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**Pacific Northwest  
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**Soil Sampling and Analysis Plan  
for the McGee Ranch-Riverlands  
and North Slope Units of the  
Hanford Reach National Monument**

B. G. Fritz  
R. L. Dirkes

December 2004



Prepared for the U.S. Department of Energy  
under Contract DE-AC05 -76RL01830

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Pacific Northwest National Laboratory  
Richland, Washington 99352

## Summary

This document describes soil sampling that will be performed on several units of the Hanford Reach National Monument: the McGee Ranch-Riverlands Unit and the North Slope which consists of the Saddle Mountain Unit and the Wahluke Slope Unit. This sampling fulfills a U.S. Department of Energy (DOE) requirement to evaluate the potential for residual radioactive contamination on this land and determine compliance with the requirements of DOE Order 5400.5 prior to radiological release of the property.

DOE Order 5400.5 requires that a request for radiological release criteria, i.e., Authorized Limits, be developed and submitted to the applicable DOE headquarters program office for approval. For the Hanford Site, this is the DOE Office of Environmental Management (EM). The Authorized Limit request, which is based on an annual exposure limit of 100 mrem to the public, was submitted to DOE-EM on December 22, 2003. DOE-EM approved the requested Authorized Limits on March 1, 2004.

The McGee Ranch-Riverlands Unit is located to the north and west of Highway 24 and is bordered by the Columbia River and private land (Figure 1.1). The North Slope consists of two distinct units: the Saddle Mountain Unit and the Wahluke Slope Unit, both located north of the Columbia River. The North Slope units do not include Columbia River islands or riverbank below the high water line.

Soil sampling as defined in this plan will be conducted on the McGee Ranch-Riverlands Unit and North Slope in an effort to demonstrate compliance with the Authorized Limits. Samples will be collected and analyzed for radioactive constituents identified in the Authorized Limits. The results of these soil samples will be compared to the approved Authorized Limits to determine compliance.

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## 1.0 Introduction

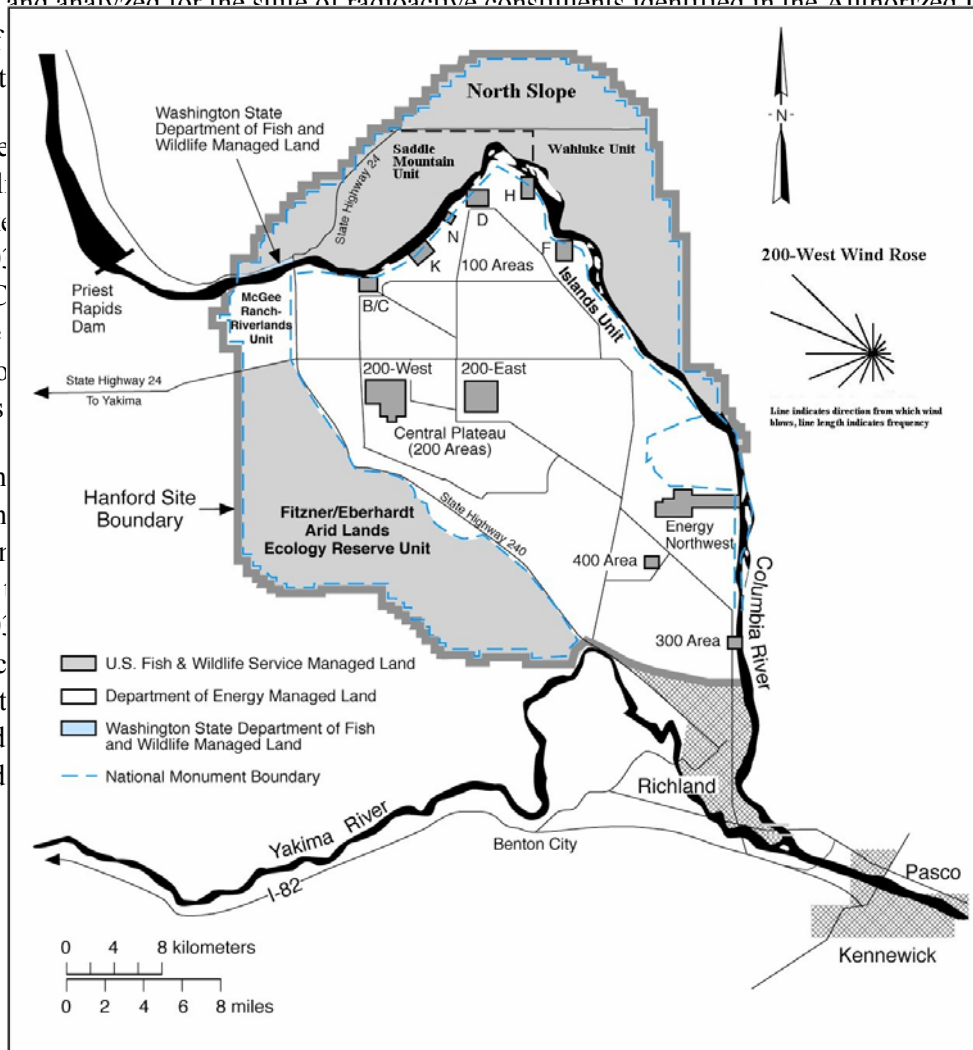
The Hanford Reach National Monument (HRNM) consists of several units, including the McGee Ranch-Riverlands Unit and the North Slope made up of the Saddle Mountain Unit and the Wahluke Slope Unit. The McGee Ranch-Riverlands Unit is located to the north and west of Highway 24 and is bordered by the Columbia River and private land (Figure 1.1). The North Slope consists of two distinct units: the Saddle Mountain Unit and the Wahluke Slope Unit, both located north of the Columbia River. The North Slope units do not include Columbia River islands or riverbank below the high water line. The exception to this is Savage Island, which is an intermittent island and is within the North Slope boundary. To fulfill an internal requirement prior to radiological release of property, the U.S. Department of Energy (DOE) must evaluate the potential for residual radioactive contamination on this land, and determine compliance with the requirements of DOE Order 5400.5 (DOE 1993).

DOE Order 5400.5 requires that a request for radiological release criteria, i.e., Authorized Limits, be developed and submitted to the applicable DOE headquarters program office for approval. For the Hanford Site, this is the DOE Office of Environmental Management (EM). The request for Authorized Limits, which is based on an annual exposure limit of 100 mrem to the public, was submitted to DOE-EM on December 22, 2003. DOE-EM approved the requested Authorized Limits on March 1, 2004.

Soil sampling as defined in this plan will be conducted on the McGee Ranch-Riverlands Unit and North Slope in an effort to demonstrate compliance with the Authorized Limits. Samples will be collected and analyzed for the suite of radioactive constituents identified in the Authorized Limits. The results of radio-

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**Figure 1.1.** Hanford Reach National Monument with Central Plateau Wind Rose

For most radionuclides, vertical movement through the soil is limited (Price 1991), so sampling the surface soil provides the most conservative measure of accumulated radionuclide concentrations and, therefore, the best data for determining compliance with the approved Authorized Limits. The goal and design criteria of this sampling effort is to collect an adequate number of soil samples to determine with a high degree of statistical confidence (99%) if the concentrations of the radionuclides of concern in soil on the McGee Ranch-Riverlands Unit and North Slope are below the approved Authorized Limits.

## **2.0 Sampling Procedure**

Sample collection will be conducted according to procedures (Hanf and Poston 2004) established and used for the Hanford Surface Environmental Surveillance Project (SESP). The soil collection procedure consists of collecting five sub-samples of the surface soil at each location and compositing them into a single sample submitted for analysis. Each sub-sample location is separated by at least 9 meters, with a minimal amount of vegetative cover, few rocks, and do not appear to have been eroded recently. The five sub-samples are collected with a 10-centimeter-diameter, 2.5-centimeter-deep “cookie cutter” sampling device. Collection staff will record the latitude and longitude of each sampling location for accurate spatial analysis of the data. This procedure is the same one used in the collection of historical soil concentration data evaluated in the historical site assessment (Fritz et al. 2003), resulting in consistent collection techniques as historic soil samples. All sample collection documentation will be consistent with the established SESP sample collection and chain-of-custody protocols.

### **2.1 Determination of the Number of Samples**

To determine the number of samples necessary to evaluate the soil concentrations of radionuclides, and provide a high degree of statistical confidence that the Authorized Limits are not exceeded, the Visual Sample Plan (VSP) computer program was used (Gilbert et al. 2001; Hassig et al. 2002). This program was developed to provide a tool for selecting the right number and location of environmental samples so the results of statistical tests performed on data collected via the sampling and analysis plan have the required confidence for decision making. As an added measure, the calculation of the number of samples necessary was done assuming the action level to be one-fourth of the approved Authorized Limits.

#### **2.1.1 North Slope Units**

The VSP program was run using the statistical information about each radionuclide from historical monitoring data. Strontium-90 is the radionuclide that requires the most samples to meet the statistical requirement of being 99% confident that North Slope soil concentrations are lower than the approved Authorized Limits. A standard deviation of 0.15 pCi/g was calculated from historical results for strontium-90 (see Appendix A). To provide a high degree of confidence that the North Slope units comply with the approved Authorized Limits, parameters were set in the VSP program to provide only a 1% chance of incorrectly concluding the site had concentrations below the approved Authorized Limits. A 5% chance of incorrectly determining that the site exceeded the Authorized Limits was allowed. It was assumed that due to atmospheric deposition patterns across the North Slope, the results might not be normally distributed; therefore, parameters in the software were set to account for a non-normal distribution of results. The results of VSP indicated that for the North Slope, 20 soil samples are required. This includes a 10% increase in the sample size to account for missing or unusable data. A detailed description of the VSP results for this sampling plan is included in Appendix A.

While the VSP program is a useful tool in determining the number of samples necessary for determining compliance with Authorized Limits approved by DOE-EM, there are some design assumptions in the VSP program that warrant further consideration in the development of a soil sampling plan. The VSP



program assumes the terrain to be flat. This is not the case on the North Slope, with elevations ranging from 115 meters in the southeastern corner to 600 meters at the top of the Saddle Mountains. To assure that the sampling design would allow for an evaluation of potential spatial differences, due to elevation or variability in concentrations across the North Slope units, a random start grid pattern rather than randomly selected individual sampling locations was used in selection of the sampling points. The random start grid pattern maintains the requirement for random sample locations and ensures that samples will be collected from different elevations and from locations evenly distributed across the North Slope. To further account for terrain and elevation effects, as well as potential radiological contaminant concentration variability, 10 additional soil samples will be collected at various locations (Section 2.2).

The Columbia River is the southern border of the North Slope units. Historical sampling results and direct radiation monitoring indicate that there is a potential for contamination to have been deposited along the shoreline of the North Slope Unit from Hanford liquid effluent during reactor operations. Results indicated that the most likely place for contamination to have accumulated is in the Savage Island slough at the southeastern corner of the North Slope. To account for the potential elevated contaminant levels along the river shore of the North Slope, an additional 18 samples will be collected from the North Slope shoreline. Since Savage Island was identified in the historical site assessment (Fritz et al. 2003) as having the highest likelihood of elevated levels of radionuclides, 6 of the 18 samples collected along the Columbia River shoreline will be collected from on and around Savage Island and the Savage Island slough.

### **2.1.2 McGee Ranch-Riverlands Unit**

The McGee Ranch-Riverlands Unit is significantly smaller than the North Slope units, and is upwind and upriver from Hanford atmospheric emissions and liquid effluent discharge. The small size of the unit and the upwind location make it unlikely that there is significant spatial variability in the soil concentrations as a result of deposition patterns. This allows for an assumption that the soil concentration results will be normally distributed. For developing the scenario for input into VSP to determine sample size, all input parameters (with the exception of the assumption of a normal distribution) were the same as those for the North Slope. The resulting number of samples in the random start grid calculated to be necessary to determine compliance with the approved Authorized Limits is seven. To provide more confidence in the results, five additional samples will be collected across the McGee Ranch-Riverlands Unit at various locations selected by collection staff (Section 2.2).

In the historical site assessment (Fritz et al. 2003), the Riverlands unit classification yard was identified as having the highest potential for radiological contamination as a result of past practices. Although previous work has concluded the Riverlands unit classification yard to have levels of radiological contamination below Washington Administrative Code (WAC) 173-340, Model Toxics Control Act residential standards (DOE et al. 1996), an additional seven soil samples will be collected within the

boundary of the old classification yard in order to verify previous results, and provide an added measure of confidence that soil concentrations on the entire McGee Ranch-Riverlands Unit are below the approved Authorized Limits.

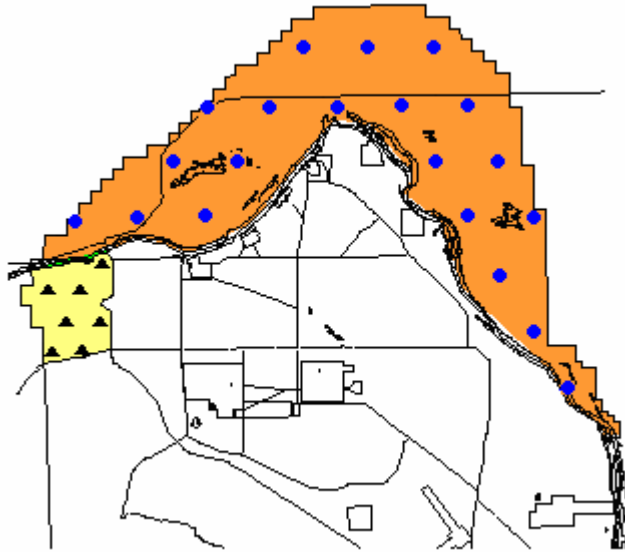
Overall, 67 soil samples will be collected across the McGee Ranch-Riverlands and the North Slope units. The number of soil samples planned for collection is outlined in Table 2.1. These 67 samples provide a sufficient sample size to allow a statistically valid determination of whether or not concentrations of radionuclides in soil on these HRNM units are below the approved Authorized Limits.

**Table 2.1.** Number of Soil Samples Planned for Collection for the McGee Ranch-Riverlands Unit and the North Slope Unit

Area	Number of Samples
North Slope random start grid	20
North Slope selected locations	10
North Slope near Columbia River shore	18
McGee Ranch-Riverlands Unit random start grid	7
McGee Ranch-Riverlands Unit selected locations	5
Riverlands unit classification yard	7
<b>Total soil samples</b>	<b>67</b>

## 2.2 Sample Locations

Using the VSP program with a systematic grid pattern and a random starting location provides good spatial coverage of the units. The sampling locations calculated by the VSP program are illustrated in Figure 2.1, and global positioning system (GPS) coordinates are provided in Table 2.2. It is assumed that due to terrain and a lack of roads in some areas, sampling exactly at the selected locations may not be possible at all locations. Every reasonable effort will be made by collection staff to collect samples from the predetermined locations, but for those locations that are deemed inaccessible, samples will be collected as close as possible to the location determined by the VSP program. For the additional samples being collected to augment the sampling locations determined by the VSP program, samples will be collected from locations that are determined to have a potential for accumulation of radionuclides, or appear to have above average use by members of the public. Samples collected near the Columbia River shoreline on the North Slope will be collected from the riparian zone since defining and identifying the high water line is problematic at some locations along the shoreline. Six samples will be collected on and around Savage Island and the Savage Island slough. The other 12 samples from near the Columbia River shore will be collected at evenly spaced intervals beginning at the Vernita Bridge and ending at the upstream edge of Savage Island.



**Figure 2.1.** Systematic Grid Sampling Locations

**Table 2.2.** Predetermined Systematic Grid Sampling Location Coordinates

North Slope			McGee Ranch-Riverlands		
Location	Longitude	Latitude	Location	Longitude	Latitude
NS 1	119.30813	46.54900	MCG 1	119.78656	46.57593
NS 2	119.33784	46.58575	MCG 2	119.75332	46.57572
NS 3	119.36759	46.62249	MCG 3	119.76967	46.59568
NS 4	119.76402	46.66216	MCG 4	119.73642	46.59546
NS 5	119.70291	46.66175	MCG 5	119.78603	46.61563
NS 6	119.64180	46.66131	MCG 6	119.75277	46.61542
NS 7	119.39738	46.65922	MCG 7	119.73586	46.63516
NS 8	119.33628	46.65861			
NS 9	119.67180	46.69797			
NS 10	119.61065	46.69751			
NS 11	119.42721	46.69594			
NS 12	119.36607	46.69535			
NS 13	119.64065	46.73418			
NS 14	119.57946	46.73370			
NS 15	119.51827	46.73320			
NS 16	119.45709	46.73266			
NS 17	119.39590	46.73208			
NS 18	119.54823	46.76989			
NS 19	119.48700	46.76936			
NS 20	119.42577	46.76881			

## 2.3 Sample Analysis

A subcontracted analytical laboratory will conduct analysis of soil samples collected. This is the same laboratory used for analysis of routine soil samples collected by SESP, again providing a measure of consistency with historical environmental monitoring data. The suite of radionuclides selected for analysis (Table 2.3) was determined from historical data and the derivation of the approved Authorized Limits (Fritz et al. 2003; Napier et al. 2004). Samples will not be analyzed for americium-241 since there is no reason to expect detectable concentrations. Americium-241 is only included in the Authorized Limits because of its use in research on another unit of the HRNM. The analytical methods will be adequate to detect concentrations well below the approved Authorized Limits. Results for other radionuclides will be obtained as an artifact of the analytical procedures. A gamma scan provides results for 23 radionuclides, and an isotopic plutonium analysis measures concentrations of plutonium-238 as well as plutonium-239/240.

**Table 2.3.** Analytes, Detection Limits, and Authorized Limits for the McGee Ranch-Riverlands Unit and the North Slope

Radionuclide	Analytical Detection Limit (pCi/g)	Authorized Limit (pCi/g)
Cobalt-60	1	11
Cesium-134	1	20
Cesium-137	1	46
Europium-152	1	24
Strontium-90	10	88
Uranium-234	100	2400
Uranium-235	10	190
Uranium-238	50	770
Plutonium-239/240	25	480
Americium-241	NA	420
NA =		

### **3.0 Quality Control/Quality Assurance**

Quality control and quality assurance will be maintained through procedures currently in place for the SESP. These include sample collection procedures, records management, chain-of-custody, database management, data verification, and analytical techniques. All samples will be split with a riffle splitter, and half of the sample will be archived to allow for future re-analysis or to analyze for other constituents that may be deemed necessary.

Another quality assurance measure in place is colocated sampling with the Washington Department of Health (WDOH). For the SESP routine soil sampling, the WDOH collects some samples at the same locations as the SESP, and analyzes them independently. This provides an added measure of assurance that the collection procedures and analytical techniques provide good quality data.

## 4.0 References

DOE - U.S. Department of Energy, Washington State Department of Ecology, and U.S. Environmental Protection Agency. 1996. *Declaration of the Record of Decision, USDOE Hanford 100 Area, 100-IU-1, 100-IU-3, 100-IU-4, and 100-IU-5 Operable Units, Hanford Site, Benton County, Washington, U.S.* Department of Energy, Richland, Washington.

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Price KR. 1991. "The Depth Distribution of Sr-90, Cs-137 and Pu-239/40 in Soil Profile Samples." *Radiochemical Acta*. 54:145-147.

**Appendix A**

**Visual Sample Plan Results**  
**for the North Slope Units**

## Appendix A

### Visual Sample Plan Results for the North Slope Units

#### A.1 Systematic Sampling Locations for Comparing a Median with a Fixed Threshold (Nonparametric - MARSSIM)

##### A.1.1 Summary

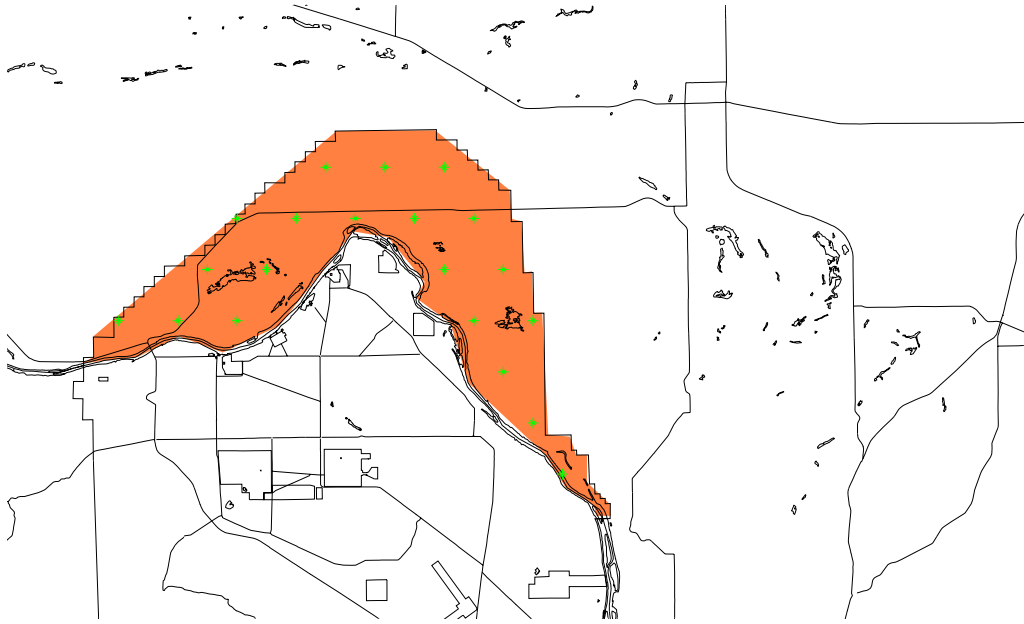
This appendix summarizes the sampling design used, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

Table A.1 summarizes the sampling design developed. Figure A.1 shows the sampling locations in the field and Table A.2 lists sampling location coordinates.

**Table A.1.** Summary of Sampling Design

Primary objective of design	Compare a site mean or median to a fixed threshold
Type of sampling design	Nonparametric
Sample placement (location) in the field	Systematic with a random start location
Working (null) hypothesis	The median(mean) value at the site exceeds the threshold
Formula for calculating number of sampling locations	Sign Test - MARSSIM version (MARSSIM 2000)
Calculated total number of samples	20
Number of samples on map <sup>(a)</sup>	20
Number of selected sample areas <sup>(b)</sup>	1
Specified sampling area <sup>(c)</sup>	379,000,000 ft <sup>2</sup>
Size of grid/area of grid cell <sup>(d)</sup>	4677 ft/1.89E+007 ft <sup>2</sup>
Grid pattern	Triangular
(a) This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas. (b) The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected. (c) The sampling area is the total surface area of the selected colored sample areas on the map of the site. (d) Size of grid/area of grid cell gives the linear and square dimensions of the grid used to systematically place samples.	





**Figure A.1.** Sampling Locations at the North Slope Units

**Table A.2.** Sampling Location Coordinates at the North Slope Units

Predetermined North Slope Sampling Locations				
Location	State Plane Coordinates		Geographic Coordinates	
	Easting	Northing	Longitude	Latitude
NS 1	591397	135811	119.30813	46.54900
NS 2	589059	139861	119.33784	46.58575
NS 3	586720	143911	119.36759	46.62249
NS 4	556322	147961	119.76402	46.66216
NS 5	560998	147961	119.70291	46.66175
NS 6	565675	147961	119.64180	46.66131
NS 7	584382	147961	119.39738	46.65922
NS 8	589059	147961	119.33628	46.65861
NS 9	563337	152011	119.67180	46.69797
NS 10	568013	152011	119.61065	46.69751
NS 11	582044	152011	119.42721	46.69594
NS 12	586720	152011	119.36607	46.69535
NS 13	565675	156062	119.64065	46.73418
NS 14	570352	156062	119.57946	46.73370
NS 15	575029	156062	119.51827	46.73320
NS 16	579705	156062	119.45709	46.73266
NS 17	584382	156062	119.39590	46.73208
NS 18	572690	160112	119.54823	46.76989
NS 19	577367	160112	119.48700	46.76936
NS 20	582044	160112	119.42577	46.76881

### A.1.2 Primary Sampling Objective

The primary purpose of sampling at this site is to compare a site median value with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the median value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the median value is less than the threshold. The Visual Sample Plan (VSP) (Gilbert et al. 2001; Hassig et al. 2002) calculates the number of samples required to reject the null hypothesis in favor of the alternative one, given a selected sampling approach and inputs to the associated equation.

### A.1.3 Selected Sampling Approach

A nonparametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A nonparametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that typical parametric assumptions may not be true.

Both parametric and nonparametric equations rely on assumptions about the population. Typically, however, nonparametric equations require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than if a nonparametric equation was used.

Locating the sample points over a systematic grid with a random start ensures spatial coverage of the site. Statistical analyses of systematically collected data are valid if a random start to the grid is used. One disadvantage of systematically collected samples is that spatial variability or patterns may not be discovered if the grid spacing is large relative to the spatial patterns.

### A.1.4 Number of Total Samples: Calculation Equation and Inputs

The equation used to calculate the number of samples is based on a Sign test (see Gilbert et al. 2001 for discussion). For this site, the null hypothesis is rejected in favor of the alternative one if the median is sufficiently smaller than the threshold.

The formula used to calculate the number of samples is:

$$n = 1.1 \left[ \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{4(\text{Sign } P - 0.5)^2} \right]$$

where

$$\text{Sign } P = \Phi \left[ \frac{\Delta}{S^2} \right]$$

$\Phi(z)$  = the cumulative standard normal distribution on  $(-\infty, z)$  (see Gilbert et al. 2001 for details)

$n$  = the number of samples

$S$  = the estimated standard deviation of the measured values including analytical error

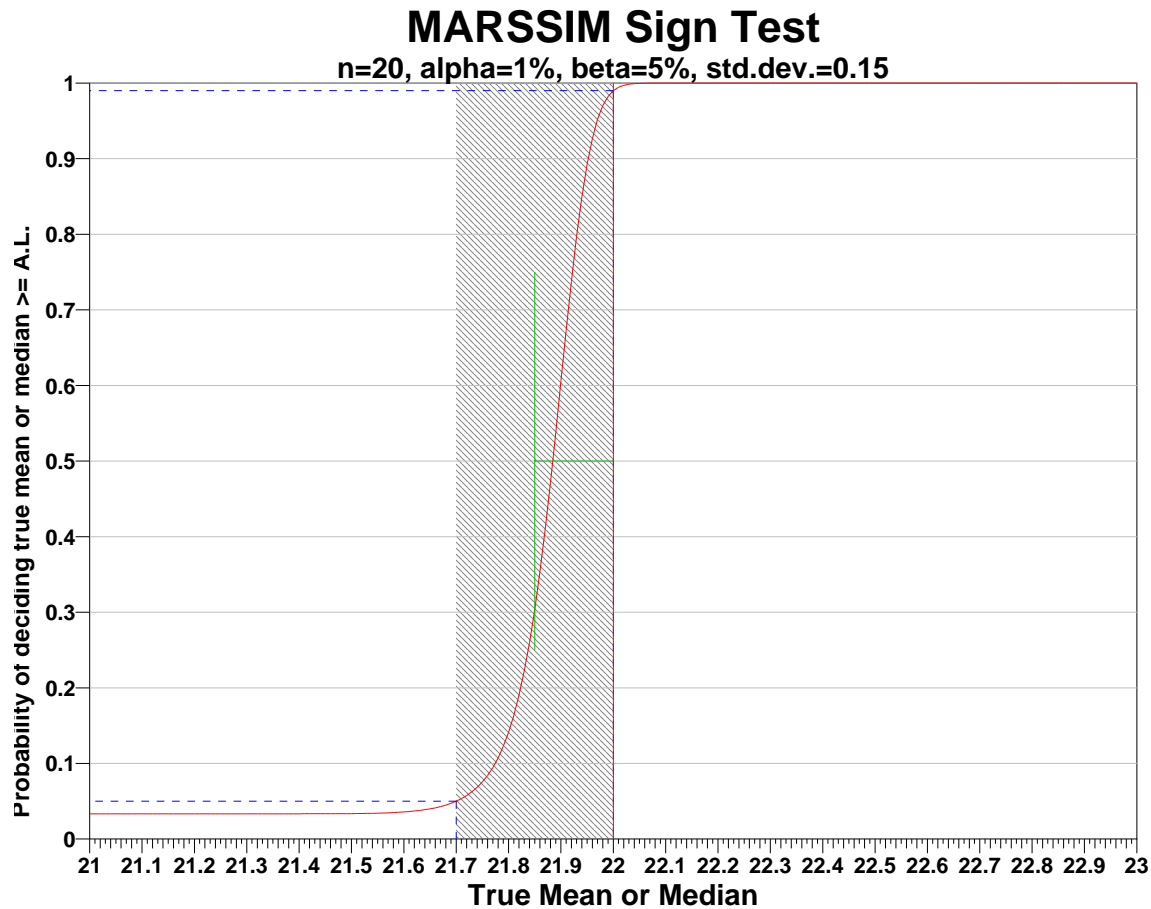
- $\Delta$  = the width of the gray region  
 $\alpha$  = the acceptable probability of incorrectly concluding the site median is less than the threshold  
 $\beta$  = the acceptable probability of incorrectly concluding the site median exceeds the threshold  
 $Z_{1-\alpha}$  = the value of the standard normal distribution such that the proportion of the distribution less than  $Z_{1-\alpha}$  is  $1-\alpha$   
 $Z_{1-\beta}$  = the value of the standard normal distribution such that the proportion of the distribution less than  $Z_{1-\beta}$  is  $1-\beta$ .

Note: MARSSIM suggests that the number of samples should be increased by at least 20% to account for missing or unusable data and uncertainty in the calculated value of  $n$ . VSP allows a user-supplied percent overage as discussed in MARSSIM (MARSSIM 2000, p. 5-33).

**Table A.3.** Input Parameters Used to Calculate the Number of Samples Collected on the North Slope

Parameter	Value
$S$	0.15
$\Delta$	0.3
$\alpha$	1%
$\beta$	5%
$Z_{1-\alpha}$	2.32635 <sup>(a)</sup>
$Z_{1-\beta}$	1.64485 <sup>(b)</sup>
MARSSIM Overage	10%
(a) This value is automatically calculated by VSP based upon the user defined value of $\alpha$ .	
(b) This value is automatically calculated by VSP based upon the user defined value of $\beta$ .	

Figure A.2 is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA 2000). It shows the probability of concluding the sample area exceeds the threshold value on the vertical axis versus a range of possible true median values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.



**Figure A.2.** Performance Goal Diagram

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to  $\Delta$ ; the upper horizontal dashed blue line is positioned at  $1-\alpha$  on the vertical axis; the lower horizontal dashed blue line is positioned at  $\beta$  on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of  $\Delta$  at  $\beta$  and the upper bound of  $\Delta$  at  $1-\alpha$ . If any of the inputs change, the number of samples that result in the correct curve changes.

#### A.1.5 Statistical Assumptions

The assumptions associated with the formulas for computing the number of samples are:

1. The computed sign test statistic is normally distributed.
2. The variance estimate,  $S^2$ , is reasonable and representative of the population being sampled.
3. The population values are not spatially or temporally correlated.
4. The sampling locations will be selected probabilistically

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

#### **A.1.6 Recommended Data Analysis Activities**

Post data collection activities generally follow those outlined in EPA's *Guidance for the Data Quality (DQO) Assessment Process* (EPA 2000). The data analysts will become familiar with the context of the problem and goals for data collection and assessment. The data will be verified and validated before being subjected to statistical or other analyses. Graphical and analytical tools will be used to verify to the extent possible the assumptions of any statistical analyses that are performed as well as to achieve a general understanding of the data. The data will be assessed to determine whether they are adequate in both quality and quantity to support the primary objective of sampling.

Because the primary objective for sampling for this site is to compare the site median value with a threshold value, the data will be assessed in this context. Assuming the data are adequate, at least one statistical test will be done to perform a comparison between the data and the threshold of interest. Results of the exploratory and quantitative assessments of the data will be reported, along with conclusions that may be supported by them.

## **A.2 References**

EPA - U.S. Environmental Protection Agency. 2000. *Guidance for the Data Quality Objectives (DQO) Process*. EPA QA/G-4, EPA/600/R-96/055, U.S. Environmental Protection Agency, Quality Staff, Washington, D.C.

Gilbert RO, JR Davidson, Jr., JE Wilson, and BA Pulsipher. 2001. *Visual Sample Plan (VSP) Models and Code Verification*. PNNL-13450, Pacific Northwest National Laboratory, Richland, Washington.

Hassig NL, RF O'Brien, JE Wilson, BA Pulsipher, RO Gilbert, CA McKinstry, DK Carlson, and DJ Bates. 2002. *Visual Sample Plan 2.0 User's Guide*. PNNL-14002, Pacific Northwest National Laboratory, Richland, Washington.

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## **Appendix B**

### **Visual Sample Plan Results for the McGee Ranch-Riverlands Unit**

## Appendix B

### Visual Sample Plan Results for the McGee Ranch-Riverlands Unit

#### B.1 Systematic Sampling Locations for Comparing a Mean with a Fixed Threshold (Parametric) Summary

This appendix summarizes the sampling design used, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater) and how to analyze the samples (in situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

Table B.1 summarizes the sampling design developed. Figure B.1 shows sampling locations in the field and Table B.2 lists sampling location coordinates.

**Table B.1.** Summary of Sampling Design

Primary objective of design	Compare a site mean to a fixed threshold
Type of sampling design	Parametric
Sample placement (location) in the field	Systematic with a random start location
Working (null) hypothesis	The mean value at the site exceeds the threshold
Formula for calculating number of sampling locations	Student's t-test
Calculated total number of samples	7
Number of samples on map <sup>(a)</sup>	7
Number of selected sample areas <sup>(b)</sup>	1
Specified sampling area <sup>(c)</sup>	39,300,000 ft <sup>2</sup>
Size of grid/area of grid cell <sup>(d)</sup>	2548 ft/5.62E+006 ft <sup>2</sup>
Grid pattern	Triangular
<p>(a) This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.</p> <p>(b) The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.</p> <p>(c) The sampling area is the total surface area of the selected colored sample areas on the map of the site.</p> <p>(d) Size of grid/Area of grid cell gives the linear and square dimensions of the grid used to systematically place samples.</p>	



**Figure B.1.** Sampling Locations at the McGee Ranch-Riverlands Unit

**Table B.2.** Sampling Location Coordinates McGee Ranch-Riverlands Unit

Predetermined McGee Ranch-Riverlands Unit Sampling Locations					
	State Plane Coordinates			Geographic Coordinates	
Location	Easting	Northing		Longitude	Latitude
MCG 1	554684	138362		119.78656	46.57593
MCG 2	557231	138362		119.75332	46.57572
MCG 3	555957	140568		119.76967	46.59568
MCG 4	558505	140568		119.73642	46.59546
MCG 5	554684	142774		119.78603	46.61563
MCG 6	557231	142774		119.75277	46.61542
MCG 7	558505	144981		119.73586	46.63516

### B.1.1 Primary Sampling Objective

The primary purpose of sampling at this site is to compare a mean value with a fixed threshold. The working hypothesis (or ‘null’ hypothesis) is that the mean value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the mean value is less than the threshold. The Visual Sample Plan (VSP) (Gilbert et al. 2001; Hassig et al. 2002) calculates the number of samples required to reject the null hypothesis in favor of the alternative one, given a selected sampling approach and inputs to the associated equation.



### B.1.2 Selected Sampling Approach

A parametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A parametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that parametric assumptions are true. These assumptions will be examined in post-sampling data analysis.

Both parametric and non-parametric equations rely on assumptions about the population. Typically, however, non-parametric equations require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than if a non-parametric equation was used.

Locating the sample points over a systematic grid with a random start ensures spatial coverage of the site. Statistical analyses of systematically collected data are valid if a random start to the grid is used. One disadvantage of systematically collected samples is that spatial variability or patterns may not be discovered if the grid spacing is large relative to the spatial patterns.

### B.1.3 Number of Total Samples: Calculation Equation and Inputs

The equation used to calculate the number of samples is based on a Student's t-test. For this site, the null hypothesis is rejected in favor of the alternative one if the sample mean is sufficiently smaller than the threshold.

The formula used to calculate the number of samples is:

$$n = \frac{S^2}{\Delta^2} (Z_{1-\alpha} + Z_{1-\beta})^2 = 0.5 Z_{1-\alpha}^2$$

where

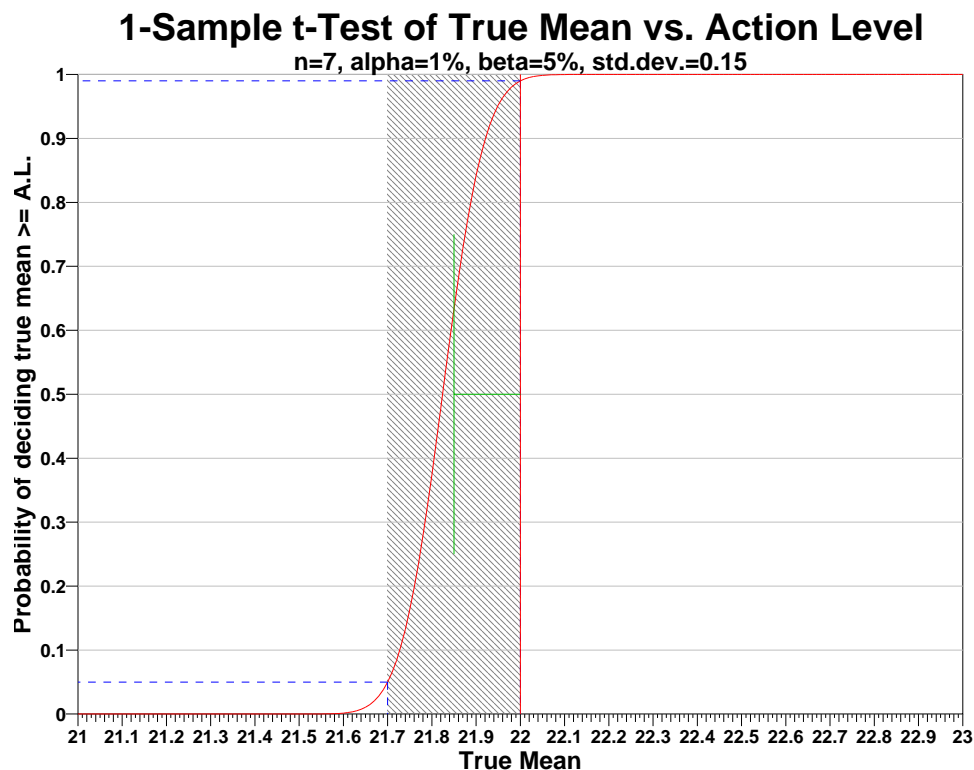
- $n$  = the number of samples
- $S$  = the estimated standard deviation of the measured values including analytical error
- $\Delta$  = the width of the gray region
- $\alpha$  = the acceptable probability of incorrectly concluding the site mean is less than the threshold
- $\beta$  = the acceptable probability of incorrectly concluding the site mean exceeds the threshold
- $Z_{1-\alpha}$  = the value of the standard normal distribution such that the proportion of the distribution less than  $Z_{1-\alpha}$  is  $1-\alpha$
- $Z_{1-\beta}$  = the value of the standard normal distribution such that the proportion of the distribution less than  $Z_{1-\beta}$  is  $1-\beta$ .

The values of these inputs that result in the calculated number of sampling locations are shown in Table B.3.

**Table B.3.** Input Parameters Used to Calculate the Number of Samples Collected on the McGee Ranch-Riverlands Unit

Parameter	Value
$S$	0.15
$\Delta$	0.3
$\alpha$	1%
$\beta$	5%
$Z_{1-\alpha}$	2.32635 <sup>(a)</sup>
$Z_{1-\beta}$	1.64485 <sup>(b)</sup>
(a) This value is automatically calculated by VSP based upon the user defined value of $\alpha$ .	
(b) This value is automatically calculated by VSP based upon the user defined value of $\beta$ .	

Figure B.2 is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA 2000). It shows the probability of concluding the sample area exceeds the threshold on the vertical axis versus a range of possible true mean values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.



**Figure B.2.** Performance Goal Diagram

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to  $\Delta$ ; the upper horizontal dashed blue line is positioned at  $1-\alpha$  on the vertical axis; the lower horizontal dashed blue line is positioned at  $\beta$  on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of  $\Delta$  at  $\beta$  and the upper bound of  $\Delta$  at  $1-\alpha$ . If any of the inputs change, the number of samples that result in the correct curve changes.

#### **B.1.4 Statistical Assumptions**

The assumptions associated with the formulas for computing the number of samples are:

1. The sample mean is normally distributed.
2. The variance estimate,  $S^2$ , is reasonable and representative of the population being sampled.
3. The population values are not spatially or temporally correlated.
4. The sampling locations will be selected probabilistically

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

#### **B.1.5 Recommended Data Analysis Activities**

Post data collection activities generally follow those outlined in EPA's *Guidance for the Data Quality Objectives (DQO) Assessment Process* (EPA 2000). The data analysts will become familiar with the context of the problem and goals for data collection and assessment. The data will be verified and validated before being subjected to statistical or other analyses. Graphical and analytical tools will be used to verify to the extent possible the assumptions of any statistical analyses that are performed as well as to achieve a general understanding of the data. The data will be assessed to determine whether they are adequate in both quality and quantity to support the primary objective of sampling.

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