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Visual Sample Plan User's Guide for the Range Sustainability Module

R. O. Gilbert
J. E. Wilson
B. A. Pulsipher

June 2005

Prepared for the U.S. Navy
under Contract GS-10F-0275K

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Visual Sample Plan User's Guide for Establishing the Boundary of Contamination

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Abstract

This user's guide provides instructions for using the boundary sampling module in Visual Sample Plan (VSP) to determine if the current boundary of a known contaminated U.S. Navy training range completely encloses the area of contaminated soil. Movement of contaminants across only a portion of a boundary line can also be evaluated. This module uses inputs supplied by a VSP user to divide the boundary into equal-length segments. In each segment one or two multiple increment (MI) soil samples are collected and measured for contaminants of concern. These measurements are used by VSP to compute an upper confidence limit (UCL) on the mean concentration for each segment. The UCL for each segment is then compared to a user-specified threshold value to statistically test if contamination has breached the boundary. If so, the boundary segment is bumped out in a triangular shape to form two new boundary segments that are the same length as the parent boundary. One or two MI samples are then obtained from each new segment and the UCL testing procedure is conducted to determine if additional bump-outs are needed. This guide describes how to use the VSP boundary module, including loading or drawing site maps, delineating the location of enclosing or partial boundaries, supplying needed design inputs such as the level of confidence required and the contaminants of concern, and transferred VSP results into project reports and publications. The appendix of this report documents the statistical methods used in VSP to compute UCLs on the mean for each segment and how those UCLs are used to test for compliance for each segment. The free VSP software can be downloaded from http://dqo.pnl.gov/vsp.

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1.0 Introduction

1.1 Purpose and Approach

This report provides guidance on how to use the boundary sampling module in the Visual Sample Plan (VSP) software to set up a sampling plan to collect and measure multiple increment (MI) soil samples to decide if soil contamination within a contaminated area has breached the current boundary line and if so, to determine the correct boundary line. The boundary may completely or partially enclose the contaminated area. The VSP boundary module was written to apply to Department of Defense (DoD) training ranges or similar areas whose soil is known to contain explosive residues or other contaminants of concern.

In brief, the sampling design and analysis approach used in the boundary module of VSP is as follows (the full details are in the Appendix to this report):

> Based on the VSP user's input about the diameter of a contaminant plume or hot spot of concentrations that would be of concern if it existed at the boundary, VSP divides the boundary into segments of equal length and indicates whether one or two MI samples per segment should be collected. VSP assumes that each MI sample collected in a segment consists of 5 x m small soil samples (increments) that have been collected in sets of m increments clustered around each of 5 "Primary Sampling Locations" that are equally spaced along the segment. The value of m should be at least 5 so that the total number of increments per MI sample is at least 25. All the increments are thoroughly mixed together to form the MI sample. Then a single measurement or the average of several measurements from each MI sample is obtained and entered into VSP. After the data for all segments with two MI samples have been entered into VSP, then VSP computes an upper confidence limit (UCL) on the mean for all segments. If the UCL for any segment and contaminant of concern equals or exceeds a specified threshold (upper limit) value, then the segment is pushed outward in the shape of a triangle whose two sides (two new segments) have the same length as the original segment. MI samples and measurements are obtained and the UCL test is performed for each of the two new segments to determine if either segment should be pushed out. This iterative process continues until the UCLs for all new segments for all contaminants of concern are less than the applicable threshold values.

The process of using the VSP boundary module can be broken down into the six steps in Table 1.1. Each step is discussed in the sections of this report indicated in the table. A comprehensive discussion of VSP features and procedures such as importing maps, saving files, editing, specifying inputs for sampling goals, etc. is provided in the VSP User's Guide (Hassig et. al, 2005). The User's Guide and the VSP software can be downloaded free from http://dqo.pnl.gov/vsp.

Table 1.1. Steps in Using the Boundary Sampling Module in VSP

Step	Action
1	VSP user defines the boundary (Section 2.0)
2	VSP user specifies the sampling design inputs and contaminants (Section 3.0)
3	VSP determines the number and location of multiple increment (MI) samples (Section 4.0)

4	VSP user obtains measurements and enters them into VSP (Section 5.0)
5	VSP conducts statistical test to see if boundary needs to be changed (Section 6.0 and the Appendix)
6	VSP documents the design (Section 7.0)

1.2 What is Visual Sample Plan?

Visual Sample Plan (VSP) is an easily used visual and graphic software tool designed to help project managers and users who are not statistical experts determine the correct number and location of environmental samples for various sampling goals so that decisions can be made with required confidence. The suite of sampling goals currently available in VSP (Version 3.2) is listed in Table 1.2. The guidance in this document focuses on the goal of establishing the boundary of contamination (the third line from the bottom of Table 1.2). Hassig et. al. (2005) should be consulted for instructions on how to use VSP to set up sampling strategies for the other goals in Table 1.2.

Table 1.2. List of Sampling Goals in VSP

Compare Average to Fixed Threshold
Compare Average to Reference Average
Estimate the Mean
Construct Confidence Interval on Mean
Compare Proportion to Fixed Threshold
Compare Proportion to Reference Proportion
Estimate the Proportion
Locating a Hot Spot
Find UXO Target Areas
Assess Degree of Confidence in UXO Presence
Non-statistical Sampling Approach
Establish Boundary of Contamination
Sampling within a Building
Port Container Sampling

VSP is structured to help implement EPA's Data Quality Objectives (DQO) systematic planning process (EPA, August 2000) for the sampling goals listed in Table 1.2. Extensive online help and tutorial guides are provided. The sampling locations determined by VSP are shown on a map of the study site, and VSP automatically prepares a summary report of the design and underlying assumptions. A list of the geographical coordinates of the sampling locations is also provided. The map, report, and list can be printed, saved, or copied and pasted directly into a quality assurance project plan, a sampling and analysis plan, or other reports and publications. The coordinates can be exported for use in a global positioning system (GPS).

For the "Establish Boundary of Contamination" sampling goal in Table 1.2, the topic of this User's Guide, VSP conducts statistical analyses on the data obtained from the developed sampling design to test if the boundary needs to be bumped out. The current version of VSP (Version 3.2) also conducts statistical analyses for some of the other goals in Table 1.2.

1.3 Download, Install, and Start VSP

VSP runs on Microsoft® Windows® 95 and later Windows operating systems. It will not run on Windows 3.1 or earlier Windows operating systems nor on Macintosh® or UNIX®/Linux systems.

VSP can be downloaded free at http://dqo.pnl.gov/vsp. The VSP user installs VSP by double clicking on the downloaded VSP setup file. The installation process copies the VSP program and auxiliary files to the **C:\Program Files\Visual Sample Plan** folder.

VSP is started by clicking **Start>Programs>Visual Sample Plan>Visual Sample Plan**, which brings up the "Welcome to Visual Sample Plan" screen. This screen is overlaid with the "Select VSP Version" box, which lists several implementation versions of VSP that can be selected. The complete suite of VSP sampling goals and tools becomes available by clicking on the "General (all inclusive) VSP" implementation version. If the "Range Sustainability Application Version" is clicked, only the features of VSP that are used in boundary sampling are made available to the VSP user.

The "VSP Advisor" box appears after the implementation version is selected. This box contains a list of questions, e.g., "What will VSP do?" and "How do I import a map?" Clicking on a question will bring up text answering the question. It might also bring up additional links to related topics. The VSP Advisor box is closed by clicking on the **Close** button or the **X** button in the upper-right corner of the box. Other questions listed on the screen such as "How Do I Create a Sample Plan?" can be explored by the VSP user.

After all questions of interest have been answered, VSP is ready to receive the inputs needed to set up the sampling plan along the boundary of interest.

2.0 Define the Boundary

To begin, the location of the boundary line of interest that may enclose the area that has contaminated soil above specified threshold values must be specified. This is accomplished as follows:

1. Set up a visual map of the site
2. Define an *enclosing boundary* on the site map that may contain all the contaminated soil,

   or

   define a *partial boundary* that may separate an area of contaminated soil from an area of uncontaminated soil

Both steps are discussed below.

2.1 Set Up a Visual Map of the Site

A complex site map can be drawn in an architectural drawing program such as Autodesk Map™ AutoCAD and saved to a .DXF (Drawing Interchange Format) file in that software package. Also, many geographical information system (GIS) software packages such as ArcView™ can be used to save maps as a .SHP (Shape) file. If a map of the site in .DXF or .SHP format has been saved in the Visual Sample Plan folder, it can be imported into the VSP project by clicking **Map>Load Map from File** on the menu bar at the top of the VSP screen and then double clicking on the desired .DXF or .SHP file that is listed. Alternatively, click the **Load Map** button on the VSP toolbar. This toolbar is located immediately below the menu bar. An example of a map stored as a DXF file is given in Figure 2.1. Figure 2.1 shows the menu bar at the top of the VSP screen and the toolbar immediately below it.

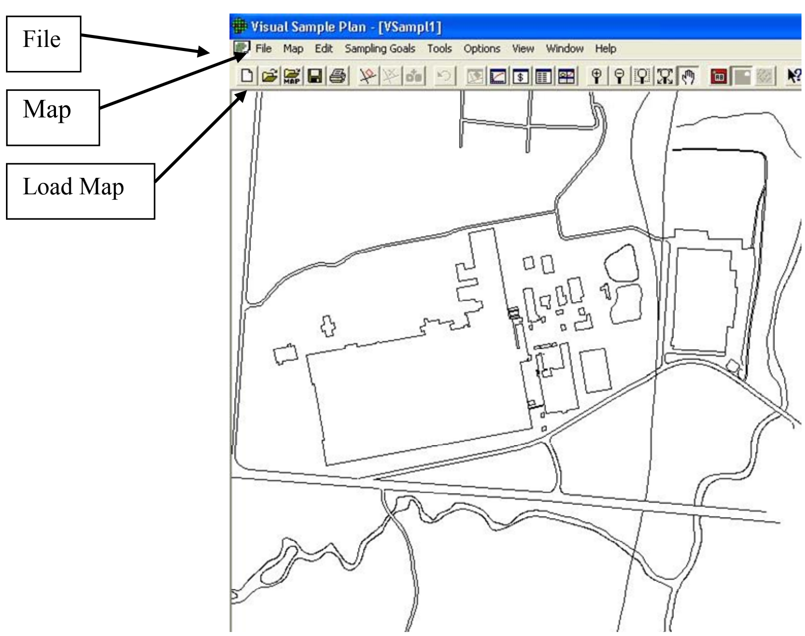


Figure 2.1 The Base.dxf File Opened in VSP

If the site map has been used in a previous VSP project, click **File>Open Project** and double click the VSP file listed that contains the map.

If the site Map is not available in a .DXF, .SHP, or VSP file, it can be drawn by hand using the VSP drawing tools. These tools are accessed by clicking **Map** on the menu bar and then clicking on the desired drawing tool. The drawing tools available are **Draw Line or Polyline, Draw Rectangle, Draw Ellipse,** or **Draw Curve**, as shown in Figure 2.2. The **Draw Line or Polyline** tool is particularly versatile because it allows the VSP user to draw essentially any shape by clicking on each vertex with the mouse (or by entering the coordinates on the keyboard). Detailed instructions for setting up, drawing, and working with maps in VSP are provided in the on-line help resources of VSP.

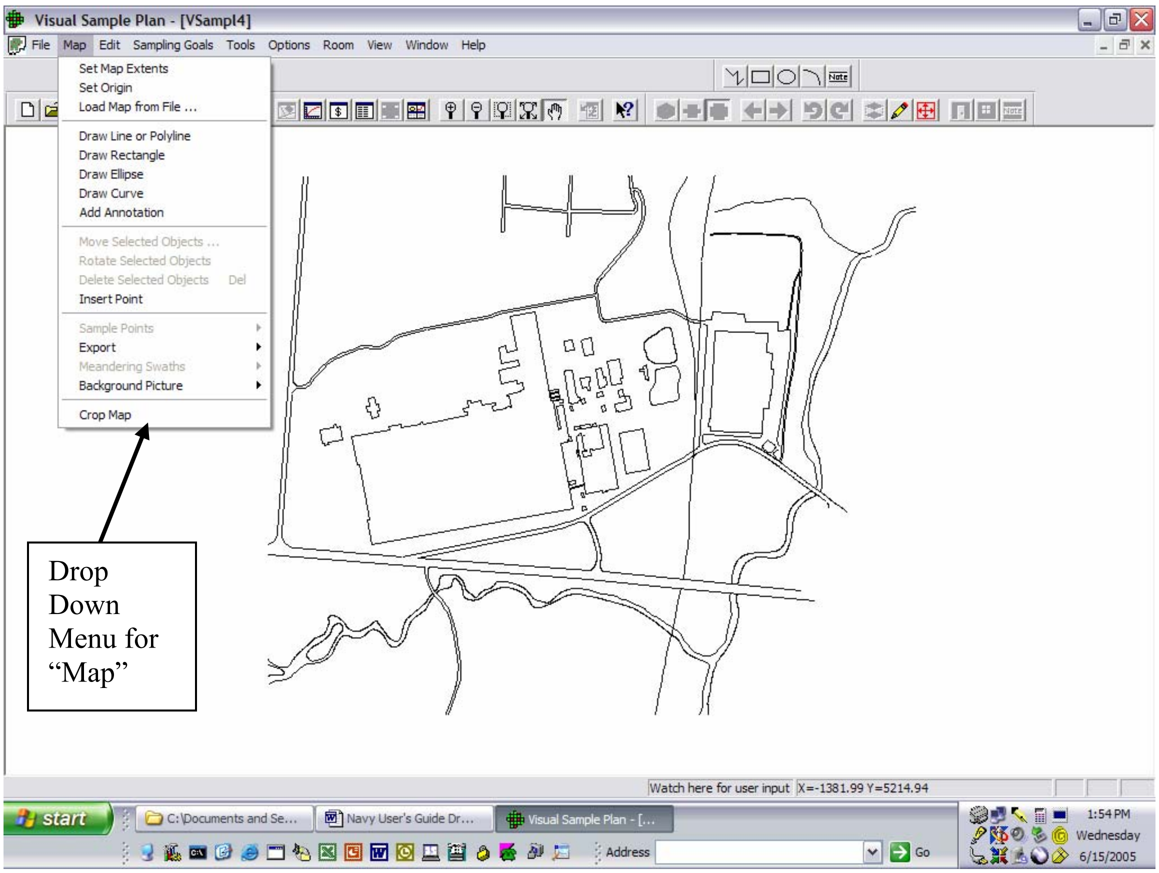


Figure 2.2. Drop Down Menu for "Map" on the Menu Bar

2.2 Define a Sample Area with an Enclosing Boundary

Once the map of the site is in VSP, the area on the map that is presumed to contain all the contaminated soil must be identified on the map. This area is called the "Sample Area." The boundary of this Sample Area completely encloses the area. MI samples will only be collected along this boundary.

The Sample Area and its boundary are defined by clicking **Edit** on the menu bar and then clicking **Sample Areas > Define New Sample Area** or by clicking the **New Area** button on the

VSP toolbar. Either action brings up the "Color Dialogue Box," which permits the VSP user to select a preferred color to highlight the Sample Area. The Sample Area is created by positioning the cursor inside the desired enclosing area on the map and right-clicking the mouse. This causes a dialogue box to appear that shows the size of the Sample Area in square meters, square feet, or square inches, as selected by the VSP user. An alternative, but more complex method for creating the Sample Area is provided in the on-line documentation and also in Hassig et. al. (2005). An example of a Sample Area (in yellow) is shown in Figure 2.3.

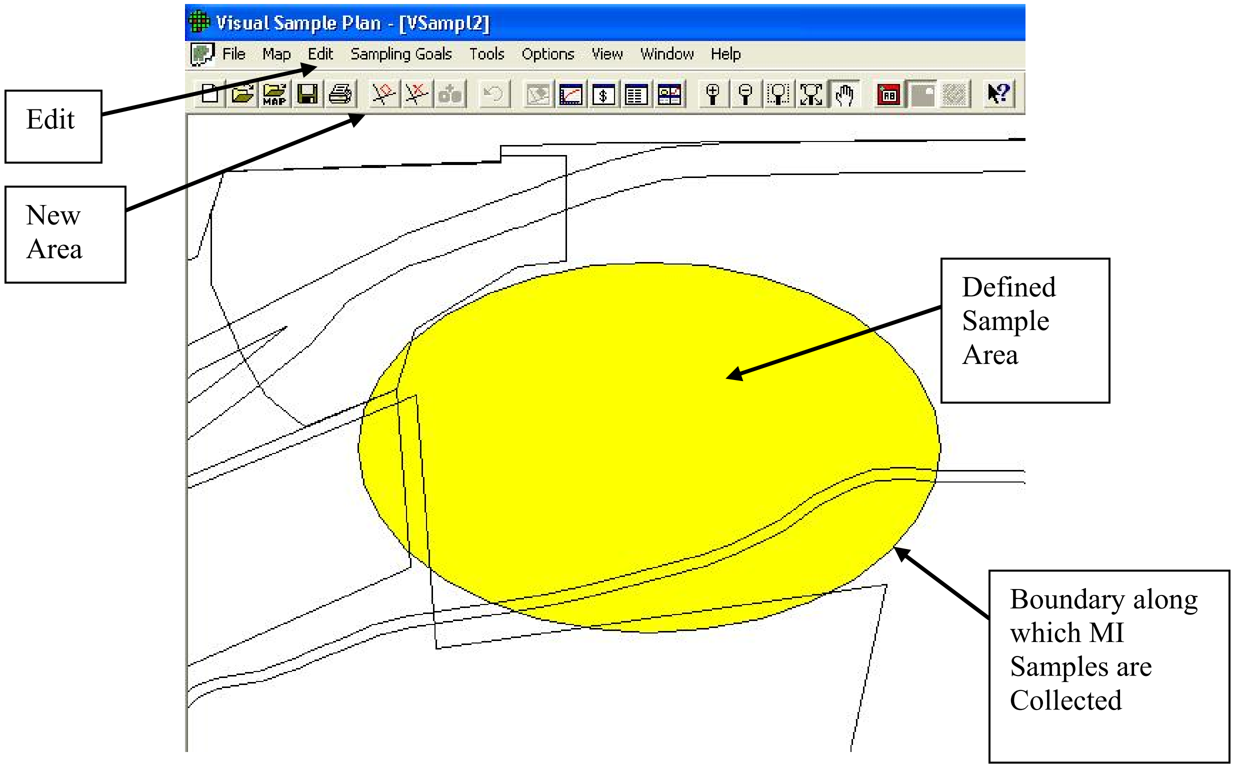


Figure 2.3. The Millsite.dxf File Opened in VSP Showing a Defined Sample Area with an Enclosing Boundary

If the Sample Area is a relatively simple shape, such as a rectangle, square, circle, or a simple polygon, it is not necessary to first load a map of the site that contains the Sample Area. The VSP user can simply draw the Sample Area on the VSP screen using one of the drawing tools mentioned in Section 2.1 and right clicking the mouse. In this case, the VSP user will want to specify the Map Extents on the screen, i.e., the spatial coordinates that correspond to the actual coordinates and distances at the physical site of interest. This is done by clicking **Map > Set Map Extents** on the menu bar (shown in Figure 2.2).

The Sample Area can also be defined by entering on the keyboard the x,y coordinates that define the shape of the sample area. First click **Map > Draw Line or Polyline**. If, for example, the Sample Area is a rectangle, then type the first x,y coordinate location (lower left corner of the rectangle) on the keyboard, say, **100, 100** and hit "enter." Then type the second coordinate (the lower right coordinate), say **200, 100** and hit "enter." Continue in this way until the rectangular sample area is completely defined. Then right click the mouse to finish defining the Sample Area. An easier method is to click **Map > Draw Rectangle** and then type **100x200** on the keyboard and hit **Enter** to create a 100 by 200 rectangular Sample Area.

2.3 Define an Open-Type Sample Area (Partial Boundary)

VSP also allows for boundaries that do not completely surround a Sample Area. For instance, suppose it is reasonable to assume that the only portion of the boundary that could be breached by soil contamination is along the downhill side of the Sample Area. In that situation, the VSP user first clicks **Edit > Sample Areas > Define New Open-Type Sample Area.** Then the user places the cursor at the starting location of the desired partial boundary and clicks on each vertex along the desired boundary until the end of the boundary is reached; then click the right mouse button. An example of a partial boundary is shown as a red line in Figure 2.4.

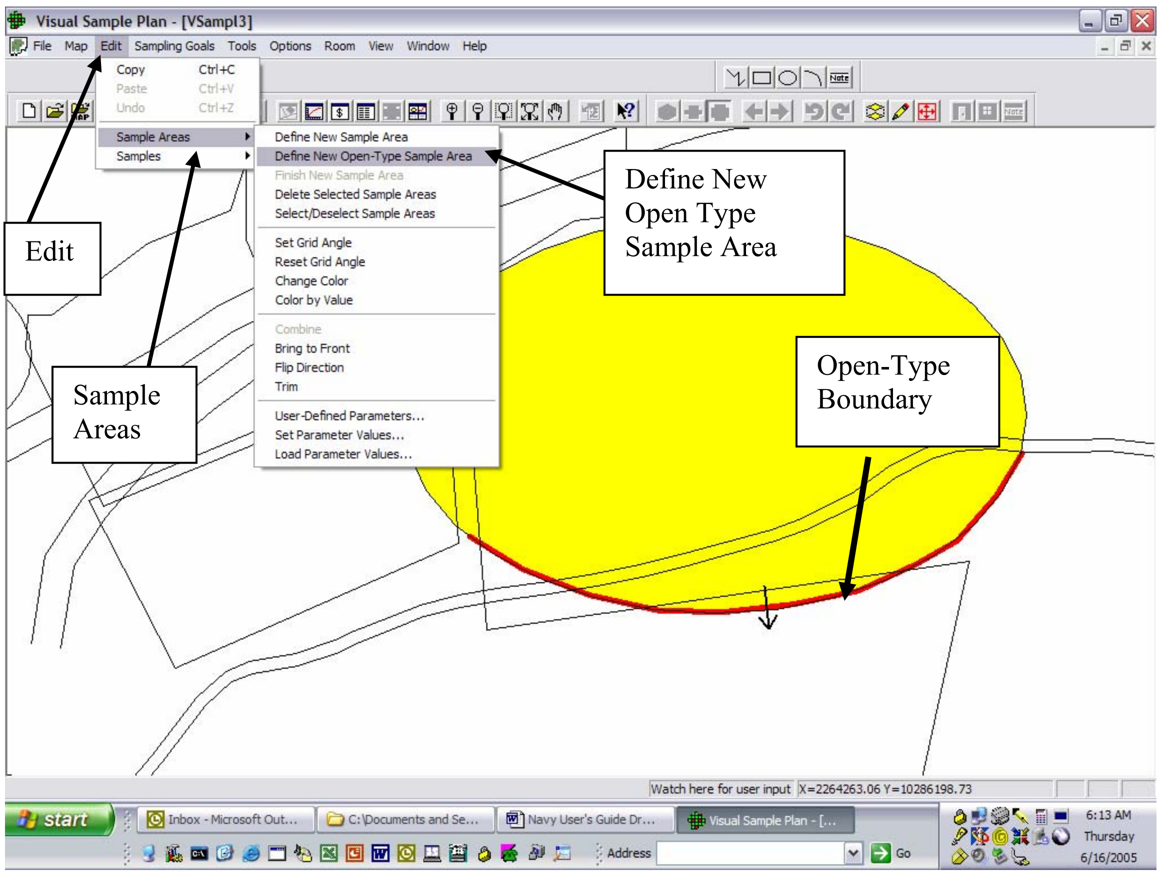


Figure 2.4. Example of an Open-Type Boundary with an Arrow to Show the Direction the Soil Contamination would be Expected to Move

Alternatively, the user may create an open-type sample area (partial boundary) using the single-click method. This is accomplished by selecting **Edit > Sample Areas > Define New Open-Type Sample Area** from the menu and then right clicking on an existing line on the map. The boundary may be shortened by selecting the **Edit > Sample Areas > Trim** from the menu and then clicking on two points on the boundary.

During the boundary selection process, VSP places an arrow on the boundary. This arrow points in the direction that contamination in soil may be expected to move, if such movement has or were to take place. If VSP points the arrow in the wrong direction, the direction of the arrow can be reversed by clicking **Edit > Sample Areas > Flip Direction**.

3.0 Specify Sampling Design Inputs and Contaminants of Concern

Once the boundary of interest has been defined, it is necessary to supply VSP with information it needs to compute the number and location of MI samples that should be taken along the boundary. There are two cases to consider: an enclosing boundary and a partial boundary. In addition, the contaminants of concern and their action limits need to be defined.

3.1 Enclosing Boundary

If the intent is to take MI samples along a boundary that completely encloses the Sample Area, then click **Sampling Goals > Establish Boundary of Contamination > Enclosing Boundary.** This action will bring up the dialogue box shown in Figure 3.1.

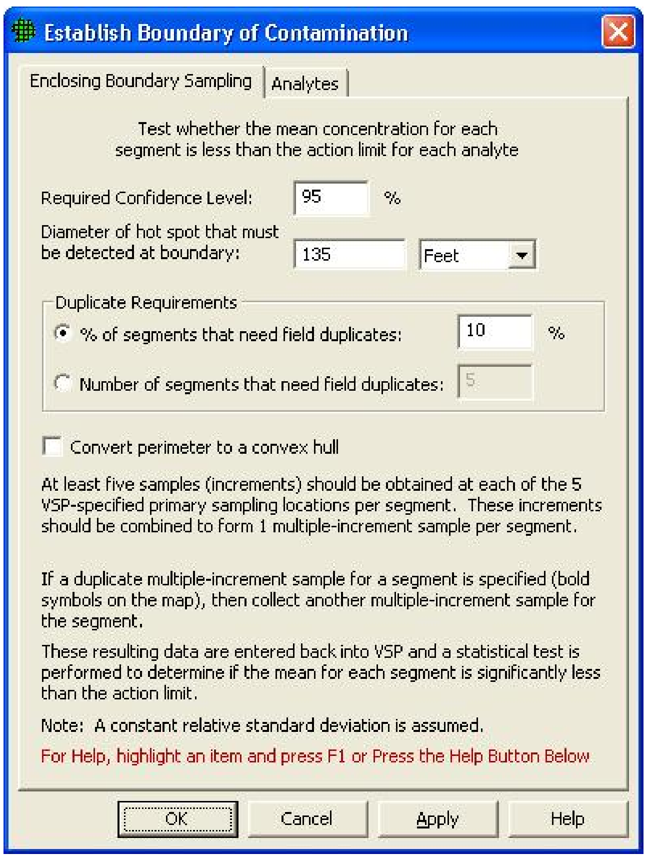


Figure 3.1. VSP Dialogue Box for Entering Design Inputs to Sample Along an Enclosing Boundary

The following design inputs are then entered into the box:

1. Required confidence level (in percent), e.g., 80% or 95%.
2. Diameter (width) of a contaminant plume or hot spot (in feet, meters, or inches) of concentrations that would be of concern if it existed at the boundary, e.g. 135 feet.

3. The percentage or number (at least five) of segments along the boundary that should have two (duplicate) MI samples instead of one. For example, 10%.
4. Whether the boundary should be converted into a convex hull.

A discussion of these inputs is provided at the end of the Appendix to this guide. Information on these inputs is also available within VSP. Just position the cursor on the input box and press the F1 key. You may also click on the **Help** button in the lower right-hand corner of the dialogue box (see Figure 3.1) and scroll down to the end of the document displayed.

3.2 Partial Boundary

If the intent is to take MI samples along a defined partial (open) boundary, then click **Sampling Goals > Establish Boundary of Contamination > Partial Boundary.** A dialogue box appears that is identical to the one that appears for the enclosing boundary case (Section 3.1) except that there is no option to convert the boundary to a convex hull. Fill in the required inputs.

3.3 Contaminants of Concern

The VSP user should next click on the **Analytes** tab at the top of the dialogue box. This action will bring up the VSP list of default contaminants of concern and their default threshold (upper limit) values, namely TNT (16 ppm), RDX (4.4 ppm), and HMX (3100 ppm), as shown in Figure 3.2. The VSP user can make changes to this list. To remove a contaminant from the list, erase the name of the contaminant and its limit. To add a contaminant, enter its name and threshold values in the blank line below the last contaminant. The action limits can also be changed by erasing the old limit and typing in the new limit.

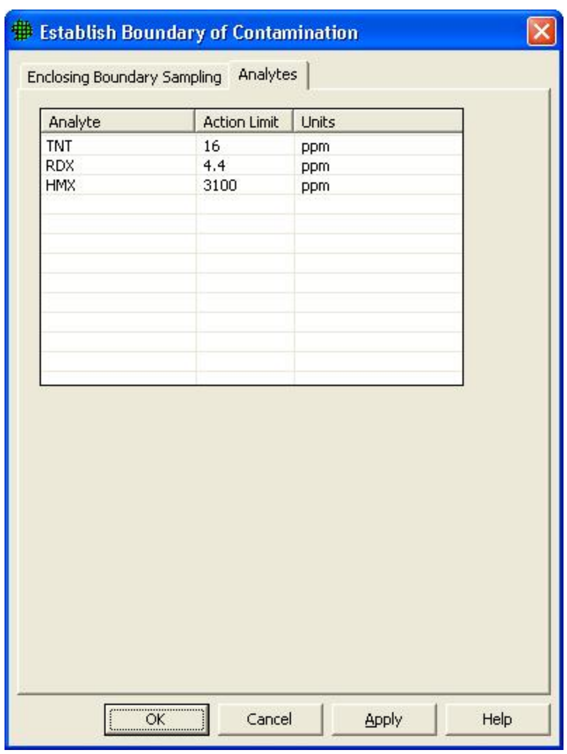


Figure 3.2. VSP List of Default Contaminants of Concern and their Action Limits

4.0 Determine the Number and Location of Multiple Increment (MI) Samples

After the design inputs have been entered into the dialogue box, click the **Apply** button at the bottom of the dialogue box. This action prompts VSP to compute the number and placement of the multiple increment (MI) samples along the enclosing or partial boundary. VSP divides the boundary into equal segments (see Appendix for the method used) and then determines 5 Primary Sample Locations in each segment. Click **View > Graph** on the menu bar or click the **Map View** button on the VSP toolbar to see the segments and locations. The segments for which the Primary Sample Locations are in **bold** type have two MI samples. VSP uses different symbols in each segment for the 5 Primary Sample Locations to delineate the segments. The symbols used have no particular meaning. Examples are shown in Figures 4.1 and 4.2 for the enclosing and partial boundary cases, respectively.

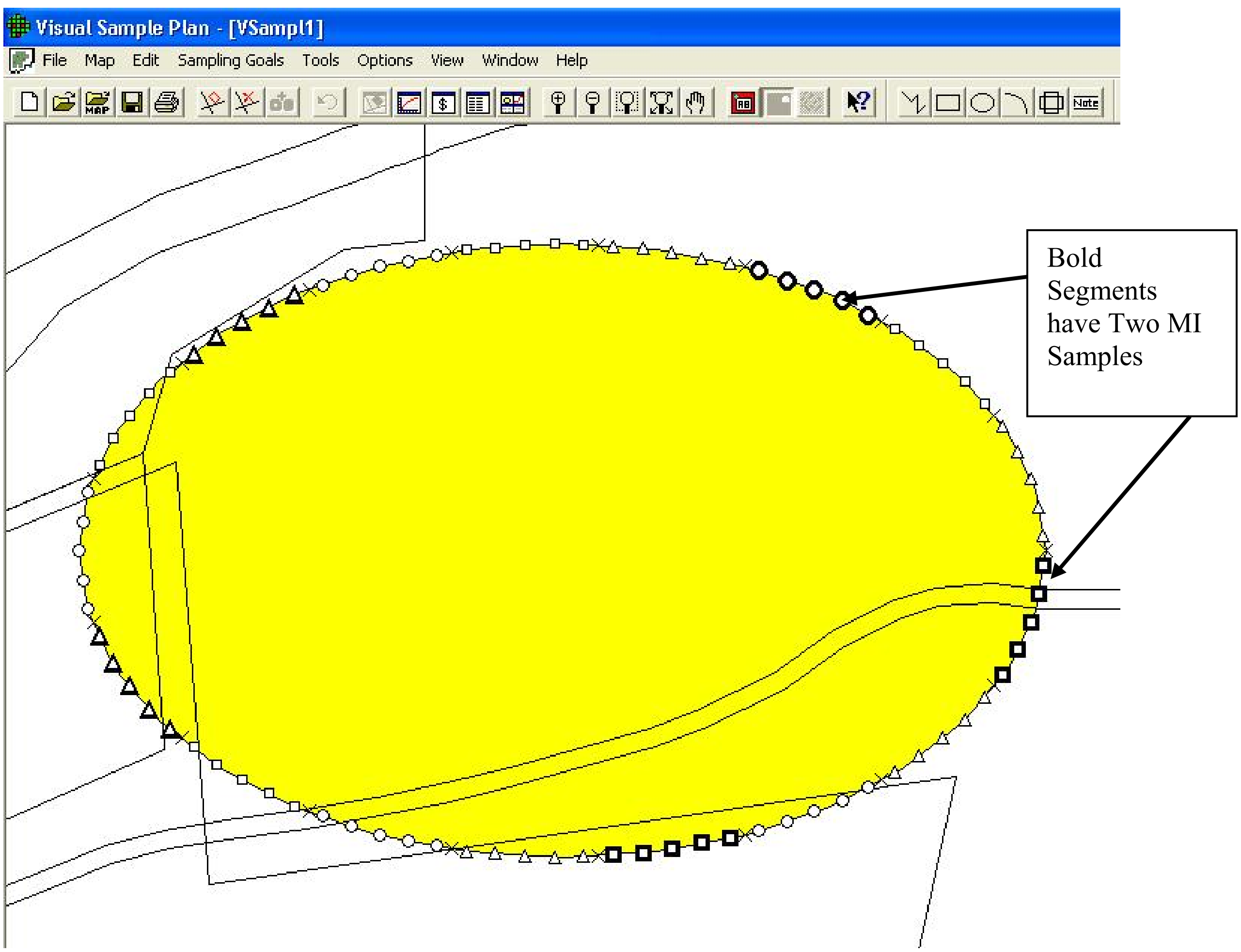


Figure 4.1. An Enclosing Boundary Showing the Five Primary Sample Locations for each of Seventeen Segments

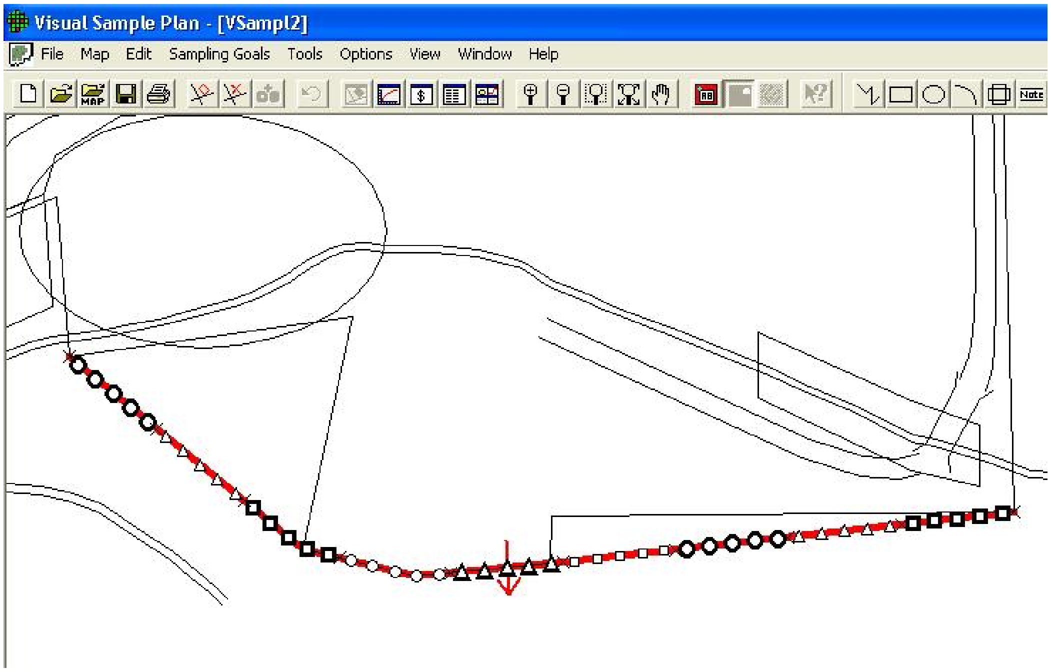


Figure 4.2. A Partial (Open-Type) Boundary Showing the Five Primary Sample Locations for each of Nine Segments

If the map that shows the boundary is too small to clearly show the Primary Sample Locations, then enlarge the map by first clicking the **+ magnifying glass** button on the VSP toolbar or by choosing **View / Zoom In** from the menu. Then position the cursor over the map and click the mouse one or more times. Each click enlarges the map a notch. Click the **+ magnifying glass** button again to turn it off when the map is sufficiently enlarged. The same procedure applies to the **– magnifying glass** button on the toolbar which progressively decreases the size of the map. The hand (**Pan**) button on the toolbar is used to move the map around on the monitor screen.

Design Notes:

VSP requires that two (duplicate) MI samples be obtained from some segments. This is done because the contaminant measurements obtained for the two MI samples in those segments are used to estimate the relative standard deviation (RSD) among MI samples within segments. It is assumed that the RSD is constant for all segments. The estimated RSD is used to compute the UCL test for each segment to determine whether soil contamination has migrated past the boundary for the segment. Additional information about how VSP determines the number of segments that require two MI samples is provided in Section 3.0 of the Appendix and in the methods description that appears when the HELP button in the right-hand bottom corner of the dialogue box is clicked.

For each segment, VSP assumes that the MI sample is formed by pooling and mixing at least 5 small soil samples (increments) collected in the vicinity of each of the 5 Primary Sample Locations that are evenly spaced along the segment. Hence, each MI sample is formed from at least 25 increments. In practice, 25 increments per MI sample may not be sufficient to have a sufficiently high probability of correctly rejecting the null hypothesis and not bumping out the segment. Hence, it is a good idea to conduct a sampling study along the site boundary to determine what constitutes a sufficient number of increment samples per MI sample. Increasing the number of increments per MI sample would, assuming proper mixing, tend to decrease the variance of the estimated mean concentration for the segment, which would decrease the computed UCL value, which would in turn tend to decrease the number of segments that are bumped out, assuming the variance among the measurements does not increase with an increased number of increments.

VSP does not specify or determine the location of the second MI sample in the segment. If the second MI sample happens to be collected adjacent (very near) to the first MI sample, the difference in the two measurements obtained (one from each MI sample) might be smaller on average than if the second MI sample was placed more distant from the first. If increasing the distance increases the variance, then increasing the distance might also increase the number of segments that are bumped out because the UCL on the mean is used to make the bump-out test. It is assumed in VSP that the distance between the duplicate MI samples has no effect on the test results.

VSP does not take into account that when many statistical tests are made, eventually one or more of those tests will be misleading. If the UCL test incorrectly indicates that the segment should be bumped out, then the UCL tests on the two new bumped-out segments are likely to indicate that no further bump-outs are required. Hence, the negative effects of that incorrect decision are minimized. If the UCL test incorrectly indicates that the segment should not be bumped out, then the spread of contamination beyond the current boundary may remain undiscovered, a serious consequence. However, the likelihood of this happening decreases as the VSP user specifies a larger confidence level for the UCL.

5. Obtain and Enter Measurements into VSP

One or more soil aliquots are withdrawn from each properly handled and well mixed MI sample. Each aliquot is measured for the contaminants of concern. For each contaminant, if two or more measurements per MI sample are obtained, it is assumed that they are averaged together to obtain a single representative measurement for the MI sample. The single (average) measurement for each contaminant is then entered into VSP.

Each measurement (or average measurement) is entered into VSP as follows:

> Click the **Map View** button on the VSP toolbar to display the map that shows the boundary. For one of the boundary segments, place the cursor over one of the Primary Sample Locations in that segment and right click the mouse. This action will bring up the **Sample Information** box. Then use the keyboard to enter the measurement value into the appropriate row in the column labeled "Value" in the **Segment Sample Results** sub-box. If the segment clicked is one for which two MI samples were collected, there will be room to enter both measurements for each contaminant listed, as shown in Figure 5.1. Click the **OK** button on the dialogue box to close the **Sample Information** box for that segment. Then repeat the above process for each of the segments to enter all the measurements. If no bump-out occurs for the boundary segment, data can be corrected. If a bump-out does occur, it cannot be undone because perimeter information is lost.

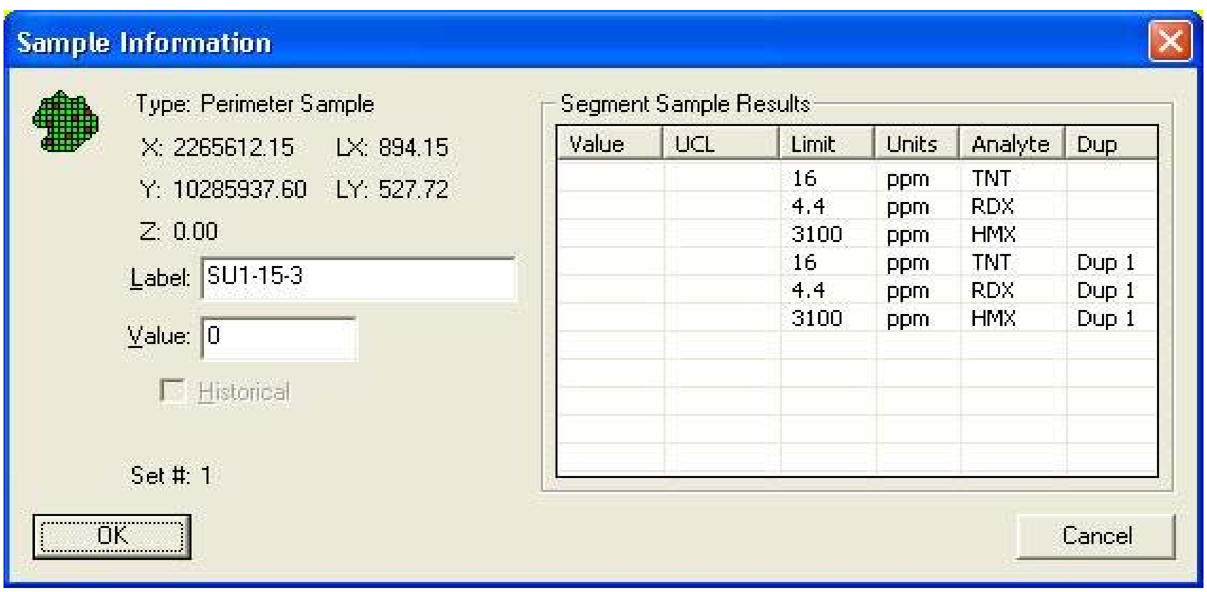


Figure 5.1. Sample Information Box for Entering Data into VSP

The **Segment Sample Results** box has a column headed "UCL," which will contain the UCL values once they are computed by VSP. The UCLs are not computed until the data for all the segments that have duplicate MI samples have been entered into VSP. However there are two cases where VSP will bump out a segment before the UCLs are computed: 1) when only one MI sample is collected in a segment and the measurement for that sample exceeds the threshold, and 2) when two MI samples are collected in a segment and the mean of those samples exceeds the threshold. For those two cases, it is a foregone conclusion that the UCLs, when computed, will exceed the threshold.

The **Segment Sample Results** box also displays the geographical coordinates of the Primary Sample Locations for the segment that was clicked. It also displays the "Label" for that location. This label provides a unique number for the location. This label is assigned by VSP, but it can be changed by the VSP user. Directly below the Label box is a "Value" box. For the Primary Sampling Location clicked (that brought up this Sample Information Box), the VSP user can enter an individual value for Primary Sampling Location #3 in Segment #15 in Survey Unit Area #1. VSP does not use that value for this boundary sample design.

An alternative, potentially simpler, and recommended method of entering the MI sample results into VSP is to use other software such as a spreadsheet (like Excel). The process is to:

1. Save the current project to a VSP file
2. Switch to the Coordinate view (**View / Coordinates**) or press the **Coordinate View** button on the toolbar
3. Copy the sample data to the clipboard (**Edit / Copy**) or press **Ctrl-C** on the keyboard
4. Switch to the spreadsheet software
5. Paste the sample data into the spreadsheet (**Edit / Paste**) or press **Ctrl-V** on the keyboard
6. Enter the MI sample result data in the appropriate spreadsheet cells
7. Verify that all data are correct
8. Select all the MI sample result data and copy it back to the clipboard (**Edit / Copy**) or press **Ctrl-C** on the keyboard
9. Switch back to the **Coordinate View** in VSP
10. Paste the data back into VSP (**Edit / Paste**) or press **Ctrl-V** on the keyboard.

6.0 Test if the Boundary Should be Enlarged

The methods VSP uses to statistically test if each boundary segment should be enlarged (bumped out) are described in the Appendix to this report.

7.0 Document the Design

VSP shows on the Map View the latest boundary as UCLs are computed for the various segments. Figure 7.1 illustrates a final jagged open boundary obtained after several segments along an open-type boundary (straight line) have been bumped out to form a new boundary line. Note that in Figure 7.1 the 5 Primary Sample Locations are assigned different colors in different segments. **White** indicates that data for the segment has not been entered. **Yellow** indicates that data have been entered, but the calculation of the UCL cannot yet be made for the segment because the data for all segments with duplicate MI samples has not yet been completely entered. **Green** indicates that the UCL has been computed and it does not exceed the threshold limit. **Red** indicates that the UCL exceeds the limit. Note that if the data for a red segment is modified (by viewing the data in the Sample Information dialog box, making the change, and pressing the "OK" button), the color is reset to yellow to indicate a change in data. This is done because VSP cannot undo a bump-out even if the new (or corrected) data so indicate.

VSP also prepares a summary report of the boundary sampling design created, including assumptions and statistical methods. This report can be viewed by clicking **View** > **Report** on the menu bar or clicking the **Report View** button on the VSP toolbar. The map of the bumped-out boundary and the report can then be copied, saved, or printed.

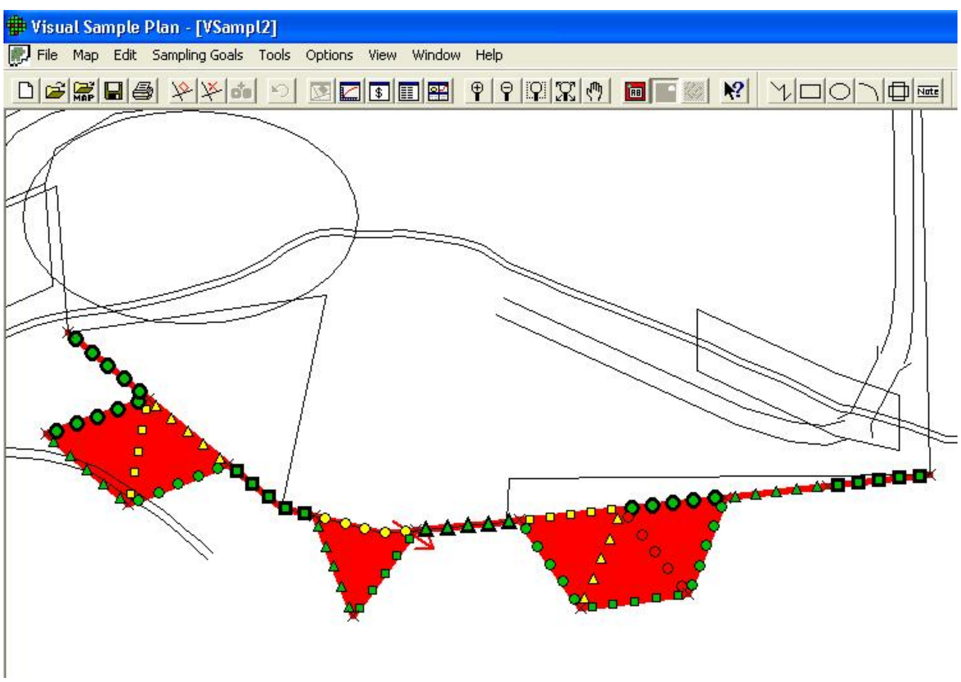
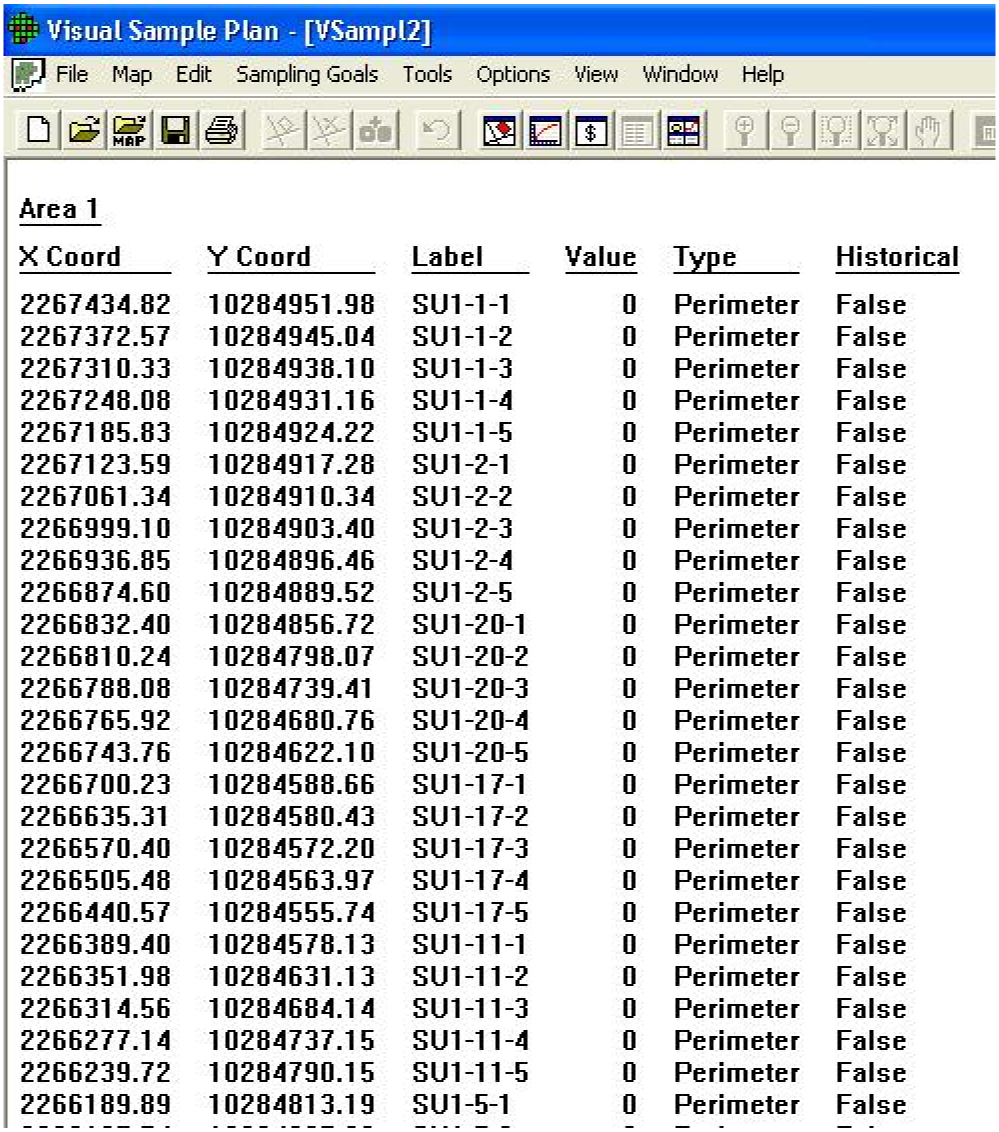


Figure 7.1. Final Open-Type Boundary Obtained by Using Measurements from Multiple Increment Samples and Computing Upper Confidence Limits on the Mean for each Segment

VSP also prepares a list of the geographical coordinates of the 5 Primary Sample Locations for all boundary segments. This list can be viewed by clicking **View** > **Coordinates** on the menu bar or the **Coordinate View** button on the VSP toolbar. A partial listing of the coordinates of the Primary Sample Locations shown in Figure 7.1 is provided in Figure 7.2. The column labeled "Type" indicates that the data locations are for the Perimeter (boundary). For other VSP sampling goals, the "Type" could be Random, RSS, Adaptive, etc. Since the Historical box was not checked on the Sample Information Box, the column headed "Historical" in Figure 7.2 shows "False" for all Primary Sample Locations.



X Coord	Y Coord	Label	Value	Type	Historical
2267434.82	10284951.98	SU1-1-1	0	Perimeter	False
2267372.57	10284945.04	SU1-1-2	0	Perimeter	False
2267310.33	10284938.10	SU1-1-3	0	Perimeter	False
2267248.08	10284931.16	SU1-1-4	0	Perimeter	False
2267185.83	10284924.22	SU1-1-5	0	Perimeter	False
2267123.59	10284917.28	SU1-2-1	0	Perimeter	False
2267061.34	10284910.34	SU1-2-2	0	Perimeter	False
2266999.10	10284903.40	SU1-2-3	0	Perimeter	False
2266936.85	10284896.46	SU1-2-4	0	Perimeter	False
2266874.60	10284889.52	SU1-2-5	0	Perimeter	False
2266832.40	10284856.72	SU1-20-1	0	Perimeter	False
2266810.24	10284798.07	SU1-20-2	0	Perimeter	False
2266788.08	10284739.41	SU1-20-3	0	Perimeter	False
2266765.92	10284680.76	SU1-20-4	0	Perimeter	False
2266743.76	10284622.10	SU1-20-5	0	Perimeter	False
2266700.23	10284588.66	SU1-17-1	0	Perimeter	False
2266635.31	10284580.43	SU1-17-2	0	Perimeter	False
2266570.40	10284572.20	SU1-17-3	0	Perimeter	False
2266505.48	10284563.97	SU1-17-4	0	Perimeter	False
2266440.57	10284555.74	SU1-17-5	0	Perimeter	False
2266389.40	10284578.13	SU1-11-1	0	Perimeter	False
2266351.98	10284631.13	SU1-11-2	0	Perimeter	False
2266314.56	10284684.14	SU1-11-3	0	Perimeter	False
2266277.14	10284737.15	SU1-11-4	0	Perimeter	False
2266239.72	10284790.15	SU1-11-5	0	Perimeter	False
2266189.89	10284813.19	SU1-5-1	0	Perimeter	False

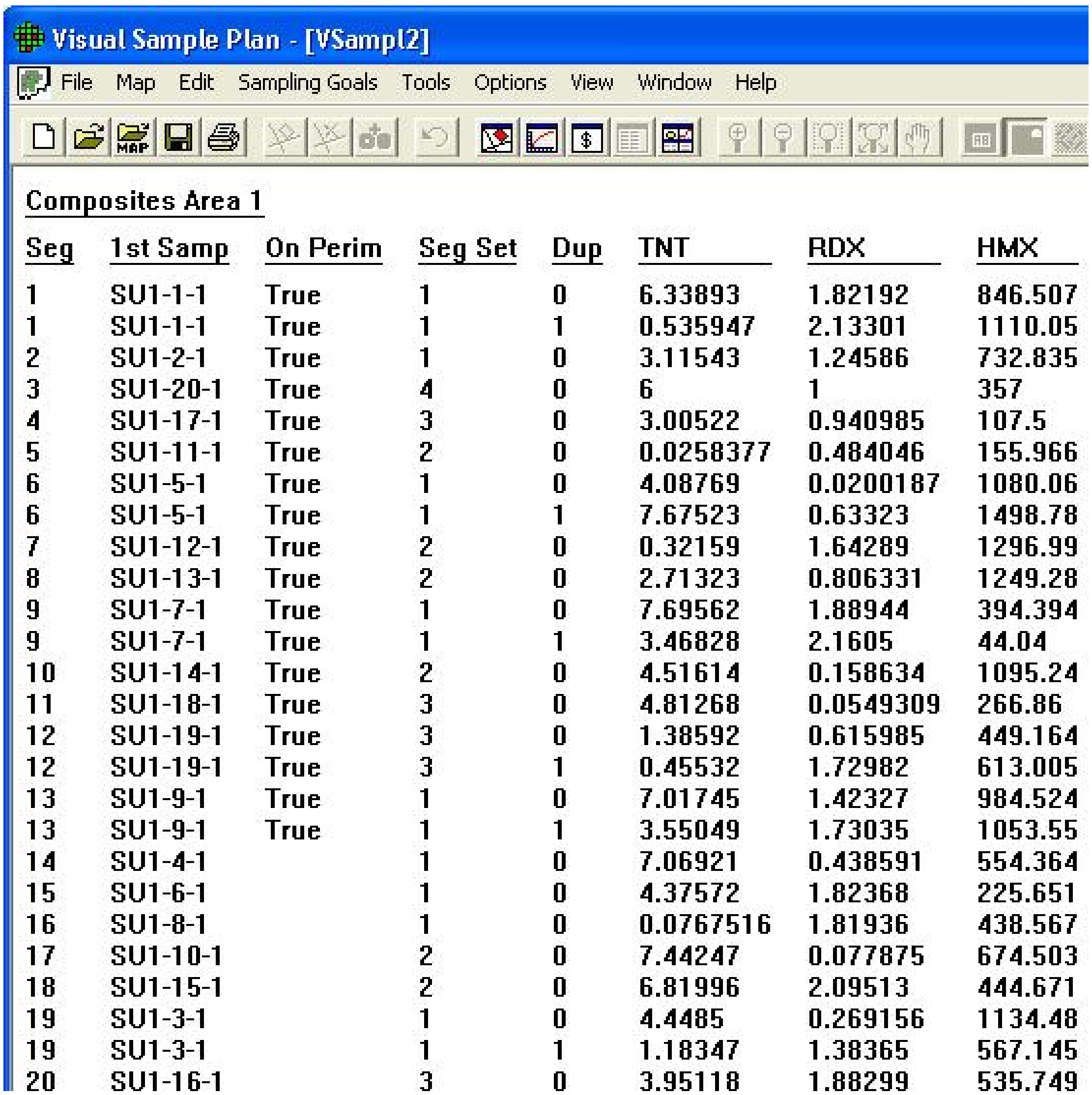
Figure 7.2. Partial Listing of Primary Sampling Location Coordinates Available in the **Coordinate View** for the Example in Figure 7.1

The **Coordinate View** also shows all of the MI sample result data. Some of the data that generated the final jagged boundary line shown in Figure 7.1 are shown in Figure 7.3. The **Coordinate View** list of data can be copied, pasted, saved, or printed.

The column headings in Figure 7.3 are defined as follows:

Seg: Segment number
1st Samp: The 1st Primary Sampling Location in the segment

On Perim:	"True" indicates this segment is currently on the outer-most boundary
Seg Set:	Segment set number (see Section 3.0 of Appendix for explanation)
Dup:	0 indicates first MI sample; 1 indicates the second MI sample
TNT:	Measurement of TNT in ppm for the MI sample
RDX:	Measurement of RDX in ppm for the MI sample
HMX:	Measurement of HMX in ppm for the MI sample



Composites Area 1

Seg	1st Samp	On Perim	Seg Set	Dup	TNT	RDX	HMX
1	SU1-1-1	True	1	0	6.33893	1.82192	846.507
1	SU1-1-1	True	1	1	0.535947	2.13301	1110.05
2	SU1-2-1	True	1	0	3.11543	1.24586	732.835
3	SU1-20-1	True	4	0	6	1	357
4	SU1-17-1	True	3	0	3.00522	0.940985	107.5
5	SU1-11-1	True	2	0	0.0258377	0.484046	155.966
6	SU1-5-1	True	1	0	4.08769	0.0200187	1080.06
6	SU1-5-1	True	1	1	7.67523	0.63323	1498.78
7	SU1-12-1	True	2	0	0.32159	1.64289	1296.99
8	SU1-13-1	True	2	0	2.71323	0.806331	1249.28
9	SU1-7-1	True	1	0	7.69562	1.88944	394.394
9	SU1-7-1	True	1	1	3.46828	2.1605	44.04
10	SU1-14-1	True	2	0	4.51614	0.158634	1095.24
11	SU1-18-1	True	3	0	4.81268	0.0549309	266.86
12	SU1-19-1	True	3	0	1.38592	0.615985	449.164
12	SU1-19-1	True	3	1	0.45532	1.72982	613.005
13	SU1-9-1	True	1	0	7.01745	1.42327	984.524
13	SU1-9-1	True	1	1	3.55049	1.73035	1053.55
14	SU1-4-1		1	0	7.06921	0.438591	554.364
15	SU1-6-1		1	0	4.37572	1.82368	225.651
16	SU1-8-1		1	0	0.0767516	1.81936	438.567
17	SU1-10-1		2	0	7.44247	0.077875	674.503
18	SU1-15-1		2	0	6.81996	2.09513	444.671
19	SU1-3-1		1	0	4.4485	0.269156	1134.48
19	SU1-3-1		1	1	1.18347	1.38365	567.145
20	SU1-16-1		3	0	3.95118	1.88299	535.749

Figure 7.3. Partial Listing of Concentration Measurements Available in the **Coordinate View** for the Example Shown in Figure 7.1

8.0 References

EPA. August 2000. *Guidance for the Data Quality Objectives Process*, *EPA QA/G-4,* EPA/600/R-96/055, Office of Environmental Information, U.S. Environmental Protection Agency, Washington, D.C.

Hassig, N.L., J.E. Wilson, R.O. Gilbert, B.A. Pulsipher, L.L. Nuffer. 2005. *Visual Sample Plan Version 3.2 User's Guide*, (Pending Publication), Pacific Northwest National Laboratory, Richland, Washington.

Appendix

Sampling the Boundary of a Site to Determine if Contamination has Moved Beyond the Boundary

1.0 Background Information

The purpose of this VSP boundary module is to set up a sampling design that uses multiple increment (MI) soil samples along the boundary of a contaminated military training range or similar site to determine if explosive residue or other contamination in soil has migrated beyond the boundary. VSP determines the number of segments using the length of the boundary and the specified width of a contaminant plume (hot spot) that would be of concern if it is present at the boundary or extends beyond the boundary line. The boundary is divided into segments, with one or two MI samples collected per segment. VSP assumes that each MI sample collected in a segment consists of at least 25 small soil samples (increments) that have been collected in sets of at least 5 increments clustered around each of 5 equally spaced Primary Sample Locations along the segment. The spacing depends on the specified width of the hot spot of concern at the boundary. It is assumed that either: 1) measurements of the contaminants in soil aliquots from the MI sample are normally distributed, or 2) that the computed mean based on those measurements is itself normally distributed.

VSP provides two versions of the design: one for enclosing boundaries and one for partial (open-type) boundaries. Partial boundaries represent a dividing line, with contamination on one side and no contamination on the other side. VSP provides special tools for creating and manipulating open-type sample areas.

An upper confidence limit (UCL) on the mean concentration for each contaminant for each segment is computed and compared to an appropriate threshold value. If the UCL for a given segment exceeds the threshold value for one or more of the contaminants of concern, then VSP extends the boundary line for that segment outward to form a triangle whose sides have the same length as the initial boundary segment. Each new side is a new segment. Then one or two MI samples (each composed of at least 25 small soil samples) are then taken from each of the two segments (sides) of the triangle and a UCL test is conducted for each segment. The final enclosing boundary for the site is the boundary that exists when all new UCL tests indicate no new segments need to be bumped out.

VSP does not consider all aspects of the sampling plan such as the methods of sample collection, the physical size, shape, and depth of soil samples collected, and the handling, transport, and laboratory analysis procedures.

2.0 Method Used to Determine the Boundary Sampling Design

The following steps are used to determine the boundary sampling design:

1. The VSP user specifies the width (feet, meters, or inches) of a contaminant plume or hot spot of concentrations that would be of concern if it existed at the perimeter boundary. The concern is that the "hot spot" may extend beyond the boundary. The dialogue box in

VSP uses "diameter of hot spot" to denote this specified width of a plume or hot spot. This width is used by VSP to determine the minimum spacing between Primary Sample Locations along the boundary, which in turn determines the length of each segment along the boundary, as explained in Step 2 below. On the **Analytes** page of the dialog box, the VSP user also specifies the contaminants of concern along with their respective action limits and units of measure. By default, VSP uses the following analytes and action levels: TNT (16 ppm), RDX (4.4 ppm), and HMX (3100 ppm).

2. VSP calculates the optimum segment length (OSL) along the current boundary line, where all segments have the same length:

   OSL = 5 x (VSP user-specified width of the contamination plume of concern),

   where 5 is the number of equally spaced Primary Sample Locations within each segment. A Primary Sample Location is a point along the boundary line around which a cluster of at least 5 small soil samples is collected. VSP assumes there are 5 Primary Sample Locations equally spaced in each segment. VSP does not consider the spatial pattern and spacing among the 5 small soil samples at each Primary Sample Location.

3. The number of segments along the boundary is computed by dividing the perimeter length (total length of the enclosing boundary) by the OSL and rounding up to the nearest whole number. This ensures that the spacing between Primary Sample Locations will not exceed the specified width of the contamination plume.

4. The actual length of the segments is computed by dividing the length of the boundary by the number of segments.

5. For each segment, VSP assumes that the field crew will collect at least 5 small soil samples (increments) in a cluster around the 5 evenly spaced Primary Sample Locations for a total of at least 25 increments per segment. It is assumed that the increments are thoroughly mixed to form a single evenly distributed MI sample of the Primary Samples for each segment.

6. VSP requires at least 5 segments or 10% of the segments to have a second (duplicate) MI sample collected using the same sampling pattern and protocol used for the first MI sample. However, the VSP dialogue box allows the VSP user to specify a larger number or percent of segments if desired. The purpose of duplicate MI samples is to estimate the relative standard deviation (RSD) of the data so that a UCL test can be conducted for each segment (see discussion below).

7. If the enclosing boundary of the site is very irregular, e.g., has various indentations, the VSP user can specify in the dialogue box that VSP should change the boundary to a convex hull. This has the effect of smoothing out the boundary irregularities, but it also enlarges the area enclosed by the initial boundary. In practice, the VSP user can try this option and view the resulting initial boundary to see if the new boundary is acceptable. (Note: the user should save a copy of the initial boundary because the act of converting a sample area to a convex hull cannot be undone.) The convex hull option is not available for partial boundaries.

3.0 Method Used to Determine if the Boundary Needs to be Moved Outward

The following steps are used to determine if the boundary needs to be moved outward:

1. A concentration value for each analyte of concern for each MI sample is entered into VSP. These data are entered into VSP by right-clicking on any of the 5 Primary Sample Locations on the map or by copying data from the clipboard into the **Coordinate View** (discussed in Section 5.0 of this main report).

2. For each analyte of concern, VSP uses the data from all the segments along the initial boundary that have duplicate MI samples to estimate the relative standard deviation (RSD). This estimated RSD (defined below) is assumed to apply to all segments along the initial boundary, including those for which only one MI sample was obtained.

3. For each segment, VSP multiplies the estimated segment mean for the analyte by the RSD to estimate the standard deviation for the segment.

4. VSP uses the estimated standard deviation and mean for the segment to compute the one-sided upper confidence limit (UCL) on the segment mean for the analyte. The VSP user inputs into the VSP dialogue box the confidence level desired, e.g., 0.90 (90%) or 0.95 (95%). The UCL is computed assuming that the analyte measurements of the MI samples are normally distributed.

5. If the UCL for any initial segment equals or exceeds the action level for the analyte, then the boundary for that segment is moved outward ("bumped out") in the shape of a triangle. The base of the triangle is the initial segment. The length of each side of the triangle is the length of the initial segments. Depending on the shape of the enclosing boundary, the bump-out may not always be a triangle; sometimes it will fill an indentation when necessary to maintain a boundary that does not cross over itself. The UCLs for the segments are not computed until all the data for segments that have duplicate MI samples have been entered into VSP. There are two special cases where VSP will bump out a triangle before the UCL is computed: 1) when only one MI sample is collected in a segment and the measurement for that sample exceeds the threshold, and 2) when two MI samples are collected in a segment and the mean of those samples exceeds the threshold.

6. One or two new MI samples are formed for each of the new bump-out segments (sides of the triangle) using the same sampling design used along the initial segments (i.e., at least 25 soil samples per MI sample). VSP computes the UCL for each new bumped-out segment to determine if any of these new segments should be further "bumped out." This iterative process continues until none of the segments are bumped out. The rule used by VSP to determine if one or two MI samples are used in a new bump-out segment is as follows: If the VSP user specified in the dialogue box that a specific number of segments with duplicate samples is required, then VSP designates those among the initial segments and no new bumped-out segment has a duplicate MI sample; but if the VSP user specified that a percentage of the segments should have duplicate MI samples, then that percentage of the bumped-out segments will have duplicate MI samples.

7. The UCLs for new (bumped-out) segments are computed using updated estimates of the RSD based on additional duplicate MI samples, the number of which is specified by the

VSP user. The following procedure is used to assure that previous bump-out decisions are not affected by the additional data and updated RSD:

Define:

- Set 1 to be the segments on the initial boundary,
- Set 2 to be the bump-out segments from Set 1 segments,
- Set 3 to be the bump-out segments from Set 2 bump-out segments, and so forth.

Then compute the RSD and UCL for:

- Segments in Set 1 using only the duplicates in Set 1,
- Segments in Set 2 using the duplicates in Sets 1 and 2,
- Segments in Set 3 using the duplicates in Sets 1, 2 and 3, and so forth.

Using this process the UCLs and decisions for Set 1 segments will not change if further bump-outs occur. Similarly, the UCLs and decisions for Set 2 won't change if further bump-outs occur, and so on.

4.0 Statistical Methods Used to Compute the UCL for each Analyte

The following steps are used to compute the UCL for each analyte:

1. Compute the relative standard deviation (RSD) for the initial set of n segments for which two MI samples were obtained

$$RSD = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\frac{s_i^2}{\overline{x}_i^2}} \qquad (1)$$

where

n	= the number of segments for which two MI samples were obtained
$s_i^2 = \sum_{j=1}^{2}\left(x_{ij} - \overline{x}_i\right)^2$	= variance of the two MI sample measurements from the i^{th} segment
$\overline{x}_i = \frac{1}{2}\sum_{j=1}^{2} x_{ij}$	= mean of the two MI sample measurements from the i^{th} segment

2. Compute the standard deviation for the i^{th} segment among all the segments along the initial boundary, even those segments that had only one MI sample

$$SD_i = (RSD)(\bar{x}_i) \tag{2}$$

where

$\bar{x}_i = \frac{1}{m_i} \sum_{j=1}^{m_i} x_{ij}$ = mean of the MI sample measurements in the i^th segment

m_i = number of MI sample measurements (1 or 2) for the i^th segment

3. Compute the 100(1-α) percent UCL on the mean for the i^th segment

$$UCL_i = \bar{x}_i + t_{1-\alpha,n} \frac{SD_i}{\sqrt{m_i}} \tag{3}$$

where

$t_{1-\alpha,n}$ = 100(1-α) percentile of the t distribution with n degrees of freedom

and SD_i is computed using Equation (2).

4. Conduct the UCL test for the i^th segment

If $UCL_i \geq$ action level, then bump-out the i^th segment, where UCL_i is computed using Equation (3). Note: the segment is bumped out if $UCL_i \geq$ action level for *one or more* of the analytes.

5. Update the estimate of the RSD using the duplicate MI measurements in Sets 1 and 2

$$RSD = \sqrt{\frac{1}{n^*} \sum_{i=1}^{n^*} \frac{S_i^2}{\bar{X}_i^2}} \tag{4}$$

where

n* = n + (number of new bumped-out segments that have two MI samples)

6. Compute the standard deviation [Equation (2)] and the UCL [Equation (3)] and conduct the UCL test for each newly bumped-out segment in Set 2.

7. Repeat Steps 5 and 6 until no new segments are bumped out.

5.0 Assumptions

- The field crew will collect at least 5 small soil samples (increments) in a cluster around the 5 evenly spaced Primary Sample Locations for a total of at least 25 increments per MI sample.
- The increments are thoroughly mixed to form a single evenly distributed MI sample of the Primary Samples for each segment.
- If a second MI sample is needed for a segment, the same sampling pattern (5 increments in a cluster around each of the 5 evenly spaced Primary Sample Locations) should be used.
- The location of the second MI sample relative to the first MI sample is determined using professional judgment under the assumption that the location or distance between the two MI samples has no effect on the RSD.
- Analyte measurements of TNT, RDX, and HMS in the MI samples have a normal (Gaussian) distribution.
- The RSD computed for a given set of segments (Set 1, Set 2, Set 3, etc.) applies to all segments in the set, that is, the RSD is assumed to be constant for all segments.
- If more than one measurement is obtained from a MI sample, then x_i in Equations 1, 2, 3 and 4 in this Appendix is the average of the several measurements.
- The sampling design (one or two MI samples per segment and at least 25 increments per MI sample) results in a sufficiently high (unspecified) probability that the UCL test will correctly indicate when a segment should not be bumped out.

6.0 Sampling Design Parameters in the Boundary Dialog Box

Required Confidence Level

The required confidence level is the probability required by the VSP user that the computed one-sided upper confidence limit (UCL) for a segment does actually exceed the true mean contamination level for the segment. For example, if the required confidence level is specified to be 0.95 (95%), then the VSP user is requiring that the probability be 0.95 that the computed one-sided UCL exceed the true mean for the segment. Conversely, the VSP user is willing to tolerate a probability of 0.05 (5%) that the computed one-sided UCL is less than the true mean for the segment.

Diameter of Hot Spot that Must be Detected at the Boundary

The "Diameter" is the width of a contaminant plume or hot spot of concentrations that would be of concern if it existed at the perimeter boundary. The concern is that the "hot spot" may extend beyond the boundary. VSP uses this width to determine the minimum spacing between the Primary Sample Locations along the boundary, which in turn determines the length of each segment along the boundary.

Percent or Number of Segments that Need Field Duplicates

The VSP user can input on the dialogue box the percent or number of the segments constructed by VSP that should have two MI soil samples rather than one. The resulting data are used to estimate the relative standard deviation (RSD), which is used in computing the UCL.

Convert the Boundary to a Convex Hull

If a boundary that completely encloses the Sample Area is very irregular, e.g., has various indentations, the VSP user can specify in the dialogue box that VSP should change the enclosing boundary to a convex hull. This has the effect of smoothing out the boundary irregularities, but it also enlarges the Sample Area enclosed by the boundary. In practice, the VSP user can try this option and view the results to see if they are acceptable. This option is available only for boundaries that completely enclose the Sample Area. A copy of the initial boundary should be saved because the act of converting an enclosing boundary to a convex hull cannot be undone.

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