for the least relative cost (i.e., has the highest benefit/cost ratio).
[d] ETD = extraction, treatment, and disposal/discharge.
[e] PRB = permeable reactive barrier.
[f] MNA = monitored natural attenuation.
[g] POU = point-of-use.

APPENDIX B: APPLICATION TO RADIOLOGICAL SITES

1.0 INTRODUCTION

The ultimate goal of environmental response actions for radiological sites is the same as that for chemical sites: to protect human health and the environment. This appendix addresses remedial objective assessments for radiologically contaminated soils and facilities. Typically, the time frame for the remedial-action phase and final closure of these sites is on the order of one to three years if sufficient funding is available.

Remediation of radiologically contaminated water sources (e.g., retention ponds, other surface water sources, ground water) is not addressed here. Remediation of radiologically contaminated water would more closely follows the remediation of chemically contaminated water. In such cases, the extended time frames for completion of remediation might allow for the possible development of more efficient and cost effective removal techniques during the remediation process. As with chemical contamination sites, the involvement of the regulatory agencies and other stakeholders from the beginning of the project will greatly streamline the remediation and closure process.

1.1 SPECIAL REGULATORY REQUIREMENTS

The regulation of radiological contamination falls under the control of the Nuclear Regulatory Commission (NRC), the EPA, and the DoD. Air Force installations are typically under federal jurisdiction of radioactive materials used and stored on the installation, and states do not have regulatory authority. However, if the radioactive material is not located on property under exclusive federal jurisdiction, the state may become involved. In any case it is a good practice to include the state regulators as one of the stakeholders.

The NRC's regulation of Air Force Radioactive Materials changed in the 1980s when the NRC granted the Air Force a Radioactive Material Master Material License. This gave the Air Force use and enforcement authority of all NRC-licensed material used on Air Force installations. The Air Force has implemented a permitting system for all radioactive material used by Air Force organizations, including issuing Air Force permits for NRC licensed sources.

Virtually all radiologically contaminated sites found on an Air Force installation will require remediation under CERCLA. The type of radioactive material (source, byproducts, and special nuclear material) and its use at the facility will determine whether additional requirements above those found in CERCLA are required. Additional requirements might include a decommissioning permit issued by the Air Force for NRC-licensed material, DOE requirements (10 CFR 835) for weapons grade material, and compliance with EPA and/or state regulations for naturally occurring radioactive materials (NORM). For radioactive material controlled by the NRC, the NRC has the final approval authority for site closure criteria including determination of applicable or relevant and appropriate requirements (ARARs) and response-complete surveys (final status surveys).

1.2 OBJECTIVES ASSESSMENT (OA)

An OA can be applied to radiological sites even though radiologically contaminated sites have typically not been closed using the complete CERCLA process. In the past, radiological sites were usually remediated and closed with federal and state regulatory approval, though in some cases no formal letter of closure was issued by the regulatory agencies.

The goal of the OA at radiological sites is to have reasonable cleanup objectives leading to a decision of no further action required (NFAR) while protecting human health and the environment. The specific steps to accomplish this goal include:

1. Coordinate the entire process with the stakeholders including federal, state and local regulators, the Air Force Radioisotope Committee (for USAF radioactive material permitted sites), the organization owning the site, the local environmental management office, and any consulting agencies approved by the group. The time for community involvement as a stakeholder is controlled by the CERCLA process and the local environmental management office.
2. Refine the conceptual site model (CSM) with site-specific findings during the conduct of the investigation
3. Apply accepted exposure pathway analysis methods to determine the Derived Concentration Guidelines (DCGLs) based on the statutory release limits for the site
4. Conduct a Radiation Survey and Site Investigation (RSSI) using the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) guidance[18]
5. Evaluate the cleanup objectives for necessity, feasibility, and reasonableness
6. Apply comparative benefit/cost analysis techniques to evaluate the most effective and efficient methods to achieve the goal of NFAR.

1.3 ARARS - RELEASE CRITERION AND DCGLS

The ARARs for radiological sites are expressed as release criteria, which are regulatory limits expressed either in terms of dose (e.g., 25 millirem per year [mrem/yr]) or risk (e.g., cancer incidence at $1x10^{-4}$). Exposure pathway models, such as the Department of Energy's (DoE) RESRAD, NRC's D&D, or EPA's Risk Calculator are used to calculate a radionuclide specific predicted concentration or surface area concentration of specific nuclides that could result in a dose or specific risk equal to the release criterion. These concentrations are referred to as the DCGLs. The DGCLs can be based either on the default input parameters or on the use of site-specific parameters in the exposure pathway models.

1.4 MARSSIM

The MARSSIM guidance document was prepared by a multiagency workgroup from the NRC, EPA, DoD, and DoE to directly address the investigation of radiological sites. Because of the multiagency consensus, MARSSIM is accepted nationwide as the guidance for conducting a RSSI.

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[18] The MARSSIM manual is available from the EPA at http://www.epa.gov/radiation/marssim/index.html.

The MARSSIM document provides detailed guidance for planning, implementing, and evaluating both environmental and facility radiological surveys conducted to demonstrate compliance with the DCGLs. As with CERCLA and RCRA, the MARSSIM guidance also uses PBM principles at every stage in order to facilitate continuous improvement along this route.

The MARSSIM guidance begins with initial notification and addresses each subsequent step in detail. The guidance ultimately focuses on the demonstration of compliance with the site release criteria by conducting a "final status survey (FSS)" (i.e., response complete survey). The MARSSIM final status survey follows a graded approach that starts with preliminary investigations and proceeds with scoping surveys, characterization surveys, and any supporting surveys required for the remedial actions. The final status survey integrates with the final steps in the CERCLA and RCRA processes and is consistent with the common purpose of producing the most efficient and effective route to a response complete decision.

1.5 RADIOLOGICAL ASSESSMENT TEAM COMPOSITION

The team composition to perform this assessment should include personnel familiar with current decommissioning and decontamination techniques approved by the NRC and EPA. At a minimum, the team should include the following:

1. Radiological risk assessor experienced in the use of the appropriate pathway analysis/dose computer models such as RESRAD and D&D
2. Radiological regulatory specialist experienced in conducting remedial investigations using the MARSSIM guidance
3. Individuals familiar with the appropriate remedial technologies.

2.0 TESTING FOR NECESSITY, FEASIBILITY, AND REASONABLENESS

2.1 NECESSITY

The two OA tests of necessity are: (1) verify that the proposed or implemented response-action decision provides the degree of protection required by the risk assessment and ARARs and (2) verify that the protective cleanup standards are ARAR at the established points of compliance.

In cases where the regulatory agency prescribes a cleanup level, it is not necessary to verify that the response-action provides the required degree of protection as part of the OA unless it is desirable to negotiate a less restrictive value. If the cleanup level is not prescribed or a less restrictive but more appropriate value may be needed (industrial vs. residential), such verification involves reevaluation of the ARARs including the release criterion and the parameter inputs to the exposure pathway models used to determine the DCGLs.

The default input parameters for exposure pathway analysis models, such as RESRAD and DandD, are generally set at conservative levels. As a result, the dose estimates produced using the default parameter values are typically high for a given concentration of radioactive material and lead to conservative DCGLs. Site investigation survey data values above a DCGL indicate that the site requires remediation. In such cases, overly conservative DCGLs will lead to unnecessary and excessive remediation efforts. Alternatively, using site-specific input parameters and realistic exposure assumptions produces more realistic DCGLs and limits the remediation to that which is necessary.

2.2 FEASIBILITY

The OA test of feasibility focuses on whether or not the objective can be achieved in a reasonable time frame using currently available means. The test of feasibility should be used to compile site-specific technical evidence that is relevant to understanding what kind of past damage can feasibly be addressed in a reasonable time frame using currently available means. The statutory test of feasibility is recognized as part of the technical impracticability waiver provision. The test applies to both the performance objective and the response action.

With radiological sites, the preferred remedial action is to decontaminate any contaminated surfaces and media at the site to below the DCGLs or to remove any contaminated surfaces and media that are above the DCGLs for offsite disposal if decontamination is not possible. If on-site decontamination or off-site disposal are not feasible due to cost, the radioactive material is typically stabilized in place and maintained under control to ensure protectiveness. Generally, there is no long-term treatment method to be evaluated for feasibility with regard to radiological issues. Issues that should be evaluated for feasibility on radiological sites include:

1. DCGLs are distinguishable from background radiation at the site
2. Instrumentation and the survey methods are capable of detecting at 50 percent, and preferably at 33 percent, of the DCGL
3. Effective remediation methods are readily available and safe to use
4. Disposal is available for the radionuclide(s) of interest at acceptable costs.

An example where feasibility is an issue might be a site where the controlling regulatory authority specifies an arbitrary cleanup level that is only slightly above the average background concentration of the natural radioactivity in site soil. This decision leads to the determination that the remediation cannot be achieved in a reasonable time frame using currently available response-action technologies. Since the regulator-proposed cleanup standard is indistinguishable from the statistical variance of the background radioactivity at the site, the performance objective is not technically achievable and the remedial objective is determined to be infeasible.

2.3 REASONABLENESS

The first test for reasonableness is to consider whether the criterion poses a greater risk to human health and the environment than an alternative. DCGLs are based on accepted release criterion, and thus there is normally no need to assess the potential for greater risks to human health and the environment. However, there might be situations where the resources consumed (e.g., fuel) and environmental pollution generated to excavate contaminated soil for off-site disposal are substantial and the alternative of on-site stabilization and capping are attractive.

As mentioned in Section 2.5.2 of the guidance, fund-balancing is not available to lead federal agencies other than the EPA and need not be considered in testing reasonableness at Air Force sites. The third test of reasonableness, inconsistent application of state requirements, should be considered in assessing the objectives for any radiological sites under state regulation.

3.0 TAILORED CLEANUP EXPECTATIONS

Although the time frames associated with the remediation of radiological site soils and facilities are typically short compared to most CERCLA/RCRA actions, it is desirable to evaluate whether compliance with the identified ARARS (via the DCGLs) will lead to response actions that are necessary, feasible, and reasonable to protect human health and the environment. The six steps described in Section 3 of the guidance should be used to focus the performance assessment so that it provides substantial evidence to justify that protectiveness can be achieved and documented by either complying with the level of control specified by the ARARs, or complying with an alternative level of control.

To illustrate the need for this type of assessment for radiological sites, consider a case where a DCGL is determined during the early stages of the investigation based on the NRC's dose limit of 25 mrem/yr. If the EPA or state regulators were to subsequently require that an ARAR based on 15 mrem/yr be used at the site, the resulting revision in the DCGL might lead to a determination that the remedial action is no longer feasible for a number of different reasons. For example, the lower DCGL might not be detectable with currently available instrumentation, the conduct of the survey method at the lower DCGL might not be achievable in a reasonable amount of time (or cost), or the resulting remedial action might produce so much radioactive waste that it would not be feasible to transport it to an authorized disposal. In such a case, the regulator-imposed ARAR might result in revising the approach to provide an alternative level of control by maintaining the site under restricted access and routine monitoring to ensure the required level of protectiveness.

4.0 STRATEGY COMPARISON USING BENEFIT/COST RATIOS

The response action completion strategies used for closure of radiological sites follow the same logic as the response action planning process of CERCLA. Typically radiological soil remediation consists of no action, removal of the contaminated material, installing a cap over the contaminated area, or a combination of these remedies. Other soil remediation techniques are usually too costly to consider for large areas with radioactive contamination. Building materials (e.g., concrete, asphalt, wood, piping, ductwork) might require decontamination by various techniques (e.g., scabbing, vacuuming, wiping) to reduce the contamination to the regulated limit or approved DCGL. If the cost or complexity of the decontamination operation prohibits remediation of the building material, the material might be wrapped in plastic to prevent the spread of contamination and be containerized for disposal.

Radiological remediation of groundwater or surface water is not addressed in detail here, but the impact of radiological contamination on water sources would depend on the nature of the radioactive material, the decay chain, daughter products, and half life of the specific radio nuclides of concern (e.g., radium, tritium, strontium, sodium, potassium). In general, removal of radioactive contamination from water is much more complicated, time consuming, and costly than remediation of soil or building materials. A typical remediation process for contaminated water might include filtration if the radioactive contamination is a solid or an ion exchange for a dissolved contaminant.

The objective of site closure at radiologically contaminated sites is to clean the site to meet the required cleanup standard (DCGLs), which then allows for reuse of the site with no restrictions. Therefore, reevaluation of the site is not required. For sites where closure activities result in restrictions on land use, the restrictions typically require only land use controls and do not require active monitoring. Annual costs after closure of radiologically contaminated sites are normally minimal.

The benefit/cost analyses described in Section 4 of the guidance should be applied in cases where reevaluation of the site is possible. Cost savings at radiologically contaminated sites might be realized during the initial characterization, remediation, and final status surveys. Decisions regarding the establishment of DCGLs, based on an approved modeling programs such as RESRAD or D&D, normally provide a site-specific risk-based cleanup standard significantly higher than regulatory limits normally used, thus reducing the area requiring remediation. Decisions regarding the proper selection and use of instrumentation, sampling grid size, number of analytical samples required, and sample analysis performed on site as opposed to sending samples to a lab all figure into the benefit/cost analysis.

5.0 NEGOTIATING CHANGES IN OBJECTIVES

Radiologically contaminated sites are normally closed using closure criteria based on a risk assessment of the site. It is normally expected that a reassessment of the remedy will not occur if the site was released for unrestricted use. This is especially true for former NRC licensed sites that were closed with the approval of the NRC. The NRC no longer licenses these sites and all regulatory actions have been concluded.

In instances where reassessment does occur, it would normally be due to new dose risk estimates for the radionuclides of concern, the failure of a protective cap, or reevaluation of current land use controls. In these cases, additional costs would be expended for reassessment, and possibly additional remediation activities.

APPENDIX C: APPLICATION TO THE MILITARY MUNITIONS RESPONSE PROGRAM

1.0 INTRODUCTION

The ultimate goal of the Military Munitions Response Program (MMRP) is to conduct response actions (RAs) as necessary to allow sites potentially affected by present or past military munitions operations to be safely and efficiently used for their intended immediate or known future purpose.

Implementation of Performance-Based Management (PBM) procedures strategies for MMRP services actions, including Munitions and Explosives of Concern (MEC) and Munitions Constituents (MC) will ensure best value to the Air Force by identifying optimization opportunities throughout the removal/remedial process. One of PBM's primary functions is to identify the RA uncertainties and to provide procedures to reduce those uncertainties. Currently, cleanup standards for the MMRP program are still evolving. The PBM process assists in managing a MMRP RA by allowing the response team to take advantage of processes and procedures that have been agreed upon or newly approved. This will allow the Air Force to implement the RA in a timely manner while meeting the latest cleanup standards.

The project team conducting the Objectives Assessment (OA) review for MMRP sites should include key team members with the appropriate unexploded ordnance (UXO) qualifications and experience in implementing MMRP RAs.

2.0 TESTING FOR NECESSITY, FEASIBILITY, AND REASONABLENESS

Typically, MMRP site cleanups are conducted over a relatively short period of time and are a one-time removal action. In these cases, the statutory-provided tests of performance (outlined in this PBM guidance document) should be applied during the ARAR evaluation prior to implementing the RA to ensure necessity, feasibility, and reasonableness of the remedial action objectives. Items to consider in evaluating feasibility and reasonableness might include the following:

1. Terrain
2. Types of munitions
3. Conditions at site
4. Condition of munitions
5. Location of munitions (spatial)
6. Detection equipment
   a. Sensitivity
   b. Portability
   c. Effectiveness
7. Availability of expert EOD personnel.

For MMRP actions conducted under CERCLA, a five-year review will be required to ensure the protectiveness of the remedy. During this review, if it is determined that the RA is not protective, these statutory tests can be applied to ensure the necessity, feasibility and reasonableness of the remedial action objectives.

3.0 TAILORED CLEANUP EXPECTATIONS FROM ARAR EVALUATIONS

There are very few accepted RA standards for MEC cleanup actions under the CERCLA process. Therefore, it is vital that site-specific cleanup criteria be developed from the ARAR evaluations prior to the RA implementation. During RA implementation, the cleanup criteria should be periodically reevaluated against the ARARs to ensure that they continue to be necessary, feasible, and reasonable to protect human health and the environment, while still meeting all stakeholder goals. If the previously developed cleanup criteria and RA processes are not protective or cost effective (due to development of newer technologies), the OA process should be used to ensure timely and efficient cleanup actions.

4.0 STRATEGY COMPARISONS USING BENEFIT/COST RATIOS

The benefit/cost ratios described in Section 4 of the guidance should be used prior to the remedial actions to develop cost-effective response-action completion plans that clarify performance expectations. These plans can then be used to evaluate progress toward achieving the cleanup goals. Benefit/cost ratios allow rational comparison of alternatives and set the stage for future optimizations by providing the basis for incorporating lessons learned about remedy implementation and costs.

5.0 NEGOTIATING CHANGES IN OBJECTIVES

The cleanup requirements at MMRP sites are still being developed and cleanup technologies are improving. Therefore, it is possible that RODs for MMRP sites may need to be changed to ensure the implementation of an optimized RA for the protection of human health and the environment. In addition, changes in site conditions (e.g., depth of clearance requirements, numbers of anomalies to be investigated) may also require that changes be made in the cleanup objectives. Any changes in objectives may have to be negotiated.

APPENDIX D: GLOSSARY

Probabilistic–the doctrine that certainty is impossible and that probability suffices to govern practice.

Remedial action objective (RAO)–the cleanup objectives that define success in an environmental cleanup and lead to response complete and site closure.

Response action–the cleanup activities undertaken to fulfill the response action decision requirements in the decision document.

Response-action decision–the course of action to meet environmental cleanup obligations at a site as documented in a decision document.

Restoration–the cleanup objective of restoring the environment and environmental resources to the condition before the release of contamination.

Substantive–essential; real or actual; permanent

Statutory test–an evaluation specifically provided in a regulation.

Stipulate–to require, as a condition for an agreement