



Designation: D6982 – 03

Standard Practice for Detecting Hot Spots and Buried Objects Using Point-Net (Grid) Search Patterns¹

This standard is issued under the fixed designation D6982; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice provides equations and nomographs, and a reference to a computer program, for calculating probabilities of detecting hot spots (that is, localized areas of soil or groundwater contamination) and buried objects using point-net (that is, grid) search patterns. Hot spots, more generally referred to as targets, are presumed to be invisible on the ground surface. Buried objects may include former surface impoundments, waste disposal pits, and utilities that have been covered by soil or paving materials. Hot spots may also include contaminant plumes in ground water or soil gas.

1.2 For purposes of calculating detection probabilities, hot spots or buried objects are presumed to be elliptically shaped when projected vertically to the ground surface, and search patterns are square, rectangular, or rhombic. Assumptions about the size and shape of suspected hot spots are the primary limitations of this practice, and must be judged by historical information. A further limitation is that hot spot boundaries are assumed to be clear and distinct. Alternative approaches to hot spot detection using discrete sampling should also be considered where feasible, such as surface geophysical measurements (see Guide D6429).

1.3 Search sampling would normally be conducted during preliminary investigations of hazardous waste sites or hazardous waste management facilities (see Guide D5730). Sampling may be conducted via drilling or by direct-push methods. In contrast, guidance on sampling for the purpose of making statistical inferences about population characteristics (for example, contaminant concentrations) can be found in Guide D6311.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

¹ This practice is under the jurisdiction of ASTM Committee D34 on Waste Management and is the direct responsibility of Subcommittee D34.01.01 on Planning for Sampling.

Current edition approved Nov. 1, 2003. Published January 2004. DOI: 10.1520/D6982-03.

2. Referenced Documents

2.1 ASTM Standards:²

- D5730 Guide for Site Characterization for Environmental Purposes With Emphasis on Soil, Rock, the Vadose Zone and Ground Water
- D6051 Guide for Composite Sampling and Field Subsampling for Environmental Waste Management Activities
- D6311 Guide for Generation of Environmental Data Related to Waste Management Activities: Selection and Optimization of Sampling Design
- D6429 Guide for Selecting Surface Geophysical Methods

3. Terminology

3.1 Definitions:

3.1.1 *hot spot*—a localized area of soil or groundwater contamination.

3.1.1.1 *Discussion*—A hot spot may be considered as a discrete volume of buried waste or contaminated soil where the concentration of a contaminant of interest exceeds some prespecified threshold value. Although elliptically shaped hot spots or targets are assumed for the purposes of calculating probabilities of detecting hot spots, hot spots are more likely to have variable sizes and shapes and not have clear and distinct boundaries. However, the concept of hot spots is consistent with known historical patterns of contaminant distributions.

3.1.2 *sampling density*—the number of borings (that is, sampling points) per unit area.

3.1.3 *semi-major axis, a*—one-half the length of the long axis of an ellipse. For a circle, this distance is simply the radius.

3.1.4 *semi-minor axis, b*—one-half the length of the short axis of an ellipse.

3.1.5 *target*—the object or “hot spot” that is being searched for.

3.1.6 *threshold concentration*—the concentration of a contaminant above which a hot spot is considered to be detected.

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

3.1.7 *unit cell*—the smallest area into which a grid can be divided so that these areas have the same shape, size and orientation. For a triangular grid, the unit cell is a 60°/120° rhombus comprised of two equilateral triangles with a common side.

3.2 *Symbols:*

a = length of the semi-major axis of an ellipse

b = length of the semi-minor axis of an ellipse

A_T = area of target or hot spot. For an ellipse, $A_T = \pi ab$.

A_S = search area

S = the “shape” of an elliptical target (that is, the ratio of the length of the semi-minor axis to the length of the semi-major axis of an ellipse, b/a)

G = the distance between nearest grid nodes of a unit cell

Q = the ratio of the length of the long side of a rectangular grid cell to the length of the short side

A_C = the area of the unit cell. For a square, $A_{sq} = G^2$. For a rectangle $A_{re} = Q \cdot G^2$. For a 60°/120° rhombus, $A_{rh} = [(\sqrt{3})/2]G^2$. The inverse of A_C is the sampling density

β = the probability of not detecting a hot spot (that is, “consumer’s risk”)

$P(hit)$ = probability of detection (that is, $1 - \beta$)

4. Significance and Use

4.1 Search sampling strategies have found wide utility in geologic exploration where drilling is required to detect subsurface mineral deposit, such as when drilling for oil. Using such strategies to search for buried wastes, subsurface contaminants, and underground structures is a logical extension of these strategies.

4.2 Systematic sampling strategies are often the most cost-effective method for searching for hot spots or buried objects.

4.3 Search sampling patterns may also be used to optimize the locations of ground water monitoring wells or to optimize the location of vadose zone monitoring devices.

4.4 This practice may be used to determine the risk of missing a target of specified size and shape given a specified sampling pattern and sampling density.

4.5 This practice may be used to determine the smallest target that can be detected with a specified probability and given sampling density.

4.6 This practice may be used to select the optimum grid sampling strategy (that is, sampling pattern and density) for a specified risk of not detecting a hot spot or buried object.

4.7 By using the algorithms given in this practice, one can balance the cost of sampling versus the risk of missing a hot spot or buried object.

5. Assumptions

5.1 One or more targets (for example, hot spots) exist and are equally likely to occur in any part of the search area.

5.2 When projected vertically upward to a level ground surface, the target appears as an ellipse or a circle (Fig. 1). The probable size and shape of a hot spot can only be guessed from past site or facility records, known layout of the site or facility, and personal knowledge.

5.3 The search pattern is either a square, a rectangular, or an equilateral triangular grid. Borings are made at the intersections of grid lines (that is, nodes) (Fig. 2).

5.4 Borings or direct-push devices are directed downward vertically and the detection of the target is unambiguous. For detection of buried solid objects, this should present little difficulty. However, for buried contaminants, such an assumption presumes that the full depth of a boring would be subject to analysis as contiguous intervals of the boring. If sampling intervals are discontinuous, then contamination might be missed if it occurred between sampled intervals. If sampling intervals are too long, then a hot spot may not be detected because of dilution of a hot spot with less contaminated portions of the sampled interval. The criteria for detection of

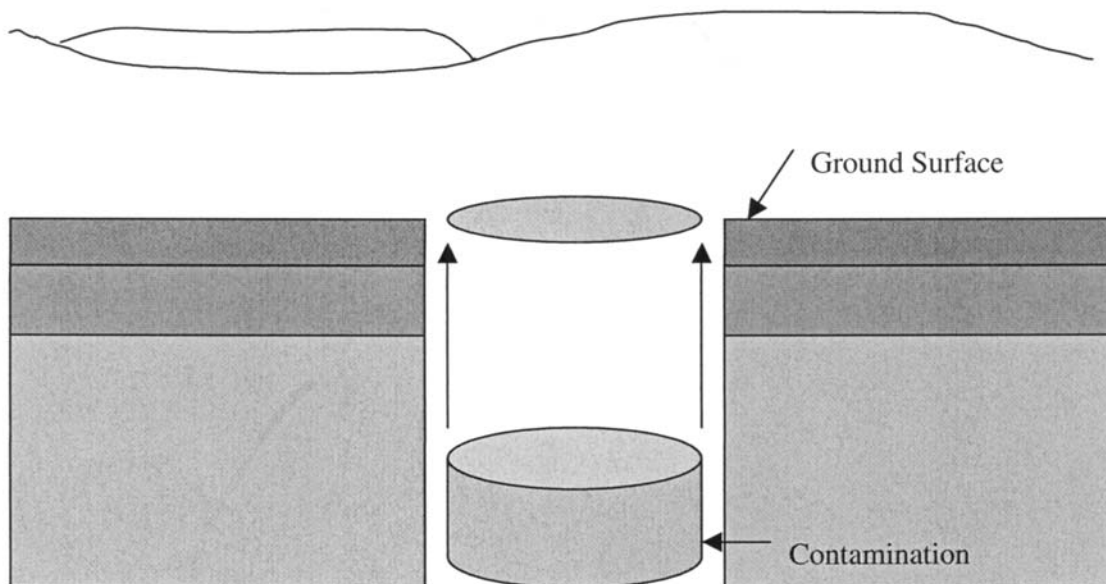


FIG. 1 Projection of Boundaries of Subsurface Contamination to the Ground Surface

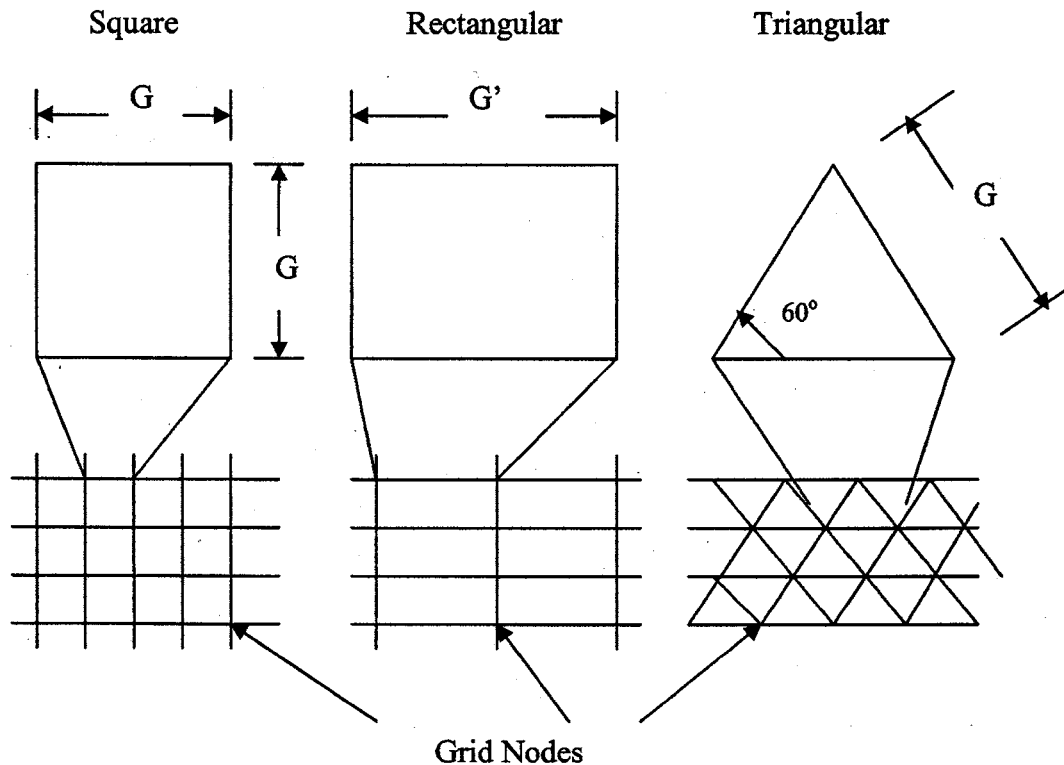


FIG. 2 Grid Patterns for Detecting Hot Spots. Borings are Made at the Grid Nodes

contaminants may be prespecified threshold concentrations (for example, screening levels) that would trigger further investigation of sites or facilities.

5.5 The area of the borehole or direct-push device is infinitely small compared to the target area. The algorithms used in this practice assume that borehole or direct-push devices have no area, but rather are treated as a vertical line.

6. Preliminary Considerations

6.1 Before designing a hot spot detection strategy, a preliminary investigation of the area containing possible hot spots or targets should be conducted. From historical records, physical layout of buildings and equipment, known transportation pathways, landscape features, and eyewitness accounts, one may be able to identify areas with a high probability of subsurface contamination or the presence of buried waste or objects such as underground storage tanks. Areas with different expected probabilities of detection of a hot spot or other target should be clearly mapped.

6.2 Within areas of relatively uniform expected probability of hot spot or target detection, sampling grids of prespecified grid spacing G and type (for example, square, rectangular, or triangular) may be overlain. Areas with higher expected occurrence of hot spots or buried objects should have correspondingly higher sampling densities compared to areas with lower expected occurrence. However, areas with greater hazard from missing a hot spot should also have correspondingly higher sampling densities than areas with a lesser hazard. Ideally, the starting point for each grid and its orientation should be randomly determined.

6.3 When searching for hot spots, threshold concentrations for detection may be established by a regulatory authority. Whether or not a threshold concentration is exceeded will depend upon the physical distribution of the contaminant, the volume of the sampling device, the sampling intervals selected, and the sensitivity of the analysis. If contamination occurs in a discrete layer, then the probability of detecting a hot spot will decrease with increasing volume of material sampled in a bore hole or if the sampling interval exceeds the depth of the discrete hot spot layer. The analytically determined contaminant concentration may then be less than the threshold concentration because of the dilution of the hot spot layer with other layers of soil or waste. Further, a hot spot confined to a discrete layer may be missed entirely by not sampling that layer. For this reason, continuous sampling is recommended.

6.4 Detection of contaminant levels in samples above threshold concentrations or the detection of buried objects may trigger further action requiring possibly more detailed drilling and sampling to better define spatially the location of hot spots or buried objects. Again, a grid sampling strategy will be the most efficient. If new boring locations are centered at the midpoints of the unit cells, the total number of borings will be exactly doubled.

7. Computing Hot Spot Detection Probabilities

7.1 *Case I*—If the longest dimension of an elliptical target is less than or equal to the grid spacing (that is, $2a \leq G$), then the target can only be hit once and the probability P of detecting the hot spot is simply equal to the ratio of the area of the target A_T to the area of the unit cell A_C (that is, $P = A_T/A_C$).