Risk-Based Siting Process For Ordnance Removal Operations Utilizing Safety Assessment for Explosive Risk

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Topics

- Short history of risk-based decision-making
- Application to Ordnance Removal
- Risk-based protocols for ordnance removal
- Protocol Tool
- Summary

What are Risk-Based Decisions?

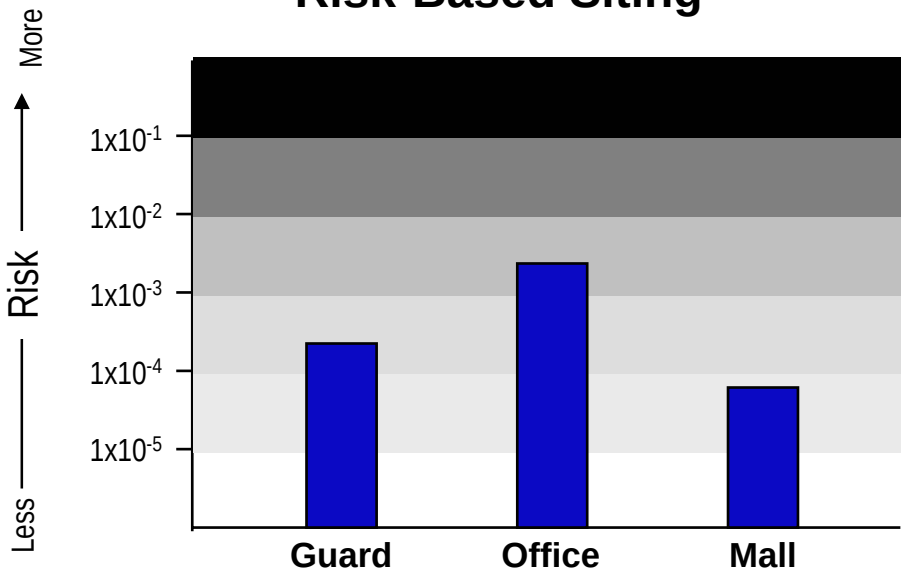
Quantity-Distance Siting

- Historical basis
- Less debate ~ arbitrary
- Good record

BUT

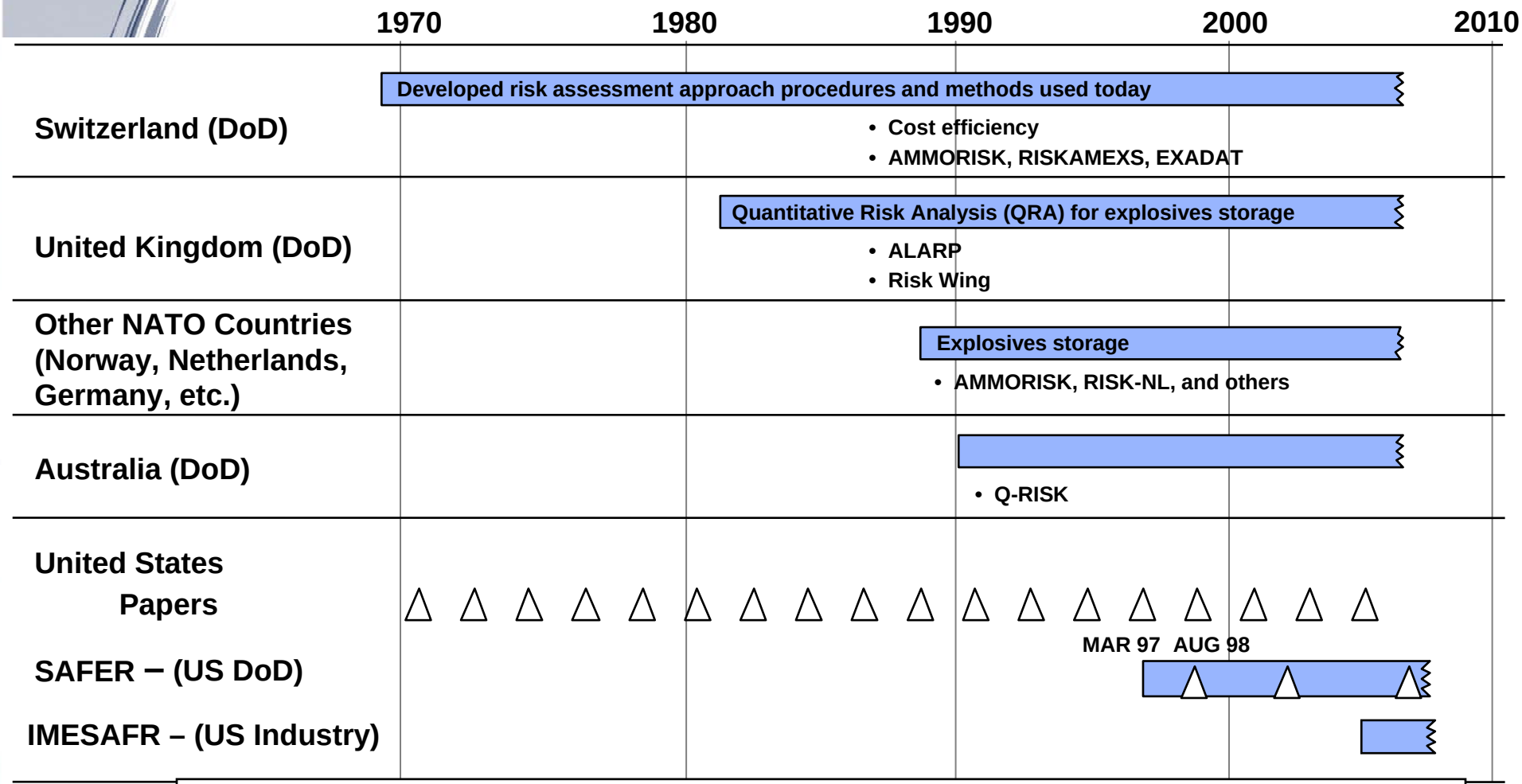
- Based on fragment density
- Does not consider:
  - number of people exposed
  - blast effects (press/impulse)
  - glass breakage

Risk-Based Siting



- Enhances safety in some cases
- Reduces resources in some cases
- Better understanding in all cases
- Allows comparison and evaluation
- Prioritize resources to highest risk
- Risk-based decisions provide a more thorough treatment of explosive effects, structures, exposure, and uncertainty in risk estimates.

Prior Use of Risk-Based Explosives Safety Criteria



Use of risk-based explosives standards for providing explosives safety has a history of acceptance among our allies. The U.S. DoD has begun using risk-based methods for siting explosives facilities. The commercial explosives manufacturing community is also moving towards use of risk-based standards.

Risk-Based Explosives Safety Criteria Team (RBESCT)

- In 1997, the Risk-Based Explosives Safety Criteria Team (RBESCT) was chartered by the DoD Explosives Safety Board (DDESB) to evaluate the feasibility of using a risk-based approach for explosives facilities siting in the U.S.
- The RBESCT acts as the technical advisor to the DDESB on risk-based methods and policy.
- Since 1997, the RBESCT has:
  - Developed a risk-based process and supporting computer model,
    - Safety Assessment for Explosives Risk (SAFER), which evaluates risk to persons from an accidental explosives event
  - Defined risk acceptance criteria, and
  - Developed recommended DoD policy for risk-based decisions.
    - DoD 6055.9-STD, "Risk Based Siting," Chapter 17 (in approval)

The work of this team forms the basis for the SAFER Ordnance Removal protocol.

About SAFER for Siting

SAFER

Safety Assessment for Explosives Risk

Sponsored by:
DoD Explosives Safety Board
U.S. Army
U.S. Air Force
U.S. Marine Corps
U.S. Navy

Disclaimer: The principles and techniques given in this software are in the opinion of the DDESB, the best available at the time of publication. Adherence to these principles should enhance the safety of ammunition and explosives

- sponsored by DDESB, U.S. military services
- uses best available principles / techniques
- peer reviewed, IV&Vd
- enhances the safety of explosive operations
- approved for use in DoD siting decisions

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Close

Current Policy on Use of SAFER

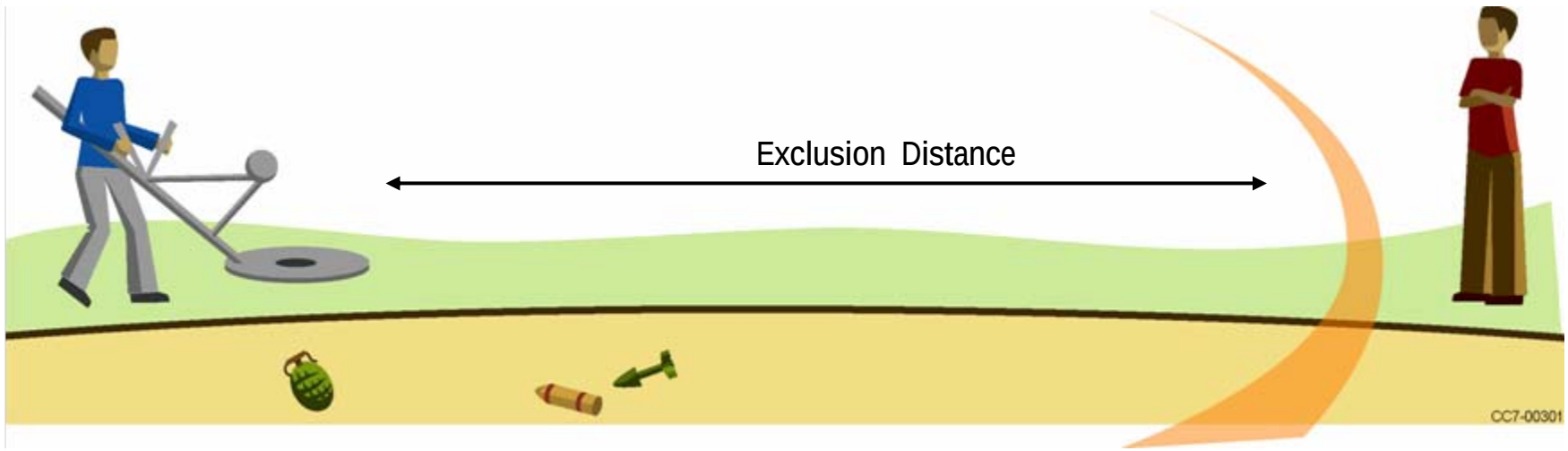
- Multi-year trial period has been completed
- RBESCT has recommended that guidance on the use of SAFER be incorporated into DoD 6055.9-STD
- Risk-based approval may be granted when:
  - Current Q-D policy would require a waiver for approval
  - Risk analysis is performed using current SAFER version or equivalent analytical model
  - Analysis uses maximum values for NEW and Yield inputs
  - Analysis demonstrates compliance with Risk Criteria:

Individual Risk	$P_f \leq$ 1E-06 (annual)
Group (collective) Risk	$E_f \leq$ 1E-05 (annual)

Application of SAFER Based Process to Ordnance Removal at FUDS, BRAC, and Range Sites

- Use of the risk-based methodology for Ordnance Removal operations is a logical extension of current policy.
- USACE recognizes the benefit of applying a risk-based method to cleanup and has begun an effort order to:
  - Develop a risk analysis protocol,
  - Define potential policy changes,
  - Identify modifications to the SAFER model, and
  - Automate protocols into analysis tool

SAFER for Ordnance Removal Concept

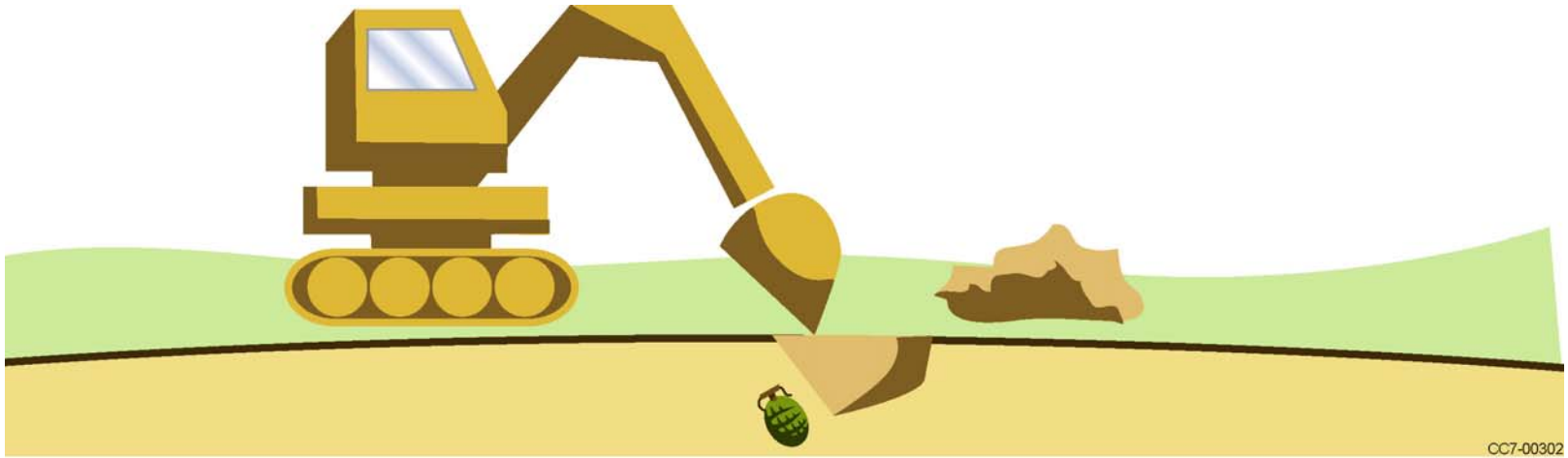


Risk = P(e) × P(f/e) × Exposure

Goal of SAFER Protocol Tool:
Determine necessary exclusion distance

SAFER MEC Protocol – Probability of Event, P(e)

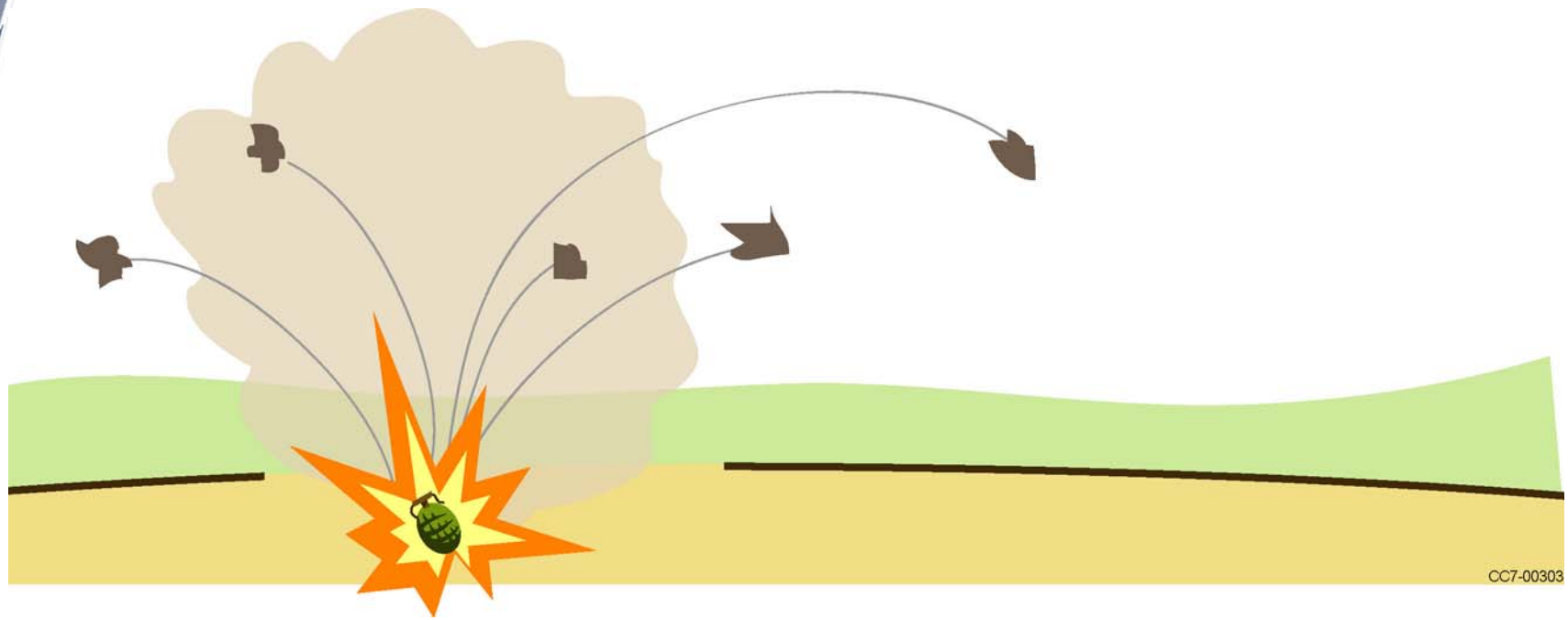
An *explosives event* is defined as an initiation and subsequent release of energy from an explosive that occurred during a munition response action while UXO procedures were being used.



Use historical data to estimate accident probability, Pe.

- Determine number of digs performed by past removal actions
- Determine number of applicable explosive events that have occurred
- Compute Pe_{DIG} and its variance using statistical methods

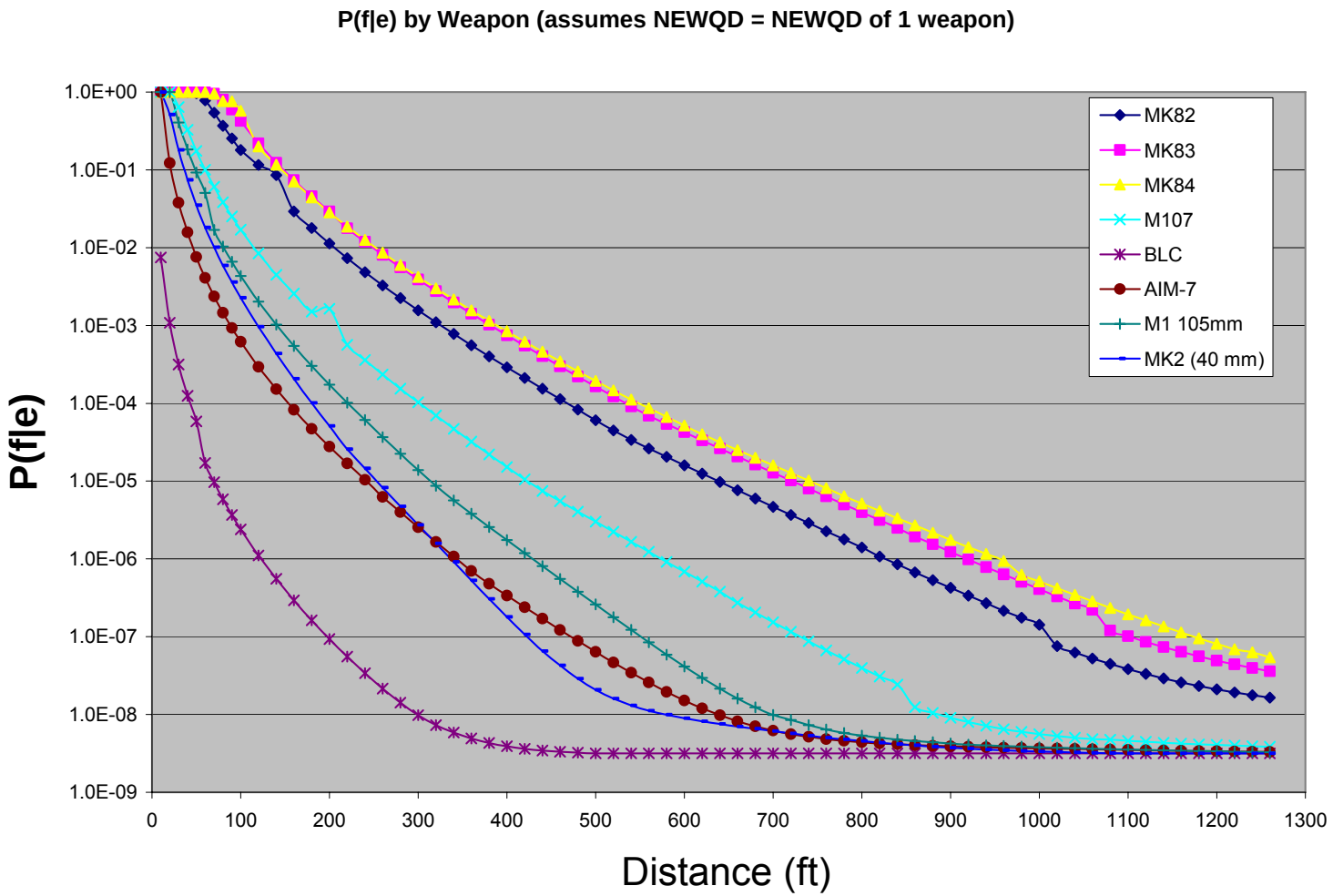
SAFER MEC Protocol – Probability of Fatality given an Event and People, P(f|e)



- Utilize existing SAFER weapon models
- Two additional weapon models have been developed for the SAFER MEC model (81mm M43 and 2.36” Rocket M6A3)
- User is asked to select largest weapon anticipated

Happening in the Background

Tool Pre-Stores Pf|e Data for All Weapon Types



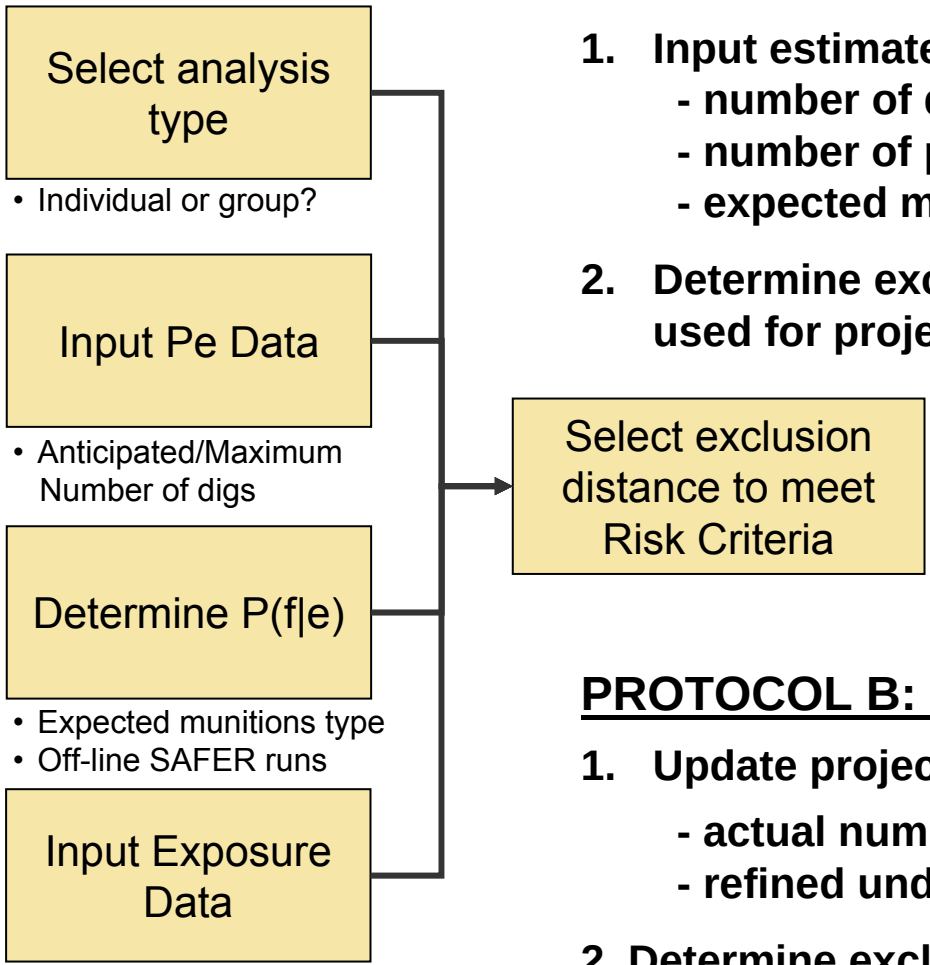
SAFER data for each munition (weapon) type have been developed off-line and pre-loaded into a "protocol tool" that runs the full Uncertainty Model of SAFER Version 3.0

SAFER MEC Protocol – Exposure

Exposure calculation will be based on site specific data

- Anticipated number of digs
- Maximum number of digs likely
- Expected / maximum number of people exposed to each dig
- Number of digs to which most exposed person is anticipated to be subjected
- Maximum number of digs to which any one person will be subjected
- User confidence in Exposure Inputs

Protocols A and B
Evacuation Planning



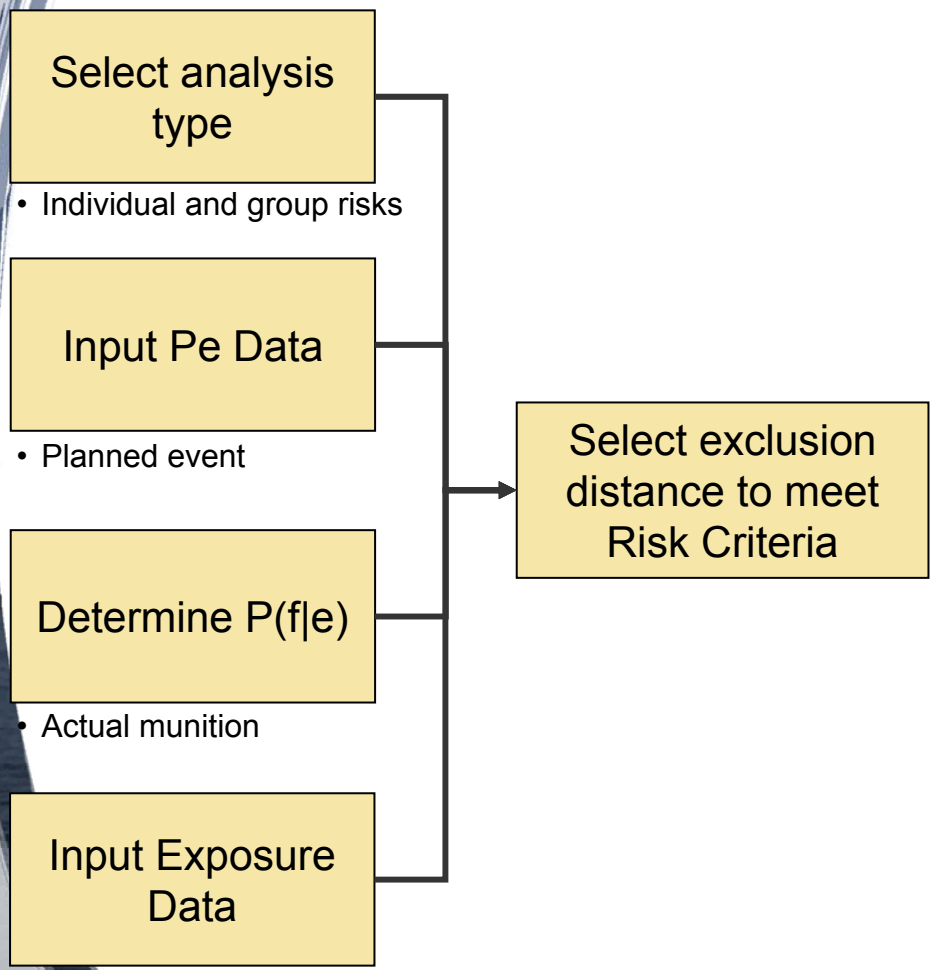
PROTOCOL A: EVACUATION PLANNING

1. **Input estimated project data**
   - **number of digs**
   - **number of people**
   - **expected munition items**
2. **Determine exclusion distance to be used for project planning**

PROTOCOL B: PLANNING UPDATE

1. **Update project data after geophysical**
   - **actual number of planned digs**
   - **refined understanding of likely items**
2. **Determine exclusion distance to be used during excavations**

Protocol C
Blow-in-Place Operations



PROTOCOL C: Blow-In-Place

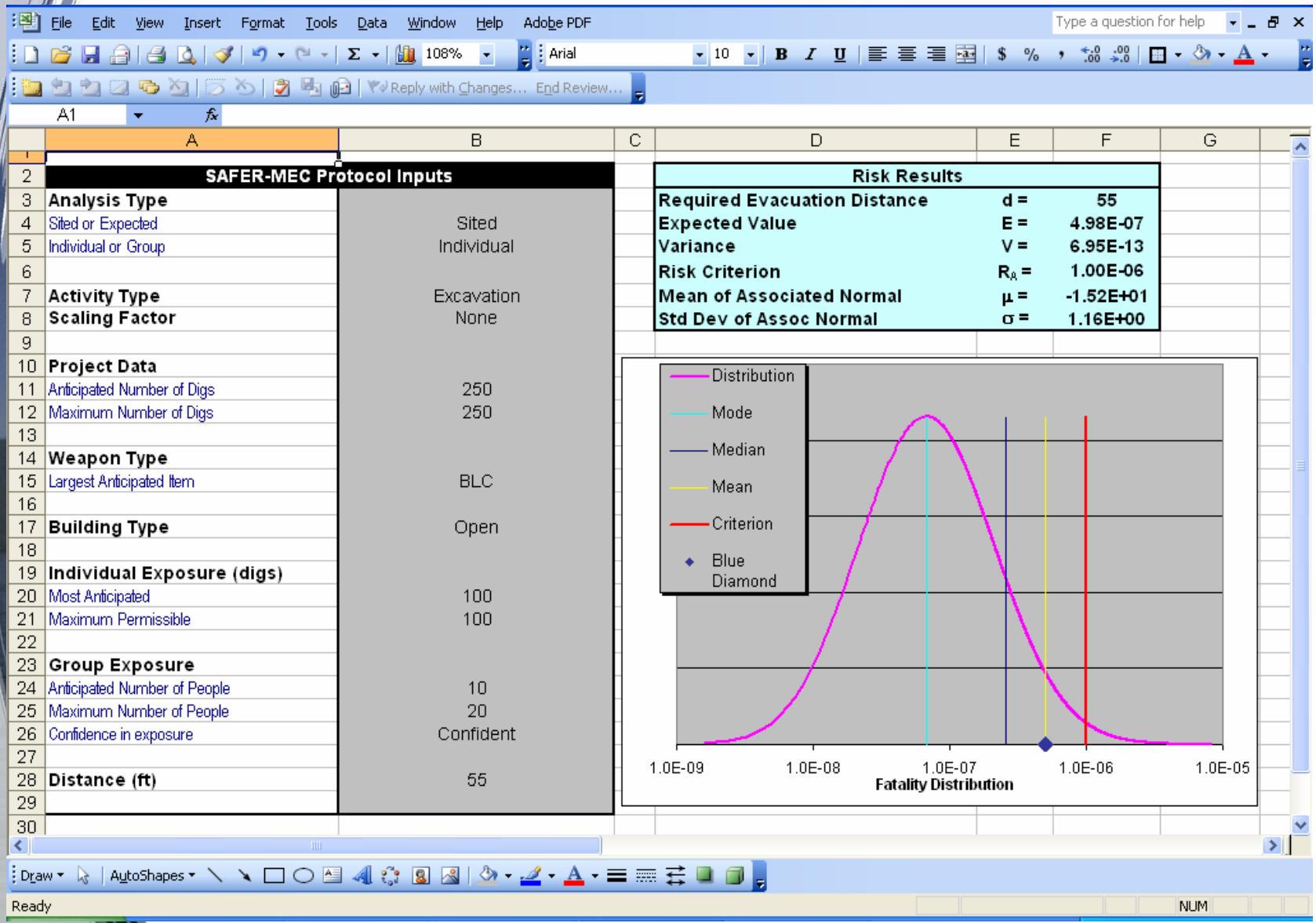
1. **Select BIP Risk analysis**
   - *sets Pe = 1.0*
   - *sets criteria based on digs in project*
2. **Enter Known Project Data**
   - *use actual weapon type*
   - *set Anticipated & Maximum number of digs to 1*
3. **Determine exclusion distance to meet risk criteria**
4. **Compare risk-based distance to exclusion distance required by Q-D**
5. **Implement local rules**

Development of SAFER MEC Protocol Tool

- Protocols have been implemented in MS Excel model
- Model incorporates the full SAFER Version 3.0 statistical model
- The SAFER version 3 model was used to calculate the P(f|e) parameters associated with:
  - Open potential explosion site (PES)
  - Varying distances (5 foot increments – 10-2000 ft)
  - User-selected weapon type
  - Open exposed site (ES)
  - SAFER outputs are pre-loaded into tool
- The user will enter required project data
- Excel model will provide risk and variance at distance user specifies

Protocol tool provides immediate capability to perform project analyses while working toward full software implementation in future SAFER release

Example Screen – SAFER MEC Protocol



SAFER-MEC Protocol Inputs	
Analysis Type	
Sited or Expected	Sited
Individual or Group	Individual
Activity Type	Excavation
Scaling Factor	None
Project Data	
Anticipated Number of Digs	250
Maximum Number of Digs	250
Weapon Type	
Largest Anticipated Item	BLC
Building Type	Open
Individual Exposure (digs)	
Most Anticipated	100
Maximum Permissible	100
Group Exposure	
Anticipated Number of People	10
Maximum Number of People	20
Confidence in exposure	Confident
Distance (ft)	55

Risk Results		
Required Evacuation Distance	d =	55
Expected Value	E =	4.98E-07
Variance	V =	6.95E-13
Risk Criterion	R_A =	1.00E-06
Mean of Associated Normal	μ =	-1.52E+01
Std Dev of Assoc Normal	σ =	1.16E+00

Summary

- The DDESB has approved use of SAFER and risk acceptance criteria for siting of explosives facilities (when Q-D criteria are not met)
- Use of the risk-based methodology for Ordnance removal operations is a logical extension of current policy.
- USACE recognizes the potential benefit of applying risk-based methods to the planning and execution of UXO removal operations
- Analysis protocols have been developed
- Development of automated tool nearing completion –-
  - future potential for full software implementation
- Approach is being evaluated by USACE and RBESCT for future use
  - For use in response action only, not applicable to Long Term Site Management
- Methodology could apply to FUDS, BRAC, Range, and other applications.

BACKUPS

SAFER Software Architecture 26-Step Process

Input

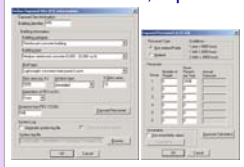
2. Enter PES data, Pe data, calculate Pe

The Potential Explosion Site (PES) inputs include the PES building number, type, and the activity at the PES. The probability of event is calculated.

1. Enter explosives data

The explosives data includes the weapon type, the hazard division, storage compatibility group, and explosives weight.

3. Select ES data, exposure data, calculate Ep



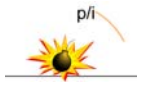
The Exposed Site (ES) inputs include the ES building number, building type, roof type, the percentage and type of glass, and the number of persons present. The personnel exposure is calculated.

4. Calculate yield(s)

NEW x $K_{Exp\ Type}$

Science

5. Determine open-air P, I



Values for open-air pressure and impulse are based on simplified Kingery-Bulmash hemispherical TNT equations.

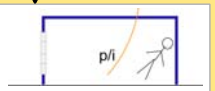
6. Adjust P, I (due to PES)

The Blast Effects Computer (BEC) is used to determine the pressure and impulse values outside of the PES. The damage to the PES is also assessed.

7. Adjust P, I (due to ES)

The pressure and impulse is adjusted again taking into account the exposed site.

8. Assess Pf(o)

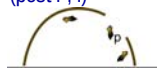


The lethality due to lung rupture, whole body displacement, and skull fracture is based on Dutch probit functions.

11. Describe primary fragments

The number of primary fragments and the maximum throw range is determined IAW with DDESB Technical Paper #16 "Methodologies for calculating primary fragment characteristics."

12. Calculate primary fragment containment by PES (post P, I)



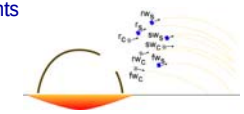
The percentage of primary fragments contained by the PES is calculated considering the percentage of the PES that is intact after the blast wave.

13. Reduce number of primary fragments (due to PES)

The number of primary fragments that exit the PES are calculated based on the percentage of the fragments that were contained within the PES.

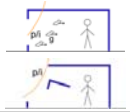
14. Describe secondary fragments and crater ejecta

The number of secondary fragments (by PES component) and the maximum throw range (by PES component) is calculated.



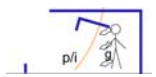
9. Determine P, I effect on ES (building failure and glass hazard)

Lethality from glass shards and building collapse is determined. The percentage of the exposed site damaged is assessed.

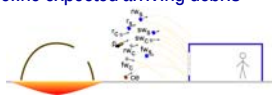


10. Assess Pf(b)

The lethality of glass fragments and building collapse is summed.



15. Define expected arriving debris table

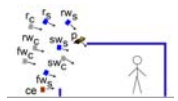


The primary, secondary, and crater debris are distributed using a bivariate normal distribution function and stored in arriving debris tables.

16. Combine PES debris

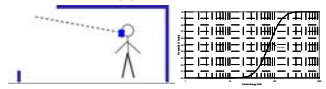
The arriving fragment Kinetic Energy (KE) tables are summed to form one arriving debris table.

17. Reduce debris due to ES



The amount of primary, secondary, and crater debris that penetrates the ES is calculated.

18. Assess Pf(d)



The lethality of the penetrating fragments is determined using the RCC debris lethality S-curve.

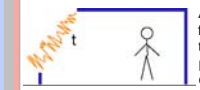
19. Determine nominal thermal hazard factor

A thermal hazard factor based on the yield and distance between the PES and the ES is calculated.

20. Adjust thermal hazard factor (due to PES)

An adjusted thermal hazard factor is calculated that considers the presence of the PES.

21. Determine ES protection



A thermal blocking factor that describes the thermal protection provided by the ES is calculated.

22. Assess Pf(t)

The lethality of thermal effects is calculated.

Summation

23. Sum Pf|e

Blast, glass, building collapse, debris, and thermal lethality mechanisms are summed.

$$P_{f/e} = P_{f(o)} + (P_{f(b)})(1-P_{f(o)}) + (P_{f(d)})(1-P_{f(o)})(1-P_{f(b)}) + (P_{f(t)})(1-P_{f(d)})(1-P_{f(b)})(1-P_{f(o)})$$

24. Calculate P(f)

The individual and group risk for a PES/ES pair is calculated.

$$E_{f(ES)} = P_e * P_{f/e} * E_p$$

$$P_{f(ES)} = \frac{E_{f(ES)}}{No.of\ people}$$

All cases done? → Next yield

All ESs done? → Next ES

25. Sum E(f) from single PES. Search for maximum P(f) for PES.

The individual and group risk for a PES is calculated.

$$E_{f(PES)} = \sum_{ES\ sites} E_{f(ES)}$$

User done? → Next PES

26. Sum E(f) for site. Search for maximum P(f) for site.

The individual and group risk for a site is calculated.

$$E_{f(site)} = \sum_{PES\ sites} E_{f(PES)}$$

- Input, P(e), Exposure Branch
- Effects and Consequence Branch
- Pressure, Impulse Branch
- Glass and Building Failure Branch
- Debris Branch
- Temperature Branch
- Risk Aggregation Branch