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Lessons Learned from PNNL Support to Army Corp of Engineers Munitions Sites

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September 2012

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PNNL developed and demonstrated statistically-based methods for characterizing sites where unexploded ordnance (UXO) is a concern. These methods, incorporated into PNNL's Visual Sample Plan (VSP) software, can be used to design geophysical transect surveys and conduct data analyses to identify potential target areas, map and estimate anomaly density across the study area, and delineate target areas where UXO are most likely to be found. These methods have been tested and demonstrated on several wide area sites under the Department of Defense Environmental Security Technology Certification Program (ESTCP).

During FY11-FY12, under the direction of The U.S. Army Corp of Engineers Huntsville Center (USACE) and Omaha District, PNNL supported several VSP applications at four sites including

- Former Camp Swift, Bastrop, TX site
- Maui Bombing Targets, Maui, HI site
- Former Camp Wheeler, Macon, GA site
- Former Pole Mountain Target and Maneuver Area, Albany County, Wyoming site.

PNNL provided technical support to guide the USACE, contractors, and regulators in the proper use of VSP for each of these sites, assisting in facilitating solicitation of VSP user parameter inputs, design of transect surveys, input of survey data into VSP, analysis of survey results to identify/delineate potential target areas and map/estimate anomaly densities, and review of technical reports.

Several lessons learned were derived from these experiences. This report documents these lessons learned and outlines how some of the encountered issues were resolved or recommends efforts that would help to resolve those issues in the future. A summary of these lessons learned is shown below followed by a detailed description of each lesson learned. These lessons learned have been grouped into 3 categories as follows.

- Best Practices Recommendations
- VSP Modifications or Improvements
- Future Needs

LESSONS LEARNED SUMMARY

Best Practices Recommendations	
	1. Avoid transect placement along roads or trail paths unless access restrictions otherwise dictate.
	2. May need to run multiple VSP simulations when above 90% detection probability range (fixed with VSP simulation speed improvements).
	3. Vary assumed parameters in VSP to explore sensitivity and present alternative options.
	4. Reserve some of the contracted transect acreage for additional transects that may be needed to further investigate and delineate potential target areas identified using initial transects.
	5. Recognize that actual transect course-over-ground will vary from as-designed transects; Small departures have little effect on target area detection probabilities.
	6. When performing combined analysis on transect and grid survey data, need to determine if spatial correlation is consistent; otherwise analyze separately.
	7. Perform separate analyses on geophysical and recon data; don't combine them into one VSP analysis.
VSP Modifications or Improvements Made	
	1. Added methodology in VSP for better handling and analysis of recon data.
	2. Improved VSP handling and analysis of combined transect and grid survey results.
	3. Power curve simulation speed in VSP was significantly improved.
	4. Converted kriged estimates to raster data layers to allow viewing of spatial maps from multiple geostatistical analyses.
Future Needs	
	1. Standardization of recon data reporting and handling with appropriate training.
	2. VSP modifications to better deal with access restrictions and use of roadways/trails for transect placement when access is limited.
	3. VSP RI process workflow and additional VSP modules that support all RI objectives.
	4. In VSP automatically create sample areas around imported transects or anomalies if sample area doesn't exist.
	5. Target size selection guidance needed.
	6. Additional training for contractors through VSP courses and VSP project support.

DETAILED DESCRIPTION OF LESSONS LEARNED

A more detailed description of each of the lessons learned summarized above is next presented. When dealing with real sites and real data, certain nuances present specific challenges. As our team encountered these, we recognized the need to solve these issues and share our resolutions and recommendations. Each lesson learned is discussed below.

Best Practices #1: ***Avoid transect placement along roads or trail paths unless access restrictions otherwise dictate.*** When transects are placed along roads or trails, more cultural anomalies are expected. This makes it more difficult to distinguish between actual target areas and areas where the anomaly density is higher because of the cultural clutter. To avoid this, we tried to place transects perpendicular to major roads or trails. The exception to this is when roads and trails may represent the only realistic location for transects within the area (i.e., very heavily forested area).

Best Practices #2: ***May need to run multiple VSP simulations when above 90% detection probability range.*** VSP performs monte-carlo simulations to produce the target area detection curves that show the probability of traversing and detecting target areas given the transect spacing and other design inputs. Sometimes when evaluating this probability over a wide range of transect spacing scenarios or target area densities, the probability curve may be relatively flat in the 90% to 99% range. In that flat part of the curve, large changes in the transect spacing may have minimal effect on the detection probability due to the lack of precision within that region of the curve. To avoid this problem, VSP should be re-run using a narrower transect spacing evaluation range or target area density range. In future releases of VSP (version 6.3 or beyond), the time required to run the monte-carlo simulations time has been significantly reduced. This reduction in computational need will provide more precise detection curves as the number of monte-carlo runs can be greatly increased for each design. This should mitigate/fix this problem for most applications, but, if issues are encountered, the user can still control the required precision parameter of the detection curves.

Best Practices #3: ***Vary assumed parameters in VSP to explore sensitivity and present alternative options.*** When designing a transect survey, it is always good practice to vary some of the VSP input parameters (assumed target area size, background density, target area density, etc.) to examine the effect on the transect survey design. Similarly when performing VSP analyses on transect, grid, or recon results, a sensitivity analysis varying some of the kriging or variogram parameters will also provide valuable information on the effect of these parameters. We found that although we would recommend a specific transect survey design, it was always good to have other options easily available if some of the parameter assumptions were called into question.

Best Practices #4: ***Reserve some of the contracted transect acreage for additional transects.*** Often the contractor's bid includes an estimation of the transect coverage planned. After a VSP target area flagging and geostatistical evaluation of the initial transect survey, there are often some areas where the results are inconclusive and a few additional transects focused in those areas would help resolve whether they represent potential target areas of concern. Thus, it is important to reserve some of the contracted transect acreage for these additional focused transects.

Best Practices #5: ***Small departures from planned course-over-ground transects will have minimal effect on target area detection probabilities.*** VSP produces parallel or lattice transects. In the field, there are rocks, trees, gullies, or other obstacles that make it impossible to exactly follow the as-designed transects perfectly. Although such departures will affect the VSP probabilities of traversal and detection, if those departures are not drastic, they will have minimal effect on the achieved probability. For areas where the departures from the as-designed transects are significant (i.e., areas where transects are not possible), obviously the as-designed detection probabilities will not be achieved for those areas.

Best Practices #6: ***When performing combined analysis on transect and grid survey data, need to determine if spatial correlation is consistent; otherwise analyze separately.*** For many sites anomaly data is available from both transect surveys and 100% grid survey areas. Although VSP can now include both sets of data in a geostatistical kriging analysis, the user should explore the spatial correlation of each data set separately. If the spatial correlation (variogram) models are very different, it is not appropriate to combine these two data sets into a single geostatistical analysis.

Best Practices #7: ***Perform separate analyses on geophysical and recon data; don't combine them into one VSP analysis.*** VSP has been modified to support geostatistical analysis of recon data. Sometimes both recon and geophysical data are available for a particular site. Although each of these data sets can provide valuable collaborative information, the spatial correlation structure for each is very different. Therefore, separate VSP geostatistical analyses should be performed. Future VSP releases will better facilitate such separate analyses and visualizations within the same VSP project.

VSP Modifications or Improvements Made #1: ***Added methodology in VSP for better handling and analysis of recon data.*** Recon data usually consists of the starting and ending location of a transect segment and the number of anomalies observed within that segment. VSP was modified to accept this type of data and perform geostatistical mapping. VSP takes the total number of observed anomalies within a segment and equally spaces those across that segment to permit geostatistical evaluation. The types of items observed (i.e., DMM, UXO, cultural debris, etc.) can also be displayed on the VSP map and separate geostatistical analyses can be performed for each type if appropriate. This feature will be available in VSP 6.3.

VSP Modifications or Improvements Made #2: ***Improved VSP handling and analysis of combined transect and grid survey results.*** VSP has now been modified to incorporate both transect survey and 100% grid survey results into a single geostatistical analysis. Density estimates from both data sets are obtained and combined to derive a single spatial map of anomaly density. As mentioned above, care should be taken to ensure that the underlying spatial correlation is similar for each data set. This feature will be available in VSP 6.3.

VSP Modifications or Improvements Made #3: ***Power curve simulation speed in VSP was significantly improved.*** The power curve simulation in VSP often took minutes to complete. This was inconvenient when multiple power curves were being created or iterative analyses were being performed to evaluate parameter sensitivity. This code has now been greatly improved to achieve over 50X improvements in computational speed. Because of this speed improvement, we have changed the default precision for the power curves which helps address the concern listed under Best Practices #2 above. This feature will be available in VSP 6.3.

VSP Modifications or Improvements Made #4: ***Converted kriged estimates to raster data layers to allow viewing of spatial maps from multiple geostatistical analyses.*** With the ability to perform geostatistical analyses on recon, transect, combined transect and grid, and subsets of anomaly types, the kriged estimates have been converted to raster data layers to allow viewing of all these spatial maps as different map layers. Now within the same project file, all these analyses can be performed and resulting maps viewed. This feature will be available in VSP 6.3.

Future Needs #1: ***Standardization of recon data reporting and handling with appropriate training.*** When working with different contractors, the data format for the recon data seemed to vary. As a result, we suggest a particular format that VSP can easily accept when importing this recon data. A standardized format that would be used across all contractors would ensure easy import into VSP while minimizing potential data entry errors. An example of the recon data format received from one contractor that was imported into VSP is shown in Appendix A.

Future Needs #2: ***VSP modifications to better deal with access restrictions and use of roadways/trails for transect placement when access is limited.*** In most of the sites, there was some access restriction. VSP should be modified to easily view and distinguish the inaccessible from the accessible areas. That could be accomplished using the VSP user defined parameters but a simpler approach may be desirable. Although not encountered in these particular sites, other sites are heavily forested with significant undergrowth, making it very difficult to access all areas of the site. Under a separate contract with the ACOE, we are modifying VSP to allow placement of transects on existing roadways and then augmenting those with additional transects that will still achieve desired probabilities of target area traversal and detection.

Future Needs #3: ***VSP RI process workflow and additional VSP modules that support all RI objectives.*** These site applications illustrated that during an RI several types of sites and multiple RI objectives are possible. During an RI one might encounter three types of regions within a site including

- Regions with potential or known target areas,
- Regions outside of target areas where there is some potential munition use,
- Regions where no munition use is suspected, but further survey evidence is necessary to validate claims.

The survey objectives and decision rules for each type of region may be very different. ESTCP is funding PNNL to determine all RI sampling/survey objectives and develop a VSP RI process workflow. We are in the process of adding VSP modules that will address all of these RI objectives.

Future Needs #4: ***In VSP automatically create sample areas around imported transects or anomalies if sample area doesn't exist.*** At times transect survey data are available but the site maps are more difficult to obtain. VSP could be easily modified to automatically create sample areas that are inclusive of the imported transect course-over-ground or anomaly files. This would then allow all the VSP geospatial analyses to be performed without a pre-loaded map.

Future Needs #5: ***Target size selection guidance needed.*** One of the most difficult to determine VSP parameter input is the target area size of concern. Most contractors struggle with determining an appropriate input for this. This parameter is typically driven by the munitions of concern and the expected frag dispersion pattern. PNNL is working with Huntsville ACOE to provide a recommended target area size for a given munition. We expect this to be completed and available in VSP within the next 6 months.

Future Needs #6: ***Additional training for contractors through VSP courses and VSP project support.*** The PNNL team worked hand-in-hand with the contractors on these 4 sites. We found that if we provided only hands on support without additional general training or the contractors attended our general VSP training course without hands-on site-specific support, the contractors generally did not completely grasp all VSP elements. However, for two of the sites, we provided both hands-on support and review as well as a detailed 2-day training course and in those cases the contractors seemed to become much more proficient at correctly applying VSP. We therefore recommend that the PNNL VSP team be supported by the ACOE to provide both the hands-on site-specific support combined with a focused 2-day training effort for various contractor organizations.

SUMMARY

PNNL provided hands-on and reviewer support to several ACOE contractors as they attempted to use VSP to support some RI objectives on four specific sites. This was an excellent experience for the PNNL VSP team and resulted in several VSP modifications and valuable lessons learned. The contractors involved also seemed to highly appreciate our involvement in developing technically defensible work plans and survey designs and spatial analysis results. We recommend that this practice of supporting PNNL to assist, review, and train contractors on specific RI applications be continued. We also recommend that the future needs identified above be supported by the ACOE where not already supported by ESTCP.

Appendix A

Example of Recon Data format for VSP Input

Data No.	SUB_HITS	SURF_HIT	FE	NON_FE	UXO	DMM	MD	RRD	CD	PNT_TYP	DESC1	DESC1_CN	DESC2	DESC2_CN	DESC3	DESC3_CN	DESC4	DESC4_CN	DESC5	DESC5_CN	NOTES	Instrumen	Fieldwork	POINT_X	POINT_Y
1	0	0	0	0	0	0	0	0	0	Recon Point		0		0		0		0		0	START	Schonsted	Mar-10	408256	4473786
2	2	1	1	0	0	0	1	0	0	Recon Poi	Small Arm	1		0		0		0		0		Schonsted	Mar-10	408291	4473753
3	3	13	12	1	0	0	13	0	0	Recon Poi	Small Arm	12	Small Arm	1		0		0		0		Schonsted	Mar-10	408326	4473717
4	1	0	0	0	0	0	0	0	0	Recon Point		0		0		0		0		0		Schonsted	Mar-10	408356	4473681
5	0	0	0	0	0	0	0	0	0	Recon Point		0		0		0		0		0		Schonsted	Mar-10	408396	4473713
6	0	1	0	1	0	0	1	0	0	Recon Poi	40mm PRJ	1		0		0		0		0		Schonsted	Mar-10	408359	4473748
7	3	4	0	4	0	0	4	0	0	Recon Poi	Small Arm	4		0		0		0		0		Schonsted	Mar-10	408326	4473788
8	1	0	0	0	0	0	0	0	0	Recon Point		0		0		0		0		0		Schonsted	Mar-10	408298	4473821
9	1	1	1	0	0	0	1	0	0	Recon Poi	Small Arm	1		0		0		0		0		Schonsted	Mar-10	408333	4473857
10	0	0	0	0	0	0	0	0	0	Recon Point		0		0		0		0		0		Schonsted	Mar-10	408371	4473820
11	0	2	0	2	0	0	2	0	0	Recon Poi	40mm GR	1	Small Arm	1		0		0		0		Schonsted	Mar-10	408400	4473780
12	0	0	0	0	0	0	0	0	0	Recon Point		0		0		0		0		0		Schonsted	Mar-10	408434	4473743
13	0	0	0	0	0	0	0	0	0	Recon Point		0		0		0		0		0		Schonsted	Mar-10	408463	4473707
14	0	0	0	0	0	0	0	0	0	Recon Point		0		0		0		0		0		Schonsted	Mar-10	408502	4473740
15	1	1	1	0	0	0	1	0	0	Recon Poi	Small Arm	1		0		0		0		0		Schonsted	Mar-10	408472	4473780
16	2	50	0	50	0	0	50	0	0	Recon Poi	Small Arm	48	Projo Casi	1	40mm G	1		0		0		Schonsted	Mar-10	408432	4473815
17	2	3	0	3	0	0	3	0	0	Recon Poi	40mm GR	3		0		0		0		0		Schonsted	Mar-10	408396	4473850
18	0	0	0	0	0	0	0	0	0	Recon Point		0		0		0		0		0		Schonsted	Mar-10	408375	4473891
19	1	3	0	3	0	0	3	0	0	Recon Poi	Flare	1	40mm GR	2		0		0		0		Schonsted	Mar-10	408404	4473923
20	2	0	0	0	0	0	0	0	0	Recon Point		0		0		0		0		0		Schonsted	Mar-10	408437	4473884
21	10	6	3	3	0	0	5	1	0	Recon Poi	Hand Grer	2	Commo W	1	40mm G	3	Target	2		0		Schonsted	Mar-10	408469	4473848
22	11	4	2	2	0	0	4	1	0	Recon Poi	Target	1	Small Arm	2	40mm G	2		0		0		Schonsted	Mar-10	408503	4473810
23	1	0	0	0	0	0	0	0	0	Recon Point		0		0		0		0		0		Schonsted	Mar-10	408537	4473776
24	8	0	0	0	0	0	0	0	0	Recon Point		0		0		0		0		0		Schonsted	Mar-10	408579	4473806
25	6	2	1	1	0	0	1	1	0	Recon Poi	40mm GR	1	Mover	1		0		0		0		Schonsted	Mar-10	408538	4473844
26	6	13	1	12	0	0	12	1	0	Recon Poi	40mm GR	6	Small Arm	6	Mover	1		0		0		Schonsted	Mar-10	408513	4473881
27	3	10	0	10	0	0	10	0	0	Recon Poi	Small Arm	8	40mm GR	2		0		0		0		Schonsted	Mar-10	408474	4473920
28	2	1	0	1	0	0	1	0	0	Recon Poi	40mm GR	1		0		0		0		0		Schonsted	Mar-10	408444	4473954
29	3	2	0	2	0	0	2	0	0	Recon Poi	60mm MC	1	Grenade C	1		0		0		0		Schonsted	Mar-10	408482	4473987
30	6	1	0	1	0	0	1	0	0	Recon Point		0	Small Arm	1		0		0		0		Schonsted	Mar-10	408515	4473954