Example 1: The Effects of α, β, and σ on Sample Size

Objectives:

(1) To familiarize attendees with creating a statistical sampling design using simple random sampling techniques.

(2) To demonstrate how changes in α, β, and σ affect the number of samples required. (Note that while this exercise uses parametric statistics, the effects of α, β, and σ are similar when using non-parametric statistics.)

Background Information:

The mission of the site under investigation was to produce components for nuclear weapons from materials such as plutonium, uranium, and beryllium. The primary processing plant is located near a one-acre field that was part of a buffer area surrounding the plant. In 1946, a fire in the primary processing plant released 30 millicuries of Pu-239. The one-acre field is now being considered for release for industrial land use, but it has never been characterized and is presumed to be contaminated (i.e. Ho = site is contaminated). The site manager has asked you to calculate the number of samples required to characterize the site for Pu-239. The regulators have decided that if the average Pu-239 level on the site is greater than 8 pCi/g, then the site will need to be remediated. They prefer limiting the chance that a contaminated site will not be remediated to 1%, however they have agreed, if necessary, to accept a 5% chance that a contaminated site will not be remediated (that is α can be set at 1% or 5%). The site manager has decided that he can live with a 15% to 20% probability of remediating a clean site (that is, β can be set at 15% or 20%). Three historical data sets from similar sites are available for estimating the value of the standard deviation of plutonium soil concentrations. One estimates the standard deviation to be 1.0 pCi/g, another at 2.0 pCi/g, and the third at 3.0 pCi/g. The Lower Bound of the Gray Region is set to 7 pCi/g (so the Width of Gray Area or Region is 1.0 pCi/g).

Exercise:

Step 1:

- Close any open windows by clicking "**x**".
- From the main menu, select **File → Open Project → OneAcreField.vsp → Open**.
- Maximize the **OneAcreField.vsp** box to fill the screen.

Step 2:

- From the main menu select **Sampling Goals → Compare Average to Fixed Threshold → Can assume data will be normally distributed → Ordinary Sampling… → True Mean vs. Action Level**. Use the tab **One-Sample t-Test**. Make sure that **True Mean >= Action Level (Assume Site is Dirty)** is selected as the null hypothesis.

E1-1 Using the information provided above**,** complete the following table, where n is the number of samples required or **Minimum Number of Samples in Survey Unit**. (Hint: to save time, click **Apply** after each parameter change.)

	α =		α =	
	β =	β =	β =	β =
σ =	n=	n=	n=	n=
σ =	n=	n=	n=	n=
σ =	n=	n=	n=	n=

Step 3:

In the space below, briefly answer the following questions:

E1-2 When n = 31 and σ = 2, the decision-maker is willing to walk away from a dirty site ____% of the time. What type of error is this?

E1-3 When n = 31 and σ = 2, the decision-maker is willing to clean up a clean site _____% of the time. What type of error is this?

E1-4 Which of the three parameters (α, β, or σ) has the biggest impact on the number of samples required?

E1-5 If σ is incorrectly underestimated, what is the impact?

Step 4:

- Close any open windows. Respond **No** to the query **Save changes to OneAcreField.vsp?**

Example 2: Judgmental Sampling versus Simple Random Sampling

Objective:

To illustrate the advantages and disadvantages of sampling plans using a fixed sample size for random sampling and for judgmental sampling.

Background Information:

A warehousing facility is being sold, and the prospective buyer is conducting an investigation to characterize existing environmental conditions and associated potential liability. One feature being assessed is a 5,000 ft^2 fenced area where drums of uranium oxide were stored temporarily during shipment. Some drums were apparently damaged during handling, leading to release of small amounts of material assumed to be yellowcake which has stained the soil yellow. However, there is no information on what contaminants the stains may contain. Eight yellowish stains have been identified, and a typical stain is about 1 ft^2.

Exercise:

Step 1:

- From the main menu, select **File → Open Project → drums.vsp → Open**. If necessary, maximize the **drums.vsp** window.

Step 2:

Select the eight yellow stains as follows:

- From the tool bar select the **Zoom In** button (Ensure that the **Main Toolbar** is activated). Using the magnifying glass cursor, click on the fenced area 5 times so that it to nearly fills the screen. Use the horizontal and vertical scrolls bars to center the fenced area. Deselect the **Zoom In** button by clicking on it.

- From the main menu select **Edit → Sample Areas → Select/Deselect Sample Areas**.

- A **Select / Deselect Areas** text box will appear. Click the **Deselect All** button to deselect all sample areas and then click **OK** to close the text box. The background gray color of all previously selected areas will disappear, leaving only the outline of the area.

- Now repeat the step of selecting **Edit → Sample Areas → Select/Deselect Sample Areas**. This time Highlight **Area 118** through **Area 125**; click **OK**. The eight ellipses will be filled in with a yellow color to form the eight stained areas

Step 3:

- Use the **Zoom In** button from the tool bar to fill the screen with the left half of the fenced area where the drums are located. Then deselect the **Zoom In** button. Use the horizontal and vertical scroll bars to move the section with the drums so that they are all in view.

- From the main menu select, **Sampling Goals → Non-statistical sampling approach→Judgement (authoritative) Sampling.** Note that the cursor has now changed to a crosshair. Click on each stained area to select one sample point within it.

Step 4:

If these eight samples constitute your sampling plan, answer the following questions (without using the computer):

E2-1 For the purpose of characterizing the eight stained areas, is this judgmental design appropriate? Explain why or why not.

E2-2 For the purpose of selling the site (and transferring any related risk), can you extrapolate data from the judgmental sampling design throughout the fenced area? Explain why or why not.

E2-3 Using the data from the judgmental sampling design, can conclusions made about this site be extended to analogous sites?

E2-4 For this sampling design, were Type I and Type II errors identified and controlled?

Step 5:

- Deselect the eight stained areas: from the main menu select **Edit → Sample Areas → Select/Deselect Sample Areas**. Deselect **Area 118** through **Area 125** by clicking the button **Deselect All**; then click **OK**. The eight yellow ellipses will disappear.

- Then select the entire fenced area: from the main menu select **Edit → Sample Areas → Select/Deselect Sample Areas**. Highlight **Area 1**; then click **OK**. The fenced area will be highlighted in gray.

- From the main menu, select **Sampling Goals → Non-statistical sampling approach → Predetermined number of samples → Ordinary placement....** Enter **8** in the **Number of Samples** box under the **Sample** tab. This option randomly places your prespecified or predetermined number of samples within the fenced area. You may want to move the **Predetermined number of samples** text box aside so that you can see the sample points more clearly. Click **Apply** and notice where the sampling points are located on the map. (Click **Apply** several times to see different random patterns of sampling points.)

- Click the **Close** button to close the text box.

Step 6:

Answer the following questions:

E2-5 How are the judgmental and predetermined sampling designs different? (Hint: Think beyond the physical layout of the sample points.)

E2-6 For the predetermined sampling design, were Type I and Type II errors controlled?

E2-7 Can these conclusions be extended to analogous sites?

Step 7:

- Now select **Sampling Goals →Compare Average to Fixed Threshold → Data not required to be normally distributed → Ordinary sampling → No distributional assumption (MARSSIM) → True Mean or Median vs. Action Level.** Assume that null hypothesis is that the site is dirty. Under the **MARSIMM Sign Test** tab, begin by setting α = 5% and β= 20%. Assume that the **Action Level** is **10** mg/kg, the **Width of Gray Region (Delta)** is **2.5** mg/kg, and the **Estimated Standard Deviation** is **6** mg/kg.

E2-8 What combination of α and β are needed to get 8 samples? (Note: There may be more than one correct answer.)

Step 8:

E2-9 Are these tolerable levels for decision errors? That is, will decision-makers find these acceptable levels for walking away from a dirty site or cleaning up a clean site? Explain why or why not.

- Now select appropriate values for α and β, insert them in the Text box, and click **Apply** to get the required sample size.

E2-10 How does this compare with the fixed sample size of 8?

Step 9:

- Close any open windows. Respond **No** to the query **Save changes to drums.vsp?**

Example 3: Parametric versus Non-Parametric Statistics

Objective:

To compare the impact of parametric versus non-parametric statistics in the number of samples required to characterize a site.

Background Information:

From 1915 to 1927, a New Jersey clock and instrument company manufactured radiant dials, using radium paint to hand-paint the dials. The small factory was severely contaminated (Ho: site is contaminated), leading to a series of demolition and decontamination efforts over several decades as radiation protection standards changed. At present, the site is now a vacant lot where a pile of rubble mixed with sand and gravel still remains. Responsibility for the site has passed to an EPA Region 2 site manager who must decide whether to send the pile of rubble, sand, and gravel to a public landfill or to a licensed radioactive waste disposal facility in Utah. The decision will be based on the residual radium-226 concentration above the site background. To dispose of the rubble at a (much less expensive) public landfill, the EPA site manager must demonstrate that the residual radium-226 concentration in the mixed rubble is no more than 5 pCi/g. The regulators want to be very sure that they do not release a contaminated site and have set α at 1%. The site manager is very anxious to avoid public controversy and err on the side of caution (sending the rubble to the more expensive Utah facility), so she is willing to send clean rubble to Utah 25% of the time (i.e., when the true mean is less than background). The width of the gray area is 1.6 pCi/g. Historical data suggests that the standard deviation for the radium is 2.5 pCi/g. The rubble pile is an ellipse with an area of approximately 740 square feet.

Exercise:

Step 1:

- From the main menu, select **File → Open Project → DialFactory.vsp → Open**. If necessary, maximize the **DialFactory** box.

Step 2:

- From the main menu select **Sampling Goals → Compare Average to Fixed Threshold → Data not required to be normally distributed → Ordinary sampling → No distributional assumption (MARSSIM)...**.

E3-1 How many samples will be required for rubble pile? (Hint: in this example, VSP functions better if you begin by entering the standard deviation.)

- Click the **OK** button to close the text box.

Step 3:

- A statistician tells the cleanup contractor that there are two options analyzing the data: parametric and non-parametric tests. Parametric tests are more powerful because they are based distributional assumptions. These assumptions allow the statistician to assign probabilities to the occurrence of events. However, before parametric statistics can be used, the distributional assumptions must be verified. Non-parametric statistics are based on much less stringent assumptions but are not as powerful and require more samples.

E3-2 Statistical tests have determined that approximately 30-50 samples are needed verify the distributional assumptions of a parametric test. Given this, determine whether it is worthwhile (in this case) to verify the distributional assumptions of a parametric test. (Hint: from the main menu select **Sampling Goals → Compare Average to Fixed Threshold → Can assume data will be normally distributed → Ordinary sampling**

Step 4:

E3-3 A new Regional Administrator drastically cuts the Superfund budget, leading the site manager to decide suddenly that she wants a much smaller chance of erroneously sending clean rubble to Utah. So she lowers β to 15%. How many samples will now be needed with either the MARSSIM Sign Test or the One Sample t-Test?

Step 5:

- **Close** any open windows. Respond **No** to the query **Save changes to DialFactory.vsp?**

Example 4: One Sample Proportion Test

Objectives:

(1) To provide practice in choosing tolerable decision error limits for a One Sample Proportion Test.

(2) To illustrate that VSP can handle a situation where action levels are not in the typical concentration units.

Background Information:

Ten thousand (10,000) cans of uranium oxide (UO2) powder are stored in a warehouse. Each can weighs approximately 10 kg. A can is termed "defective" if its weight is not within 100 g of the value in the records system. If 20% or more of the cans are found to be defective, then all the cans will require repackaging.

Your task is to advise the plant manager of the minimum number of drums that need to be inspected to estimate the percentage of defective cans in the population. The consequences of leaving defective cans in-place without repackaging has a very low risk. Repackaging however is very expensive, so she wants to guard against unnecessarily repackaging the cans.

Exercise:

Step 1:

From the main menu, select **File → Open Project → warehouse.vsp → Open**.

Step 2:

E4-1 What is the Null Hypothesis for this project?

E4-2 What is the Action Level for this project?

E4-3 Why is the Action Level for this project high?

E4-4 How is this Action Level different from those normally encountered in soil remediation or D&D projects?

E4-5 Given the Null Hypothesis: The proportion of defective cans in the warehouse is ≥ 20%; would you advise the plant manager to set the Type I error to 1%, 5%, 10% or 20%? Explain your answer.

E4-6 Given the Null Hypothesis: The proportion of defective cans in the warehouse is ≥ 20%; would you advise the plant manager to set a Type II error to 1%, 5%, 10% or 20%? Explain you answer.

From main menu, select **Sampling Goals →Compare Proportion to Fixed Threshold → Data not required to be normally distributed → Ordinary sampling.**

E4-7 Given the Null Hypothesis: The proportion of defective cans in the warehouse is ≥ 20%; Type I error = 20%, Type II error = 1%, and the Width of the Gray Area (Region) is 0.1, what is the minimum number of drums that need to be inspected to check the Null Hypothesis.

Step 4:

Close any open windows. Respond **No** to the query **Save changes to warehouse.vsp?**

Example 5: Finding Hot Spots

Objective:

To illustrate how to create sampling designs for locating hot spots.

Background Information:

Ten (10) one-acre sites in the 100 Area have been remediated down to 5 feet below grade. Before remediating further, the contractor wants to know if there are any remaining circular hot spots with a radius greater than 10 feet (Ho: Site is contaminated). The contractor decides to conduct an assessment of one of the one-acre plots.

He plans to send the samples he collects to a reputable laboratory for analysis. In addition to locating hot spots, the data will also be used to estimate the variance of the contaminant of concern at the site.

Exercise:

Step 1:

In the main menu, select **File → Open Project → 100AreaField.vsp**

Step 2:

From the main menu, select **Window → Quad Window**. The map you loaded should appear in the upper left-hand window. The other three windows are essentially blank at this point.

Step 3:

From the main menu, select **Sampling Goals → Locating a Hot Spot → Hot spot….** (Ensure that the **Random Start** box is checked in the box **Hot Spot** tab.)

Step 4:

Click the **Locating a Hot Spot** tab, select **Hot Spot Size** if it is not already selected. Enter **95%** as the **Probability of Hit.** Click the **Grid** tab**.** Select **Triangular** as the **Grid Type.**

Click the **Costs** tab. The default value for **Fixed Planning and Validation Cost** is **$0.00**. The default value for **Field Collection Cost per Sample** is **$100.00** and the default value for **Analytical Cost per Analysis** is **$400.00**. Click **Apply**.

Review the information presented in the Report Window (the lower left-hand window).

Step 5:

Answer the following questions:

E5-1 How many samples will be required to have 95% confidence that a hot spot with a 10-ft radius or larger will be detected?

E5-2 What is the required spacing for the triangular grid?

E5-3 How much will it cost to have 95% confidence that a hot spot with 10-ft radius (or larger) will be detected? (Remember that the numbers are generated for a single one-acre site.)

E5-4 If none of the criteria (95% confidence and 10-ft radius of the hot spot) can be relaxed, what other options are open to the contractor?

E5-5 Change the size of the hot spot to have a radius of 20-ft. How does this affect the total cost if the confidence remains at 95% and a triangular grid is used?

E5-6 Change the shape of the hot spot by entering **0.6** in the **Shape (0.1 – 1.0)** box under the **Hot Spot** tab, keeping the other parameters the same. Set the **Length of the Semi-Major Axis** to ≈**10** ft by changing the **Length of grid size** (for triangular **Grid Type** under the **Grid** tab) to **14.0 ft**. How does it affect the total cost if the confidence remains at 95% and a triangular grid is used?

Step 6:

Close any open windows. Respond **No** to the query **Save changes to 100AreaField.vsp?**

Example 6: What if I don't know anything about the site?

Objective:

To show how VSP can be used to create sampling designs even when there is no historical data about the site.

Background Information:

The site of a former low-level liquid waste evaporation pond in the Idaho National Environmental and Engineering Laboratory is being examined to determine the need for remediation. Process knowledge is available to determine the species and activities of radionuclides, which flowed into the pond, but no soil or sediment sampling has been performed as yet.

The action level has been set at 3.5 pCi/kg for the total gamma-emitting radionuclides, α and β are set at 5% and 20% respectively, and the lower bound of the gray area is 3 pCi/kg. However there is no historical information available with which to estimate the standard deviation.

Exercise:

Step 1:

- In the main menu, select **File → Open Project → evaporationpond.vsp → Open**. Then select **Sampling Goals → Compare Average to Fixed Threshold → Can assume data will be normally distributed → Ordinary sampling…**.

Step 2:

E6-1 One relatively conservative approach **is to assume that the standard deviation is equal to the action level**. This approach can be used when there is no information whatsoever about the contaminant of concern. Using this assumption, find the number of samples needed for a parametric test.

Step 3:

- If the range (the maximum minus the minimum activity or concentration) can be estimated, and if the general shape of the population distribution is known, then several other approaches are possible. Assume that the likely minimum value is 0.5 pCi/kg and the likely maximum value is 6.5 pCi/kg.

- Please note that the relationship between range and standard deviation of a data set is discussed in *Some Theory Sampling, by William Edward Deming, Dover Publications, Inc, New York, 1950.*

E6-2 If the shape is **completely unknown or if a bimodal distribution (background plus contamination)** is expected, then estimate the standard deviation as the **range divided by 2.8.** Using this assumption, find the number of samples needed for a parametric test.

E6-3 If the population distribution is **uniform,** then estimate the standard deviation as the **range divided by 3.5.** Using this assumption, find the number of samples needed for a parametric test.

E6-4 If the standard deviation is **a right or left triangular (extremely positively or negatively skewed, respectively),** then estimate the standard deviation as the **range divided by 4.** Using this assumption, find the number of samples needed for a parametric test.

E6-5 If the population distribution is **pyramidal**, then estimate the standard deviation as the **range divided by 5.** Using this assumption, find the number of samples needed for a parametric test.

E6-6 If the population distribution is **bell-shaped**, then estimate the standard deviation as the **range divided by 6.** Using this assumption, find the number of samples needed for a parametric test.

E6-7 Is it worthwhile to investigate historical data to try to estimate the standard deviation?

Step 4:

Close any open windows. Respond **No** to the query **Save changes to evaporationpond.vsp?**