Hazard Assessment for Munitions and Explosives of Concern: Workgroup Briefing Book

Section D: Table of Contents

HAZARD ASSESSMENT METHODOLOGY COMPARISON TABLE

The table that follows is designed to highlight the similarities and differences between four existing risk assessment methodologies (Interim Range Rule Risk Methodology (IR3M), Ordnance and Explosives Risk Impact Assessment (OERIA), Fort Ord Ordnance and Explosives Risk Assessment Protocol, and Adak Island OU B Explosives Safety Hazard Assessment Methodology). It is divided into four categories: Input Factors, Complexity, Output, and Other Comments, with details entered for each applicable category for each methodology.

The Input Factor Category outlines all of the input factors used in each method and describes the approach of each method. The intent is to provide information about the characteristics of each of these models in a comparative format so that the reader can easily identify items that are similar or different across the different methodologies.

		HAZARD ASSESSMENT METHODOLOGY COMPARISONS			
		IR3M	**OERIA**	**Fort Ord**	**Adak**
INPUT FACTORS					
Source/Hazard (inherent hazard of the UXO/MEC)	MEC type	UXO Hazard type, using a scale of 1 to 5 with 1 being the least hazardous and 5 being the most hazardous.	Uses a scale from 0 to 3 with 0 being inert and 3 being the most hazardous.	Munitions Type is categorized using a scale from 0 to 3 with 0 being inert, and 3 being potentially deadly.	Uses a scale from A to E where A means no explosive hazard and E indicates catastrophic hazard.
	Fuze sensitivity	Fuze Sensitivity uses a binary scale of 1 or 2 for fuzed or unfuzed.	Uses a scale from 0 to 3 with 0 being inert or scrap and 3 being very sensitive.	Because of the site-specific situation, the Ft. Ord protocol assumes worst case for fuzing—that all are fuzed.	Incorporated into value for MEC type.
	Amount of energetic material (Net Explosive Weight NEW)	Uses a scale from 1 to 5 with each number representing a range of energetic material by weight.	N/A	Because of the site-specific situation, the Ft. Ord protocol assumes that the NEW is inherent to the MEC type.	Uses a scale from A to E with each letter indicating a range of NEW.
	Distribution of UXO contamination	N/A	N/A	N/A	Uses a factor called “Ordnance Search/Removal status” which incorporates the distribution of UXO contamination. The factor categorizes the search/removal status using A or B, based on a number of criteria.
Pathway (accessibility/ activity)	Site accessibility	N/A	Uses descriptive terms for three categories of access ranging from complete restriction of access to no restriction of access.	N/A	N/A
	Current or future land use	N/A	N/A	N/A	Land use is a component of the Frequency of Entry Sub factor and is categorized using a scale from of A to D where A is subsistence and D is residential.

KEY:
IR3M=Interim Range Rule Risk Methodology
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NOTE:
These four methodologies are described in more detail in their individual methodology summaries, however this table is designed to highlight the similarities and differences between them.

		HAZARD ASSESSMENT METHODOLOGY COMPARISONS			
		IR3M	**OERIA**	**Fort Ord**	**Adak**
INPUT FACTORS, *continued*					
Pathway (accessibility/activity), *continued*	UXO depth	Uses a scale from 1 to 5 with each number representing a range for depth below ground surface with 1 being all UXO greater than 10 ft bgs and 5 being UXO less than 1 ft bgs.	N/A	Uses a scale from 1 to 8 with 1 being "all OE has been removed" and 8 indicating "OE on the surface".	Uses a scale from A to E with each number representing a depth range. A indicates all UXO is greater than 10 ft. bgs and E indicates all UXO less than 1 ft bgs.
	Migration/erosion	Uses a scale of 1 to 5 with 1 being very stable and 5 being highly dynamic.	Uses descriptive terms for three categories of site stability ranging from site stable to site unstable.	Uses a scale from 1 to 3 with 1 being very stable and 3 being significant migration.	Uses a scale from A to E with A being very stable and E being highly dynamic.
	Intensity of activity	Uses a scale of 1 to 5 with 1 being very low intensity activity and 5 being very high intensity activity.	N/A	Uses a scale of 1 to 5 with each number representing a range of hours of activity each day, 1 being the lowest amount of activity and 5 being the highest.	Uses a scale from A to C with A being Low and C being High.
	Activity	N/A	Uses a table that incorporates a description of the activity type (such as children playing, jogging, etc), the actual depth of munitions (using ranges from 0 to 12") and a description of the probability level of contact (significant, moderate or low)	N/A	N/A
Receptor (probability of encounter)	Frequency of entry	Uses a scale of 1 to 5 with 1 being rare and 5 being very frequent	N/A	Uses a scale of 1 to 4 with 1 being rare and 4 being frequent.	Made up of two components: Ease of Access, and Current and/or Future Land Use.

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INPUT FACTORS, *continued*					
Receptor (probability of encounter)	Ease of Access	N/A	N/A	N/A	Is a component of Frequency of Entry and is measured on a scale of A to E with A being inaccessible and E being an Area served by an improved road.
	Intrusion level of activity	Uses a scale of 1 to 5 with 1 being non-intrusive and 5 being highly intrusive.	N/A	Uses a scale from 1 to 5 with 1 being non-intrusive and 5 being highly intrusive.	Uses a scale from A to E with A being non-intrusive and E being highly intrusive.
	UXO density	Uses a scale of 1 to 5, with each number representing a range of UXO per acre.	N/A	Uses a scale from 1 to 4 where 1 indicates that 100% of UXO was removed to the level of intensity and 4 means high density, or more than 1 item per acre.	N/A
Receptor (probability of encounter), *continued*	Population	N/A	The population is entered into the Risk Evaluation table. Population refers to the number of people using the site and the frequency of that use.	N/A	N/A
	Portability	Uses a scale from 1 to 5 with 1 being not portable and 5 being portable by child.	N/A	N/A	Uses a scale of A to C with A being very low, not portable and C being easily portable.

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	IR3M	OERIA	Fort Ord	Adak
HAZARD ASSESSMENT METHODOLOGY COMPARISONS				
METHOD COMPLEXITY				
	Complex This method uses a 7-step process to assess risk and follow through the whole series of actions and closeout. There are ten sub factors, in three factor categories; all evaluated using detailed weighting and scoring rules.	Simple This method uses six input factors and table to combine them into a qualitative risk assessment. The purpose is to create a risk assessment that is easily understood by stakeholders.	Moderate. This method streamlines input factors to meet the specific site situation, and also uses matrices in place of algorithms to increase understanding of the method.	Moderate This method somewhat streamlines input factors than IR3M and uses more qualitative measures for those input factors. It does use scoring and weighting factors in a scoring matrix.
OUTPUT				
	The first three steps deal with the assessment and evaluation of risk. Information on the input factors is combined to obtain a qualitative Baseline Explosives Safety Risk Score. A similar process is used to determine a score for the Baseline Other Constituents Risk Assessment.	"The OERIA provides a qualitative risk assessment in lieu of a statistically based risk assessment that will allow more effective, clear risk communication among all stakeholders." The end result is a ranking of response alternatives with the alternative with the highest impact (i.e. most reduction in risk) ranked with an 'A'.	The scores from each input factor are combined to obtain an Overall OE Risk Score, which is ranked with A having the lowest overall risk and E having the highest overall risk. "The Fort Ord OE Risk Assessment Protocol is not designed to assess absolute risk. Rather, the Overall OE Risk score is used to compare the relative risks among remedial alternatives on an OE-impacted sector at Fort Ord."	The scores for each input factor are combined to obtain an overall "relative explosives safety hazard categorization. This categorization may be used to support making a binary risk management decision for an AOC in the baseline risk assessment, or to form the basis of an assessment of hazard reduction potential afforded by a particular remedial response option based on a five-step scale from lowest relative hazard to highest relative hazard."

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	HAZARD ASSESSMENT METHODOLOGY COMPARISONS			
	IR3M	**OERIA**	**Fort Ord**	**Adak**
OTHER COMMENTS				
	The full IR3M process is designed to carry the project team not only through risk assessment, but also through the steps of choosing a response action and carrying it through to completion. This is a 7-step process which involves extensive data collection. Risk is evaluated in the first three steps of the process. Steps 4 through 7 deal with implementation once risk is evaluated	The first step of this three-step process includes an opportunity to identify additional factors that may be needed in the analysis, based on the specific site and situation.	The methodology is based on the IR3M but adapted specifically for use at Ft. Ord. The full Ft. Ord methodology specifies the changes it made from IR3M, however of particular note the Ft. Ord Methodology uses matrices instead of "process algorithms" in determining the risk calculation. In addition some of the inputs were streamlined and adapted to the specific site (see Source/ Hazard above)	The methodology is based on the IR3M but adapted specifically for use at Adak Island. The full source document details the differences between the two methodologies, however they particularly adapted the inputs for the unique situation of Adak Island. In addition the project team made changes to make the method more qualitative in its assessment of UXO hazard.

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GENERAL INFORMATION	
METHODOLOGY NAME / ID	Adak Island Operable Unit B Explosives Safety Hazard Assessment Methodology
DEVELOPER	
PUBLISHED SOURCE	Adak Island Operable Unit B Explosives Safety Hazard Assessment Methodology, Draft Version 11
DATE OF PUBLICATION	January 26, 2001
PEER REVIEW	None
PURPOSE	The purpose was to develop a site-specific methodology to address the munitions concerns at Adak Island, Alaska. It is based on an evaluation of the IR3M risk assessment methodology. This evaluation resulted in the development of a qualitative Adak-specific ordnance hazard assessment framework that makes use of a combination of quantitative and qualitative inputs.
PAST APPLICATIONS	Not applicable
SITE SPECIFIC SUITABILITY	This methodology was specifically developed for Adak Island, and is not a general approach.

OUTPUTS	
DEFINITION OF RISK	Not specified
HOW RISK IS ESTIMATED	Using an approach based on the IR3M process risk is estimated using both quantitative and qualitative inputs. "The overall framework and the hazard assessment scoring, however, are qualitative in nature. The assessment has the objective of assigning relative scores to qualitative estimates of the potential OE/UXO hazard for each Area of Concern on the Island; not defining quantitative measures of known risk."
KEY ASSUMPTIONS	The methodology "reflects the following premises about ordnance risk or hazard on Adak: • areas where OE/UXO are known or indicated to be present create more potential for explosive hazards than areas where ordnance items have been purposefully searched for and have not been found or where all known ordnance items in the area have been removed; • different types of ordnance present more or less potential to detonate if disturbed, and, if detonated, can produce a range of potential consequences; • the potential for explosive hazards is created when energetic ordnance items are located at a depth in the ground where they would be likely to be disturbed by current and/or future projected activities in the area; and • there is greater potential for explosive hazards when the opportunity for public exposure is greatest (e.g., people interact with the land more intensively or the area is easier to access and utilize)."

INTERFACE WITH RISK MANAGEMENT	A series of scoring rules and weighting factors are proposed for combining the sub factor characteristics into a qualitative summary score for each of the four primary hazard factors (with the exception of Ordnance Search/Removal Status which is not further broken down into sub factors). In the case of the sub factor for Frequency of Public Access, an initial scoring matrix is used to develop a qualitative sub factor score from the component scores for the relative Ease of Access to the area and the Current and/or Future Land Use for the area. Another set of scoring rules and weighting factors is then used to combine the four primary hazard factors to obtain a relative explosives safety hazard categorization. This categorization may be used to support making a binary risk management decision for an AOC in the baseline risk assessment (i.e., "Adak NOFA/Baseline Institutional Controls" (as defined specifically for Adak) vs. "Further Evaluation in the Feasibility Study"), or to form the basis of an assessment of hazard reduction potential afforded by a particular remedial response option based on a five-step scale from lowest relative hazard to highest relative hazard."

INPUTS	
SOURCES OF DATA/INFO	Both qualitative and quantitative data are used in this process and combined using a series of scoring rules and weighting factors. Some specific sources of information are identified (e.g. an EOD identification guide, historical land use maps, etc) in the publication.
DATA QUALITY PROCESS	Uses EPA's Data Quality Objective process.
RISK INPUT FACTOR	**ORDNANCE SEARCH/REMOVAL STATUS**
SUB FACTOR NAME	SCALE
Ordnance Search/Removal Status	**A=OE Not Found or OE Detected and Removed** One of the following conditions must be true to assign a score of "A" to an area: 1. OE are not detected during a 100% geophysical survey. 2. OE are only detected below the projected activity intrusion depth during a 100% geophysical survey. 3. OE are detected during a 100% geophysical survey and are removed. 4. OE are not detected during a <100% geophysical survey approved for the designated AOC type. 5. Only OE associated with a different AOC type are detected during a <100% geophysical survey approved [4] for the designated AOC type (i.e., only non-confirming OE finds) and are removed. 6. Single items of OE are detected during a <100% geophysical survey approved for the designated AOC type. The item is removed and subsequent grid or star pattern searches indicate that no other OE is present. B=OE Known or Indicated to be Present

	One of the following conditions must be true to assign a score of "B" to an area: 1. OE are detected above the projected activity intrusion depth during a 100% geophysical survey and are not removed. 2. Any OE are detected during a <100% geophysical survey approved for the designated AOC type and are not removed. 3. OE associated with the designated AOC type are detected during a <100% geophysical survey approved [4] for the designated AOC type. Any other condition not covered by the set of conditions defined for Category A above.
RISK INPUT FACTOR	**ORDNANCE CHARACTERISTICS**
SUB FACTOR NAME	SCALE
Ordnance Hazard Severity (Type and Fuzing)	A=No Explosive Hazard, Non-energetic objects including ordnance debris and practice ordnance without spotting charges which present no explosive hazard in the event of disturbance or exposure. B=Negligible Hazard, Complete and ready to fire small arms ammunition (including blanks) 0.50 caliber or less (including the projectile, case, powder and primer). C=Marginal Hazard, Ordnance and energetic items that have not been deployed as designed or have been subjected to attempted disposal by discarding or burial. (This category does not include any fuzed items or ordnance items for which the fuzing is uncertain.) D=Critical Hazard, All ordnance and energetic items in any configuration that have been deployed and failed to function as designed. This category includes all fuzed, armed, dud fired items with the exception of the Catastrophic Hazard ordnance in Category E and any items that have been subjected to attempted disposal by detonation or burning. (This category includes all fuzed items or items for which the fuzing is uncertain.) E=Catastrophic Hazard, Highest hazard ordnance including ordnance items with highly sensitive fuzing (such as 40mm anti-personnel projectiles), emplaced minefields, and chemical warfare materiel (CWM)
Amount of Energetic Material (Impact Scale)	A=< 0.5 pounds NEW [1,3] B=0.5 to 1.0 pounds NEW C=1 to 10 pounds NEW D=10 to 100 pounds NEW E=> 100 pounds NEW.
RISK INPUT FACTOR	**ORDNANCE ACCESSIBILITY**
SUB FACTOR NAME	SCALE
Depth Below Ground Surface	A= all UXO is >10 ft. B= all UXO is >4 ft. C= all UXO is >2 ft. D= all UXO is ≥1 ft. E= all UXO is <1 ft.

Migration / Erosion Potential	A=*Very stable*: Ordnance will not migrate. B=*Moderate*: Ordnance may surface over long period of time and/or through recurring natural events. C=*Significant*: Recurring and extreme natural events will bring ordnance to surface within first recurring review.
Level of Public Activity (Intrusion Depth)	A=*Non-intrusive*: Activity on ground surface only B=*Minor intrusions*: active on surface and with hand tool to 1 ft. C=*Moderate intrusions*: Ground disturbance with equipment to 2 ft. D=*Significant intrusions*: Ground disturbance with equipment to 4 ft. E=*Highly intrusive*: Ground disturbance more than 4 ft.
RISK INPUT FACTOR	**PUBLIC EXPOSURE**
SUB FACTOR NAME	SCALE
Frequency of Public Access Sub factor (Includes Components: Ease of Access and Current and/or Future Land Use)	
Ease of Access Component	A=*Inaccessible*. Area with a slope greater than 30%, or an area completely surrounded by area with a slope greater than 30% B=*No Established Road, Trail or Boat Access*. All cases that are not Category A or Categories C through E C=*Area Served by an Established Trail*. An established trail leads up to or passes through the AOC boundary D=*Area Containing a Cabin, Served by an Unimproved Road, Near a Historically Used Boat Landing, or Near a Recreational Lake or Beach*. An occupiable cabin maintained by U.S. F&WS or maintained by the U.S. Navy within the AOC boundary; or an unimproved road passes through or within 1/8 mile of the AOC boundary; or an historically used boat landing area is located on the boundary of the AOC or within 1/4 mile of the AOC boundary, or the shoreline of a documented recreational lake or section of ocean beach is within the AOC or within 1/50 mile of the AOC boundary E=*Area Served by an Improved Road*. A road that has an improved surface passes through or within 1/4 mile of the AOC boundary
Current and/or Future Land Use Component	A=Subsistence, Recreational or Wildlife Management. Land Use Outside the Core Development Area. As indicated on the Future Land Use Projection Map for Adak Island - See Attachment D B=Subsistence, Recreational or Wildlife Management Land Use Within the Core Development Area. As indicated on the Future Land Use Projection Map for Adak Island - See Attachment D C=Aviation / Commercial / Marine Industrial / Public Facilities Land Use. As indicated on the Future Land Use Projection Map for Adak Island - See Attachment D D=Residential Land Use. As indicated on the Future Land Use Projection Map for Adak Island - See Attachment D
Intensity of Public	A=Low. Typically associated with activities such as hunting,

Activity (Energy Imparted to the Ground)	hiking, fresh water fishing and beach combing. B=Moderate. Typically associated with activities such as salt-water fishing, long term camping, residential landscaping, or off-road driving by a wildlife manager or researcher. C=High. Typically associated with activities such as excavation or demolition activities, post hole digging, vehicle parking on an unpaved surface, or off-road driving by a subsistence hunter/fisherman or member of the general public.
Portability	A=Very Low. Not portable or portable only by motorized vehicle or livestock B=Low. Portable by 1 or more adults without mechanical assistance C=Easily Portable. Portable by a child

GENERAL INFORMATION	
METHODOLOGY NAME / ID	Fort Ord Ordnance and Explosives Risk Assessment Protocol
DEVELOPER	The Fort Ord OE Risk Assessment Protocol was prepared through a combined effort of the Army, the California Environmental Protection Agency's Department of Toxic Substances Control (DTSC), and the United States Environmental Protection Agency (EPA).
PUBLISHED SOURCE	Final, Fort Ord Ordnance And Explosives Risk, Assessment Protocol Based On Outcomes Of Ordnance And Explosives Risk Assessment Project Team Meetings
DATE OF PUBLICATION	October 2002
PEER REVIEW	None
PURPOSE	The purpose of the Protocol is to allow for review of ordnance and explosives (OE) risks at OE-impacted sites at the former Fort Ord Installation.
PAST APPLICATIONS	Not applicable.
SITE SPECIFIC SUITABILITY	The protocol is based on the IR3M, adapted specifically for use at Ft. Ord.

OUTPUTS	
DEFINITION OF RISK	The probability that a substance or situation will produce harm under specified conditions. Risk is a consideration of two factors: (1) the probability that an adverse event will occur, and (2) the consequences of an adverse event.
HOW RISK IS ESTIMATED	The Fort Ord OE Risk Assessment Protocol is a qualitative risk assessment approach based on seven input factors. The input factors are both qualitative and quantitative. Two process matrices combine six of the input factors into scores for Accessibility and Exposure. A third process matrix combines the scores for Accessibility, Exposure, and Overall Hazard (the seventh input factor) into a single qualitative score for estimating OE Risk. The output of the approach was tested using a sensitivity analysis and a Beta Test to determine effectiveness. The results of these tests were used to improve the OE risk assessment approach, and to ensure that the drafted approach was fully implementable.
KEY ASSUMPTIONS	The overall OE risk score determined using this Protocol should not be compared to other OE- impacted facilities because it was developed using site-specific categories. The overall OE risk score will be reevaluated as part of the five-year reviews of Fort Ord.
INTERFACE WITH RISK MANAGEMENT	The Fort Ord OE Risk Assessment Protocol is not designed to assess absolute risk. The overall OE risk score is an approach for comparing the relative risks between remedial alternatives on an OE-impacted site at the Fort Ord facility.

INPUTS	
SOURCES OF DATA/INFO	A wide variety of historical and field data specific to the site.
USE OF STATISTICS	Not applicable.
DATA QUALITY PROCESS	Data Quality Objectives process.
RISK INPUT FACTOR	**Accessibility Factor**
SUB FACTOR NAME	SCALE
Depth Below Ground Surface	1=100% of detected OE was removed considering the data quality for the site 2=All OE > 5 feet bgs 3=All OE > 4 feet bgs 4=All OE > 3 feet bgs 5=All OE > 2 feet bgs 6=All OE > 1 foot bgs 7=No OE on the surface and OE below surface 8=Any OE on surface
Migration/Erosion	1=very stable: OE will not migrate. Erosion is equal to or less than the sitewide average of 3/100 inch per year. 2=minor Migration: Recurring and extreme natural events may cause OE to migrate upward, potentially reaching the intrusion level, over a long period of time (more than two five-year reviews). Erosion is greater than the average condition but less than one inch per year. 3=significant migration: Recurring and extreme natural events will bring OE to the surface within the first recurring review. Erosion is more than one inch per year.
Level of Intrusion	1=Non-Intrusive: Activity on the ground surface, none below the surface 2=Minor Intrusions: Activity on ground surface and ground disturbances to a depth of one foot bgs 3=Moderate Intrusions: Ground disturbances to a depth of two feet bgs 4=Significant Intrusions: Ground disturbances to a depth of four feet bgs 5=Highly Intrusive: Ground disturbances greater than four feet bgs

RISK INPUT FACTOR	**Overall Hazard**
SUB FACTOR NAME	SCALE
OE Hazard Type	Unlike IR3M, because of the site-specific situation, the Ft. Ord protocol assumes worst case for fuzing and that the NEW is inherent to the ordnance type. Therefore, all items are considered to be fuzed and NEW is incorporated in the development of the OE Type. 0=Inert OE, will cause no injury 1=OE that will cause an injury, in extreme cases could cause major injury or death, to an individual if functioned by an individual's activities 2=OE that will cause major injury, in extreme cases could cause death, to an individual if functioned by an individual's activities 3=OE that will kill an individual if detonated by an individual's activities
RISK INPUT FACTOR	**Exposure**
SUB FACTOR NAME	SCALE
Frequency of Entry	1=*Rare*: Is not likely to occur (less than once per year to once per year) 2=Infrequent: Will seldom occur (less than once per season to once per month) 3=Occasional: Will likely occur from time to time (more than once per month) 4=Frequent: Will occur frequently (once a week to more than once a week)
UXO Density	1= 100% of detected OE was removed to the Level of Intrusion 2=Low OE Density (< 0.1 items per acre) 3=Medium OE Density (0.1 to 1 items per acre) 4=High OE Density (> 1 items per acre)
Intensity of Activity	1=very low, $\leq$1 hour/day 2=low $\leq$3 hours/day 3=moderate $\leq$6 hours/day 4=high $\leq$9 hours/day 5=very high >9 hours/day.
Portability	The vast majority of expected OE at Ft. Ord are small and quite portable. Therefore portability it assumed to be worst-case and not included as a separate factor.

GENERAL INFORMATION

METHODOLOGY NAME / ID	The Fort Meade Risk Assessment Methodology
DEVELOPER	U.S. Army Environmental Center Aberdeen Proving Ground and Science Applications International Corporation (SAIC)
PUBLISHED SOURCE(S)	"Risk Assessment Methodology for use in Managing Sites Containing Unexploded Ordnance". By S. A Hill (U.S. Army Environmental Center) and F. A Zafran, J. Skibinski, A. N. Unger, M. B. Lustik and L. G. Cain (SAIC); Proceedings of the UXO Forum '96, Williamsburg, VA. "UXO Risk Assessment Methodology Developed for Fort Meade Base Realignment and Closure Parcel", By S.A. Hill, U.S. Army Environmental Center, Aberdeen Proving Ground.
DATE OF PUBLICATION	1996
PEER REVIEW	None

PURPOSE	To evaluate the UXO risk present at Ft. George G. Meade [Base realignment and Closure (BRAC) installation] and to form the basis for risk management decisions with the goal of creating an acceptably safe reuse of the property.
PAST APPLICATIONS	Only known application
SITE SPECIFIC SUITABILITY	Developed specifically for Ft. Meade. May or may not be translated to other sites.

OUTPUTS	
DEFINITION OF RISK	"Risk" is the probability that a receptor will encounter at least one UXO per day of activity. Risk is defined as a single contact of any type with the subject UXO. It assumes a single, simple exposure endpoint.
HOW RISK IS ESTIMATED	The probability that the receptor does not avoid all UXO present (i.e., that there is at least one exposure to UXO) is calculated quantitatively using an algebraic relationship.
RISK EXPRESSION	For Relatively Greater Risk: $R_k = 1 - [1 - [a/A(k)]]\text{^}[m_k * A(k)]$ For Small Risk (linear approximation); $R_k = [s_k * a / A(k)]$

PARAMETER DEFINITIONS	R_k = Probability that the receptor does not avoid all UXO a = Area impacted by the specified activity [acres] A(k)= Area of the subarea or sector being investigated [acres] k = the "k^{th}" subarea or sector being investigated [index] m_k = Average UXO density in the subarea [UXO/acre] s_k = Number of UXO in the subarea being investigated [#]
KEY ASSUMPTIONS	• The study area is divided into subareas within which the distribution of UXO is considered to be random and homogeneous (enabling the Poisson statistical distribution to be used to describe the spatial distribution of UXO). This results in the distribution having the following properties: 1. The number of UXO in the defined subareas is independent of the number that occurs in any other area; 2. The probability of finding ordnance in a very small area is proportional to the size of the area and does not depend on the number of UXO found outside that small area; and 3. The probability that more than one UXO will be found in a very small area is considered negligible.
INTERFACE WITH RISK MANAGEMENT	Deterministic and probabilistic (80% confidence intervals) on the probability of UXO exposure are projected for different levels of UXO removal and reuse scenarios. No explicit linkage to risk management decision criteria associated with acceptability are provided.

INPUTS	
SOURCES OF DATA/INFO	Map evaluation to determine the overall size of the subarea or sector; pecification of a certain amount of area within the subarea to be investigated (here approximately 30 acres out to 8,895 acres, or 0.33%); Field investigation to collect data on the numbers, type, depths, and locations of UXO by depth interval.
DATA QUALITY PROCESS	Not explicitly noted
ROLE(S) OF STATISTICS	Statistically-based survey of the land parcel using a systematic random grid sample design; Grids to be surveyed were selected randomly; Deterministic and probabilistic estimates of site characteristics and risk (i.e., probabilities of exposure) were developed (80% confidence intervals); Descriptive statistics used to estimate the point estimates of the UXO densities (e.g., # UXO found / are investigated).

GENERAL INFORMATION	
METHODOLOGY NAME / ID	Interim Range Rule Risk Methodology
DEVELOPER	Department of Defense
PUBLISHED SOURCE	R3M: RANGE RULE RISK METHODOLOGY, A Process for Managing, Assessing, & Communicating About Risk on Closed, Transferred, or Transferring U.S. Ranges, INTERIM PROCEDURES MANUAL
DATE OF PUBLICATION	January 2000
PEER REVIEW	
PURPOSE	"The Department of Defense (DoD) has developed a comprehensive process for managing, assessing, and communicating about risk on these former ranges located within the United States. Under the proposed Range Rule (1997), DoD has developed the R3M, a process to effectively manage risks posed by unexploded ordnance and other constituents often found on former military training areas."
PAST APPLICATIONS	Not applicable
SITE SPECIFIC SUITABILITY	The methodology involves detailed site evaluation in the first three steps, so that response actions are based on the site-specific evaluation data.

OUTPUTS	
DEFINITION OF RISK	Risk is the probability that a substance or situation will produce harm under specific conditions. It is an important part of the Risk Methodology Process as Project Teams try to assess, communicate and manage risk to minimize any effects unexploded ordnance or other constituents may have on people or the environment.
HOW RISK IS ESTIMATED	The R3M process uses a 7-step process and extensive data collection. Risk is evaluated in the first three steps of the process: **Step 1 – Range Identification**, involves verifying the status of the range. At any step, If data suggests that there is an immediate danger to human health or the environment, an accelerated response may also be undertaken. **Step 2 – Range Assessment**. The project team conducts a preliminary study to assess the nature of the hazards in the response area. **Step 3 – Range Evaluation.** This step involves a more detailed study and further evaluation of the hazards, particularly in terms of location and type of hazard.
KEY ASSUMPTIONS	Specific assumptions not delineated, however the project team are instructed to be aware of assumptions that may affect the data collection process.

INTERFACE WITH RISK MANAGEMENT	Steps 4 through 7 deal with the implementation once risk is evaluated, as outlined below: **Step 4 – Response Selection.** Data collected in steps 2 & 3 is used to evaluate possible response actions and selects the one most appropriate for the risk reduction goals. Nine criteria are used in the evaluation: 1) Overall protection of human health and the environment 2) Compliance with ARAR's 3) Long term effectiveness and Permanence 4) Reduction in Toxicity, Mobility and Volume 5) Short term effectiveness 6) Implementability 7) Cost 8) Acceptance by appropriate regulatory agencies or agencies with jurisdiction over affected resources 9) Community acceptance **Step 5 – Site-Specific Action.** The response actions are implemented and evaluated for effectiveness and whether goals are met. **Step 6 – Recurring Review.** After implementation, the team reevaluates conditions and potential new developments or technologies. **Step 7 – Close-Out.** When decision-makers have sufficiently determined that actions continue to protect human health and the environment, Closeout can be considered. However, operations and maintenance activities may still be occurring.

INPUTS	
SOURCES OF DATA/INFO	Each data input opportunity includes a question regarding the source of information, whether it is "actual data" or "best professional judgment."
DATA QUALITY PROCESS	Uses the Data Quality Objective process, developed by EPA, to ensure that the appropriate type, quality, and quantity of data are gathered to make informed decisions.
ROLE(S) OF STATISTICS	Not applicable
RISK INPUT FACTOR	**Accessibility Factor**
SUB FACTOR NAME	SCALE
Depth Below Ground Surface	1= all UXO is >10 ft. 2= all UXO is >4 ft. 3= all UXO is >2 ft. 4= all UXO is ≥1 ft. 5= all UXO is <1 ft.

Migration/Erosion	1=*Very stable*: No UXO will migrate. 2=*Minor migration*: UXO not expected to migrate due to recurring natural events. 3=*Moderate migration*: UXO may surface over long period of time and/or through recurring natural events. 4=*Significant migration*: Recurring and extreme natural events will bring UXO to surface 5=*Highly dynamic*: UXO will surface within first recurring review
Intrusion Level of Activity	1=*Non-intrusive*: Activity on ground surface only 2=*Minor intrusions*: active on surface and with hand tool to 1 ft. 3=*Moderate intrusions*: Ground disturbance with equipment to 2 ft. 4=*Significant intrusions*: Ground disturbance with equipment to 4 ft. 5=*Highly intrusive*: Ground disturbance more than 4 ft.
RISK INPUT FACTOR	**Overall Hazard**
SUB FACTOR NAME	SCALE
UXO Hazard Type	1=Explosive substance or article, very sensitive (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)
Fuzing	1=Non-fuzed (low sensitivity) 2=Fuzed (high sensitivity)
Amount of Energetic Material	1= <0.5 lbs. 2=0.5 to 1 lbs. 3=1 to 10 lbs. 4=10 to 100 lbs. 5= >100 lbs
RISK INPUT FACTOR	**Exposure**
SUB FACTOR NAME	SCALE
Frequency of Entry	1=*Rare*: ≤1 per month 2=*Occasional*: 2-8 per month 3=*Often*: 9-15 per month 4=*Frequent*: 16-22 per month 5=*Very frequent*: >22 per month
UXO Density	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	1=*Very low*: <1 hour per day, light activity 2=*Low*: ≤3 hours per day, light activity 3=*Moderate*: ≤6 hours per day, moderate or light activity 4=*High*: ≤9 hours per day, moderate activity 5=*Very high*: > 9 hours per day or heavy activity;
Portability	1=Not portable 2=Moved by motorized vehicle / livestock (very low portability) 3=Portable by 2 adults (low portability) 4=Portable by 1 adult (moderately portable) 5=Portable by child (easily portable).

GENERAL INFORMATION

METHODOLOGY NAME / ID	The Jefferson Proving Grounds / Tierrasanta UXO Protectiveness Evaluation Methodology
DEVELOPER	U.S. Army Corps of Engineers Design Center / Center of Expertise Engineering and Support Center Huntsville, AL
PUBLISHED SOURCE	"Reviewing Protectiveness", Slide presentation to CALEPA relative to the Long Term Monitoring and 5-Year Recurring Review of the UXO Remedial Actions Performed at the Tierrasanta Site, July 27, 1999 Telephone communications between Mr. Ron Marnicio (Foster Wheeler) and Mr. Glenn Earhart (Design Center) and Mr. Robert Wilcox (Center of Expertise) of the U.S. Army Corps of Engineers, Engineering and Support Center, Huntsville, AL
DATE OF PUBLICATION	July 1999
PEER REVIEW	None

PURPOSE	- To develop a measure of the protectiveness or potential for harm associated with ***site conditions, ordnance characteristics and the behavior of people*** to aid in the evaluation and decision making regarding alternative remedial options and the design and implementation of long term monitoring activities at UXO sites where remedial actions have been performed. - To indirectly evaluate potential changes to the level of protectiveness afforded at a site based on the direct measurement of a number of factors impacting the potential for harm or level of hazard. - To evaluate UXO protectiveness using a stakeholder-oriented process that can be tailored to site-specific needs and is easy to understand. - To focus UXO hazard assessments on the conditions that are most influential to decision making.
PAST APPLICATIONS	Proposed as part of the alternatives evaluation to be performed for the EE/CA for the Jefferson Proving Ground (JPG) Project and as part of the analysis performed in support of the 5-Year Review Report and the long term monitoring associated with the Tierrasanta UXO Cleanup Project (San Diego).
SITE SPECIFIC SUITABILITY	Site specific method

OUTPUTS	
DEFINITION OF RISK	"Risk" is not defined. The assessment methodology is defined in terms of scaling the potential for harm or the prevention of the deterioration of the level of protectiveness from potential UXO accidents. Protectiveness is identified to be influenced positively or negatively by a set of factors that can be tailored to fit site circumstances and stakeholder input.
HOW RISK IS ESTIMATED	Risk is estimated indirectly based on the assessment of nine factors contributing to the level of risk or hazardous conditions associated with a site (Note: These nine factors were defined for the Tierrasanta Project; only 6 were used for the JPG Project). The nine factors relate to three main groups: - the type of ordnance present (i.e., the character, density and distribution of the ordnance); - site features (i.e., the character of the site, its use, and its accessibility); - and the behavior of people/stakeholders (i.e., individual's behavior, institutional behavior; - and the commitment of the stakeholder parties). Each of these nine factors is tracked and subjectively/qualitatively assessed to determine if conditions over time relative to that factor have been characterized by: • No Change, • Significant Improvement, • Sustained Improvement, • Needs Improvement, or • Serious Deterioration These factors are rated relative to the conditions that existed following the completion of the remedial action. Tracking potential changes in these factors, and the manner in which those changes influence the level of protectiveness that exists is the focus of the long term monitoring program.
KEY ASSUMPTIONS	Not specified
INTERFACE WITH RISK MANAGEMENT	The risk management strategy is based on a philosophy of continuous improvement in the level of protectiveness as measured by these nine factors. Factors assessed as "Needs Improvement" or showing "Serious Deterioration" trigger an evaluation of a possible additional response. Conditions represented by "No Change", "Significant Improvement", or "Sustained Improvement" indicate that the project remains protective.

INPUTS	
SOURCES OF DATA/INFO	A range of site reconnaissance and interview activities to assess current conditions relative to the nine contributing factors.
DATA QUALITY PROCESS	Not specified.
ROLE(S) OF STATISTICS	Not applicable

GENERAL INFORMATION	
METHODOLOGY NAME / ID	The Kaho'olawe UXO Site Characterization Risk Assessment Methodology
DEVELOPER	Adapted from MIL-STD-882C, the U.S. Army Corps of Engineers procedures for conducting preliminary assessments, and MIL-STD-1916
PUBLISHED SOURCE	Report on the Site Characterization for Unexploded Ordnance, Kaho'olawe Island, Hawaii Volume I - II and III
DATE OF PUBLICATION	March 1998
PEER REVIEW	None

PURPOSE	To develop an assessment of the UXO hazard at Kaho'olawe Island based on a characterization of potential UXO concentrations and environmental conditions affecting UXO distribution. To develop a categorization of hazards according to risk level criteria based on hazard severity and probability to support the elimination or control of as many hazards as possible and to prioritize hazards for corrective action.
PAST APPLICATIONS	This variation applied only at Kaho'olawe
SITE SPECIFIC SUITABILITY	Specific to this site only.

OUTPUTS	
DEFINITION OF RISK	Risk is a measure of hazards (conditions that are prerequisite to a mishap- an exposure equates accessibility to the UXO) and their impact, considering the probability of their occurrence.
HOW RISK IS ESTIMATED	A Hazard Severity Code and a Hazard Probability Category are estimated based on the results of the site characterization using visual reconnaissance procedures. The results of the site investigation are used to enter a matrix where the various combinations are translated into a Risk Assessment Code (RAC) for a discrete area.
KEY ASSUMPTIONS	• The land's projected end use must be changed in those cases where UXO detection systems are not sensitive enough or funds are not available to remove UXO to the planned remediation depth. • UXO are an imminent hazard and immediate cause of death or disablement to the general public if disturbed. • Initially, the worst case data is used, assessment is refined as additional data is collected

INPUTS	
SOURCES OF DATA/INFO	The categorization of hazard is based upon the characteristics of fuzing found, contained in ordnance items, or presumed worst case if the potential ordnance item was subsurface. For data, each 1000 meter by 1000 meter grid was assessed along Visual Characterization Routes (VCR). Along each route, data was collected on the following parameters: topography; surface texture; overgrowth type; overgrowth density; ordnance / residue contamination; ordnance / residue density; crater distribution; crater size / dimension; crater depth; target material; and assumed hazard level.
DATA QUALITY PROCESS	Kaho'olawe SC Plan
ROLE(S) OF STATISTICS	Number of data points based upon terrain or other limiting factors.

SPECIFIC INFORMATION		
RISK FACTOR	Hazard Severity Code	
TYPE	Qualitative	
HOW DEFINED	To provide a measure of the worst credible mishap resulting from personnel error or environmental conditions.	
DESCRIPTION	CATEGORY	DEFINITION
CATASTROPHIC	I	Death
CRITICAL	II	Severe Injury
MARGINAL	III	Minor Injury
NEGLIGIBLE	IV	Less than Minor Injury
NONE	V	None
OTHER NOTES/COMMENTS	The critical characteristic was taken to be the type of fuzing on the ordnance. Those ordnance with the most sensitive fuzing were identified as the worst-case category (I).	

RISK FACTOR	Hazard Probability Category	
TYPE	Qualitative	
HOW DEFINED	Probability that a hazard would be encountered.	
DESCRIPTION	LEVEL	COMMENT
FREQUENT	A	Continuously experienced
PROBABLE	B	Will occur frequently
OCCASSIONAL	C	Will occur several times
REMOTE	D	Unlikely but can reasonably be expected to occur
IMPROBABLE	E	Unlikely to occur, but possible
OTHER NOTES/COMMENTS	For the Kaho'olawe assessment, it was assumed that an individual would encounter and interact with an ordnance item if it was present.	

RISK ASSESSMENT FRAMEWORK	The Risk Assessment Code is determined using the following table based on the Hazard Severity Code and the Hazard

		Probability Category				
TYPE		Qualitative				
Hazard Frequency =>>>		A	B	C	D	E
Hazard Severity						
Catastrophic	I	1	1	1	2	3
Critical	II	1	1	2	3	4
Marginal	III	1	2	3	4	4
Negligible	IV	2	3	4	4	4

INTERFACE WITH RISK MANAGEMENT	Each Risk Assessment Code (RAC) is related to a recommended course of action according to this table. Used to prioritize areas for RA based upon Land Use and accessibility. Also, becomes the initial input into the Long Range Risk Management Plan/Program.
RAC CODE	RECOMMENDED ACTION
1	Unacceptable, full mitigation required
2	Undesirable, full mitigation required
3	Acceptable with review by Certifying Official (CO), mitigation required
4	Acceptable without review by CO, mitigation required
5	NOFA required
In addition, maps of Hazard Severity and RAC Code are plotted to illustrate and communicate the findings of the qualitative assessment and serve as an input to the risk management process. Maps can be tailored to present only areas of surface or subsurface hazard.	

GENERAL INFORMATION	

METHODOLOGY NAME / ID	The MIL-STD-882D Risk Assessment Methodology
DEVELOPER	U.S. Department of Defense Military Standard System Safety Program
PUBLISHED SOURCE	MIL-STD-882D
DATE OF PUBLICATION	October, 1999
PEER REVIEW	None

PURPOSE	To enable decision makers to properly understand the amount of risk involved relative to what it will cost in schedule and dollars to reduce that risk to an acceptable level as part of determining what actions to take to eliminate / control identified hazards.
PAST APPLICATIONS	Not applicable
SITE SPECIFIC SUITABILITY	Not applicable.

OUTPUTS	
DEFINITION OF RISK	Risk is an expression of the probability / impact of a mishap in terms of hazard severity and hazard probability.
HOW RISK IS ESTIMATED	The hazard category and the hazard frequency are estimated and used to enter a matrix where the various combinations are assigned to either a Hazard Risk Index or Hazard Risk Level.
KEY ASSUMPTIONS	Not specified
INTERFACE WITH RISK MANAGEMENT	Each Hazard Risk Index or Hazard Risk Level is related to a suggested risk management criteria or recommended risk management authority decision, respectively.

INPUTS	
SOURCES OF DATA/INFO	Best available information resulting from records searches, reports of EOD detachment actions, and filed observations, interviews and measurements
DATA QUALITY PROCESS	Not explicitly noted.
ROLE(S) OF STATISTICS	Not applicable

SPECIFIC INFORMATION

RISK FACTOR	Hazard Category	
TYPE	Qualitative	
HOW DEFINED	Subjectively by assessor	
VALUE	HOW EXPRESSED	GUIDANCE PROVIDED
CATASTROPHIC	-	None
CRITICAL	-	None
MARGINAL	-	None
NEGLIGIBLE	-	None
OTHER NOTES/COMMENTS	No guidance provided relative to assigning the Hazard Category.	

RISK FACTOR	Hazard Frequency	
TYPE	Qualitative or Quantitative	
HOW DEFINED	Subjectively by assessor (if Qualitative) or using illustrative probability ranges (if Quantitative)	
VALUE	HOW EXPRESSED	GUIDANCE PROVIDED
FREQUENCY	f > 1/10	Qualitative or Frequency
PROBABLE	1/10 > f > 1/100	Qualitative or Frequency
OCCASIONAL	1/100 > f > 1/1000	Qualitative or Frequency
REMOTE	1/1000 > f > 1/1,000,000	Qualitative or Frequency
IMPROBABLE	f < 1,000,000	Qualitative or Frequency
OTHER NOTES/COMMENTS		

RISK ASSESSMENT FRAMEWORK (Example 1)	The Hazard Risk is determined using the following tables based on Hazard Category and Frequency.
TYPE	Qualitative

Frequency =>>>		Frequent	Probable	Occasional	Remote	Improbable
Hazard Category						
Catastrophic		1A	1B	1C	1D	1E
Critical		2A	2B	2C	2D	2E
Marginal		3A	3B	3C	3D	3E
Negligible		4A	4B	4C	4D	4E

INTERFACE WITH RISK MANAGEMENT	Each Hazard Risk Index is related to a Suggested Criteria according to this table

HAZARD RISK INDEX	SUGGESTED CRITERIA
1A, 1B, 1C, 2A, 2B, 3A	Unacceptable
1D, 2C, 2D, 3B, 3C	Undesirable (Risk Management activity required)
1E, 2E, 3D, 3E, 4A, 4B	Acceptable with Risk Management review
4C, 4D, 4E	Acceptable without review

RISK ASSESSMENT FRAMEWORK (Example 2)	The Hazard Risk Index is determined using the following tables based on Hazard Category and Frequency.
TYPE	Qualitative

Frequency =>>>		Frequent	Probable	Occasional	Remote	Improbable
Hazard Category						
Catastrophic		1	2	4	8	12
Critical		3	5	6	10	15
Marginal		7	9	11	14	17
Negligible		13	16	18	19	20

INTERFACE WITH RISK MANAGEMENT	Each Hazard Risk Index is related to a Suggested Criteria according to this table

HAZARD RISK INDEX	SUGGESTED CRITERIA
1 - 5	Unacceptable
6 - 9	Undesirable (Risk Management activity required)
10 - 17	Acceptable with Risk Management review
18 - 20	Acceptable without review

RISK ASSESSMENT FRAMEWORK (Example 3)	The Hazard Risk Level is determined using the following tables based on Hazard Category and Frequency.
TYPE	Qualitative

Frequency =>>>		Frequent	Probable	Occasional	Remote	Improbable
Hazard Category						
Catastrophic		HIGH	HIGH	HIGH	HIGH	MEDIUM
Critical		HIGH	HIGH	HIGH	MEDIUM	LOW
Marginal		HIGH	MEDIUM	MEDIUM	LOW	LOW
Negligible		MEDIUM	LOW	LOW	LOW	LOW

INTERFACE WITH RISK MANAGEMENT	Each Hazard Risk Level is related to a recommended Decision Authority according to this table

HAZARD RISK LEVEL	DECISION AUTHORITY
HIGH	Service Acquisition Executive
MEDIUM	Program Executive Officer
LOW	Program Manager

OTHER CONSIDERATIONS	When two or more hazardous situations have the same Hazard Risk Index, other factors may be considered to further differentiate and prioritize among them. These factors include the effect of the hazard on the mission/operation, or a range of potential economic, social, or political implications of the presence of the hazard.

GENERAL INFORMATION

METHODOLOGY NAME / ID	The Ordnance and Explosives Cost-Effectiveness Risk Tool (OE*Cert*) Methodology
DEVELOPER	QuantiTech, Inc. 500 Boulevard South Suite 102 Huntsville, AL
PUBLISHED SOURCE(S)	Ordnance and Explosives Cost-Effectiveness Risk Tool (OE*Cert*) Final Report, Version E TECHNICAL REPORT 93R004vE
DATE OF PUBLICATION	August 31, 1995
PEER REVIEW	Yes, Reviewed by: -Western Governors Association (Sept 94, Oct 93) -Society for Risk Analysis (Dec 93) -Naval Post Graduate School, Operations Research (Jan 94) -Harvard University Center for Risk Analysis (Feb 94) -Operations Research Society of America, ORSA, (Apr 94) -George Mason University, Dept. of Engineering (Apr 94) -Army Environmental Policy Institute, Georgia Tech (Dec 95) -Lawrence Livermore National Laboratories (Jan 96) -Oak Ridge National Laboratories (July 1998) All comments were responded to, clarifications and changes to method made with agreement with reviewer.

PURPOSE	- To provide a risk assessment methodology for estimating the degree of risk associated with UXO contamination that may pose an imminent hazard to the public. - To provide a tool for prioritizing UXO site remediation efforts based on risk. - To estimate the levels of residual risk associated with various remediation or response actions. - To reduce the amount of subjective evaluation used in UXO site management and remediation planning.
PAST APPLICATIONS	The OE*Cert* methodology has been applied at 40 sites with UXO contamination (See Table 1 at the end of this summary for a list of the sites for which a full OE*Cert* analysis was performed)
SITE SPECIFIC SUITABILITY	Has been used in a variety of locations.

OUTPUTS	
DEFINITION OF RISK	Risk is defined as the number of expected exposures to OE multiplied by the unexploded ordnance (OE) Hazard Factor. The Hazard Factor is a measure of the sensitivity of the OE to detonation and the severity of the consequences. Exposure is conservatively defined to be a member of the public in near proximity to the OE.
HOW RISK IS ESTIMATED	For each sector (with either dispersed or localized distributions of OE items), the expected number of exposures for a single individual participating in a specific activity is calculated. Next, the number of people expected to participate annually in that activity in that sector is determined based either on the demographics surrounding the FUDS and activity participation data or on site-specific estimates. These two quantities are combined to give the total annual number of exposures (as defined above) that would be expected to occur for all participants in that activity. These calculations are repeated for all activities considered to be plausible for that sector under current and future land use scenarios. The expected number of exposures resulting from participation in each activity is than multiplied by the appropriate hazard factors corresponding to that activity and type of OE. The resulting products are then summed over all projected activities within the sector to give the overall risk estimate for that sector. Total sector risks are then summed to get the sitewide risk estimate.

RISK EXPRESSION	R = (No. of Exposures to OE) * (OE Hazard Factor)
PARAMETER DEFINITIONS	R = Risk due to OE No. of Exposures to OE = Number of annual public exposures to OE [The expected number of exposures to surface UXO per entrant into a sector is dependent on the UXO density, the proportion of UXO on the surface of the ground, and the activity participant's exposure area. The expected number of subsurface UXO exposures per entrant into a sector is dependent on the UXO density, the proportion of UXO on the surface of the ground, the density distribution of the subsurface UXO, and the area associated with an activity performed in the sector.] = μ_{ind} * N_p μ_{ind} = Number of exposures for a single participant in a given activity = $\rho * \Delta * A_{Eff} * (1- \eta)$^NS ρ = UXO density (# of UXO/acre) Δ = Fraction of UXO in a given depth range within the soil (unitless) A_{eff} = Effective area impacted by a given activity (acres) η = UXO clearance sweep efficiency (unitless) NS = Number of clearance sweeps assumed (#) N_p = The number of participants in that activity OE Hazard Factor = Adjusted Hazard Factor constructed from the product of a UXO-specific Sensitivity Factor and a UXO-specific Consequence Factor, normalized to a scale of 1 to 100 (See Table 2 at the end of this summary) [The Sensitivity Factors and Consequence Factors were developed using the Analytic Hierarchy Process (AHP) and the elicitation of expert opinions from a number of UXO professionals.]
KEY ASSUMPTIONS	• The overall site can be divided into homogeneous areas or sectors based on vegetation density, the slope of the terrain, soil types, contaminant density and land usage • An individual performing some activity in a UXO-contaminated sector can be characterized by a Poisson process

INTERFACE WITH RISK MANAGEMENT	An OECert analysis can generate estimates of the number of annual exposures to OE projected by sector and activity assuming no response action (i.e., the baseline or "No Action" scenario) and response actions of varying degrees (e.g., surface clearance or clearance to 4 feet below ground surface). These results can be developed as single point estimates or as ranges reflecting a specified confidence level (e.g., 90%). These estimates allow potential response actions to be focused on the sectors and depth ranges in the soil that contribute the most to the projected number of exposures. An OECert analysis can also generate estimates of the probability of an individual exposure to OE for each assumed activity given the specified response action. OE*Cert* analysis results for the overall site also have been compared to the sitewide results for other sites to provide a relative perspective on the level of risk from one site to another. A comparative risk assessment methodology provides a "translation" and comparison of the absolute levels of projected UXO risk (developed using OE*Cert*) to more common, everyday risks. This methodology was based on an analysis of the results of OE*Cert* assessments performed for 18 FUDS and BRAC sites. Historical OE-related accident data for these same sites over typically a 50-year period were employed to develop a statistical regression equation, or predictor, of the number of UXO injuries and deaths that may be expected given the number of annual OE*Cert* exposures projected.

INPUTS	
SOURCES OF DATA/INFO	The total UXO density and the distribution of OE contamination with depth in the soil are estimated by a count of ordnance items found in sampling grids during intrusive investigation. Geographic variables (slope, vegetation density, ground covering, type of soil, and the presence of creatures and foliage) also are observed during the field characterization effort. The types of recreational and occupational activities currently occurring in the area or projected for the future are identified based on observation and interviews with individuals familiar with the area.
DATA QUALITY PROCESS	Not explicitly defined
ROLE(S) OF STATISTICS	The Poisson process (and associated statistics) is used to describe the probability of exposure of an individual to a specified number of OE. Inferential statistics often are used to generate a single value estimate of the UXO density or a confidence interval for the UXO density based on the results of the field characterization effort.

Table 1 Sites Where OECert Has Been Applied			
SITE	***STATE***	***U.S. EPA REGION***	***COMMENT***
Adak NAF Priority Areas I, II and III	*AK*	*10*	*Completed OECert analysis (*)*
Attu, Ak	*AK*	*10*	*Completed OECert analysis*
Baywood Park Training Area	*CA*	*9*	*Completed OECert analysis (*)*
Benicia Arsenal	*CA*	*9*	*Completed OECert analysis*
Buckley Bombing Range	*CO*	*8*	*Completed OECert analysis*
Camp Bonneville	*WA*	*10*	*Completed OECert analysis (*)*
Camp Claiborne	*LA*	*6*	*Completed OECert analysis*
Camp Croft (OOU6)	*SC*	*4*	*Completed OECert analysis*
Camp Grant	*IL*	*5*	*Completed OECert analysis*
Camp Greene	*NC*	*4*	*Completed OECert analysis*
Camp Howze	*TX*	*6*	*Completed OECert analysis*
Camp Maxey	*TX*	*6*	*Completed OECert analysis*
Camp McCain	*MS*	*4*	*Completed OECert analysis*
Camp Wellfleet	*MA*	*1*	*Completed OECert analysis*
Castner Range	*TX*	*6*	*Completed OECert analysis*
Culebra Island Wildlife Refuge	*PR*	*2*	*Completed OECert analysis*
Diamond Springs Road Area	*MN*	*5*	*Completed OECert analysis*
Dolly Sods Wilderness Area	*WV*	*3*	*Completed OECert analysis*
Duck Target Facility	*NC*	*4*	*Completed OECert analysis*
Duck Target Facility (Currituck Sound)	*NC*	*4*	*Completed OECert analysis*
Dutch Harbor	*AK*	*10*	*Completed OECert analysis*
Fort Hancock (Sandy Hook)	*NJ*	*2*	*Completed OECert analysis*
Fort Monroe	*VA*	*3*	*Completed OECert analysis*
Fort Ord EE/CA Phase I Sites	*CA*	*9*	*Completed OECert analysis (*)*
Fort Ritchie	*MD*	*3*	*Completed OECert analysis (*)*
Hancock Range	*MS*	*4*	*Completed OECert analysis*
Illinois Ordnance Plant	*IL*	*5*	*Completed OECert analysis (*)*
Jefferson Barracks	*MO*	*7*	*Completed OECert analysis*
McGregor Range	*NM*	*6*	*Completed OECert analysis*
Morgan Army Depot	*NJ*	*2*	*Completed OECert analysis*
Motlow Range	*TN*	*4*	*Completed OECert analysis*
Nansemond Ordnance Depot	*VA*	*3*	*Completed OECert analysis (*)*
Pantex Ordnance Plant	*TX*	*6*	*Completed OECert analysis*
Pole Mountain	*WY*	*8*	*Completed OECert analysis*
Raritan Arsenal	*NJ*	*2*	*Completed OECert analysis*
Salton Sea Test Range	*CA*	*9*	*Completed OECert analysis (*)*
Sioux Army Depot	*NE*	*7*	*Completed OECert analysis*
Southwest Proving Ground	*AR*	*9*	*Completed OECert analysis*
Mission Trails (Tierrasanta)	*CA*	*9*	*Completed OECert analysis*
Umatilla	*OR*	*10*	*Completed OECert analysis (*)*
Waikoloa Maneuver Area	*HI*	*9*	*Completed OECert analysis*
** Indicates projects with Regional EPA involvement at a level greater than document review (e.g., as part of the typical EE/CA process)*			

Table 2 UXO Hazard Factors in OECert				
UXO Type	*Sensitivity Factor*	*Consequence Factor*	*Product*	*Adjusted Hazard Factor*
DISPERSED				
Unexploded Ordnance	*126*	*80*	*10,080*	*29*
Unexploded Ordnance Light Motion Sensitive	*327*	*80*	*26,160*	*76*
Unexploded Ordnance White Phosphorus	*126*	*36*	*4,536*	*13*
Controlled Chemical, Biological and Radiological	*126*	*273*	*34,398*	*100*
LOCALIZED				
Unexploded Ordnance Armed	*126*	*80*	*10,080*	*29*
Unexploded Ordnance Unarmed	*16*	*80*	*1,280*	*4*
Explosives and Materiel	*24*	*36*	*864*	*3*
Propellants and Pyrotechnics	*43*	*18*	*774*	*3*
Non-Controlled Chemical	*22*	*15*	*330*	*1*
White Phosphorus	*44*	*20*	*880*	*3*
Controlled Chemical, Biological and Radiological	*22*	*281*	*6,182*	*18*

GENERAL INFORMATION	
METHODOLOGY NAME / ID	Ordnance and Explosives Risk Impact Assessment (OERIA)
DEVELOPER	U.S. Army Engineering and Support Center, Huntsville
PUBLISHED SOURCE	Interim Guidance, Ordnance and Explosives Risk Impact Assessment
DATE OF PUBLICATION	March 27, 2001
PEER REVIEW	None
PURPOSE	The purpose is to provide a qualitative risk assessment for Ordnance and Explosives that is easily understood by and communicated to stakeholders.
PAST APPLICATIONS	Not applicable
SITE SPECIFIC SUITABILITY	The first step of this three-step process includes an opportunity to identify additional factors, based on the specific site and situation, that may be needed in the analysis.

OUTPUTS	
DEFINITION OF RISK	Not specified
HOW RISK IS ESTIMATED	This is a three-step process using the steps below: 1. Review base factors and identify additional factors to assess. 2. Develop baseline risk assessment 3. Assess the response alternatives Other risk factors may be evaluated as identified in Step 1. The factors are used to conduct the baseline risk assessment in Step 2 and the assessments are entered into the OERIA table. Step 3 involves assessment of the response action alternatives, using a scale of A to D with A being the highest impact and D being the lowest impact. The ranking is comparative, so that the response action with the greatest potential to reduce the impact of OE will be assigned an A.
KEY ASSUMPTIONS	Not specified
INTERFACE WITH RISK MANAGEMENT	Using the assessment table and the various inputs and response action evaluation the “OERIA will qualitatively compare the level of protectiveness and potential for harm as a result of implementing each response action.” This process does not provide quantitative results, but allows the team to choose the response action for risk management that will have the greatest impact in reducing risk.

INPUTS	
SOURCES OF DATA/INFO	Will vary based on the specific site and situation.
USE OF STATISTICS	“The OERIA provides a qualitative risk assessment in lieu of a statistically based risk assessment that will allow more effective, clear risk communication among all stakeholders.”
DATA QUALITY PROCESS	Not specified

RISK INPUT FACTOR	**ORDNANCE AND EXPLOSIVES FACTORS**
SUB FACTOR NAME	SCALE
Type	0=inert or scrap 1=will cause minor injury, to an individual if detonated by an individual's activities 2= will cause major injury, to an individual if detonated by an individual's activities 3=OE that will kill an individual if functioned by an individual's activities.
Sensitivity	0=inert or scrap 1=may have functioned correctly or is unfuzed but has a residual risk 2=is less sensitive; and 3=is very sensitive
Quantity or Density	Scale not specified. However, the methodology states "Density or quantity: OE density or quantity affects the likelihood that an individual will encounter OE at the site. Relationships exist between density/quantity and the likelihood of encountering OE on the site. The nature of the density or quantity of OE at the site (e.g., distribution, location, etc.) Should be explained in as much detail as possible."
Depth	Scale not specified. However the methodology states**: "**Depth. OE depth, when considered along with site activities, affects the likelihood that an individual will encounter OE present at a site. Generally speaking, the deeper the OE, the less likely anyone will encounter it. However, the site activities must also be examined to ensure this general rule holds true for a given site."
RISK INPUT FACTOR	**SITE CHARACTERISTICS FACTORS**
SUB FACTOR NAME	SCALE
Accessibility	*No Restriction to Site*: No man-made barriers, gentle sloping terrain, no *vegetation that restricts access, no water that restricts access* *Limited Restriction to Access*: Man-made barriers, vegetation that restricts access, water, snow or ice cover, and/or terrain restricts access *Complete Restriction to Access*: All points of entry are controlled
Stability	*Site Stable*: OE should not be exposed by natural events *Moderately Stable Site*: OE may be exposed by natural events *Site Unstable*: OE most likely will be exposed by natural events

RISK INPUT FACTOR	**HUMAN FACTORS**
SUB FACTOR NAME	SCALE
Activities	Examples of Activities Actual Depth of OE Contact Level Child Play, Short Cuts, Hunting, Fishing, Hiking, Swimming, and Jogging, 0-6” significant 6”-12” low >12” low Picnic, camping metal detecting 0-6” significant 6”-12” moderate >12” low Construction, archaeology, crop farming 0-6” significant 6”-12” significant >12” moderate
Population	An estimate of the number of people using a site, and the frequency of that use, is determined based on the type and location of the site, access restrictions, natural and/or man-made barriers, surrounding population, and other demographics.

GENERAL INFORMATION

METHODOLOGY NAME / ID	Statistical Assessment of Risk and Sampling (STARS) Methodology
DEVELOPER	QuantiTech, Inc. 500 Boulevard South Suite 102 Huntsville, AL
PUBLISHED SOURCE	"Statistical Assessment of Risk and Sampling (STARS)" flyer
DATE OF PUBLICATION	August 1999
PEER REVIEW	None

PURPOSE	- To facilitate integrated site management regarding UXO risks at Formerly Utilized Defense Sites (FUDS) and US Army Base realignment and Closure (BRAC) sites. - To capture the lessons learned from the assessment and management support activities (OeCert) provided relative to over 40 sites contaminated with ordnance and explosives. - To combine proven and accepted site characterization and risk assessment methodologies with custom-fit innovative approaches. - To facilitate the direct and early involvement of an open communications between all Stakeholders in the UXO site management process. - To provide approaches for collecting better and more cost-effective site characterization data for use in risk assessment and site management decision making.
PAST APPLICATIONS	Currently under development. Variations of OeCert have been applied at many previous sites.
SITE SPECIFIC SUITABILITY	Not applicable.

OUTPUTS	
DEFINITION OF RISK	STARS makes use of the Ordnance and Explosives Cost-Effectiveness Risk Tool (OE*Cert*) to perform parametric risk assessment and risk assessment/residual risk projections. Risk to the public due to unexploded ordnance is quantified by measuring the probability that a person will be exposed to UXO while performing a common recreational or occupational activity at a site contaminated with UXO.
HOW RISK IS ESTIMATED	QuantiTech Methodology: OeCerts, GridStats/SiteStats.
KEY ASSUMPTIONS	Not applicable

INTERFACE WITH RISK MANAGEMENT	The STARS methodology includes procedures and tools for: • Determining Site Management Decision Criteria, • Performing Parametric Risk Assessment, • Completing Site-Specific Sampling and Characterization, • Performing Final Risk Assessment, • Estimating Residual Risk Measures, and • Deciding Site Management Strategy. STARS also utilizes a number of existing and new statistical sampling tools, such as SiteStats, GridStats, Density Estimator (a newly developed tool), and the UXO Calculator.

GENERAL INFORMATION

METHODOLOGY NAME / ID	NAVEODTECHDIV
DEVELOPER	Naval Explosive Ordnance Disposal Technology Division (NAVEODTECHDIV) and PRC Environmental Management, Inc.
PUBLISHED SOURCE(S)	"Unexploded Ordnance Risk Assessment Framework". 1996 By R. J. Mulvihill, K. Kruk and M. Keefe (PRC, Inc.), and J. Sperka, Maj N. Lantzer, A. Pedersen (Naval EOD Technology Division "Unexploded Ordnance Risk Assessment Framework". By R. J. Mulvihill (PRC, Inc), K. Kruk and M. Keefe (PRC, Inc.), and J. Sperka and A. Pedersen (Naval EOD Technology Division); Proceedings of the UXO Forum 1996, Williamsburg, VA. "Navy Tech Division expands UXO risk assessment model". By A. Pedersen and J. Sperka, Naval EOD Technology Division, Internet File
DATE OF PUBLICATION	1996
PEER REVIEW	None

PURPOSE	- To assess the absolute level of risk associated with UXO in a manner that specifically accounts for the likelihood of UXO encounter, UXO detonation, and the consequences of detonation. - To refine existing UXO risk assessment methods to account for that dud-fired ordnance that did not detonate solely from an encounter. That the risk of unintended detonation is directly related to the type of fuzing and the degree of disturbance to the item. An absolute risk model could be used to set standards for land end-use options. - To explicitly account for uncertainties associated with ordnance in an unknown condition. - To integrate UXO risk assessment into the NAVEODTECHDIV's Site Management Model (SMM) software tool.
PAST APPLICATIONS	Used at the U.S. Marine Corps Air Ground Combat Center, Twenty Nine Palms, CA as part of their active range risk management program. Note. MARSYSCOM is currently looking at putting the SMM at all USMC training ranges.
SITE SPECIFIC SUITABILITY	Not applicable

OUTPUTS	
DEFINITION OF RISK	UXO risk is the probability of detonation given an encounter and the distribution of consequences associated with the detonation.
HOW RISK IS ESTIMATED	Risk is a function of the conditional probability distribution of detonation given an encounter and the distribution of consequences associated with that encounter.
RISK EXPRESSION	$R = P_E * P_{D\|E} * C$
PARAMETER DEFINITIONS	R = Risk due to UXO P_E = Probability of an encounter with a UXO item = function {(L_{jk}/A), D_{ijk}, N_j, I} $P_{D\|E}$ = Conditional probability of a detonation given an encounter = function {P_t, P_l } C = Distribution of consequences associated with the detonation where: L_{jk} = Portion of the area of concern influenced by an activity (j) to a given depth (k) [acres] A = Total size of the area of concern [acres] D_{ijk} = Number of UXO items of a given fuze type (i) for an activity (j) to a given depth (k) within the entire area of concern. (This parameter would typically be best represented by a distribution, rather than a single value) [#] N_j = Number of participants in an activity (j) [#] I = Awareness coefficient, or an individual's awareness of UXO that impacts the behavior of that individual (An individual's awareness may be impacted by UXO size, topography, vegetation, soil type, and climate.) [unitless] P_t = Probability that the activity energy level exceeds the UXO detonation energy level threshold P_l = Probability of a detonation given that the activity energy level exceeds the UXO detonation energy level
KEY ASSUMPTIONS	• The distribution of UXO is assumed to be random within the area of concern • The awareness coefficient is assumed to be 1 • There are a number of variables that affect the probability of an encounter (P_E): 1. UXO density 2. UXO depth distribution 3. Activity of individual 4. Awareness of an individual, which can be affected by vegetation, topography, UXO size, soil type, and climate • The variables affecting the probability of detonation (P_D) are:

	1. UXO fuze sensitivity 2. Activity of an individual • The consequences associated with detonation are assumed to be serious injury or death of the person who encounters the UXO item that detonates.
INTERFACE WITH RISK MANAGEMENT	Linkage provided by mapping the mean risk level calculated for each area of concern or subarea according to 5 or more ranges or categories. The risk category associated with each area of concern can be represented on a color-coded risk map that would visually depict the range of mean risk associated with a site. (No risk ranges or categories were suggested)

INPUTS	
SOURCES OF DATA/INFO	The data regarding the fuze sensitivity of dud-fired ordnance and the influence required for fuze activation is obtained by expert opinion elicitation. Multiple expert opinions (such as obtained using questionnaires) are combined to obtain more accurate results than could be derived from opinions of a single expert. The expert opinion data is than combined with available background or historical data. If the background or historical data is uncertain, Bayes' Theorem can be used to update this information, by combining the distribution of the two data sets. Field sampling must also be performed to estimate types of ordnance present, and their density and depth distributions. Observations must also be made of the types of activities projected for an area of concern and the amount of disturbance these activities cause relative to the land.
DATA QUALITY PROCESS	Not explicitly noted
ROLE(S) OF STATISTICS	P_E and P_D will be input into Monte Carlo software to develop a probability distribution of risk. The software performs a statistical analysis of the distribution of data, including mean standard error, coefficient of variability, and variance. This distribution of risk values, not an absolute value, will be determined. Bayes' Theorem may be used to estimate the various conditional probabilities required for this methodology. Recommended to be evaluated in a probabilistic manner using Monte Carlo simulation techniques. Statistics would be used to develop appropriate distributions for the various model inputs.