FINAL REPORT

Assessing Alternative Endpoints for Groundwater Remediation at Contaminated Sites

ESTCP Project ER-200832

MAY 2011

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ACRONYMS AND ABBREVIATIONS

ACL	alternate concentration limit
AEC	Army Environmental Command
AFB	Air Force Base
AFCEE	Air Force Center for Engineering and the Environment
AFRL	Air Force Research Laboratory
ANPR	advanced notice of public rulemaking
ARAR	applicable or relevant and appropriate requirement
BRAC	Base Realignment and Closure
CAO	correction action order
CBSG	Colorado Basic Standards for Groundwater
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CFR	Code of Federal Regulations
CSM	conceptual site model
CZ	containment zone
DERP	Defense Environmental Restoration Program
DEQ	Department of Environmental Quality
DNAPL	dense non-aqueous phase liquid
DoD	Department of Defense
DRMO	Defense Reutilization and Marketing Office
ER	Environmental Restoration
ERP-O	Environmental Restoration Program – Optimization
ESD	explanation of significant differences
ESTCP	Environmental Security Technology Certification Program
FS	feasibility study
FUDS	Formerly Used Defense Sites
GPRA	Government Performance and Results Act
GMZ	groundwater management zone
HRC	hydrogen release compound
HSWA	Hazardous and Solid Waste Amendments
IC	institutional control
IR	installation restoration
IRP	Installation Restoration Program
ISCO	in situ chemical oxidation
ITRC	Interstate Technology and Regulatory Council
LNAPL	light non-aqueous phase liquid
LTM	long-term monitoring

ACRONYMS AND ABBREVIATIONS (continued)

MCL	maximum contaminant level
MCLG	Maximum Contaminant Level Goal
MCS	media cleanup standard
MMRP	Military Munitions Response Program
MNA	monitored natural attenuation
MSD	municipal setting designation
NAPL	non-aqueous phase liquid
NAS	Naval Air Station
NAVFAC	Naval Facilities Engineering Command
NCP	National Contingency Plan
NPL	National Priorities List
NRC	National Research Council
NSWC	Naval Surface Warfare Center
NTC	Naval Training Center
NWIRP	Naval Weapons Industrial Reserve Plant
OSWER	Office of Solid Waste and Emergency Response
OU	operable unit
PAH	poly-aromatic hydrocarbon
PCB	poly-chlorinated biphenyl
PCE	perchloroethylene
PMZ	plume management zone
RAO	remedial action objective
RC	response complete
RCRA	Resource Conservation and Recovery Act
RDX	Royal Demolition eXplosive
RI	remedial investigation
RIP	remedy in place
ROD	record of decision
RPM	Remedial Program Manager
RRM	Remediation Risk Management
RWQCB	Regional Water Quality Control Board
SARA	Superfund Amendment and Reauthorization Act
SERDP	Strategic Environmental Research and Development Program
SB	Senate Bill
SF	San Francisco
SVE	soil vapor extraction
SWMU	Solid Waste Management Unit
TAC	Texas Administrative Code
TCE	trichloroethylene

TCEQ	Texas Commission on Environmental Quality
TI	technical impracticability
TMDL	total maximum daily load
USD	urban setting designation
USEPA	U.S. Environmental Protection Agency
VOC	volatile organic compound
WMA	Waste Management Area

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1.0 EXECUTIVE SUMMARY

1.1 OVERVIEW

This report is intended to provide Department of Defense (DoD) site managers and other stakeholders an overview of alternative endpoints and approaches to address cleanup complexities or challenges. Examples of alternative endpoints and approaches include applicable or relevant and appropriate requirement (ARAR) waivers, alternate concentration limits (ACL), adaptive site management approaches, and the use of passive remedies over long time frames. Per regulatory requirements, these alternative endpoints and approaches must be protective of human health and the environment. The report helps increase awareness of different designations used at other sites, how sites have formulated alternative endpoints and metrics, and how they have documented their decisions. Findings described in this report are based on an analysis of case studies of site remediation under a variety of cleanup programs (Comprehensive Environmental Response, Compensation and Liability Act [CERCLA], Resource Conservation and Recovery Act [RCRA], and state lead/voluntary cleanup programs) that have implemented or considered alternative endpoints or approaches for groundwater.

Several factors have made alternative endpoints and approaches beneficial or necessary. These include the underlying technical limitations to groundwater cleanup, as well as several factors that would be considered during a comprehensive analysis of the costs and benefits to society of removing residual contamination (e.g., life-cycle costs, sustainability impacts, resource consumption). Technical limitations have been understood for years; however, new technical challenges continue to be documented. In the presence of dense non-aqueous phase liquid (DNAPL), pump-and-treat, and other technologies targeting dissolved-phase contamination in hydraulic contact with DNAPL are limited by DNAPL dissolution time frames, which can be on the order of hundreds of years. In geologic settings where transmissive zones are a small fraction of the aquifer's total volume (e.g., fractured rock settings, sites with interbedded low-permeability zones), matrix diffusion and matrix storage can also extend cleanup time frames (see, e.g., Pankow and Cherry, 1996). Aquifer restoration to drinking water standards at sites with complex geologic and contaminant characteristics has rarely been achieved (National Research Council [NRC], 2005), with fewer than five examples cited in recent literature (see, e.g., U.S. Environmental Protection Agency [USEPA], 2009a).

In addition, DoD site managers face programmatic expectations regarding site cleanup progress (e.g., remedy in place/response complete [RIP/RC] deadlines). DoD has made substantial progress in site cleanup; however, approximately 13% of sites (a total of 3545) still require additional investigation and remediation (Defense Environmental Restoration Program [DERP], 2009). A number of these sites are complex and difficult to remediate, making the topic of alternative endpoints and approaches for groundwater cleanup relevant throughout DoD.

DoD, USEPA, state regulators, and other organizations have been grappling with these challenges for years. These organizations have published technical and policy guidance documents to protect human health and the environment more effectively and more efficiently. Selected reports include the following:

- USEPA, 2003. The DNAPL remediation challenge: Is there a case for source depletion?
- USEPA, 2005. Use of ACLs in Superfund cleanups.
- USEPA, 2007. Recommendations from the USEPA Ground Water Task Force.
- USEPA, 2009a. DNAPL remediation: Selected projects where regulatory closure goals have been achieved. Status update. Office of Solid Waste and Emergency Response (OSWER). USEPA 542/R-09/008. August.
- USEPA, 2009b. Summary of key existing USEPA CERCLA policies for groundwater restoration, OSWER Directive 9283.1-33.
- USEPA, 2010. Institutional controls (IC): A guide to planning, implementing, maintaining, and enforcing ICs at contaminated sites, EPA-540-R-09-001. November.
- Malcolm Pirnie, 2004. Technical impracticability (TI) assessments: Guidelines for site applicability and implementation. Phase II report.
- Naval Facilities Engineering Command (NAVFAC), 2008. Groundwater risk management handbook.
- NRC, 2003. Adaptive site management.
- NRC, 2005. Contaminants in the subsurface: Source zone assessment and remediation.
- Sale et al., 2008. Frequently asked questions regarding management of chlorinated solvents in soils and groundwater.
- Updated USEPA fact sheets describing CERCLA sites that have received TI waivers in the past (Charsky, personal communication, 2010).

1.2 ALTERNATIVE ENDPOINTS AND APPROACHES

The term “alternative endpoints” is used in this report to describe formal designations for alternative final remedial goals that are permitted by regulations (e.g., ARAR waivers, ACLs, Texas plume management zones [PMZ]) and are protective of human health and the environment. “Alternative approaches” is a term used in this report to refer to alternative approaches to meeting traditional endpoints over the long-term. Examples include the use of monitored natural attenuation (MNA) or groundwater management zones (GMZ) over long time frames without waiving ARARs. Alternative approaches are primarily focused on site-specific remedial objectives, which may be qualitative and/or quantitative, in order to eventually achieve long-term remedial goals.

Regardless of the approach and terminology, all selected remedies must be protective of human health and welfare and of the environment. The alternative endpoints and approaches addressed in this report include the following:

- TI waivers
- Other ARAR waivers (greater risk, interim measures, equivalent standard of performance, inconsistent application of state standards, fund balancing)
- ACLs
- Groundwater management/containment zones (CZ)
- Groundwater reclassification/classification exemptions
- MNA over long time frames
- Adaptive site management
- Remediation to the extent practicable.

1.3 REGULATORY REQUIREMENTS

Alternative endpoints and approaches must comply with regulatory requirements, which differ depending on the cleanup program. Regulatory requirements for groundwater cleanup under CERCLA, RCRA, and state-led programs are described generally in this report. These regulations are substantive, but not procedural, and are therefore subject to interpretation. For example, CERCLA regulations describe the overarching goal of the program (protecting public health and welfare and the environment) and overall USEPA expectations for restoring usable groundwater to beneficial use. USEPA expectations are open to site-specific interpretation of terms such as “reasonable time frame” and “particular circumstances of the site.” According to the National Contingency Plan (NCP) Preamble (dated March 8, 1990), “by stating ‘expectations’ rather than issuing strict rules, USEPA believes that critical flexibility can be retained in the remedy selection process.” CERCLA describes the need to comply with ARARs unless one of six options for waiving an ARAR applies (40 Code of Federal Regulations [CFR] 300.430(f)(1)(ii)(C)). CERCLA Section 121(d)(2)(B)(ii) describes conditions under which ACLs may be established.

Similarly, RCRA regulations and guidance describe the overall goal of remediation as protection of human health and the environment, attaining media cleanup objectives, controlling source(s) of releases so as to reduce or eliminate, to the extent practicable, further releases of hazardous waste, and complying with applicable standards for waste management. RCRA regulations allow for greater site-specific flexibility in setting cleanup standards (including the use of site-specific, risk-based media cleanup standards (MCS), designated points of compliance, cleanup time frames, and other details). Like CERCLA, RCRA recognizes technical limitations to groundwater restoration and allows the use of ACLs, under certain circumstances.

State Superfund programs and state voluntary cleanup programs typically pattern their objectives after RCRA and CERCLA. Many state policies allow for flexibility regarding alternative endpoints, primarily through groundwater classification and groundwater management/CZ designations. Most states have classified groundwater according to use, value or vulnerability. Some states have non-degradation policies that are interpreted as cleanup objectives. Other states have state-wide mapping systems for groundwater resources. Most states allow for site-specific variations or exceptions to groundwater classification. At least 13 states (California, Delaware, Georgia, Illinois, Michigan, Missouri, Nebraska, New Hampshire, New Jersey, Ohio, Tennessee, Texas, and Wyoming) consider some form of groundwater CZs in their corrective action policies.

In summary, regulations are substantive but not procedural and are therefore subject to some interpretation, opening up possibilities for alternative endpoints and approaches at complex sites facing technical limitations to complete restoration.

1.4 ANALYSIS

CERCLA sites using alternative endpoints and approaches can be identified through a keyword search of the database of site decision documents. This method was used to identify a population of 77 CERCLA sites with TI determinations for groundwater as of November 2010, as well as several sites that received greater risk ARAR waivers, and several other sites implementing ACLs. Fact sheets for each of the 77 sites are presented in Appendix A. An analysis of TI waiver site data is presented in Appendix C of this report, including a discussion of common site characteristics, the particular circumstances leading to a TI waiver, and data used in support of the TI assessment.

Data were not readily available to comprehensively identify case studies and trends in alternative endpoints and approaches at RCRA and state sites. Instead, Malcolm Pirnie identified several examples of case studies using alternative endpoints and approaches. These case studies illustrate the types of underlying technical limitations to cleanup faced at each site, conceptual site model (CSM) detail, technology evaluation, tools and metrics used in support of the alternative endpoint or approach, and more. Details on each case study are provided in Section 4 of this report and in Appendix B. A summary of these case studies is shown in Table 1.

Malcolm Pirnie's methodology for researching and preparing this report focused on identifying and reviewing site-specific information from publicly available documents. In some cases, site managers and regulators were contacted for more information.

Table 1. Summary of case studies described in this document.

Alternative Endpoint or Approach	Appendix	Site #	Site Name
TI waivers	A and C	1-77*	CERCLA sites with TI waivers
Greater risk ARAR waivers	B	1a	E.I. du Pont de Nemours & Co., Inc. (Newport Pigment Landfill), Operable Unit (OU) 1, Newport, Delaware
		1b	Onondaga Lake OU 5, Syracuse, New York
		1c	Moss-American Co. Inc. (Kerr-McGee Oil Co.), OU 1, Milwaukee, Wisconsin
Other ARAR waivers	B	2a	Hastings Ground Water Contamination OU 19, Hastings, Nebraska (interim remedy)
		2b	Brandywine Defense Reutilization and Marketing Office (DRMO) Site SS-01, Andrews Air Force Base (AFB), Maryland (interim remedy)
		3a	Rocky Mountain Arsenal OU 4, Adams County, Colorado (inconsistent application of state standards considered)

Table 1. Summary of case studies described in this document. (continued)

Alternative Endpoint or Approach	Appendix	Site #	Site Name
ACLs	B	4a	Waterloo Coal Gasification Plant, OU 1, Waterloo, Iowa
		4b	Winthrop Landfill Superfund Site, OU 1, Winthrop, Maine
		4c	Naval Surface Warfare Center (NSWC), Solid Waste Management Unit (SWMU) 3, Crane, Indiana
		4d	Former Long Beach Naval Complex, Installation Restoration (IR) Sites 1 and 2, Long Beach, California
		4e	Jacksonville Naval Air Station (NAS) OU 3, Jacksonville, Florida (planned)
Groundwater management/ containment	B	5a	Joliet Army Ammunition Plant (Load-Assembly Packing Area and Manufacturing Area), Illinois (GMZ)
		5b	Naval Weapons Industrial Reserve Plant (NWIRP) Dallas, Texas (PMZ)
		5c	Fairchild Semiconductor Corporation (South San Jose Plant), San Jose, California (CZ considered)
		5d	Barstow Marine Corps Logistics Base OU 1, Barstow, California (Waste Management Area [WMA])
Groundwater reclassification	B	6a	Altus AFB, Altus, Oklahoma (Class III groundwater reclassification)
		6b	Porter Cable/Rockwell site, Tennessee (site-specific impaired groundwater)
		6c	Hardy Street Rail Yard site, Texas (PMZ)
MNA over a long time frame	B	7a	Solvents Recovery Service of New England, OU 3, Southington, Connecticut
		7b	Office Naval Training Center (NTC) SA17, Orlando, Florida
Adaptive site management	B	8a	Hanscom Field/Hanscom AFB OU 1, Massachusetts
		8b	Watervliet Arsenal Building 40, Watervliet, New York
Remediation to the extent practicable	B	9a	Union Pacific Railroad Co. Tie-Treating Plant, OU 1, The Dalles, Oregon

1.5 CONCLUSIONS

A summary of key findings from the analysis of alternative endpoints and approaches is presented in Section 5 of this report and includes the following:

- A wide variety of alternative endpoints and approaches have been used at complex sites, including ARAR waivers, ACLs, formal state designations such as CZs, passive remedies over long time frames, designated points of compliance, changes in groundwater zoning, and remediation to the extent practicable. Sites that consider but do not adopt alternative endpoints often implement one of these informal approaches.
- Alternative endpoints and approaches are applicable under a variety of cleanup programs, including CERCLA, RCRA, state Superfund programs, and state voluntary cleanup programs. Regulatory language is generally flexible and

substantial, rather than procedural, which allows for site-specific approaches to meet overall cleanup expectations.

- Sites implementing alternative approaches benefit from setting up functional, short-term objectives and metrics in addition to absolute, long-term remedial objectives (e.g., meeting ARARs) (NRC, 2005). Short-term objectives and metrics provide a basis for making remedial decisions and tracking remedial progress (e.g., declining contaminant concentrations), particularly when using an adaptive site management approach, where the exact pathway to site closure is long or unclear. At CERCLA sites, site-specific remedial action objectives (RAO) may provide an appropriate way to document short-term objectives of an alternative approach without necessarily changing long-term endpoints (e.g., ARARs). Traditional endpoints still apply over the long term.
- Regardless of the specific type of alternative endpoint or approach chosen, similar management actions have been required as part of the overall remedy. For example, sites with similar issues but differing alternative endpoints still have implemented similar remedial strategies. The remedy packages selected often include partial source area remediation, containment, MNA, ICs, and long-term monitoring (LTM). This finding indicates that the same underlying technical issues drive the selection of remedies at these complex sites, since the remedies still have to be protective of human health and the environment.

The analysis presented in this report is based on examples of alternative endpoints and approaches. The analysis will hopefully stimulate thought and careful consideration of alternative, beneficial, and cost-effective cleanup objectives and metrics that can be achieved over the short term (while eventually meeting long-term cleanup objectives or demonstrating the applicability of alternative endpoints). Where they are appropriate, alternative endpoints and approaches can be used to improve the site cleanup process at complex sites.

2.0 BACKGROUND

2.1 REPORT OVERVIEW AND OBJECTIVES

This report was funded by ESTCP to provide DoD with an overview of different tools, metrics, and other information to evaluate alternative endpoints and approaches for groundwater remediation, particularly at sites with complex hydrogeologic settings, extensive or long-lived contamination, and other complex circumstances. Alternative endpoints and approaches may provide ways to achieve cleanup objectives that are protective of human health and the environment and that comply with regulatory requirements, while reducing resource consumption, life-cycle costs, and other adverse environmental impacts associated with remediation activities. This report will help DoD site managers and other site stakeholders continue to improve cleanup efforts at DoD sites by formulating, incorporating, and documenting alternative endpoints and approaches at complex sites where appropriate. This report also presents alternative endpoints and approaches in the context of achieving absolute or functional cleanup objectives.

Section 2 of this report describes the background or context for the report, an overview of DoD sites with contaminated groundwater, technical limitations to cleanup, cost-benefit and sustainability considerations, and programmatic challenges facing DoD site managers. These factors have made alternative endpoints and approaches for groundwater cleanup beneficial and/or necessary.

Section 3 summarizes regulatory requirements for groundwater cleanup under CERCLA, RCRA, and similar State-led programs. All remedial approaches must comply with these regulations, including alternative endpoints and approaches.

Section 4 describes alternative endpoints and approaches that have been used at other sites in a variety of cleanup programs and presents case studies of their usage. Examples of alternative endpoints include waivers of ARARs, similar designations established for sites under state and local jurisdictions (e.g., Texas PMZs), ACLs, GMZs, and alternative designations of RAOs such as remediation to the extent practicable.

2.2 DOD CLEANUP PROGRAM

DoD has been conducting environmental restoration activities for more than 30 years in response to and under the guidance of key statutes such as RCRA passed by Congress in 1976, CERCLA passed by Congress in 1980, and the Superfund Amendments and Reauthorization Act (SARA) in 1986. Currently, DoD site investigation and cleanup is handled by each military branch under DERP (DERP, 2009). As shown in Table 2, DoD has made substantial progress in selecting and implementing remedies and cleaning up contaminated sites (DERP, 2009).

Table 2. Status of cleanup at DoD sites as of 2009.

DoD Cleanup Program*	# of Sites*	DoD Cleanup Status				
		Investigation	Remediation	RIP	RC	RC/LTM
Formerly used sites (FUDS)	2879	491	352	14	1977	45
Active (ER)	21,333	2457	605	1671	15,771	829
Closed (BRAC)	5126	578	113	411	3616	408
TOTAL	**29,338**	**3526**	**1070**	**2096**	**21,364**	**1282**
%		**12%**	**4%**	**7%**	**73%**	**4%**

*Does not include Military Munitions Response Program (MMRP) sites. ER - Environmental Restoration, BRAC - Base Realignment and Closure, FUDS - Formerly Used Defense Sites, RIP – remedy in place, RC – response complete, LTM – long-term monitoring.

As shown, the majority of DoD sites (77%) have reached RC, though a small percentage of these sites are still conducting LTM. An additional 7% of sites have reached RIP (DERP, 2009). This leaves approximately 16% of sites (a total of 4596) that still require additional investigation and remediation. In addition, a fraction of the sites that have reached RIP may have approved remedies with RAOs that are not achievable within a reasonable time frame or at reasonable cost, thereby potentially requiring future changes to the selected remedy.

One indication of the amount of work remaining at DoD sites is the estimated cost-to-complete. At the end of fiscal year 2009, the estimated cost-to-complete for sites in the Environmental Restoration (ER), Base Realignment and Closure (BRAC), and Formerly Used Defense Sites (FUDS) programs was $12.2 billion. In comparison, DERP has spent a total of $29.6 billion since its creation in 1986 (not including MMRP sites), as reported recently to Congress (Table C-2 in DERP, 2009). (Note that costs are not normalized to a common baseline year.) Regardless, this illustrates that significant cleanup work still remains to be done.

2.3 REMEDIATION CHALLENGES

2.3.1 Technical Challenges

Although our understanding of groundwater remediation has evolved considerably since the 1980s, this understanding has revealed additional complexities in subsurface contaminant behavior, creating new challenges for remediation (NRC, 2005; Sale et al., 2008).

Since the early 1990s, environmental remediation professionals have recognized that pump-and-treat technologies are often limited in their ability to restore aquifers due to their exclusive focus on dissolved-phase contaminants present in transmissive portions of aquifers. Pump-and-treat technologies, however, are fairly successful in preventing further contaminant migration (Pankow and Cherry, 1996). At sites where DNAPL is present in the subsurface as separate-phase contamination, contamination continually dissolves from the DNAPL into groundwater, causing dissolved-phase concentrations to remain high over time. Pump-and-treat and other technologies targeting dissolved-phase contamination have been projected to take hundreds or even thousands of years to achieve maximum contaminant levels (MCL), based on time frames for DNAPL dissolution.

As efforts to address DNAPL continued through the 1990s, including aggressive in situ treatment techniques, environmental professionals recognized that dissolved and sorbed-phase contaminants in low permeability zones are yet another source of contaminants stored in the subsurface that prolongs dissolved-phase contamination (see, e.g., Chapman and Parker, 2005). As contaminants in transmissive zones are depleted or flushed from the system, contaminants stored in low-permeability zones diffuse slowly back into the transmissive zones, a process termed *matrix back-diffusion*. As with DNAPL, this prolongs elevated contaminant concentrations in the surrounding groundwater. In geologic settings where transmissive zones are a small fraction of the aquifer's total volume (e.g., fractured rock settings or sites with interbedded low-permeability zones), matrix diffusion and matrix storage can have a significant impact on cleanup time frames. At these sites, the secondary source of contaminants in the subsurface matrix makes it difficult to differentiate between source and plume areas.

Despite advances in technologies and the increased use of in situ technologies to address DNAPL zones, aquifer restoration at sites with complex geologic and contaminant characteristics has rarely been achieved (NRC, 2005; Sale et al., 2008). Successes in complete restoration to drinking water standards in the presence of DNAPL are rare, with only four sites cited in a set of 13 case studies where regulatory closure goals have been achieved (USEPA, 2009a). Several prior reports have recommended establishing near-term cleanup objectives that are attainable, considering alternate or intermediate performance goals and phased remedial action approaches, and considering alternate endpoints and approaches (USEPA, 2003; NRC, 2005; Sale et al., 2008).

2.3.2 Cost-Benefit and Sustainability Considerations

There are ongoing, site-specific discussions about the benefits of achieving cleanup goals at some sites. Attempting to reach MCLs or background concentrations in groundwater aquifers is projected to cost millions of dollars at some complex sites while achieving little practical or measureable benefit to human health or environment; that is, the estimated cost-to-benefit ratio of attempting to achieve cleanup goals may be low. For example, treatment systems may have reached asymptotic low levels of mass extraction without yet meeting cleanup goals. Continuing to operate these systems would yield very little environmental benefit but significant cost. Switching to a different technology may remove additional mass from the subsurface (USEPA, 2009a); however, in complex hydrogeologic settings, all existing technologies may be unable to remove significant additional mass.

During the past 5 years, an increased awareness of global warming and carbon emissions has given remediation professionals a broader perspective of the total benefits, costs, and trade-offs through remedial efforts. Energy-intensive remedies and pump-and-treat systems that operate over long time frames may have significant carbon footprints compared with monitoring and long-term management approaches.

DoD, USEPA, state regulators, and other organizations are starting to incorporate sustainability and other values into decision-making frameworks, including the true cost of resources used for remediation (e.g., energy consumption, carbon footprint), planning and designation of resource end use, mitigation of environmental damages, green remediation, risk-based management and local community priorities and values (Interstate Technology and Regulatory Council [ITRC], 2009b; AFCEE, 2009). For example, USEPA has been working with private and public partners to foster the use of Best Management Practices for green remediation at contaminated sites (USEPA, 2009c). A broader analysis of remedial options would illustrate the benefits and trade-offs to society of removing residual contamination.

2.3.3 Programmatic Expectations

In addition to technical challenges, DoD site managers are expected to meet programmatic expectations regarding site cleanup progress. As indicated in the DERP annual reports to Congress (DERP, 2009), one of the primary administrative metrics for the DoD Installation Restoration Program (IRP) is achieving milestones in the cleanup process.

DoD has established various dates as goals for achieving RIP/RC, in addition to meeting financial metrics and regulatory objectives at these sites. Goals for achieving RIP/RC at DoD sites (not including MMRP sites) are as follows (DERP, 2009):

- End of FY 2011 – Reduce risk or achieve RIP/RC at all medium relative-risk IRP sites at active installations and FUDS properties
- End of FY 2014 – Achieve RIP/RC at all active installation sites and BRAC 2005 sites
- End of FY 2015 – Achieve RIP/RC at all legacy BRAC sites
- End of FY 2020 – Achieve RIP/RC at all FUDS properties.

To meet these goals, DoD site managers are moving sites forward in the cleanup process, issuing more guaranteed fixed-price remediation contracts and making other decisions to propel short-term cleanup progress. However, cleanup challenges may remain, even after RIP/RC has been achieved. Long-term liabilities are still uncertain for DoD at sites where the absolute RAOs do not take technical limitations into account.

2.4 OPTIMIZING CLEANUP EFFORTS

To address these challenges (e.g., technical, sustainable, cost-benefit, and programmatic goals), USEPA, states, DoD, and other organizations have published guidance and technical analyses to achieve cleanup objectives that are protective of human health and the environment but minimize the use of resources and life-cycle costs. Selected activities are described in the following sections, illustrating how this document builds upon (and relates to) the common theme expressed in a substantial amount of previous work, that is, improving the use of resources and results of contaminant cleanup and management at complex sites, while protecting human health and the environment.

2.4.1 USEPA

Technical limitations to groundwater restoration and policy implications have been addressed by USEPA in several guidance documents under the CERCLA and RCRA programs. Guidance on the evaluation of TI waivers at CERCLA sites was issued in 1993 (USEPA, 1993). TI waivers are one of the six types of waivers for ARARs listed in the NCP. More recently, USEPA has prepared brief fact sheets describing CERCLA sites that have received TI waivers in the past (Charsky, personal communication, 2010).

USEPA has also published several guidance documents on the investigation and remediation at DNAPL sites for both RCRA and CERCLA programs. Recently, USEPA published the results of an expert panel report titled "The DNAPL Challenge: Is There a Case for Source Depletion?" summarizing the state of knowledge and research needs related to partial DNAPL source depletion (USEPA, 2003). In 2007, USEPA Ground Water Task Force published recommendations for addressing DNAPL cleanup decisions as well as groundwater use, value, and vulnerability (USEPA, 2007). These two topics are closely related to setting cleanup goals and restoring groundwater to beneficial use. In 2009, USEPA issued the OSWER Directive 9283.1-33, titled "Summary of Key Existing USEPA CERCLA Policies for Groundwater Restoration." This memorandum reiterates important USEPA policies to assist USEPA Regions with making decisions regarding groundwater restoration at CERCLA sites (USEPA, 2009b).

2.4.2 ITRC

ITRC is a state-led coalition working together with industry, DoD, and stakeholders to achieve regulatory acceptance of environmental technologies. ITRC accomplishes its mission by developing guidance documents and training courses to meet the needs of regulators, DoD, environmental consultants, and others. ITRC also conducts outreach to state regulators and technology users (ITRC, 2010a). ITRC has published a number of documents to improve groundwater remediation efforts, including documents about DNAPLs (see e.g., "DNAPL Source Reduction: Facing the Challenge" [ITRC, 2002]) and remediation process optimization (see e.g., "Performance-Based Management" and "Exit Strategy - Seeing the Forest Beyond the Trees" [ITRC, 2006a; 2006b]). In Fall 2010, as of the writing of this document, an ITRC team (Remediation Risk Management [RRM]) was in the process of preparing guidance on project risk management, identifying potential activities or circumstances that may result in negative consequences to remediation system performance and managing the associated risks (ITRC, 2011a). This team is also preparing an overview document titled "Assessing Alternative Endpoints and Remedial Approaches to Address Groundwater Cleanup Challenges: Remediation Risk Management" (ITRC, 2011b). Another ITRC team on Integrated DNAPL Source Strategy was in the process of preparing a technical and regulatory document, to be completed in Spring 2011.

2.4.3 NRC

NRC has published numerous documents on site cleanup, including a book titled *Alternatives for Ground Water Cleanup* in 1994, which analyzed the major technical and public policy issues arising from technical limits to aquifer remediation. NRC concluded that, theoretically, restoration to drinking water standards was possible; however, there were a number of technically complex and significant obstacles to cleanup, including physical heterogeneities, the presence of non-aqueous phase liquids (NAPL), contaminants in inaccessible regions, sorption and difficulties in characterizing the subsurface (NRC, 1994). NRC has also published several books on environmental characterization and cleanup at Navy sites, including *Adaptive Site Management* (NRC, 2003). A 2005 NRC study titled "Contaminants in the Subsurface: Source Zone Assessment and Remediation" clearly acknowledged the limitations of mass removal in complex settings (i.e., low permeability zones, fractured systems) and framed remedial decision making in terms of characterizing the site and clearly setting objectives and metrics. The NRC study described the complexities of groundwater remediation and raised questions regarding impracticability of complete restoration. Recently, a new NRC committee was formed to address these issues and is in the process of preparing a report titled “Future Options for Management in the Nation’s Subsurface Remediation Effort” (National Academy of Sciences, 2010).

2.4.4 DoD

The Army Environmental Command (AEC) has issued guidance documents to Army Remedial Program Managers (RPM) and has supported site-specific technical assessments at complex Army sites in an effort to set realistic cleanup objectives and use program cleanup dollars effectively (see, e.g., Malcolm Pirnie, 2002). The Army has also prepared a document summarizing CERCLA sites that have received TI waivers in the past, a summary of site characteristics, reasons for the determination, and other findings (Malcolm Pirnie, 2004).

Recognizing the benefits of alternative endpoints for groundwater cleanup, the Air Force issued a memorandum stating that all site-specific cleanup goals must be reviewed to determine if an ARAR waiver could apply prior to signing decision documents or authorizing resources to meet ARARs (Air Force, 2004). Under AFCEE, the site-specific Environmental Restoration Program – Optimization (ERP-O) was created to maximize the effectiveness and minimize the financial liabilities and environmental footprint of the Air Force Restoration Program through technical leadership and guidance. ERP-O is a continuous process in that the program is evaluated throughout its life cycle. The management focus is shifted to the results attained rather than steps completed. Streamlined site characterization techniques are used to develop and update the CSM, which is used as a planning tool throughout the project. A realistic exit strategy is an essential element that should be developed early in the project and modified as necessary to serve as a road map to site closure. Innovative contracting methods are used where appropriate to implement the cleanup, and optimization reviews of the cleanup operation are conducted periodically.

The Navy has published several documents offering guidance on the topic of groundwater remediation, including the *Groundwater Risk Management Handbook* (NAVFAC, 2008) and *Guidance for Optimizing Remedy Evaluation, Selection, and Design* (NAVFAC, 2004). These documents provide guidance to Navy RPMs on considering the use of risk management strategies to guide decision making. The document describes factors affecting groundwater restoration, elements of a CSM, risk management approaches, remediation strategies, and case studies. This topic was the subject of the Fall 2010 Navy Remediation Innovative Technology Series training seminars for Navy RPMs and Navy contracts at each NAVFAC region.

Other DoD organizations have recognized the importance of this topic. The Strategic Environmental Research and Development Program (SERDP) and ESTCP sponsored a DNAPL source zone initiative, resulting in several reports and expert panel workshops on DNAPL source zone characterization and remediation (see, e.g., SERDP/ESTCP, 2009).

2.4.5 Summary

The organizations described in the preceding section are all grappling with similar issues to the ones addressed in this report, namely technical limitations to achieving certain absolute cleanup objectives in groundwater, cost-benefit and sustainability considerations, and administrative/programmatic expectations for cleanup progress. Alternative endpoints and approaches for groundwater cleanup may provide useful concepts for designing and selecting final remedies and closure strategies. Alternative cleanup goals and approaches need to be evaluated in the context of state and federal statutory and regulatory requirements for groundwater cleanup, as described in Section 3.

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3.0 REGULATORY REQUIREMENTS FOR GROUNDWATER REMEDIATION

Regulatory requirements for groundwater remediation vary with the type of cleanup program. Those described in this chapter include 1) CERCLA/NCP requirements, 2) RCRA requirements, and 3) selected examples of regulatory requirements and cleanup programs established under state laws to address state Superfund sites, state Voluntary Cleanup Programs, and other remediation programs. These regulations provide context for considering alternative endpoints and approaches for groundwater remediation, as described in Section 4.

3.1 CERCLA PROGRAM

3.1.1 Overall Objectives and Expectations

The NCP was formulated with the passage of CERCLA in 1980 and amended in 1986 with the passage of SARA. The NCP described the overall objective and purpose of remedial actions as follows (40 CFR Section 300.430(a)(1)):

> "The purpose of the remedy selection process is to implement remedies that eliminate, reduce, or control risks to human health and the environment."
>
> "The national goal of the remedy selection process is to select remedies that are protective of human health and the environment, that maintain protection over time, and that minimize untreated waste."
>
> "EPA expects to **return usable groundwater to their beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site**. When restoration of groundwater to beneficial uses is not practicable, EPA expects to prevent further migration of the plume, prevent exposure to the contaminated groundwater, and evaluate further risk reduction."

According to the NCP Preamble (dated March 8, 1990), "by stating 'expectations' rather than issuing strict rules, EPA believes that critical flexibility can be retained in the remedy selection process."

3.1.2 Threshold Criteria

The overarching objectives and expectations for remedial actions translate into two criteria that all final remedies must meet:

1. Overall protection of human health and the environment
2. Compliance with ARARs.

Overall protection of human health and the environment refers to protection in "both the short- and long-term from unacceptable risks posed by hazardous substances, pollutants, or contaminants present at the site by eliminating, reducing, or controlling exposures to levels established during development of remediation goals" (40 CFR Section 300.430(e)(9)(iii)(A)). Protectiveness is typically supported by the results of a risk assessment, after carefully identifying potential current and future receptors, routes of exposure, sources of contamination, and transport pathways in the environment to receptors. Protectiveness of human health can be enhanced via ICs (e.g., land use controls, groundwater restrictions, fencing, and posting signs) to eliminate or reduce exposure pathways as well as remediation to eliminate or reduce contamination. Protection of the environment is typically achieved by source removal, treatment, containment, and MNA.

Compliance with ARARs includes both federal and state ARARs. Only state standards that are more stringent than federal ARARs may be applicable. The only grounds for waiving an ARAR are the following six options (40 CFR 300.430(f)(1)(ii)(C)):

1. *Interim Measure.* If the remedy is an interim action, ARARs need not be met. However, the final remedy still needs to achieve ARARs.
2. *Greater Risk.* If compliance with the ARAR would result in greater risk to human health and environment compared with an alternative that does not comply with ARARs.
3. *Technical Impracticability.* If compliance with ARARs is technically impracticable from an engineering standpoint, within a reasonable time frame.
4. *Equivalent Standard of Performance.* If the selected remedy will attain a standard of performance that is equivalent to the ARAR. This waiver is typically used for action-specific or location-specific ARARs.
5. *Inconsistent Application of State Standards.* If the ARAR is a state standard that has not been consistently applied to other remedial actions within the state.
6. *Fund Balancing.* If compliance with the ARAR would threaten the ability of the Fund to respond to and achieve protectiveness at other sites. This waiver is not applicable at DoD sites that do not use the Superfund.

Each of these circumstances is described in more detail in Section 4 Alternative Endpoints and Approaches for Groundwater Remediation. In addition to the two threshold criteria, seven other criteria (five “primary balancing criteria” and two “modifying criteria”) are used in comparing and selecting the final remedial alternative. These include long-term effectiveness and permanence; reduction in toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; cost; state acceptance; and community acceptance.

3.1.3 Remedial Action Objectives and Remedial Goals

Both the text of the CERCLA statute and the NCP regulation specify a process for establishing RAOs and remedial goals. As described in the NCP, the following factors must be considered when establishing remedial goals (40 CFR Section 300.430 (e)(2)(i)(A)-(G)):

- Federal ARARs and more stringent state ARARs. Several were specifically mentioned in the regulation, including the following:
    - Safe Drinking Water Act Maximum Contaminant Level Goals (MCLG) greater than zero, for current and potential sources of drinking water, where they are relevant and appropriate.

  - Safe Drinking Water Act MCLs, for current and potential sources of drinking water, where they are relevant and appropriate.
  - Water quality criteria established under the Clean Water Act, Sections 303 and 304.
- Other factors, including the following:
  - Risk-based levels corresponding to a hazard index of 1 or less, and a 10-4 to 10-6 incremental cancer risk for known or suspected carcinogens.
  - When ARARs are not available or are not sufficiently protective because of the presence of multiple contaminants or multiple exposure pathways, the 10-6 risk level shall be used as the point of departure for determining remediation goals.
  - Technical limitations such as detection/quantification limits for contaminants.
  - Factors related to uncertainty.
  - Other pertinent information.
- An ACL, which may be established in accordance with CERCLA Section 121(d)(2)(B)(ii).

As described in the CERCLA text, "Such remedial action shall require a level or standard of control which at least attains Maximum Contaminant Level Goals established under the Safe Drinking Water Act and water quality criteria established under section 304 or 303 of the Clean Water Act, where such goals or criteria are relevant and appropriate under the circumstances of the release or threatened release."

CERCLA then goes on to describe conditions under which ACLs may be considered (Section 121(d)(2)(B)(ii)). ACLs are risk-based concentrations that will not pose a substantial hazard to human health or environmental receptors (given exposure pathways and other factors). An ACL replaces an ARAR as the new regulatory-approved cleanup concentration, as opposed to waiving the ARAR entirely. In general, ACLs may be considered as part of response actions provided that the following three conditions are met:

- Groundwater discharges into surface water (there are "known and projected points of entry" to surface water).
- Groundwater discharge does not lead to a "statistically significant increase" of contaminants in the surface water or any "accumulation" of contaminants downstream.
- ICs prevent human exposure to contaminated groundwater between the facility boundary and the discharge points of groundwater into surface water.

Finally, in determining whether or not water quality criteria are relevant and appropriate, CERCLA states that the designated or potential uses of the surface water or groundwater and other information will be considered (CERCLA Section 121(d)(2)(B)(i)).

3.1.4 Functional Objectives and Metrics

The overall objectives of CERCLA are termed “absolute objectives” by NRC (2005). The NRC report distinguished between absolute objectives and functional objectives. Absolute objectives are those that are important in themselves, whereas functional objectives are a “means to achieve the absolute objectives” (NRC, 2005).

Examples of functional objectives include meeting specific short-term numerical remediation goals, plume containment, reduction in groundwater concentrations, mass flux reduction, risk management, mass reduction, and decreased plume longevity (Sale et al., 2008). NRC recommended that sites differentiate between absolute and functional objectives, and establish functional objectives and metrics to measure short-term remedial progress at complex sites where absolute objectives would only be achieved over long time frames or only within some portions of the contaminated aquifer.

In summary, language in the relevant statutes and regulations provides considerable flexibility in the approach for addressing risks posed by site contamination, while clearly stating expectations that the selected remedy will be protective of human health and the environment and will comply with ARARs, thereby restoring usable aquifers to their highest beneficial use.

3.2 RCRA PROGRAM

The RCRA statute was first passed in 1976. RCRA focused on life-cycle waste tracking and permitting of generation, treatment, storage, and disposal facilities to prevent future environmental problems. Corrective action authority at RCRA sites was expanded in 1984, with the Hazardous and Solid Waste Amendments (HSWA). HSWA allowed USEPA to regulate underground tanks. It also authorized corrective action at sites not covered by the original law and tightened land disposal restrictions. An owner of a RCRA facility can become responsible for aquifer cleanup if cleanup requirements are written into the facility permit, named in a correction action order (CAO), or in a RCRA 3008(h) order. Risk-based cleanup levels can be developed for either permit-driven or CAO-driven corrective action.

In July 1990, USEPA published a proposed corrective action rule (55 FR 30.798 (1990)) and, in May 1996, an advanced notice of public rulemaking (ANPR) regarding corrective action at RCRA sites (40 CFR Chapter I in Federal Register, May 1, 1996). These proposed rules focused the RCRA corrective action process on site-specific risk assessment and risk-based corrective action. However, the proposed rules were never finalized. At that time, most states were becoming authorized to implement RCRA corrective action in place of USEPA and were in the process of issuing their own policies. RCRA is primarily implemented by the states, with 40 states authorized as lead agencies (42 United States Code Section 6926(b)). To avoid creating conflicting regulations, USEPA therefore announced that the ANPR should serve as corrective action guidance. USEPA has issued subsequent guidance including the living document, *Handbook of Groundwater Protection and Cleanup Policies for RCRA Corrective Action* (USEPA, 2004).

In 1993, the Government Performance and Results Act (GPRA) placed new expectations and requirements on federal agencies. Federal agencies were required to clearly describe the goals and objectives of their programs, identify resources and actions to accomplish their goals and objectives, develop a means of measuring progress, and regularly report on their achievements. The GPRA framework provided the RCRA Corrective Action program with intermediate goals and objectives. Environmental Indicators for human exposure and groundwater control are used to measure progress in environmental terms rather than administrative process steps. More information is available on USEPA's RCRA Corrective Action website (USEPA, 2010b).

3.2.1 Overall Expectations

USEPA guidance states the following expectations and objectives for corrective action at RCRA sites (ANPR Section III(C)(5)(b)-(j)):

- Protection of human health and the environment
- Attainment of media cleanup objectives (site-specific, risk-based description of MCSs, points of compliance, cleanup time frames, and other details)
- Control of the source(s) of releases so as to reduce or eliminate, to the extent practicable, further releases of hazardous waste (including hazardous constituents) that might pose threats to human health and the environment
- Compliance with applicable standards for waste management.

USEPA proposed these four criteria as threshold criteria for any RCRA remedy. In addition, five balancing criteria were proposed to aid in remedy selection: 1) long-term reliability and effectiveness; 2) reduction of toxicity, mobility, or volume of wastes; 3) short-term effectiveness; 4) implementability; and 5) cost.

3.2.2 Comparison with CERCLA

One of the key differences between RCRA and CERCLA is the greater site-specific flexibility of setting cleanup standards. Under RCRA, sites are under no legal requirement to meet ARARs, only MCSs. MCSs are broad cleanup objectives that incorporate specific criteria including cleanup levels, points of compliance, and compliance time frames. Under RCRA, groundwater cleanup levels may be set at background concentrations, at the maximum concentrations established in 40 CFR 264.94, or at risk-based concentrations developed from exposure scenarios that are appropriate for current and future land use and aquifer beneficial uses (i.e., alternative concentration limits). If MCSs are exceeded at a regulated unit, the RCRA facility permit will be amended to require an investigation and corrective measures to restore groundwater to MCSs, which are recorded in the facility's permit.

Consistency with CERCLA is encouraged, despite differences in definitions, jurisdiction, enforcement methods, and cost recovery framework between the two regulations (Garrett, 2004). Like CERCLA, the goal of RCRA is to return usable groundwaters to the maximum beneficial use (USEPA, 2004). At some sites, USEPA may require adherence to ARARs to maintain consistency with CERCLA response actions, even if the site is being regulated under RCRA (Malcolm Pirnie, 2002). Source control and plume containment are common remedial approaches implemented under both RCRA and CERCLA to protect human health and the environment. Like CERCLA, RCRA also recognizes technical limitations to groundwater restoration. Where aquifer restoration is deemed technically impracticable from an engineering perspective at a RCRA site, a TI determination may be made (ANPR Section III(C)(5)(h)). Under RCRA, a TI determination indicates that no fixed MCS, point of compliance, or compliance time frame need be established within a defined volume of the plume. Alternatively, a non-risk-based performance measure could be established. Areas of the groundwater plume outside the TI zone must still be remediated to MCSs.

3.3 STATE LEAD/VOLUNTARY CLEANUP PROGRAMS

Environmental remediation under other programs (such as voluntary cleanups under state oversight) is typically patterned after RCRA or CERCLA. A review of state-specific statutes, regulations, and policy is beyond the scope of this report. However, in general, based on research and other reports (e.g., USEPA, 2007), many states have policies that allow for flexibility regarding alternative endpoints, primarily through groundwater classification and containment/ management zone designations.

Most states have groundwater classification systems in place that indicate the groundwater use, value, and vulnerability. The groundwater designation and states' associated expectations provide context for defining ARARs and determining cleanup goals. Almost all states have some form of nondegradation policies, that is, further degradation of groundwater supplies is not permitted. As described in Section 3, state agencies in Maine, Rhode Island, Wyoming, and California (California Regional Water Quality Control Board [RWQCB] – Central Valley Region) have broadly interpreted nondegradation policies to specify groundwater quality goals, objectives, and even cleanup standards (e.g., MCLGs or background levels). Other states (e.g., Connecticut) have formal state-wide mapped classification systems for groundwater resources. States with nondegradation policies may use these to determine cleanup endpoints. Some state regulatory agencies express anti-degradation policies as a goal, whereas others view them as remedial cleanup objectives.

In addition to general groundwater classifications, most states allow for site-specific variations or exceptions for groundwater classification, sometimes limited to the cleanup program (e.g., site-specific classification methods for urban brownfields sites, voluntary cleanup programs, or underground storage tank programs). Different states use different nomenclature to describe similar management zones. The purpose of the zones may vary by state, with some zones established primarily as a way to keep track of areas with contaminated groundwater and the related ICs. Other zone designations are related to technical and economic feasibility of cleanup. A preliminary review of available information indicates that at least 13 states (California, Delaware, Georgia, Illinois, Michigan, Missouri, Nebraska, New Hampshire, New Jersey, Ohio, Tennessee, Texas, and Wyoming) consider some form of groundwater CZs in their corrective action policies (Malcolm Pirnie, 2002). Several examples of state designations are shown in Table 3. These designations may allow for consideration of alternative endpoints and approaches.

Table 3. Examples of state designations for groundwater.

State	Designation	Reference
California, State Water Resources Control Board	CZ	State Water Resources Control Board Resolution No. 92-49
California, RWQCB, San Francisco (SF) Bay Region	Low-threat closures	California RWQCB, 2009
California Department of Public Health (formerly Department of Health Services)	Extremely impaired sources	State of California Department of Health Services Policy Memorandum 97-005
Delaware Department of Natural Resources and Environmental Control	GMZs	Remediation Standards Guidance under the Delaware Hazardous Substance Cleanup Act
Georgia Voluntary Remediation Program Act	TI	Senate Bill (SB) 78 (Amended Article 3 of Chapter 8 of Title 12 of the Official Code of Georgia Annotated)
Illinois EPA RCRA Facilities	GMZ	35 Illinois Administrative Code Part 620.250
Illinois EPA	Consideration of TI through risk-based corrective action programs, tiered remedial objectives	35 Illinois Administrative Code Part 742
Michigan Department of Environmental Quality (DEQ) Waste Management Division	Groundwater-not-in-an-aquifer determinations	Michigan Natural Resources and Environmental Protection Act, 1994 PA 451; Part 31, Water Resources Protection; Part 111, Hazardous Waste Management and Part 115, Solid Waste Management
Missouri Department of Natural Resources Voluntary Cleanup Program	Tiered cleanup levels	Missouri Department of Natural Resources, Cleanup Levels for Missouri Fact Sheet
Nebraska DEQ	Procedures for changing a groundwater classification; institutional control area	Nebraska DEQ Title 118, Chapter 8
New Hampshire Department of Environmental Services	GMZ	New Hampshire Code of Administrative Rules, Chapter Env-Or 600
New Jersey Department of Environmental Protection	Classification exemption areas	New Jersey Administrative Code 7:9-6:6
New Jersey Department of Environmental Protection	TI	New Jersey Administrative Code 7:26E-6.1(d)
Ohio EPA's Voluntary Action Program	Urban setting designation (USD)	Ohio Administrative Code Rule 3745-300-10
Tennessee Department of Environment and Conservation, Tennessee Water Quality Control Board, Division of Water Pollution Control	Site-specific impaired groundwater	Rule 1200-04-03
Texas Commission on Environmental Quality (TCEQ)	Municipal setting designation (MSD)	Chapter 361, Texas Health and Safety Code, §§361.801-808
TCEQ	PMZ	30 Texas Administrative Code (TAC) § 350.33(f)(3)(A)-(E); 30 TAC § 350.37(1)(4)
Wyoming DEQ Voluntary Remediation Program	TI determination and establishment of alternative cleanup levels	Wyoming Statutes § 35-11-1605(d)

A number of these designations were discussed in a recent report by the USEPA Ground Water Task Force (USEPA, 2007). This document highlighted the need to summarize how individual USEPA and state cleanup programs consider groundwater use, value, and vulnerability in setting cleanup goals. Although a comprehensive identification of state policies is beyond the scope of this report, several case studies are presented in Section 4.

The CERCLA and RCRA regulatory frameworks, along with state policies and regulations, have provided flexibility to accommodate several alternative endpoints and approaches, as described in Section 4.

4.0 ALTERNATIVE ENDPOINTS AND APPROACHES FOR GROUNDWATER REMEDIATION

4.1 OVERVIEW OF ALTERNATIVE ENDPOINTS AND APPROACHES

Per regulatory statute, all remedial endpoints (i.e., final cleanup standards) must be protective of human health and the environment. All remedial endpoints must fulfill statutory requirements of different federal, state, and local regulations, as documented in the NCP, Federal Register, or in similar state and local government codes. However, regulations allow for site-specific conditions by describing general remedial goals, expectations, and process requirements. These regulations are substantive rather than procedural and are therefore subject to some interpretation, opening up possibilities for alternative endpoints and approaches.

The term "alternative endpoints" is used in this report to describe formal designations for alternative final remedial goals. These include the six types of ARAR waivers, ACLs (which can be established for CERCLA sites meeting specific conditions and at RCRA sites), and analogous formal designations under state and local cleanup programs (e.g., California CZ under the State Water Control Board Resolution 92-49).

"Alternative approaches" is a term used in this report to describe alternative approaches to a final remedy in order to achieve the same long-term, absolute, objective. Examples of alternative approaches include remedies with very long time frames needed to achieve cleanup objectives, methods of zoning of groundwater aquifers to preclude stringent ARARs, and remedies that establish functional objectives, such as designated locations for determining compliance with cleanup objectives or qualitative language regarding mass removal to the extent practicable. Complex sites that consider formal alternative endpoints often implement these approaches; some decision documents discuss alternative endpoints as a potential future remedy.

Based on research efforts and professional experience, Malcolm Pirnie staff compiled a list of different types of alternative endpoints and approaches. The list includes the following:

- TI waivers
- Greater risk ARAR waivers
- Other ARAR waivers based on equivalent performance, inconsistent application of state standards, fund balancing, or interim remedy
- ACLs
- Groundwater management/CZs (e.g., California CZs)
- Groundwater reclassification/classification exemptions
- MNA over long time frames
- Adaptive site management
- Remediation to the extent practicable.

Most of these terms are used in regulations and/or site decision documents. Other terms (e.g., adaptive site management) may not be used in site documents and are merely descriptive terms in this report to group a variety of similar processes and approaches.

Although alternative endpoints are specifically accepted by regulations as viable components of a final remedy, many factors are often considered before deciding whether an alternative endpoint is appropriate for a site and prior to documenting the decision. For example, what other components of the final remedy will maintain protectiveness? What area of the site will be subject to the alternative endpoint and how will the extent of that area be determined? What tools and metrics will be used in support of the alternative endpoint evaluation and decision? The way these questions have been addressed at other sites is described later in this section.

As with alternative endpoints, there is much to be learned from sites where alternative approaches are reflected in the selected final remedy. What approaches have been used at these sites? How were regulations interpreted by each remedy? What other approaches were considered? What data or analyses were used as the basis of the decision? Did the selected remedy advance the site along the pathway towards site closure?

To better understand alternative endpoints and approaches in practice, Malcolm Pirnie researched each type of alternative endpoint and approach and identified case studies that have implemented these approaches.

4.2 METHODOLOGY

Remedies selected at CERCLA sites are well-documented in site records of decision (ROD), ROD amendments, and explanations of significant differences (ESD). This made it possible for Malcolm Pirnie to identify and research CERCLA sites considering ARAR waivers and other alternative endpoints and approaches. The project team used a keyword search for the terms "impracticability" and "impracticable," then reviewed each ROD referencing these keywords to identify whether the site had in fact received a TI waiver or other alternative endpoint. Examples of CERCLA sites obtaining other types of ARAR waivers were similarly identified through professional experience and a keyword search of the CERCLA ROD database, Five-Year Review database, general online research, and project team professional experience. Results are described in Sections 4.3 through 4.11.

Case studies of RCRA and state sites implementing other alternative endpoints and approaches were identified through professional experience, communications with DoD and federal and state regulators, and general online research (particularly state websites). The project team identified at least one case study for each type of alternative endpoint and approach. Where additional case studies were easily identified, they were also referenced in this report. Results are presented in Section 4.4 through Section 4.11.

4.3 TECHNICAL IMPRACTICABILITY

4.3.1 Description

TI is one of six reasons for an ARAR waiver under CERCLA and is the most widely used ARAR waiver. It has also been applied to non-CERCLA sites, including several state cleanup programs. USEPA has discussed the use of TI waivers at RCRA sites (see, e.g., USEPA, 1993); however, TI waivers are not often used at RCRA sites. Sites incorporating TI waivers into final decision documents must ensure that the final remedy is protective of human health and the environment. In addition, the remedy must specify the spatial three-dimensional area (TI zone) in which ARARs or other cleanup standards will not be achieved. Outside the TI zone, traditional cleanup objectives will still remain as the final cleanup goal. Details on the TI evaluation process at CERCLA sites are described in USEPA guidance (USEPA, 1993).

4.3.2 Case Studies

A number of CERCLA sites receiving TI waivers for groundwater contamination were identified through research efforts. The project team attempted to comprehensively identify all CERCLA sites with TI waivers using a keyword search of the CERCLA ROD database. Approximately 77 sites were identified as of November 2010, as listed in Table 4. Fact sheets on each site are provided in Appendix A.

Table 4. List of CERCLA sites with TI waivers for groundwater.

#	Site Name	St	USEPA ID	Doc Date	USEPA Region
1	Aberdeen Proving Ground (Edgewood Area) - Canal Creek Beach Point	MD	MD2210020036	9/24/1997	3
2	Aberdeen Proving Ground (Edgewood Area) - J-Field	MD	MD2210020036	9/28/2001	3
3	Aladdin Plating	PA	PAD075993378	12/30/1993	3
4	Aluminum Company of America - Davenport	IA	IAD005270160	9/28/2004	7
5	Anaconda Co. Smelter	MT	MTD093291656	9/29/1998	8
6	Broderick Wood Products	CO	COD000110254	3/24/1992	8
7	Brodhead Creek	PA	PAD981033285	6/30/1995	3
8	Caldwell Trucking Company	NJ	NJD048798953	9/28/1989	2
9	California Gulch	CO	COD980717938	9/22/2009	8
10	Charles-George Reclamation Trust Landfill	MA	MAD003809266	9/29/1988	3
11	Chemical Insecticide Corp.	NJ	NJD980484653	12/22/2003	2
12	Cherokee County (Galena)	KS	KSD980741862	9/18/1989	7
13	Cherokee County (Treece/Baxter)	KS	KSD980741862	8/20/1997	7
14	Conrail Rail Yard (Elkhart)	IN	IND000715490	9/27/2000	5
15	Continental Steel Corp.	IN	IND001213503	9/30/1998	5
16	Crystal Chemical Company	TX	TXD990707010	3/19/1997	6
17	Del Norte Pesticide Storage	CA	CAD000626176	8/29/2000	9
18	Dorney Road	PA	PAD980508832	9/30/1991	3
19	DuPont/Necco Park	NY	NYD980532162	9/18/1998	2
20	Durham Meadows	CT	CTD001452093	9/30/2005	1
21	Edwards AFB South Air Force Research Laboratory	CA	CA1570024504	9/24/2007	9

Table 4. List of CERCLA sites with TI waivers for groundwater. (continued)

#	Site Name	St	USEPA ID	Doc Date	USEPA Region
22	Eielson AFB OU 2	AK	AK1570028646	9/29/1998	10
23	Eielson AFB ST58, OU 4	AK	AK1570028646	9/29/1998	10
24	Elizabeth Mine Superfund Site	VT	VTD988366621	9/28/2006	1
25	Federal Creosote	NJ	NJ0001900281	9/30/2002	2
26	Garland Creosoting	TX	TXD007330053	9/15/2006	6
27	GE Moreau	NY	NYD980528335	10/4/1994	2
28	Hardage/Criner	OK	OKD000400093	11/22/1989	6
29	Hart Creosoting Company	TX	TXD050299577	9/21/2006	6
30	Heleva Landfill	PA	PAD980537716	9/30/1991	3
31	Highway 71/72 Refinery	LA	LAD981054075	9/28/2000	6
32	Hocomonco Pond	MA	MAD980732341	9/21/1999	1
33	Horseshoe Road/Atlantic Resources	NJ	NJD980663678	9/30/2004	2
34	Hunterstown Road	PA	PAD980830897	8/2/1993	3
35	Iowa City Former Manufactured Gas Plant	IA	IAD984591172	9/26/2006	7
36	J.H. Baxter & Co	CA	CAD000625731	3/27/1998	9
37	Jasper Creosoting Company Inc.	TX	TXD008096240	9/20/2006	6
38	Keystone Sanitation Landfill	PA	PAD054142781	6/25/1999	3
39	Koppers Co., Inc. (Oroville Plant)	CA	CAD009112087	9/23/1999	9
40	Libby Groundwater Contamination	MT	MTD980502736	9/14/1993	8
41	Lindane Dump	PA	PAD980712798	3/31/1992	3
42	Loring AFB Entomology Shop/Jet Engine Build-Up Shop	ME	ME9570024522	9/19/1999	1
43	Loring AFB Quarry Site	ME	ME9570024522	9/19/1999	1
44	Love Canal	NY	NYD000606947	5/15/1991	2
45	McKin Co.	ME	MED980524078	3/30/2001	1
46	Middletown Air Field	PA	PAD980538763	12/17/1990	3
47	Midland Products	AR	ARD980745665	6/9/2006	6
48	Missouri Electric Works	MO	MOD980965982	9/28/2005	7
49	Montrose/Del Amo	CA	CAD029544731 CAD008242711	3/30/1999	9
50	Naval Air Development Center (8 Waste Areas)	PA	PA6170024545	9/27/2000	3
51	Niagra Mohawk Power Corp. (Saratoga Springs Plant)	NY	NYD980664361	9/29/1995	2
52	O'Connor Co.	ME	MED980731475	9/26/2002	1
53	Old Springfield Landfill	VT	VTD000860239	9/28/1990	1
54	Oronogo-Duenweg Mining Belt	MO	MOD980686281	7/29/1998	7
55	Pease AFB	NH	NH7570024847	9/26/1995	1
56	Petro-Chemical Systems, Inc. (Turtle Bayou)	TX	TXD980873350	9/22/2006	6
57	Pinette's Salvage Yard	ME	MED980732291	5/30/1989	1
58	Popile, Inc.	AR	ARD008052508	9/28/2001	6
59	Revere Chemical Corporation	PA	PAD051395499	6/20/1996	3
60	Riverfront	MO	MOD981720246	3/26/2009	7
61	Rodale Manufacturing Site	PA	PAD981033285	9/30/1999	3
62	Roebling Steel Company	NJ	NJD073732257	9/1/2003	2
63	Schofield Barracks	HI	HI7210090026	2/7/1997	9
64	Silver Bow Creek/Butte Area	MT	MTD980502777	9/29/1994	8
65	South Municipal Water Supply Well Site	NH	NHD980671069	2/3/1997	1
66	Sullivan's Ledge	MA	MAD9807343	6/28/1989	1
67	Tansitor Electronics, Inc.	VT	VTD000509174	9/29/1995	1

Table 4. List of CERCLA sites with TI waivers for groundwater. (continued)

#	Site Name	St	USEPA ID	Doc Date	USEPA Region
68	Tucson International Airport Area	AZ	AZD980737530	9/30/1997	9
69	UGI Columbia Gas Plant	PA	PAD980539126	9/24/2007	3
70	Vertac, Inc.	AR	ARD000023440	9/17/1996	6
71	Waterloo Coal Gasification Plant	IA	IAD984566356	8/11/2006	7
72	West Site/Hows Corners	ME	MED985466168	9/28/2006	1
73	Westinghouse Electric Corp. (Sharon Plant)	PA	PAD005000575	2/20/2003	3
74	Westinghouse Electric Corp. (Sunnyvale Plant)	CA	CAD001864081	10/16/1991	9
75	Westinghouse Elevator Co. Plant	PA	PAD043882281	6/30/1992	3
76	Whitewood Creek	SD	SDD980717136	3/30/1990	8
77	Whitmoyer Laboratories	PA	PAD003005014	12/31/1990	3
78	Yellow Water Road Dump*	FL	FLD980844179	6/30/1992	4

*TI waiver was later revoked at this site.

Recent groundwater TI waivers were approved at Edwards AFB South Air Force Research Laboratory (AFRL) (ROD dated 9/24/2007) and the California Gulch site OU 12 (ROD dated 9/22/2009). Edwards AFB South AFRL has a large TI zone, extending over 16 square miles. The site has known solvent releases from historical rocket motor/fuel testing and subsequent cleaning and disposal into sumps and dry wells. Contaminants include perchloroethylene (PCE) and trichloroethylene (TCE). There are suspected DNAPL source areas in fractured rock. The geology at the site consists of a thin zone of unconsolidated soil (silty sand) overlying granitic bedrock. The depth to first groundwater ranges from 20 to 200 ft, averaging 120 ft, flowing through a network of fractures. Hydraulic conductivity has a similarly broad range, from 10^{-7} to 10-1 centimeters per second (3.3×10^{-9} to 10^{-3} ft per second). Wells generally pump at less than 0.5 gallons per minute (gpm).

A significant effort was made over the past decade to characterize the South AFRL and evaluate remedial technologies through treatability studies. Site characterization techniques included the installation of monitoring wells, preparation of boring logs, quarterly water level measurements, surface fracture and mapping of lineaments, high-resolution 3-D seismic reflection survey, aquifer tests, tracer studies, and rock coring. Treatability studies evaluated dual phase extraction, pump-and-treat, soil vapor extraction (SVE), blast fracturing, in situ bioremediation, thermal treatment, and steam injection. A model was developed to simulate contaminant transport over a large area (the three plumes cover approximately 7.7 square miles). The closest town of Boron, CA, is approximately 2 miles from the leading edge of the closest plume. Other potential future receptors include production wells located on- and off-base (6 and 2 miles from plumes, respectively). Based on the CSM substantiated by the significant level of effort and documented field studies, stakeholders supported an ROD that included a TI decision.

Another front-end TI waiver was incorporated into the final remedy for shallow groundwater at a small portion of a former mining site, OU 12 of the California Gulch Superfund site in Leadville, CO. The remedy waived drinking water MCLs for lead and cadmium throughout the TI zone. Metal concentrations in groundwater monitoring wells have been shown to decrease as mine waste features were removed or capped. However, MCLs were not expected to be met within a reasonable time frame (100 years) due to large amounts of waste left in place. Large-scale excavation would need to cover a section of waste rock approximately 100 to 200 ft wide, 4 miles long, and 50 ft deep. Costs for complete excavation were expected to be $200 million at a minimum. Complete excavation would potentially damage watershed drainage patterns, require a location to put excavated material, and cause general disruption to the community. Excavation was therefore not considered a realistic alternative. In addition to the TI waiver, the selected remedy included LTM, five-year reviews, and ICs to restrict the use of contaminated groundwater as drinking water.

4.3.3 TI Waivers for Media Other than Groundwater

The use of TI waivers for media other than groundwater is not the focus of this report. However, as a result of this research, examples of CERCLA sites receiving TI waivers for chemical-specific ARARs for soil, sediments, and surface water were identified, as well as several examples of sites receiving TI waivers for location-specific and action-specific ARARs. These are listed in Table 5.

Table 5. Examples of TI waivers granted for other media.
(Soil, sediments, surface water)

Name	OU	Document	Date	Media/ARAR
Butler Mine Tunnel	1	ROD	7/15/95	Surface water – National Pollutant Discharge Elimination System and State water quality criterion
EI Du Pont De Nemours & Co., Inc. (Newport Pigment Plant Landfill)	1	ROD	9/29/93	Surface water – State water quality standards
Milltown Reservoir Sediments	3	ROD	4/29/04	Surface water; sediments – State water quality standards; Floodplain mine waste removal
Summitville Mine	8	ROD	9/28/01	Surface water – State water quality standards
Commencement Bay, Near Shore/Tide Flats	19	ROD	7/14/00	Sediments (off-shore) – All ARARs
E.H. Schilling Landfill	1	ROD	9/29/89	Soil (cap) – State landfill capping requirement
Global Sanitary Landfill	1	ROD	9/11/91	Soil (cap) – State landfill capping requirement
JIS Landfill	1	ROD	8/15/95	Soil (cap) – State landfill capping requirement
Naval Undersea Warfare Engineering Station (4 waste areas)	2	ROD	9/1/94	Soil – State of Washington’s Model Toxics Control Act cleanup level; use of Practical Quantification Limit and soil ingestion cleanup level instead
Weldon Spring Quarry/Plant/Pits (U.S. Department of Energy/Army)	1	ROD	9/27/93	Soil – Land disposal restrictions, State Radon 222 requirement

4.4 GREATER RISK

4.4.1 Description

This ARAR waiver applies if activities undertaken to meet an ARAR would result in greater risk or harm to human health and the environment than waiving that ARAR and choosing another alternative. The nature of the potential greater risks may vary with the site circumstances. Some examples include the following:

- Greater risk to drinking water aquifer(s) due to potential contaminant mobilization during remedial activity. This line of reasoning might be particularly applicable at a site with DNAPL.
- Greater risk to nearby wetlands, agriculture, and ecosystems of implementing pump-and-treat remedies that lead to dewatering or land subsidence.
- Greater risk to sensitive ecosystems in areas where remediation activities would be a disturbance.
- Greater risk posed by explosive hazards or other health and safety hazards associated with particular remedial technologies. If the only technologies suitable for meeting ARARs were determined to pose a greater risk than other technologies, this waiver would be applicable.
- Greater risk to ecosystem of sediment disturbance during dredging or excavation. This waiver would more likely be applicable to sediments or surface waters than groundwater.
- Liner or capping requirements that affect the amount of natural flushing that occurs could potentially extend the time for groundwater to reach ARARs, resulting in greater risk.

Several examples of greater risk waivers were identified via ROD keyword searches. Fact sheets of case studies using greater risk ARAR waivers for groundwater are provided in Appendix B. Case studies are briefly described in the following section.

4.4.2 Case Studies

Although it is beyond the scope of this project to comprehensively identify sites that have received ARAR waivers based on greater risk, several examples were identified from a preliminary search through the CERCLA ROD database. These are listed in Table 6.

Table 6. Examples of ARAR waivers based on greater risk.

Site Name	OU	Document	Date	Media/ARAR waived
E.I. Du Pont de Nemours & Co., Inc. (Newport Pigment Plant Landfill)	1	ROD	9/29/93	Groundwater – ARARs in Potomac and Columbia Aquifers
Onondaga Lake	5	ROD	9/29/00	Groundwater – ARARs within CZ
Moss American Superfund Site	1	ROD	9/27/90	Cap requirements that would adversely impact groundwater quality
Maxey Flats Nuclear Disposal	1	ROD	9/30/91	Soil – Land disposal restrictions for chemicals
New Bedford	1	ROD	9/25/98	Surface water and seafood – Clean Water Act and Food, Drug and Cosmetic Act
U.S. Navy Air Station Cecil Field	1	ROD	10/2/95	Surface water – State surface water quality standards for iron, lead, and nickel

The E.I. du Pont de Nemours & Co. site (Appendix B, site 1a) received two types of ARAR waivers: an ARAR waiver for groundwater based on greater risk and a TI waiver for surface water ARARs. This site includes a paint pigment production facility, a chromium dioxide production facility, and two industrial landfills separated by a river. The selected remedy for groundwater consisted of LTM, installation of a public water supply line, and establishment of a GMZ. Based on data collected during the remedial investigation/feasibility study (RI/FS), attempts to remediate the lower (Potomac) aquifer would draw more contamination into this aquifer from the more contaminated upper (Columbia) aquifer. Remedial attempts in the upper aquifer would adversely affect wetland areas. More details on the site background and selected remedy can be found in the original 1993 ROD.

An ARAR waiver for groundwater based on greater risk was approved for the Onondaga Lake site in Syracuse, NY (Appendix B, site 1b). This site was a manufacturing facility for sodium hydroxide and liquid chlorine using a mercury cell process, followed by subsequent manufacturing of hydrochloric acid and bleach production. The primary groundwater contaminant is elemental mercury DNAPL. The groundwater remedy selected in 2000 consisted of a barrier wall installed in the top 55 ft down to glacial till, hydraulic containment within the barrier using pump-and-treat, LTM, and deed restrictions. A time frame of 30,000 years to reach ARARs was estimated, indicating that complete restoration of groundwater was also technically impracticable. However, groundwater ARARs were waived on the basis of greater risk, citing losses of wetlands from dewatering if a more aggressive pump-and-treat system were installed. Greater risks from on-site soil excavation and treatment included lots of truck traffic, fugitive dusts and air pollution, lack of community acceptance, and increased traffic accidents.

At the Moss-American Superfund site (Appendix B, site 1c), a greater risk waiver was applied to RCRA Subtitle C capping requirements and state requirements for a double-liner/leachate collection system as part of the original 1990 ROD. Installing an impermeable cap and liner would have reduced the natural flushing and prolonged the groundwater treatment time. This greater risk waiver was later revoked by a 1997 ESD, based on new information that indicated a greater presence of DNAPL. Source control measures were then taken for soils in the area.

ARAR waivers based on greater risk have been approved for soil, surface water, and seafood (fish tissues), as listed in Table 6. More details can be found in the referenced RODs.

4.5 OTHER ARAR WAIVERS

4.5.1 Description

In addition to ARAR waivers based on TI and greater risk, four other types of waivers are identified in CERCLA regulations. These include ARAR waivers for 1) interim measures, 2) equivalent standard of performance, 3) inconsistent application of state standards, and 4) fund-balancing (Section 2.1.2). As with TI waivers and ARAR waivers based on greater risk, a search for case studies was conducted via keyword search of the CERCLA ROD database, Five-Year Review database, general online search, and project team professional experience. Each type of ARAR waiver is described in more detail as follows.

Interim measures, or interim remedies, do not have to meet ARARs. However, all interim remedies must be replaced by final remedies prior to meeting RIP and other cleanup milestones. Therefore, this type of ARAR waiver does not provide an alternative endpoint. ARAR waivers for interim measures may be used in conjunction with or be replaced by another type of alternative endpoint and approach described in this document. At complex sites, interim remedies may be in place for many years as RI, pilot-testing, and remedy selection proceeds. (See, for example, the case study of Hastings Ground Water Contamination described in Section 3.4.2). As stated in the NCP preamble, however, interim measures should be followed within a reasonable time by complete measures that attain ARARs.

An ARAR waiver based on equivalent standard of performance would be considered if the proposed alternative to complying with the ARAR provided equivalent performance and protection of human health and the environment. The intent of this ARAR waiver was clarified in the NCP Preamble: "... the purpose of the waiver is to allow alternative technologies that provide a degree of protection as great or greater as the specified technology. ... EPA believes that the... degree of protection, level of performance, and future reliability, should at least be equaled for an alternative to be considered equivalent. While it is possible that there may be redundancy among the three, a lesser level in any of these criteria would compromise equivalency with the original standard" (55 Federal Register 8749-8750, March 8, 1990). No case studies of application of this waiver to groundwater were identified.

Inconsistent application of state requirements refers to a waiver of state ARARs if the state has not consistently applied it to other sites. No specific procedure was established in the NCP for tracking ARARs and demonstrating that they had been applied consistently at sites. The NCP Preamble stated that a standard would be presumed to be consistently applied unless there was reason to believe otherwise. In other words, the burden of proof lies with the individual site rather than with the state.

Fund balancing is another reason for waiving an ARAR. This waiver first appeared in the 1985 NCP and was codified by SARA in 1986. This waiver may apply when the costs needed to meet ARARs would be so high as to threaten the Superfund's ability to address other sites. The purpose of the waiver was to ensure that USEPA's ability to carry out a comprehensive national response program was not compromised by a single disproportionately high expenditure at a site (USEPA, 1991). Some state cleanup programs may have parallel concerns. This waiver is not applicable at DoD sites, which do not use Superfund dollars.

4.5.2 Case Studies

Based on a search of the RODs database, ARAR waivers based on equivalent performance, inconsistent application of state standards, and fund-balancing have never been used for groundwater.

Significant discussion of "inconsistent application of state standards" occurred prior to finalizing the off-post ROD dated 12/19/1995 at Rocky Mountain Arsenal (Appendix B, site 3a); at issue were Colorado Basic Standards for Groundwater (CBSG) that had recently been promulgated for contaminants primarily found at Rocky Mountain Arsenal. However, the CBSGs were accepted as ARARs in the final ROD, and the ARAR waiver does not appear to have been used.

The "equivalent standard of performance" waiver has been commonly applied to landfill capping requirements, for example, when a more cost-effective type of capping material could be substituted without compromising cap integrity. It does not appear to have been used for groundwater.

ARAR waivers based on interim measures have been used at many sites. However, this is a temporary ARAR waiver, as interim remedies must eventually be replaced with final remedies. At some complex sites operating under interim remedies, an alternative endpoint or approach is likely to be a component of the final remedy. For example, the Hastings Ground Water Contamination site, OU 19 (Appendix B, site 2a), selected an interim remedy for groundwater which primarily consists of ICs and groundwater monitoring. As stated in the ROD, dated 6/25/2001, none of the alternatives achieved ARARs and therefore could not be selected as a final remedy. USEPA stated that monitoring would be conducted to determine if it would be technically impracticable to meet ARARs. In response to a public comment, the ROD stated that alternative endpoints (TI waiver or ACLs) might be considered as part of the final remedy:

> "However, EPA would not consider an application for a TI waiver or ACLs appropriate until response actions have indicated that contaminant concentrations have leveled off after a period of time, or further improvement in ground water quality using available technologies is shown to be impractical."

At Hastings, data were not sufficient to support a final ROD incorporating a TI decision; therefore, an interim remedy was proposed instead. USEPA's recommendation to consider TI early in the CERCLA cleanup process and to continually refine the CSM during the RI phase may be useful for avoiding further delay of final remedies (USEPA, 1993).

Site SS-01 of Brandywine DRMO, Andrews AFB, MD (Appendix B, site 2b), is another complex site operating under an interim remedy. The interim ROD, dated 9/2006, stated that it is impractical to treat groundwater within the source zone area to MCLs, due to the presence of DNAPL. Data from the interim remedy (hydraulic containment, ICs, enhanced bioremediation, and bioaugmentation) will be used to evaluate the remediation potential of the final remedy.

4.6 ACLS

4.6.1 Description

As described previously in Section 3, ACLs were authorized at CERCLA sites under CERCLA Section 121(d)(2)(B)(ii). The regulation stated that ACLs may be considered as part of response actions in place of ARAR cleanup levels (e.g., MCLs) provided that the following criteria are met:

- Groundwater discharges into surface water (there are “known and projected points of entry” to surface water).
- Groundwater discharge does not lead to a “statistically significant increase” of contaminants in the surface water or any “accumulation” of contaminants downstream.
- ICs prevent human exposure to contaminated groundwater between the facility boundary and the discharge points of groundwater into surface water.

A recent USEPA policy memorandum (USEPA, 2005) specified several additional factors to consider prior to establishing ACLs, including the following:

- Whether all plumes of contaminated groundwater are discharging to surface water (e.g., are contaminants present in a deeper aquifer that does not discharge to surface water?)
- Whether significant degradation of the aquifer might occur prior to discharge to surface water (e.g., could the plume spread to uncontaminated portions of the aquifer?)
- Whether “known and projected” points of entry of the plume(s) into surface water have been, or can be, specifically identified
- Consideration of accumulation of contaminants in sediments or below points of entry into surface waters
- Whether groundwater can be restored
- The potential for degradation byproducts within the zone between the source and points of entry to surface waters, and the potential for “statistically significant” increase in degradation products in surface water and corresponding risks.
- Whether ICs and other enforceable measures can preclude human exposure to groundwater contaminants above health-based levels
- Whether total maximum daily loads (TMDL) have been established for surface waters and whether the ACL could result in a TMDL exceedance.

In contrast, the criteria for determining whether ACLs are appropriate at RCRA sites are not as prescriptive. Per RCRA regulations (40 CFR 264.94), ACLs can be established as long as the concentration level does not pose a substantial risk to human health or environment. This determination is made after considering the potential adverse effects on groundwater quality, and the potential adverse effects on hydraulically connected surface water quality. When considering the potential adverse effects of an ACL decision, several factors were deemed important, including waste characteristics and mobility, hydrogeologic setting, groundwater flow, groundwater and surface water usage (current and future), surface water quality standards, existing groundwater and surface water quality and quantity, rainfall patterns, proximity of source zone to surface waters, potential for human exposure and related health risks, potential for other risks, and the permanence of potential adverse effects (40 CFR 264.94).

4.6.2 Case Studies

The USEPA memorandum (2005) appears to make the use of ACLs more difficult at CERCLA sites. The Waterloo Coal Gasification Plant (Appendix B, site 4a) is a CERCLA site in Iowa that recently rescinded ACLs and approved a TI waiver instead. The decision was documented in an ESD for OU 1 dated August 11, 2006. Although a 2004 ROD had approved ACLs, the actual ACL values had not been approved at the time of the ROD. According to the ESD, USEPA (the lead agency) decided as a policy matter not to use the ACL approach to address groundwater at the site. This is consistent with the timing of the USEPA memorandum titled “Use of Alternate Concentration Limits in Superfund Cleanups” (USEPA, 2005).

At the Winthrop Landfill site (OU 1) (Appendix B, site 4b), an ESD dated 2/14/2007 upheld ACLs that had been approved in a 1985 ROD. A groundwater pump-and-treat system had been operating from 1995 to 2002 and was determined to no longer be needed in order to meet ACLs.

Several Navy sites have approved or are considering ACLs. NSWC Crane, located in Crane, IN, is a RCRA site that has adopted ACLs based on a site-specific risk assessment (Appendix B, site 4c). A variety of Navy waste management practices at SWMU 3, including open burn techniques, historically contaminated groundwater beneath the site with Royal Demolition eXplosive (RDX) and other compounds. Contaminated groundwater flows through karst conduits and discharges through surface springs to the nearby Little Sulphur Creek. RDX concentrations have been shown to decrease downstream of the springs due to dilution/mixing effects. In addition, significant natural attenuation was demonstrated to occur over time. The final remedy accepted by stakeholders included Land Use Controls and ACLs for the springs, calculated to achieve state water quality standards for point-source discharge limits. The proposed water quality standards were 140 µg/L RDX in water discharging from the spring, 240 µg/L RDX in (nonpotable) surface water, and 3 µg/L RDX at the public water supply intake located approximately 11 miles downstream. This site was included as a case study of groundwater risk management practices in a handbook recently published by the Navy (NAVFAC, 2008).

Another Navy site with ACLs is the former Long Beach Naval Complex, Long Beach, CA (Appendix B, site 4d), where groundwater beneath a peninsula is contaminated with volatile organic compounds (VOC). ACLS were developed at the land’s edge based on California Ocean Plan criteria. The site reached RC in 2007 and has ceased groundwater monitoring. The Navy is still maintaining ICs and conducting five-year reviews. Finally, Jacksonville NAS OU 3 (Appendix B, site 4e) recently updated their CSM and is in the process of conducting fate and transport modeling and a mixing zone analysis to develop ACLs for groundwater that discharges into the St. Johns River (NAVFAC, 2008).

At Oak Ridge National Laboratory, an approach similar to ACLs was used for ^{226}Ra and ^{232}Th, as documented in RODs dated 4/19/2005 (OU 15) and 4/21/2006 (OU 50). Details are provided in the RODs.

4.7 GROUNDWATER MANAGEMENT/CONTAINMENT

4.7.1 Description

The basic concept of a GMZ, CZ, or WMA is similar, although the terminology and exact meaning vary among states. These zones indicate that groundwater contamination is present above permissible levels. Groundwater within these zones may or may not be expected to meet MCLs or other final cleanup goals. In some cases, the zone designation provides context for specifying alternative cleanup levels (i.e., final cleanup levels are not expected to be met within the designated zone). The idea of a containment or management zone is inherent in RCRA corrective action regulations and in the RCRA approach to managing landfills and other SWMUs. This approach has been adopted at several CERCLA sites as “waste management areas.” More details on various groundwater management/CZs are provided in the following section on case studies.

Soil and groundwater within these zones are managed to protect human health and the environment. Exposure is often prevented through capping, groundwater use restrictions, and other ICs. GMZs often make it easier for states to designate and track ICs and area/property use restrictions. Contamination is prevented from spreading beyond the GMZ through the use of hydraulic and/or barrier containment and/or monitoring. Examples of states with groundwater management/CZ terminology include cleanup programs in California, Delaware, Illinois, New Hampshire, New Jersey, Texas, Wyoming, and Georgia. Terminology and citations to underlying regulations are listed in Table 3. More details on several states are provided in the following section.

4.7.2 Case Studies

Groundwater Management Zones

At Joliet Army Ammunition Plant, IL (Load-Assembly Packing Area and Manufacturing Area) (Appendix B, site 5a), GMZs were established around three areas of contaminated groundwater that did not meet remedial goals. Contaminants included trinitrotoluene, 2,6-dinitrotoluene, and RDX; remedial goals are typically based on Class I and Class II state groundwater standards. Contamination within the GMZs will be addressed via limited action including deeding and zoning restrictions, periodic site inspections, groundwater and surface water monitoring, and natural attenuation. The GMZs will be in place until cleanup activities are complete. Time frame estimates for meeting remedial goals in groundwater range from 20 to 340 years. Remedial time frame estimates will be refined during remedial design. If the time frames are determined to be unacceptable, alternative remedial actions will be developed and implemented in accordance with the NCP. This information is documented in the OUs 01 and 02 ROD, dated 10/30/1998. The first five-year review report, in 2004, recalculated groundwater cleanup time frames at several monitoring wells, estimating a maximum of 404 years to reach cleanup goals at specific wells. There was no discussion in the Five-Year Review report of these time frames being unacceptable.

GMZ terminology is also used in Delaware and New Hampshire. In Delaware, GMZs have been approved at 105 sites as of January 2009, including CERCLA sites, Voluntary Cleanup Program sites, and Hazardous Substances Control Act sites (Delaware, 2009). GMZs prevent the use of groundwater and restrict drilling any new potable water supply wells. They are used to describe an area where a TI exists for groundwater remediation (Delaware, 2008). A GMZ is being used at the Halby Chemical Co. in New Castle where carbon disulfide is present as a DNAPL and cleanup time frame estimates range from 50 to several hundred years. In New Hampshire, the term does not imply TI but is merely used to designate the subsurface volume where groundwater contamination is being managed and remediated.

Plume Management Zones

Several sites in Texas have designated groundwater PMZs, including the NWIRP in Dallas, TX (Appendix B, site 5b). NWIRP Dallas is a RCRA facility with chlorinated solvents in groundwater. Contamination was being addressed by three boundary pump-and-treat systems for over 10 years. The Navy proposed installing two permeable reactive barriers, designating a PMZ, conducting monitoring, and maintaining ICs. The remedy was supported by the partnering team and implemented. LTM is being conducted to ensure that the plume remains within PMZ boundaries.

Other sites with designated PMZs include the Red River Army Depot Ordnance Training Center Landfill, Spector Salvage Yard, Pioneer Oil Refining Company, Mountain Creek Industrial Center (proposed PMZ), and State Hwy 123 PCE plume (state Superfund sites). More details on these sites are presented in original site-specific documents (Texas Register, 2007; TCEQ, 2007; TCEQ, 2004; Reed and James, 2010; U.S. Army, 2007).

Containment Zones

The California State Water Resources Control Board's CZ designation is similar to a TI waiver. It may be considered at sites where cleanup to water quality objectives is technologically or economically infeasible, per Resolution No. 92-49, amended in October 1996. CZs are intended for sites where residual contamination is not expected to degrade significantly over time. Monitoring is often required to ensure that the plume is contained. CZ sites are expected to remain open indefinitely.

The California State Water Resources Board has a website listing all sites with CZs: J.H. Baxter site in Weed, Edwards AFB South AFRL in Kern County (both CERCLA sites that also have TI waivers), Edwards AFB Arroyos AFRL in Kern County, and Georgia-Pacific (former Peterbilt Motor Co.) site in Newark (California State Water Resources Board, 2010). More information on these sites is provided in the original references.

Two other facilities, Intel Fab 1 in Santa Clara and Norge Cleaners in Napa, had CZs at one time but these were rescinded (California State Water Resources Board, 2010). The Intel Fab 1 site received an order from the Regional Board establishing the CZ in 1999 for chlorinated solvents in groundwater that had reached asymptotic concentrations but were still above MCLs after years of pump-and-treat. In 2005, the Regional Board determined that the site met criteria for low-risk closure and the order was rescinded. Further groundwater monitoring is no longer needed (California RWQCB SF Bay Region, 2005). The distinction between CZs and low-risk closure, and between MNA remedies and low-risk closure, was recently summarized by the San Francisco Regional Board (California RWQCB SF Bay Region, 2009). This document described "low-threat" closures as potentially applicable before groundwater has been fully restored to beneficial uses, as long as stakeholders have concluded that the site will reach cleanup standards under natural conditions within a reasonable time frame.

Some of the difficulties associated with approving CZs are illustrated by the Fairchild Semiconductor Corporation South San Jose site (Appendix B, site 5d). The site had been operating a pump-and-treat system (as well as maintaining a slurry wall) to address chlorinated solvent contamination in groundwater. When contaminant removal by the pump-and-treat system approached asymptotic limits, stakeholders considered a CZ designation. However, the site is located in a sensitive hydrogeologic area (classified as a recharge zone for groundwater by the local Santa Clara Valley Water District). To avoid potential conflicts with local groundwater management policies, stakeholders decided not to implement any official CZ policy; however, the approach taken is, in fact, a CZ system. According to a recent state five-year review report, the slurry wall is containing contamination above MCLs. ICs are preventing exposure to contamination. Overall, the remedy is protective, despite several new developments including the detection of 1,4-dioxane inside the slurry wall at concentrations up to 850 μg/L and the evaluation of potential vapor intrusion risks. This is an example of an informal groundwater management/containment approach without a formal CZ designation.

Waste Management Areas

Based on conversations with NAVFAC Southwest representatives, the Navy has considered CZs and does not accept the procedural requirements outlined in Resolution 92-49. Referencing this resolution and using CZ language would give the state an expanded role in the remedial decision-making process. The Navy has therefore used other alternative endpoints and approaches, including WMAs in California.

An example of a site with designated WMAs is the Barstow Marine Corps Logistics Base Yermo Annex plume (Appendix B, site 5e). WMAs are similar to RCRA Waste Management Units. Waste is being managed in place and cleanup requirements will be met at a downgradient point of compliance. The Navy proposed additional areas as WMAs but USEPA did not agree; USEPA and the Navy "agreed to disagree." The Navy will comply with groundwater cleanup standards throughout the plume as a conservative means of demonstrating attainment at the point of compliance, but reserves the right to propose the use of designated points of compliance for these areas in the future. The Navy has considered similar WMA designations at CERCLA sites with RCRA-like characteristics (e.g., unregulated landfills), using the RCRA WMU designation as an ARAR at CERCLA sites.

4.8 GROUNDWATER RECLASSIFICATION/CLASSIFICATION EXEMPTION

4.8.1 Description

Groundwater reclassification is a request to state regulators to change the designation of site-specific groundwater and/or the aquifer to more accurately reflect the current and potential future groundwater use, value, or vulnerability. In most states, groundwater that is not classified as a potential drinking water will not be expected to meet MCLs or other drinking water requirements. Reasons for reclassifying groundwater vary from state to state. In some states (e.g., Florida, Oklahoma), the water quality basis for reclassification depends on the saltiness of the water as measured by total dissolved solids concentrations. Other states (e.g., New Jersey, Tennessee, Texas, and Vermont) consider site-specific groundwater reclassification due to contamination and other water quality factors that prevent the use of the aquifer as drinking water. Site-specific groundwater reclassification designations are frequently used in conjunction with groundwater use restrictions, land use covenants, and other ICs. Groundwater reclassification can be a lengthy process that involves multiple regulatory agencies.

Examples of states with site-specific groundwater reclassification/classification exemption policies include cleanup programs in Michigan, Nebraska, New Jersey, Ohio, Tennessee, Texas, and Vermont. Multiple states, including California, Nebraska, and Oklahoma, describe reasons for reclassifying aquifers. State-specific terminology and citations to underlying regulations are listed in Table 3. More details on several states are provided in the following sections.

4.8.2 Case Studies

Altus AFB (Appendix B, site 6a) is a RCRA corrective action site. The Air Force, State of Oklahoma, and USEPA prepared a groundwater classification report in 2006. Oklahoma Water Resources Board criteria were used to reclassify the upper aquifer to Class III (agricultural and municipal/industrial cooling beneficial uses). Altus AFB then proposed risk-based concentrations as cleanup levels for several groundwater contaminants; however, these were not approved by USEPA. Instead, USEPA and the Oklahoma DEQ agreed that complete restoration of groundwater was not practicable given the presence of DNAPL and the site hydrogeology. A sentinel well system was designed to monitor different zones of the aquifer to verify containment; a contingency of engineered containment will be triggered if the sentinel wells indicate that the plume is expanding. In addition, Altus AFB must remove or treat source material in soils and groundwater to the extent practicable. The base boundary is the point of compliance.

Two sites in Tennessee have been classified as site-specific impaired groundwater, as indicated in the June 2008 revision of the Rules of the Tennessee Department of Environment and Conservation, Chapter 1200-4-3. This designation is essentially a TI zone, referring to "groundwater that has been contaminated by human activity and the board finds that either it is not technologically feasible to remediate the groundwater… or it is not reasonable to remediate to that criteria…." One site is the Porter Cable/Rockwell site (Appendix B, site 6b), where a slow-moving solvent plume will naturally attenuate before it can leave the property boundary. The second site is the former Isabella/Eureka Mine, an area abandoned in bankruptcy court that is now in the hands of a court-appointed receiver or trustee of the Tennessee Chemical Company.

Additional details about these two sites were not provided in Chapter 1200-4-3 and no other site-specific documents could be found online. Based on the description in Chapter 1200-4-3, these sites do not seem to have any particularly unusual characteristics for contaminated sites, suggesting that the designation may be appropriate for other sites in Tennessee.

Sites receiving the MSD under the TCEQ are tracked by the state. Approximately 132 properties have received this designation since this legislation was passed in 2003. Eleven more sites are pending approval, one request was denied, one request was withdrawn, and one site was determined to be ineligible (TCEQ, 2010). One site is the Hardy Street Rail Yard site, under the Texas Voluntary Cleanup Program (Appendix B, site 6c). The MSD designation prevents the current and future use of shallow contaminated groundwater for potable purposes. At the Hardy Street Rail Yard site, over 80,000 gallons of diesel fuel NAPL was recovered using 17 recovery wells. Chlorinated solvent plumes in groundwater at this site have been shown to be naturally attenuating. Both groundwater and residual NAPL are being addressed by MNA. In 2008, the TCEQ issued a conditional Certificate of Completion (i.e., conditional site closure) approving conditional residential land use at the site.

Similarly, sites receiving the Ohio USD under the Ohio Voluntary Action Program are tracked by the state. As of December 2010, 60 sites had received this designation (Ohio EPA, 2010). At least 1879 sites in New Jersey have received Classification Exemption Area designations, totaling over 32,500 acres (51 square miles) (New Jersey Department of Environmental Protection, 2009). DoD sites with CEAs include Fort Dix and the Naval Air Engineering Center in Lakehurst (New Jersey Department of Environmental Protection, 2009).

4.9 MNA OVER LONG TIME FRAMES

4.9.1 Description

"MNA over long time frames" is a term used in this document to refer to the selection of MNA as a primary component of a final remedy for time frames greater than 30 years.

MNA is a well-accepted component of a final groundwater remedy, as evidenced by USEPA memoranda such as "Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites" (USEPA, 1999), "Region 5 Framework for Monitored Natural Attenuation Decisions for Ground Water" (USEPA, 2000a), and several technical reports published in 2007 on MNA of inorganic contaminants in groundwater and MNA of tertiary butyl alcohol in groundwater at gas stations. MNA may also offer more benefits compared with active technologies, such as minimal ecological disturbance of sensitive areas, reduced energy consumption, waste generation, and remediation costs.

Language in the NCP (Section 300.430(a)(iii)(F)) introduces USEPA's expectations for groundwater restoration, and uses the terms "wherever practicable," "reasonable time frame," and "particular circumstances of the site" to explain USEPA's expectations. When setting remedial objectives, sites typically focus on the nature of site circumstances including risk assessments, changes in potential future resource uses, and preventing human exposure. Flexibility in defining a reasonable time frame is often overlooked.

There is no standard definition of "reasonable time frame;" instead, the definition of "reasonable" is assessed for each site. Generic time frames of 30 years and 100 years are often used to define reasonable. However, these time frames have ambiguous origins, with the 30-year duration typically chosen for economic purposes (i.e., there is an economic basis for a 30-year discount rate documented by USEPA (1985) and the majority of long-term net present value will be captured in the first 30 years of costs). The use of a 100-year time frame as "reasonable" is an order-of-magnitude number used as an example by USEPA in its TI waiver guidance document (USEPA, 1993). In that same document, USEPA states that "no single time frame can be specified during which restoration must be achieved to be considered technically practicable" (USEPA, 1993). Some stakeholders have interpreted timescales on the order of 600 years to be technically practicable whereas others have viewed timescales greater than 30 years to be technically impracticable (see, e.g., DuPont/Necco Park 1998 ROD).

The lack of a definition of "reasonable time frame" has increased the flexibility of site stakeholders to accept longer time frames to reach cleanup requirements and allows for the use of MNA rather than considering remediation to be technically impracticable. At complex sites, remedial time frame estimates using MNA may be similar to that of active remediation technologies; hence the time frame for MNA may be reasonable. During interviews in 2003, several USEPA and state regulators referred to MNA as an alternative for sites considering TI waivers (Malcolm Pirnie, 2004). Complex sites with similar time frame estimates may select MNA rather than an alternative endpoint, based on site-specific differences in interpreting "reasonable time frame." Thus, MNA over long time frames is an alternative approach.

ICs are often used in conjunction with MNA over long time frames. The appropriate role of ICs was described in a June 2009 memorandum published by USEPA. USEPA restated NCP expectations that ICs were generally not substitutes for active remediation but were supplementary protective measures during the implementation of groundwater remedies (USEPA, 2009b). Detailed guidance on ICs, including full life-cycle planning recommendations, effective implementation, maintenance recommendations, and enforcement tools, is summarized in recent interim guidance from USEPA (USEPA, 2010c).

4.9.2 Case Studies

The Solvents Recovery Service of New England (Appendix B, site 7a) is a CERCLA site where MNA was approved over a long time frame. Millions of gallons of waste solvents and oils were handled, stored, and processed at the site for over 30 years. The OU 3 ROD, dated 9/30/2005, describes the selection of a remedy for groundwater in the overburden and bedrock. The remedy selected for the overburden consisted of in situ thermal treatment in the NAPL area, excavation and capping of soils and wetland soils, pump-and-treat for containment, MNA for areas outside of the pump-and-treat system CZ, and ICs to prevent human exposure. The selected remedy for bedrock contamination consisted of pump-and-treat and MNA in the NAPL area. The pump-and-treat system will be modified as appropriate based on expected reductions in contamination. Modeling indicated that bedrock plumes would not reach ARARs for approximately 400 to 500 years under baseline conditions. Assuming that in situ thermal treatment in the overburden was successful in removing 95% to 99% of the mass present in the overburden, the time frame for restoration of the bedrock plume was estimated to be approximately 250 years to reach ARARs in the bedrock aquifer. This time frame was considered reasonable relative to the time frame of other remedial alternatives at the site.

MNA was approved at site SA-17 of the Office NTC in Orlando, FL (Appendix B, site 7b). At this site, TCE DNAPL source area has been addressed by several technologies, including in-situ chemical oxidation (ISCO) using Fenton's Reagent followed by enhanced bioremediation. The transition to MNA was supported by Natural Attenuation Software modeling results and multiple lines of evidence, including favorable geochemical conditions, the presence of functional genes for dehalogenation, as measured using molecular biological tools, the presence of daughter products cis-1,2-dichloroethylene downgradient, and concentrations approaching the State's default criteria for natural attenuation. Remedial time frame predictions ranged from 60 to 70 years for the downgradient plume.

MNA over long time frames has also been used at other CERCLA sites as a primary remedial component. Savannah River site OU 131C ROD dated May 2008 and a ROD for Sixty-One Industrial Park Site dated 9/28/08 have both approved MNA remedies for approximately 70 years to meet ARARs. More details are provided in the RODs.

4.10 ADAPTIVE SITE MANAGEMENT

4.10.1 Description

Adaptive site management is a term that has been used to describe an efficient empirical process that allows for evaluating results and making adaptive decisions as data are gathered. NRC used the term to describe this process as it applies to site investigation and characterization at Navy facilities (NRC, 2003). In this document, it is used to describe the process of adapting the final remedy or transition from one remedial approach to the next based on performance results. The term "adaptive site management" has not been used by USEPA in policy or regulations.

Adaptive site management is a term similar to the observational approach described by Terzaghi and Peck (1948) for geotechnical practices. Terzaghi and Peck described the method as consisting of the following steps:

- Exploration sufficient to establish at least the general nature, pattern, and properties of the deposits, but not necessarily in detail
- Assessment of the most probable conditions and the most unfavorable conceivable deviations from these conditions
- Establishment of the design based on a working hypothesis of behavior anticipated under the most probable conditions
- Selection of quantities to be observed as construction proceeds and calculation of their anticipated values on the basis of the working hypothesis
- Calculation of values of the same quantities under the most unfavorable conditions compatible with the available data concerning the subsurface conditions

- Selection in advance of a course of action or modification of design for every foreseeable significant deviation of the observational findings from those predicted on the basis of the working hypothesis
- Measurement of quantities to be observed and evaluation of actual conditions
- Modification of design to suit actual conditions.

There are many parallels between the adaptive site management approach and the philosophy of AFCEE's ERP-O process, as well as the thought process described by the ITRC RRM team (ITRC, 2009b), namely a focus on building, validating, and improving a CSM; establishing metrics for evaluating the success of remedial technologies; and continuously evaluating and optimizing modeling predictions, remedial performance, and LTM.

One of the main challenges of using adaptive site management is fitting the iterative approach into the CERCLA process, which is perceived as a "highly linear, unidirectional march from site investigation to remedial action and eventually to site closure" (NRC, 2003). However, the adaptive site management approach can be consistent with the CERCLA process. Adaptive site management does not avoid setting cleanup objectives; it simply uses more flexible language for RAOs. Initial remedial decisions are based on the CSM or technology performance results. Contingency language or triggers for transitioning from one technology to another are built into the final remedy; technology performance objectives and metrics are selected ahead of time and approved by stakeholders. Changes to remedies are documented through ROD amendments and ESDs. The Five-Year Review process provides a mechanism to evaluate and implement changes to the remedy (NRC, 2003).

Adaptive site management is often used at complex sites where there is high uncertainty and no clearly defined pathway to site closure. The approach focuses on remedial progress at the site, making continual corrections to avoid straying too far off course from remedial objectives, documenting remedial progress towards metrics, adapting, being innovative, and furthering technology. There has been a growing recognition that a more iterative approach is needed at complex sites and that a broader approach of effective knowledge generation and use would improve site decision making and overall remedial performance (NRC, 2003).

4.10.2 Case Studies

Many sites can be used to illustrate adaptive site management principles (see, e.g., case studies featured in NRC, 2003). The approach taken at Hanscom Field/Hanscom AFB illustrates several adaptive site management principles. The Air Force saw remedial progress as a priority and was open to making treatment system modifications and optimizations and accommodating changes to the remedy through a dynamic approach.

Hanscom Field/Hanscom AFB OU 1 in Massachusetts (Appendix B, site 8a) had been operating under an interim remedy until 2007 consisting of source treatment in three source areas (permanganate injections, molasses injections to enhance biodegradation, and vacuum-enhanced vapor extraction), long-term groundwater pump-and-treat system, LTM, and ICs. The pump-and-treat system and source treatment are operated dynamically, and the frequency of source zone injections is determined empirically, based on monitoring data. The site is underlain by an upper aquifer, lower aquifer, and bedrock (predominately fractured granite). The final ROD essentially codified the interim remedy and referenced model-predicted time frames of 30 to 50 years to reach ARARs in the upper and lower aquifer. The ROD did not estimate cleanup time frames in the bedrock, where DNAPL concentrations of VOCs had been detected. A recent AFCEE ERP-O team recommended that the site begin developing a case for TI in fractured bedrock by documenting the limitations of different technologies for restoring the DNAPL area to MCLs. The group concluded that site closure was unlikely in the near future unless alternate cleanup standards or a TI waiver were evaluated and implemented for bedrock.

At Building 40, Watervliet Arsenal, New York (Appendix B, site 8b), DNAPL concentrations of PCE were present in fractured shale down to 150 ft below ground surface. The ultimate long-term goal was meeting MCLs. In an attempt to remove mass to the extent practicable, the Army agreed to conduct 5 years of ISCO injections using sodium permanganate, and evaluate the results before determining whether an alternative endpoint was warranted. Extensive site characterization was performed including borehole geophysical and hydrological logging and interflow testing, innovative diagnostic tools including mass flux measurement with multilevel sampling systems, and rock core crushing to evaluate PCE concentrations diffused into the rock matrix. Results indicated no measureable benefit of ISCO in terms of rock core concentrations or mass flux reduction. The Army and other stakeholders are now considering different alternative endpoints including ACLs. The iterative field test design and responsiveness to test data provided a technical basis for the revised remedy.

4.11 REMEDIATION TO THE EXTENT PRACTICABLE

4.11.1 Description

This category of alternative approaches for groundwater remediation was created to address sites that clearly acknowledge the TI of meeting final cleanup goals, yet have not actually obtained a TI waiver. Presumably, these sites will require an ARAR waiver in the future, documented in a ROD Amendment or ESD, in order to fully comply with the NCP. RODs are written using language that clearly states the positives of the selected remedy (removal to the extent practicable), yet references final cleanup goals under the NCP. These RODs differ somewhat from those with contingency TI waivers in that TI waivers are not mentioned in the document.

4.11.2 Case study

The Union Pacific Railroad Co. Tie-Treating Plant (The Dalles, Oregon) signed a ROD for OU 1 on 3/27/1996 to restore groundwater to the extent practicable. The site was contaminated with wood treatment compounds and fuel oil (coal tar creosote, poly-aromatic hydrocarbons (PAHs), pentachlorophenol, arsenic, chromium, copper, naphthalene, and benzene) from site operations since 1923. The selected remedy for groundwater consisted of DNAPL removal to the extent practicable using extraction wells and "water flooding" to push DNAPL towards recovery wells, hydraulic containment of the DNAPL areas, plume monitoring and hydraulic containment of the plume if needed, LTM sitewide, and ICs. The ROD states in several locations that numerical groundwater cleanup goals will likely not be achievable at the site. The estimated time frame to achieve cleanup goals was unknown; an estimate of "hundreds of years" was given for the no-action alternative, based on the presence of DNAPL. The second Five-Year Review, dated

December 2007, stated that two ARAR waivers (greater risk waiver or a TI waiver) potentially apply to the site. Union Pacific plans to prepare a TI waiver evaluation after DNAPL removal modules are shut down. At the time of the Five-Year Review, over 81,000 gallons of DNAPL had been recovered by the system.

4.12 SUMMARY

The variety of different alternative endpoints and approaches described in this section will hopefully provide DoD with a broad perspective of the types of approaches that have been used at complex sites facing technical challenges to complete groundwater restoration. Case studies provide examples to illustrate the use of each type of alternative endpoint and approach in practice. Common themes and considerations for any complex site evaluating remedial options are described in Section 5.

5.0 KEY FINDINGS

This section is intended to provide project managers with more context for evaluating alternative endpoints and approaches at a specific site. Topics covered include the following:

- Types of complexities encountered at sites
- Assessment tools and methods
- Considerations for testing and evaluating technologies
- Data basis for alternative endpoints and approaches
- Typical role of alternative endpoints and approaches in the final remedy
- Other considerations.

The content and case study examples described in this section are drawn from a review of complex sites that have considered and implemented alternative endpoints and other approaches. Each site is described in more detail in Appendices A and B.

5.1 NATURE OF TECHNICAL CHALLENGES FACED AT COMPLEX SITES

Complex sites may face one or several technical challenges to groundwater remediation that impact the ability to meet groundwater cleanup goals and objectives regardless of the type of remedial technology used. Examples include the presence of DNAPL in fractured rock environment or extensive regional contamination from multiple sources. (Technology-specific challenges are not the focus of this section. These would likely need to be assessed on a site-specific basis as part of an FS.) Based on a review of case studies, the following technical challenges are commonly encountered at complex sites.

5.1.1 Observed or Suspected NAPL

One of the most common contaminant-related challenges for groundwater remediation is the presence of contaminants such as DNAPL or light non-aqueous phase liquid (LNAPL), although the presence of NAPL does not necessarily mean that remediation is infeasible (USEPA, 1993). DNAPL was present at the majority of the sites that were identified as having adopted alternative endpoints and approaches; the cleanup goal was typically MCLs at these sites. The primary difficulties with remediating DNAPL to MCLs include the following:

- DNAPL longevity, despite pump-and-treat or other technologies that target dissolved-phase contamination. As contaminated groundwater is removed, more contamination dissolves from the DNAPL phase into groundwater, keeping concentrations high over time (see, e.g., Sale et al., 2007).

- Inability to characterize the DNAPL zone, at some sites, although DNAPL characterization and remedial technologies are evolving to enable the detection and removal of substantial contaminant mass. In situ remediation technologies, such as thermal treatment, can achieve partial mass removal and reduce groundwater concentrations.

- The presence of DNAPL in heterogeneous and/or fractured geologic media continues to pose significant remediation challenges.

According to a recent USEPA report titled "DNAPL Remediation: Selected Projects where Regulatory Closure Goals Have Been Achieved" (USEPA, 2009a), only a few DNAPL sites have reached drinking water standards for groundwater throughout the aquifer. One site successfully met MCLs for PCE after 3.5 years of ISCO, SVE, and pump-and-treat system operation within a sandy area that was relatively small (800 ft by 300 ft area to a depth of 68 ft) (USEPA, 2009a). Another DNAPL site successfully used SVE and air sparging to remediate *trans*-1,2-dichloroethene and other chlorinated solvents in sands and gravels within a 60 by 400 ft area (USEPA, 2009a). Aquifer restoration to drinking water standards at sites with DNAPL has rarely been achieved by the environmental remediation community in its 30-year history (NRC, 2005). USEPA summarized these cleanup challenges in a report titled "Recommendations from the USEPA Ground Water Task Force" and published a discussion paper titled "Cleanup Goals Appropriate for DNAPL Source Zones" as Attachment A to that report (USEPA, 2007).

Equally challenging for remediation professionals are high concentrations of contaminants that have diffused into rock matrix, clay lenses, or other low-permeability zones. Mass storage and subsequent slow diffusion into transmissive zones has been recognized as a challenge to aquifer restoration downgradient of a DNAPL source zone (Sale et al., 2007). The implication of this realization is that areas within the plume may also remain above cleanup goals for a long time; these areas may therefore need to be included in the assessment of alternative endpoints/ approaches.

Over half (56%) of the 77 sites implementing TI waivers had NAPL present. 37 of these 43 sites approved the TI waiver after USEPA guidance in 1993, representing 65% of the 57 TI waivers approved after 1993. NAPL was present at a minimum of 11 out of the 23 case studies included in Appendix B. Key difficulties that these case studies described included the presence of DNAPL contamination in fractured bedrock, heterogeneity, inability to characterize DNAPL in the subsurface, and exposure to mercury DNAPL during handling.

5.1.2 Widespread Regional Contamination

Sites with large areas of contamination have also evaluated and used alternative endpoints and approaches. Many are former mining sites where thousands of acres have been impacted by acid mine drainage, low pH and high concentrations of metals. Several military and industrial sites have also considered alternative endpoints and approaches because of the extensiveness of dilute groundwater contamination and regional off-site sources.

Like DNAPL sites, mining sites act as an ongoing source of contaminants for hundreds or even thousands of years. Geochemical conditions created by mining can oxidize rock wall, rock waste, and other mining wastes. The karst-like topography of mine voids can extend for miles, making it difficult to characterize and contain subsurface flow. Open-pit mines and mine voids can fill with water that drains into local creeks, leading to surface water and groundwater contamination. Subsequently, large areas may exceed water quality standards for groundwater and surface water.

USEPA Regions 8, 9, and 10 published a handbook titled *Abandoned Mine Site Characterization and Cleanup Handbook* (USEPA, 2000b). This document discusses ARAR waivers and other site management strategies that may be appropriate at complex mining sites. In determining appropriate goals and measurements of success at these sites, USEPA recommends working with state agencies, the local community, and others to share values and make choices accordingly.

Some mining sites have chosen to incorporate TI waivers and other alternative endpoints and approaches into the final remedy. Examples include Cherokee County (Galena and Treece/Baxter subsites), California Gulch, Anaconda Co. Smelter, Oronogo-Duenweg Mining Belt, Silver Bow Creek/Butte Area, Whitewood Creek, and the Elizabeth Mine. More details about the nature of mining contamination are presented in site-specific summaries (Appendices A and B).

Several military/industrial sites have adopted alternative endpoints and approaches based in part on extensive contaminant plumes and/or multiple sources. Examples include Whitmoyer Laboratories (15 acres contaminated with arsenic and aniline present in clays and rock fractures), Highway 71/72 Refinery (215 acres contaminated with LNAPL where groundwater was not being used and source removal would disrupt buildings and other community development), and the Schofield Barracks site (covering the area of the entire plume to depths of 500 to 700 ft in fractured rock).

5.1.3 Persistent Immobile Contamination

Other complex sites have evaluated alternative endpoints and approaches to address persistent and relatively immobile contaminants such as metals, poly-chlorinated biphenyls (PCBs), and PAHs. At these sites, plumes were found to be relatively immobile or slowly shrinking and were not expected to migrate over time. Contaminants that are relatively immobile are easier to manage in place or contain. The remedy is protective of human health and environment, even when an alternative endpoint or approach is used. For example, leaded gasoline was present in groundwater from a tank leak at a site at Eielson AFB. Lead was the only constitute of concern that was not naturally attenuating. Because of site circumstances and the immobility of the lead, alternative endpoints were accepted for lead and a natural attenuation remedy was chosen for the other contaminants. Another example of a site implementing alternative endpoints is Roebling Steel Company where arsenic, beryllium and lead standards were waived in groundwater based on their immobility in the aquifer and model predictions of long remedial time frames regardless of source removal efforts. Mobility was another reason in support of an alternative endpoint at the Porter Cable/Rockwell site in Tennessee, where a slowly moving plume would attenuate naturally before ever reaching the property boundary.

5.1.4 Hydrogeology and/or Depth Makes Contamination Inaccessible

The hydrogeologic setting is a common contributor to groundwater remediation challenges at complex sites and may be the primary difficulty at some sites. USEPA recognized that “locating and remediating subsurface sources can be difficult at sites due to complex geology or waste disposal practices” (USEPA, 1993).

Remedial difficulties arise at sites with highly heterogeneous geologies, particularly those with areas of low permeability. Complexities in site characterization and remediation result from local variations in porosity, hydraulic conductivity, and other parameters that originate during the natural development of geological systems. High-resolution next-generation site characterization tools have been developed to delineate contaminant distribution in the subsurface (see, e.g., Malcolm Pirnie, 2011). However, these tools are generally not adequate in the most complex hydrogeologic settings such as deep alluvial basins, karst aquifers, and fractured bedrock aquifers. A discussion of the unique challenges presented at karst sites is presented in a report prepared for the U.S. Army Environmental Center (Malcolm Pirnie, 2002). Several sites using alternative endpoints and approaches due to fractured rock settings include Loring AFB, Watervliet Arsenal, Solvent Recovery Service, McKin Superfund Site, O'Connor Superfund Site, and West Site/Hows Corner. See Appendices A and B for more details.

Sites with contamination present in low permeability clay soils or interbedded clay lenses also evaluated alternative endpoints and approaches, primarily based on the ineffectiveness of in situ technologies, large storage potential for contaminant, and the slow rate of contaminant desorption or diffusion from clay soils. Examples include the Horseshoe Road/Atlantic Resources site and Petro-Chemical Systems Inc. (Turtle Bayou) site. See Appendix A for more details.

There can be other hydrogeologic obstacles to implementing effective treatment or hydraulic containment systems, leading to consideration of alternative endpoints and approaches. Examples include subsurface barriers to remediating contaminated media, such as low-yield aquifers or hydraulic connections to nearby rivers.

The depth of contamination can also be a complicating factor limiting the efficacy of remedial technologies. Sites may have contaminants present several hundred feet below ground surface, potentially exceeding the natural depth limits of common environmental remediation technologies. Sites considering alternative endpoints and approaches for deep contaminants typically also have low potential for human and ecological exposure.

5.1.5 Surface Activities or Features Make Contamination Inaccessible

Other factors may contribute to the infeasibility of complete groundwater remediation. These may include surface barriers to accessing contaminated media, such as buildings and other structures, surface activities, wetlands, endangered species habitats, or uncontrollable factors such as neighboring sites that contribute contamination to the groundwater plume and would effectively re-contaminate the area as treatment progressed. Sites considering alternative endpoints because of these difficulties (perhaps as contributing factors) include Highway 71/72 Refinery, Iowa City Former Manufactured Gas Plant, and Pease AFB.

5.1.6 Remediation Attempts May Pose a Greater Risk

This is the primary reason for approving one type of ARAR waiver at CERCLA sites, the greater risk ARAR waiver. It can also be a contributing reason for approving other types of alternative endpoints and approaches. As discussed in Section 4.3, several examples of potential greater risk include greater short-term exposure during excavation or sediment dredging, greater risk to sensitive species and ecosystems due to disturbances during active remedial efforts, and the greater risk of DNAPL mobilization.

5.1.7 Low Risk to Human Health and Environment

Protection of human health and environment is the primary goal of environmental remediation at all sites. Sites adopting alternative endpoints and approaches are no exception. Some types of alternative endpoints and approaches are intended to address low-risk sites where contamination is expected to ultimately meet groundwater cleanup standards. For example, the San Francisco Bay RWQCB has recently published guidance on site closure at low-threat chlorinated solvent sites (California RWQCB, SF Bay Region, 2009). Other states have underground storage tank programs with similar alternative endpoints and approaches or early site closeout criteria at low-risk sites. These alternative endpoints and other approaches are not particularly intended for use at complex sites. However, complex sites that pose low risk may be better candidates for limited action alternatives or passive approaches.

5.2 CONCEPTUAL EVALUATION TOOLS, METHODS, AND METRICS

Sites have used a number of different methods to assess the likelihood that intrinsic technical challenges will prevent groundwater cleanup goals and objectives from being achieved. A brief summary of some of the tools that have been used at sites adopting alternative endpoints and approaches is presented in this section. These predictive tools and analyses have been described in previous publications by ITRC, USEPA, and others (for example, ITRC, 2004b; USEPA, 2003; NRC, 2005). The assessment methods are fairly straightforward in principle. Their practical application at specific sites may require additional resources such as the collection of supplemental field data and professional assessment.

Simple assessments, which illustrate key technical challenges or remediation time frame constraints, can be performed at any stage of the cleanup process using available site characterization data. Examples include the following:

- Mass estimates in support of the CSM
- Groundwater trends, extrapolated to predict remedial performance over time
- DNAPL dissolution rates, which can limit remedy effectiveness and prolong cleanup time frames
- Likelihood of DNAPL mobilization during remedial activities
- Matrix back-diffusion, which can limit remedy effectiveness and lengthen cleanup time frames in hydrogeologic settings with significant matrix porosity (e.g., clay, fractured rock)
- Rough cost estimates to illustrate inordinate costs, if applicable.

At some sites, site-specific treatability data is available from pilot- or full-scale treatment. A detailed assessment can also be conducted, including an evaluation of the system’s performance and limitations. Such data can be analyzed using modeling software to predict remedial performance, cleanup time frames, and plume stability under a variety of natural and treatment scenarios.

5.2.1 Mass Estimates

The following assessments can be used to evaluate the intrinsic technical challenges and predict time frames that would be required to completely remediate contaminated groundwater.

Subsurface mass estimates form the basis of a number of remedial performances, time frames, and cost assessments. For example, Rodale Manufacturing Company (Appendix A, site 61) and the South Municipal Water Supply Well site (Appendix A, site 65) estimated the mass of DNAPL present in the subsurface and used these estimates to predict remedial time frames under various scenarios. Mass estimates can be expressed as a rough approximation or as a range of values. Typically, contaminant mass is quantified using an approach that illustrates the amount of mass present in different forms (DNAPL, aqueous, gaseous, sorbed, diffused into solid pore spaces) and at different depths (e.g., saturated versus unsaturated zone, in different aquifers and aquitards). The mass estimate therefore illustrates the overall magnitude of the contamination problem in each contamination zone and identifies the type of mass storage reservoirs (e.g., soil, rock fractures and rock matrix) where contaminants are expected to be present. General mass balance equations and estimates of DNAPL residual saturation have been previously published (e.g., Mayer and Hassanizadeh, 2005). The distribution of mass in different zones can also be used in support of an alternative endpoint or approach (see Appendix B, site 1a and 7a for examples).

A wide range of estimated mass indicates a high level of uncertainty that may make it difficult to design treatment systems and will increase the project risk of remedial performance. The wide range in contaminant mass estimates and hydrogeologic characteristics at Loring AFB (Appendix A, sites 42 and 43) were described in the TI evaluation report to emphasize the uncertainty in remedial success within a reasonable time frame. At some sites, particularly if they are early along in the site cleanup process, this uncertainty can be reduced through more site characterization. At other sites, extensive characterization data have already been collected, yet a high degree of uncertainty remains because of the nature of the hydrogeologic setting, magnitude of the contaminated area, and/or inability of current technology to effectively characterize the site. Natural heterogeneity may occur over a small scale so that two samples collected in close proximity to each other will nevertheless yield different results. A high degree of uncertainty in subsurface conditions, despite best efforts at site characterization, may indicate that there is a significant project risk of not meeting groundwater cleanup goals.

5.2.2 Groundwater Concentration Trends

At most sites, contaminant concentration trends in groundwater monitoring wells are typically analyzed over time and space. These data can be used to assess plume stability and migration over time, evaluate natural attenuation mechanisms or treatment system performance, and predict remedial time frames. Plume stability over time is a key question if preventing migration is one of the remedial objectives or if natural attenuation is being evaluated as a potential remedy. For example, plume stability was a key factor contributing to the use of an alternative endpoint at the Porter Cable/Rockwell site (Appendix B, site 6b). Concentration trends as evidence of natural attenuation were used in support of an alternative endpoint at the NSWC Crane site (Appendix B, site 4c) and the Former NTC Orlando site (Appendix B, site 7b). Declining trends in groundwater were used as evidence that groundwater monitoring was no longer needed at the

Former Long Beach Naval Complex (Appendix B, site 4d). Trends were used to predict remedial time frames under natural and treatment scenarios at the Solvents Recovery Site of New England (Appendix B, site 7a). A comparison of actual contaminant trends with model predictions under different technologies helped to illustrate the minor impact of aggressive technologies on remedial time frame.

Other lines of evidence used in support of MNA are illustrated by the Former NTC Orlando site (Appendix B, site 7b). These include modeling predictions, groundwater geochemical conditions, the presence of degradation products, the presence of functional genes for dehalogenation, plume stability, and the overall magnitude of contaminant concentrations.

5.2.3 DNAPL Dissolution Rates

At sites where DNAPL is thought to be present, the rate of DNAPL dissolution can be used to predict the minimum remediation time frame and determine whether it is reasonable for the site. One method for predicting DNAPL dissolution rates is to measure mass discharge coming from the source area per unit time (pounds per day) while dissolved-phase contaminant concentrations remain fairly steady (ITRC, 2011b). Based on the projected rates of removal, the total mass in the source area can be divided by the projected mass removal rates to estimate the remedial time frame. This approach assumes that DNAPL is completely accessible to dissolve into the flowing groundwater and that the dissolution rate is constant until the entire mass of DNAPL has dissolved. In reality, DNAPL in high- and low-flow zones may dissolve at different rates. By not taking this into account, the method will likely underestimate the actual required time frame.

DNAPL dissolution rates have been shown to be enhanced through bioremediation. For example, anaerobic enhanced bioremediation has been demonstrated to enhance tetrachloroethylene DNAPL dissolution (Carr et al., 2000; Yang and McCarty, 2002; Ward et al., 2009). In the field, demonstrations of enhanced DNAPL dissolution rates may be confounded by associated changes in subsurface permeability and groundwater flow (Malcolm Pirnie, 2008). Further calculations can be used to estimate how much enhancement in DNAPL dissolution rate would be needed to reduce remedial time frames to a reasonable time frame. Case studies did not reference DNAPL dissolution rates directly; time frame estimates were more often based on extrapolating mass removal rates to remove sufficient subsurface mass (see, e.g., South Municipal Water Supply well (Appendix A, site 65)).

5.2.4 DNAPL Mobilization

Remedial activity in source areas has the potential to mobilize DNAPL pools and ganglia. Without a containment system or an underlying confining layer, DNAPL can move downward, spreading contamination to deeper aquifers. DNAPL mobilization can be calculated as a function of entry pressure and pore size/fracture aperture. The ability to prevent DNAPL mobilization is a function of uncertainty in DNAPL extent and the feasibility of hydraulically controlling the area where in situ remedial technologies are applied. The project risk of DNAPL mobilization may preclude the use of a number of remedial technologies in source areas. Case studies did not directly reference DNAPL mobilization as a factor in their decision to adopt alternative endpoints or approaches; however, it may have factored into the evaluations of specific technologies for the source area. Contaminant spreading was discussed at the E.I. du Pont de Nemours site (Appendix B, site 1a) as a reason for approving a greater risk ARAR waiver.

5.2.5 Matrix Back-Diffusion Time Frames

Matrix diffusion refers to the process of contaminant dissolution into groundwater and diffusion under a concentration gradient from open fractures into the matrix pore water until aqueous concentrations in the fractures and the matrix equilibrate (see, e.g., Parker et al., 1994). In the presence of DNAPL, this process eventually decreases the DNAPL mass held in the pore space, slowing the migration of the concentration front in the matrix at the leading edge of the plume. In fractured rock settings, the storage capacity of the matrix can be significant compared with the storage capacity of the fractures. Matrix diffusion can account for the complete disappearance of DNAPL from fractures (Parker et al., 1994). For example, in rock with fracture apertures less than 1 millimeter and matrix porosity greater than 5%, the total void space in the matrix of fractured media is orders of magnitude larger than the void space provided by the fracture network. Matrix diffusion can also be significant in low-permeability zones (silts and clays). An implication of matrix diffusion is that the bulk of dissolved- and sorbed-phase contamination may be located in the matrix and not in the interconnected fractures when the void space of the matrix is larger than the void space of the fractures. This is also true in non-fractured environments with high heterogeneity, where high permeability zones may be coarse-grained sands and gravels interbedded with low-permeability silts and clays with significant storage capacity.

After DNAPL has been depleted, dissolved concentrations in the fractures decline below solubility. The concentration gradient between the fracture and the rock matrix reverses, causing mass to back-diffuse out from the matrix into the fracture. This process, known as back-diffusion, is limited by the diffusion rate and is often slower than forward diffusion because the concentration gradient is not as high. The mass flux coming from the matrix will continue to feed contaminant mass into groundwater over this time period (Reynolds and Kueper, 2002).

At sites with significant matrix storage capacity and high contaminant concentrations (e.g., historical presence of DNAPL in contact with clays or fractured rock), the back-diffusion of stored contaminants into the pore space from the matrix can significantly prolong elevated groundwater concentrations, contribute to rebound after treatment system operation, and lengthen cleanup time frames. Several sites described this phenomenon qualitatively (see for example, Hardage/Criner, Loring AFB, Riverfront and Rodale Manufacturing sites (Appendix A, sites 28, 42, 43, 60 and 61). At Watervliet Arsenal (Appendix B, site 8b), the diffusion rate of permanganate into the rock matrix was actually estimated based on treatability test results and rock core sampling. This was used as a line of evidence in support of an alternative endpoint.

5.2.6 Cost Estimates

Rough cost estimates, using unit costs, can illustrate the impact of remedial complexities and technical challenges on cost. Under most cleanup programs, remediation is not subject to a cost-benefit analysis and cost is not as important as protectiveness (see Section 3.1; USEPA, 1993). However, inordinate cost (a term used in the NCP preamble; see 55 Federal Register 8748, March 8, 1990) or a similar state designation can be used as a way to describe TI. Inordinate cost is a relative term rather than an absolute term. Quantitative cost estimates of treatment scenarios must be compared to other equally effective treatment options in order to assess whether or not costs are inordinate. For example, partial source treatment at a cost of $50 million might be considered inordinate to reduce time frames by 20% relative to natural attenuation. There are several published examples of CERCLA sites where costs/magnitude of the problem were deemed inordinate, leading to TI assessments (Malcolm Pirnie, 2004), including Anaconda Co. Smelter, California Gulch, Cherokee County Treece/Baxter, Oronogo-Duenweg Mining Belt, and Silver Bow Creek/Butte Area (Appendix A, sites 5, 9, 13, 54, 64).

"Inordinate cost" is another factor that may preclude complete remediation. The term is described in relative, rather than absolute, terms (USEPA, 1993). Cost is one of several factors considered during the remedy selection process. Although this document focuses primarily on technical challenges to remediation, some sites have expressed these challenges in terms of inordinate cost.

5.2.7 Time Frame Estimates

Per the NCP, remediation must be completed within a "reasonable time frame," a duration that is not defined in absolute terms but is assessed on a site-specific basis (USEPA, 1993). Time frame estimates at sites adopting alternative endpoints and approaches were typically on the order of several hundred years, with a few sites estimating 50 to 100 years, and a few sites estimating time frames on the order of thousands of years for complete remediation. Examples of time frame estimates and references to specific case studies are shown in Table 7.

Table 7. Remedial time frame estimates at sites with alternative endpoints and approaches.

Approximate Range of Remedial Time Frame (Years)	Number of Sites	Reference
< 50	7	Appendix A sites 20, 29, 30, 39, 45, 77; Appendix B site 8a
50 to 100	6	Appendix A sites 14, 22, 23, 49, 55, 60; Appendix B site 7b
100 to 200	7	Appendix A sites 1, 4, 8, 52, 56, 65, 67
200 to 500	8	Appendix A sites 15, 27, 33, 42, 43, 72; Appendix B site 7a
500 to 1000	5	Appendix A sites 16, 24, 61, 69; Appendix B site 4a
> 1000	4	Appendix A sites 7, 21, 36, 62

The basis for estimating remedial time frames varied from one site to the next. Some sites estimated the time frame to dilute groundwater concentrations to MCLs using natural gradient flushing and/or pump-and-treat. Some ran fate and transport models of dissolved-phase contamination under natural or biologically enhanced remediation scenarios. Others extrapolated groundwater trends in monitoring wells. Still others did not describe the underlying basis of the remedial time frame estimate in the decision document; more details are likely provided in other site reports not readily available for review.

5.2.8 Regulatory Reclassification

It is recognized that complete remediation may be possible in the future as remediation technology advances over time. However, most sites facing groundwater restoration have not overcome technical challenges during the past 25 years of advancement of the environmental remediation industry. Nonetheless, as regulatory oversight requirements and CSM conditions evolve over time, there may be instances where sites are reclassified in accordance with a different regulatory alternative approach. For example, two sites in California that received CZ designations in the late 1980s and 1990s have replaced them by low-threat closure designations (California RWQCB, SF Bay Region, 2009). Other examples of sites receiving regulatory reclassification are provided in Table 8.

Table 8. Examples of sites with regulatory reclassification.

Site	Change in Alternative Endpoint	Reason for Reclassification	Activities Required Following Regulatory Reclassification
Yellow Water Road Dump, FL (Appendix A, site 78)	TI waiver revoked	Original TI waiver was granted due to an analytical error (concentrations appeared to exceed MCLs). Revised analytical methods no longer detected PCBs in groundwater	Delisted from the National Priorities List (NPL), contingency pump-and-treat, monitoring, and ICs
Moss-American Company (Kerr-McGee Oil Co.), OU 1, Milwaukee, WI (Appendix B, site 1C)	Greater risk ARAR waiver was rescinded	Unexpected discovery of DNAPL	ESD-based optimized free product recovery, modification of groundwater design and operation, modify soil treatment technology and soil cleanup standards, clarify cap design and purpose, modify sediment remediation plan
Waterloo Coal Gasification Plant OU1, Waterloo, IA (Appendix A, site 71 and Appendix B, site 4A)	ACLs revoked; TI waiver implemented	Change in USEPA policy regarding the use of ACLs at CERCLA sites	ESD with TI waiver, MNA, LTM, vapor intrusion controls, source removal actions

5.2.9 Basis for ACLs

For the case studies adopting ACLs, acceptable groundwater concentrations were calculated using models or mixing zone analyses. Most were back-calculated from published surface water quality criteria, including state water quality standards (Appendix B, site 4c) and California Ocean Plan criteria (Appendix B, site 4d). At another site, ACLs were set at federal MCLs along the edge of a former landfill at the site (Appendix B, site 4b).

5.3 TECHNOLOGY TESTING AND EVALUATION

At some sites, pilot-scale or full-scale remediation technologies have already been in place and operating. The technology performance data (and any limitations for operation) can be included in the assessment of whether cleanup goals will likely be met. From the perspective of streamlining the site remediation process, it is better to address the potential project risk event early in the cleanup process, prior to conducting pilot-scale or full-scale technology demonstrations. However, from the perspective of data needed to assess the significance of the potential project risk event, sites that are farther along in the cleanup process have an advantage. These sites are more likely to reach stakeholder consensus on the need for an alternative endpoint or approach. Below is a discussion of the types of questions that can be answered using treatability study and full-scale remediation data to assess remedial potential.

5.3.1 Treatability Testing (Bench or Pilot Tests)

When evaluating treatability test plans or existing data from a site with potential challenges to groundwater restoration, a number of questions warrant consideration, including the following. (Documentation of these questions may be required by regulatory programs or kept for internal planning purposes only.)

- What were the study objectives? Were they clearly defined? If so, were the objectives helpful in evaluating intrinsic and/or technology-specific challenges of groundwater restoration? Did the objectives relate only to the feasibility of the technology or also to performance?
- What was the rationale for selecting this technology for testing? Was the technology considered "best available technology" for the site? Does the CSM suggest that other technologies could yield more promising results? Was the technology innovative, with the potential to overcome or lessen groundwater cleanup challenges? Could the results of the study be extrapolated to evaluate other technologies?
- How was the study designed? What metrics and measurement methods were used to evaluate the technology's performance? Were the benefits/drawbacks of the technology appropriately captured by these metrics and measurement methods?
- What level of technology performance would be required for the technology to meet groundwater cleanup goals? Could this question be addressed quantitatively or just qualitatively?
- What scale-up issues and other uncertainties might exist when extrapolating the study results and challenges to full-scale remedial systems? A discussion of key uncertainties of extrapolating study results to full-scale systems is critical to ensuring that pilot-study results can be evaluated. Is the scale of a full-scale remedial system cost-prohibitive or subject to other limitations?
- Were comments solicited from stakeholders (i.e., stakeholders agreed with the study's objectives, design, and performance matrices) and were they satisfactorily addressed?

Data evaluation and interpretation may be enhanced by referencing lessons learned from technology applications at other sites. A review of technology performance at similar sites could be used to supplement site-specific treatability test results.

As described in Appendix C, the majority of sites with TI waivers (55 out of 77) approved this alternative endpoint primarily on the basis of RI and feasibility studies, without collecting data from full-scale system operation. Eleven of the 55 sites conducted modeling (Appendix A, sites 3, 8, 15, 21, 42, 43, 49, 55, 61, 62 and 67). At least 10 of the 55 sites conducted one or more pilot-scale or treatability studies of technologies including tar extraction, thermal treatment (steam or hot water injection), ISCO, enhanced bioremediation, hydrogen release compound (HRC), SVE, in-well aeration, phytoremediation, excavation, and pump-and-treat) (Appendix A, sites 2, 7, 21, 42, 43, 48, 55, 69, 72, and 77). Three additional sites operated full-scale interim pump-and-treat systems prior to approving a TI waiver (Appendix A, sites 46, 50, and 61). The majority of sites (40 out of 77) do not appear to have conducted site-specific technology field testing for groundwater remediation (Appendix A). Note that remedial activities to address site soils may have occurred at these sites, perhaps for different OUs.

5.3.2 Full-Scale Remedy (Interim or Final)

An existing full-scale interim remedy may not be making sufficient progress towards cleanup goals and stakeholders may like to take these challenges into account when selecting the final remedy. Or, the potential project risk event of not meeting groundwater cleanup goals may already be occurring at these sites. A "failed remedy" may not have performed as expected or a technology may have reached a point where it is no longer making effective progress towards cleanup goals. The next steps at these sites may involve re-opening the ROD conducting additional technology evaluations, feasibility studies, and perhaps issuing a new decision document (e.g., ROD amendment or ESD at CERCLA sites).

In either case, it is important to evaluate the reasons that the treatment system did not make sufficient progress towards meeting remedial goals or objectives. The improper selection, design, or operation of a technology must be ruled out as the cause of poor performance (USEPA, 1993). An assessment of alternative endpoints and approaches should consider the following questions to clarify whether the remediation system is limited by underlying technical issues or by improper technology design and construction:

- Are the operations data sufficient to evaluate treatment system performance? Demonstrate that the monitoring program is of sufficient quality and detail to evaluate remedial action performance (e.g., analyze plume stability, containment, and concentration trends).
- What evidence indicates that groundwater cleanup levels will not likely be achieved within a reasonable time frame using the technologies selected and demonstrated at full-scale? Describe relevant trends in subsurface contaminant concentrations, types and quantities of contaminant mass removed, removal rates, whether the plume is shrinking or stable, and the extent to which these trends are occurring naturally or as a result of treatment conditions. Include other relevant information regarding underlying cleanup challenges, such as whether aqueous-phase concentrations rebounded when the system was shut down or whether contaminated soils on site are contaminating the groundwater.
- Did the remedy function as intended? How did actual system performance compare with the predicted performance? If there were discrepancies between

predicted and actual performance, what were the likely reasons for these discrepancies? Were there opportunities to modify operations based on lessons learned or optimization efforts?

- How was the remedy designed and operated? Describe the design and as-built construction information, design basis, operating parameters, system downtime, and any operation and maintenance problems. Demonstrate that the existing remedy was effectively operated and adequately maintained.
- Were enhancements to the original design considered or implemented? Describe and evaluate the effectiveness of any modifications or enhancements to the physical treatment system or operational parameters. Present monitoring data and analyses that illustrate the impact of these enhancements on system performance.
- How was the remedy selected? Would any other remediation technologies likely be more successful? Were these technologies ever evaluated at the site previously? Have new data become available since that time that would change the analysis?

These questions can provide the basis for a rigorous demonstration that the observed system performance is due not to inadequate technology selection, design, implementation, operation or maintenance but rather to attempting to achieve goals that are not feasible within a reasonable time frame using the best available technologies. Such an evaluation may also provide insights into potential effective remedy modifications.

Sites amending final remedies after those remedies did not make sufficient progress towards cleanup include NTC Orlando, Fairchild Semiconductor and 19 sites with post-implementation TI waivers (Appendix A; Appendix B sites 5c and 7b). NTC Orlando evaluated multiple technologies and implemented full-scale ISCO and in-situ bioremediation before approving MNA over a long time frame. Fairchild Semiconductor site and several sites receiving post-implementation TI waivers had operated pump-and-treat systems for several years but failed to make sufficient progress towards cleanup objectives (Appendix A, sites 14, 16, 17, 27, 39, 45, and 47). Some sites reached asymptotic removal rates. Pump-and-treat system optimization was attempted at some sites, including pulsed pumping (Appendix A, site 27). Several sites continued to use the same technologies but revised their remedial expectations (e.g., used the system for containment instead of remediation) (Appendix A, sites 30, 32, 36, 38, 52, and 65). Some sites transitioned to MNA by estimating remedial time frames that were similar to pump-and-treat (Appendix A, sites 27, 45, and 47). Other sites began with a variety of source treatment technologies, including SVE/bioventing, enhanced bioremediation, free product removal, thermal treatment, and excavation. These sites also either continued using the same technology with different remedial expectations or transitioned to MNA, containment, or contingency containment systems (Appendix A, sites 22 and 23, 40, 52, 56, 58 and 71).

Contingency language (stating that Plan B will be evaluated in the future if Plan A does not meet performance expectations) may be included in the original decision document in an attempt to mitigate the potential project risk event of not meeting groundwater cleanup goals. The use of contingency language may preclude re-opening the ROD and may facilitate the transition to the alternative endpoint or approach, perhaps using metrics that were previously agreed upon. Sites that have used contingency language referencing TI waivers (but have not yet needed to approve TI waivers) are listed in Appendix C, Table C-4. Watervliet Arsenal (Appendix B, site 8b) used contingency language referencing alternative endpoints prior to undertaking 5 years of ISCO testing. Union Pacific Railroad Co. Tie-Treating Plant (Appendix B, site 9a) included contingency language in a 5-year review report referencing two types of alternative endpoints as potentially applicable. Despite this forward-thinking communication, significant effort may still be needed to demonstrate or justify the alternative endpoint or approach.

5.4 ROLE OF ENDPOINTS IN THE FINAL REMEDY

One of the common misconceptions about alternative endpoints and approaches is that they provide an opportunity to walk away from a site, or "do nothing." Depending on the approach, numeric cleanup goals for contaminant concentrations may remain unchanged, may be replaced with alternative concentration goals, or may be waived for specific contaminants within a defined volume. When facing technological challenges to groundwater cleanup, a combination of partial source and/or plume treatment, containment, LTM, periodic reviews, ICs or engineering controls will likely be required to protect human health and the environment. Thus, the components of a final remedy may be similar between sites that implement alternative endpoints and approaches and those that do not. However, the long-term remedial expectations will be different for the two sites.

The benefits of source zone treatment are uncertain at complex sites where there are technical challenges to groundwater cleanup (see, for example, USEPA, 2003; SERDP, 2008). Source zone benefits are difficult to quantify due to uncertainties in the mass of contamination present, and the distribution of mass or architecture of the source zone. More research and experience is often needed at the site to quantify the impact of mass removal from source areas on cleanup time frames, volume of aquifer restored, or reduction of concentrations at potential points of exposure. For example, Loring AFB set aside the TI zone as a research area for thermal treatment of fractured rock and contributed demonstration funding dollars (see Appendix A, sites 42 and 43). Other sites with alternative endpoints and approaches have conducted excavation, free product recovery, thermal, ISCO and bioremediation, or air sparging and SVE for partial mass removal and risk reduction (see Appendix A, sites 2, 14, 22, 23, 29, 31, 33, 35, 51, 52, 60, 65, 66, 76; Appendix B, sites 1b, 1c, 2b, 4a, 4d, 4e, 5c, 5d, 6a, 6b, 7a, 7b, 8a, 8b, and 9a) in addition to containment, monitoring, and ICs.

Planning the transition from an aggressive mass removal technology to a less aggressive technology or to MNA has been made empirically or on a nontechnical basis. The case study of NTC Orlando (Appendix B, site 7b) is a good example of when and how remedy transition decisions can be made. At this site, ISCO was used to remove significant mass; however, rebound was observed after the system was shut down, indicating that substantial contamination still remained in the subsurface. Site remediation professionals followed up with enhanced in situ bioremediation and operated the system for several years until removal rates declined. They then petitioned stakeholders to transition to MNA. Mass flux reduction has been considered at some sites as a useful metric for transitioning from an active to a more passive technology (ITRC, 2010b). Mass flux was used as a technology performance metric at Watervliet Arsenal (see Appendix B, site 8b).

5.5 OTHER CONSIDERATIONS

Stakeholder input is a critical part of the remedy selection and implementation process at any site. Sites adopting alternative endpoints and approaches are no exception. Consensus on the need for an alternative endpoint and overall remedial approach can be fostered through early involvement of all stakeholders, agreement or refinement of the CSM, and participation in regular partnership meetings. Stakeholders may need to follow different procedural requirements and policies, depending on cleanup program jurisdiction. Roles and responsibilities of all stakeholders should be made clear, as well as any jurisdiction issues. For example, USEPA may not recognize various state groundwater management terminologies; at a state-lead CERCLA site, these would only apply to state ARARs, not federal ARARs. Similarly, states cannot implement groundwater use restrictions that conflict with local water management plans. Case studies provided in Appendix B illustrate how compromise can be reached on these difficult issues.

The evaluation of alternative endpoints and approaches requires some level of effort for data analysis and reporting. Most sites do not track or report the level of effort involved in the evaluation of alternative endpoints and approaches, making it difficult to research net costs or cost benefits of conducting an evaluation. A previous study of TI waivers found that TI evaluation reports ranged in length from 10 to 70 pages. Some were stand-alone reports with several appendices (Malcolm Pirnie, 2004). Similarly, an analysis of case studies of other types of alternative endpoints and approaches seems to indicate a wide range in the time and money needed to evaluate whether they are appropriate at a site. For example, at Watervliet Arsenal, a five-year pilot study was conducted to evaluate mass removal and its impact on downgradient mass flux. At other sites, little or no additional field work/significant data analysis appears to have been conducted.

Finally, it is difficult to evaluate the success rate of incorporating an alternative endpoint or approach. Project researchers found that the number of sites that evaluate TI waivers but do not approve them is not documented (Malcolm Pirnie, 2004). Formal evaluation reports are not typically prepared until stakeholders agree there is likely a need for a TI waiver (Malcolm Pirnie, 2004). Interviews with USEPA and state regulators revealed only a few site examples where TI waivers had been discussed but never formally evaluated (Malcolm Pirnie, 2004).

5.6 SUMMARY

This report is intended to provide DoD site managers and other stakeholders with an overview of alternative endpoints and approaches for groundwater cleanup. A variety of case studies referenced in this report provide the reader with details of alternative approaches that have been used in the past at a variety of sites under various regulatory programs, including CERCLA, RCRA, and state cleanup programs. Key findings described in this report include the following:

- Alternative endpoints and approaches are applicable under a variety of cleanup programs, including CERCLA, RCRA, state Superfund programs, and state voluntary cleanup programs. Regulatory language is generally flexible rather than prescriptive and allows for site-specific approaches to meet overall cleanup expectations. CERCLA and RCRA allow for alternative site-specific cleanup objectives through TI waivers, ACLs, other ARAR waivers, or site-specific cleanup standards. Most states have patterned their cleanup programs after regulations developed under CERCLA and RCRA statutes and have similar provisions. In addition, at least 13 states have groundwater classification systems that indicate groundwater use, value, and/or vulnerability. These designations (Table 3) may allow for consideration of alternative endpoints.

- Many types of alternative endpoints and approaches have been used at complex sites nationwide, including formal designations of alternative final remedial goals (e.g., ARAR waivers, ACLs, and formal state designations such as CZs) as well as alternative approaches that intend to eventually meet cleanup requirements but clearly communicate nontraditional remedial expectations (e.g., very long time frames to achieve cleanup requirements, designated points of compliance downgradient of the source zone, groundwater zoning to preclude drinking water standards as cleanup requirements, remediation to the extent practicable).

- TI waivers have been used for groundwater at a total of 77 CERCLA sites, with approximately 70% of them granted after USEPA's 1993 guidance. TI determinations have been made in 24 states and nine out of ten USEPA regions. Regions 1 and 3 have used the TI alternative endpoint process the most; Region 4 has not used the process. Based on a keyword search of CERCLA site RODs, sites that consider but do not adopt TI waivers implement another type of alternative endpoint or approach.

- Several other alternative endpoints and approaches may be applicable at complex sites. Examples include remedies that change long-term "absolute" objectives by invoking ARAR waivers based on greater risk or ACLs. Many of the case studies illustrate the important distinction between absolute, long-term, remedial objectives (e.g., meeting ARARs) and functional, short-term, objectives and metrics for making remedial decisions and tracking remedial progress. This distinction is particularly important when using an adaptive site management approach, where there may be no clear pathway to achieving the ultimate cleanup objectives. The distinction may enhance communication between stakeholders and focus the group's discussion onto achievable, short-term remedial expectations and objectives, and common expectations for reasonable time frames (perhaps assessed relative to other alternatives at a given site) to achieve ultimate objectives.

- Approaches such as MNA over a long time frame, adaptive site management, and remediation to the extent practicable may leave absolute objectives unchanged but establish functional or shorter-term objectives, as reflected in site-specific remedial objectives and RAOs. At CERCLA sites, site-specific RAOs have been used as an appropriate way to document alternative approaches without necessarily changing long-term endpoints (e.g., ARARs). RAOs may be qualitative or quantitative; they may describe absolute objectives or functional objectives in order to protect human health and the environment. ACLs are authorized under CERCLA and RCRA; however, a recent USEPA memorandum has identified additional factors to consider prior to establishing ACLs at

CERCLA sites, making the process more rigorous. MNA over long time frames, sometimes hundreds of years, has been used at sites as an alternative to TI designations based on the interpretation of "reasonable time frame." Benefits of an adaptive site management approach include a strong focus on remedial progress, documentation of progress towards RAOs, functional objectives or other short-term metrics, encouraging adaptability and innovation and furthering technology. Remediation to the extent practicable is another way of stating short-term remedial expectations without waiving cleanup requirements.

- Reasons for selecting one type of alternative endpoint or approach over another likely vary with site circumstances. Relative cost comparison among options, drivers for selecting one approach over another, and regulatory perspectives on the appropriateness of one approach versus another are generally not documented in written reports and are therefore unknown.
- Regardless of the specific type of alternative endpoint or approach chosen, similar management actions have been required as part of the overall remedy. For example, remedy packages at highly complex sites using different alternative endpoints and approaches often include partial source area remediation, containment, MNA, ICs, and LTM. Case studies illustrate how compromise may be expressed through careful wording of the final selected remedy. For example, stakeholders who are not receptive to one type of alternative endpoint or approach may agree to implement a remedy that results in essentially the same type of remedial systems to protect the environment.

Most importantly, final remedies must protect human health and the environment and comply with regulations. Consideration of alternative endpoints and approaches may help site stakeholders with remedy selection and site closure processes, particularly at complex sites.

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6.0 REFERENCES

AFCEE. 2009. Sustainable remediation tool. Available online at www.afcee.af.mil/resources/technologytransfer/programsandinitiatives/sustainableremediation/srt/index.asp.

Air Force. 2004. Memorandum from SAF/IEE regarding Air Force cleanup program performance-based management policy. October 27.

California RWQCB SF Bay Region. 2005. Executive Officer's Report. September 14. Available online at www.swrcb.ca.gov/rwqcb2/board_info/agendas/2005/september/09-21-05-4eosr.doc.

California RWQCB SF Bay Region. 2009. Assessment tool for closure of low-threat chlorinated solvent sites. Draft Final. July 31.

California State Water Resources Control Board. 2010. GAMA – Groundwater Ambient Monitoring Program. Sites with Containment Zones. Available online at http://www.swrcb.ca.gov/water_issues/programs/gama/containment_zones.shtml.

Carr, C.S., S. Garg, and J.B. Hughes. 2000. Effect of dechlorinating bacteria on the longevity and composition of PCE-containing nonaqueous phase liquids under equilibrium conditions. Environmental Science and Technology 34 (6): 1088-1094.

Chapman, S.W., and B.L. Parker. 2005. Plume persistence due to aquitard back diffusion following dense nonaqueous phase liquid removal or isolation. Water Resources Research 41(12): W12411.

Charsky, M. 2010. Personal communication of Dr. Matt Charsky, USEPA, with Dr. Rula A. Deeb, Malcolm Pirnie. October.

Delaware. 2008. Coordinated state agency response policy to detections of volatile synthetic organic contaminants in ground-water and/or drinking water. February. Available online at www.awm.delaware.gov/SIRB/Documents/State%20Response.pdf.

Delaware. 2009. HSCA, VCP, and NPL Sites with Groundwater Management Zones (GMZs) Requirements. January. Available online at www.awm.delaware.gov/SIRB/Documents/GMZ_sites.pdf.

DERP. 2009. Fiscal Year 2009 Defense Environmental Program Annual Report to Congress. Defense Environmental Restoration Program. Available online at http://www.denix.osd.mil/arc/ARCFY2009.cfm.

Garrett, T.L. 2004. RCRA practice manual – 2nd edition. Copyright American Bar Association. Editor: Theodore L. Garrett.

ITRC. 2002. DNAPL source reduction: Facing the challenge. Regulatory overview. April. Available online at www.itrcweb.org/Documents/DNAPLs-2.pdf.

ITRC. 2004b. Strategies for monitoring the performance of DNAPL source zone remedies. Technical/regulatory guidelines. Interstate Technology & Regulatory Council DNAPL Team. August.

ITRC. 2006a. Performance-Based Management. Technology Overview. Fifth in a series of Remediation Process Optimization Advanced Topics. March. Available online at www.itrcweb.org/Documents/RPO-6.pdf.

ITRC. 2006b. Exit Strategy - Seeing the Forest beyond the Trees. Technology overview. Second in a series of Remediation Process Optimization Advanced Topics. March. Available online at www.itrcweb.org/Documents/RPO-3.pdf.

ITRC. 2009b. Remediation risk management. Available online at www.itrcweb.org.

ITRC. 2010a. About ITRC. Available online at www.itrcweb.org.

ITRC. 2010b. Use and measurement of mass flux and mass discharge. Technology overview document. August. Available online at http://www.itrcweb.org/Documents/MASSFLUX1.pdf.

ITRC. 2011a. Assessing alternative endpoints and remedial approaches to address groundwater cleanup challenges: Remediation risk management. Technical and Regulatory Guidance document. March. Available online at www.itrcweb.org.

ITRC. 2011b. Project risk management for site remediation. Overview document. Available online at www.itrcweb.org.

Malcolm Pirnie. 2002. Guidance to site managers at Army installations: Groundwater evaluation and development of remediation strategies where aquifer restoration may be technically impracticable. Prepared for the Army Environmental Center by an expert panel. December.

Malcolm Pirnie. 2004. Technical impracticability assessments: Guidelines for site applicability and implementation. Phase II report. Prepared for the Army Environmental Center. March.

Malcolm Pirnie. 2008. Applying diagnostic tools for performance evaluation of in-situ bioremediation of a chlorinated solvent source area. ESTCP Project ER-200318. November. Final draft. Available online at www.serdp-estcp.org.

Malcolm Pirnie. 2011. Technology status of diagnostic tools for site characterization and remedial selection, design, and performance assessment at chlorinated solvent sites. ESTCP Project ER-200318. Final draft. Available online at www.serdp-estcp.org.

Mayer, A.S., and A.M. Hassanizadeh (editors). 2005. Soil and groundwater contamination: Nonaqueous phase liquids – Principles and observations. American Geophysical Union, Washington DC, 216 p.

National Academy of Sciences. 2010. Study in progress: Upcoming report. Future options for management of the nation's subsurface remediation effort. National Research Council, Division on Earth & Life Studies. Available online at http://dels.nas.edu/Study-In-Progress/Future-Options-Management/DELS-WSTB-09-02.

NAVFAC. 2004. Guidance for optimizing remedy evaluation, selection, and design. Naval Facilities Engineering Command. Prepared by NAVFAC Optimization Workgroup. April.

NAVFAC. 2008. Groundwater risk management handbook. Naval Facilities Engineering Command.

New Jersey Department of Environmental Protection. 2009. Classification Exception Areas/Well Restriction Areas Polygon Maps for New Jersey. Available online at http://www.state.nj.us/dep/gis/stateshp.html#CEA.

NRC. 1994. Alternatives for ground water cleanup. National Research Council, National Academies Press, Washington, D.C.

NRC. 2003. Environmental cleanup at Navy facilities: Adaptive site management. National Research Council, National Academies Press, Washington, D.C.

NRC. 2005. Contaminants in the subsurface: Source zone assessment and remediation. National Research Council, National Academies Press, Washington, D.C.

Ohio EPA. 2010. Table listing sites that have received the Urban Setting Designation in Ohio. Available online at http://www.epa.ohio.gov/portals/30/vap/docs/Urban%20 Setting%20Designations.pdf.

Pankow, J.F., and J.A. Cherry. 1996. Dense chlorinated solvents and other DNAPLs in groundwater, Waterloo Press, Portland, Oregon.

Parker, B.L., R.W. Gillham, and J.A. Cherry. 1994. Diffusive disappearance of immiscible-phase organic liquids in fractured geologic media. Ground Water 32(5):805-820.

Reed, S., and J. James. 2010. Environmental Restoration Overview, Mountain Creek Industrial Center. July 16. Presentation available online at http://mountaincreekindustrial center.com/downloads/MCIC_Industry_Day_Environmental_Presentation.pdf.

Reynolds, D.A., and B.H. Kueper. 2002. Numerical examination of the factors controlling DNAPL migration through a single fracture. Ground Water 40(4): 368-377.

Sale, T., T. Illangasekare, J. Zimbron, D. Rodriguez, B. Wilking, and F. Marinelli. 2007. AFCEE source zone initiative final report. Prepared for the Air Force Center for Environmental Excellence, May.

Sale, T., C. Newell, H. Stroo, R. Hinchee, and P. Johnson. 2008. Frequently asked questions regarding management of chlorinated solvents in soils and groundwater. Developed for the Environmental Security Technology Certification Program, July.

SERDP. 2008. Development of assessment tools for evaluation of the benefits of DNAPL source zone treatment. Project ER-1293. September.

SERDP/ESTCP. 2009. DNAPL source zone initiative. Available online at http://www.serdp-estcp.org/dnapl.cfm.

TCEQ. 2004. Proposed Remedial Action document for State Hwy 123 PCE plume, Proposed state Superfund site, San Marcos, Hays County, Texas. December 9.

TCEQ. 2007. Proposed Remedial Action document for Spector Salvage Yard, Proposed state Superfund site, Orange, Orange County, Texas. January.

TCEQ. 2010. Municipal Setting Designations. Available online at www.tceq.state.tx.us/remediation/msd.html.

Terzaghi, K., and R. B. Peck. 1948. Soil mechanics in engineering practice. John Wiley and Sons, New York; Chapman and Hall, London.

Texas Register. 2007. Notice of intent to designate a groundwater plume management zone, Spector Salvage Yard, Orange, Texas. 32 Texas Register 966-967. February 23.

U.S. Army. 2007. Red River Army Depot Installation Action Plan. Available online at https://aero.apgea.army.mil/pIAP-Doc/redriverarmydepot/redriverarmydepot.html.

USEPA. 1985. Guidance on feasibility studies under CERCLA. June. Superseded by USEPA, 1988. Guidance for conducting remedial investigations and feasibility studies under CERCLA, Interim Final, USEPA 540/G/89/004, OSWER 9355.3-01, October.

USEPA. 1991. ARARs Q's and A's: The fund-balancing waiver. Office of Solid Waste and Emergency Response (OSWER) Quick Reference Fact Sheet. January. Available online at epa.gov/superfund/policy/remedy/pdfs/92-34213fs-s.pdf.

USEPA. 1993. Guidance for evaluating the technical impracticability of ground-water restoration. OSWER Directive 9234.2-25. USEPA/540-R-93-080. September.

USEPA. 1999. Use of monitored natural attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites. OSWER Directive 9200.4-17P. April 21. Available online at www.cluin.org/download/reg/d9200417.pdf.

USEPA. 2000a. Region 5 framework for monitored natural attenuation decisions for ground water. September 19. Available online at www.epa.gov/region5/cleanup/region5-mna-framework-2000.pdf.

USEPA. 2000b. Abandoned mine site characterization and cleanup handbook. Regions 8, 9, and 10. USEPA 910-B-00-001. August.

USEPA. 2003. The DNAPL remediation challenge: Is there a case for source depletion? EPA/600/R-03/143. Findings of an USEPA expert panel.

USEPA. 2004. Handbook of groundwater protection and cleanup policies for RCRA Corrective Action. USEPA530-R-04-030. Revised April. Available online at www.epa.gov/waste/hazard/correctiveaction/resources/guidance/gw/gwhandbk/index.htm.

USEPA. 2005. Use of Alternate Concentration Limits in Superfund cleanups. OSWER 9200.4-39. July 19. Available online at epa.gov/superfund/health/conmedia/gwdocs/ pdfs/aclmemo.pdf.

USEPA. 2007. Recommendations from the USEPA ground water task force. USEPA 500-R-07-001. December.

USEPA. 2009a. DNAPL remediation: Selected projects where regulatory closure goals have been achieved. Status update. Office of Solid Waste and Emergency Response. USEPA 542/R-09/008. August.

USEPA. 2009b. Summary of key existing USEPA CERCLA policies for groundwater restoration, USEPA OSWER Directive 9283.1-33. Available online at www.epa.gov/superfund/health/conmedia/gwdocs/pdfs/9283_1-33.pdf.

USEPA. 2009c. Green remediation focus. Available online at www.cluin.org/greenremediation/index.cfm.

USEPA. 2010a. Green remediation focus. Available online at www.clu-in.org/greenremediation/index.cfm.

USEPA. 2010b. Environmental indicators. Available online at www.epa.gov/epawaste/hazard/ correctiveaction/eis/index.htm.

USEPA. 2010c. Institutional controls: A guide to planning, implementing, maintaining, and enforcing institutional controls at contaminated sites. Interim final. USEPA-540-R-09-001. November.

Ward, C., P. Alvarez, D. Gomez, J. Hughes, and M. da Silva. 2009. Final report: Reductions in DNAPL longevity through biological flux enhancement. Prepared for Environmental Security Technology Certification Program by Rice University, Houston, Texas; the Georgia Institute of Technology, Atlanta, Georgia; and the Universidade Federal de Santa Catarina, Florianópolis, Santa Catarina, Brazil.

Yang, Y., and P.L. McCarty. 2002. Comparison between donor substrates for biologically enhanced tetrachloroethene DNAPL dissolution. Environmental Science and Technology 36: 3400-3404.

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APPENDIX A

TECHNICAL IMPRACTICABILITY WAIVER SITE SUMMARIES

Site No. 1: Aberdeen Proving Ground (Edgewood Area) – Canal Creek Beach Point, Maryland

General:	
Site:	Canal Creek Beach Point Test Site (OU 2)
Site setting:	This site was a testing range for the Army. The military used chemical warfare agents to test Army clothing
Contaminants:	Pentachloroethane, TCE, and other chlorinated VOCs, other VOCs, petroleum hydrocarbons, and unexploded ordinance
NAPL:	Yes, DNAPL is present
Hydrogeology:	Shallow aquifer (sands and silts) to a depth of 65 feet, below which is a confining clay layer. The site drains to Bush River and into an estuarine channel of the Chesapeake Bay
CSM:	Dilution is protecting Bush River from high concentrations of contaminants; no routes for public exposure to contaminants
Timeline:	1990s Removed debris and conducted several ecological studies of the Bush River 1994-1995 Soil and soil gas sampling 1995 Qualitative risk assessment for human and ecological health 1996 FS conducted 1997 ROD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	DNAPL remediation is impracticable due to a lack of ability to characterize the DNAPL zone and continual dissolution of DNAPL into groundwater
Secondary reasons:	Low risk - no human exposure routes to contamination, low concentrations in Bush River; No disapproval from the public or from the State
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation is an Appendix to the FS, issued 1 year before the ROD
ARARs waived:	MCLs and MCLGs, both Federal and for the state of Maryland
TI zone:	All areas that exceed cleanup levels down to 75 ft below ground surface (the base of the aquifer)
Data basis for waiver:	Soil and groundwater sampling completed before the FS; other studies done on nearby rivers
Years of characterization:	3
Timeframe estimate:	Time to meet ARARs is expected to be well over 100 years
Cost estimate:	Not given
Final remedy:	Monitoring contaminant concentrations in the Bush River, ICs
Alternatives to TI waiver:	Considered several technologies, including a slurry wall, in-situ dehalogenation, UV oxidation/air stripping, and hydraulic containment. Objections were found in each case, including the generation of cis-1,2-DCE and the presence of unexploded ordnance
Stakeholders:	
Agencies:	Army and EPA Region 3 approved the remedy. Maryland Department of the Environment tacitly approved the waiver
General Comments:	
Other:	None

Site 2: Aberdeen Proving Ground (Edgewood Area) – J-Field, Maryland

General:	
Site:	J-Field study area (OU 8)
Site setting:	J-Field was used to dispose of chemicals and conduct limited testing of chemical agents. The source of the groundwater plume is the Toxic Burning Pit
Contaminants:	Chlorinated VOCs, metals, petroleum hydrocarbons, and unexploded ordinance
NAPL:	Yes, free-phase and residual DNAPL is present
Hydrogeology:	Shallow aquifer (sands and silts) to a depth of 65 feet, below which is a confining clay layer. The confined aquifer is also contaminated due to leaky wells in past years
CSM:	Groundwater contamination is primarily present in the upper 20 feet of the surficial aquifer. It has reached marsh areas on both sites of the plume where it is significantly degraded before discharging to surface water.
Timeline:	1977 Early survey of contamination 1991-1996 RI was conducted 1990s (late) Several treatability studies were conducting, including in-well aeration using groundwater circulation wells, HRC-enhanced biodegradation, MNA, and phytoremediation 2001 FS, TI evaluation, and ROD
Reason(s) for TI Approval:	
Primary reasons:	DNAPL is present in the surficial aquifer (concentrations exceed 100 mg/L)
Secondary reasons:	Lack of technologies – Treatment is not practicable based on results of treatability studies; limited extraction rates from the surficial aquifer and limitations for in-situ technologies due to low permeability aquifer materials. Excavation is not practicable. Prohibitive costs associated with containment of large area and with UXO clearance
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation report is an Appendix to the FS, issued the same year as the ROD
ARARs waived:	MCLs and MCLGs, both Federal and for the state of Maryland
TI zone:	All portions of the aquifer that exceed MCLs down to 40 feet below ground surface (the base of the confining layer)
Data basis for waiver:	Treatability studies and conceptual site model
Years of characterization:	~10 years
Timeframe estimate:	Not given
Cost estimate:	Not given
Final remedy:	Free-phase DNAPL recovery in a localized area, continued phytoremediation, monitored biodegradation, continued monitoring of the confined aquifer, and ICs
Alternatives to TI waiver:	Source treatment, plume containment and plume treatment were found to be technically impracticable
Stakeholders:	
Agencies:	Army and EPA Region 3 approved the remedy and the Maryland Department of the Environment concurred with the remedy
General Comments:	
Other:	None

Site No. 3: Aladdin Plating, Pennsylvania

General:	
Site:	OU 02 groundwater
Site setting:	The property is 6 acres. It is located in a rural residential area with unpaved roads. The property is not fenced, and could be accessed by foot via private property. About 50 homes are located within a half-mile of the site. There is little public involvement or knowledge about the historical electroplating activities, chemical storage and fire
Contaminants:	Chromium (max 188 mg/L). Lead, cyanide are present but are not included in the TI waiver
NAPL:	No, NAPL is not present
Hydrogeology:	The shallow overburden is glacial till, underlain by weathered, then competent, fractured limestone/dolomite bedrock. The groundwater velocity is less than 1 ft/year and the aquifer is low yield (less than 2 gallons per day)
CSM:	The shallow overburden is contaminated with chromium. There is limited migration of the chromium
Timeline:	1947-1982 Electroplating activities and waste disposal into two unlined pits 1982 Fire destroyed the operation 1983 Soil sampling by Pennsylvania Department of Environmental Restoration 1987 Removal response action to remove and dispose of the building 1987 Preliminary site assessment, per extraction test, soil was toxic and qualified as hazardous waste. Chromium was detected in 2 out of 62 residential wells. There were no detections in bedrock wells 1987 NPL listing 1988 ROD for soil (OU 01). Cleanup financed by the Superfund 1990 RI/FS for OU 02 groundwater 1993 OU 02 ROD and TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Technologies evaluated have not been shown to be effective at this site
Secondary reasons:	Migration is very limited due to low groundwater velocities
TI Waiver Details:	
Documentation:	Original ROD (Front-end waiver)
TI evaluation report:	No TI evaluation report was prepared (pre-1993)
ARARs waived:	Background levels for chromium (state ARARs) were waived. MCLs will still be achieved.
TI zone:	Shallow and intermediate water-bearing zones
Data basis for waiver:	Modeling of groundwater flow and chromium transport in the bedrock aquifer
Years of characterization:	6
Timeframe estimate:	No remedial timeframes were given. The model estimated over 2,000 years for chromium to migrate to a drinking water aquifer
Cost estimate:	The overall present worth of the chosen remedial strategy is $178,300
Final remedy:	Monitoring and ICs (prohibit well installation)
Alternatives to TI waiver:	No action; electrokinetic extraction and off-site disposal; electrokinetic extraction and on-site treatment (chemical precipitation of chromium), chemical barriers, and stabilization were also evaluated
Stakeholders:	
Agencies:	EPA Region 3 approved the remedy. Pennsylvania did not concur with the selected remedy
General Comments:	
Other:	None

Site No. 4: Aluminum Company of America (Alcoa) - Davenport, Iowa

General:	
Site:	OU 1, including 10 miles of the Mississippi River (Pool 15)
Site setting:	The site is 460 acres, including an unlined waste oil impoundment approximately 150 feet from the Mississippi River. The neighborhood around the site is connected to city drinking water supplies; no groundwater wells are currently in use
Contaminants:	PCE, TCE and PCBs as a NAPL; other VOCs, semi-volatile organic compounds (SVOCs), polyaromatic hydrocarbons (PAHs), metals, and hydrocarbons
NAPL:	Yes, DNAPL is present. LNAPL is also present.
Hydrogeology:	Layer of unconsolidated sediments underlain by fractured limestone/dolomite and shale bedrock. Historically groundwater flows towards the Mississippi River. Since 1989, an industrial process well pump has been pulling groundwater inwards.
CSM:	There are multiple sources. NAPLs are present in the fractured bedrock aquifer. There is a large volume of contaminated groundwater extending to 400 feet below ground surface
Timeline:	1979 Removal of PCB-containing oils from hydraulic lines 1980 Removal of PCB-containing waste oil and sludge (2.8 million gallons) 1984-1985 Alcoa installed oil interception and recovery trench to collect oil released by the plant before it entered the Mississippi River. Capped impoundment. Used high-pressure wash for PCBs in industrial waste sewer line 1986 Groundwater monitoring began 1990s Cleaning of equipment sump pits, re-piping, tank removal, and excavation of PCE and PCB-contaminated soils (1,430 cubic yards) 2002 RI report 2004 FS report and ROD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Presence of NAPL in fractured rock, depth and extent of contamination
Secondary reasons:	Fractures are poorly connected, making it difficult to fully delineate DNAPL and increasing remedial timeframes
TI Waiver Details:	
Documentation:	Original ROD (Front-end waiver)
TI evaluation report:	TI evaluation was submitted as part of the FS, the same year as the ROD.
ARARs waived:	Federal MCLs
TI zone:	Encompasses NAPL and dissolved phase contamination, within Alcoa property
Data basis for waiver:	Groundwater monitoring data
Years of characterization:	18
Timeframe estimate:	Uncertain, but expected to exceed 100 years
Cost estimate:	Net present value ranges from $2.3 to 2.7 million over 30 years. Costs likely to be higher, since O&M will last longer than 30 years
Final remedy:	ICs
Alternatives to TI waiver:	ISCO, in-situ chemical reduction, bioremediation, air sparging, in well stripping, permeable reactive barriers were all evaluated for removing groundwater contamination. None are practicable
Stakeholders:	
Agencies:	EPA Region 7, Iowa Department of Natural Resources, and the City of Davenport Public Works Department
General Comments:	
Other:	None

Site No. 5: Anaconda Co. Smelter, Montana

General:	
Site:	OU 4, Anaconda regional waste, water and soil
Site setting:	Mining operations have been causing contamination in this 28,600-acre area for over 100 years
Contaminants:	Arsenic. Cadmium and copper are also elevated
NAPL:	No, NAPL is not present
Hydrogeology:	Alluvial and deeper bedrock; Mill Creek nearby has elevated arsenic
CSM:	See ROD for details. Per Appendix D of the 1998 ROD, additional characterization may be needed to estimate flux from arsenic source zones.
Timeline:	1884-1980 Mining operations and mine waste disposal 1983 NPL listing 1984 ARCO heads cleanup phase 1988 Relocated Mill Creek residents 1991 Time-critical removal action of arsenic and other metals from residential soils, soils investigation 1992 Arsenic exposure study with University of Cincinnati 1992-1993 RI/FS 1996 TI evaluation 1998 ROD
Reason(s) for TI Approval:	
Primary reasons:	Complex geology and deep percolation of arsenic into fractures; excessive cost
Secondary reasons:	No ability to pump the bedrock aquifer
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation is a separate report issued 3 years after the FS and 2 years before the ROD
ARARs waived:	State of Montana groundwater standard for arsenic (18 ug/L)
TI zone:	28,000 + acres of bedrock aquifer, including Old Works/Stucky Ridge, Smelter Hill and Opportunity Ponds. TI Zone boundaries in the original TI evaluation report were enlarged based on site data gathered in summer 1997
Data basis for waiver:	RI/FS
Years of characterization:	5
Timeframe estimate:	Not given
Cost estimate:	Waste removal would cost more than $2.2 billion. The current remedy costs $88 million (M) to $150 M present worth
Final remedy:	Remove waste soils near streams and place them in a Waste Management Area (WMA). Reduce surface soil concentrations to 250 to 1000 parts per million. Vegetate remaining areas. Prevent exposure to wastes left in place. Monitor around the TI zone to ensure containment. Maintain fully-funded ICs program at local level.
Alternatives to TI waiver:	None evaluated
Stakeholders:	
Agencies:	Montana Department of Environmental Quality, EPA Region 8, PRP is ARCO
General Comments:	
Other:	None

Site No. 6: Broderick Wood Products, Colorado

General:	
Site:	OU 02
Site setting:	The site is situated in a primarily industrial area and is bounded on the southwest and southeast by railroad tracks and on the north by Fisher Ditch. The nearest residences are less than 1/8-mile north of the property line
Contaminants:	Benzene, toluene, ethylbenzene and xylenes (BTEX), PAHs, pentachlorophenol, phenol, dioxins, furans, arsenic, cadmium, lead, zinc, carbozole, pyrene, naphthalene
NAPL:	Yes, LNAPL is present
Hydrogeology:	Alluvial deposits underlain by weathered and unweathered bedrock. Three aquifers: unconfined surficial aquifer, confined Denver aquifer, and the confined Arapahoe aquifer
CSM:	See ROD for details
Timeline:	1947-1981 Wood treatment facility operations 1981 Start of site investigations 1984 NPL listing 1988 ROD 1985-1990 RI/FS 1991 ROD 1992 ROD for OU 02 with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Hydrogeologic characteristics of the Denver aquifer, including small lenses of permeable sandstones interbedded in near-impermeable claystone. This significantly limits the ability to pump-and-treat contaminated groundwater
Secondary reasons:	Low migration - Contaminated groundwater is believed to be confined to within a few feet of the impoundments, due to the small areal extent of the permeable lenses
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	None (pre-1993)
ARARs waived:	Federal and state ARARs; Chemical-specific waiver
TI zone:	Denver aquifer
Data basis for waiver:	Knowledge of site geology
Years of characterization:	8 years
Timeframe estimate:	Not given. 30 years was assumed for monitoring and cost estimates
Cost estimate:	Present worth of $15.6 M over 30 years
Final remedy:	Free-product recovery from Denver Aquifer monitoring wells; groundwater extraction from shallow aquifer, separation and reclamation of LNAPL from groundwater, and groundwater treatment using a two-phase fixed-film bioreactor
Alternatives to TI waiver:	None
Stakeholders:	
Agencies:	EPA Region 8 and the Colorado Department of Health
General Comments:	
Other:	None

Site No. 7: Brodhead Creek, Pennsylvania

General:	
Site:	OU 2 groundwater
Site setting:	This 12-acre site is located on the bank of Brodhead Creek. Coal tar was disposed of in an open pit on the site, resulting in groundwater contamination
Contaminants:	Contaminants include BTEX, PAHs, pentachlorophenol, arsenic and cyanide
NAPL:	Yes, DNAPL is likely present
Hydrogeology:	Fill, stream gravel, glacial overburden and glacial till is layered over bedrock. Groundwater flows to Brodhead Creek
CSM:	Immobile free coal tar is present in two small areas on site. There is no contamination in the deep aquifer
Timeline:	1888-1944 Coal tar disposal into open pits during site operations 1981 EPA constructs underground slurry wall, pumps out coal tar 1983 NPL listing 1990 RI report for soils (OU 1) 1991 FS report; CROW process (injection and extraction of hot water) was used as an interim action for soils 1992 RI investigation of bedrock aquifer. Several emergency response measures used to contain the plume. 1995 ROD for OU 2, with TI waiver 1999 Five-year review 2000 Final completion report 2001 Site deleted from NPL
Reason(s) for TI Approval:	
Primary reasons:	Site constraints: on-site wetlands and two earthen flood control levees make excavation not feasible
Secondary reasons:	Low risk - site conditions prevent future exposure to contaminated groundwater
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation report is dated one day prior to the ROD (6/29 and 6/30/1995)
ARARs waived:	Federal MCLs and state ARARs regarding restoration to background levels
TI zone:	Shallow aquifer, approximating the area with free and residual coal tar (~3 acres, 27,000 cu yards), and extending to the depth of the bedrock.
Data basis for waiver:	Performance of CROW process in the source area, RI/FS
Years of characterization:	12
Timeframe estimate:	Indefinite
Cost estimate:	The present value of the CROW process is $4.12 M
Final remedy:	The existing slurry wall will prevent free-phase coal tar from entering Brodhead Creek, though it is not an absolute barrier to groundwater flow. Monitoring stream sediments, biota, and groundwater will continue. Deed restrictions are in progress.
Alternatives to TI waiver:	Alternatives included no further action, in-situ stabilization/solidification, in-situ bioremediation and excavation
Stakeholders:	
Agencies:	EPA Region 3. Pennsylvania Power & Light and the Union Gas Company are two PRPs
General Comments:	
Other:	None

Site No. 8: Caldwell Trucking Company, New Jersey

General:	
Site:	OU 2
Site setting:	The 11-acre property was used for disposal of mixed wastes (residential, commercial, industrial septic waste) into unlined lagoons for over 20 years. Groundwater flows towards the Passaic River, which is a drinking water source. The Passaic River has been minimally impacted. About 500 homes are located within 1 mile of the site. A nearby municipal well was contaminated from the site
Contaminants:	TCE, 1,1,1-trichloroethane, other VOCs, PAHs, PCBs and metals (including lead)
NAPL:	Yes, DNAPL is likely present
Hydrogeology:	Two aquifers separated by a clay layer, including the upper aquifer (A zone) and three deeper bedrock zones (B, C, and D)
CSM:	No detailed given
Timeline:	1950s to 1973 Waste disposal into unlined lagoons 1973 Wastes were stored in underground tanks 1983 NPL listing 1986 First ROD: 1) Air stripping at a municipal well 2) alternative water supply to residents 3) soil excavation, low temperature thermal treatment and landfill 1989 Second ROD with TI waiver; installation of groundwater wells to intercept the plume, contingency plan for containment if access rights to private properties were not obtained 1990 Institutional controls (fences, signs, covering tanks) 1991 ESD to delete municipal wellhead treatment system as this well was replaced by a different drinking water source 1993 ESD to document remedy modification and increased remedial action costs 1994 On-site waste stabilization, also excavation and off-site disposal 1995 Third ROD addressing soil contamination modification
Reason(s) for TI Approval:	
Primary reasons:	Magnitude and extent of the plume (plume is 2000 ft wide and 4000 ft long, with other overlapping plumes); Impact of other sources on the plume
Secondary reasons:	Model-predicted timeframes exceeding 100 years
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	None (pre-1993)
ARARs waived:	Federal and state MCLs
TI zone:	Assume zone includes whole site and off-site areas as well. Contaminated zone extends from the water table to bedrock (~370 feet)
Data basis for waiver:	RI/FS, off-site investigation, modeling
Years of characterization:	3 years (1986 to 1989)
Timeframe estimate:	Up to 200 years using pump and treat, based on computer modeling
Cost estimate:	For the entire remedy, the cost estimate in 1989 ROD was $11.54 M over 30 years
Final remedy:	Pump-and-treat with discharge to the river, ICs (fencing), alternative municipal water supply
Alternatives to TI waiver:	None were discussed
Stakeholders:	
Agencies:	EPA Region 2, PRPs, State of New Jersey
General Comments:	
Other:	None

Site No. 9: California Gulch, Colorado

General:	
Site:	OU 12 (surface water and groundwater)
Site setting:	Mining, mineral processing, and smelting have occurred in the 18-square mile area since 1859
Contaminants:	Cadmium and lead
NAPL:	No, NAPL is not present
Hydrogeology:	Unconsolidated alluvial glacial deposits, heavily disturbed by mining activities. The depth to groundwater is approximately 250 feet. Groundwater and surface water flow to the Arkansas River
CSM:	Mining-related wastes are a source of metal contamination to surface water and groundwater
Timeline:	1983 Added to the NPL
Reason(s) for TI Approval:	
Primary reasons:	Large volume of waste left in place, including capped tailings and/or waste rock piles, will act as an ongoing source of these metals over time
Secondary reasons:	None given
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation was included as an Appendix to the ROD (7 pages)
ARARs waived:	MCLs
TI zone:	Shallow groundwater to a depth of 50 feet below ground surface, over an area along the river drawn on a map, approximately 4 miles long and 100 to 200 feet wide
Data basis for waiver:	RI and FS reports
Years of characterization:	
Timeframe estimate:	Not quantified; ROD states it would not be reasonable
Cost estimate:	Cost of excavation would be hundreds of millions (FS report estimated $142 M).
Final remedy:	Monitoring, ICs (Area of Attainment), and TI waiver
Alternatives to TI waiver:	Excavation of waste materials over entire TI zone
Stakeholders:	
Agencies:	EPA Region 8 approved the remedy. The State of Colorado also signed the ROD
General Comments:	
Other:	None

Site No. 10: Charles-George Reclamation Trust Landfill, Massachusetts

General:	
Site:	OU 3 and 4
Site setting:	This site is a 70-acre mixed hazardous, industrial and municipal waste landfill
Contaminants:	Benzene, arsenic, and cadmium in deep bedrock; chlorinated VOCs in landfill leachate and gas
NAPL:	No, NAPL is not likely present
Hydrogeology:	Shallow overburden, shallow bedrock and deep bedrock
CSM:	Maximum concentrations in bedrock are 69 ug/L benzene, 93 ug/L arsenic, and 19 ug/L cadmium. Deep plume discharges to Merrimack River.
Timeline:	1950s-1967 Small municipal dump 1967-1983 Began accepting industrial wastes, including drummed and bulk chemicals and metal sludges 1981-1984 Removal actions including a replacement water line, fencing, soil cover, and gas vents 1983 NPL listing 1983 ROD for OU 1, to extend public water supply line 1985 ROD for OU 2, cap, surface water diversion, leachate and off-gas collection 1988 RI/FS report and ROD for OU 3 and 4 with TI waiver 2005 Five-year review
Reason(s) for TI Approval:	
Primary reasons:	Given the uncertainties in the spatial extent of the deep bedrock plume and the difficulty in predicting groundwater flow in bedrock, it is considered infeasible to extract the entire deep bedrock plume.
Secondary reasons:	Deep aquifer will no longer be used for drinking water as of fall 1988; Plume should attenuate naturally within 1000 ft of the landfill in an undevelopable area of marsh and highway
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	None (pre-1993)
ARARs waived:	Federal MCLs for benzene, arsenic, and cadmium
TI zone:	Contaminated deep bedrock groundwater (Eastern Deep Bedrock Plume) below 100 feet below ground surface
Data basis for waiver:	RI/FS data and CSM
Years of characterization:	3
Timeframe estimate:	Not estimated
Cost estimate:	Range from $1.2 M to $9.9 M for most FS alternatives with a cost estimate of $117 M present worth to comply with ARARs
Final remedy:	Pump-and-treat for the overburden and shallow bedrock, landfill capping, monitoring, alternate water supply, ICs
Alternatives to TI waiver:	Pump, storage and off-site treatment of contaminated groundwater and leachate
Stakeholders:	
Agencies:	EPA Region 3 and the Massachusetts Department of Environmental Quality
General Comments:	
Other:	None

Site No. 11: Chemical Insecticide Corp., New Jersey

General:	
Site:	OU 4 (groundwater)
Site setting:	The site is 5.7 acres within a 94-acre industrial complex, formerly used for pesticide and herbicide manufacturing
Contaminants:	Arsenic is the primary contaminant addressed by the TI waiver. In addition, VOCs (TCE, PCE), SVOCs, pesticides (BHCs, chlordane), herbicides (dinoseb), and metals exceed federal and state standards. TCE is an off-site contaminant.
NAPL:	NAPL was never observed.
Hydrogeology:	The subsurface is made up of two water-bearing units separated by a leaky confining unit. Lithology includes fill material, fluvio-glacial deposits, red clay and silt, and consolidated bedrock shale
CSM:	Arsenic concentrations are as high as 17,400 ug/L
Timeline:	1954-1970 Site was used for manufacturing pesticides and herbicides. Many complaints (off-site discharges, fires, odors) to the local health department about site operations. Local health official ordered backfill of four wastewater lagoons 1970 Company declared bankruptcy and stopped production 1975 Buildings were demolished and site was fenced-off 1989 Interim ROD issued to address soil and surface water runoff (OU 1) 1990 NPL listing 1994 Installed interim cap and created a run-off diversion system 1995 OU 3 ROD for soil and sediment in off-site creek areas 1996-1997 Started soil removal and disposal in OU 3 2000 OU 2 RI/FS, ROD for surface and subsurface soils 2003-2005 OU 2 soil excavation 2004 OU 4 ROD for groundwater, with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	High arsenic concentrations in poorly conductive overburden and fractured bedrock would not be expected to meet drinking water standards within a reasonable timeframe, even with aggressive remedial attempts
Secondary reasons:	Low risk - Limited mobility of groundwater and contaminations, source removal (OU 2) is expected to reduce groundwater concentrations
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation report was an addendum to the RI/FS
ARARs waived:	Federal MCLs
TI zone:	50-acre area, corresponding to the majority of the industrial complex
Data basis for waiver:	RI/FS data
Years of characterization:	17
Timeframe estimate:	To be determined by pilot study based on long-term groundwater monitoring
Cost estimate:	$2.6 M
Final remedy:	ICs
Alternatives to TI waiver:	Pump and treat, which was not expected to meet drinking water standards within a reasonable timeframe
Stakeholders:	
Agencies:	EPA Region 2 and the New Jersey Department of Environmental Protection
General Comments:	
Other:	None

Site No. 12: Cherokee County (Galena), Kansas

General:	
Site:	OU 1, Galena subsite
Site setting:	Site is part of a larger area of CERCLA sites created by historical lead and zinc mining activities and smelting. The Galena subsite is 25 square miles. The area was mined as recently as the 1970s. Soil and shallow groundwater in residential areas are contaminated by lead and zinc. Heavy metals have been released to creeks, where ecological impacts are evident. There are approximately 3,800 people living in the town of Galena
Contaminants:	Heavy metals including zinc, lead, cadmium, and selenium
NAPL:	No, NAPL is not present
Hydrogeology:	Karst-like topography from mine voids with conduit flow. There are two separate hydrologic units beneath the site
CSM:	See ROD for details
Timeline:	1986-1987 Investigation. EPA installed water treatment units on 8 contaminated wells. Countywide survey of wells, added 2 more water treatment units that were later replaced by an alternate water supply. New wells were drilled in the area 1989 ROD with TI waiver 1993 Remedial design 1994 Construction complete 1995 Interim removal actions for soil at 62 properties including daycare centers. EPA investigated using phosphorus to sequester metals instead of excavating 2005 Five-year review
Reason(s) for TI Approval:	
Primary reasons:	Continued presence of waste materials makes remediation impracticable. Inordinately costly to treat all surface mine wastes and stabilize the remaining minerals in the mine.
Secondary reasons:	Consistency with prior EPA decisions and existing remedies in the tri-state mining district
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	None (pre-1993)
ARARs waived:	MCLs and other Safe Drinking Water Act criteria for shallow aquifer
TI zone:	Not explicitly addressed. Assume that TI waiver applies to the entire site
Data basis for waiver:	RI/FS
Years of characterization:	4
Timeframe estimate:	Not estimated
Cost estimate:	Present worth of remedial action totaled $8.3 M, per FS Addendum (1994 dollars)
Final remedy:	Reduce metal loading to streams and groundwater by excavating mine tailings and disposing these into impoundments, contouring and vegetating waste piles, capping source materials, and constructing stream diversion structures. Soil remediation in residential yards; alternate water supply for the City of Galena; ICs (land use restrictions and restrictions on the use of mine wastes)
Alternatives to TI waiver:	Treat all surface mine wastes and strip mine the remaining mineralization. This would be inordinately costly and would require destroying endangered species habitat, removing all surface soils, and permanently relocating the town of Galena
Stakeholders:	
Agencies:	EPA Regions 6 and 7 were involved due to the site's location in the tri-state mining district
General Comments:	
Other:	Two waivers were obtained for Cherokee County

Site No. 13: Cherokee County (Treece/Baxter), Kansas

General:	
Site:	OU 3 and 4 - Treece (Tar Creek) and Baxter Springs Subsites
Site setting:	Site is part of a larger area of CERCLA sites created by historical lead and zinc mining activities and smelting (115 square miles). The Treece and Baxter Springs subsites are 28 square miles. The area was mined as recently as the 1970s. Soil and shallow groundwater in residential areas are contaminated by lead and zinc. Heavy metals have been released to creeks, where ecological impacts are evident
Contaminants:	Heavy metals including zinc, lead, cadmium, and selenium
NAPL:	No, NAPL is not present
Hydrogeology:	Karst-like topography from mine voids with conduit flow, approximately 200 to 500 feet deep. There are two different watersheds impacted by the Treece and Baxter Springs subsites
CSM:	See ROD for details
Timeline:	1986-1987 Investigation at Baxter Springs. EPA installed water treatment units on 8 contaminated wells, completed a countywide survey of wells, added 2 water treatment units later replaced by an alternate water supply, and drilled new wells. 1988 Investigation started at Treece subsite 1995 Interim removal actions for soil at 62 properties including daycare centers. EPA investigated using phosphorus to sequester metals instead of excavating 1997 ROD for OU 3 and 4 with TI waiver 2000 Construction complete
Reason(s) for TI Approval:	
Primary reasons:	Size of the site, including the huge volume of source materials (4.3 M tons); and the karst-like topography, mine voids, waste piles and adjacent mine waste areas would constitute inordinate cost from an engineering perspective, especially when considering the limited environmental gain associated with these expenditures
Secondary reasons:	Consistency with prior EPA decisions in the tri-state mining district
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation report date is unknown
ARARs waived:	Chemical-specific ARARs including MCLs, state standards for lead and surface water standards under Clean Water Act. ROD lists specific ARARs
TI zone:	Not explicitly addressed. Assume the waiver applies to the entire site
Data basis for waiver:	RI/FS
Years of characterization:	9 to 10
Timeframe estimate:	Not given
Cost estimate:	The ROD estimated $7.1 M for the selected remedy, compared with $93.2 M for the most costly alternative evaluated (1997 dollars)
Final remedy:	For groundwater, provision of clean drinking water and ICs (land use restrictions and restrictions on the user of mine wastes)
Alternatives to TI waiver:	Excavation and/or consolidation of mining wastes followed by capping and revegetation
Stakeholders:	
Agencies:	EPA Regions 6 and 7 were involved due to the site's location in the tri-state mining district
General Comments:	
Other:	Two waivers were obtained for Cherokee County

Site No. 14: Conrail Rail Yard (Elkhart), Indiana

General:	
Site:	OU 2
Site setting:	The site is industrial with active railroad yard operations at the time of the remedy decision
Contaminants:	PCE, TCE, 1,2-DCE, 1,1-DCE, vinyl chloride, carbon tetrachloride and chloroform
NAPL:	Yes, DNAPL is likely present at the site
Hydrogeology:	Sands and gravel overburden overlying bedrock
CSM:	Contamination is as deep as 60 to 80 feet below ground surface
Timeline:	1986 EPA sampled and found contamination, gave bottled water to nearby residents 1988 Added to NPL 1994 Final ROD approving pump-and-treat to reach MCLs 2000 Petition for TI waiver and reconsideration of remedy 2000 ROD amendment with TI waiver and containment approach 2004 Five-year review
Reason(s) for TI Approval:	
Primary reasons:	Using current technologies, it is not technically feasible to clean up two DNAPL areas within a reasonable timeframe
Secondary reasons:	Active railyard operations present a formidable restriction on the practicability of available alternatives
TI Waiver Details:	
Documentation:	ROD amendment (post-implementation waiver)
TI evaluation report:	TI evaluation report was a separate report (petition)
ARARs waived:	Federal MCLs for all contaminants
TI zone:	Applies to two source zone areas (Track 65/66 and Track 69)
Data basis for waiver:	Data collected from full-scale operation of pump-and-treat system
Years of characterization:	12
Timeframe estimate:	Hundreds of years, estimated to be 70 to 125 yrs for some remedial technologies
Cost estimate:	$4 - $10 million for remedial alternatives
Final remedy:	The original remedy called for pump-and-treat for restoration. The revised remedy continued the pump-and-treat system for containment, along with MNA and ICs (deed restrictions to protect the pump-and-treat system)
Alternatives to TI waiver:	None mentioned
Stakeholders:	
Agencies:	EPA Region 5, Indiana Department of Environmental Management
General Comments:	
Other:	None

Site No. 15: Continental Steel Corp., Indiana

General:	
Site:	OU 1, groundwater
Site setting:	Former steel manufacturing facility that is approximately 183 acres. Nearby are creeks and residential areas
Contaminants:	Chlorinated VOCs, including PCE, TCE, 1,2-DCE and vinyl chloride. Other contaminants are also included in the TI waiver
NAPL:	Yes, DNAPL is present at the site
Hydrogeology:	Three separate but hydraulically connected aquifers. The deepest is fractured bedrock
CSM:	DNAPL is likely present in all three aquifers
Timeline:	1985 Company filed for bankruptcy, liquidated 1989-1990 Lagoon area, other areas placed on NPL 1990-1991 EPA removal actions, due to runoff complaints. This included about a thousand empty, crushed drums, about 200 drums of product material, about 50 containers of lead cadmium batteries, and about 5,000 gallons of base-neutral liquids. No evidence of "gross radiological contamination" FS in 1998; ROD 1999
Reason(s) for TI Approval:	
Primary reasons:	Regardless of technology, groundwater cannot be restored in the next 200 years. If an active pump-and-treat system is used, the timeframe will not be reduced but costs will be higher
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation report was submitted with the FS report, one year before the ROD
ARARs waived:	Presented in an Appendix to the ROD
TI zone:	Intermediate and lower groundwater zones for the entire site (from the source area to Martin Marietta Quarry)
Data basis for waiver:	Contaminant fate and transport modeling as part of the RI/FS
Years of characterization:	9
Timeframe estimate:	Over 200 years to attain ARARs, based on fate and transport modeling
Cost estimate:	Present worth of the selected remedy is estimated at $6.4 M over 30 years
Final remedy:	Downgradient collection of contaminated groundwater from the lower aquifer and discharge to the local wastewater treatment plant, i.e., containment without needing to install extraction wells. Also monitoring and ICs (deed restrictions and fish advisory)
Alternatives to TI waiver:	Pump-and-treat and MNA were also considered in the FS
Stakeholders:	
Agencies:	The lead agency for remediation was the Indiana Department of Environmental Management. EPA Region 5 was also a stakeholder
General Comments:	
Other:	None

Site No. 16: Crystal Chemical Company, Texas

General:	
Site:	OU 1, groundwater
Site setting:	The site is 6.8 acres and is located in a residential and light industrial area
Contaminants:	Arsenic
NAPL:	No, NAPL is not present
Hydrogeology:	More complex than originally hypothesized in the original ROD, with off-channel deposits, fine-grained sediments and lake deposits, overbank, relic channel and flood plain deposits
CSM:	Site geology inhibits arsenic migration to extraction wells, limiting the effectiveness of pump-and-treat. Arsenic adsorbs to the sediments.
Timeline:	1981 Site activities ceased 1983 NPL listing 1990 Original ROD approving pump-and-treat remedy, with contingency TI waiver language if pump-and-treat was ineffective 1996 TI evaluation report 1997 ESD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	The subsurface geology and nature and extent of arsenic contamination are more complex than originally thought. Revised predictions indicate that 200 times more groundwater needs to be extracted to meet ARARs compared with original ROD estimates
Secondary reasons:	Remedial design studies and modeling indicates cleanup is technically impracticable using pump-and-treat
TI Waiver Details:	
Documentation:	ESD (post-implementation waiver)
TI evaluation report:	TI evaluation report was submitted one year prior to the ROD
ARARs waived:	MCL for arsenic (50 µg/L)
TI zone:	Area under a portion of the property where arsenic MCLs are exceeded, including two sand zones, roughly 15 and 35 feet below ground surface
Data basis for waiver:	Modeling results, laboratory soil column tests and field measurements to better extrapolate pump-and-treat system performance.
Years of characterization:	14
Timeframe estimate:	Modeling indicates a timeframe of 650 years to meet ARARs
Cost estimate:	None given
Final remedy:	Construction of a slurry wall around the TI zone, continued limiting pumping, monitoring, and ICs
Alternatives to TI waiver:	Remedies evaluated in the FS included no action, limited action, and extraction without treatment (discharge to the local wastewater treatment plan). None of these alternatives would meet ARARs
Stakeholders:	
Agencies:	EPA Region 6 and the Texas Commission on Environmental Quality
General Comments:	
Other:	None

Site No. 17: Del Norte Pesticide Storage, California

General:	
Site:	OU 3, groundwater
Site setting:	The site is less than 1 acre, surrounded by land owned by the county. The site is located about 2000 feet from a public beach. The closest private water supply wells are ¼ mile away
Contaminants:	1,2-dichloropropane, 2,4-dichloropropane, and chromium
NAPL:	Yes, residual 1,2-dichloropropane is acting as a NAPL
Hydrogeology:	Well-sorted fine sands, silts and clays with moderate permeability. The groundwater table fluctuates. Groundwater is classified as Class II (agricultural and domestic purposes)
CSM:	See ROD for details
Timeline:	1981 Contamination discovered 1983 NPL listing 1985 ROD 1987 Soil removal in source area (sump), began operating groundwater pump-and-treat system 1990-1994 Groundwater pump-and-treat system reached asymptotic levels. Air sparging was added 1995-1996 Operation was modified. System turned off in 1997 2000 ROD amendment and TI waiver approved 2002 Site was deleted from the NPL
Reason(s) for TI Approval:	
Primary reasons:	Pump-and-treat system reached an asymptotic low values (15 to 40 ug/L) and system modifications were not effective
Secondary reasons:	Concentrations continue to decline without pump-and-treat
TI Waiver Details:	
Documentation:	ROD amendment (post-implementation waiver)
TI evaluation report:	TI evaluation report was an attachment to the ROD amendment
ARARs waived:	Health advisory level of 10 µg/L 1,2-dichloropropane. The MCL is now 5 µg/L.
TI zone:	The area of the plume greater than 5 µg/L, approximately 5,000 square feet. The depth extends to about 30 feet below ground surface
Data basis for waiver:	Full-scale treatment system performance and optimization data
Years of remedial action:	7
Timeframe estimate:	Unknown
Cost estimate:	Remedy present worth totaled $4.2 M
Final remedy:	Plume containment, monitoring and ICs (land restrictions on groundwater use that might affect plume migration)
Alternatives to TI waiver:	None evaluated
Stakeholders:	
Agencies:	EPA Region 9 is the lead agency. The California RWQCB is also a stakeholder. The California Department of Toxic Substances Control (DTSC) is in charge of monitoring and reporting
General Comments:	
Other:	None

Site No. 18: Dorney Road, Pennsylvania

General:	
Site:	OU 2, groundwater
Site setting:	This site is a 27-acre landfill located in a former iron pit mine. The landfill accepted mostly municipal wastes and some industrial wastes. Several residences are located nearby (3 within a 3,000 feet radius). There are some wetlands in the southern portion of the site
Contaminants:	TCE, benzene, chromium, and lead
NAPL:	No, NAPL is not likely present
Hydrogeology:	Fractured bedrock consisting of dolomite, limestone, and sandstone. Bedrock is as shallow as 7.5 feet and as deep as 80 feet. Fractures are the main flowpaths. Regional groundwater flows to the southeast
CSM:	See ROD for details
Timeline:	1984 NPL listing 1986 EPA created ponds to limit runoff from the site and increase filtration through the vadose zone into groundwater 1986 Emergency removal actions including removal of waste sticking out of landfill 1989 RI for groundwater 1991 ROD including TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Lack of discharge areas with the necessary capacity within 1 mile of the site to dispose of extracted groundwater. Lack of confidence in the reliability of groundwater reinjection in the vicinity of the site. Disturbance of agricultural land if a pump-and-treat system was put in place
Secondary reasons:	Data indicated that groundwater is naturally attenuating
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	None (pre-1993)
ARARs waived:	State background levels for on-site groundwater and Federal MCLs for off-site groundwater
TI zone:	Includes on-site and off-site groundwater that is contaminated
Data basis for waiver:	RI/FS data
Years of characterization:	7
Timeframe estimate:	None
Cost estimate:	Present worth of $0.3 M (1991 dollars)
Final remedy:	Monitoring and ICs (wellhead treatment for residents if MCLs are exceeded)
Alternatives to TI waiver:	Other alternatives evaluated in the FS included no action, alternative water supply, plume containment and aquifer restoration
Stakeholders:	
Agencies:	Pennsylvania Department of Environmental Resources was the initial lead agency for the site. EPA Region 3 prepared the ROD
General Comments:	
Other:	None

Site No. 19: DuPont/Necco Park, New York

General:	
Site:	OU 1, groundwater
Site setting:	The site is located in a heavily industrialized area of Niagara Falls and is bounded on three sides by commercial disposal facilities. Residential neighborhoods are located approximately 2,000 to 2,500 feet from the site.
Contaminants:	Chlorinated VOCs and SVOCs including PCE, TCE, carbon tetrachloride, chloroform, hexachlorobenzene, hexachlorobutadiene, hexachloroethane, and methylene chloride
NAPL:	Yes, DNAPL is present at the site
Hydrogeology:	Unconsolidated overburden material (glacially derived sand, silt, and clay, and miscellaneous fill); Queenston formation (thick, soft red-brown mudstone with minor sandstone bed); Silurian system including the Medina, Clinton, and Lockport groups). Groundwater in the Lockport formation, which is extensively fractured. As a result, there are distinct water-producing units; fractured bedrock
CSM:	See ROD for details
Timeline:	1930s-1977 Disposal of industrial and process wastes 1977 Facility closed, groundwater investigations began 1984-1988 Investigation and remedial studies 1994 Investigation report 1996 Analysis of alternatives report 1998 ROD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	No technology is available to remove DNAPLs from the fractured bedrock.
Secondary reasons:	Removal of all DNAPL would require excavation of > 1M cubic yards
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	None (pre-1993)
ARARs waived:	Federal and state MCLs
TI zone:	The source area (24-acre landfill)
Data basis for waiver:	Monitoring data indicating DNAPL is present in fractured rock
Years of characterization:	15-20
Timeframe estimate:	Not estimated. 30 years was used for cost-estimating
Cost estimate:	Present worth of $65.1 M over 30 years (1998 dollars)
Final remedy:	DNAPL recovery, pump-and-treat for hydraulic containment, and ICs
Alternatives to TI waiver:	None were evaluated
Stakeholders:	
Agencies:	EPA Region 2
General Comments:	
Other:	The site ranking was too low to be included on the NPL

Site No. 20: Durham Meadows, Connecticut

General:	
Site:	OU 1, sitewide groundwater
Site setting:	The site includes properties of Durham Manufacturing Company and Merriam Manufacturing Company, where metal products were manufactured as early as 1851. Sitewide groundwater includes groundwater in the bedrock aquifer within the limits of the site, as well as residential areas impacted by site groundwater contamination. All homes in the area have individual bedrock supply wells
Contaminants:	VOCs (PCE, TCE, 1,2-DCA, 1,2-DCE, 1,1-DCA, 1,1-DCE, vinyl chloride, methylene chloride), benzene, xylene, 1,2,4-trimethylbenzene, bis(2-ethylhexyl) phthalate, PAHs, pentachlorophenol, 1,4-dioxane and metals
NAPL:	Yes, DNAPL is likely present
Hydrogeology:	Low-permeability overburden of fractured till above fractured bedrock. Groundwater flow is controlled by bedrock structural features and a fault line. Groundwater pumping has created vertical gradients
CSM:	Contaminants have been detected in residential wells, indicating that there is a pathway from the source areas to the bedrock aquifer. DNAPL may have migrated laterally from the source area. Contaminants may have been spread historically by deep, open-hole production wells
Timeline:	1851 Metal products manufactured at the site 1970 PCE and chloroform detected at the Strong School 1981 CT DEP conducted a site investigation due to RCRA violations, detected VOCs above MCLs in wells near the site 1989 NPL listing 1990-1995 Phase II site investigation and addendum; soil gas survey; USGS study 1998 Fire that destroyed the facility exposed old storage tanks 1998 Field investigations, tank and contaminated soil removal 2003-2004 1,4-dioxane detected 2005 RI/FS and ROD with TI evaluation report
Reason(s) for TI Approval:	
Primary reasons:	Widespread contamination in fractured sedimentary bedrock, unknown depth of contamination, likely pooled or residual DNAPL present in fractures
Secondary reasons:	No effective technologies for remediating DNAPL in bedrock
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation report was prepared in 2005, the same year as the ROD
ARARs waived:	Federal MCLs and state standards
TI zone:	The TI zone encompasses all areas in the overburden and bedrock aquifers that are currently or conceivably could be impacted by site contamination
Data basis for waiver:	RI/FS data
Years of characterization:	23
Timeframe estimate:	Not quantified, not reasonable (> 100 years)
Cost estimate:	Costs total roughly $12.8 M for excavation, SVE, monitoring and alternate water supply, plus $15.3 M for contingency pump-and-treat and contingency alternate water supply
Final remedy:	Soil excavation and off-site disposal, SVE, monitoring, contingency pump-and-treat system for containment, ICs, and alternate water supply (from a nearby city and/or development of a new groundwater source, with well monitoring, filtration and bottled water provided as an interim measure)
Alternatives to TI waiver:	Pump-and-treat of the plume
Stakeholders:	
Agencies:	EPA Region 1. The state of Connecticut partially concurs with the selected remedy
General Comments:	
Other:	None

Site No. 21: Edwards Air Force Base South AFRL, California

General:	
Site	OU 4 (ERP sites 37, 120, and 133) and OU 9 (ERP site 321), groundwater, soil vapor, and soil. There are 8 other OUs at Edwards AFB
Site setting:	High desert environment
Contaminants:	VOCs (PCE and TCE), and naturally-occurring arsenic
NAPL:	Yes, DNAPL is suspected in the fractured bedrock
Hydrogeology:	Thin layer of unconsolidated materials overlying crystalline granitic bedrock (fractured weathered bedrock above fractured competent bedrock). Per the basin plan, groundwater beneath the site is part (~0.02% by volume) of the larger Antelope Valley basin and has beneficial uses including municipal, agricultural, industrial, and freshwater replenishment. The area has very low groundwater yields
CSM:	See ROD for details
Timeline:	1950s Site used as a rocket research and testing facility 1960-1997 10,000-gallon PCE spill at Site 37 1990 NPL listing 1991-1993 Expanded source investigation/RCRA facility assessment 1995-1999 Removed catch tanks, underground storage tanks, cleaned and backfilled leaking sumps, renovated on-site treatment plant 1996-2004 OU 4 RI period 1999-2001 Pump-and-treat studies at Site 37, 133 2000-2001 Removed tanks from former fire training area, destroyed waste discharge wells, excavated soils 2001-2005 OU 9 RI period; Installed final AFRL landfill cover system 2004 Pilot tests at Site 37 2007 ROD including TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Fractured granitic bedrock restoration is deemed technically impracticable. The site is large, has low groundwater connectivity and low pumping rates
Secondary reasons:	DNAPL is inferred to be present in the fractured bedrock
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation report is part of the Focused FS
ARARs waived:	Federal MCLs
TI zone:	Zone covers 16.4 square miles and extends to 500 feet below ground surface. The TI zone boundary corresponds to the California Containment Zone boundary
Data basis for waiver:	Pilot studies, modeling, and RI/FS data
Years of characterization:	16
Timeframe estimate:	Models of various remedial alternatives indicate that contamination still exceeds MCLs to some degree after 1,000 years
Cost estimate:	The 30-year present value of the selected remedy is $3.4 M. A hypothetical cost estimate using pump-and-treat had a present value of $195 M
Final remedy:	Monitoring and ICs to prevent exposure to contaminated groundwater, with active containment measures as a contingency (triggered by detection at the TI zone/CZ boundary). Further pilot-testing not to exceed $250,000 will be conducted for promising technologies are identified in future five-year reviews
Alternatives to TI waiver:	Pump-and-treat for containment, hot spot containment, and aggressive source treatment using blast fracturing, bioenhancement, or chemical oxidation. All remedies still required a TI waiver for ARARs
Stakeholders:	
Agencies:	Air Force, EPA Region 9, California RWQCB Lahontan Region, California DTSC
General Comments:	
Other:	None

Sites No. 22 and 23: Eielson Air Force Base OU 2 and ST 58, OU 4, Alaska

General:	
Site:	OU 2 drum burial areas (subsites ST13, E-4 Diesel Fuel Spill and DP26, E-10 Fuel Tank Sludge Burial Site); OU 4 (ST58)
Site setting:	The 19,780-acre facility was used jointly by the Army and Air Force for training and industrial operations, resulting in fuel-contaminated areas, TCE spill areas, tank sludge areas, drum burial and storage areas, and closed and active unlined landfills. There are ~600 drinking water wells within 3 miles of the site. Fish contaminated with PCBs have been found in a nearby slough
Contaminants:	Lead, from leaded fuel stored in underground tanks. Other site contaminants include, TCE, BTEX, petroleum compounds and PCBs
NAPL:	Yes, NAPL has been detected as free-product in some areas
Hydrogeology:	Fluvial and glacial fluvial deposits (sands and gravels) comprise a sole-source shallow unconfined aquifer under the site. The aquifer has high transmissivity and a low hydraulic gradient. Discontinuous permafrost is present in the soils
CSM:	See ROD for details
Timeline:	1989 Listed on NPL 1991 Sitewide investigation. 1992 Investigation of TCE spill area and landfill areas 1994 ROD for OU 2, including pump-and-treat, landfill capping, bioventing/SVE, monitoring, ICs 1995 ROD for OU 3-5, including ST58, for bioventing/SVE, monitoring, ICs 1996 Pilot-scale SVE in TCE spill area with negative recommendation 1996 PCB-contaminated sediments and soils removed to <10 parts per million 1997 Landfill capping 1998 ROD amendment for OU 3-5 with a TI waiver for site ST 58 of OU 4, monitoring and ICs 1998 ROD amendment for OU 2 with TI waiver, passive skimming of floating fuel, monitoring and ICs
Reason(s) for TI Approval:	
Primary reasons:	Lead is immobile in soil, so the plume will remain stable over time
Secondary reasons:	Excavation in saturated zone is not practical; modeling indicates pump-and-treat will require >100 years to remove lead
Post-Implementation Waiver:	
Documentation:	ROD amendment (post-implementation waiver)
TI evaluation report:	TI evaluation report was part of the ROD amendment
ARARs waived:	Federal action level for lead (15 µg/L)
TI zone:	Two TI zones, each covering a portion of the site as denoted by site landmarks. The depth of each TI zone extends to 30 feet below the average annual water table.
Data basis for waiver:	Modeling indicated that lead would not move appreciably over the next 100 years. Reviewers commented that the RandomWalk model overstated lead's mobility, i.e., was conservative
Years of remedial action:	9
Timeframe estimate:	Over 100 years using pump-and-treat
Cost estimate:	The cost estimate for the selected remedy decreased from a present worth of $9.86 M (1994 dollars) to $1.19 M (1998 dollars). This reflects cost savings from no pump-and-treat, no bioventing at ST58, and additional monitoring costs
Final remedy:	SVE, bioventing, monitoring, and ICs. Bioventing is decreasing BTEX plume
Alternatives to TI waiver:	Pump-and-treat and excavation were considered impracticable for removing lead
Stakeholders:	
Agencies:	EPA Region 10, EPA Technical Review Committee, Restoration Advisory Board, and the state of Alaska, who concurred with the ROD amendment
General Comments:	
Other:	None

Site No. 24: Elizabeth Mine Superfund Site, Vermont

General:	
Site:	OU 1
Site setting:	This site was historically a copper mine
Contaminants:	Metals (cadmium, copper, manganese, mercury and nickel)
NAPL:	No, NAPL is not present
Hydrogeology:	Underground Workings of the mine site, which are flooded in some areas and act as a large tunnel or drain for groundwater. There are two water-bearing zones separated by a 75-foot thick glacial basal till layer. The shallow zone is only 3 to 4 feet thick and the deeper zone is in fractured bedrock
CSM:	See ROD for details
Timeline:	1793 Massive sulfide ore discovered and mined 1809-1880s Major production of iron sulfide (copperas) and copper from the mine 1920s-1930s Mine operated intermittently, was reopened during world war II 1954 Mining ceased 2001 Placed on the NPL 2003-2005 Time-critical removal action to stabilize Tailings Dam and improve drainage 2006 RI/FS report 2006 ROD with TI waiver, authorizing containment and surface water controls, in addition to monitoring and institutional controls; controls for acid mine drainage
Reason(s) for TI Approval:	
Primary reasons:	The source of contamination generates conditions that will cause metal concentrations to exceed standards
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation report was an Appendix to the FS report
ARARs waived:	Federal MCLs, MCLGs, and Vermont Primary Groundwater Quality Standards
TI zone:	Applies to groundwater in the Underground Workings area. Does not include groundwater in the adjacent bedrock aquifer.
Data basis for waiver:	CSM and RI/FS data regarding nature and extent of contamination and site setting
Years of characterization:	7
Timeframe estimate:	Hundreds if not thousands of years
Cost estimate:	Present worth ranged from $0.032 (no action) to $7.4 M. The selected remedy had an estimated present worth of $0.54 M (2006 dollars)
Final remedy:	Monitoring and ICs (land use, well and groundwater use restrictions)
Alternatives to TI waiver:	No action
Stakeholders:	
Agencies:	EPA Region 1 was the lead agency. The state of Vermont concurred with the remedy
General Comments:	
Other:	None

Site No. 25: Federal Creosote, New Jersey

General:	
Site:	OU 3, site-wide groundwater, sediments, and surface water, as well as contaminated soils at the Rustic Mall site
Site setting:	The site includes a 15-acre commercial development (Rustic Mall) and a 35-acre residential area (Claremont). Land use is not expected to change
Contaminants:	PAHs, benzene, naphthalene, and naturally-occurring metals in soils
NAPL:	Yes, DNAPL has been detected at depths of 120 feet
Hydrogeology:	The site is underlain by sands and gravels, then fractured bedrock starting at 22 to 37 feet below ground surface. Depth to groundwater varies from 11 to 24 feet. The site is approximately 2,000 feet southwest of the Raritan River and 1,200 northwest of the Millstone River. Groundwater flows to the east-southeast
CSM:	DNAPL is found in both the overburden aquifer and the fractured bedrock aquifer, at depths of up to 200 feet below ground surface
Timeline:	1910-1950 Site was used as a creosote plant 1960s 15 acres redeveloped into retail and commercial space (Rustic Mall) 1960s Residential development built (Claremont) 1996 Tar reportedly discharged from a sump located inside a Claremont residence 1997 NJDEP and EPA began site investigation after black tar-like material is found in soil near a sewer pipe 1998 Removal activities, mulch and groundcover addition 1999 NPL listing; Investigation area extended to include Rustic mall, site-wide groundwater, sediments, and surface water 1999 ROD for OU 1, with thermal treatment of off-site lagoon and canal materials and relocating several residents 2000 ROD for OU 2, addressing residual soil contamination 2002 ROD for OU 3 with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	DNAPL removal from subsurface is not practicable, particularly in fractured bedrock.
Secondary reasons:	Technologies cannot reliably treat DNAPL in fractured rock; significant short or long-term disruption to residential and commercial neighborhood would result from remedial attempts
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation report was an Appendix to the FS report
ARARs waived:	Federal MCLs, New Jersey drinking water standards, and New Jersey groundwater quality standards
TI zone:	Includes both overburden and bedrock aquifers and covers 119 acres
Data basis for waiver:	RI/FS
Years of characterization:	5
Timeframe estimate:	Not estimated
Cost estimate:	$1.2 M for the selected remedy
Final remedy:	Excavation, monitoring and ICs (deed restrictions, NJ Classification Exemption Area), as well as a TI waiver
Alternatives to TI waiver:	Enhanced pump-and-treat (steam injection and groundwater extraction), pump-and-treat, containment, and in-situ treatment were also evaluated, but were not expected to meet ARARs within 30 years
Stakeholders:	
Agencies:	EPA Region 2 and the New Jersey Department of Environmental Protection
General Comments:	
Other:	None

Site No. 26: Garland Creosoting, Texas

General:	
Site:	OU 1, the only expected OU for the site
Site setting:	The site is a 12-acre abandoned wood treatment facility in Longview, Texas that is surrounded by industrial facilities, woods, and residential properties
Contaminants:	Pentachlorophenol, PAHs, and naphthalene are the primary contaminants. Chlorinated VOCs (including TCE, 1,2-DCA, 1,4-dichlorobenzene, and vinyl chloride) are not included in the TI waiver
NAPL:	Yes, DNAPL is present (2 to 15 inches thick over 1 acre)
Hydrogeology:	Lithology includes three layers of the Queen City formation: an upper clay layer, a silt/sand unit, and a glauconitic clay layer. The silt/sand unit ranges in thickness from 4 to 14 feet, and corresponds to the shallow water-bearing zone. The glauconitic clay layer appears to act as a barrier to groundwater flow. Groundwater flows south-southwest, towards an unnamed tributary that borders the site and into the Sabine River. The aquifer is Class II, i.e., a potential drinking water source. Two drainage ditches on the site also drain to the unnamed tributary.
CSM:	Assuming an average thickness of 6 inches DNAPL, more than 35,700 gallons are present. DNAPL extent may be greater than currently known and its movement in the subsurface is difficult to predict.
Timeline:	1985-1989 Installed 12 groundwater monitoring wells, closed impoundments, removed water and creosote sludge, and capped contaminated soils in place 1990s Installed groundwater recovery trench 1997 Owner declared bankruptcy and shut down pump-and-treat system. Oils observed downgradient flowing into the unnamed tributary 1997 State-led emergency response to stop discharges and stabilize the site 1999 Time-critical removal action to empty storage tanks, remove site buildings, and excavate contaminated soils 1999 NPL listing 2000 Engineering evaluation/cost analysis and installation of new wells 2001-2002 RI/FS to fully delineate groundwater contamination 2003 New interceptor trench installed and operated 2006 ROD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	DNAPL is present in low permeability zones in the subsurface
Secondary reasons:	Movement of DNAPL is hard to predict
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation report was an appendix to the FS report
ARARs waived:	Federal MCLs
TI zone:	Includes the area captured by interceptor collector trench system and extends vertically down to the glauconitic clay layer
Data basis for waiver:	RI/FS data
Years of characterization:	21
Timeframe estimate:	Greater than a reasonable timeframe due to DNAPL
Cost estimate:	$3.69 M for the selected remedy
Final remedy:	An interceptor trench to collect DNAPL and contaminated groundwater, pump-and-treat system for off-site vinyl chloride, MNA, and ICs (to prevent the use of groundwater)
Alternatives to TI waiver:	Considered adding thermal treatment and/or in-situ bioremediation to enhance the remedy. Neither was expected to significantly reduce remedial timeframes
Stakeholders:	
Agencies:	EPA Region 6. Texas Commission on Environmental Quality concurred
General Comments:	
Other:	This site used Superfund cleanup dollars as no PRPs were identified

Site No. 27: GE Moreau, New York

General:	
Site:	OU 1, groundwater
Site setting:	This site was used to dispose of industrial waste generated by GE
Contaminants:	TCE is the primary groundwater contaminant. Other solvents, oils, PCBs, sludge and miscellaneous wastes are present at the site
NAPL:	Yes, TCE DNAPL is present
Hydrogeology:	Primarily sands and gravels with occasional silts and clays (75% coarse to fine sand with occasional silt and clay lenses; 25% interbedded fine sand, silt and clay seams). Groundwater discharges to surface water. Variability in hydraulic conductivity is the most important hydrogeologic feature
CSM:	The TCE plume is about 4,800 feet long and up to 2,000 feet wide. See ROD for more details
Timeline:	1982 NPL listing 1987 ROD approving a soil-bentonite cutoff wall and cap for containment, air stripping, monitoring and a permanent public water supply for ~100 residents 1989 District Court ruled that EPA had not complied with New York state ARARs and EPA was forced to reevaluation the groundwater portion of the remedy 1992 Five-year review with updated estimate of remediation timeframes 1994 ESD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Updated analysis leading to longer predictions for remedial timeframes, based on revised evaluation of aquifer heterogeneity, nature and extent of contamination, and contaminant phases (DNAPL). Hydrogeology and nature and extent of contamination more complex than originally thought
Secondary reasons:	Reducing the number of pore volumes treated is just as effective and less costly
TI Waiver Details:	
Documentation:	ESD (post-implementation waiver)
TI evaluation report:	TI evaluation report was part of ESD?
ARARs waived:	Federal MCLs and state ambient water quality standards and guidance values (5 ug/L TCE, 2 ug/L vinyl chloride, 7 ug/L 1,1-DCE, 100 ug/L total trihalomethanes, 50 ug/L trans 1,2-DCE and 50 ug/L methylene chloride)
TI zone:	Entire plume area (approximately 4800 feet long and 2000 feet at the widest point) to an average depth of 60 feet
Data basis for waiver:	Updated modeling of contaminant fate and transport that assessed variations in hydraulic conductivity, variations in sorption capacity of the aquifer material, and desorption non-equilibrium. Pulsed pumping and natural gradient flushing had comparable remediation timeframes
Years of remedial action:	12
Timeframe estimate:	>200 years to meet ARARs, much longer than in the original ROD. Pulsed pumping (191-404 years) is similar to natural gradient flushing (237-542 years). The "reasonable timeframe" definition was discussed to mean several decades (NCP Preamble) to 100 years (EPA 1993 guidance)
Cost estimate:	Pulsed pumping would cost $17 M and natural gradient flushing would cost $1.5 M (net present value in 1987 dollars over 30 years)
Final remedy:	Continue the original remedy without pump-and-treat (cap and soil-bentonite cutoff wall, dewatering to minimize exfiltration, monitoring and ICs)
Alternatives to TI waiver:	Considered variations on pump-and-treat including continuous pumping, pulsed pumping, one-time pulsing; air sparging; and permeable reactive barriers
Stakeholders:	
Agencies:	EPA Region 2 and the New York State Department of Environmental Conservation, as the supporting agency
General Comments:	
Other:	None

Site No. 28: Hardage/Criner, Oklahoma

General:	
Site:	OU 2, groundwater, soil, and debris
Site setting:	The site was permitted as an industrial and hazardous landfill, including everything except radioactive waste. Pits were unlined and eventually filled to capacity with 18-20 million gallons of hazardous wastes and 10,000 to 20,000 unemptied drums. Wastes were then placed into temporary ponds and piled as sludge mounds over tens of acres
Contaminants:	Contaminants included VOCs, PCBs, toxaphene and other pesticides, and metals
NAPL:	Yes, DNAPLs are present
Hydrogeology:	The site is underlain by "redbed" sediments and Hennessy Formation fractured shales, mudstone and sandstone bedrock. Groundwater flows southwest and east, following the topography. Groundwater flow velocity is extremely high, due to fractures -- 33 feet per year near the sludge mound. There is a downward flow component as well. Surface water at the site flows into streams and south to the creek. Most groundwater wells are in the alluvial aquifer, but some are screened in the bedrock aquifer
CSM:	The plume is about 1,000 feet long in the alluvial aquifer. Contamination extends at least 50 feet into the bedrock
Timeline:	1980 Waste permit revoked by the State Department of Health 1982 Decontamination and closure efforts 1983 Listed on NPL 1985 Data Summary Report of efforts and sampling results 1986 ROD to finalize source control measures. Monitoring wells along the property boundary show uniformly high concentrations 1989 ROD for groundwater, with TI waiver. The selected remedy was opposed by the State and PRPs
Reason(s) for TI Approval:	
Primary reasons:	Presence of DNAPL beyond the source area and into fractures and fine-grained materials. Contamination has diffused into the bedrock and will release slowly over time
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	None (pre-1993)
ARARs waived:	Not specified
TI zone:	Bedrock aquifer
Data basis for waiver:	RI/FS data
Years of remedial action:	6
Timeframe estimate:	No estimate was made. Exceeds reasonable estimate of "a few decades"
Cost estimate:	Present worth of $68 M (1989 dollars)
Final remedy:	Source control measures, containment approach using interceptor trench in the source area, pump-and-treat from downgradient wells, ICs
Alternatives to TI waiver:	
Stakeholders:	
Agencies:	EPA Region 6, Oklahoma State, and PRPs (organized into the Harding Steering Committee)
General Comments:	
Other:	None

Site No. 29: Hart Creosoting Company, Texas

General:	
Site:	OU 1, sitewide contamination
Site setting:	The site is a former wood treatment facility located in Jasper County, Texas, near the City of Jasper. 1,063 people live within one mile of the site. The 23-acre site is bounded by densely-forested private property to the south and west, commercial property to the north, and Highway 96 to the east
Contaminants:	VOCs, SVOCs, PAHs, naphthalene, benzene, and phenols
NAPL:	Yes, free-phase and residual DNAPL has been observed
Hydrogeology:	Alluvium (clay, silt, and sand), with three permeable (P-2, P-4, P-6) and impermeable (I-1, I-3, I-5) zones. The groundwater table is in zone P-2; groundwater flows south-southeast at 50 feet per year and discharges into Big Walnut Run Creek 3,000 feet downgradient. The aquifer is the sole water source for the Cities of Jasper and Newton
CSM:	See ROD for details
Timeline:	1958 Wood treatment activities began 1977-1985 Creosote waste was discharged into ponds. Mandatory hydrogeologic investigation and monitoring well installation, per Texas Department of Water Resources 1988 Waste ponds closed under Texas Water Commission oversight; visual site inspection 1993 Wood treatment activities ceased 1995 EPA time-critical removal action to drain waste ponds and stabilize sludge 1999 Site listed on NPL 2000 Engineering Evaluation and Cost Analysis 2004-2006 RI field investigation and supplemental investigation. Observed free-phase NAPL in a well (approximately 1.5 feet thick 2006 ROD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Presence of free phase and residual NAPL, physical chemical properties of groundwater COCs (primarily PAHs)
Secondary reasons:	Subsurface geologic conditions
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	Unknown
ARARs waived:	Federal MCLs and groundwater preliminary remediation goals
TI zone:	All onsite areas that do not meet groundwater cleanup levels, defined as areas where naphthalene exceeds 100 ug/L. Based on modeling results, this is approximately 13 acres. The TI zone extends to P-4, about 200 feet below ground surface. Final TI zone boundaries will be defined in pre-design investigation
Data basis for waiver:	RI/FS
Years of characterization:	29
Timeframe estimate:	More than 30 years, exceeding a reasonable timeframe for site conditions
Cost estimate:	$5.3 to 8.2 M for the selected groundwater remedy with/without hydraulic containment. An additional $8 M was estimated for the soil remedy
Final remedy:	The final remedy includes a NAPL recovery system, excavating soil and sediment and disposing of it in a containment cell, MNA, and ICs in addition to a TI waiver and Plume Management Zone. Plume containment will be implemented if necessary.
Alternatives to TI waiver:	In-situ bioremediation was evaluated in the ROD but also would not achieve MCLs within a reasonable timeframe
Stakeholders:	
Agencies:	EPA Region 6 and Texas Commission on Environmental Quality
General Comments:	
Other:	None

Site No. 30: Heleva Landfill, Pennsylvania

General:	
Site:	OU 1
Site setting:	This 20-acre landfill accepted municipal and industrial wastes, including liquid TCE. Prior to remedial action, approximately 150 people lived within a quarter of a mile of the site and used groundwater as drinking water
Contaminants:	VOCs (TCE, PCE, vinyl chloride, acetone) and BTEX compounds
NAPL:	Yes, DNAPL is likely present (>1% contaminant solubility)
Hydrogeology:	Karst environment with fractured bedrock and sinkholes
CSM:	See ROD for details
Timeline:	1981 Landfill was closed by the state due to operational deficiencies 1982 NPL listing 1984 RI/FS, led by the State 1985 ROD 1989-1990 Further site investigations during pre-design of pump-and-treat system indicated that DNAPL is likely present in the source area 1991 ROD amendment with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Presence of DNAPL in near-source area
TI Waiver Details:	
Documentation:	ROD amendment (post-implementation waiver)
TI evaluation report:	None (pre-1993)
ARARs waived:	Federal MCLs and state background levels for VOCs. State regulations were not considered ARARs until 1986.
TI zone:	TI zone includes the source area, with contingency language to include the downgradient plume
Data basis for waiver:	Site investigations led to a revised estimate of remedial timeframe
Years of remedial action:	9
Timeframe estimate:	With source containment, the downgradient plume was expected to take 30-40 years to remediate. No timeframe estimate for source area remediation
Cost estimate:	The selected (amended) remedy had a present value of $41 M over 30 years (1991 dollars)
Final remedy:	Pump-and-treat for containment, source zone delineation, capping, air venting, diverting source water, monitoring, ICs, and alternative water supply (extended an existing water main). There will be a periodic re-evaluation of remedial technologies. The decision to implement the contingency TI zone for the downgradient plume will be made during five-year reviews.
Alternatives to TI waiver:	Placing wells at the bottom of the aquifer and pumping
Stakeholders:	
Agencies:	EPA Region 3 was the lead agency. Pennsylvania Department of Environmental Resources provided secondary input. An EPA hydrologist recommended that the TI waiver be approved
General Comments:	
Other:	None

Site No. 31: Highway 71/72 Refinery, Louisiana

General:	
Site:	OU 00, sitewide
Site setting:	The site includes 215 acres of a former refinery located in downtown Bossier City, Louisiana
Contaminants:	Petroleum hydrocarbons and other “sludge and refinery waste” contaminants. Off-site contaminants are also present
NAPL:	Yes, LNAPL is present
Hydrogeology:	Alluvial sediments, comprised of sands and clayey/silty sands. Groundwater migration is about 7 feet per year
CSM:	This site has a large source area. LNAPL was estimated to cover about 32 acres of the site with a saturated thickness of 15 feet. Tar-like PAHs were found oozing to the surface in some residential and commercial areas, and elevated benzene concentrations were detected in indoor air. Three LNAPL plumes were identified by soil and groundwater sampling.
Timeline:	1991-1994 Site investigation 1995 NPL listing 1999 RI/FS 2000 ROD including TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Over half of the site is covered by residential and commercial buildings in a downtown area. The community has requested a “non-intrusive” remedial approach so as not to disturb development
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	The TI evaluation report is an appendix to the ROD
ARARs waived:	Federal MCLs and MCLGs
TI zone:	Includes the property area and extends to a depth of 10 to 60 feet below ground surface, to the shallow Red River Alluvial Aquifer
Data basis for waiver:	Plume is stable, due to low flowrate and bioattenuation
Years of characterization:	~9
Timeframe estimate:	Not estimated
Cost estimate:	Not given
Final remedy:	Dual phase extraction of LNAPL sources, removal of contaminated surface soils, monitoring, and ICs (city ordinance preventing groundwater use)
Alternatives to TI waiver:	None evaluated
Stakeholders:	
Agencies:	EPA Region 6 and the Louisiana Department of Environmental Quality
General Comments:	
Other:	None

Site No. 32: Hocomonco Pond, Massachusetts

General:	
Site:	OU 01
Site setting:	A wood-treating facility operated at the site, followed by an asphalt mixing plant. An area of the site was used as a lagoon for waste creosote, spillage, sludge, and wastewater. The former lagoon was later used to discard aggregate and asphalt
Contaminants:	Creosote, PAHs, phenols, arsenic, and chromium
NAPL:	Yes, DNAPL is likely present
Hydrogeology:	Stratified and unstratified glacial drift deposits including clay and silt to gravels, underlain by fractured rock. Groundwater in the area is used as drinking water
CSM:	DNAPL creosote is present at depths of 120 feet below ground surface
Timeline:	1928-1946 Wood treatment operations 1982 Site investigations 1985 ROD 1987 PRPs were required to design and construct the selected remedy 1992 Cleanup levels established 1994-1995 Pump-and-treat system and DNAPL recovery and treatment system began operating 1998 TI evaluation report 1999 ESD with TI waiver approved
Reason(s) for TI Approval:	
Primary reasons:	Presence of DNAPL creosote contamination at depth
Secondary reasons:	TI decisions at similar DNAPL creosote sites; contamination is hydraulically contained
TI Waiver Details:	
Documentation:	ESD (post-implementation waiver)
TI evaluation report:	TI evaluation was a stand-alone report, prepared one year before the ESD
ARARs waived:	All original ARARs were waived
TI zone:	Described in Figures 3-1 and 3-2 in the TI evaluation report
Data basis for waiver:	Site investigation including sediment sampling in 1999
Years of remedial action:	5 (from starting up of the system)/ 17 (from first site investigations)
Timeframe estimate:	Not estimated
Cost estimate:	Present worth estimate of $2.2 M for the selected remedy (1999 dollars)
Final remedy:	Pump-and-treat for containment, continued DNAPL recovery, monitoring and ICs
Alternatives to TI waiver:	None described
Stakeholders:	
Agencies:	EPA Region 1 and the Massachusetts Department of Environmental Protection
General Comments:	
Other:	None

Site No. 33: Horseshoe Road/Atlantic Resources, New Jersey

General:	
Site:	OU 2, including two adjacent but separate sites: Horseshoe Road (Sayerville Pesticide Dump), and Atlantic Resources Corporation
Site setting:	The 12-acre Horseshoe Road site is adjacent to the 4.5-acre Atlantic Resources Corporation. Site uses included landfill, pesticide dump, and a precious metals recovery facility. Public drinking water wells within four miles of the sites serve approximately 14,000 people
Contaminants:	VOCs and SVOCs (1,1,2,2-tetrachloroethane, 1,1,2-trichloroethane, 1,1,1-trichloroethane, PCE, TCE, cis-1,2-DCE, 1,2-DCA, 1,1-DCA, 1,1-DCE, vinyl chloride, chloroform, methylene chloride, BTX, 1,2,4-trichlorobenzene, 1,4-dichlorobenzene, chlorobenzene, nitrobenzene, hexachloroethane, methoxychlor, bis(2-chloroethyl)ether, isophorone), metals, PCBs, PAHs, and pesticides (aldrin, and dieldrin)
NAPL:	NAPL was suspected based on high groundwater concentrations
Hydrogeology:	A layer of silt and clay underlies the entire area, with discontinuous layers of fine sand. Depth to groundwater is one to four feet below ground surface. Groundwater flows to the Raritan River
CSM:	Groundwater contamination is shallow (less than 30 feet). Shallow groundwater is not being used as a water source and unlikely will be in the future due to low permeability and pumping rates
Timeline:	1950s-1980s Various industrial activities and disposal 1981 Brush fire exposed 70 partially filled drums 1985 Removal actions for >3,000 drums, dioxin and mercury spills, tanks 1995 NPL listing for Horseshoe Road site 1999 RI report 1999 Focused FS 2000 ROD for OU 1 regarding building demolition 2002 NPL listing for Atlantic Resources Corporation site 2002 FS report for OU 2 2004 ROD for OU 2 with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Low permeability soils will make active remedies ineffective; substantial mass removal during soil and source control activities
Secondary reasons:	Low risk – limited contaminant mobility and absence of potential receptors
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation is an addendum to the RI/FS, submitted one year before the ROD
ARARs waived:	Federal MCLs, New Jersey Primary Drinking Water Standards and Groundwater Quality Standards
TI zone:	Covers a 17-acre area on site
Data basis for waiver:	RI/FS
Years of characterization:	7
Timeframe estimate:	About 2,000 years
Cost estimate:	Present value of $20.6 M for both sites
Final remedy:	Excavation of 16,000 cubic yards of contaminated soil, MNA and ICs, including a New Jersey Classification Excemption Area to restrict well installation and groundwater use
Alternatives to TI waiver:	Slurry wall and active pump-and-treat with a downgradient collection trench were also evaluated but would still require a TI waiver
Stakeholders:	
Agencies:	EPA Region 2 and the New Jersey Department of Environmental Protection
General Comments:	
Other:	None

Site No. 34: Hunterstown Road, Pennsylvania

General:	
Site:	OU 01
Site setting:	This site was a landfill in the 1970s. Approximately 9,500 people live in the area and use wells within 3 miles of the site for drinking water
Contaminants:	TCE, 1,1,1-TCA, 1,1-DCE, 1,1-DCA, 1,2-DCA, and vinyl chloride
NAPL:	Yes, DNAPL is likely present
Hydrogeology:	Gray silty clay/clayey silt with rock fragments above fractured bedrock (soft argillaceous red shale sedimentary rock of the Gettysburg formation). Shallow and deep bedrock aquifers
CSM:	See ROD for details
Timeline:	1970-1980 Site receives wastes 1975 Investigations initiated by the state after a complaint 1984 EPA initiates site investigations 1986 Listed on NPL 1986-1988 Removal action for drums 1989 RI/FS Phase I 1991 Final RI/FS 1993 ROD with TI waiver for deep groundwater contamination (> 800 feet) 1998 ESD discussing feasibility of remediation above 800 feet 2003 Pump-and-treat system begins operating 2005 Five-year review report
Reason(s) for TI Approval:	
Primary reasons:	DNAPL is present in fractured rock at depths greater than 800 feet
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	None (waiver was approved in 1993)
ARARs waived:	Federal MCLs and state background requirements
TI zone:	Groundwater deeper than 800 feet; contingency language for contamination above 800 feet
Data basis for waiver:	RI/FS data
Years of characterization:	7
Timeframe estimate:	30 years (monitoring)
Cost estimate:	Present worth of $9 M (1993) over 30 years
Final remedy:	Pump-and-treat for containment above a depth of 800 feet using air stripping/catalytic oxidation, and ICs. Not practical to capture or treat contamination below 800 feet in fractured bedrock
Alternatives to TI waiver:	None
Stakeholders:	
Agencies:	EPA Region 3 and Pennsylvania Department of Environmental Resources
General Comments:	
Other:	None

Site No. 35: Iowa City Former Manufactured Gas Plant, Iowa

General:	
Site:	OU 1, contaminated groundwater, soil, sediments, surface water, and vapors
Site setting:	The site was formerly a manufactured coal gas plant. There are multiple off-site sources so it is not feasible to determine the specific source of contaminants Currently, the site is residential
Contaminants:	PAHs, BTEX, naphthalene, cyanide and metals
NAPL:	Yes, DNAPL and LNAPL have been observed in several wells
Hydrogeology:	Unconsolidated fractured bedrock aquifer (dolomite, karst features)
CSM:	See ROD for details
Timeline:	1857-1937 Manufactured coal gas produced on site 1940-1971 Site used as a service facility by Iowa-Illinois Gas and Electric 1983 Site investigation, building modifications to prevent vapor intrusion 1998 EPA investigations and expanded site investigation report 2003 RI report stating that time-critical removal action was needed 2004 PRP removed underground tanks, recovered LNAPL, and operated pump-and-treat system 2006 FS report and ROD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Presence of LNAPL and DNAPL
Secondary reasons:	Fractured rock environment
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	The TI evaluation was part of the FS report
ARARs waived:	Federal MCLs for PAHs, BTEX and cyanide
TI zone:	Includes probable NAPL area and extends to bedrock. Includes off-site areas and may be expanded to the southwest in the future
Data basis for waiver:	RI/FS report, mass estimates, timeframe estimate
Years of characterization:	8
Timeframe estimate:	Greater than 20,000 years based on the SourceDK Remediation Timeframe Decision Support System for PAHs
Cost estimate:	Present worth of $1.6 million (2006 dollars)
Final remedy:	Recovery of LNAPL from the unconsolidated aquifer using absorbent socks, MNA, monitoring, and ICs (environmental covenants, county and city ordinances)
Alternatives to TI waiver:	Biosparging and groundwater extraction and treatment were also included in the ROD, but neither was expected to reduce contaminated volume as they may increase DNAPL mobility
Stakeholders:	
Agencies:	EPA Region 7 and the Iowa Department of Natural Resources
General Comments:	
Other:	None

Site No. 36: J.H. Baxter & Co., California

General:	
Site:	OU 01 groundwater, liquid waste, soil and sediment
Site setting:	Wood treatment facility
Contaminants:	Creosote, pentachlorophenol, PAHs, arsenic, dioxins/dibenzofurans, metals, pesticides
NAPL:	Yes, free-phase and residual DNAPL are present
Hydrogeology:	Two aquifers separated by an aquitard: the shallow aquifer (artificial fill, younger clastic assemblage, pre-shastina alluvial assemblage), aquitard (older clastic assemblage), and the bedrock aquifer. The depth to groundwater is less than 20 feet. The persistent downward vertical gradient of as much as 20 feet
CSM:	The aquitard is a barrier to contaminant migration; the deeper aquifer is not contaminated
Timeline:	1937 Wood treatment activities began 1983 Site investigation began on the request of the California RWQCB, North Coast 1989 Listed on NPL 1989 RI report 1990 ROD 1997 FS report and TI evaluation report 1998 ROD amendment with TI waiver 1999 Slurry wall installed
Reason(s) for TI Approval:	
Primary reasons:	DNAPLs are present in the source zone
Secondary reasons:	Timeframe estimates for remediation
TI Waiver Details:	
Documentation:	ROD amendment (post-implementation waiver)
TI evaluation report:	TI evaluation report was issued with the FS, one year before the ROD amendment was approved
ARARs waived:	All ARARs specified in the 1990 ROD
TI zone:	DNAPL zone source areas extending to the aquitard
Data basis for waiver:	Remedial design investigations after 1990 that indicated DNAPLs were present and that contamination was more widespread than previously thought
Years of remedial action:	14
Timeframe estimate:	Greater than 400 years, assuming 95% mass removal
Cost estimate:	Present worth of $10.9 M to continue the 1990 remedy, with an additional $1.3 M for the selected remedy
Final remedy:	Slurry wall with pump-and-treat for containment, monitoring, and ICs
Alternatives to TI waiver:	None identified
Stakeholders:	
Agencies:	EPA Region 9, California RWQCB, and California Department of Toxic Substances Control (DTSC). California RWQCB issued a short concurrence with the TI waiver
General Comments:	
Other:	None

Site No. 37: Jasper Creosoting Company Inc., Texas

General:	
Site:	OU 01, for groundwater, soil, sediment, and surface water
Site setting:	The site is a former wood treating facility, approximately 11 acres in size
Contaminants:	PAHs, pentachlorophenol, creosols, naphthalene, benzene, arsenic, chromium, and metals (iron, thallium, vanadium), 2,3,7,8-TCDD, dibenzofuran, 2,4-dimethylphenol, 2-methylnaphthalene, carbazole, and m- and p- xylenes
NAPL:	Yes, free-phase and residual DNAPL is present
Hydrogeology:	Clay, silt, sand, and gravel alluvium in three distinct layers including permeable zone P1, low-permeability zone I2, and permeable zone P3 to a depth of 150 feet. The aquifer is a potential, but not a current, source of drinking water
CSM:	See ROD for details
Timeline:	1946-1986 Wood treatment operations at the site 1946-1964, 1971-1982 Wastewater discharged directly into a drainage ditch 1981 Fishkill in the Sandy Creek linked to site operations 1983 Samples taken in a nearby ditch measured 15,570 ppm pentachlorophenol 1983-1985 Environmental-related site investigations 1992 Facility was abandoned 1995 EPA initiated a removal assessment 1998 Site listed on NPL 2000 Engineering evaluation and cost analysis 2005 Final RI/FS report 2006 Supplemental RI 1996, 1999 and 2005 Time-critical response actions of structures, tanks, facility equipment, and contaminated soils 2006 ROD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Presence of PAHs and DNAPL in multi-lithology zones
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	Unknown. Part of the ROD?
ARARs waived:	Federal MCLs and groundwater PRGs
TI zone:	All contaminated groundwater (source and plume), including off-site contamination, and extending 150 feet below ground surface
Data basis for waiver:	RI/FS
Years of characterization:	2
Timeframe estimate:	Not estimated
Cost estimate:	Over $5.6 M if hydraulic containment is not necessary, $7.8 M if hydraulic containment is necessary
Final remedy:	DNAPL removal, pump-and-treat for hydraulic containment, MNA, monitoring, and ICs (including plume management zone to prevent groundwater development within the TI zone)
Alternatives to TI waiver:	None evaluated
Stakeholders:	
Agencies:	EPA Region 6 and the Texas Commission on Environmental Quality
General Comments:	
Other:	None

Site No. 38: Keystone Sanitation Landfill, Pennsylvania

General:	
Site:	OU 01
Site setting:	This site is a landfill located in a rural, residential, agricultural area
Contaminants:	Iron and manganese above background concentrations
NAPL:	No, NAPL is not present
Hydrogeology:	Includes silty clay soil above fractured bedrock. There are numerous small springs in the area that discharge to surface waters
CSM:	Iron and manganese are elevated with respect to background but are likely naturally occurring
Timeline:	1982 VOCs detected in nearby springs 1984 Site investigation 1987 Placed on NPL 1990 End of landfill operations 1990 ROD calling for a landfill cap and gas recovery system, pump-and-treat, monitoring, ICs (deed restrictions), point-of-use treatment for residents 1999 ROD amendment with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Contamination-related factors
TI Waiver Details:	
Documentation:	ROD amendment (post-implementation waiver)
TI evaluation report:	Unknown. Part of ROD amendment?
ARARs waived:	Secondary MCLs for iron and manganese
TI zone:	Property
Data basis for waiver:	Full-scale operation
Years of characterization:	6
Timeframe estimate:	Not given
Cost estimate:	Present worth of approximately $1.8 M for final remedy
Final remedy:	Pump and treat, monitoring, and point-of-use filters for residences
Alternatives to TI waiver:	None identified
Stakeholders:	
Agencies:	EPA Region 3, Pennsylvania Department of Environmental Resources, two environmental groups, and elected officials from Maryland and Pennsylvania
General Comments:	
Other:	None

Site No. 39: Koppers Co., Inc. (Oroville Plant), California

General:	
Site:	OU 1
Site setting:	This site is approximately 200 acres and has been operating as a wood treatment facility for the past 50 years
Contaminants:	PAHs, pentachlorophenol, creosote, chlorinated PAHs, dioxins, furans, and heavy metals including copper, chromium and arsenic
NAPL:	Yes, DNAPL is likely present
Hydrogeology:	Clay layer
CSM:	Groundwater is contaminated both on- and off-site, including drinking water wells 2 miles away
Timeline:	1984 NPL listing 1986 Alternative water supply provided 1989 ROD (pump-and-treat, reinjection, and in-situ soil remediation and capping) 1989 Treatability studies for soil 1994 On-site landfill is constructed 1995-1998 Dioxins hinder remedial options. Pilot-scale biotreatment system removes 160 gallons of creosote and 220 gallons of creosote emulsion out of a potential million gallons of free product 1995 FS report, off-site pump-and-treat system taken offline 1996 ROD amendment for on-site landfilling, industrial cleanup standards and deed restrictions for industrial use 1999 ROD amendment 2 including TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Presence of DNAPL in low-permeability clays 30 to 300 feet below ground surface. No technology exists to restore the aquifer to drinking water standards. The cost of removing additional contaminants is high and will not lower concentrations
Secondary reasons:	Low risk - no surface contamination, containment achieved, creosote is relatively immobile, and ICs are in place
TI Waiver Details:	
Documentation:	ROD amendment (post-implementation waiver)
TI evaluation report:	Draft TI evaluation report was issued two years before the ROD amendment
ARARs waived:	Federal MCL for pentachlorophenol and remedial standards for dioxin and total chlorinated PAHs
TI zone:	Includes 4 acres of the site, including the Former Creosote Pond and the Cellon Blowdown areas, and extending to depths of 250 feet
Data basis for waiver:	3.5 years of pilot-scale treatability study data showed that biotreatment was ineffective, data from soil washing and soil fixation studies, groundwater leachability study, and monitoring data illustrating containment
Years of remedial action:	15
Timeframe estimate:	Cost analysis only considers 20 to 30 years. The site was compared with J.H. Baxter Superfund site where timeframes ranged from 50-400 years if bioremediation was considered and 3,000 years for pump-and-treat alone
Cost estimate:	Cost estimate ranged from $20 to $67 M for attempting remediation compared with $0.8 M for the proposed remedy with a TI zone
Final remedy:	Enhanced bioremediation outside of the TI zone, containment, monitoring, ICs (deed restrictions) and contingency pump-and-treat
Alternatives to TI waiver:	Considered no action, grout curtain wall, thermal, steam-enhanced pump-and-treat, and pump-and-treat; none met drinking water standards
Stakeholders:	
Agencies:	EPA Region 9 (lead agency), California RWQCB, DTSC, and Beazer East (PRP)
General Comments:	
Other:	An annual review of industrial activity around the TI zone is required. The site was compared to Brodhead Creek and other Superfund sites in the TI evaluation report

Site No. 40: Libby Groundwater Contamination, Montana

General:	
Site:	0U 2
Site setting:	Wood treatment facility
Contaminants:	Pentachlorophenol, naphthalene, and PAHs present as NAPL
NAPL:	Yes, NAPL is present in the Lower Aquifer
Hydrogeology:	Varied alluvial and glacial sediments and discontinuous lenses. The Lower Aquifer is separated from the Upper Aquifer by a relatively low permeability layer that may not be laterally continuous
CSM:	See ROD for details
Timeline:	1979 Groundwater contamination in a city well 1980 Site investigation began 1983 Placed on NPL 1986 RI 1988 ROD calling for feasibility testing of bioremediation 1990 Bench-tests for in-situ bioremediation 1993 Lower Aquifer characterization report and technology evaluation report, ESD with TI waiver 1999 Second TI waiver approved but never implemented
Reason(s) for TI Approval:	
Primary reasons:	DNAPL remediation impracticable using available technologies
Secondary reasons:	Low-risk: plumes have stabilized, small potential for vertical spreading, ICs in place to eliminate potential exposure pathways
TI Waiver Details:	
Documentation:	ESD (post-implementation waiver)
TI evaluation report:	None (pre-1993)
ARARs waived:	Federal MCLs, also health advisory limit for naphthalene
TI zone:	Includes all groundwater in the Lower Aquifer beneath the site
Data basis for waiver:	Bench-scale studies and additional investigation of pump-and-treat, in-situ bioremediation, and the use of surfactants
Years of characterization:	13
Timeframe estimate:	Not given
Cost estimate:	Not given
Final remedy:	Monitoring, ICs preventing well installation in Lower Aquifer
Alternatives to TI waiver:	Unknown
Stakeholders:	
Agencies:	EPA Region 8, Montana Department of Health and Environmental Services, Champion International Corporation as a PRP
General Comments:	
Other:	None

Site No. 41: Lindane Dump, Pennsylvania

General:	
Site:	01
Site setting:	The site was a former coal mine and landfill. Residents near the site obtain water from a nearby river
Contaminants:	Benzene, pesticides (DDT, lindane, gamma BHC), phenols, arsenic, and lead
NAPL:	No, NAPL is not present
Hydrogeology:	There are two aquifers: one unconsolidated in stream channel alluvial deposits, and the second in Paleozoic bedrock (shales with numerous sandstone beds, coal and clay layers)
CSM:	See ROD for details
Timeline:	1850-1940 Salt manufacturing, production of sulfuric acid and alumina, coal mining 1947-1959 Various organics (including pesticides) and inorganics manufactured 1960s-1970s Waste disposal 1976-1977 Community park constructed on site 1980-1985 Investigations, monitoring, interim remedial measures 1983 NPL listing 1984 Interim leachate collection/Treatment system installed 1990 Supplemental RI 1992 FS and ROD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Complex hydrogeologic conditions, the possibility of subsidence and site damage from extensive pumping, and the potential for contaminant migration during pumping
Secondary reasons:	Not a potential drinking water source; effective containment through leachate/groundwater collection system
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	None (pre-1993)
ARARs waived:	Federal MCLs and background levels
TI zone:	Shallow aquifer
Data basis for waiver:	Regional and local data
Years of characterization:	9
Timeframe estimate:	Not estimated. A timeframe of 30 years was assumed for cost purposes
Cost estimate:	The final remedy has a present worth of $14.1 M over 30 years (1992 dollars)
Final remedy:	Multi-layer cap, upgraded leachate/shallow groundwater collection system, pump-and-treat for leachate and shallow groundwater, and ICs (deed and access restrictions)
Alternatives to TI waiver:	None
Stakeholders:	
Agencies:	EPA Region 3 and the Pennsylvania Department of Environmental Resources
General Comments:	
Other:	None

Sites No. 42 and 43: Loring Air Force Base Entomology Shop (ES)/ Jet Engine Build-Up Shop (JEBS) and Quarry Site, Maine

General:	
Site:	OU 12, groundwater
Site setting:	The Quarry site was used for disposal of unknown wastes (hundreds of drums). The ES/JEBS site was used for manufacturing and waste treatment
Contaminants:	VOCs (TCE, cis-1, 2 DCE, vinyl chloride), SVOCs (naphthalene), and BTEX. In the Quarry Site, there is also PCE, 1,2-DCA, 1,1-DCE, 1,1,2-trichloroethane, chlorobenzene, and ethylbenzene. Only PCE and TCE are included in the TI waiver for the Quarry site
NAPL:	Both DNAPL and LNAPL are present in the Quarry Site
Hydrogeology:	Shallow overburden (fill and till) overlying bedrock with various degrees of weathering and fracturing. The bedrock is high permeability and high flow. Flow is not homogenous but governed by fracture networks and faults; between some wells in close proximity, no hydraulic connection was observed
CSM:	Groundwater contamination extends into bedrock in some source areas. A detailed CSM was prepared as part of the RI and JEBS site investigation reports
Timeline:	1950s Site operations began 1990 NPL listing 1994-1999 Removal actions for source control, drum and soil disposal 1997 RI report 1998 Site investigation report for JEBS 1999 ROD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Contaminants are diffusing into and out of rock fractures, due to concentration gradients. Diffusion out of the bedrock is a slow process, and pump-and-treat does not significantly increase this diffusion rate. Contaminants in the fractures are often not hydraulically accessible. In the Quarry area, the presence of DNAPL and LNAPL further complicates cleanup
Secondary reasons:	Uncertainty in subsurface contaminant mass estimates and hydraulic conditions were used to emphasize the uncertainty in remedial success within a reasonable timeframe
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	Separate TI evaluation reports were prepared for these two areas in the same year as the ROD
ARARs waived:	Federal and State MCLs were waived for PCE and TCE
TI zone:	Includes the source and plume areas in the Quarry and ES/JEBS areas. The TI zone extends down to about 300 feet below ground surface and includes 150 feet of competent bedrock beneath the weathered bedrock
Data basis for waiver:	Modeling to demonstrate that remediation technologies could not meet ARARs within 100 years, site characterization, and post-ROD thermal pilot testing
Years of characterization:	4
Timeframe estimate:	Approximately 320 years in the ES/JEBS area, and from 160 to 1,150 years in the Quarry area
Cost estimate:	Costs varied from $0 for no action to $11.4 M for enhanced fractured pump-and-treat
Final remedy:	Groundwater management including MNA (dilution, dispersion, biodegradation), long-term monitoring, and ICs (groundwater use restrictions). An alternative water supply was also established
Alternatives to TI waiver:	None were applicable based on modeling results, including no action, limited action, containment, pump-and-treat, ISCO, and in-situ bioremediation
Stakeholders:	
Agencies:	The Air Force was the lead agency. EPA Region 1 and the state were stakeholders.
General Comments:	
Other:	None

Site No. 44: Love Canal, New York

General:	
Site:	OU 09
Site setting:	The site is a former hazardous waste landfill located in Niagara Falls, New York
Contaminants:	Mixed (not listed in ROD)
NAPL:	Yes, NAPL is being recovered with the barrier drain system
Hydrogeology:	Overburden glacial till (clay, silt, fine sands, and fill) over bedrock
CSM:	Historically, low-level contamination has been present both upgradient and downgradient of the site
Timeline:	1980 Nearby school was closed due to contamination 1988 RI/FS began 1988 ROD 1991 ROD with TI waiver language
Reason(s) for TI Approval:	
Primary reasons:	Contamination (background, other sources)
Secondary reasons:	Low risk – groundwater is not being used
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	None (pre-1993)
ARARs waived:	Unknown
TI zone:	Property
Data basis for waiver:	Not given
Years of characterization:	Unknown
Timeframe estimate:	Not estimated
Cost estimate:	Not given
Final remedy:	Excavation, on-site stabilization/solidification, backfill, and capping for soils and a shallow interceptor trench for groundwater
Alternatives to TI waiver:	None mentioned
Stakeholders:	
Agencies:	EPA Region 2 and the New York State Department of Environmental Conservation
General Comments:	
Other:	According to the site EPA remedial project manager, this TI waiver may not have ever been implemented. However, a sentence in the 1991 ROD referencing technical impracticability remains

Site No. 45: McKin Co., Maine

General:	
Site:	OU 2, off-site groundwater
Site setting:	The 7-acre property is located in a residential neighborhood. Off-site contamination totals 660 acres of commercial, residential, agricultural, and undeveloped properties
Contaminants:	VOCs (PCE, TCE, 1,1,1-TCA, cis-1,2-DCE, 1,1-DCE, and vinyl chloride)
NAPL:	Yes, DNAPL may be present based on elevated concentrations
Hydrogeology:	Fine- and coarse-grained glaciomarine deposits, flood plain alluvium, and glacial till. Depth to competent granitic bedrock varies from 37 to 200 feet. The upper portion of bedrock is highly fractured. The overburden aquifer plume bifurcates with the majority of the groundwater and contamination flowing eastward to the Royal River. The remaining groundwater contamination attenuates prior to reaching surface water.
CSM:	See ROD amendment for details
Timeline:	Pre-1965 The site was used as a sand and gravel borrow pit 1965-1977 Transfer facility for oils and industrial process waste 1973 Facility expanded to include an asphalt-lined lagoon and incinerator 1973-1974 Resident complaints 1977 TCE and 1,1,1-TCA were identified in water; facility ordered to shut down 1983 Site was listed on NPL 1983 Aboveground tanks, barrels, and containers were cleaned and removed 1985 ROD for OU 2, off-site groundwater 1986-1987 PRPs treat and backfill contaminated soil from 5 locations and the lagoon 1987 ROD for OU 1, on-site source control 1990 ESD changes treated groundwater discharge to onsite reinjection Early to mid-1990s Three amendments to the work plan were made regarding the feasibility of restoring groundwater to drinking water standards 1991 Pump-and-treat system starts operating 1997 Stakeholders enter mediation. EPA agrees to prepare a TI evaluation report 2001 ROD amendment with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Pump-and-treat did not achieve ARARs much faster than natural attenuation
Secondary reasons:	Pathway from the McKin property through the bedrock aquifer is difficult to locate. Likely residual DNAPL, contaminants in bedrock. For the overburden aquifer (>100 feet), wells have limited effectiveness as DNAPL will act as a source for more permeable units, and likely seepage from the bedrock to the overburden
TI Waiver Details:	
Documentation:	ROD amendment (post-implementation waiver)
TI evaluation report:	TI evaluation report was prepared the same year as the ROD
ARARs waived:	Federal MCLs and MCLGs, and Maine Maximum Exposure Guidelines (MEGs)
TI zone:	All areas where contaminated groundwater exceeds MCLs. Horizontally, this extends to Collyer Brook, Merrill Road, just beyond Royal River, to Yarmouth Toad (at Mayall Road) and to Depot Road. Vertically, it extends to deep bedrock
Data basis for waiver:	RI/FS and understanding of hydrogeology and DNAPL presence
Years of remedial action:	5 to 10 from original ROD; 25 from initial cleanup actions
Timeframe estimate:	50 years for the interior bedrock plume, 20 years for the outer bedrock plume with MNA, 20 to 30 years for the northern plume, 50 years for the center of the plume
Cost estimate:	$1. 6 M
Final remedy:	End of pump-and-treat, MNA, ICs, and contingency for surface water contamination
Alternatives to TI waiver:	Continued operation of the pump-and-treat system
Stakeholders:	
Agencies:	EPA Region 1, Maine Department of Environmental Protection, Town of Gray, and Gray Water District, PRPs, and community members
General Comments:	
Other:	None

Site No. 46: Middletown Air Field, Pennsylvania

General:	
Site:	OU 01
Site setting:	This site is 500 acres and is currently known as the Harrisburg International Airport
Contaminants:	VOCs (TCE, PCE), PAHs, and metals (arsenic, chromium, and lead)
NAPL:	Yes, NAPL is suspected
Hydrogeology:	Overburden, shallow bedrock, and deep bedrock. Deep bedrock groundwater is used for drinking water
CSM:	See ROD for details
Timeline:	1984 Sludge and liquid removal in the waste collection building, waste drums, etc. 1987 ROD for groundwater 1988 Investigation into the five source areas 1990 Remedy implementation by PRPs (airport owner and Pennsylvania Department of Transportation) 1993 State requests further soil investigation 1996 ROD for soil 2010 Cleanup is now complete and the site has been deleted from the NPL
Reason(s) for TI Approval:	
Primary reasons:	BAT for VOC removal (air stripping) with 99% removal may not achieve background levels of VOCs. Background levels for the inorganic compounds to below detection limits: antimony, arsenic, beryllium, cadmium, cobalt, copper, lead, mercury, nickel, selenium, silver, vanadium, and cyanide.
Secondary reasons:	Will be treating large amounts of river water in addition if pump-and-treat is used.
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	None (pre-1993)
TI zone:	Unknown
ARARs waived:	State ARARs to background levels were waived
Data basis for waiver:	Quarterly monitoring data from interim remedy operation
Years of remedial action:	6
Timeframe estimate:	Not estimated
Cost estimate:	Present worth is $0.95 M for the selected remedy. Other alternatives ranged from $6 to $8 M.
Final remedy:	Pump-and-treat (ion exchange and air stripping), monitoring, ICs, and chlorination of a production well
Alternatives to TI waiver:	No action, different types of ex-situ treatment. None met ARARs
Stakeholders:	
Agencies:	EPA Region 3 and the Commonwealth (state) of Pennsylvania
General Comments:	
Other:	None

Site No. 47: Midland Products, Arkansas

General:	
Site:	OU 01, groundwater
Site setting:	The 32-acre site operated a sawmill and wood preserving plant in the 1970s
Contaminants:	Pentachlorophenol and benzo(a)pyrene
NAPL:	LNAPL and DNAPL have been observed in several wells
Hydrogeology:	Fractured bedrock
CSM:	See ROD for details
Timeline:	1969-1979 Wood preserving plant operated. Aerial photos indicate operations may have begun in 1960 1986 NPL listing 1988 ROD approving pump-and-treat 2006 ROD amendment with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	High groundwater concentrations and LNAPL and DNAPL remain after years of pump-and-treat (12 million gallons)
TI Waiver Details:	
Documentation:	ROD amendment (post-implementation waiver)
TI evaluation report:	TI evaluation is a section in the ROD amendment
ARARs waived:	Federal MCLs
TI zone:	Source area and downgradient plume enclosed by monitoring wells. The zone extends vertically down to 40 feet below ground surface
Data basis for waiver:	Years of operating a pump-and-treat system and extracting over 12 MG of groundwater (20 plume volumes) with little impact on concentrations
Years of characterization:	18
Timeframe estimate:	Not estimated but exceeds a reasonable timeframe for site conditions
Cost estimate:	Not estimated
Final remedy:	MNA and ICs are included in the revised remedy, along with the TI waiver.
Alternatives to TI waiver:	The old remedy included pump-and-treat.
Stakeholders:	
Agencies:	EPA Region 6 and the state of Arkansas
General Comments:	
Other:	None

Site No. 48: Missouri Electric Works, Missouri

General:	
Site:	OU 2 (groundwater contamination).
Site setting:	The site is contaminated with PCBs from historical electrical repair activities. The site is located in a commercial/industrial area in the hills in a regional hub, with 37,000 permanent residents and up to 50,000 daily visitors
Contaminants:	VOCs (PCE, TCE, 1,1,1-TCA, 1,1-DCA, 1,1-DCE, 1,2-DCE, benzene, chlorobenzene, 1,2,4-TCB, 1,2-DCB, 1-3, DCB, 1,4-DCB, 1,4-DCA), PAHs
NAPL:	No, NAPL is not likely present
Geology:	Undifferentiated loess (silts and silty clays) up to 30 feet thick, overlying up to 400 feet of fractured limestone bedrock. The upper 50 feet of bedrock is weathered. There are numerous faults in the area and significant fractures/fracture zones. Groundwater flow occurs in the upper and intermediate bedrock. Currently, no one drinks the groundwater.
CSM:	PCB contamination has been found at depths of 405 feet within solution features. Due to the fractures and solution features, groundwater flow within the bedrock is impossible to predict
Timeline:	1954-1992 Electrical repair, service, and resale business operated at the site 1984 Waste oil removed (5,000 gallons) 1985-1988 Site investigations by EPA, high PCB levels detected 1986 EPA required the site owner to stop handling oil-filled electrical equipment with PCB concentrations > 2 parts per million, place erosion barriers, and stop selling or giving away fruits and vegetables grown on the site 1989-1990 RI for soils and sediment 1990 Site listed on NPL; first ROD issued 1994 FFS for soil remediation 1995 ROD amendment for thermal treatment of soils 2000-2005 Groundwater investigation 2000 Thermal treatment performance testing and application to contaminated soils 2005 TI evaluation report and ROD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Highly complex and variable fractured bedrock hydrogeology
Secondary reasons:	Pumping groundwater from karst environments often spreads contamination
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation report was submitted the same year as the ROD
ARARs waived:	Federal MCLs
TI zone:	The TI zone covers the contaminated fractured bedrock aquifer. The alluvial aquifer is not included in the TI waiver
Data basis for waiver:	Pilot-scale thermal treatment tests, CSM, and RI/FS data
Timeframe estimate:	Possibly more than 100 years and at least 30 years
Years of characterization:	5
Cost estimate:	Present worth of $2.2 M for the fractured bedrock aquifer and $4.8 M for the alluvial aquifer (total $7.06 M)
Final remedy:	Monitoring, ICs (restrictive covenant and grant of access, designation as a “special use” area, use of ordinances, inspection regimes, property notices, public information), and wellhead treatment (activated carbon or air strippers)
Alternatives to TI waiver:	None identified
Stakeholders:	
Agencies:	EPA Region 7 and the Missouri Department of Natural Resources
General Comments:	
Other:	None

Site No. 49: Montrose/Del Amo, California

General:	
Site:	OU 3 for Montrose Chemical Corporation
Site setting:	These two sites are addressed by a combined remedy for joint superfund sites
Contaminants:	TCE, chlorobenzene, and benzene are the main contaminants. Others include PAHs, naphthalene, pesticides, VOCs, and SVOCs
NAPL:	Yes, LNAPL is likely present
Hydrogeology:	Alluvial deposit of sands, silts, and clays that extend downwards hundreds of feet. There are four distinct and separate aquifers (upper, middle B, middle C and lower Bellflower sands) The middle C and lower aquifers are used for municipal drinking water. Water moves slowly in the shallow aquifers and more quickly in the deeper layers.
CSM:	Plumes are long (1.3 miles) and commingled
Timeline:	1947-1982 DDT was manufactured on the Montrose site 1992 Action against Del Amo 1996 Two sites were united under the CERCLA framework 1997 ROD for Del Amo 1999 ROD for joint site groundwater including TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Existing technologies are incapable of recovering enough NAPL to meet groundwater standards; restoration cannot be achieved in the presence of NAPL
Secondary reasons:	Upper and middle B aquifers cannot be successfully pumped because of the small radius of influence in this fine-grained area. Pumping from the middle C aquifer, under the LNAPL would cause contaminants to migrate downwards and spread.
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation was a section in the ROD
ARARs waived:	ISGS levels and other ARARs are waived inside the containment zone
TI zone:	The LNAPL area, also known as the “containment zone”
Data basis for waiver:	Modeling and RI/FS data
Years of characterization:	16 years for Montrose and 8 years for Del Amo
Timeframe estimate:	Greater than 50 years. Modeling predictions predict two-thirds of the chlorobenzene plume would be removed after 25 years
Cost estimate:	Range from $0 (no action) to $39.8 M (pump-and-treat at a higher pumping rate)
Final remedy:	Containment zone, pump-and-treat, reinjection and MNA
Alternatives to TI waiver:	None – The TI zone cannot be cleaned to drinking water standards in a reasonable timeframe because there is no feasible way to remove all of the NAPL
Stakeholders:	
Agencies:	EPA Region 9 in consultation with California DTSC and the California RWQCB, Los Angeles
General Comments:	
Other:	None

Site No. 50: Naval Air Development Center (8 Waste Areas), Pennsylvania

General:	
Site:	OU 12A: Area A groundwater
Site setting:	The 8 waste areas total 15 acres. This is one of the 8 areas
Contaminants:	TCE, PCE, and carbon tetrachloride. The TI waiver explicitly does not apply to any other compounds within the area
NAPL:	Yes, DNAPL is likely present
Hydrogeology:	Fractured bedrock
CSM:	See original ROD
Timeline:	1989 Added to the NPL 1990 Property owned by Navy 1993 Interim remedy 1993 Renamed the Naval Air Warfare Center (NAWC) Aircraft Division 1996 Targeted for transfer to private sector 1996 to 1999 Soil removal actions 2000 ROD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	High concentrations indicative of DNAPL
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation report was an Appendix in the FS report
ARARs waived:	Federal and State MCLs
TI zone:	Corresponds to the probable DNAPL zone, which is roughly 80 feet in diameter, and extends from the water table to a depth of 70 feet below ground surface
Data basis for waiver:	RI/FS data
Years of remedial action:	11
Timeframe estimate:	Not estimated
Cost estimate:	Not given
Final remedy:	Continue pump-and-treat (existing interim system), monitoring, and ICs
Alternatives to TI waiver:	None identified
Stakeholders:	
Agencies:	Department of the Navy is the lead agency for cleanup. Worked with EPA Region 3 and the Pennsylvania Department of Environmental Resources, who concurred with the remedy
General Comments:	
Other:	None

Site No. 51: Niagara Mohawk Power Company, New York

General:	
Site:	OU 0, sitewide
Site setting:	The site was historically a manufactured gas plant and gas storage area. It is located in a residential area of Saratoga Springs, New York. Residents obtain drinking water from nearby private wells and city municipal wells
Contaminants:	PAHs, VOCs, and inorganics associated with coal tar
NAPL:	Yes, DNAPL is present
Hydrogeology:	Layered fill (fine to medium-grained sands and clay, rock fragment, and construction debris) above a shallow unconfined aquifer (fine to coarse-grained sand with silt, clay, and minor organic matter, peat materials, sorted, medium to coarse-grained sediments); glaciolacustrine clay; till (poorly sorted mix of boulders, cobbles, gravel, sand, silt, and clay) and then a deep bedrock aquifer
CSM:	See ROD for details
Timeline:	1896-1950 Manufactured gas plant and gas storage area at the site 1950- Niagara Mohawk Power Corporation owned the site 1965-1985 Site investigations 1990 NPL list 1992 RI report 1995 FS and proposed plan 1995 ROD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Technical limitations to recovering DNAPL (excavation not feasible)
Secondary reasons:	Areal extent of DNAPL contamination (7 acres); need to demolish operating facilities to access the contamination
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	Unknown. Part of ROD?
ARARs waived:	Federal and state MCLs
TI zone:	Shallow aquifer contamination in the source area (beneath the cap)
Data basis for waiver:	RI/FS data, technical limitations to recovering residual DNAPL
Years of characterization:	5
Timeframe estimate:	Not estimated
Cost estimate:	Present worth of $15.3 M for selected remedy, including soil and sediment remedy
Final remedy:	Pump-and-treat, barrier containment, cap, soil and sediment removal, monitoring and ICs
Alternatives to TI waiver:	None considered
Stakeholders:	
Agencies:	EPA Region 2, New York State Department of Environmental Conservation
General Comments:	
Other:	None

Site No. 52: O'Connor Co., Maine

General:	
Site:	OU 2, groundwater
Site setting:	The 23-acre site was used for transformer salvage operations. It is located in a predominately rural neighborhood, bordered by woodlands and a small poultry farm, highway, private properties and residences and wetlands
Contaminants:	PCBs, benzene and chlorinated benzenes
NAPL:	Yes, a separate-phase PCB-laden oil is present
Hydrogeology:	There are fractured clays (glacial marine silts and clays and glacial till) overlying fractured bedrock (hard, minimally weathered, quartz monzonite). The interface is the primary migration pathway of contaminants. Under static conditions, there is very little vertical mixing between the low-permeability overburden and bedrock aquifers
CSM:	The bedrock forms a saddle, with a former lagoon located at the bottom of the saddle
Timeline:	1950s-1970s Site was used for transformer salvaging processes 1983 Site was placed on NPL 1989 ROD for OU 1, source control 1992 Remedial design pump tests, separate-phase oil found in bedrock 1994 ESD revising source control remedy, contingency remedy invoked in 1995 1996-1997 Source control remedy (cleaning, demolition, off-site disposal of structures, lagoon water, excavation of 20,000 tons of soil, recovery of 28 gallons of PCB-laden oil from shallow bedrock using vacuum-enhanced pumping) 1997-2001 Recovered 27 gallons of PCB-laden oil from shallow bedrock using vacuum-enhanced pumping 2002 Five-year review, TI evaluation report, ROD amendment with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Hydrogeology and the continued presence of PCB-laden oil 4 years after the completion of the source control remedial action
Secondary reasons:	Clay fractures are thought to be the primary source of oil and chlorobenzenes
TI Waiver Details:	
Documentation:	ROD amendment (post-implementation waiver)
TI evaluation report:	TI evaluation report was issued the same year as the ROD amendment
ARARs waived:	Federal MCLs, MCLGs, and Maine state MEGs
TI zone:	Includes the area where PCBs and VOCs exceed MCLs and MEGs in groundwater. The TI zone extends vertically into the bedrock. (A figure in the ROD amendment shows the TI zone boundaries, including TWA II Area and shallow groundwater to the south)
Data basis for waiver:	Performance of vacuum-enhanced pumping of separate-phase oil, RI/FS data
Years of remedial action:	8
Timeframe estimate:	Hundreds of years within the TI zone, and approximately 5 to 10 years outside of the zone
Cost estimate:	Present worth of $1.05 M (2002 dollars)
Final remedy:	Separate-phase oil recovery using vacuum-enhanced system, passive recovery between annual implementations, monitoring, and ICs
Alternatives to TI waiver:	No further action was another alternative evaluated; this would not achieve MCLs
Stakeholders:	
Agencies:	EPA Region 1, Maine Department of Environmental Protection
General Comments:	
Other:	None

Site No. 53: Old Springfield Landfill, Vermont

General:	
Site:	02 soils and groundwater
Site setting:	The site was a landfill accepting hazardous industrial liquid, semi-liquid waste, and municipal solid waste until 1968. The property was then used as a residential trailer park until 1990. Surrounding land use includes low-density residential housing, light agriculture, undeveloped forest land, and commercial development. Most residences use public water supply
Contaminants:	VOCs (PCE, TCE, BTX and vinyl chloride) in groundwater. PAHs and PCBs are present in soils only
NAPL:	NAPL is potentially present, due to historic disposal practices
Hydrogeology:	Low-permeability unsaturated sands, saturated glacial till/high permeability sands and gravel/fractured bedrock. The water table is near the top of the glacial till
CSM:	See ROD for details
Timeline:	1947-1968 Landfill disposal of hazardous industrial liquid, semi-liquid waste, and municipal solid waste 1976 Investigations began after a resident complained about water quality 1983 Listed on NPL 1985 RI report 1988 FS and additional RI report delineating former waste disposal areas 1988 ROD for OU 1 seeps and groundwater 1990 ROD for OU 2 soils and TI waiver
Reason(s) for TI Approval:	
Primary reasons:	At this time, the Vermont state standard for PCE was below the Practical Quantification Level (PQL) and could not be reliably met
Secondary reasons:	None given
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	None (pre-1993)
TI zone:	The compliance boundary is the downgradient edge of the waste management unit
ARARs waived:	State groundwater standards for PCE
Data basis for waiver:	RI/FS data
Years of characterization:	7
Timeframe estimate:	At least 30 years (the timeframe used for cost purposes)
Cost estimate:	Present worth of $8.7 M for the selected remedy over 30 years (1990 dollars)
Final remedy:	Cap, leachate collection with underground drains, pump-and-treat, stabilization of landfill side slopes, collection and venting of landfill gases, and ICs
Alternatives to TI waiver:	None evaluated
Stakeholders:	
Agencies:	EPA Region 1, state of Vermont
General Comments:	
Other:	The state standard (and ARAR) is now equal to the MCL, rendering the original TI waiver moot

Site No. 54: Oronogo-Duenweg Mining Belt, Missouri

General:	
Site:	OU 4
Site setting:	The site is part of a 7,000-acre area of the tri-state mining district that has been contaminated by hundreds of mines and 17 smelters. The site is an inactive lead and zinc mining and smelting area. Prior to remediation, there was over 10 million tons of uncovered, unstable, surface waste, with leachate and runoff entering groundwater and surface streams. Groundwater supplied drinking water to about 500 homes, with approximately 100 exceeding lead and cadmium action levels. Residences have unacceptable concentrations of lead in soil. Blood-lead levels are high in the surrounding area (14% of seven-year olds exceed the 10 µg/dl level). Cherokee County and Tar Creek site are neighboring Superfund sites
Contaminants:	Lead, zinc, nickel and cadmium
NAPL:	No, NAPL is not present
Hydrogeology:	Fractured breccia zones and secondary openings created by mining and bedrock formations. The shallow aquifer is approximately 300 feet thick on average
CSM:	There is no evidence of natural attenuation. See ROD for additional details
Timeline:	1990 Listed on the NPL 1994 Supplied bottled water to residents 1995 Completed site investigations 1998 ROD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Inordinate cost for any full-scale remedial activities due to the size and volume of mining wastes at this site
Secondary reasons:	Pump-and-treat would be ineffective in this fractured environment
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation report was an attachment to the ROD
ARARs waived:	Includes Federal MCLs for cadmium and nickel, secondary drinking water standards for manganese and lead action levels
TI zone:	Entire watershed within Jasper County (9 million cubic yards)
Data basis for waiver:	Site investigations
Years of characterization:	5
Timeframe estimate:	Not estimated
Cost estimate:	Present worth of $60 to $90 M if pump-and-treat were to be used
Final remedy:	ICs and provision of clean drinking water (bottled water supply to 350 homes, point of use treatment units, public water supply hookups), cleaning soil in residential yards
Alternatives to TI waiver:	Pump-and-treat was considered, but it is inordinately costly and would have negative effects on the environment (lower natural water levels in local streams and disrupt natural wetlands and ecological systems). Extensive pumping could draw down the shallow aquifer preventing its use for agriculture and industrial purposes
Stakeholders:	
Agencies:	EPA Region 7, Missouri state, public
General Comments:	
Other:	None

Site No. 55: Pease Air Force Base, New Hampshire

General:	
Site:	Site 32, OU 4
Site setting:	Site 32 has a TCE plume emanating from underground storage tank. The entire Air Force Base is over 4,360 acres. The site is now a commercial airport
Contaminants:	TCE and daughter products, as well as benzene
NAPL:	Yes, residual DNAPL likely exists based on TCE concentrations
Hydrogeology:	Five units: upper sand, marine clay and silt, lower sand/glacial till, shallow bedrock and deeper bedrock. All five units are hydraulically connected
CSM:	Dissolved contaminants migrate through preferential pathways in the shallow bedrock. Vertical hydraulic gradients (downward at the source area, upward in other areas) were used to explain presence of contaminants far from the source
Timeline:	1983 Early site investigations 1988 TCE solvent tank was removed 1990 Listed on the NPL 1991 Interim remedial measures, pump-and-treat system, treatability studies 1992 RI/FS 1993-1997 Eleven RODs were approved 1994 Draft TI evaluation report 1995 ROD with a TI waiver was approved for Site 32
Reason(s) for TI Approval:	
Primary reasons:	Presence of residual DNAPL in complex low-yield hydrogeology, resulting in minimal mass removal using pump-and-treat, and undesirable subsidence
Secondary reasons:	Limited success of other technologies (SVE, air sparging, physical barriers) due to the fractured nature of bedrock and shallow depth to groundwater)
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation report is fairly extensive. The draft report was issued a year before the ROD was approved
ARARs waived:	Federal MCLs and state ARARs
TI zone:	Site 32 source zone and some of the plume area that is hydraulically contained by the vertical barrier/pump-and-treat system. The area is approximately 700 by 500 square feet and extends vertically 20 feet into the shallow bedrock
Data basis for waiver:	Interim pump-and-treat system performance, modeling (3D geologic model, MODFLOW), site characterization data, and research into technology performance in similar settings. Efforts to locate DNAPL included installation of monitoring wells at the lower sand/glacial till and shallow bedrock interface, rotasonic drilling, the use of hydrophobic dye and fluorescence techniques to evaluate cores, and sampling without well development and purging. Concluded DNAPL was present and attempted to identify DNAPL areas using drive point profiling (U. Waterloo)
Years of characterization:	10
Timeframe estimate:	Ranged from 37 to 220 years using pump-and-treat over time for the mass of contaminants originally released (3,200 to 17,000 gallons)
Cost estimate:	According to a newspaper article, the TI waiver saved about $4 M in potential costs
Final remedy:	Vertical and hydraulic barriers for source containment, and ICs (land-use restrictions, deed restrictions)
Alternatives to TI waiver:	Alternatives considered in the FS included pump-and-treat (with ex-situ thermal or chemical oxidation treatment), SVE/air sparging, excavation, barriers, passive adsorption, pneumatic fracturing of bedrock, and dual-phase extraction
Stakeholders:	
Agencies:	The Air Force is the lead agency, working with EPA Region 1 and the state of New Hampshire. The site is leased to the Pease Development Authority
General Comments:	
Other:	This is the first site to have obtained a front-end TI waiver in EPA Region 1

Site No. 56: Petro-Chemical Systems, Inc. (Turtle Bayou), Texas

General:	
Site:	OU 2
Site setting:	Unpermitted waste disposal occurred at this 500-acre site is located in rural Liberty County, Texas. Six families live on the site, but not on any of the known waste disposal areas
Contaminants:	VOCs (TCE, cis and trans 1,2-DCE, 1,2-DCA, 1,1-DCA, 1,1,2-trichloroethane, 1,1-DCE, vinyl chloride, methylene chloride, chloroform, chloroethane, chloromethane, BTEX, 1,2-dichloropropane, cis-1,3-dichloropropene, chlorobenzene, styrene), PNAs, arsenic, various metals and more
NAPL:	Yes, residual NAPL is likely present
Hydrogeology:	Surface clay unit, about 12 feet thick, above a silt and a basal sand unit (S1), second clay layer, and a second sand unit (S2). Water in S1 and S2 is not currently used as drinking water. Most wells in the area are screened below S2, in a deeper aquifer
CSM:	See ROD for details
Timeline:	1960s Un-permitted waste disposal, including waste oils, into unlined pits 1971 State did not approve a permit application for an industrial waste disposal facility at the site, due to community opposition 1974 Petro Chemical divided and sold the site for residential use 1986 Site listed on NPL 1986 Warning signs and fence put up 1986-1988 RI/FS for OU 1 and 2 1987 ROD for OU 1; excavation of 5,900 cubic yards of soil 1991 Supplemental RI/FS and ROD for OU 2 1998 ROD amendment for OU 2 1997-2006 Tried SVE, excavation, in-situ thermal, ISCO, in-situ bioremediation, and bioaugmentation 2006 Second ROD amendment for OU 2, with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Technologies have not been effective due to layered hydrogeology and contaminant distribution. Over 99% of the mass is thought to be present in the low-permeability clay layer between S1 and S2 and will act as an ongoing source through diffusion
Secondary reasons:	The effectiveness of the 1991 and 1998 remedies has reached a plateau
TI Waiver Details:	
Documentation:	ROD amendment (post-implementation waiver)
TI evaluation report:	TI evaluation report was part of ROD amendment
ARARs waived:	Federal MCLs
TI zone:	Includes 3 acres in the S1 aquifer and 5 acres in the S2 aquifer, drawn around the source areas through peripheral wells with concentrations below MCLs
Data basis for waiver:	Field studies, full-scale remedial actions, “data gathered over the years”
Years of remedial action:	7
Timeframe estimate:	Within 160 years with active remediation. ROD amendment states that ICs are expected to remain in effect in perpetuity
Cost estimate:	The cost would have been $80.6 M over the next 160 years without the TI waiver
Final remedy:	Excavation and in-situ chemical treatment, ISCO and ICs (deed notice, land and groundwater use restrictions)
Alternatives to TI waiver:	Considered excavation and/or in-situ chemical oxidation, SVE, air sparging, pump-and-treat and/or in-situ biodegradation, MNA, enhanced natural attenuation, and slurry wall/reactive barrier. None would meet MCLs within a reasonable timeframe.
Stakeholders:	
Agencies:	EPA Region 6, Texas Commission on Environmental Quality
General Comments:	
Other:	The 2006 ROD amendment redefines the site as 500 acres due to the unknown nature of disposal activities that occurred

Site No. 57: Pinette's Salvage Yard, Maine

General:	
Site:	01
Site setting:	The site was formerly a vehicle repair and salvage yard. Land surrounding the site is used for residential, general industrial, and agricultural purposes. An undeveloped forest and a wetlands area are adjacent to the site. Nearby private water supply wells are screened in the deep bedrock aquifer (8 to 10 residences within a half-mile)
Contaminants:	PCBs, benzene, chlorinated benzenes, and lead
NAPL:	Yes, from a 1,000-gallon spill of dielectric fluids containing PCBs
Hydrogeology:	Alluvium, a clay silt confining unit, sequence of glacial till outwash, overlying a bedrock unit (weathered and fractured upper unit and deeper less fractured unit). Two distinct aquifers (shallow overburden and glacial till/fractured bedrock) separated by an intervening clay layer
CSM:	See ROD for details
Timeline:	1979 Leak of 1,000 gallons of dielectric fluid containing PCBs 1980-1981 Site investigations 1982 NPL listing 1983 Removal action of PCBs (excavation and off-site disposal of soils) 1985 Deletion Remedial Investigation (DRI) 1989 ROD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Maximum PCB concentrations in unfiltered groundwater samples contained particle-bound PCBs
Secondary reasons:	Not practicable to meet low PCB levels in soil
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	None (pre-1993)
ARARs:	State of Maine Maximum Exposure Guideline (MEG) for PCBs
TI zone:	Sitewide assumed (not specified)
Data basis for waiver:	Chemical property of PCBs to strongly bind to soil particles
Years of characterization:	7
Timeframe estimate:	Not estimated
Cost estimate:	Present worth of $4.4 M over 30 years for the final remedy (1989 dollars)
Final remedy:	Excavation and off-incineration of soils > 50 parts per million PCBs, containment through pump-and-treat/interceptor trenches, monitoring, and ICs (access restrictions)
Alternatives to TI waiver:	None
Stakeholders:	
Agencies:	EPA Region 1 and the state of Maine
General Comments:	
Other:	None

Site No. 58: Popile, Inc., Arkansas

General:	
Site:	01
Site setting:	Wood treatment operations were conducted at the site for 35 years
Contaminants:	Creosote, pentachlorophenol, PAHs, petroleum distillates
NAPL:	Yes, both residual and free-phase NAPL is present
Hydrogeology:	Low permeability soils including an upper fine-grained unit of silts and clays with a lower carbonaceous rich sand layer and a lower unit of clays and silty clays. Shallow groundwater within a half-mile is used for livestock watering but not for drinking
CSM:	See ROD and ROD amendment for details
Timeline:	1947-1982 Wood treatment operation 1984 Closed impoundments 1990 Removal actions (excavation, capping, stabilization, institutional controls) 1992 NPL listing 1993 ROD approving in-situ bioremediation and on-site biological treatment of soils and sludge. Monitoring and contingency plan if migration towards Bayou occurs. There is also contingency language for a TI waiver 1998-2000 Monitoring showed no off-site migration 2001 ROD amendment with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Pump-and-treat and in-situ bioremediation technologies were not successful due to the low permeability of site soils. Both residual and free-phase NAPL are present.
Secondary reasons:	Plume is stable and not expanding
TI Waiver Details:	
Documentation:	ROD amendment (post-implementation waiver)
TI evaluation report:	TI evaluation is part of ROD amendment
ARARs waived:	MCLs for PAHs and pentachlorophenol
TI zone:	Area with residual DNAPL and soil contamination beneath the former impoundment area (approximately 4 acres), extending vertically to 55 feet below ground surface
Data basis for waiver:	Treatability studies, including in-situ bioremediation pilot study that was unsuccessful; modeling showing plume is stable, RI/FS data including low permeability of soils
Years of remedial action:	9
Timeframe estimate:	Exceeds reasonable timeframe for site conditions
Cost estimate:	Present worth of $7.5 M over 30 years for the final remedy
Final remedy:	Extraction and off-site disposal of NAPL, in-situ treatment, biological land treatment of contaminated soils and sludge, contingency containment plan, monitoring, and ICs (deed restrictions, land use and well installation restrictions). Pump-and-treat is unnecessary
Alternatives to TI waiver:	Incineration was considered
Stakeholders:	
Agencies:	EPA Region 6 and the state of Arkansas, who was considerably involved in selecting the remedial action
General Comments:	
Other:	None

Site No. 59: Revere Chemical Corporation, Pennsylvania

General:	
Site:	OU 2, shallow groundwater and sediments
Site setting:	The site was used for waste reclamation and on-site treatment. The property is approximately 113 acres; approximately 25 acres was used as the process area, which included process buildings, waste lagoons, and storage and process lagoons. Land use in the vicinity includes state game land and a state park
Contaminants:	VOCs (PCE, TCE, 1,1,1-trichloroethane and toluene) and SVOCs (1,2,4-trichlorobenzene, 1,2-dichlorobenzene, and bis(2-ethylhexyl)phthalate)
NAPL:	No, NAPL is not likely present
Hydrogeology:	Argillites with local occurrences of very tight Triassic shales and siltstones. Fractures are found along bedding plances and as joints cutting across beds
CSM:	See ROD for details
Timeline:	1963-1969 Waste reclamation facility operated at the site, involving transport and on-site treatment of hazardous substances. Operators abandoned the site in1969, when the county and state took enforcement actions 1970-1971 State took response actions and removed 3.5 million gallons of waste sludges and liquids 1984 Fire that destroyed facility operation documents; additional response work 1987 Site was placed on the NPL 1990 RI report 1993 ROD for OU 1 for off-site disposal, soil treatment using SVE, slurry wall containment of the source area and capping, revegetation, deed restrictions, and monitoring 1996 ROD for OU 2 with TI waiver for shallow groundwater, monitoring, and ICs
Reason(s) for TI Approval:	
Primary reasons:	Pump-and-treat is not practicable because of insufficient yield from wells in the tight shales
Secondary reasons:	Low risk – groundwater is only marginally above MCLs, the plume has been stable and does not extend beyond the area to be capped. Cap will improve the quality of shallow groundwater
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	Unknown. Part of ROD?
ARARs waived:	Federal MCLs
TI zone:	Shallow groundwater beneath the limited area that will be capped
Data basis for waiver:	CSM and RI/FS data
Years of characterization:	6
Timeframe estimate:	Not estimated
Cost estimate:	Approximately $45,000 for stream corridor monitoring for seven years and ICs
Final remedy:	Monitoring and ICs
Alternatives to TI waiver:	None identified that could meet Federal MCLs
Stakeholders:	
Agencies:	EPA Region 3 and the Pennsylvania Department of Environmental Resources
General Comments:	
Other:	None

Site No. 60: Riverfront, Missouri

General:	
Site:	OU 4, soils and groundwater
Site setting:	Multiple regional sources; investigation prompted by municipal well contamination
Contaminants:	PCE, TCE and daughter products
NAPL:	Yes, DNAPL is likely present
Hydrogeology:	Fractured bedrock
CSM:	Contaminated groundwater may extend to 400 feet below ground surface or deeper. DNAPL may be present in the bedrock. Detailed fracture information cannot be known, fate and transport pathways cannot be mapped. Dissolved-phase PCE is likely present in the matrix and other spaces where remediation will be diffusion-controlled. Plume is likely stable or declining in size.
Timeline:	1986 VOCs were detected in public water supply well 1990s Site investigations 1998 US Geological Survey study of area hydrogeology 2000 Placed on NPL 2005 Riverfront site was identified as the likely source of PCE 2007 ISCO in site soils (Phase I and II injections) 2009 ROD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Fractured rock hydrogeology
Secondary reasons:	Plume size and depth, heavy residential development over the plume (steep and rugged area)
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation was a separate report
ARARs waived:	Federal MCLs, MCLGs
TI zone:	Source and plume
Data basis for waiver:	Data from post FS
Years of characterization:	19
Timeframe estimate:	100 years; greater than 30 years
Cost estimate:	Present worth of $0.22 to $1.4 M
Final remedy:	Source removal, monitoring, and ICs
Alternatives to TI waiver:	None mentioned
Stakeholders:	
Agencies:	EPA Region 7 and the Missouri Department of Natural Resources
General Comments:	
Other:	None

Site No. 61: Rodale Manufacturing Site, Pennsylvania

General:	
Site:	OU 1, sitewide
Site setting:	The site was used for manufacturing silk, publishing and printing (Rodale Press), manufacturing electrical connectors, and electroplating (Rodale Manufacturing + Bell Electric). Wells were used for waste disposal (approximately 3,000 gallons per day of electroplating wastewater)
Contaminants:	TCE, breakdown products and related chlorinated solvents, metals and cyanide
NAPL:	Yes, DNAPL is likely present based on TCE concentrations (up to 570 mg/L)
Hydrogeology:	Overburden and fractured bedrock aquifers with preferential pathways. Groundwater is deep (105 to 115 feet below ground surface)
CSM:	The source is wastewater discharge wells 1-3, 5, and 8
Timeline:	1981 Several wells historically used for waste disposal were discovered 1984 Pump-and-treat system with air stripping 1988 Additional monitoring wells installed, groundwater monitoring plan 1989 Buildings demolished, two underground storage tanks removed, and another waste disposal well (Well 8) was discovered 1991 NPL listing 1996-1998 Interim measure groundwater pump-and-treat operated and reached asymptotic removal rates, indicating DNAPL 1999 TI evaluation submitted with FS, ROD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	DNAPL is likely present deep in fractured bedrock, where there is significant storage capacity and restoration will be limited by diffusion rates from the matrix back into the fractures
Secondary reasons:	Pump-and-treat system performance illustrating that mass removal had reached asymptotic removal rates after two years of operation. No proven technologies for DNAPL contamination in bedrock; some pose unacceptable risks of mobilizing DNAPL or drilling through DNAPL to install wells
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation report was submitted with the FS in 1999, the same year as the ROD
ARARs waived:	Federal MCL for TCE
TI zone:	Corresponds with the probable DNAPL zone, defined by contouring the 1% solubility of TCE. The area is about 200 feet wide, 350 feet long, and 320 feet thick, with over 830,000 cubic yards of impacted soils
Data basis for waiver:	Pump-and-treat system performance (removal slowed to asymptotic levels after two years of operation), simulations of matrix diffusion, RI/FS data used in mass estimates, timeframe estimates
Years of characterization:	8
Timeframe estimate:	Estimated 590 to 2,370 years for restoration to MCLs using pump-and-treat. With more conservative estimates, the timeframe still ranged from 200 to 850 years
Cost estimate:	The cost of the selected remedy is $4.2 M
Final remedy:	Pump-and-treat for containment, MNA outside the TI zone, and ICs
Alternatives to TI waiver:	Many technologies were evaluated in detail, but none were thought to be effective at remediating DNAPL sources. Considered no action and natural attenuation with a TI waiver in the FS
Stakeholders:	
Agencies:	EPA Region 3 and the Pennsylvania Department of Environmental Resources
General Comments:	
Other:	None

Site No. 62: Roebling Steel Company, New Jersey

General:	
Site:	OU 5 and 3 for groundwater, soils, and sediments
Site setting:	This 200-acre site is an inactive steel plant used during the 1900s
Contaminants:	Arsenic, beryllium, and lead
NAPL:	No, LNAPL areas in soils have been remediated
Hydrogeology:	Sequence of fill materials, sands, clays, silts, and gravels
CSM:	Extraction of organics would be very difficult due to high partition coefficient values of arsenic, beryllium and lead
Timeline:	1906-1982 Steel plant manufacturing activities 1978-1988 Variety of other industrial activities 1983 NPL listing 1985-1998 RI/FS activities and removal actions 1990 ROD for source removal 1991 ROD for OU 2 and 3 1996 ROD for OU 3 2003 ROD for OU 5 with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Metals are nearly immobile in the aquifer
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation was an appendix to the ROD
Remedial activities:	2003 ROD selected capping of site soils, TI waiver, and ICs
ARARs waived:	New Jersey groundwater quality standards
TI zone:	Not specified. The site is 200 acres
Data basis for waiver:	Contaminant transport modeling (USGS MODPATH 96 and MT3DMS) and conceptual site model regarding remedial timeframes under various scenarios
Years of characterization:	18
Timeframe estimate:	90,000 years to achieve MCLs using source removal and MNA; 35,000 years to achieve MCLs using pump-and-treat (1.7 trillion gals); indefinite timeframe without source removal
Cost estimate:	Not given
Final remedy:	Monitoring, ICs (groundwater use restrictions)
Alternatives to TI waiver:	None evaluated
Stakeholders:	
Agencies:	EPA Region 2 and the New Jersey Department of Environmental Protection
General Comments:	
Other:	None

Site No. 63: Schofield Barracks, Hawaii

General:	
Site:	OU 02, groundwater
Site setting:	The Schofield Barracks site has contamination from several source areas including an abandoned landfill and water supply well
Contaminants:	TCE and carbon tetrachloride
NAPL:	Yes, residual DNAPL is likely present
Hydrogeology:	Soil and saprolite (low permeability clay-rich silt) grading with depth to weathered basaltic bedrock to about 100 to 200 feet below ground surface, then unweathered basaltic bedrock. Bedrock is highly heterogeneous with high transmissivity (about 900,000 feet per day). Groundwater is the principal source of drinking water. There are springs and manmade tunnels in the area
CSM:	There are two plumes of TCE covering several square miles
Timeline:	1985 Contamination was discovered on the base (up to 30 ug/L TCE in four wells) 1986 Air stripper installed to take out TCE 1990 Listed on NPL 1991 FFA outlining investigation of potential sources 1997 ROD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Several reasons, including the depth of contamination (500 to 700 feet), the thickness of aquifer (>2,000 feet), fractured lava characteristics with extreme heterogeneity, and the age and large size of the plumes
Secondary reasons:	Lack of ability to find source after significant effort, combined with a probability of residual DNAPL; not enough power on the island to operate the required number of pumps for full-scale pump-and-treat
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation report was prepared the same year as the ROD
ARARs waived:	Federal MCLs
TI zone:	Includes all areas that exceed MCLs (source areas and plume)
Data basis for waiver:	CSM and RI/FS data regarding the nature and extent of contamination and hydrogeology, inability to identify the source
Years of remedial action:	7
Timeframe estimate:	Hundreds of years
Cost estimate:	Approximately $350 M for a pump-and-treat system of this size
Final remedy:	Pump-and-treat for containment, geologic barriers, natural attenuation, ICs (land and groundwater restrictions) and wellhead treatment for Schofield supply wells
Alternatives to TI waiver:	Pump-and-treat and in-situ treatment. Depth is too great for physical barriers
Stakeholders:	
Agencies:	The Army was lead agency and worked with EPA Region 9 and Hawaii. The TI evaluation report was prepared for the U.S. Army Environmental Center
General Comments:	
Other:	None

Site No. 64: Silver Bow Creek/Butte Area, Montana

General:	
Site:	OU 03 groundwater
Site setting:	The site includes 3,000 miles of mine workings, including the Berkeley Pit site
Contaminants:	Heavy metals from acid mine drainage (including cadmium, arsenic, lead, copper) and sulfate, if an MCL for sulfate is established
NAPL:	No, NAPL is not present
Hydrogeology:	Weathered and competent bedrock, with very little alluvium. Sulfide ores (FeS_2, CuS_2) oxidize on contact with water and air. Surface water and groundwater flow into the Berkeley Pit at a rate of 4.75 million gallons per day (MGD)
CSM:	See ROD for details
Timeline:	1983 Listed on NPL 1987 Butte Area was included in the NPL site 1990 RI/FS report 1994 ROD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Extent of contamination is too great, including the size of the source (27 billion cubic yards of rock and 125 billion gallons of contaminated groundwater)
Secondary reasons:	Technologies have not been proven in similar conditions
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation was an appendix to the ROD
ARARs waived:	Federal MCLs
TI zone:	Includes all contaminated underground mine workings and their influence, over a 6.75-square mile area. (The deepest is 1,500 feet above mean sea level)
Data basis for waiver:	CSM and RI/FS data
Years of characterization:	7
Timeframe estimate:	Very long time (indefinite)
Cost estimate:	Excessive costs ranging from $27 M to $11.8 B for various remedial alternatives
Final remedy:	Inundation of the Berkeley Pit site (maintaining water levels to ensure the pit acts as a hydraulic sink), and monitoring
Alternatives to TI waiver:	Considered pump-and-treat, inundation, grouting, and the injection of acid neutralizing fluids. None would meet ARARs
Stakeholders:	
Agencies:	EPA Region 8 and the state of Montana
General:	
Other:	None

Site No. 65: South Municipal Water Supply Well Site, New Hampshire

General:	
Site:	OU 1
Site setting:	The site includes a municipal well, where contamination was discovered during routine sampling and the New Hampshire Ball-Bearing Site, which was identified as the likely source
Contaminants:	VOCs (PCE, TCE, 1,1,1-trichloroethane, 1,2-DCE, vinyl chloride, toluene) PCBs, PAHs, and metals
NAPL:	Yes, DNAPL has been observed at the site and is suspected to be present in other areas, based on past disposal practices and groundwater quality
Hydrogeology:	Glacial/fluvial overburden aquifer (sands, gravels and interspersed silt layers) hydraulically connected with the underlying bedrock aquifer. The overburden aquifer is semi-confined to unconfined and the bedrock aquifer behaves as a leaky confined aquifer
CSM:	See ROD for details
Timeline:	1982 VOCs detected in a municipal well and the well was shut down 1984 Listed on NPL 1985 New Hampshire Ball-Bearing site identified as a likely source; PRPs involved 1989 RI/FS report 1989 ROD approving pump-and-treat, SVE, and air sparging 1993 Remedy design and construction 1994-1997 Pump-and-treat system and vacuum extraction operation 1997 ESD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Better understanding of DNAPL implications since the original ROD
Secondary reasons:	Performance data from operating pump-and-treat, SVE, and air sparging for several years
Post-Implementation Waiver:	
Documentation:	ESD (post-implementation waiver)
TI evaluation report:	TI evaluation report is 8 pages, attached to the ESD
ARARs waived:	Federal MCLs
TI zone:	Comprises the NHBB area plume (as referred in the ROD). Includes both the overburden aquifer and underlying bedrock. are waived for a portion of the aquifer currently affected by DNAPLs
Data basis for waiver:	Quarterly groundwater sampling data during full-scale operation of pump-and-treat, SVE, and air sparging for 3 years; RI/FS data
Years of remedial action:	15
Timeframe estimate:	Average of 108 years, based on estimated DNAPL mass (20,400 g/m^3), groundwater velocity, porosity, groundwater concentration, and DNAPL cross-sectional area. (The original ROD estimated 32 years).
Cost estimate:	Estimated $3.5 M in savings over the next 30 years due to a change in pumping rate (now pumping for containment, not for cleanup). The original ROD estimated a present worth of $7.4 M
Final remedy:	Pump-and-treat for containment within TI zone, monitoring, and ICs (following excavation, off-site disposal, and 3 years of SVE and air sparging in the source area)
Alternatives to TI waiver:	Considered excavation, DNAPL pumping, in-situ bioremediation, barrier walls/ PRBs for containment, soil flushing, and MNA. None would achieve MCLs within a reasonable timeframe. Some would be even less effective than pump-and-treat
Stakeholders:	
Agencies:	EPA Region 1, New Hampshire Department of Environmental Services
General Comments:	
Other:	None

Site No. 66: Sullivan's Ledge, Massachusetts

General:	
Site:	OU 01, groundwater
Site setting:	Four 150-foot deep quarry pits were used for disposing of hazardous material and other wastes. The surrounding land use is residential
Contaminants:	VOCs (TCE, benzene), PCBs, and lead; PAHs in soils
NAPL:	Yes, DNAPL is suspected in deep bedrock
Hydrogeology:	Fill (derived from glacial deposit, silt, sand, gravel, and rock fragments), glacial till and swamp material, highly fractured shallow bedrock and deep fractured bedrock
CSM:	See ROD for details
Timeline:	1940s-1970s Disposal of hazardous material and other wastes including electrical capacitors, fuel oil, volatile liquids tires, scrap rubber, demolition material, brush 1970s Fire, followed by backfill of an open pit and exposed refuse 1982 Electrical capacitors were unearthed 1984 NPL listing 1984-1985 Site is fenced to limit access, potential exposure 1986-1988 Site investigations revealed high concentrations of PCBs in soil 1989 ROD with TI waiver 1999 Pump-and-treat operation began
Reason(s) for TI Approval:	
Primary reasons:	Quarry pits and bedrock fractures contain DNAPL
Secondary reasons:	Not possible to locate and extract highly contaminated wastes from the quarry pits and bedrock fractures using conventional excavation and pumping methods
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	None (pre-1993)
ARARs waived:	Federal MCLs and state drinking water and groundwater quality standards
TI zone:	Groundwater on-site and immediately off-site
Data basis for waiver:	RI/FS data and site history indicating complex geology and presence of DNAPL
Years of characterization:	5
Timeframe estimate:	Not estimated
Cost estimate:	Present worth of $2.8 M over 30 years for the selected remedy; and $7.8 M for the contingency remedy
Final remedy:	Excavation and disposal of sediments, cap quarry pits, pump-and-treat, passive collection system for shallow groundwater and seeps, monitoring, ICs, and wetlands restoration
Alternatives to TI waiver:	Evaluated combinations of containment, solidification, incineration, and vitrification with passive or active groundwater collection and no action. None were expected to meet MCLs
Stakeholders:	
Agencies:	EPA Region 1 and the state of Massachusetts
General Comments:	
Other:	None

Site No. 67: Tansitor Electronics, Inc., Vermont

General:	
Site:	OU 1, shallow groundwater
Site setting:	Over 115 drums of process wastes were dumped into a stream or onto the ground at this site. Contaminated runoff and groundwater resulted
Contaminants:	VOCs (1,1,1-trichloroethane, 1,1-DCE, PCE, TCE, vinyl chloride, others), silver, and boron
NAPL:	Yes, DNAPL is thought to be present based on high concentrations of 1,1,1-TCA and breakdown product 1,1-DCE
Hydrogeology:	Low-permeability glacial till
CSM:	See ROD for details
Timeline:	1989 Listed on the NPL 1990 Comprehensive site investigation 1994 State reclassified the aquifer as non-potable (Class IV) 1995 ROD with TI waiver 1999 Deleted from NPL
Reason(s) for TI Approval:	
Primary reasons:	Low-permeability overburden soils, high contaminant concentrations, likely presence of DNAPL make restoration technically impracticable
Secondary reasons:	Short-term pumping did not significantly decrease the mass or time to meet MCLs
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation is a section in the ROD
ARARs waived:	Federal MCLs, state MCLs and non-zero MCLGs
TI zone:	Approximately 9.6 acres including the contaminated area and beyond. The TI zone boundary corresponds to the Class IV Aquifer zone boundaries to simplify water management
Data basis for waiver:	Computer modeling to estimate restoration potential and remedial timeframes; RI/FS evaluation
Years of characterization:	5-6
Timeframe estimate:	Modeling predicted 160 to 630 years, or 300 years on average. The timeframe for MNA was approximately 450 years on average
Cost estimate:	Present worth of $0.39 M for 30 years (1995 dollars)
Final remedy:	MNA and ICs; also contingency measures if concentrations increase
Alternatives to TI waiver:	Pump-and-treat for 50 years, followed by 300 years of MNA
Stakeholders:	
Agencies:	EPA Region 1, Department of Justice, and the Vermont Agency of Natural Resources
General Comments:	
Other:	State agreed to reclassify the aquifer from Class I to Class IV

Site No. 68: Tucson International Airport Area, Arizona

General:	
Site:	OU 2, groundwater
Site setting:	The site is located on airport property and two adjoining properties, where TCE is a result of historical activities in the Hughes area, Three Hangars complex, and airport landfill
Contaminants:	VOCs (PCE, TCE, 1,1-DCE, 1,2-dichloropropane, benzene, methylene chloride, chloroform), PCBs, nitrate, and chromium
NAPL:	Yes, DNAPL is likely present (TCE concentrations exceed 10% solubility)
Hydrogeology:	Low permeability clay layer (hydraulic conductivity 10^{-6} to 10^{-5} cm/s) underlain by a gravel zone. Shallow groundwater is at 85 feet below ground surface. The regional aquifer used for drinking water purposes is 140 feet below ground surface
CSM:	DNAPL is likely present (immobile) in the clay layer and in the gravel layer beneath the clay. TCE has also been detected in the Regional Aquifer (500 feet deep)
Timeline:	1950s Anecdotal evidence of TCE in well water 1981 Groundwater contamination formally detected 1983 Listed on NPL 1997 FS report, ROD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Low-permeability clay geology with high TCE concentrations indicative of DNAPL (up to 110 feet deep) make it difficult to remove contamination
Secondary reasons:	Low yield when pumping TCE from the shallow groundwater; no remedial technologies for trapped DNAPL
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation report was submitted the same year as the FS and ROD
ARARs waived:	Federal MCLs
TI zone:	Approximately 2 acres of the shallow groundwater south of the Three Hangars Area, extending vertically to 5 feet below the gravel zone (approximately 180 feet below ground surface)
Data basis for waiver:	Based on RI/FS data and the CSM
Years of characterization:	14
Timeframe estimate:	Not estimated
Cost estimate:	ROD estimated a range of $7 to $25 M (1997 dollars)
Final remedy:	SVE, excavation of PCBs, excavation and landfill of sludge pipeline, closure, capping, and monitoring of airport landfill; Pump-and-treat to contain shallow groundwater, and ICs
Alternatives to TI waiver:	No technologies could meet MCLs
Stakeholders:	
Agencies:	EPA Region 9 is the lead agency for remediation. Arizona Department of Environmental Protection concurred with the ROD
General Comments:	
Other:	None

Site No. 69: UGI Columbia Gas Plant, Pennsylvania

General:	
Site:	OU 1, sitewide
Site setting:	This former manufactured gas plant is located on a 2-acre site about 400 feet from Susquehanna River. Land use in the area is industrial
Contaminants:	Manufactured gas plant-related wastes (coal tar), VOCs, SVOCs, and inorganics
NAPL:	Yes, residual DNAPL is present
Hydrogeology:	Fill and alluvium above fractured bedrock
CSM:	See ROD or proposed plan for more details
Timeline:	1994 Added to the NPL 1996 Consent order with site owner to start RI/FS 1997 Steam and hot water injection, tar extraction, sheet piling wall installation, and removal of contaminated sediments 1998 Risk assessment report 2002 RI/FS report 2006 Groundwater engineering analysis report, including TI waiver evaluation; Unilateral order for more soil excavation and capping 2007 Proposed plan and ROD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	Presence of a large amount of viscous residual DNAPL in fractured rock, that will slowly dissolve over centuries
Secondary reasons:	No known technologies to address residual DNAPL in fractured rock; attempts to mobilize DNAPL may cause ecological and human health risks
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation report was part of the 2006 Groundwater Engineering Analysis report, issued four years after the RI/FS and one year before the ROD
ARARs waived:	Federal MCLs and state risk-based concentration ARARs
TI zone:	Includes the DNAPL zone (about 6 acres) to a depth of 160 feet (overburden, shallow, and deep bedrock). Includes the site and off-site areas to the south and west
Data basis for waiver:	RI/FS report and post-FS analysis
Years of characterization:	15
Timeframe estimate:	Several centuries to 1,000 years, based on DNAPL dissolution timeframe
Cost estimate:	Present worth ranges from $0.9 to $10 M for groundwater remediation
Final remedy:	Monitored natural gradient flushing and ICs
Alternatives to TI waiver:	None mentioned
Stakeholders:	
Agencies:	EPA Region 3, Pennsylvania Department of Environmental Restoration
General Comments:	
Other:	None

Site No. 70: Vertac, Inc., Arkansas

General:	
Site:	OU 3, Unit 06, groundwater
Site setting:	Herbicides including Agent Orange were manufactured at this site using inadequate production and disposal methods
Contaminants:	Herbicide production waste, dioxins, chlorinated VOCs, others
NAPL:	Yes, free-phase NAPLs (> 1 inch thick) have been observed at the site
Hydrogeology:	Fractured, tilted bedrock (Atoka Formation)
CSM:	See ROD for details
Timeline:	1948 Reasor Hill produced 2,4,5-T 1961 Hercules purchased the plant and produced Agent Orange 1971-76 Transvaal leased the plant, produced 2,4-D; 2,4,5-T and 2,4,5-TP 1976 Vertac organized 1979 Production of 2,4,5-T and 2,4,5-TP ceased 1983 Listed on the NPL 1986 All production ceased 1986 PRP began removal activities with EPA oversight 1987 PRP filed bankruptcy, EPA led cleanup 1989 Off-site removal complete 1994-1996 Off-site incineration of D-waste and T-waste 1995 RI/FS complete 1996 ROD and TI waiver 1997-1998 Monitoring well installation 1998 ESD based on further investigation
Reason(s) for TI Approval:	
Primary reasons:	Substantial amounts of highly viscous NAPL may be present in the subsurface, based on past site activities; some have relatively low solubilities
Secondary reasons:	Hydrogeologic characteristics of the weathered and unweathered bedrock, including interstitial fractures and matrix storage
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation report was approved a month after it was submitted, the same year as the ROD
ARARs waived:	Federal MCLs
TI zone:	Includes the suspected DNAPL areas and surrounding area to account for potential DNAPL migration (Northern central process area, and on-site waste burial areas)
Data basis for waiver:	RI/FS data
Years of characterization:	13
Timeframe estimate:	Not estimated; exceeds reasonable timeframe for site conditions
Cost estimate:	Present worth ranged from $2.5 to $3.5 M (1996 dollars)
Final remedy:	For groundwater, includes pump-and-treat and continued use of a French drain for containment, monitoring, and ICs (deed restrictions, prohibit groundwater wells)
Alternatives to TI waiver:	None would meet MCLs
Stakeholders:	
Agencies:	EPA Region 6 was the lead agency for site remediation; PRP Vertac went bankrupt after litigation so the cleanup was funded by Superfund
General Comments:	
Other:	None

Site No. 71: Waterloo Coal Gasification Plant, Iowa

General:	
Site:	OU 1, groundwater
Site setting:	The 5-acre site was used for manufactured gas plant operations until 1956. The site is adjacent to the Cedar River and approximately 3/4 of a mile downstream from downtown Waterloo, Iowa. The site is bounded by other industrial facilities, railroad tracks, and a flood wall to the Cedar River
Contaminants:	PAHs, naphthalene, BTEX, metals from the manufactured gas process (antimony, arsenic, cadmium, chromium, iron, lead, manganese, nickel), and cyanide
NAPL:	Yes, NAPL is likely present in the alluvial aquifer
Hydrogeology:	Alluvial aquifer consists of alluvial and glacial outwash units
CSM:	See ROD for details
Timeline:	1901-1956 Manufactured gas facility operations 1965-1967 Plant was dismantled 1994 (Phase I) excavation of 10,000 tons of contaminated soil and coal tar 1996-1998 RI data collection 1997 (Phase II) excavation and thermal desorption treatment of 14,000 tons of soil 2000 RI report 2002 Baseline risk assessment and screening level ecological risk assessment 2003 (Phase III) excavation and treatment of 400 tons of surface soil 2004 FS report 2004 ROD for monitoring, ICs, and ACLs (to be determined) 2006 TI evaluation report 2006 ESD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	PAHs account for 99% of the contaminant mass in groundwater as NAPL. These contaminants have low aqueous solubility and are bound to soils. Impracticable to remediate in the alluvial aquifer where low permeability zones are intermixed with high permeability zones. The proximity of the Cedar River would not allow effective pump-and-treat of the alluvial aquifer
Secondary reasons:	The original ROD used ACLs as part of the selected remedial strategy. EPA then decided not to use ACLs due to a policy change, causing the need for an ESD and TI evaluation
TI Waiver Details:	
Documentation:	ESD (post-implementation waiver)
TI evaluation report:	TI evaluation report was issued a year before the ESD; parts are attached to the ESD
ARARs waived:	Federal MCLs and risk-based cleanup levels
TI zone:	Area of suspected NAPL and residual soil contamination. Extends vertically through the alluvial aquifer, but does not include the deeper bedrock aquifer
Data basis for waiver:	Modeling results, mass estimates and distribution, and RI/FS data
Years of characterization:	10
Timeframe estimate:	Using an MNA scenario and the SourceDK Remediation Timeframe Decision Support System, timeframes ranged from 52 to 834 years for benzene, 14,600 to 234,000 years for benzo(a)pyrene, and 631 to 10,100 years for naphthalene
Cost estimate:	Present worth of $0.97 M over 30 years (2006 dollars)
Final remedy:	MNA, monitoring, and ICs (prohibiting well installation, land use restrictions, and future engineering vapor intrusion controls), and previous source removal actions
Alternatives to TI waiver:	Biosparging, pump-and-treat, in-situ solidification, and additional excavation were all evaluated. None were expected to meet MCLs within a reasonable timeframe
Stakeholders:	
Agencies:	EPA Region 7 and Iowa Department of Natural Resources
General Comments:	
Other:	None

Site No. 72: West Site/Hows Corners, Maine

General:	
Site:	OU 1, groundwater
Site setting:	The site is 2 acres on a 17-acre property where a waste oil and transfer facility operated for 15 years. Over 235,000 gallons of waste oil and other liquids were received at the facility. The site is located in proximity to residential areas
Contaminants:	VOCs (PCE, TCE, 1,1,1-trichloroethane, 1,1-DCE, cis and trans 1,2-DCE, vinyl chloride, 1,2,4-trichlorobenzene), dieldrin, PCBs, manganese, and arsenic
NAPL:	Yes, DNAPL is suspected based on VOC concentrations
Hydrogeology:	Fractured meta-sedimentary bedrock of phyllite grade, becoming more competent with depth. Three sets of fractures have been identified and described. The deeper bedrock does not transmit water as easily as the upper, more fractured, portions
CSM:	The source area is located at the high elevation area of the site. Groundwater beneath the source area moves laterally and discharges to the surface. Springs and small water ponds are found on the flanks of the hill and drain downhill through intermittent streams. See ROD for more CSM details
Timeline:	1965-1980 Site was used as a waste oil storage and transfer facility 1980 Tanks were disassembled and sold as scrap 1987 Residential well contamination detected during a pre-purchase assessment 1988 Site investigations, bottled water and carbon filters provided to affected homes 1990-1991 Removal action to excavate and dispose of 850 tons of contaminated soil and fence the 2-acre source area, preliminary groundwater investigation 1994 Public water system constructed for affected residences 1995 Site placed on NPL 1999 RI initiated 2001 Pilot study to assess ISCO 2001 Final RI and baseline risk assessment 2002 Interim ROD for non-source area groundwater 2003-2004 Additional site characterization 2006 ROD with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	The likely presence of DNAPLs in fractured bedrock within the source area
Secondary reasons:	Complex heterogeneous structure of the fractured bedrock; ISCO was ineffective
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation was a separate report
ARARs waived:	Federal MCLs and Maine maximum exposure guidelines
TI zone:	Source areas (defined by VOC concentrations exceeding 10 mg/L), extending vertically to the deep bedrock
Data basis for waiver:	Ineffective pilot study for ISCO, modeling, and FS technology assessment
Years of remedial action:	2
Timeframe estimate:	For the source area, 470 to 540 years via MNA. For the non-source area, 40 to 80 years via MNA
Cost estimate:	Costs from the interim ROD, plus an additional $0.1 to $0.2 M for vapor intrusion characterization
Final remedy:	MNA, monitoring, ICs (ordinance prohibiting drinking water wells), public drinking water system connections, and a vapor intrusion investigation
Alternatives to TI waiver:	Considered pump-and-treat, physical barriers, collection trenches and wells, ISCO, chemical flushing, enhanced biodegradation, air sparging, and nanoscale particle injection. None of these alternatives would be effective and implementable
Stakeholders:	
Agencies:	EPA Region 1 and the Maine Department of Environmental Protection
General Comments:	
Other:	None

Site No. 73: Westinghouse Electric Corp. (Sharon Plant), Pennsylvania

General:	
Site:	OU 2, for groundwater, river sediments, drainage ways, and riparian soils
Site setting:	The 58-acre site and its surroundings have been used for industrial, rail, or commercial purposes since the mid-1800s. The area around the site is urban residential, commercial, institutional, recreational, and light industrial. The Shenango River is approximately 800 feet away from the site
Contaminants:	PCBs, chlorinated benzenes, VOCs (PCE, TCE, 1,2-DCA, 1,2-DCE, vinyl chloride), benzene, 2,3,7,8-TCDD, bis(2-ethylhexyl)phthalate, arsenic, barium, beryllium, cadmium, cyanide, mercury and manganese (believed to be naturally-occurring)
NAPL:	Yes, both LNAPL and DNAPL are present
Hydrogeology:	Low-permeability glacial till deposits separate two aquifers: an unconfined alluvial aquifer and semi-confined bedrock aquifer. Groundwater velocity in the alluvial aquifer is 38 feet per year
CSM:	~60,000 gallons LNAPL and 3,000 to 7,300 tons DNAPL in the alluvial aquifer
Timeline:	1936-1976 Westinghouse used Inerteen (containing PCBs) at plant 1976-1986 Westinghouse removed and disposed of 7,800 tons of contaminated soils, five underground storage tanks, cleaned up a large spill, removed PCB-contaminated fly ash, incinerated 104 gallons of PCB-contaminated liquid and over 4,500 PCB-containing capacitors 1983 Site investigation 1990 Listed on NPL 1995 Pilot study report and subsequent LNAPL removal 1996 RI report 1997 Baseline human health risk and screening-level ecological risk assessment 1998 FS report for soils 2000 ROD for OU 1 soils 2000 FS report for groundwater, NAPLs, and sediment; addendum in 2001 2002 TI evaluation report 2003 ROD for OU 2 groundwater, with TI waiver
Reason(s) for TI Approval:	
Primary reasons:	LNAPL and DNAPL cannot practicably be contained to a smaller area or removed
Secondary reasons:	No receptors or threats to human health or environment; contamination is relatively immobile but concern for mobilizing it via in-situ treatment attempts
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	TI evaluation report was submitted two years after the FS report and one year before the final ROD
ARARs waived:	Federal MCLs and non-zero MCLGs
TI zone:	Area with contamination, approximately the entire site (bounded by Clark Street, Sharpsville Avenue, Wishart Court continuing west to Shenango Avenue (from Reno Street), Broad Street, and the Norfolk Southern railroad tracks). Extends vertically throughout the alluvial aquifer
Data basis for waiver:	6.5 years of LNAPL recovery only yielded 650 gallons (1% estimated total);
Years of characterization:	20
Timeframe estimate:	Not estimated (not possible); not likely less than 100 years based on mass estimate
Cost estimate:	Present worth of $2.38 M (2003 dollars) for groundwater
Final remedy:	Monitoring and ICs (land use restrictions). LNAPL removal since 1994 will stop
Alternatives to TI waiver:	Evaluated NAPL source removal, pump-and-treat, and in-situ groundwater treatment. These methods may not meet ARARs, and they cost $10.5 to $17.3 M
Stakeholders:	
Agencies:	EPA Region 3 and the Pennsylvania Department of Environmental Resources
General Comments:	
Other:	None

Site No. 74: Westinghouse Electric Corp. (Sunnyvale Plant), California

General:	
Site:	OU 1
Site setting:	In the 1950s, transformers were manufactured at the site using "Inerteen" and mineral oil, which contained PCBs. Inerteen was also used as a weed killer on site and disposed of carelessly
Contaminants:	PCBs, 1,2,4-Trichlorobenzene, 1,3-dichlorobenzene
NAPL:	Yes, DNAPL has been observed in the A and B aquifers
Hydrogeology:	Alluvial sands and gravels with silts and clays. The A aquifer (45 to 50 feet deep) and B aquifer (50 to 70 feet deep) are drinking water quality but are not being used. The C aquifer is 100 to 150 feet deep
CSM:	See ROD for details
Timeline:	1981 Westinghouse conducted a study on PCBs in response to public concern 1984-85 Removal of shallow soils per California RWQCB orders 1986 Listed on NPL 1991 Final RI/FS, ROD with TI waiver 1997 ESD
Reason(s) for TI Approval:	
Primary reasons:	Presence of DNAPL containing PCBs, characteristics of PCBs to sorb to soil
Secondary reasons:	Heterogeneous soil of low permeability
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	None (pre-1993)
ARARs waived:	Federal MCLs for PCB
TI zone:	Includes the source area and extends vertically throughout the A aquifer
Data basis for waiver:	RI/FS data
Years of characterization:	10
Timeframe estimate:	Not estimated
Cost estimate:	The ROD estimated a present worth of $8.3 M (1991 dollars)
Final remedy:	Source removal and incineration, pump-and-treat for restoration of other contaminants and containment of PCBs, monitoring and ICs (land use restrictions)
Alternatives to TI waiver:	None evaluated
Stakeholders:	
Agencies:	Westinghouse (PRP), the California Department of Health Services and the California RWQCB. EPA Region 9 became the lead agency in 1987
General Comments:	
Other:	This was the first TI waiver invoked in Region 9

Site No. 75: Westinghouse Elevator Co. Plant, Pennsylvania

General:	
Site:	OU 01
Site setting:	Site operations resulting in chlorinated solvent contamination
Contaminants:	TCE, 1,1,1-trichloroethane, 1,1-DCE, 1,1-DCA, 1,2-DCE
NAPL:	Yes, DNAPL is likely present due to high VOC concentrations
Hydrogeology:	Fill material, red to brown clay, then generally fractured and weathered red and gray siltstones and shales. The shallow aquifer is in the saturated soils and weathered bedrock. The deep aquifer is below the weathered bedrock
CSM:	See ROD for details
Timeline:	1968 Elevator plant operated 1983 Local residents complaints prompt sampling and removal activities 1984 Additional site investigations, interim pump-and-treat system with air stripping 1986 NPL listing 1991 RI and draft FS reports issued; 1,1,1-trichloroethane spilled on site 1993 ROD with TI waiver 1997 Pump-and-treat system installed
Reason(s) for TI Approval:	
Primary reasons:	Complex hydrogeology and likely presence of DNAPL
Secondary reasons:	Greater risk to human health and the environment if pumping spreads contamination
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	None (pre-1993)
ARARs waived:	Background concentrations
TI zone:	Includes on-site and off-site groundwater
Data basis for waiver:	RI/FS data
Years of characterization:	7
Timeframe estimate:	Not estimated
Cost estimate:	Present worth of $4.4 M over 30 years for the selected remedy
Final remedy:	Pump-and-treat with air stripping for containment, ICs and alternate water supply if requested
Alternatives to TI waiver:	None evaluated
Stakeholders:	
Agencies:	EPA Region 3, Pennsylvania Department of Environmental Restoration
General Comments:	
Other:	None

Site No. 76: Whitewood Creek, South Dakota

General:	
Site:	OU 1, groundwater and surface water
Site setting:	This site was mined for gold and ore for over 100 years. An open pit mine and subsurface shaft mines covered over 2,000 acres of land. Mine tailings deposits discharged to groundwater and to the nearby Whitewood Creek. Woodlands, farmlands and residential homes are located in the area
Contaminants:	Arsenic, cadmium, and selenium
Hydrogeology:	Shallow alluvial aquifer overlying the bedrock aquifer. Bedrock includes granite and schist, thick-bedded limestone and sedimentary rocks containing shale and gypsum with thin sandstone and limestone beds
CSM:	See ROD for details
Timeline:	1877-1977 Gold mine operations 1970 Use of mercury was discontinued at the mine due to EPA investigation 1974-1975 Cattle died of arsenic poisoning after mine wastes were accidental mixed 1983 NPL listing 1985 Request to delist the site from the NPL was denied 1989 FS report 1990 ROD with TI waiver 1996 Deleted from NPL
Reason(s) for TI Approval:	
Primary reasons:	Size of the problem (2,000+ acres, 18 miles of floodplain), continued presence of mine tailings that act as a contaminant source
Secondary reasons:	Surface water entering the site does not meet surface water requirements
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	None (pre-1993)
ARARs waived:	National and state drinking water standards for groundwater
TI zone:	Alluvial groundwater
Data basis for waiver:	Site investigation data, magnitude of the problem
Years of characterization:	7
Timeframe estimate:	Not estimated
Cost estimate:	Present worth of $0.88 M (1990 dollars)
Final remedy:	Cover and remove soils with over 100 mg/kg arsenic, monitoring, ICs (fencing tailings, restrict future development in floodplain, groundwater well restrictions, educational measures)
Alternatives to TI waiver:	None evaluated
Stakeholders:	
Agencies:	South Dakota Department of Water and Natural Resources, EPA Region 8, and Homestake Mining Company (a PRP)
General Comments:	
Other:	None

Site No. 77: Whitmoyer Laboratories, Pennsylvania

General:	
Site:	OU 03
Site setting:	The surrounding land use is residential. Tulpehocken Creek is adjacent to the site
Contaminants:	Aniline, arsenic, VOCs (PCE, TCE, and benzene) and PAHs
NAPL:	NAPL could be present
Hydrogeology:	Silty and clayey soils with fill material overlying carbonate bedrock of the Ontelaunee formation (dark gray to dark grayish brown dolomite). There is a heterogeneous, unconfined aquifer in the carbonate bedrock. The porosity of the carbonate aquifer is almost entirely secondary, with enlarged fractures due to solution channeling. Fractures are the primary groundwater migration pathways
CSM:	Estimated 350 million gallons of contaminated groundwater
Timeline:	1900 Oil pipeline constructed on site 1934-1984 Industrial activities 1986 NPL listing, EPA provides bottled water to residents 1988 Removal of abandoned drums from the site, full-scale pump-and-treat begins 1989 RI report 1990 FS report, ROD
Reason(s) for TI Approval:	
Primary reasons:	Extensive contamination present as NAPL and sorbed onto clays within the bedrock fractures
Secondary reasons:	Observed asymptotic leveling of contaminant concentrations with pump-and-treat
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	None (pre-1993)
ARARs waived:	Background concentrations waived, with contingency to waive Federal MCLs
TI zone:	Includes an area of 215 acres to a depth of 500 feet
Data basis for waiver:	Asymptotic leveling of contaminant concentrations; RI/FS data
Years of characterization:	4
Timeframe estimate:	Indefinite
Cost estimate:	Present worth of $77.3 M for the selected remedy (1990 dollars)
Final remedy:	Pump-and-treat, with contingency operation as plume containment
Alternatives to TI waiver:	None evaluated
Stakeholders:	
Agencies:	EPA Region 3 and the Pennsylvania Department of Environmental Resources, representing the Commonwealth of Pennsylvania
General Comments:	
Other:	It is unclear whether the contingency remedy, including a TI waiver for Federal MCLs, has been implemented

Site No. 78*: Yellow Water Road Dump, Florida

General:	
Site:	OU 2, groundwater
Site setting:	The site was a former storage area for PCBs and other waste liquids
Contaminants:	PCBs and VOCs
NAPL:	No, there is no mention of NAPL at the site
Hydrogeology:	Upper sand, clay, lower sand, and limestone. There is a shallow aquifer (not drinking water quality) and a Floridian aquifer
CSM:	See ROD for details
Timeline:	1982 Spilled oils with PCBs (discovered as a result of criminal action) 1984-1988 EPA removal actions 1986 Listed on NPL 1987 Yellow Water Steering Committee formed, started RI/FS 1990 RI/FS and ROD for soil contamination 1992 ROD for groundwater with TI waiver 1998 ESD stating that groundwater monitoring could be terminated when the MCL for PCBs was reached. MCL for PCBs had been reached 1999 Site was delisted from the NPL
Reason(s) for TI Approval:	
Primary reasons:	Impracticable to remove PCBs using pump-and-treat
TI Waiver Details:	
Documentation:	Original ROD (front-end waiver)
TI evaluation report:	None (pre-1993)
ARARs waived:	Federal MCL for PCBs, Florida drinking water standards, and other action-specific and location-specific ARARs listed in the ROD
TI zone:	Source area
Data basis for waiver:	CSM and experience supported the impracticability of removing particle-associated PCBs. PCB detections were later shown to exceed MCLs due to an analytical error. The TI waiver was then retracted, as the MCL was met, and the site was delisted
Years of characterization:	6
Timeframe estimate:	Greater than 1,000 years
Cost estimate:	Estimated to be $0.4 M initially and an addition $1.4 M with contingency measures
Final remedy:	Pump-and-treat for containment as a contingency, monitoring, and ICs (limit groundwater use through well permitting, security fence)
Alternatives to TI waiver:	Considered no action, monitoring and ICs, and pump-and-treat with different ex-situ treatment methods
Stakeholders:	
Agencies:	EPA Region 4, Florida Department of Environmental Protection, and a group of 53 out of 67 PRPs known as the Yellow Water Road Steering Committee
General Comments:	
*Other	This waiver was later revoked after meeting PCB concentrations in groundwater

APPENDIX B

CASE STUDY SITE SUMMARIES

1. GREATER RISK ARAR WAIVERS

1a. E.I. du Pont de Nemours & Co., Inc. (Newport Pigment Landfill) OU 1, Newport, Delaware

1b. Onondaga Lake OU 5, Syracuse, New York

1c. Moss-American Co., Inc. (Kerr-McGee Oil Co.) OU 1, Milwaukee, Wisconsin

1a. E.I. du Pont de Nemours & Co., Inc. (Newport Pigment Landfill) OU 1, Newport, Delaware

Alternative Approach

A waiver of ARARs based on “greater risk” was incorporated into the groundwater remedy in the original 1993 ROD. This ARAR waiver applies to the Columbia and Potomac Aquifers beneath the site. The site is also located within a designated groundwater management zone.

Groundwater management is being conducted at the DuPont Newport site. Photo is taken from EPA Region 3’s website.

Site Timeline

Feb 1990	Listed on the NPL
Aug 1993	First ROD, incorporating ARAR waiver based on greater risk
Mar 2000	First five-year review
Sep 2002	Preliminary close-out report (construction complete)
2005	Second five-year review

Conceptual Site Model

Groundwater contaminants include chlorinated solvents (PCE, TCE, vinyl chloride, carbon tetrachloride), aromatics (benzene, chlorobenzene, 1,2-dichlorobenzene, and 1,4-dichlorobenzene) and metals (antimony, arsenic, barium, beryllium, cadmium, cobalt, lead, manganese and zinc). The site is underlain by fill material placed over low-lying farmland. Most of the fill is contaminated with heavy metals as a result of past waste disposal and handling. The baseline human health assessment identified unacceptably high levels of risk for several scenarios including site workers, trespassers, recreational users, and future residents drinking groundwater. Ecological receptors include plants and animals in the wetland areas.

Several issues have been raised since the ARAR waiver was approved in the ROD. A post-ROD remedial design report found that there is a continuous clay layer separating the wetlands from the aquifer. This clay layer naturally limits groundwater migration and would protect the wetlands if a pump-and-treat system were installed. After the ROD was approved, a tide-gate fell into disrepair and the wetlands became tidal. The State has no plans to fix the gate and the wetlands are expected to remain tidal. Regardless of these two findings however, the ARAR waiver remains in place.

Tools, Lines of Evidence, and Metrics

No specific tools, analyses, or metrics were identified in the ROD in support of this decision. The ROD explained that attempting to remediate the Potomac Aquifer via pumping would be counter-productive, pulling contamination downwards from the more highly contaminated

Columbia aquifer. Remedial attempts in the Columbia aquifer were predicted to damage wetlands near the south landfill.

Remedy Description

Long-term groundwater monitoring and institutional controls are the primary components of the selected remedy. Groundwater monitoring is conducted to make sure that the groundwater plume is not growing. Institutional controls are in place to prevent people from using existing wells for drinking water purposes or installing new wells. The site is within a State-designated groundwater management zone.

Pathway to Site Closure/Long Term Monitoring

The site is already conducting long-term monitoring. The remedy is currently protective of human health and the environment, according to the most recent five-year review report (EPA, 2005). Despite changes in wetland conditions (described in the previous section), EPA has determined that there is no need to revisit the groundwater remedy as long as the plume does not grow (per groundwater monitoring program).

Stakeholders

Stakeholders include EPA, the Delaware Department of Natural Resources and Environmental Control, DuPont, CibaSC, and the City of Newport.

References

EPA, 1993. Record of Decision. E.I. du Pont de Nemours & Co., Inc. (Newport Pigment Plant Landfill), OU 01. EPA ID DED980555122. Newport, Delaware. EPA/ROD/R03-93/170, September 29.

EPA, 2005. Second five-year review report. E.I. du Pont de Nemours & Co., Inc. (Newport Pigment Plant Landfill) Superfund site (a.k.a. DuPont-Newport Site), Newport, Delaware. Prepared by EPA Region 3. March 31.

1b. Onondaga Lake OU 5, Syracuse, New York

Alternative Approach

Onondaga Lake Bridge Street subsite (OU 5) with mercury remediation system. Photo from www.onondagalake.org

An ARAR waiver based on greater risk was incorporated into the final ROD for this site in 2000. The ARAR waiver applied to liquid elemental mercury present as DNAPL, VOCs, and metals contained by a cap and slurry wall at the Linden Chemicals and Plastics Bridge Street sub-site of the Onondaga Lake site (OU 5). The ROD described a greater risk and lack of community acceptance associated with truck traffic, air emissions, fugitive dust, and traffic accident risk associated with excavation of contaminated soils and off-site disposal. The ROD also described the risk of losing wetlands associated with dewatering activities during excavation.

Site Timeline

1953	Manufacturing of caustic soda (NaOH) and liquid chlorine (Cl_2) using the mercury cell process
1988	Plant is shut down
1990-1995	Preliminary cleanup efforts
2000	OU 5 ROD
2003	Excavation of contaminated soils in several areas
2004	Cleanup efforts began for contaminated sediment removal, soil-washing process to recover mercury from shallow soils, installation of a slurry wall, temporary cap, and groundwater collection system
2009	Five-year review report concludes that the remedial action is expected to be protective upon completion and is functioning as intended

Conceptual Site Model

The primary contaminant of concern at the site is mercury. Historical activities conducted at the site include manufacturing NaOH and Cl_2 using a mercury cell process. A small portion of the site was also used for ten years for manufacturing hydrogen peroxide (H_2O_2). Site soils had mercury concentrations up to 19,000 parts per million. Elemental (i.e., liquid) mercury was found in the central area of the site at depths of up to 55 feet below ground. OU 5 was identified as the single largest source of mercury to Onondaga Lake via a drainage ditch (the West Flume). PCBs, xylene and other VOCs were found in portions of the site, also elevated levels of antimony and lead in groundwater. VOCs emanate from upgradient of OU 5 and dissipate to non-detectable levels on-site.

Groundwater generally occurs at three to eight feet below ground surface. There are three distinct saturated units separated by two aquitards: fill/clay underlain by silt/clay/fine sand underlain by bedrock (Vernon shale). The on-site aquifers are not used for drinking water. Groundwater near OU 5 is not expected to be used for drinking water in the future. The property and surrounding areas are zoned for industrial use. Land use is not expected to change in the future. Two wetlands are located to the west of OU 5. The site is approximately 30 acres.

Tools, Lines of Evidence, and Metrics

The ROD described a greater risk (and lack of community acceptance) associated with truck traffic, air emissions, fugitive dust, and traffic accident risk associated with excavation of contaminated soils and off-site disposal; also a loss of wetlands associated with dewatering activities during excavation. No additional tools or metrics were described in support of this decision.

Remedy Description

The selected remedy will not achieve groundwater ARARs within the containment area (a fenced area contained by a temporary cap and a 30 to 70 feet deep slurry wall filled with bentonite clay). In addition, the ROD called for implementation of institutional controls to prohibit the use of groundwater at OU 5 and prevent disturbance of the subsite cap and slurry wall. An on-site groundwater collection system was also installed and operated. Other remedial actions conducted at the site included sewer system closure, removal and recovery of 7 tons of mercury from top soils using a soil-washing process, and excavation of contaminated sediments from surrounding areas and placement into the containment area. Long-term monitoring of groundwater, surface water, sediment, and biota will be conducted to ensure the effectiveness of the selected remedy. In the future, a final cap has to be installed over the 20-acre site.

Pathway to Site Closure/Long Term Monitoring

The final remedy is in place, although a final cap still needs to be installed. Groundwater pumping rates could be adjusted. The groundwater pump-and-treat system, slurry wall and cap will likely need to be operated and maintained indefinitely. It would take more than 30,000 years to meet groundwater standards using pump-and-treat, as stated in the 2000 ROD.

Stakeholders

Cleanup was conducted under EPA and the New York State Department of Environmental Conservation. Responsible parties included Honeywell International, Inc. and LCP Chemicals.

References

EPA, 2000. Record of Decision for Onondaga Lake Superfund site OU 05 LCP Bridge Street Site. EPA ID NYD986913580, EPA/ROD/R02-00/544. Syracuse, New York, September 29.

New York State Department of Environmental Conservation, 2010. Fact sheet #8. LCP Bridge Street, a sub-site of the Onondaga Lake Superfund Site and New York State Superfund Site Registry #7-34-049. Available online at http://www.onondagalake.org/

EPA, 2009. First five-year review report, LCP Bridge Street Subsite (OU 5), Onondaga Lake Superfund Site. Prepared by EPA Region 2, New York, NY, October.

1c. Moss-American Co., Inc. (Kerr-McGee Oil Co.) OU 1, Milwaukee, Wisconsin

Alternative Approach

Action-specific ARARs regarding RCRA impermeable cap requirements, liner, and leachate collection system were waived based on greater risk in the original 1990 ROD. The ROD stated that such a cover would prevent natural groundwater flushing and prolong the remedial timeframe for groundwater to greater than 200 years. The greater risk ARAR waiver was withdrawn in 1998.

Free product oozing into open excavation at Moss-American site in 1995-1997. Photo from EPA Region 5 website.

Site Timeline

1921-1976	Creosote operations were conducted at the site as part of wood treatment operations
1963	Kerr-McGee purchased the property
1971	Ceased discharge of wastes to settling ponds and into Little Memomonee River
1976	Facility production ceased
1983	NPL listing
1985	EPA and Potentially Responsible Party (PRP) negotiations regarding the RI/FS
1990	EPA completes FS and signs ROD citing greater risk.
1994	DNAPL free product is discovered over a 1-acre area
1995-1998	DNAPL recovery using extraction wells and storage tanks
1997	ESD issued to optimize free product recovery and modify groundwater system
1998	ROD Amendment, withdrawing greater risk ARAR waiver
1999-2001	Treatment of soil and groundwater at 1-acre site to minimize sediment recontamination
2000	Five-year review report
2002	Site sediments addressed
2005	Second five-year review report
2007	Second ESD regarding sediment remediation and river re-routing

Conceptual Site Model

The CSM has changed over time, particularly with the discovery of DNAPL at the site. The original remedy emphasized the use of an impermeable cover over contaminated soils to allow for natural flushing of contaminants and faster groundwater remediation timeframes. With the discovery of DNAPL, EPA's conceptual understanding of groundwater remediation timeframes changed. As stated in the 1998 ROD amendment, a greater risk ARAR waiver was no longer justified.

Tools, Lines of Evidence, and Metrics

The original ROD did not cite any quantitative tools or analyses in support of the greater risk ARAR waiver. The waiver was explained conceptually, as was the revised remedy that no longer supported the waiver.

Remedy Description

The original 1990 remedy called for excavation and bioslurry treatment of highly contaminated soils, on-site disposal and cover of lightly contaminated soils (including the greater risk ARAR waiver), extraction and biological treatment of groundwater, collection and off-site disposal of contaminated sediments, and re-routing river flow to a new channel. The remedy has since been modified to 1) optimize free product recovery and modify groundwater extraction and treatment system design (1997 ESD); 2) change the soil treatment technology, soil cleanup standards, and clarification of cap purpose and design (1998 ROD amendment); and 3) change the plan for sediment remediation and river re-routing (2007 ESD).

Pathway to Site Closure/Long Term Monitoring

The site no longer has a greater risk ARAR waiver. Instead, a cap is in place. The most recent five-year review found that the site has several unrelated issues left to address but that the remedy is expected to be protective of human health and the environment once it has been completed.

Stakeholders

EPA Region 5 was the lead agency at the site. The state of Wisconsin Department of Natural Resources concurred with the selected remedy.

References

EPA, 1990. Record of Decision for the Moss-American Site, Milwaukee, Wisconsin, September 27.

EPA, 1998. Record of Decision Amendment for the Moss-American Co., Inc. (Kerr-McGee Oil Co.), EPA ID: WID039052626, OU 1, Milwaukee, Wisconsin. September 30.

EPA, 2005. Five-Year Review Report. Second Five-Year Review Report for Moss-American Site, Milwaukee, Wisconsin, September 20.

2. INTERIM REMEDY ARAR WAIVER

2a. Hastings Ground Water Contamination OU 19, Hastings, Nebraska

2b. Brandywine DRMO Site SS-01, Andrews Air Force Base, Maryland

2a. Hastings Ground Water Contamination, OU 19, Hastings, Nebraska

Alternative Approach

An interim remedy was approved at the site instead of a final remedy because none of the alternatives achieved ARARs. Monitoring will be conducted to determine whether it is technically impracticable to meet ARARs. Meanwhile, institutional controls will be implemented to maintain protectiveness.

Photo of Hastings site posted on EPA's website

Site Timeline

1984	EPA began investigating groundwater contamination after municipal wells were impacted with VOCs
1996	Area-wide RI completed
2000	Area-wide FS completed
2001	Interim ROD, with interim measures ARAR waiver
2004	Consent decree with PRPs
2007	Third five-year review report

Conceptual Site Model

The site is located in south-central Nebraska, where farming is the most important economic activity. The site was divided into seven subsites plus area-wide groundwater, for investigation and remediation purposes. Each subsite has multiple OUs. Several subsites are located in industrialized areas of the city of Hastings; others are adjacent to residential communities.

Key contaminants include chlorinated solvents such as PCE, TCE and daughter products; 1,1,1-trichloroethane and daughter products; 1,4-dioxane; carbon tetrachloride; benzene and other fuel constitutents; ethylene dibromide; and PAHs. Various sources have been discovered, including a grain storage facility, vapor degreasing process, manufactured gas plant, municipal/industrial waste landfill, and grain fumigant operations. Nearly all of the soils are deep and are formed in calcareous loess, eolian sands, or mixed silty/sandy alluvium.

Tools, Lines of Evidence, and Metrics

Support for an interim remedy at the site included the FS analysis, which indicated that none of the final remedial alternatives could meet ARARs, and a lack of data to support a TI waiver. Monitoring data will be collected to assess the effectiveness of remedial actions at individual sub-sites and allow a technical evaluation of practicability of meeting ARARs in groundwater sitewide.

Remedy Description

The selected interim remedy for sitewide groundwater included establishing an institutional control area (ICA), which was enacted through a city ordinance. The ICA prohibits property owners from using groundwater within the ICA for domestic purposes unless it is demonstrated through sampling that the groundwater is suitable for use. A well registration process was set up to ensure that new wells were not installed within the ICA and that samples were collected from numerous private wells on a regular basis. Alternate drinking water must be provided if drinking water wells are contaminated above MCLs. The ROD also called for a comprehensive survey of all existing groundwater wells (domestic, irrigation, industrial, and monitoring) and organization of well logs, well location, depth, usage data, and analytical results. Per the Consent Decree, additional monitoring wells will be installed as needed and periodically monitored to determine if VOCs exceed MCLs.

Pathway to Site Closure/Long Term Monitoring

Long-term monitoring will continue to be conducted. Data will be analyzed to determine whether sufficient progress towards ARARs is being made as a result of interim and final remedial actions at sub-sites or whether it may be technically impracticable to meet ARARs. A final area-wide ROD will be issued that establishes final cleanup levels after all sub-sites issue Final RODs. Furthermore, the 2007 five-year review report found that the number of monitoring wells and extent of ICA need to be increased to encompass all groundwater plumes and maintain protectiveness. 1,4-dioxane needs to be added to the list of contaminants of concern.

Stakeholders

EPA, the Nebraska Department of Environmental Quality, and PRPs are leading remedial activities at the site.

References

EPA, 2001. Record of Decision for Hastings Ground Water Contamination Superfund site OU 19. EPA ID NED980862668, EPA/ROD/R07-01/511. Hastings, Nebraska, June 25.

EPA, 2007. Third Five-Year Review Report for the Hastings Ground Water Contamination Superfund site, Adams County, Hastings, Nebraska. EPA ID NED980862668. July 17.

2b. Brandywine Defense Reutilization and Marketing Office (DRMO) Site SS-01, Andrews AFB, Maryland

Alternative Approach

An interim remedy was recently selected for this site. The interim ROD stated that it is impractical to treat groundwater in a DNAPL source zone area to MCLs, due to the presence of DNAPL. The final remedial action will address the management of DNAPL located in the source zone.

Site SS-01, Andrews AFB, Maryland Copyright 2010 DigitalGlobe, Google maps

Site Timeline

1943-1987	Used as a storage area for drums of waste solvents, capacitors, transformers, and excess materials generated at Andrews AFB by the Navy and Air Force
1985-1990	Phase I records search, site investigation
1993-1994	Soil and tank removal
1999	NPL listing
2002	RI report
2006	Focused FS report, groundwater treatability studies
2006	Interim ROD

Conceptual Site Model

Organic solvents and materials containing PCBs were historically stored at the site and have contributed to site contamination. Maximum concentrations of TCE and PCE are 224 mg/L and 0.35 mg/L, respectively. Other contaminants of concern include cis-1,2-DCE, vinyl chloride, naphthalene, 2-methylnaphthalene, iron and manganese.

Tools, Lines of Evidence, and Metrics

The need for an interim approach was explained in the ROD as follows: "*Due to the presence of DNAPL, incomplete characterization of the DNAPL source area, and the heterogeneity of the shallow groundwater aquifer, it was determined to be prudent to initiate groundwater cleanup in two stages.*" Data from the operation of the interim remedy will be used to evaluate remediation potential of a final remedy.

Remedy Description

The interim remedial action addresses groundwater contamination outside of the source area with enhanced bioremediation and bioaugmentation and hydraulically contains groundwater in the source area. It also establishes institutional controls. The final remedial action will address the containment or removal of source area contaminants.

Pathway to Site Closure/Long Term Monitoring

The interim remedy is expected to achieve MCLs outside of the DNAPL source zone in seven years (this timeframe will be refined through groundwater monitoring data). The goals of the interim action are to halt the spread of the contaminant plume, remove contaminant mass, collect data on aquifer and contaminant response to remediation measures and define the area containing DNAPL more accurately. The final remedy will then be selected.

Stakeholders

US Air Force and EPA, with concurrence from the Maryland Department of Environment.

References

US Air Force and EPA Region III, 2006. Interim Record of Decision for Site SS-01, Brandywine DRMO, Andrews AFB, Maryland. September.

3. INCONSISTENT APPLICATION OF STATE STANDARDS ARAR WAIVER

3a. Rocky Mountain Arsenal OU 4, Adams County, Colorado

3a. Rocky Mountain Arsenal OU 4, Adams County, Colorado

Alternative Approach

The ROD for OU 4 at this site does not indicate that any ARARs have been waived; however, the comments and response to comments for the proposed plan present significant discussion of whether the State of Colorado's Basic Standards for Groundwater (CBSGs) are ARARs and whether they can be waived because of inconsistent application. The proposed plan was issued two years prior the final 1995 ROD.

Portions of Rocky Mountain Arsenal have been transformed into a National Wildlife Refuge

Site Timeline

1942	Congress established Rocky Mountain Arsenal (RMA) for chemical weapons manufacturing, test firing, and detonation or burning of obsolete ordnance
1946-1952	Private entities leased parts of RMA
1953-1957	Facility produced nerve agent Sarin and disposed of byproduct diisomethylpropyl phosphonate (DIMP) into surface impoundments; Sarin handling continued until 1969
1970-1984	Disposal of chemical warfare material by incineration and caustic neutralization
1975	Army began groundwater monitoring program
Early 1980s	Army began operating boundary pump-and-treat systems
1981	EPA began RI/FS in offpost study area, due to detection of organic chemicals in municipal wells
Mid-1980s	Private well survey
1987	Colorado Basic Standards for Groundwater are adopted for ~55 chemicals
1987	Most of RMA was added to NPL
1989	Colorado Senate Bill 181 was adopted, with provisions that apply when the Commission adopts "rules more stringent than the corresponding enforceable federal requirements"
1989	ROD for off-post interim response action (pump-and-treat system)
1989	EPA issues lifetime health advisory of 600 µg/L DIMP, a byproduct of Sarin manufacturing
1990	State supplies residents with bottled water due to DIMP contamination. State Department of Health recommends DIMP standard of 8 µg/L, using EPA risk assessment methodology
1993	Statewide interim ground water quality standard for DIMP of 8 µg/L adopted by Colorado. The standard is fully effective and enforceable once promulgated. The state recognized the potential for future modifications.
1993	Off-post interim pump-and-treat system remedy starts operating; proposed plan
1995	ROD for the off-post OU, with comments regarding inconsistent application of state standards

2004 Creation of Rocky Mountain Wildlife Refuge. As of 2005, nearly 80% was deleted from the NPL and more than 12,000 acres transferred to the US Fish and Wildlife Service

Conceptual Site Model

The off-post OU (OU 4) is defined as the portion of a 27-square-mile off-post study area where contaminants are found in groundwater, a total of approximately 590 acres (~0.9 square miles). Land is used for rangeland and farming with some residential areas. The most widespread groundwater contaminant off-post is DIMP, a byproduct from manufacturing nerve agent Sarin at RMA in the 1950s. Other groundwater contaminants include chloroform, chlorobenzene, TCE, PCE, dibromochloropropane, dieldrin, endrin, dicyclopentadiene, arsenic, chloride, fluoride and sulfate. Groundwater contamination migrated off-site before the boundary pump-and-treat system was installed and optimized to provide complete containment. DIMP has an estimated half-life in the environment of 500 years and has been detected in certain drinking water wells located up to 5 miles downgradient of RMA.

Site geology is unconsolidated alluvial and eolian deposits varying from clays to coarse gravels (ranging from 10 to 100+ feet thick) above the confined aquifer flow system in the Denver Formation (250 to 300 feet of interbedded shale, claystone, siltstone and sandstone). Paleochannels affect groundwater flow. Contaminant plumes are in and near the paleochannels.

Tools, Lines of Evidence, and Metrics

The Army's written response to comments states that, after extensive discussion with all parties, CBSGs do not meet the criteria for ARARs because of inconsistent application and ambiguous language. Instead, site ARARs are based on Federal drinking water standards. The state of Colorado's and EPA Region 8's comments to the draft final ROD at OU 4 question the Army's exclusion of CBSGs, stating that they have been used at other CERCLA sites in Colorado, including interim response actions at RMA. Under CERCLA, state environmental laws that are more stringent than federal standards must be used as cleanup standards at CERCLA sites, as long as they are promulgated and identified in a timely manner. The state of Colorado's position was clearly stated in the 1993 revisions to State Regulation No. 41, Basic Standards for Ground Water regarding the DIMP standard.

Tools and lines of evidence used to develop the final remedy included groundwater modeling for pump-and-treat with reinjection off-post. Results indicated that the time to achieve ARARs ranged from 15 to over 30 years for one remedial alternative, 10 to 20 years for another alternative, and only 3 to 8 years for a third. The State reviewed the groundwater model and believes that the Army significantly underestimated the actual time necessary to clean the groundwater to a safe level.

Remedy Description

ARARs for the off-post OU are listed in Table 10.1 in the ROD, and include State standards that are more stringent than federal standards, including CBSGs. Other ARARs include MCLs, proposed MCLs, nonzero MCLGs, and action levels.

The selected remedy includes 1) continued operation of the off-post pump-and-treat system (with granular activated carbon treatment) and recharge using wells and trenches, 2) monitoring, 3) institutional controls, 4) natural attenuation of inorganics,5) continued operation of on-post pump-and-treat systems, 6) exposure control and provision of alternate water supplies for well owners affected by DIMP, 7) closure of poorly-constructed wells in the study area, 8) continued monitoring and assessment of the N-nitrosodimethylamine plume, 9) re-vegetate 160 acres, etc.

Pathway to Site Closure/Long Term Monitoring

The latest five-year review report states that groundwater is being treated to the ROD remediation goals and clarified that pump-and-treat systems were being operated for mass removal, not for containment. Shut-off criteria for individual extraction wells are specified in the ROD. The Army will continue to operate (and improve if necessary) treatment systems, better define the N-nitrosodimethylamine plume, continue long-term monitoring, provision of alternative water supplies, and implement institutional controls. The Army also plans to review and revise the off-post water quality network as part of the 2007 long-term monitoring program update. The state of Colorado has prepared a natural resources damages assessment plan, indicating that after ROD cleanup goals have been met, additional work may be required to remedy or compensate for natural resources damages.

Stakeholders

The Army was designated as the lead agency. Parties of the 1989 Federal Facilities Agreement included the Army, Shell, EPA Region 8, US Department of the Interior, US Department of Justice, and the US Agency for Toxic Substances and Disease Registry. The Colorado Department of Health and Environment is also a stakeholder. Several settlement discussions involving municipalities, local health departments, special districts, and citizen groups were held in 1994 and 1995. In 1995, intensive public involvement helped the Army, Shell, the US Fish and Wildlife Service, Colorado Department of Public Health and the Environment, and the EPA reach decisions on the on-post and off-post RODs.

References

Colorado Department of Public Health and Environment, 2009. Regulation No. 41. The Basic Standards for Ground Water. 5 Colorado Code of Regulations 1002-41. Water Quality Control Commission. Adopted January 5, 1987. Last amended November, 30, 2009.

EPA, 1995. Record of Decision for Rocky Mountain Arsenal (US Army), OU 4, Adams County, Colorado. EPA ID CO5210020769. December 19.

Natural Resource Trustees for the State of Colorado, 2007. Natural Resource Damage Assessment Plan for the Rocky Mountain Arsenal, Commerce City, Colorado. October 24.

4. ALTERNATE CONCENTRATION LIMITS (ACLS)

4a. Waterloo Coal Gasification Plant OU 1, Waterloo, Iowa

4b. Winthrop Landfill Superfund Site OU 1, Winthrop, Maine

4c. Naval Surface Warfare Center (NSWC), SWMU 3 – Ammunition Burning Grounds, Crane, Indiana

4d. Former Long Beach Naval Complex, IR Sites 1 and 2, Long Beach, California

4e. Jacksonville Naval Air Station (NAS) OU 3, Jacksonville, Florida

4a. Waterloo Coal Gasification Plant OU 1, Waterloo, Iowa

Alternative Approach

The original selected remedy documented in a 2004 ROD included ACLs, which were never implemented due to an EPA policy decision. Instead an ESD was issued in 2006 to revoke ACLs and issue a TI waiver.

Site Timeline

1901-1956	Manufactured gas facility operations were conducted
1988	Initial environmental site investigation
1994-1996	Removal actions for coal tar followed by thermal treatment
2000	RI report
2004	FS report
2004	ROD, specifying institutional controls, groundwater monitoring and ACLs (actual concentration values were still to be determined)
2005	EPA policy memorandum on ACLs
2006	TI evaluation report and ESD

Conceptual Site Model

The site is a former manufactured gas plant, approximately 5 acres in size, located next to the Cedar River and just outside of downtown Waterloo, Iowa. The site is bounded by other industrial facilities, railroad tracks, and a flood wall at the Cedar River.

Contaminants of concern include PAHs, coal tar, BTEX compounds, naphthalene, and metals from the manufactured gas process. Site geology consists of 5 to 15 feet of silty fill overlying alluvial floodplain deposits and an uncontaminated deeper bedrock aquifer. Sixteen water wells were identified within a one-mile radius of the site in 2004, but none were used for domestic purposes.

Tools, Lines of Evidence, and Metrics

US Geologic Survey, under the direction of EPA, performed a modeling analysis to demonstrate that site groundwater had a negligible impact on water quality in Cedar River, i.e., MCLs and/or health advisory levels were not exceeded at the point of entry or at any point downstream. The contaminant plume boundary (and therefore, known and projected points of entry of groundwater to surface water) was defined by the RI and subsequent field investigations. Cedar River sediment and surface water data collected during the RI supported the modeling conclusions. Exposure to contaminated groundwater could be reliably controlled through institutional controls. Therefore, EPA initially supported a remedy including ACLs.

Lines of evidence used in support of the TI waiver included estimates of remedial timeframe for different technologies, including biosparging, groundwater extraction and treatment, MNA, in-situ solidification, and additional excavation. None of the alternatives were expected to achieve chemical-specific ARARs within a reasonable timeframe. For example, under MNA conditions, up to 830 years for benzene and up to 10,000 years for naphthalene would be required to meet remedial goals, due to the nature of site contaminants (e.g., the low solubility and soil binding capacity of PAHs).

Remedy Description

The ROD established a final remedy consisting of ACLs, institutional controls, groundwater monitoring to confirm plume stability and determine if ACLs were being met, and periodic surface water samples from the nearby Cedar River to confirm compliance with ACLs. At the time of the ROD, the ACL values had not been established.

EPA then decided as a policy matter not to use ACLs to address groundwater at the Site and issued an ESD. The ESD rescinded the ACL and surface water monitoring requirements and instead approved a TI waiver and an MNA component to the final remedy. More details can be found in the summary report on technical impracticability for this site (Appendix A).

Pathway to Site Closure/Long Term Monitoring

The amended remedy is now in place at the Waterloo Coal Gasification Plant site. Monitoring and five-year reviews will be required.

Stakeholders

EPA is the lead agency. The Iowa Department of Natural Resources concurred with the ESD. The primary responsible party is Mid American Energy Company, a site owner.

References

EPA, 2006. Explanation of significant differences, Waterloo Coal Gasification Plant, EPA ID: IAD980566356, OU 1, Waterloo, Iowa. August 11.

EPA, 2004. Record of decision, Waterloo Coal Gasification Plant, EPA ID IAD980566356, OU 1, Waterloo, Iowa. September 24.

4b. Winthrop Landfill Superfund Site OU 1, Winthrop, Maine

Alternative Approach

ACLs were approved for this landfill in a ROD from 1985. The decision was recently upheld in a 2007 ESD.

View of Annabessacook Lake, adjacent to Winthrop Landfill

Site Timeline

1920s	Sand and gravel pit
1930s	Received mixed municipal, commercial and industrial wastes
1950s-70s	Hazardous waste disposal and open burning till 1972
1980	Up to 400 parts per million of VOCs were detected in residential wells
1981	Listed on NPL
1985	RI/FS completed
1985	ROD, town ordinance prohibiting groundwater use
1993	ACL demonstration report approved; ACLs were set at Federal MCLs along the edge of the solid waste disposal area
1993	First ESD approving vapor extraction system
1995	Operation began of newly-constructed contingency pump-and-treat system
2002	Rebound study of pump-and-treat system
2006	Vapor intrusion study
2007	Second ESD

Conceptual Site Model

The site is approximately 20 acres and is located on the western shore of Annabessacook Lake, a large controlled reservoir. Groundwater discharges to Annabessacook Lake to the south and to Hoyt Brook to the north. The site received all types of wastes, including more than 3 million gallons of chemical wastes, for several decades. Early RI studies determined that liquid wastes migrated from the landfill in three separate flows in shallow and deep groundwater. Contaminants have been detected in bedrock beneath the site and in lake sediments south of the landfill.

Tools, Lines of Evidence, and Metrics

The ROD called for a demonstration of ACLs for each groundwater constituent to determine the effect on the lake, brook, and wetlands, and on recreational users of these areas. The actual ACL values were established with the ACL demonstration report. A copy of this report was not available for review. However, ACLs were set at Federal MCLs along the edge of the solid waste disposal area. Protective concentration limits were set for points of potential exposure.

Remedy Description

The ROD required the contingency construction and operation of a groundwater pump-and-treat system and landfill cap if contaminant levels exceeded ACLs. The contingency system was built and operated until November 2002, then shut down to test rebound. The ESD documented 1) a decision to decommission the pump-and-treat system, 2) need to monitor and evaluate contamination at points of exposure, and 3) address the risk of potential vapor intrusion.

Pathway to Site Closure/Long Term Monitoring

Removal/treatment of contamination in groundwater beneath the landfill has significantly reduced concentrations of all contaminants except arsenic in the downgradient plumes, to the point that ACLs are or will soon be reached. Arsenic is naturally occurring but is being mobilized by the anaerobic/reducing geochemical conditions under the landfill. Therefore, arsenic is not being remediated by the extraction system. Per the ESD, arsenic will be addressed through natural processes over an extended period of time. Monitoring and evaluation of arsenic accumulation in sediment will be conducted as well as vapor intrusion studies.

Stakeholders

The lead agency is the EPA. The Maine Department of Environmental Protection is the supporting agency and concurred with the ACL decision in the 1985 ROD, as well as the ESD.

References

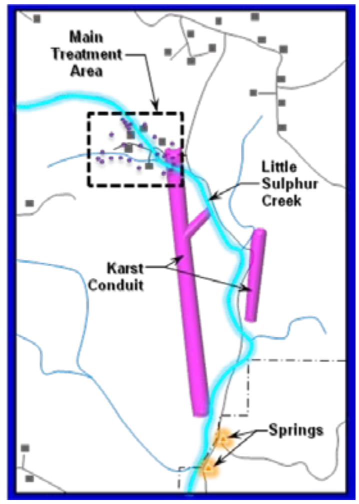
EPA, 2007. Explanation of significant differences, Winthrop Landfill, OU 1, Maine, EPA ID MED980504435. February 14.

EPA, 1985. Record of decision, Winthrop Landfill, OU 1, Winthrop, Maine, EPA ID MED980504435. November 22.

4c. Naval Surface Warfare Center (NSWC) SWMU 3 – Ammunition Burning Grounds, Crane, Indiana

Alternative Approach

ACLs were approved at this RCRA site for RDX and TCE in groundwater that discharges into springs feeding a local creek. ACLs were supported by the conceptual site model, understanding of fate and transport including natural attenuation processes, and protective institutional controls.



Groundwater beneath the site flows through karst conduits to springs

Site Timeline

1941	The NSWC facility opened as Burns City Indiana Naval Ammunition Depot for ammunition production
1981	Discovery of a potentially hazardous substance release and initial assessment study
1985	Navy submitted a report to EPA identifying SWMUs
1989	EPA requires Remedial Feasibility Investigations at 30 SWMUs
1994	Phase III Remedial Feasibility Investigation completed at SWMU 3, Ammunition Burning Grounds
1993	Navy proposed a series of voluntary cleanup actions or interim measures, including revegetation, composting of explosives contaminants, and pump-and-treat of contaminated groundwater
2008	Navy groundwater risk management handbook features site as a case study

Conceptual Site Model

The NSWC Crane site is over 60,000 acres, located in a rural area of south-central Indiana, surrounded by forest. SWMU 3, the Ammunition Burning Grounds, has been used for open burning of pyrotechnics, explosives, and propellants since the 1940s. Groundwater contaminants include RDX, TCE and metals (barium). SWMU 3 is underlain by Big Clifty Sandstone and Beech Creek Limestone formations, which provide a karst environment for contaminant transport in groundwater. Downgradient of the site are several springs that discharge into a nearby creek, which serves as a public water supply 11 miles downstream.

Tools, Lines of Evidence, and Metrics

Hydrologic and dye tracer studies were conducted to illustrate how groundwater beneath the site travels through a karst conduit and discharges to nearby surface springs. RDX concentrations were shown to decrease downstream of the springs due to dilution and mixing. Stakeholder acceptance of ACLs was facilitated by the significant natural attenuation of RDX and ability to use land use controls on Navy property to prevent exposure and on-site groundwater use. In addition, SWMU 3 is not a viable ecological habitat due to ongoing use of the open burn treatment unit.

Remedy Description

ACLs for the spring were calculated so that Indiana Water Quality Standards would be achieved at point source discharge limits. This translated to a maximum of 240 parts per billion in non-potable surface water, 140 parts per billion RDX at the spring, and 3 parts per billion RDX at the public water supply. The remedy also includes land use controls to protect the current uses of the Ammunition Burning Grounds and Little Sulphur Creek. Other actions taken at SWMU 3 to date include composting of explosives-contaminated soils and revegetation and pump-and-treat of contaminated groundwater.

Pathway to Site Closure/Long Term Monitoring

Remedial actions are being conducted on a voluntary basis at SWMU 3. No information was found regarding additional steps to be completed in the future prior to site closure.

Stakeholders

Remediation is being conducted by the Navy under oversight by the Indiana Department of Environmental Management.

References

NAVFAC, 2008. Groundwater risk management handbook. Naval Facilities Engineering Command. January.

Indiana Department of Environmental Management, 2010. Naval Surface Warfare Center - Crane, Indiana. Available online at www.in.gov/idem/4225.htm

4d. Former Long Beach Naval Complex, IR Sites 1 and 2, Long Beach, California

ACLs at Sites 1 and 2 are based on compliance with the California Ocean Plan.

Alternative Approach

ACLs were approved for VOCs in groundwater. Groundwater remedial objectives are based on meeting California Ocean Plan criteria at land's edge.

Site Timeline

1940s-90s	Operation of former Naval Station Long Beach and Long Beach Naval Shipyard
1990	Property closed under Defense Base Closure and Realignment Act Properties were leased or transferred to the Port of Long Beach
1998	ROD
2000-2001	Excavation and off-site removal of shallow soil and debris
2001-2003	Air sparge/soil vapor extraction system operation
2003-2005	Quarterly groundwater monitoring
2007	Remedial action completion report to achieve response complete
2007	Removal of air sparge/soil vapor extraction system, end of groundwater monitoring
2010	Five-year review

Conceptual Site Model

VOCs in site groundwater include benzene, TCE, 1,2-DCE, and vinyl chloride from site activities such as solid and liquid waste disposal, chemical storage, ship manufacturing, degreasing, paint removal, dry cleaning, electrical and weapons shop operations, fueling operations, and other industrial activities. Site groundwater discharges to the ocean. Remedial objectives are to minimize the potential for migration of groundwater contaminants at concentrations that exceed California Ocean Plan criteria as well as prevent human exposure to groundwater.

Tools, Lines of Evidence, and Metrics

None of the documents available for review for this site provided details on the tools or lines of evidence in support of ACLs.

The Navy ceased groundwater monitoring based on results from October 2006 and March 2007 sampling events, which indicated that contaminant concentrations were stable or decreasing.

Remedy Description

The selected remedy included ACLs with the point of compliance at land's edge, long-term monitoring, institutional controls, and five-year reviews. This followed excavation of contaminated soils and two years of treatment using air sparge/vapor extraction.

Pathway to Site Closure/Long Term Monitoring

Sites 1 and 2 reached response complete in 2007. The Navy is currently conducting long-term management, maintaining land use controls (fencing, property use restrictions) and conducting five-year reviews. The Navy is no longer performing groundwater monitoring, as they have already achieved the remedial action objective of preventing contaminants from reaching surface water at concentrations exceeding California Ocean Plan criteria.

Stakeholders

RODs were signed by the Navy and two divisions of the California Environmental Protection Agency: the Department of Toxic Substances Control and the Regional Water Quality Control Board. EPA has no formal concurrence role but it reviewed and provided comments on the RODs.

References

Navy, 2010. Draft ARTT white paper on alternative endpoints. Alternative Restoration Technology Team.

Navy, 2010. Fact sheet. Former Long Beach Naval Complex. Five-Year Review of the Installation Restoration Sites 1-6A and 8-14. January.

4e. Jacksonville Naval Air Station (NAS) OU 3, Jacksonville, Florida

Alternative Approach

Remedy optimization efforts are ongoing to perform a mixing zone analysis as the basis for developing ACLs and amending the final remedy.

Jacksonville NAS plans to develop ACLs based on a mixing zone analysis

Site Timeline

1940	Site was commissioned as a pilot training facility. Activities at OU 3 included repair, rework and modification of aircraft engines and other components
1989	Added to NPL
1998	RI/FS for OU 3
2000	ROD for OU 3 (except groundwater beneath Areas A and E)
2002	RI/FS Addendum
2005	Five-year review/optimization report
2007	ROD for OU 3 Area A, designating MNA as the selected remedy
2008	Remedy optimization efforts and ACL plans underway

Conceptual Site Model

Jacksonville NAS OU 3 is 134 acres, located on the western bank of the St. Johns River. Historical industrial activities (including dry cleaning, painting, and chemical stripping) resulted in groundwater contamination with PCE, TCE, 1,1-DCE and vinyl chloride. Contaminant concentrations indicate the potential for residual DNAPL. OU 3 is underlain by a complex stratigraphy of interbedded layers of sand, clayey sand, sandy clay, and clay. An extensive low permeability clay layer divides the aquifer into an upper slow-moving zone influenced by storm discharges, and a lower fast-moving zone which discharges to the St. Johns River. Current and anticipated future land use is industrial, and there is currently no groundwater use at the site.

Tools, Lines of Evidence, and Metrics

The decision to incorporate MNA into the final remedy was based on groundwater monitoring results. Data in support of an optimized remedial strategy incorporating ACLs included a direct push/membrane interface probe investigation to update the CSM with additional geologic information and information about contaminant extent in soil and groundwater, followed by fate and transport modeling to gauge the effect of contaminated groundwater mixing with surface water.

Remedy Description

The 2000 ROD for OU 3 included designating ongoing interim removal actions (air sparging, SVE, pump-and-treat) for groundwater hot spot areas, enhanced biodegradation in Areas C and D, ISCO in Area F, MNA in Areas B and G, and selective removal of tar balls from surface soils at another area (PSC 16). MNA was the preferred remedy for Areas A and E; however, additional data were needed before selecting this as a final remedy in 2000.

The 2007 ROD for OU 3 Area A groundwater included natural attenuation, land use controls, and monitoring. This remedy was selected and implemented after interim remedial actions were conducted. Interim actions included air sparging with soil vapor extraction at one source area and groundwater pump-and-treat with soil vapor extraction at a second source area. Interim remedy operation ceased after a five-year review concluded that the systems were no longer effective in removing contaminant mass.

Pathway to Site Closure/Long Term Monitoring

The optimized remedial strategy being developed includes a risk management approach, focusing on discharge of groundwater to St. Johns River as the primary receptor. The CSM has been updated and will be used in a groundwater fate and transport model to perform a mixing zone analysis, which will be the basis for developing ACLs as new groundwater cleanup standards. ICs will also be developed to prevent exposure to contaminated soil and groundwater remaining at the site. A ROD amendment would be needed to document the revised remedy.

Stakeholders

Key stakeholders include the Florida Department of Environmental Protection, EPA Region 4, and the US Navy. These three agencies comprise the NAS Jacksonville Partnering Team.

References

NAVFAC, 2008. Groundwater risk management handbook. Naval Facilities Engineering Command. January.

NAVFAC, 2006. Record of Decision for Operable Unit 3, Area A, Naval Air Station Jacksonville, Jacksonville, Florida. September.

EPA, 2000. Record of Decision for Jacksonville Naval Air Station, OU 03, Jacksonville, Florida, EPA ID FL6170024412, EPA/ROD/R04-00/074. September 28.

5. GROUNDWATER MANAGEMENT/CONTAINMENT

5a. Joliet Army Ammunition Plant (Load-Assembly Packing Area and Manufacturing Area), Illinois – Groundwater management zone

5b. Naval Weapons Industrial Reserve Plant (NWIRP) Dallas, Texas – Plume management zone

5c. Fairchild Semiconductor Corporation (South San Jose Plant), San Jose, California – Containment zone considered

5d. Barstow Marine Corps Logistics Base OU 1, Barstow, California – Waste management area

5a. Joliet Army Ammunition Plant (Load-Assembly Packing Area and Manufacturing Area), Illinois

Alternative Approach

The selected remedy for groundwater at Joliet Army Ammunition Plant (Load-Assembly Packing Area and Manufacturing Area) is MNA over long timeframes and the establishment of a groundwater management zone (GMZ). This designation is not an alternative endpoint; it is a state designation for areas that do not yet meet cleanup standards to delineate and track institutional controls. It may make it easier to select a groundwater management strategy for the site.

Aerial view of Joliet Army Ammunition Plant. Photo is from Google maps.

Site Timeline

1940s	Explosives were manufactured, loaded, assembled, packed and shipped during World War II. Production was reactivated for the Korean and Vietnam wars
1978	Installation Assessment and first report of potential environmental impacts
1987	Listed on NPL
1998	ROD, including GMZ
2003	ESD to extend the GMZ at Site M1
2004	Five-year review report

Conceptual Site Model

Contaminants included TNT, 2,6-DNT and RDX; remedial goals are state standards.

Tools, Lines of Evidence, and Metrics

Timeframe estimates for meeting remedial goals in groundwater range from 20 to 340 years. Remedial timeframe estimates will be refined during remedial design. If the timeframes are determined to be unacceptable, alternative remedial actions will be developed and implemented in accordance with the NCP. This information is documented in the OUs 01 and 02 ROD, dated October 30, 1998. The first five-year review report, in 2004, recalculated groundwater cleanup timeframes at several monitoring wells, estimating a maximum of 404 years to reach cleanup goals at specific wells. There was no discussion in the five-year review report of these timeframes being unacceptable.

Remedy Description

At Joliet Army Ammunition Plant, GMZs were established around three areas of contaminated groundwater that did not meet remedial goals. Contamination within the GMZs will be addressed via limited action including deeding and zoning restrictions, periodic site inspections, groundwater and surface water monitoring, and natural attenuation.

Pathway to Site Closure/Long Term Monitoring

The GMZ designation will be in place until cleanup activities are complete.

Stakeholders

EPA Region 5, Illinois EPA and the Army were the main stakeholders/decision-makers.

References

EPA, 1998. Record of Decision for Joliet Army Ammunition Plant (Load-Assembly-Packing Area) and Joliet Army Ammunition Plant (Manufacturing Area), EPA ID IL0210090049 and IL7213820460. OUs 01, 02 and OUs 01 and 02, Joliet, Illinois. EPA/ROD/R05-99/041. October 30.

EPA, 2004. Five-Year Review Groundwater Operable Unit, Joliet Army Ammunition Plant, Wilmington, Illinois. Final. First review period May 5, 1999 through May 4, 2004. April.

5b. Naval Weapons Industrial Reserve Plant (NWIRP) Dallas, Texas

Alternative Approach

A plume management zone (PMZ) was approved at this site. Within the zone, groundwater and soil contamination is managed in place.

NWIRP Dallas. Photo is from NAVFAC, 2008.

Site Timeline

1941	NWIRP facility constructed to support World War II efforts, primarily manufacturing military aircraft
1985-89	First environmental studies
1988	Facility applied for a RCRA Part B permit
1993	EPA completed a RCRA facility assessment; identified SWMUs and areas of concern
1994	State issued RCRA Part B permit, required RCRA facility investigation
1997	Three boundary pump-and-treat systems installed (Southern and Eastern property boundaries)
1997-2001	More wells installed, additional sampling to address data gaps; results summarized in 2001 "Affected property assessment report"
2004	Navy submitted a Response Action Plan to State and EPA incorporating PMZ

Conceptual Site Model

Chlorinated solvents are present in soil and groundwater at the site, including TCE, 1,1,1-trichloroethane, and degradation products as a result of historical manufacturing and waste disposal practices.

Tools, Lines of Evidence, and Metrics

The decision to approve a PMZ as part of the remedial action plan was supported by a failure to identify any viable technologies to meet remedial goals, despite pilot studies. Site data indicated a limited natural degradation potential due to low carbon content in the aquifer. Finally, the Navy stated that operation of the boundary pump-and-treat systems did not reduce the plume footprint. The decision was validated by an EPA study in December 2003 study which concluded that remediation to protective concentration levels has never been achieved in a source zone such as that at NWIRP Dallas.

Remedy Description

In addition to the PMZ, institutional controls, and long-term monitoring, two permeable reactive barriers were installed. Implementation of the PMZ significantly reduced the amount of soil that required treatment, as the soil-to-groundwater pathway was no longer the risk driver for soil remediation.

Pathway to Site Closure/Long Term Monitoring

Long term monitoring must be conducted over the next 30 years to verify that the plume is not expanding or migrating beyond PMZ boundaries. Institutional controls, including deed restrictions, and a land use covenant, are in place.

Stakeholders

An active Tier I Partnering Team includes EPA, TCEQ, the Navy, and its contractors. A Texas Tier II Partnering Team, composed of senior officials from the regulatory agencies and the Navy, also supports the Tier I Team. Additionally, a Restoration Advisory Board, co-chaired by the Navy RPM and a community member, meets regularly to monitor cleanup progress, discuss significant issues and provide input. The Navy considers these partnerships and involvement to have been vital to the cleanup success and to the establishment of the PMZ.

References

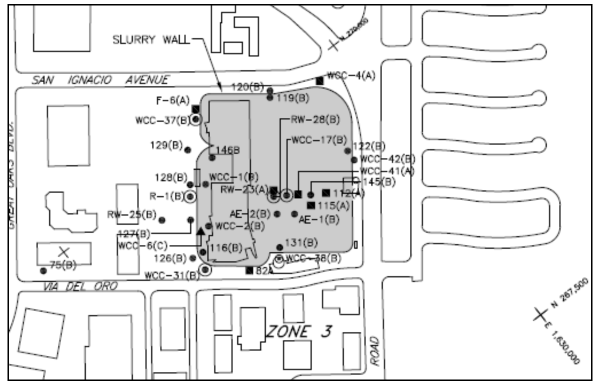
NAVFAC, 2008. Plume management zone (PMZ) to manage chlorinated solvents. Naval Weapons Industrial Reserve Plant (NWIRP) Dallas, Texas. Spring ’08 Remedial Project Manager (RPM) News. NFESC.

Navy, 2008. 2008 Progress Report. Department of the Navy, Environmental Restoration Program.

5c. Fairchild Semiconductor Corporation (South San Jose Plant), San Jose, California

Alternative Approach

PRPs at this site requested a containment zone designation for portions of this site; however, the containment zone was not approved by the RWQCB.



Site layout with slurry cut-off wall (EPA, 2009).

Site Timeline

1977-1983	Fairchild Corporation conducted semiconductor manufacturing operations at the site
1981	Discovery of a failure in an underground storage tank containing organic solvent waste
1982	Groundwater pump-and-treat systems begin operation
1986	Slurry wall installed at the site
1988	Listed on NPL
1989	ROD for OU 1
1990	SVE system operated and removed ~16,000 lbs of VOCs before removal dropped to <10 lbs/day. Soil remediation then ceased. However, VOCs were still above cleanup goals. In 1995, RWQCB approved end of saturated soil remediation.
1994	Off-site pump-and-treat ends
1998	Application for containment zone filed with RWQCB. RWQCB approved on-site pump-and-treat system shut-off to test the slurry wall
2004	Five-year review report, noting presence of 1,4-dioxane within the slurry wall
2009	Five-year review report, noting that MNA is slowly reducing groundwater concentrations inside the slurry wall and calling for a ROD amendment to address lack of pump-and-treat and set a final cleanup goal for 1,4-dioxane.

Conceptual Site Model

Groundwater contaminants include 1,1,1-trichloroethane, 1,1-DCE, and 1,4-dioxane. 1,1,1-trichloroethane contamination was discovered exceeding drinking water standards in a public drinking water supply well located approximately 1,800 feet downgradient from the site. Currently off-site groundwater no longer exceeds MCLs. Concentrations inside the slurry wall still exceed MCLs (e.g., 690 µg/L 1,1-DCE, 120 µg/L 1,1,1-trichloroethane, 79 µg/L 1,4-dioxane) but are slowly declining.

Tools, Lines of Evidence, and Metrics

At the time of the request for the containment zone (1991), SVE system removal had reached asymptotic levels (~6 lbs VOCs/day). Off-site groundwater met drinking water standards. Fairchild predicted that on-site VOCs would not migrate past the slurry wall. This has been verified by monitoring data. Stakeholders decided not to implement any official containment zone policy to avoid potential conflicts with local groundwater management policies. The site is located in a sensitive hydrogeologic area that is classified as a recharge zone for local groundwater.

Remedy Description

The remedy for groundwater at this site has included soil excavation, construction of a slurry cut-off wall around the site, groundwater pump-and-treat system, soil vapor extraction, monitoring, and institutional controls. Land use restrictions prevent the use of groundwater as drinking water.

Pathway to Site Closure/Long Term Monitoring

All cleanup remedy construction has been completed. Contaminated soils have been removed and treated, private wells have been closed, the groundwater treatment system operated until asymptotic levels were reached, and a slurry wall was installed, all of which reduce the potential exposure to hazardous substances.

Stakeholders

Stakeholders include EPA, SF RWQCB, PRPs, Santa Clara Valley Water District, the City of San Jose, and the public. SF RWQCB was the lead agency at the site and is responsible for reviewing the containment zone proposal. EPA concurred with the selected remedy.

References

EPA, 1989. Record of decision for the Fairchild Semiconductor Corp. (South San Jose Plant), San Jose, California. OU 1. EPA ID CAD097012298. March 20.

EPA, 2004. Five-year review report for the Fairchild Semiconductor Corp. Superfund Site, San Jose, California. September 30.

EPA, 2009. Fourth five-year review, Fairchild Semiconductor – San Jose Site, California. September.

5d. Barstow Marine Corps Logistics Base OU 1, Barstow, California

Alternative Approach

At this site, the Navy designated several CERCLA areas of concern (23, 35, and 15/17) in the Yermo Annex plume as Waste Management Areas (WMAs) and will meet State and Federal MCLs at points of compliance along the downgradient boundaries. The Navy and EPA agreed to disagree about the appropriateness of WMA designations at several other locations on-site.

Barstow's Yermo Annex has several designated waste management areas. Photo from Google maps

Site Timeline

1989 NPL listing
1995 RI and FS reports for OUs 1 and 2
1998 ROD for OUs 1 and 2, designating WMAs
2003 First five-year review report
2006 ROD for OU 2
2008 Second five-year review report

Conceptual Site Model

This site has several groundwater plumes of PCE, TCE, and other VOCs. Site geology is composed of up to 600 feet of alluvial fan deposits of gravel, sand, silt, and clay, underlain by bedrock. Groundwater is ~150 feet below ground surface.

Tools, Lines of Evidence, and Metrics

The basis for a WMA designation comes from the CERCLA NCP preamble, which states that "*EPA believes that remediation levels should generally be attained throughout the contaminated plume, or at and beyond the edge of the waste management area when the waste is left in place*" (i.e., the "point of compliance").

The NCP preamble also states that there may be certain circumstances where groundwater plumes are caused by several distinct sources/releases in close proximity to each other. The preamble states that the most cost-effective groundwater cleanup strategy in this case may be to address the problem as a whole rather than on a source-by-source basis, and to draw a common "point of compliance" that encompasses all the sources of release (55 Federal Register 8753, 8 March 1990).

EPA and the Navy "agreed to disagree" regarding the appropriateness of additional WMAs at areas of concern 6, 16, 26, and Warehouse 2. In an Appendix to the ROD, the Navy reserved the right to propose the use of designated points of compliance for these areas in the future. EPA's position is that a designated point of compliance is only acceptable at RCRA-regulated units. The Navy referenced several other RODs approved by EPA where non-RCRA regulated units where contaminated soil/waste was left in place and a downgradient point of compliance was designated, including Teledyne Wah Chang (6/10/94), Montana Pole & Treating Plant (9/21/93), Naval Air Station Ault Field (12/20/93), Reilly Tar & Chemical (9/30/93), American Crossarm & Conduit (6/30/93), and Reilly Tar & Chemical (6/30/92). The RWQCB did not agree with Navy's proposed point of compliance; however, the issue was not contested as the Navy agreed to comply with the groundwater cleanup standards throughout the plume as a conservative means of demonstrating attainment at the point of compliance. The Navy stated that their agreement to the RAO under this ROD should not be construed as establishing precedent for any other Navy sites.

Remedy Description

The remedial approach to the groundwater and soil contamination is to reduce the contaminant mass in groundwater and the vadose zone to meet federal and state MCLs, except directly beneath WMAs. The OU 1 remedy consists of pump-and-treat with GAC treatment, recharge at the upgradient edge of the plume, continued operation of existing AS/SVE systems, monitoring, and institutional controls.

Pathway to Site Closure/Long Term Monitoring

The footprint of the OU 1 groundwater plumes have decreased over time, as have TCE concentrations. The 2008 five-year review report described several remedy optimization efforts that were ongoing as well as recommendations for ensuring that the remedy continues to be protective in the future. Five-year reviews, system operation, monitoring and institutional controls will continue until remedial objectives are met.

Stakeholders

Stakeholders include the Marine Corps, Navy, EPA, California EPA's Department of Toxic Substances Control, and the Lahontan RWQCB. These parties all concurred with the selected remedy in 1998.

EPA and the Navy reached an "agreed to disagree" compromise regarding the point of compliance at several other source areas at Barstow. The Navy reserves the right to propose the use of WMAs at Barstow OU 1 in the future.

References

EPA, 1998. Record of Decision for Barstow Marine Corps Logistics Base, OUs 1 and 2, Barstow, California. EPA ID CA8170024261. March 22.

EPA, 2008. Second Five-Year Review Report, Operable units 1–6, Marine Corps Logistics Base Barstow, California. May 27.

6. GROUNDWATER RECLASSIFICATION

6a. Altus Air Force Base, Altus, Oklahoma – Reclassification to Class III groundwater

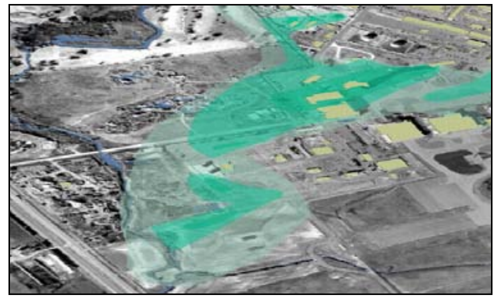
6b. Porter Cable/Rockwell Site, Tennessee – Site-specific impaired groundwater classification

6c. Hardy Street Rail Yard, Houston, Texas – Municipal setting designation classification

6a. Altus Air Force Base, Altus, Oklahoma

Alternative Approach

The impacted aquifer was reclassified as Class III Aquifer, implying limited use (TDS concentrations ranging from 3,000 to 5,000 mg/L). The Statement of Basis stated that groundwater restoration is not practicable at the site, given the presence of DNAPL and fractured hydrogeology.



Approximate TCE plume location along Altus Air Force Base boundary.

Site Timeline

1942	Flight training base operations begin. Activities include aircraft and equipment cleaning, and fire training activities
1996	EPA issued Section 3008(h) order with corrective action requirements
1999	Pump-and-treat system installed along the southern boundary
2001	Letter from Oklahoma Water Resources Board concurring with Air Force's request to reclassify groundwater within the base boundary as a non-potable source, due to high TDS concentrations
2002	Air Force submitted Remedial Feasibility Investigation/Interim Action/Corrective Measures Study report; biowall pilot study
2005	Public meeting regarding groundwater reclassification off-base
2005	Pump-and-treat system replaced by a full-scale biowall (bark mulch wall)
2006	Biowall enhancement testing (oil/lactate injections)
2004	Final groundwater classification monitoring report
2007	Final Corrective Measures Study report and Statement of Basis

Conceptual Site Model

Chemicals of concern at the site include TCE, 1,2-DCE, PCE, carbon tetrachloride, and BTEX compounds. Geology at the site consists of 10 to 25 feet of surface soils (sandy loam, sandy clay loam) underlain by reddish-brown shale with thin interbedded siltstone and sandstone (the Hennessey Group). The weathered shale becomes more competent with depth. In the weathered rock, gypsum mineralization occurs in what were presumably fractures and bedding planes in the original rock matrix. Fractures are transmissive in the competent rock.

Tools, Lines of Evidence, and Metrics

The decision to reclassify groundwater was primarily based on TDS concentrations in the aquifer. The decision to implement groundwater management units was supported by the corrective action objectives (see below for more details).

Remedy Description

Corrective action requirements state that complete restoration of groundwater at Altus AFB site is not practicable given the likely presence of DNAPL and fractured rock setting. The final cleanup objective is to contain the plume, rather than restore it to its maximum beneficial use. (Beneficial uses of Class III water include agriculture, industrial processes and cooling, and municipal processes). Four groundwater management units were defined, within which groundwater will be contained. Sentinel monitoring wells are present to demonstrate that each groundwater management unit is stable. Altus must remove or treat source material in soils and groundwater to the extent practicable within these zones. The point of compliance will be the base boundary. The remedy includes soil excavation, enhanced reductive dechlorination using bioreactors in the source zone, mulch biowalls for containment, an enhanced reductive dechlorination system with injection well circulation, and optimization of groundwater recovery wells.

Pathway to Site Closure/Long Term Monitoring

The remedial timeframes were uncertain and were not estimated in the Statement of Basis. For costing purposes, remedial timeframes of 30 years were assumed.

Stakeholders

EPA was the lead agency at this site. EPA selected the final remedy in consultation with the Oklahoma Department of Environmental Quality and the Air Force. The Oklahoma Water Resources Board approved the groundwater reclassification.

References

EPA, 2007. Statement of Basis for RCRA Corrective Action, Altus Air Force Base, Altus, Oklahoma. OK9571824045.

6b. Porter Cable/Rockwell Site, Tennessee

Alternative Approach

Groundwater beneath this site was given the "site-specific impaired" groundwater classification, per Tennessee Department of Environmental Conservation Chapter 1200-04-03. Within the boundary of classification, groundwater will not be used as drinking water.

Porter Cable Rockwell site. Photo from Google maps.

Site Timeline

Mid-1970s	Plant began operation
1999	Tennessee Rule 1200-04-03 filed
1999	Groundwater classification was changed at this site and one other site
2008	Tennessee Rule 1200-04-03 modified

Conceptual Site Model

Per the description in Tennessee Rule 1200-04-03, a solvent plume under the western edge of the building is moving very slowly to the north-northwest. Since the 1970s, the plume has migrated approximately 400 feet, with the property boundary another 1500 feet downgradient. Sampling has shown that the plume is degrading to a certain extent by natural and biologic processes, and this process can be enhanced with the addition of nutrients to fuel the biologic activity in the contaminated zone.

Tools, Lines of Evidence, and Metrics

The plume is fairly stable and will degrade naturally before reaching the property boundary. Other considerations required to be addressed in the petition for this groundwater classification include a description of the site history, nature and extent of contamination, hydrogeology, corrective actions taken or proposed, feasibility study, evaluation of current and potential future groundwater and land use, risk/exposure pathway analysis, monitoring program, classification that would apply if groundwater were not contaminated, and other information as requested.

Remedy Description

Nutrient addition is allowed to promote enhanced natural attenuation of the plume in accordance with the remediation remedy being used at that site. Deed restrictions will ensure that the site will not be used for residential purposes and that groundwater will not be used as drinking water. The point of classification (site-specific impaired groundwater classification boundary) is totally within the property boundaries. The plume shall not cross the point of classification at levels exceeding general use criteria.

Pathway to Site Closure/Long Term Monitoring

No additional information was found about the remedy at this site.

Stakeholders

The Tennessee groundwater classification requires petition review and approval by the Tennessee Water Quality Control Board.

References

Tennessee Department of Environmental Conservation Chapter 1200-4-3.

6c. Hardy Street Rail Yard, Houston, Texas

Alternative Approach

A Municipal Setting Designation (MSD) was issued at this site, restricting the current and future use of shallow groundwater for potable purposes. This designation applies to sites under the Texas voluntary cleanup program.

The Hardy Street Railroad Yard site "then and now". Site photos obtained from a public presentation (Chapin, 2009).

Site Timeline

1800s-1990s	Railroad yard was active
1998	Site enters Voluntary Cleanup Program
2005	CR V Hardy Yards LP bought the property with known contamination
2008	TCEQ Phased Conditional Certificate of Completion for residential land-use
2009	TCEQ approved MSD

Conceptual Site Model

Historical sources of contamination include spills and leaks from rail car maintenance and servicing operations, and from above ground and underground storage tanks. Shallow groundwater is contaminated with chlorinated solvents and diesel. Diesel NAPL is approximately 650 feet long and extends over about 3.5 acres. Chlorinated solvent plumes in groundwater affect the upper and second water-bearing zones. Both plumes have been horizontally and vertically delineated, but the second water-bearing zone plume is approximately 2,000 feet long and has migrated off-site. Each plume is being monitored for stability and natural attenuation. Surface soil was affected by metals and petroleum compounds prior to excavation and remediation to residential standards. Planned development is mixed use with potential residential, retail, green space and commercial elements.

Tools, Lines of Evidence, and Metrics

There are several reasons why an MSD was approved at this site.

1. The site had been thoroughly investigated using the Triad approach. Over 50 groundwater monitoring wells and over 200 soil borings were completed on the 37-acre property.
2. Ten years of monitoring data indicate that the areas of affected shallow groundwater are stable or decreasing in size.
3. Shallow groundwater does not pose a health risk, and would not be a suitable drinking water source even if it were not impacted. Shallow contaminated groundwater is separated from

deeper uncontaminated zones by several hundred feet. The MSD minimizes risk by restricting the use of the property's affected shallow groundwater.

4. The MSD enables redevelopment, which contributes to the renewal of the near-downtown Houston area and creates local work.

Remedy Description

A diesel recovery system operated at the site for 3 years. Over 80,000 gallons of diesel fuel were recovered using 17 wells prior to system shutdown in early 2006. Recovered fluids were treated in an oil/water separator and polished with granular activated carbon prior to permitted discharge to a storm sewer.

Approximately 130,000 cubic yards of shallow soils (up to 7 feet deep) were excavated and disposed of off-site. Soil with high concentrations of lead and other heavy metals was first stabilized on-site to render it non-hazardous.

Groundwater monitoring is ongoing, with 50 monitoring wells sampled semi-annually and diesel monitoring quarterly.

Pathway to Site Closure/Long Term Monitoring

Property cleanup has been completed to residential land-use scenario under TCEQ's Texas Risk Reduction Program. Soils received TCEQ approval and Response Complete in 2007. The MSD was approved in 2009.

Stakeholders

TCEQ, prior site owners, the developer and consultants, the public, and insurance underwriter agencies were stakeholders in the cleanup.

References

Chapin, R., 2009. Municipal Setting Designations (MSDs): A new tool for Houston. Available online at http://documents.publicworks.houstontx.gov/documents/divisions/planning/msd/public_meeting_presentation_2009_018_hardy_yards.pdf

City of Houston, 2009. Ordinance number 2009-1323. Municipal Setting Designation ordinance. Available online at http://documents.publicworks.houstontx.gov/documents/divisions/planning/msd/ordinance_2009_1323.pdf

SKA Consulting, 2010. Hardy Street Railroad Yard. Featured Project. Available online at www.skaconsulting.com/RailroadYard.asp

Weston Solutions, 2009. City of Houston municipal setting designation application. Designated property: Hardy Street Rail Yard, Houston, Harris County, Texas. Prepared for CR V Hardy Yards, L.P. May.

7. MONITORED NATURAL ATTENUATION (MNA) OVER LONG TIMEFRAMES

7a. Solvents Recovery Service of New England OU 3, Southington, Connecticut

7b. Office Naval Training Center (NTC) SA17, Orlando, Florida

7a. Solvents Recovery Service of New England OU 3, Southington, Connecticut

Alternative Approach

At this CERCLA site, MNA was approved over a long timeframe. Modeling indicated that bedrock plumes would not reach ARARs for approximately 400 to 500 years under baseline conditions. Assuming 95% to 99% mass removal from the overburden, the remedial timeframe for bedrock plume was still estimated to be approximately 250 years.

Solvents Recovery Service site. Photo from http://www.srsnesite.com/

Site Timeline

1955-91	Spent solvent processing and reclamation facility operated
1983	NPL listing
1995	Interim response measure (groundwater extraction from overburden)
1998	RI report
1999	Second groundwater extraction system as an interim measure for bedrock
2005	FS report and OU 3 ROD
2008-09	Consent decree with PRPs; remedial design began

Conceptual Site Model

Millions of gallons of waste solvents and oils were handled, stored, and processed at the site for over 30 years. VOCs likely entered the subsurface in varying quantities at many locations within the Operations Area, including two unlined lagoons, drum storage areas, and truck loading/unloading areas. Approximately 84% of the subsurface contaminant mass is thought to be present as NAPL in the overburden. NAPL is known to be present in the bedrock but its extent has not been defined.

Tools, Lines of Evidence, and Metrics

Modeling indicated that bedrock plumes would not reach ARARs for approximately 400 to 500 years under baseline conditions. Assuming that in-situ thermal treatment in the overburden was successful in removing 95% to 99% of the mass present in the overburden, the timeframe for restoration of the bedrock plume was estimated to be approximately 250 years to reach ARARs in the bedrock aquifer. Per the ROD, this timeframe was considered reasonable relative to the timeframe of other remedial alternatives at the site.

Remedy Description

The remedy selected for the overburden consisted of in-situ thermal treatment in the NAPL area, excavation and capping of soils and wetland soils, pump-and-treat for containment, MNA for areas outside of the pump-and-treat system containment zone, and ICs to prevent human exposure.

The selected remedy for bedrock contamination consisted of pump-and-treat and MNA in the NAPL area. The pump-and-treat system will be modified as appropriate based on expected reductions in contamination.

Pathway to Site Closure/Long Term Monitoring

Monitoring and five-year reviews will continue at this site. Restrictions on property uses may be required indefinitely.

Stakeholders

The remedy was selected by EPA Region I with concurrence from the Connecticut Department of Environmental Protection. (The state did not concur with the ROD's use of institutional controls to prevent vapor intrusion). A number of PRPs have been working with EPA and the state and have been performing cleanup work since the 1994 consent decree.

References

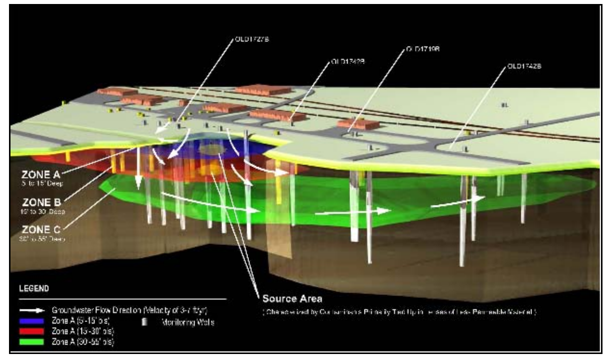
EPA, 2005. Record of Decision for the Solvents Recovery Service of New England, OU 3, Southington, Connecticut. EPA ID CTD009717604. September 30.

SRSNE Site Group, 2010. Solvents Recovery Service of New England Superfund Site. Web resources located at www.srsnesite.com/

7b. Office Naval Training Center (NTC) SA17, Orlando, Florida

Alternative Approach

At this site, MNA is being used to address contamination in the downgradient plume from a TCE DNAPL source zone. Remedial timeframes predictions indicated that MCLs would be achieved after 60 to 70 years and that additional source removal would have an insignificant impact on the remediation timeframe.



Model showing groundwater plumes at SA17 at different depths. Figure is from CH2M Hill report.

Site Timeline

2000-02	ISCO for the TCE source area
2006	Enhanced bioremediation as polishing technique for the source area
2006	MNA for the remaining dissolved plume

Conceptual Site Model

The site is a former Defense Property Disposal Office (DPDO), where vehicle maintenance was conducted, waste oil/fuel drums, and wash racks were located. TCE concentrations are indicative of DNAPL (up to 577,000 µg/L TCE). The CSM was updated based on the results of MIP investigation following ISCO testing. Detailed results permitted modeling and 3D visualization of the groundwater plumes at several depths.

Tools, Lines of Evidence, and Metrics

Natural Attenuation Software was used to predict remediation timeframes under MNA and other remedial approaches. Results indicated that the plume is stable and that remediation timeframe range from 60 to 70 years for the downgradient plume area. Additional source removal was found to have an insignificant impact on remediation timeframe.

Other lines of evidence in support of MNA included favorable geochemical conditions (iron and sulfate-reducing conditions, depleted oxygen), the presence of functional genes in the natural microbial population for conducting dehalogenation, and the presence of degradation byproducts including cis-1,2-DCE and vinyl chloride. Finally, total VOC concentrations are approaching Florida's Natural Attenuation Default Criteria, which are typically 10 to 100 times higher than the MCLs. The MNA evaluation showed that conditions supported sustained natural attenuation.

Remedy Description

ISCO using Fenton's reagent was applied in the source area as an interim remedial action to reduce total chlorinated VOCs to 500 µg/L. However, ISCO was unable to treat some portions of source area due to a lack of hydraulic connection, preferential flow paths, and back-diffusion. After measuring a rebound in VOC concentrations, the Navy conducted some enhanced bioremediation (with emulsified vegetable oil substrate) using a recirculation well field design. Based on the modeling demonstration and other lines of evidence described above, the Navy is now transitioning the remedy to MNA.

Pathway to Site Closure/Long Term Monitoring

No additional information on the pathway to site closure was found for this site.

Stakeholders

Stakeholders in the Orlando Partnering Team include the Navy, EPA, and the Florida Department of Environmental Protection. Community representatives actively participate in the cleanup process through a Restoration Advisory Board.

References

Singletary, M. 2010. Personal communication with Michael Singletary, NAVFAC Southeast.

Favara, P.J., Singletary, M.A., Nwokike, B. and Tsangaris, S. Using a Treatment Train to Optimize DNAPL Source Zone Remediation. Fifth International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey California, May 2006. Battelle Press, Columbus, Ohio.

Tsangaris, S., Nwokike, B., Bryant, D. and Levin, R. Fenton’s Reagent In-Situ Chemical Oxidation of TCE Source Area, NTC Orlando, Florida.

8. ADAPTIVE SITE MANAGEMENT

8a. Hanscom Field/Hanscom Air Force Base OU 1, Massachusetts

8b. Watervliet Arsenal Building 40, Watervliet, New York

8a. Hanscom Field/Hanscom Air Force Base OU 1, Massachusetts

Alternative Approach

A final remedy is in place at the site, involving a combination of technologies to address VOCs in groundwater in fractured rock. A recent Air Force optimization review recommended developing additional changes. The dynamic operation of the interim/final remedy, with the empirical determination of frequency of source zone injections based on the data, is an example of adaptive site management.

Aerial photo of Hanscom Field/Hanscom Air Force Base posted on Wikipedia.

Site Timeline

1982-83	Discovery of groundwater contamination
1994	NPL listing
1996-99	RI/FS activities
2000	Interim ROD
2002	Five-year review report
2007	Revised focused FS, proposed plan, and ROD
2007	Five-year review report

Conceptual Site Model

As summarized in a recent Air Force review, Hanscom AFB is located in a portion of a Pleistocene age lake, with 5 to 100 feet of soil and unconsolidated glacial deposits overlying fractured gray granite bedrock. Groundwater flow occurs in two aquifers in the unconsolidated soils, as well as in the fractured and weathered bedrock. Flowrates in the fractured bedrock range from 0 to 3.3 feet/day. DNAPL is present in fractured bedrock.

Tools, Lines of Evidence, and Metrics

The adaptive management and remediation of groundwater contamination over the years is a management decision at the site and has not been documented in site reports. Groundwater fate and transport modeling was used to predict and update cleanup timeframes (modeling does not include the bedrock aquifer).

Remedy Description

The 2007 final ROD codified the interim remedy, which consisted of source treatment in three source areas (permanganate injections, molasses injections to enhance biodegradation, and vacuum-enhanced vapor extraction), long-term groundwater pump-and-treat system, long-term monitoring, and institutional controls.

The pump-and-treat system and source treatment are operated dynamically, and the frequency of source zone injections is determined empirically, based on monitoring data.

Pathway to Site Closure/Long Term Monitoring

The remedy is in place and is protective. The final ROD essentially referenced model-predicted timeframes of 30 to 50 years to reach ARARs in the upper and lower aquifer. However, the ROD did not estimate cleanup timeframes in the bedrock, where DNAPL concentrations of VOCs had been detected. A recent AFCEE ERP-O team recommended that the site begin developing a case for technical impracticability in fractured bedrock by documenting the limitations of different technologies for restoring the DNAPL area to MCLs. The group concluded that site closure was unlikely in the near future unless alternate cleanup standards and/or a TI waiver were evaluated and implemented for bedrock. The group reported a general deficiency in the transparency and accessibility of site exit strategy and decision processes.

Stakeholders

Stakeholders include the Air Force, who is the lead agency, EPA Region 1, and the Massachusetts Department of Environmental Protection. Both EPA and the state concurred with the final remedy.

References

AFCEE, 2008. Hanscom AFB Environmental Restoration Program Optimization “Phase I” Outbrief, October 24.

EPA, 2007. Record of Decision for Hanscom AFB/Hanscom Field, OU 1, Massachusetts. September 28.

EPA, 2007. Third Five-Year Review Report for Hanscom Field/Hanscom Air Force Base Superfund Site, Bedford, Concord, Lexington, Lincoln Middlesex County, Massachusetts. August.

8b. Watervliet Arsenal Building 40, Watervliet, New York

Alternative Approach

The Army conducted full-scale ISCO injections for five years to treat DNAPL PCE within a fractured rock matrix. Based on no measureable benefits, the Army adapted their approach to include alternative endpoints, first evaluating TI waivers and then ACLs. The Army's iterative field test design, responsiveness to test data, and flexibility with the final remedy make this an adaptive site management approach.

Watervliet Arsenal

Site Timeline

Mid-1800s	Site was used to manufacture small arms ammunition, cannons, and guns
1990	3008(h) Order issued to Army from EPA and state to implement interim corrective measures
2004	Army began 5 years of permanganate injections into fractured bedrock in the Main Manufacturing Area, followed by 5 years of monitoring
2007	Indoor air assessment workplan approved
2008	Draft Statement of Basis

Conceptual Site Model

The site is located adjacent to the Hudson River. Chlorinated solvents, primarily PCE, TCE and their degradation products are present in groundwater beneath the site due to a suspected degreaser operation. DNAPL has been detected at one well and PCE concentrations are as high as 170 mg/L. The geology consists of 1 to 5 feet of fill, 5 to 10 feet of overburden, and black medium-hard laminated shale. Contamination extends into bedrock, to a total depth of 150 feet below ground surface.

Tools, Lines of Evidence, and Metrics

The Army conducted extensive technology testing over a five-year period with no measureable benefit to groundwater quality, mass discharge, or contaminant concentrations in the rock matrix (as measured by rock coring, crushing, and contaminant extraction from the rock matrix). Site characterization was performed via multiple multilevel sampling systems, including borehole geophysical and hydrological logging and interflow testing, VOC sub-sampling from the rock core, rock matrix characterization, and matrix interaction with permanganate (performed in a laboratory). Rock oxidant demand tests, permanganate invasion tests, and diffusion rate modeling were also conducted to evaluate likely remedial effectiveness and remedial timeframes.

Remedy Description

The intention of ISCO was to reduce mass discharge leaving the site. However, testing results indicated that increased conductivity of the injection wells impeded the delivery of MNO_4 and in-situ oxidation, likely via precipitation of manganese dioxide within or near the injection boreholes or hydraulically connected fractures. Based on these results, corrective action including the development of ACLs, institutional controls, long-term monitoring, and other corrective action measures is being planned.

Pathway to Site Closure/Long Term Monitoring

The next step in the pathway to site closure is to finalize the corrective action and Statement of Basis. Long-term monitoring, periodic reviews, and institutional controls will likely be required over the next 30+ years.

Stakeholders

Stakeholders include the Army, EPA, and New York State Department of Environmental Conservation.

References

EPA, 2010. Fractured bedrock project profiles. Watervliet Arsenal, Building 40, Watervliet, New York. Available online at http://clu-in.info/products/fracrock/sitedtl.cfm?mid=238

Navon, Daria; Andrew R. Vitolins; Kenneth J. Goldstein; Beth Parker; John Cherry; Grant A. Anderson; Stephen P. Wood. 2004. In Situ Chemical Oxidation Using Permanganate for Remediation of Chlorinated VOCs in Fractured Shale. The Fourth International Remediation of Chlorinated and Recalcitrant Compounds Conference, Monterey, California. May 24-27.

EPA, 2010. US Army Watervliet Arsenal. New York RCRA Cleanup Fact Sheet. Available online at www.epa.gov/region02/waste/fswaterv.htm

9. REMEDIATION TO THE EXTENT PRACTICABLE

9a. Union Pacific Railroad Co. Tie-Treating Plant OU 1, The Dalles, Oregon

9a. Union Pacific Railroad Co. Tie-Treating Plant OU 1, The Dalles, Oregon

Alternative Approach

The 1996 ROD states that ARARs will not be achieved using this remedy, yet no ARAR waiver was issued as part of that ROD. Instead, the ROD calls for "*remediation to the extent practicable*".

Tie-treating plant located at Riverfront Park, The Dalles, Oregon. Photo from Google maps, 2010.

The Five-Year Review report notes this potential inconsistency with the NCP and states that two ARAR waivers potentially apply at the site: TI waivers and greater risk ARAR waivers.

Site Timeline

1923	Railroad tie treating facility operates at the site
1980	Waste disposal into four onsite ponds ceases
1984	Oregon Department of Environmental Quality initiates groundwater quality investigations
1989	Union Pacific enters into an administrative consent order with Oregon Department of Environmental Quality
1990	NPL listing; Oregon Department of Environmental Quality remains the lead agency
1995	RI/FS report
1996	ROD
1998	Natural attenuation study completed
2004	DNAPL removal systems begin operation; Construction Complete designation
2005	Five-year review

Conceptual Site Model

Creosote DNAPL is present at the site, consisting of carcinogenic PAHs, naphthalene, pentachlorophenol, benzene, and arsenic.

Tools, Lines of Evidence, and Metrics

No specific tools or lines of evidence were presented in support of "*remediation to the extent practicable*". The ROD states that "*based on the information obtained during the remedial investigation, Oregon Department of Environmental Quality believes that the selected remedy may not achieve the concentration levels presented [in the ROD] in the unconfined water-bearing zone nor in a portion of the Sand Hollow I aquifer*." The ROD also references "*widely understood problems with restoring groundwater to drinking water quality when contaminated* *by creosote DNAPL*." Oregon Department of Environmental Quality stated that the remedy is consistent with the NCP because it removes source material to the maximum extent practicable.

Remedy Description

The approved remedy at this state-lead federal Superfund site includes removing DNAPL from subsurface soils, pumping and treating groundwater to prevent migration, institutional controls, and groundwater monitoring to verify that concentrations are decreasing. A phased DNAPL removal system was approved, but the approach was accelerated and all three modules have been operating concurrently since 2004. MNA is the selected remedy for the Sand Hollow I aquifer.

Pathway to Site Closure/Long Term Monitoring

The site has achieved "*construction complete*". Through 2007, 81,000 gallons of DNAPL have been removed. The 2005 Five-year review report states that a TI evaluation should be prepared for the site as soon as the DNAPL removal systems are shut down.

Stakeholders

Oregon Department of Environmental Quality is the lead agency at the site. Other stakeholders include EPA Region 9 and responsible party Union Pacific.

References

EPA, 1996. Record of Decision, Union Pacific Railroad Co. Tie-Treating Plant OU 1, The Dalles, Oregon. EPA ID ORD009049412. March 27.

Oregon Department of Environmental Quality, 2007. Five-Year Record of Decision Review. Second five-year review report, Tie Treating Plant, The Dalles, Oregon. December 20.

APPENDIX C

ANALYSIS OF TI WAIVERS FOR GROUNDWATER AT CERCLA SITES

ANALYSIS OF TI WAIVERS FOR GROUNDWATER AT CERCLA SITES

As stated in Section 3, Malcolm Pirnie conducted a comprehensive search of the CERCLA ROD database to identify all CERCLA sites that have received TI waivers for groundwater as of November 2010. A total of 77 TI waivers were identified (Table 3-1), including several sites that received two TI waivers for different areas of the facility. A TI waiver was used at a 78th site (Yellow Water Road Dump site) but was later revoked after correcting an analytical error in PCB measurement technique. Several additional sites are in the process of TI evaluations, including the Burlington Northern (Somers Plant), MT and Fairfield Coal Gasification Plant, IA. These sites were not researched further, as final decisions are still pending.

Several aspects of the population of 77 sites were analyzed to provide insights into the following:

1. Nature of technical impracticability
2. Basis of the TI evaluation
3. Regional/state distribution of TI waivers
4. Changes over time
5. Use of contingency language

Results are presented in this Appendix. Details on specific sites are provided in Appendix A.

C.1 Nature of Technical Impracticability

Primary Reasons for Technical Impracticability

Consistent with EPA guidance (EPA, 1993), the most common reason for technical impracticability was the <u>hydrogeologic setting and/or the nature of contamination</u>. This accounted for 77% of all TI waivers and 81% of TI waivers granted after the publication of EPA guidance on TI waivers in 1993. The rest of the TI waivers were attributed to physical site constraints such as the presence of on-site buildings or wetlands, economic reasons, some combination of these factors with site contamination, or in general, to the limitations of current technology (Figure C-1).

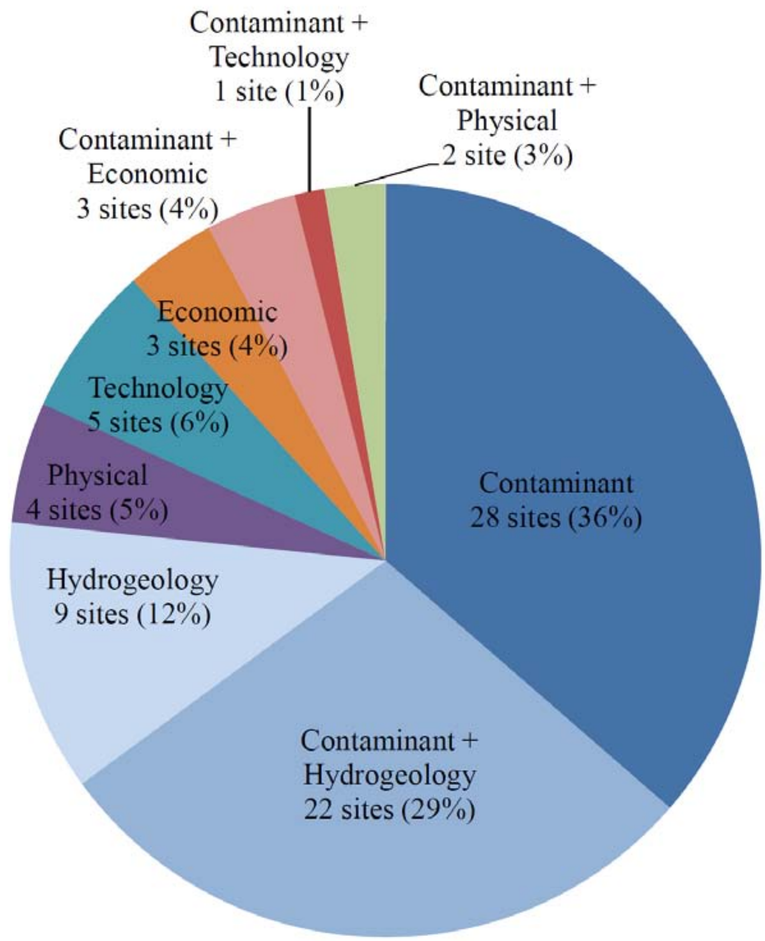


Figure C-1. Overall Reasons for TI Waivers

An in-depth look at hydrogeologic settings and the nature of contamination encountered at the 77 sites is provided in the following section. More details on the nature of technical challenges faced at these sites are provided in the text of this report (Section 4.1), with site-specific details provided in Appendix A.

Hydrogeologic Settings

Thirty-one sites listed hydrogeology as a primary reason for technical impracticability, as shown in Figure C-1. The majority of these sites (68%) had contamination present in fractured bedrock, karst, or a karst-like environment due to underground mine voids. Fractured bedrock was the most common type of hydrogeologic setting overall at the 77 sites. It was the main hydrogeologic setting at 36 sites and was present beneath the contaminated overburden at 9 additional sites receiving TI waivers.

Low-permeability hydrogeologic settings, primarily silts and clays, was the second most common problematic hydrogeology, contributing to technical impracticability at six sites. Other complex hydrogeologic settings included highly heterogeneous environments such as glacial till, and layered high-permeability and low-permeability settings, where DNAPL was sequestered in the low-permeability units. The range of hydrogeologic settings is shown in Table C-1.

Table C-1. Hydrogeologic Settings at Sites with TI Waivers

Hydrogeologic Setting	# Sites	# Sites where hydrogeology led to TI	Percent of Total
Fractured rock/karst/mining voids	36	21	47%
High heterogeneity	10	2	13%
High heterogeneity overlying bedrock	4	-	5%
Layered high- and low-permeability	9	2	12%
High-permeability sands and gravels	7	-	9%
High-permeability sands and gravels overlying bedrock	2	-	3%
Low-permeability silts and clays	6	6	8%
Low-permeability silts and clays overlying bedrock	3	-	4%
TOTAL	77	31	100%

Types of Contaminants

Chemical-specific ARARs for a variety of different groundwater contaminants were waived. At most sites, a mixture of contaminants were waived, including VOCs, BTEX and other fuel constituents, metals, PAHs, PCBs, perchlorate, N-nitrosodimethylamine, and/or pesticides. The most common site contaminants were determined to be chlorinated solvents and other VOCs, creosote/PAHs/coal tar, metals, and mixtures of three or more contaminants (Table C-2). The types of contaminants addressed did not appear to change over time.

Table C-2. Number of TI Waivers for Different Types of Contaminants

Compounds	Number of Sites
Chlorinated solvents, VOCs	16
Coal tar, PAHs, creosote	11
Metals	14
BTEX	1
PCBs	2
Pesticides	2
Mixture (2 or more types)	20
Mixture (3 or more types)	11
TOTAL	**77**

NAPL was thought to be present at more than half of the sites (at 56% of all sites and at 65% of sites receiving TI waivers after 1993). Most NAPLs were DNAPLs. As noted in the EPA guidance document, the presence of DNAPL is not sufficient to justify a TI determination (EPA, 1993), but it frequently contributes to the underlying technical limitations of remediation.

When viewed from the perspective of operations that historically led to the contamination, site histories varied. Of the 12 different categories of industries identified, the most common was landfills, followed by military operations and wood treatment facilities. Looking only at sites with TI waivers granted after EPA guidance in 1993, the most common types of industry/activity included military operations, wood treatment facilities, pesticides, and metal working operations (Table C-3).

Table C-3. Types of Historical Operations Resulting in Groundwater Contamination at Sites with TI Waivers

Type of Business	# Sites	# Post-1993 Sites
Landfill	14	4
Military	11	10
Wood Treatment	11	9
Metal working	8	6
Mining	8	6
Pesticides	5	5
Manufactured gas plant	5	5
Electronics	5	4
Waste handling/Recycling	5	4
Transportation (Air, rail)	2	2
Industrial/Multiple sources	1	1
Refinery	1	1
Laboratory	1	0
TOTAL	**77**	**57**

ARARs waived

The majority of TI waivers have been issued for Federal MCLs with or without other cleanup requirements, as shown in Figure C-2. MCLs were included in TI waivers at 84% of all sites. Other ARARs waived prior to 1993 included background concentration cleanup requirements and state guidelines (Maine maximum exposure guideline for PCBs). Other ARARs waived after 1993 included secondary MCLs for iron and manganese, a Federal action level for lead, and a Federal health advisory level for the pesticide 1,2-dichloropropane.

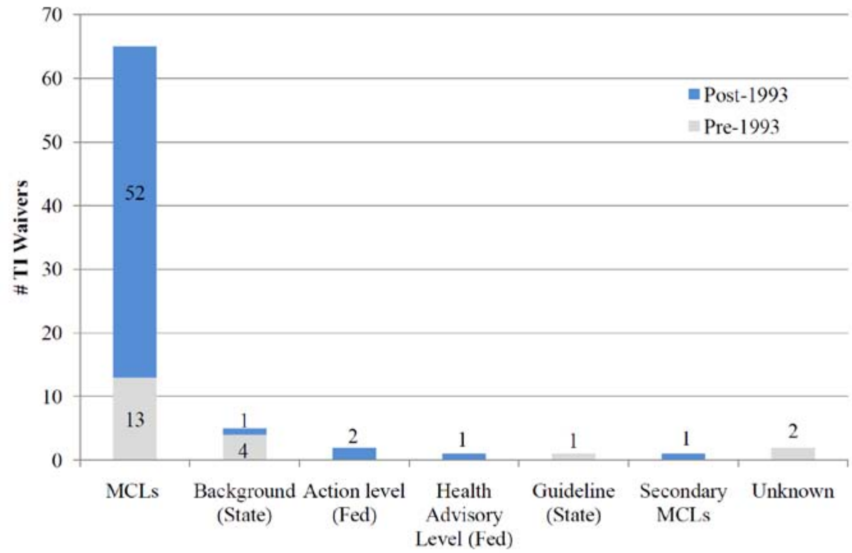


Figure C-2. Types of ARARs Waived

Spatial extent of TI zone

The TI zone is defined as the zone where ARARs can be exceeded; outside the TI zone, ARARs still apply. The spatial horizontal and vertical extent of the TI zone must be specified for each site, per EPA guidance. The areal extent of TI zones was easily identified at 36 of the 77 sites. The size distribution covers a wide range from 0.11 to 28,000 acres (Figure C-3).

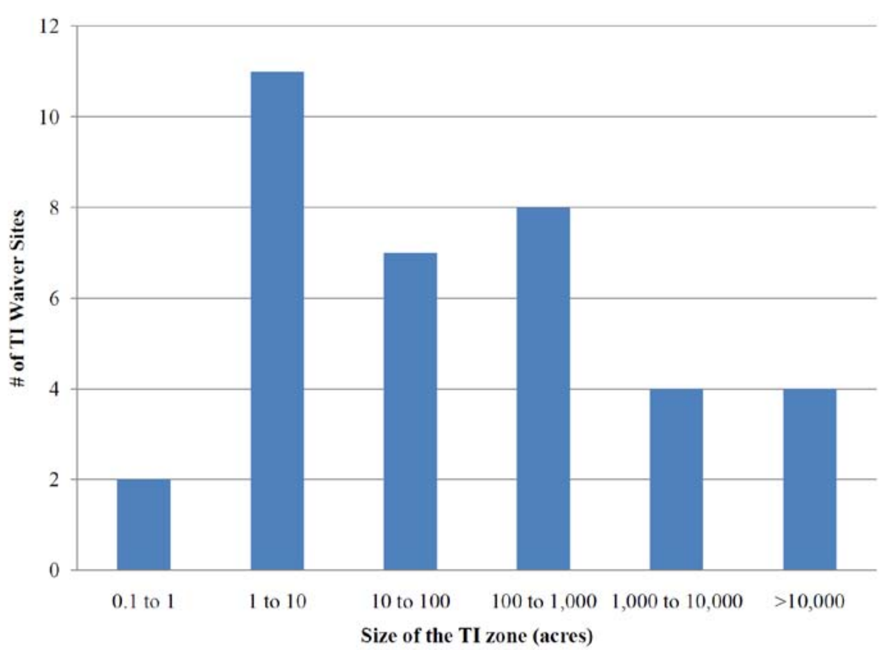


Figure C-3. Acreage of TI Zones Designated for Groundwater

Rationale for designated which areas to include within the TI zone varied from one site to the next. Designations included the following:

- Source area, as determined by high contaminant concentrations and/or knowledge of historic activities
- Source and plume areas, as determined by the extent of contamination exceeding MCLs or other cleanup requirements
- Entire site, as determined by the property boundaries
- Aquifer/geology, as determined by natural hydrogeologic boundaries, typically on a regional scale

The most common TI zone designation (at 33 sites or 43%) included the source area and the plume, as determined by contaminant concentrations (Figure C-4). This designation has been used primarily after 1993. This may reflect the growing understanding of the impact of matrix diffusion on cleanup timeframes for plumes, as well as difficulty in characterizing and treating plumes in fractured rock. At 8 of these sites, this TI zone designation included off-site contamination as well as on-site contamination.

The next most common TI zone designation is the source area. This designation was used at 22 or 29% of all sites. Source areas were defined based on the areal extent of former landfills, waste lagoons, or other historical areas where contamination occurred. Others were defined based on RI/FS and monitoring data regarding the likely extent of DNAPL or LNAPL, including areas where contaminant concentrations exceeded 1% of solubility, a rule of thumb to indicate the presence of DNAPL.

TI zones that included the entire property have been used for at least 6 sites (8%). Per EPA’s 1993 guidance, there should be a technical basis for the TI zone delineation. In some cases, the extent of contamination approximated the property extent.

Regional or hydrogeologic boundaries have been used to define the TI zone area at 4 additional sites (5%), particularly for regional mining-related contamination. Off-site contamination was included in some of these TI zone designations as well. The basis for determining the TI zone was unclear at the remaining 12 sites (16%), based on a preliminary review of the RODs.

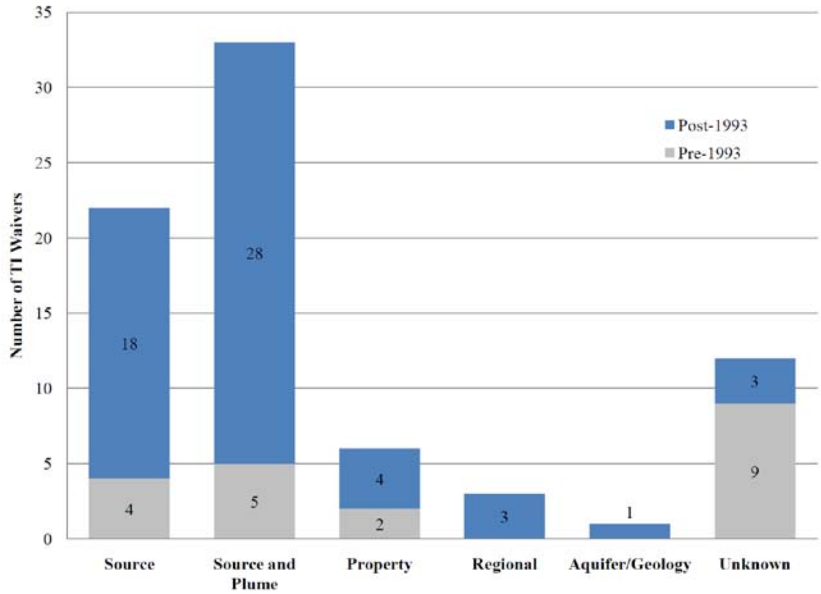


Figure C-4. Extent of TI Zones Designated for Groundwater

The vertical extent of the TI zones ranged from 15 to 30 feet below ground surface to deeper than 800 feet. Aquifer/hydrogeologic descriptions were commonly used to delineate the vertical extent of the TI zone (e.g., a specific Aquifer).

C.2 Basis of the TI Evaluation

Full-Scale Remedy Operation

EPA guidance differentiates between TI waivers received after a full-scale interim or final remedy has been operating (*"post-implementation waivers"*) and those received prior to full-scale remedial attempts, as part of the original ROD (*"front-end waivers")* (EPA, 1993). EPA guidance states that, in many cases, post-implementation waivers are necessary because it is often difficult to predict the effectiveness of remedies based on site characterization data. However, our analysis found that only a minority of TI waivers were post-implementation waivers: 19 (or 25%) of all TI waivers and 17 (or 30%) of waivers implemented after 1993. Full-scale remedy operation is therefore not necessary to demonstrate technical impracticability at most complex sites (Table C-4). Subsequent EPA guidance regarding groundwater cleanup at CERCLA sites encouraged the earliest consideration of TI waivers in the evolution of an overall cleanup strategy for groundwater at complex sites (EPA, 1996).

Table C-4. Number of Sites Operating Full-Scale Remedy Prior to TI Waiver

Type	# Sites	Pre-1993	Post-1993
Full-scale operation (Final remedy)	19	2	17
Full-scale operation (Interim remedy)	3	1	2
No full-scale technologies implemented prior to TI waiver	55	17	38
TOTAL	**77**	**20**	**57**

Pilot-Scale Technology Testing

Of the 55 sites that did not implement an interim or final full-scale remedy, at least 9 collected technology performance data at the pilot-scale or as a treatability study (Table C-5). Several sites with full-scale remedies also conducted pilot studies or treatability studies for other technologies.

Table C-5. Examples of Technologies Evaluated Prior to TI Waiver Decision

Technology	Site(s)
Blast fracturing	Edwards Air Force Base South AFRL (#21)
Dual-phase extraction	Edwards Air Force Base South AFRL (#21)
Excavation	Petro-Chemical Systems, Inc. (#56)
Hydrogen Release Compound (HRC)	Aberdeen Proving Ground (Edgewood Area) - J-Field (#2)
In-situ bioremediation	Aberdeen Proving Ground (Edgewood Area) - J-Field (#2) Edwards Air Force Base South AFRL (#21) Petro-Chemical Systems, Inc. (#56)
In-well aeration	Aberdeen Proving Ground (Edgewood Area) - J-Field (#2)
ISCO	Petro-Chemical Systems, Inc. (#56) Riverfront (#60), West Site/Hows Corner (#72)
NAPL recovery/tar extraction	Aluminum Company of America (#4) Garland Creosoting (#26) Westinghouse Electric Corp. (Sharon Plant) (#73)
Phytoremediation	Aberdeen Proving Ground (Edgewood Area) - J-Field (#2)
Pump-and-treat	Edwards Air Force Base South AFRL (#21) Pease Air Force Base (#55) Rodale Manufacturing Site (#61) Whitmoyer Laboratories (#77)
SVE system	Edwards Air Force Base South AFRL (#21) Petro-Chemical Systems, Inc. (#56)
Thermal treatment (steam or hot-water injection)	Brodhead Creek (#7) Edwards Air Force Base South AFRL (#21) Missouri Electric Works (#48) Petro-Chemical Systems, Inc. (#56)

Modeling and/or Conceptual Analysis of Site Data

At least 10 sites conducted modeling as part of their evaluation of restoration potential (sites 3, 8, 15, 21, 42, 43, 49, 55, 61, 62 and 67). Modeling was used to evaluate the impact of various remedial scenarios on remediation timeframes or to illustrate contaminant fate and transport/ plume stability over time. The remaining 39 TI waivers appear to have been granted on the basis of RI/FS data and evaluations, supplemental investigations, routine groundwater monitoring data, CSM, and general knowledge/professional experience with remedial technologies in similar settings. These sites do not appear to have conducted site-specific technology field testing for groundwater remediation. Note that remedial activities to address site soils may have occurred at these sites, perhaps for different OUs.

Type of Documentation

Per EPA guidance, a written evaluation of technical impracticability (TI evaluation report) must be prepared and submitted for regulatory approval or concurrence. The report identifies which ARARs would be waived, defines the three-dimensional TI zone where the waiver would apply, describes the CSM, evaluates the potential for restoration, provides a cost estimate, and describes the final remedy (EPA, 1993).

The timing and documentation style of TI evaluation reports appears to be mixed. Some sites prepared the TI evaluation as a separate report, allowing stakeholders to review the TI evaluation independently of the rest of the CERCLA process. Others combined the TI evaluation with an FS report, perhaps simplifying the analysis. Still other sites prepared TI evaluation reports after the FS report, perhaps indicating that the FS analysis led to stakeholder consensus regarding the lack of viable technologies to meet cleanup requirements.

Approximately one-third of all waivers (20) were granted before written TI evaluation reports were required (pre-1993). Seventeen out of the remaining 57 waivers (35%) were issued after a final remedy had been operating. Roughly half of these TI evaluation reports were documented in a separate report issued after the ROD and before the ESD or ROD amendment. The other half of the TI evaluation reports were issued as a section or Appendix to the ESD or ROD amendment. Out of the 40 sites with front-end TI waivers issued after 1993, 16 of the TI evaluation reports were separate stand-alone reports. These were issued either concurrently with the FS report, as an FS addendum, or after the FS report but before the ROD. The remaining 24 sites included the TI evaluation as a section or Appendix to the FS report or ROD.

C.3 Regional/State Distribution of TI Waivers

Regions 1, 3 and 6 have approved the most TI waivers, with 11, 9 and 9 TI waivers, respectively. Counting pre-1993 TI waivers, Region 3 has the most TI waivers. (Four of the eight pre-1993 waivers in Region 3 waived a state of Pennsylvania ARAR regarding cleanup to background concentrations). Region 4 is the only region that has not approved a TI waiver since 1993 (Table C-5).

Table C-5. Distribution of Sites Across EPA Regions

EPA Region	# Sites	# Post-1993 Sites
Region 1	14	11
Region 2	9	7
Region 3	18	9
Region 4	1*	0
Region 5	2	2
Region 6	10	9
Region 7	8	7
Region 8	6	3
Region 9	8	7
Region 10	2	2
TOTAL	**77***	**57**

**One additional TI waiver was used and later revoked.*

The number of TI waivers granted in each state is shown below in Figure C-5. TI waivers have been issued in approximately 25 states. Approximately half of all states have never been through the TI waiver process. Four additional states (Colorado, Florida, Oklahoma, and South Dakota) have not completed the TI waiver process since 1993.

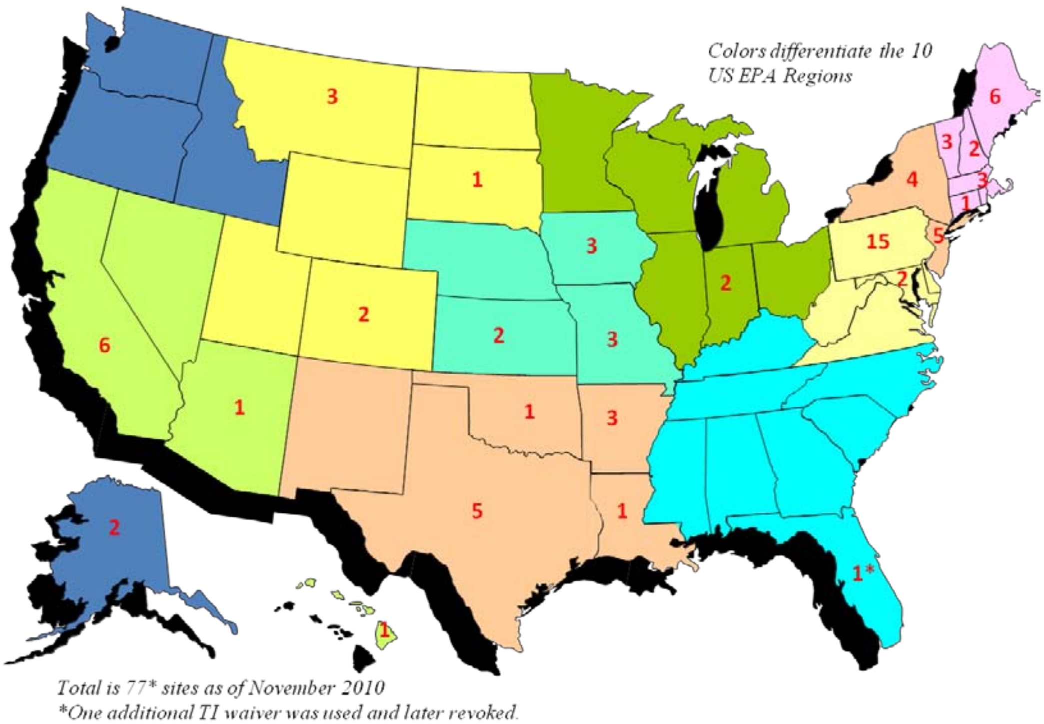


Figure C-5. Distribution of TI waivers for Groundwater in Different States and EPA Regions

One potential explanation for the uneven distribution of TI waivers among different states and EPA regions is variation in the total number of CERCLA sites in each state/region. The number of CERCLA sites in each region varies with time, making it difficult to normalize the number of TI waivers per region by the total number of CERCLA sites. Using the current number of CERCLA sites in each state (as of November 2010) as a rough estimate indicated that Regions 1, 3, 6, 7 and 8 had similar number of TI waivers when normalized by the total number of CERCLA sites in their regions. Regions 2 and 9 had a lower normalized number of TI waivers. Regions 4 and 5 had the lowest number of TI waivers, normalized by the total number of CERCLA sites.

Other potential explanations for the varying distribution in TI waivers among different states and EPA regions include the type of hydrogeology found in different states/regions, and differences in TI waiver policy implementation among regions. For example, other types of alternative endpoints and approaches may be used instead of TI waivers.

C.4 Changes over Time

Number of TI Waivers Approved

The number of TI waivers approved per year ranged from 0 to 9. Approximately one-quarter of all TI waivers (20 waivers) were approved prior to EPA guidance in September 1993. Approximately another quarter (20 waivers) were approved in the late 1990s, from 1997 to 1999.

The year 2006 had the highest number of waivers approved and 2008 had the fewest. A distribution is shown in Figure C-6.

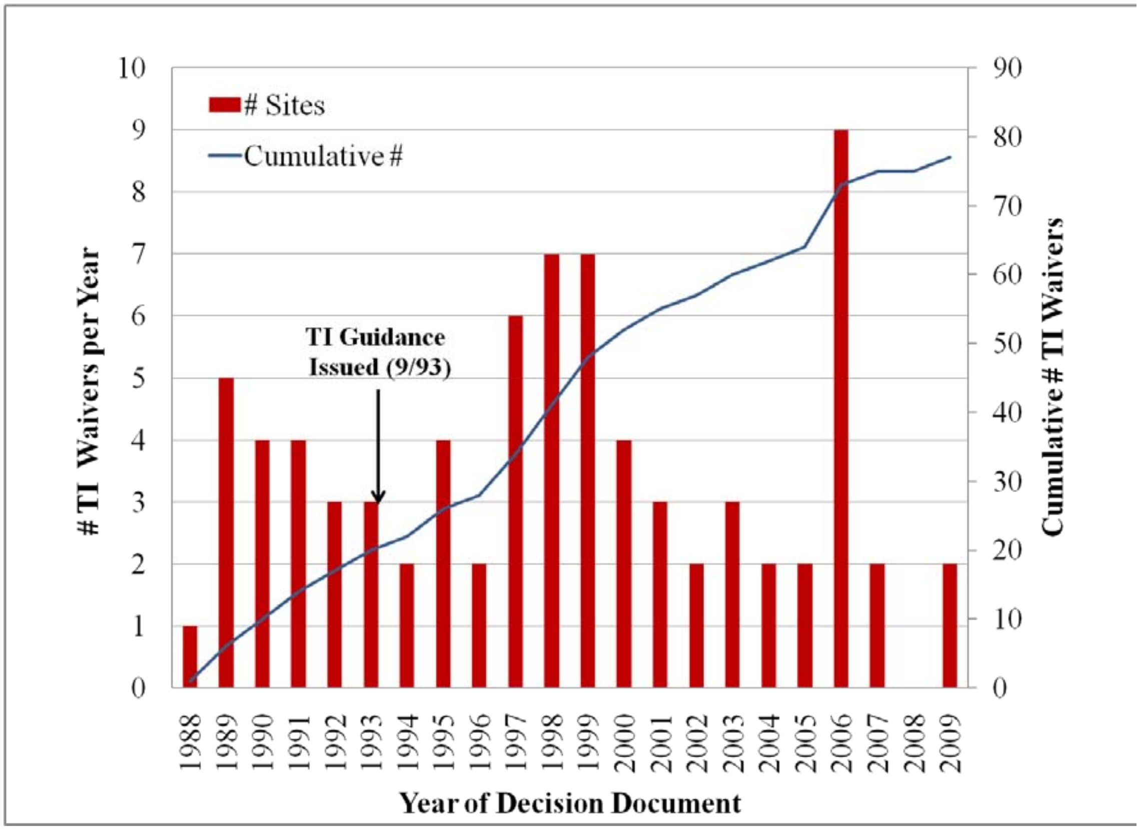


Figure C-6. Distribution of TI Waivers Issued each Year

These data do not suggest any clear trend in the number of TI waivers approved over time. Due to the small number of waivers granted per year, it is difficult to statistically analyze trends over time. When grouped into the number of waivers approved every five years, the results clearly indicate that the number of TI waivers granted is decreasing over time. However, the number of CERCLA decision documents is also decreasing over time, and the percentage of sites receiving TI waivers is fairly steady, at approximately 1 to 3% of all CERCLA sites (Table C-6).

Table C-6. Number of TI Waivers Granted in Decision Documents Every Five Years

Timeframe of Decision Document	# Sites with TI Waivers	# Decision Documents	Percent Total
1988-1992	17	873	1.9%
1993-1997	17	980	1.7%
1998-2002	23	823	2.8%
2003-2007	18	590	3.1%
2008-2010	2	224	0.9%

There did not seem to be any trend in the types of sites receiving TI waivers over time (i.e., different types of contaminants, geologic settings).

C.5 Use of Contingency Language

A contingency remedy addresses actions to be taken in the event that the selected remedy is unable to achieve required cleanup levels. Contingency language has been used in some RODs to indicate that a TI waiver may be needed in the future. However, a TI evaluation will still need to be written, a decision made by stakeholders, and documentation in a ROD amendment or ESD regardless of contingency language in the original ROD. EPA guidance (1993) suggests avoiding language that identifies a TI decision as a future contingency. There do not appear to be any administrative advantages of using contingency language regarding TI in a ROD. Such language merely communicates stakeholders' shared expectations regarding remedy performance and documents key uncertainties at the time of the ROD and does not simplify the TI waiver process, public participation, or ESD/ROD amendment documentation.

No TI waivers have been approved on the basis of contingency language used in prior decision documents. Petro-Chemical Systems, Inc. (Turtle Bayou) used contingency language referencing technical impracticability in the original 1991 ROD. This language was repeated in the 1998 ESD. A post-implementation TI waiver was incorporated into a ROD amendment in 2006, 15 years later. Keystone Sanitation Landfill and Crystal Chemical Co. used similar contingency language in 1990 RODs prior to receiving post-implementation TI waivers in subsequent decision documents.

Several sites have recently used contingency language in RODs, including the following:

- Carolina Transformer Co.
- Naval Air Engineering Center
- Drake Chemical

Carolina Transformer Co., Operable Unit (OU) 1 ROD amendment, dated 7/22/2005, called for excavation of contaminated soil, building demolition, off-site landfilling of debris and solid waste, groundwater extraction and treatment to address metals and low-level organics, aquifer monitoring, and ICs. The ROD amendment stated that the pump-and-treat system would operate for about 10 years, during which time extraction system modifications and adjustments would be conducted if treatment system concentrations level off. Contingency language stated the following: *"If it is determined, on the basis of the preceding criteria and the system performance data, that certain portions of the aquifer cannot be restored to their beneficial use, all the following measures involving long-term management may occur…b) chemical-specific ARARs will be waived for the cleanup of those portions of the aquifer based on the technical impracticability of achieving further contaminant reduction"*

Naval Air Engineering Center, OU 26 ESD, dated 9/30/2003, modified a previous ROD dated 9/27/1999, by describing the injection of nanoscale particles at two areas in lieu of cometabolism, which was determined to be ineffective. The ESD referred to technical impracticability in the following: *"…[I]f the nanoscale particle treatment is not effective, a Technical Impracticability decision will be requested for treatment of the higher areas of groundwater contamination in accordance with Section 300.430(f)(1)(ii)(c)(3) of the NCP."*

Language pertaining to technical impracticability was even more general for Drake Chemical Site, OU 4. The two latest Five-Year Review reports (dated 9/25/2003 and 9/22/2008) refer to a 6/14/1995 ESD which "*changed treatment to regular activated carbon and further defined the scope of work, periodic sampling requirements, operation and maintenance plans and the possibility for a technical impracticability waiver*". Several chemical-specific performance standards were identified for organic contaminants. The ESD also "*discussed specific criteria for demonstration that no further decrease in concentrations of the target constituents could be achieved and presented a concept that Alternate Performance Standards could be determined by EPA in consultation with Pennsylvania Department of Environmental Protection*".

These are just several examples of the ways in which final decision documents have referred to technical impracticability, without specifically identifying it as a contingency remedy. A list of sites using similar language in decision documents issued after 1993 is provided in Table C-7.

Table C-7. Examples of Decision Documents with Contingency TI Language

Name	Type	OU	Date
A.I.W. Frank/Mid-County Mustang	ROD	1	9/29/95
Allegany Ballistics Laboratory	ROD	3	5/29/97
American Creosote Works, Inc. (Pensacola Plant)	ROD	2	2/3/94
Bangor Naval Submarine Base	ROD	1	9/28/94
Barstow Marine Corps Logistics Base	ROD	1, 2	4/22/98
Better Brite Plating Co. Chrome and Zinc Shops	ROD	1	9/24/96
Calhoun Park Area	ROD	1	9/30/98
Carolina Transformer Co.	AMD	1	7/22/05
Chemsol, Inc.	ROD	1	9/18/98
Cleburn Street Well	ROD	1	6/7/96
Cortese Landfill	ROD	1	9/30/94
Davis Park Road TCE	ROD	1	9/29/98
Dover Gas Light Co.	ROD	1	8/16/94
Drake Chemical Site	ESD	4	6/14/95
Fort Richardson (U.S. Army)	ROD	2	9/15/97
Fresno Municipal Sanitary Landfill	ROD	2	9/30/96

Name	Type	OU	Date
GCL Tie and Treating Inc.	ROD	2	3/31/95
General Electric Co/Shepherd Farm	ROD	1	9/29/95
Gulf State Utilities - North Ryan Street	ROD	1	9/27/00
Hewlett-Packard (620-640 Page Mill Road)	ROD	1	3/24/95
Hill Air Force Base	ROD	2 1	9/30/96, 9/29/98
Hooker Chemical & Plastics Corp./Ruco Polymer Corp.	ROD	1	1/28/94
Idaho National Engineering Laboratory	ROD	1, 7	8/18/95, 9/28/99
Interstate Lead Co. (ILCO)	ROD	2	10/13/94
Iron Mountain Mine	ROD	4	9/30/97
Kopper Co. Inc (Charleston Plant)	ROD	1	3/29/95
MacGillis & Gibbs Co./Bell Lumber & Pole Co.	ROD	3	9/22/94
Malvern TCE	ROD	1	11/26/97
Mason City Coal Gasification Plant	ROD	1	9/19/00
Murray Smelter	ROD	0	4/1/98
Muskego Sanitary Landfill	ROD	2	2/2/95
N.W. Mauthe Co., Inc.	ROD	1	3/31/94
National Presto Industries, Inc.	ROD	3	5/15/96
Naval Air Engineering Center	ESD	26	9/30/03
NL Industries	ROD	1	7/8/94
North Belmont PCE	ROD	1	9/24/97
North Carolina State University (Lot 86, Farm Unit #1)	ROD	1	9/30/96
North Penn - Areas 6, 12	ROD	1, 3	9/30/97, 8/10/00
Penta Wood Products	ROD	1	9/29/98
Preferred Plating Corp.	AMD	1	9/30/97
Ralston Site	ROD	1	9/30/99
Rock Hill Chemical Co.	ROD	1	6/24/94
Scrap Processing Co., Inc.	ROD	1	9/30/97
Shuron, Inc.	ROD	1	9/9/98
Standard Chlorine of Delaware, Inc.	ROD	1	3/9/95
Tutu Wellfield	ROD	1	8/5/96
Van Dale Junkyard	ROD	1	3/31/94
Waste Inc. Landfill	ROD	1	8/18/94
Weldon Spring Quarry/Plant/Pits (DOE/Army)	ROD	5	9/30/98
Zellwood Groundwater Contamination	ROD	2	8/24/95

Summary

Highlights of the analysis of 77 TI waivers granted at CERCLA sites include the following:

- Most TI waivers are granted because of contaminant-specific and/or hydrogeologic complexities that limit remedial progress. This is the primary reason given for the use of TI waivers at 75 to 80% of sites.

- The most common type of hydrogeologic setting was a fractured rock, karstic, or karst-like environment. Other complex hydrogeologic settings included the presence of contaminated low-permeability silts and clays, highly heterogeneous or layered environments, and in some cases, high-permeability sands and gravels.

- NAPL is typically present at more than half of the sites. Types of contaminants present varied, including chlorinated solvents, coal tar/PAHs, metals, and mixtures of two or more types. Federal MCLs were the most common ARAR waived, accounting for 94% of all TI waivers issued in the time period from 1994 to mid-2009.

- The areal extent of TI zones varies from 0.1 to >10,000 acres, and from <30 to >800 feet below ground surface. The most common TI zone designation included both the source area and the plume, with the second most common designation including just the source area. Other TI zone designations reflect property boundaries and natural hydrogeologic and/or regional boundaries.

- The majority of the 77 CERCLA sites (65% of all sites to 73% of post-1993 sites) received TI waivers based on conceptual analyses, modeling, treatability studies, and pilot-scale studies (front-end waivers). The rest of the sites installed and operated a full-scale treatment system prior to approving a TI waiver (post-implementation waivers).

- TI waivers have been implemented in nearly every EPA region and approximately half of all states (1 to 16 waivers per region). States and regions that have used the TI waiver process the most include Regions 1 and 3, Pennsylvania, California, Texas, Maine, New York, New Jersey and Montana. Regions least likely to be using the process include Regions 4 and 10.

- Based on the research presented in this report, TI waivers have been included in an average of 2% of CERCLA decision documents issued from 1989 through mid-2009.

- Contingency language pertaining to TI waivers is frequently used in RODs; however, such language does not expedite the evaluation, approval or documentation process and merely communicates stakeholders' expectations and key uncertainties in attaining cleanup objectives at the time of the ROD.