A Bayesian Approach for Munitions Risk at Fort Missoula, Montana

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MEC Cleanup Issues

- High costs for characterization & cleanup of munitions sites
  - Need to be more cost effective
- Tendency to look for “needle in a haystack”
- Current approaches not always adequate
- A Bayesian approach
  - Quantitative
  - Provide insights into potential risks
  - Help prioritize MRS actions
  - Inform and defend risk reduction options
  - Great for sites where little to no MEC is expected

Bayesian Decision Analysis

- Integrate all sources of information to maximize information output
  - Historical Information (leases, aerial photos)
  - Expert Opinion
  - Survey Data
- Account for uncertainty
- Include cost information and value judgements
  - minimize costs ("costs" in a general sense)
- Iteratively update analysis as new information is collected


Blue Mountain Training Area at
Fort Missoula, Montana

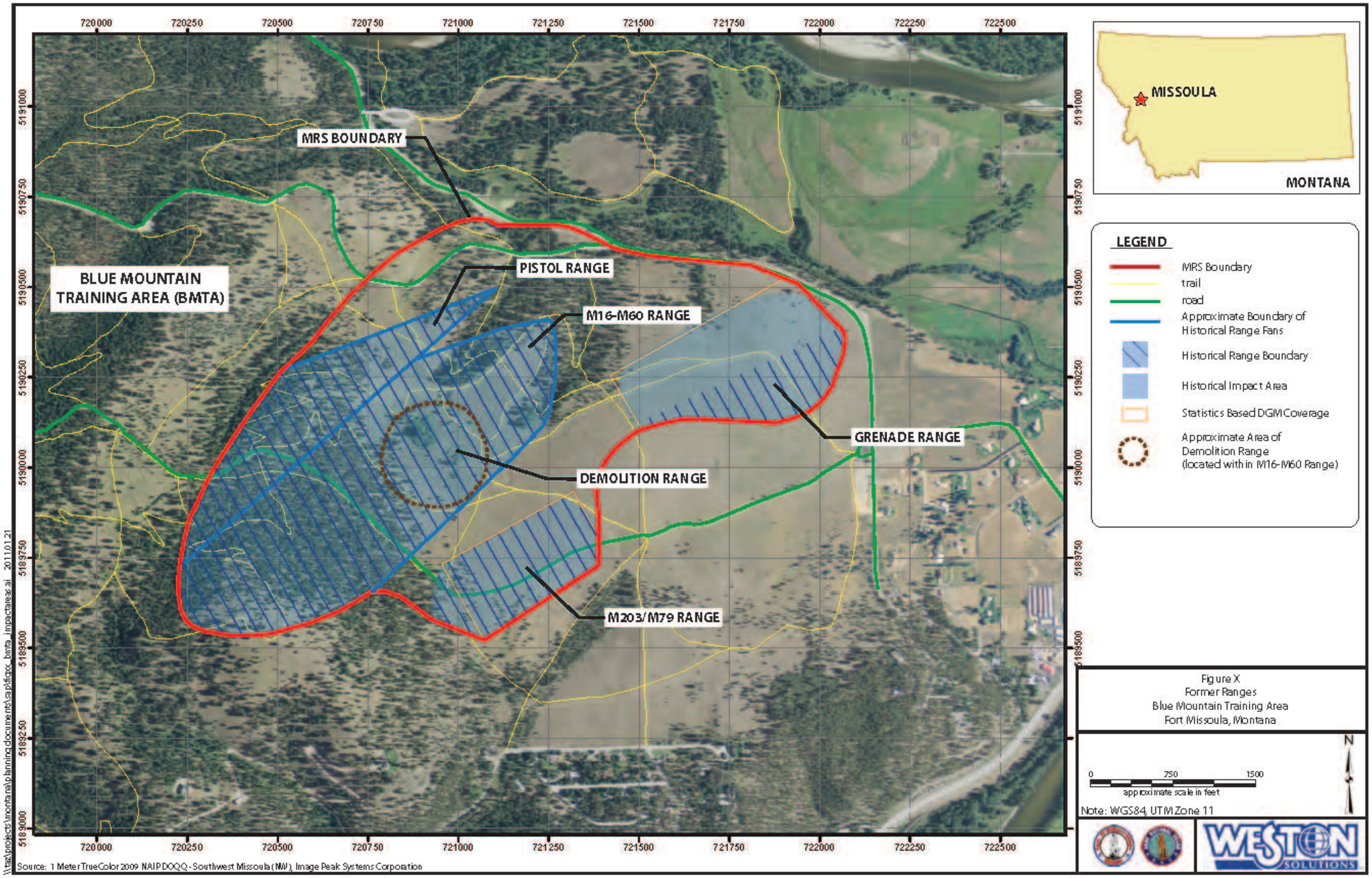
Project Overview

- Montana Army National Guard site
- Weston Solutions, Inc., Lakewood, CO
  - Prime Contractor - Management, Safety, and Quality
- Neptune and Company
  - Sampling, Strategy, Decision Analysis, and Risk Assessment
- Other project team members:
  - Geolex, Inc., Matrix Consulting Group, Inc., TLI Solutions Inc., Golden, CO
- RI/FS, with a time-critical removal action (TCRA)
  - Currently in the FS phase

Fort Missoula Site History

- Used in the mid to late 20th century for live-fire weapons training by Montana Army National Guard
- Potential MEC: 3.5” rockets, 40 mm rocket grenades, hand-held grenades
- Small arms range, as well
- Little to no UXO expected

BMTA Site



MRS BOUNDARY
PISTOL RANGE
M16-M60 RANGE
BLUE MOUNTAIN TRAINING AREA (BMTA)
DEMOLITION RANGE
GRENADE RANGE
M203/M79 RANGE
MISSOULA
MONTANA
LEGEND
MRS Boundary
trail
road
Approximate Boundary of Historical Range Fans
Historical Range Boundary
Historical Impact Area
Statistics Based DGM Coverage
Approximate Area of Demolition Range (located within M16-M60 Range)
Figure X
Former Ranges
Blue Mountain Training Area
Fort Missoula, Montana
approximate scale in feet
Note: WGS84, UTM Zone 11
Source: 1 Meter TrueColor 2009 NAIP DOQQ - Southwest Missoula (MV), Image Peak Systems Corporation

Standard Methods

- Visual Sample Plan (VSP)
  - Sample size given in number of transects to achieve X% confidence that Y% of *transects* are MEC-free
    - Same sample size for different transect size?
- UXO Estimator
  - Sample size given in acreage needed to have X% confidence that MEC *rate* is lower than Y/acre.
    - Must assume constant rate across site
- *Neither of these is a risk statement*

Needle in a Haystack

- In classical statistics, to confirm that an event is rare, use high sampling
  - Target: 2.0 MEC/acre, sample 1.5 acres
  - Target: 0.5 MEC/acre, sample 6 acres
- How are the targets set?
  - Maybe based on tolerable risk …
  - Prior information about the true rates?
  - Shouldn't we spend effort looking where we think we might find MEC?
  - And where the risk is greatest?

MEC Risk

- Should be computing:
  - Prob(incident) or Rate(incident)
  - Rate(incident) =
    Prob(incident | public encounter) ×
    Prob(public encounter | MEC) ×
    Rate of MEC
  - Could break these down further
    - Type of encounter – hiker, construction, etc.
    - Type of MEC

Ft. Missoula – Toward Risk

- Sample design for remedial investigation approved based upon UXO Estimator approach
  - Sampling acreage was specified prior to our involvement
  - We allocated sampling effort

Ft. Missoula – Toward Risk

- Bayesian approach
  - Incorporate prior information regarding rates of MEC at site
  - Use non-homogeneous Poisson model for spatial distribution of MEC
  - For now, use posterior rates as final result
- Risk-based design
  - Prioritize digs of anomalies from analog sensors
  - Specify DGM sample locations

Implementing the Approach

- Information Needed
  - Base Rate of MEC
  - Prob. of Public Encounter
  - Prob. of Incident given Encounter
- Source of Information
  - Experienced UXO experts
    - Informed by historical accounts
    - Preliminary site efforts
    - Experience drawn from other sites

Expert Elicitation: Base Rate

- Base rate of MEC
  - Partition site based on military use
  - Partition site based on public access
    - MEC on trails likely to have been found
- Resulted in 12 regions with different rates in each
  - For analysis purposes, treated each region as having a constant rate within the region
  - For sample design, further prioritized primary target areas

Expert Elicitation: Incident Rate

- Probability of public encounter
  - Presence of vegetation
  - Steep slope [Marsh]
  - Public Areas Difficult: Future encounter bad, but lower likelihood of MEC presence - offsetting?
- Probability of incident given encounter
  - Not willing to discuss human behavior
  - Relative risk based on behavior of field team, for different kinds of MEC

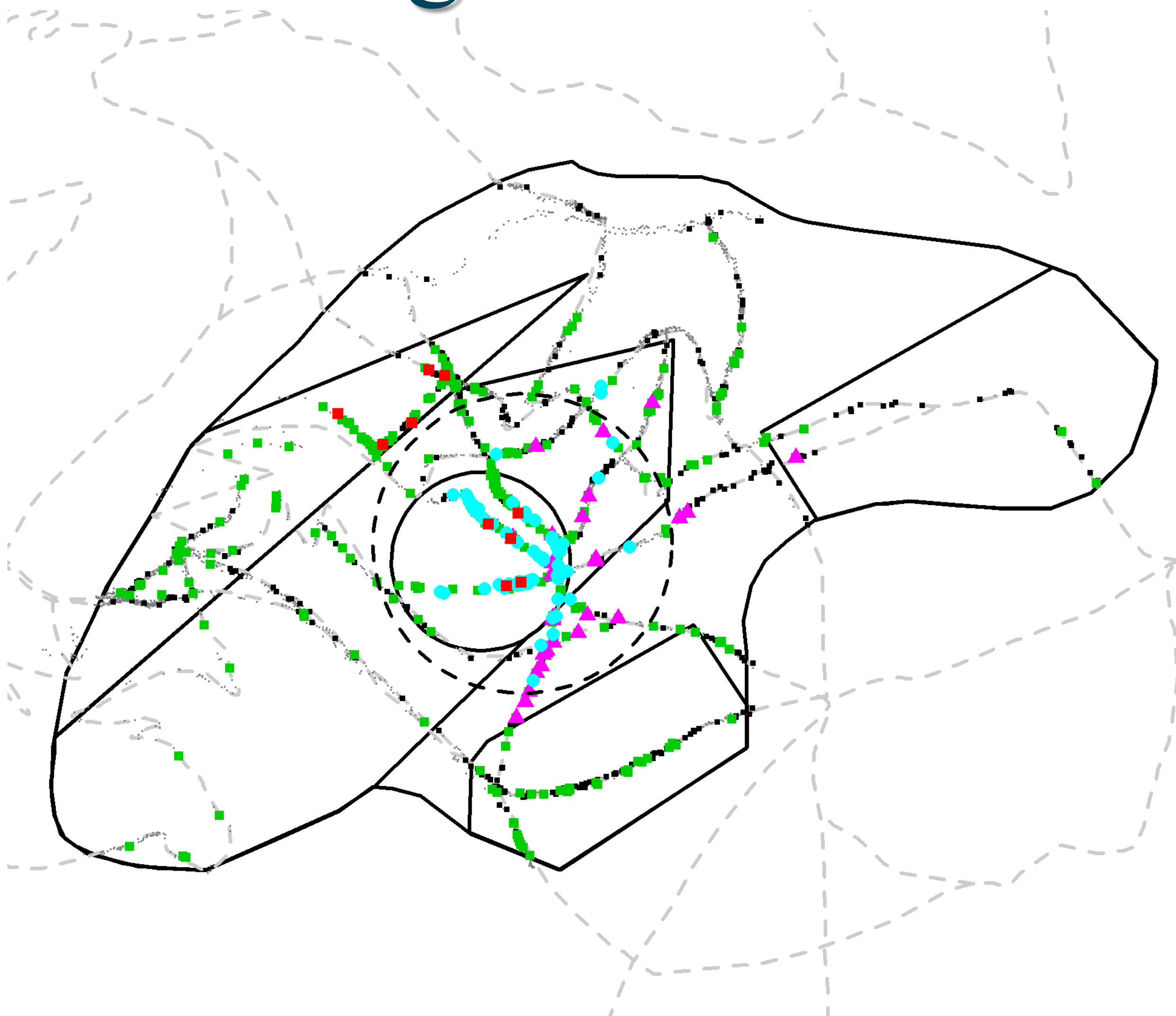
Expert Elicitation: Anomalies

- Probability of MEC given an anomaly
  - Cultural debris present?
  - “Large” hit
  - Experience-based hunch
  - Discussion with field experts revealed that they know a lot more than they can quantify

Anomaly Prioritization

- All trails sampled with analog device
- About 20% of anomalies were dug
  - All anomalies above threshold risk sampled
  - Remaining anomalies randomly sampled with probability proportional to risk weights
  - Some manually chosen sample locations to ensure balance across site

Digs Chosen



Adaptive Design

- Some practical – physical impediments
  - Field team always wanted statistical OK
- Some risk-based
  - High density of anomalies along trail led to re-definition of demolition area
  - Lack of debris in rifle range shifted priority to other areas
  - On-the-fly elicitation moved pistol range southward
- No substitute for being there!

Results

- MEC rates were adequately low by region to “pass” by original design specification
- Bayesian risk-based approach allowed for considerably greater sampling in area of greatest risk concern
  - Bayesian approach more easily incorporates adaptive design
  - Acceptable rate estimates for regions of lower concern, as well

Conclusions

- Bayesian approach resulted in a lower value of the residual density of munitions than did the classical statistical approach
- Bayesian approach especially good for sites with low expected MEC rates
  - Currently used as a tool for *allocating* effort rather than determining *level* of effort