FORMERLY USED DEFENSE SITE (FUDS)
OEW COST EFFECTIVENESS RISK TOOL (*OEWCert*)

Dr. Jeffrey L. Riggs
Vice President
QuantiTech, Inc.
6703 Odyssey Drive, Suite 304
Huntsville, AL 35806
205-922-9650

Mr. Arkie Fanning, P.E.
Systems Engineer
U.S. Army Corps of Engineers
Huntsville Division
P.O. Box 1600
Huntsville, AL 358067-4301
205-955-5256

1.0 INTRODUCTION

Efficient and effective allocation of resources has always been a prime management consideration. Due to the public perception of risk and the political considerations related to the Ordnance Explosive Waste (OEW) Program, a quantitative management tool was developed to calculate the amount of risk reduction that can be achieved per dollar spent on OEW site remediation. This tool, developed by QuantiTech, Inc., is the OEW Cost Effectiveness Risk Tool (OEW*Cert*). Effective use of the model will allow the U.S. Army Engineer Division, Huntsville, OEW Mandatory Center of Expertise and Design Center to prioritize Formerly Used Defense Sites (FUDS) remediation based on cost effectiveness. In addition, the model will facilitate cost planning and aid in the formulation of remediation standards for all FUDS. The following sections provide a general overview of each of the model applications addressing background, methodology, data requirements, and model output products.

Currently, FUDS are characterized by a Risk Assessment Code (RAC) classification. The RAC system was developed in accordance with Army Regulation 385-10, The Army Safety Program, and Military Standard 882B, System Safety Program Requirements, and assigns subjective values to assess hazard sensitivity and hazard consequence levels. The cumulative severity and probability values for a site are summed and compared to a matrix of set values. Based on this comparison, a site is given a RAC classification ranging from one to five. RAC one indicates the OEW contamination at the FUDS presents an imminent hazard and emergency actions are required. RAC five indicates no action is required at the FUDS.

The RAC classifications, as a prioritization method, can provide a coarse discriminator between sites with obvious differences in hazard severity and probability levels. Due to the

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **AUG 1994**	2. REPORT TYPE	3. DATES COVERED **00-00-1994 to 00-00-1994**

4. TITLE AND SUBTITLE **Formerly Used Defense Site (FUDS) OEW Cost Effectiveness Risk Tool (OEWCert)**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Army Corps of Engineers,Huntsville Division,P.O. Box 1600,Huntsville,AL,35807-4301**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM000767. Proceedings of the Twenty-Sixth DoD Explosives Safety Seminar Held in Miami, FL on 16-18 August 1994.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**10**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

large number of FUDS currently awaiting remediation, a prioritization and planning tool is needed to differentiate between sites having the same RAC classification.

The generality inherent in the RAC system does not allow for differentiation between sites with different ordnance dispersions, contamination density, or surrounding population density. The site risk mitigation prioritization model provides a standardized set of risk measures for all FUDS by including each of these variables in the analysis of risk.

OEW*Cert* prioritizes sites based on a cost effectiveness ratio. Effectiveness is measured by the risk reduction that can be obtained through remediation of a site. As shown in Figure 1, cost and risk reduction are dependent on a large number of variables. Cost, for prioritization purposes, is measured in constant year dollars and includes the direct and indirect cost of remediation. The following summary explains how risk and cost are estimated, as well as how the cost effectiveness ratio is calculated.

2.0 RISK ESTIMATION

A widely accepted definition of risk states that risk is equal to the product of the probability of an event occurring and the consequences of that event. This parallels the estimation approach used in OEW*Cert*. An event is defined as the exposure by one member of the public to at least one ordnance item. The consequence of this event is defined as the relative hazard associated with the OEW located on the site. Hazard subjectively combines both the sensitivity of the ordnance and the consequence of its explosion.

The expected number of exposures to ordnance at a FUDS is a function of the number of people entering the site, the activities they are performing, and the amount, type, and visibility of ordnance contamination at the site.

For each activity occurring at a site, the expected number of exposures for a single individual performing that activity is determined based on the area covered by the individual, the OEW contamination density, and the surface/subsurface distribution of the OEW. Next, the expected number of participants in that activity for the particular site is calculated using the local demographics, activity participation rates and percentages, and the presence/absence of “competing” sites to perform the activity. These values are calculated and summed for all activities occurring in the site, yielding a total expected number of exposures. Risk then is calculated as the product of the expected exposures and the hazard factor for the OEW contamination at the site.

FIGURE 1. OEWCERT VARIABLES

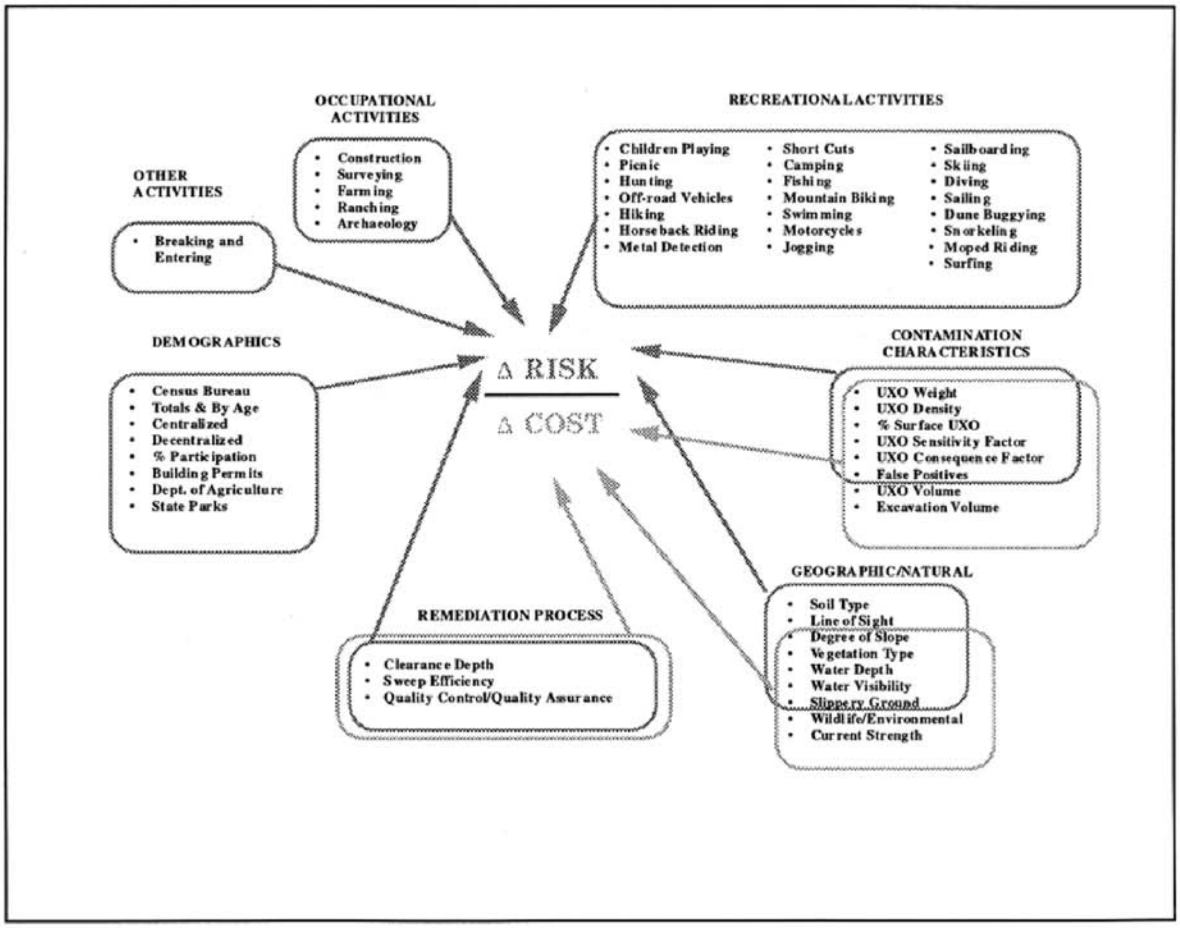

Figure 1. OEW*Cert* Variables

The amount of UXO contamination at a FUDS may be described in terms of density or area and visibility of contamination. If the ordnance is spread over a relatively large geographic area (i.e. dispersed sites), density (expressed as the number of UXO items per unit of area) is used to describe the extent of ordnance contamination. Intuitively, the higher the density, the higher the risk of exposure. If the ordnance is confined to a relatively well defined area (i.e. localized sites), the two dimensional area containing the ordnance or line of sight surrounding the contaminated area is the measure that describes the extent of contamination. It is assumed that the larger the area the hazard occupies, or the more visible the hazard is, the higher the risk of public exposure.

The type of ordnance contamination at a FUDS may be classified into one of eleven categories. These categories were identified by UXO professionals from ISSI UXO, Inc. and are as follows: dispersed UXO; dispersed UXO with special fuzing mechanisms; dispersed UXO with a charge of white phosphorus; dispersed controlled chemical, biological or radiological weapons; localized armed UXO; localized unarmed UXO; explosives and materiel; propellants and pyrotechnics; non-controlled chemicals; bulk white phosphorus; localized controlled chemical, biological, and radiological weapons. Each of these ordnance categories has two relative hazard factors associated with it. These relative values describe the consequence of an ordnance item detonating and the sensitivity to detonation of the ordnance in each hazard classification.

3.0 COST ESTIMATION

A FUDS life-cycle is made up of three parts: pre-remediation, remediation, and post-remediation. Cost estimates are made for these phases and the sum of these estimates provides a total site life cycle cost estimate.

Pre-remediation is the time period beginning when the site is identified and placed on the list of FUDS to be prioritized, and ending when remediation begins. Costs associated with this phase include any personnel, equipment, and material costs incurred during activities, such as feasibility studies, engineering evaluations, and site planning, that take place to facilitate the site being prioritized and/or remediated.

Remediation is the time period when the physical site clean-up occurs. Costs associated with this phase include all personnel, equipment, and material costs directly or indirectly related to the actual clean-up of ordnance contamination at the FUDS. Remediation is expected to be the most cost intensive phase of the site life-cycle.

Post-remediation is the time period beginning when the site remediation effort ends and ending at the end of the analysis period. The total site life-cycle is assumed to be 30 years. Post-remediation under this assumption would be 30 years minus the number of years required for pre-remediation and remediation. Costs associated with this phase include any personnel, equipment, and material costs relating to activities required to limit public entry to the site (i.e. fence maintenance, guards, etc.). If the site is completely turned over for public use after remediation, there will be no post remediation cost associated with the site.

The cost module uses a combination of all four widely accepted cost estimating methods depending on the data available. This combination of methods takes place within a framework of a "bottoms-up" work breakdown structure. The four methods are parametrics, engineering (bottoms-up), analogies, and expert opinion. Parametric estimates are those that apply quantitative methods to arrive at estimating relationships between cost elements. For example, by gathering actual contract data and applying regression analysis, a relationship of x percentage can be applied to remediation clearance time to arrive at quality assurance time. The engineering, or bottoms-up approach, estimates at a piece part level and requires a great deal of knowledge. Analogies are costs that are estimated using actual costs from programs based on similarities that characterize the programs. Often, with analogies, complexity factors are used to adjust the cost upward or downward to account for the differences between technical considerations. Expert opinion estimates are judgments expressed by those with education and experience in the particular area being estimated.

Currently, the cost module's estimates are built on actual data collected at Mission Trails/Tierrasanta and Raritan sites and data from the OEW-CWM Generic Cost Estimate. For prioritization and cost planning purposes, a database is being developed to supplement and enhance the previously gathered data. This database will provide consistency for studies, analyses, and budget and planning exercises and result in the reduction of cost analysis subjectivity.

The data is available to build the database. The data requirements include gathering actual contract cost data, interviewing remediation participants and experts, analysis of data, and making provisions for cost feedback over time.

The model output for the cost module will consist of a series of reports and briefing charts that summarize life-cycle cost. These reports will be arranged by pre-remediation, remediation, post-remediation, and cost of no remediation. Reports will also be available to meet the various needs of the budgeting exercises, trade studies, and various other analyses. Within the four life cycle elements, the work breakdown structure will be employed to show costs at the lower levels. The cost module also shows costs either held constant or adjusted for inflation (escalated,) and calculates both present and future values for the purpose of economic analyses dealing with the time value of money and alternate investment strategies.

4.0 COST-EFFECTIVENESS MEASURE

The prioritization of sites is based on a calculated cost effectiveness ratio for each site. The cost effectiveness measure compares delta risk to delta cost for each site. Delta risk is the difference between the estimated level of risk associated with the site before remediation occurs and the risk level established as the remediation standard. Delta cost is the difference between the life-cycle cost including remediation and the life cycle cost with no remediation phase included. The ratio resulting from these calculations gives the amount of expected risk reduction per dollar spent at the site under analysis. When sites are compared on the basis of their cost effectiveness ratio, the site with the highest ratio is assigned the highest priority.

5.0 DATA REQUIREMENTS

The data required to execute the OEW site mitigation prioritization model can be placed into four broad categories: demographic data, parametric data, expert opinion data, and site assessment data. Data categories and sources gathered thus far are presented in tabular form. Data values that currently are nominal have potential data sources listed.

Demographic data includes population totals, activity participation rates, gross and new construction building permit totals, average construction site sizes, surveying activity totals, and state and national park totals. These data values, with the exception of construction site size, are used in the calculation of the potential number of entrants to a FUDS. Construction site size is used in the calculation of subsurface risk area.

Population totals are collected by county or city and are broken down into nine age categories. Activity participation rate data is broken down into the same nine age categories and is based on national participation statistics. Building permits are collected at the city and county level. Surveying activity is a nominal value based on local information and uses the number of “new” building permits issued. "New" construction is assumed to be all building not related to renovation, alteration, or addition. The number of state and national parks is collected on a state by state basis, but is implemented at the regional level. Table 1 summarizes the demographic data sources.

Table 1. Demographic Data Sources

Data Required	Source
Population Totals	United States Census Bureau 1990 Census CD ROM's
Activity Participation Rates	American Sports Data, Inc. American Sports Analysis, 1992 Summary Report
Building Permits	United States Census Bureau Construction Statistics Dept. 1988-1992 diskettes
Surveying Activity	Local data indicated surveying activity is equal to six times the number of "new" building permits issued in an area.
Average Construction Site Size	Nominal value based on estimates of local Realtor
State and National Park Totals	The Outdoor Atlas and Recreation Guide published by Houghton Mifflin Co. 1992

Table 1. Demographic Data Sources

The parametric data set consists of the parameters needed to describe an individual's participation in identified activities. These parameters are: subsurface area covered by an individual, path width of an individual, an individual's activity participation time, an individual's velocity while performing an activity, and velocity degradation resulting from the terrain conditions. Not all parameters are applicable to all activities. The values are used in the calculation of the area an individual covers while at a FUDS. Table 2 presents the current parametric data requirements, sources for "hard" numbers, and proposed sources for nominal values.

Table 2. Parametric Data Sources

Data Required	Source	Proposed Source
Per Activity:		
Subsurface Area	*	Outdoor recreational guides
Path Width	*	Ergonomics and/or anthropometric sources; independent studies
Participation Time	*	Marketing surveys, independent studies
Velocity	Army Field Manual 21-18 Foot Marches; June 1990	*
Velocity Degradation	Army Field Manual 21-18 Foot Marches; June 1990	*

Table 2. Parametric Data Sources

Expert opinion data requirements consist of hazard factors elicited from UXO/EOD professionals through application of the Analytic Hierarchy Process (AHP). The AHP is an analytic technique that requires subject matter experts to compare the importance, in this case, sensitivity and consequence, of one ordnance item to another on a 1 to 9 scale of absolute numbers; 1 indicating equal importance and 9 indicating absolute superiority of one item to the other. A team of UXO safety professionals from the Corps of Engineers, Huntsville Division, (HND) participated in an AHP session and their input became the basis for the hazard factors. These hazard factors represent the relative consequence of an ordnance item detonating and the relative sensitivity to detonation of the ordnance in each hazard classification. Table 3 lists the eleven hazard classifications along with their respective hazard factor values.

Table 3. Expert Opinion Data

Sector Classification		Sensitivity Factor	Consequence Factor
Dispersed:			
A.	Unexploded Ordnance	126	80
B.	Unexploded Ordnance Light/Motion Sensitive	327	80
C.	Unexploded Ordnance White Phosphorus	126	36
D.	Controlled Chemical, Biological, and Radiological	126	273
Localized:			
E.	Unexploded Ordnance Armed	126	80
F.	Unexploded Ordnance Unarmed	16	80
G.	Explosives and Materiel	24	36
H.	Propellants and Pyrotechnics	43	18
I.	Non-Controlled Chemicals	22	15
J.	White Phosphorus	44	20
K.	Controlled Chemical, Biological, and Radiological	22	281

Table 3. Expert Opinion Data

6.0 MODEL EXECUTION

To run the OEW site risk mitigation prioritization model, several key pieces of information must be obtained. The information needed for a dispersed site includes the following items: hazard type; degree of slope; vegetation type; presence of slippery ground cover; percentage of UXO on the surface; sector UXO and total item density; weighted average of UXO weights; soil type; sector acreage; presence of bees, snakes, and poisonous foliage; presence of archeological activity; presence of environmentally sensitive plants and wildlife; fencing required; number of guards needed; and knowledge of which activities occur at the site.

For a localized site the following information is needed: hazard type, degree of slope, vegetation type, presence of slippery ground cover, area of hazard, maximum line of sight distance surrounding the hazard, excavation volume, area to be reconstituted, environmental factors, sifter requirement, fencing required, number of guards needed, knowledge of which activities occur at the site, OEW removal volume, area to be prepared for clearance, and area of original FUDS.

The model outputs from the prioritization module will consist of a list of sites prioritized by risk, cost, or cost effectiveness ratio (see Figure 2). The prioritized list may consist of any subset of the FUDS present in the database at the time of analysis. Additionally, detail risk estimates are provided at a “per activity” level, as well as is a life cycle cost template.

FIGURE 2. ORDANANCE AND EXPLOSIVE WASTE COST EFFECTIVENESS RISK TOOL (OEWCERT) SITE REMEDIATION PRIORITIZATION

GIVEN: A Set of Formerly Used Defense Sites Contaminated with Ordnance and Explosive Waste

PROBLEM: What is the Recommended Priority of Remediation?

FUNCTION OF:

- **Public Risk Before and After Remediation**
- **Site and Remediation Characteristics**
- **Remediation Cost**

TECHNIQUES:

- **Probabilistic Risk Analysis**
- **Life Cycle Cost Analysis**
- **Cost Effectiveness Analysis**

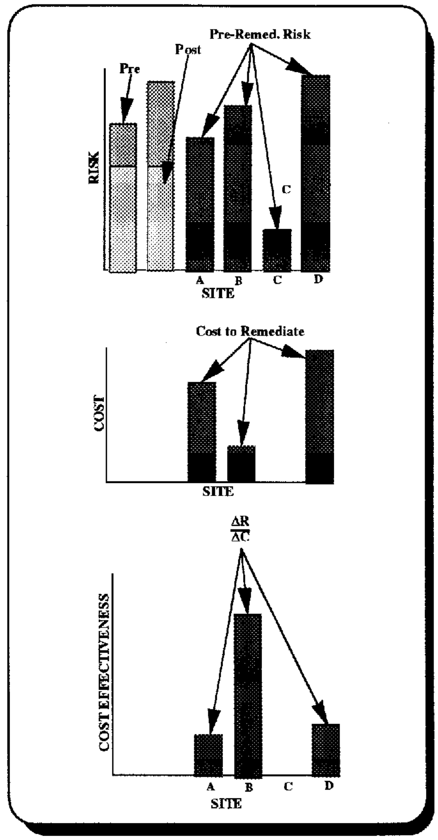

Figure 2. Ordnance and Explosive Waste Cost Effectiveness Risk Tool (OEW*Cert)* Site Remediation Prioritization