Oregon Riparian Assessment Framework

THE OREGON PLAN FOR *salmon & watersheds*

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OREGON PLAN FOR SALMON AND WATERSHEDS

OREGON RIPARIAN ASSESSMENT FRAMEWORK

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BACKGROUND

This document is designed to complement the Oregon Watershed Enhancement Board's *Water Quality Monitoring Technical Guidebook* (OWEB 1999). Many of the broader monitoring concepts presented in the *Water Quality Monitoring Technical Guidebook* apply to riparian assessment and monitoring.

CREDITS

A riparian assessment work group, formed in 2001 as a subcommittee to the Oregon Plan for Salmon and Watersheds Monitoring Team, developed this document. The work group was comprised of representatives from the Oregon Department of Agriculture (ODA), Oregon Department of Forestry (ODF), Oregon Department of Fish and Wildlife (ODFW), Oregon State University Extension, Oregon State University, and the Oregon Natural Heritage Program. In addition to the primary authors, key contributors to this work included Bruce McIntosh, Derek Godwin, Jimmy Kagan, and Barbara Schrader.

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Chapter 1: Introduction

PURPOSE OF DOCUMENT

The purpose of this document is two-fold: to provide guidance for 1) assessing riparian conditions, functions, processes, and management or project actions; and 2) tracking changes in riparian characteristics over time. With vegetation as the key variable of interest, this document focuses on three critical areas in developing a riparian assessment framework: the importance of planning; data collection methods to assess riparian conditions, functions, or processes; and analysis to support project evaluation. Understanding the entire process of assessment, from the reasons for doing an assessment to the interpretation of information, is essential for the success of any riparian project and is critical for effective implementation of the Oregon Plan for Salmon and Watersheds.

This guide helps practitioners develop an assessment approach to answering questions about a wide range of issues including riparian conditions, functions, or processes related to a project. The assessment also helps practitioners understand changes in management, or the current status or trend in a riparian area. Assessment questions can focus on relatively simple issues such as a riparian project at a single site: *Did the vegetation planted in the riparian area survive?* On the other hand, assessment questions can focus on complex issues involving an entire watershed and multiple projects: *Is the riparian vegetation strategy applied across the watershed effective for changing water temperatures?*

This document is organized to provide a roadmap for planning a riparian assessment strategy and designing approaches for collecting information. The steps identified and discussed in this document include: a) planning a riparian assessment project; b) developing and documenting the study design; c) selecting the appropriate data collection methods; d) assuring the quality of the information; and e) evaluating and reporting on the final assessment results.

This guide describes three methods for obtaining information on riparian characteristics: using existing information; collecting field data; and employing remote sensing techniques (aerial photography, satellite sensors, and others). Figure 1-1 illustrates the riparian assessment process and the chapters that cover the steps.

This document is intended for anyone engaged in riparian assessment or riparian project planning, including watershed councils, Soil and Water Conservation Districts, government agencies, and other land managers. It is meant for people who have a basic knowledge about watershed assessments, project planning, and the need for watershed or project monitoring.

SUMMARY OF RIPARIAN ASSESSMENT PLANNING STEPS

1. **DEFINE GOALS, QUESTIONS and TYPE:** Clearly identify the assessment rationale, goals and questions of interest. Prioritizing is helpful, since more goals and questions are likely to exist than can be addressed with one assessment. For example, one goal may characterize conditions and trends of riparian areas in eastern Oregon, while another may evaluate the effectiveness of a riparian planting project. These two assessment goals require different scopes, sampling designs, and analyses. Project goals are a foundation for the development of assessment questions and the identification of assessment type. *(Chapter 2)*

2. **DRAFT ASSESSMENT PLAN DOCUMENT:** The project coordinator should draft this document with input from stakeholders and project partners. Identifying and involving these partners at this stage will increase the success of the project and the ultimate utility of the assessment. The plan describes the need for the assessment, the precise assessment goals and assessment questions, what is currently known about the issue, how this assessment will fill the need, and an estimated budget. The plan also lays out the study design, data needs and analyses, quality assurance quality control, data collection procedures, general database structure, as described in steps 3 - 8. *(Chapter 2)*

3. **STUDY DESIGN:** The study design describes the scale of interest (reach, watershed, or region) and how sites or the study area will be selected for the riparian assessment project. Once sites are selected, practitioners may need to contact landowners and ask permission to access their land for the assessments. For some studies a random selection process is advisable. In other instances a random selection process is not needed--for example, if a particular project will be assessed or if the assessment evaluates site data before and after a management activity takes place. The study design also describes the sampling design. A variety of sampling designs are available to choose from depending on assessment goals and future use of data. A case-study approach may be used to study a particular site when statistical inference is not an issue. Randomly chosen study sites or stratified random sampling is best used to avoid bias in sampling design. Once all of the above elements have been considered, available budget and resource needs can be calculated. *(Chapter 3)*

4. **DATA NEEDS:** It is important to carefully describe the riparian data needs. For example, what types of data are indicators of the management or project you are assessing? Choose an indicator that is sensitive to change, linked to management, and representative of the resource. Will you use existing riparian information (current or historical), or collect field, and/or remote sensing data? *(Chapter 3)*

5. **DATA ANALYSIS PLANS:** At the beginning of the project, determining what techniques will be used for data analysis is essential. This will guide decisions such as sample size and data types. *(Chapter 3)*

6. **DATA COLLECTION:** Clearly document data collection procedures, including describing what data will be collected, how it will be measured, and how it will be recorded. When possible, draw from existing protocols and established research methods. The data collection protocol is the "how, when, and where" part of the project. This piece of the study plan becomes a guidebook/reference for the data collectors and future data users. This document describes the use of existing

data, field data collection, and/or remote sensing data collection.

Existing data *(Chapter 4)*: Few existing datasets meet the exact needs of a new riparian assessment project. However, after a careful evaluation of existing data there may be a variety of ways to extract useful information from non-ideal datasets.

Before using existing data, gather all supporting documentation on the project. Some of the factors to evaluate and discuss include:

Goals and Objectives: What were the goals and objectives of the original study or data collection effort and how do they relate to the new riparian assessment goals?

Data Quality: Are the precision, accuracy, representativeness, and reliability of sufficient quality to meet the needs of the new riparian assessment? The process of evaluating these questions is often referred to as quality assurance and quality control or "QA/QC".

Scale: How do the temporal and spatial scales of the existing data align with those of the new riparian assessment?

Field data *(Chapter 5)*: Field methods and protocols depend on the management goals, assessment objectives, riparian characteristics, and time and resource constraints. There are some basic plot designs, techniques and parameters that are common to most monitoring objectives. Three levels of field data collection and associated assessment types are described and related to particular assessment types:

Level I (Implementation or Baseline Assessment): Project documentation and tracking.

Level II (Baseline and/or Trend Assessment): Assessing riparian restoration and structure.

Level III (Effectiveness Assessment): Assessing effectiveness of restoration projects.

Remote sensing data *(Chapter 6)*: Photographs, videos, or imagery collected from either an airplane or a satellite are the primary remote sensing methods. These methods vary in their ability for characterizing the status of riparian areas and detecting trends in conditions over time. The science of remote sensing is rapidly evolving as higher spatial and spectral resolution sensors are deployed and methods of analysis are improved. Because of rapidly changing technology, changes in costs and availability of data, and a wide range of potential applications, a variety of useful remote sensing methods exists.

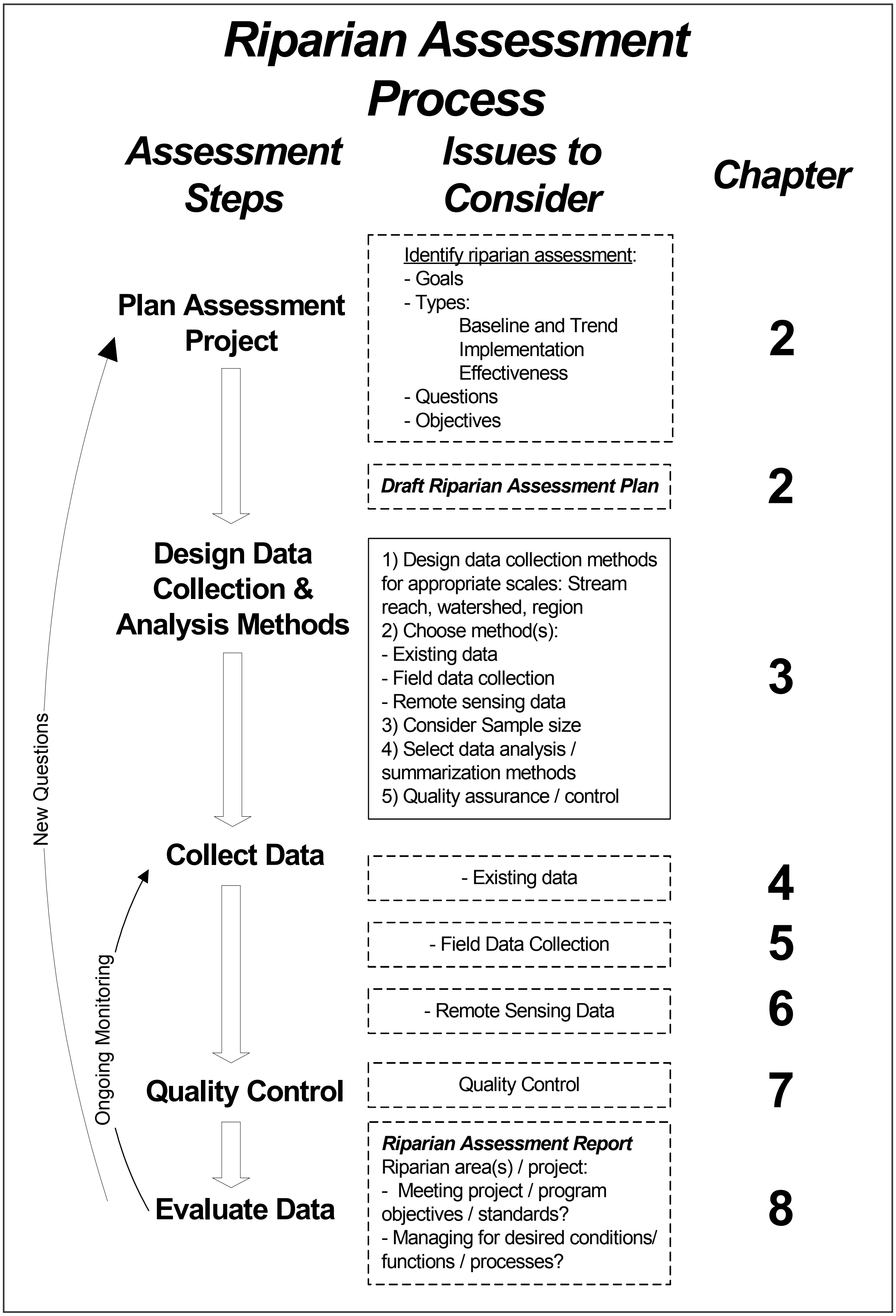
7. **QUALITY ASSURANCE QUALITY CONTROL:** Document how you will ensure the quality of your data. Develop a data quality assurance plan that serves as a guidebook/reference for data collectors. The quality of remotely sensed data is assessed with data of finer resolution, such as higher resolution remotely sensed data or field plots (*Chapter 6)*. Repeat measurements of field data test the reliability and repeatability of the data collection methods and equipment calibration *(Chapter 7).*

8. **DATA MANAGEMENT/DOCUMENTATION and ANALYSIS:** Data management begins before data collection is complete with the finalized database structure serving as the repository for field data. A "data dictionary" (i.e. a file that defines the organization of a database and how data was collected) can facilitate data sharing. Once data collection and management is complete, data analysis begins. Researchers studying similar issues can be consulted along the way. (*Chapters 4, 5 and 6*

describe data management and analysis approaches for example data.)

9. **DECISION-MAKING/COMMUNICATE FINDINGS:** Define how to communicate the findings (web site, presentation, poster, report, peer-reviewed journal article), and to whom (appropriate audience). Key findings and recommendations should be relayed to project partners and funding sources. *(Chapter 8)*

Figure 1-1. Steps in the riparian assessment process.



What is Assessment?

*The term "*assessment*"* can have different meanings, often with many terms used interchangeably. For this document, assessment is a planning process, or the steps involved in making inquiries about the riparian ecosystem. Because riparian assessment entails a series of steps, it requires thorough preparation and planning. The assessment steps often incorporate the following: goals; questions of interest; an overall assessment plan; a study design; identifying data needs; data analysis plans; quality assurance/quality control; data collection; data management and documentation; data analysis; evaluation and decision-making; and a monitoring plan (Figure 1-1).

Goals, in the broad sense, are what you set out to achieve, or what category of information you are interested in. For example, do you want to characterize riparian conditions or functions? Measure a project's impact? Determine if policies are being met? Goals define the assessment *type*, which can be thought of as the method of inquiry. Assessment *questions* incorporate variables and details about the "what, where, and when" of a study.

An *inventory* can be defined as an active observation involving data collection, whereas an *evaluation* is the process of judging or categorizing what is found in an inventory. *Monitoring* is inquiring about the status of something over time. Monitoring can be thought of as a final component of the assessment framework, but since it is repeated over time, or cyclical (Figure 1-1), it can occur in more than one place in the assessment framework, such as in the questions of interest.

Landowners, land managers, and researchers often assess riparian ecosystems for different purposes. How, what, where, and when riparian data are collected influence the usefulness and effectiveness of the data for both the intended purpose and for other potential users of the information, regardless of the purpose.

Since vegetation is often the most common variable considered in riparian assessments, and because riparian vegetation characteristics can be slow to change, effective assessment requires a long-term commitment. The assessment question ultimately determines the length of commitment.

Riparian Area Definition

Riparian areas are dynamic zones of interaction between upland and aquatic systems. A riparian area can be defined as the zone of transition from any water body to a terrestrial ecosystem. A riparian area may be located adjacent to a lake, reservoir, estuary, spring, bog, wet meadow, muskeg, or ephemeral, intermittent, or perennial stream (ORS 541.351 (10)). Aquatic systems and riparian areas work together, with each influencing the other and changing across the landscape and over time. The riparian area can include the plants that hang over the aquatic system as well as vegetation growing farther away that might shade or fall into the water. The aquatic system, in turn, can influence the riparian area by maintaining soil moisture and creating new soil surfaces on which plants can grow, among other processes.

The characteristics of riparian vegetation – types, distribution, and other attributes – either directly or indirectly provide key *functions* and building blocks for fish and wildlife habitat and water quality and quantity. Some key riparian area ecological functions include:

- Providing organic material and terrestrial insects that serve as food for fish and other aquatic life.
- Contributing large wood that creates pools and hiding cover for fish.
- Creating a vegetation canopy to provide hiding areas for fish and shade to help moderate water temperatures.
- Slowing floodwaters to create areas for fish to hide during high flows and slow-water zones for sediment deposition.
- Providing bank stability through vegetation root strength.
- 'Filtering' pollution run-off.
- Providing critical wildlife habitat and access to water. (Gregory and Swanson 1991, FEMAT 1993, Naiman et al. 2000)

Riparian *conditions* are traits that describe what we see in a riparian area and its interaction with the stream channel at any given time. Examples include: 25% shrubs, many old trees; incised stream banks. Riparian conditions change in time and space as vegetation grows, but functions and processes might not change. One way to think about these terms is to say that we manage *conditions* to provide *functions* or *processes*; or, riparian conditions influence the key functions and processes related to fish and wildlife habitat and water quality and quantity.

The zone of interaction, or width of the riparian area, is not set by a defined boundary. This zone of interaction can vary widely, depending on the characteristics of the riparian and aquatic areas and the surrounding landscape. For some functions, the riparian zone of interaction can range from a relatively narrow corridor along a small stream to an entire valley floor along a large river. For other functions, such as providing large wood for fish habitat, the zone of interaction can extend across large parts of the landscape, for example, when trees are carried into streams by landslides.

Understanding that riparian *conditions* are ever changing through time and across the landscape is critically important when thinking about riparian assessment. Riparian areas are not neatly packaged, discrete areas. Treating them as such will generate an inaccurate interpretation that denies the existence of the processes that shape them. Understanding key *functions* of riparian areas before conducting an assessment is also essential. Being aware of key riparian functions before carrying out a riparian assessment will result in a better understanding of cause and effect and offer more realistic expected outcomes and clearer definitions of project success.

Chapter 2: Riparian Assessment Planning

INTRODUCTION

This chapter outlines the process for planning a riparian assessment. The chapter focuses on understanding assessment goals and questions and assessment types, and on thoroughly documenting a plan before collecting data. Planning a riparian assessment requires understanding the various methods available to answer the intended questions, and understanding the extent and intensity of the effort required to use each method. For this reason, we recommend reading through the entire document before carrying out a riparian assessment.

RIPARIAN ASSESSMENT GOALS

The first step in any assessment is to clearly identify the assessment goal(s). Assessment goals can be thought of in the broad sense—i.e. what, overall, is the required or desired information about the riparian area? For example, is there a desire to characterize riparian vegetation type across the watershed? Is there a need to evaluate whether the tree and shrub planting met the stated project goal of restoring riparian functions? Assessment goals often arise from our interests and values. The reasons (or rationale) for carrying out any assessment or restoration project often stem from our underlying ideals about a natural resource (Smith and Gilden 2000, OSU 2002). What we want to know about the landscape reflects our concerns or ideas regarding the natural resources involved. Making the rationale explicit at the beginning of the assessment, along with the goals, can help clarify who is involved and why, who might be most appropriate for making decisions, and what set of management options might be available.

Often, more goals are identified than can be addressed with one assessment, so establishing priorities can be helpful. Many approaches exist to prioritize which assessment goal to carry out first. The key to developing clear assessment goals and priorities is to first ask what you are interested in learning about and why. The idea is to make choices that you can explain. The assessment goal usually follows simply from the original intent of the project. If, for example, you have completed a riparian tree-planting project, your assessment goal might be to *measure the success* of the project in relation to the desired project goals. If there is no treatment (project) and you want to learn about particular characteristics of riparian areas, the assessment goal might be "to characterize or compare conditions."

RIPARIAN ASSESSMENT QUESTIONS

Riparian assessment questions supply the details about the goals and incorporate specific information about the *what, where,* and *when* of the goal. Assessment questions address the variable(s) of interest. What exactly do you want to characterize, describe, compare or measure? To arrive at an assessment question, first identify a single variable of interest and then get more specific. For example, you might want to describe vegetation. Next you can ask yourself, what *about* the vegetation do you want to describe? What is the number of conifers over 60 cm in diameter? What is the percentage of hardwoods? *Where* exactly do you want to know about the percentage of hardwood--along the creek or within the whole watershed? Do you want to know about the *current* percentage of hardwoods, what the percentage will be sometime in the *future*, or at various *points over time*? The most effective assessment questions leading to the clearest answers entail critical thinking about the *what, where*, and *when* of the project's interest. Most importantly, as with goals, for every question of interest, the answer will only have meaning if investigators can express *why* they want to know.

RIPARIAN ASSESSMENT TYPES

An assessment goal might be thought of as a category of information (*characterizing* conditions or *determining* the success of a project), with the assessment questions adding the detail. The assessment *type* can be thought of as the method of inquiry. Different assessment goals entail different geographic scopes, sampling designs, and analyses methods. Determining the assessment type can help provide the guidance for developing the study plan and identifying the data to collect.

Assessment goals are the foundation for the identification of assessment type and development of assessment questions. However, understanding the differences between assessment types is helpful in further clarifying your goals and questions, and explicitly stating what the assessment project will achieve. In this respect, the assessment type might be determined simultaneously with the assessment goal and questions, or possibly before the goal and questions are at their final stage.

A number of assessment types are available. The Oregon Plan's *Water Quality Monitoring Technical Guidebook* (OWEB 1999) outlines six different monitoring and assessment types. This framework will focus on four assessment types:

- Baseline
- Trend
- Implementation
- Effectiveness

In addition, this framework briefly discusses a fifth type of assessment--validation assessment.

BASELINE ASSESSMENT

A baseline assessment is used to *characterize* riparian conditions at one point in time. A watershed assessment that describes riparian vegetation (type, extent, density, and other attributes) throughout a watershed is an example of a baseline assessment. This kind of assessment is useful as a starting point for other assessment efforts. Once the baseline of riparian conditions is documented, researchers and managers can measure changes over time (trends assessment) and evaluate whether management strategies are meeting the desired resource goals (effectiveness assessment).

Example: Delivery of Large Wood to Streams from Riparian Areas

Overview: The Trout Creek Watershed Council wants to improve fish habitat throughout their watershed. From the results of stream habitat inventories, they have learned that very little large wood in the stream channels is present, particularly in some of the valley reaches. The absence of significant amounts of large wood in the streams channels has impacted fish habitat quality by limiting the formation of deep pools and reducing hiding cover. The council is interested in understanding how riparian conditions influence the current status of large wood inputs and how large wood recruitment into the streams might change in the future.

Assessment Goal: The goal of the assessment is to characterize the current status of riparian areas (baseline) and to track changes (trends) in riparian conditions as it relates to delivery of large wood into stream channels.

To develop the assessment question, the group thought about the process of large wood delivery; what it takes for large wood to enter streams in their watershed. After consulting their own group members and various natural resource organizations, they learned that the potential for large wood delivery and its impact on stream habitat is influenced by the location of the tree relative to the stream, type of tree (conifer or deciduous), and height of the tree.

For simplicity, all trees in the riparian extent are assumed to have an equal probability of falling and entering the channel. The first step is to decide what constitutes large wood. ODF&W benchmarks for large woody debris in forested basins (WPN 1999 Appendix IX-A) count pieces at least 15 cm in diameter and 3 m long. Key pieces are > 60 cm in diameter and 10 m long. We excluded wood delivery from episodic debris flows.

Assessment Question: What is the current and future delivery potential of large wood (>60 cm diameter and 10 m long) into stream channels, given the current location, type, and size of riparian trees in the Trout Creek watershed?

Some examples of baseline assessment questions:

- What forested riparian areas within the watershed have widths greater than 15 m from the active stream channel?
- Where are the large conifer trees along the creek?
- What is the current potential for trees within the watershed to contribute large wood to stream channels?
- What streams in the watershed have stream channel shade levels greater than (50%) (measured as canopy cover)?

TREND ASSESSMENT

A trend assessment records riparian conditions *over time*. Measuring trends requires that the methods are repeatable over the assessment period and that the approach is sensitive to the kinds of changes that investigators intend to detect.

Some examples of trend assessment questions:

- How have stream shade levels changed along the fenced section of stream?
- Following a wildfire, how many riparian conifers are established within the riparian area at 5, 10, and 20 years?
- What are the shade levels over headwater streams 5 years after timber harvest?
- What are the composition and extent of riparian "weed" species at 5, 10, and 15 years?

IMPLEMENTATION ASSESSMENT

Understanding whether the project plan was carried out as intended *before* measuring the effectiveness of the project is critical. Implementation assessments document whether the activities were carried out as planned. Assessing implementation, for example, can be as simple as recording where and what riparian plant species were planted and comparing the actual results with the plan.

Some examples of implementation assessment questions:

- Did the contractor plant the riparian trees at the proper locations using the planned species?
- Did the riparian tree thinning operation achieve the specified canopy closure levels?
- Was the fencing installed at the specified distance from the stream channel?
- Did 90% of the trees planted in the riparian area survive after the first year, as specified in the contract?

EFFECTIVENESS ASSESSMENT

Effectiveness assessment is used to determine how well a project is meeting the stated goals and achieving the desired riparian functions or processes. This type of assessment focuses on the response of the stream or riparian area to a management activity. For example, did water temperatures respond to the increased shade levels from the riparian planting? Because this assessment type requires looking at the impacts on complex and variable characteristics such as water temperature, fish and wildlife habitat, or vegetation characteristics, the assessment questions and study design require additional consideration. For example, investigators must consider whether enough time has elapsed for the measured variable to display a detectable change, or account for other possible explanatory variables such as stream flow or weather. Effectiveness assessment also requires exceptionally clear and specific goals at the beginning to define and determine the success of the outcomes.

VALIDATION ASSESSMENT

Validation assessment is similar to effectiveness assessment, in that they both ask if the project is meeting stated goals. However, validation assessments include the question of *why* investigators are getting the identified response. This latter component gets at *how* the "success" or "failure" is related to management actions. This may or may not be a relevant question in all assessments, but since validation questions require an added set of considerations and approaches, some examples of validation assessment questions are provided below.

Some examples of effectiveness and validation assessment questions:

- Did the planting of riparian trees and shrubs result in multiple vegetation layers that contribute to wildlife habitat (effectiveness)?
- Are shade levels over the targeted stream reach increasing to greater than 50% (effectiveness)?
- Is the change in riparian management increasing the delivery of large wood to the stream channel over time (validation)?
- Are water temperatures decreasing throughout the watershed as a result of changed riparian management practices (effectiveness)?

Example: Riparian Restoration Project Effectiveness

Overview: *Friends of Oak Creek* is planning a riparian restoration project. The intent of the project is to create wildlife habitat and improve stream conditions for water quality. One tool to accomplish these project goals is to strategically plant vegetation. This is the group's first project and they would like to learn what is required to assure that the planted vegetation has a high survival rate. The group's grant application stated that the project objective was to achieve 80% survival of the planted vegetation after the 1st year.

Assessment Goal: The goal of the assessment is to measure how effective the planting strategy is at establishing a mix of trees and shrubs along Oak Creek.

The group has promised the funding organization a report evaluating the project at the end of the 1st and 2nd years after planting. In addition, they would like to track long-term survival at the site.

Assessment Question: What are the survival rates of planted trees and shrubs at a restoration site along Oak Creek at 1, 2, 5, and 10 years?

In addition to this goal and question, the group developed other effectiveness assessment goals and questions that focused on how effective the project was for creating wildlife habitat (for example, were multiple canopy layers created?), and improving stream conditions for water quality (e.g. is the project resulting in increased shade over the stream channel?).

Drafting the Assessment Plan

Once the riparian assessment goal(s), type(s), and question(s), are defined, the process for obtaining the data, quality assurance, and analyzing the information can be developed. Writing an assessment plan can help to clarify the intent and approach. A clear assessment plan provides the foundation for communicating the approach, allocating the necessary resources and budget for collecting data, data management, analysis, and reporting, and helps you to stick with your plan over time. The assessment plan can serve as a reference document throughout the entire assessment process (Figure 1-1). Chapter 3 provides information on developing a study design, which provides a structure to answer the assessment questions, documents the study methods, and communicates the assessment design to other interests.

Chapter 3: Study Design

Introduction

After riparian assessment goals and questions have been defined (as described in chapter 2) the next step is to design a study to answer the assessment questions. There are a number of elements to consider when designing a riparian study including:

Available Resources: What personnel, budget, equipment, etc. are needed to do the study?

Data Needs: What variables or data will best answer the assessment question? Will existing or original data be used? Will remote sensing or field data be used?

Spatial and Temporal Scales: What are the spatial and temporal scales of interest?

Sampling Design: What sampling method and design should be used?

Sample Size: What sample size is needed?

Data Analyses: How will the data be analyzed?

Many documents, books, and manuals are available that provide instruction on study design and statistical considerations, some of which are listed as references at the end of this guide. The goals of this chapter are to introduce and summarize the key concepts in the context of riparian assessments, and provide some tools and references to assist the user in designing the riparian assessment framework.

Examples of statistical methods for hypothesis testing and trend analysis of riparian data are presented in Appendix 3-A: *Non-Parametric Methods for Hypothesis Testing and Trend Analysis*

Pilot Project

When planning the riparian assessment, consider running a *pilot project*. A pilot project is a trial run of the planned project, where only small amounts of data are collected from a limited number of sites. Pilot projects are also useful to test the reliability of existing data. A pilot project can be used to refine data collection methods, identify flaws in the study design, assess the quality of existing data, and provide preliminary data to answer questions or plan the final project. Data from a pilot project can also be used to test analysis plans and calculate the sample size needed to achieve desired statistical results. Finally, the trial run can better quantify resource and budget needs.

Available Resources

The resources (workforce, budget, equipment, technical expertise) available to carry out a project will ultimately define the assessment approach and study design. Who is available to do the work? If laboratory work is needed, what lab services are available and how much do they cost? Will computers, software, and field equipment need to be purchased? What funding is available? Answers to these questions will shape the study design.

If funding and/or available staff could increase or decrease significantly during the life of the project, consider developing a phased approach to monitoring. Design a project that takes advantage of resources when they become available. For example, the project may start in April, but full funding may not be expected until July. In this situation, begin the project by collecting and reviewing existing data (see the section on using existing data in Chapter 4) and doing data verification (also discussed in Chapter 4) prior to having resources for more intensive work.

Data Needs

Selecting Measurement Variables

The assessment question, scale of monitoring, resource availability, and analysis plans determine the type of data that is needed. Researchers should give a great deal of thought to what *variables* will be measured and at what temporal and spatial scales. If the goal is to monitor change due to a management activity, a variable that is linked to the management activity and sensitive to change is necessary. This is somewhat complicated by the fact that multiple activities and conditions may affect a given variable. For example, when monitoring riparian planting projects, the vegetation survival rate may be affected by herbivory, human and "natural" disturbance, and soil and weather conditions. In addition, multiple variables may affect a given resource. For instance, when evaluating the effectiveness of riparian planting in reducing stream temperature, consider that stream temperature is also influenced by other factors such as upstream vegetation conditions, beaver ponds, and stream azimuth.

The ideal variable is:

- Sensitive to change
- Linked to the management activity of interest
- Directly related to the resource of concern
- Measurable

Riparian assessment typically involves the collection of data on one or more of the following variables:

- Vegetation species composition (species of herbs, shrubs, and trees)
- Vegetation density (how many of these species per a given area)
- Vegetation characteristics (height, diameter, canopy)
- Vegetation extent (how much of a stream reach, watershed or region has this vegetation)
- Vegetation mortality (survival of plantings, snags, blowdown)
- Amount of shade provided by the vegetation to the stream (often times cover is used to substitute for shade measurements)

When the assessment is investigating effectiveness of a management activity or structural characteristics of a riparian area, data collection may include one or more of the following variables:

- Stream bank physical condition (stability of the bank, degree of overhang)
- Snags and downed wood (number, size, and volume of wood laying on the ground)
- Stream temperature (hourly temperature during the time period of interest)
- Instream wood (number, size, and volume of wood in the stream)
- Insect and animal populations and species diversity

Methods of data analysis are introduced later in this chapter. These examples should be carefully considered to aid in selecting the appropriate variables to monitor. You may also find that some of the planned variables don't need to be measured. Measurements of the variables discussed in this section can be combined and used in different ways to answer a multitude of questions on riparian condition.

ORIGINAL OR EXISTING DATA

The assessment may lend itself to the use of existing data, require the collection of original data, or a combination of both. Chapter 4 describes considerations for evaluating and using existing data. Considerations for the collection of original field data are described in Chapter 5. Collection and use of remote sensing data are described in Chapter 6.

SURROGATES AND EXTRAPOLATIONS

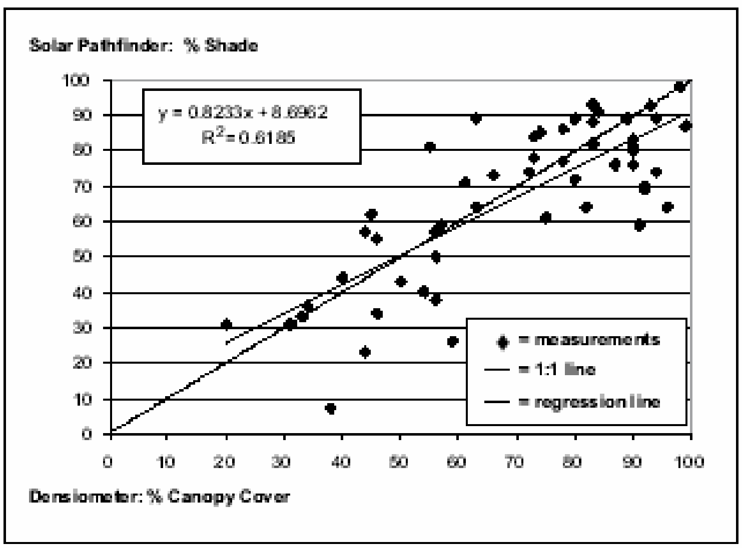
Finding surrogates and developing extrapolations are effective ways to use data. For example, measures of canopy cover can be used as surrogates for measurements of shade. Extrapolation refers to extending data or information obtained from a data set beyond the time or area constraints of its original collection. General data about overstory species, for example, can be extrapolated to make conclusions about likely understory composition based on established plant community associations.

SURROGATES

The word "surrogate" means to substitute. In the context of riparian assessment, one riparian variable may be used as a surrogate for another. Many reasons to use surrogates exist. It may be less expensive and/or faster to collect one type of data instead of another, or there may be existing data for one feature but not another. A number of surrogate relationships are reasonable and valid to use. For example, broad relationships between vegetation community associations and variables such as geographic region, soils, and elevation have been well established. In these examples the investigator could make general statements about the vegetation community based on the geographic region or soil type. Other types of surrogate relationships include vegetation density as a surrogate for canopy closure, or bank stability and plant size for root density (for bank stability calculations).

When using surrogates, investigators need to establish the relationship between the target variable and the surrogate (e.g. shade versus cover) and develop a good estimate of the reliability of the relationship. For example, Figure 3-1 displays the relationship between shade and cover. These data were collected by the Oregon Department of Forestry (ODF). Shade was measured with a fish-eye lens camera and cover was measured with a densiometer. By performing linear regression analysis, ODF established the relationship between shade and cover as indicated by the use of the Pearson's correlation coefficient.

Figure 3-1. Shade (measured with a solar pathfinder) versus canopy cover (densitometer). From the* Stream Shade and Canopy Cover Monitoring Methods *(OWEB 2002).



Extrapolations

Riparian assessment data can often be extrapolated beyond their original intended use, again when followed up with field verification. Investigators can extrapolate data along different reaches of the same stream, within a watershed, between basins, and sometimes over a time interval. Such extrapolations involve comparing the existing data quality to the project's needs AND deciding whether the quality of such an extrapolation would be sufficient to meet the needs of the targeted project. In addition, investigators must consider the scale of the existing data compared to the targeted project scale, and verify the quality and currency of the existing data and the extrapolated data.

Many riparian assessments that use box or transect surveys essentially extrapolate data collected in limited areas over an entire reach (or at least between transects/plots). Trend surveys of riparian conditions also extrapolate data collected at a point in time over a longer length of time. These are *implicit* extrapolations of data. This section focuses on *explicit* extrapolations – ones where the investigator extrapolates from pre-existing data, versus situations where a researcher extrapolates his or her own data over space or time.

In some cases, investigators can extrapolate a previous researcher's box plot/transect data over a longer stream reach or onto a nearby watershed. Many approaches are available for doing these types of extrapolations. For example, investigators may run across data from a limited study that only measured streambank stability with a few surveyed cross sections over a quarter mile of stream. If the investigator knows that land use, geologic setting, streamflow, climate and soil conditions are similar over two to three miles downstream of the existing data, then extrapolating the streambank stability conditions over the larger area should not be problematic. This can also be done between watersheds. Even if the physiologic/anthropomorphic conditions of the targeted reach match the conditions of the reach with the existing data, investigators still need to make field verifications to confirm these conditions.

Investigators can also extrapolate by using surrogates. For instance, suppose greenline survey data for a 200 yard reach of stream in a valley setting exists, where the entire valley has the same land use, same geologic setting, and same streamflow conditions. The goal of the new assessment is to evaluate bank stability, so the greenline survey gives extensive information on riparian condition over 200 yards of the stream. Investigators can use this as a surrogate for bank stability with the addition of soils and bank height/repose data. Plus, with some field verification, investigators can extrapolate this data throughout the valley. Another approach to extrapolating with surrogates is by finding a correlation between one variable identified by existing data and another variable identified as a surrogate to the riparian condition of interest.

Data can also be extrapolated over a time interval if supporting information shows a low probability of disturbance to the areas of concern between measurements. This is essentially the same assumption used in trend monitoring, where the extrapolation is implicit. However, investigators should be careful about making assumptions regarding the rate of change of a variable when extrapolating over time, particularly in high disturbance systems such as riparian areas.

For instance, if in 1980 the alder density was X, in 1990 it was X+10, and in 2000 it was X+20, investigators could be tempted to say that alder growth changed by one every year. This may be the case, but under closer examination of the data, the extrapolation would most likely be less accurate. Growth *averaged* one per year over a twenty year period, but whether growth was specifically one every year, given disturbance events (floods, debris torrents, etc.) or other variability, is doubtful. The relationship of the variable to time will vary depending on the time scale for the assessment.

Selecting Appropriate Scales For Data Collection

Spatial Scale

Choosing a sampling method appropriate to the question, resource availability, and target variable(s) depends on the spatial scale of the monitoring program. One question to ask is whether data should be collected on a reach scale, a watershed scale, or a regional scale? Riparian areas are noted for their high *spatial variability* in vegetative characteristics at *reach, watershed, and regional scales.* This means that at different locations on the same stream the riparian area may look quite different. Likewise riparian vegetation along streams in Eastern Oregon is different than riparian vegetation along streams in Western Oregon. In general, riparian characteristics vary greatly with distance from the stream and vary longitudinally as the stream flows from high elevation to low elevation. For example, overstory and brush species nearest the stream can differ markedly from overstory and brush species farther away from the stream. Likewise conifers may dominate vegetation near the headwaters of a stream, while vegetation at lower elevations may be more diverse with patches of willows, grasses and sedges intermixed with patches of berries and hardwoods. Sources of spatial variability include climate, elevation, geology, soils, stream size, slope gradient, and aspect. Disturbances such as fires, floods, droughts, landslides, debris torrents, insects, diseases, windstorms, and landuse also create variability in both space and time. Figure 3-2 illustrates some considerations for choosing among different scales. The following discussion should assist in decisions regarding the appropriate scale for use in a riparian assessment.

Reach Scale Monitoring

The reach scale is commonly used to monitor effectiveness of specific management practices and restoration efforts. Reach scale monitoring efforts are "point" measurements that can be aggregated to larger scales. Select a reach that is representative of the area of interest for the project. How to select a representative reach is discussed in greater detail later in this chapter. Collection of pre-treatment (e.g. prior to management or restoration activity) data greatly enhances the ability to answer questions about changes in riparian and stream characteristics due to management practices and restoration efforts. Measurements collected upstream and downstream of the management practice can also be utilized to understand effectiveness of management practices and strategies.

Examples of assessment questions that could be appropriate for reach scale assessments include:

1. Were planting efforts successful at establishing native vegetation along Spore Creek?
2. Has establishing native vegetation along Tenuous Creek provided increased shade to the stream?
3. How has bank stability changed as the result of reduced livestock access to the East Fork of Squawk Creek?
4. How has recruitment of large wood to stream channels changed as a result of riparian restoration efforts?

Questions that are intended to assess riparian condition (e.g. question #1) do not require pre-management data collection. Questions that are intended to assess a change due to management are best answered with pre-management and post-management data for the variable of interest. When assessing a change in shade or bank stability, as in example questions #2 and #3, the investigator should consider collecting data on shade or bank stability prior to the restoration actions. Furthermore, the post-restoration monitoring period should occur at appropriate time scales to capture the change. In question #2, for example, the plants may not be tall enough to cast a shadow on the stream one year after planting native vegetation. Therefore, the investigator should consider monitoring shade at set intervals after the vegetation has been established (e.g. 3 year, 5 years, and 10 years after planting).

Watershed Scale Monitoring

Monitoring efforts at the watershed scale are useful for characterizing general riparian conditions, identifying trends, and comparing differences between variables that affect riparian conditions. The watershed scale is particularly important for examining historic watershed processes, analyzing how multiple or overlapping disturbances have shaped current conditions, or evaluating cumulative effects. Examples of assessment questions that would be appropriate for the watershed scale include:

1. What percent of stream length in the Clay Creek Basin has desired shade conditions?

2. What types of vegetation dominate riparian areas in the Clay Creek Basin?

3. How has riparian vegetation density changed after increasing instream water flows in the Resource Creek basin?

Questions #1 and #2 would not require pre-project data to be answered. Question #3 would require data on riparian conditions prior to increasing instream water flows. For questions #1 and #2, a project plan might involve sampling multiple representative reaches within the basin, instead of trying to measure shade and vegetation type everywhere in the basins. A discussion on picking representative reaches is included later in this chapter.

Regional Scale Monitoring

Regional scale monitoring efforts are typically used to monitor status and trends over large geographic areas. Generally, monitoring any area larger than a 4^{th} field hydrologic unit can be considered regional scale. Regional scale projects also can cover portions of many larger watersheds.

Large sample sizes are needed to capture the wide range of conditions that exist in riparian areas throughout the state of Oregon. One way of doing this is to distribute (i.e. stratify) the sample such that data are captured from ecoregions of the state that exhibit similarity in characteristics such as vegetation, hydrology, climate, soils, and geology (e.g. Coast Range, Cascades, Blue Mountains, Siskiyous). A census approach can also be used, which would involve sampling individual streams (or some other appropriate unit of analysis) in each basin of the region of interest. Another way is to distribute the sample throughout areas that are significant in terms of salmonid life history. For instance, NOAA Fisheries and the Oregon Department of Fish and Wildlife have established management boundaries around large geographic areas of the state. *Evolutionary Significant Units* (ESU) represent distinctive groupings of Pacific salmonid species, usually on the scale of multiple basins. Coho gene conservation group areas are subsets of ESU's that represent groups of similar populations of coho salmon in coastal drainages.

Regional scale monitoring can be done as a cooperative effort among different groups, each concentrating on individual basins. Watershed councils and other entities can combine monitoring data to examine conditions at a regional scale. These efforts can be used to answer a variety of questions, such as:

1. What are riparian vegetation characteristics throughout the Southeastern Oregon region?
2. How has urbanization affected riparian conditions in the Willamette Valley?
3. How have riparian characteristics changed in the past 50 years in Western Oregon?
4. What proportion of riparian corridors is in degraded condition in the North Coast basin area?

Temporal Scale

In addition to variability over the landscape (*spatial variability*) riparian characteristics at a given site change over time (*temporal variability*). Sources of temporal variability include fire, floods, droughts, landslides, debris torrents, insects, diseases, windstorms, succession, mortality, and landuse. Some assessments can be specifically designed to evaluate the influence of these disturbances on riparian characteristics and may collect data over long periods of time or over large spatial scales to capture areas of the landscape influenced by these disturbances. Other assessments may evaluate how a restoration project is working over time or how a particular landuse influences riparian function. Short-term studies may only evaluate data or a site for one to two years. Longer-term studies may evaluate data collected over decades. In all instances, incorporating riparian spatial and temporal variability is critically important as a part of the sampling design.

Reach

Types of Monitoring
- Effectiveness of riparian management or restoration actions
- Implementation

Selecting a Reach
- Consistent channel, vegetation, stream type, and management

Potential Sample Schemes
- Entire treated area
- Riparian sample plots
- Systematic channel and cover measurements

Multiple Reaches

Types of Monitoring
- Effectiveness of riparian management or restoration actions under variable conditions
- Baseline: Characterize conditions prior to management or other changes
- Implementation

Selecting Multiple Reaches
- Different management strategies in similar vegetation and channel types
- Similar management activities in different vegetation and channel types

Potential Sample Schemes
- Entire treated area
- Riparian sample plots

Watershed

Types of Monitoring
- Effectiveness of riparian management or restoration actions under variable conditions
- Trend over time and space
- Baseline
- Cumulative Effects

Selecting Multiple Reaches In a Watershed
- Sample reaches throughout the watershed representing the range of soil, vegetation, channel types and elevations

Potential Sample Schemes
- 30-50 sample reaches per channel, vegetation and management type

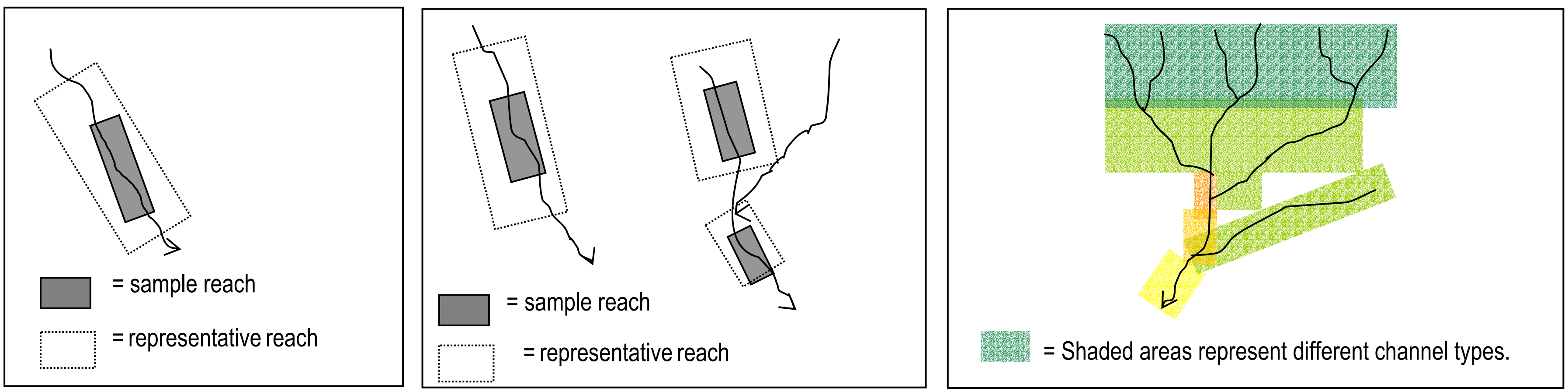


Figure 3-2. Potential study design approaches for different spatial scales and types of monitoring.

SITE SELECTION

Once the data needs and scales of interest have been identified, it is time to choose the area of study and design the sampling approach. Among other things, the assessment goals, questions, and scales of interest influence the sampling design. In some instances, surveying the entire *population* of interest may be appropriate (100% survey). For example, when there is a relatively small area that has been managed and/or the assessment team has time and resources, then measuring every tree is practical. A census approach can also be used, where an entire area is assessed without measuring the entire population. Typically, limited resources require sampling a subset of the larger population (e.g. planted riparian areas). The sampling period is typically limited to a fixed time period or set of time periods. If a sampling approach is to be used, a number of key elements should be considered when selecting sites:

- Stratification
- Representative Reaches
- Reference Reaches
- Random vs. Non-random Site Selection

Stratification

Stratification simply refers to the process of categorizing areas of the landscape into subgroups that share similar qualities. The subgroups are referred to as *strata*. Some strata typically used for riparian monitoring include geology, region, stream size or stream order, vegetation type, or land use. The use of stratification in riparian assessments can increase the usefulness of the results by ensuring the features of interest are represented in the sample population. Stratification can be used to target scarce resources to a particular region or landscape type. Stratification allows the allocation of samples to underrepresented subsets of the population. For example, if sample locations were drawn from the population of all streams, the sample would be biased towards small streams. Stratification of the population into small, medium, and large streams would allow enough samples to be drawn from the underrepresented large streams resulting in a more meaningful conclusion regarding riparian conditions. As an example, suppose a project is assessing vegetation density in a sub-watershed that consists of two geologic settings (e.g. basalt flows and marine sediments) where the basaltic area is more prone to landslides and other mass wasting events that cause disturbances to riparian areas. Sampling sites should be established in both settings (i.e. the sample should be stratified). The stratified sample should include more measurements in the basaltic setting, because the increased disturbance in that area means there will be greater variability in measurements of riparian conditions.

Selecting Representative Reaches

A *representative* reach is one that can be considered typical within the scale of the project. It can also be used as an index site--a site that has all the desired characteristics of riparian areas. When picking representative reaches, characteristics of a riparian area that should be considered generally include the following:

<u>Stream channel type</u>: gradient, width, depth, stream flow, valley constraint, substrate, sinuosity, bedform (e. g. braided, with bars, smooth, etc.).

<u>Vegetation community</u>: composition, age classes, and density.

<u>Land use activity</u>: including dams and diversions, bridges and roads, and other infrastructure.

Sometimes the channel or valley type has a greater effect on riparian characteristics than the management or restoration strategy. For example, a channel with steep valley walls may have relatively homogenous, conifer-dominated, riparian vegetation while a channel with a wide floodplain may be patchier, comprised of a mosaic of hardwoods, conifers and shrubs. These landscape influences on riparian vegetation should be considered when designing the sampling approach and designating representative reach. The OWEB Watershed Assessment Manual (WPN 1999) describes classification methods that can be used to define vegetation and channel types.

Some variability is inevitable, but there shouldn't be major changes in channel type, stream size, vegetation community, or land use *within* the reach of stream being monitored, or *between* the reach being monitored and the segment of the watershed it is meant to represent. This helps to assure that the results are "representative" of the condition being evaluated. Consider surveying the stream prior to monitoring to determine where the major changes occur. The survey results can be used to define the maximum extent of the reach. The sample reach can be placed anywhere within the "representative" reach and may be determined based on locations of management or restoration projects.

Selecting Reference Reaches

Reference reaches can be established to document comparisons for "optimal" or 'desired" conditions, functions, or processes, or for examining the local range in variation over time or space. Reference reaches typically represent the best available conditions and have minimal levels of anthropogenic disturbance. Reference reaches should be selected to represent variable disturbance regimes that can be tracked over time, and are likely to affect the treatment reaches, as well. Avoid comparing vegetative conditions between a reference reach that is in a different region, soil type, disturbance regime, or elevation than the treatment reach.

Because of the great variability that exists in riparian characteristics throughout the state, recognizing that each reference reach represents one possible condition that will change over time is important. They can be used in judging the effectiveness of a restoration project, or as criteria for evaluating the condition of riparian areas on a larger scale. Selecting a reference site is discussed in Chapter 3 of the *Water Quality Monitoring Technical Guidebook* (OWEB 1999).

Random vs. Non-random Site Selection of Samples

When investigators collect data, they are trying to obtain enough to answer questions about a population – the entire group of interest. Rarely will there be enough resources to collect data on the entire population, so instead investigators need a representative sample of the population. Two basic approaches to sampling exist, random and non-random. In random sampling, chance determines which items are included in the sample. In non-random sampling, the investigator deliberately selects what will be included in the sample.

A properly made random sample will contain no bias and is therefore relatively representative of the entire population. All the items in the population should have an equal chance (probability) of being chosen for the sample. The probability of an item being included in the sample is simply the number of items in the sample divided by the size of the population. This is called the sampling ratio.

A weighted random sample is often used when the population contains a small number of items that are of greater importance to the project, because there is a greater chance that this group will be missed. In this situation investigators can increase the sampling ratio for the group of interest, as long as they correct for this imbalance when the results of the sampling are combined.

Non-random sampling is done when the researcher exercises discretion on what is chosen for the sample. A non-random selection is most useful when the assessment focus is on a specific management, land use, or restoration project requiring hand-selection of sites that represent that activity or project. In this case it is more powerful to replace a random selection with a design that will utilize comparisons between pre- and post- "treatment" conditions and "control" or reference reaches.

SAMPLE SIZE

Knowing in advance how much data, both over space and time, is necessary to meet objectives is an important step in planning the project. An adequate sample size will provide enough data to answer the assessment question with a satisfactory *level of confidence*. The needed sample size can be calculated (1) if there is an understanding of the *variability* of the data and (2) after selecting a *confidence level*. *Variability* or *variance* is the tendency of an observation to differ from an average of multiple observations. *Confidence level* can be thought of as a measure of how sure you are about an answer (i.e., "are you 95% sure about that?").

Sample size requirements also depend on whether investigators are attempting to characterize a population or attempting to detect a change (establish a trend.)

Estimating and Calculating the Variability

The variability or variance of the variable being monitored determines how much data are needed to answer the questions. Sometimes previous studies can be used to estimate or quantify the variability. If no data are available to estimate the variability, consider implementing a pilot project. A pilot project can be used to refine data collection protocols, identify flaws in the study design, and provide preliminary data to answer questions or plan the final project.

Existing or pilot project data can be used to calculate the variance. Most spreadsheet software programs, and many calculators, can compute the variance of a sample. The variance can also be calculated using the following equation:

$$S^2 = (1/n - 1)\sum(x_i - x_m)^2$$

Where S^2 is the variance, n is the number of data points you have, x_i is a sample value, and x_m is the mean of the sample values. The symbol $\sum$ refers to the operation of summing the subtraction of the mean from each data point.

Deciding on the Confidence Level

The *confidence level* is selected by the investigator and is a measure of belief in the statistical results. Confidence levels range between 0-1 (or 0%-100%). Setting confidence levels depends on the goals of the project and somewhat on the characteristics of the variable being measured. If the consequences of not adequately representing the population are severe, the confidence level should be high (95-100%). If the subject is highly variable, consider lowering the confidence level, cautiously weighing the confidence versus the consequences of inaccurately representing the population. Typically a confidence level of 80 to 85% is acceptable when dealing with the variability inherent in vegetation data.

Calculating the Sample Size Needed

The variance and confidence levels are used to calculate the desired sample size. An adequate sample size will provide enough data to answer the assessment question with a satisfactory level of confidence. This can be done by applying the simple equation:

$$n = [\ 2(v)/W]^2(S^2)$$

Where n is the number of data points needed, v is a constant that depends on the desired level of confidence (v = 1.96 for a 95% confidence level, 1.645 for 90%, and 1.282 for 80%). W is the desired confidence width, and S^2 is the sample variance.

The confidence width is essentially a value of how detailed investigators want the results to be. For instance, if knowledge about shrub densities is important, but investigators are not concerned if counts of shrubs are off by less than 20 per acre, then the confidence width is 20. However, this also means that the S^2 calculated has to be based on sampling on a per acre basis, and the n value from the equation also informs how many samples are needed from an acre. If investigators are taking samples for laboratory analyses, then the confidence width can not be any less than the laboratory's detection limits.

When investigators use this method to calculate sample size, they are determining how many samples will be needed to calculate the mean of a population within one-half of the confidence interval. This method is also suitable for trend monitoring, assuming that the sample size is calculated for a season's worth of data, not for the entire length of the trend being monitored.

Determining how many years of data are needed depends mostly on the objective of the study and the variable being monitored. Some variables, such as the growth rates of a single species, will become apparent over a relatively short period of time, while variables such as changes in bank stability may take more than ten years of data to determine. There are three main ways to calculate how many years/ seasons of data are needed. One is to use the n calculation described above, given a good measure of variance over time, as opposed to over space. The second method involves developing a trend that has a predictable pattern. For example, if change in willow growth is being monitored, the number or size of willows can be graphed versus time. Assuming little or no disturbance to the riparian areas, after four or five years a trend may be detected that can be mathematically modeled into the future. The third method is simply to monitor until some target is reached, like 90% bank stability or 85% effective shade.

DATA ANALYSIS

Performing basic *descriptive statistics* and graphing data is an important first step in understanding the nature of the data and how best to proceed with analyses. Descriptive statistics are routine mathematical procedures that are commonly applied to all sciences. Examples include calculating average, minimum, and maximum values. The two most common types of data analyses involve *hypothesis testing* and *trend analysis*. Hypothesis testing involves posing a question and running a statistical test to decide whether the question is true or false. Trend analysis involves looking at data over time or space to determine whether or not there is a trend (e.g. increasing or decreasing over time) in the variable of concern. These approaches are described below.

Descriptive Statistics

The most basic data analyses are referred to as descriptive statistics. The easiest way to produce descriptive statistics is to enter data into a computer software package and let the computer do the number crunching. Basic descriptive statistics include the maximum, minimum, mean, median, standard deviation, variance (discussed previously), correlation coefficient, skew, and kurtosis. Basic descriptive procedures that can be applied to the statistics include frequencies and distributions. Once these statistics have been generated, graph the data to visually identify trends, patterns, or potential data errors. An example of graphed data with a calculated trend is shown in Figure 3-3, later in this section.

The maximum and minimum are the highest and lowest observed values from a set of data for a given variable. The data *mean* represents the average value of all the data (i.e. sum all data observations divided by the number of observations). The *median* is the observed value at which half the observations are greater and the other half are less.

Most statistical tests require knowing if the data are *normally distributed*. The mean and median will be virtually the same for a single data set if the data are normally distributed. If the data are ***not*** normally distributed then *non-parametric statistical tests* are the most appropriate tests to use. Appendix A discusses three non-parametric tests, which are appropriate for data that are not normally distributed (most natural resource-related data will not be normally distributed).

The *standard deviation* is a measure of the *spread or distribution* of the data. For normally distributed data, 95% of all data fall within two standard deviations of each side of the mean. Because of this, the standard deviation indicates how closely spaced the data are. However, if the data are not normally distributed (non-normal), then the standard deviation isn't a good measure of the spread. With non-normal data, the *range* and *percentile* groups are useful for looking at the spread of data. Range essentially describes the minimum and maximum values, and percentiles tell how much of your data fall below a certain value.

The data distribution can also be visually assessed by graphing it with the data points on the x- (horizontal) axis, and the frequency of each data point on the y-axis. Normally distributed data will form a bell shape. However, this is not easy to do on some spreadsheet programs, so it may need to be done using a graphing or statistical program.

Skew and kurtosis are measures of how the data distribution differs from a normal distribution. Measuring the skewness of the data tells how asymmetrically distributed the data are, while measuring kurtosis tells whether most of the data have a central tendency or are distributed away from the median value. If the data are normally distributed, then both the skew and kurtosis will be zero. Negative skew values mean that there is a wider range of data less than the median value than there is greater than the median, and positive skew has the opposite meaning. Negative kurtosis values indicate that most of the data are distributed close to the median, while positive values mean that most of the data are distributed above and below the value of the median. These two statistical measures can be applied to riparian monitoring data in many different ways. Here are a few examples of how skew and kurtosis can be applied to different riparian variables:

Bank stability: Skew and kurtosis can indicate whether a difference in bank stability over time or space is evident. If the bank angle is measured at ten locations each year on a stream for five years, compare the skew of the data to see whether there is an increasing or decreasing trend in the steepness by whether the skew is getting larger or smaller. The same comparison can be made between different reaches.

Trees per acre, or other vegetation density data: For this type of data, skew and kurtosis can indicate if growth rates are better or worse than in a reference reach, or are changing over time or space.

Skew, kurtosis, standard deviation, and variance (discussed previously) can all be used for comparing data sets to determine if differences exist between them. For example, when comparing species diversity between a reference and study reach, the skew and kurtosis of the species composition can be compared between the data sets to see if they are the same. Skew and kurtosis of multiple reaches of the same stream can also be compared to see if they have similar characteristics.

Correlation coefficients are very useful for indicating relationships between riparian conditions, and for identifying surrogate measures of riparian characteristics (see discussion of surrogates in this chapter). Note that they can *indicate* a relationship – they don't *prove* a cause and effect mechanism. Correlations are probably abused as much as they are used. An infinite number of false relationships (*spurious correlations*) are possible, so make sure the relationship of the variables being correlated is well established by other research or monitoring. The most common way to determine a correlation is to calculate Pearson's coefficient of correlation, usually signified by the character R^2. Most spreadsheets can calculate this. When R^2 is close to 1, a good relationship between the variables being compared is evident.

Hypothesis Testing and Trend Analysis

The two most common types of data analyses involve hypothesis testing and trend analysis. Sometimes these two approaches are used together; for example, when a hypothesis is posed regarding the significance of a trend. Hypothesis testing essentially is posing a question and running a statistical test to decide the potential for it to be false. Trend analysis involves looking at a time series of data to determine whether or not there is an upward or downward trend in the variable of concern.

An example of hypothesis testing is evaluating whether a significant difference in willow survival between a reference reach and reaches that were actively managed on Bag Creek exists. The hypothesis could be worded like this:

Ho: Willow survival rates are higher on the managed portions of Bag Creek than on the reference reach.
H_1: Willow survival rates are not higher on the managed portions of Bag Creek than on the reference reach.

Ho and **H_1** refer to the null and alternate hypothesis, respectively. The statistical test will indicate whether to accept or reject the null hypothesis. The alternative hypothesis must be written so that it is true if the null hypothesis is rejected: questions must be posed with either a yes or no answer. When using hypothesis testing, make sure that the question is narrowly focused. This type of test can lead to false conclusions if the question is too broad or vague. Also, make sure the test is designed so that the question asked has a known relation to an ecological function of the riparian area.

The other common type of analysis is trend analysis. Trend analysis is used to detect if something is changing as time goes by. Figure 3-3 is an example of a trend calculated for a time series of blackberry plant cover within the riparian area along Bag Creek. These data were collected at the reach scale. This example shows a decrease in blackberry cover over time. In this example a *linear trend* was calculated, but trend lines commonly aren't linear. You may want to calculate a non-linear trend, like a logarithmic, quadratic, or exponential trend for your data. A complete discussion of this subject is beyond the scope of this document, but more information on this subject can be found in the sources included in the references for this chapter.

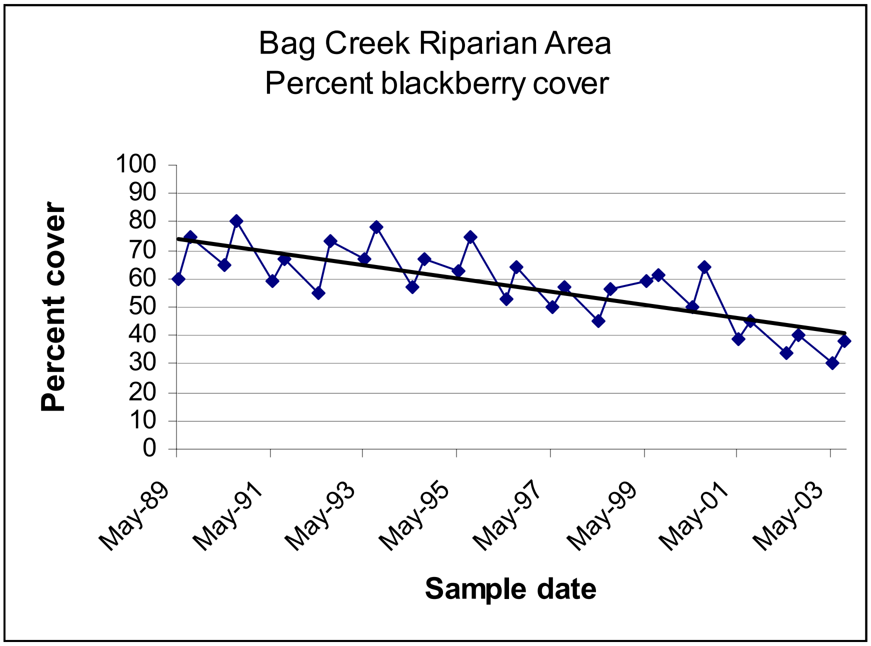


Figure 3-3. Example of graphed riparian area blackberry percent cover (reach scale) data with a linear trend line added. The trend line was calculated in the spreadsheet program that generated the graph.

Both hypothesis testing and trend analysis require statistical tests to determine whether or not the hypothesis or trend is statistically significant. As previously discussed, riparian data are usually not normally distributed. Non-normal data typically require the use of *non-parametric tests,* or *data transformations* using logarithmic or power transformations. Appendix 3-A discusses three non-parametric tests, which are appropriate for data that are not normally distributed. More can be learned about these methods in some of the references included for this chapter. Make sure to spend enough time getting familiar with various statistical methods before deciding on one or more for the assessment.

Appendix 3-A: Non-Parametric Methods for Hypothesis Testing and Trend Analysis

HYPOTHESIS TESTING

Using the Mann-Whitney Test

This is a fairly simple procedure that is also called the "Wilcoxon rank sum test" (Wrs). When using this procedure, investigators are testing whether the distributions of two data sets are the same. The null hypothesis would be: *no difference exists between data sets*, which makes the procedure useful for comparing one stream reach to another, such as when using a reference reach. Below is an example of how the procedure works if both data sets contain ten or more data points:

Combine the two data sets, but remember to keep track of which set each data point came from. Rank the combined data set from smallest to largest value. Then assign a rank number to each data point. If you have ties, then give each of those points the same value. The highest rank must equal the total number of data points (this value is designated m), so the rank of the tied values should be 1.5 greater than the previous value if only two values are equal, 2 greater than the previous value if three values are equal, etc.

Calculate *Wrs*, which is the sum of all the ranks for the first group of data, *g* which is the number of ties (not number of data points that are tied, but the number of equal values), and *tn* values, which are the number of tied data points for each g.

Here's an example of steps 1 through 3. Let's say you have the following data sets:

Group 1	Group 2
17	13
12	4
9	33
22	9
31	16
16	5
9	27
23	29
28	6
15	11

Combine them, rank the values, and keep track of the groups, so the data looks like this:

data	**group**	**rank**
4	2	1
5	2	2
6	2	3
9	1	5
9	1	5
9	2	5
11	2	8
12	1	9
13	2	10
15	1	11
16	1	12.5
16	2	12.5
17	1	13
22	1	14
23	1	15
27	2	16
28	1	17
29	2	18
31	1	19
33	2	20

Then calculate Wrs, g, and t values. For this example Wrs = 120.5, g = 2, t1 = 3, and t2 = 2.

Once you have done this, you need to calculate the Z statistic, which tells you whether or not to reject the null hypothesis. The equation for this is:

$Z = [Wrs – n1(m + 1)/2] \div [n1n2/12(m + 1 – (\Sigma tn(tn^2 – 1)/m(m-1))]$

Where m is the total number of data points, n1 is the number of data points in group 1, n1n2 is the number of data points in group 1 times the number of data points in group 2, and the other symbols are as described above. For our example, the equation would end up looking like this:

$Z = [120.5 – 10(20 + 1)/2] \div [100/12(20 + 1 – ((3(3^2 –1) + 2(2^2 –1))/20(20-1))]$

In this example, Z = 0.090. It is not necessary to calculate Z beyond three decimal places. At a 95% confidence interval your calculated Z should be compared to 1.96. If Z is less than 1.96, then you do not reject the null hypothesis that the two data sets are the same.

TREND ANALYSIS

Sen's test

This is a fairly simple procedure that is useful for finding linear trends in data. This test cannot be used if the trend you see on a graph is non-linear, or if there is a seasonal effect observed in the data. It does involve many calculations and is more practically accomplished using a spreadsheet program. The Sen test tells you whether or not a linear trend in your data is statistically significant by looking at the median value of the slope between each data point. If your median value is close to zero, then no significant trend exists. Medians less than zero show a downward trend, positive medians show an upward trend.

To do the test, first make sure that any dates in your data are formatted so that they can be subtracted from each other. Three options for date formats are Julian days (calculated from whatever datum you choose), decimal years, or yyyymmdd (e.g. May 17, 2001 would be 20010517). Put your data in chronological order, then calculate the slope between each data point. Most spreadsheet programs have a SLOPE command that will do this for you. But if you need to do it manually, follow this method:

If your data consisted of a column of X values and a column of Y values, you would calculate X1 –X2/Y1 –Y2, X2-X3/Y2-Y3, etc. Once you have done this, calculate the median value of all the slopes. The median is not the same as the mean – unless your data has a perfect normal distribution (which it won't have, otherwise we wouldn't be using non-parametric methods). To find the median manually (assuming you don't have any other way to calculate it) arrange all your slopes in order from smallest to largest. If you have an odd number of data points, then the median is the middle observation; if you have an even number, the median is the average of the two center observations (e.g. if there are 21 data points, data point 11 is your median. For example, if you have 22 data points, then your median is (data point 11 plus data point 12)/2).

Seasonal Sen test

You can modify the Sen test if there is definite seasonality to your data by computing the median slope values for each month or other appropriate time period separately. For instance, if you have data for the period April through October for four years, you can compare find the median for all April slopes, all May slopes, etc.

Chapter 4: Using Existing Data

INTRODUCTION

Many government and private entities have collected data on riparian conditions, and often these existing data can augment, or at least provide a starting point, for a new riparian assessment project. Admittedly, it is rare to find an existing dataset that meets the exact needs of a new riparian project. However, after a careful evaluation of existing data, investigators may find a variety of ways to extract useful information from non-ideal datasets. This chapter provides guidance for evaluating existing data and provides some examples of how existing data can support new projects.

Before using existing data, gather all supporting documentation on the project and visit with the principal investigator if possible. Some of the factors to evaluate and discuss include:

Goals and Objectives: What were the goals and objectives of the original study or data collection effort and how do they relate to the new riparian assessment goals?

Data Quality: Are the precision, accuracy, representativeness, and reliability of sufficient quality to meet the needs of the new riparian assessment? The process of evaluating these questions is often referred to as quality assurance and quality control or “QA/QC”.

Scale: How do the temporal and spatial scales of the existing data align with those of the new riparian assessment?

The following sections discuss these considerations, and provide basic guidance in obtaining useful information from existing data.

GATHER REPORTS AND INFORMATION

When considering the use of existing data, the first step is to obtain all the documentation on how that study was performed. The main question, when evaluating these materials, is simply: “Are the data collected by this project applicable in some way to my study?”

One of the best ways to evaluate this question is to talk with the principal investigator of the original study. Discuss the assessment goals for the new project and ideas on how existing data might be utilized. Ask if the project approach or methods were altered relative to any published material that might be available. Read published papers and supporting documents to evaluate the utility of the data. Some of the key aspects to evaluate include: the variables that were collected; at what scale; and with what level of quality. Scale and QA/QC are discussed briefly below and in more detail in Chapters 3 and 7.

GOALS AND OBJECTIVES

As discussed in Chapter 3, the project goals define key characteristics of the study including the assessment questions and data collection variables. For example, one goal may characterize conditions and trends of riparian areas in western Oregon, while another may evaluate the effectiveness of a riparian planting project to re-establish native vegetation. These two assessment goals require different scopes, sampling designs, and analyses.

A project with different goals may still provide valuable existing data for the new project. For example, imagine a study was designed to evaluate large wood recruitment from a riparian area in eastern Oregon. Data were collected on species, diameter, and distance from stream on all the trees in 50 randomly placed plots in the Drudge Creek Watershed. These data might also be used to evaluate species composition of overstory trees in riparian areas in the Drudge Creek Watershed. However, the data may not be useful for evaluating the composition of riparian structure (e.g. the original study did not collect data on shrubs or trees <15 cm in diameter). Nor may it be used to evaluate species composition of overstory trees throughout eastern Oregon (e.g. the original study did not collect data outside of the Drudge Creek Watershed).

QUALITY OF EXISTING DATA

Precision and Accuracy

Does the study have the desired precision and accuracy levels to meet the needs of the new assessment project? To answer this question, the desired precision and accuracy of the new assessment must be known (for more information on data precision and accuracy, see Chapter 7). Once this is established, compare these values with that of the existing data. Some studies have not established nor reported on data precision and accuracy. In such cases, it is possible to test data precision using a data verification process. Field verification of existing data is the process of checking to see if individual observations made by previous investigators match replicated observations. This involves revisiting sites or re-evaluating remotely sensed data to determine if the measurements can be repeated. Accuracy is evaluated by comparing the existing data to known or expected values.

Evaluating precision through the verification process requires a 'spot check' or *replicate* of past observations. The appropriate number of replications can be determined by looking at the variability of the existing data – the greater the variability, the more replications needed. A simple comparison can be made between existing data and replicate data. If the differences are within the acceptable limits of the new study (where the limits are pre-designated by the designers of the study), then the existing data have an adequate *precision*. For example, verification may reveal that existing stream cover data are plus or minus 5% different than the replicate sample. The new study established 10% as an acceptable precision, so the existing data will be adequate.

Grouping or categorizing is also a useful way to assess the precision of existing data. This is especially valuable when assessing indexed data. For example, if the existing data divides vegetation cover into groups of 0-20%, 20-40%, etc., then pick a sub-population of riparian vegetation and determine whether the same numbers of 0-20%, 20-40%, etc. groups as the previous investigator are reached. The results of field verification can be used to establish confidence limits for the existing data, as described in the previous chapter on study design.

There are limitations to the utility of verification. For example, some characteristics are expected to change over time. Variables such as vegetation composition, shade, or channel morphology might have changed regardless of the measurement precision. Another limitation is the ability of either data-collection effort to collect representative data. This is less of a limitation if individual plots are being compared. But if the data are summarized at a reach, watershed, or regional level, it is imperative that both samples are representative of the larger population. These issues are discussed more in the next sections dealing with representativeness and scale.

Representativeness

Does the study represent the population, condition, or trend that the new assessment project intends to represent? Evaluate the study design and goals to answer this question. Suppose the new riparian project goal is to assess trends in species composition in restored reaches along Dreck Creek in eastern Oregon. If data exist from those same reaches prior to restoration, then the new project can assess the trends in vegetation composition over time and in relationship to the restoration activities.

SCALE CONSIDERATIONS

Does the existing project cover an adequate spatial and temporal scale to meet the needs of the new project? Given the variability and desired confidence limits of the new study, was an adequate sample design used for the desired spatial and temporal scale to provide a representative sample?

Spatial Scale of Existing Data

Existing riparian data are often available at a finer or coarser scale than what is required. For example, there may be data from box plot or transect surveys for 12 acres (fine scale), when the new assessment requires remote sensing for 50,000 acres (course scale). Conversely, as an example of existing data at too coarse of a scale, there may be data collected from LANDSAT satellite images for all the Grande Ronde, John Day and Umatilla Basins (coarse scale), when the assessment requires herb, shrub, and tree species composition along 5 km of stream along a tributary to the John Day River (fine scale). In both cases the existing data can still be of some value.

Finer Spatial Scale than Needed

For the case of existing data at too fine a scale, there are two basic ways to put it to use. The first one is to use the data to aid in the classification of remote sensing imagery or as part of a *ground truthing* effort, assuming an adequate level of confidence in the quality and currency of the data. Most remote sensing data efforts are combined with some ground truthing to confirm the interpretation and accuracy of remotely sensed data. If the quality is questionable, then the data can be evaluated with higher resolution data or field data, as described above, or by resampling a portion or subset of the area covered by the existing data.

The second way to use finer data is to interpret information obtained from the new effort. The finer scale data can help explain phenomena observed during a coarser scale effort. As an example of this technique, suppose an analysis of satellite imagery of a mountain stream was performed with images obtained in late fall. The area is dominated by evergreens, yet very little green is observed in the riparian zones. Initially this is interpreted to mean an absence of trees. However, a look at existing data from transect surveys of the stream reports that larch trees dominate the riparian areas. Larch trees lose their needles in the fall, just like deciduous trees, even though they are conifers.

Coarser Spatial Scale than Needed

When data represent a coarser scale than needed, it can be used to identify areas that would be most appropriate for finer scale study. For example, if the assessment requires sampling shrub assemblages at the species level, then course scale data can be used to locate the shrubs. It can also be used to stratify the sample. The study may be designed to disperse ground-based samples across the various riparian species or channel types within a given watershed or region. Aerial photographs can be used to stratify the watershed before selecting or identifying the samples. Another application is to correlate new finer-scale data to existing coarse-scale data so the finer-scale data can be extrapolated to a larger area

Temporal Scale of Existing Data

Evaluating the applicability of the existing data with regard to time is also important. The new riparian assessment may require the use of data that represents conditions this year, 5 years ago, 25 years ago or more. The appropriate timeframe will depend on the objectives and design of the new study. If the objective is to evaluate changes over time, existing data dating back 5, 10 or 20 years is extremely helpful. If the objective is to report on existing conditions, then the 5 year old data may be helpful, but the 10 or 20 year old data will most likely not be helpful. The "currency" of the data will depend somewhat on the variables. Some variables will be very sensitive to changes over time while others may not be. Some may be sensitive to changes over long time periods but not over short time periods, while other variables show the opposite trend. Table 4-1 provides some examples of how certain variables would be expected to change over time. The appropriate timeframe will also depend on management practices. If the riparian assessment is evaluating the effects of certain management practices, then the existing data must come from a time period when those management practices were in place.

TABLE 4-1. Expected changes in riparian variable characteristics over time, assuming no human impacts or catastrophic events.

Variable	Time Frame	Expected Change
Stream bank shape/height/ Position	<3 years	little to none
	3-5 years	noticeable change when surveyed
	5-10 years	noticeable change based on visual exam
	10+ years	noticeable change by remote sensing
Tree height and canopy width	3-10 years	significant height increase, little canopy width change
	10+ years	noticeable increases in height and canopy
Vegetation density	1-5 years	noticeable increase based on visual exam
	5 years	noticeable increase by remote sensing
Vegetation diversity	1-20 years	little change
	20-50 years	potential change
Individual species abundance	1-5 years	noticeable increase based on visual exam
	5 years	noticeable increase by remote sensing

PRIORITIZATION

Existing riparian assessments may be useful for prioritizing restoration efforts. This may also be the goal for a new riparian assessment. The assessments may identify areas with undesirable riparian conditions or areas that if improved would provide benefits for large portions of the watershed. Existing data can also be used to prioritize monitoring efforts. For example if certain parts of a watershed or certain functions have been well studied, consider complimentary work that will not duplicate the existing efforts. Conversely, if existing assessments or studies make conclusions that are not supported by previous studies, there may be value in duplicating the effort. Existing studies may have recommendations for the focus of future studies. Regardless of the utility of existing data to the new study, becoming familiar with the research and monitoring that relates to the new riparian assessment will add value and improve the final product.

SOURCES FOR AVAILABLE RIPARIAN DATA

This is a partial list of sources for existing riparian data that is available to the public:

Oregon Department of Transportation (ODOT)

ODOT has developed a list of the expected vegetation types in five different eco-regions of the state. This list also includes the types of riparian areas – in terms of type of wetland, etc. – and the expected elevation in which the vegetation would be located. ODOT also maps riparian zones within 500 feet of highway corridors.

Oregon Department of Forestry (ODF)

ODF collects a wide variety of information on riparian zones in forested lands. Their assessments have included canopy cover, woodland composition, shade measurements, and other types of studies.

Oregon Department of Environmental Quality (DEQ)

DEQ primarily collects information on riparian vegetation for evaluating the shade potential of stream reaches related to water temperature. They also develop estimates of expected changes in riparian vegetation over time, and their LASAR database has some information on indexed riparian conditions for various stream reaches.

Oregon Department of Fish and Wildlife (ODFW)

ODFW has collected a large amount of data on riparian conditions within a short distance of stream channels. These data are of varying detail, but they do represent wide areas of the state.

USDA Forest Service

The Forest Service has conducted many riparian assessments on Federal lands throughout the state. Specific information on data available can be obtained by contacting the individual Forest Service District Offices. Their Regional Office in Portland also has a group called the National Riparian Survey team, which works with the Bureau of Land Management.

Natural Resource Conservation Service (NRCS)

Many NRCS researchers have reported on soil-plant relationships, where vegetation communities are related to mapped soil series. These data are often reported in USDA Natural Resource Conservation Service county Soil surveys, though not all soil surveys include riparian soils.

Example
Using Existing Data to Estimate the Potential for Large Wood Delivery to Streams

What is the current and future delivery potential of large wood into stream channels, given the current location, type, and size of riparian trees in the Trout Creek watershed?

In planning to answer this question, the investigators find aerial photographs at a scale of 1:12,000 taken ten years earlier of the Trout Creek watershed. These photographs, in conjunction with current aerial photography, provide a way to gauge the patterns of vegetation throughout the watershed over time. A comparison of vegetation density at a ten-year interval provides valuable information on the future delivery of large wood. Growth rates, combined with knowledge about areas that have been cleared of vegetation, can tell the researchers the potential delivery of large wood within different areas of the watershed.

The old photos also help with the ground truthing effort, because the areas that have the lowest densities of trees would have the lowest potential for large wood delivery. These areas wouldn't be representative of the watershed as a whole, but they would represent the low end of large wood delivery potential. Field plots would then avoid these areas.

Chapter 5: Field Methods

INTRODUCTION

This chapter summarizes commonly used field-based approaches and parameters for assessing riparian structure and restoration. Decisions regarding which field methods and protocols to use depend on the management goals, assessment objectives, riparian characteristics, and time and resource constraints involved. However, some basic plot designs, techniques and parameters are well-established in the fields of riparian and vegetation ecology research and evaluations. These approaches are common to most monitoring objectives and available for review in the references section at the end of this document (Adamus 2001, ODSL 1996, Bell and Dillworth 1988, ODF 2001 and 2002, EPA 1993, USDA Forest Service 2001, Winward, 2000).

Collecting field data can be time consuming and expensive. Therefore, investigators should consider other potential uses for the field data and decide how they can gain the most benefit from the data collection effort. One simple technique to facilitate data sharing is establishing common protocols and nomenclature when gathering data. Collecting additional information, such as the active channel width or the location by river mile, can make the data useful for other purposes including questions that address different scales. For example, if the finer scale data (reach or site level) are linked to data at a broader scale (watershed or region), results can be extrapolated beyond the status or condition at the reach scale to the status or condition at the broader scale. Such approaches are discussed further at the end of this chapter and in Chapter 6.

Three levels of field data collection are described here and related to particular assessment types:

<u>Level I (Implementation or Baseline Assessment)</u>:
Project Documentation and Tracking
Level I involves careful documentation of restoration activities. Level I often necessitates making general surveys of plant survival and vigor through follow-up surveys of project success over several years.

<u>Level II (Baseline and/or Trend Assessment)</u>:
Assessing Riparian Restoration and Structure
Level II data collection usually involves taking field measures for evaluating the survival and establishment of riparian plantings or riparian structure and typically requires a more rigorous approach.

<u>Level III (Effectiveness Assessment)</u>:
Assessing Effectiveness of Restoration Projects
At this level, riparian functions such as providing shade, cool stream temperatures, and bank stability are measured to gauge the effectiveness of restoration activities.

Detailed examples of how to establish and lay out permanent plots, measurement and consistently record data are provided in a series of appendices to help investigators develop credible field data:

<u>Appendix 5-A</u>: *Vegetation Sampling Plot Designs and Layout Techniques*

<u>Appendix 5-B</u>: *Measuring Tree Heights and Live Crown Ratios*

<u>Appendix 5-C</u>: *Field Data Collection Codes: Trees, Shrubs, and Animal Damage*

Level I: Project Documentation and Tracking

Goals

- Document implementation of riparian restoration projects.
- Monitor the success of establishing vegetation (e.g. survival) and maintenance of restoration projects

Success of Level I monitoring depends on (1) **careful documentation** of restoration activities, and (2) **routine, systematic, follow-up visits** to track projects. Careful documentation of exactly what management or restoration activities took place, and when those activities occurred, establishes a baseline for future monitoring efforts and, ultimately, a way to increase success in riparian restoration and management. By documenting management activities that influence survival and vigor of riparian plantings, the investigator can determine which strategies most efficiently provide the desired results. These data can be captured on a form such as the one provided below (Figure 5-1).

The other critical element in Level I monitoring is to establish a systematic, routine schedule (e.g. once each spring, summer and fall) to revisit sites and track the success of restoration until the desired outcome is reached (e.g. plants are “free-to-grow”). The purpose of the follow-up site visits is to monitor the success of the restoration activity and to take action, when necessary, to curtail failures. Examples include monitoring survival and vigor of plantings, stubble height, or fence conditions. If plants are alive but overtopped by competing, non-target species (e.g. invasive blackberries), then brush control measures should be implemented to increase plant vigor. If stubble height is lower than desired, then range management should be altered. If a fence is breached, then the fence should be repaired.

The Level I approach provides a general structure that can be used to evaluate project success, adapt to unintended outcomes, and minimize failures. Because restoration success (e.g. survival and vigor, fence soundness) will vary throughout the restored riparian area, investigators should visually inspect the entire site during follow-up visits (e.g. walk a series of paths parallel to the stream and spaced 10-13 meters apart, or walk the entire length of a fence). Often tree or shrub plantings will have high survival rates and be vigorous near the road where herbivory and plant competition may be lower, but plant vigor and survival may be quite different near the stream. Also, soil and moisture conditions may vary depending on topography and, thus, affect vigor and survival.

Did the planted trees survive and are they vigorous?

Document restoration activities as described in Level I. Revisit the site each spring, summer and fall until the planted trees are free-to-grow. Each time: document and map observations, tree survival and vigor, and take photos at photo points. Document activities such as replanting areas, brush or herbivory control. Information on establishing photo points can be found in the OWEB Stream Shade and Canopy Cover Monitoring Methods Manual. (http://www.oweb.state.or.us/publications/mon_guide99.shtml)

Project Documentation

The following data can be collected to document the restoration activity. Update the data when follow-up visits are conducted to reflect observations and maintenance activities.

1. Project Contact: Name of person managing project.
2. Stream Name and Location: GPS, Legal description.
3. Field Survey Dates: Keep a list of initial and follow-up site visits.
4. Area Treated or Planted: Hectares (or acres), kilometers (or miles) of stream, and average width (meters or feet) for one side of stream. Use a separate form for the other side of the stream and label in such a way to indicate the forms are related (e.g. Deer Creek side A,

Deer Creek side B). For future reference and comparisons, provide context such as left and right bank, and whether looking up- or downstream.

5. Initial Treatment: Planting, fencing, hardwood conversion, range management, or other treatments.
6. Plant Data: Species and number of trees or shrubs planted, age of plants, type of plant (bare root, container, etc.), nursery source, planting date.
7. Method of Planting: Shovel, hoedad, auger, water jet, or other.
8. Site Treatments to Control Competing Vegetation: Mowing, scalping, herbicides, fertilization, weed mat, or other. Dates of treatment.
9. Tree Protection to Control Herbivory: None, fencing, tubes, vexar, foil wrap, printing plate, chicken wire, cage, or other. Dates of maintenance.
10. Photo Log/Documentation (Figure 5-2): The landowner can simply take photos and keep a log of date, location, and subject of photo. Establish a storage system for the photos to accompany the field forms.
11. Permanent Photo Plots: Consider establishing permanent photo plots as detailed in the OWEB Water Quality Monitoring Guidebook Chapter 14 (OWEB 1999), particularly if no additional field data will be collected. If done correctly, permanent photo plots can provide a reliable record of vegetation and channel changes over time. Establish a photo storage system to accompany field forms.
12. Site Map (Figure 5-3): Sketch a map of the stream and the treated riparian area. Reference planting characteristics, fence locations, and site conditions. Make copies of the original map to record changes observed during follow-up site visits (e.g. areas with poor planting survival, heaving, grazing, or fence breaches). Record follow-up site visit dates.

Routine Follow-up Visits

For each site visit, document the date and any observed changes in plant survival and vigor, fence condition, and other observations. Consider using a form for documentation, such as Figure 5-4, noting the following:

1. Date: Document the date of the site visit.
2. Management Activity Log: Note any restoration activities that have taken place since the previous visit.
3. Survival: If a significant number of plantings have died, document the cause of death. Note details about mortality such as whether mortality is confined to a single species, to an isolated area of the restoration project, or due to competition or herbivory.
4. Vigor: The following is an example of how to rate plant vigor:
   - *High*: good color, dense foliage; branches on > 60% of the stems; stems well able to support top growth
   - *Moderate*: moderate foliage and color; branches on 40-60% of stems; stems thin but adequate
   - *Low*: poor color, sparse foliage; branches on less than 40% of the stems; stems thin and likely to topple in wind or flood
   - *For shrubs*: look for color and density of foliage as well as density of stems appropriate for the species
5. Competing Vegetation: If brush or grass is encroaching to within one plant-height from the restoration planting, consider brush control measures to reduce rodent damage, nutrient and water competition. Note locations for maintenance needs.
6. Herbivory and Herbivory Control Measures: If a significant number of plants are being browsed, girdled, or otherwise damaged by animals, consider herbivory control measures.
7. Other Observations: Note observations about site conditions, weather, management activities.
8. Photos and Maps: Repeat 10 or 11, and 12 as described above.
9. Recommendations: Summarize recommendations for improving vigor or preventing mortality.

This record should be updated with each follow-up treatment such as re-planting, competitive vegetation management, and/or herbivory control and the date of follow-up treatments.

FIELD FORMS:

Figure 5-1. Level I Example project documentation form.

Planting Record: Fill out one for each side of the stream

Project Contact:	Planting/Treatment Length
Stream Name:	GPS Location Downstream or Legal
Field Survey Dates:	GPS Location Upstream or Legal
Describe Initial Treatment:	

Area Treated:	Both Sides of Stream: Yes or No	Side of Stream:

Track Follow Up Field Visit Dates:

Species	# of plants	Age (2+, 1+1, etc.)	Type (bare root, container, pole)	Nursery or source	Planting date

Site Preparation, Planting methods, and Protection measures. (Mark all that apply, please provide info requested, add others as needed.)

Site treatments	Planting	Tree protection
Mowing	Shovel	Tubes (size, color, stake type)
Scalping (depth and diameter)	Hoedad	Vexar
Herbicide (pre-planting)	Auger	Foil wrap or collar
Fertilization (type and formula)	Water jet	Printing plate
Weed mat	Other	Chicken wire
Brush removal (method)		Cage (type and height)
Mychorizae treatment		Other
Other		

Figure 5-2. Example follow-up visits field form.

Follow-up Field Visits		
Project Contact:		Planting/Treatment length (right bank or left bank)
Stream Name:		GPS Location Downstream or Legal
Field Survey Dates:		GPS Location Upstream or Legal
Area Treated (acres):	Both Sides of Stream: Yes or No	Side of Stream:
Management or restoration since last visit:		
	*Observations (Is it confined to a specific species, recommendations for follow-up management, are there observable reasons for successes or failures (e.g. too much moisture, too dry, etc.) is there greater survival in one part of the treatment than another	
Approximate survival or mortality rate (percent by species)		
Vigor (High, Moderate, Low)		
Competing vegetation		
Herbivory		
Summary of observations and/or recommendations		

Figure 5-3. Level I Example photo and observation log.

Photo and Observation Log	
Project Contact:	Planting/Treatment length (right bank or left bank)
Stream Name:	GPS Location Downstream or Legal
Field Survey Dates:	GPS Location Upstream or Legal
Date and Location/Photo Subject:	**Observation:**

Figure 5-4. Level I: Example site map form.

Planting Map and Description

Stream Name	Quad Name and GPS or Legal (attach copy of quad field map)
Project Contact	Field Visit Dates:

Map: (Identify streambanks, fencelines, planting zones, species and landmarks, with estimated distances. GPS where appropriate.)

LEVEL II: PLANT SURVIVAL AND RIPARIAN STRUCTURE

Goals

- Conduct a systematic evaluation to monitor the success of riparian restoration projects over time.
- Assess vegetation to characterize riparian structure.

Level II provides more detailed information on plant survival, establishment, and riparian structure than Level I. Level II involves gathering data in an unbiased, structured, and repeatable format following established procedures. The data can be used to evaluate tree/shrub survival and growth of newly planted species, or to evaluate the structure and plant communities of riparian areas. Data are typically collected on each individual tree or shrub within the treated riparian area or within sample plots.

Success of "repeat visit" approaches relies on getting back to the exact same place year after year. Thus, take care to "monument" the site, keep a record of how it was monumented, and note directions for access (Figure 5-5). Establishing and monumenting the sample plots are described in Appendix 5-A.

This section describes parameters commonly measured to monitor restoration success or to describe riparian vegetation structure.

Riparian Planting Projects

This section describes parameters that are commonly measured to monitor the survival and establishment of trees or shrubs planted in riparian areas. The following set of data can be collected on every tree or shrub within the treated riparian area. If the planted area is too large, then measure all the trees/shrubs within plots as described in the plot design section of Appendix 5-A. The plot size will vary depending on objectives and riparian characteristics but commonly ranges from 50-200 m^2. (Optional: consider tagging each tree/shrub with a metal tag. If this approach is used, the tree number should be recorded on the data sheet.) Consider recording the data on a form such as the one provided in Figure 5-5. Data collection on each tree or shrub includes, but is not limited to:

1. Tree or Shrub Species: Document the tree/shrub species consistently, using established codes. Code examples are provided in Appendix 5-C.

2. Tree or Shrub Height: Measure the height of tree/shrub from the base to the tip. If the trees are very tall (>10.5 m) consider collecting height on a subset of trees or record tree height as being greater than a pre-established upper limit (e.g. >9 m). Methods for sub-sampling trees and measuring tree heights on very tall trees are described in Appendix 5-B.

3. Dead Trees and Shrubs: If a planted tree or shrub is dead, note it in a separate dead-tree column with a comment for the source of mortality (if known) using the following codes:
   - HB- Herbivory
   - WT- Too Wet
   - DY- Too Dry
   - FD- Frost Damage
   - SS- Sun Scald
   - MD- Mechanical Damage
   - VG-Vegetation Competition
   - UK-Unknown
   - Other: describe

4. Shrub Stem Class: Shrubs are classified as sprout, young, mature, decadent, or dead. This is based on the number of stems at the ground surface (Bauer 1993, Winward 2000):
   - Sprout = 1 stem above ground
   - Young = 2 to 10 stems above ground
   - Mature = >10 stems above ground, >1/2 alive
   - Decadent = >10 stems above ground, <1/2 alive
   - Dead = > 1 stem above ground, none alive

5. Grass Competition: Identify the level of grass competition for each tree or shrub.

Record N/A (not applicable) for trees greater than 1.5 m tall. If known, identify species of grass in comments.

- 0 – No sod within 0.5 m
- 1 – Sod within 30 cm
- 2 – Sod within 15 cm
- 3 – Sod to stem

6. Brush Competition: Identify level of brush competition for each tree or shrub. Identify brush species in comments.
    - 0 – no brush shading or brush within 0.5 m
    - 1 – brush within 0.5 m and shading <25%
    - 2 – brush within 0.5 m and shading 25-50%
    - 3 – brush within 0.5 m and shading >50%

What are the survival rates of planted trees and shrubs at a restoration site along Oak Creek at 1, 2, 5, and 10 years?

To answer this question: collect the data as described in Levels I & II at one, two, and five year intervals after planting. "Percent Survival Rate" equals the number of trees/shrubs alive divided by the number of trees/shrubs that were planted. For example, suppose 100 trees were planted and 80 were alive after one year. The survival rate equals 80/100, or 80%. Recording other information that might help to understand the cause of death will help identify alternative strategies that might increase survival rates in the future. For example, was the site too wet or dry for the selected species? Is there brush or grass competition? Did deer, elk, or beaver damage the plant? Answers to these questions will help with future riparian restoration decisions.

7. Landform: For each measured tree/shrub or plot document the landform it is growing on:
    - LT – low terrace
    - HT – high terrace
    - HS – hillslope
    - BF – within bankfull width
    - EB – on a vertical or steep eroding/erodible bank
    - BG – Bog
    - AC – abandoned channel
    - Other: describe

8. Animal Damage: Using the codes provided in Appendix 5-B, document the animal (if known) and the animal damage on each measured tree/shrub.

9. Observations/Notes: Describe your observations. For example: "Most of the plantings survived. Those that died were Douglas-firs planted in a depression that is boggy."

Data Summary Ideas: Riparian Planting

- Trees/acre: overall and by species
- Shrubs/acre: overall and by species
- % Survival: overall, by species, by landform, by distance from stream
- Percent of seedlings by species and distance (Figure 5-6)
- Shrub stem class: number of shrubs in each stem class
- % Animal damage by source

Figure 5-5. Level II Example plant survival field form.

Plant Survival and Herbaceous Monitoring

Site Name:	Description of Location: GPS (plot stake or post) or Legal:
Plot Number:	
Project Contact:	Date:

Monument Information: Description of what it is and how many:
Monument Location: Description of where it is and how to get there:

Monument Label: Site Name_____ Plot Number_____
GPS Coordinates:
Witness Trees or Features: Description of what they are and label Information: Site Name____Plot Number____,
Tree Number_____Species____Bearings to Monument____Slope distance to Monument_____
Tree Number____ Species____ Bearings to Monument____Slope distance to Monument_____
Tree Number____ Species____ Bearings to Monument____Slope distance to Monument_____

Project Comments: For example: Fence Conditions, restoration or management activities, etc.

Tree or Shrub	Species	Height/ Hgt. Class	Live Or Dead	Cause of Death	Diameter/ Stem Class	Landform	Brush Compet.	Grass Compet.	Animal Damage	Herbaceous Community Type	Herbaceous Height	Herba-ceous % cover

Figure 5-6. Relative seedling species abundance at 6, 15, and 25 meters from the stream for five Coastal streams. High variability between plots decreased certainty in results and precluded strong conclusions about regeneration trends in the Coast Range in this 1999 ODF study.

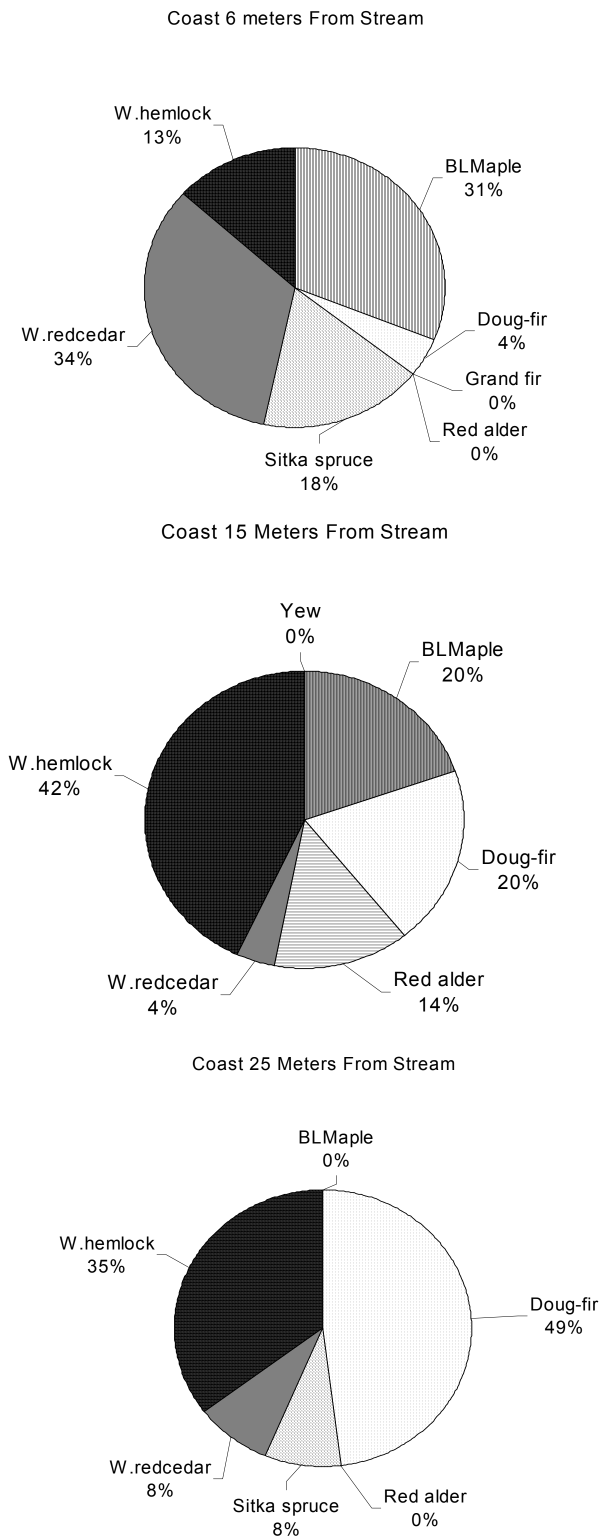
Western red cedar, and bigleaf maple were the most common seedlings within 6 m of the stream, but Sitka spruce and western hemlock were also present. Other species occurred in such low numbers to preclude certainty about trends.

↓

Western hemlock becomes more common and western redcedar disappears around 15 m from the stream.

↓

Management farther away from the stream (25-30 m) favors Douglas-fir. Bigleaf maple and red alder drop out as a result of "brush" control measures.



Herbaceous Community

If a restoration project is intended to protect grasses and forbs from grazing, the investigator may want to monitor "stubble height" along with the shrub and tree measurements and project documentation described above.

Measurements include but are not limited to:

Herbaceous Vegetation Community Type: Grass, sedge, or forb.

Herbaceous Vegetation Height: For each community type record the height in inches.

Percent Cover: Percent of the ground covered for each community type.

Fence Condition: If applicable, survey the condition of the fence by walking the length and noting existing or potential breaches.

Shrubs: Some range management strategies are designed to re-establish shrubs and hardwoods. Incorporate shrub measurements as described in # 1-4 above ("Riparian Planting Projects").

Herbaceous surveys are most efficiently measured in small plots. Circular plots or greenline transects are most commonly used (Appendix 5-A). Record the average height of grasses, sedges, and forbs within plots. For example, consider establishing multiple, small, circular plots to measure stubble height along the centerline of rectangular plots used to measure shrubs and trees, or measure along 1 m of each side of a linear transect that runs parallel to the stream.

Data Summary Ideas: Livestock Utilization

- Calculate the average stubble height by plant community type.
- Calculate the overall average stubble height.
- Calculate the numbers of shrubs per acre

Other Riparian Structure and Plant Ecology Parameters

This section describes some additional data collection parameters that will further describe riparian structure beyond questions of tree and shrub establishment. These types of data combined with data in the previous section can describe the ecology and structure of riparian areas, overall health and vigor, and wildlife habitat. Consider the use of a field data form such as the one in Figure 5-7. Additional measurements can include but are not limited to:

Tree Diameter: Measure the diameter at breast height (DBH). DBH is always 1.3 m (4.5 feet) above the ground, measured from the uphill side of the tree. Consider setting a lower limit of DBH, below which DBH is *not* measured (e.g. do *not* measure DBH on trees with <15 cm DBH). Instead capture these in a tally in regeneration plots.

Live Crown Ratio: The percentage of the tree's height with live branches and leaves, expressed as a ratio of the length of the tree *with* a live crown to the total length of the tree. Use the same procedures described in Appendix 5-B for measuring height, and use the same subset of trees for which height is measured as described in the appendix.

Data Summary Ideas: Riparian Structure and Ecology

- Number of snags/acre by size class
- Percent shrubs, grasses, sedges and forbs/acre by species
- Percent canopy cover
- Noxious weeds/acre
- Species Distribution: overall, hardwood and conifer by distance from stream (Figure 5-8)
- DBH: Distribution by size class (Figure 5-9), mean, average, median, minimum, maximum overall, by species and/or distance from stream

What is the current and future delivery potential of large wood into stream channels, given the current location, type, and size of riparian trees in the Cow Creek watershed?

To answer this question: collect tree data as described in Level II (species, height, diameter and distance from stream) throughout the watershed. Stratify the sample to collect data in different riparian stand, channel and valley types. These data can be used to predict the probability of a tree to fall into the stream. More complex models can account for mortality and disturbance mechanisms such as insect and disease, wind, flood and fire. Of key interest is the percent of recruitment comprised of hardwood versus conifer species and diameter distributions.

Snags: Document if the snag is a conifer or hardwood (document species if discernable). Measure the diameter (at 1.3 m above the ground) and height of every snag in the entire treated riparian area or plot. Snags are unevenly and sparsely distributed throughout riparian areas, so small sub-sampling designs risk in-accurately representing snag presence and numbers. Document the decay class:

Decay Class:
1 = dead but fully intact, with bark, dead or dying needles
2 = extensive decay but with bark and holds form
3 = cannot hold form (elliptical shape begins), no bark, can be broken through

Distance from Stream: Estimate the distance to the active channel for each tree, shrub, and snag. If plots were used for shrubs, then use the same plot distance for all the shrubs in that plot.

Noxious Species: Document species and percent of plot or treated riparian area with noxious ("weed") species. Noxious and invasive species lists can be attained from a local NRCS office or the NRSC web site: (http://plants.usda.gov/).

Downed Wood: Identify volume per acre and decay class. The challenge in accurately representing downed wood in a riparian area is similar to that of snags. The distribution is generally erratic and therefore systematic approaches may not accurately represent wood loading. However, 100% surveys of downed wood are not economically feasible. Therefore, the following measurements are taken along linear transects. For any downed wood that crosses the transect measure the:

- Diameter at the intersection with the transect line (inches or centimeters)
- Large and small end diameter (inches or centimeters)
- Length (feet or meters)
- Species: Use tree species codes. If species cannot be identified, then classify as hardwood or conifer
- Decay Class: As described above

Canopy Cover: Using a densiometer or other repeatable method measure the percent canopy cover in each plot or along the transect at systematic intervals (refer to the "Shade and Canopy Cover" chapter in OWEB's *Water Quality Monitoring Guidebook (*1999*)* for more on cover and shade measurements).

Percent Impervious Area (if in an urban environment): This is usually accomplished through interpretation of aerial photography or other remote sensing. The objective is to quantify the percentage of ground cover occupied by impervious surfaces (houses, pavement, and other areas) in comparison to the percent of area occupied by vegetation, soil and other natural cover features.

Figure 5-7. Level II: Example riparian structure field form.

Riparian Monitoring

Site Name:	GPS (plot stake or post)				
Plot Number:	Description of Location				
Date:					

Monument Information: Description of what it is and how many:
Monument Location: Description of where it is and how to get there:

Monument Label: Site Name_____ Plot Number_____
GPS Coordinates:
Witness Trees or Features: Description of what they are and label Information: Site Name____Plot Number____,
Tree Number_____ Species____ Bearings to Monument____Slope distance to Monument_____
Tree Number____ Species____ Bearings to Monument____Slope distance to Monument_____
Tree Number____ Species____ Bearings to Monument____Slope distance to Monument_____

Comments:

Tree, Snag, Shrub	Species (Code)	Height/ Hgt. Class	Live Crown Ratio	Diameter or Stem Class	Distance From Stream	Landform	Percent of plot covered (for shrub or herb component)	Noxious Weeds (% of plot Cover)	Cover (%)

Figure 5-8. Dominant riparian overstory vegetation versus distance from stream for a small stream in the Siskiyou georegion. Basal area represents the cross-sectional area of the tree at DBH (1.3 m or 4.5 feet) from the ground. Hardwoods are more common within the first 10 meters of the stream, whereas conifer species are more common from 10 meters to 30 meters from the stream (ODF 1999).

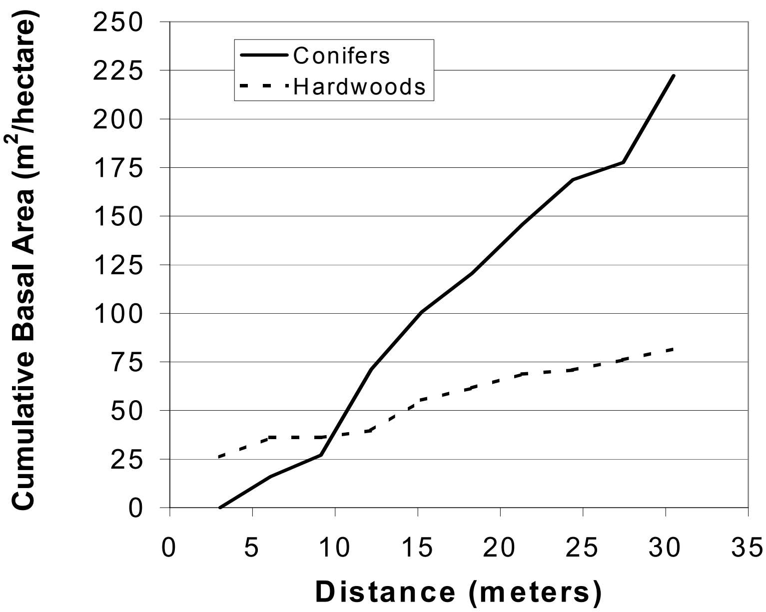
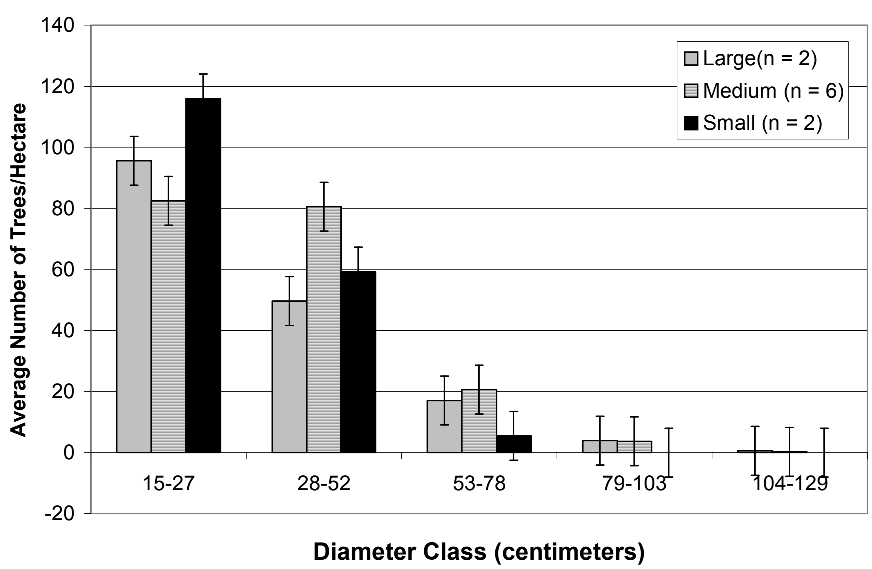


Figure 5-9. Number of trees per hectare within each diameter class for small, medium, and large streams (ODF 2002). Notice the greater error (vertical error bars on each box) associated with the smaller sample of larger diameter trees.



LEVEL III: MONITORING EFFECTIVENESS OF RESTORATION PROJECTS

Goal

- Determine if projects are achieving restoration goals.

It is important to understand whether the restoration and management practices are meeting intended goals. Some goals will be met within a few years, while others may take decades. Regardless of the response time, it is critically important to establish baseline conditions before (pre-treatment) and immediately after treatment (post-treatment).

"Pre-treatment" data provides a measure of the baseline conditions. An evaluation of changes due to the management or restoration can be compared to the baseline condition to determine if the activity has had the desired effect. Baseline conditions can vary between years due to factors other than the management activity. So consider adding a control reach or multiple pre-treatment data collection years. Once these baseline conditions have been established, the frequency of follow up data collection will depend on the management goal. For example, if the goal was to reduce summer stream temperature within ten years, then investigators should consider monitoring summer stream temperature for 1-2 years prior to treatment, immediately following treatment, and for each year for ten years thereafter. The key is to establish a systematic interval following treatment (e.g. temperature every summer, shade every 3 years, tree/shrub planting surveys every 2 years, overstory surveys every 5 years).

A wide range of environmental factors can influence water quality and fish habitat, many of which may originate upstream of the restoration project. Caution should be used in implementing and interpreting results at a reach scale. What follows is a brief discussion of common functions for which riparian areas are typically managed.

Stream Temperature and Shade

Riparian function and structure are closely linked with instream habitat quality. In some cases the management goals in and around the riparian area are geared towards promoting or restoring high quality fish habitat. In particular, there has been a tremendous focus on the role of riparian vegetation in promoting shaded streams and associated cool stream temperatures. If the monitoring project goal is to determine whether a riparian restoration project is increasing shade and decreasing stream temperature, then it makes sense to monitor shade and stream temperature in concert with the riparian vegetation. The *Water Quality Monitoring Technical Guidebook* provides guidance on stream temperature, shade and cover field methods.

As described above, monitoring should ideally begin prior to management or restoration. Place temperature probes in the stream at the upstream and downstream ends of the treated reach and take the appropriate vegetation measurements as described in this chapter. Measure the shade or cover as described in Chapter 14 of the *Water Quality Monitoring Technical Guidebook*. Repeat these vegetation, shade, and temperature measurements at the same time of year, following the same procedures, after management or restoration activities have taken place.

Repeat on an appropriate interval thereafter. Repeat samples, for example, can be conducted every year, every other year, or every third year. (Note: shade is also a function of aspect, so document the stream aspect as well.)

Did the restoration project along Oak Creek result in increased shade and decreased water temperatures?
Collect data as described in levels I, II, & III. Compare shade and stream temperature before the treatment to shade and stream temperature after the treatment.

Channel Morphology and Hydrology

Riparian ecosystems interact with a stream's fluvial processes, which contribute to the channel shape and profile. The goal of restoration may be to reestablish channel characteristics that will improve the hydrologic and sediment routing function of the site. There are many approaches to evaluating channel morphology, some of which are based on fish habitat units (ODFW Aquatic Habitat Inventory, Moore et al. 1999) while others simply use a systematic approach (e.g. every 30 meters, Rosgen 1994). Below are some examples of channel morphology parameters of interest that can be collected systematically to determine whether the restoration project is Peck et al. 2000 and Kaufmann et al. 1999 for detailed data collection descriptions.

Wetted Width: Using a surveyor's rod or tape, measure the width of the wetted surface, subtracting mid-channel point bars that are out of the water. When monitoring wetted width, investigators should ensure that the stream discharge is the same for every monitoring event. At the very least, investigators should keep track of the stream discharge so they know how it relates to changes in wetted width over time.

Channel Profile Surveys: These are surveys of a cross-section of a channel. The bankfull width, amount of channel incision, bank stability condition, and thalweg depth are four particular geomorphic features that can be monitored with profile surveys. Profile surveys can be done with a rod and level, a transect, or even with a tape and compass. Make sure to start the survey at least 7.5 meters above the bankfull part of the channel, so that a stable reference point for future monitoring will be established.

Data Analysis Ideas: Effectiveness Question

- Temperature versus shade
- Difference in shade or cover after treatment (See Figure 5-10)
- Channel profiles and bank stability over time
- Shade versus riparian characteristics (tree height, trees/acre, or shrubs/acre)
- Pre- and post-project stream temperature comparisons

Long Channel Profile: A long channel profile is a survey of the deepest part of the channel along a reach of stream. These profile surveys use the same types of equipment as for channel profile surveys. The gradient of the channel can be determined using this method. Gradients for short reaches of stream (less than approximately 60 meters) can be measured with a clinometer. One person stands at the top of a riffle or pool and another person at the top of an upstream riffle or pool. The downstream person looks upstream through the clinometer aiming at the other person. Long channel profiles are also valuable for looking at changes in lateral movement of a stream and in establishing the location and type of stream bars and other sediment deposits.

Substrate: Estimate the percent of channel bed composed of each size class of material (Bedrock, bolder, cobble, gravel, sand or fines).

Sinuosity: Length of stream miles compared to horizontal miles. Measure the actual stream length by walking the middle of the channel with a hip-chain between two obvious landmarks that can be picked out of an air photo. Measure the distance between the starting point and the ending point on a map or air photo. Sinuosity is the ratio of the distance to the channel length.

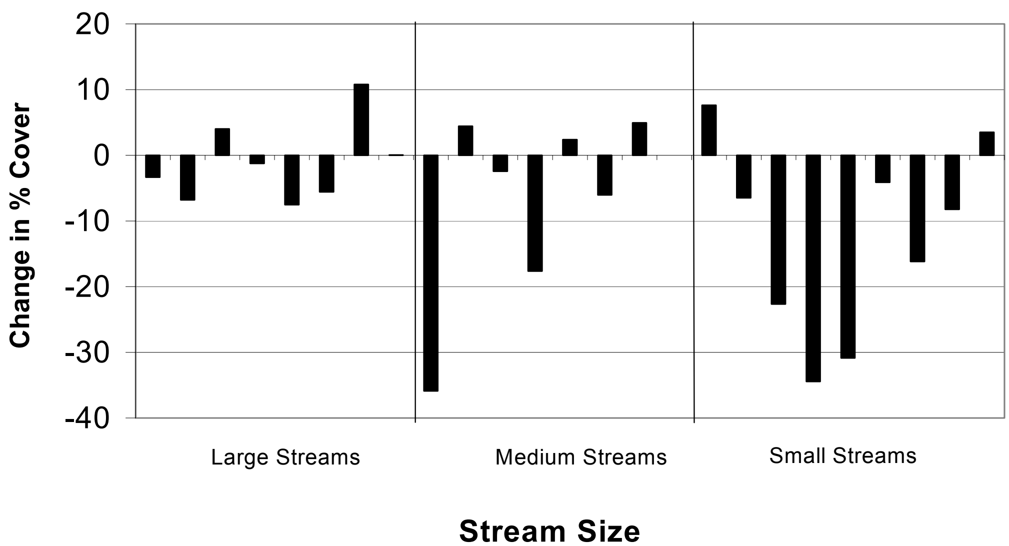
Bank Stability Monitoring: As described above, bank stability can be measured by doing channel cross sections. These can be compared over time to detect significant lateral or vertical movements of a channel. Stability can also be assessed by comparing the bank morphology to that expected for the given stream type, and by identifying actively eroding areas (areas devoid of living vegetation and/or areas with tension cracks, gullies, rills, slumps, and slides). Bauer and Burton (1993) provides information on how to compare streambank morphology to that expected for a given stream type.

Refer to the ODFW Aquatic Habitat Inventory methods for a fish habitat-based approach (Moore et al. 1999).

Biotic Response

Commonly, the goal of riparian restoration is to improve water quality and riparian function so that the aquatic biota will flourish. If biotic response is a goal of a restoration project, investigators should consider evaluating the biotic response as part of the project. Chapter 12 of the *Water Quality Monitoring Technical Guidebook* provides detailed protocols for evaluating macroinvertebrates. Contact local ODFW Fish biologists for information on monitoring fish.

Figure 5-10. Change in cover after forest harvest for small, medium and large streams. The measures were taken with a densiometer, an instrument with a measurement error of approximately 10%. The only statistically significant differences between pre- and post-harvest cover were on small streams (paired t-test, p-value = 0.03)(ODF 2002). The results suggest that reduction in cover associated with harvesting are the largest for small streams, mixed for medium streams, and non-detectable for large streams.



SHARING INFORMATION

The benefits of data sharing are well accepted. The challenge is structuring the data collection effort to maximize data sharing opportunities. Different project goals ultimately lead to unique data needs, but opportunities often exist to share portions of the data with others. Investigate who might be doing similar work and whether a few additional data collection parameters can be gathered for each project to allow for data sharing. Coordination and cooperation can pay off.

Chapter 3 discusses the importance of considering scale in the study design. A thoughtful design that blends field data collection with remote sensing data collection can yield an understanding of riparian condition at scales beyond the reach being monitored in the field. This notion is often referred to as "scaling up" (i.e. taking what is learned at a reach scale and applying it to a watershed scale) and "scaling down" (i.e. taking what is learned at a watershed scale and relating it to what is known at a reach scale). In this way, the two different scales of data collection (fine and broad) can be applicable to the opposite-scale question. For example, field data can be used in concert with remote sensing data to increase confidence in the accuracy of the remote sensing data. Conversely, the relationship between the fine and broad scales can be used to extrapolate riparian characteristics at a reach scale to the watershed scale.

Fine-scale data are essential in remotely sensed applications to ground-truth data for accuracy assessments. (See Chapter 6 for more on remote sensing). Fine-scale data can also stand alone to make assessments over large areas if the data are selected with a statistically rigorous design. An example of this is Oregon Plan for Salmon and Watershed's use of reach-scale data to make regional-scale assessments of status and trends (Stevens 2002).

Another important use of fine-scale data is to test and identify interactions and relationships between resources. For example, relating large wood to pool formation, shade to stream temperature, or either of these data to anadromous fish distribution or abundance.

These fine-scale data can be used to test existing or new hypotheses about how we think resource components interact. Providing contextual information such as stream size, channel type, inherent landscape characteristics, current and historical management practices helps identify the population for which the identified relationships are valid.

On the flip side, broader-scale data collected over large geographical areas can be useful for narrowing the area of interest and sorting the data into rough classes. For example, there is no reason to send a crew out to sample a riparian area if no riparian vegetation exists. Higher-resolution photos are also useful in stratifying sites for field visits. They can be used as a first cut to differentiate areas where plantings are vigorous versus struggling. If resources are scarce, such photos may be used to replace site visits or be used in off years.

Common Data Parameters that may broaden the application of reach scale data:

- ✓ Stream size
- ✓ Channel type
- ✓ Geology
- ✓ Soils
- ✓ Watershed area above reach
- ✓ River mile (RM)
- ✓ Current management
- ✓ Historic management
- ✓ Dominant riparian species
- ✓ River or fifth field watershed name

Appendix 5-A: Vegetation Sampling Plot Designs and Layout Techniques

Assuming the investigator does not have the time or resources to measure all the vegetation within the riparian area of interest, a sub-sample of the riparian area can be measured in plots that will depict the overall characteristics. In general, riparian characteristics vary in two ways: 1) in relation to the distance from the stream, and 2) longitudinally as the stream flows from high elevation to low elevation. For example, overstory and brush species nearest the stream can differ markedly from overstory and brush species farther away from the stream. Likewise vegetation near the stream's headwaters may be dominated by conifers, while vegetation at lower elevations may be more diverse with willows, grasses and sedges. Therefore, part of the sampling design should capture the gradient from the stream's edge upslope. If you are sampling throughout a basin, be sure to sample in the different vegetation community types along the elevation gradient. Another consideration is the area immediately paralleling the stream, often referred to as the "Green Line." A sampling design oriented parallel to the stream is important for capturing characteristics of this critical area. Currently, three common plot designs are employed: (1) circular plots, (2) rectangular-shaped plots, and (3) linear transects. These designs should be distributed (circular), or oriented (rectangular), in such a fashion that they capture both the gradient away from the stream (perpendicular to flow) and the characteristics that parallel the stream.

Circular Plots

Circular plots can be placed randomly or systematically within the riparian area. Another option is to randomize the placement of the first plot and then systematically place all subsequent plots. Plot centers should be placed such that plots do not overlap or straddle the stream. Circular plots can be placed systematically along lines that run both perpendicular or parallel to the stream.

Methods to establish the circular plot:

1. Monument the study reach at a visible location as described on the next page. Record the monument location and how to access on the data sheet.

2. Drive a stake or fence post in the ground at the center point of the plot, spray paint it and tie flagging to it. Record the site name and plot number on flagging and record on data sheet. Monument each plot as described on the next page.

3. Fix one end of a measuring tape to the plot center. If two investigators are available, one person can stand in the middle and hold the tape over the stake.

4. Holding the other end of the measuring tape at the chosen radius, travel in a circle around the fixed center point. Measure or tally the characteristics of trees and/or shrubs as you travel the edge of the circle for all trees and/or shrubs within the circle. The radius will vary depending on the objectives. Trees must have at least 1/2 of their diameter within the circle to be measured. A 4 m radius is recommended for small trees (e.g. less than 10-15 cm DBH), and 4-8 m radius is recommended for shrubs and large trees. In general, the larger the DBH or shrub, or greater the tree spacing, the larger the radius required to capture a desirable sample.

5. Once you have established a few plots, you can usually visualize the circular plot dimensions and only measure those trees or shrubs that are near the outside radius.

RECTANGULAR OR SQUARE PLOTS

This method establishes rectangular plots *perpendicular* to the stream course. The length and width of the rectangle can be set to meet the needs of the monitoring project. Measurements are taken on all trees and shrubs that are within a fixed distance of each side of the centerline of the rectangle. Thus, if measurements are taken within 15 meters of each side of a 30 meter long centerline, the transect is 30 meters wide and 30 meters long (900 square meters = 0.1 hectares).

Methods to establish the transect:

1. Randomly place and monument the first transect within 30 meters of the upstream or downstream boundary of the study reach, and record this distance on the field data sheet. The remainder of the transects will be evenly spaced throughout the study reach on both sides of the stream.

2. Permanently mark subsequent transect locations so they can be seen from the stream (Nail aluminum tags to a tree such that it can be seen from the stream, or drive a wooden stake or metal fence post into the bank).

3. Mark the study reach location on the map. If you have a GPS unit, take a reading at the stream's edge and record the reading on the field data sheet.

4. Determine the azimuth that is 90° (perpendicular) to the **valley** azimuth. This is the orientation of the transect centerline for **all of the transects**. For example, if the compass azimuth reads 40° when facing downstream, the stream runs from southwest to northeast. The centerline of the transect will run to the northwest, (azimuth of 120°).

5. Tie off the hip chain and begin walking away from the channel along the perpendicular azimuth (e.g. 120°). Continue to stay on the correct orientation by referencing your compass frequently.

6. Tie flagging at a fixed interval (e.g. every 8 meters) and label the flagging accordingly (Transect # 1: 8 m, Transect #2: 16 m, etc.). This flagging can be used to estimate distance from stream channel of measured trees, shrubs or subplots. The length of the centerline will vary depending on the monitoring objectives and width of the treated area. A minimum width of 30 meters is recommended for forested environments.

7. Correct slope distance to reflect horizontal distance. Most forest mensuration techniques require correcting

Monument Site and/or Plot

A variety of ways exist to "monument" a site. The goal is to use or install a "permanent" feature as a marker for the site or plot and establish repeatable means to find it in the future. This requires accurate descriptions and records of the monument. For example:

Establish the monument at either the upstream or downstream edge of the study area, in an area easily found on return visits (e.g. highly visible from stream or road) and record location on data sheet. Pound rebar into the ground so that approximately 1/3 m remains exposed and cover with a PVC pipe. Label the PVC with the site name and plot number. Record coordinates of the site monument with GPS equipment as well as a general description of how to get to the monument. These monuments can also be established at each plot if practical. If 1/3 m of exposure is not practical because of management activities, then decrease the height accordingly.

In addition, if possible, establish and tag three trees or (other obvious feature) near the monument as witness trees. If the trees closest to the monument are small and/or apparently in poor health, larger, vigorous trees farther from the monument may be used as witness trees. Tag witness trees at breast height with aluminum tags labeled with the site and plot identifiers and tree number (1, 2, or 3). Record tree number, site number and species. Also measure and record the bearings and slope distances from each witness tree to the monument.

slope distance to reflect horizontal distance such that all plots measure the exact same area as represented on a flat projection (e.g. map or air photo). This can be done in the following manner. Every time there is a change in the gradient of the hillslope, measure the gradient in degrees using a clinometer, and record slope and distance traveled on field data sheet. (For example, 0-10 m, 3°; 10-30 m, 15°). Convert slope distance to horizontal distance at each change in slope, and/or as you approach 30 m (100 feet) ($y = \cos\theta x$; where y = horizontal distance, θ is the slope angle in degrees, and x is the slope distance). Once you have traveled 30 horizontal meters (100 horizontal feet), mark the end of the transect with a labeled double flagging (e.g. "End Transect #4").

8. Transect Width. The transect width will vary depending on the monitoring objectives. The width is established by taking measurements within a fixed distance on each side of the centerline. Consider 15 m on each side of the centerline, for a total transect width of 30 m, is recommended for large diameter, overstory vegetation. For shrubs, grasses, and forbs the measurements can be taken in smaller bands (within 1 m of each side of the centerline) or in 4-8 m radius circular plots centered on the centerline of the transect. These circular plots should not overlap.

9. Repeat steps 2 through 8 to establish subsequent transects using the same azimuth as the initial transect. The number of transects needed will vary depending on the variability of the site conditions. The more variable the conditions, the more transects that will be needed.

10. Data collection within transects: overstory species can be measured within broad widths (15 m on each side of the centerline). Shrubs, grasses, forbs, and young trees, can be measured along narrower widths (1 – 3 m on each side of the centerline) or in circular plots established along the centerline of the rectangular plot. Downed wood that intersects the centerline can be measured.

GREENLINE TRANSECTS

NOTE: In order to maintain consistency with the scientific literature and common forest industry use standards, dimensions and formulas for greenline layout techniques are provided in English units instead of metric.

Established methodologies commonly refer to the use of "greenline" transects (Winward 2000, Bauer 1993), particularly for meadow or shrub dominated riparian areas. A greenline transect is basically a long, narrow rectangular plot established parallel to the stream. The greenline is commonly located at or near the bankfull stage. However, the location will vary depending on channel condition. Winward (2000) describes this variability in the following way:

> "*As flows recede and the vegetation continues to develop summer growth, [the greenline] may be located part way out on a gravel or sandbar. At times when banks are freshly eroding or, especially when a stream has become entrenched, the greenline may be located several feet above bank-full stage.*"

Greenline Transect Location: These can vary, but generally they are sited at or near bankfull. The greenline transect should not cross plant community types (e.g. Community Type 1: Cottonwood, Community Type II: Willow/grass.)

Greenline Transect Length and Width: The area sampled should approximate a 1/10 acre plot (4,356 square feet). If you are only sampling one side of the stream, then the transect should be 726 feet long by 6 feet wide, which approximates a 1/10 acre plot (Windward 2000). If the treated reach or reach of interest is shorter than 726 feet, increase the width such that the resulting area sampled (Width X Length) is 4,356 square feet. If sampling both sides of the stream, the transect should be 365 feet long and 6 feet wide on each side of the stream. Remember you need a new greenline for each plant community type.

Measurements Along the Greenline: The greenline is the centerline of the plot. All small trees, and shrubs within 3 feet of each side of the greenline are measured. Average height of grasses, sedges and forbs within 12 ft.-radius, circular plots (10 evenly distributed along the greenline) is recorded. Downed wood that intersects the greenline can be measured. Downed wood should also be measured on a line farther away from the stream and lines perpendicular to the stream.

Appendix 5-B: Measuring Tree Heights and Live Crown Ratio

Measuring tree heights of trees taller than 10-15 m can be time consuming. What follows is a description of how to collect data using a clinomter and measuring tape. If the resources are available to purchase a rangefinder or laser rangefinder, the measuring process can be less time consuming.

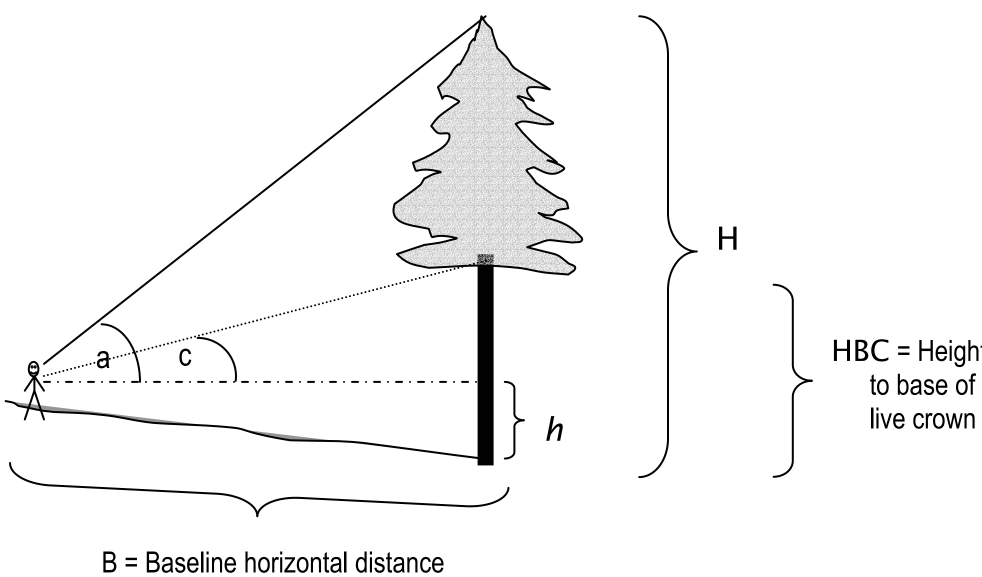
HEIGHT MEASUREMENTS

Heights can be measured on a subset of trees within each tree species in established diameter classes rather than for every tree. For example, measure 10 trees within each species in the following diameter size classes: 15-25 cm; 26-50 cm; 51-75 cm; etc. Measure the first tree you encounter for each species and each new diameter size class until you have reached the target (e.g. 10 trees per diameter class). Calculate all heights at each tree in the field so that accuracy can be immediately checked. Tree height is calculated from the collected information with the following relationship:

$$H = h + B*\tan(a)$$

Where (see drawing):

- H = height of the tree
- B = Baseline distance between the tree and your eye along a horizontal trajectory (measure with tape or rangefinder)
- h = height at which the baseline is established (estimate or measure with tape or rod)
- a = angel in degrees between the horizontal baseline and the top of the tree (using a clinometer or rangefinder and aim at the top of leader for conifers or to middle of crown for hardwoods, where branches begin to divide significantly.)



<u>Calculating Live Crown Ratio:</u>

If this is to be calculated, an additional height, to the base of live crown (HBC) is needed:

$$HBC = h + B*\tan(c)$$

Where (see drawing):

- HBC = height to the base of the live crown
- B = Baseline distance between the tree and your eye along a horizontal trajectory (measure with tape or rangefinder)
- h = height at which the baseline is established (estimate or measure with tape or rod)
- c = angle to base of live crown (use a clinometer or rangefinder and aim at a point on the tree trunk where the lowest live branches originate.)

The live crown ratio, measures the relative proportions of the live crown to the total tree height. It is calculated by subtracting the height to the base of the live crown from the total tree height. Then divide this number by the total tree height. For instance, if a tree is 30 meters tall, and the height to base of the live crown is 20 meters, then 10 meters of the tree has live crown, or 30%.

$$30 \text{ m} - 20 \text{ m} = 10 \text{ m}$$
$$10 \text{ m} / 30 \text{ m} = 0.3 \text{ m}$$

A tree with less than 30% live crown is considered to have poor vigor.

Appendix 5-C: Field Data Collection Codes: Trees, Shrubs, and Animal Damage

When documenting tree species, shrub species and animal damage, use consistent nomenclature and codes. Examples are provided in Table D-1, D-2, and D-3. Other species and codes can be found at http://plants.usda.gov/

Table D-1. Conifer and hardwood tree codes and common names.

Code	Common name Conifers	Code	Common name Hardwoods
ABAM	Pacific silver fir	ACGL	Rocky Mountain maple
ABCO	white fir	ACMA3	bigleaf maple
ABGR	grand fir	ALIN2	mountain alder
ABLA	sub-alpine fir	ALRH2	white alder
ABMAS	Shasta red fir	ALRU2	red alder
ABPR	noble fir	ALSI3	Sitka alder
CADE27	incense cedar	ARME	madrone
CHLA	port orford cedar	BEOC2	western birch
JUOC	western juniper	CACH7	chinquapin
JUSC2	Rocky Mt. juniper	CONU4	Pacific dogwood
LAOC	western larch	FRLA	Oregon ash
PICO	lodgepole pine	LIDE3	tanoak
PIEN	Engelmann spruce	MYCA	myrtle
PISI	Sitka spruce	POTR5	quaking aspen
PIJE	Jeffrey pine	POTR15	cottonwood
PILA	sugar pine	PREM	bitter cherry
PIMO3	western white pine	PRVI	chokecherry
PIPO	ponderosa pine	QUGA4	Oregon white oak
PSME	Douglas-fir	QUKE	California black oak
SESE3	coast redwood	RHPU	cascara
TABR2	Pacific yew	SALIX	willow
THPL	western redcedar	**Snag Types**	
TSHE	western hemlock	CNS	conifer snag
TSME	mountain hemlock	HDS	hardwood snag

Table D-2. Shrub codes and common names.

Code	Common name	Code	Common name
ACCI	vine maple	RHCA	coffeeberry
AMAL2	serviceberry	RHDI6	poison oak
ARCO3	Columbia manzanita	RHMA3	Pacific rhododendron
ARTRT	basin big sagebrush	RHOC	western azalea
MANE2	dwarf Oregon grape	RIAU	golden current
CACH7	chinquapin	RICE	squaw current
CECU	buckbrush	ROSA5	rose
COCO6	hazel	RUDI2	Himalaya blackberry
COST4	creek dogwood	RULA	evergreen blackberry
CRDO2	black hawthorn	RUPA	thimbleberry
GASH	salal	RUSP	salmonberry
HODI	oceanspray	SALIX	willow
LIDEE	tanoak (shrub)	SANIC5	blue elderberry
OPPO	devils club	SARA2	red elderberry
PHMA5	ninebark	SPDO	spiraea
POMU	sword fern	SYAL	snowberry
PRSU2	klamath plum	UMCA	California laurel
PUTR2	bitterbrush	VAME	thinleaf huckleberry
QUSA2	Sadler oak	VAOV2	evergreen huckleberry
QUVA	huckleberry oak	VAPA	red huckleberry

Table D-3. Examples of animal and damage codes.

Animal	Code	Damage	Code
Beaver	BV	browsed	BR
Domestic Ungulate (cow, sheep, etc.)	DU	severed	SV
Wild Ungulate (Deer, Elk)	WU	uprooted	UR
Rodent	RD	bud collar damage	BC
		girdling (bark removed from lower stem)	GI
Unknown	UK	broken leader	BL
Others		crooked leader	CL
		diseased leader	DI
		dead top	DT
		multiple leaders	ML
		pushed over or leaning	PO
		weed eater or machine damage	WE
		trampled	TR
		wind burn or breakage	WI

Chapter 6: Remote Sensing Data

Introduction

The purpose of this chapter is to provide information on the use of remote sensing imagery for assessing and monitoring riparian conditions. The term "remote sensing" is broadly used to refer to any data collection method where the observer is not in direct contact with the observed. The emphasis in this document will be on photographs, videos, or imagery collected via airplane or satellite.

The methods are described in terms of their usefulness for characterizing the status of, and detecting trends in, riparian conditions. The science of remote sensing is rapidly evolving as higher spatial and spectral resolution sensors are deployed and methods of analysis are improved. The focus of this discussion is on existing or well-tested methods. The description will not cover new remote sensing platforms, sensors, or methods. Because of rapidly changing technology, changes in costs and availability of data, and a wide range of potential applications, the focus of this chapter is on describing useful remote sensing methods and not recommending one approach.

Several completed studies demonstrate the wide range of applications and methodologies for mapping riparian areas. These studies highlight the need to select methods that address the questions being asked and also provide examples of creative applications. Researching the literature and documentation from past projects can provide methods to address the objective of your study and allows you to learn from other's experience. The studies highlight the need to match the spatial resolution of the data to the question being asked, to make sure that temporal variability is accounted for and capitalized on, and where possible to limit the analysis to the riparian area to minimize the confusion with non-riparian cover types.

Remote sensing data examples and sources of current and historical aerial photography can be found in Appendix 6-A, *Examples of Using Remote Sensing Data for Assessing Riparian Characteristics.*

Why use remote sensing to characterize riparian areas?

By providing a method to capture riparian conditions over large areas and through time, remote sensing enhances the ability to conduct some riparian assessments. The potential advantages of monitoring riparian areas with remotely sensed data over traditional field surveys include: 1) economy, 2) timeliness, 3) favorable viewing perspectives, 4) synoptic observation, and 5) creating a permanent photographic and/or digital record (Roller 1977).

Using traditional field methods to assess riparian conditions over time and large areas can be prohibitively expensive and difficult. Remote sensing data provide a permanent record of conditions, which can be reevaluated to answer additional questions in the future or in the context of other information. Photographic and digital archives can provide historical sources for remote sensing images. For many parts of Oregon, historical aerial photography (beginning in the 1930s) and satellite imagery (beginning in the 1970s) are available. Figure 6-1 shows aerial photography for a riparian area in 1944 and again in 2000. In addition, digital, geo-referenced remote sensing data can be used in conjunction with other spatial data sets, such as information on stream channels and road networks. The use of Geographic Information Systems (GIS) can help interpret riparian data or look for spatial relationships.

Coupling traditional field methods with remote sensing data is essential for the correct interpretation of digital imagery or aerial photography. Riparian field data also provide investigators the ability to extrapolate finer-scale information (for example, plot data) to larger spatial scales (for example, watersheds or regions). Ideally, field data should be collected concurrently with remote sensing data, although that is not often possible or may create logistical difficulties (Lee and Lunetta 1995).

ISSUES TO CONSIDER

The suitability of remote sensing methods is highly dependent on the spatial scale, size and contrast of the riparian features being examined. The application of remote sensing techniques will vary depending on riparian assessment objectives at the reach, watershed, or regional scales. Within each of these spatial scales, the size of the features to be resolved (for example, the width and length of the riparian area) is a major determinant in the selection of an appropriate remote sensing technique.

Figure 6-1. Aerial photographs of the McKenzie River and associated riparian area near Springfield, Oregon, 1944 and 2000 (Alsea Geospatial 2000). The 1944 aerial photograph courtesy of the University of Oregon's Map Library.

Contrast, which is a criterion investigators can use to determine the suitability of different remote sensing methods, is based on the inherent characteristics of the landscape. For a forested landscape, the inherent characteristics for contrast include the size of tree crowns, canopy roughness, number of species within vegetation types, shape and extent of patches in a forest type, spectral contrast with the matrix around the forest type, and heterogeneity produced by patchiness within the forest type (White and MacKenzie 1986). Because of these factors, no one remote sensing scale or resolution will be perfect for even a single vegetation mapping goal. These examples hold true for riparian areas in non-forested areas, as well. In addition, delineating a forested riparian area in a forested region is more difficult than in an agricultural, urban, or rangeland environment.

Riparian Assessment Indicators

Understanding the characteristics of the riparian area to be assessed is important before determining the usefulness of various remote sensing methods. Three useful biological indicators for assessing riparian areas are (Barker et al. 2000):

1. The degree of tree canopy closure over the stream and adjacent riparian forest.

2. The size and amount of vegetation in the riparian corridor including tree-size classes, deciduous and conifer tree cover proportions, and shrub and herbaceous vegetation cover.

3. The number and size of conifer and deciduous snags.

Some remote sensing techniques are better suited for collecting information about these indicators than others. For example the deciduous/conifer proportions in a targeted area would be more accessible using high resolution data; data on snags would require very fine-scale data, and understory characteristics can usually only be obtained through studying relationships with other characteristics (for example, the certain kinds of trees are indicators of floodplain landforms) or using radar. However, if the canopy is sparse, some understory characteristics can be obtained through remote sensing methods.

Identification of the Riparian Area

The spatial extent (width and length) of the riparian area chosen for assessment has implications for acquisition, classification, analysis, and reporting of remote sensing data. From an acquisition perspective, the spatial extent of the riparian zone can influence the cost of the project. Riparian areas are linear features across the landscape, which makes it difficult to easily capture their extent. The major decision facing investigators hinges on whether to include the areas adjacent to all streams (perennial, intermittent, and ephemeral) or a subclass of streams such as perennial or fish-bearing streams.

Image classification accuracy can be improved by reducing spectral variability and potential vegetation or land use/land cover class options. This can be accomplished by limiting the classification to a buffer area adjacent to a stream network. All of these factors influence remote sensing project planning, especially when new data is acquired. Key considerations in project planning include the flight line paths, the number of photos or images needed, and the time required for interpretation or classification.

Analysis and reporting of study results is influenced by the length (extent up the stream network) and width (distance from the edge the stream) of the riparian area examined. This is important to keep in mind when using other sources of information in an analysis. A consistent method of determining the spatial extent of the riparian area is essential when comparing study results to other areas and time periods.

Riparian areas can be delineated with a fixed or variable width. A variable width buffer tries to delineate the functional riparian area based on hydrology, geomorphology, soils, and vegetation. A fixed width definition is easier to determine using GIS, but this approach has the potential to include non-riparian areas or exclude riparian areas. A fixed width riparian classification may not represent riparian conditions across the landscape. Varying the width by stream size is an improvement, but does not eliminate the problem.

The Riparian Component of the Oregon Watershed Assessment Manual (WPN 1999) suggests delineating riparian area widths within two zones (one closest to the stream and the second the remainder of the recruitment zone) by ecoregion and channel constraint group. The quality of the stream layer (i.e. positional accuracy and extent) used to create the riparian area delineation will influence the resultant quality of the buffer.

Riparian Assessment Classification Schemes

The data quality of remotely assessed riparian conditions is influenced by the selection of an appropriate minimum mapping unit (MMU) and rests primarily on the system selected to classify the riparian features (Muller 1997). The MMU is the smallest size polygon to be mapped as a separate class. A small MMU allows the identification of detailed features. Selecting an MMU that is too large may result in the loss of important information such as failing to map a wetland. Conversely, selecting an MMU that is too small may increase project costs and introduce unnecessary and confusing information. For example, gaps in a forest canopy could be mapped as open areas, confusing them with meadows and clear cuts.

Over broad spatial scales, obtaining detailed information on riparian vegetation is prohibitively expensive, yet detailed information is often needed for site-specific work. A hierarchical classification system provides the framework that can accommodate finer-scale information, such as riparian plot data or high-resolution aerial photographs. This also allows finer-scale data to be used in classifying or evaluating the quality of the broader remotely sensed data. An additional advantage of the hierarchical classification approach is that the classification will not become obsolete as platforms, sensors, and remote sensing techniques improve.

The Anderson et al. (1976) hierarchical classification scheme provides flexibility to add detailed categories at the third and fourth levels. Three classification schemes that have application for riparian assessments are presented here:

1. A landscape classification scheme (Table 6-1);

2. A hierarchical riparian landscape classification developed for an

Oregon study using aerial photography (Table 6-2); and

3. The riparian classification used in OWEB's Watershed Assessment Manual (Table 6-3).

All of these approaches use different methods of classifying riparian vegetation. For example, riparian canopy density is classified in different ways. Obviously, it would be difficult to compare areas or changes through time using data classified by more than one scheme. For this reason, investigators should carefully consider their choice of which riparian classification scheme is appropriate.

Table 6-1. This landscape classification scheme is an example of a hierarchical classification approach (adapted from Avery and Berlin 1992).

Level I	Level II	Level III
100 Urban or built-up	110 Residential	
	120 Commercial and services	
	130 Industrial	
	140 Transportation	
	150 Communications and utilities	
	160 Institutional	
	170 Recreation	
	180 Mixed	
	190 Open land and others	
200 Agriculture	210 Cropland and pasture	211 Row crops
		212 Field crops
		213 Pasture
	220 Orchards, vineyards, etc.	
	230 Confined-feeding operations	
	240 Other agriculture	
300 Rangeland	310 Grassland	
	320 Shrub and brushland	
400 Forest land	410 Deciduous forest	411 Deciduous 10-50% crown cover
		412 Deciduous greater than 50% crown cover
	420 Evergreen forest	421 Evergreen 10-50% crown cover
		422 Evergreen greater than 50% crown cover
	430 Mixed forest	431 Mixed 10-50% crown cover
		432 Mixed greater than 50% crown cover
	440 Clear-cut areas	
	450 Burned areas	
500 Water	510 Streams	
	520 Lakes and ponds	
	530 Bays and estuaries	
600 Wetlands	610 Forested wetlands	611 Deciduous forested wetland
		612 Evergreen forested wetland
		613 Mixed forested wetland
	620 Nonforested wetlands	621 Freshwater nonforested wetland
		622 Brackish and saltwater nonforested wetland
700 Barren land	720 Beaches	
	730 Sand & gravel other than beaches	
	740 Exposed rock	
	750 Quarries and gravel pits	
	760 Transitional areas	

For manual interpretation of land use and land cover, Avery and Berlin (1992) recommend the following range of image scales: for Level 1-1:250,000 to 1:3,000,000; for Level II-1:60,000 to 1:125,000; for Level III-1:20,000 to 1:60,000; and for Level IV-1:8,000-1:20,000.

Table 6-2. A modified Anderson et al. (1976) hierarchical classification used to map riparian vegetation and some of the adjacent agricultural areas in Oregon (Schuff at el. 1999). For this study, the researchers digitized land cover classes on scanned, spliced, and georeferenced 1:24,000 color aerial photography with a 300 meter buffer around selected streams. Polygon boundaries were interpreted using the original aerial photographic prints.

I. Forest
- 1. Coniferous Forest
  - a. Closed canopy (70-100%)
  - b. Partially closed canopy (40-69%)
  - c. Open canopy (10-39%)
- 2. Deciduous Forest
  - a. Closed canopy (70-100%)
  - b. Partially closed canopy (40-69%)
  - c. Open canopy (10-39%)
- 3. Mixed Forest
  - a. Closed canopy (70-100%)
  - b. Partially closed canopy (40-69%)
  - c. Open canopy (10-39%)
- 4. Clear Cut
- 5. Tree Farm

II. Shrub/Scrub

III. Grass/Forb

IV Agriculture
- 1. Cropland
  - a. Field crops
  - b. Row crops
  - c. Orchards
- 2. Christmas Tree Farms
- 3. Confined Animal Feeding
- 4. Nurseries
  - a. Tree and Shrub
  - b. Greenhouse
- 5. Farmsteads
- 6. Other agriculture

V. Urban/Built-up
- 1. Residential
- 2. Roads and Railroads
- 3. Industrial and Commercial
- 4. Other

IV. Barren Land

VII. Water

VIII. Other

Table 6-3. The riparian classification approach used in OWEB's Watershed Assessment Manual (WPN 1999) is amenable to a hierarchical approach. The approach uses Riparian Condition Units (RCUs) to delineate riparian areas based on vegetation (size, type, and density), stream size, changes in land use (roads or other infrastucture, for example), channel habitat type (defined by gradient and constraint), ecoregion, and subwatershed.

	Vegetation Type
C	Mostly conifer trees (>70% of area)
H	Mostly hardwood trees (>70% of area)
M	Mixed conifer/hardwoods
B	Brush species
G	Grass/meadow
N	No riparian vegetation
	Tree Size Classes
R	Regeneration (< 4-inch average diameter at breast height (DBH))
S	Small (4-12-inch average DBH)
M	Medium (>12 to 24-inch average DBH)
L	Large (>24-inch average DBH)
N	Nonforest (applies to vegetation Types B, G, and N
	Stand Density
D	Dense (<1/3 ground exposed)
S	Sparse (>1/3 ground exposed)
N	Nonforest (applies to vegetation Types B, G, and N

COMPARING REMOTE SENSING METHODS

Assessing suitability for any remote sensing method has to be made in the context of the riparian assessment questions and the level of precision and accuracy required to address the questions. Investigators should also consider remote sensing approaches based on cost-effectiveness: what is the relative cost of the system versus the degree of precision required to answer the riparian assessment question?

The following discussion describes three primary remote sensing platforms and sensors and provides some cost information for:
Aerial Photography
Videography
Satellite Imagery

Table 6-4 provides a general comparison of the utility of each of the methods for assessing riparian conditions. Examples of using remote sensing methods for assessing riparian characteristics are described in Appendix 6-A. Table 6-5 provides some guidance on the appropriate scale and remote sensing approach for the different riparian assessment issues.

Table 6-4. Comparing the utility of three remote sensing approaches for assessing riparian conditions.

Remote Sensing Approach	**Spatial Resolution**	**Historical Data**	**Advantages for Riparian Assessment**	**Disadvantages for Riparian Assessment**
Aerial Photography	1:2000-1:80,000	1930s to present	- Fine scale - Historical archives - Stereographic coverage for resolving topographic details - Adapt acquisition time to weather conditions	-Must be scanned for digital use or interpreted and digitized -Variable hues and colors -Needs rectification
Videography	0.15-4 m	Limited: 1990s to present	-Timely multi-band imagery in digital format -Consistent representation of hues and colors -Ability to error proof in-flight - Adapt acquisition time to weather conditions	-Lower spatial resolution -Poor geometric fidelity -Smaller area coverage
Satellite Imagery	>61 cm	LANDSAT: 1970s to present	-Digital image processing can save time and reduce the potential sources of errors. -Large area coverage	-Impacted by weather conditions -Smaller spatial resolution

Table 6-5. A guide for determining the appropriate scale for riparian assessment questions. Adapted from Clemmer (2001).

Task/Application	Scale[1]	Remote Sensing Method[2]	Comments
Project Planning			
Synoptic view	Region / Watershed	Satellite	Provides an overall perspective of the area
Area identification	Region / Watershed Site / Reach	Photography: B&W, I, C Satellite	Locating areas in need of further examination
Monitoring and Inventory of Riparian Vegetation			
Density	Site / Reach Watershed	Photography: B&W, I, C Videography	Density can be assessed within the riparian area and over the stream
Structure	Site / Reach Watershed	Photography: C Videography	Height of vegetation; snags
Streambank shade	Site / Reach Watershed	Photography: C Videography	
Streambank stability	Site / Reach Watershed	Photography: I, C Videography	Associated with vegetation composition
Species composition	Site / Reach Watershed	Photography: I, C Videography	Individual species and tree type (deciduous, coniferous)
Percent cover	Site / Reach Watershed	Photography: I, C Videography	Trees, shrubs, herbaceous, bare soils
Stream width	Site / Reach Watershed	Photography: C Videography	
Floodplain width	Site / Reach Watershed	Photography: I, C Satellite (large floodplain systems)	Stereo viewing helps to distinguish topographic features
Channel sinuosity	Site / Reach Watershed	Photography: I, C Videography Satellite	Photos often identify current patterns better than older 7.5-minute topographic maps
Change detection	Site / Reach Watershed	Photography: I, C, B&W Videography Satellite	Compare historical photography to determine past management practices and changes over time

1 Scale

Site / Reach: Large scale (1:2,400-1:12,000)

Watershed: Medium scale (1:15,840-1:30,000)

Region: Small scale (> 1:30,000)

2 Photographic Remote Sensing Method

B&W=Black and White

C=Natural Color

I=False color infrared

For site and reach-scale analysis, fine-scale photo interpretation or image analysis can be used to classify riparian vegetation in order to observe status and trends and for effectiveness and compliance monitoring. The OWEB Watershed Assessment Manual provides a detailed methodology to accomplish fine-scale riparian assessments using aerial photography. Through stereoscopic viewing, detailed riparian information, such as plant height, structure, condition, and identification to the species level, can be obtained from aerial photography. If sites are selected through a sub-sampling frame, then this set of fine-scale data can be used to extrapolate to the whole population for broader-scale watershed and regional analyses. If a complete census of riparian conditions (status) is needed at the regional or province-scale, a tiered approach with a simple classification scheme is useful to balance cost versus resolution. Coarser resolution data (for example, satellite imagery) would be used at higher levels in this classification and finer-scale data (for example, aerial photography) would be used to calibrate or evaluate this data and target specific areas where more detailed riparian information is needed.

For larger streams or in areas with high contrast between the riparian areas and the uplands such as agriculture, urban, and rangelands, a coarser resolution sensor such as Landsat TM is adequate. This can be used as a first cut in other areas. Then finer-scale information can be used in areas of high importance or in areas of lesser confidence or accuracy- smaller streams and in areas of minimal contrast. For example, finer-scale satellite imagery could be appropriate for medium-size systems and fine-scale aerial photography or videography for small streams.

AERIAL PHOTOGRAPHY

Aerial photos are frequently used to assess riparian conditions. Three advantages of using aerial photographs are: 1) the ability to see the terrain by stereoscopically viewing the photos, 2) acquiring photos for a specific time period, and 3) access to historical aerial photos (in some cases to the 1930s) for assessing trends through time. Choosing the most appropriate photo scale and type of film will improve the success of a project. Knowing the aerial photo characteristics of existing data is helpful in evaluating the usefulness of the data for riparian assessments. For new aerial photo acquisitions, photo scale, film type, landscape coverage, and other factors need to be specified to the aerial photography contractor.

The season and time of day the photographs are taken will influence the ability to interpret riparian features, because the degree of vegetation development and shade features can hinder or assist in interpretation of aerial photographs. In arid areas, for example, photographs taken later in the growing season can provide better contrast between riparian and upland vegetation. The time of day photos are taken is important especially if the areas have deep canyons. Having the photos taken with a higher sun angle (maximum sun angle corresponds to the summer solstice in June) will reduce the amount of shadowing.

Natural color film is adequate when general information such as canopy cover, channel widths, stream lengths, or increase/decrease in riparian vegetation is needed. Color infrared film should be used if vegetation composition is needed. Color infrared film captures a greater range of spectral reflectance variation between vegetation types and between wetland and non-wetland environments than does panchromatic (Pan) or natural color film (Lillesand and Kiefer 2000). Film transparencies (diapositives) provide sharper images than prints and are preferred when using stereoscopic equipment.

Investigators need to balance the photographic scale necessary to adequately visualize and analyze the area of interest against the costs, time and potential for misinterpretation inherent in choosing an inappropriate scale. Investigators should choose the smallest scale possible that will accomplish the project goals, because the fewer small-scale photos needed to cover an area, the lower the cost of acquisition and the decreased amount of time needed to interpret the photo and transfer it to a map base. However, the scale needs to be large enough to interpret the detail needed. A scale of 1:2,400 to 1:6,000 is needed to visually analyze, delineate and measure areas to the community level for narrow strips of riparian-wetland vegetation (Clemmer 2001). For most riparian classifications, a photographic scale of 1:4,800 to 1:12,000 is adequate. The most common scale aerial photography available for most parts of the state is at 1:12,000. Table 6-6 outlines estimated aerial photography coverage based on scale.

Table 6-6. Estimating photo coverage based on scale. Adapted from Aldrich (1979).

Photo scale	Number acres per square inch	Number photos per 100,000 acres	Approximate number of photos for the State of Oregon (61,441,280 acres)
1:2,400	1	4,348	2,669,672
1:4,800	4	1,099	674,786
1:6,000	6	735	451,290
1:12,000	23	192	117,888
1:15,840	40	110	67,540
1:20,000	64	69	42,366
1:24,000	92	48	29,472
1:40,000	255	17	10,438

Once the photographs have been obtained[1] they need interpretation and analysis. If possible, someone familiar with the local riparian vegetation and ecosystem characteristics should do the interpretation. As an alternative, a local expert can identify characteristic vegetation types to be used to train an interpreter. A photo interpreter uses tone, texture, shape, size, shadow height, and spatial relationships to identify and delineate specific features. Viewing the photos stereoscopically allows the interpreter to observe the vertical as well as the horizontal vegetation characteristics and topographic features. The basic steps for preparing photographs for interpretation are: 1) delimiting the effective area of each photo and preparing the mylar overlays; 2) selecting the minimum mapping unit; 3) developing the classification; 4) analyzing the photos; and 5) determining photo scale and calculating acreage. The accuracy of the interpretation is dependent on the quality of the photos, the experience of the photo interpreter, and the amount of field verification conducted to assess accuracy.

Appendix 6-B provides sources for current and historical aerial photography.

1 For an overview of the steps involved if an aerial contract will be initiatied, see Clemmer (2001).

VIDEOGRAPHY

Airborne videography systems obtain digital images directly from analog or digital cameras mounted on an airplane. Riparian features such as vegetation types, soils, vegetation density and cover, standing water, wetland areas, instream hydraulic features, and exposed banks can be automatically extracted using computer image classification of calibrated digital multispectral video imagery. Multispectral (also called multi-band) videography and other imagery (such as that captured by satellites, as opposed to black and white, captures a range of colors (different wavelengths of light) including, in some cases, colors that are not visible to the naked eye, such as infrared. The range of colors captured through multispectral imagery facilitates computer classification because the colors can be grouped to display different features of interest, such as highlighting diseased foliage

There are advantages and disadvantages of airborne multispectral videography in comparison to aerial photography and satellite imagery (Neale 1997). Airborne videography can provide a quick turnaround of multi-band imagery in digital form ready for computer processing, in contrast to aerial photographic film, which is expensive and involves scanning the photographs for computer use in digital form, or interpreting and digitizing features of interest from the photographs. In addition, calibrated video imagery can consistently reproduce hues and colors, as opposed to the variability of aerial photographs due to changes in emulsion and in the film development process. Because video images can be viewed during collection, investigators can identify and correct data quality issues during the flight. The other advantage of videography is the ability to select cloud-free days and not be constrained to days determined by the orbital paths of a satellite.

The disadvantages of videography include: 1) lower spatial resolution; 2) poor geometric fidelity (the image does not correspond to the map base in a consistent manner); and 3) smaller area coverage. However, the spatial resolution of videography is much higher than commercially available satellite imagery. Video imagery pixel sizes range from 0.15 m to 4 m, depending on the kind of sensor, the focal length of the lens, and the flight altitude above ground level. The image pixel resolution can be selected prior to the flight depending upon the desired use of the imagery and the size of the stream and its riparian zone. Digital cameras, which capture single images, can also be used instead of videography (multiple images). Digital cameras can provide high resolution images and eliminate the need to select from multiple images in videography (Michael Golden pers. comm.).

SATELLITE IMAGERY

In comparison to digitizing or scanning a manually interpreted photo or image, digital image processing can save time and reduce the potential sources of errors. The primary satellite imagery sources are Landsat, SPOT (Systeme Pour l'Observation de la Terre), IRS (Indian Remote Sensing), ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer), and IKONOS. Satellite technology is rapidly evolving. On October 18, 2001, Quickbird, a new satellite, was launched. Table 6-7 provides a comparison of some of the most common satellite remote sensing data sources.

It is also possible to get digital imagery from aircraft. Aircraft imagery offers greater flexibility in terms of resolution, timing, and finer spectral resolution. Most multispectral systems are also equipped with mapping cameras to allow simultaneous collection of aerial photography (Lee and Lunetta 1995). Acquiring digital data with an aircraft gives the user the ability to target the riparian areas.

A multi-spectral image provides simultaneous information on different bands of the electromagnetic spectrum from the same geometric vantage point. Because the same feature types under different conditions (e.g. season and time of day) will normally reflect differently for different spectral bands, multispectral imagery can be used to identify these differences. Table 6-8 compares the wavelengths for various sensors. Band combinations are chosen for the specific feature of interest in spectral regions where the maximum spectral reflectance differences are known, or are anticipated, to exist (Lillesand and Kiefer 2000). Table 6-9 shows the principal applications of the Thematic Mapper spectral bands (Lillesand and Kiefer 2000).

Table 6-7. Comparison of Remote Sensing Platforms (adapted from Lee and Lunetta 1995 with information from Verbyla 1995 and Leroux[1]).

Sensor Type	Spatial Resolution	Spectral Bands-Quantization Levels	Date of Frst Imagery	Temporal Cycle	Coverage (square mile)	Approximate Cost[2] (square mile)[3]
Landsat MSS[4,5]	60 x 80m MS	4-127	1972	18 days	13,214	$0.02
Landsat TM[4,5]	30m MS 120 thermal infrared (TIR)	6 (+1 TIR) –255	1984	16 days	12,285	$0.03
Landsat ETM[4,5,6]	30m MS 15m Pan 60m TIR	6 (+1 TIR and 1 Pan)	1999	16 days	12,285	$0.05
ASTER[5,7]	15m/30m MS 90m TIR	14-255 and 12 bit	1999	16 days	1390	$0.04
SPOT[8]	10m MS 2.5 and 5 m Pan	4 (+1 Pan)-255	1986	3-26 days	1390	$1.80 ($0.21-$0.33)[8]
IKONOS-2[6]	4m MS 1m Pan	4 (+1 Pan)	1999	1.5-3 days	65	$2.70-32.00[9]
IRS[6]	20m MS 5m Pan	4 (+1 Pan)	1995	24 days	1892 (Pan) 7785 (MS)	$4.40-$14.70
Quikbird[10]	2.4m MS (0.61mPan)	4 (+1 Pan)	2001	1-3.5 days	7 to 21 mi depending on altitude	$8.70-12.00
ALI[11]	30m MS 10m Pan	9 (+1 Pan)	1999	16 days	12,285	$0.04-0.20
AVIRIS	20m	224	1987	Variable	3398	$500 per flight line $0.15
Color Infrared Photo (for comparison)	1-3 m (1:40,000)	N/A	N/A	Variable	32	$10-$15

1 http://www/matox.com/agisrs/arsist

2 Newly commissioned imagery may be more costly; archived, older imagery may be less expensive.

3 Area of Oregon: 96,002 square miles

4 http://edcsns17.cr.usgs.gov/EarthExplorer

5 http://edcwww.cr.usgs.gov/products/satellite.html

6 http://www.spaceimaging.com/products/imagery.htm

7 http://asterweb.jpl.nasa.gov

8 http://www.spotimage.fr/home/proser/welcome.htm Lower prices available from statewide image database http://www.spot.com/HOME/NEWS/spotusaselect.htm

9 Lower price reflects archived radiometrically-and geometrically-corrected imagery and the higher range encompasses orthorectified products which apply geometric corrections to account for terrain and other scale variations to produce map-accurate imagery.

10 http://www.ball.com/aerospace/quickbird.html and http://www.digitalglobe.com/products/standard.shtml

11 http://eo1.usgs.gov

Table 6-8. Comparison of multispectral sensor wavelength (μm) and spatial resolution.

Wavelength	Landsat MSS	Landsat TM and ETM (Band)	IRS-IC and ID	SPOT	ASTER (Band)	IKONSOS	Aerial Photographs	AVIRIS
Pan		0.52-0.90 15m ETM	0.5-0.75 5.8m	0.51-0.73 2.5 and 5m		0.45-0.90 1m	0.40-0.70	224 adjacent
Blue		0.45-0.52(1) 30m				0.450.52 4m	0.40-0.70 Natural Color	bands from
Green	0.50-0.60 82m	0.52-0.60(2) 30m	0.52-0.59 23m	0.50-0.59 20m	0.52-0.60 (1) 15 m	0.52-0.60 4m	0.50-0.575 Color IR	0.40-2.50
Red	0.6-0.70 82m	0.63-0.69(3) 30m	0.62-0.68 23m	0.61-0.68 20m	0.63-0.69 (2) 15 m	0.63-0.69 4m	0.575-0.675 Color IR	
Near-IR	0.70-0.80 82m	0.76-0.90(4) 30m	0.77-0.86 23m	0.79-0.89 20m	0.76-0.86 (3) 15 m	0.76-0.90 4m	0.675-0.90 Color IR	
Mid-IR	0.80-1.1 82m	1.55-1.75(5) 30m	1.55-1.70 70m		1.60-1.70 (4) 30m			
Mid-IR		2.08-2.35(7) 30m			2.145-2.185 2.185-2.225 2.235-2.285 2.295-2.365 2.36-2.43 30m			
Thermal-IR		10.4-12.4(6) 120m			8.125-8.475 8.475-8.825 8.925-9.275 10.25-10.95 10.95-11.65 90m			

Table 6-9. Thematic Mapper Spectral Bands (Lillesand and Kiefer 2000).

Band	Wavelength (µm)	Nominal Spectral Location	Principal Applications
1	0.45-0.52	Blue	Water body penetration Soil/vegetation discrimination Forest type mapping Cultural feature identification
2	0.52-0.60	Green	Vegetation discrimination and vigor assessment Cultural feature assessment
3	0.63-0.69	Red	Plant species differentiation
4	0.76-0.90	Near IR	Determining vegetation types, vigor and biomass Soil moisture discrimination
5	1.55-1.75	Mid IR	Indicative of vegetation moisture content and soil moisture Differentiating snow from clouds
6	10.4-12.5	Thermal IR	Useful in vegetation stress analysis, soil moisture discrimination, and thermal mapping applications
7	2.08-2.35	Mid IR	Useful for discrimination of mineral and rock types Sensitive to vegetation moisture content

Hyperspectral data have been used to determine soil type and erosion, vegetation type, leaf water content, and crop type. These systems can discriminate among features that have diagnostic absorption and reflection characteristics over narrow wavelength intervals that are "lost" within the relatively coarse bands of conventional multispectral scanners (Lillesand and Kiefer 2000). Hyperspectral systems are available that acquire images in numerous, narrow, contiguous spectral bands. As part of a validation/demonstration mission, NASA collects and distributes Hyperion hyperspectral products (http://eo1.usgs.gov). Aircraft hyperspectral data are also collected by NASA using AVIRIS (Airborne Visible InfraRed Imaging Spectrometer). This sensor acquires spectral radiance in 224 bands. Data from existing flight lines can be purchased and additional flight lines can be requested.

Digital image processing is the method of processing reflectance or spectral patterns of pixels into land cover or vegetation categories (Lee and Lunetta 1985). Image data are organized into a matrix with each pixel (or cell) covering a certain dimension on the ground dependent on the sensor. Each pixel represents the spectral intensity of that location on the earth's surface for a particular wavelength or spectral band at the time of image acquisition. Because the proportion of energy reflected, absorbed, and transmitted for each cover type varies depending on the material and ground condition, land cover and vegetation cover types can be identified based upon their spectral signature (Lillesand and Kiefer 2000).

Two general types of classification techniques are used to assign the spectral data to land cover or vegetation types: *supervised* or *unsupervised* (Lee and Lunetta 1995). Supervised classification locates the known land cover types (such as coniferous and deciduous forest, shrubs or grass) on a satellite image that have been identified through fieldwork, aerial photography, or personal experience. Homogenous examples of these cover types are delineated and used as training sites, because their spectral characteristics are related to known resources and can be used to "train" the classification algorithm. Statistical information is generated for each identified training type and used to classify all unknown pixels remaining in the image.

Conversely, with an unsupervised classification, the statistical parameters required to define the training classes are determined with clustering algorithms because the location of particular cover types is unknown. The image analyst labels each cluster with the appropriate land cover or vegetation type.

Other useful techniques are available that can provide different types of data. For example, instead of using predefined classes, Cohen et al. (2001) modeled four forest vegetation attributes as continuous variables for western Oregon using regression analysis. This allows the user to specify class breaks that are the most appropriate for his or her study, and it provides a better representation of data that are inherently continuous, such as tree age.

The two advantages for using aerial photographs noted earlier (i.e. the ability to see the terrain by stereoscopically viewing the photos, and acquiring photos for a specific time period) are no longer exclusive to aerial photography. Some satellites, such as SPOT and Quickbird, also provide stereographic views. SPOT also has pointable optics that allow revisits to an area in between the 26-day satellite passes. This is particularly useful in areas of high cloud cover or when data are required for an event such as a flood or fire. Quickbird has the capability to provide multispectral stereoscopic data.

Pixels representing areas of transitions (boundary pixels) have a spectral response that is a mixture of adjacent cover types, so they can be easily misclassified. Occasionally they have their own unique spectral response recognized as a separate cover class. This makes classification difficult in riparian systems that are linear in nature and often fragmented. The problem is magnified for narrow riparian zones or larger pixels. Finer-resolution data may reduce the number of pixels that represent more than one cover class. Finer-resolution pixels can also detect subclass level differences that can cause difficulty or errors in classification (Quattrochi and Pelletier 1991). For example, shadows, sun-lit crowns, canopy gaps, rocks, and even livestock may get classified as a different cover type.

"Mixture models" are one attempt to address this issue (Woodcock and Strahler 1987). Mixture models are designed to estimate the proportion of several elements for each pixel. They provide information about lower levels of the scene model, but do not substitute for the spectral classifiers at these resolutions. For example, in a forested environment, the mixture models would estimate the proportion of pixels covered by elements such as trees and background, rather than classifying pixels according to the characteristics of the trees in the pixel.

Investigators can combine data sets to produce imagery with high spatial and spectral resolutions in a process known variously as *multisensor merging*, *fusion*, or *sharpening of the lower resolution image* (Schowengerdt 1997). SPOT was explicitly designed to provide such imagery by having a set of multispectral bands co-registered with a higher spatial resolution panchromatic band. The newer Landsat 7 ETM data are also designed for this purpose.

Other potential sources of error with digital imagery include: atmospheric scattering, sun angle, topographic influences, and the process of geographical rectification of the imagery. For an additional fee, imagery can be obtained that addresses these problems. This is not possible with older archived imagery, however. Ortho rectified, aligned, and georeferenced IKONOS images can be useful for DEM overlays that help identify and resolve the errors associated with the influence of topography on spectral reflectance (Childs 2001). These images also supply information on sun angle and azimuth.

Use of Ancillary Data

Economy, repeatability, and broad spatial coverage make the use of remotely sensed data attractive. However, usefulness of remotely sensed data is sometimes hampered by resolution, similar spectral reflection for different vegetation, and limited ability to capture understory conditions. Using supporting information and data can make the classification more accurate and help enhance and extend the usefulness of remotely sensed data.

GIS is a tool that facilitates merging remote sensing data with other sources of data and is beneficial for both the interpretation and analysis of remotely sensed data. Field data can be related to the spectral data to improve and evaluate classification accuracy. Information on soils, streams, topography, geology, climate, and ecoregions can provide information useful to classifying spectral data. The finished riparian classification can be related to other spatial data layers through the use of GIS. This helps identify relationships and areas for additional study. Information on soils, topography, ownership, fish and wildlife, streams, roads, geology, and climate could be used in these analyses.

The following discussion will focus on four potential sources of supporting information:

Field data
Digital Elevation Models (DEM)
Soils data
Wetland data

Field Data

Field data are an essential component of most remote sensing projects. They are most often used in the classification phase, such as in defining training areas for supervised classifications and in accuracy assessments. For these uses it is important to have accurate locational information and to make sure that the classification scheme used in the field is compatible with the classification used in the image or photo interpretation. Use of a Global Positioning System (GPS) is essential for accurate locational information. Lisa Levien (personal comm. to Janine Salwasser) recommends using a stratified random sample to ensure that a representative sample is obtained across all cover types. In a simple random design, some of the more rare cover types might be missed and it is important that these have the potential to be detected.

One of the major drawbacks of using most remote sensing data is the lack of ability to penetrate the canopy and obtain information on structural and understory characteristics. In a creative use of field data, Ohmann and Gregory (2002) used regional grids of field plots along with mapped environmental data and geographic locational data to ascribe detailed ground attributes of vegetation to each pixel on Landsat TM imagery for the Coast Range Province of Oregon. They caution that as with other Landsat TM-based maps, their vegetation maps are appropriately used for regional-level planning, policy analysis, and research, not for guiding local management decisions. However very few of the regional plots they used were located in riparian areas and the plots were not designed to sample linear features (Ohmann pers. comm.). In a report for the Oregon Department of Forestry, Runyon and Andrus (2000) address the forest riparian vegetation and stream information needs to develop a comprehensive riparian inventory approach. These data would be designed to complement the field plots used by Ohmann and Gregory (2002).

Digital Elevation Models (DEMs)

Ten-meter drainage enforced (DE)-DEMs are available statewide (http://www.or.blm.gov/gis/resources/) These can be used directly in image classification to help distinguish classes that are spectrally similar but may differ in elevation, aspect, or slope (Lillesand and Kiefer 2000) and also to help identify shadow areas.

The 10 m DE-DEMs can be used to produce a stream layer and associated attributes: valley width, gradient, stream order, and drainage area. The stream layer and attributes can be used to help classify riparian condition or reduce spectral variability by providing stratification criteria to limit the classification extent to areas in close proximity to a stream. An indication of active channel width can be obtained using a relationship with mean annual flow and an approximation of valley constraint can be determined from the valley width and active channel width. (http://www.fsl.orst.edu/clams/prj_wtr_str_indx.html)

Soil Data

The USDA National Resources Conservation Service is in the process of producing national databases of soils. SSURGO is a soil survey geographic database and provides the most detailed level of information (http://www.ftw.nrcs.usda.gov/ssur_data.html). Information on hydric soils flood potential, landforms, and potential national vegetation can be used to help limit the area of analysis and improve classification accuracy. Currently certified mapping is available for most of Western Oregon and the Columbia Plateau. (http://nm6.ftw.nrcs.usda.gov/website/archived_ssurgo/viewer.htm).

Wetland Data

The National Wetland Inventory has complete hard copy maps for most of Oregon. Digital coverage is available for some areas. (http://enterprise.nwi.fws.gov/index.html.). Wetlands and riparian areas were delineated using 1:62,000-scale aerial photographs from 1986 and transferred to 7.5-minute USGS topographic maps. OWEB is working with Division of State Lands to update this layer for some areas of the state. However the data may not have been collected consistently and it is out of date.

Quality Assurance/Quality Control

A number of factors influence the quality of photo interpretation and digital imagery classifications (Bolstad and Smith 1995). For photo interpretation, the skill and background of the interpreter, the methods used, the classes or categories, and the characteristics of the aerial photography all influence the quality of the photo interpretation. Sensor type, radiometric and atmospheric corrections, classification method, season of acquisition, and categories to be identified affect the quality of information developed from digital images.

An integral component of any classification is the evaluation with field data or higher resolution remotely sensed data (Bolstad and Smith 1995). The methods used to assess accuracy need to reflect the goals and objectives of the project. Often the desired accuracy and the obtainable accuracy are different. Investigators should not use the same data to assess quality as they used in developing the classification because it heavily biases the results (Lee and Lunetta 1995). It is recommended that a 1% sample should be obtained for assessing the accuracy of classified remote sensing data (Congalton 1988). For an assessment of riparian areas that are inherently edge areas, selecting sample points from harder to interpret edges is important.

Story and Congalton (1986) outline a method to assess the agreement between reference data and the classification. Site-specific comparisons are made by calculating the frequency of correctly classified areas and reporting these values in an error matrix (sometimes called a “confusion” or “contingency table”). The total overall percent correct is the ratio of the sum of diagonal values to total number of cell counts in the matrix. Errors of commission and omission are calculated from the error matrix and reported as user’s and producer’s accuracy.

Congalton and Green (1999) discuss some adaptations to the confusion tables that better describe boundaries which are fuzzy and not absolute. For example, a small conifer incorrectly classified as a medium conifer is less severe than incorrectly classed as large conifer. Several methods are available to try and capture the relationship of classes. An observation is correct if it falls on the correct class or the class on either side of it. This can be adapted to encompass any combination of classes in either direction. A further modification is to weight the correctness of the adjacent classes (Cohen et al. 2001). However, the distribution of error could be uneven across the landscape. If this is the case, it may be advisable to do separate mapping for each area of local variability (Fassnacht, et al. in prep.). In a final caution, Fassnacht et al. (in prep.) notes that it is important when comparing map products to ensure that the methods used to assess accuracy were calculated using a similar technique.

Metadata Generation

An important component of producing any data layer is providing complete metadata (data about the data) and making sure the completed metadata and data are placed in a stable location ensuring that it can be acquired at some future date. The production of metadata has been likened to food labeling. Knowing how the data were processed is important as new techniques and sensors are developed to be able to compare the resultant products. Metadata are vital to a dataset’s accessibility and longevity for reuse, allowing others to know what datasets exist to address a particular problem, how the data were produced, who to contact for additional information, and how to obtain the data.

The quality of change detection relies on the ability to acquire and use historical remote sensing data and classifications. It is very difficult to compare two dates of classified imagery if the methods used in the classification and assessments of quality are not well documented.

The Federal Geographic Data Committee web sites have more information on the importance of metadata: (http://www.fgdc.gov/metadata/metadata.html), the content standards: (http://www.fgdc.gov/standards/standards.html,) and their clearinghouse: (http://www.fgdc.gov/clearinghouse/index.html).

The content standard includes:

Identification information such as title, geographic area covered, currentness, and rules for acquiring or using the data;

Data quality information such as positional and attribute accuracy, completeness, consistency, sources of information, and methods used to produce the data;

Spatial data organization information such as raster or vector and the number of spatial objects in the data set;

Spatial reference information such as map projection or grid coordinate systems, horizontal and vertical datum, and the coordinate system resolution;

Entity and attribute information such as name and definition of feature attributes and attribute values;

Distribution information such as contact for distributor, available formats, information about how to obtain data layers online or on physical media, and fees for the data; and

Metadata reference information contains information on the currentness of the metadata information and the responsible party.

EXAMPLE

What is the current and future delivery potential of large wood into stream channels, given the current location, type, and size of riparian trees in the Cow Creek (Western Oregon) and Trout Creek (Eastern Oregon) watersheds?

What level of classification is needed to adequately address this question?
Rate of large woody debris decay in the channel will vary by forest type, species, and size. Relationships between canopy cover or spectral reflectance and tree height will differ by forest type. Potential for tree fall and mortality may also vary by forest type and species. We will assume that data down to forest type and size class will answer the question adequately.

ODF&W has benchmarks for riparian conifers (WPN 1999) based on the number of conifers > 20" DBH and > 35" DBH within 30 m on both sides of a stream.

What is the source area for large wood delivery into a stream channel?
We will assume that any wood that falls onto the valley floor has the potential to be delivered to the stream channel. The first step is to acquire the best stream layer for the watershed. Streams should be positionally accurate, represent the extent of the stream network, and density consistent across the watershed (i.e. not changing at jurisdictional or quadrangle boundaries). The extent of the source area will be identified relative to the stream. Ideally, the extent of the area of interest would approximate the valley floor plus one site potential tree height (The height of the site potential tree will vary for these two watersheds). DEMS, soil surveys, or topographic maps can be used to approximate the valley floor. Less time consuming options would be to identify a fixed or variable width buffer. For this example we exclude wood delivery from episodic debris flows.

What resolution or scale of data is needed to answer this question?
Remotely sensed data can be used in conjunction with field data to answer this question. *Number of trees over a prescribed size* (based on relationships between diameter of pieces used for ODF&W benchmark determination and diameter at breast height measurements) is the critical piece of information that will be used to determine large wood delivery potential. Stand type and density and average tree sizes can be used to address this question. The choice of resolution will be based on the ability to resolve the smallest riparian width and length in the vegetation types with the least contrast. Contrast is expected to be greater for the Trout Creek watershed. Additional considerations in choosing data are: cost, accuracy of the analysis, and time.

Remotely sensed data can be used to provide complete coverage of the watershed. Field data can be used to provide the detailed site-level information that cannot be obtained remotely. It is imperative that accurate ground location information is obtained for field plots. For large-sale aerial photo, relationships between crown diameter and trees size can be made. However, this will require numerous photos (Table 6-10) and interpretation time. Using smaller-scale aerial photos requires fewer photos (Table 6-10) and less interpretation time. However, individual crowns will not be identifiable, so the interpreter will be using color and texture to make assumptions about tree size. Field data will be essential to making these relationships. Will satellite imagery meet the needs? Coarser resolution (30 meter) satellite data can be used to identify density (sparse/coarse) and tree type (conifer/deciduous) for medium sized streams with a distinctive riparian zone. If the riparian zone is less than 30 meters, then satellite data will not be able to discern it. Image classification done specifically to address this question would focus on making relationships between tree diameter from plot data and spectral reflectance. Existing classification can also be used, but they will require making assumptions about tree size in the predefined classes.

Are there any existing data layers that could be used to answer this question?
Ideally, there would be existing data that exactly meet the project needs. Usually, existing data are not ideal, but could be used. So once again the tradeoff in cost, accuracy of the analysis and time needed should be assessed in the context of using existing data versus collecting new data. It is also a good idea to check and see if any other agencies or groups have need of the same or similar data, in which case there may exist opportunities to cost share.

EXAMPLE (Continued)

What is the future delivery potential of large wood?
Future delivery potential would be based on growth rates of the canopy and understory vegetation, and assumptions about management intentions. Change detection could be used to infer future change based on past change, or the project plan could direct investigators to redo the analysis at some time in the future.

Table 6-10. Number of aerial photos needed to cover a 6th-field watershed (approximately 25,000 acres (10,000 ha) based on photo scale.

Photo scale	Number photos per 25,000 acres
1:2,400	1087
1:6,000	183
1:15,840	28
1:24,000	12
1:40,000	5

Appendix 6-A: Examples of Using Remote Sensing Data for Assessing Riparian Characteristics

For riparian landscape modeling and analysis in the Oregon Coast Range, Wright (2000) found through field verification that the accuracy of magnified aerial photo interpreted data for riparian vegetation (especially hardwoods) was “much better” than for remotely sensed (25 m TM) vegetation data from the Coastal Landscape Analysis and Modeling Study (CLAMS) (http://www.cof.orst.edu/CLAMS/). Muller (1997) stated that satellite remote sensing is better adapted for mapping broad land cover categories rather than vegetation communities.

Congalton et al. (2000) compared riparian vegetation mapped from aerial photography and Landsat TM imagery for a 57,000 acre forested watershed for the Coastal Province of Oregon. They used a classification system of structural features that could be cost-effectively mapped using aerial photography-large conifer, closed canopy conifer, sparse conifer/seed-sapling-pole, hardwoods, brush and recent clear-cut, persistent brush, grass, pasture, open or agricultural. They located riparian vegetation changes along the 1:24,000-scale stream channel from 1-50’ and 50-200’ buffers using 1:24,000-scale panchromatic digital orthophotoquads. They chose a method called “dynamic segmentation” (streams are coded with the adjacent riparian class) over the traditional photo interpretation polygon approach because it was cost effective over large geographic areas. They compared this to TM imagery classified using a combined supervised/unsupervised classification approach. They found that the satellite imagery was too coarse to identify riparian vegetation. For the 50’ buffers they found on overall agreement of 25% and an agreement of 36% for the 50-200’ buffers. They caution that not all error could be attributed to the satellite classification, but there is little doubt that the increased spatial resolution of the photos produced a more accurate map. Using aerial photography to map large areas is very expensive, but they say that using their dynamic segmentation approach with public domain photography would reduce the cost. Even with this, they predict it would cost millions of dollars to classify all the riparian vegetation in Oregon using aerial photographs. They recommend looking at the new finer-resolution satellite imagery.

As a result of this work, the Oregon Department of Forestry, in coordination with the PNW Research Station and Space Imaging, are comparing an aerial photo classification and three-satellite remote sensing methods for mapping structural riparian vegetation. They will compare Landsat 25 meter multispectral merged with IRC-C 5 meter panchromatic, IKONOS 4 meter multispectral, and IKONOS 4 meter multispectral merged with IKONOS 1 meter panchromatic (Kevin Birch email comm.).

Aerial photography and Landsat TM data were compared for the Willamette Basin of Oregon (J. Wigington pers. comm.). The classification accuracy of a general landscape-level land cover map developed from TM imagery was compared to the accuracy of a more detailed coverage of riparian area conditions derived from aerial photographs (1:31,680-scale stereo coverage). To facilitate comparisons, both classifications were aggregated into land use and vegetation types: forest, shrub/scrub, grass/forb, agriculture-row crops, agriculture-other, built-up, barren, and water. Overall accuracy for the aerial photography was 92% and 81% for the TM data. The accuracy of the aerial photography would have been much higher if there had not been a disparity between the date of photography and the ground truth data that resulted in a very low accuracy for the agricultural-row crops class. The TM error matrix showed very low accuracies for the shrub/scrub class (35%) and the grass/forb class (44%). Both classes had almost half of the observations confused with the agriculture-other class. They also compared land cover-land use proportions for several areas of influence, incremental bands adjacent to the stream network. They found that the correlation between the estimates tended to increase as sample area increased. The classification differences are attributable to the decreased spatial resolution of the TM data and to the spectral similarities between natural vegetation and certain agricultural crops (e.g. orchards and riparian hardwood forest, natural grasslands and grass seed crops).

Russell et al. (1997) used an unsupervised classification on an April, 1992 Landsat TM scene to map land cover for the San Luis Rey River watershed in Southern California. They mapped 7 classes: 1) Urban; 2) agriculture; 3) scrub; 4) trees (oak and pine); 5) bare/herbaceous; 6) riparian (cottonwood, sycamore, willow, and arundo); and 7) water. They found that the riparian class was impossible to distinguish based solely on spectral data because the spectral signatures were nearly identical to those of some upland species. As a "work around" they enforced a proximity limitation on the classification scheme, such that pixels were classified as riparian only if they were located within 210 m of either side of the stream network. They had to manually narrow this buffer region for upland tributaries. For an accuracy assessment, they compared the TM derived cover classes with manual interpretation of aerial videography with a 1.5 m resolution. The riparian class had an accuracy of 43%. They acknowledge that using a spring scene when most of the vegetation was growing vigorously may have added some confusion. They conclude that identifying a distinct riparian class based on spectral data proved to be a formidable task. The authors recommend careful manual interpretation of high-resolution data as the best way to identify riparian communities. They provide some useful information of project costs (Table A-1). Additionally, they used Level 1 30 m DEMs to map relative wetness as function of slope and drainage area in a Southern California Basin. They ranked sites in terms of potential for restoration or preservation based on their wetness value (low, medium, and high), size, and proximity to existing riparian vegetation. Potential preservation sites had medium or high wetness values and extant riparian vegetation. Agricultural or barren sites with these same wetness values were identified as potential restoration sites.

Table A-1. Estimated cost for acquiring and processing 1 Landsat TM scene for a 1500 km^2 area. Personnel costs were estimated at $20/hr.

Task	Time (wk)	Cost of materials ($)	Cost of personnel ($)	Total cost of task ($)
Data Acquisition	4-6	3,000-4,000	3,200-4,800	6,200-8,800
Data Processing	4-8		3,200-6,400	3,200-6,400

Hewitt (1990) used Landsat TM imagery to map riparian areas along the Yakima River in Washington. He used a supervised classification to distinguish 3 classes-water, riparian, and other and had an overall map accuracy of 81%. To improve the accuracy he suggested: 1) Employing a temporal approach by selecting imagery from winter or spring and another from summer. 2) Using a buffer to mask out all pixels greater than a certain distance from the water class.

Iverson et al. (2001) compared Landsat TM data to NHAP photography (1:24,000-scale) for evaluating riparian wildlife habitat in Illinois. Broad land cover classes were determined for three hundred meter buffers adjacent to streams that drained at least 10 mi^2 and for the entire Vermillion basin. The TM data compared favorably to the NHAP data. The authors concluded that NHAP provided very good information, but use of this data is not practical on a statewide basis because of the manual interpretation involved. They did note that the NHAP data identified a larger percentage of forested land cover and they attribute this to decreased resolution of the TM data.

Hemstrom et al. (2002) propose a method to delineate a geomorphic riparian zone using DEMs that will be used to characterize streamside vegetation. They assume the degree of influence the adjacent topographic and vegetative features might have on streams is related to the "cost" of transporting materials between the channel and surrounding terrain. GIS is used to produce a "path distance" from the channel to upslope grid cells as a function of vertical and horizontal distance (Strager et al. 2000). The CLAMS Aquatic Group is using the right and left valley floor widths obtained from 10 m Drainage-Enforced DEMs (http://www.fsl.orst.edu/clams/prj_wtr_str_indx.html) to model riparian conditions and develop relationships to inchannel fish habitat and salmonid distributions.

An accurate representation of streams can be improved by using remotely sensed data. A study in Iowa by Narumalani et al. (1997) integrated US Geological Survey Digital Line Graph (DLG) hydrography data and remotely sensed data to produce an updated composite hydrography layer. The remotely sensed data can be used to produce an up-to-date hydrography layer, especially useful in low gradient systems where the stream channel is in a constant state of flux. The DLG hydrography data are used for small streams, especially in areas of closed canopies that would not be resolved with satellite imagery.

Appendix 6-B: Sources of Current and Historical Aerial Photography

AERIAL PHOTOGRAPHY

The Earth Science Information Center (ESIC) of the United State Geological Survey (USGS) maintains a photography database called the Aerial Photography Summary Record System (APSRS). (http://mac.usgs.gov/mac/isb/pubs/factsheets/fs22096.html). This system is useful for researching photography through 1995 only and is limited in that it will provide information by 7.5' quad (i.e. it will tell you that for the geographic point you specify, 70% of the quad that it falls on is covered by a particular photo project. You really don't know, using this system, if your point falls in the 70% covered or the 30% not covered). (Susan Nelson, BLM personal comm.)

The BLM has acquired a considerable amount of aerial photography that is archived at BLM's Aerial Photography Archive and Processing Lab, Denver Federal Center, CO 80225 or the EROS Data Center (http://edcwww.cr.usgs.gov/). Individual Forest Service offices are often a good source of current and historical aerial photographs. BLM film is in Denver.

WAC Corporation has a large collection of aerial photography for Oregon and conducts contract flying (http://www.waccorp.com/). Bergman Photographic Services carries aerial photography for public access and does specialty contract flying. (http://bergmanphotographic.com). Companies that fly digital cameras include Emerge (http://www.emergeweb.com/) and Terra-Mar.

High altitude photography is available from several sources. The National High Altitude Photography (NHAP) program acquired photos from 1979-1987. These photos are useful for providing a historical perspective. Photos are available in color infrared at 1:58,000 and in black and white at 1:80,000. The scale of the photos is appropriate for synoptic viewing of an area, general riparian-wetland analysis, and change detection applications. The National Aerial Photography Program (NAPP) replaced NHAP in 1987. Original NAPP photos were color infrared at a scale of 1:40,000. NAPP now only uses black and white film at 1:40,000 because they are used for the Digital Orthophotography Quadrangle (DOQ) program. Oregon west of 120° was flown in 2000. East of 120° was flown in 2001. (Susan Nelson, BLM).

Digital Ortho Quads (DOQs) can be an important primary or secondary data source. Orthophotos combine the image characteristics of a photograph with the geometric qualities of a map. The standard digital orthophoto produced by the USGS is a black and white, 1 meter ground resolution quarter quadrangle image. See (http://wgsc.wr.usgs.gov/doq/), USGS Ortho documentation, and (http://rockyweb.cr.usgs.gov/nmpstds/doqstds.html) for more information. Orthophotos are available for the state of Oregon in the state Lambert projection from (http://www.odf.state.or.us/divisions/administrative_services/services/gis/doq.html). Oregon has complete coverage ranging from 1993-1996. Updated DOQ's for 2000 are available for Forest Service Lands.

Historical photos can be very useful for detecting change or determining a reference condition. Many sets of aerial photography at various scales have been flown over the Pacific Northwest since the 1930's. These historical photos can be valuable when conducting retroactive studies that attempt to reveal changes in land cover patterns through time. A common problem associated with these retroactive studies is the difficulty in locating and obtaining copies of the necessary aerial photography. The information on this page was taken from a list of U.S. government sources of historical aerial photography. These government data archives often form a valuable starting point for gathering historical aerial photography. In addition, Ward Carson (University of Washington) has put together a list of sources for historical photographs.

It should be noted that many other sets of aerial photography exist which were flown by private aerial photography firms. Unlike the government agencies involved with collecting and archiving aerial photography, these private firms and the datasets they offer are often much more difficult to locate simply because they are scattered throughout the country and a central index does not yet exist. Efforts are being made to develop a system to catalog and display various sets of aerial photography through the Internet. Until then, persons interested in obtaining these data coverages must continue to go through the ordinary channels of calling knowledgeable people in an area to locate the desired imagery. Digitization and electronic cataloguing of available aerial photography will enable researchers to obtain required datasets much more efficiently.

Sources of Historical Aerial Photos for Use in Natural Resource Evaluation and Management

In Oregon contact:

Dr. Peter Stark or Ms. Sue Trevitt-Clark
University of Oregon Map Library
165 Condon Hall
Eugene, OR 97403
telephone: 503-346-3051

The University of Oregon staff is knowledgeable and has thousands of well-referenced aerial photos in the library. You can check them out to make laser copies at Kinko's. With special permission, you may be able to check them out for a week at a time. Also ask about the ESIO, computerized search prepared by the USGS. The Air Photo Summary Record can be searched by selected criteria (who flew the project, the date, project number, scale, location, film type, etc.) and includes photos from many sources.

The various federal agencies cartographic branches, GIS divisions, and historians, are good sources for information.
A few examples:

Chris Edwards, Aerial Photography
Army Corps of Engineers
319 SW Pine St.
Portland, OR 97204
Bob Peak, GIS, Head of Division
telephone: 503-326-6473

Bill Willingham
Historian, North Pacific Division
Army Corps of Engineers
Portland, OR
telephone: 503-326-5609

Charles Hendrix
Office of History
Army Corps of Engineers - Headquarters
telephone: 703-355-3564

BLM, Aerial Photography
Building 50/ Denver Federal Center
P.O. Box 25047
Denver, CO 80225-0047
telephone: 303-236-7991
FTS: 776-7991

Defense Intelligence Agency
Office of Public Affairs
telephone: 703-695-0071
Depending upon your photo needs!? They have mostly non-U.S. and need a really good reason to let you have the photos.

Cartographic Branch
National Archives
Trust Fund Board
Washington, D.C. 20408
telephone: 703-756-6700
Send a map with the area of interest highlighted and a letter explaining exactly what you are looking for (date, scale, etc.). Their photos are indexed by latitude/longitude. They will get back to you after searching their files to let you know what might be available. Do not put too much stock in information you get from them over the phone as the instantaneous search is not as thorough.

National Archives
Trust Fund Board
P.O. Box 100793
Atlanta, GA 30384
If you know the roll and exposure numbers, send letter and payment (not purchase order) to this address. If you must use a purchase order, the procedure is to send the order to this address and the P.O. to Cashier's Office, National Archives, Trust Fund Board, Washington, D.C. 20408 and hope that the money and the photo order connect somewhere in officialdom.

National Archives
Pacific NW Region
6125 Sand Point Way
Seattle, WA
telephone: 206-526-6507

U.S. Department of Agriculture
Agricultural Stabilization and Conservation Service
Aerial Photography Field Office
2222 West 2300 South
P.O. Box 30010
Salt Lake City, UT 84130-0010
telephone: 801-524-5856

They have A.S.C.S., Soil Conservation Service, and Forest Service photos back to 1950. They also have some NASA photos taken for Department of Agriculture. Anything older goes to the National Archives.

U.S. Department of Interior
Geological Survey
EROS Data Center
Sioux Falls, South Dakota 57198
telephone: 605-594 6151
Maintains photo library for about 20 different agencies (BLM, USGS, DoD, USFWS, BIA, EPA, NASA, Army Corp). Photos go back to the 1940's.

USGS, Calibration Department
Reston, Virginia 22092
telephone: 703-648-4682
Try obtaining the reports for cameras back into the 1950s. You will need the camera number, agency, and date. You can have the camera calibration report faxed directly to you.

Ask around. There are lots of stashes of aerial photos. Check with the power companies, historical societies, private timber companies, and newspaper archives if the sources above don't have what you want. Good luck!

Chapter 7: Quality Assurance & Quality Control

The EPA and others have published a number of excellent documents that guide the reader on how to establish quality assurance and quality control plans (For example see the Environmental Protection Agency's. *Guidance for Data Quality Assessment: Practical Methods for Data Analysis* (http://www.epa.gov/quality1/qs-docs/g9-final.pdf). Quality assurance and quality control (QA/QC) plans can be used to both assure the quality of original data as well as evaluate the quality of existing data.

Some of the key elements to consider when developing a quality assurance and quality control plan include:

Precision: A measure of mutual agreement between multiple measures taken under similar conditions.

Accuracy: The degree to which the measurement reflects the true or expected value.

Representativeness: Defines the likelihood that the measurement accurately reflects a characteristic of a population, variations of a sampling point, environmental condition or trend.

Reliability: Internal QA/QC checks, performance audits, QA/QC reports, published field sampling procedures, and chain of custody procedures are all mechanisms for increasing the reliability of the data. Appropriate credentials and/or experience of the principal investigator and data collection personnel also reflect on the reliability of the data.

Equipment Calibration: Most equipment requires some level of maintenance and calibration. Documentation of calibration processes with dates and results assures the quality of the data collected with that equipment.

If data are being collected to assess riparian areas, it is important to document the quality assurance plan. The QA/QC plan should describe what measures will be taken to test the data quality. If existing data are being used, look for QA/QC plans and evaluate if the existing data are of sufficient quality to meet the needs of the project.

Chapter 8: Data Evaluation and Reporting

Introduction

Whether you are working at the stream reach, watershed, or regional scales, assessment and monitoring of riparian conditions is directly linked to project evaluation and adaptive management. Information from the riparian assessment will provide the foundation for evaluating whether the restoration project or watershed strategies are functioning as planned and achieving the desired goals. It is important to document both successes and failures, and report the findings to interested stakeholders and funding sources.

Evaluation Process

The evaluation report will document valuable lessons that can be applied to future restoration and assessment efforts. Even with the best plans and project implementation, the evaluation will usually identify unforeseen problems. Most restoration efforts require oversight and changing plans based on new information. Sometimes identifying problems will require a midcourse correction. For example, from assessment of a riparian restoration project, after the first year investigators learn that over 50% of planted seedlings died from inadequate moisture. With this information, investigators can decide on the proper course of action to correct the problem.

The evaluation of riparian assessment information should focus on addressing the original goals and answering the questions, as outlined in the assessment plan. It is important to answer the following questions:

Is the restoration project or watershed riparian strategy progressing toward the desired goals?

Is maintenance or an adjustment in the strategy required to keep the restoration project or management approach on course to meet the goals?

Should the project goals be modified because the riparian area is progressing toward a system with other desirable functions?

The evaluation report will include:

A detailed description of the project and the assessment process. For the restoration and assessment portions, describe whether the implementation met the planned design or why the project deviated from the plan.

A statement of what the original project goals and questions were. This documentation should include any quantified performance criteria (e.g., the restoration project's goal was to achieve 50% shade over the channel).

An analysis of the project relative to the goals and the questions.

An explanation of any deficiencies found in the evaluation. For example, the report might include data summaries that indicate tree and shrub seedling survival was not as high as expected due to inadequate soil moisture. In the future, watering or another course of action (perhaps different species that are more drought resistant) is recommended.

Data Reporting

The Oregon Plan Monitoring Team is currently exploring options for storage of data collected in support of watershed assessment and monitoring actions. The Oregon Watershed Enhancement Board (OWEB) maintains a restoration project database that includes data on riparian monitoring (Section H: Project Monitoring Activity). The project inventory reporting form can be found at:

(http://www.oweb.state.or.us/monitoring/wri_forms.shtml).

For information about this form and the restoration database, contact Bobbi Riggers, Oregon Watershed Enhancement Board:

bobbi.riggers@orst.edu

541-757-4263 x235

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