WSDOT Wetland Mitigation Site Monitoring Methods

WSDOT Updated 6/12/08

Purpose

As science warrants and as customer needs evolve, WSDOT seeks to keep pace with the best available science with regard to wetland monitoring methods. Current methods at WSDOT rely on standard ecological and biostatistical methods.[1] This document is divided into three sections: Principles that Guide WSDOT Wetland Monitoring Methods, a Description of WSDOT Wetland Monitoring Methods, and a section of Questions and Answers.

To the degree possible, we have informed jurisdictional authorities at all levels, and sought regulatory support and approval as our protocol has evolved for monitoring wetland mitigation sites. A substantive change was made in recent years with approval of the Army Corps of Engineers, Environmental Protection Agency, Ecology, King County, and other entities. Presentations detailing these changes were made to internal staff at WSDOT, to regulatory agencies, and at conferences such as the Society of Wetland Scientists (SWS) and Society for Ecological Restoration (SER). Support was overwhelming for our efforts to better quantify and measure compliance with mitigation success criteria.

We will continue to keep an open dialogue regarding methods we use for monitoring wetland mitigation sites.

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[1] These methods are based on techniques described in Bonham (1989), Elzinga et al. (2001), Krebs (1999), Zar (1999), and other sources.

Principles that Guide WSDOT Wetland Monitoring Methods

Objective-based Monitoring

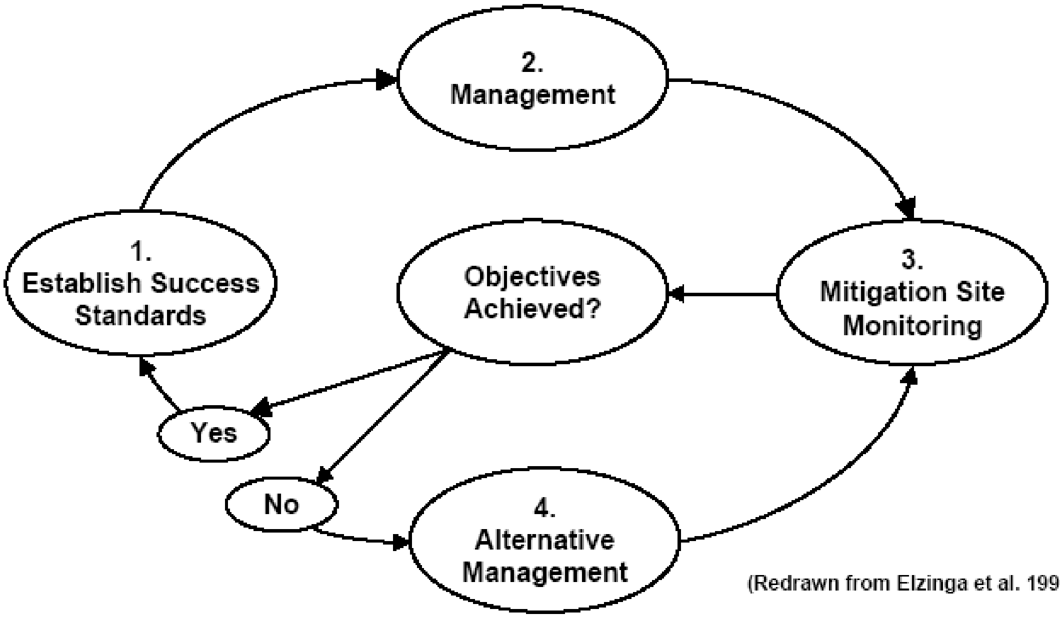
We collect data using a monitoring plan and sampling design developed specifically for each site. The monitoring plan and sampling design address success standards, performance measures, permit requirements, contingencies, and other considerations as appropriate.

Adaptive Management

Adaptive management is a critical component of WSDOT's monitoring and site management. The adaptive management process includes four iterative steps:

1. Success Standard (or performance measures) are developed to describe the desired condition,
2. management action is implemented to achieve the desired condition,
3. the resource is monitored to determine if the desired condition has been achieved, and
4. an alternate management plan is initiated if the desired condition is not achieved.

Monitoring is integral to the success of an effective adaptive management strategy. Without valid monitoring data, management actions may or may not result in improved conditions or compliance with regulatory permits. Timely decisions, based on valid monitoring data, result in increased efficiency and higher probabilities of success (Shabman 1995; Thom and Wellman 1996). The adaptive management process is illustrated in Figure 1.



(Redrawn from Elzinga et al. 1998)

Figure 1 The Adaptive Management Process

Statistical Rigor
WSDOT's monitoring approach strives to minimize subjectivity and increase the reliability of data collection and analysis. Important considerations include appropriate sampling design, sampling resolution, random sampling procedures, and sample size analysis. Our goal is to provide customers with an objective evaluation of site conditions based on valid and reliable monitoring data.

Sampling Objectives
Sampling objectives are developed to establish a measure of reliability for collected data. In a typical WSDOT monitoring situation, biologists set a target confidence level and confidence interval half width in a sampling objective to guide the data collection process. Sample size analysis confirms when sampling objectives have been achieved. When success standards and performance measures are ultimately addressed in a report, the confidence level and confidence interval are noted following the estimated value as (CI x = Y_1-Y_2), where:

- *CI = confidence interval*
- *X = confidence level*
- *Y_1 low estimate*
- *Y_2 high estimate*

For example, an estimated cover provided by woody species reported as 65% ($CI_{80\%}$ = 52-78% cover) means that we are 80% confident that the true cover value is between 52% and 78% (Figure 2).

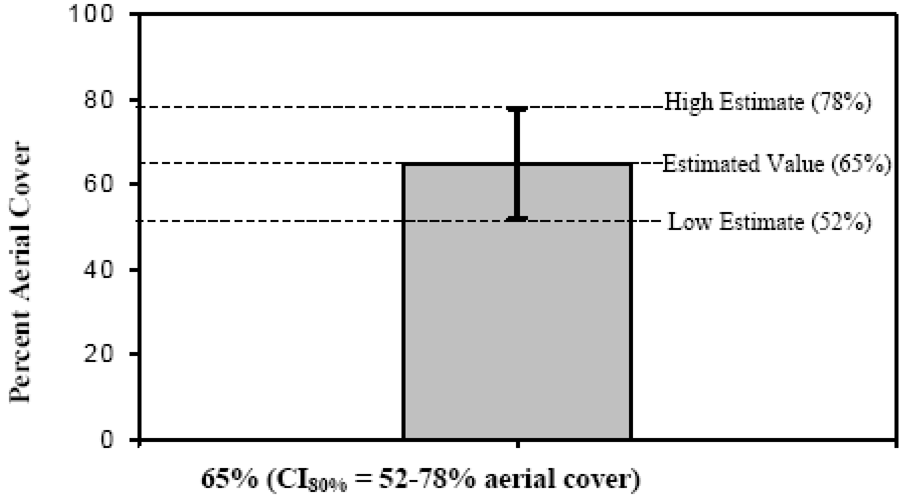


Figure 2 Estimated Cover Value Expressed with Confidence Interval Range

Description of WSDOT Wetland Monitoring Methods

Process

Monitoring typically begins the first spring after a site is planted and continues for the time period designated by the permit or mitigation plan. Sites may be monitored beyond the designated period to track the development of appropriate characteristics.

Monitoring activities are driven by site-specific performance criteria detailed in the mitigation plan or permits. Data may be collected on a variety of environmental parameters including vegetation, soils, hydrology, or wildlife. When data analysis is complete, information on site development is communicated to region staff to facilitate management activities as part of an adaptive management process. Monitoring reports are issued to regulatory agencies and published on the web.

Sampling Design

When sampling is required, a sampling design is developed for the site or zone of interest. Sampling designs can vary from simple to complex depending on the number and type of attributes to be measured. Specific elements such as the size and shape of the site, the presence of environmental gradients, and plant distribution patterns are factors that influence the sampling design. Elements of the sampling design may include the location of the baseline, orientation of transects (Figure 3), the method of data collection, and the number and type of sample units to be used. Independence and interspersion of sample units are also important requirements. Depending on the sampling objective and site characteristics, transects may vary in number, length, and separation distance. Sampling transect locations are determined by using either a simple, systematic, stratified, or restricted random sampling method. A detailed explanation of the above sampling procedures can be found in *Monitoring Plant and Animal Populations* (Elzinga et al. 2001).

Figure 3 Baseline and Sampling Transects

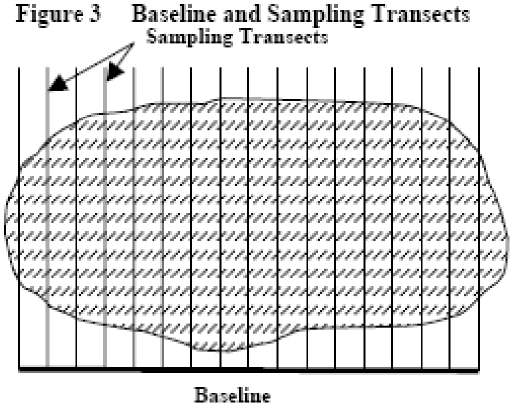
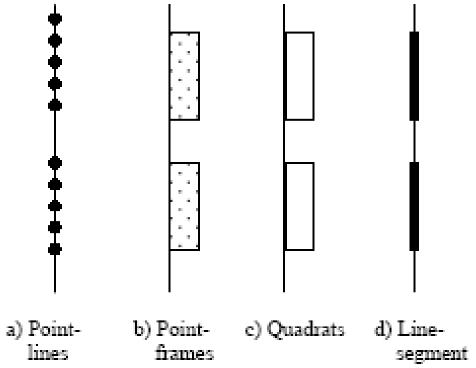


Figure 4 (a-d) Examples of Sampling Transects and Sample Units



A diagram showing the sampling design is typically included in mitigation site reports. Sample units appropriate to one or more of the methods described below are randomly located on or adjacent to the sampling transects (Figure 4 a-d). These drawings are general representations of the actual sampling designs and do not include specific details.

Vegetation Monitoring

Point-Line Method

The point-line method (Bonham 1989; Coulloudon et al. 1999) is used to estimate vegetative cover. With this technique, sample units consisting of fixed sets of points are randomly placed along sampling transects (Figure 4a). Point-line data is collected using point-intercept devices, pin flags, or densitometers to determine plant species intercepted at that point location. For each sample unit, cover is determined based on the number of times target vegetation is encountered divided by the total number of points. For example, if invasive species were encountered on 20 points from a sample unit composed of 100 points, the aerial cover of invasive species for that sample unit is 20 percent.

Point-Frame Method

Point-frames are used to measure vegetative cover (Bonham 1989; Coulloudon et al. 1999). A point-frame is a rectangular frame that encloses a set of points collectively serving as a sample unit (Figure 4b).[2] The sample unit is lowered over herbaceous vegetation and data is recorded where target vegetation intercepts point locations. As with the point-line method, a cover value for each sample unit is determined. For example, if native species were encountered on 20 points in a point-frame composed of 40 points, the aerial cover of native species for that point-frame sample unit is 50 percent.

Quadrat Method

To measure survival or density of planted trees and shrubs in an area, quadrat sample units are randomly located along sampling transects (Bonham 1989; Coul!oudon et al. 1999). Quadrat width and length are based on characteristics of the vegetative community and patterns of plant distribution. Quadrats are typically located lengthwise along sampling transects (Figure 4c). Plants within a quadrat are recorded as alive, stressed or dead. The success standard or contingency threshold can be addressed with a percent survival estimate of plantings, or a density per unit area of living plantings as appropriate. For example, if eight planted woody species were recorded as alive and two were recorded as dead in a sample unit measuring 1 x 20 meters, the survival of planted woody species for that sample unit would be 80%, and the density would be 0.4 live plants per square meter.

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[2] The WSDOT Wetland Assessment and Monitoring Program typically uses a frame formed with polyvinyl chloride (PVC). Strings span the frame lengthwise and points are marked on the strings using a standard randomization method.

Line-Intercept Method

Cover data for the woody species community is collected using the line-intercept method (Bonham 1989; Coulloudon et al. 1999).[3] Line-segments, serving as sample units, are randomly located along sampling transects (Figure 4d). All woody vegetation intercepting the length of each sample unit is identified and the length of each canopy intercept recorded. For each sample unit, the sum of the canopy intercept lengths is divided by the total length to calculate an aerial cover value. For example, if woody vegetation was encountered on 80 meters from a 100-meter sample unit, the aerial cover for that sample unit is 80 percent.

Unequal-Area Belt Transect Method

For surveys of irregularly shaped regions, the unequal-area belt transect method provides an easy-to-implement sampling protocol that may be particularly useful for assessments of woody species density or survival (Stehman and Salzer 2000). With this technique, fixed-width belt transects (quadrats) are positioned perpendicular to a baseline using a simple, systematic, or restricted random sampling method. Once a belt transect has been located, field crews traverse the entire length of the transect counting all plants within the perimeter of the belt transect.

The following equations are used to analyze plant density data collected from unequal-area belt transects.

First, density is estimated using a ratio estimator of the mean number of plants per transect divided by the mean area per transect.

$$\hat{D} = \frac{\bar{y}}{\bar{a}}$$

$\hat{D} =$ sample-based estimator of density
$\bar{y} =$ sample mean plants per transect
$\bar{a} =$ sample mean transect area

Second, variance of the sample-based density estimator is derived from the following equation.

$$\hat{V}(\hat{D}) = \frac{1}{\bar{a}^2}\left(\frac{N-n}{N}\right)\frac{s_e^2}{n}$$

N = population size
n = sample size
s_e^2 = pooled variance[4]
$\hat{V}(\hat{D})$ = variance of the density

Finally, a confidence interval for the sample-based estimator is calculated as follows.

$$\hat{D} \pm (t)[SE(\hat{D})]$$

$\hat{D} =$ sample-based estimator of density
$SE =$ sample standard error

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[3] Depending on site conditions and other considerations, woody cover data may be collected using the point-line method and a densitometer.

[4] $s_e^2 = \sum_s \left(y_u - \hat{D}a_u\right)^2 \Big/ (n-1)$

For more information on the unequal-area belt transect method and data analysis techniques see Stehman and Salzer (2000).

Sample Size Analysis

With each of the above methods, sample size analysis is performed in the field to ensure that an adequate number of sample units are obtained to report the data at the specified confidence level and interval. The mean percent aerial cover value and standard deviation are calculated from the data, and sample size analysis is conducted. The following sample size equation for estimating a single population mean or a population total within a specified level of precision is used to perform this analysis (Elzinga et al. 2001).

$$n = \frac{(z)^2(s)^2}{(B)^2}$$

z = standard normal deviate
s = sample standard deviation
B = precision level[5]
n = unadjusted sample size

A sample size correction to n is necessary for adjusting "point-in-time" parameter estimates.[6] It is the adjusted n value that reveals the number of sample units required to report the estimated mean value at a specified level of confidence.

Hydrology Monitoring

Primary and secondary field indicators of wetland hydrology (Ecology 1997) are recorded to address hydrology standards and to aid in future delineation efforts. These indicators are recorded during each site visit over the monitoring period of the site. Mitigation sites are delineated during their third year of monitoring to determine if sufficient wetland area has been provided. Mid-course corrections or adaptive management are initiated if necessary. Each site is also delineated in the spring following the last year of vegetation monitoring so the actual wetland area can be compared to the planned wetland area.

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[5] In this equation, the precision level equals half the maximum acceptable confidence interval width multiplied by the sample mean.

[6] Adjusted *n* values found in this report were obtained using the algorithm for a one-sample tolerance probability of 0.90 (Kupper and Hafner 1989; Elzinga et al 2001).

Questions and Answers

Why does WSDOT use temporary instead of permanent transects?

In most monitoring situations, the intent of WSDOT biologists is to numerically estimate vegetation attributes at a point-in-time. Factors such as the shape and size of the area to be addressed, environmental gradients, and plant distributions influence how monitoring is best conducted. Success standards and performance measures may require measurement of different attributes, over different spatial areas, in different years of the monitoring period. Consequently, sampling designs using temporary transects appropriate for each sampling event are either necessary or desirable. Additionally, invasive plant species may colonize an area of a site that cannot be satisfactorily sampled by already established permanent transects. Monitoring reports issued annually by WSDOT include diagrams of sampling designs, details of methods used, and a confidence interval for quantitative results. Additional information is found in *Monitoring Plant and Animal Populations* (Elzinga et al. 2001; Chapt. 8).

How does WSDOT incorporate randomization into its methods?

Randomization is a fundamental requirement of all statistical sampling procedures (Sokal and Rohlf 1995; Zar 1999). Therefore, randomization is incorporated on at least two levels when sampling is conducted on a WSDOT mitigation site. Techniques are used that assure each sample unit in a statistical population has an equal chance of being included in a sample. Sampling transect locations are determined by using either a simple, systematic, stratified, or restricted random sampling method. Sample units are also randomly located using similar techniques along sampling transects. Under certain circumstances, further randomization is appropriate, such as when macroplots are used to sample an especially large area (Elzinga et al. 2001).

Are objective methods better than methods based on visual estimates?

The primary problem with visual estimates is the unknown level of observer bias involved (Greig-Smith 1983; Hatton et al. 1986). For this reason, WSDOT favors objective methods based on biostatistics for use in measuring success standards and performance measures. In addition to providing better and more credible information for measuring compliance criteria, proper site management depends on having valid information with a known level of reliability.

How many sample units are needed to address a success standard?

The number of sample units needed to address a particular success standard or performance measure is influenced by several factors and cannot be known prior to sampling. WSDOT uses pilot sampling techniques, and data are run through sample-size equations. Results provide an estimate of how many sample units will be required to obtain an estimated value (to address performance criteria) at a certain level of statistical confidence. Variation of the measured attribute between individual sample units (standard deviation) heavily influences the number of sample units required. The greater the variation between sample units, the greater the number of sample units required. A thoughtful sampling design that considers environmental gradients and plant distributions often greatly reduces the number of sample units needed to address success standards or performance measures.

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