UNEXPLODED ORDNANCE (UXO) SAMPLING PROTOCOL

1. Purpose. This protocol provides the preferred sampling techniques and strategies to be used in conducting engineering evaluation/cost analysis (EE/CA) investigations at U.S. Army Engineering and Support Center, Huntsville (USAESCH) ordnance and explosives (OE) sites. USAESCH encourages innovative thinking, but insists that any statistical tools different than those presented in this protocol be evaluated and approved by the USAESCH OE Mandatory Center of Expertise (MCX) prior to use at a USAESCH site. The technical point of contact (POC) for this activity is Arkie Fanning, PE, 256-895-1762. The administrative POC for this activity is James Manthey, PE, 256-895-1588.

2. Overview. The UXO statistical process is meant to answer two questions. First, do I have a homogeneous sector? Second, what is the number of UXO items in the sector? The first question is important because we need to make sure that our sample is representative. When we can answer the first question affirmatively, we know that our sample is representative. The second question is important because the answer to this question constitutes a significant factor in our decision-making process. If, for example, there are only small amounts of UXO at a site, removals may not be necessary.

a. Currently, we answer the "do I have a homogeneous sector" question by the use of a spatial statistic called the "hopkins statistic." This statistic is presented at appendix A. One should be aware, however, that the sectorization problem is the most difficult statistical problem in the UXO arena. One must be able to define the area of the sector, determine that it is homogeneous (sector homogeneity has no given definition), and determine the expected number of UXO items in the sector. A statistical sector may or may not be the same as a risk sector or a removal sector. Engineering judgment plays a large role in the decision making for response actions. For example, a sector may be shown to be homogeneous, but still only a small portion of that sector will have removals.

b. The density statistics developed by USAESCH have been based on the hypergeometric distribution, the binomial distribution, or the negative binomial distribution. All of these distributions are classic sampling distributions when the question to be answered is, "is this a good or a bad item?" Usually, the major difference between binomial distribution and hypergeometric distribution is that the binomial assumes sampling with replacement and the hypergeometric assumes sampling without replacement. However, USAESCH has developed a special statistical methodology (UXO Calculator) that is based on the binomial (negative binomial, actually) but uses sampling without replacement in the statistic. An example of how to perform density calculations using UXO Calculator is presented at appendix B.

3. Decision-Making Process. The UXO statistics at an OE site must support an open decision-making process. The process requires that many stakeholders have a voice in what the ultimate decision is at a site. There are three National Oil and Hazardous

Substances Pollution Contingency Plan (NCP) criteria that must be considered with respect to each sector in order to

determine the best response for that sector. These criteria are implementability, effectiveness, and cost. There is no specific requirement for evaluation of statistics in the NCP criteria.

a. The UXO statistics are used to determine the nature and extent of UXO in a sector so that an intelligent decision concerning response action can be made. There are no standards, however, which define an acceptable level of precision for the statistic or at what level of sector UXO a given decision is appropriate (e.g., there is no standard that states that a removal response action must occur when density is "x").

b. The amount of sampling required to support the decision-making process is highly variable. At some sites, very little sampling is needed to determine what the appropriate response action should be. At others, much more sampling is required. The amount of sampling that should be performed at a site depends on the estimate precision required for each sector, the budget available to perform the sampling, alternatives that are to be considered for each sector, and many other variables. It is the responsibility of the OE team to determine what sampling must be done and whether or not the EE/CA budget can meet the sampling requirement.

4. When Not to Use the USAESCH Statistics. The USAESCH-developed statistics should not be used to search for pits, to search for random burials, and in dynamic environments (i.e., environments in which the amount of UXO is changing, such as a beach area). The statistics assume that the sample is representative of the population, and this may not be true for those cases cited, and possibly others. The OE team should make the determination that the statistics are proper to use for the particular site in question. If there are questions concerning the appropriate statistic to use for a site, then the team should contact the USAESCH OE MCX for advice.

5. When Should a Sample be Taken? The USAESCH-developed statistics assume that there is a probability of finding UXO. If there is no proof that OE has ever been fired into the area under investigation, a statistical approach may not be necessary. Sampling is expensive and should be used only when the results are likely to justify the expense. The team should determine if there should be some exploratory sampling (sampling that is not statistically sufficient but is logically sufficient) if it is determined that sampling is required in an area where there are no historical indicators of OE. The team may choose to randomly sample 0.5 to 1 percent on the surface to see if there are any indications of OE scrap. If there are no such indications, there may be no need to perform statistical sampling for the sector at all.

6. UXO Statistical Process. Following is the current process used by USAESCH to determine the appropriate UXO statistics for OE sectors.