APPENDIX F

Beyond Prevention: Site-Specific Invasive Plant Treatment Project

Clallam, Grays Harbor, Jefferson, and
Mason Counties in the State of Washington

2003 Guidelines for Revegetation of Invasive Weed Sites and Other Disturbed Areas on National Forests and Grasslands in the Pacific Northwest

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Introduction

This document provides methods and guidance for revegetation of invasive weed sites and other disturbed areas on National Forests and Grasslands in the Pacific Northwest (Region 6). Steps are outlined for assessing existing and potential site conditions, and for developing long-term revegetation strategies that are effective, affordable, and consistent with the ecological context and land management objectives of the site and surrounding landscape. The need for this document was driven by relatively new policies and programs that promote the use of native plant materials in revegetation projects (Appendix A,B). Historically, resource managers in the western United States have relied on introduced species (e.g., smooth brome, orchardgrass, timothy, crested wheatgrass) that have been selectively bred for characteristics that, at least in the short-term, made them logical choices for revegetation projects. Although some introduced species will continue to play an important role in site restoration, it has become increasingly clear that the widespread and excessive use of highly competitive and persistent non-native species has had adverse impacts on the diversity and health of our native forest, rangeland, and aquatic ecosystems (Detwyler 1971; Covington and Moore 1994; Kaufmann *et al*. 1994; Kay 1994; Mills *et al*. 1994; Brown 1995, Lesica and DeLuca 1996; Bartos and Campbell 1998; Schoennagel and Waller 1999; Brown and Rice 2000) As a consequence, new direction for revegetation projects strives for a balance between rapid establishment of high levels of competitive plant cover, and broader, more long-term objectives aimed at restoring inherent ecosystem properties (e.g., genetic and species diversity, vegetation structure) and processes (e.g., disturbance regimes, succession patterns, hydrologic regimes, and nutrient cycles).

Revegetation with carefully selected plant materials is a critical component of integrated weed management strategies. Commonly used control tactics, such as manual or chemical treatments, may eliminate or suppress invasive species in the short term, but the resulting gaps and bare soil create open niches that are susceptible to further invasion by the same or other undesirable plant species (Westman 1990; Jacobs *et al.* 1999; D'Antonio and Meyerson 2002). On degraded weed sites where reproducing individuals of desirable species are absent or in low abundance, revegetation with well-adapted and competitive grasses, forbs, and legumes can be used to direct and accelerate plant community recovery, and achieve site management objectives in a reasonable timeframe (Hobbs and Mooney 1993; Sheley *et al*. 1996, Brown and Amacher

1998). This document incorporates a landscape ecology approach to revegetation that first considers and prioritizes individual projects in the context of watershed scales. More fine-scale elements of a successful revegetation design are also addressed, including evaluation of existing and potential site conditions, identification of realistic site goals, and development and implementation of appropriate action strategies. Because the science and practice of restoration is rapidly evolving, and the potential and most effective usage of many native species has not been fully explored, an experimental approach to revegetation is advocated. Sections and references on monitoring principles and techniques are therefore included to provide tools for resource specialists to evaluate the efficacy of alternative revegetation treatments, and gain insights into how methods may be refined to better achieve desired outcomes (i.e., adaptive management).

The recommendations in this document follow National and Regional Forest Service authorities and policy guidelines (see Appendix A, B), and are intended to provide a conceptual framework from which site-specific revegetation prescriptions can be developed. A number of sections, including the Decision Matrix and Site Prescriptions, were initially developed by resource specialists on the Siuslaw National Forest (Region 6), and refined and augmented by multi-Forest revegetation teams in Region 2 in cooperation with the National Park Service (http://fsweb.arnfpng.r2.fs.fed.us/). Detailed treatment descriptions and management scenarios are beyond the scope of this document, and specialists including District and Forest botanists, silviculturists, geneticists, ecologists, soil scientists, and range conservationists should be consulted as necessary to refine revegetation prescriptions and identify the most appropriate plant materials (species and seed sources) and revegetation methods for a particular site. Restoration of disturbed sites should be approached as a multi-disciplinary effort, and will be most successful when local knowledge and expertise are fully utilized and integrated into comprehensive revegetation strategies.

Revegetation in a Landscape Context

Revegetation programs and strategies should be developed using a landscape ecology approach that considers individual projects in the context of watershed scales. Thus, revegetation of invasive weed sites should fit into broader ecological strategies that address other major restoration issues of a given watershed, including departures from historical vegetative conditions, at-risk aquatic/wildlife/plant species, hydrology, uncharacteristic wildfire risks, etc.. Projects can then designed and prioritized so that they contribute to the overall goals for the particular watershed or landscape planning area. In addition, efforts should be taken to ensure that revegetation projects are fully integrated with the suite of other ongoing resource management projects, both spatially and temporally. One obvious example is that weed control operations must be tightly linked and coordinated with post-removal revegetation plans. A landscape ecology approach to revegetation also requires a thorough understanding of the underlying problems contributing to the need for revegetation, and how they interact with other processes within the watershed. This may be accomplished through assessments of the larger landscape area and its connection to the problem site. A key question is whether the site problem is unique, or symptomatic of other problems within the watershed that need to be addressed at a larger scale. Finally, in an era where the extent and intensity of management is declining and more aligned with natural processes, revegetation projects must be compatible with the dominant disturbance processes of the site and surrounding area (e.g., wildfire cycles, herbivory).

Some of the major issues to consider during the development of landscape-scale revegetation strategies for invasive weed sites include:

(the following section is not compete)

1. <u>The current extent and patterns of spread of invasive species</u>: Design projects to cut off or slow the spread paths and corridors using spatial strategies similar to those of wildfire management. Interrupt dominant vectors to minimize the degree and rate of propagule spread. Identify recurring points of invasion (e.g., roads/trails); revegetate the sites with highly competitive species. Tier revegetation to control prioritization scheme. Because funding for invasive spp. management efforts is typically limited, it is essential to prioritize revegetation of sites occupied by species and populations that are most important to control. Prioritization should be based on impacts of invader species, site characteristics, and potential for success.

2. <u>Grazing and hydrologic issues in riparian systems</u>: Revegetion species should be chosen based on consideration of site and landscape level aquatic strategies and goals. Utilize the Rosgen or other hydrologic classification schemes to determine succession on the stream and physical site characteristics to help select species for

revegetation that will be compatible with the dominant hydrologic disturbance processes. Design projects with hydrologic disturbance in mind. Ungulate herbivory can be the dominate disturbance process (e.g., in the Blue Mountains) and must be factored into design and cost of revegetation.

3. Historical range of variability (HRV) and degree of departure: Quantify historical range and variability of landscape pattern dynamics to assess current landscape conditions and define limits of acceptable change. Design appropriate landscape vegetation treatments consistent with overarching ecosystem management goals. In upland settings, consider implications of fire regime (e.g., low intensity, frequent return interval versus infrequent high intensity). In high intensity fire areas, for example, revegetation efforts may emphasize use of species that disperse and spread rapidly, have high seed production, and are tolerant of fire.

Site Assessment

Following the development of larger scale landscape strategies, site assessment is the next critical phase in the design of a successful revegetation project. There are 3 primary steps in determining whether a given site requires active revegetation. These include:

- Evaluation of site history and existing conditions
- Defining land management and site goals
- Determining the need for action

Site History and Existing Conditions:

The evaluation of existing site conditions involves first determining what resources or values are at risk from degradation of the site. Example of site risks to be considered include: (1) erosion and soil loss potential, (2) the likelihood of invasion or re-invasion by undesirable plant species, (3) loss of cultural, visual, or social values, and (4) potential effects on threatened, endangered, or sensitive (TES) species, and their forage and habitat.

Site dominated by invasive weed species may have an increased risk of surface run-off and soil erosion due to the loss of vegetative cover and native plants that have inherent soil stabilizing growth habits (e.g., extensive fibrous root systems). Risk of erosion will be higher on steep slopes (>40-50%) and sites with crusted, shallow, compacted, or highly erodible soils. Erosion can have negative effects on "downstream" ecosystem processes and species through sediment transport and deposition. On site, loss of the soil surface layer may strongly affect the degree and speed of revegetation due to depletion of organic matter, water holding capacity, and critical nutrient reserves.

Risk of noxious weed invasion or re-invasion on a site is largely dependent on the abundance of undesirable species in the seed bank, the size and proximity of surrounding weed populations, the ease of seed movement to the site, and the growth and spread characteristics of any adjacent weed species (D'Antonio and Meyerson 2002). For example, a population of an aggressive knapweed less than a quarter mile down a well-traveled road renders a site highly susceptible to invasion. In contrast, a site surrounded by several miles of dense forest that separates it from a population of a rhizomatous weed species such as white top is at fairly low risk of invasion.

Loss of native vegetative cover may negatively impact the availability and abundance of culturally important medicinal or food species. Artifacts present in the soil also may be at risk of being disturbed or transported by soil erosion accompanying the loss of vegetative cover. Aesthetics and recreational quality are diminished by patches of bare soil, as well as by unattractive invasive plants that have sharp spines or thorns. Wildlife species have co-evolved with native plant species and are highly dependent on them for food, or cover, or both. Of special concern are TES species that may be directly or indirectly affected by degraded vegetative conditions resulting from weed invasions. For example, listed fish species may be adversely affected by altered seasonal water flows or by increased sediment loads in streams due to erosion of disturbed weed sites. Propagules from weed sites in close proximity to special management areas of high social or ecological value can disperse and become established in the pristine habitats that often harbor TES plant species. Finally, revegetation of invasive weed sites with aggressive non-native cover species may unintentionally introduce equally invasive, though not officially designated as noxious, plants into the vicinity of TES plant populations resulting in excessive competition with rare native species that are already in decline or at risk of extirpation.

In additional to risk assessment, it is also important to determine the causes of site degradation. Broad categories include soil disturbance, loss of native species, and loss of whole plant communities whose structure normally regulates the processes of nutrient cycling and water retention. Within these broad categories, the agents contributing to disturbance and their relationship to ecosystem degradation should be identified and evaluated in terms of their continued presence and ongoing effects. For instance, if road construction has disturbed soils in the past, is the road still maintained (bladed annually, subject to ditch cleaning, sprayed annually to control existing weed infestations), or has it been closed or even obliterated? Or, if native plants have been lost due to heavy grazing pressure by domestic or wild ungulates, do those animals still have access to the area? Revegetation, especially with native species, is difficult to impossible in the face of continuing disturbance. Passive restoration (the removal of the disturbing agent so that unassisted site recovery can take place) will be the simplest and most cost-effective step towards revegetation of some sites, and is requisite to the success of active revegetation methods.

Desired Future Condition:

Defining revegetative goals, or desired future condition, for a given site is a crucial step in site assessment. In many cases, the recovery of natural ecosystem processes and pre-disturbance conditions, or some close approximation, will be assumed as the preferred state. This suggests a plant community that is structurally diverse, fully functioning in all ecosystem processes, and consisting of locally adapted native species. A knowledgeable botanist or a plant ecologist should be consulted at this stage to help in identifying realistic goals for site revegetation. In some cases, such as in the presence of ongoing degradation or large-scale infestations, complete recovery to pre-disturbance conditions may not be an appropriate objective. Revegetation goals must also be realistic, both in the sense that they may actually be achieved, and that they are affordable. Some common and overarching goals for revegetation of National Forests and Grasslands include:

- Contribute to the restoration of ecosystem structure and function.
- Minimize or contain surface erosion, particularly if the project or downstream area is susceptible to impacts of erosion and/or sedimentation.
- Maintain or re-establish nutrient cycling as quickly as possible through establishment of desirable vegetative cover for nutrient uptake, and placement of woody debris or mulch for nutrient input.
- Avoid or minimize stream or riparian area sedimentation
- Exclude noxious weeds and undesirable non-native species by revegetating sites with local native species or non-persistent cover crops that will not be overly competitive with native vegetation in the target area.

- Give special consideration to sites of high ecological or social value, and areas containing TES species or habitat. Revegetation with local native species (local ecotypes) is a high priority within intact and pristine ecosystems, core conservation areas, and their buffers and connecting corridors.

Need For Action:

Determining the need for action on a specific site requires consideration of the potential for natural recovery. For example, is there adequate moisture available to support natural regeneration, sprouting, and establishment of native vegetation within a reasonable period of time? The degree of disturbance, as indicated by the proportion of the existing plant cover that consists of desirable native species, will also affect revegetation outcome. Ten to twenty percent native cover is considered a minimum required to facilitate natural recovery of a site (James 1992, Sheley *et al*. 1996, Goodwin and Sheley 2003). The diversity, abundance, and viability of plant propagules of desirable species in the seed bank or within the immediate vicinity are additional important determinants in natural recruitment and recovery. A novel method for quantifying site disturbance and the potential for natural recovery based on the plant cover of individual species, and their longevity and native/non-native status is described in McArthur *et al*. (1995). The formula[1] could easily be modified to incorporate information on additional life history traits such as root morphology (e.g,. rhizomatous vs. non-rhizomatous) and seral status. Sites dominated by propagule pools of early seral (pioneering) native species are predicted to have the greatest likelihood of natural colonization and recovery, while those reliant on late seral species for regeneration or dominated by undesirable rhizomatous species will generally be less successful.

The size of the invasion and the length of time that weeds have been present may strongly influence revegetation strategies and the need for active manipulations. Very small sites are the most easily re-colonized by the extant seed bank and by plant propagules dispersed from surrounding sources. Depending on the ecological setting, it is reasonable to allow revegetation to occur on its own on sites less than about 0.25 acres, or to possibly assist natural recovery through the redistribution of seed from surrounding plants by hand. The longer the site has been

[1] Disturbance value = Sum[Cover*(Longevity-Origin Scores)]/Number of Species. Longevity: 1=annual, 2=biennial, 3=biennial to perennial, 4=perennial. Origin: 1=native to local area, 2=exotic to the area, but native to North America, 3=exotic to North America.

occupied by invasive plants, the greater the potential for the seed bank to become dominated by undesirable species, and for chemical or physical changes in soil conditions (e.g., shifts in nitrogen pools and pH) and associated microbial communities that may adversely affect species replacement dynamics and natural site recovery (Evans *et al*. 2001; Svejcar and Sheley 2001; D'Antonio and Meyerson 2002).

Other soil conditions influencing outcome include the degree of substrate disturbance (loss or mixing of soil horizons) and seedbed physical characteristics, including the extent of crusting and compaction. As fertility and water holding capacity are lost with the A and B soil horizons it becomes increasingly difficult to establish vegetation. Regardless of the method of regeneration, cultural amendments and manipulations may be required on highly degraded sites to help decrease the competitive advantage of exotic species, and improve the number and condition of regeneration sites available for germination and root extension of desired species. Examples include topsoil replacement, incorporation of organic matter, mulching, seedbed disking and imprinting to aid water infiltration and soil aeration, liming to adjust pH, and nutrient enhancements/manipulations. An experimental technique of great promise in *Bromus tectorum* dominated communities is the application of sucrose to reduce plant-available nitrogen and create a soil environment more conducive to the establishment of native perennial vegetation (McLendon and Redente 1992; Young *et al*. 1999;Paschke *et al*. 2000).

Selection of Plant Materials

Regional Priorities and Guidelines:

When site assessment indicates a need for active revegetation, the next critical step is to determine the species and seed sources that will establish and perform well on the site without impeding natural community recovery and succession, or compromising the diversity, genetic integrity, and long-term viability of resident wild populations. The potential risks and impacts of revegetation treatments are greatest for seeding and planting projects that involve large acreages, or that occur in or near management areas of high social or ecological value. In 1994, Region 6 formulated revegetation policy that set general guidelines and priorities for plant material usage in disturbed areas on national forests and grasslands, including sites occupied by invasive exotic plants (see Appendix B). Regional priorities, as well as definitions and rational, are as follows:

Priority 1 - Local Native: Plant materials of native species that originate from genetically local sources. Benefits of use include high adaptation to spatial and temporal extremes, and low input requirements (e.g., supplemental water, fertilizer). Local native plant materials are recommended for projects of all sizes (Fig. 1, adapted from Lesica and Allendorf 1999), especially in and around pristine or relatively intact habitats and ecosystems such as designated or proposed wilderness, roadless areas, wild and scenic river corridors, Research Natural Areas (RNAs), Special Interest Areas (SIAs), riparian areas, wetlands, cultural use areas, TES species habitat and connecting corridors, etc. For severe and large-scale disturbances, a mixture of genotypes or seed sources from ecologically different populations has been suggested as a strategy for maximizing genetic variation and enhancing the likelihood of plant establishment and persistence in stressful environments (Fig. 1, adapted from Lesica and Allendorf 1999).

The ecological and geographic boundaries that define a local population are determined primarily by the heterogeneity of the climate and habitat, the genetic structuring of the populations, the extent of local adaptation, and the consequences of mixing distant gene pools (Fenstar and Dudash 1994; Knapp and Rice 1994; Linhart 1995; Montalvo *et al*. 1997; Lesica and Allendorf 1999; Hufford and Mazer 2003). Although seed zones and transfer guidelines have been developed for most Pacific Northwest conifer species (USDA 1973; Randall and Berrang 2002), such information is generally lacking for other native plant species. As a consequence, elevational restrictions along with existing spatial frameworks such as EPA ecoregions, 5th field watersheds, and conifer seed zones are frequently used to guide seed movement in native shrubs, grasses, and forbs (Erickson *et al.*, submitted).

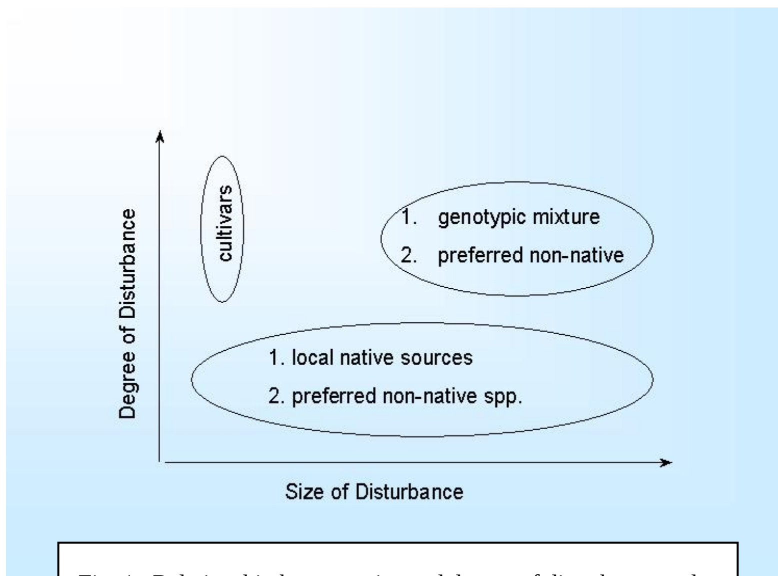

Fig. 1. Relationship between size and degree of disturbance and primary and secondary preferences for plant material for revegetation on National Forests and Grasslands in Region 6. (Adapted from Lesica and Allendorf 1999).

Use of local sources of native seed requires carefully coordinated and integrated programs to ensure adequate quantities of suitable seed are available at critical times for project work. A new 5-year Regional contract for native grass and forb seed production (53-04R3-03-14, http://www.fs.fed.us/r6/uma/native/) will help facilitate this process at reasonable cost. Table C-1 (Appendix C) contains seed yield and cost figures for native grass and forb species included in the contract. Table C-2 (Appendix C) describes ecological attributes and suggested seeding rates for a broad array of native species that have successfully been used in revegetation projects in the Pacific Northwest.

Priority 2 - Preferred Non-Native: The volume of seed needed for large-scale restoration may at times preclude the use of local native seed, particularly for unplanned events such as wildfires, or other disturbances where it is critical to quickly establish vegetation in order to protect basic resources values and prevent weed invasions. In these instances, a second choice would be sterile hybrids or annuals/biennial/perennial introduced plant species that are non-persistent and non-invasive (Fig.1, adapted from Lesica and Allendorf 1999). Preferred non-native species are those that will not aggressively compete with the naturally occurring native plant community, will not invade plant communities outside the project area, persist in the ecosystem over the long term, or exchange genetic material with local native plant species. Appendix D includes recommendations for non-native species that may be seeded as temporary ground cover for both erosion control and as noxious weed competitors until native species can become established and occupy the site. The list includes sterile hybrids, such as REGREEN and annuals such as white oats (*Avena sativa*) and winter wheat (*Triticum aestivum*). A more complete list of perennial non-natives that are suitably non-persistent may be developed on Districts/Forests by examining past revegetation efforts where the seeded species are known. Exotic species that have not already been introduced into the area, or that have been found to be aggressive and/or persistent, should be avoided. Table E-1 (Appendix E) provides a listing of non-native species that, although commonly used in the past, are generally no longer recommended due to their highly aggressive nature that has resulted in widespread loss or displacement of native species and plant communities in western wildlands. These include Kentucky bluegrass (*Poa pratensis*); smooth brome (*Bromus inermis*); crested wheatgrass (*Agropyron cristatum)*; orchard grass (*Dactylis glomerata*); yellow and white sweetclover (*Melilotus officinale* and *M. albus*); alsike clover (*Trifolium hybridum*) and alfalfa (*Medicago sativa* to name a few. As a last resort, some of these “species-to-avoid” may play a limited role in revegetation of small, highly degraded sites where there is poor potential for native plant community recovery, or in settings where there is little risk of spread beyond the original site of introduction (e.g., seeding around buildings on administrative sites).

Priority 3 - Non-local Native: This category includes native species that do not occur naturally in the local ecosystem, or native plant material that does not originate from genetically local sources. These types of plant materials, including most commercial cultivars (Table E-2, Appendix E), are generally not preferable for wildland use due to concerns over adaptability, genetic diversity level, and the potential for genetic contamination or "swamping" of local native gene pools, including those of TES plants (Millar and Libby 1989; Knapp and Rice 1994; Linhart 1995; Montalvo *et al*. 1997; Lesica and Allendorf 1999; Hufford and Mazer 2003). Because commercial cultivars are typically selected for agronomic traits such as high fecundity, vegetative vigor, and competitive ability, their use may also adversely impact resident natural populations through direct competition and displacement. Moreover, cultivars of native species (and introduced look-alikes such as sheep fescue, *Festuca ovina*) can be very difficult to distinguish from native germplasm, which could severely complicate efforts to collect and propagate local material and waste valuable economic resources. Because of these concerns, cultivars are recommended for use only on small, highly disturbed sites (Fig. 1, adapted from Lesica and Allendorf 1999) that are not in close proximity to areas of high social or ecological value such as designated or proposed wilderness areas; Research Natural Areas (RNAs); Special Interest Areas (SIAs), TES species habitat or corridors, and riparian/wetland areas. Where cultivars have been used, it is important to document and map their locations so these areas can be avoided during seed harvesting activities.

Designing Seed Mixes

The design of an effective seed mixes incorporates a number of factors, including land-use objectives and site characteristics such as existing and potential vegetation, weed density and biomass, precipitation/temperature regimes, soil characteristics, and shade conditions. In addition, short-term objectives of quick establishment of competitive plant cover must be balanced with more long-term goals of restoring fully functioning and self-sustaining plant communities that will be resilient to further disturbances (i.e., will not degrade to pre-treatment, weed-dominated conditions). This may be achieved by devising seed mixes containing compatible species that (1) maximally occupy available niches (enhance functional diversity), and (2) possess physiological and growth characteristics that facilitate their establishment, competitiveness, and tolerance of stress.

Researchers have found that sites with high functional group diversity, especially with respect to native forbs, are more competitive and resistant to weed invasion and establishment because site resources are fully utilized (Carpinelli 2000; Symstad 2000; Pokomy 2002). Although the full spectrum and diversity of the desired plant community rarely will be achieved during revegetation, niche occupation and resources use can be enhanced by combining key species that vary in their seasonal growth pattern, seral status, reproductive mechanisms, and growth form and root morphology (e.g., fibrous-rooted grasses and forbs with deep taproots) (Panetta and Groves 1990; Jacobs *et al*. 1999; Goodwin and Sheley 2003). Example of native cool-season grasses (grow in the early spring/summer and utilize soil resources in the upper soil profile) that can be competitive against invasive weeds include blue wildrye (*Elymus glaucus*), squirreltail (*Elymus elymoides*), mountain brome (*Bromus carinatus*), thickspike wheatgrass (*Elymus lanceolatus*), slender wheatgrass (*Elymus trachycaulus*), bluestem or western wheatgrass (*Pascopyrum smithii*), and prairie junegrass (Koelaria macrantha), Sandberg bluegrass (*Poa secunda*) (Borman et al. 1991; Brown and Amacher 1999; Goodwin and Sheley 2003). Idaho fescue (*Festuca idahoensis*), a cool-season bunchgrass, can also be a strongly competitive once mature stands are established. Competitive native forbs and legumes include blue flax, (*Linum lewisii*), common yarrow (*Achillea millefolium*), pearly everlasting (*Anaphalis margaritacea*), fireflower (*Epilobium angustifolium*) and various lupine (*Lupinus*) and vetch (*Vicia*) spp.

Native grass-like species, such as sedges, spikerushes, rushes, and bulrushes, may be useful in revegetating riparian and wetland areas. Under these conditions, containerized seedlings often show better survival and establishment than seeding. Deep-rooted shrubs may also be seeded or planted to more fully utilize resources from the lower soil profile, especially late in the growing season. Shrub vegetation can facilitate the establishment of understory species by increasing water availability and reducing understory temperatures and evapotranspiraation. Over the long term, perennial shrubs will also enhance soil fertility and structure and increase nutrient cycling (West 1989).

A more complete list of native species suitable for revegetation activities should be developed on Districts/Forests by knowledgeable plant resource specialists (i.e., range specialists, botanists, ecologists, etc.) through examination of target sites and nearby undisturbed reference areas. There's a broad array of competitive native species that may be useful in revegetation; however, research efforts have not fully explored their potential or the conditions under which they would be most effective. In general, characteristics that make a species well-suited for revegetation include broad ecological amplitude, rapid germination and early seedling growth, and aggressive root systems. Such species are often early seral natural colonizers of disturbed sites. Late seral species often have lower growth rates than colonizers, but still can be an important component of a seed mix because they tend to be highly competitive and often have high root/shoot ratios (Brown and Amacher 1999). Combining native and non-native species in seeding or planting mixes, however, is generally not recommended due to incompatible growth and life history strategies. An exception would involve the mixing of one or two long-lived perennial native species with a non-native temporary cover crop type species (e.g., from the list in Table D-1, Appendix D) that will rapidly colonize and occupy the site until the slower perennial species become established.

Seed Labeling and Testing

The genetic origin of all native seed used in restoration should be known; purchased seed should be certified as to source identity. Purchased seed, both native and non-native, must have documented and recent (<1 year old) germination, purity, and "All State's Noxious Weed" test results. The more recent the test, the more likely it is to reflect the true condition of the seed . Testing should be conducted by a National Association of Official Seed Certification Analysis (AOSCA) approved seed testing laboratory (Table C-2, Appendix C). Copies of seed test results should be retained in associated project files.

Purity testing verifies the proportion of pure seed contained in the seed lot and identifies contaminants, including other crop seed, weed seed, and inert matter (e.g, stems, chaff, small stones). Graminoid seed with more than 10-15 percent inert matter will be difficult to apply through a rotary seeder or rangeland drill. Germination tests provide information on how well the pure seed portion of the seed lot will perform under favorable field conditions. The percentage of pure live seed (PLS), calculated as the percent purity multiplied by the percent germination, is commonly used as a standardized indicator of seed quality. See Table C-2,

Appendix C, for suggested minimum acceptable germination and purity standards for grass and forb seed.

Many native species produce seeds that are dormant and won't germinate without afterripening (time) or special germination enhancement treatments (stratification, scarification, gibberellic acid, etc.). In these cases, seed viability may be estimated using other procedures. Most widely used is the fast and inexpensive tetrazolium (TZ) test, which involves a biochemical staining technique with tetrazolium chloride that visibly stains live, germinable seed (Young and Young 1986).

Seed test results should verify that the seed lot contain no "Prohibited" noxious weed seed, and that seed meets or exceed standards for "Restricted" or "Other Weed Seed" content according to Oregon and/or Washington State standards for Certified Seed (Table C-2, Appendix C). Because each state has different lists of prohibited and restricted noxious weeds, request that the seed be tested with an "All-States Noxious Weed Exam". The name and number of seeds per pound of weed and other crop seed will be listed on the seed label. Be on the alert for aggressive non-natives that, although not prohibited or restricted by the State, may still pose a threat to native plant communities.

Determining Seeding Rates

Seeding rates for grasses and forbs can vary greatly depending on site condition, species, and methods of application. Recommended seeding rates for pure grass seed mixtures are generally in the range of 20-50 viable seeds per square foot (Goodwin and Sheley 2003); pure forb and shrub mixes will be lower (you wouldn't want 10 Elderberry shrubs in every square foot for example). Higher rates are often recommended for severely disturbed sites to compensate for high seedling morality due to limiting environmental factors and competition. Goodwin and Sheley (2003), for example, suggest a seeding rate of 80 PLS/ft^2 for perennial grasses in severely burned areas, and doubling or tripling rates when seeding to prevent weed invasions, or if broadcast seeding or hydroseeding. Brown and Amacher (1999) recommend 250-350 PLS seeds per ft^2 on severe disturbances. Increasing the seeding rate, however, will never make up for poor seedbed preparation, poor seeding methods, or improper timing of seeding.

Seeding rates are calculated using the following information:

1) total number of seeds per pound

2) percentage of each pound that is pure, live seed (PLS)
3) number of acres to be treated
4) target PLS /ft^2 after considering site conditions and seeding method

Example calculations for a single species seed mix: seed 1 acre with blue wildrye which has 131,000 seeds per pound and is 83% PLS to get a result of 20 PLS /ft^2:

(1 acre) x (43,560 ft^2/acre) x (20 PLS/ft^2) = 871,200 PLS

(131,000 seeds/lb) x (0.83) = 108,730 PLS/lb.

871,200 ÷ 108,730 = 8.01 lb.

Example calculations for a multi-species seed mixture: seed 1 acre with 4 species at different rates (to equalize competition) to obtain a coverage of 40 PLS/ft.^{2}:

Species	Seeds per pound	PLS	Target Coverage (PLS/ft2)
Blue wildrye	131,000	0.83	10
Mountain brome	81,500	0.86	10
Prairie junegrass [a]	2,300,000	0.80	10
Sandberg's bluegrass	925,000	0.80	10
		Total Coverage:	40 PLS/ft^2

[a] Bluebunch wheatgrass may be substituted on drier sites. Idaho fescue would be a good addition to this mix if available.

Blue wildrye: (1 acres) x (43,560 ft^2/acre) x (10 PLS/ft^2) = 435,600 PLS
(131,000 seeds/lb) x (0.83) = 108,730 PLS/lb.
435,600 ÷ 108,730 = **4.01 lb/acre**.

Mountain brome: (1 acre) x (43,560 ft^2/acre) x (10 PLS/ft^2) = 435,600 PLS
(81,500 seeds/lb) x (0.86) = 70,090 PLS/lb.
435,600 ÷ 70,090 = **6.21 lb/acre**.

Prairie junegrass: (1 acre) x (43,560 ft^2/acre) x (10 PLS/ft^2) = 435,600 PLS

(2,300,000 seeds/lb) x (0.80) = 1,840,000 PLS/lb.

435,600 ÷ 1,840,000 = **0.24 lb/acre**.

Sandberg's bluegrass: (1 acre) x (43,560 ft^2/acre) x (10 PLS/ft^2) = 435,600 PLS

(925,000 seeds/lb) x (0.80) = 740,000 PLS/lb**.**

435,600 ÷ 740,000 = **0.59 lb/acre**.

Total Mix = 11.05 lb/acre

How to use PLS: If the plan calls for a certain amount of pounds of PLS seed per acre, how much bulk seed is needed? To calculate the corresponding bulk amount, divide the PLS percentage into the number of pounds recommended. Example: You want to plant 5 PLS pounds of Idaho Fescue per acre. The analysis label indicates 85% purity and the germination is 79%. .85 x .79 = .67 PLS. Divide .67 into 5 lbs/acre = 7.5 lbs of BULK seed/acre.