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Department of
Agriculture**

Forest Service

Intermountain Region

Bridger-Teton National Forest Fire Effects & Fuel Treatments Monitoring Handbook

Corral Creek Fire Photo: Dean Burnham

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Bridger-Teton National Forest

Fire Effects Monitoring Handbook

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INTRODUCTION

This document provides direction and reference information for fire effects monitoring of prescribed burns and mechanical fuel treatments on the Bridger-Teton National Forest.

Minimum requirements for monitoring before, during, and after prescribed burns and mechanical fuels projects are outlined here. All prescribed burns and mechanical fuel treatments will require a monitoring plan, which must be based on project objectives. Objectives may dictate more comprehensive monitoring than the minimum requirements can address.

This plan also provides the Forest's guidelines for setting project objectives, developing a monitoring plan and choosing sampling methods. It is intended to standardize the monitoring protocol to the extent possible. A variety of approved methods and data sheets are included in the appendices.

Silviculture prescriptions and burn plans without a monitoring plan will not be authorized. Line officers are ultimately responsible for assuring that fire effects monitoring is carried out, reported, and coordinated with resource managers from all affected disciplines.

GOALS & OBJECTIVES

The following are specific goals and objectives for fuels and fire effects monitoring on the Forest:

- Use monitoring results to determine whether the project meets management objectives.
- Document and analyze both short-term and long-term effects of prescribed fire and mechanical fuels treatments on vegetation.

- Document fire behavior to allow managers to validate burn prescriptions to determine if they achieve the fuels and resource objectives.
- Document efficacy of fuel treatments if a wildfire burns through the project area.
- Track the longevity of fuels treatment effectiveness.
- Detect unforeseen results of prescribed fire and fuels reduction programs.
- Follow trends in plant communities where fire effects literature exists or research has been conducted.
- Determine if the project moves the area towards Forest Plan desired conditions.
- Identify areas where additional research is needed.

BACKGROUND

The Bridger-Teton has been conducting prescribed burns in natural fuels since 1974. Monitoring of fire effects has ranged from research level intensity to little or no monitoring with not even a map of the burn area. Duration of monitoring also varied, with many burns monitored immediate post burn, and others having long term (3-10 year) post fire monitoring. Several research projects have had recurring monitoring for over 20 years.

During the mid 1980's there was an increased interest in using prescribed fire as a tool for habitat management by the Wyoming Game and Fish Department. Most projects initiated and completed at this time were supported financially by the Department as well as the Rocky Mountain Elk Foundation (RMEF). A substantial amount of Game and Fish personnel time was dedicated to these projects in the form of inventory, pre-burn and post-burn monitoring. Game and Fish personnel have continued to monitor projects throughout the forest, either individually or jointly with the Forest Service, and hence have a high degree of ownership in the program.

In 1998, Grand Teton National Park fire management staff established a fire effects monitoring crew. The National Park Service has standardized requirements for fire effects monitoring of all prescribed burning, contained in the NPS Fire Monitoring Handbook. In 1999, the Forest agreed to support the fire effects crew and the Interagency Fire Effects Crew was established.

In the aftermath of the severe wildfire season in 2000, the National Fire Plan (September 2000) and the 10-year Comprehensive Strategy (August 2001) were developed. Both provide direction for managing impacts of wildfire on communities and the environment and reducing wildfire risk. In May 2002, an Implementation Plan for the 10-year Comprehensive Strategy was completed by Federal, State, tribal and local government and non-government representatives. This Plan set forth four primary goals: 1) Improve fire prevention and suppression, 2) reduce hazardous fuels, 3) restore fire-adapted ecosystems, and 4) promote community assistance. Mechanical fuels reduction projects in the wildland urban interface have increased.

The Healthy Forest Restoration Act (2003) requires monitoring of hazardous fuels reduction projects to evaluate progress towards goals and to recommend project modifications.

In 2005, mechanical treatments monitoring was added to the fire effects program. This monitoring helps to determine how mechanical treatments change predicted fire behavior. It also tracks long term changes in forest structure to determine when maintenance treatments are needed.

REQUIRED MONITORING

Forest Service Handbook direction (FSH 1909.12) requires Forests and Ranger Districts to conduct implementation and effectiveness monitoring to determine if plans, prescriptions, projects, and activities are implemented as designed, in compliance with the forest plan and are effective in meeting management direction.

The Bridger-Teton National Forest Land and Resource Management Plan (Forest Plan) requires project level monitoring and evaluation. This monitoring allows quantitative measurement of the progress and results of projects. Table 1 displays the minimum requirements for fire effects monitoring for all prescribed burns on the BTNF. Table 2 describes the minimum monitoring requirements for projects involving mechanical fuel treatments

Table 1. Minimum Acceptable Levels of Rx Fire Monitoring

Inventory • Landscape scale mapped data • Vegetation description obtained from walkthrough or intensive data plots	• Project map including vegetation cover type and structural stage
Pre–Burn • Data collected pre-burn	• Map of project area showing burn unit boundaries, fuel types, plant community and any sensitive plant or animal species locations (including noxious weeds) that require special actions to be taken • Live and dead fuel moisture information • Installation of pre-burn photopoints or vegetation plots, as determined by objectives
During Burn • Data collected during burn; often includes fire behavior, weather and smoke characteristics	• Weather observations recorded at least every hour to include: Temperature, relative humidity, wind speed and direction • Fire behavior: rate of spread, flame length, other specific prescription elements related to time and location of weather observations • Smoke dispersal direction and height related to time and location of weather observations • Live and dead fuel moisture samples collected on site the day of burn for later comparison • Firing pattern and type of ignition used must be documented
Immediate Post-Burn • Data collected immediately post burn, but occasionally up to 3 years post-burn	• Perimeter map of burn • Number of burned and unburned acres in the unit, mapped • Retakes of photopoints if established prior to burn • If a fuels reduction burn, woody fuel and duff reduction, tree/shrub percent mortality
Long Term Fire Effects • Data often collected up to 20 years post-burn.	• Retakes of photopoints if established prior to burn • 1 and/or 3 year post-burn walk-through to detect new noxious weed presence, and further walk-throughs if weeds are detected • If a noxious weed eradication burn, annual monitoring is required

Table 2. Minimum Acceptable Levels of Mechanical Fuel Treatments Monitoring	
Inventory • Landscape scale mapped data • Vegetation description obtained from walkthrough or intensive data plots	• Project map including vegetation cover type and structural stage.
Pre–Treatment • Data collected prior to project implementation.	• Map of project area showing treatment unit boundaries, areas of special consideration such as sensitive plants, cultural resources or wildlife habitat. • Installation of pre-treatment photopoints or vegetation plots as determined by objectives.
During Treatment • Data collected during implementation; often included in contract inspection	• Data collected will depend on parameters of objectives. • Data collected will follow common stand exam protocol.
Post-Treatment • Data collected up to 15 years following mechanical treatment	• Retake photopoints if established prior to treatment. • Data collected will follow common stand exam protocol.
Long Term Mechanical Fuel Treatment Effects • Data collected 15-20 years following treatment. • Data collected following a wildfire within treatment area.	• Data collected will determine need for maintenance treatments. • Retake photopoints if established prior to treatment. • If a wildfire occurs in treatment area, observations of fire behavior. Collect data to determine if treatments were effective.

WILDLAND FIRE USE MONITORING

The extent of Wildland Fire Use for Resource Benefit (WFURB) monitoring should be addressed on a case-by-case basis. Existing resource objectives, fire effects monitor availability, access and other factors should be considered. Perimeter maps for large wildland fire use fires should be considered the minimum acceptable monitoring. Monitoring of WFURB outside the wilderness will be critical in order to determine if objectives are met. Monitoring objectives and methods for WFRB and wildfires will be developed in the coming years.

MONITORING PLANS

Every prescribed burn and mechanical fuels treatment project will include a monitoring plan, outlining the monitoring requirements.

Monitoring plans will include:

1. Map(s) of burn unit showing and describing vegetation cover type and structural stage
2. Measurable and quantifiable monitoring objectives tiered to management objectives in the NEPA document
3. GPS locations and descriptions of monitoring plots and/or photopoints
4. Monitoring methods used
5. Monitoring schedule

A monitoring plan template, writing guide and example is included in Appendix A.

DEVELOPING OBJECTIVES

Measurable project objectives are crucial to project monitoring and are used to evaluate project effectiveness. Objectives should be specific to a project goal, quantifiable and within a specified time. Table 3 displays how objectives can be put into measurable terms.

Table 3. Components of a Measurable Monitoring Objective

Component	Example
1. Target population	Native bunch grasses
2. Time frame	Two years post burn
3. Direction and amount of change / trend *-or-* Target / threshold condition	Increase by 40-60% *-or-* At least 40% cover
4. Variable to be measured	Percent cover
5. Location	Pup Creek
6. Statistical certainty	80%

Measurable Objective Example: *"Increase the percent cover of native bunch grasses in Pup Creek by 40-60% (or "to at least 40%") two years post burn with 80% statistical certainty."*

Furthermore, the way monitoring objectives are stated will determine the amount of plots required, and the statistical methods used in data analysis. Coordination among all involved staff will help determine appropriate objective setting methods and evaluation.

DATA COLLECTION

Appropriate sampling methods for long-term fire and mechanical treatment effects will be developed according to objectives set by management staff. The choices of sampling methods will be guided by agency protocols and regional staff recommendations; however customary, peer-reviewed and/or published methods are required. Consideration should also be given to available resources.

Data collection is made possible by incorporating monitoring talent from multi- and interagency efforts. While it is unimportant who is doing monitoring, fire effects monitors should be competent in local plant identification. Correct species identification will reduce the often high amount of sampling error incurred into monitoring programs.

Table 4 shows many of the accepted methodologies for measuring treatment variables.

Table 4. Established Fire Effects Monitoring Methods for the Bridger-Teton National Forest		
Monitoring Variable	**Method**	**Appendix A Page Number or Other Source**
INVENTORY		
Project Area Map	GIS or Hand drawn	FS Corporate Database or Other Map Source
Project Area Vegetation Maps Showing Cover Types and Structural Stages	GIS, Aerial Photography, Inventory Data	FS Corporate Database, Veg. Specialist
PRE-TREATMENT		
Fuel Moisture	(Norum and Miller 1984) Method Drying Oven or Computrac	12
Photopoint Installation	R4 Range Handbook or FMH	11
Pre-Burn Plot Installation (see immediate and long term effects sections, below)	(see immediate and long term effects sections, below)	
DURING TREATMENT		
Weather Observations: Temp. RH Wind Cloud Cover	On-Site Fire Monitor	Fireline Handbook; Field Observer Reference p. 19
Fire Behavior: Rate of Spread Flame length Flame Height Flame Zone depth	On-Site Fire Monitor	
Smoke: Plume Height Color Drift Direction	On-Site Fire Monitor	
Fuel Moistures (for later comparison) Live Dead	(Norum and Miller 1984) method Drying Oven or Computrac	12
Contract Inspections	Common Stand Exam (CSE) Protocol or Inspection Procedures described in contract	11
IMMEDIATE POST-BURN (First Order Fire Effects)		
Perimeter Map	GPS, Satellite Imagery, Aerial Photography	
Burn Severity	Hand Drawn with Severity Categories based on (Ryan and Noste 1983) or Satellite Imagery based on (Key and Benson 1999)	19
Treatment Acreage Breakdown	Dot Grid or GIS	
Woody Fuels and Duff Reduction	Brown 1982 Method	21
Shrub Mortality	Shrub Transect or "Belt" (Nested Frequency, FMH, or Macroplot)	11
Tree Mortality	FMH, Macroplot, Circular Aspen Plots, CSE Tree Data Form	11, 57
Scorch Height	FMH	21
LONG-TERM (Second Order Fire Effects)		
Random Plot Location	GIS Applications, Grid Map Method, or XY Coordinates Method	32
Ground Cover	Point Samples, CSE Vegetation Composition Form	11

	(Table 4 continued)	
Species Diversity	FMH Veg. Line, Line-Point Intercept, CSE Vegetation Composition Form	11
Herbaceous Vegetation Frequency	Nested Frequency, CSE Vegetation Composition Form	11
Herbaceous Cover or Composition	Line intercept, Line-point intercept (Macroplot), FMH Veg. Line, CSE Vegetation Composition Form	11
Shrub Vegetation Canopy Cover, age class, height	Line Intercept FMH Veg. Line Sampling, CSE Vegetation Composition Form	11
Shrub Density, Height, Age class	Shrub Transect or "Belt" (Nested Frequency, FMH, or Macroplot)	11
Riparian Plant Community or Habitat Type Size	Cross-Section, Greenline	33
Riparian Woody Species Density, Age Class, Mortality and Regeneration	Woody Species Regeneration	
Tree Density, DBH, canopy class	FMH, Macroplot, Circular Aspen Plots, CSE variable or Fixed plot	11, 56
Tree Canopy Cover	Densiometer	60
Tree Mortality	FMH, Macroplot, Circular Aspen Plots , CSE Variable or Fixed Plot	11, 56
Tree Seedling / Resprout Density and Height	FMH, Macroplot, Circular Aspen Plots , CSE Variable or Fixed Plot	11, 56
Photopoint	R4 Range Handbook Method, FMH	11
Fuel Loading	Brown 1982 Method, Photo Index	21

SCHEDULING

Monitoring plans should be initiated simultaneously with the silviculture prescription. Measurable objectives should be developed during the NEPA process in an interdisciplinary manner. Monitoring plans must be provided in a timely manner in order to ensure pre-treatment data is collected and monitoring is scheduled. An annual monitoring scheduling meeting will be held early spring each year to assign monitoring workload. All monitoring plans to be implemented that season must be completed prior to that meeting. This meeting will include multiple agencies partnering in the monitoring effort. Table 5 displays the ideal timeline and responsible personnel for developing and implementing monitoring plans.

DATA STORAGE AND ACCESS

A monitoring folder will be established for all fire effects and fuel treatment plots. See Table 1 in appendix A for a complete list of the folder contents. The original monitoring folder will be stored and maintained at the Bridger-Teton National Forest Supervisor's Office. A central storage location will allow convenient access to the data. A project file is maintained for each project residing at the Ranger District where the project occurred. Along with appropriate NEPA documents, silviculture prescription, burn plan and, all monitoring data and analyses of monitoring data will be included.

All electronic versions of monitoring documents and data will be filed:
K:\btnf\fire_management_pow\5140_prescribed_fire\monitoring

A Monitoring Instruction sheet will be completed at the time of pre treatment monitoring. See appendix A. This sheet includes plot locations, exact protocols, and photopoint information.

DATA ANALYSIS AND SUMMARY REPORTS

Monitoring data analysis will occur after the field season ends. Fire effects data can be analyzed with the FMH software, other statistical software, or spreadsheet. Mechanical treatment data can be analyzed with FSVeg, NRIS or FVS software. An end-of-season monitoring report will be completed and/or presented by March 30 for each preceding field season. A summary report of

each project will be prepared following treatment, and updated as any further post-burn monitoring occurs. Managers may request that the summary is also provided in an oral presentation. Table 5 displays the monitoring timeline and responsible personnel for each step of the project.

Table 5. Monitoring Timeline and Responsibilities

Process	Responsible Entity	
Project proposed	Unit (Ranger District, Park)	
Initial data collected and diagnosed	Unit (Ranger District, Park)	
Nepa Process	Unit (Ranger District, Park)	
Silvicultural Prescription	Heidi Whitlach or Liz Davy	
Develop Monitoring Plan	Zone FMO	
Prescribed Burn Plan	Zone FMO	
Service Contract or Force Account	Zone FMO	
Timber Sale or Stewardship Contract	Zone Timber	
Monitoring Data Collection	Zone FMO	
Monitoring Data Analysis	**Responsible Entity**	**Date Due**
Initial data entry and summary	Data collection crew	January 1
Interpretation of data summary	Zone FMO	March 1
Monitoring files updated	Zone FMO	March 1
Forest Annual Monitoring Report	Forest Silviculturist	March 30

GIS AND MAPPING

All fire projects monitored under this plan must have a mapped burn perimeter and all mechanical fuels projects must have a map of the treatment area. This information is important for project implementation and other aspects of the fire/fuels program including prescribed and wildfire pre-planning.

Where applicable and determined by project objectives, burn severity can be mapped by hand or with satellite imagery. The *Ryan and Noste* (*1983)* severity categories should be followed for appropriate map coarseness and format. GIS produced severity maps should follow methods from *Key and Benson 1999*.

Any associated GIS maps kept for long-term monitoring will be prepared according to Bridger-Teton GIS standards. Standard metadata will be included. Annually, all landscape prescribed burns and fire use fires will be entered into the Bridger-Teton corporate database.

<u>Natural Resource Information System</u>

FSVeg is a database containing inventory data for the Bridger-Teton National Forest and other National Forests. Information contained in the system includes spatial data, vegetation attributes, information on soils, water, wildlife and noxious weeds. This database will be the source and storage area of inventory data used in fire effects and mechanical fuels treatment monitoring.

APPENDIX A

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Internet Resources

USDA Natural Resources Conservation Service Plant Database.
Plant taxonomic hierarchy, classification, characteristics, distribution and symbols. Also a good resource for T&E species, and noxious & invasive species.
http://plants.usda.gov/

Fire Effects Information System (FEIS).
Fire effects and ecological information for selected flora and fauna.
http://www.fs.fed.us/database/feis/

US Fish and Wildlife Service; Fuel and Fire Effects Monitoring Guide
A different slant on many of the monitoring techniques used in this guide.
Insightful, with complete explanations of many aspects of monitoring.
http://fire.r9.fws.gov/ifcc/monitor/RefGuide/cover/

FIREMON Fire Effects Monitoring System; Sampling Methods for Tree Data
A sampling method useful for monitoring tree species and tall shrubs. Good for capturing mortality, survival, growth, and seedling recruitment.
http://fire.org/firemon/td

USGS Northern Rocky Mountain Science Center; Normalized Burn Ratio (NBR) Methods for Measuring Burn Severity
Using remote sensing images (TM bands 4 and 7) to map burn severity in the Northern Rockies.
http://nrmsc.usgs.gov/research/ndbr/.htm

Fire Monitoring Handbook
A comprehensive guide to fire effects monitoring. Contains the protocol used by the National Park Service for fire effects monitoring.
Linked to: http:fire.r9.fws.gov/ifcc/monitor/Refguide/default.html

Common Stand Exam Protocols
fsweb.nris.fs.fed.us/products/FSVeg/documentation

Information on NRIS
fsweb.nris.fs.fed.us

FSH 2209.21 - RANGELAND ECOSYSTEM ANALYSIS AND MANAGEMENT HANDBOOK
fsweb.r4.fs.fed.us/directives/fsh/2209.21

Live and Dead Fuel Moisture Sampling Methods

Equipment Needed

Containers---- Containers for fuel moisture samples should have tight-fitting lids and be rustproof, permanently numbered, and of a material that can be put directly into a drying oven. From our experience, the best containers are drawn aluminum soil sample cans. The tight-fitting lids limit evaporation, and they do not oxidize, which is important in preventing errors caused by reduction in the weight of cans. Cans 2 1/2 inches in diameter and 1 3/4 inches high work well for all fuels except large-leaved shrubs, such as Wood's rose (*Rosa woodsii*) and buffaloberry (*Sheperdia canadensis*). For these species, a can 3 1/4 inches in diameter by 2 inches high is better. Glass jars are too heavy and fragile. Paint cans eventually lose their tight-fitting seal and are too large for most sampling purposes. Plastic containers tolerant of high temperatures are suitable in some cases.

Both the lids and the sides of containers should be permanently identified with a number. Each empty container and lid should be weighed together, to the nearest 0.1 gram (tare weight[3]), and the identification number and weight permanently recorded in your files.

Sample carrying case--- A carrying case (fig. 1) for sample cans should be constructed from plywood or other sturdy material. The case should hold the samples securely, have a hasp or other type of latch and a carrying handle, and provide a place to put field data sheets (an envelope taped to the inside of the case works well). The size of the case depends on the dimensions of the sample cans and the number of samples to be collected each time, but the case should be easy to carry through vegetation and compact enough to fit in vehicles and aircraft.

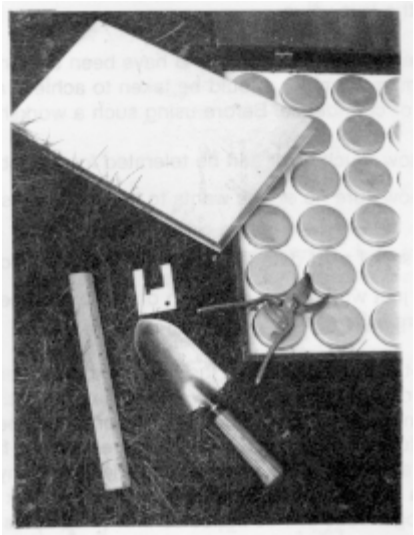


Figure 1--- A carrying case for sample cans should hold the samples securely. A covered notebook, clippers, trowel, ruler, and fuel gauge are standard sampling equipment.

[3] **The weight of the empty clean container.**

Clippers--- Good quality pruning shears (fig. 1) with two curved sharp blades are most effective for clipping fuels. At least two pair should be used: one for dead woody fuels and the other for live fuels. Sharpening may be necessary during the field season.

Garden trowel--- A trowel (fig. 1) with a heavy shank and a sharp blade is used for duff and soil moisture sampling.

Fuel gauge--- Cut from rolled steel or heavy aluminum, a fuel gauge (fig. 1) is used to check the diameter of a particle of dead woody fuel.

Ruler--- A ruler that resists breakage and repels water and is long enough to measure duff depths should be included.

Tape--- One-half-inch-wide drafting tape is the best tape for sealing sampling cans because it can be readily removed from the can. Masking tape can be used, but it frequently leaves a residue that is hard to remove, particularly if the exterior of the can becomes damp or hot. Wide rubber bands or cross sections of motorcycle tire inner tubes have also been used successfully and are reusable.

Clipboard--- A covered clipboard for holding the data sheets, field notes, or this sampling guide is a great aid in the field.

Gloves--- Heat-resistant gloves with a fair amount of flexibility are needed to remove heated samples from the drying oven.

Data sheets--- All data sheets should be designed specifically for a particular sampling job. Two sheets are required: one for field use and one for fuel moisture calculations in the laboratory. The field data sheets are used to list the locations, dates, sampling times, name of person doing the sampling, all fuels to be collected, the number of each sample can, and any observations or comments. Because the field sheets often become smudged and rumpled, the laboratory sheets should be used for recording drying times and calculations of sample weights and moisture content of the fuel. Both sheets are retained for transferring and documenting data.

Drying oven--- An electric oven specifically designed for drying samples should be obtained. The best type is a mechanical convection oven with a built-in fan to circulate the heated air and ventilate the oven. Fuels dry more uniformly and rapidly than in a gravity convection oven. This agrees with guidance given by Countryman and Dean (1979). The oven must be able to maintain a regulated temperature of 100 °C and have adequate volume to allow air to circulate freely around all samples. Depending on the number of samples to be processed at one time and the size of the oven, an extra shelf and mounting brackets can be purchased to increase the capacity of the oven without impairing its performance.

Scale--- A scale is needed for weighing the samples. The same scale should be used both times the sample is weighed. A top loading, beam or torsion balance scale, capable of accurately measuring to the nearest 0.1 gram, is adequate for weighing most fuel samples. If an electronic balance is available, the job can be done more accurately and quickly. The cost, however, is justified only if many samples will be processed over a long period or if greater precision is necessary.

The scale should be checked for accuracy before the field season and regularly during use. The calibration of beam or torsion balances must be performed according to the manufacturer's directions, using the calibration weights provided. Almost without exception, precision electronic scales must be adjusted by the manufacturer.

The scale must be placed on a firm, level surface such as a heavy table or counter top. The area must be free from drafts that cause movement of the scale mechanism and lead to inaccurate readings.

Collecting the Sample

On arrival at the sampling site, place the sample case in a shady spot and prepare the field data sheet. Record the site number, date, time, name of observer, and the can number for each fuel sample to be collected.

Live Fuels--- Do not collect live fuels if waterdrops are present on leaves or stems. Such free surface water will cause large errors in calculated values of moisture content. Shaking the leaves to remove excess water is not adequate because enough free water can remain to bias the sample. If rain prevents collection of certain samples, write rain in the space where the can number for these samples would be recorded. If no rain has fallen for several hours, the moisture may have evaporated from some of the plants, and sampling can proceed. Dead fuel samples and lichens and mosses may be collected if recent precipitation has occurred, but the presence of any free surface water should be recorded on the data sheet. Duff and organic layer samples may be collected even if rain is falling, but great care must be taken to prevent raindrops from getting into the sample can.

Materials such as mosses, lichens, shrubs, herbaceous plants, and grasses become fairly stiff as they dry, and they may spring from their cans while in the drying oven. This makes the lid difficult to replace, and some of the sample may fall out. For this reason, pack mosses, lichens, leaf litter, organic layer material, and duff loosely in the sample cans. Never compress them to get additional material into the can. It is better to fill several cans than to force too much into one can. Collect an adequate amount of sample material, filling the can about three-fourths full.

Cut the stems of each shrub and herbaceous plant into small pieces as they are dropped into the can. Clip all of the sample again after it is in the can. Cutting the plants into smaller pieces also allows a greater amount of material to fit into a can. Clip grass and sedge leaves from various plants, holding the entire sample in one hand. Then cut all leaves together into short sections as they are dropped into the can (fig. 2).

Figure 2. While holding the grass and sedge sample material in one hand, clip all blades into a size that will fit into the can without bending them.

Stack the large leaves from such shrubs as rose or buffaloberry in one hand and cut them into halves, then quarters or smaller sections as shown in figure 3. Do not drop the cut sections of leaves into the can-place each stack of leaves on its side in the can.

This is important because the leaves curl as they dry, greatly increasing both the space they occupy and the chance of losing part of the sample in the oven.

Figure 3. Cut a stack of large leaves into smaller segments and carefully fit them into the sample can.

As you move about the site and collect material, replace the lid on the can to cover materials already collected. When the can is filled, immediately replace the lid tightly and seal it by encircling the lid with one layer of drafting tape (fig. 4). It is easier to remove the tape if a small length of the end is folded onto itself, to form a tab. Be sure no dirt or debris clings to the outside of the sample container. Any comments or observations about plant phenology (as discussed later) should be recorded on the field data sheet.

Figure 4. Use one layer of drafting tape to seal the sampling can. Be sure to tape around the entire lid.

Collecting Dead Fuels

Down and Dead Woody Fuels--- Samples of 0- to 1/4-inch- and 1/4- to 1-inch-diameter down and dead woody fuels should be taken from several branches resting on the ground. Do not collect the entire sample from one location or from a single branch. Collect twigs of as many sizes as possible within the size class. All samples must be collected from dead wood that is detached from its growth point. Do not collect parts buried in the litter, duff, or moss. Do not collect dead branches attached to the bases of live trees or detached branches inclined more than 45' from the horizontal. Do not sample from trees or branches that have recently fallen. Cut several 1- to 11/2-inch-long sections from each 0- to 1/4-inch diameter down, dead branch. Collect only one piece from each 1/4- to 1-inch down, dead branch (fig. 5). Remove all lichen or

other debris and very loose pieces of bark from the samples. The wood collected does not have to be completely sound but should not be decayed to the point of being easily rendered into powder or splinters when rubbed between your fingers. Some splitting caused by drying is acceptable. Wood in various stages of decay should be collected in

proportion to its presence on the site, as long as the rules just stated are followed.

Figure 5. When collecting 1/4- to 1-inch down and dead woody fuels, cut one piece about 1 to 11/2 inches long from each dead branch on the forest floor.

Arrange the cans in numerical order in the carrying case, along with the field data sheets. Keep the samples cool and dry until they are weighed. If the collected samples receive even moderate heat, some moisture will evaporate, possibly escaping the can, or else remain as vapor and be lost when the sample is opened, yielding an error. Further, decomposition could begin, again causing a loss in weight of the sample and an error. Refrigerate the samples if they cannot be weighed the same day as collected.

Weighing the Sample

Preheat the drying oven to 100 degrees Centigrade. Transfer the information from the field data sheet to the laboratory calculation sheet. Remove the tape from the can lid. Make sure no tape or other debris is stuck to the outside of the can. Adjust the scale to zero. Place a can on the center of the scale platform. Read the scale and record it as the "wet" weight on the laboratory calculation sheet. Check to see that the identification and contents of the can match those recorded on the field and laboratory sheets. Remove the can from the scale and replace the lid. If any sample material falls out during weighing or when placing it in the oven, weigh the sample again.

Repeat this procedure until all samples are weighed. Be sure to set the scale to zero before each sample is weighed, because the adjustment can be changed by minor vibrations and movement of the scale, causing errors.

Remove the lid and place it under the can as you put the sample in the drying oven. Arrange the cans in numerical order, with numbers facing toward you. Space the samples evenly in the oven so that air circulates freely around every can. If few samples are being dried, center them on the middle rack of the oven. Record the date and time that the samples were put into the oven.

Drying the Sample
Dry the sample for 24 hours at 100 °C, or 18 hours at 100 °C if only live fuels are being processed. Large samples of very wet duff should dry 48 hours. **Do not** put additional samples into the oven while drying a set of samples. If you do, the original samples will absorb moisture from the new samples and must then be dried an additional 24 hours.

At the end of the required drying time, take the samples from the oven and quickly replace the lid tightly as each can is removed. This prevents the absorption of moisture from the air. **Do not** leave the oven door open. It should be opened only long enough to remove a few samples, because moisture from the room will enter the oven and will be quickly absorbed by the dried samples inside. Enough moisture could easily be added to the samples to cause a significant error. If any sample material falls from a can during the drying process, throw the sample away unless you know which can it fell from and you can replace all of it in the right can.

Allow the covered cans to cool to room temperature before weighing them. Hot air in the can causes buoyancy and may result in a weighing error, particularly if the samples are very light. If you cannot wait for the samples to cool, remove the lid just before each sample is weighed, place the lid beneath the can and then put the sample on the scale. Weigh the sample quickly and record its (dry) weight. If the sample was cooled to room temperature before it was weighed, it can be weighed with the lid on. In either case, check the can number and its contents before you record the dry weight on the laboratory sheet. Check the scale for a zero weight setting before weighing the next sample.

After each dried sample is weighed, replace the lid tightly on the can and save the sample until the fuel moisture content is calculated. If an obvious error appears in the calculation, the sample can be weighed again and the source of the error may be found. Once fuel moisture calculations have been made, discard the sample and clean the cans for reuse. Remove **all** sample and tape residue from the cans. Wiping with a clean rag is sometimes enough to clean the insides of the cans, but they must be washed and scrubbed frequently. Containers must be free of soap residue and completely dry before the lids are replaced and the cans are stored for future use. Air drying is more effective than wiping the cans dry.

Calculating Moisture Content
The formula for calculating percent moisture content is:

$$\frac{\text{Weight of water in sample}}{\text{dry weight of sample}}(100) = \text{percent moisture content.}$$

This is equal to:

$$\frac{\text{Wet weight of sample - dry weight of sample}}{\text{dry weight of sample}}(100) = \text{percent moisture content.}$$

This is most easily done by the following formula:

$$\frac{\text{Wet sample weight - dry sample weight}}{\text{dry sample weight - container tare weight}}(100) = \text{percent moisture content.}$$

Here is an example:

Wet sample weight = 48.2 grams. Dry sample weight = 46.9 grams. Container tare weight = 38.1 grams. By the formula above:

$$\frac{(48.2 - 46.9)}{(46.9 - 38.1)} (100) = \frac{1.3}{8.8} (100) = 0.1477 (100) = 14.77 \text{ percent}$$

or: ≈14.8 percent moisture content.

If the averages of many similar samples are to be calculated, one decimal place should be kept, to maintain precision, rather than rounding to the nearest whole number.

If a programmable calculator capable of storing information in three registers is available, the writing of a program for this procedure will greatly increase the speed and accuracy of the calculations. Whether the computations are done by hand or with a calculator, **repeat** the calculations to be sure they are correct.

Adapted from: *Norum, Rodney A. and Melanie Miller. 1984. Measuring Fuel Moisture Content in Alaska: Standard Methods and Procedures. Gen. Tech. Rep. PNW-171. U.S. Department of Agiculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 34 p.*

Burn Severity Rating System
Visual Character of Ground Char from Observation of Depth of Burn

Ground Char Class	Timber / Slash	Shrub Fields	Grass Lands
Unburned	The fire did not burn on the forest floor. Some damage may occur to vegetation due to radiated or convected heat from adjacent areas. Ten to twenty percent of the area within slash burns is commonly unburned. There is a wide range in the percent of unburned areas within fires in natural fuels.	See timber / slash	See timber / slash
Light Ground Char	Leaf litter is charred or consumed. Upper duff may be charred, but the duff layer is not altered over the entire depth. The surface generally appears black immediately after the fire. Woody debris is partially burned. Light ground char commonly makes up 0-100 percent of burned areas with natural fuels and 5-75 percent of slash areas.	Leaf litter is charred or consumed, and some lead structure is still discernible The surface is predominantly black, although some gray ash may be present immediately after the fire. Gray ash soon becomes inconspicuous. Charring may extend slightly into the soil surface where leaf litter is sparse, but the mineral soil is not otherwise altered. Some leaves and small twigs remain on the plants. Burns are irregular and spotty. Less than 60 percent of the brush canopy is commonly consumed.	Litter is charred or consumed, but some plant parts are still discernible Charring may extend slightly into the soils surface, but the mineral soil is not otherwise altered. Some plant parts may still be standing. Bases of plants are not deeply burned and are still recognizable. Surface is predominantly black immediately after the burn, but this soon becomes inconspicuous. Burns may be spotty to uniform, depending on the continuity of the grass.
Moderate Ground Char	Litter is consumed Duff is deeply charred or consumed but the underlying mineral soil is not visibly altered. Light-colored ash prevails immediately after the fire. Woody debris is largely consumed. Some branch wood is largely consumed. Some branch wood is present, but no foliage or twigs remain. Logs are deeply charred. Moderate ground char commonly occurs on 0-100 percent of natural burn areas and 10-75 percent on slash burns. Trees with lateral roots in the duff are often left on pedestals or topple. Burned-out stump holes are common.	Surface lead litter is consumed. Some charred litter may remain but is sparse. Charring extends up to 0.5 inches into mineral soil but does not otherwise alter the mineral soil. Gray or white ash is conspicuous immediately after the burn, but this quickly disappears. Some charred stems remain on the plants, and these are generally greater than 0.25-0.50 inches in diameter. Burns are more uniform than in previous classes. Between 40 and 80 percent	Litter is consumed, and the surface is covered with gray or white ash immediately after the burn. Ash soon disappears, leaving bare mineral soil. Charring extends lightly into mineral soil, but the soil is not otherwise altered. Plant parts are no longer discernable, no plant parts standing, and the bases of plants are burned to ground level. Plant bases are obscured in the ash immediately after burning. Burns tend to be uniform. Moderate ground char is

		of the brush canopy is commonly consumed.	generally limited to backing fires and fires burning during dry conditions.
Deep Ground Char	Litter and duff are completely consumed, and the top layer of mineral soil is visibly altered, often reddish. Structure of the surface soil may be altered. Below the colored zone ½ inch or more of the mineral soil is blackened from organic material that has been charred or deposited by heat conducted downward. Twigs and small branches are completely consumed. Few large branches may remain, but those are deeply charred. Sound logs are deeply charred, and rotten logs are completely consumed. Deep ground char occurs in scattered patches under slash concentrations or where logs or stumps produced prolonged, intense heat. Deep ground char generally covers less than 10 percent of natural and slash areas. One extreme case of 31 percent was reported in a slash burn. In extreme cases, clinkers or fused soil may be present. These are generally restricted to areas where slash was piled.	Leaf litter is completely consumed, leaving a fluffy white ash surface. All organic matter is consumed in the mineral soil to a depth of 0.5-1.0 inches. This is underlain by a zone of black organic material. Colloidal structure of the surface mineral soil may be altered. Large branches with main stems are burned, and only stubs greater than 0.5 inches in diameter remain.	Deep ground char is uncommon due to short burnout time of grasses. Surface consists of fluffy white ash immediately after the burn. This soon disappears, leaving bare mineral soil. Charring extends up to 0.5 inches into the soil. Soil structure is slightly altered (for consistency with other fuel types, no citations specifically mention soil alteration). Deep ground char is generally limited to situations where heavy loadings on mesic sites have burned under dry conditions and low wind.
Not Applicable	Inorganic substrate, no vegetation (rock, talus, water etc.)	Inorganic substrate, no vegetation	Inorganic substrate, no vegetation

From: *Ryan, K. C. and N. V. Noste. Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.*

Scorch Height

Individual Tree Scorch Height

Estimate the maximum scorch height on each overstory tree two weeks to two months after the fire has burned across the monitoring plot. **Note:** If another time frame (e.g. three months or year 1 post burn exposes scorch patterns more definitely, measure scorch height again at that time and make a note of it.

Maximum scorch height is measured from ground level to the **highest point** in the crown where foliar death is evident. Some trees will show no signs of scorch but the surrounding fuels and vegetation will have obviously burned. In this case, you can estimate scorch height by examining adjacent vegetation. It may be useful to produce a graph of scorch heights to show the variation around the average. Managers may want to correlate scorch height with the pre-burn locations of large dead and down fuels; these correlations usually require photographs or maps of fuel pockets.

Percent Crown Scorched

For each overstory tree, estimate the percent of the entire crown that is scorched. Average percent crown scorched may be calculated.

Adapted from: *National Park Service National Fire Monitoring Handbook. 2000. U.S. Dept. of the Interior. National Park Service. 318 p.*

Field Methods for Inventorying Fuels

Sampling Intensity

Number And Size Of Sampling Planes

Choose sampling plane lengths from the following tabulation:

Table 1. Suggested Sample Plane Lengths (Feet)			
	Diameter of Dead Down Woody Material		
Downed Material	0 - 0.24” & 0.25” - 0.99”	1” - 2.99”	3”+
Non-Slash (Natural)	6 feet	10 – 12 feet	35 – 50 feet
Discontinuous Light Slash	6 feet	10 – 12 feet	35 – 50 feet
Continuous Heavy Slash	3 feet	6 feet	15 – 25 feet

For any area where the material is discontinuous, 15 to 20 sample points should be located using the sampling plane lengths shown in the tabulation. This sampling intensity will often yield estimates having standard errors within percent of the mean estimates (See Appendix A). Areas larger than approximately 50 acres that contain a high diversity in amount and distribution of downed material should be sampled with more than 20 points. If material larger than 3 inches in diameter is scanty or unevenly distributed, the longer sampling planes in the tabulation should be used.

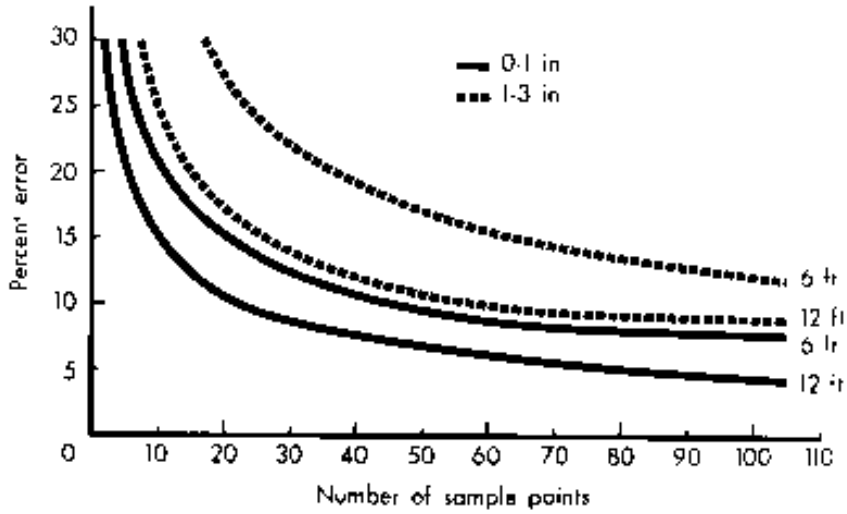


Figure 1. Percent errors for number of particle intersections along a 6- and 12-foot length sampling planes related to number of sample points for quantities of light slash and nonslash. Percent error is 100X (standard error of the estimate divided by the mean estimate).

The amount and distribution of downed woody material vary greatly among and within stands. Thus, these sampling recommendations should be considered approximate because a greater or fewer number of plots may be required to furnish adequate precision for any given area. Sampling intensities are discussed further in.

Sampling precision can be controlled by altering the number of plots and length of sampling planes. As a general rule, the more downed material on an area, the fewer the number and shorter the length of sampling planes required to achieve a given level of precision. The data in the figure is based on average sampling variation for number of intersections of 0- to 1 -inch and I- to 3 -inch particles and can help in choosing number of plots and length of sampling planes.

The data the figure are from many stands of varying composition and downed debris accumulations in northern Idaho and western Montana. Curves for all material under 3 inches in diameter would fall between those for the 0- to 1 -inch and 1 - to 3 inch classes.

Percent errors of 20 percent or less are probably adequate levels of precision for assessing most fuel problems. Percent error is the standard error of the estimate divided by the mean estimate and expressed as a percentage. More precision, such as percent errors of 10 to 15 percent, may be desirable for evaluating utilization potential of downed woody material.

Precision is maximized using a different length of sampling plane for each size class. However, considering both field effort and precision, it is more efficient to use the same plane length for sampling the 0- to 0.25- and 0.25- to 1-inch classes. The following suggestions will help determine the most efficient number and length of sampling planes for a given area:

1 . Record data from about 20 sampling planes in an area and calculate the variation for guiding further sampling.

2. For material larger than 3 inches in diameter, the sampling plane should be long enough so that on the average at least one intersection occurs with three-fourths or more of the planes. A large sampling variance results when many zeros are recorded for intersections. In areas where very little downed material exists, sampling planes should actually be one to several hundred feet long to provide respectable precision. Where many sampling planes have zero entries, other methods such as measurement of length and diameter of all downed pieces may be the most efficient method of inventory.

3. The number and length of sampling planes should be chosen so that for a piece size of interest, such as material over 3 inches in diameter, at least 35 to 50 intersections occur over an entire sampled area.

Sampling Precision For Depth Measurements

To achieve percent errors of 15 and 20 percent using two-stage sampling, the most efficient number of secondary sampling units appears to be three for fuel depth and two for duff depth.

The data for the figure at the fight represents average variation from sampling a wide variety of forest and downed fuel conditions in northern Idaho and western Montana. Several thousand measurements were taken using two secondary sample points for duff depth and three secondary sample points for fuel depth. Vegetation qualifying for fuel depth measurements included all dead downed woody material and dead brush, grass, and forbs. The data were subjected to analysis of variance for two stage sampling.

The number of sample plots required to attain a given level of precision varies considerably among different areas. For choosing sampling intensities for specific areas the number of primary sample points in the figure could be adjusted up or down considerably, depending on homogeneity of the dead vegetation strata.

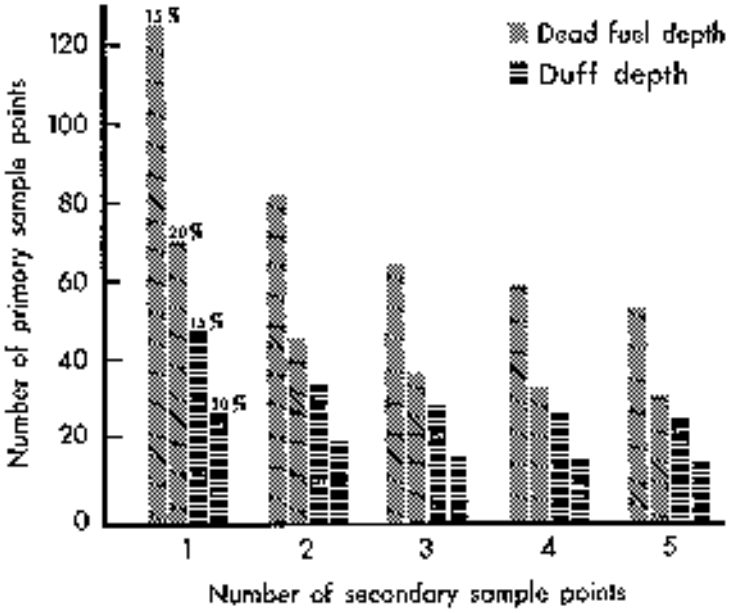


Figure 2. Number of primary and secondary points needed to achieve percent errors of 15 and 20 percent for fuel depth and duff depth.

Field Equipment

The following equipment is suggested to accomplish the field sampling:

	Table 2. Field Equipment	
	Item	**Use**
1	Hand Compass	Transect and Plot Layout Random Orientation of Sampling Planes
2	Fifty (50) Foot Tape and Chaining Pin	Delineate the Sampling Planes
3	Plot Rod	Delineate Sampling Planes and if Calibrated, Measure Fuel Depth
4	Go-No-Go Gage (Figure 2)	Determine Size Class of Borderline Particles
5	One Foot Ruler (preferably marked in tenths of inches)	Measure Duff Depth and Diameters of Pieces Over 3 Inches. Fuel Depth Could be Measured With S
6	Clinometer With Percent Scale	Slope Measurement
7	Sampling Forms	Record Data

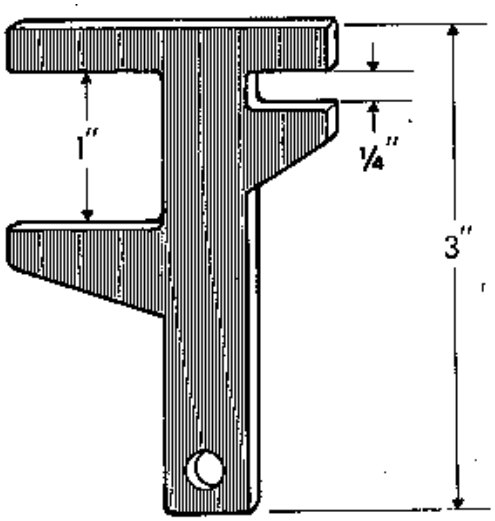


Figure 3. A Go-No-Go Gage

Locating Sample Points
Locate plots systematically; two methods are:

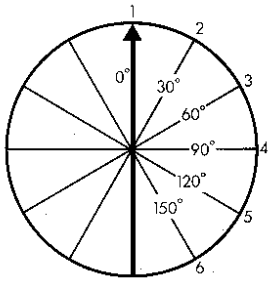
Locate plots at a fixed interval along transects that lace regularly across a sample area (uniform sampling grid). For example, on a sample area, mark off parallel transects that are 5 to 10 chains apart. Then along the transects locate plots at 2- to 5-chain intervals.

Locate plots at a fixed interval along a transect that runs diagonally through the sample area. To minimize bias, have the transect cross obvious changes in fuels. Before entering the sample area, determine a transect azimuth and distance between plots.

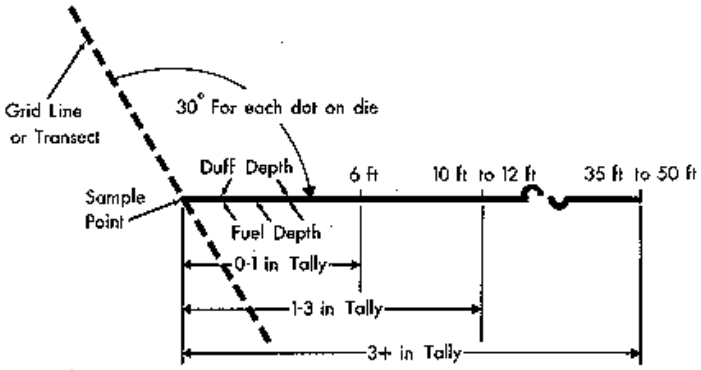
Sample Point Procedures

Step 1
Mark the sampling point with a chaining pin (No. 9 wire or similar item). Avoid disturbing material around the point. Accurate estimates require measurements of undisturbed material. If standing tree measurements (d.b.h. and height) are a part of the inventory, measure downed material first.

Step 2
Determine direction ofsamplingplane by turning a compass to indicate one of six 300 angles between 0 degrees and 150 degrees. The 0 degree heading is the transect direction. Turn a fixed direction, such as clockwise, to position the sampling plane. As an alternative for indicating direction ofthe sampling plane, use the position of the second hand on a watch at a given instant. To avoid bias in placement of the sampling plane, do not look at the fuel or ground while turning the interval.



Step 3
Denote position of the sampling plane by running a tape or string out from the sampling point *parallel to the ground* in the direction determined in Step 2. Extend the tape to the length of the longest sampling plane. A fiberglass rod or 1/2-inch aluminum tube placed along the string beginning at the sampling point facilitates counting pieces less than 1 inch in diameter. The rod should be 6 feet long, the length of sampling plane for small particles. The tape and rod fix the position of vertical sampling planes.



Step 4
Measure or estimate slope by sighting along the sampling plane from the sample point using an Abney level or similar device. Ample precision is the nearest 10 percent, which can be coded using one digit (10 percent = 1, 90 percent = 9, etc.).

Step 5

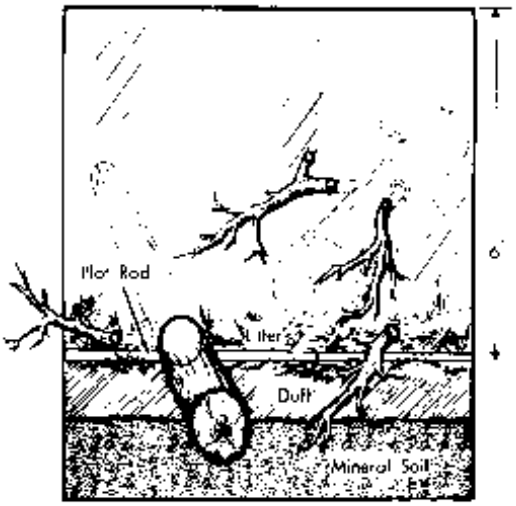
Tally the number of particles that intersect the sampling plane by the following size classes:

0 .0 to 0.2411 (O to 0.6 cm)
0.25" to 0.99" (0.6 to 2.5 cm)
1.0" to 2.99" (2.5 to 7.6 cm)

The intersections can be counted one size class at a time or "dot tallied," which takes slightly longer than counting.

The actual diameter of the particle at the point of intersection determines its size class. A go-no-go gage with openings 0.25 inch, 1 inch, and 3 inches works well for separating borderline particles into size classes and for training the eye to recognize size classes (see figure on left below).

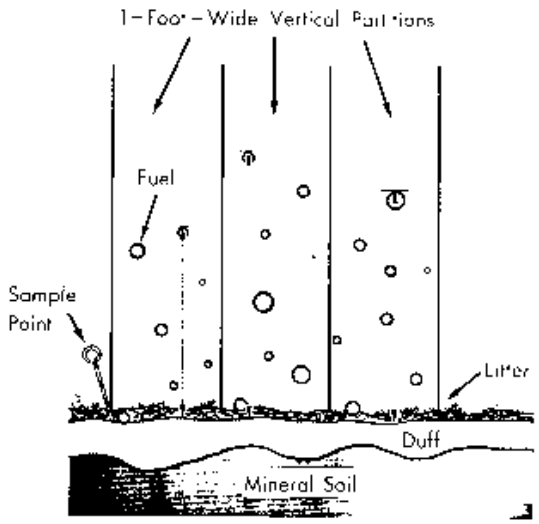
The vertical plane is a plot. Consequently, in counting particle intersections, it is very important to visualize the plane passing through one edge ofthe plot rod and terminating along an imaginary fixed line on the ground. once *visualized on the ground, the position of* the line should not *be changed white counting particles* (see figure on right below). See tally rules for qualifying particles.



O Intersections

Step 6

Take three measurements of dead fuel depth. Record depth as the vertical distance from the bottom of the litter layer to the highest intersected dead particle for each of three adjacent 1-foot-wide vertical partitions of the sampling plane. Litter is the surface layer of the forest floor and consists of freshly fallen leaves, needles, twigs, bark, and fruits. Begin the vertical partitions at the sample point. Record to the nearest whole inch.

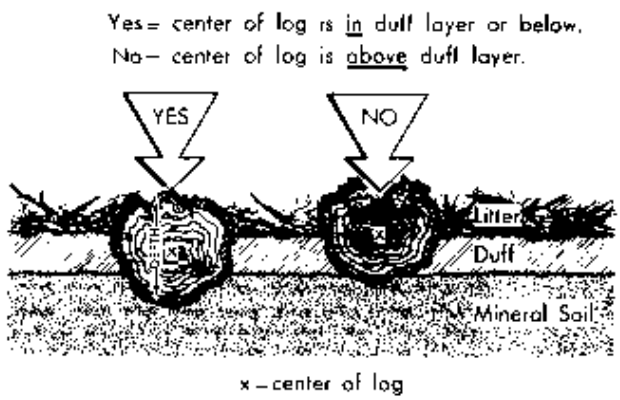


Depth should be measured from only those particles included in the inventory for loading. For example, particles acceptable for measurement by the planar intersect technique are also acceptable for determining depth. If other techniques are used to estimate weight per acre of grass and forbs, this vegetation would also qualify for determining depth.

Step 7

Measure vertical depth of duff to the nearest 0.1 inch using a ruler along the sampling plane at two points: (1) I foot from the plot center; and (2) a fixed distance of 3 to 5 feet from the first measurement.

Duff is the fermentation and humus layers of the forest floor. It does not include the freshly cast material in the litter layer. The top of the duff is where needles, leaves, and other castoff vegetative material have noticeably begun to decompose. Individual particles usually will be bound by fungal mycelium. When moss is present, the top of the moss. The bottom of the duff is mineral soil.



Carefully expose a profile of the forest floor for the measurement. A knife or hatchet helps but is not essential. Avoid compacting or loosening the duff where the depth is measured.

When stumps, logs, and trees occur at the point of measurement, offset one foot perpendicular to the right side of the sampling plane. Measure through rotten logs whose central axis is in the duff layer.

Step 8

Measure or estimate the diameters of all pieces 3 inches in diameter and larger that intersect the sampling plane, Measure the diameters at the point of intersection to the nearest whole inch.

Record diameters separately for rotten and non-rotten pieces. Consider pieces rotten when the piece at the intersection is obviously punky or can be easily kicked apart.

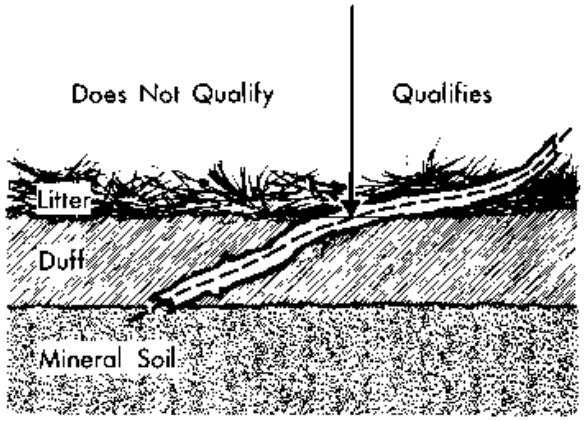
A ruler laid perpendicularly across a large piece of fuel works satisfactorily for measuring diameter. Be sure to avoid parallax in reading the ruler. Calipers also work well for measuring diameter. A diameter tape, however, is unsatisfactory for pieces in contact with the ground.

Step 9
For the entire sample area, record the predominate species of the 0- to 0.99-inch-diameter branchwood. An average diameter for the 0- to 0.24-inch, and 0.25- to 0.99-inch size classes will be selected from this information. If several species comprise the downed debris, estimate the proportion of the two or three most common species. Base this estimate on a general impression of what exists on the sample area and record as percentages of total 0- to 0.99-inch branchwood. Or, for a slight reduction in accuracy, omit this step and in the calculations use an average diameter for a composite of species.

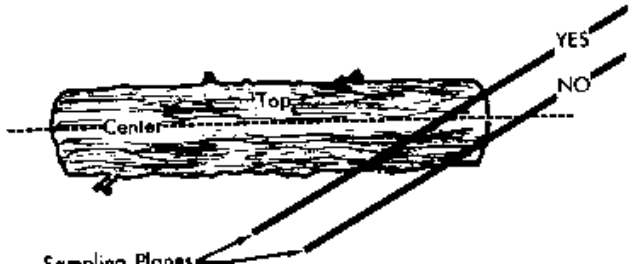
Tally Rules
The following rules apply to downed woody pieces of all diameters:

1 . Particles qualifying for tally include *downed, dead* woody material (twigs, stems, branches, and bolewood) from trees and shrubs. Dead branches attached to boles of standing trees are omitted because they are not downed vegetation. Consider a particle downed when it has fallen to the ground or is severed from its original source of growth. Cones, bark flakes, needles, leaves, grass, and forbs are not counted. *Dead woody stems and branches still attached to standing brush and trees are not counted.*

2. Twigs or branches lying in the litter layer and above are counted. However, they are not counted when the intersection between the central axis of the particle and the sampling plane lies in the duff (forest floor below the litter).

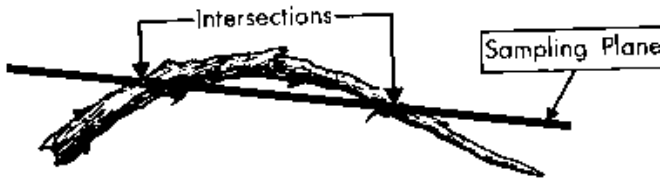


3. If the sampling plane intersects the end of a piece, tally only if the central axis is crossed. If the plane exactly intersects the central axis, tally every other such piece.



4. Don't tally any particle having a central axis that coincides perfectly with the sampling plane. (This should rarely happen.)

5. If the sampling plane intersects a curved piece more than once, tally each intersection .



6. Tally wood slivers and chunks left after logging. Visually mold these pieces into cylinders for determining size class or recording diameters.

7. Tally uprooted stumps and roots not encased in dirt. For tallying, consider uprooted stumps as tree boles or individual roots, depending on where the sampling planes intersect the stumps. Do not tally undisturbed stumps.

8. For rotten logs that have fallen apart, visually construct a cylinder containing the rotten material and estimate its diameter. The cylinder will probably be smaller in diameter than the original log.

9. Be sure to look up from the ground when sampling because downed material can be tallied up to any height. A practical upper cutoff is about 6 feet. However, in deep slash it may be necessary to tally above 6 feet.

When standing trees are inventoried along with downed material, it is necessary to fix a limit above the ground for sampling downed material. An upper limit helps define a downed tree so that inventory of standing and downed materials will not overlap.

Options When There Is a Large Amount Of Material

1. A yardstick attached to a Jacob's staff is useful for marking the sampling plane and speeds the counting of small particles (Figure 12). Erect the Jacob's staff at the sample point. A line the yardstick with the direction of the sample plane and level it using an attached bubble level.

2. In areas with considerable slash, sampling efficiency is improved by ocularly estimating the number of 0- to 0.25-inch intersections and actually counting the number of intersections at a sub-sample of points. The ocular-estimates are adjusted using the ratio of ocular estimates-to-actual counts. This method, incorporating 3P sampling, is described in detail by Beaufait and others (1974).

3. For each sampling plane, estimate the proportion of 0- to 1 -inch-diameter branchwood to the nearest 10 percent for the three most common species.

Figure 12. Using a Jacob's Staff to establish the sampling plane.

Adapted From: *Brown, James K. 1972. Handbook for Inventorying Downed Woody Material. Gen. Tech. Rep. INT-16. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 24 p.*

Randomly Assigning Plot Location Points

Using a Geographic Information System

A Geographic Information System (GIS) may be used to select and record random monitoring plot origin points in the field. In order to use GIS to randomly assign sample plot locations you need several base cartographic layers. These layers should include your best available vegetation layers as well as elevation, slope, and aspect. It would also be useful to have a layer that displays the location and type of all existing sample plots.

There are currently three approaches available to randomly select PLP's using GIS tools:

- ArcView extension (for version 3.1) developed by Alaska Support Office GIS (USDI NPS 1999)
- ArcView extension developed by SEKI GIS
- ArcInfo Grid function <Rand>

The first tow approaches offer a fairly automated procedure for experienced users of ArcView. The third approach offers the most control and flexibility for advanced users of ArcInfo. For further information or to obtain copies of the ArcView extensions, contact your GIS coordinator, or visit the FMH web page <http://fire.nifc.nps.gov/fmh>

Grid Map Method

The random grid map method is a low-tech method for random selection of monitoring plots. On a map, draw (or place) a grid atop each of the areas to be sampled. Assign each cell of the grid a unique number, and randomly select cells in each portion (between two and ten, depending on the likelihood of rejecting the plot location points; use a random number generator). The center point of the cell is the plot location point.

XY Coordinates Method

This method is similar to the grid map method, but uses an XY grid. Overlay an XY grid on the map or orthophoto containing the portion of the monitoring type. A clear plastique ruler or transparent grid works well for this purpose. Using the lower left-hand corner as the origin where X, Y = 0, 0, select pairs of random numbers to define X and Y points on the grid. The intersection of the XY coordinates on the map is the plot location point. As in the grid map method, you will randomly select a certain number of plot location points in each portion of the area to be monitored.

Adapted from: *National Park Service National Fire Monitoring Handbook. 2000. U.S. Dept. of the Interior. National Park Service. 318 p.*

Riparian Monitoring Methods

Vegetation Cross-Section Composition

Each riparian complex is usually composed of a mix of stands of six to 12 community types. This procedure is designed to quantify the percent of each community type in a particular complex. These data may be used to indicate how much change has occurred in a particular complex (percent of acreage supporting altered community types), or how closely the composition of types in that area represents a previously described desired condition. Composition of types such as Kentucky bluegrass or redtop, which represent disturbance situations, can provide a measure of the percent of the complex that has been altered. Or, sampling data from similar unmodified or minimally modified riparian settings can be used as a standard to measure degree of change that may have occurred (successional status). Either of these values may then be used to compare how well an area is being managed, based on the pre-set desired conditions. Subsequent measurements in the same complex will provide information on the long-term trend of vegetation communities in that complex.

Several step transects (at least five) are established perpendicular to the grade in a riparian complex in such a way as to cross the entire riparian area (fig. 5). Each of these transects should be randomly placed in such a way as to best represent the entire complex. An aerial photograph often helps. Pacing transects has been found to be as reliable as using a measuring tape when calculating community type composition.

The beginning and ending points for each transect are permanently marked with stakes. These stakes should be placed far enough back into the non-riparian area (usually several feet) to allow subsequent quantification in case the riparian area expands in size. Placement there also helps ensure that stakes are not damaged or lost during an unusually high flooding event.

Community type composition is obtained by taking the number of steps encountered for each type in all five transects divided by the total number of steps taken in all five transects.

$$\frac{\text{Number of steps in each community type}}{\text{Total number of steps}} = \frac{\text{Community type}}{\text{Composition}}$$

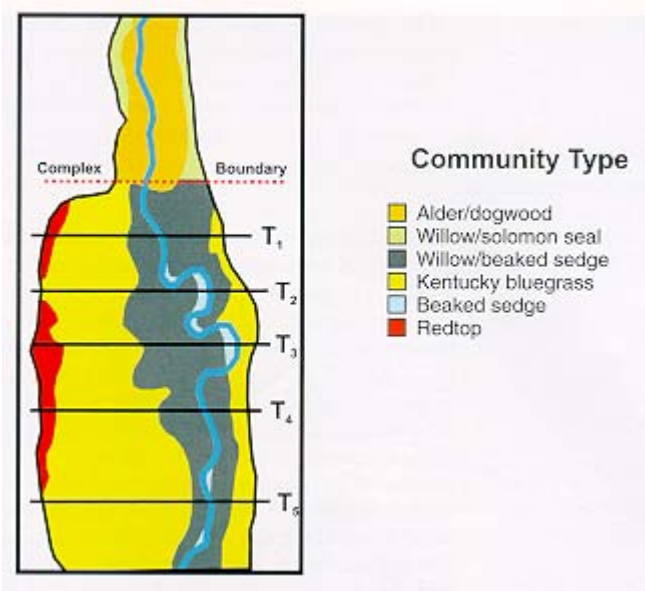


Figure 5-Vegetation cross-section measurement. Use of the line intercept method to measure amount of change in community type composition within a complex after unnatural disturbances.

Example:

Community type	T1	T2	T3	T4	T5		Steps (ct)		Steps total		Percent comp
Willow/beaked sedge	40	45	40	35	20	=	180	/	480	=	38
Kentucky bluegrass	50	50	45	45	75	=	265	/	480	=	55
Beakedsedge	0	5	10	0	0	=	15	/	480	=	3
Redtop	5	0	10	5	0	=	20	/	480	=	4
					Total	=	480				100

Since the Kentucky bluegrass community type (55 percent) and the redtop community type (4 percent) represent disturbance types in this complex, 59 percent of the area (55 + 4) has altered types present. Specific procedures for evaluating cross-sectional data are shown in the Data Analysis Procedures.

Since the number of steps in each community type is ultimately calculated to percent composition, average length of each step does not need to be measured as long as one person performs all pacing on any given transect and the overall width of the riparian-wetland area is not needed. (Generally, aerial extent of the riparian area can be more accurately obtained using GIS technology.)

A hand-held tally counter will aid in using this sampling process.

Any community type fragment encountered that is less than one step in length will normally not be tallied separately. Instead that fragment will be tallied with the most common adjacent type.

Photographs should be taken, as a minimum, at each of the permanent cross-section stakes and should display the general setting of the transect. Photographs may also be taken where the transect crosses the stream channel or at other locations along the transect where a pictorial record will be useful in visualizing specific features of the area.

Greenline Composition

Sampling community type composition along the greenline can provide additional information over that collected by the crosssection process. Presence of more or less permanent water in the plantrooting zone allows growth of robust, hydrophytic plant species that play an important role in buffering the forces of water. Additionally, vegetation in these favorable environments can often recover rapidly after either natural or induced disturbances. This permits the land manager to make an early evaluation of effects of management on a particular area. If subsequent measurements are made in the same area 3 to 5 years apart, data can be compared to provide indications of long-term trend for that riparian area.

Also, there is a strong interrelationship between amount and kind of vegetation along the water's edge and bank stability (Dunaway and others 1994; KJeinfelder and others 1992; Manning and others 1989; Weixelman and others 1996). The majority of naturally occurring plant species in this more or less permanently watered area have rooting characteristics (including strength, length, and mass) that enhance bank stability.

Evaluation of the vegetation on the greenline area provides a good indication of a streambank's ability to buffer the hydrologic forces of moving water. And, since the greenline is located where the forces of water are greatest, a greenline measurement can provide an indication of health of the total watershed above the point of sampling.

Locating and Measuring the Greenline --- In most riparian settings, there is a continual natural process in place to develop a buffering line of protective vegetation on each side of the stream. At the same time, there is continual cutting action by water forces to erode away this vegetation. Each stream or river must develop adequate amounts and kinds of plant species to maintain, over time, a balance between the eroding and rebuilding forces of water. Specific amounts depend on the erosive features of the riparian complex involved, particularly stream gradient and substrate materials. Those with the greatest water forces and weaker substrate materials will naturally have a higher percentage of the greenline made up of colonizing or early successional plant species compared to stabilizing hydrophytic species. Generally, not every foot of bank will be totally protected by a continuous coverage of robust, hydrophytic species. In some riparian complexes, large boulders, bedrock, or occasionally anchored logs or debris play a similar role in reducing bank erosion. Based on the hydrologic features of each riparian complex, there must be sufficient bank protection to maintain function of that stream type.

Most often the greenline is located at or near the bankful stage (fig. 6). As flows recede and the vegetation continues to develop summer growth, it may be located part way out on a gravel or sandbar (fig. 7). 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 (fig. 8).

Figure 6--- Location of the greenline at or near the bank-full stage

Figure 7--- Location of the greenline after summer water flows have decreased.

Figure 8--- Location of the greenline on an eroded bank. Following the definition of greenline, "the first line of perennial vegetation that forms a lineal grouping of community types on or near the waters edge," the eroded non-riparian portion of the streambank serves as the current greenline (see further discussion on location of the greenline in fig. 9).

In these situations, the vegetation is seldom represented by hydrophytic species and, in fact, may be composed of non-riparian species (fig. 9).

Greenline Sampling --- The greenline measurement is designed to account for a continuous line of vegetation on each side of the stream even when this line of vegetation occurs several feet above or away from the stream's edge. The only (rare) exception to this continuous line is where a road or trail crosses the stream or where a sidestream enters the stream being measured. In these cases, the width, in steps, should be tallied as road/trail or stream and included in the tally of early successional representation (discussed later). It is important that the greenline sampling process follow these continuous lines of vegetation rather than the seasonally fluctuating water's edge. This helps ensure that measurements are made on the best representative area for evaluating changes in vegetation over more than one sampling period.

Disturbance activities, such as overgrazing or trampling by animals or people, result in vegetation changes to shallower, weakly rooted species such as Kentucky bluegrass or redtop (fig. 10). These species have a reduced ability to buffer the forces of moving water and keep the stream's hydrologic features in balance. Therefore, an evaluation of the vegetation composition on the greenline can provide a valuable indication of the general health of a riparian area (successional status) as well as the current strength of the streambanks in buffering the forces of water (streambank stability).

Figure 9--- Example of greenline supporting non-riparian vegetation. As areas such as this begin to heal, the angle of the bank will become less steep and a greenline composed primarily of hydrophytic vegetation will begin to form near the water's edge. Over a period of time the sinuosity of the stream channel will adjust to fit the hydrologic features of the site in concert with the appropriate amounts and kinds of greenline vegetation. Until this occurs, non-riparian community types may serve as the measured greenline edge.

Figure 10-Example of a greenline dominated by non-hydrophytic plant species. Note the excessive streambank erosion on portions of this bank due to dominance of shallow-rooted species.

The greenline sampling procedure requires that a vegetation community type classification be completed for the area being measured (fig. 11). Since plant species on an area generally act together as groups, an evaluation based on community type composition provides a better measurement of health and strength of the vegetation components on an area than a more complicated process where individual plants are measured and evaluated separately.

The greenline sampling measurement should be taken within one riparian complex (fig. 12). Depending on length of the complex, one or more samples may be necessary to provide adequate representation of that complex. To minimize efforts and dollars, sampling placement

should emphasize measurements in the complex, or complexes, most subject to influences by the particular disturbance factors in that drainage.

General location of the transect(s) within the complex should be selected to best represent influences of major activities in that complex and should be agreed on by individuals from all disciplines interested in management of the area. Often an aerial photo can be helpful in selecting the sampling locations). In settings where a stream has multiple channels, the current, most active channel should be followed.

The starting point for the transect may be randomly selected within the complex or it may be located where a cross-section transect intercepts the stream (fig. 13). If both greenline and cross-section measurements are taken in the same general area, a more complete evaluation of the streamside and valley bottom health within a given complex will be possible.

A greenline transect begins on the right-hand side looking downstream and proceeds down the greenline using a step transect approach as described in the cross-section measurement.

Figure 11 --- Stands of several community types in the riparian complex.

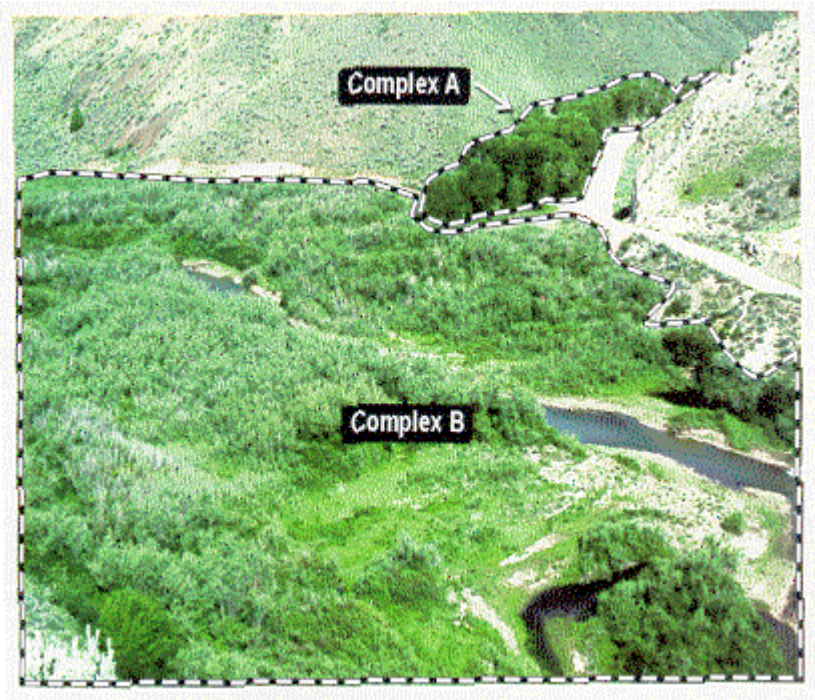


Figure 12--- Example of two riparian complexes: Complex A-Narrowleaf cottonwood/Kentucky bluegrass, Haploboroll, moderate gradient, narrow valley bottom, and Complex B-Coyote willow/Kentucky bluegrass, Cryaquoll, low gradient, broad valley bottom riparian complexes.

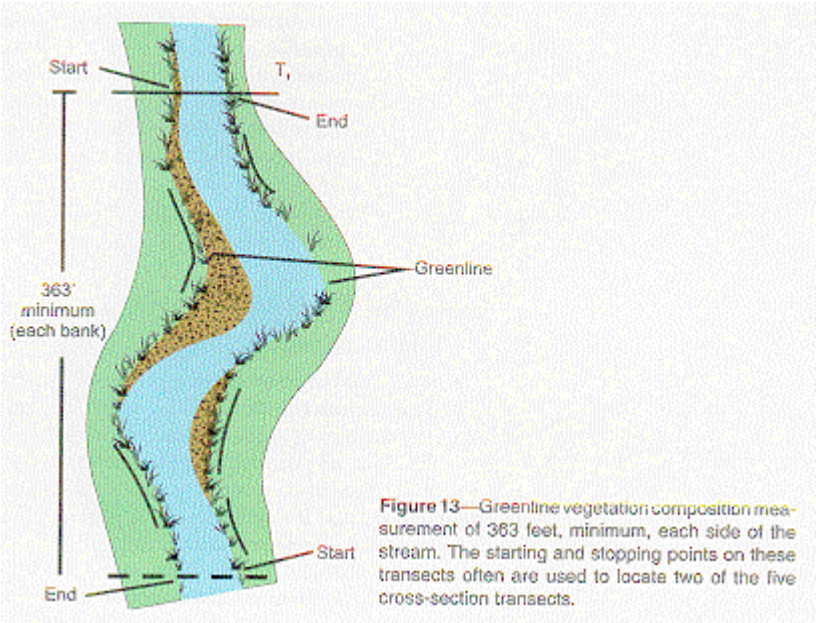


Figure13--- Greenline vegetation composition measurement of 363 feet, minimum, each side of the stream. The starting and stopping points on these transects often are used to locate two of the five cross-section transects.

For each greenline measurement, enough steps should be taken to total a minimum of 363 feet lineal distance on each side of the stream. This minimum distance (363 feet each side) will help ensure that the sampler measures an adequate length of stream to encompass the potential variation within a riparian complex. Additionally, this length is important when conducting data collection of woody species regeneration (described later). A temporary marker is placed at the end of the transect for location of the follow-up measurement of woody species regeneration. The beginning and ending points of these transects may be permanently marked with stakes to provide for greater repeatability for future and different workers. However, because of the transient movement of stream channels, it is recommended that these points be tied to a nearby reference point, away from stream edges, so that subsequent sampling will be done as near to the initial sampling area as is feasible. The overall goal is to get a reliable measurement of streamside vegetation in that complex.

The sampler then crosses the stream and repeats the sampling process for 363 feet upstream. It is important to measure both sides of the stream since grazing pressures or water forces may be different on each side. (NOTE: The stopping point may not coincide with the initial starting point on the other side of the stream due to differences in lengths of meanders on each side of the stream. Divide the average length of the person's step doing the sampling

into 363 feet to determine minimum number of steps to take on each side of the stream, for example, 363 feet divided by 2.5 ft/step = 145 steps each side).

On certain streams, especially those with steeper gradients, large rocks and downed logs may serve, along with the vegetation, to buffer water forces on the greenline. The number of feet of large anchored rocks or logs encountered on the greenline edge should be tallied in place of the vegetation. These rocks and logs must be large enough to withstand the forces of water and must appear stable in the setting. The number of feet of these rocks and logs will be counted as a natural, stable percentage of the greenline.

The greenline measurement becomes less valuable in monitoring steeper (greater than 4 percent gradient) streams since the large, permanently anchored rocks are generally less susceptible to management activities. Also, the greenline measurement may be a less valuable measurement on very large rivers where landform features play the dominant role in regulating hydrologic influences compared to vegetation influences.

The total number of steps of each community type encountered along the greenline on both sides of the stream is tallied and percent composition for each type computed, as described in the cross-section composition measurement. For example:

$$\frac{\text{Total steps of each type (both sides)}}{\text{Total steps taken both sides}} = \frac{\text{Percent community type}}{\text{Composition}}$$

If one is interested in evaluating whether one side of the stream has been impacted more than the other side, divide the community type values on each side by the number of steps for each side and compare values.

An evaluation of percent of disturbance types in relation to percent of natural types (see cross-section computation) provides a general indication of ecological status. If available, a comparison of areas where the complex is as close to potential natural community (PNC) as possible may be used as a standard or reference to evaluate successional status of the area being measured. Subsequent measurements of the same area will provide a measurement of trend for that complex. See the Data Analyses Procedures section to find descriptions of all methods for analyzing greenline data.

A photograph should be taken at the starting and ending points of the greenline transect. Additional photos may be taken along the transect if desired. These photographs should contain relatively permanent reference points or markers (such as boulders or large trees) so the photographs can be re-established in the future.

Woody Species Regeneration

A measurement of woody species regeneration is made using a 6-foot wide belt along the same transects used for the greenline measurements (figs. 14 and 15).

The sampler uses a 6-foot pole that has the center marked. Measurements are made by walking a minimum of 363 feet on each side of the stream (726 total feet), with the marked center of the pole held directly over the inside edge of the greenline.

Use of the greenline edge as the center of the measurement helps to ensure that sampling is done in a setting where regeneration of woody species is most likely to occur. The distances indicated will result in sampling 0.1 acre (726 x 6 = 4,356 sq ft), which is normally considered an adequate sample area for this type of measurement. NOTE: Where the greenline edge is immediately adjacent to the stream edge, 3 feet of the pole will extend over water (fig. 16).

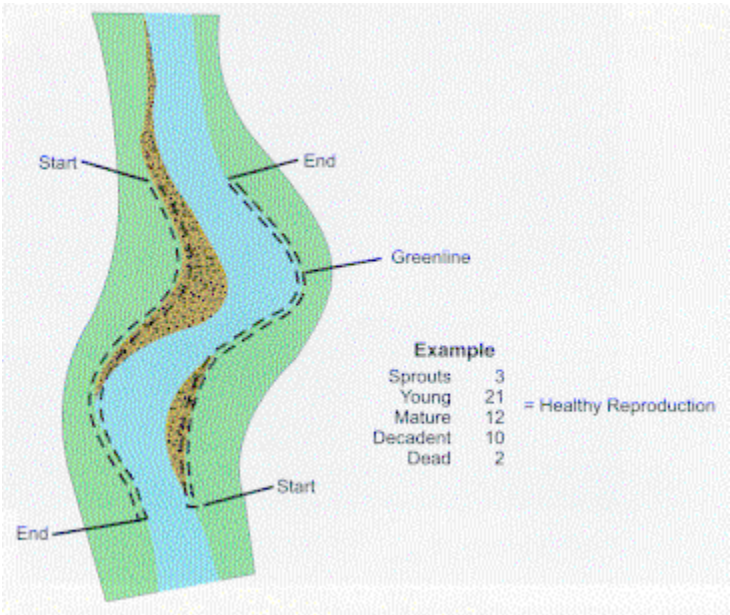


Figure 14--- Woody species counts by age class.

But, where a recently developed gravel or sand bar is present (see fig. 7, page 11), this measurement will allow sampling on the most likely place where most woody species regenerate, the open bars. Additionally, using this approach will result in consistently sampling 0. 1 acre.

A modification of this procedure will be necessary for situations where the stream is less than 3 feet across. Where this occurs, the measurer should not allow the left tip of the pole to extend beyond the center of the stream, as this would result in double sampling of the middle portion of the stream when the other side is measured (fig. 17).

Figure 15--- Samplers using a 6-foot pole to measure woody species regeneration along the greenline.

Figure 16--- Correct placement of the sampling pole along the greenline water interface.

All, or selected, woody plants rooted within the ends of the pole are tallied based on the following age-class categories:

Clumped, multiple-stemmed species (most willows).

Number of stems at ground surface	**Age class**
1	Sprout
2 to 10	Young
>10, >1/2 stems alive	Mature
>10, <1/2 stems alive	Decadent
0 stems alive	Dead

Rhizomatous species (patches):

For rhizomatous willow species that form more or less continuous patches, such as wolf willow *(Salix wolfii)*, planeleaf willow *(S. planifolia)*, or wild rose *(Rosa* spp.), use permanently marked line transect measurements to follow changes in patch sizes over time. Use both greenline and cross-section transect data or establish several permanently marked 100-foot transects randomly located within the complex (fig. 18).

Figure 17-Placement of the measuring pole such that the left end does not reach beyond the center of a stream less than 6 feet wide.

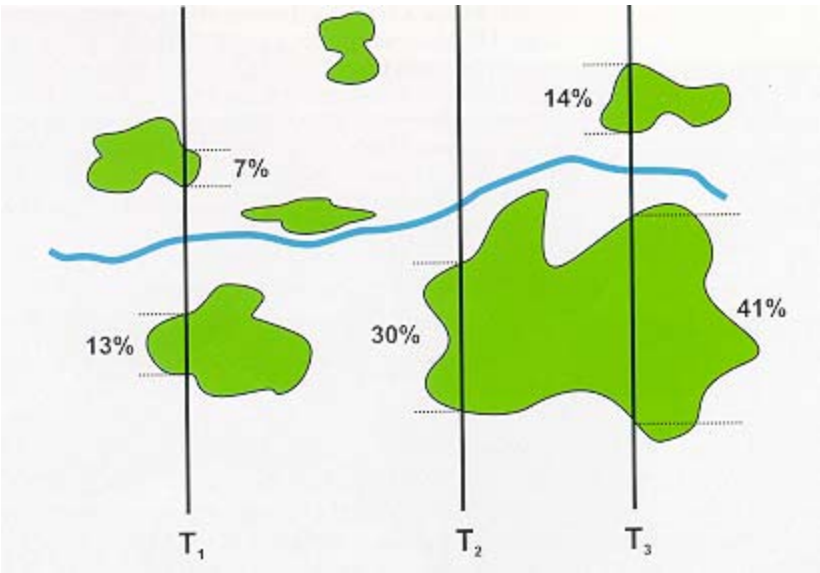


Figure 18--- Use of line transect data to determine percent shrub or tree canopy for species that occur in patches.
Tl = 7 + 13 = 20; T2 = 30; T3 = 14 + 41 = 55.
Total = 20 + 30 + 55 = 105. (105/300 = 35% willow canopy cover.

Single-stemmed species:

For shrub and tree species that tend to grow more single stemmed, such as coyote willow *(Salix exigua), birch (Betula* spp.), alder *(Alnus* spp.), and cottonwoods or quaking aspen *(Populus* spp.), count each stem that occurs 12 or more inches from any other at ground level as a separate plant, and age them by pre-established categories. As a minimum, four categories---sprout, young, mature, and dead---should be developed based on a combination of both growth rings and unbrowsed height.

Example:

Growth rings*	Height	Age class
1-2	<1/4 mature	sprout
3-10	<1/2 mature	young
>10	near full	mature
---	---	dead

*Specific values vary by species.

NOTE: Stems cut or cored for developing growth ring categories should not be taken from within the 6-foot wide transect belt. Observations or measurements of the mature shrubs and trees in the general area can usually serve as references for age and height categories.

Even though there may be little or no information concerning potential densities of the shrub and tree species on an area, measurement of the age class distribution can provide an evaluation of whether management is satisfactory to maintain or eventually reach appropriate coverages and densities of woody species capable of being present on that area. It is assumed that if management is such that sustained recruitment is in progress, eventually that area will support appropriate amounts of woody species needed to provide a naturally functioning complex.

Several factors can influence recruitment and death ratios of woody plants at any one location.

Recruitment:

1. Seed crop year - there is a high amount of variation in seed production between years.
2. Amount and availability of sites suitable for establishment any given year (see continuing discussion in this section).

Death:

1. Excessive drying or prolonged ponding of sites due to lowering or raising of water tables or movement of the stream channel to a new location in the valley bottom.
2. Cutting away of the root wad due to channel adjustments.
3. Occasional death from diseases.
4. Prolonged excessive browsing along with any of the above factors.
5. A combination of beaver cutting along with any of the above factors.

Not all riparian areas are well suited for growing woody species. This is especially true where the complex has a low gradient and a limited amount of natural stream channel movement, and on anaerobic meadow soils that are often saturated to or near the surface during the growing season. In these settings, understory sedges and rushes often are able to buffer the forces of water without the addition of woody species. Most woody riparian species regenerate best on settings where there are aerobic soil conditions and, at least temporarily, minimal competition from herbaceous species. Generally speaking, if the stream being monitored has a gradient over 0.5 percent or has water forces adequate to periodically cut banks and deposit bars, it is capable of supporting a woody overstory of willows, alder, birch, or cottonwood. On streams with gradients of less than 0.5 percent, streambanks generally can be adequately protected by robust sedges, rushes, and grasses. Woody species are seldom naturally present on the greenline in these settings.

The amount and continuity of stream riffles, as tied to gradient, may be used to broadly identify streams with water forces adequate to provide habitat for woody species. A stream can support a considerable coverage of shrubs and trees if it has a more or less continuous presence of riffles. An exception to this is small spring-fed systems where gradients are sufficient to provide riffles in the stream, but the relatively stable water forces are not adequate to cut streambanks and deposit bars. In these settings robust herbaceous species are adequate to protect the streambanks and maintain hydrologic processes; a shrubby component will not likely be present.

A stream that has intermittent riffles with long pools of dead water generally supports islands or patches of woody vegetation in the complex. Once established, these patches may persist for many years, even as the stream, over time, meanders to new locations in that complex.

An accurate evaluation of the cover or density of shrubs and trees that should be present on an area cannot be known or approximated without having data from a similar complex that is in a somewhat natural condition. In absence of this information, a measurement of age-class distribution of woody species can indicate whether current management is allowing an adequate amount of recruitment to sustain or recover the woody component in a particular complex. Generally, there should be several times more plants present in the sprout and young categories as in the mature and dead categories. This is especially true if an area has recently begun recovery of the woody component. Complexes where the sprouts and young age classes are less than the mature and dead classes will not likely sustain a shrub and tree component over the long term.

Even though the current shoots on multi-stemmed species, such as willows, resprout every 10 to 20 years, the crown portion of these plants may remain alive for over 100 years - as long as the habitat features, especially water tables, remain in place.

Where the willow component has been completely lost from an area, mounded areas that develop under long-term presence of shrub crowns may provide evidence that willows or other woody species were once present in a particular complex. These remnant mounds, or in some cases remnant stems or crowns, may persist for several decades after the plants have been lost from an area.

Recent studies have shown that it is extremely difficult and time consuming to accurately measure utilization (browsing) impacts on many riparian shrubs (Hall 1999). Until more acceptable methodologies are developed, it is suggested that only a general estimate on overall browsing on the woody plants be recorded in the comments section of the form. For example (USDA 1993):

Percent use	**Use class**
0-5	No use
6-20	Slight
21-40	Light
41-60	Moderate
61-80	Heavy
81-100	Severe

There generally is a reduction in seed production on those plants that have utilization values above 55 percent. There can be a reduction in the overall health of plants, including size and root strength, when heavy and severe utilization levels are sustained over time.

It is important that measurements or estimates be taken on the younger aged shrubs since these plants are most likely to have, and show, impacts from browsing. These young plants must have an opportunity to develop into mature plants over time. If there is sustained recruitment of shrubs and trees, an area will maintain or eventually support appropriate amounts of woody plants to provide a naturally functioning system.

Data Analysis Procedures

These procedures are in addition to the procedure described on pages 8-16, where percent of a complex that has altered types present provides an indication of impact. Use vegetation composition data from the cross-section or greenline measurements to rate status of an area in one or more of the following ways:

Successional Status---Using Coefficient of Community Type Similarity (2w/a + b)

(a) = Sum of PNC values measured in a similar complex in an unmodified condition.
(b) = Sum of values for present composition.
(w) = Sum of the values common to both.

This procedure requires use of data from a similar complex sampled in as unaltered condition as is possible (see Potential Natural Community (PNC) values, table 1).

Therefore, similarity index (2w/a + b) = (2 x 45/100 + 100) = 45 percent, or mid successional status. NOTE: When values used in "a" and "b" have been calculated to percent composition (100 percent), the successional status rating and the "w" value are the same; no calculation is necessary.

Similarity to PNC		Successional status
0-15		Very early seral
16-40		Early seral
41-60	→	Mid seral
61-85		Late seral
86+		PNC

Desired Condition---Using Coefficient of Community Type Similarity

Use where a decision has been made to manage an area for a seral stage other than PNC (2w/a + b) - table 2.

A similarity value of 75 percent or greater is often used to differentiate between meeting or not meeting management objectives.

Therefore, Area One similarity index (2w/a + b) of (2 x 78/100 + 100) = 78 percent. (Area One is 78 percent of desired condition = meeting management objectives.)

Therefore, Area Two similarity index of (2 x 19/100 + 100) = 19 percent. (Area Two is 19 percent of desired condition = not meeting management objectives.)

Table 1 -Example of successional status of vegetation using Coefficient of Community Similarity (modified from Winward 1989).

Community type	Composition potential natural community	Composition present community	Amount in common
	----------	*Percent*	----------
Booth willow/beaked sedge	65	30	30
Water sedge	5	5	5
Beaked sedge	15	10	10
Kentucky bluegrass	0	55	0
Solomon-seal/winged sedge	15	0	0
	a = 100	b = 100	w = 45

Table 2--- Examples of ratings for two different areas representing the Booth willow/beaked sedge-moderate gradient riparian type in relation to desired community type composition values (modified from Winward 1989).

Community Type	**Composition**	**Desired composition**		**Amount in common**	
		Area One	**Area Two**	**Area One**	**Area Two**
	----------		*Percent*	----------	
Booth willow/beaked sedge	20	16	3	16	3
Wolfs willow/hairgrass	5	3	1	3	1
Water sedge	7	2	1	2	1
Beaked sedge	60	50	8	50	8
Baltic rush	3	10	10	3	3
Kentucky bluegrass	0	5	47	0	0
Mesic forb	3	13	30	3	3
False-hellebore	2	1	0	1	0
	a = 1 00	b = 100	b = 100	w = 78	w = 19

Greenline Successional Status and Bank Stability

Since there often is limited information concerning which community types indicate excessive or unnatural disturbances, and because it is extremely difficult to find examples of PNC

situations in riparian areas, the following procedures may be used to broadly rate riparian areas as to their successional status and relative bank stability.

Ten capability groups have been developed based on:

1. Percent stream gradient (similar to those presented in Rosgen 1996).
2. Certain substrate features that may substantially influence erosiveness of streambanks:
   (a) dominant soil particle sizes such as silts, sands, gravels, and
   (b) presence of at least one major soil horizon within the rooting zone that consists of strongly compacted, cohesive, or cemented particles (consolidated materials) (fig. 19).

Each of these 10 groups has specific, inherent environmental characteristics, which influence the amount and kind of vegetation necessary for them to function properly. An "expected value" percent of late successional community types along the greenline has been assigned to each of these groups. These percent values are based on the minimum amount of late successional community types that would be expected to occur when areas representing each capability group are in good health and functioning properly.

Figure 19-Substrate features, in this case a consolidated soil layer, may substantially influence erosiveness of stream banks.

Additionally, a list has been developed of all community types known to occur on lands administered by the Intermountain Region, Forest Service. In this list, each community type has been assigned an "L" if it is known to occur in later successional stages along the greenline, or an "E" if known to occur in earlier stages of succession along the greenline.

Each community type also has been assigned a stability class ranking. This ranking ranges from 1, those types least capable of buffering the forces of moving water, to 10, those types with the highest buffering capabilities. The rating is based on the strength, amount, and depth of roots, as well as special leaf and crown features. As community type classifications are developed for other areas, successional status categories (early or late) and bank stability ratings (I to 10) will need to be developed for each of these types.

Percent composition of each community type from the greenline measurements is used to make both the successional status and bank stability ratings. The procedures are:

Greenline Successional Status Based On Capability Groups--- To determine greenline successional status, use information provided in Appendix B, page 35, to arrange the community type composition values into either the Early or Late columns. Summarize all types that occur in the Late column and divide by the expected value for that particular capability group (Appendix A). This will provide an intertie to the ecological potential of the area being measured. Rating of ecological status is then determined by comparing this number with those assigned to each of the five status values:

0-15 = Very early
16-40 = Early
41-60 = Mid
61-85 = Late
86+ = PNC

Greenline Bank Stability--- The greenline stability rating is calculated by multiplying the percent composition of each community type along the greenline by the stability class rating assigned to that type (Appendix B, page 35). These index values are then summed and compared to the appropriate rating classes:

1-2 = Very low
3-4 = Low
5-6 = Mid
7-8 = High
9-10 = Excellent

See example of Greenline Stability calculations (Appendix C, page 40).

These successional status and stability ratings may now be evaluated against standards set for the general area being studied; management can be adjusted if these standards are not being met.

Procedures for Refining the Calculation of Successional Status

Proportioning Transitional Types--- Because of the many natural, or induced, disturbances that are ongoing in riparian areas, it is not uncommon to encounter community types that are in transition, developing into new or different community types. For example, as an area progressively recovers from a past disturbance, successional processes may move it from a Kentucky bluegrass community type toward a Nebraska sedge type. The community type classification keys generally handle these situations by prioritizing which plant species occur first in the keys. For example, an area supporting greater than 20 percent cover of both Nebraska sedge and Kentucky bluegrass would key to a Nebraska sedge type because Nebraska sedge occurs ahead of Kentucky bluegrass in the community type key. A pure Nebraska sedge type is higher on the successional scale than a mixed Nebraska sedgeKentucky bluegrass type and the interned influences on such things as bank stability are likewise considerably different.

If an area being sampled is going through a relatively rapid rate of recovery or degradation, and if one is having difficulty discerning which of two community types are being encountered in the area being sampled (near equal amounts of two different indicator species are occurring together), one should consider using the following approach:

- Determine which of the two indicator species is more prominent.

- Record the more prominent species first with the secondary indicator species immediately behind it-in parentheses.

  For example, *Juncus balticus (Poa pratensis)* would indicate that *Juncus* is slightly more prominent than *Poa.*

- Initially record and calculate percent composition of this blended type as one "type."

- When calculating successional status and streambank stability, count the species listed first (in this case *Juncus)* as 60 percent of the composition and the species in parentheses as 40 percent.

  For example, if the composition of this blended type = 30 percent of all types on the area, then

  30% compositions x 60% = 18% of *Juncus*
  30% composition x 40% = 12% of *Poa*

The 60/40 percent values have been selected to provide a refinement in calculation of successional status and streambank stability over a process that does not recognize this relatively common blending of types. It is recommended that this proportioning procedure be used where there are relatively high composition values of more than one indicator species in the community type being evaluated. Any subsequent measurements, taken several years later, should allow one to determine which of the indicators is becoming more prominent under current management.

Examples: Assume the area is in a transitional mode of recovery; *Poa pratensis (Popr)* is prevalent throughout the area, but plants of *Carex nebrascensis (Cane)* and *Juncus balticus (Juba)* are increasing enough to appear near codominant with the *Poa*.

Community types	**Steps**	**Percent composition**
Popr	200 / 230 =	87%
Juba	30 / 230 =	13%
	Total = 230	100%

(a) Not proportioning types

Successional status	**Early**	**Late**
Kentucky bluegrass	87	
Baltic rush		13

13% Late seral types = Very Early successional status

(b) Proportioning types

Popr(Cane) 87% x 60 = Popr = 52%

87% x 40 = Cane = 35%

Juba(popr) 13% x 60 = Juba = 8%
13% x 40 = Popr = 5%
100%

Popr = 52 + 5 = 57% = Early
Cane = 35% = Late
Juba = 8% = Late
100%
35%+ 8% = 43% Late seral types = Mid successional status

Proportioning of the types has indicated there is a high enough presence of the late successional species to rate the area mid, compared to very early ecological status, where types were not proportioned. Continuation of the proportioning process into the streambank stability calculations will likewise allow one to make a more sensitive evaluation of bank stability.

Adjusting the Successional Status Rating for Areas Where a woody Overstory Component Should be Present but Currently is not Present--- Calculation of successional status for riparian areas that historically supported trees or shrubs, but currently have little or no woody overstory present, may result in an over-inflated rating. For example, if an area historically supported a Booth willow/beaked sedge community type, but due to various disturbances currently only supports a beaked sedge type, the rating process described under (a) "Greenline Successional Status Based on Capability Groups," would rate both types the same. This results because both types are rated in the Late Succession category (see Appendix B). If an area historically supported the willow/sedge community, it can generally be assumed the area is adapted to function better with both the willow and sedge components present. Consequently, an ecological status rating would need to account for this difference.

Solution:

If the stream being monitored has a gradient greater than 0.5 percent and has water forces adequate to periodically cut banks and deposit bars (see discussion, page 21), it likely should support a hydrophytic woody overstory component. If it does not, as evaluated using the Woody Species Regeneration data:

Lower the calculated Ecological Status score:

- Twenty (20) points if no hydrophytic woody plants are present.

- Ten (10) points if all age classes are present but one or more of the age classes is nearly absent or obviously under-represented.

NOTE: A healthy age class representation should include slightly more plants in the sprouts and young categories than in the mature and dead categories.

There are several important reasons to have woody species on streams that historically had them, including:

1. Protection and strengthening of streambanks (woody plant roots generally extend deeper into the soil profile and are stronger than roots of herbaceous species).
2. Structural diversity.
3. Species diversity.
4. Stream shading.
5. Habitat values tied to foraging, hiding and thermal cover, nesting sites, and others.

There is limited information to establish numerical values for all these factors. Consequently, values provided to adjust the ecological status ratings when woody species are absent, or not adequately represented, are meant to be approximations. They are given to provide more consistency for workers calculating ecological status ratings than if no values were given.

It is essential that the sampler(s) record in the comments section of the forms what adjustments were made and why.

Adapted from: *Winward, Alma H. 2000. Monitoring the vegetation resources in riparian areas. Gen. Tech. Rep. RMRS-GTR-47. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 49 p.*

Sampling Methodology for Willows

The following methodology has been partly taken from "Monitoring the Vegetation Resources in Riparian Areas" by Alma Winward (USDA General Technical Report, April 2000). Additionally, these methods have been discussed between WGFD personnel and Alma Winward during field trips to NW Wyoming. Managers have determined this methodology to be an efficient way to get useful, repeatable data on long-term riparian transects. These transects should be read in the spring and fall in the same way except offtake will only be read in the spring.

Sampling steps

Randomly establish 2-5 permanent cross-section transects, perpendicular to the waterway, in a riparian complex. These transects should be randomly placed in such a way as to best represent the entire complex (use aerial photography when possible).

Each cross-section line should have beginning and ending points permanently marked with stakes. The stakes should be far enough back into the non-riparian area (usually several feet) to allow subsequent quantification in case the riparian area expands in size. At the beginning of each cross-section establish a permanent photopoint and record GPS coordinates (including Datum) and tag number on the stake at the start and end of each cross-section. If the riparian complex can be adequately captured without crossing the river/stream, the cross-section can go across the complex towards the river/stream and not cross it. Please see Diagram on the next page.

A minimum of 50 stops will be sampled at predetermined pace intervals for each set of cross-section transects. Divide the approximate total length (ft.) of the two to five transects by 50 to determine the pace intervals at which you will sample. (Example: transect total length is 1 mile (5,280 ft). 5,280/50 = 106 ft. between sampling sites. The average pace (2 steps) is 6.5 ft. 106/6.5 = 16 paces (32 steps) between sampling sites.) At the end of each pace interval the following needs to be recorded on all the willow plants within a 5 foot radius around each stopping point:

- Plant species
- Plant age class (sprout, young, mature, dead)
- Plant height class (one-foot increments), five leaders per plant (if less < 5 leaders present, measure all of them)
- Offtake (number of leaders browsed - spring only), monitor 10 leaders per plant (if <10 leaders present, monitor all of them)

Note: If there are 1-3 species that are consistently found within each plot (i.e. several plants of each species consistently present in each circular plot), monitoring modifications can be made. Record the age class for all plants within the circular plots. When recording height and off take, randomly select one quarter of the circular plot (using a second hand on a watch works well), and select the closest plant of that species within the circular plot for monitoring.

Details on how to record the necessary information:

Species could be difficult to determine in the spring. If you are unable to identify the species in the spring, record the information as an unknown species.

Plant age classes are indicated as follows:

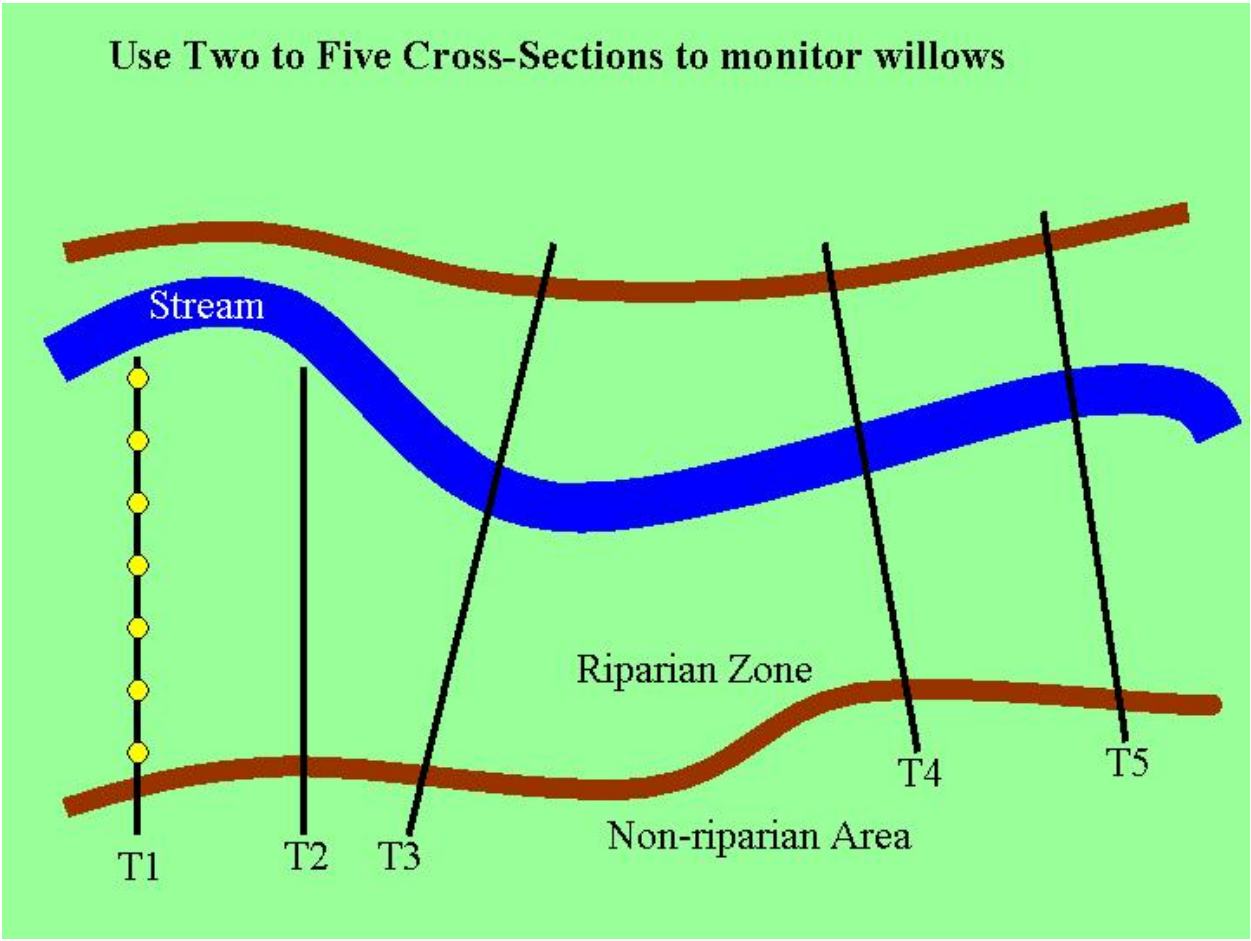
Clumped, multiple-stemmed species (most willows):

Number of stems at ground surface	Age class
Sprout	
Young	

>10	Mature
0 stems alive	Dead

For willow species such as S. wolffii and S. brachycarpa, do not follow the above age chart. These species have near continuous horizontal root systems and do not grow in “clumps”. Therefore, it is only necessary to record species presence within the 5’ radius at each stop. Plant Height should be recorded in one-foot increments and to the nearest foot in total height. Each one-foot increment should include the six inches before and after the foot mark (example: 6’3” would be recorded as 6’ and 6’10” would be recorded as 7’). Measure the heights of 5 randomly selected mature stems, and calculate the average. When fewer than 5 stems are present, measure each stem and calculate the average.
Offtake should be recorded in the same random way as plant height, except using 10 randomly selected stems. Measure height and browsed/not browsed on the first 5 random mature leaders. On the 5 leaders sampled for height, also record the number of hits and non-hits from the past winter’s browsing. And then count an additional 5 stems for browse use only. Be sure not to count only current year browsing on live stems.

Diagram 1.



Sampling Methodology for Aspen

The following methodology has been use by habitat managers in NW Wyoming to assess stem densities within treated and untreated stands/clones. The following methodology was part of a paper presented at the Conference on Fire, Fuel Treatments and Restoration: Proper Place, Appropriate Time, April 16-18, 2002, Ft. Collins, CO. The paper was subsequently peer reviewed and published in the conference proceedings. The following sampling protocol has proven to be an efficient methodology in acquiring statistically reliable aspen stem densities. Managers felt sampling efficiency was acceptable for acquiring sample sizes necessary for predicting aspen stem densities with 80% confidence and 20% error. . In addition to density, height and annual leader growth are also collected. Once on site, a clone/stand can be sampled in 1 – 2 hours with two individuals.

Sampling steps

Randomly establish a permanent photo point near the center of the clone/stand (five-foot steel post optional). Record GPS coordinates (including Datum).

Take photos in one to all four cardinal directions.

Select a random azimuth from the permanent photo point.

Select a random pace distance.

Select circular plot size. (Recommend 1/50 to 1/100 ac. for pre-treatment mature tree densities estimated at 150 – 250 trees/acre. Recommend 1/100 – 1/500 acre plots size for post-treatment densities of 4,000 –15,000 stems/acre, respectively. Also, increase the plot size with increased stand/clone heterogeneity.

Proceed along random azimuth sampling plots at the selected random pace interval. Record:

a) number of stems per plot by height or dbh class (eg. <1, 1-2, 2-3…….>10 & < 2”dbh). If stems are connected above the ground level, it is counted as one stem. If stems are connected below the ground it is counted as multiple stems.)

b) annual leader growth on 2 stems/plot) .

Stop proceeding along random azimuth when a different community type or ecotone is encountered.

Select a new random azimuth that intercepts the stand/clone and proceed sampling with the same random pace interval and plot size as above

Continue the above procedure until the required sample size and statistical reliability is achieved using the following formula (eg. 80% reliability with 20% error).

$$N = (t)^2 * (s)^2 / (P * x)^2$$

N = required sample size

t = t table value for desired distribution (eg. 80% , 90% C.I.)

s = standard deviation

P = percent error (eg. 20% = 0.20)

x = mean # stems/plot

An example of our sampling methodology is illustrated in Figure 1. Bartos and Winward, (2000), recommend the following post-treatment conditions for successful aspen clone reestablishment; > 1,000 stems/acre, > 10 feet in height within 10 years post-treatment. They also suggest mean sucker height should increase by one foot/year post-treatment. The above recommendations are often transformed into objectives for aspen treatments.

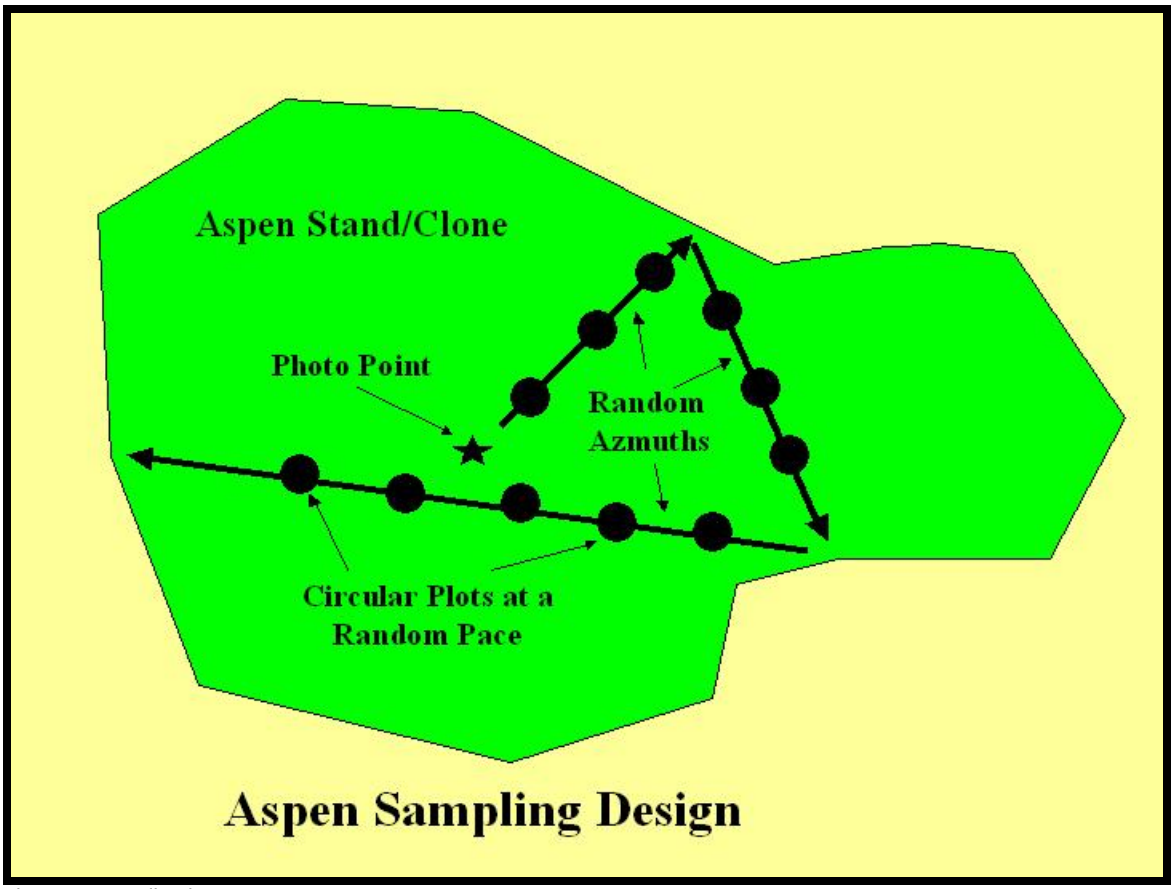


Figure 1. Sampling layout

ASPEN CIRCULAR PLOT DATA SHEET

SITE/NAME/#:	DATE:	PLOT SIZE:	Other
RECORDED BY:		PHOTO LOCATION: E	N NAD
COMMENTS:			

		PLOT #																					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Tot #	Stems/acre
Height Class	<1																					0	
	1-2																					0	
	2-3																					0	
	3-4																					0	
	4-5																					0	
	5-6																					0	
	6-7																					0	
	7-8																					0	
	8-9																					0	
	9-10																					0	
>10 & <2"																						0	
2-4" dbh																						0	
>4" dbh																						0	
Annual leader growth of 2 stems																						0	
																						0	
Mean annual leader growth		###																					
																			Total Stems/ac				

MECHANICAL TREATMENT PROTOCOL - FUELS PROJECTS

Mechanical treatments will be monitored for effectiveness based on criteria in project specific NEPA document and silvicultural prescription. Assess existing data and data collection methods to assure data collected for monitoring parameters is adequate.

Monitoring methods for mechanical treatments in nonforested vegetation will follow monitoring methods used for prescribed burning and wildfire. Suggested timing is prior to treatment at a time that accurately measures the parameters to be treated. This information could come from range condition class surveys, data collected for the Forest's or Park's vegetation layer or noxious weed surveys. Monitoring following treatment may be included in range condition class surveys, noxious weed inventories and will follow timing determined by NEPA or Forest Plan documents.

Suggested monitoring methods for forested vegetation (including aspen) are permanent photo points and/or fixed and/or variable plots that measure specified parameters. Suggested timing for monitoring is prior to the treatments and can include stand exams for stand diagnosis at the NEPA stage. Monitoring following treatment can include contract inspection results, regeneration surveys, stand exams or photo points at the specified times of monitoring. Monitoring of forested vegetation will follow Common Stand Exam (CSE) protocol and data collected for the Bridger-Teton National Forest will be entered into FSVeg or FACTS data bases. Mechanical fuels treatment monitoring in Grand Teton National Park will follow the draft monitoring protocols for the Park.

At the minimum for each mechanical treatment project establish permanent photo points to document changes overtime and compare pre-treatment with post treatment conditions. Photo point protocol is as follows.

Establish permanent photo points marked with rebar and record GPS coordinates. Use a minimum of two photopoints, and a maximum of four (only for large acreages). Use a photo board to display photopoint number, azimuth, project location, and date. Place the sightability board in the picture at 50 ft. Use a digital camera. Record this data as well as GPS coordinates on a photo record sheet. Choose sights that show a distinguishable feature that can be referenced in future photos if possible.

An exhaustive list of parameters and methodology for collection for monitoring forested vegetation according to CSE protocols can be found in CSE Chapter 4 or on the website *fsweb.nris.fs.fed.us/products/FSVeg/documentation*. The parameters selected to monitor will depend on the NEPA document and silvicultural prescription.

Quick plots, extensive or intensive exams may be used depending on type of information to be collected. Available forms are setting, sample design, plot data, tree data, vegetation composition, down woody and ground surface. Be sure to enter all required information as described in CSE data collection manual.

Spherical Densiometer Instructions

(An instrument for measuring forest overstory density)

Hold the instrument level, 12” – 18” in front of body and at elbow height so that operator’s head is just outside of grid area.

Assume four equi-spaced dots in each square of the grid and systematically count dots equivalent to quarter-square canopy **openings.**

Multiply the total count by 1.04 to obtain percent of the overhead area **not occupied** by canopy. The difference between this and 100 is an estimation of overstory density in percent. (Assuming each dot to represent one percent is often accurate enough.)

Make four readings per location – facing North, East, South and West – **record and average.**

From: Robert E. Lemmon, Forest Densiometers

Fire Effects Monitoring Plan Bridger-Teton National Forest	
Unit Name:	Ranger District
Project Name:	Responsible FMO:
Implementation Year: Season	Project Lead:
Type of Treatment:	Monitoring Leader:

Project Files (Provide on rewritable CD):		
File Type:	**File name (s):**	**Projection:**
Unit Shape file (s)		
Orthophoto Quarter Quad Files		
Digital Topo Map Image Files		
Other GIS maps or coverages if available		
This monitoring plan	.doc	n/a
Silvicultural RX	.doc	n/a
NEPA Document	.doc	n/a
Burn Plan – if available	.doc	n/a

Monitoring Objectives, Methods, and Schedules: Provide the following info for each objective you have chosen to monitor. NEPA objectives should dictate these. **Two to four total objectives are recommended.** Delete or add tables as needed. See examples in **"Monitoring Plan Writer's Guide."**

Monitoring Objective 1:	
Objective Target	
Variables being measured	
Methods / plot types	
Schedule for plot visits	

Monitoring Objective 2:	
Objective Target	
Variables being measured	
Methods / plot types	
Schedule for plot visits	

Monitoring Objective 3:	
Objective Target	
Variables being measured	
Methods / plot types	
Schedule for plot visits	

Monitoring Objective 4:	
Objective Target	
Variables being measured	
Methods / plot types	
Schedule for plot visits	

Monitoring Plan Writer's Guide

FMO's are responsible for providing a fire effects monitoring plan for each project at least one field season prior to implementation. Fire effects monitors are available to help you with monitoring plan writing. Please feel free to contact:

Diane Abendroth, GTNP Fire Effects, 307-739-3665
Brandon Scurlock, Jared Rogerson, Erik Maichak, Dan Stroud: WGFD Pinedale, 307-367-4353
Jill Miller, Steve Kilpatrick WGFD Jackson, 307-733-2321
Liz Davy, Silviculturist 307-739-5562

Fire Effects Monitoring Plan EXAMPLE Bridger-Teton National Forest	
Unit Name: Lake Rim	Ranger District: Pinedale
Project Name: New Fork / Boulder	Responsible FMO: Paul Hutta
Implementation Year: Season 2005:Fall	Project Lead: Mark Randall
Type of Treatment: Prescribed Burn	Monitoring Leader: Jared Rogerson

1. **Unit Name**: Name of this project or sub-project. On single projects this may be the same as the Project Name
2. **Project Name:** Name of overall project. This will often be the same name as used in the NEPA document
3. **Implementation Year: Season:** Make your best estimate. If more than one season of treatment is possible, list both – "2006: Spring or Fall."
4. **Type of Treatment:** Prescribed burn, Broadcast burn, Thin and Pile, etc.
5. **Ranger District**: If more than one, list both
6. **Responsible FMO:** Fire Management Officer who is overseeing this project.
7. **Project Lead:** ID Team Leader and/or main person managing this project

8. Monitoring Leader: Person who is responsible for data collection, data entry, and results analysis for this project. Likely this person will be consulted in writing this plan.

10. Electronic files provided: List these files and provide them on a CD to Liz Davy who will give them to the monitoring leader. You can request help from fire SO GIS personnel in assembling the shape files – **Dirk Shupe** 739-5024

Project Files (Provide on rewritable CD): EXAMPLE		
File Type:	**File name (s):**	**Projection:**
Unit Shape file (s)	Lakerim .dbf, .shx., .sbn, .prj	NAD 83
Orthophoto Quarter Quad Files	Bull Lake WestNE, Bull Lake West SE, New Fork lakes NW	NAD 27
Digital Topo Map Image Files	New Fork Lakes, Bull Lake West	NAD 27
Other GIS maps or coverages if available		
This monitoring plan	Lakerim monplan.doc	n/a
Silvicultural RX	New Fork/Boulder.doc	n/a
NEPA Document	New Fork/Boulder EA.doc	n/a
Burn Plan – if available	Lakerim burnplan.doc	n/a

11. Monitoring Objectives, Methods, and Schedules: Two to four of these should be adequate for evaluating your success. So think about what info you really need! **See Genericburnobjectives.doc on the BTNF web page for some ideas.**

Monitoring Objective 1: INSTRUCTIONS	
Objective Target	A specific and measurable statement that addresses a major goal of the project. Make it realistic and specify a target or amount of change desired and a time that this target should be reached by.
Variables being measured	Such as density, percent cover, height, percent browsed, percent mortality, frequency of the target
Methods / plot types	See the BTNF Fire Effects Monitoring Handbook for a list of protocols.
Schedule for plot visits	When plots will be installed and when they must be re-visited and re-measured. This should correspond with the time target of the objective.

Monitoring Objective 1: EXAMPLE 1 – ASPEN REGENERATION	
Objective Target	Increase 10 foot height aspen sucker density to at least 1000 stems/ac before or at ten years post-burn in all burned areas.
Variables being measured	sucker height/density of aspen
Methods / plot types	Non-permanent circular fixed-radius plots
Schedule for plot visits	Conduct plots in spring before new stem growth begins. Pre burn, 2 years post burn, 5 years post burn, 10 years post burn.

Monitoring Objective 1: EXAMPLE 2 –BURN MOSAIC	
Objective Target	Burn in a mosaic pattern with 40-60% black and maximum burned patch size smaller than 20 acres
Variables being measured	Distribution and extent of blackened vegetation immediately post burn
Methods / plot types	Aerial photography from helicopter and transfer to GIS map for spatial analysis
Schedule for plot visits	Overflight for digital photography immediately post burn

Monitoring Objective 1: EXAMPLE 3 – SAGEBRUSH AGE CLASS DIVERSITY	
Objective Target	Decrease live mature and decadent sagebrush density by at least 50% one year post burn and increase immature sagebrush density to at least 1500 stems per acre 5 years post burn
Variables being measured	Live sagebrush density by age class
Methods / plot types	Shrub belts
Schedule for plot visits	Pre burn, one year post burn and five years post burn

Monitoring Objective 1: EXAMPLE 4 - NATIVE GRASS VIGOR	
Objective Target	Increase the percent cover of native grasses two years post burn
Variables being measured	Percent cover of native grass species
Methods / plot types	Point line intercept transects paired in treated locations paired with untreated control plots
Schedule for plot visits	Pre burn, two years post burn

*** Complete BTNF Fire Effects Monitoring Instruction Sheet after pre monitoring has been completed

BTNF Fire Effects Monitoring Instruction Sheet	
Project Unit Name:	Date:
Written By (Project Monitoring Leader):	
Monitoring Protocols (plot types, layouts, etc.):	
Plot Location and Navigation Info (include relevant UTMs and datum):	
Photo Info:	
Equipment Needed:	