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Understanding "Unlimited Use/Unrestricted Exposure" at Military Munitions Response Program Sites: Implications for Long-Term Risk Management

Final Report

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State Federal Coordination Focus Group
Federal Facilities Subcommittee

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Acronym List

ASTSWMO	Association of State and Territorial Solid Waste Management Officials
BRA	Baseline Risk Assessment
BRAC	Base Realignment and Closure
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
DERP	Defense Environmental Restoration Program
DoD	U.S. Department of Defense
DoDM	DoD Manual
DUA	Data Usability Assessment
EPA	United States Environmental Protection Agency
FS	Feasibility Study
FUDS	Formerly Used Defense Site
FYR	Five-Year Review
IC	Institutional Control
LTM	Long-Term Management
LUC	Land Use Control
MD	Munition Debris
MEC	Munitions and Explosives of Concern
MMRP	Military Munitions Response Program
MR	Munitions Response
MRDD	Maximum Reliable Detection Depth
MRS	Munitions Response Site
MRSPP	Munitions Response Site Prioritization Protocol
NDAI	No DoD Action Indicated
NEU	No Evidence of Use
NFA	No Further Action
NFRAP	No Further Remedial Action Planned
OSWER	Office of Solid Waste and Emergency Response
OU	operable unit
PA/SI	Preliminary Assessment/Site Inspection
PDT	Project Delivery Team
QAPP	Quality Assurance Project Plan
RACR	Remedial Action Completion Report
RAGS	Risk Assessment Guidance for Superfund
RC	Response Complete
RI	Remedial Investigation
RIP	Remedy In Place
RMM	Risk Management Methodology
ROD	Record of Decision
SC	Site Closeout
SERDP	Strategic Environmental Research and Development Program
SFC	State-Federal Coordination
UU/UE	Unlimited Use/Unrestricted Exposure

1. Introduction

The U.S. Department of Defense (DoD) and States struggle to apply a consistent definition of Unlimited Use and Unrestricted Exposure (UU/UE) to explosives hazards at military munitions response program (MMRP) sites. During the development of DoD munitions response tools [Risk Management Methodology (RMM) and Munitions Response Quality Assurance Project Plan (MR-QAPP) Toolkit], States raised concerns about implementation due to fundamental differences in how UU/UE is defined, interpreted, and applied. This paper proposes a consistent set of requirements the DoD and States must consider to reach a UU/UE determination at an MMRP site.

The National Contingency Plan (NCP) requires Five-Year Reviews (FYR) to be conducted at sites where remedial action resulted in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for UU/UE.[1] U.S. Environmental Protection Agency (EPA) guidance defines UU/UE to mean "the selected remedy will place no restrictions on the potential use of land or other natural resources"[2]; whereas DoD defines UU/UE to mean “the selected remedy does not include a restriction on land or groundwater use to be protective.”[3] Though both definitions indicate that no waste remains above acceptable levels for any use or exposure scenario, this UU/UE determination enables DoD to achieve Site Closeout (SC)—the final milestone in environmental restoration where all requirements are complete and with no additional restoration funds expended.

Achieving UU/UE at MMRP sites presents unique challenges because unrestricted exposure to explosive hazards from munitions and explosives of concern (MEC) is never acceptable. Unlike traditional contaminants with established risk assessment methodologies and acceptable exposure levels (duration and continued exposure over time), State regulators usually require complete removal or proof of absence of MEC items at MMRP sites due to their acute, rather than chronic, danger. Consequently, DoD rarely achieves the preferred SC milestone at MMRP sites, instead reaching Response Complete (RC) status, which requires, at a minimum, Long-Term Management (LTM) and FYRs to maintain and ensure remedy protectiveness.

The lack of agreement between States and DoD regarding processes and evidence required to support UU/UE at MMRP sites creates challenges in determining when UU/UE designation is appropriate. While the MR-QAPP Toolkit clarifies evidence collection processes, challenges remain in evaluating and applying UU/UE to both pre- and post-Record of Decision (ROD) and No Further Action (NFA) determinations.

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[1] U.S. Code of Federal Regulations. *Title 40, § 300.430(f)(4)(ii)* (2024). https://www.epa.gov/superfund/superfund-five-year-reviews.

[2] U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. *Comprehensive Five-Year Review Guidance*. EPA 540-R-01-007, OSWER No. 9355.7-03B-P. Washington, DC: U.S. Environmental Protection Agency, June 2001. https://semspub.epa.gov/work/HQ/128607.pdf.

[3] U.S. Department of Defense. Defense Environmental Restoration Program (DERP) Management. DoD Manual 4715.20, Page 96. Washington, DC: U.S. Department of Defense, March 9, 2012. Incorporating Change 1, August 31, 2018. https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodm/471520m.pdf.

1.1 Objectives

This paper clarifies UU/UE application at MMRP sites by:

- Establishing a collective understanding of MMRP terminology and processes;
- Identifying challenges and limitations in achieving UU/UE for explosive hazard cleanups;
- Discussing criteria for classifying MMRP sites as UU/UE and differentiating from other terms and site designations like NFA; and
- Analyzing the implementation of LTM when UU/UE is either infeasible or unachievable.

This paper restricts its analysis of UU/UE to a limited scope based upon the following criteria:

- Explosive hazards associated with MEC, and not munitions constituents or other contaminants; and
- UU/UE under CERCLA and the requirements for FYR.

1.2 Methodology

The ASTSWMO State and Federal Coordination (SFC) Focus Group developed this paper via:

- Extensive regulatory document review;
- Analysis of regulatory guidance, policy documents, and technical reports related to UU/UE classification;
- Information collected from States on UU/UE; and
- Review of previous UU/UE determinations.

1.3 State Information Request

ASTSWMO polled State regulators about their experiences with UU/UE at MMRP sites. Of thirty-six respondents, only six indicated their State achieved UU/UE designation at munitions sites. Based on responses, confusion exists among regulators about UU/UE and its MMRP site application.

The survey determined that no sites achieved UU/UE through traditional MEC removal methods, and States have no official internal policy or guidance for cleaning MMRP sites to UU/UE. Currently, the only guidance for achieving UU/UE at MMRP sites is the MR-QAPP Toolkit, developed in partnership between DoD, EPA, and States.

2. Background

This paper presents a general overview of UU/UE under CERCLA and its unique aspects at MMRP sites, clarifies common misconceptions, and provides State regulators with an overview of UU/UE application within the MMRP.

2.1 UU/UE under CERCLA

Federal EPA CERCLA guidance specifies that sites achieving UU/UE status are clean to a degree where no exposure limitations are necessary for any potential receptor under any foreseeable future land use.[4] This represents the highest standard of cleanup and allows for flexibility in future land use decisions.

When all contamination is removed or reduced to levels that pose no unacceptable risk to human health or the environment under any use or exposure scenario, UU/UE is achieved. The designation of UU/UE is significant because CERCLA requires FYR for remedial actions that, upon completion, will leave hazardous substances, pollutants, or contaminants onsite above levels that allow for UU/UE.[5] If UU/UE is achieved, then an FYR is not required. The CERCLA ROD must, among other requirements, discuss the applicability of the FYR to the selected remedy and if the remedy is intended to result in hazards remaining at the site above UU/UE.[6]

In general, if the selected remedy relies on restrictions of land use by humans or ecological populations to be protective, then FYRs are used to periodically verify the protectiveness as related to the conditions of the selected remedy at the site. If a site seeks to reach recreational use, and other types of uses are restricted (e.g., residential use), then UU/UE is not possible. Along those same lines, an MMRP site with restrictions on the depth of intrusive activities may do so through a land use control (LUC) as part of the remedy, where UU/UE is not achieved and FYRs are required.[7]

2.2 UU/UE at MMRP Sites

The designation of UU/UE at munitions sites is difficult to attain due to the acute nature of explosives hazards associated with individual MEC items, technology limitations, depth of munitions, terrain and lack of agreement on acceptable risks. Traditional contaminants have an

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[4] U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. *Comprehensive Five-Year Review Guidance*. EPA 540-R-01-007, OSWER No. 9355.7-03B-P. Washington, DC: U.S. Environmental Protection Agency, June 2001. https://semspub.epa.gov/work/HQ/128607.pdf.

[5] *Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 U.S.C. § 9621(c).*

[6] U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents*. EPA 540-R-98-031, OSWER 9200.1-23P. Washington, DC: U.S. Environmental Protection Agency, July 1999. http://semspub.epa.gov/work/HQ/500009392.pdf.

[7] U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. *Comprehensive Five-Year Review Guidance*. EPA 540-R-01-007, OSWER No. 9355.7-03B-P. Washington, DC: U.S. Environmental Protection Agency, June 2001. https://semspub.epa.gov/work/HQ/128607.pdf.

agreed risk assessment methodology and exposure levels considered acceptable for evaluating unrestricted land use, along with concentrations determined to be safe for worst case exposure scenarios. This is not the case with munitions, where the worst-case scenario of a person's direct interaction with MEC (explosive hazards) may result in bodily harm, and even death. Therefore, UU/UE at MMRP sites typically requires demonstration that all MEC items no longer remain or were never present.

When potential MEC remains onsite, land use must be restricted or controlled to avoid direct exposure to explosive hazards. For example, public education of hazards via the 3Rs of Explosive Safety – Recognize, Retreat, Report, is an institutional control that precludes UU/UE but is often overlooked in attempts to assign UU/UE on MMRP projects.[8] Sites with potential MEC hazards may be determined protective based on current and anticipated future use assumptions that limit MEC exposure potential. However, remedies including use restrictions or other controls are not UU/UE, nor are remedies assuming limited future uses. For MMRP sites, the UU/UE designation requires all lines of evidence to support high confidence that munition hazards no longer exist or were never present, regardless of land use assumptions.

2.3 What does NOT Constitute UU/UE

Common misconceptions exist regarding distinctions between UU/UE, no action determinations, and protectiveness. The following conditions do not constitute UU/UE:

- NFA based on limited land use assumptions;
- Approval for residential use without UU/UE evaluation;
- Surface or Subsurface MEC removal complete with the requirement for ongoing Land Use Controls;
- No action determinations [e.g., NFA, No Further Remedial Action Planned (NFRAP)] without UU/UE demonstrated;
- Sites that have LTM.

When evaluating whether UU/UE has been achieved after implementing a remedy at an MMRP site, State regulators must answer one fundamental question: "Is it possible that an unacceptable risk remains at the site?" If yes, UU/UE is not appropriate for the site.

[8] U.S. Department of Defense. *UXO Safety*. DENIX (Defense Environmental Network & Information Exchange). https://www.denix.osd.mil/uxo/.

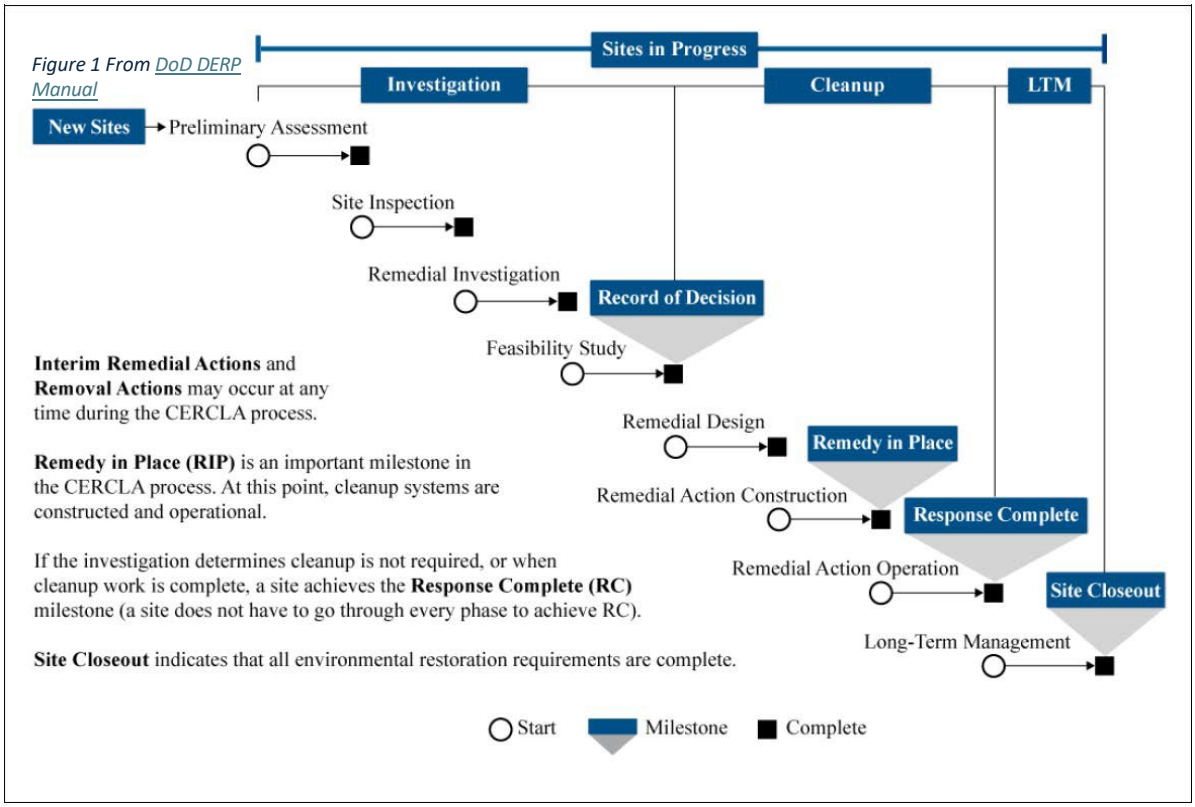

Figure 1 From DoD DERP Manual

2.4 UU/UE in the Defense Environmental Restoration Program (DERP)

The DoD measures cleanup progress against major environmental restoration milestones described in the DERP Manual.[9] DERP environmental restoration has three phases: investigation, cleanup, and LTM. Major milestones include ROD, Remedy In Place (RIP), Response Complete (RC), and SC (see ***Figure 1*** above).

The RC milestone signifies that the DoD Component has met the remedial action objectives for the site, documented the determination, and sought regulatory agreement. SC is the final milestone (preferred by State regulators) and indicates that all environmental restoration requirements are complete (i.e., no further LTM or FYRs required) and no additional environmental restoration funds will be expended. SC is equivalent to UU/UE. Sites that cannot achieve UU/UE remain in the LTM phase in perpetuity, unable to achieve SC, unless additional work is completed at the site. RC is the final milestone achievable at MMRP sites where MEC may potentially remain, with LTM and FYRs required, at a minimum.

2.4.1 UU/UE at MMRP Investigation and Feasibility Phases

The MMRP Investigation and Feasibility Phases include site assessment [Preliminary Assessment/Site Inspection (PA/SI)], site characterization [Remedial Investigation (RI) /Feasibility

[9] U.S. Department of Defense. *Defense Environmental Restoration Program (DERP) Management*. DoD Manual 4715.20. Washington, DC: U.S. Department of Defense, March 9, 2012. Incorporating Change 1, August 31, 2018.

Study (FS)], and decision document (ROD). Primary cleanup decision considerations include:

- A PA/SI phase No-action determination is only appropriate when: 1) no hazardous substances or pollutants or contaminants that are DoD responsibility are potentially present; or 2) no releases that are DoD responsibility are present at the site which pose a significant threat to public health or the environment.[10]
- At MMRP sites, a project delivery team (PDT[11]) determination that there is no evidence of use (NEU) of military munitions supports a no-action determination and achieves UU/UE by default.
- If the presence of munitions is not ruled out, it is unlikely the site will meet a No Action or UU/UE threshold and should progress through the CERCLA process.
- If the RI/FS Baseline Risk Assessment (BRA) concludes that the site poses no unacceptable risks based on current and reasonably anticipated land use, a no-action alternative may be warranted, but may or may not allow for UU/UE.[12]
- The BRA must evaluate a UU/UE exposure scenario, which will enable comprehensive consideration of the feasibility for alternative remedial actions to be assessed.
- Decision documents must include descriptions of any MEC potentially remaining at sites post-remedial action above acceptable UU/UE levels.[13] This requirement applies to all decision documents, including no-action decisions based on the RI and BRA.

2.4.2 UU/UE at MMRP Cleanup Phase

The MR-QAPP Toolkit includes processes for demonstrating successful remedy implementation, documenting quality, assembling evidence necessary to support UU/UE determinations, and preparing documentation supporting or rejecting UU/UE consideration.[14]

As noted above, the RC milestone signifies that remedial action objectives have been met, documented, and agreement has been sought by regulators, allowing the site to transition into LTM or SC. Following RC milestone achievement, the DoD may monitor long-term remedy protectiveness during the LTM phase. LTM is required when remedial action objectives do not allow unrestricted property use or when remedies cannot achieve UU/UE. Actions during this phase range from monitoring site conditions to implementing LUCs. If no LTM, the MMRP site

[10] U.S. Department of Defense. *Defense Environmental Restoration Program (DERP) Management*. DoD Manual 4715.20.

[11] The PDT includes the lead DOD agency project manager, technical experts, regulators, specialists, consultants/contractors, stakeholders, and representatives from other federal and state agencies, where appropriate.

[12] U.S. Department of Defense. *Defense Environmental Restoration Program (DERP) Management*. DoD Manual 4715.20, § 8(8)(f).

[13] U.S. Department of Defense. Defense Environmental Restoration Program (DERP) Management. DoD Manual 4715.20, § 8(d)(5).

[14] U.S. Environmental Protection Agency. *Uniform Federal Policy For Quality Assurance Project Plans, Munitions Response QAPP Toolkit*. https://www.epa.gov/fedfac/uniform-federal-policy-quality-assurance-project-plans- munitions-response-qapp-toolkit.

may achieve SC, which is equivalent to UU/UE.

2.5 NFA, NFRAP, and NDAI

The terms NFA, NFRAP, and NDAI often lead to confusion among State regulators in determining whether a site is appropriate for UU/UE. These determinations are all similar, but different in their scope and implementation. An NFA or NFRAP may be used to signify a site is protective, but may not signify UU/UE. Remedial actions must be protective of current and anticipated future land use, while a UU/UE determination is based on unlimited use and unrestricted exposure for all uses. These are significantly different thresholds of protectiveness depending on the land use and exposure assumptions.

PDTs should ensure there is a common understanding of these terms when used in CERCLA documentation. For example, any MMRP site with an NFA determination based on current use may be protective and require no further cleanup actions but will still need FYRs if the final remedy did not achieve UU/UE. Moreover, NFRAP is only determined via the EPA after a site assessment which finds that a site does not pose a threat to warrant Superfund listing.

Additionally, the term NDAI in the DERP Manual specifies FUDS property specifically. NDAI is not a CERCLA term and has no relationship to potential for munitions hazards or protectiveness of a site. From the DERP Manual, NDAI are determinations intended solely to assist the Secretary of the Army in demonstrating its accomplishments of DERP program goals and objectives to the DoD.[15]

NDAI signifies a FUDS property or DERP project that meets any of these conditions:

- It is not eligible for FUDS program consideration;
- It is excluded from the FUDS program; or
- Contains hazards that were not the result of DoD actions on or before October 17, 1986; pose no threat to human health or safety or the environment; and require no additional environmental restoration activities.

Where the selected remedy leaves munitions hazards onsite and results in conditions that do not support UU/UE, States should ensure DoD conducts, at a minimum, FYRs at those MMRP sites. Sites which are designated NFA or NFRAP may be under passive or active long-term management status and not considered appropriate for UU/UE.

3. Achieving UU/UE at MMRP Sites

Reaching UU/UE at an MMRP site involves regulatory and technical considerations to justify the determination. Outlined below is DoD's process for demonstrating achievement of UU/UE and discussing regulatory and technical challenges from the State perspective.

[15] U.S. Department of Defense. *Defense Environmental Restoration Program (DERP) Management*. DoD Manual 4715.20. Washington, DC: U.S. Department of Defense, March 9, 2012. Incorporating Change 1, August 31, 2018.

3.1 DoD Process

In collaboration with the States and EPA, the DoD developed the MR-QAPP Toolkits (Module 1 and Module 2). The *MR-QAPP Toolkit Module 2* includes an example process for demonstrating the successful implementation of a remedy, documenting quality, assembling lines of evidence necessary to support a determination of UU/UE, and preparing documentation supporting or rejecting UU/UE for consideration.[16] The *MR-QAPP Toolkit Module 2* example can be found in Appendix E of the document.

The MR-QAPP Toolkit provides comprehensive quality requirements for demonstrating complete removal. There should be evidence supporting a determination that munitions are no longer onsite, and all munitions items are successfully detected and removed. Documenting the quality of both the characterization and removal of munitions and managing uncertainty due to technical challenges are key considerations. Technical challenges may include physical impediments (vegetation, terrain), limiting site accessibility for complete coverage, and detection depth limitations of geophysical technology. Munitions removal must cover entire sites with detection technology demonstrating sufficient buffers between maximum reliable detection depths and actual munition recovery depths. For example, if portions of the site are inaccessible for munitions removal or munitions are recovered below maximum reliable detection depth, this is evidence that additional munitions may remain. Due to this uncertainty, making a UU/UE determination in this case would not be appropriate.

A UU/UE evaluation and recommendation is the final step in the remedial action and should be documented as part of a data usability assessment (DUA) report and included in the remedial action completion report (RACR). The DUA report should focus on information collected during subsurface munitions removal, and associated quality and efficacy in demonstrating munitions hazards are unlikely to remain. PDTs, including State regulators, must agree with UU/UE recommendations, which consider all lines of evidence.

3.2 State Regulatory Considerations

To achieve UU/UE the remedy selected in the ROD must include complete removal of explosives hazards with no LTM. At most sites, the goal of UU/UE is aspirational and difficult to achieve.

Before concurring with a remedy that includes UU/UE, the State regulator first must decide whether UU/UE is potentially achievable, then ensure their expectations for removal of munitions and required levels of evidence necessary to demonstrate achievement of UU/UE are documented in the ROD. From a State regulator's perspective, multiple challenges exist before concurring that DoD successfully demonstrated UU/UE attainment at a site. State regulators must decide whether the determination is appropriate and if the DoD compiled the required decision data (e.g., munition types, characterized distribution, density, range of depth, site

[16] U.S. Environmental Protection Agency. "Uniform Federal Policy For Quality Assurance Project Plans, Munitions Response QAPP Toolkit." https://www.epa.gov/fedfac/uniform-federal-policy-quality-assurance-project-plans-munitions-response-qapp-toolkit.

conditions, and matching detection and recovery capability that can feasibly address site specific requirements). MR-QAPP, Appendix E, includes criteria which should be referred to when evaluating the MMRP site for UU/UE.

Several challenges commonly associated with attaining UU/UE are listed in ***Table 1*** and elaborated in further detail within subsections **3.2.1** and **3.2.2**.

Table 1 Common Challenges to Attaining UU/UE at MMRP Sites

Regulatory Considerations

Consideration	Description	Challenge
Remedy Selection	Does the selected remedy support a UU/UE determination?	• There are no standards for acceptable levels of removal for munitions. • Level of evidence to demonstrate achieving UU/UE can be cost prohibitive.
Risk Evaluation	Do the assumptions in the risk assessment support UU/UE determination?	• No agreement between States and DoD on methodology for evaluating protectiveness of remedy. • Acute risk from exposure to munitions hazards.
Regulatory experience	Does the regulator have necessary training and experience to evaluate UU/UE determination?	• Lack of institutional knowledge and expertise. • Limited training resources, and travel/funding restrictions on State staff to attend training. • States may subcontract munitions experts to assist with munitions site work.

Technical Considerations

Consideration	Description	Challenge
Site Specific Limitations	Physical site conditions can pose significant obstacles to complete site- wide munitions hazard removal.	• Accessibility to portions of a site for munitions removal. • Physical obstructions such as buildings and utilities. • Environmental impacts of munitions removal. • Community safety.
Detection Depths for Munitions	Can munitions hazards be reliably detected and removed?	• Maximum reliable detection depths are variable. • Detectability of certain munition types (for example fuzes and other hazardous components). • Geophysical noise and other impacts on geophysical surveys
Depth of Burial of Munitions	Accurate estimation of the maximum depth at which munitions may be present on a site.	• Limitations and evidence needed to establish maximum munitions penetration depths.

3.2.1 Regulatory Challenges to Attaining UU/UE

Remedy Selection

Remedy selection involves site-specific balancing of munitions removal cost and implementability with residual hazard management. For State regulators, these create difficult challenges due to variabilities in the munitions site cleanup requirements and how site challenges may impact the extent to which removal can be achieved. Critical considerations when selecting final MRS remedies include determining which remedial alternatives support UU/UE and evidence levels required to demonstrate successful UU/UE attainment. When considering final remedy selection with UU/UE, there must be consensus on how to measure successful implementation, manage uncertainty, and demonstrate UU/UE achievement.

Risk Evaluation

Due to the acute health risks explosive hazards present, MRS characterization requires significant effort and resources. State Regulators are encouraged to review or assess work to support discussions of MEC presence or absence determinations. Where data gaps exist, these efforts may be impractical or infeasible, resulting in uncertainties posing challenges in determining explosive hazard levels.

There are challenges with assessing explosive hazards at MMRP sites. There is limited available guidance addressing a receptor's interaction with a MEC item (acute exposure) and understanding the adverse reaction.[17] Given these limitations, the most conservative approach requires either complete site characterization (100%) and cleanup or robust engineering and institutional controls. However, new tools are now available to demonstrate effective mitigation and removal of MEC hazards.

State Regulatory Experience and Authority

Complexities related to understanding nature, extent, and relative risk from historical military land use containing explosive hazards present significant challenges for State regulators. Most States lack staff with significant munitions expertise due to the limited number of MMRP sites in the State or the regulators' limited military operations experience. The States acknowledge the DoD provides some training each year for regulators, however the opportunities to attend the training are limited by available State staff, obtaining approval for travel, and funding.

As an alternative to limited training opportunities, States can seek contracted support for work at munitions sites. While advantageous, contract support is not feasible for every State. State regulators must navigate internal priorities and limit contractor funding. Beyond limited internal resources, available contractor pools are small due to this work's specialized nature in private sectors.

[17] U.S. Environmental Protection Agency. *Risk Assessment Guidance for Superfund (RAGS) Part A*. https://www.epa.gov/risk/risk-assessment-guidance-superfund-rags-part.

3.2.2 Technical Challenges to Attaining UU/UE

MMRP sites present unique challenges to effective MEC removal due to variation in site conditions that can significantly impact the remedy selection and feasibility of supporting a UU/UE determination.

Site Specific Limitations

The location of MMRP sites can pose significant obstacles in terms of accessibility, environmental impact, and community safety. These MMRP sites can span across remote regions such as deserts, mountains and other rugged terrain, and dense forests, making access for assessment and remediation difficult and costly. These MMRP sites exist inside and near protected ecosystems, wetlands, or bodies of water requiring careful remediation to avoid environmental damage. The size and scale of these locations affect the feasibility and scope of remediation efforts as well, requiring prioritization strategies to determine which sections pose the highest risk.

Some MMRP sites consist of a larger complex with multiple ranges such as former grenade ranges, firing ranges, and impact zones, requiring extensive planning for necessary surveys and mapping. These conceptual site model variabilities increase the complexity of managing and coordinating cleanup efforts.

A separate subsection of MMRP sites are underwater and remain uninvestigated due to the challenging environment. However, new developments in underwater technologies and guidance for surveying underwater sites are in discussion. This type of site differs substantially from terrestrial sites, and it is expensive to assess and conduct removals of MEC. Providing more details on the challenges of underwater munitions site cleanup is outside the scope of this paper.

The need for specialized equipment and trained personnel at unique site topographies creates logistical challenges. Incomplete site surveys, which include cultural, historical, and Endangered Species Act (ESA) surveys, can also lead to data gaps where potential for UXO (Unexploded Ordnance) can remain. Finally, some historical MMRP sites are near or within growing urban areas, which creates a separate set of challenges between economic development and public safety concerns. Potential exposure to civilians increases the urgency and complexity of MMRP site cleanups.

Detection Depth for Munitions

A critical consideration in evaluating the ability of a remedy to achieve UU/UE is confidence in the detectability of munition items of concern. Regulators should **refer to the *MR-QAPP Toolkit* for specific examples.** The physics of geophysical sensor technology, the size of each munition item, its orientation relative to the sensor, and site noise (geologic vibrations unique to the surveyed area) constrain detection depths. Sensor response curves determine detection depths based on these factors.

Maximum Reliable Detection Depth (MRDD) is the limiting detection depth for munition items at a site. MRDD is based on a munition in its worst orientation (i.e., horizontal) and site-specific

noise levels. Munitions deeper than the MRDD may be detected if they are in a more favorable orientation, but others may be missed. If there is evidence that munitions items may be deeper than the MRDD, a UU/UE determination is not appropriate by using the capability of a specific type of technology as the sole line of evidence. To demonstrate confidence in complete removal, recovered munition items must be within the MRDD.

Coupled with intact munitions, the PDT must evaluate potential hazardous components. Many types of MMRP sites possess potentially hazardous components such as fuzes, boosters, or bursters that can be a limiting factor in ensuring full munitions hazard removal.

Geophysical noise needs scrutiny when considering a site for UU/UE. Areas near sources of interference (i.e., powerlines, fences, buried utilities) may have higher noise levels and increased uncertainty in the efficacy of the removal.

There are techniques to increase the MRDD in certain situations, including lowering the geophysical sensors closer to the ground surface and reducing the signal to noise ratio used to select anomalies. These techniques can result in significant false positive detections and increased costs. Detection depths can also increase by removing layers of soil across a site and resurveying after each layer is removed.

When subsurface removal is complete, the PDT should review the depths of recovered munitions to determine if items were located near or below their MRDD. The PDT will consider the distribution of items recovered, the density, and the deepest item recovered and its MRDD. While these conditions are dependent on the specific site conditions, a buffer could provide confidence that detection depth did not limit the ability to remove munitions hazards from the site. If there is no sufficient buffer between the deepest items and their MRDDs, this raises concern that deeper munitions could remain undetected at the site.

Depth of Burial for Munitions

Accurate estimation of the depth to which munitions may be present on a site is critical to demonstrating full removal of munitions hazards and UU/UE. A remedial investigation typically provides anomaly densities and large quantities of information to support the distribution profile for munitions both laterally and vertically. Although a subset of anomalies are investigated and a limited number of munitions removed, the remedial investigation supports an understanding of the most likely range for munitions recovery in future remedial actions. The *MR-QAPP Toolkit Module 1* describes what data is needed for a complete remedial investigation. Supplemental remedial investigations may be needed to ensure there is a complete understanding of the site distribution. After complete subsurface removal, additional data is available to establish penetration depths. However, significant uncertainty can remain when munitions are recovered at or near their detection depth limits. Geophysical data is limited to establishing depth profiles from the ground surface to the MRDD of the munition. If there is a sufficient buffer between the deepest recovered item and its MRDD, one can assume the depth profile is complete and deeper items are unlikely to be present.

However, if there are several munition items detected near or beyond the MRDD, the depth

profile may be incomplete and the potential for munitions hazards may remain. There is no current guidance on the appropriate size of a buffer between the deepest recovered munition item and its MRDD. The PDT must rely on their professional judgment in determining if there is sufficient evidence to demonstrate the removal of all munitions hazards to support a UU/UE determination.

Recent work by the Strategic Environmental Research and Development Program (SERDP) focused on providing a means of predicting depth of burial to aid in munitions site remediation.[18] The project draws from the fields of terminal ballistics and soil mechanics to develop a computer model GeoPoncelet for using cone-penetrometer test data along with the shape of the MEC to estimate a penetration depth probability profile.[19] To date, this work has not been demonstrated at an MRS; but, if successful, could significantly reduce the uncertainty associated with depth of burial when evaluating a UU/UE determination.

4. Evaluating UU/UE in Remedy Selection

State regulators' evaluation of an MMRP site for UU/UE starts at the RI/FS scoping, when identifying potential remedial options and goals.[20] The PDT must refine remedial options during the RI to support evaluation in the FS. Simultaneously, they must establish or identify current and potential future land use assumptions, and available LTM measures. It is also critical to understand landowner acceptance and implementability of LTM measures during the RI/FS before considering them for the remedy.

State regulators should consider the full range of remedial alternatives available at each site. If achievable, UU/UE is the preferred remedial option, allowing for any future land use without any exposure restrictions. On the other end of the remedial alternative spectrum is a prohibition on site use, which prevents access and eliminates any potential exposure pathway in perpetuity. Most munitions sites will fall somewhere between the two and will require LTM measures to ensure long-term protectiveness.

When weighing potential remedial alternatives at MMRP sites, State regulators must carefully balance the desire to remove all munitions hazards and achieve UU/UE with practical limitations on removal efficacy (site conditions, technology, and cost) and funding. Sites unlikely to achieve UU/UE must include an evaluation of strategies for LTM to ensure remedy protectiveness.

DoD describes LTM as managing long-term protectiveness of the remedy at sites that do not allow for unrestricted use. Actions during the LTM phase may involve monitoring site conditions, implementing and managing LUCs, and includes periodic assessment of the remedy

[18] Strategic Environmental Research and Development Program (SERDP). *Project MR19-1277*. https://serdp-estcp.mil/projects/details/f6bbb585-3880-4d68-b505-910b2bc8ef48/mr19-1277-project-overview.

[19] GeoPoncelet Model for Munitions Penetration Depth Prediction. *ASCE Library Journal of Geotechnical and Geoenvironmental Engineering*. https://ascelibrary.org/doi/10.1061/JGGEFK.GTENG-13286.

[20] U.S. Code of Federal Regulations. *Title 40, § 300.430(b)(3)* (2024).

protectiveness by conducting FYRs.[21] A long-term management strategy should consider the range of possible post-remedy site conditions, including residual munitions hazards, and potential exposure routes in determining the appropriate layering of LTM measures for munitions hazard management.

***Figure 2* MMRP Site Long-Term Management** illustrates the general relationship between post-remedy site conditions and LTM measures to ensure long-term remedy protectiveness. Layering LTM measures helps to address residual munitions risk hazards.

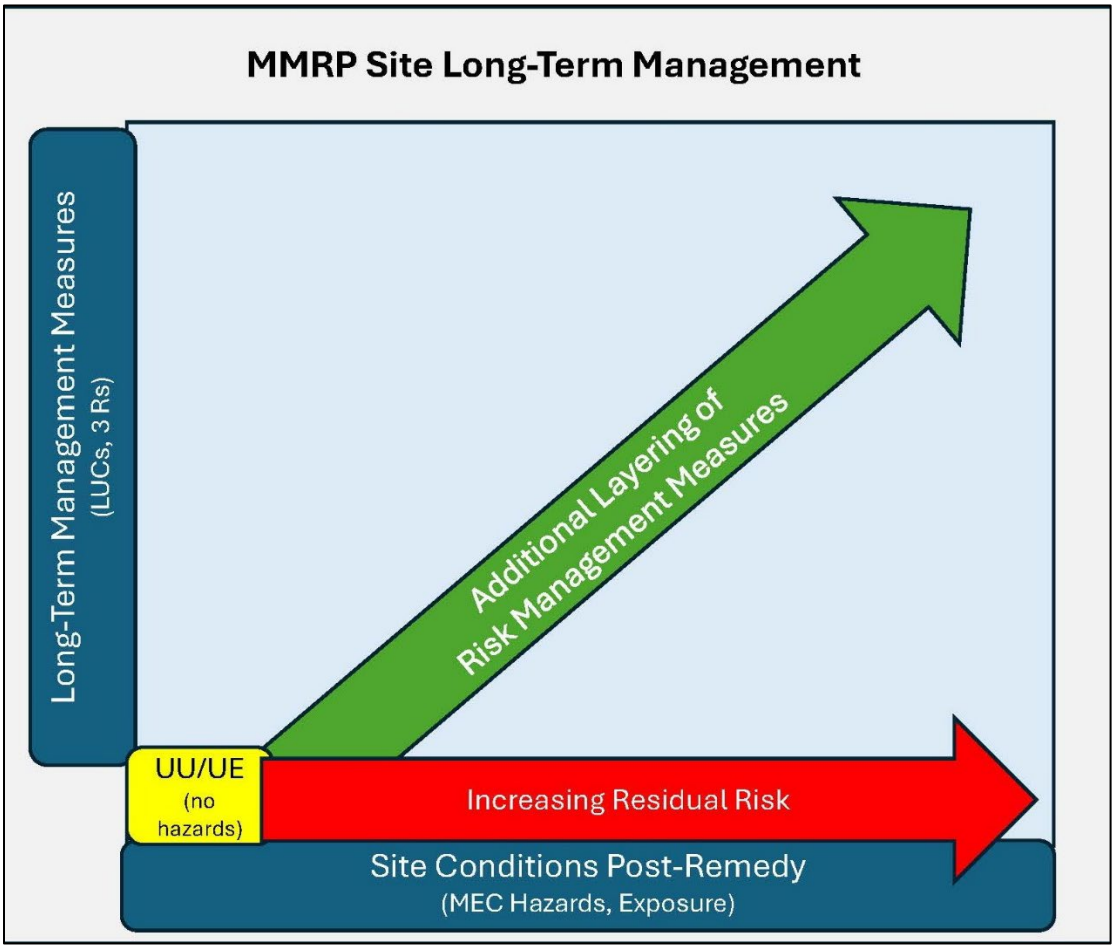

Figure 2 Illustration of the increased layering of long-term management measures to address increasing residual risks from munitions hazards after cleanup implementation. Including the relationship of UU/UE and NFA MMRP site designations.

A more detailed chart at the end of Section 4 (***Figure 3* LTM Considerations**) identifies LTM

[21] U.S. Department of Defense. *Defense Environmental Restoration Program (DERP) Management*. DoD Manual 4715.20. Washington, DC: U.S. Department of Defense, March 9, 2012. Incorporating Change 1, August 31, 2018.

measures and specific risk management approaches for MMRP sites.

4.1 What If You Cannot Reach UU/UE: LTM

Starting with the end goal in mind is critical to ensuring long-term protectiveness at MMRP sites. Most munitions cleanups have the potential for residual contamination after the remedy is implemented, excluding the site from UU/UE and requiring a form of LTM. State regulators should identify an LTM strategy during RI/FS scoping and refine it during the RI to support the FS.

State regulators should consult ***Figure 2*** above and the more detailed ***Figure 3*** at the end of this Section during RI/FS scoping to identify potential end-states, constraints on site uses associated with cleanup options, and available LTM measures.

Munitions hazards may remain at munitions sites post-remedy for a variety of reasons, including:

- Complete MEC removal is not achievable due to technology limitations or site conditions.
- Partial MEC removal remedy that allows munitions to remain in specific areas, due to a balancing of cleanup costs, technical constraints, site uses and exposure assumptions.
- Decisions leaving MEC in place based on acceptable risk for munitions hazards to current and anticipated future land uses.

In each of these instances, additional restrictions and/or controls are required to support protectiveness and will require FYRs. FYRs are triggered by the start of remedial action and conducted every five years until UU/UE is achieved. LTM fulfills statutory requirements and ensures long-term protectiveness. The risk management measures required will vary depending on site conditions including residual hazards and potential exposure routes.

4.2 LTM Considerations Chart

Figure 3 **LTM Considerations** chart can be referred to by State regulators during the RI/FS phase to help ensure the plan and design of the remedy is protective long-term. The figure presents a high-level review of considerations in balancing long-term management over varying site conditions, illustrating the use of different LTM measures, and the layering of those measures as land use controls that are selected as a component of (or the entire) remedy to address risk at the site. ***Figure 3*** is not official policy, nor should it take the place of site-specific considerations but rather it can be used to cross-reference with site-specific conditions and factors to address risk.

4.2.1 Long-Term Management Measures

Decisions on appropriate LTM measures balance the level of active cleanup at a site with remaining munitions hazards and reasonably anticipated use. During the FS, remedial alternatives layer measures that may be selected as land use controls based on site conditions anticipated after the active cleanup are layered based on anticipated post-cleanup site conditions, specifically site hazards and exposure scenarios, as illustrated in ***Figure 3***.

There are a limited number of LTM measures available for MMRP sites, ranging from monitoring

to active management and land use restrictions. These measures are implemented through specific LUC components engineered to address site-specific conditions.

To facilitate the review of MMRP site cleanup options we have grouped LTM measures into the following categories:

- **Active use restrictions** which limit access, activities, or types of uses in specific areas to break the exposure pathway and avoid exposure to munitions hazards at a site. Active use restrictions include restrictions on entry to specific areas (fences, signage, administrative controls) and restrictions on specific activities (digging restrictions, building moratorium, use restrictions). Active use restrictions require agreement by the property owner to implement. It is critical to understand landowner concerns and evaluate acceptance and implementability of active use restrictions before relying on them as a component of a remedy.

- **Active risk management measures** which minimize and/or manage exposure to munitions hazards during specific site activities without limiting or restricting the activities. Active risk management measures include anomaly avoidance and construction support (on-site and on-call). As with active restrictions, active risk management measures require property owner agreement to be implemented.

- **Passive risk management measures** minimize risk to current users from exposure to munitions hazards at a site without restricting site access or use. These measures include warning signs, advisories, hazards, real estate disclosures, 3Rs educational programs, munitions recognition and safety training, community outreach, and other site-specific training programs. Developing contingencies for responding to suspected munition is a valuable tool and may not require property owner agreement to implement.

- **Manage changes to current land use** to monitor, but not restrict, land use to ensure any future changes in use are consistent with assumptions in the remedy and the site remains protective. If future use becomes inconsistent, the remedy needs to be re-evaluated.

  Change management measures can be effective LTM measures at sites where current uses present low risks and changes to use are unlikely to occur. Rather than place a restriction on use of a property, the site is monitored to ensure that if any changes in use do occur in the future, the site will remain protective. If a future use is inconsistent with the assumptions in the remedy, the remedy will be reevaluated to address the change. Change management measures do not require property owner agreements for implementation.

State regulators should consider the efficacy, implementability and community acceptance of each LTM measure to ensure protective and acceptable measures are used.

Regulators must ensure that land use controls that incorporate these LTM measures are described in sufficient detail in the FS and ROD to define how the measures support site remedial

action objectives and protectiveness. To be effective over time, land use controls must also include performance goals to measure success, monitoring to verify success, and enforcement mechanisms to address non-compliance.

4.2.2 LTM Measures Based on Site Conditions

When deciding on the necessary land use controls (including LTM measures) at a site beyond physical removal, State regulators must understand the potential completeness of the munitions removal that is achievable at a site based on site conditions. As the anticipated level of residual munitions hazards increases across FS alternatives, the layering of risk management measures and MMRP site use restrictions should also increase.

No Munitions Hazards Remain (UU/UE)

"UU/UE," when no munitions hazards remain post-remedy and LTM measures are not necessary, refers to sites where no munitions hazards were present (e.g., NEU), and where munitions remedial actions were completed and demonstrated complete removal of all munitions hazards. All sites that do not achieve UU/UE require an FYR.

Sensitive Uses Exposure Scenarios

Sites with sensitive uses (e.g., residential, schools, playgrounds) where there is a heightened expectation of safety should undergo additional scrutiny to ensure protectiveness from munitions hazards. However, unlike UU/UE, these sites may be determined acceptable for sensitive uses with LUCs as part of the remedy. For example, a site could be approved for residential development with the requirement for on-call construction support and education and awareness programs during site development, followed by site monitoring. Such complex remedies do not meet UU/UE and require FYRs.

Land Use Monitoring

If protectiveness of the remedy is based on specific land use and exposure assumptions, how those uses will be monitored or controlled must be considered. Change management is an important consideration for these sites. LTM measures for change management include passive monitoring of site uses and placing formal restrictions on use.

State regulators should consider implementability and efficacy in deciding between monitoring programs and use restrictions. At FUDS sites where formal land use restriction may not be acceptable to the landowner, change monitoring may be the most effective measure to ensure that remedies based on current and future land use and exposure assumptions remain protective.

MEC Exposure Management

MEC Exposure Management includes LTM measures focused on managing site user encounters with MEC items. These are active or passive risk management measures. This can include sites where a MEC removal action has been completed and post-removal residual risks are managed, as well as sites that rely solely on LUCs as the remedy. Where the likelihood of encountering MEC

during site use or activities in these scenarios is considered low, LTM measures may include education and awareness programs and on-call construction support. If the likelihood of encountering MEC is determined to be moderate to high, PDTs should consider layering additional LTM measures, where the anticipation of future disturbance may include requirements for anomaly avoidance or on-site construction support to reduce the chances of site users encountering MEC.

MEC Exposure Controls

These LTM measures can range from restrictions on specific site activities, such as digging restrictions, to measures to restrict access to portions of a site. State regulators should consider the long-term implementability of access and activity restrictions and their impact on current and future use of the site.

As illustrated in ***Figure 3***, remedial alternatives and the final remedy documented in the ROD can include multiple LTM measures as a component of the remedy so that a comprehensive set of measures to prevent exposure to MEC are applied to match site-specific conditions.

Figure 3

Long-Term Management Considerations

	Long-Term Management Measure	Risk Management Measure
Increasing Level of Risk	**Active Use Restrictions** on access, activities, or types of use in specific areas with risk of encountering MEC. Manages risks by breaking exposure	**Restrict access** to specific areas on the site.
		Restrict specific activities or uses in specific areas of the site.
	Active Risk Management Measures to minimize risk to current users from encountering MEC during specific "higher-risk" site activities	**On-site construction support** to search for and remove potential explosives hazards to manage potential exposure to hazards (MEC) during specific site activities (i.e., intrusive or ground distrubing activities).
		Anomaly Avoidance Construction Support to avoid potentially hazardous subsurface anomalies during intrusive activity when the location of the activity can be adjusted (i.e., sign posts.)
		On-call construction support to provide munitions recognition and safety training to manage potential exposure to hazardous substances during specific site activities (i.e., intrusive or ground disturbing activities.)
	Passive Risk Management Measures to minimize risk to current users from encountering MEC.	**Education & Awareness** Program to manage exposures to hazardous substance during current use, such as warning signs, advisories, 3Rs outreach, or other training programs.
	Manage Changes to Current Land Use - Manage risks from future changes in land use	**Restrict future uses** to ensure changes to land use are consistent with the remedy.
		Monitor, but do not restrict, land use to ensure any future changes to land use are consistent with remedy and site remains protective. If future use inconsistent, reevaluate remedy.
UU/UE	**None**	**None**

Conclusions and Recommendations

Despite significant progress in the standardization of the DoD's cleanup program through collaboration with State regulators and other stakeholders, demonstrating MEC absence or complete MEC removal continues to challenge regulators and can affect the ability to achieve UU/UE (or SC) at MMRP sites. States must understand the benefit of LTM at MMRP sites where munitions hazards potentially remain and recognize that protective remedies and UU/UE are different remedial end-states.

This paper is not intended to be used as official guidance for State regulators, but rather to foster a discussion between Federal and State agencies regarding UU/UE, which has become confounded, misused, and misapplied with remedial end-states including, but not limited to, NFA, NDAI, NEU, NFRAP, RC, and SC. However, this paper will ensure common terminology is used when participating in PDTs. It is critical that State regulators understand and recognize the dangers of accepting a UU/UE determination at an MMRP site without proper due diligence. For those who utilize MMRP sites for public and private activities, this could quite literally be the difference between life and death.

5.1 Recommendations

The SFC Focus Group recommends the following:

Begin Your Site Evaluation with UU/UE as a Goal

- While this paper describes the difficulties and instances where UU/UE is not achieved in detail, this should not dissuade State regulators from proposing cleanup of MMRP sites to UU/UE. Evaluating different LTM measures during the remedial alternatives development phase is critical if it has been determined that UU/UE is not a realistic cleanup goal.

Scrutinize and Review Historical Data at MMRP Sites with a UU/UE Determination

- Review any site with a proposed UU/UE designation via multiple lines of evidence, consensus planning, and define necessary information to support decision logic to achieve UU/UE. Be sure to review historical data and match potential receptor pathways to the investigations undertaken by the DoD in the PA/SI stage through completion of the remedial action.

Maintain Consistency in Terminology/Definitions in Documentation

- Ensure terminology is consistently applied and definitions in decision documents and during engagements with stakeholders are understood by the entire PDT. DoD components may use differing criteria and considerations for their CERCLA-equivalent decision charts. These definitions are not always one-to-one equivalent to the CERCLA process but may be unique to internal DoD policy and procedure.

Increase MMRP Training Opportunities for State Regulators

- Attend training on munitions risk management, remedial decision making, and appropriate remedies. The DoD and US EPA offer training on MR-QAPP and other munitions specific content to help State regulators build their knowledge of MMRP outside of project-specific experiences.

Recognize the Unique Challenges of UU/UE Determinations at MMRP Sites

- Understand the acute and potentially extreme risks associated with UU/UE at MMRP sites. As the steward of the land in perpetuity, it is the State regulator's responsibility to understand the multiple lines of evidence, and to support the most responsible approach to reach protectiveness for human health and the environment at MMRP sites.

If UU/UE is not Realistic Based on Active Measures Alone, LTM Measures Can Support an Effective Remedy

- Oftentimes, UU/UE is not feasible at an MMRP site. That is why land use controls to implement LTM exist as a remedial alternative. Recognize that long-term costs for LTM can be low initially compared to removal costs but can also accumulate over time. LTM can be an effective deterrent to potential receptors and can help to significantly reduce MMRP site risks.

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