APPENDIX B

Overview and Detailed Description of the Interim Range Rule Risk Methodology (R3M)

Overview and Detailed Description of the Interim Range Rule Risk Methodology (R3M)[4]

BACKGROUND

The U.S. Department of Defense (DOD) proposed a Range Rule to evaluate response actions on closed, transferred, and transferring (CTT) ranges (DOD 1997). Response actions address safety, human health, and the environment. The rule contains a five-part process that is not inconsistent with Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). It is tailored to the special risks posed by military munitions and military ranges. The rule required DOD to develop a process to address risks from military munitions, unexploded ordnance (UXO), and other constituents. The rule also required the process to incorporate (to the maximum extent possible) the protocols developed by the U.S. Environmental Protection Agency (EPA) to assess acute and chronic risks posed by releases at sites regulated under CERCLA and the Resource Conservation and Recovery Act (RCRA) (DOD 1997).

Following publication of the Proposed Range Rule, it was apparent that a comprehensive process to manage, assess, and communicate risks at CTT ranges was needed. In response to this need, DOD and EPA collaboratively developed a quantitative, three-phased military munitions and UXO safety risk model (QRE, SRE, DRE). The basic concepts of the model, including the quantitative output of exposures in a 1×10^{-6} format, were presented to the Range Rule Partnering Initiative in Reno, Nevada on December 3, 1997. Concerns led to the formation of an Interim R3M Partnering Initiative geared toward development of a completely different and qualitative R3M. This partnering effort was formed to provide a forum where Federal and State environmental regulators, tribal governments, and public representatives could raise concerns, formulate resolutions, and develop a widely accepted R3M.

DOD hosted a series of meetings and teleconferences with the Partnering Initiative to produce the current version of the Interim R3M (March 2000). Those invited to participate include Federal non-DOD agencies such as EPA and the U.S. Departments of Interior, Agriculture, and Energy. Other groups such as state agencies, Native American tribal governments, and several non-government organizations (e.g., Association of State and Territorial Solid Waste Management Officials [ASTSWMO] and Center for Public Environmental Oversight [CPEO]) were invited to participate.

The Partnering Initiative split the R3M development process into two separate phases: an Interim R3M and a Final R3M. The Interim R3M focuses on risk reduction. This Interim R3M underwent a Preliminary Validation aimed at testing the general application of the models on military ranges where assessment and response actions already have taken place or are ongoing. The Final R3M was to be developed after the Interim R3M and would contain the additional criteria and tools necessary to complete the range response process, specifically addressing the Recurring Review Phase and Administrative Close Out.

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[4] Overview summarized from text included in the DOD Interim R3M Deliberative Draft Version, May 1999 and DoD Draft Interim R3M, March 2000.

NATURE OF RISK

The National Academy of Sciences (NAS) defines risk as the potential for adverse effects to an exposed population (NAS 1983). It is a function of the probability of an accident (or adverse situation) occurring within a certain period of time and resulting in consequences to people, property, or the environment. More recently, other groups have developed a definition of risk that seems more specific to risks at CTT ranges. The Interim R3M Partnering Initiative agreed in September 1998 to adopt the following definition of risk from the Presidential/Congressional Commission on Risk Assessment and Risk Management, 1997:

> Risk is the probability that a substance or situation will produce harm under specified conditions and is a combination of two factors: (1) the probability that an adverse event will occur, and (2) the consequences of an adverse event.

EPA has developed general risk assessment methods for evaluating human health and environmental risks at hazardous and toxic waste sites that follow the basic relationship established by NAS. These general risk assessment methods are conducted through four basic steps: (1) hazard identification, (2) exposure assessment, (3) dose response modeling, and (4) risk characterization (NAS 1983, EPA 1989). These methods are typically used to quantify risk from long-term, chronic exposure to low level chemical contamination.

Explosives Safety risks can occur when a military munition detonates or functions. These risks are associated with physical forces (e.g., thermal transfer, overpressure, fragmentation, and impact). Exposure to military munitions and OE can occur if a receptor enters a range with military munitions or OE, or if they are removed from a range. The explosives safety threat from military munitions and OE, however, typically results from a single exposure and may have one of three outcomes: no effect; injury; or death. Therefore, the established methods for characterizing risk associated with chemical exposures are not directly applicable to explosive safety risks. Consequently, analytical tools to assess the unique nature of explosive safety risks have been developed and incorporated into the Interim R3M.

NATURE OF EXPLOSIVES SAFETY RISK

The potential for risk depends on the presence of three critical items: a source of contamination (in this case, military munitions or OE), a pathway, and a receptor. Without a source (such as presence of military munitions or OE), a pathway (such as range access), or a receptor (such as someone in close proximity to military munitions or OE), no potential for risk exists. Military munition and OE risk for a range may be based on the characterization of the source, the reasonableness of the potential pathway, and the ease or frequency with which a receptor has exposure to military munitions or OE. These are critical concepts that the project team must understand in order to evaluate the potential risks posed by military munitions and OE at a range. The following critical items form the basis for assessing explosives safety risks:

- Potential accessibility of receptors to UXO
- Overall UXO hazard
- Relative exposure potential (allowing for an encounter)

When collecting data to estimate explosive safety risk, certain information is required:

- The relative exposure potential, including consideration of the following characteristics of receptor behavior:
  - Frequency of range entry
  - Intensity of activity

- The military munition and UXO density on the range

- The types of military munitions and UXO, including consideration of:
  - Scale of impact
  - Sensitivity
  - Portability

- The potential accessibility of receptors to military munition and UXO, including consideration of:
  - Military munition or UXO depth
  - Intrusion level of activities
  - Natural migration

<table>
<tr><th>ACCESIBILITY</th><th>OVERALL HAZARD</th><th>EXPOSURE</th></tr>
<tr><td><u>SUBFACTORS</u>
• Depth Below Ground Surface
• Migration/Erosion Potential
• Intrusion Level of Activity</td><td><u>SUBFACTORS</u>
• UXO Hazard Type
• Fuzing
• Amount of Energetic Material</td><td><u>SUBFACTORS</u>
• Frequency of Entry
• UXO Density
• Intensity of Activity
• Portability</td></tr>
<tr><td>↓</td><td>↓</td><td>↓</td></tr>
<tr><td>Accessibility
Weighting Factors and Scoring Rules</td><td>Overall Hazard
Weighting Factors and Scoring Rules</td><td>Exposure
Weighting Factors and Scoring Rules</td></tr>
<tr><td>↓</td><td>↓</td><td>↓</td></tr>
<tr><td>ACCESSIBILITY SCORE</td><td>OVERALL HAZARD SCORE</td><td>EXPOSURE
SCORE</td></tr>
<tr><td>↓</td><td>↓</td><td>↓</td></tr>
<tr><td colspan="3">Explosive Safety Risk
Weighting Factors and Scoring Rules</td></tr>
<tr><td>↓</td><td>↓</td><td>↓</td></tr>
<tr><td colspan="3">EXPLOSIVE SAFETY RISK SCORE</td></tr>
<tr><td colspan="3">(Lowest Relative Hazard Level)
A
B
C
D
E
(Highest Relative Hazard Level)</td></tr>
</table>

ALGORITHMS

The Interim R3M contains several tools to aid decision-makers in assessing risk and evaluating response alternatives. These tools contain three common elements: input variables, process algorithms, and results. Using these tools, decision-makers assign scores to each input variable and use process algorithms to combine the input variables producing results. For example, a "process algorithm" combines scores for frequency of entry, UXO density, intensity of activity, and portability, which are all "input variables" in the Explosives Safety Risk Tool, to generate a "result" for exposure. This result is then combined with other variables to generate an overall result for explosive safety risk.

The Explosives Safety Risk Tool is composed of ten input variables. Three process algorithms combine these ten input variables into scores for accessibility, overall hazard, and exposure. A fourth process algorithm combines these three scores into a single score for explosives safety risk. Below are descriptions of these algorithms and a basic explanation of the logic behind each. In addition, the definition of scores is provided at the end of each section for your reference.

EXPLOSIVE SAFETY RISK

Risk is determined by: accessibility; overall hazard; and exposure. Where in accessibility and exposure equally affect the overall risk score and overall hazard is a modifying factor. Overall hazard is treated in this manner because it is difficult to change the overall hazard as a result of conducting a remedial action.

Some general observations associated with the risk algorithm are:

- When overall hazard is a 4 or a 5 it results in worsening the risk score by one, except in the case where accessibility and exposure are #2.
- The worse score between accessibility and exposure drive the risk score.
- There is no difference in the outcome scoring when accessibility and/or exposure are 1 or 2.

Explosive Safety Risk Algorithm

Score	Definition
A	Accessibility = 2, Overall Hazard = 3, Exposure = 2
B	Accessibility = 2, Overall Hazard = 5, Exposure = 2 **OR** Accessibility = 3, Overall Hazard = 3, Exposure = 3
C	Accessibility = 4, Overall Hazard = 3, Exposure = 4 **OR** Accessibility = 3, Overall Hazard = 5, Exposure = 3 **OR** Accessibility = 5, Overall Hazard = 3, Exposure = 2 **OR** Accessibility = 2, Overall Hazard = 3, Exposure = 5
D	Accessibility = 4, Overall Hazard = 5, Exposure = 4 **OR** Accessibility = 5, Overall Hazard = 3, Exposure = 5
E	Accessibility = 5, Overall Hazard = 5, Exposure = 5

ACCESSIBILITY

Accessibility is determined by: depth below ground surface; migration/erosion potential; and intrusion level of activity. The minimum depth at which the energetic ordnance items are found (relative to the maximum intrusion depth associated with the projected activities) for the land use in the area (currently or in the future) primarily drives the default scoring for the accessibility factor. Adjustments are made to reflect the potential for migration or erosion in the area. These adjustments are used to effectively reduce the minimum depth at which the ordnance items may be found.

Some general observations associated with the accessibility algorithm are:

- The worst score (5) is provided to those situations where ordnance is found at <1 foot (5).
- In situations where the ordnance depth is in the same range as the intrusion depth, thus an encounter is possible, the accessibility score will always be greater than or equal to 3. For example,
    - *If* ordnance is found at greater than or equal to one foot (shallowest OE found), the OE depth score is 4,
    - *And if* intrusion/ground disturbances are to a maximum of one foot with hand tools, the intrusion depth score is 2,

- ⇒ *Then*, assuming the migration/erosion is not significant or worse, there is a direct possibility of an encounter. Thus the overall accessibility score of 3 would be provided.
- ➢ When there is a buffer zone between the intrusion depth and the ordnance depth the score is either 1 or 2 (the two lowest scores). A buffer zone equates to a situation where ordnance is present at a greater depth than there is intrusion and significant erosion is not present. For example,
  - o *If* ordnance is at greater than four feet (shallowest OE found), the OE depth score is 2,
  - o *And if* intrusion/ground disturbances are to a maximum of two feet with mechanized equipment, the Intrusion depth score is 3,
  - ⇒ *Then*, unless migration was considered significant or worse, then the likelihood of an encounter is very low and an overall accessibility score of 2 would be provided.
- ➢ As the overlap between the ordnance depth and the intrusion depth increases the accessibility scores worsen.

Depth Below Ground Surface

Score	Definition
1	All UXO >10 feet below ground surface (bgs)
2	All UXO >4 feet bgs
3	All UXO >2 feet bgs
4	All UXO =1 feet bgs
5	All UXO <1 feet bgs

Migration/Erosion Potential

Score	Definition
1	Very Stable: no UXO will migrate
2	Minor Migration: UXO not expected to migrate due to reoccurring natural events; extreme natural events may cause migration
3	Moderate Migration: UXO may surface over a long period of time and/or through reoccurring natural events
4	Significant Migration: Reoccurring and extreme natural events will bring UXO to the surface
5	Highly Dynamic: UXO will surface within the first Recurring Review

Intrusion Level of Activity

Score	Definition
1	Non-Intrusive: Activity on the ground surface, none below the surface
2	Minor Intrusions: Activity only on ground surface, ground disturbances to a depth of 1 foot bgs and hand tools only
3	Moderate Intrusions: Ground disturbances to a depth of 2 feet bgs and intrusions by mechanized equipment
4	Significant Intrusions: Ground disturbances to a depth of 4 feet bgs and intrusions by mechanized equipment
5	Highly Intrusive: Ground disturbances greater than 4 feet bgs

Accessibility Algorithm

Score	Definition
1	Depth = 1, Migration = 2, Intrusion = 2
2	Depth = 1, Migration = 5, Intrusion = 5 **OR** Depth = 2, Migration = 5, Intrusion = 3
3	Depth = 2, Migration = 5, Intrusion = 5 **OR** Depth = 3, Migration = 4, Intrusion = 4 **OR** Depth = 4, Migration = 2, Intrusion = 2
4	Depth = 4, Migration = 5, Intrusion = 5
5	Depth = 5, Migration = 5, Intrusion = 5

OVERALL HAZARD

Overall Hazard is determined by: UXO hazard type; fuzing; and amount of energetic material. UXO hazard type is the primary driver for the overall hazard score. UXO hazard type is increased one level if the ordnance item is fuzed and decreased one level if it is not fuzed. In instances where you are not sure of the fuzing, or ordnance type, or there are mixed types/fuzing the tool relies on worst-case ordnance and fuzing status.

Some general observations associated with the overall hazard algorithm are:

- If the ordnance item has 10-100 lbs of energetic material, then the minimum overall hazard score is 2.
- If the ordnance item has greater than 100 lbs of energetic material the minimum overall hazard score is 3.

UXO Hazard Type

Score	Definition
1	Explosives substance or article very or extremely insensitive (DoD Class 1 Divisions 1.5 and 1.6)*
2	Moderate fire, no blast or fragment (1.4)
3	Mass Fire, minor blast, or fragment (1.3)
4	Non-mass explosion, fragment producing (1.2)
5	Mass explosion (1.1)

* DoD Ammunition and Explosives Hazard Classification Procedures: Joint Technical Bulletin, DoD 1998

Fuzing

Score	Definition
1	Not fuzed (low sensitivity)
2	Fuzed (high sensitivity)

AMOUNT OF ENERGETIC MATERIAL

Score	Definition
1	<0.5 lbs.
2	0.5 to 1 lbs
3	1 to 10 lbs
4	10 to 100 lbs
5	>100 lbs

Overall Hazard Algorithm

Score	Definition
1	(UXO Hazard + Fuzing) = 1, Energetic Material = 3
2	(UXO Hazard + Fuzing) = 2, Energetic Material = 4
3	(UXO Hazard + Fuzing) = 3, Energetic Material = 5
4	(UXO Hazard + Fuzing) = 4, Energetic Material = 5
5	(UXO Hazard + Fuzing) = 5 (maximum score), Energetic Material = 5

EXPOSURE

Exposure is determined by: frequency of entry; UXO density; intensity of activity; and portability. The exposure score is driven primarily by the frequency of entry and UXO density scores and minor adjustments are made in situations where either the intensity of activity and/or portability are at the worst-case or highest score (5).

Some general observations associated with the exposure algorithm are:

- The lowest score (1) is provided in situations where frequency and density are 2 or less and portability and intensity of activity are less than the worst-case (5).
  - This situation arises when no more than 8 people come on to the area in a given month (frequency of entry score #2), and there are less than 10 UXO per acre (density score #2). And those UXO are not portable by a child (portability #4) nor are they spending greater than 9 hours per day on the area, or using motorized vehicles to get around the area (intensity of activity #4).
- As either the frequency of entry or the UXO density increase there is a direct correlation to the increase in the exposure score. For example a frequency of entry or density of 4 directly results in an increase exposure to 3.
- The highest score (5) is provided in any situation where Frequency or Density are 5 and one of the modifying factors, portability and/or intensity are 5.

Frequency of Entry

Score	Definition
1	Rare: One or fewer range entries per month
2	Occasional: Two to 8 range entries per month
3	Often: Nine to 15 range entries per month
4	Frequent: Sixteen to 22 range entries per month
5	Very Frequent: More than 22 range entries per month

UXO Density

Score	Definition
1	<2 per acre
2	2-10 per acre
3	11-50 per acre
4	50-100 per acre
5	> 100 per acre

Intensity of Activity

Score	Definition
1	Very Low: Less than 1 hour per day and light activ ity
2	Low: Up to 3 hours per day and light activity
3	Moderate: Up to 6 hours per day and moderate or light activity
4	High: Up to 9 hours per day and moderate activity
5	Very High: Greater than 9 hours per day or heavy activity

Portability

Score	Definition
1	Not Portable
2	Portable by motorized vehicle/livestock (very low portability)
3	Portable by 2 adults (low portability)
4	Portable by 1 adult (moderate portability)
5	Portable by a child (easily portable)

Exposure Algorithm

Score	Definition
1	Frequency = 2, Density = 2, Intensity = 4, Portability = 4
2	Frequency = 3, Density = 3, Intensity = 5, Portability = 5
3	Frequency = 4, Density = 4, Intensity = 5, Portability = 5
4	Frequency = 5, Density = 5, Intensity = 4, Portability = 4
5	Frequency = 5, Density = 5, Intensity = 5, Portability = 5

VALIDATION[5]

DoD, EPA, and other members of the Interim R3M Partnering Initiative determined that Preliminary Validation should test the general application of the Interim R3M's tools, models, and protocols at military ranges where risk management actions have already taken place or are ongoing. The validation included testing the

- ***Explosive Safety Risk Assessment Tool***—looking specifically at the function of the utility of the risk assessment tools in aiding risk management.

The methodology used in testing each of the critical elements was developed based on the following guidelines:

- Use the general philosophy of the scientific, logical approach established by EPA to validate chemical data
- Follow concepts outlined in the Validation Concept Paper (DoD 1999b)
- Maintain the purpose of Preliminary Validation, which is to demonstrate the nationwide utility of the Interim R3M to support Range Rule promulgation (DoD 1997).

Although several standard techniques are available for conducting sensitivity analyses, each technique relies on different ways of systematically altering scores for input variables to evaluate changes to the results.

Two techniques were used to conduct sensitivity analyses for Interim R3M. Deterministic analyses were used to determine all theoretically possible results for each tool. That is, the deterministic analyses were used to determine how many times that scores of "A" through "E" would theoretically occur for each tool.

Probabilistic analysis was conducted to determine the dependence of each input variable relative to the result. In other words, it shows how much a result would change for a proportional change to an input variable. Sensitivity analysis is the computation of the effect of changes to input variables on the results. For quantitative models, sensitivity analysis evaluates mathematical equations used to combine multiple input variables into results. In the Interim R3M, the tools are qualitative. In place of equations, process algorithms are used to combine the input variables into qualitative results. (Scales ranging from "A" through "E" (for explosives safety) represent the input variables.) Thus, the sensitivity analysis for the Preliminary Validation of the Interim R3M evaluates changes from "A" through "E" for each input variable and evaluates their effect on the results.

The process of entering scores for each input variable, using a process algorithm, and recording results is repeated in the sensitivity analyses.

The results of the deterministic analysis are provided numerically and graphically. Below is the total number of possible scores and percentages for each score ranging from "A" through "E" for all the tools tested.

[5] Validation Overview from Draft Validation Report July 2000. Validation discussed in this section pertains only to the Explosives Safety Risk Assessment Tool.

EXPLOSIVES SAFETY RISK TOOL

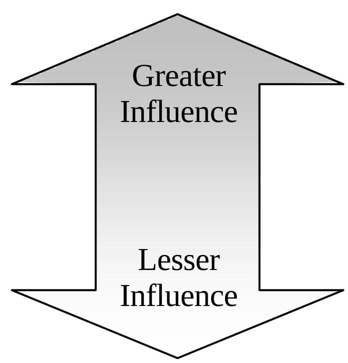
Score	Possible Outcomes	% of Possible Outcomes
A	229,500	6%
B	763,500	20%
C	**1,450,370**	**37%**
D	988,380	25%
E	474,500	12%
Total	3,906,250	100%

The most notable finding tabulated and illustrated above is that situations exist for every possible score. That is, it is possible to arrive at scores of “A” through “E” when using the tool. In addition, note that score of “C” represents the most likely outcome and the risk assessment more frequently provides a C to E outcome.

Below is an illustration of each input variable included in the analysis conducted. They are displayed from top-to-bottom in order of highest rank relative to its dependence on the result. The values provided for the correlation coefficients indicate the relative strength of the dependence between the input variable and result (i.e., coefficients closer to zero indicate weaker dependencies).

SENSITIVITY ANALYSIS: EXPLOSIVES SAFETY RISK TOOL

Depth	0.52
UXO Hazard Type	0.34
UXO Density	0.25
Frequency of Entry	0.25
Fuzing	0.18
Migration/Erosion	0.07
Intrusion Level of Activity	0.07
Intensity of Activity	0.05
Portability	0.04
Amount of Energetic Material	-0.00



The sensitivity analysis for the Explosives Safety Risk Tool evaluated changes to all ten of the input variables on explosives safety risk. Four process algorithms combine the ten input variables in the Explosives Safety Risk Tool. The analysis indicated that depth is the most sensitive input variable with respect to the explosives safety risk. This means that as the score for the depth variable increases, there is a consequent increase in the score for explosives safety risk. Note, that the scores for the depth variable increase as UXO becomes closer to land surface, so that UXO located at land surface has the highest score.

The sensitivities described compare well with the process algorithms in the Explosives Safety Risk Tool. For example, in examining the process algorithm for accessibility, lower scores for depth are paired with higher scores for migration/erosion and intrusion level of activity. This condition is indicative of higher sensitivity for depth than for migration/erosion and intrusion level in the accessibility process algorithm. Similar logic applies in interpreting the process algorithms for all the tools in the Interim R3M.

CURRENT STATUS OF THE INTERIM R3M

The Interim R3M has been put on hold with the latest available version dated March 2000 version. This was the version released for public comment. The public availability period resulted in the following general comments on the Interim R3M: concern about the method in which numbers are combined for final scores and concern about the sensitivity of the IR3M. Both of which can be modified with input from the stakeholders.

At this time there are validation comments, comments received from the public comment period, and an analysis of the strengths and the weaknesses conducted by the Interim R3M Partnering Initiative that have not been formally included in the March 2000 document. A full description of the comments and recommendations will be provided during the risk assessment meeting on July 17-18, 2001. This will set the stage for the Risk Assessment Team to move forward in evaluating and modifying the Interim R3M to meet the needs of the Ft. Ord OE RI/FS risk assessment.

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