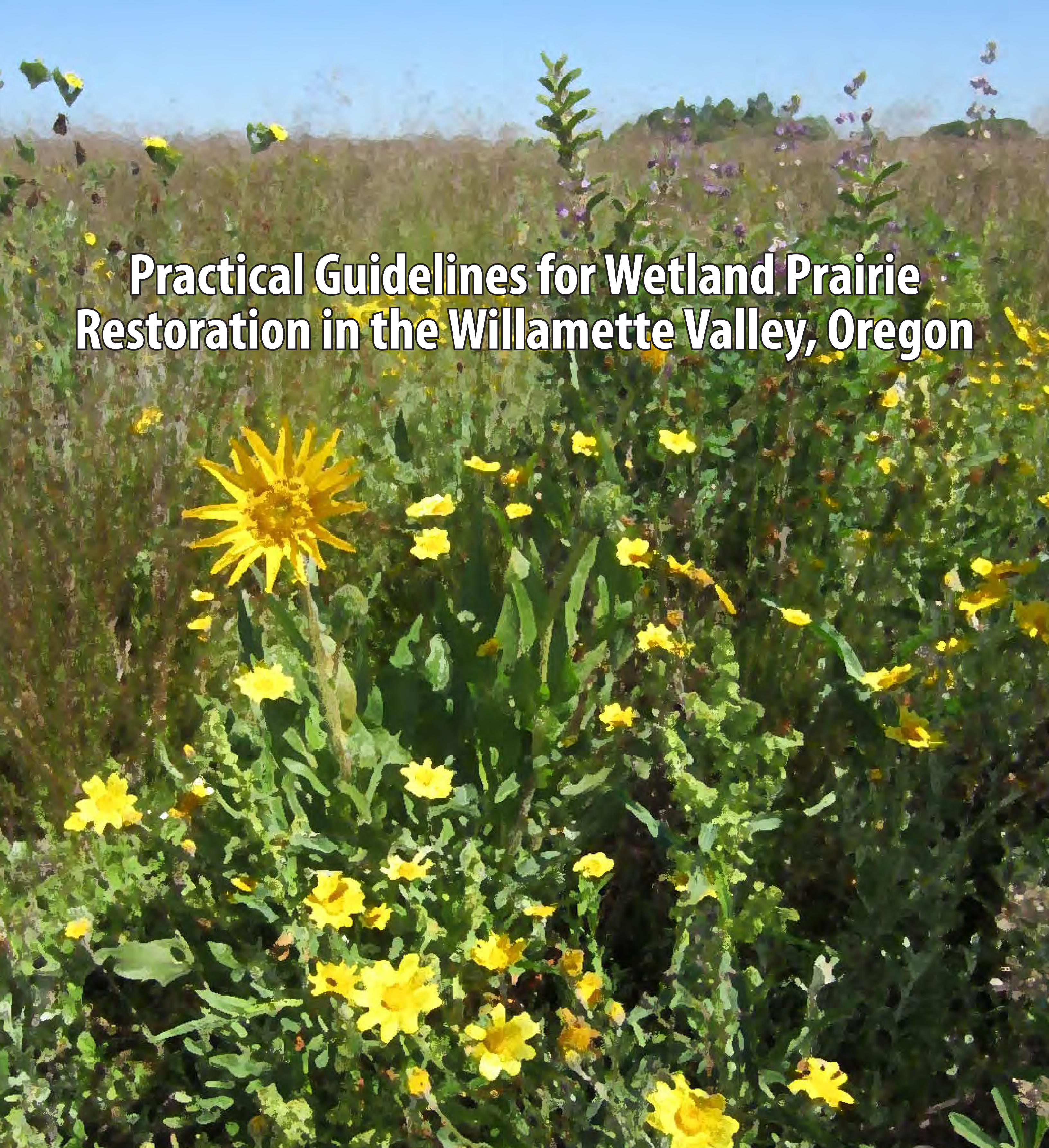
Practical Guidelines for Wetland Prairie Restoration in the Willamette Valley, Oregon



Field-Tested Methods and Techniques

August 2014

Guide Produced By

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Chapter 1: Background and Purpose

1.1 Purpose and Focus of Guide

The science of wetland prairie restoration has made significant strides in recent years, building on lessons learned locally in Oregon and Washington and on applied research and practice from prairie restoration efforts in the Midwest. This guide documents the valuable lessons learned in the Pacific Northwest so they can be successfully replicated. The focus is on agricultural lands, in part because a large percentage of the historic wetland prairie lands have been converted to agricultural uses and therefore some of the greatest potential for large scale restoration exists in these areas. An estimated 50% of the valley floor is currently in agricultural uses (Morlan et al. 2011). Many mitigation banks have focused their restoration efforts in agricultural areas. Although the guide focuses on wetland prairie restoration in agricultural fields, the information contained in Chapter 6, which is related to management of wetland prairies for maintaining diversity and limiting invasion by non-native plants, is applicable to all types of wetland prairies including remnant and degraded areas.

Contents

The guide is organized into the following six chapters, with chapters 4, 5, and 6 providing the specific detail on the three major on-the-ground phases of wetland prairie restoration.

Lands that are currently in production for grass seed, including *Lolium multiflorum* (annual ryegrass), *Lolium perenne* (perennial ryegrass), *Agrostis* spp. (bentgrass), and *Festuca* spp. (fescue) are highly suitable candidates for large-scale prairie restoration in the Willamette Valley for several reasons. Many grass seed fields are currently located on lands that were previously wetland prairie, so there is a high likelihood that the soil and hydrologic conditions would be suitable for restoration of native wetland prairie. There are currently over 180,000 hectares (445,000 acres) of land in grass seed production in the Willamette Valley, which represents nearly half of the entire Valley's agriculture (Oregon State University Extension Service 2010). The intensive farming practices used in grass seed production, including the aggressive elimination of non-crop species, produce near monoculture conditions with relatively low invasive species presence that make restoration easier than in other degraded sites (Wold et al. 2011).

Restored wetland prairie at Coyote Prairie near Eugene

The content of this guide is based on a variety of sources including the findings of several EPA funded research projects conducted in the West Eugene Wetlands area between 2006 and 2013, extensive literature reviews, and lessons learned over nearly two decades of on-the-ground experience by the West Eugene Wetlands Mitigation Bank (and Coyote Prairie North Mitigation Bank). Target users of this guide include wetland mitigation banks in the Pacific Northwest, wetland scientists and researchers, restoration ecologists, private land owners, and land managers from state and federal agencies, municipalities, tribes, and land trusts. Although the geographic focus of the guide is the Willamette Valley, much of the information presented here can be applied to other types of open habitats such as upland prairie and savanna and to areas elsewhere in the United States containing similar habitats.

Prairie
The term prairie, originally derived from the French word for meadow, is used to describe open plant communities dominated by grasses and forbs, with little or no woody vegetation present. Within the Willamette Valley, prairie plant communities are distinguished by hydrology into two categories: upland and wetland prairies. This guide focuses specifically on wetland prairie communities.

1.2 Background

Once an abundant ecosystem within the Willamette Valley, native wetland prairies have declined dramatically in extent since the mid-1800s due to a variety of factors including agricultural conversion, urbanization, drainage, and colonization by invasive and woody vegetation. Today, wetland prairie habitat is regarded as one of the most imperiled in the Willamette Valley ecoregion, with less than 2% of its historic range remaining (Johannessen et al. 1971, Towle 1982). The wetland prairie that remains is generally in a degraded condition and highly fragmented (Altman et al. 2001). Because of the dynamic nature of this habitat, it is highly subject to ecological succession and invasion by non-native species, and generally requires fire and active management to maintain its diversity and function. A recently completed study of wetland changes in the Willamette Valley covering a period between 1994 and 2005 indicates that overall loss of wetlands in the valley continued over that period, with a net loss of 3,960 acres, or 1.3% of the 1994 total. The largest percentage of this loss occurred in palustrine farmed wetlands, which tend to be the areas with highest potential for future wetland prairie restoration (Morlan et al. 2010).

In the Pacific Northwest, prairies are found at low elevations west of the Cascades, from the Willamette Valley of Oregon north to the Georgia Basin of southwest British Columbia, and in small areas of the Palouse region of eastern Washington, Washington's San Juan Islands, and Oregon's Rogue and Umpqua Valleys (Sinclair et al. 2006).

Based on the significant decline in quantity and quality of prairies and the related presence of rare species of plants and animals, this natural community has been identified as an important component of multiple regional conservation strategies for the Willamette Valley of Oregon and Southwestern Washington. Conservation planning efforts such as the Oregon Conservation Strategy (ODFW 2006) and the Recovery Plan for the Prairie Species of Western Oregon and Southwestern Washington (USFWS 2010), have highlighted the urgent need for preservation and restoration of these communities to ensure the long-term viability of native plant and animal species that rely on them. Some noteworthy progress toward protecting and restoring wetland prairies in the Willamette Valley has occurred over the past two decades, driven to a large extent by the requirement for compensatory mitigation for loss of wetlands under State and Federal wetland protection laws and improvements in management expertise by land managers. During this period, a great deal has been learned about restoring and maintaining these complex ecological communities through scientific study, adaptive management, and collaboration.

Remnant wetland prairie

In an attempt to help further refine the success of wetland prairie restoration efforts, the U.S. Environmental Protection Agency (EPA) has funded a series of field studies in the southern Willamette Valley to help fill knowledge gaps on topics such as site preparation, plant establishment, and long-term management of wetland prairies. The EPA has supported the compilation of results (such as this guide and associated web resources) so that these lessons learned can be shared with a broad audience and implemented on a broad scale.

Chapter 2: Wetland Prairie of the Willamette Valley

2.1 Historical Extent and Condition

The geographic focus of this guide is the Willamette Valley ecoregion of Oregon, although wetland prairies historically extended throughout the Puget Trough-Georgia Basin to the north. The Willamette Valley ecoregion, which is bounded on the west by the Coast Range and on the east by the Cascade Mountains, covers 13,748 square kilometers (5,308 square miles) and includes the level alluvial plain of the valley floor and scattered groups of low basalt hills. Accounts from early explorers and settlers to the Willamette Valley indicate that, prior to Euro-American settlement in the mid-1800s, much of the valley floor was covered by expansive prairies consisting of a diverse mix of grasses and forbs with widely scattered trees on the hill slopes and riparian forest along the rivers. In general, prairie occupied a central position of the valley surrounded by bands of savanna, woodland, and closed forest. Prairie and savanna dominated the southern and central valley, while forest and woodland were more commonly mixed within the prairie and savanna habitats in the northern portion of the valley (Christy et al. 2011). The climate of the Willamette Valley ecoregion is characterized by mild wet winters and warm dry summers, which result in significant hydrologic variation. Based on information derived from the General Land Office (GLO) survey notes from the 1850s and other research, it is estimated that approximately 31% of this Willamette Valley ecoregion was in prairie condition prior to Euro-American settlement (Hulse et al. 2002). Although wetland and upland prairies were not differentiated in the GLO surveys, the general condition can be derived based on the presence of hydric soils. It is estimated that approximately 1/3 of the area was wetland prairie (Altman et al. 2001, Christy et al. 2011). Further analysis conducted by Lane Council of Governments (LCOG) in 2012 that combines the historical extent of prairies with the mapped locations of hydric soils confirms this approximation, indicating that an estimated 133,956 hectares (331,014 acres) of wetland prairie and 300,301 hectares (742,000 acres) of upland prairie were present in the Willamette Valley in the 1850s. As is shown on the Willamette Valley General Land Office 1850 Vegetation Map (LCOG 2012), the upland and wetland prairie communities formed a complex mosaic of intertwined habitats that extended across much of the valley floor.

> ***"Country undulating; soil rich, light, with beautiful solitary oaks and pines interspersed through it, and must have a fine effect, but being burned and not a single blade of grass except on the margins of rivulets to be seen. This obliged us to camp earlier than we would have otherwise done"***
>
> -David Douglas, journal entry describing his journey through the Willamette Valley, September 27, 1826.

Figure 2-1: ***Historical Vegetation of the Willamette Valley***

Vegetation Community (ca. 1850)	Acres	Hectares
Riparian Forest and Ash Savanna	238,676	96,588
Savanna, mixed	320,444	129,679
Savanna, Oak and Oak-Conifer	286,761	116048
Shrubland, Brush, Thickets	1,376	556
Unvegetated, Sand and Gravel	597	241
Unvegetated, Sand, Gravel, Rock Outcrop	48	19
Upland Forest, Fir	922,534	373,336
Upland Forest, Oak and Oak-Conifer	15,654	6,334
Upland Prairie (include mounded prairie)	742,060	300,301
Water as mapped by GLO	50,624	20,486
Wetland Prairie*	**331,014**	**133,956**
Woodland, Fir and Fir-Oak	486,687	196,955
Herbaceous Upland Communities	239	96
Total Acreage:	**3,396,713**	**1,374,600**

Source: LCOG, derived from GLO and NRCS data

* *wetland prairie category total includes 9,559 acres emergent wetland and 11,514 acres shrub swamp*

2.2 Wetland Prairie Ecology

Wetland prairies of the Willamette Valley are seasonally flooded ecosystems dominated by herbaceous plants occurring on poorly drained lowland soils. Poorly drained soils, combined with the relatively flat topography of the valley bottom, cause seasonal precipitation to collect, saturating the soil and often producing standing water, typically from November through April or May. Although soils dry during the typical summer drought, wetland prairie soils have hydric characteristics of wetlands and support facultative or obligate wetland plant species (Wilson 1998). The ecology of wetland and upland prairie ecosystems was highly influenced by native people through their use of fire as a tool to modify the ecological condition of the valley floor until the mid-1800s. This regular disturbance regime was critical for maintaining this early successional habitat, which is otherwise highly subject to colonization by woody vegetation over time. Most upland and many wetland prairies of the Willamette Valley will ultimately transition to woodland or forest vegetation without ongoing management or disturbance.

Willamette Valley Ecoregion, Oregon

1850 Vegetation

Figure 2-2

General Classification

- Upland Prairie (742,060 Ac)
- Wet Prairie, Mounded Prairie, Emergent Wetland, Shrub Swamps (331,014 Ac)
- Herbaceous Upland Communities (239 Ac)
- Savanna, mixed, Oak, & Oak-Conifer (607,205 Ac)
- Woodland, Fir, & Fir-Oak (486,687 Ac)
- Riparian Forest, Ash Savanna, Scrub, Brush, & Thickets (240,051 Ac)
- Upland Forest, Fir, Oak, & Oak-Conifer (938,188 Ac)
- Unvegetated, Rock Outcrop, Sand & Gravel (645 Ac)
- Water as mapped by GLO (50,624 Ac)

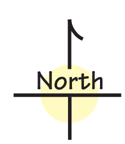
Rivers (current location)

"On the 10th, the country was somewhat more hilly than the day previous, but still fine grazing land. …The country had an uninviting look, from the fact that it had been overrun by fire, which had destroyed all the vegetation except the oak trees, which appeared not to be injured."

-Lieutenant Charles Wilkes, describing a location along the Willamette River, September 1841.

0 10 20 miles

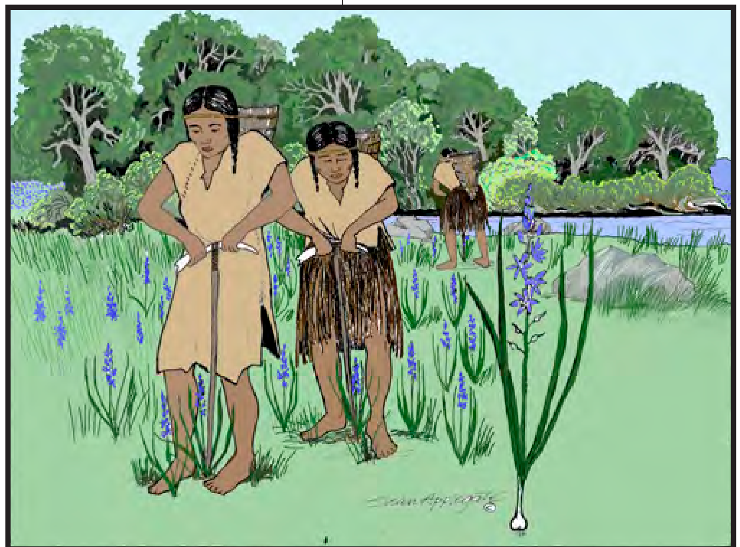
Scale



2.2.1 Native American Influences and Cultural Significance

Humans have lived in the Willamette Valley for an estimated 10,000 years. Prior to Euro-American habitation, most native inhabitants belonged to the Kalapuyan family, made up of several tribes included the Calapooia, Luckiamute, and Yamhill. The Kalapuya family were known to have regularly set fires throughout the Willamette Valley, likely in an effort to manage the land to improve hunting, forage, and travel (Johannessen 1971). These fires helped maintain the valley's mosaic of open prairies and oak savannas that the early Euro-American explorers and settlers encountered (ODFW 2006). With increased pressure from settlers to control fire and the rapid decline of the Kalapuyans through disease and displacement, the practice had largely ended by the late 1840s (Hulse et al. 2002).

The Kalapuyans were known to have used prairies intensively for food production and utilized at least 50 species of plants. Important food plants included bulbs of *Camassia* spp. (camas), *Brodiaea* spp. (brodiaea), and *Fritillaria affinis* (checker lily); roots of *Lomatium* spp. (biscuitroot) and *Perideridia* spp. (yampah); and seeds of *Madia* spp. (tarweed) and *Balsamorhiza* spp. (balsamroot) (Christy et al. 2011). Evidence of these food production practices can be found in the form of camas oven remnants located throughout the Willamette Valley. The oldest archeological evidence of camas ovens and charred bulbs in the Willamette Valley date back 7,750 years. Several ovens excavated near Eugene measure six feet in diameter and contain the remains of cooked camas and baking stones (Sultany et al. 2007).



Source: Susan Applegate

The Kalapuyans were known to have used prairies intensively for food production and utilized at least 50 species of plants. The illustration above depicts a Kalapuyan camas harvest.

Camas as a Food Source for the Kalapuyans

Camas bulbs, which formed a dietary staple for the Kalapuyans, not only provided a bounty when harvested, but could be processed and stored for winter use. Archaeological excavations have uncovered evidence which indicates that camas has been part of the diet of Native American inhabitants of the Willamette Valley for nearly 8,000 years.

Harvested during the spring and early summer when the ground was soft, several hundred pounds of bulbs were needed to meet a family's needs throughout the year. Groups of women would proceed through the camas patches digging the bulbs using a wooden digging stick with a fire-hardened point and an antler handle and placing the bulbs in woven burden baskets which they wore on their backs. When the women returned to the special camas processing camps along streams near the camas patches the bulbs were washed and then placed in earth ovens where they were baked for twenty-four hours. Earth ovens were made by digging a one-and-one-half to two foot deep, oval-shaped pit two or three feet in diameter and filling it with fist-sized rocks. A fire was built on the rocks and kept burning until the rocks were very hot. Then the ashes were swept out, a layer of grass was placed over the rocks, the cleaned camas bulbs were placed on the grass, more grass was placed over the top of the bulbs, then rocks which had been heated in an adjacent fire were placed on top of this. Finally, a layer of dirt was thrown over the top of the rocks and a fire built and kept burning for twenty-four hours. Archaeologists recognize camas processing sites by the large amounts of fire-cracked rock from the "lids" of the ovens and by the rock filled pits which often contain a few charred camas bulbs in the bottom.

When the camas bulbs were removed from the earth oven they were ready to eat. At this time they could also be crushed and formed into cakes about three inches thick, weighing nearly ten pounds. Dried and wrapped the cakes would keep for a year. These dried cakes of crushed camas bulbs were traded by the Kalapuya to neighboring tribes for food items or materials which were not found in the Kalapuya homeland.

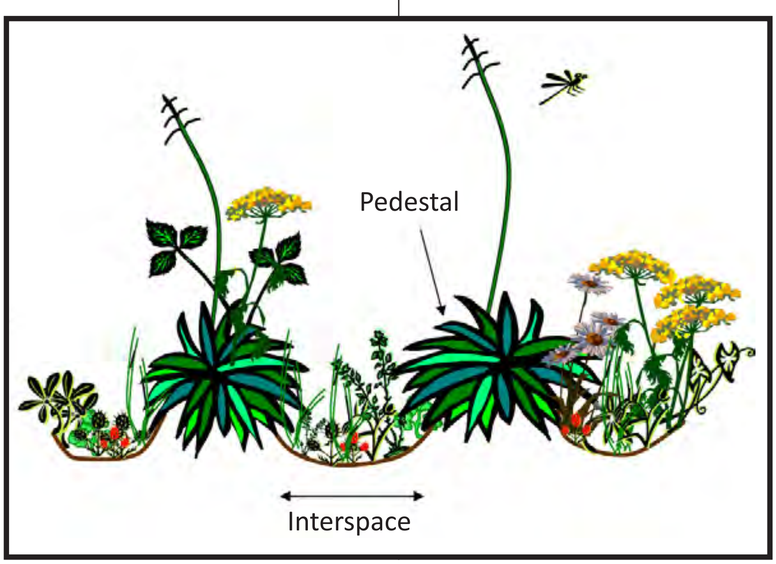
– U.S. Bureau of Land Management

2.2.2 Geomorphology, Topography, and Hydrology

Wetland prairies are typically located on poorly drained, very low gradient lands found in the valley bottom. They are generally found on expanses of heavy clay soils, but can also occur on well-drained soils with shallow bedrock impeding subsurface drainage, or along swales or drainages. Although limited published research exists on the subject, soil scientists conducting mapping for the Lane County soil survey noted considerable complexities in the geomorphic surfaces found in soils associated with wetland prairies, particularly in the southern end of the Willamette Valley. This is evident on the Calapooyia geomorphic surfaces found primarily to the north and west of Eugene, where slightly higher circular or oval mounded landforms are interspersed with lower, poorly drained braided areas (Balster and Parsons 1968). The variation in topography, up to one-half meter, and associated variation in surface hydrology, tends to promote much greater degree of plant species diversity than in areas with more uniform topography. Although these topographic traits were not specifically mentioned in the GLO survey notes, the Calapooyia geomorphic surface is visually evident on many 1936 and 1940 aerial photos taken in the southern Willamette Valley. Much of this geomorphic surface has been modified over the past several decades as most agricultural fields in the area have been mechanically smoothed in an effort to improve conditions for grass seed production.

The oval mounded landforms of the 'Calapooyia' geomorphic surface are evident in this 1940 aerial photo taken of the west Eugene area.

Topographic variation also exists on a much finer scale, as many wetland prairies also contain a complex vertical structure in the form of raised pedestals. It has been widely observed that over time, a pattern of raised pedestals 3 to 20 centimeters in height form above a lower level of soil within many wetland prairies. These raised areas range from 15 to 400 square centimeters in area and tend to remain above water between winter storms, resulting in several types of micro-habitats in a relatively small area. Grasses and forbs tend to thrive on the higher portions of the pedestals, while more water tolerant rushes, sedges, and annual forbs are often found in the low spaces between pedestals, which are inundated for much of the wet season (Wilson 1998). The origin of this pedestal-interspace microtopography is unknown, but observations suggest that the formation of mature clumps of bunch grasses such as *Deschampsia cespi-*



Source: Jean Jancaitis

Pedestals provide complex horizontal structure resulting in a diversity of microhabitats within a small area.

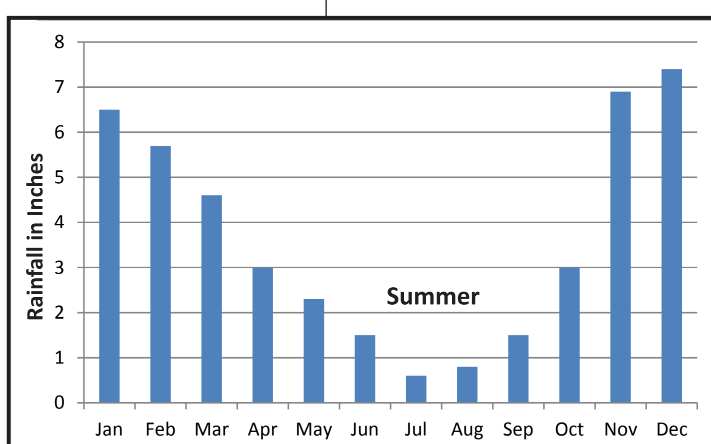
tosa (tufted hairgrass) and/or large ant mounds may play a role as they interact with site hydrology. Wetland restoration practitioners have observed that pedestals will often begin to form within a few years following the re-establishment of wetland prairie vegetation in previously cultivated and flattened grass seed fields in the west Eugene area, although this has not been documented through research (Trevor Taylor, personal communication, 2012).

The Willow Creek Natural Area in west Eugene is a remnant of the vast network of prairies that once extended across much of the Willamette Valley.

2.2.3 Vegetation

Willamette Valley wetland prairie vascular plant communities are comprised of a diversity of forbs, sedges, rushes, and grasses. The best record of the pre-settlement vegetation pattern for the Willamette Valley is derived from the General Land Office (GLO) survey notes of the 1850s that recorded vegetation communities and other significant features present at the time. These detailed notes documented generalized vegetation types and locations of major landforms. These survey notes, along with accounts by the first naturalists and pioneers in the Willamette Valley, describe wide expanses of prairie and savanna across much of the valley floor, often showing evidence of recent fires. It was reported that trees were so scarce in some portions of the valley at that time that the land surveyors had to build rock piles to marks section corners instead of using traditional witness trees (Vesely 2004). At the time of the GLO surveys, the native communities were presumably grazed to an unknown extent by free-ranging livestock brought in by early settlers, but otherwise largely undisturbed by drainage or tilling (Christy et al. 2011). Historically, these prairies were persistent features on the landscape, not short-lived early successional stages of otherwise forested sites. This was due to the high frequency of Kalapuya set fires, which effectively controlled the establishment of woody vegetation (Johannessen 1971). This continued persistence of prairies over an extended period of time led to the establishment of a highly diverse assemblage of perennial and annual forbs and grasses. It is estimated that approximately 350 species, subspecies, and varieties of native plants are found within upland and wetland prairies in the lowland valleys of the Pacific Northwest. Most of these plants have a moderate to high degree of fidelity to prairies and are infrequent in other communities (Sinclair et al. 2006).

Figure 2-3: ***Average Precipitation by Month in Inches*** *(Corvallis Data Shown)*



Source: National Climate Data Center (NOAA)

The moist, mild winters and long summer droughts that define the climate of the Willamette Valley greatly influence the period of plant growth in wetland prairies, which occurs mainly in the winter and spring when soil moisture is high. In a typical season, the pooled water and saturated soils have dried entirely by July and most grasses and forbs have senesced and gone to seed by mid-August.

Because so few high-quality remnant prairies remain today, it is not possible to fully reconstruct their exact historical plant composition. In a very high quality remnant prairie today, it is possible to find up to 30 native species

Erigeron decumbens (Willamette daisy) is one of three Federally listed T&E species associated with wetland prairies.

in a one-square meter plot (Sinclair et al. 2006), while poorer quality remnants tend to have lower native diversity and higher composition of non-native species. Native wetland prairies in most of the valley are dominated by native *Deschampsia cespitosa*, *Danthonia californica* (California oatgrass), *Hordeum brachyantherium* (meadow barley), *Juncus* spp. (rushes), and *Carex* spp. (sedges) along with a varying diversity of perennial and annual forbs (Christy et al. 2011). GLO surveyors occasionally described wetland prairie as camas prairie because of the abundance of *Camassia quamash* and *Camassia leichtlinii*. Woody species such as *Rosa nutkana* (nootka rose), *Symphoricarpos albus* (snowberry), *Spiraea douglasii* var. *Menziesii* (Menzies' spiraea), and *Fraxinus latifolia* (Oregon ash) are often found as a component of a wetland prairie, with densities generally increasing in the absence of disturbances such as fire. Due to the dramatic decline in the geographic extent of wetland prairies in the Willamette Valley, a number of prairie plant species are now rare or at risk of extinction. Federally listed Threatened and Endangered (T&E) species associated with wetland prairies include *Lomatium bradshawii* (Bradshaw's lomatium), *Sidalcea nelsoniana* (Nelson's checkermallow), and *Erigeron decumbens* (Willamette daisy). Although not currently given T&E status, numerous other plant species that are reliant on wetland prairie habitats have declined significantly including *Sericocarpus rigidus* (White-topped aster), *Pyrrocoma racemosa* var. *racemosa* (racemed goldenweed), and *Cicendia quadrangularis* (timwort).

Vulpia myuros (rattail fescue) is a problematic invasive species in many wetland prairies.

Today, almost all remaining wetland prairies in the valley are colonized to some extent by non-native plants, many of which are highly invasive. Among the most dominant and persistent of these non-native species are, *Festuca arundinacea* (tall fescue), *Agrostis capillaris* and *A. stolonifera* (non-native bentgrasses), *Holcus lanatus* (velvet grass), *Anthoxanthum odoratum* (sweet vernal grass), *Vulpia myuros* (rattail fescue), *Hypochaeris radicata* (hairy cat's ear), *Mentha pulegium* (pennyroyal), *Alopecurus pratensis* (meadow foxtail), and *Phalaris arundinacea* (reed canarygrass). Many of these species are all capable of dominating a wetland prairie to the exclusion of almost all native species and in some cases will form large patches of monocultures. Other non-native species, such as *Lolium multiflorum* (annual ryegrass), *Daucus carota* (Queen Ann's lace), *Rumex crispus* (curly dock), and *Myosotis discolor* (changing forget-me-not) persist in the habitat, but tend to be less invasive and coexist with native prairie species. (See Appendix A: Vascular Plants of the Willamette Valley Wetland Prairies)

2.2.4 Wildlife

Knowledge of the wildlife communities that were present in pre-settlement Willamette Valley prairies is largely based on accounts of Native Americans, explorers, and early settlers. These accounts tended to be focused on game species, predators, and other large- to medium-size mammals of economic importance. Therefore, the best approach to construct a comprehensive list of wildlife species present in the historic landscape is to base it on geographic range maps and wildlife-habitat relationship models. Based on this approach, it is estimated that 97 vertebrate species (amphibians, reptiles, birds and mammals) likely used Willamette Valley prairies for feeding and reproduction (Vesely et al. 2010). There has not been an analysis conducted on species present specifically in wetland prairies, but it is likely that most of these 97 vertebrate species inhabited both upland and wetland prairies at various times of the year due to the structural similarities of these habitats.

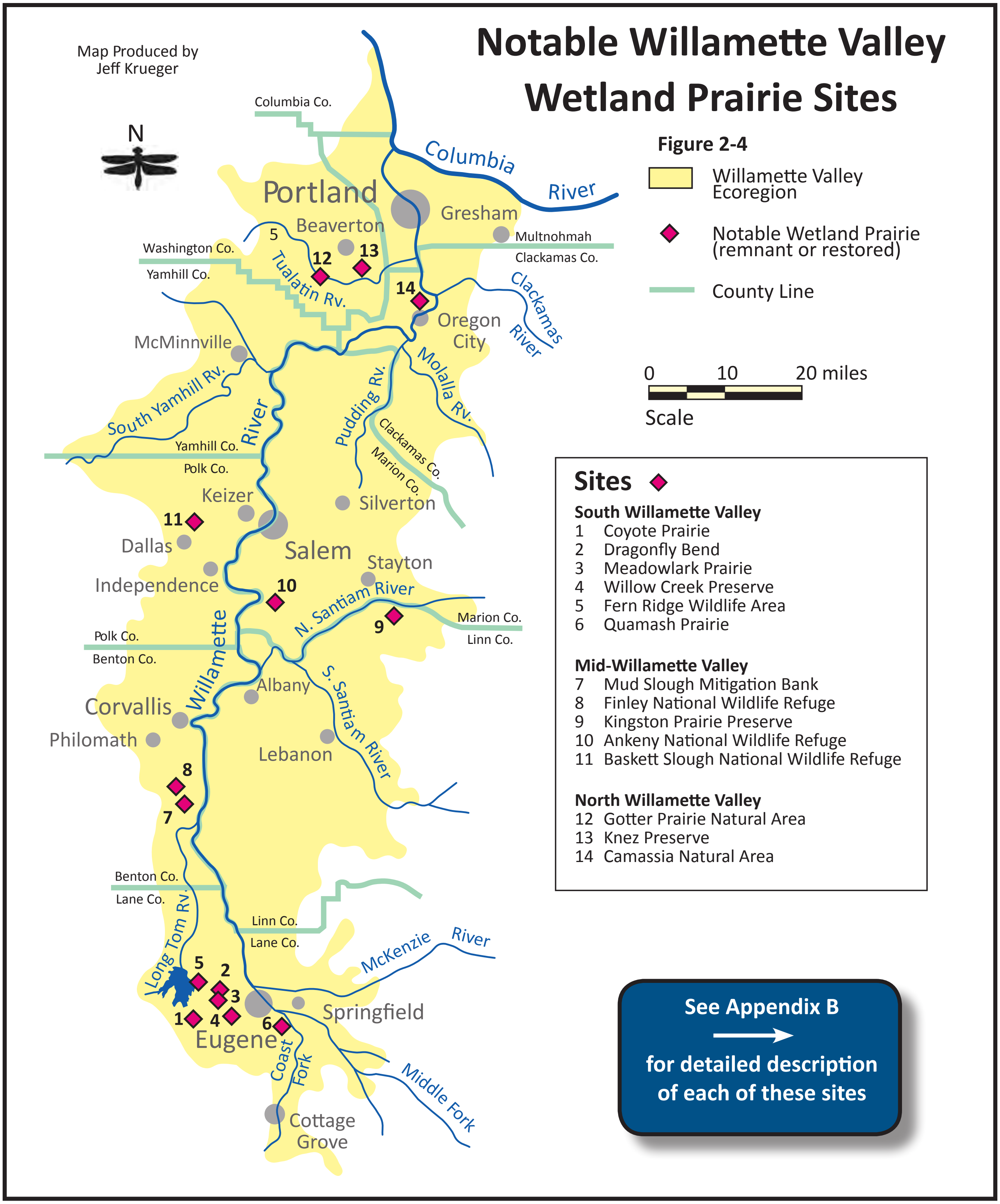
Pacific chorus frog in wetland prairie

At the time of Euro-American settlement of the valley in the mid-1800s, Roosevelt elk (*Cervus canadensis roosevelti*), Columbian white-tailed deer (*Odocoileus virginianus leucurus*), and black-tailed jackrabbit (*lepus californicus*) were reportedly common in the prairies of the valley, along with observances of grizzly bears (*Ursus arctos horribilis*) and gray wolves (*Canis lupus*). As settlement occurred in the valley, these species were greatly reduced, or in the case of the gray wolf and grizzly bear, extirpated. Grizzly bears were last observed in approximately 1845 and the final records of gray wolves in the Willamette Valley were of 13 individuals from Lane, Linn, and Clackamas Counties taken for bounties during 1913-1914 (Vesely et al. 2010). A number of prairie dependent bird species once common to the Willamette Valley including Wilson's snipe (*Gallinago delicate*), northern harrier (*Circus cyaneus*), short-eared owl (*Asio flammeus*), Western bluebird (*Sialia Mexicana*), and Western meadowlark (*Sturnella neglecta*) have suffered greatly from loss of habitat and have declined dramatically. The loggerhead shrike (*Lanius ludovicianus*) and black-billed magpie (*Pica hudsonia*) were also once present, but have been extirpated from the valley (Institute for Applied Ecology 2010).

The Western Meadowlark is one of several grassland dependent birds that have declined dramatically due to loss of habitat.

2.3 Current Extent and Significant Wetland Prairie Sites

It is well documented that Willamette Valley wetland prairie is greatly reduced in extent from its historic range, with less than 2% estimated to remain (e.g., Johannessen et al. 1971, Towle 1982, Altman et al. 2001). Remaining wetland prairie is generally degraded and typically found in small and highly fragmented patches. However, several notable concentrations of remnant, or recently restored, wetland prairies do exist in the Willamette Valley. These sites are extremely important from the perspective of preserving associated plant species and creating viable habitat blocks for dependent wildlife. In addition, many also function as reference sites that can be used to guide future wetland prairie restoration efforts. The section below highlights some of the more significant sites found within the Willamette Valley.



2.4 Issues and Challenges of Restoration and Long-Term Management

In addition to the dramatic decrease in the geographic extent of wetland prairie habitat in the Willamette Valley, this ecosystem has been degraded in a number of additional ways that present significant challenges for its restoration and long-term management.

2.4.1 Hydrologic Modification

Modifications to natural surface hydrology have had significant impact on wetland prairies in the valley and can pose challenges to restoration projects if not addressed. The common practice of installing ditches and drainage tiles in agricultural lands as a way of reducing surface water to improve production and access can reduce the depth and duration of standing water and prevent natural sheet flow from occurring. These hydrologic modifications may reduce surface water and soil saturation to the extent that the area no longer supports wetland species. The construction of levees, roadways, and railroads can have the opposite effect on hydrology, by blocking flow and causing water to pond. This ponded hydrology is often too deep to support many wetland prairie species. The construction-related disturbance and resultant hydrology often result in these areas becoming choked with invasive species such as *Phalaris arundinacea*.

Agricultural drainage ditch at Coyote Prairie prior to restoration

2.4.2 Scale and Edge Effect

Extensive wetland prairies that once covered broad expanses of the valley floor have been greatly reduced in extent (less than 2% of historic levels), leaving a highly fragmented system of relatively small and isolated prairie remnants. Remaining wetland prairies, which historically were bordered by other open habitats such as upland prairie and savanna, are today often bordered by agricultural fields, roadways, railroads, and urban land uses. Remaining patches are often too small and isolated to provide adequate habitat conditions to support species of native wildlife such as raptors, grassland birds, and amphibians. In addition, the isolated plant and animal populations may be unable to recolonize prairie remnants following events that affect the majority of the remnant (such as fire or a 10-year flood event), may lack resilience to other periodic events such as drought, and may lose genetic diversity which could increase their susceptibility to pathogens or disease. The smaller habitat patches also tend to suffer an amplified edge effect, in which invasive species from bordering lands may readily colonize the habitat.

The edge effect is significant on smaller sites such as this wetland prairie restoration project at the confluence of Willow and Amazon Creeks.

2.4.3 Colonization by Non-Native Plant Species

Virtually all remaining wetland prairies in the valley are colonized to some extent by non-native plants. Wetland prairies are particularly susceptible to invasion by non-native species due to the dynamic nature of the habitat, which historically was maintained in an open state through periodic fires, which created space for plant re-emergence and colonization. Many non-native species are well adapted for colonizing

A common invader of restored prairies is *Hypochaeris radicata*

recently disturbed areas and are often present within the soil seedbank of a wetland prairie or have colonized adjacent sites. Seed from non-native invasive plant species can be carried onto a site by the wind, birds, grazing animals, humans and their equipment, or surface water flowing across a site, which is common in wetland prairies. Invasive plant species such as *Festuca arundinacea*, *Holcus lanatus*, *Phalaris arundinacea*, *Hypochaeris radicata*, *Dipsacus fullonum*, and *Alopecurus pratensis* are examples of highly aggressive species that can significantly compete with native species if not controlled. The integration of non-native species into wetland prairie plant communities can significantly impact the structure and function of these communities with alterations to wildlife such as pollinators, alterations to the three dimensional structure by tall, dense growing species such as *Festuca arundinacea* and *Phalaris arundinacea*, alterations to the forb/grass ratios by aggressive invasive non-native grass species, and other likely alterations including possibly soil nutrient/microbial conditions.

Woody vegetation encroaching into a wetland prairie

2.4.4 Woody Vegetation Encroachment

In the absence of fire or other disturbance such as mowing that mimics some of its effects, woody vegetation will successfully colonize most wetland prairies in the Willamette Valley over time through the natural process of succession. Typical colonizing woody vegetation includes native species such as *Spiraea douglasii* (Menzies' spiraea), *Rosa nutkana* (Nootka rose), *Crataegus suksdorfii* (Suksdorf's hawthorn), *Fraxinus latifolia*, and non-native species such *Rubus* spp., *Cytisus scoparius*, *Rosa eglanteria* (sweetbriar rose), and *Pyrus* spp. (pear). There are many remnant areas in the valley where the prairie structure has been completely converted to a shrub/scrub, savanna or even woodland structure, with dramatic impacts to biotic and abiotic attributes of the former prairie.

Wetland prairie site dominated by *Deschampsia cespitosa*

2.4.5 Species Imbalance and Loss of Diversity

Many remnant prairies are species-poor assemblages dominated by a few dominant species. For example, it is common for remnant communities to be forb depleted and dominated by grasses including native grasses such as *Deschampsia cespitosa* and native rushes such as *Juncus occidentalis* (western rush). It may be that these sites experienced substantial past soil disturbance such as repeated plowing, intense livestock grazing, or hydrologic modification, that eliminated the majority of their native flora and, in the absence of significant introduction of non-native species such as tall fescue and creeping bent-grass, the native perennial grasses and rushes persisted. *Deschampsia cespitosa* in particular tends to form dense stands, with heavy leaf thatch, that appears to be very effective in suppressing the colonization or emergence of other species. Other examples of species imbalances that may affect wetland prairie remnants include vole populations (which may be artificially high due to abundance in surrounding grass-seed fields), the absence or low abundance of other once-significant grazers (such as black-tailed jackrabbits), and reduction in raptors and mammalian mesopredators, such as foxes, coyotes, and bobcat. Once lost, plant community diversity is often difficult to reestablish due to factors such as fragmentation and isolation from remaining native plant populations, altered abiotic conditions (e.g., soil disturbance, nutrient imbalances, hydrology, etc.), or competitive exclusion by more aggressive species.

Grass thatch

2.4.6 Thatch Build-Up

Thatch build-up in wetland prairies from high concentrations of perennial grasses has been found to inhibit successful seed germination, resulting in reduced diversity, particularly of forbs and annual grasses. This pattern of thatch build-up and loss of diversity has been noted in numerous wetland prairie restoration projects over time, particularly if management actions (e.g., controlled burning or haying) are not regularly implemented. Thatch build-up would have been minimized in the pre-settlement wetland prairie ecosystem due to the regular fires set by the Kalapuya up until the mid-1800s (Johannessen 1971).

2.4.7 Loss of Topographic Variation

The topographic variation found within native wetland prairie habitats either in the form of naturally occurring mound-swale topography or micro-topographic variation associated with pedestals (see section 2.2.2) create hydrologic variation and therefore higher species diversity. This naturally occurring topography has been eliminated from many remnant sites as a result of mechanical smoothing to improve agricultural production. The loss of topographic variation is one of the factors facilitating species diversity loss at sites as it facilitates dominance by a less diverse species assemblage. Re-creation of this topography can greatly improve site diversity and habitat in a wetland prairie restoration project.

Smoothed agricultural field

2.4.8 Climate Change

Climate change impacts to wetland prairies are not yet well understood. However, it is anticipated that there may be changes in temperature extremes as well as the timing and extent of wetting and drying over time, which will likely affect species assemblages. These factors may change in ways that are detrimental to some species, while simultaneously creating more favorable conditions for other species, including species not currently found in Willamette Valley wetland prairie communities. Such changes, in combination with other pressures such as habitat fragmentation, migration barriers, and genetic isolation, may prevent some species from moving to more favorable habitat conditions, leading to localized extinctions. Similarly, new species may migrate into existing communities, or existing populations may expand their dominance, placing further pressure on existing species assemblages. Together, these factors, which

could cause losses of some species and expansion of others, will likely lead to further simplification of wetland prairie communities. A recent assessment suggests that many rare or endangered plants and animals in the Willamette Valley are vulnerable to climate change while some invasive plants will remain stable or increase further (Kaye et al. 2012).

2.4.9 Soil Structure and Nutrient Alterations

Soils throughout the Willamette Valley have been impacted directly through grazing, farming, and other site specific impacts as well as through atmospheric deposition of pollution. Structurally, many soils have been compacted by farm equipment or animals. In addition, tilling, installation of drain tiles, ditching, levee creation and other alterations have disrupted historic soil horizons with impacts to vegetation. Historic soil nutrient conditions throughout the Willamette Valley have also been impacted through chemical additives including fertilizers and pesticides in farmed wetland prairie areas and through atmospheric deposition of pollutants such as nitrogen, phosphorous, and sulfur, among others.

Soils throughout the Willamette Valley have been impacted directly through grazing, farming (tilling,smoothing, and fertilization), and other site specific impacts.

Chapter 3: Wetland Prairie Restoration, Enhancement, and Management Overview

3.1 Range of Condition Prior to Restoration and Enhancement

As discussed earlier, it is well documented that Willamette Valley wetland prairies have been greatly reduced in geographic extent over the past 150 years due to a variety of causes including agricultural conversion, urbanization, and hydrologic modification. Remaining wetland prairies in the valley, which total approximately 2% of historic extent, are generally degraded and highly fragmented. Agricultural conversion has been the most common activity leading to this dramatic decline. Although agricultural practices have generally eliminated the native plant community in these areas, the soils and hydrologic conditions that once supported the ecosystem are sometimes still intact or only moderately altered, therefore making these areas well suited for wetland prairie restoration.

The Willow Creek Natural Area (below) is an example of a higher quality remnant wetland prairie that has been carefully managed to preserve and improve quality.

With the exception of wetland prairie habitats that have been displaced by urban uses or roads and are unlikely to ever be restored, many other former wetland prairie areas and remnants possess high potential for restoration or enhancement. These lands fall into the following basic categories (listed from least- to most-impacted):

3.1.1 Managed/Restored High to Moderate Quality Wetland Prairies

Rare, but increasing in the Willamette Valley, this category includes remnant wetland prairies where significant management actions have been undertaken and in areas where successful wetland prairie restoration projects have been implemented. In both cases, extensive efforts have been undertaken to control invasive species and encroachment by woody vegetation, to reintroduce a high diversity native wetland prairie plant community, and to manage the vegetation in a way that replicates historic disturbances such as fire. These areas will require continued management to maintain this high level of native composition and diversity over time.

Quammash Prairie (left) and Dragonfly Bend (right) are two examples of higher quality wetland prairies that were restored from former agricultural sites for wetland mitigation. Both sites now have high native cover and diversity.

This low quality remnant prairie has been colonized by invasive species and woody vegetation, but has some native plant composition remaining.

3.1.2 Low to Moderate Remnant Wetland Prairies

Rare in the Willamette Valley, these are patches of native wetland prairie that have persisted over time with limited impacts from agriculture uses or hydrologic modification. These areas tend to have a somewhat higher level of native plant cover and diversity, as compared to abandoned agricultural fields, and often include hydrologic complexities in the form of mound-swale topography and/or pedestals, which are associated with species richness (see section 2.2.2). Non-native plants are typically present in these areas, but not dominant. Invasion by woody vegetation through natural succession will often become an issue in these areas over time in the absence of management.

3.1.3 Degraded Old Field Wetland Prairies

These include remnant wetland prairies that have been heavily impacted by past agricultural practices such as tilling or grazing and sometimes also have modified hydrology, but are not actively being farmed. These areas tend to be dominated by non-native species but often have some native species present in lesser quantities. Woody vegetation will establish in these areas over time.

Old field

Agricultural wetland

3.1.4 Agricultural Wetlands

These are areas that were native wetland prairie previously, but have been converted to agriculture use and are being actively farmed. Plant composition in these areas is typically limited to a single crop species, often one of several non-native grass species that have been planted for grass seed production. Many of these agricultural areas have been mechanically smoothed during the past several decades as a way of improving agricultural production, but most retain wetland hydrology, or the hydrology could be restored through the removal of ditches or drainage tiles. Agricultural wetlands are the most common condition of former wetland prairies in the valley today and the restoration of these areas is the focus of this guide. There are currently and estimated 180,000 hectares (445,000 acres) of land in grass seed production in the valley (Oregon State University Extension Service 2010), and much of this land possesses wetland hydrology.

Agricultural wetlands are typically limited to a single crop species such as *Lolium multiflorum* (pictured at right), but possess wetland soil types and hydrology.

3.1.5 Filled Wetlands

These are former wetland prairies that have been filled with imported material, often in anticipation of future development or simply because they were a convenient location for disposal of excess soil or debris. These areas have potential to be restored to native wetland prairie, although the cost tends to be very high. With care, the fill material can be removed to the historic grade and native wetland prairie hydrology and vegetation can be restored. It has been observed in several restoration projects in the west Eugene area that the native seed-bank has persisted under fill material for many years and will germinate once the fill is removed. However, non-native invasive species contained in the soil seed-bank at the time the fill occurred may also emerge.

Nearly 45,000 cubic yards of fill material (pictured above) were removed as a component of the *Willow Corner Wetland Restoration Project* in order to restore the historic grade of the site, which had previously been wetland (pictured left prior to planting). In this case, proximity to the adjacent Willow Creek Natural Area helped justify the high cost of the fill removal.

3.2 Wetland Prairie Restoration Process

A successful wetland prairie restoration project involves a series of basic steps that should be followed to ensure the restoration site is appropriate and well understood and so that a diverse native ecosystem can be established and maintained over time. As is true with the management of any natural area, an adaptive management approach is recommended so that emerging threats can be identified and addressed. The six step process listed below is recommended to ensure a successful wetland prairie restoration project.

Step 1: Site Selection

Selecting a site that possesses appropriate soil types and hydrology along with consideration of the size and geographic context are critical evaluation factors for identifying sites that are likely to support a high quality wetland prairie ecosystem.

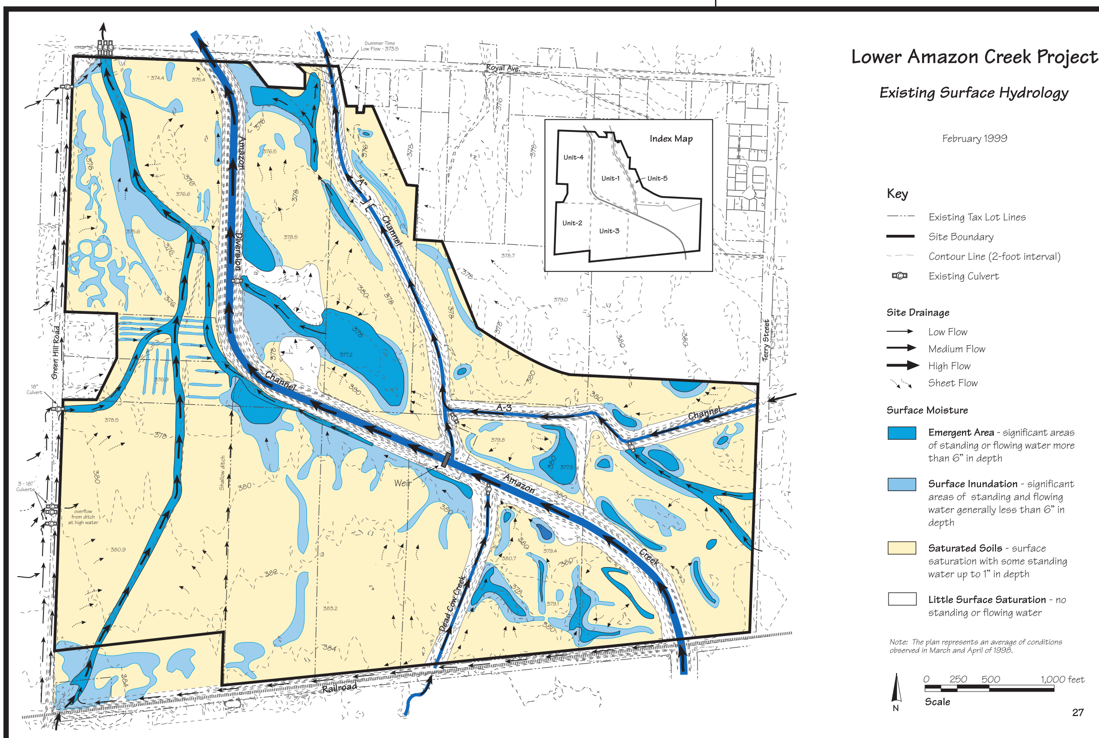
Coyote Prairie (outlined in red) was selected as a restoration site due to presence of hydric soils and wetland hydrology, plus its proximity to other protected natural areas.

- Soils: Hydric soils must be present (NRCS classification for wetland soil types).
- Hydrology: Suitable wetland prairie hydrology should exist or have potential to be reestablished through removal of agricultural drainage features. Soils must be saturated or have shallow inundation during the wet season and become dry during the summer and early fall.
- Historic Condition: Evidence that the site supported a prairie ecosystem in the past should be established through interpretation of historic vegetation maps or historic aerial photos.
- Size: Wetland prairie restoration may occur on a site of any size, but larger sites tend to have higher potential for supporting a diverse native ecosystem and are less prone to invasion by non-native vegetation (lower edge to area ratio). Larger sites generally produce higher quality results, benefit from economies of scale, and are easier to manage over the long term.
- Proximity: Sites that are situated in close proximity to other natural areas or provide critical connectivity are preferred. The Oregon Conservation Strategy (ODFW, 2006) and Willamette Synthesis Project (TNC, ongoing) provide direction toward selecting sites that provide strategic connectivity and support larger regional conservation goals.

Step 2: Site Analysis

Once a site has been selected, a thorough analysis should be conducted to gain a greater understanding of site attributes and to inform the planning and design process. Site analysis should include the following elements:

- Site History: Review of resources such as GLO historic vegetation mapping, historic aerial photos, agricultural records, and interviews of previous owners will help document the site history and provide explanation about current condition.
- Soils and Geomorphology: Provide an understanding of how the site's geomorphic surface formed and the characteristics of the soils (based on NRCS mapping).
- Surface Hydrology: Determine and map the extent and depth of surface water and document flow patterns including artificial drainage feature. Understanding the site's surface hydrology is important for selecting appropriate seed mixes, modifying drainage features if needed, and planning for erosion control during restoration. A typical Surface Hydrology Map for a wetland prairie site could include the following categories:
    - o Non-saturated soil (often not a wetland)
    - o Saturated soils, not inundated (no standing water above the soil surface)
    - o Inundated areas (up to 2 inches of standing water)
    - o Pools (2 to 6 inches of standing water)
    - o Persistent pools (>6 inches of standing water)
    - o Ditch or swale
    - o Direction of flow (for ditches, swales, and general direction of sheet flow)
- Wetland Delineation: Determine the extent of the jurisdictional wetland. This is an important step if the site is being used for wetland mitigation or if earth-moving is planned (e.g., to reduce agricultural flattening) that may require permits. Otherwise, careful mapping of soil and hydrologic conditions may be suitable.
- Topography: Collect detailed topographic information to help interpret direction of flow, gradient, and whether there have been major modifications such as flattening or installation of drainage features.
- Vegetation: Document existing vegetation, including major invasive species populations. Non-native species may exist in the soil seed-bank, but be absent above-

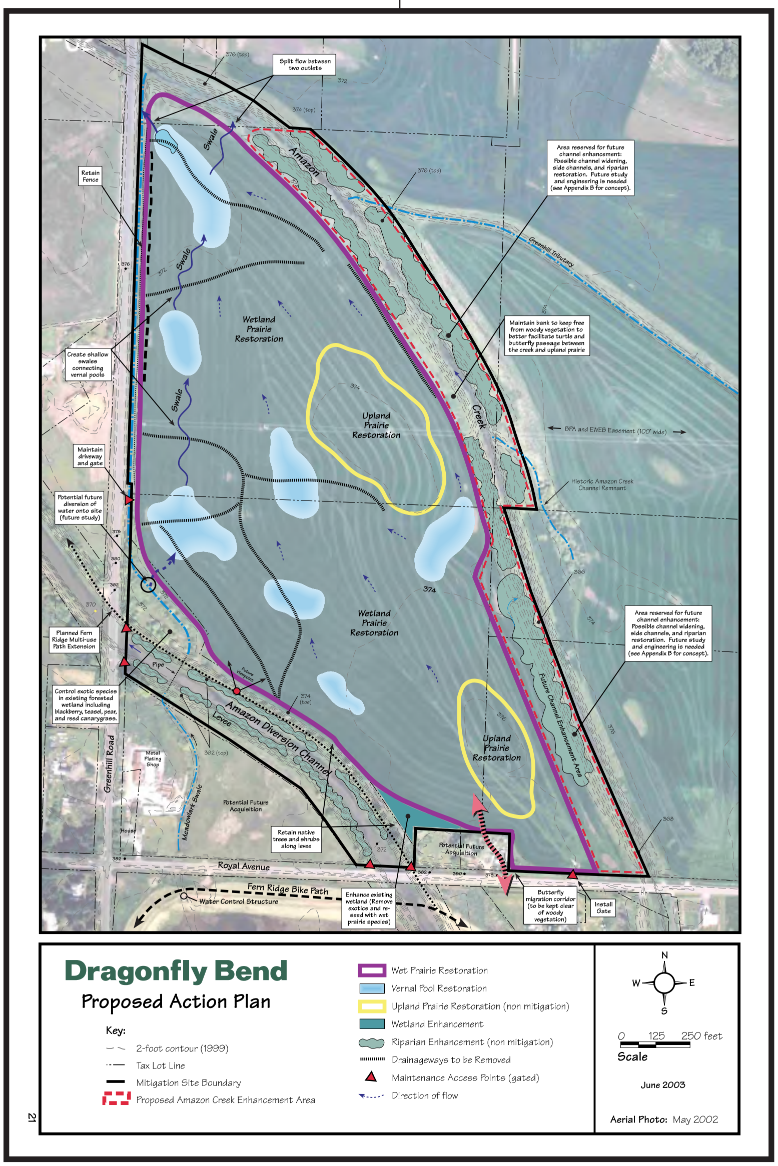


Sample site analysis map showing surface hydrology and direction of flow.

ground. Some practitioners recommend germinating soil samples during the planning period to better understand the full suite of non-native invasive species likely to emerge after existing dominant vegetation is removed. Surveys for rare plants may also be useful on some sites and may be required prior to issuance of state and federal permits.

- Wildlife: Record baseline wildlife data if feasible to help gauge long-term project success. This could include formal breeding bird surveys, reptile and amphibian surveys, or simple notation of wildlife observed during site visits.
- Context: Assess adjacent lands to help understand potential threats such as invasive species or changes to hydrology or potential opportunities such as proximity to other natural areas.
- Issues and Opportunities: Develop a comprehensive list of issues and opportunities that have been identified during the site analysis process. Issues and opportunities may relate to biotic and abiotic features, but may also relate to management issues such as site access or adjacent land uses, among others. Having these defined is very helpful for guiding the planning and design phase.

Step 3: Planning and Design



The planning and design process should be collaborative and include a project coordinator and a technical team to provide input. The information gathered during the site analysis process (step 2) should be carefully considered by the team, including the list of issues and opportunities. The planning and design process should produce the following elements:

- Restoration Goals: Define the desired outcome of the restoration project and develop goals for habitat, hydrology, access, maintenance, and other key factors.
- Proposed Actions and Prescriptions: Develop proposed actions and restoration prescriptions to describe how the restoration goals will be met. This would include topics such as hydrologic modification, site preparation, invasive species control, seeding, and sequencing.
- Scheduling: It is typical for a project to span six years or more and it is critical to have a well-considered schedule in order to avoid missing key actions, which could set a project back a full year or more.
- Plant Materials Planning: Plant material can be one of the most limiting factors in successfully restoring biologically diverse plant communities. Early planning is valuable to ensure adequate seed collection, seed and plug/bulb grow-out, and other plant material needs will be met when needed.
- Action Plan Map: Develop an Action Plan Map that depicts the desired future condition for the site including geographic extent of habitats, access, and other proposed actions.

- Monitoring Plan: Establish a set of monitoring goals, performance criteria, and quantitative monitoring objectives that can be used to gauge success. Categories typically include vegetation, hydrology, soils, and wildlife.
- Baseline Monitoring: Conduct baseline monitoring to document pre-project condition. Monitoring can include vegetation inventory, wildlife surveys, and establishment of photo points.
- Permitting: Prior to any significant site modification, applicable state and federal permits should be obtained including Removal-Fill permits. The Oregon Department of State Lands (*http://www.oregon.gov/dsl/permits/pages/index.aspx* or Washington Department of Ecology (*http://www.ecy.wa.gov/*) are both good starting points for the most up-to-date permitting requirements.

Vegetation monitoring

The Oregon Rapid Wetland Assessment Protocol (DSL 2010) provides valuable metrics for developing restoration goals and criteria to evaluate during baseline monitoring and developing performance criteria.

Step 4: Site Preparation

This is the process of preparing the site for the eventual establishment of native vegetation and typically includes the following:

- Hydrologic Modification: Complete hydrologic modifications such as ditch removal, installation of water control structures, or incorporation of hydrologic variation such as vernal pools or shallow swales if desired. In some cases this can also include removing fill piles or smoothing or removing spoils from ditch digging.
- Access: Identify temporary and permanent access points, staging areas, and access routes and install proposed access controls to prevent trespass (fences and/or gates as needed)
- Vegetation: Eradicate existing non-native vegetation and the associated seed-bank. This typically involves multiple treatments over an extended period of time. The specific removal methods are often species-specific.

See Chapter 4 →

for detailed description of site preparation techniques and recommended approaches.

Grading a site to create hydrologic complexity and remove drainage features during the site preparation process is a component of some restoration projects.

Step 5: Establishment

Following successful site preparation, the beginning of a diverse native wetland prairie plant community is established, typically over a two to three year period

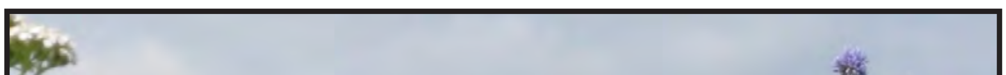
Broadcast seeder

• Seed and Plant: Seed and plant native wetland prairie species based on site goals, hydrologic conditions, and expected control needs for non-native invasive species. Site-specific planting strategies, which incorporate the microsite variation found across a site, will have the greatest chance of success.

If starting with an agricultural wetland, typically emphasize forbs and hard-to-establish grasses, sedges, and rushes during the first two years, adding more competitive grasses in year three, once other species are better established. This strategy is often chosen in situations where non-native grasses are the dominant pre-restoration vegetation or the last farmed crop, because a soil seed bank of invasive grasses will exist, requiring control of these species for several years.

- Assess and Adjust: Annually assess the establishment of the species seeded in prior years and the emergence and density of non-native species, and adjust native seeding rates, planting palettes, planting locations, and species composition to achieve diversity, cover, and wildlife goals.

See Chapter 5 → for detailed description of plant establishment techniques and recommended approaches.



Step 6: Long-Term Management

A management strategy should address how to guide the developing native wetland prairie community toward a state of persistence and resilience. Wetland prairies will require management in perpetuity to maintain species diversity and control invasive species. Apply timely disturbances (e.g., fire, mowing) and other actions to maintain structural and functional goals.

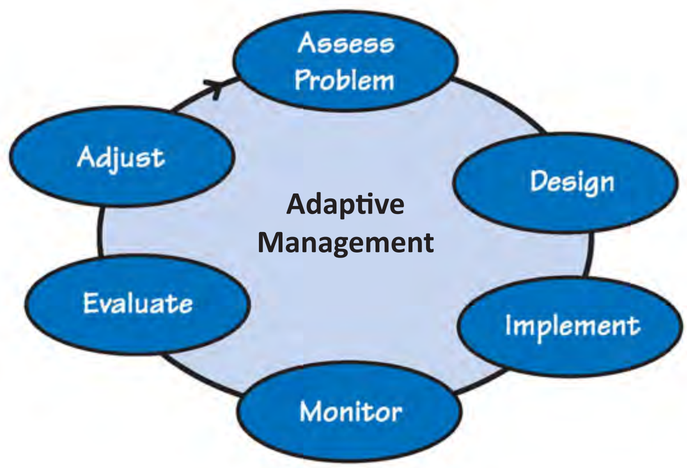
- Monitoring: Successful long-term management depends on a system to assess success in controlling invasive non-native species, achieving desired site hydrology and controlling erosion, maintaining diverse plant and animal communities, and managing site access, if needed.

- Adaptive Management: Management strategies should be adapted based on the results of formal or informal assessments. Under an adaptive management approach, site conditions are evaluated on a continual basis and future management actions and priorities are adjusted accordingly to address emerging issues and to improve conditions. To successfully utilize the adaptive management approach, pre- and post- project conditions are recorded and techniques and the geographic extent of major enhancement and restoration activities are carefully documented. New strategies should be considered where persistent problems occur.

See Chapter 6 →

for detailed description of long-term management techniques and recommended approaches.

Figure 3-1: ***Adaptive Management Model***



Ecological burns are an important tool for managing prairie habitats.

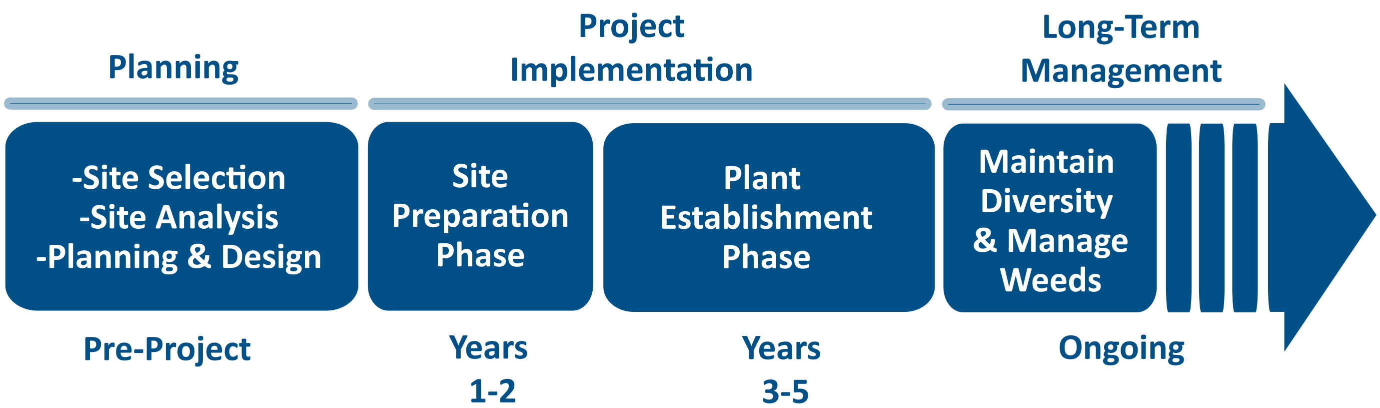


Figure 3-2: ***Restoration Timeline***

3.3 Defining Success

Determining the success of a wetland prairie restoration project is based on the site specific project goals and whether the defined quantitative monitoring objectives have been met. Criteria for success will vary from project to project.

The Coyote Prairie North Mitigation Bank considers a typical wetland prairie restoration project to be successful if it achieves the following minimum guidelines:

Coyote Prairie North Mitigation Bank wetland restoration project.

Typical CPN Mitigation Bank Success Criteria

- Plant diversity (at least 50 species)
- >70% native plant cover
- <10% invasive plant cover
- Restored Hydrology
- Habitat for Native Wildlife
- Resistant to Invasion by Non-Native Vegetation
- Resilient to Disturbance

The Oregon Department of State Lands (2012) has the following regulatory routine standards for vegetation monitoring:

- >60% native plant cover
- <10% invasive plant cover
- <20% bare substrate
- >6 species at >5% cover and occurring in at least 10% of the plots sampled.

Chapter 4: Site Preparation Phase (Years 1-2)

4.1 Importance of Site Preparation

Once the analysis and planning phases of the wetland prairie restoration process are completed (site selection, analysis, design, and permitting), the on-the-ground work of wetland prairie restoration can begin. Site preparation is the first step of implementation and includes making any necessary modifications to the site's topography and surface hydrology and eliminating existing non-native vegetation prior to reestablishment of native wetland prairie vegetation. The experience of wetland restoration practitioners in the Willamette Valley and throughout the country suggests that effective site preparation is among the most important factors for determining the ultimate success of a prairie restoration project (Pfeifer-Meister et al. 2007). Poor site preparation can result in unsuitable hydrologic conditions and/or heavy colonization by invasive non-native vegetation, which are both limiting factors for successfully establishing native wetland prairie. Not unlike building a new house on a poor foundation, inadequate site preparation can lead to low quality results and long-term management issues. If poorly executed, the site preparation phase may need to be repeated, wasting resources including expensive native seed.

4.2 Pre-Existing Site Conditions

During the analysis and planning stages of restoration, the pre-existing conditions of the site should be well-defined. The site preparation techniques described in this guide are specific to the most common pre-project site conditions found in the Willamette Valley. These are lands in active agricultural production as well as *old fields*, which are former agricultural sites that have not been farmed for several years and are typically dominated by non-native vegetation (see Section 3.1.3 for *old field* definition). In both cases, the intent of site preparation is to eradicate all existing vegetation and associated seed bank to the greatest extent possible. In situations where *old field* or *remnant* sites contain a significant component of native vegetation, the restoration goals may include retaining this existing native cover. In this case, the site preparation techniques described here may not be desirable and implementation of the long-term management techniques described in Chapter 6 of this guide would be a more appropriate starting point.

Lands in active agricultural production (right side of photo above) are a common pre-project condition in the Willamette Valley. The area on the left side of the photo is in the early phases of restoration.

Sites in active agricultural production in the Willamette Valley today are typically dominated by a single plant species such as *Lolium multiflorum* (annual ryegrass) or *Festuca arundinacea* (tall fescue). Under these agricultural conditions, non-crop plant species have been actively controlled over an extended time period through repeated herbicide applications in an effort to keep the crop as pure as possible. These agricultural fields will likely contain an extensive soil seed bank of the crop species and potentially other non-native species (Wold et al. 2011). This is important to note for the restoration process because the seed bank has the potential to rapidly establish with the cessation of farming, especially if left fallow or if the soil is disturbed by tilling or other activity. In most respects, the site preparation process on sites that are being actively farmed is more straightforward than on an *old field* site because a single species of vegetation can be targeted for eradication and the seed bank is likely to contain lower quantities and variety of non-native vegetation (Pfeifer-Meister et al. 2007).

Old fields are characteristically more challenging from a site preparation perspective due to the presence of a variety of well-established, non-native vegetation. These species are also likely to be present in the soil seed bank (U.S. Army Corps of Engineers 1995). This vegetation can include highly invasive and persistent species such as *Hypochaeris radicata* (hairy cat's ear), *Mentha pulegium* (pennyroyal), *Rumex crispus* (curly dock), *Agrostis capillaris and Agrostis stolonifera* (non-native bentgrasses), *Holcus lanatus* (velvet grass), *Anthoxanthum odoratum* (sweet vernal grass), *Vulpia myuros* (rattail fescue), rhizomatous plants such as *Phalaris arundinacea* (reed canarygrass), and those with extensive seed banks, such as *Alopecurus pratensis* (meadow foxtail), and *Festuca arundinacea* (tall fescue). *Rubus spp.* (blackberry), C*ytisus scoparius* (Scotch broom), *Rosa eglanteria* (sweetbriar rose), and other non-native woody vegetation are often found in *old field* conditions along with establishing native woody vegetation. Careful documentation of existing vegetation is essential in *old field* conditions so that appropriate site preparation methods can be used. Successful site preparation of *old fields* sites may require additional time (up to three years) before they are ready to be moved into plant establishment phase.

4.3 Hydrologic and Topographic Modifications

Hydrologic modification can include the removal of drainage features to reestablish appropriate wetland hydrology, removal of fill material, and/or modification of the site's micro-topography in order to increase vegetative diversity and improve habitat conditions. All topographic modifications should be implemented early on in the site preparation process if possible so that any emerging problems associated non-native vegetation contained within the exposed seed bank can be addressed prior to seeding or planting.

4.3.1 Assessing and Documenting Surface Hydrology

The assessment of pre-project hydrologic conditions should have been completed during the site analysis process (see Section 3.2, Step 2) and is an important resource for understanding how water is moving across the property, what level of hydrologic diversity already exists, and if drainage features are dewatering the wetland. Because most wetland prairie sites tend to have very subtle gradients, topographic maps are generally of limited usefulness for evaluating how water is moving and where wetter and dryer areas exist. Obtaining winter aerial photos or detailed LiDAR surface elevation maps can be useful if available.

Pre-project condition in an agricultural wetland

A time tested method for evaluating and mapping a site's surface hydrology is to visit the site during the wettest time of the year, ideally during or after a major rainfall event. During these wet periods, water is actively moving across a site, either by sheet flow or though channels or ditches, and subtle variations in the site's surface hydrology are most apparent. Observing the approximate depth of the standing water and recording boundaries between distinct areas can be done during this time. Data can be recorded using GPS or by making notations on an aerial photos and later converted to map format. The surface hydrology map should include arrows indicating the general direction of flow and any observed water features. Map categories describing the depth of surface inundation can vary depending on the range of conditions (see Section 3.2 for categories). Re-mapping the surface hydrology once the restoration project is underway is recommended as a way to help evaluate the need for any further modifications. [Insert Surface Hydrology Map sample]

Smaller agricultural drainages like the one above can be eliminated using a cultipacker or ripper shank pulled behind a small tractor.

4.3.2 Removal or Conversion of Agricultural Drainage Features

In order to help maximize agricultural production, farmers often install drainage features to remove unwanted water. These range in complexity from simple shallow trenches cut into a field on a seasonal basis to permanent ditches or swales. In some cases, permanent underground drainage tiles are also used. Pre-project drainage features should be mapped and assessed during the site analysis process to determine if they are negatively impacting the site's hydrology in terms of potential for wetland prairie restoration. If so, an approach should be devised to remove or modify these features.

Shallow drainage trenches can typically be removed by simply smoothing soil back into the low spots by pulling a cultipacker, roller, or ripper shank over the trench with a small tractor. Deeper, more established ditches can be filled using a similar technique, particularly if the spoils (soil removed to create the ditch) are still present, although larger equipment may be required. If the ditch is substantial enough, a small excavator or grader may be necessary to push soil back into larger ditches and for smoothing. Occasionally, fill material may need to be imported to fill the ditch to the desired grade. Any imported soil should be of a similar classification to what is present on the site, should have enough clay content to prevent sub-surface drainage from occurring, and should be sourced to limit importation of invasive species.

In some cases, there may be potential to convert an existing ditch in a way that it does not drain the surrounding wetland, but instead provides habitat diversity to a site. This can be done by re-grading the ditch to create a very broad and shallow swale that provides areas of deeper surface water and holds water later into the summer. Shallow swales and vernal pools add hydrologic and vegetative diversity to a wetland and provide habitat conditions important for the life cycle of many native amphibians such as Pacific chorus frogs and long-toed salamanders and numerous aquatic invertebrate species. Vernal pools and shallow swales were common features in historic wetland prairies (see Section 2.2.2).

An agricultural ditch can be re-contoured into a broad, shallow swale as shown above, adding hydrologic diversity to a site (shown prior to planting).

When drainage features are removed or modified, installation of erosion control features such as jute matting, coir logs, compost filter berms, biobags, or river rock may be necessary to prevent rilling, incision, or other soil movement while vegetation is establishing. These features can also be used to slow and pool the water moving through the swale. In most cases, an adaptive approach to erosion control for disturbed areas will be beneficial as the site adjusts to its new hydrology regime.

Another agricultural technique used by farmers in the Willamette Valley to drain agricultural fields is the installation of drainage tiles. These are perforated pipes installed below the soil surface. If present, these should be identified during the site analysis, and if it is determined that the pipes are adversely impacting the site's hydrology, they can be removed, capped at their outfall point, or severed and capped at several locations along the pipe. Finding their locations may take some on-site investigation during the wet season. Consultation with the previous land owner or leasing farmer can also be helpful for locating drainage tiles.

In all cases, the site hydrology should be re-assessed and mapped after the modifications have been made. Accurately determining and mapping the site's hydrology is important for ensuring that appropriate native seed mixes are used later in the restoration process.

4.3.3 Fill Removal

Some sites may contain areas of fill that have been dumped on the site from off-site sources, or result from spoil materials excavated during ditch digging, often deposited adjacent and parallel to the ditch. In both cases, it is desirable to remove or re-distribute this material so that it does not disrupt surface hydrology or present other management issues. It is recommended that imported fill material be hauled off of the site when feasible, since it is unlikely to be the proper soil type for a wetland prairie or may contain construction debris or seed from invasive non-native plants. Spoil material, which originated from the site, can often be graded back into the ditch or otherwise smoothed onto the site to avoid the cost of hauling. In both cases, the result should be the restoration of the pre-existing grade and desirable wetland prairie hydrology and soil conditions. It should be noted that compaction may be an issue affecting re-vegetation success in areas with substantial historic fill.

4.3.4 Modifying Hydrology to Benefit Habitat Conditions

On many restoration projects, topographic modifications can be made during the site preparation process that will provide hydrologic variation and help achieve overall diversity goals for the site. Historically, many native wetland prairies of the Willamette Valley were known to have included significant topographic variation. This included variation at the macro-scale that took the form of wetter vernal pools, shallow swales, and drier mounds (Balster and Parsons 1968) as well as variation on a finer scale in the form of raised pedestals, which were common within many native wetland prairies (Wilson 1998). The naturally occurring variation in topography has been eliminated across much of the Willamette Valley through decades of agricultural use, which in many cases included large scale mechanical smoothing. Re-introduction of some topographic variation can be a useful tool for re-creating more varied hydrologic conditions and more diverse species assemblages.

Re-grading a smoothed agricultural field during site preparation to create topographic variation and vernal pools conditions

To re-establish hydrologic variation at the macro scale, modifications can be made to a site by re-contouring areas to create a series of shallow excavations that will form wetter vernal pools and interconnecting swales. These areas will retain surface water later into the season and support a varied suite of wetland plant species and populations of native amphibians and aquatic invertebrates.

Vernal pool hydrology with jute fabric for erosion control and large wood to improve amphibian and reptile habitat (shown just after grading and prior to planting)

An example of this technique being successfully employed is at the Coyote Prairie North wetland mitigation site located west of Eugene. To re-establish a more complex microtopography on an 84-acre phase of the restoration project, a series of vernal pools and connecting swales was constructed to direct and retain water on the site later into the spring. Initial grading was completed in 2009. The 16 vernal pools now support a robust population of native annual forbs and 2012 monitoring revealed that all 16 pools support aquatic invertebrates, 12 pools supported breeding Pacific chorus frogs, and 1 supported breeding Long-toed Salamanders (Trevor Taylor personal communication 2012).

There is currently no known method for re-creating raised pedestals during site preparation. However, it has been observed on at least three restoration sites in west Eugene that pedestals do form naturally over time once native vegetation is established on a previously smoothed agricultural field (Trevor Taylor personal communication, July, 2013). Further study of these features and potential re-establishment is needed.

Raised pedestals shown forming around *Deschampsia cespitosa* at Dragonfly Bend, approximately four years after initial site preparation (photo taken a few months following a burn)

A constructed vernal pool area at Coyote Prairie pictured approximately three years after site preparation and grading (photo taken in June)

The techniques described in Section 4.4 are specific to sites where the pre-project vegetation is primarily non-native and the intent of the site preparation is to eradicate all existing vegetation and associated seed bank.

If significant native vegetation exists, the management techniques described in Chapter 6 may be a more appropriate starting point.

4.4 Eradicating Existing Non-Native Vegetation and Associated Seed Bank

Once the hydrology has been addressed at the site, the site preparation process will focus on eliminating existing vegetative cover. The techniques described in this section assume that the pre-project vegetative cover of the restoration site is primarily non-native and the intent of the site preparation is to eradicate all existing vegetation and associated seed bank to the greatest extent possible. This will help create the most suitable environment for the re-establishment of native wetland prairie plant species (see Chapter 5: Establishment Phase).

If significant native vegetation already exists on the site, then one possible course of action will be to manage the site in a way that improves native cover and diversity over time as opposed to full eradication of existing vegetation (see Chapter 6: Long Term Management Phase). The decision to retain vegetation should be made carefully as invasive species embedded in the retained plant community can be time consuming, costly, and technically challenging to manage. In many cases, sacrificing some remnant native species in order to more thoroughly prepare the site will result in a better restoration over the long term.

While several potential approaches to site preparation exist (see Section 4.4.1), experience by Willamette Valley wetland restoration practitioners, including two decades of experience by the West Eugene Wetlands Mitigation Bank indicate that, in general, techniques that limit soil disturbance such as strategically timed herbicide applications yield the best results (Wold et al. 2011). This is consistent with the results of a site preparation research effort (Pfeifer-Meister et al. 2007), which found that tilling yielded the poorest results of all techniques studied in terms of decreasing the seed bank, reducing exotic cover, and establishing native cover (see section 4.4 for study overview and results). Any soil disturbing activities associated with hydrologic modification or grading (see Section 4.3.4) should therefore be completed prior to the step of eradicating existing vegetation.

4.4.1 Range of Site Preparation Techniques

A wide variety of site preparation techniques have been utilized in prairie restoration projects throughout the nation over the past several decades. A literature review conducted by Greg Fitzpatrick of The Nature Conservancy in 2004 titled *Enhancement Techniques for Restoring Upland and Wetland Prairies in the Midwest the West Coast Regions of North America* has documented the advantages and disadvantages of many of these techniques. Combinations of techniques, or repeated applications of individual techniques, are often used on a particular site prior to reintroducing native plant species. Techniques used singly or in combination include:

- disking and tilling
- broad-spectrum herbicide application (conventional and organic)
- selective herbicide application (grass or forb specific)
- ecological burns
- flaming or infrared burning
- sod or soil removal
- hydrologic modification including temporary flooding
- solarization
- smothering (shade cloth or plastic)
- mowing

Most of these techniques have been applied in some form within the Willamette Valley with varying levels of success. The *Rivers to Ridges* partners (formerly West Eugene Wetland partnership), for example, has experimented with a variety of techniques since the early 1990s and monitored success. Sod and soil removal, disking, and use of infrared burners were all utilized, but tended to yield poor results, so have been generally discontinued. This type of trial-and-error by land managers, along with careful monitoring of results, and utilization of results from replicated field experiments (see Section 4.4.2) has led to a better understanding of the effectiveness of each technique and helped narrow preferred practices, leading to greatly improved on-the-ground success and reduced cost.

Standard practices of site preparation for wetland prairie restoration in the West Eugene Wetlands area and elsewhere in the Willamette Valley now typically include some form of pre-project thatch removal (burning or haying), an initial round or multiple rounds of broad-spectrum herbicide application, follow-up applications of grass-specific and/or broadleaf specific herbicides as needed, and in some cases, hand weeding or spot spraying of specific invasive vegetation (Wold et al,. 2011) (see section 4.5 below for a recommended site preparation process and variations). It has been found that herbicide use, although initially required site-wide to remove the last agricultural crop or invasive non-native species that have established, can gradually be reduced to occasional spot-spraying within two to three years once native cover is established. This can be viewed as a "phase out" of agricultural herbicide applications, which typically occurs on a repeated annual basis.

Tilling (especially heavy disking), sod removal, and other soil disturbing activities are now generally avoided as independent site preparation strategies over large areas in wetland prairie restoration projects, although they may be used in specific regions of a restoration site. These prescriptions have been found to disturb and activate the non-native seed bank in the soil and can also disrupt a site's surface hydrology. Ground disturbing activities have been found to greatly increase the likelihood of invasion by non-native plant species, and in the case of sod removal, can also reduce soil fertility (Pfeifer-Meister et al. 2007 and Pfeifer-Meister 2008). Light disking may still a useful technique in cases where the surface is too uneven to accommodate movement of equipment such as seed drill or spray buggy.

Solarization has been used in the Willamette Valley with some success on a small scale, but the cost and associated plastic waste material has generally been a deterrent to large scale utilization of this technique. The 2007 site preparation study (described below in Section 4.4.2) found that solarization was one of the more effective treatments tested for decreasing the seed bank and exotic cover initially with a starting condition of an agricultural field planted in *Lolium multiflorum*.

However, solarization has potential to be a suitable technique in areas where herbicide use is restricted and can also be a useful tool for introducing patches of diversity into already established low diversity prairies.

4.4.2 Overview and Results of Site Preparation Field Experiments (2004-2007)

In 2004, Lane Council of Governments and the City of Eugene received an EPA Wetland Program Development Grant to specifically test site preparation techniques for wetland prairie restoration in terms of their ability to establish diverse native plant communities and their effects on soil attributes. This included a large replicated field experiment implemented on fifty 15 x 15 meter test plots at Coyote Prairie, along with the retroactive study of seven past wetland restorations performed by the West Eugene Wetlands Partnership. The University of Oregon team of Laurel Pfeifer-Meister, Scott Bridgham, Bitty Roy, and Bart Johnson were contracted to lead the research. Their results are summarized in a 2007 report titled *Testing the Effectiveness of Site Preparation Techniques for Wetland Prairie Restoration.* The remainder of Section 4.4, below, is a summary of that report.

Coyote Prairie test plots

Photo by: RaptorViews

Figure 4-1: ***Site Preparation Technique Combinations Tested***

Treatment Combinations	
1	Summer Herbicide
2	Till
3	Till, Summer Herbicide
4	Summer Herbicide, Thermal
5	Till, Thermal
6	Till, Summer Herbicide, Thermal
7	Summer and Fall Herbicide
8	Till, Summer and Fall Herbicide
9	Till, Solarization
10	Till, Summer Herbicide, Solarization

The objective of the research was to guide future restoration activities by assessing 10 site preparation techniques in terms of:

- Plant community structure, diversity, and productivity,
- Seasonal measurements of functional soil ecosystem attributes, and
- Changes in chemical and physical attributes of the soil

A total of 10 site preparation techniques, or combinations of techniques, were selected as part of the experiment (see Table 4-1). These included various combinations of tilling, herbicide application, solarization, and thermal treatments. An 11-acre site within Coyote Prairie (a City of Eugene owned site) was selected for implementation of the experiments. This 240-acre site had been in agricultural use for *Lolium multiflorum* production until the start of the field experiment in 2004. The Coyote Prairie site was ideal for this research since it possessed very consistent hydrologic conditions with seasonal inundation across its extent. During the wet season, this site has approximately 5-8 cm of standing water, which is typical wetland prairie hydrology. A total of fifty 15-meter by 15-meter experimental plots were established on the site in 2004, each separated by a 10-meter buffer strip. The relatively large size of the experimental plots enabled the use of heavy agricultural equipment and minimized edge effects.

Pre-treatment data was collected within the experimental plots and site preparation was conducted on each of the test plots between in May and October 2004. The plots were planted with a broadcast seeder in October 2004 with a wetland prairie seed mix consisting of 15 species of native grasses and forbs including *Agrostis exerata, Aster hallii, Camassia quamash, Carex densa, Danthonia californica, Deschampsia cespitosa, Grindelia integrifolia, Epilobium densiflorum, Juncus tenuis, Madia glomerata, Microseris laciniata, Plagiobothrys*

Pre-treatment condition

figuratus, Potentilla gracilis, Prunella vulgaris ssp*. lanceolata,* and *Wyethia angustifolia.* The seed was carefully weighed and divided into fifty identical batches to ensure consistent distribution on each of the plots.

The following site preparation techniques were used in various combinations for these experiments:

Solarization: This technique involved placing a layer of 6 mm clear plastic over the entire plot beginning in mid-July after the plot was tilled and then watered to add soil moisture. A trench was dug around the perimeter to bury the edges of the plastic and create a tighter seal. The plastic was then removed in early October. This treatment creates high soil temperatures which kill the existing vegetation as well as a portion of the soil seed bank.

Tilling: This involved making two passes over the plots with a large field disk in alternating directions as soon as the soil was sufficiently dry (late June). This was followed by another round of tilling about two weeks later to further break up the soil and vegetation, this time using a harrow and culti-mulcher.

Thermal Treatment: A propane burner was pulled in a single slow pass over the test plots to burn off vegetation and seed near the soil surface. The particular machine used (*Sunburst*) applies a thin film of water to the vegetation and then subjects the plants and seeds to intense heat that is transferred to them through infrared energy, turbulent hot air, and boiling water. This was done in mid-August.

Herbicide Application: This involved spraying the vegetation in the test plots with a glyphosate-based herbicide (Roundup with a surfactant). A first treatment was applied in early-July, with a second follow-up treatment to selected plots in early October after the seed bank germinated.

Three years of post-treatment data were collected in each of the 50 experimental plots, the adjacent farm field planted in annual ryegrass, and three high quality remnant prairies (reference sites) to assess how the various site preparation techniques impacted the following four categories of response variables:

- Establishment of native Willamette Valley wetland plant species relative to non-native plant species in terms of percent cover and species diversity
- Aboveground and belowground productivity of the vegetation
- Functional soil ecosystem attributes, including nitrogen, phosphorus, and carbon cycling rates, and microbial biomass and respiration
- Physical and chemical properties of the soil

Solarization

Tilling (field disk)

Thermal (Sunburst burner)

Herbicide (glyphosate)

Summary of Site Preparation Study Results

The following results and ecological lessons learned were drawn from *Testing the Effectiveness of Site Preparation Techniques for Wetland Prairie Restoration* (Pfeifer-Meister et al.2007):

- The tilling treatment, which disturbs the soil and brings up the seed bank, yielded the poorest results in terms of decreasing the seed bank and exotic cover.
- Solarization and the summer/fall herbicide application were the two most effective treatments for decreasing the seed bank and exotic cover initially.
- The solarization treatment resulted in high native plant cover in the first year and lowest exotic plant cover throughout the experiment, but this treatment also had low native and overall species richness and diversity due to the dominance of the native bunchgrasses *Deschampsia cespitosa* (tufted hairgrass) and *Agrostis exerata* (spike bentgrass). This demonstrated that there is a trade-off between high abundance of competitive native bunchgrasses and species diversity.
- The July herbicide application had no detectable effect on plant communities. If the herbicide could have been applied earlier in the growing season, it may have had a greater effect, but weather conditions in the year of the experiment limited early site access.

Coyote Prairie test plots

- The heat from the thermal treatment did not significantly penetrate the soil and as a result, did not decrease the seed bank. Instead, it acted more like a surface fire and was only effective at killing small seedlings. To reduce the seed bank, this technique would need to be applied at the time of seed germination.
- It was found that the solarization treatment most effectively reduced the seed bank, followed by the fall herbicide application. The thermal application and tilling did not significantly reduce the seed bank. These results were based on a 3-month greenhouse grow-out of post treatment soil cores collected from every plot in winter 2005.
- Over the course of the experiment, all treatments had low exotic cover because *Lolium multiflorum* (the pre-project crop) was not a dominant competitor and no other dominant exotic species colonized the plots.
- In general, none of the treatments resulted in a significant change in the belowground responses (physical or chemical properties of the soils) after the first year. It was found that the adjacent farm field had higher nutrient levels, mineralization, nitrification, and respiration rates, and more belowground biomass than any of the test plots. This was most likely the result of ongoing fertilization for grass seed production.
- The glyphosate-based herbicide applications had no detectable effect on soil variables measured.
- A concurrent retroactive study of nearby restoration sites where sod removal had been used as a site preparation technique found that sod removal resulted in significantly altered ecosystem functioning when compared to all of the other site preparation techniques tested in the Coyote Prairie field experiment. This included significantly lower aboveground productivity, microbial biomass, mycorrhizal infection of native grasses, and total soil carbon and nitrogen (Pfeifer-Meister 2008). It should be noted that although these sod removal areas had very low productivity, these areas were generally dominated by natives with relatively fewer non-native species present (Trevor Taylor personal communication, July 2013).
- Over time, plant community structure converged among treatments and became more similar to the reference sites due to a reduction in the cover of *Lolium multiflorum*, a loss of early successional species (including those which were planted), and increasing dominance of perennial grasses.
- As a result of these successional dynamics, where native perennial grasses quickly became dominant, there was an overall decrease in diversity (native and non-native combined) and native plant species diversity over time in all treatments.
- A trade-off was evident between native plant cover and diversity. These results suggest that future research efforts should be focused on establishing management techniques that will help maintain native plant diversity in wetland restorations and limit invasion by non-native plants (see summary of replicated field experiment in Chapter 6, which assessed the effectiveness of management techniques combined with over-seeding).

4.5 Recommended Site Preparation Approach and Timeline

The following is a recommended approach and timeline for the site preparation phase of a wetland prairie restoration project. This approach is based on research results and lessons learned from multiple wetland restoration projects implemented by the West Eugene Wetlands and Coyote Prairie North Wetland mitigation banks. This general approach was used in recent years on both the Dragonfly Bend and Coyote Prairie wetland restoration projects (Wold et al. 2011). Both project areas had a starting condition of an annual ryegrass field and the site preparation phase was completed in a single year. Other sites that have more non-native species present may require a second year of site preparation.

Figure 4-2: ***Recommended Site Preparation Strategy***

Step	Timing	Task
Year One		
1	Summer	**Harvest**: Last agricultural crop harvested (grass seed or other)
2	Aug/Sept	**Grading**: Implement any planned site grading actions including removal of drainage features and installation of habitat features such as vernal pools and swales.
3	Sept/Oct	**Thatch Removal**: Conduct ecological burn if possible or hay the site to remove thatch and biomass. This improves effectiveness of herbicide applications and seeding.
4	Sept/Oct	**Herbicide Application**: Apply first broadcast application of broad-spectrum herbicide (glyphosate or other) to kill emerging grass crop and other vegetation. The timing is based on factors including weather, site hydrology, and emergence of vegetation. Conduct frequent site visits to monitor conditions and look for windows of opportunity.
5	May/June	**Herbicide Application**: Apply second broadcast application of broad-spectrum herbicide to kill emerging vegetation.
6	May/June	**Evaluate Plant Community**: Determine presence of emerging non-native plant species and map if needed to guide the second year of site preparation. If evaluation shows good success, the second year of site preparation can be skipped and the establishment phase may begin (see Section 5).
Year Two [ONLY IF NEEDED]		
7	Summer	**Invasive Vegetation Control**: Control emerging non-native vegetation as needed, either through spot broad-spectrum herbicide application or hand weeding. Conduct frequent site visits to monitor conditions.
8	Early Fall	**Additional Invasive Vegetation Control:** Control emerging non-native vegetation as needed, either through spot broad-spectrum herbicide application or hand weeding. **Treat Non-native Grasses**: Monitor for the presence of aggressive non-native annual grass species such as *Vulpia myuros* and treat with another round of broad-spectrum herbicide or a grass-specific herbicide if present.
9	Fall	**Re-evaluate Plant Community**: Re-evaluate plant community to determine if site preparation has been adequately effective to move into the plant establishment phase (see Section 5.0). If significant invasive vegetation issues persist, one additional year of treatment may be necessary before planting. Most *old field* sites would likely require this additional year of treatment.

See Chapter 5 →

for the next step of the restoration process (plant establishment)

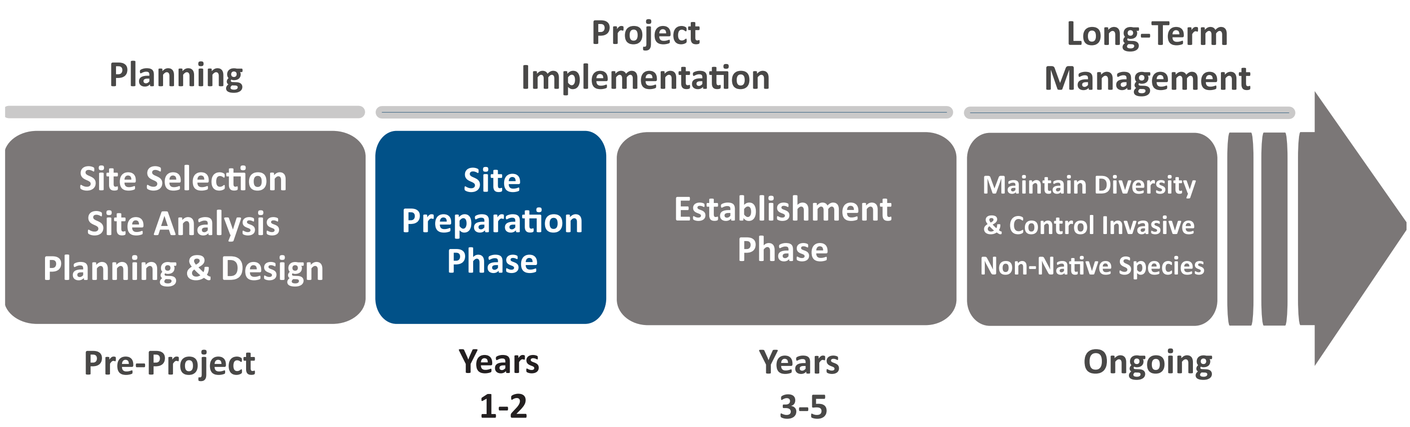


Figure 4-3: ***Relationship of the Site Preparation Phase within the Restoration Timeline***

4.6 Common Themes and Variations in Site Preparation

In 2012 and 2013, phone surveys and discussions were conducted with several, targeted wetland restoration practitioners in the Willamette Valley and southern Washington (see Figure 4-4). From these surveys, there was general consensus with the use of the site preparation techniques described above with some variations. Key themes and observations from these surveys related to site preparation are as follows:

- Larger restoration sites are preferred over smaller sites because the edge-effect is minimized (lower edge to area ratio) and as a result tend to produce better results. Weed invasion from the perimeter is particularly problematic on smaller sites.
- Agricultural fields that have been in active production are much easier to restore to wetland prairie than old fields. Many mitigation banks focus on restoration of agricultural fields, particularly annual ryegrass, for this reason. One practitioner noted that they had their best success on a site that had previously been in cultivation for corn and potatoes (achieved high native cover very quickly).
- *Old field* sites, where the restoration goals include preserving existing native cover, present the most challenging site preparation scenarios. In this situation, broad-spectrum herbicide application may not be an option, especially in the spring. Several practitioners used grass-specific herbicide or a late fall application of broad-spectrum herbicide as a way to address major invasive vegetation issues without significantly impacting natives such as camas, but did impact sedges and rushes. Two practitioners noted that they would not attempt a restoration project on an old field site if they had to work around a small amount of existing native cover. They would prefer to start from scratch (eradicate all vegetation) and preferably in an agricultural field with a single crop species.
- One practitioner has found that leasing a site back to a farmer for an extended period prior to restoration can be problematic since the farmer will lose incentive to control weeds, knowing that it's not a long-term investment. They recommend starting the restoration process as soon as possible after the site is purchased.
- Soil disturbing activities such as tilling are generally avoided as a sole site preparation technique due to poor results. Several practitioners noted that tilling can be useful on fields that are immediately coming out of agricultural production as a way to eliminate existing crop species, but follow-up herbicide applications are still necessary.
- Herbicide application as a site preparation technique is the most common practice used, with glyphosate (broad-spectrum) being the most common herbicide used.

One practitioner noted that they make the assumption that they will need up to five applications of herbicide for a successful restoration project, although in some cases, fewer applications may be needed.

- Paying careful attention to site conditions throughout the site preparation process is critical for catching invasions of non-native vegetation early enough for effective treatment. The timing of herbicide application is critical.
- Scheduling early season herbicide application in wetland prairie conditions can be challenging due to saturated soils, extended periods of rainfall, and lack of days with adequately high temperatures.
- Several practitioners noted that removing thatch, either through burning or haying, was a beneficial early step in site preparation.
- Most wetland restoration projects included some level of hydrologic modification to eliminate agricultural drainage features. Several, but not all, projects included site grading for the purpose of introducing hydrologic/vegetation diversity for habitat enhancement.
- Three practitioners noted that it was sometimes desirable to lightly smooth a restoration site with a harrow prior to planting so that the surface is less bumpy and easier to drive over with a spray buggy or seed drill. As noted in section 4.3.4, desirable microtopography (pedestals) has been observed to return to a smoothed site over time.
- There were no examples noted of solarization being used on a large scale. Three practitioners did note using solarization on a small scale (less than 1/10 acre) with some success and had the following recommendations: it is important to use 4 mm or greater density plastic to avoid ripping and piercing by deer or elk; tilling before solarization plastic is installed can help expose the seed bank and increase effectiveness; because soils should be moist when covered plastic should be installed quickly following late spring rains or water should be imported prior to plastic application; plastic should be installed by mid-June to take advantage of warm weather in July/August for heating; trenching is necessary to seal the edges but is time consuming and disturbs the seed bank.
- One practitioner noted that they are using solarization strips in restoration areas where native perennial grasses have become well established as a way to increase native forb diversity on the site, particularly for nectar species.
- *Vulpia myuros* was cited by several people as being the most problematic non-native invasive species in wetland prairie restoration projects. *Agrostis capillaris* and *Agrostis stolonifera* (Non-native bentgrasses), *Holcus lanatus*, *Alopecurus pratensis*, and *Hypochaeris radicata* were also consistently mentioned as being very problematic.

Figure 4-4:
Wetland Restoration Practitioners Interviewed

Name	Affiliation
Hannah Anderson	Center for Natural Lands Management (Olympia, WA)
Matt Benotsch	The Nature Conservancy
Matt Blakeley-Smith	Greenbelt Land Trust (formerly Institute for Applied Ecology)
Lynda Boyer	Heritage Seedlings, Inc.
Eric Delvin	The Nature Conservancy (Olympia, WA)
Paul Gordon	City of Eugene Parks and Open Space Division
Ray Fiori	RTF Consulting and Oregon Wetlands LLC
Chad Hoffman	Lane County Waste Management
Mark Knaupp	Mud Slough Mitigation Bank
Esther Lev	Wetlands Conservancy
Jeff Reams	Turnstone Environmental Consultants
Curt Zonick	Metro Natural Areas Program

4.7 Site Preparation Approaches for Special Habitat Conditions

In order to meet special habitat goals within an established wetland prairie, it may be desirable to re-implement the site preparation process within a smaller designated portion of the site. For example, if a management goal is to improve habitat conditions for pollinators, a designated area could be prepped for replanting. The site preparation technique could utilize herbicide applications, but at this smaller scale, solarization could also be a viable option. The goal of the site preparation would be to knock back or eliminate competing vegetation such as native or non-native perennial grasses. Following site preparation, the open area would be replanted with a heavy concentration of nectar producing forbs, creating a concentrated area of desirable habitat for the target species. Another example would be creating special habitat conditions for streaked-horned lark. The streaked hornded lark prefers grassland habitats with very sparse vegetation. It has been noted that streaked horned larks are nesting in west Eugene on a former restoration site that utilized sod removal as a site preparation technique. Due to the removal of top soil, vegetation in this area is very sparse and stunted with patches of bare soil, which is ideal habitat for the streak horned lark.

This specialized planting strip at The Nature Conservancy's Willow Creek Preserve incorporates nectar and host plants for the Fender's blue butterfly within a larger upland prairie. Solarization was used as the site preparation technique.

4.8 Knowledge Gaps Related to Site Preparation

We recognize the following knowledge gaps related to site preparation. Further study of these topics could lead to improved understanding and better restoration results:

- Can solarization/smothering methods be improved so they can be cost effectively applied at a large scale (cover area greater than one acre) and with limited waste? Solarization has shown good results as a site preparation technique for wetland prairie restoration, but only on a very small scale. As currently used, it requires large amounts of non-reusable plastic and causes soil disturbance along the solarization perimeter, leading to infestation of invasive non-native plants on the edges.
- Are there types of organic herbicide that can be effectively substituted for chemical standard herbicides? There has been limited research in Oregon on use of organic herbicides in prairie restoration projects.

Chapter 5: Establishment Phase (Years 3-5)

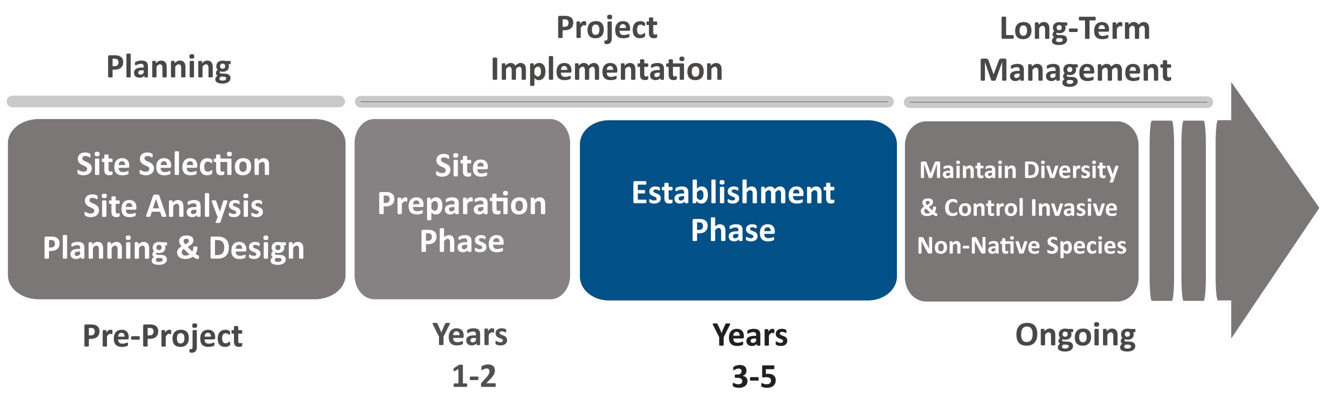


Figure 5-1: ***Relationship of the Establishment Phase within the Restoration Timeline***

Successfully establishing a diverse native plant community is a critical step in a wetland prairie restoration project. This chapter focuses on establishing the wetland prairie plant community, following successful completion of site preparation (see Chapter 4.0), and does not address the direct introductions of animal species. However, it does address the creation of animal habitat in wetland prairie restorations, such as the inclusion of plants that provide food, shelter and nesting habitat; the placement of habitat structures such as snags or downed wood; and hydrologic features that support the life histories of specific animal species or guilds.

5.1 Planning Plant Establishment

If site preparation has been thorough and non-native invasive species are nearly absent, success in establishing the wetland prairie plant community will depend primarily on the method and type of native plant materials introduced, their competitive interactions, the influences of environmental factors in the first few years after introduction (precipitation patterns, pathogens, predators), and new non-native colonists. Although factors such as precipitation patterns and pathogens are outside the control of the restoration planner, specific strategies can be employed to reduce their influence on project success.

Planning to ensure the availability of diverse plant materials for prairie restorations requires numerous steps and ideally should be started two or more years in

Steps in planning for plant materials:

1. Determine what to introduce

- Define preferred species
  - use reference sites and information on historical distribution
  - address restoration goals
  - consider species, genetic, and functional diversity
- Identify and map unique seeding areas (e.g., vernal pools, grass buffers, etc.)
- Determine in what form to introduce plant materials (e.g., seed, bulb, bare-root)
- Identify the source of the desired species within the timeline of the project
  - open market available species and sources
  - collection
  - seed increase via contracting, and/or partnering with others

2. Define how to introduce it to the site

- Identify seed mixes that can achieve project goals
  - Ratio of forbs to grasses
  - Diversity of species
  - Specialty seed mixes for project sub-areas
  - Seeding rates
- Identify seeding and planting methods and configurations
  - broadcasting vs. drilling
  - seeding and planting schedules

advance of the date material will need to be sown or planted.

5.1.1 Plant Species Lists

The decision of which native plant species to introduce will depend on the project's goals, budget, and plant material availability. The initial list of desired species can be compiled from high quality local reference sites or using species lists based on current and historic range data.

This chapter assumes that native plant diversity is a key goal of the wetland prairie restoration.

A comprehensive plant species list used by Pacific Northwest prairie restoration practitioners has been compiled by Alverson (E. Alverson, unpublished data). Among other information, it indicates the likelihood that a species is found primarily in prairie communities in western Oregon and Washington, a term referred to as "prairie fidelity". Those species considered to have high and moderate fidelity to wetland prairies, and that occurred in local prairie remnants, became the basis for inclusion in prairie restorations in the West Eugene Wetlands. The subset of 180 native plant species that occur in wetland prairies, and have moderate to high fidelity to prairies in general, is included as a "working list" in Appendix A.

While remnant prairies may provide the initial list of desired species, this will likely be winnowed down based on availability. Availability will depend on the following factors:

- seed zones identified for the project,
- species currently grown by nurseries for the open market,
- budget available for project-specific seed increase and seed collection,
- available areas from which to collect or salvage seed and other plant materials, and
- time required for production of plant materials.

Diverse remnant prairie area at Coyote Prairie

5.1.2 Diversity

Pacific Northwest prairies support a diverse assemblage of plant species, with 350 native plant taxa found in wet and upland prairies combined, most of which occur primarily in prairie communities (Sinclair et al. 2006). In the southern Willamette Valley, the number of native plant species in eight monitored prairie remnants ranged from 30 to 84 (Wold et al. 2011, from data in Pendergrass 1995, City of Eugene 2004). The West Eugene Wetlands Program has consequently identified a species richness objective of establishing at least 50 native plant taxa in wetland prairie enhancements and restoration sites ranging from 8 to 40 acres (Wold et al. 2011).

The values of diverse plant communities are many. Several studies suggest that plant diversity reduces susceptibility to invasion by non-native invasive species, at least on a site-wide basis (Tilman 1997, Naeem et al. 2000). By providing wetland prairie seed mixes of high diversity, there is a greater chance that available ecological niches (e.g., due to variation in site hydrology, substrate, or rodent activity) will be filled by native seeded species rather than non-native invasive species (Wold et al. 2011).

Diverse plant communities are also thought to be more resilient in their response to environmental disturbances, such as fire, extended flooding, or drought (Seabloom 2007). While resilience will not necessarily mean a return to the same composition of species after disturbance, it does imply a return to pre-disturbance levels of important community measures, such as native species richness or evenness, and a continuation of wetland functions, such as sediment trapping, providing songbird habitat, or pollinator support.

In addition to species diversity, diversity in function should be incorporated when designing seed mixes (Tilman 2001, Diaz and Cabido 2001). While much remains to be learned about how specific native plant species function in Willamette Valley wetland prairie communities, lists that categorize species by growth forms, phenology, growth rates, and ecological tolerances can be useful when determining which species to include in restorations and whether or not the established community is likely to meet project goals.

An example of a species functional list could include categories such as:

- Graminoid/Forb
- Annual/Perennial
- Early colonizer
- Nitrogen-fixer
- Provides pollen or nectar resources (early, mid-season, late)
- Provides food resources for grassland birds (early, mid-season, late)
- Deep-rooted
- Low growth form
- Competitive in the wetland prairie environment

Other species groups that may be desired are those with cultural importance and rare species.

5.1.3 Seed Zones

In addition to species and functional diversity, genetic diversity should be addressed in restoration planning. As numerous studies have found, locally sourced plant materials are more often successful due to the potential for adaptation to local conditions (Rogers and Montalvo 2004; although see Jones 2013). Therefore, obtaining plant material from "local" sources is important.

Important considerations in determining what is a "local" or appropriate seed zone (the area from which the source seed originates) are reviewed in several articles and guides (e.g., Falk et al. 2001; Rogers and Montalvo 2004; McKay et al. 2005; Withrow-Robinson and Johnson 2006) and are not discussed further here. A seed zone may be species-specific, as several studies in the Pacific Northwest, both with native grasses and forbs, have determined. However, for practical purposes, many restoration practitioners define a region from which they acquire plant materials, for example, within a specified distance of the restoration site, within specific elevational boundaries of a watershed, or within an ecoregion.

As a result of common garden research, the Willamette Valley ecoregion has been suggested as an appropriate seed zone for several prairie species (Miller et al. 2010). In other cases in the Willamette Valley, agencies or organizations have chosen to use a more restrictive geographic range, for instance the West Eugene Wetland program has restricted their plant material sources to the southern Willamette Valley, specifically a 20-mile radius of the Eugene area (LCOG 1996). Restoration practitioners should give careful consideration to the source of the plant material they choose and may use one

Grindelia integrifolia is an example of why seed zones should be carefully considered. This species varies significantly between the north and south Willamette Valley and in the south, plants are thought to be *Grindelia integrifolia* x *nana* hybrids.

Practitioners should consider the following prior to deciding on a particular seed source:

- Location: Location of collection and how similar collection location is to the target restoration site.
- Collection Strategy: Guidelines under which the collection was made (e.g., population size; specific factors the collector may have intentionally targeted, such as impressive flower color or large plant size, that could result in a less diverse source population).
- Generations: Number of generations in production and how similar production conditions are to the target restoration site.
- Grow-Out Selection: Specific characteristics the grower may have selected (e.g.,an accession that flowers and matures seed uniformly or within a narrow harvest window; a highly competitive accession that resists weed invasion in production fields).
- Adjacent Wild Populations: Potential to negatively influence (e.g., through outbreeding depression) remnant wild populations of the same species surrounding the restoration site.
- Identification: Existence of similar-appearing non-native taxa that could be confused with the target species and the collector's and grower's ability to confirm identification of the production material (e.g., via voucher specimens or collector/grower expertise). Two examples of non-native taxa in the Willamette Valley that look similar to natives found in wetland prairies are:
    - o *Potentilla recta* (Sulpher cinquefoil); native: *Potentilla gracilis* (slender cinquefoil))
    - o *Prunella vulgaris* var. *vulgaris* (Eurasian self-heal); native: *P. vulgaris* var. *lanceolata* (lance self-heal).

  Other wetland prairie taxa in which identification in the Pacific Northwest, west of the Cascades, may be problematic include those in the genera *Luzula* (woodrush) and *Glyceria* (mannagrass).

of several tools (e.g. Rogers and Montalvo 2004), and request the opinion of local experts, to help determine a sound biological approach to appropriate source material. Nurseries and seed producers should be willing to provide source and generational information on the plant materials they provide. Species that have been grown for production in agricultural settings may have reduced genetic diversity if the initial source collection was from only a single site or a few plants at several sites. Genetic diversity may also diminish with succeeding generations of seed produced, for instance if harvest over successive years is limited to those individuals that mature at a preferred harvest period (Darris 2005).

5.1.4 Succession Theory and Priority Effects

Considering how species co-exist or replace one another across the landscape can be beneficial when designing planting plans and seed mixes. Succession theory as it relates to prairies, where soils are already suitable for all colonizing species, suggests that species influence other members of the plant community in one of three ways. Plant species may (from Connell and Slayter 1977):

- facilitate establishment and growth of their neighbors or the species that follow them; for instance by altering soil characteristics or germination sites in beneficial ways;
- inhibit or suppress neighboring species or those trying to establish after them, for instance, by creating shade, extracting soil nutrients, or exuding allelopathic chemicals;
- neither benefit nor suppress (tolerance model) neighboring or successive species, such that the eventual community that develops consists of those species that can persist among surrounding neighbors.

Consideration of these models in prairie restoration has focused in part on the interactions of non-native and native species. One study found that a perennial invasive non-native grass inhibited native species, but that native perennial grasses in the community did not have the same inhibitory effect on other natives (Bakker and Scott 2004). In other research, when plants were given a 5-week head start on germination and growth, by being planted first, both native and non-native plant species inhibited those species that followed them. Although early planted natives inhibited later colonizing natives, the level of suppression was less than that exerted by early planted non-natives. In addition, only the non-native species tested had an inhibitory effect on natives due to alterations of soil characteristics. Natives planted early, and then removed, did not affect the soils in a way that suppressed either later-colonizing non-natives or natives (Grman and Suding 2010).

In some cases, restoration practitioners in the Willamette Valley have incorporated succession models into their prairie restoration strategies. For instance, the concept that wetland prairie annuals may facilitate native perennial establishment while inhibiting non-native species establishment, has resulted in some practitioners emphasizing annuals in first year seed mixes, as compared to native perennials (Wold et al. 2011). Typically, native annual species that are able to colonize wetland prairies following site preparation, will diminish in abundance within the first 5 years, as perennial natives increase, although the annuals likely remain in the soil seed bank. In the West Eugene Wetlands, the common native annuals that exist in the soil seed bank even after decades of grass seed farming are *Epilobium brachycarpum*, *Gnaphalium palustre* (western marsh cudweed) *Juncus bufonius* (toad rush) and *Rorippa curvisiliqua* (curvepod yellowcress) (Wold et al. 2011; City of Eugene 2012b).

Given the complexity of species interactions, species identity and site conditions may be more important than generalizations about the characteristics of a given guild (e.g., annual/perennial). The restoration practitioner seeking high species diversity should carefully consider seeding rates of native annual species that have a high potential to have an inhibitory effect on other species (Figure 5-2). These species can be introduced in patches, rather than in a broadcast seed mix. They may also be valuable in situations where invasive non-native species are particularly problematic or soil conditions (e.g., compaction) make establishment of species diversity difficult.

Figure 5-2: ***Examples of Categories of Plant Species that may not be Included in a Typical Wetland prairie Seed Mix***

Category		Species
Species that are likely to be present as a soil seed bank, even where grass seed fields have existed for decades. These species emerged in abundance in at least two West Eugene Wetland prairie restorations/enhancements without being seeded.	1	*Epilobium brachycarpum*
	2	*Epilobium ciliatum*
	3	*Gnaphalium palustre*
	4	*Juncus bufonius*
	5	*Rorripa curvisiliqua*
Species that may reach high cover even at a seeding rate of 1 – 4 seeds/ft^2. Should be used with caution in situations where diversity is goal, but may be particularly useful in areas where the ability to compete with invasive non-native species is desired	1	*Deschampsia cespitosa*
	2	*Juncus occidentalis*
	4	*Madia glomerata*
	5	*Madia sativa*
	6	*Acmispon americanus*
Slow-growing species or those for which seed may be limited. These have been frequently introduced as plugs, container plants, or bare-root in the West Eugene Wetlands	1	*Juncus bolanderi*
	2	*Juncus ensifolius*
	3	*Juncus nevadensis*
	4	*Juncus oxymeris*
	5	*Micranthes oregana*
	6	*Symphiotrichum hallii*
	7	*Triteleia hyacinthina*
	8	*Toxicoscordion venenosum* var. *venenosum*
	9	*Wyethia angustifolia*

Seed is generally the least expensive form of plant material to purchase, store, and plant, and many native wetland prairie species establish well by seed.

5.2 Plant Material Type and Acquisition

An important step in creating a plant material strategy for a prairie restoration is to define the form in which plant materials will be introduced (e.g., seed, plants, bulbs, or rhizomes).

5.2.1 Plant Material Type

For wetland prairies, seed is generally the cheapest form to purchase, store, and plant, and many native wetland prairie species establish well by seed (Wold et al. 2011; City of Eugene 2012b). This is in contrast to large deeper water wetland habitats where container or bare-root plants are often the dominant material type introduced.

Although there are often reasons to introduce some species to a restoration site as plants, rather than seeds, in most cases the plant populations established will need to reproduce by seed in the future to persist. Methods that may enhance native establishment from seed in an existing restored prairie, such as prescribed fires, are discussed more thoroughly in Chapter 6.

Defining the form in which the plant materials will be introduced and a strategy for obtaining them for the entire proposed species list will help ensure plant materials are available within the project timeline. An example from a plant supply strategy is provided in Figure 5-3 (West Eugene Wetlands 2006).

Figure 5-3: ***Example Section of the Plant Supply Strategy for the West Eugene Wetlands Program***

Category	Strategy	Species
1	Species that do well from seed. We can buy a sufficient supply on the open market.	*Agrostis exarata*
		Danthonia californica
		Deschampsia cespitosa
2	High priority for grow out: Species that do well from seed. We do not have a sufficient supply.	*Eriophyllum lanatum var. leucophyllum*
		Grindelia integrifolia
		Potentilla gracilis
3	Medium priority for grow out: Moderately successful from seed. We do not have a sufficient supply.	*Lupinus polyphyllus*
		Lotus formosissimus (*Hosackia gracilis*)
		Perideridia spp. (*montana* and *oregana*)
4	Low priority for grow out: We have little to no prior experience propagating these species, but would like to include them in the future	*Carex aurea*
		Dichanthelium acuminatum ssp. *fasciculatum*
		Trifolium variegatum
5	Species establish well from bulbs, plugs, or bare root.	*Allium amplectens*
		Micranthes oregano (*Saxafraga oregana*)
		Triteleia hyacinthina
6	Species that are found in remnant areas, but we are not currently including them in the planting effort.	*Barbarea orthoceras*
		Carex scoparia
		Hypericum anagalloides
7	Use both seed and bulbs because species is important and takes a long time to establish.	*Camassia quamash* ssp. *maxima*
8	Species for which we need more information and/or collection sites.	*Agoseris grandiflora*
		Hypericum formosum var. scouleri
		Spiranthes romanzoffiana

Although seeding is typically effective, introducing container grown plants may be preferred in cases where:

- Mature or juvenile plants can immediately serve a specific necessary function. For example, bare-root sedges planted densely to reduce erosion or trap sediment in a newly constructed swale; or forbs that will provide next-growing season nectar to a declining butterfly population.
- Species are long-lived, but slow to mature. They are poor competitors with neighboring species during the 4 to 5 years required for them to reach reproductive size in a wildland setting (e.g., *Triteleia* (brodiaea) *Wyethia* (mule's ear). Establishing bulb-forming wetland prairie species is discussed further in section 5.8.1.
- A supply of non-seed plant material is available from a site about to be destroyed (e.g., *Camassia* bulbs) or from beds in an existing nursery (e.g., *Sidalcea* (checkermallow) roots).
- Propagation from vegetative starts is vastly more efficient than current seed production methods (e.g., *Frageria virginiana* (mountain strawberry), *Symphoritrichum hallii* (Hall's aster).
- Temporary site conditions reduce the likelihood that seed will establish where originally distributed. For example, when large amounts of water will be flowing across a site devoid of existing vegetation.
- Wild collected seed may be so limited that some planting as container grown plants is preferred, until nursery seed increase is possible (e.g., for rare species).
- Mature or juvenile plants are needed to provide an initial competitive advantage over non-natives emerging from the soil seed bank. It can be particularly advantageous to introduce bare-root plants of rhizamotous species (e.g., *Juncus oxymeris* (pointed rush) *Carex obnupta* (slough sedge)), to get rapid native cover.

Carex plug

5.2.2 Plant Material Acquisition

Native seeds and plants may be purchased directly from nurseries from what is commercially available or a contract with a grower may be developed to produce a consistent supply of source-identified seeds or plants. Because commercial availability of native wetland prairie species is very limited, early planning is essential in either case.

Commercial Availability: Buying native seed on the open market can be challenging due to the lack of availability of seed that originates from local, tracked, high quality collections. The Willamette Valley is fortunate to have several growers that are experimenting with commercial production of local native wetland prairie species on scales ranging from a few hundred square feet to several acres (Boyer 2008). If contract grow-out is not possible, then commercial growers should be contacted in early spring (if not before) about availability of seed for the following fall. Early contact allows the restoration planner to place a reserve order and to determine the likelihood that an adequate amount of locally produced native seed will be clean and tested by the restoration planting date.

Plant populations will ultimately need to reproduce by seed to persist on the site over the long-term.

Currently, sources of native seed in western Oregon and Washington can be found in a searchable database managed by the Native Seed Network in Corvallis, Oregon (*www.nativeseednetwork.org*). Lists of commercial growers of native local seeds and plants can also be found on the websites of the Native Plant Society of Oregon, the Washington Native Plant Society..

Grindelia integrifolia in contract grow-out beds

Contracted seed-increase: Contracting for seed increase provides the greatest assurance that the required species and amount of source-identified seed will be available when needed for planting. It requires advance planning of several years, available growers experienced with native species or reliable information on propagation and harvest methods, and clear expectations between grower and purchaser on seed quality and delivery dates.

Contracted seed-increase can result in large amounts of seed from small initial wild collections. Below are three examples from the West Eugene Wetlands program of harvest levels from small scale (0.1 acre) nursery production, without annual fertilization or supplemental watering.

Figure 5-4: *Annual Harvest from Collected Seed*

Species	Amount of Wild Collected Seed Sown in 0.1 acre (lbs of PLS)	Annual Harvest (average from 3 years; lbs)
Eriophyllum lanatum ssp. *leucophyllum*	0.2	15
Grindelia integrifolia	1.0	63
Plagiobothrys figuratus	0.6	9

To contract with a nursery to produce seed of a native perennial, the nursery should be identified and wild seed collected 2 to 3 years prior to the date the restoration seed is needed. Timing can be further complicated for species which reproduce late in the growing season and are not harvested until September or October. An example of a seed-increase timeline for *Grindelia integrifolia* (Willamette Valley gumplant), a late-season maturing species, and *Potentilla gracilis*, is shown in Figure 5-5. This example is for seed increase fields that are established from direct seeding rather than greenhouse-grown plant starts.

Figure 5-5: *Example Timelines for Seed Production of Two Native, Wetland Prairie, Perennial Forbs*

Grindelia integrifolia **(late season flowering biennial or short-lived perennial)**			
Year 1	**Year 2**	**Year 3**	**Year 4**
Spring (or earlier): Establish agreement with grower. Grower prepares field. Summer: Collect wild seed (Generation 0 (G0)). Seed matures late season. Fall: Grower plants field.	Spring: Assess field establishment. Fall: No harvest in first year.	Spring: Coordinate with grower on date to begin next field rotation to supply seed annually. Year 4 will typically be the final harvest for the original bed. Fall: First harvest (G1 seed) in September or October. Seed cleaning and testing will likely mean this year's harvest is unavailable for this fall's restoration seeding into wet prairie.	Fall: Seed produced in Year 3 is available for this year's seeding. Year 4 harvest will likely be smaller than that in Year 3. Store year 4 harvest for application to restoration in Year 5. Field done. Bed planted in Year 3 will produce in Year 5.
Potentilla gracilis **(perennial)**			
Year 1	Year 2	Year 3	Year 4
(as above, however seed matures mid-season).	(as above)	First harvest. Peak may be this or subsequent years.	Second harvest. Seed production bed may produce well for 6 or more years.

One of the greatest obstacles to implementing a contracted grow-out appears to be the commitment of funding needed for a multiple year effort. One method to address this is via multi-agency partnerships. In addition to their other benefits, partnerships have been essential to overcome the variability of annual budgets and provide a relatively consistent funding source for seed increase programs, such as the West Eugene Wetlands. Another cooperative venture, the Willamette Valley Native Plant Materials Partnership, which began in 2012, anticipates its contracted funding of native seed production will eventually increase the availability of native prairie seed throughout the Willamette Valley.

Collection: Collection of seeds from wild populations may be needed to provide local source seed for

- contracted seed increase program,
- the creation of plugs or bulbs, and
- direct placement onto a restoration site.

Numerous publications and internet sources are available that describe general seed collection methods (Apfelbaurm et al. 2005; Erickson 2008). However, due to the limited extent of remnant prairies in the Willamette Valley, collection limitations deserve discussion here.

Seed collection

Collection from Limited Collecting Sites: Due to the small size and fragmented condition of remaining wetland prairies, and competition from invasive non-native species, many wetland prairie plant populations are already declining or threatened. Therefore, seed collection from them should be extremely limited and be designed to provide a net conservation benefit. Research supports a cautious approach. In a study in the Pacific Northwest using models developed from field data, researchers sought to estimate how plant populations respond to collection amounts (i.e. removal of some portion of their propagules). They identified three categories of response for the species in their sample: insensitive to harvest, sensitive to harvest, and extinction-prone (Menges 2004). They did not include annuals in their modelling due to lack of appropriate field data.

Based on their analysis they present three rules to guide collections:

1. Collecting 10/10, that is 10% of the propagules from the population in 10% of the years (collecting 1 out of every 10 years), is typically a safe level of collection in herbaceous perennials.
2. Collecting 50/50, that is collecting 50% of the propagules from the population in 50% of the years, is typically unsafe for populations of herbaceous perennials that have 500 or fewer individuals.
3. In general, collecting smaller amounts frequently (e.g., 10% collected in 80% of years) is less likely to do harm than proportionately large collections made less frequently (e.g., 80% collectequd in 10% of years).

Although these rules do not identify a specific collection limit, other programs do. The mostly widely influential of these is the Seeds of Success program. Seeds of Success

Salvaged *Camassia* sp. bulbs

is a program coordinated by the U.S. Bureau of Land Management (BLM) which funds seed collections from native plant populations, including in Oregon, to conserve and develop native plant materials for revegetation and restoration in the United States. It limits collection to no more than 20% of the seed ripe on the day of the collection.

Salvage: Salvage of seed, bulbs, or rhizomes from plant populations that will soon be destroyed is a source of wild plant materials in specific cases. In most instances, it represents the final opportunity to conserve the local genetic material of a plant population when other options have been lost. If the timing for salvage does not coincide with the opportunity to place the material on the restoration site or into seed increase beds, an interim holding period in a nursery may be necessary. While salvage provides an opportunity to conserve genetic material that would otherwise be lost, it can be expensive to extract material from an old field setting, both in the time required to remove the material and the need to remove soil from the roots or bulbs, if it is likely to contain a large seed bank of invasive non-native species.

Due to these costs, it may be most beneficial to harvest seed of species not available commercially, to harvest dormant plants of long-lived bulb-forming species such as *Camassia* or rhizomatous species (e.g., some *Juncus* (rush)), and for situations when the genetic material is considered particularly valuable for species conservation. In the latter case, when seed is collected, consider submitting part of the collection to a long-term conservation seed banking program like the Rae Selling Berry Seed Bank and Plant Conservation Program in Portland, Oregon, or the National Seeds of Success Program.

Seed Storage: Storage of seeds under cool dry conditions is essential to maintain seed viability. If seed is not used in the year it is produced, viability will typically be best maintained when stored at constant low temperatures (e.g. 40 degrees F) in a low humidity environment (e.g. 45% relative humidity (RH)). For restoration seed that will be used in a few years, practitioners recommend that the storage RH and temperature should not sum to more than 100 (Apfelbaum et al. 2005; Tallgrass Prairie Center undated). Conservation collections are dried to lower levels and then frozen.

5.3 Developing Seed Mixes

In a well-prepared site, the seed mixes distributed during the first two years of a restoration are one of the most significant factors influencing the composition of the future native plant community. The composition of seed mixes should address restoration goals, including desired functional and species diversity.

Unique seed mixes may be needed to:

- address variations in hydrology across the restoration site,
- provide highly competitive assemblages of native species where invasive non-native species are particularly problematic (see section 5.x, buffers),
- re-vegetate challenging soil conditions (e.g., compaction) where species with more exacting habitat requirements are unlikely to establish,
- Meet goals related to wildlife habitat (e.g., creation of nesting habitat for grassland birds; or nectar-rich associations for rare butterflies).

Samples of native seed, sorted by species

The first step in designing seed mixes is to determine the desired species and their desired general proportions in the mature plant community. Clearly, ecosystems are dynamic and there may not be a single desired mature community, but instead several alternative desired states, depending on fire and flood regimes. In either case, having a vision of future desired plant composition is valuable in planning the appropriate seed composition for the project.

In addition, the restoration planner should anticipate certain competitive interactions among seeded species and adjust seed ratios and timing to resolve conflicts. An inherent conflict exists in the need to fill growing space to repel non-native species and the need to leave openings in which slow-growing species can establish. To achieve balance, know your site conditions and adjust the planting plan to reflect them. For instance, identify areas with the lowest likelihood of invasive species establishment (e.g., where site preparation was the most successful, where surface water flow is least likely to bring propagules from adjacent land), and seed slow-growing species there while excluding the most competitive natives from these areas. Greater knowledge about site conditions is an additional benefit of a multi-year seeding plan. Methods to achieve balance in establishment of seeded species are discussed further below.

Camassia quamash seed produced after 5-6 years in grow-out

Once the restoration planner has identified the desired relative proportions of species or guilds in the established community, the seeding rates should be adjusted based on the following:

Site Conditions: Numerous site variables, such as seed predation and herbivory, and surface hydrology, interact to make conditions more or less suitable than anticipated for the establishment and growth of the seeded species. In particular, site topographic

Topographic variations of just a few inches can alter winter and spring hydrology and strongly influence plant species persistence.

variations of just a few inches can alter winter and spring inundation levels and strongly influence plant species persistence. Defining multiple seed mixes based on inundation variation can reduce seed waste, but requires greater time for mixing and distributing on-site.

Planting Method: For some grass species, using a seed drill for planting results in much higher establishment, so that the seeding rate can be halved when drilling versus broadcasting (Darris and Gonzalves 2008; for *Danthonia californica* California oatgrass).

Competitive Interactions with Other Species in the Native Seed Mix: Because plant species vary in the speed with which they germinate and grow, achieving a diverse community often requires limiting competition between species that would typically be seeded together. This can be achieved by:

- Altering the timing of seeding; for instance seeding slower growing species (e.g., perennial forbs and less competitive grasses) in the first year and introducing more competitive grasses in later years,
- Altering the seeding rate; for instance increasing the seeding rate of slower-growing species and decreasing the proportion of competitors in the mix,
- Altering the form in which species are introduced; for instance, planting very slow-growing species (e.g., *Wyethia*, *Brodiaea* sp.) as 2-year old container plants rather than as seed,
- Introducing less competitive species using tools (e.g., seed drill) that favor their establishment or evenness across the restoration site,
- Altering the distribution of species across the site. For example:
    - Slow-growing species can be placed in mapped plots throughout the restoration that lack more competitive species and that are easier to monitor and manage.
    - Highly competitive grasses can be limited to a quarter of the site, in dispersed patches, with further grass seedings delayed until their establishment at initial seed rates can be assessed.

Working with Pure Live Seed (PLS)

PLS = purity x viability x seed weight. For example, if the target is 30 pure live seeds/sq ft, then seeding at 47 seeds/sq ft would be required for seeds of 98% purity and 65% viability (47 seeds x 0.98 x 0.65 = 30 PLS).

Seed Quality: Pure Live Seed (PLS) is the amount of material in the seed bag that is live seed (as determined by viability or germination tests) of the target species (as determined by the purity test). Purity identifies the amount of material in the seed bag that is actually seed of the target species, rather than chaff, clearly immature seed, and seed of other species. In order to sell seed in Oregon, test results conducted within the last 18 months must be supplied by the grower that identifies seed viability and purity (ORS 633.651). However, viability information is not always available for seed that has been stored for one or more years after harvest by the restoration practitioner. Even in the absence of a recent viability test, having an estimate of seed purity and viability, and increasing seed rates to account for it, can help avoid surprising failures in germination and establishment.

See Appendix C for some examples of wetland prairie seed mixes and seed rates used in the West Eugene Wetlands.

Know Your Highly Competitive Native Perennial Grasses

In Willamette Valley wetland prairie remnants, two small-seeded native grasses occur that can be highly competitive: *Agrostis exerata* (spike bent-grass) and *Deschampsia cespitosa* (tufted hairgrass). With appropriate hydrologic conditions, these species can achieve large size (in the case of *Deschampsia*) and high densities in restoration areas, overtopping neighboring lower-growing forbs and slow-growing grasses. In a replicated field experiment conducted in the West Eugene Wetlands, over a period of five years, *Deschampsia cespitosa* seeded at 0.46 lb/acre (15 seeds per square foot) in a mix with 14 wetland prairie forbs, grasses, and rushes, achieved high cover throughout the test plots, except where conditions were drier and the annual forb, *Madia glomerata* (cluster tarplant) dominated. At this rate, *Deschampsia cespitosa* appeared to substantially inhibit desired native species richness. This was regardless of the initial site preparation techniques or initial plant composition (Pfeifer-Meister et al. 2012) and this pattern was still evident 9 years after the initial 2004 seeding. It should be noted that plots dominated by tufted hairgrass also had the lowest cover of non-native species (Boise et al. 2013). In the same experiment, *Agrostis exerata*, seeded at 2.5 times the rate of *Deschampsia cespitosa* (41 seeds/per square foot), had average cover values per plot of only 6% 5 years after seeding (Amanda Taylor, unpublished data). This, and similar observations in grass buffer plantings in the West Eugene Wetlands, suggests A. exerata does not possess the long-term competitive ability of Deschampsia cespitosa when the two are co-seeded.

As a result of these observations, in the West Eugene Wetlands, in sites where non-native grasses, including agricultural grass crops, were the dominant species prior to site preparation, seed mixes are distributed the first two years that contain only forbs, sedges, and rushes (Appendix C). Competitive native grasses are excluded from the first two years of seeding to allow forbs, sedges, and rushes, an opportunity to establish. This staggered introduction also allows continued use of grass-specific herbicides in the first two years after seeding, to eliminate non-native grasses which remain in the soil seed bank (Wold et al. 2011). Slow-establishing grasses, such as *Danthonia californica* (California oatgrass) and *Dichanthelium acuminatum* var. *fasciculatum* (tapered rosette grass) could also be included during the first two years of seeding, but their presence would preclude the opportunity to broadcast grass-specific herbicides if needed to control non-native invasive grasses.

In addition to delaying seeding of the competitive wetland grasses *Agrostis exerata* and *Deschampsia cespitosa*, these species can be distributed in patches or broadcast over only half of the restoration site in their first seeding. Because native perennial bunchgrasses take several years to establish (Darris 2003), evaluations of grass cover should be timed for early fall, preferably of the second growing year, before additional grass seeding is scheduled. Significant grass growth can occur in the summer months in the Willamette Valley, thus earlier assessments in June may underestimate grass establishment.

Deschampsia cespitosa can often become dominant in a restoration project and result in low diversity.

Seed mix

5.3.1 Seed Ratios of Forbs to Grasses
Native grasses are an essential component of Northwest native wetland prairies (Sinclair et al. 2006). However, prairie restoration practitioners throughout the country are recognizing that easily available and strongly competitive native grasses can reduce overall native diversity if seeded too heavily (Dickson and Busby 2009, Pfeifer-Meister et al. 2012). Midwestern prairie restoration practitioners recommend forb to grass ratios that range from 2:1 by weight (Kurtz 2013), or 3:2 for forb-rich restored prairies (Packard and Mutel 2005), to suggestions that at least 40% of the total seeds distributed per square foot be forbs (USDA NRCS 2013; a 2:3 forb-grass ratio by seed density). In addition to sowing at lower seed densities than forbs, two other strategies to balance forb and grass cover are (1) geographically separating grasses and forbs (Schramm 1992; Dickson and Busby 2009) and (2) phasing their introduction (Pywell et al. 2003).

5.3.2 Calculating Seed Mixes by Seed Weight or Seed Number
Seeding rate is usually measured by weight per unit area (grams or pounds of seed per acre) or by number of seeds per unit area (seeds per square foot or square meter). Midwest prairie restoration practitioners also occasionally measure seed rates by volume, primarily when working with very large amounts of partially cleaned seed (Steinauer et al. 2003).

See Appendix C: Seeding Rates

→

for an example of single-year seed mixes and seeding rates successful in the West Eugene Wetlands

Measuring seeding rate by weight can lead to misconceptions if the scale of seed weight differences is not fully recognized. For instance, the native wetland prairie perennial grass *Deschampsia cespitosa* has about 18 times the number of seeds per gram as the native perennial grass *Danthonia californica* (Guerrant and Raven 1995).

Many prairie studies continue to use seed weight as the standard, rather than seed number, however, in part due to research from grasslands in Sweden that showed positive correlations between seed weight and establishment; that is, larger seeded species established better than smaller seeded grassland species (Jakobsson and Eriksson 2000). Whether this relationship holds true for Pacific Northwest wetland prairie species has not been studied.

It is obvious to the restoration practitioner that species establish at different rates, even given sowing of the same number of live seeds, due to competitive ability, selective herbivory/granivory and, potentially, the match between site conditions and seed source. To address this in a methodical way, Weber (1999) recommends developing an 'aggressiveness factor' for each species which takes into account the level of recruitment common in restoration settings. Although it does not include a factor for each species, Figure-5-2 and Appendix C draw on data from West Eugene Wetland wetland prairie restorations to identify those species which frequently have high establishment in a wetland prairie restoration setting.

5.3.3 Total Seeding Rate
Total seeding rates suggested in the Midwest for prairie restorations range from 4.5 lbs to about 10 lbs pure live seed (PLS) per acre (Steinauer 2003 et al.; Kilde and Fuge

2000). Others recommend 15 pounds per acre if percent seed viability is unknown (Kurtz 2013). Using seeds per unit area, several Midwest prairie practitioners recommend 40 to 60 pure live seeds (PLS) per square foot (USDA NRCS 2013; Packard and Mutel 1997), and suggest that seeding rates could be as low as 30 PLS per square foot when site preparation has been thorough (Packard and Mutel 1997).

Juncus species typically produce abundant, very small seeds. Many Northwest species have between 10 million and 30 million seeds per pound.

In the Willamette Valley, reported seeding rates for 3 wetland prairie restorations in the Portland Metro area ranged from 14 to 22 pounds per acre (Taylor 2011). In the West Eugene Wetlands, typical wetland prairie restoration seeding rates in recently retired agricultural fields are 9.9 to 12.7 pounds per acre, with that total distributed over 3 years (Wold et al. 2011). Although these are not calculated as PLS rates, viability is known for most species, so PLS rates would be 10-15% lower (9 – 11 lbs/acre). In the West Eugene Wetland seed mixes, this equates to 150 to 250 seeds per square foot distributed over 3 years (mixes with 50 to 90 seeds per ft2 per year for wetland prairie and 90 to 180 seeds per ft2 for vernal pools) (Steeck, unpublished data). In the West Eugene Wetlands, forb, sedge, and rush seed is typically broadcast in fall of years 1 and 2 and grass seed is broadcast or drilled with a no-till drill in fall of year 3 (Wold et al. 2011). Typical wetland prairie seed mix rates that have been successful in the West Eugene Wetlands are reported in Appendix C.

The seeding rates discussed above assume a thorough site preparation that has substantially reduced any non-native soil seed bank. In the West Eugene Wetlands these seeding rates have been successful in restoration sites retired from decades of grass seed production, making them relatively free of non-native species other than cropped *Lolium multiflorum* (annual ryegrass) or *Schedonorus arundinaceus* (tall fescue) which were controlled during one year of site preparation with glyphosate and during the first year of forb, sedge, and rush seeding with grass-specific herbicides (see Chapter 4.0).

In the West Eugene Wetlands, forb, sedge, and rush seed are typically broadcast in fall of the first two years of seeding and grass seed is broadcast or drilled with a no-till drill in fall of the third year.

Consider the recommended seeding rates of native species, above, as compared to levels of persistent seed in the soil of old fields and degraded prairies. One study of a degraded Willamette Valley wetland prairie, found that soil samples 5 cm deep contained on average 1,859 seeds square foot of which 40 percent were non-native (Wilson et al. 2004). This is approximately 750 seeds per square foot of non-native species.

In the same study, sowing native species at rates of 66 seeds per square foot (14.3 pounds per acre) in wetland prairie plots with prior treatments of burning, tilling, and solarization, resulted in native cover values of only 0 – 4 percent after 2 years as compared to unseeded species which contributed 58% cover (Wilson et al. 2004). Similarly, a study in coastal terrace prairie in California, a plant community which shares many of the same genera with Willamette Valley wetland prairie, concluded that seeding eight native grasses and forbs at a total rate of 376 seeds per ft2 in each of two years, combined with vegetation management (clipping and soil disturbance), increased native cover in only 2 of 8 species, a bunchgrass and a *Sisyrinchium* (blue-eyed grass) (Hayes and Holl 2011). These projects clearly demonstrate the need for effective site preparation to eliminate or significantly diminish the non-native seed bank prior to seeding native species.

5.4 Seeding Methods

Native prairie seed can be planted using a seed drill, which places the seed in the soil, or a seed broadcaster, which distributes the seed on the soil surface. Several books describe these seeding methods as they relate to prairie restoration in general (Steinauer et al. 2003; Packard and Mutel 2005). There is not consensus in the Pacific Northwest restoration community on the best method to sow native seeds of wetland prairie species, as there are advantages and disadvantages of both methods.

Seed drill

5.4.1 Seed Drills

Seed drills are used to increase soil-seed contact and meter out a precise amount of seed. In most cases, the wetland prairie restoration site will not have been recently tilled, to avoid disturbing a potential soil seed bank of non-native species, so a no-till seed drill is the preferred drill type. The no-till drill uses disks to slice a small furrow for the seed, followed by a wheel to press the soil over the seed, creating little disruption to the soil surface. Many restoration practitioners in the Willamette Valley use no-till drills, such as the Truax FLEX series, for sowing native grasses (e.g. the City of Eugene, the US Fish and Wildlife Service at Finley National Wildlife Refuge). Others report drilling both grass and forb seed into wetland prairies (Moore 2012; R. Fiori pers. comm 2013), for instance, seeding both grasses and forbs simultaneously by placing them in different bins of the drill and spacing grasses 4 feet apart with forbs in the intervening drill lines (R. Fiori pers. comm. 2013). Some practitioners report using broadcasting when soils are unvegetated, for instance, for first year seed mixes. They use drills to achieve better seed-soil contact primarily when seeding into existing vegetation or into a recently burned site with vegetation (C. Zonick pers. comm. 2013).

The no-till drill uses disks to slice a small furrow for the seed, followed by a wheel to press the soil over the seed, creating little disruption to the soil surface.

Advantages of using a no-till drill for sowing natives in wetland prairie restoration are that it provides excellent soil-seed contact and thus typically produces higher germination rates. Midwest restoration practitioners estimate it can double germination and establishment rates of upland prairie grasses and forbs as compared to broadcast seeding (Morgan 1997). Willamette Valley practitioners have made similar recommendations that some native grasses, such as *Danthonia californica*, can be drilled at half the seeding rate one would use for broadcasting (Darris and Gonzalves 2008).

Although it can improve establishment in some species, there are also disadvantages of drill sowing. Many plant species need light to germinate, so drill depths must be shallow. Drills can be expensive to purchase and difficult to transport (Steinauer et al. 2003). Seeding a comparable area takes substantially longer with a no-till drill than with an ATV and associated broadcast seeder, such as a Truax Seed Slinger. In addition, drilled plants establish in evenly spaced rows, lending a more 'artificial' appearance to the plant community initially. Researchers have theorized that competition may be greater in rows, however, in direct comparisons of composition, researchers found that seed planting depth, rather than later plant-plant competition due to seed arrangement, was the driver of composition differences between drilled and broadcast-seeded prairies in Iowa (Yurkonis et al. 2009). Boyer (2013) discusses several options for drilling and broadcasting seed to reduce competition between grasses and forbs and reduce the pattern of drill lines.

Deschampsia cespitosa planted using a seed drill

For wetland prairies, the weight of the tractor and drill can be a disadvantage. When drill seeding, soils should be firm to avoid compaction of wetland clay soils. If sowing must be delayed until after fall rains have softened soils, for instance when a fall herbicide application is needed prior to fall seeding, then broadcasting is the better method.

5.4.2 Other Drill Options

In small or sloped sites where use of a large seed drill is impractical, a couple options exist. The Dew Drop Drill has been designed to be pulled behind an ATV and therefore can maneuver through swales and other sloping lands. Its mechanism differs from the tractor mounted Truax drill in having cross disks in front of tines to provide the roughened soil surface, however, so it functions more similar to a broadcaster, in that the seeds are dropped on the roughed surface rather than being pressed into the furrow created by a no-till disk. Users in the Willamette Valley report that it probably works best on even ground where small machinery is needed. On uneven ground, broadcast seeding followed by harrowing may be more successful (J. Jabousek pers comm. 2013).

5.4.3 Broadcaster

Broadcast seeders mounted on an ATV have been used successfully for native wetland prairie forb, rush, sedge, and grass seeding. The Truax Seed Slinger is used by partners in the West Eugene Wetlands for seed broadcasting. Small sites may be broadcast with a hand held seed slinger, although some types tend to clog with seed of variable size.

Broadcast seeder mounted on an ATV

The advantage of broadcasting native seed is the shorter amount of time required for distribution, the ease of transporting smaller equipment to distant restoration sites, and the more dispersed, less consistent, pattern of plant establishment it promotes. Broadcaster-ATV combinations can also make tight turns, useful when planning for seeding of relatively small areas, and can be used in somewhat wetter conditions than seed drills. In addition, if the seed has a high level of chaff then a broadcaster will be needed, since the chaff can clog the drill tubes (Kilde and Fuge 2000). The disadvantage of broadcast seeding is the potential for reduced soil seed contact and increased seed predation by birds and small mammals, resulting in greater seed costs for similar establishment rates. For native grasses that are relatively inexpensive in the Willamette Valley (e.g., *Deschampsia cespitosa*,

Broadcaster

Agrostis exarata, *Hordeum brachyantherum* (meadow barley), the West Eugene Wetlands program has found broadcasting grasses provides variability in establishment with minimal additional seed costs.

It is useful to add a dry carrier, such as ground corn cob or rice hull (Darris 2005; P. Gordon pers comm. 2013) to native seed mixes to be broadcast sown. Suspending native seeds in a carrier prevents them from being dispersed too densely or unevenly due to widely varying seed size. In addition, the large size and light color of a corn cob carrier makes it visible on the soil surface, permitting more accurate distribution of the seed mix. Cracked grains and vermiculite are other carriers that have been used with native seed (Steinauer et al. 2003; Darris 2005; Boyer 2013).

5.4.4 Harrowing

Harrowing is a method of roughening the soil surface to promote seed contact with the soil. It typically involves dragging an implement with down-facing tines behind an ATV or tractor before or after broadcasting seed. Where a soil seed bank of non-native species is present, the tines may be pointed up to reduce the level of soil roughening. Harrowing is regularly used in Midwest prairie restorations, but is less commonly used in the Willamette Valley, due to concerns that disturbing the soil surface will stimulate germination of seeds of non-native species from the soil seed bank. The West Eugene Wetland program has had good success broadcasting seed in October on untilled wetland prairie restoration sites with no harrowing.

Harrow (photo credit: Ian Silverman)

5.4.5 Hydroseeding

Hydroseeding, in which seeds are mixed with a wet slurry of mulch fiber and applied as a spray, is sometimes used in restoration situations to stabilize seeds on slopes or where soils are unstable and access with other seeding machinery is difficult. Sinclair et al. (2006) reports its use in prairies of the Pacific Northwest, although no detail is provided. Dunn (1998) reports that hydroseeding requires high seed rates and that seed drying due to poor contact with the soil can be a problem. To combat drying, some restorationists suggest that seeding be followed by harrowing and that a second, light application of mulch be applied without seed (Morgan et al. 1995). Broadcast and drill seeding is effective for most seeding of native wetland prairies in the Willamette Valley. Except for very specific applications, high seed costs and potential establishment problems make hydroseeding unnecessary.

5.5 Challenging Growing Situations: Topsoil Removal and Soil Amendments

In situations where the top layers of soil will be excavated and in some cases where fill removal occurs, the restoration planner may be left with a subsoil that is not conducive to robust plant growth. This can result in stunted plant communities with substantial amounts of bare-ground surrounding them. While greater areas of bareground can be advantageous for native annual plant species that require openings in the wetland prairie community to persist, it can also benefit non-native invasive species that excel at colonizing bare soil.

Although vegetation remains stunted and sparse in wetland prairie restoration projects that used sod removal as a site preparation technique, the higher levels of surrounding bare soil may be conducive to nesting for some grassland birds.

For example, in several wetland prairie enhancements in the West Eugene Wetlands the primary site preparation technique consisted of removal of upland fill or removal of the top 4 – 6 inches of agricultural grass field sod. After topsoil removal, native seed was planted using a Truax drill. Native grasses and forbs established in most areas, but remain stunted, with plants typically under a foot tall, bare soil between them, and drill lines still visible 10 years after planting. While these plant communities have an undesirable appearance they do provide habitat openings that are difficult to maintain in more densely populated prairies. In all three cases in the West Eugene Wetlands, the bare soil has continued to provide colonization sites for native annuals, such as *Orthocarpus bracteosus* (rosey owl's clover) and *Microsteris gracilis* (slender phlox) or for reintroduced federally listed or sensitive species, such as *Horkelia congesta* (shaggy horkelia) and *Lomatium bradshawii* (Bradshaw's lomatium) (BLM 2008). In comparable West Eugene Wetland restoration sites where no soil removal occurred, low-growing annual species tend to disappear from the above-ground prairie plant community as the density of perennials increases, except following controlled ecological burns and at the vernal pool/wetland prairie interface where fluctuating inundation can maintain bare soils. Unfortunately, persistent open space due to topsoil removal also provides a colonization site for agricultural weeds, such as *Hypochaeris radicata* (false dandelion), either from the soil seed bank or from wind-borne seeds.

The stunted wetland prairie vegetation with higher levels of surrounding bare soil created by topsoil removal may, however, be conducive to nesting for some grassland birds. Streaked horned larks have been noted in one wetland prairie that was restored in 2002 using sod-removal techniques and currently supports low, relatively sparse vegetation (B. Altman pers. comm. 2013).

Most prairie restoration practitioners recommend against additions of compost or other soil amendments which may be high in nitrogen. Research with native plant species from the Pacific Northwest supports assertions that non-native invasive plant species often grow vigorously in high nitrogen conditions and native plant species are typically less effective competitors in these environments (Hough-Snee et al. 2011; Mangla et al. 2011). In addition, soil amendments are difficult to apply on a large scale and are likely to shift with surface water flow or inundation. Recently, preliminary work has begun to explore the use of carbon additions as a method to favor native prairie species in restoration settings (Gray 2013).

Numerous wetland prairie species require cold stratification or show increased germination rates following cold stratification. Fall seeding allow this to occur in the field.

5.6 Timing

Fall Seeding: Once site preparation is complete, rapidly establishing the native plant community with a fall seeding is beneficial to competitively repress or displace invasive non-native species that emerge from the soil seed bank or disperse into the restoration site from surrounding areas. A recent study compared the effects of timing on the relative growth and suppression of two native forbs and one bunchgrass planted simultaneously with non-native forbs and grasses (Grman and Suding 2010). When the two groups (invasive non-native and native) were planted together simultaneously, the non-natives inhibited growth of the natives, but the natives had little effect on the non-natives. However, when the same species of natives were introduced 5 weeks earlier than the non-native group, the growth of the non-natives was reduced by 85% (Grman and Suding 2010). This suggests that adding fall-germinating native seed by September, that can germinate following the first fall rains, may be important at sites with residual invasive species in the soil seed bank. Adding seed this early may be impossible in some cases, however. For instance, depending on site history, it may be necessary to delay seed-

Figure 5-6: ***Cold Stratification Requirements for Wetland prairie Species***

Species that require or benefit from cold stratification			
	Alopecurus geniculatus	*Acmispon americanus*	*Potentilla gracilis*
	Cammasia quamash	*Lupinus albicaulis*	*Micranthes integrifolia*
	Carex densa	*Lupinus polyphyllus*	*Micranthes oregana*
	Carex leporina	*Madia elegans*	*Sidalcea campestris*
	Carex unilateralis	*Madia gracilis*	*Trifolium wildenovii*
	Deschampsia cespitosa	*Navarrretia intertexta*	*Toxicoscordion venenosum var. venenosum*
	Epilobium densiflorum	*Orthocarpus bracteosus*	*Veronica americana*
	Eriophyllum lanatum	*Phlox gracilis*	*Wyethia angustifolia*
Species that germinate well without cold stratification (>85% germination)			
	Camassia leichtlinii ssp. *suksdorfii*		
	Geum macrophyllum		
	Hordeum brachyantherum		
	Prunella vulgaris var. lanceolata		
Species with moderate-high germination without cold stratification (50%-84% germination)			
	Allium amplectens	***Rumex salicifolius***	
	Carex aurea		
	Downingia elegans		
	Grindelia integrifolia		
	Myosotis laxa		

Data from Drake and Ewing 1997; Guerrant and Raven 1996, Wilson et al. 2004, Russell 2011.

ing until after the first fall rains and flush of seedlings to determine if site preparation techniques have sufficiently controlled non-native species.

Seed germination of native forb species shown at the end of November

Some practitioners have suggested seeding in early spring. There are no controlled, replicated comparisons of plant community composition following fall versus spring sowing in Pacific Northwest wetland prairies. However, numerous wetland prairie species require cold stratification (a period of several weeks to months of cold wet conditions) or show increased germination rates following cold stratification (Figure 5-6).

In addition to those included in Figure 5-6, the germination response of these wetland prairie species varied between studies: *Danthonia californica*, *Lomatium nudicaule*, *Perideridia oregana* (Oregon yampah) and *Wyethia angustifolia*. It's unclear if the varying results are due to differences in populations, seed storage conditions, or other factors.

The need for cold stratification indicates that fall is the best time to seed a native wetland prairie unless a specific suite of species is desired that lack cold stratification requirements. In cases where a weed control action makes a spring planting in one portion of the site necessary, species can be selected from among those that had relatively high germination in the absence of a cold stratification period in at least one study.

Lomatium nudicaule (barestem biscuitroot)

Multiple Seeding Events: Planning for multiple seeding events over two to three years reduces the risk that annual variation in weather will substantially disrupt establishment of the native plant community. Delvin (2013) recommends following a scaled approach to prairie restoration, using small scale replicated plots to initially test local site conditions and restoration strategies, prior to implementing restoration on a larger scale. He found large variation in restoration outcomes due to annual variation in weather and to site differences, even when similar restoration treatments were employed. Incoporating multiple seeding events into the restoration strategy is one method of reducing the risks of annual weather variation.

The West Eugene Wetlands program uses an approach that involves seeding forbs, sedges and rushes in the first two years, splitting the seeding to ensure that if environmental conditions are unusually harsh in one year, a second opportunity for establishment exists. This is followed by addition of the more competitive native grasses over a portion of the restoration site (Wold et al. 2011). Grass seeding may also be split across two years to allow monitoring of establishment rates for a given site. Less competitive grasses, such as *Danthonia californica* or *Dichanthelium acuminatum* var. *fasciculatum*, may be introduced earlier, with forbs, although this would preclude the use of grass-specific herbicides which can be useful if non-native invasive grasses are continuing to emerge from the soil seed bank.

Vole trail

5.7 Seed Predation and Herbivory

Seed and plant predation by small mammals, particularly Microtus species (voles), birds (including geese), and molluscs (slugs and snails) may play a significant role in limiting the number and abundance of plant species that establish in wetland prairie restoration projects. Voles, in particular, have been found to significantly influence wetland prairie plant communities in the Midwest and they achieve high abundance periodically in Pacific Northwest prairies (Verts and Carraway 1998).

Voles are herbivores that feed on grasses and forbs, and are most commonly reported to feed on stems and leaves, rather than fruit or seeds. Plant species reported as common in the diet of *Microtus canicaudus* (the gray-tailed vole), include grasses, *Trifolium* sp. (clovers), *Allium amplectens* (wild onions), and *Hypochaeris radicata* (Maser and Storm 1970 as reported in Verts and Carraway 1998). Voles also feed on rare wetland prairie species, such as Lomatium bradshawii (Drew 2000). Research shows that vole densities in commercial grass seed fields in the Willamette Valley can exceed thousands of individuals per hectare (Edge et al. 1995).

Research in Illinois wetland prairie restorations shows that voles can substantially alter plant community composition. In a 4-year exclusion experiment, vole herbivory almost eliminated a common legume and grass species, which promoted an increase in other prairie species not preferred by voles (Howe and Lane 2004). No similar research has been published for Pacific Northwest prairies.

Diverse native forb seed is expensive, so finding ways to reduce seed losses would likely improve establishment and reduce restoration costs. Providing raptor perches in the restoration in the form of snags or wooden posts may increase predation on vole populations, although attempts to cause a similar increase using barn owl nesting boxes in Willamette Valley grass seed fields was not successful (Gervais and Young 2009).

5.8 Supplemental Plantings

Planting of species as bulbs, plugs, or other container material is most effective in the first two years of the restoration. The first year offers the greatest amount of bare substrate and therefore would typically offer the greatest establishment. However, splitting the planting between the first two years ensures that if climate or other environmental conditions are unusually harsh in one year, a second opportunity for establishment exists.

In the Willamette Valley, planting should occur after fall rains are frequent enough to provide consistent moisture and have wetted soils (e.g., November 1) and before mid-March to allow sufficient rooting prior to summer dry weather. Detailed recommendations for selecting healthy native container plants can be found in the guide "An Introduction to Using Native Plants for Restoration Projects" (Dorner undated), which also contains detailed tips on planting container and plug material.

5.8.1 Bulb-forming Species

Bulb-forming wetland prairie plants, such as species of *Camassia*, *Allium*, *Brodiaea*, and *Toxicoscordion* (death camas), have a high fidelity to prairies, but can be difficult to establish in restorations (Wold et al. 2011; E. Alverson unpublished data). Three methods to establish these species in prairie restorations are direct seeding, planting of bulbs grown from seed for 2 or 4 years in a nursery setting, and planting of bulbs salvaged from a site to be destroyed.

Toxicoscordion venenosum
(death camas)

Direct Seeding:

One of the problems encountered when direct seeding these species into restorations is low establishment. There are several reasons for an actual or perceived failure to establish following seeding:

- Seeding rates are too low. Because peak seed production of these species may require 5 or more years in a nursery setting, seed is expensive and requires a long lead time for a nursery to produce. These factors frequently result in initially high cost, low seed purchases, and consequently low seeding rates.
- Young plants are extremely small for 3 to 5 years and may succumb to competition from surrounding vegetation prior to reproducing. *Cammassia quamash* ssp. *maxima* (common camas) are only about 2 inches tall their first growing season and resemble a single blade of grass.
- Plants may go unnoticed during early monitoring, due to the 3 to 5 year period between seeding and first flowering and the grass-like appearance of non-flowering plants. Even after they reach flowering size, bulb-forming species frequently experience periods of dormancy of 1 or more years, with no visible above-ground parts, making it difficult to accurately quantify establishment.

Allium amplectens
(slim-leaf wild onion)

Direct seeding into wetland prairie restorations has had varying results for several bulb-forming species in the Willamette Valley:

- Anecdotally, *Allium amplectens* (slim-leaf wild onion) has established well from seed in at least one wetland prairie location at The Nature Conservancy's Willow Creek Preserve (J. Nuckols pers comm. 2011).
- Several studies suggest *Camassia quamash* establishes well from seed in wetland prairie restorations.
- The West Eugene Wetlands program has had limited success establishing populations of Toxicoscordion venenosum var. venenosum and Brodiaea elegans in wetland prairie settings from seed or 3-year old bulbs.

One method to increase the likelihood of success is to sow seed into marked plots placed throughout the restoration rather than including the seed at lower rates in large seed mixes. This has several advantages:

- Increased seeding rates are possible, due to the small area. Ideally this will

result in a population with a flower display large enough to attract pollinators and with individuals near enough to one another to promote successful pollination and seed production.
- Seeding of other prairie species can be selective, with lower rates of a few short-statured or annual species, to limit competition in these areas.
- Management methods, such as control of invasive species, can be designed to avoid adversely affecting the survival of the target geophytes within the marked plots.
- Success can be more easily tracked.

Bulb Planting:
- A small unreplicated project comparing seed and 3-year old bulbs of *Brodiaea*, *Allium*, and *Toxicoscordion* species in a wetland prairie restoration, found that the 3-year old nursery-grown bulbs performed poorly. However, the 3-year old *Allium amplectens* and *Toxicoscordion venenosum* var. *venenosum* bulbs grown without greenhouse conditions and fertilization were very small (1/4” – 1/2” diameter) and the surface flow of water in winter may have eroded soil from the small bulbs, reducing survival (Steeck unpublished data 2012).
- One difficulty when introducing containerized or bare-root bulb-forming species 2 to 3 years old is identifying the appropriate planting depth that will be adequate to allow the bulbs to escape predation (e.g., from rodents) and persist through the summer dry season, while avoiding adverse effects of extended inundation in winter and spring. Bulbs at this stage are still producing contractile roots to position themselves at an appropriate soil depth, so likely can make some downward movement themselves after planting. Even for small bulbs, planting must be deep enough to avoid exposure due to soil loss from surface water flow in wetland prairie restorations.
- Rodent predation on newly planted bulbs can be extensive. Other practitioners, however, report good results in transplanting mature *Camassia* bulbs from natural situations from which they are being salvaged (C. Hoffman pers. comm. 2013).

Camassia leichtlinii in grow-out bed

5.8.2 Establishing Camas

Camassia quamash ssp. *maxima*. and *Camassia leichtlinii* ssp. *suksdorfii* are two important members of wetland prairie plant communities. They begin flowering in April, providing one of the earliest spring sources of nectar and pollen. They are visited by a wide variety of insects, including native bumblebees, solitary bees, and bee flies (Kephardt et al. 2008) and are a nectar source for the endangered Fender’s blue butterfly. They also have cultural significance as a historically important food plant for native peoples of the Northwest.

Camassia bulbs occur at depths of 2 - 8 inches (*Camassia quamash*) to 16 or more inches (*Camassia leichtlinii* ssp. *suksdorfi*i) below the soil surface at maturity (Stevens et al. 2000). Reproduction by bulb division is more commonly reported for *Camassia leichtlinii*, while *C. quamash* is described as either not reproducing by offsets or very rarely doing so (Thoms 1989 as reported in Stevens and Darris 2006; Alverson 2012). *Camassia* species require 4 or more years to first initiate flowering (Darris and Northway 2012). In one study of *Camassia quamash* ssp. *maxima* in a wetland prairie restoration, less than 5% of plants flowered in their 4th growing season and about 22% flowered their 5th year, although flowering proportion by plot was highly variable in year 5, ranging from 1% to 48% (Steeck 2014).

Container-grown *Camassia* showing contractile root, which bulb-forming species use to position themselves in the soil.

Camassia species can be introduced to a restoration site either as a bulb or seed. Two recent studies suggest that seeding *Camassia quamash* ssp. *maxima* is an effective method to establish this species in wetland prairie restorations in the Willamette Valley if sufficient seed is available (Steeck 2014; Darris and Northway 2012). In one study, *Cammasia quamash* ssp. *maxima* was seeded into a restoration site previously in agricultural production that had one year of site preparation, with very little weed cover (Steeck 2014). Results indicated:

- Seeding Camassia by itself, without other plant community members, at 20 lbs/acre as compared to 10 lbs/acre resulted in only about a 42% increase in plants established after 5 years in the 20 lbs/acre plots, even though the higher seeding rate was double the lower rate.
- Seeding *Camassia quamash* ssp. *maxima* only with the native annual *Epilobium densiflorum* (dense spike-primrose) improved its establishment over seeding Camassia alone in bare soil. It is unknown in what way *Epilobium* facilitated *Camassia* survival.
- About 1% to 3% of the *Cammasia quamash* ssp. *maxima* sown as seed survived to flower and reproduce at age 5.

Another study compared the effects of site preparation treatments on establishment of *Camassia quamash* ssp. *maxima* and C. *leichtlinii* (Darris and Northway 2012). It concluded:

- Sowing seeds on the soil surface was as effective as raking them in or adding mulch in terms of survival and establishment after 9 years.
- When sown into unprepared areas dominated by non-native grasses, there were no significant differences in establishment after 9 years between rates of 20 vs 60 seeds per square foot. This suggests the availability of safe sites for germination and growth was a limiting factor rather than seed availability.
- Site preparations such as mowing, burning, and tilling all seemed to improve establishment when compared to sowing into control areas, although the study was not specifically designed to make such a comparison.
- About 6% – 8% of seeds sown survived to 9 years, although variability in survival was high in some locations.
- *Camassia quamash* ssp. *maxima* established better in upslope areas without inundation than it did in areas that had soil surface ponding until April and were 4 – 8 inches lower in elevation.

5.9 Control of Invasive, Non-native Plant Species During Initial Establishment

As indicated in Chapter 4, effective control of non-native invasive plant species during site preparation is one of the most critical factors in the success of a restoration. However, even with excellent site preparation, non-native species will appear and persist. For example, in West Eugene Wetland Mitigation Bank wetland prairie restorations in their fifth year of monitoring, staff found 24 to 38 non-native vascular plant species in sites that were 20 to 40 acres in size, although cover by non-native species was less than 10% (City of Eugene 2010, 2011, 2012b, 2013). Control actions during the first five years following first seeding focused on 10 - 15 species in any given year, typically those that had been problematic in previous restoration settings or in prairie remnants.

Budgeting for aggressive control in the first several years after seeding, while populations of non-native species are small, is one of the most effective uses of limited funding for invasive species control. Two key aspects of weed control in these early stages are ensuring weed control actions are appropriately timed and that they are frequent enough to address the range of invasive species that may emerge on a site.

With a limited budget, determining which species should be controlled in the first few years after initial restoration seeding is essential. Several assessment tools and strategies for prioritizing control of invasive species in wildland settings are available: Hiebert and Stubbendieck 1993, Buck et al. 2011, Zimmerman et al. 2011. These strategies focus on evaluating the impacts of invaders and identifying the objectives and effectiveness of potential control methods. The species which will be most problematic in a given Willamette Valley wetland prairie restoration will vary, due to a given site's specific hydrologic regime and initial conditions when large amounts of bare soil are exposed. In general, rhizomatous species, such as *Rumex acetosella* (sheep sorrel) and *Agrostis capillaris* (colonial bentgrass) and those that also produce copious, easily transported seed, such as *Mentha pulegium* (pennyroyal) (Warner 2000) are particularly problematic.

Buffer of aggressive native perennial grasses planted along perimeter of restoration area at Coyote Prairie to limit weed invasion

5.9.1 Buffer Planting to Limit Weed Invasion

New restoration sites can be strongly influenced by activities and organisms that occur just beyond their boundaries, on adjacent land (edge effects). In Willamette Valley wetland prairies these range from the flow of waterborne pollutants to the arrival of waterborne and airborne seeds of non-native invasive species.

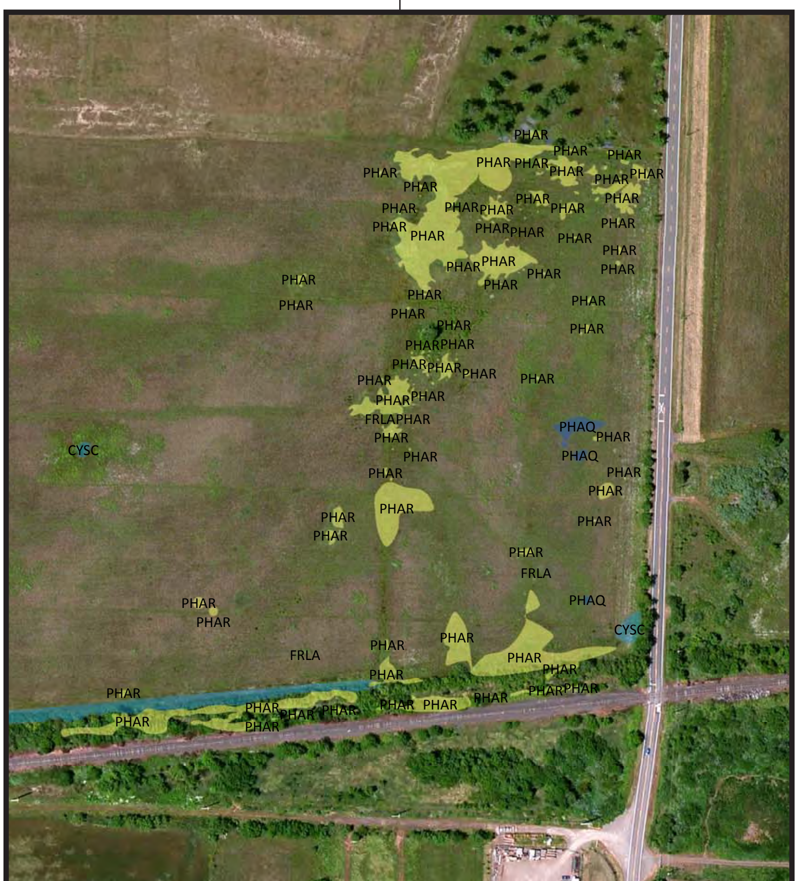
Anticipating and addressing the potential flow of negative influences across site boundaries is an important step in planning for the long-term integrity of a restoration. The restoration planner can use specific plant groupings, referred to here as "buffer plantings," to ameliorate some of these negative effects. For restoration sites that are bounded by agricultural wetlands, or along boundaries with abundant invasive forbs, one strategy is to plant a 15 to 30 foot buffer of dense competitive native wetland prairie grasses along the site's perimeter. Some practitioners have found effective buffers can be composed of the commonly available native wetland prairie grasses *Deschampsia cespitosa* (for sustained high cover) and *Agrostis exerata* (for rapid early growth), drilled at a rate of 8 lbs/acre, combined (over 700 seeds/ft2; City of Eugene 2009). Inclusion of other less competitive native grasses (such as *Hordeum brachyantherum* and *Danthonia californica*) with *D. cespitosa* and *A. exerata* at these rates has not resulted in the establishment of the less competitive species. The resulting region of native grasses provides high cover, including thatch over the soil surface, to repel colonization by non-native plant species. The height of flowering *D. cespitosa* may also help impede low-drifting airborne seed. In addition, if invasive non-native forbs do become established in the buffer, they are easier to locate during hand weeding due to the buffer's low plant diversity or they can be controlled with a broadleaf-specific herbicide that will not affect the surrounding grass matrix.

To repel adjacent non-native invasive grasses, buffers with the appropriate hydrology could potentially be composed of sedges and rushes, such as *Juncus occidentalis* (western rush), *Carex densa* (dense sedge), *Carex stipata* (one-sided sedge), and *Carex unilateralis* (awl-fruit sedge). Although there are no publications suggesting this has been tried, these sedge species can develop large overlapping leaf areas and their presence would still allow the use of grass-specific herbicides.

5.9.2 Other Control Strategies During Initial Establishment

In addition to buffer plantings and focused seeding of competitive native species on problem areas, other strategies to control invasive non-native species include the following:

<u>Weed assessments</u>: Conduct weed assessments, followed by effective manual, mechanical, or chemical control, 3 or more times in the first year (e.g., November, May, July). Repeated assessments in the first year are used to track abundance, maturation, and control windows for the most challenging species, such as the early-flowering annual grasses *Vulpia myuros* (rattail fescue) or *V. bromoides* (brome fescue) that may mature and disperse seed as early as May. Frequent visits will help identify the optimal control window, based on phenology and environmental conditions (e.g., soils moist enough for hand-pulling). GPS can be used to create maps to direct contractors or staff weed-control crews or track weed control results.



Sample of weed mapping

<u>Manual/mechanical control</u>:
Identifying the best timing for effective manual control requires experience with the target non-native species and close attention to site conditions to determine:

- Variation in seed maturation times that may occur due to annual weather variation.
- Whether soils are soft enough to allow hand-pulling. Weeding crews can remove shallow-rooted or tap-rooted species that are easy to hand-pull when soils are moist, such as *Echinocloa crus-galli* (barnyard grass), *Daucus carota* (wild carrot),

and *Rumex crispus* (curly dock).

- Whether a non-native species will have sufficient energy and appropriate growing conditions to re-sprout and flower if cut. If seeds will be viable if cut material is left on the site, bagging and removal of material for off-site disposal is necessary.
- Willamette Valley spring rains frequently interfere with use of herbicides, particularly in April and May when plant growth rates are high, but rains are still frequent. In this case, hand-held motorized weed cutters or whips may be necessary to remove seed of annual species, such as *Vulpia myuros*, prior to seed maturation, but late enough in the growing season that re-flowering is precluded.

Spot spraying with glyphosate based herbicide

Chemical control:

- Use of spot applications of broad spectrum glyphosate-based herbicides requires consideration of whether there are adequately trained applicators who can identify the target species and avoid native species, if the herbicide will work rapidly enough to stop seed maturation, and if weather (temperatures and precipitation) and site conditions are sufficiently dry and warm to allow chemical control. A recent thorough review of the herbicide Glyphosate and associated surfactants can be found in Durkin 2011.
- Small applications of guild-specific herbicides, such as those with active ingredients Clethodim, Sethoxydim, or Fluazifop to target non-native grasses and Triclopyr formulations to control broadleaved species can be useful to allow surrounding native species of other guilds to establish. The use of grass-specific herbicides still allows the introduction of native graminoids, such as Juncus and Carex, while non-native grasses are being controlled.

Spray buggy applying grass specific herbicide in the season prior to the seeding of the native grasses

Useful Web Resources

Summarized evaluations of herbicides:

Thurston County Noxious Weed Control Agency: http://*www.co.thurston.wa.us/health/ehipm/terrestrialreview.html*

Integrated pest management handbooks:

Oregon State University Integrated Plant Protection Center: *http://www.ipmnet.org/*

5.10 Wildlife (habitat features and processes)

Due to the ease and regulatory importance of monitoring plant populations and their critical importance at the base of food webs, plant establishment is typically the initial focus of restorations. This guide does not address the direct introduction of animal species to wetland prairie restoration sites. However, it is important for the restoration planner to consider the specific habitat features needed by target wildlife species, including those of local conservation concern, to ensure that wetland prairie processes and structures are included and maintained that will attract and support diverse native animal communities. Habitat features that should be considered are listed below:

5.10.1 Plant Seasonality

To support a diversity of native nectar- and pollen-feeding invertebrates and seed-eating bird populations, wetland prairie restoration plantings should include native plants that flower and mature seed through the majority of the growing season, from April through October. The typical flowering period of many native prairie species in the Willamette Valley has been compiled by Newhouse (B. Newhouse, unpublished data).

Butterfly species are often closely adapted to specific host plants for larval food and shelter. To benefit butterfly species of conservation concern that depend on wetland prairie in the Willamette Valley, such as the Great Copper butterfly (*Lycaena xanthoides*) and the field crescent butterfly (*Phyciodes pulchella* nr. *pulchella*) (Schultz et al. 2011), the restoration planting plan should include populations of both the larval host plant species and a diversity of nectar-producing plant species that flower during the adult butterflies flight season, which in some cases may be only a few weeks. The habitat needs of butterflies provide an excellent example of the importance of plant diversity, particularly in large restorations. Because plant species vary in the quality and abundance of nectar they produce, consistency in flowering annually, and response to climate change, a diverse assemblage of nectar-producing plant species will be more likely to provide continuing adequate nectar resources for animal populations.

Useful Web Resources

Other sources of information on Willamette Valley plant-insect relationships, include:

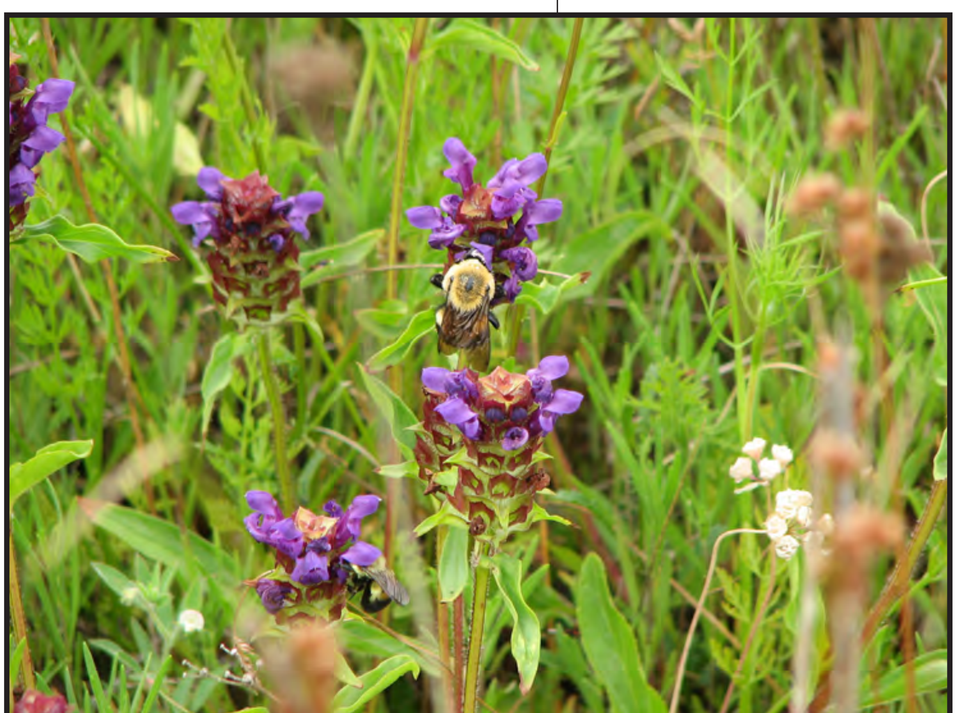
Oregon Plants for Pollinators list from NRCS: *http://plants.usda.gov/pollinators/NRCSdocuments.html*

List of WV native host plants and butterflies: *http://www.salixassociates.com/resources.html*

Plant Seasonality: Information provided by Salix Associates at: *http://www.salixassociates.com/resources.html*

5.10.2 Low-growing Herbaceous Vegetation

Regions of low-growing plants (less than 2 feet tall) interspersed with openings of sparsely vegetated or prostrate vegetation are important for breeding grassland bird and for foraging butterflies in wetland prairie restorations.



Bumblebee on *Prunella vulgaris*

Based on research on western meadowlarks in the Willamette Valley, a current "working" definition for meadowlark habitat of moderate to high quality, includes herbaceous forb cover of greater than 15%, and three categories of graminoid cover: 25% averaging less than 12 inches tall, 50% averaging 12 – 24 inches tall, and 25% being greater than 24 inches tall. Similar to recommendations for maintaining plant diversity, additional recommendations for habitat structure that will support breeding western meadowlarks includes: (1) creating forb-rich, non-uniform plant communities, with multiple height classes, (2) minimizing high densities of tall-statured grass species, such as *Deschampsia cespitosa*, and

Diversity of plant heights at Coyote Prairie

(3) retaining bare ground of greater than 5% (Altman et al. 2011; Blakely-Smith and Altman 2013). For Willamette Valley grassland birds in general, recommendations are for 10 – 30% forbs and at least 3 species of grasses (Oregon Department of Fish and Wildlife, undated). Other grassland birds of conservation concern in Oregon that regularly forage or breed in wetland prairies in the Willamette Valley include northern harriers (*Circus cyaneusand*) and streaked horned larks (*Eremophila alpestris strigata*), the latter of which prefers unvegetated openings within low-statured, treeless prairies.

Low-statured vegetation that is free of tall, non-native invasive grasses, has also been identified as important to several butterfly species in Pacific Northwest prairies (Schultz et al. 2011). Recent research concluded that tall non-native grasses reduced egg-laying behavior in Fender's blue butterfly and interfered with access to high quality basking sites (Severns 2007).

Two native grass species that can be combined with forbs to provide a low-statured plant community are *Danthonia californica* and *Dichanthelium acuminatum* var. *fasciculatum*. Although *Dichanthelium acuminatum* var. *fasciculatum* is not available yet in the Willamette Valley, restoration practitioners in the West Eugene Wetlands are beginning to experiment with it in restorations.

Useful Web Resources

For landowner guides and recent federal publications about Willamette Valley grassland birds:

Oregon Department of Fish and Wildlife Grassland Birds:
http://www.dfw.state.or.us/conservationstrategy/grassland_birds.asp

US Fish and Wildlife Streaked Horned Lark:
http://www.fws.gov/oregonfwo/Species/Data/StreakedHornedLark/

5.10.3 Bare Soil

Both native bees and some bird species use bare soil for nesting or foraging. The majority of native bees in the United States are solitary and nest in the ground. Ground-nesting bees typically prefer bare soils that are well-drained and on south-facing slopes with species preferences varying from flat to almost vertical slopes (USDA 2007). Such areas could be created on the upper extent of berms or existing upland adjacent to wetland prairie restorations or enhancements.

Native bees nesting in bare soil

Birds will also use areas that lack vegetation or support prostrate vegetation, either for winter foraging, in the case of waterfowl or shorebird use of inundated areas or for nesting. In the Willamette Valley, if soils dry by March or early April and if landscape conditions are appropriate, bare areas may also attract breeding streaked horned larks. Streaked horned larks, a federally threatened species, prefer landscapes without trees and with patches of bare soil or very sparse vegetation (Moore 2013).

Bare soil may be an ephemeral and shifting phenomenon in a wetland restoration, resulting from overland water flow, inundation, or controlled ecological burns. Although bare soil in a matrix of the wetland prairie community has values for wildlife, bare sites are also likely to be colonized by invasive non-native plant species. Therefore, they provide a challenge to maintain in an unvegetated state. The level and type of maintenance required to sustain these areas in the desired state should be carefully considered when defining restoration goals and incorporating this feature in a restoration.

5.10.4 Vernal Pools

Vernal pools in the Willamette Valley consist of shallow, precipitation-fed, inundated areas, underlain by a clay pan or other impermeable geologic substrate, that hold water for weeks to months in the winter and spring. Willamette Valley vernal pools are often surrounded by wetland prairie, unlike vernal pools in southern Oregon and farther south in the California Floristic Province, which typically occur within an upland plant community. Vernal pool plant genera that occur in both California and Pacific Northwest vernal pools include *Lasthenia* (goldfields), *Downingia*, *Eryngium* (coyote-thistle), *Plagiobothrys* (popcorn flower), *Gratiola*, and *Navarretia* (NatureServe 2014, Barbour et al. 2007).

Constructed vernal pool at Coyote Prairie

Vernally inundated areas in the Willamette Valley also support numerous freshwater micro- and macro-invertebrates, such as cladocerans, ostracods, copepods, flat worms, snails, and insect larvae such as those of caddisflies and dragonflies (Wille et al. 2003, Wyss 2011). Many aquatic organisms have relatively short aquatic life cycles and persist as dormant eggs or cysts during the dry season or have mature life stages that exit the pool as it dries. Even pooled water only 2 - 3 inches deep can support high density invertebrate communities in the Willamette Valley (Wyss 2011). In addition to being important in their own right, vernal pools with substantial aquatic invertebrate populations are an important food resource for waterfowl, shorebirds, songblongirds, and amphibians.

Pacific chorus frog

Vernal pools in restored Willamette Valley wetland prairies have been documented to support breeding amphibians, such as long-toed salamanders (*Ambystoma macrodactylum*) and Pacific chorus frogs (*Pseudacris regilla*), within the first two years of pool creation when colonization from adjacent lands is possible (City of Eugene 2012a). In the Willamette Valley, these two amphibian taxa breed in January and February *(A. macrodactylum*) or February and March (*P. regilla*) and require 2 – 5 months to metamor-

Long-toed salamander

Threespine stickleback (Photo Credit: Jeffrey S. McKinnon, University of Wisconsin-Whitewater)

phose (USGS 2004). Providing shallow pools that are inundated from January through April or May most years should support these taxa. Other recommendations for creating pools that support native amphibians are to avoid creating connections to permanent streams or wetlands (to avoid presence of non-native predatory fish), and to create pools shallower than 0.75 m (USGS 2004).

5.10.5 Swales and Intermittent Drainages with Connections to Permanent Water

Existing drainages that occur in Willamette Valley wetland prairies that connect to river channels can be important temporary habitat for fish. Mid-Willamette Valley intermittent streams and drainages, including those in grass-seed fields of the Calapooia, Mary's, and Long Tom Rivers, and Muddy Creek, have been found to support a surprising abundance of native fish fauna (Colvin et al. 2009). The three most abundant species found in a study of these ephemeral drainages in winter and spring were the Threespine stickleback (*Gasterosteus aculeatus*), redside shiner (*Richardsonius balteatus*), and reticulate sculpin (*Cottus perplexus*). These drainages, with their significant connection to rivers or large streams, provide winter and spawning habitat for adults and nursery habitat for juveniles of some species and may be critical sites to escape non-native predaceous fish (Colvin, et al. 2009; Gianico et al. 2005). Although recommendations to conserve this habitat are not specific to wetland prairie restorations, several would apply in a restoration setting, such as:

- Maintaining connectivity to downstream perennial water if it exists,
- Retaining the seasonal, non-perennial nature of the drainage,
- Reducing in-stream barriers to fish passage,
- Enhancing habitat components that support aquatic invertebrates, the primary food of the four most common fish species found (Colvin, et al. 2009; Gianico et al. 2005).

5.10.6 Downed Wood

Although prairies have sparse woody resources, it is likely that historical annual flooding of rivers and associated drainages periodically carried small-diameter wood into wetland prairies. In the highly modified systems that are the basis for wetland prairie restorations today, downed wood provides nesting and sheltering locations for species which historically may not have depended on it in wetland prairie communities.

Wood on the soil surface can be important habitat for insects, including acting as nesting locations for bees, termites, and wood-boring insects. In a study of native bees in the West Eugene Wetlands, 78 different bee taxa in 18 genera were found in remnant and restored wetlands. One of the restored wetland prairie sites, Dragonfly

Bend, had high species richness with 52 bee taxa collected. Downed wood, in the form of large stumps with root wads which supported bee nesting, was considered one of the factors likely contributing to the high bee diversity at this restoration site (Bergh et al. 2010).

Wood placed in recently constructed vernal pool

Downed wood also provides sheltering locations for amphibians, reptiles, and small mammals. The high temperatures and dry conditions of Willamette Valley wetland prairies in mid-summer increase the importance of sheltering locations, particularly for recently metamorphosed amphibians, with their small body size and high need for moisture. While many amphibians shelter in the burrows of small mammals, few other sheltering locations may exist in previously farmed sites. In one southern Willamette Valley wetland prairie restoration site, amphibians were found sheltering under temporary erosion control materials and bags left on the ground for just a few days, probably due to the severe lack of sheltering habitat in the initial stages of the restoration (City of Eugene 2012a). Wood in vernal pools can provide alternative surfaces for aquatic invertebrates to shelter, forage, and lay eggs. In general, downed wood with some intact bark will provide more crevices for sheltering.

In wetland prairies, as decay breaks down large downed wood, it will need to be replaced. In addition, when controlled ecological burns are planned, large downed wood should be protected or replaced. Maintaining adequate sheltering areas may be critical to retain amphibian populations during harsh post-fire conditions.

Snag installation

5.10.7 Snags and Other Perches

Snags, or standing dead trees, are important breeding habitat for cavity nesting birds in the Willamette Valley, such as woodpeckers, nuthatches, bluebirds, and swallows (Gumtow-Farrior 1991). Snags also provide roosting habitat for bats (Taylor 2006), provide foraging locations for songbirds and woodpeckers, and perches for raptors and fly-catchers. Some Willamette Valley prairie species, such as breeding streaked horned larks, will avoid landscapes with trees; it is not clear if this also applies to snags, but it seems likely given that lark predators include birds such as raptors and crows that may favor snags as perch sites (USFWS 2010).

Snags may occur in buffers and boundaries adjacent to a prairie restoration site and are an important resource that should be retained unless the specific goals of the restoration conflict with snag retention. Large diameter oak snags were found to supply many more bird nesting cavities than big-leaf maple and Douglas-fir snags in the Willamette Valley and larger snags are generally considered to have greater value for bats than smaller snags and to retain bark longer, providing additional roosting habitat (Taylor 2006). If absent from a prairie restoration, and consistent with the site's goals, snags can be created from live trees or brought to the site and installed.

Rosa nutkana (Nootka rose)

5.10.8 Shrubs

Shrubs in a prairie matrix provide structural diversity, food sources in the form of seeds or berries, over-wintering locations for invertebrates in pithy stems, and bird nesting sites and perches for territorial displays or flycatching. Western meadowlarks prefer positions slightly higher than the surrounding prairie vegetation for calling and singing and thus will use shrubs or low trees. Posts, snags, and downed wood are also used by western meadowlarks as perches (Oregon Conservation Strategy 2006). Chipping sparrows (*Spizella passerina*) a potentially declining species in the northern Willamette Valley (Altman 2011) nest low in shrubs or trees, whereas savannah sparrows are typically ground-nesting species, but will occasionally nest in low shrubs.

In tall grass prairie habitats in the Midwest, researchers have found that some snake species preferentially rest in shrub habitats and may prey on grassland bird eggs (Klug et al. 2010). For those prairies, where grassland bird conservation is a goal, they recommend keeping shrub cover at under 5% or less of total prairie area (Klug et al. 2010). Given the conservation status of several Willamette Valley grassland birds and their need for only scattered shrubs (Oregon Conservation Strategy 2006)), planners of wetland prairie restorations in the Willamette Valley should consider even less shrub area – for example, no greater than 2% of prairie area in shrub cover.

Western meadowlark perched on willow (photo credit: Cary Kerst)

Species to consider for small shrub clusters in Willamette Valley wetland prairie restorations include:

- *Rosa nutkana* (Nootka rose)
- *Spiraea douglasii* (Douglas spiraea)
- *Amelanchier alnifolia* (service berry)
- *Salix lasiandra* var. *lasiandra* (Pacific willow)
- *Salix hookeriana* (coastal willow)

These native species have all been documented to occur in or adjacent to the Valley's wetland prairies (Alverson 1993; Pendergrass 1995). In the right hydrologic conditions, *Salix* species (willows) can be prolific colonizers, so a maintenance strategy may be needed to keep them at desired cover levels.

5.11 Monitoring During the Establishment Phase

Assessing the progress and success of a wetland prairie restoration is an ongoing process, but it is particularly important in the early phases of a project, when tailoring restoration strategies to the unique conditions of the restoration site will have the greatest effect. Assessments provide the information needed to refine ongoing management techniques and to discard management actions that are ineffective for a particular site. They also promote the adoption of improved restoration strategies for future projects. This chapter addresses assessments during the first 2-5 years after the initial restoration planting.

Vegetation monitoring

Assessments may be quantitative or qualitative, but should be formally identified in the restoration plan to ensure they are implemented. Wetland assessments during the first three years of a restoration commonly address questions of hydrology and vegetation:

1. Hydrology:

a. Were ditches successfully removed, promoting sheet flow rather than channeled drainage?

b. Did created vernal pools fill, capture sediment, and hold water for the desired periods?

c. Are hydrologic modifications stabilized or is additional erosion control required?

2. Vegetation

a. Are the seed mixes distributed during the first years of the restoration successfully establishing?
   - i. Are desired levels of species richness met?
   - ii. Are desired levels of native cover met?
   - iii. Do initial trends in diversity and cover suggest a community that will be be dominated by, or include, desired native species?

b. How will invasive plant species be controlled?
   - i. What are the most important invasive species to control?
   - ii. Where are they occurring?
   - iii. How many different treatments will be required during the year to control target species?
   - iv. What time of year will control be needed?
   - v. Are there adjustments, such as increased buffer plantings, hydrology alterations, or localized native seed mixes, that may be implemented to address site specific weed issues?

In addition to hydrology and vegetation, assessments can be based on indicators of wetland function identified in formal assessment tools. Two primary assessment tools applicable to wetland prairie and commonly used in a regulatory context in Oregon are the Hydrogeomorphic (HGM)-based Assessment of Oregon Wetland and Riparian Sites (Willamette Valley ecoregion, slope/flats subclasses; Adamus and Field 2001) and a rapid assessment protocol that addresses a broader range of wetland types in Oregon, the Oregon Rapid Wetland Assessment Protocol (ORWAP) (Adamus et al. 2010). These assessment tools were developed to provide consistent and easily obtainable information in multiple wetland types. They can be conducted prior to enhancement or restoration activities to identify pre-restoration functions and values and then repeated at a pre-identified year in the restoration to determine if the anticipated improvement in functions and values was achieved. These tools were designed for rapid assessment, so should not be the sole measure of improvement in wetland functions obtained in a restoration. Typically, restoration practitioners will have a greater understanding and more detailed data set for their site than that obtained with these tools. For instance they may know that new colonization of amphibians is occurring rather than relying on changes in pool depth to measure whether their performance goals were achieved.

Hydrology: Hydrologic changes can be tracked with simple observations of surface water, documented by photos and mapping, or can be more detailed, relying on staff gauges, piezometers, and monitoring wells, depending on budget and level of detail desired. Although not region-specific, the Minnesota Board of Water and Soil Resources (2013), offers a concise and current discussion of methods and tools for hydrologic monitoring. An Oregon Wetland Monitoring Working Group will be developing and refining tools for assessments specific to understanding change in Oregon's wetlands (Oregon DSL 2012).


Staff gauge (foreground)

Vegetation: Two of the most common quantitative measures of the herbaceous plant community in wetland prairies are plant cover and species richness (i.e., number of species present in a given area). Monitoring plant cover is currently the method recommended by the Department of State Lands for wetland prairie restorations or enhancements used as mitigation for wetland losses (Oregon DSL 2009). Species richness data can be collected in plot frames (for small areas) or via transect or meandering surveys (for large areas). It can be useful when combined with cover monitoring, since species with low cover are frequently missed unless sampling is intense.

Two of the most common methods of cover monitoring in Oregon's wetland prairies use visual assessment and point-intercept. Visual assessment using a plot frame is often considered quicker to complete and better at capturing species with low cover values. It is relatively accurate if conducted by an experienced botanist. The point-intercept method is frequently recommended for grasslands. It can be more time-consuming to conduct than visual cover estimates, but is often considered more objective and consistent, especially with changing and less experienced monitoring crews. An excellent resource for designing and implementing plant monitoring is available in Elzinga et al. (1998).

Animals: Due to their mobility, animals are typically more difficult to monitor than plants, so presence of plants and habitat features, such as pooled water or cavities for nesting, are often used as surrogate measures of suitable animal habitat. A recent practitioner's guide to monitoring animals, that covers the design and implementation of monitoring programs from start to finish, is available in McComb et al. (2010). Occasionally, college classes or citizen groups, such as the North American Butterfly Association, may be willing to monitor or survey for animals at developing restorations.

<u>Other Wetland Functions</u>: Wetland functions, such as sediment retention, nitrate removal, and nutrient cycling are infrequently directly monitored due to complexity and expense. The two wetland assessments applicable for Willamette Valley wetland prairie, ORWAP and the HGM-based functional assessments, use models to evaluate these functions based on a series of observations about the site. For instance, to evaluate sediment retention observations are made related to gradient, plant cover, outflows, surface water, drainage, and soil type.

5.12 Recommended Site Preparation Approach and Timeline

The following is a recommended approach and timeline for the plant establishment phase of a wetland prairie restoration project. This approach is based on research results and lessons learned from multiple wetland restoration projects implemented by the West Eugene Wetlands and Coyote Prairie North Wetland mitigation banks. This general approach was used in recent years on both the Dragonfly Bend and Coyote Prairie wetland restoration projects. Both project areas had a starting condition of an annual ryegrass field and were pre-treated with the site preparation techniques described in Table 4-2 for only one year. In both cases, high native cover and diversity was achieved using the technique described below.

Figure 5-7: ***Plant Establishment Techniques and Timing used in the West Eugene Wetlands***

Step	Timing	Task
Year One and Two		
1-9	Multi-year	**Site Preparation**: See Table 4-2
10	Fall	**Buffer Planting**: Plant a buffer strip of aggressive native grasses around the perimeter of the restoration area, approximately fifteen feet in width, to help prevent invasive non-native vegetation from spreading into the project area. Utilize a no-till seed drill to insure good coverage. Recommended grass species include *Agrostis exarata, Deschampsia cespitosa, Elymus glaucus* (blue wildrye)*, Hordeum brachyantherium* (meadow barley).
11	Fall	**First Round Planting**: Seed restoration area with native forbs/sedges/rushes using a broadcast seeder (See *Section 5.0 – Plant Establishment* for detail). Do not plant competitive native grasses in this round. This will allow forbs time to establish and allow for the use of grass-specific herbicide if needed.
12	Nov-July	**Invasive Vegetation Control**: Monitor closely for the presence of invasive non-native vegetation and spot spray, manually remove, and/or mow as necessary to control. **Control Emerging Non-Native Grasses**: Monitor site closely for the presence of non-native grasses and apply grass-specific herbicide if necessary. This can usually be done in select areas as needed using a backpack or ATV with sprayer. The timing of the application is dependent on species (eg. *Vulpia* would be treated earlier than *Lolium*) and weather conditions.
Year Three		
13	Fall	**Second Round Planting**: Plant native grasses via no-till seed drill and additional forbs/sedges/rushes via broadcast seeder (See *Section 5.0 – Plant Establishment* for detail).
14	April-July	**Evaluate Plant Community**: Determine emerging invasive non-native vegetation and map locations to guide any necessary third year actions. Spot spray, manually remove, or mow as necessary to control remaining concentrations of invasive non-native vegetation.

5.13 Knowledge Gaps Related to Plant Establishment

- Use of specific tools in wetland prairie seeding and planting. Certain techniques have both proponents and detractors, with no controlled replicated comparisons having been made.
    - How does the use of a harrow affect the establishment of native wetland prairie species? Some restoration practitioners routinely harrow the site after seed has been broadcast to improve the seed/soil contact. Data from controlled comparisons are not available on whether this practice substantially improves native establishment or stimulates the non-native seed bank.
    - Use of a dibble for planting plugs allows rapid creation of the planting hole. However in the wetland prairie's clay soils does it increase compaction in the root zone and lead to lower survival?
    - Comparisons of using drills and broadcasting for forb seed.
- What role do pathogens, virus, and soil microbial communities play in establishment and resistance to invasive species and resilience following disturbance?
- What role do voles play in initial community establishment and the resistance and resilience of communities to non-native species invasion?
- What are the best methods to establish viable populations of *Brodiaea, Allium*, and *Toxicoscordion* species in wetland prairie restorations.

Chapter 6: Long-Term Management Phase

6.1 Importance of Ongoing Management

The ongoing management of restored or remnant wetland prairies is critical for maintaining native plant abundance and diversity, limiting establishment of non-native invasive species, and preventing colonization by woody vegetation over time. This section focuses on the long-term management needs of wetland prairies once the establishment phase of the restoration process is completed (typically after year five) as well as management of remnant wetland prairies. In both cases, the wetland prairie will require some level of management in perpetuity, which will include ongoing assessment of site conditions, a flexible approach, and timely disturbances to sustain this early successional habitat. Factors that affect succession through time include disturbance, colonization, and competition. Management is an attempt to manipulate these factors in a way that supports the habitat and diversity goals for the site.

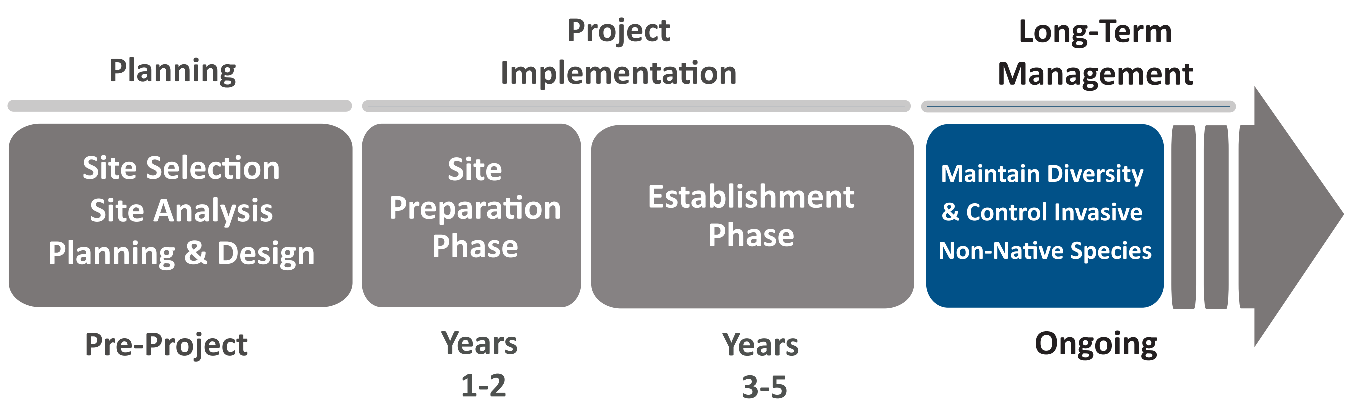


Figure 6-1: ***Relationship of the Long-Term Management Phase within the Restoration Timeline***

6.1.1 Establishing a Maintenance Plan

Long-term management should be guided by a detailed management plan specific to the site with room for adaptive management based on ongoing successes or failures as informed by monitoring. While every site is unique and has different challenges and assets, this section strives to address common management goals, issues, and useful practices. Goals at this stage of restoration typically include:

- Maintaining and enhancing the existing plant and animal community diversity;
- Reducing non-native invasive species;
- Maintaining habitat structure and function through woody species removal, control of thatch buildup, and protection of micro-topographic diversity of the site.

Overall, this stage of management is less intense and costly than site preparation and plant establishment phases and is designed to maintain desired structure and function. It is valuable to develop strategies and action thresholds for each of these three goals. Plan the timing, frequency and intensity of management actions while integrating the ability to adapt to emerging issues.

Prairie systems are considered early successional habitats and, as such, require some form of continued management and timely disturbance to maintain structure and function.

For example, continuing to enhance native plant diversity will require a plan to acquire plant materials well in advance, as noted in chapter 5, while remaining flexible to take advantage of actions, such as burning or spot herbicide applications, that provide opportunities to add plant materials for maintaining or increasing native plant cover and diversity.

The City of Eugene's 2013 Integrated Pest Management (IPM) Policy and Operations Manual (*www.eugene-or.gov*) provides good recommendations for control of many non-native invasive species in the Willamette Valley.

To control emerging non-native invasive species, developing an Integrated Pest Management (IPM) plan that identifies action thresholds and evaluates the benefits and challenges of different control techniques will help prioritize actions. A good IPM plan includes criteria for deciding the risk that a species represents, the threshold above which action is recommended, and an analysis of detailed control approaches for different species frameworks for implementing pest management actions.

To address woody species control and thatch buildup, develop a schedule to provide routine removal with some flexibility. For example, planning an ecological burn rotation on a 3-5 year schedule would be ideal. However, in some cases this frequency may not be feasible and some burns may need to be replaced by mowing if burning is not possible in some years. Similarly, to retain site micro-topographic heterogeneity, disturbance may need to be limited to certain portions of the site in any given year. An example plan may call for mowing up to 30% of a site every other year while burning 30%-50% of the site every 5 years. Again, preparing a strategy is useful but it should remain flexible so that managers can adapt to emerging issues.

Point-intercept sampling of vegetation at a wetland restoration site (photo credit: Institute for Applied Ecology)

Finally, a long term management plan should also consider other practical issues that affect the site such as access for equipment, or the public; routine repair of infrastructure such as fences, signs, water control structures, etc.;and influences from adjacent properties such as runoff or seed rain from invasive plants.

6.1.2 Site Assessment and Monitoring

A key element of successfully managing a restored or remnant prairie site is regular assessment or monitoring. Annual informal site visits are critical for early identification of emerging issues. A lower intensity assessment program may include a winter or early spring visit to subjectively identify the effectiveness of a prior year's actions and plan actions for the upcoming season. This would be followed by an early spring visit to map non-native invasive species and refine the action strategy, such as hand-pulling or herbicide application. This level of assessment can be an effective way to develop a formal action plan to ensure that resources are available to address issues in a timely fashion.

A more formal quantitative monitoring effort can be implemented on a longer timeline, e.g., every three to five years. Gathering objective data on habitat quality such as cover of native and exotic species with quadrats or point-intercept methods or other statistically quantifiable methods, will help identify more subtle threats and trends facing the plant community.

Effective site assessments, whether qualitative or quantitative, yield information that can be summarized as habitat indicators, such as abundance of woody vegetation or invasive species, which are tied to specific thresholds that trigger a management response. For example, the West Eugene Wetland Monitoring Plan (Bureau of Land Management 2007) uses both informal, low-intensity (annual) and more quantitative, high intensity (every three years) approaches to site assessment, and results are evaluated for four habitat indicators, including invasive species, thatch accumulation, native plant abundance and diversity, and woody vegetation. Thatch cover in excess of 10-20%, for instance, can trigger a management action aimed at reducing thatch and litter, such as ecological burning.

These monitoring methods and their rationales are described below:

Low Intensity Monitoring: Low intensity monitoring is conducted annually to measure four habitat indicators: woody plants, invasive species, litter/thatch, and native plants. It relies on the random or non-random placement of a small number of sample plots within each habitat type of each site and can be accomplished quickly by one or two people. Plot size is variable according to habitat type and the characteristics of each indicator are measured by visual estimation and recorded on data sheets. Information from this monitoring is used to determine if maintenance treatments and/or small scale management treatments are needed in a specific area. Additionally this rapid assessment method can capture general habitat trends efficiently and allow managers to evaluate an upward or downward trend of habitat conditions. Low intensity monitoring is conducted annually during the growing season (May through June) according to funding availability. It is intended for coarse data gathering only, and is not designed to provide the detail nor statistical rigor of quantitative monitoring. The detailed protocol can be found in Villegas-Moore et al. (2007).

High Intensity Monitoring: High intensity monitoring is conducted to thoroughly document baseline conditions prior to management actions, site-wide trends in habitats, and responses to management actions. High intensity monitoring is based on point-intercept (for ground cover and open areas) and line-intercept (for woody and forested vegetation) methods, which are described in detail in Villegas-Moore et al. (2007). It measures the effects of management treatments in a defensible and repeatable manner and allows managers to determine if site specific objectives have been met.

Typical objectives of monitoring protocols are to determine if the restoration actions have reduced the threat posed by exotic and woody species, improved the over-all habitat quality, and increased the abundance and/or diversity of native plant species.

Figure 6-2: ***Example of Monitoring Indicators and Corresponding Thresholds of Management Actions***

Habitat indicator	Threshold for Management
Invasive species	When combined encroachment reaches 10%-35% or greater of the habitat block and/or a weed population covers >50% of a 1-meter squared area, depending on site conditions and species present
Thatch	When the litter layer exceeds 10-20% cover and litter layer is detrimentally impacting native forb plant diversity or rare plant habitat
Native Species	When there is a loss of 5%-10% of a site's existing cover and number of native plant species
Woody vegetation	When canopy cover exceeds the level appropriate for the local habitat type (developed for each type individually).

Source: West Eugene Wetland Monitoring Plan (Bureau of Land Management 2007).

6.2 Management Techniques

Prairie systems are considered early successional habitats and, as such, require some form of continued management and timely disturbance to maintain structure and function. In addition, wetland prairies face invasion by non-native species that can significantly alter native plant diversity and abundance, and affect habitat quality for wildlife. Management treatments are needed to address invasive species in on-going prairie management or to reduce excessive dominance of native grasses and maintain plant diversity. The techniques listed below include those more commonly used to manage a wetland prairie system for native plant community health and to address invasive species, as well as some more novel techniques in need of additional research and field trials. The benefits and potential disadvantages to each are highlighted. An Integrated Pest Management approach is more likely to achieve the desired effects on the many weedy plants that invade wetland prairies than any single one of the treatments described below, and many of these management techniques are more effective when used in combination (e.g., Stanley et al 2011), as noted where this information is available.

Unmanaged prairie with woody vegetation establishing

6.2.1 Woody Vegetation Removal

Without continued management or disturbance, even prairies with high native diversity succumb to the natural processes of plant succession. Woody vegetation, including trees and shrubs, will encroach into Willamette Valley prairie habitats naturally without management or natural disturbances that remove them. In order to maintain early successional wetland prairie, removal of woody vegetation on a regular basis will be necessary. Some management plans may have a threshold (as noted in the section on Site Assessment) for woody plant canopy cover that, if exceeded, triggers a management treatment. For larger woody plants, trees may be girdled, cut down and left in place for habitat, piled and burned, or ground into chips. Re-sprouting species, such as *Fraxinus latifolia*, *Rosa* sp., and *Crataegus* sp., may be controlled using cut-and-wipe methods involving herbicides. Tree seedlings and smaller woody plants and shrubs may be treated with techniques such as mowing or burning as detailed in the following sections.

An ecological burn in an area where ash trees are encroaching

6.2.2 Ecological Burning

The prairies of the Willamette Valley were historically maintained by native people through their use of fire up until the mid-1800s. Fire continues to be a highly valuable management tool in prairies where feasible and can be used to limit establishment of woody species, remove thatch and litter, encourage new germination, and control many non-native species.

Thatch buildup can detrimentally impact native species diversity, including rare species, by inhibiting plant germination, establishment and growth. Burning is a highly effective method for reducing thatch and often produces patches of bare soil which are ideal for recruitment of native seedlings in wetlands. In experiments conducted at Coyote Prairie, burning was found to be the most effective treatment tested for reducing cover of the dominant perennial bunchgrass, *Deschampsia cespitosa* (tufted hairgrass), and removing the deep thatch layer created by this species (Bois et al. 2014).

A wetland prairie pictured in the spring following a fall burn

The effects of fire differ among species, years, and sites and may be harmful or beneficial to native and non-native species alike. For example, in a long term study (Nuckols et al. 2011) of the effects of fire and mowing on a wetland prairie remnant near Eugene, Oregon, 15 of 61 species responded in a desirable way to fire (i.e., increase in abundance of natives and decrease in abundance of non-natives) while 8 species responded in an undesirable way. In that study, burning suppressed weedy forbs as a group in the short-term, but increased annual invasive grasses. For example, burning reduced the abundance of vegetative *Leucanthemum vulgare* (oxeye daisy). In contrast, fire benefitted 7 of ten perennial forbs, 5 of which were bulbs in the lily family (*Brodiaea coronaria/elegans*, *Camassia quamash*, *Camassia leichtlinii*, T*oxicoscordion venenosum*, and *Triteleia hyacinthina*). The perennial forb *Potentilla gracilis* and the perennial graminoids *D. cespitosa* and *Juncus occidentalis* all responded positively to fire. Wetland restoration practitioners in the Willamette Valley have noted that some aggressive invaders increase rapidly in response to fire, such as *Anthoxanthum oderatum* (sweet vernal grass) and *Holcus lanatus* (velvet grass). In another study of fire effects in Willamette Valley wetlands, populations of the threatened *Lomatium bradshawii* (Bradshaw's lomatium) were stimulated to grow with frequent fire, while they declined in unburned prairies (Kaye et al. 2001). Therefore, the decision to use ecological burning for management of a restored wetland will depend on site conditions, including which weedy and native species are present.

Ecological burning should be implemented in late summer or early fall after most native species have produced seed and become dormant.

To protect existing native plant populations, controlled ecological burning should be implemented in late summer or early fall after most native species have produced seed and become dormant. The open soil conditions after a burn provide an opportunity for seed germination and plant diversity within a wetland prairie site in the year after a fire. Burning in wetland prairies creates an opportunity to seed with native plants to increase native vegetation abundance and diversity. In upland prairies, the cover of native forbs and grasses was often significantly improved by seeding after ecological burns (Stanley 2008, 2010). Over-seeding should be done within two weeks of the ecological burn (if no herbicide is applied) or 1-2 weeks after application of glyphosate, if used.

The open soil conditions created by fire also increase a site's vulnerability to invasion by non-native species (Bois et al. 2014). Therefore, it is critical to ensure adequate available resources for assessing and managing emerging invasive species issues during the year after a burn. For sites where non-native grasses and forbs are a problem, many practitioners have found that an ecological burn followed by an herbicide application 2 to 3 weeks following a burn works well to reduce non-native plant cover, and this effect has been demonstrated in regional experiments (Stanley et al. 2011). This can be effective because many non-native species re-sprout more rapidly than desirable native species after fires and may be treated during this brief window when they are green and susceptible to herbicides but most natives are not. The use of herbicide after burning to control rapidly re-sprouting weeds has been shown to be compatible with rare species such as *Lupinus oreganus* (Kincaid's lupine) and *Erigeron decumbens* (Willamette daisy).

Burning is also one of the more compatible management techniques for maintaining the heterogeneity and microtopography desired in restored wetland prairies. The fire itself often creates a mosaic of burned and un-burned areas without damaging natural topographic features of the site such as soil pedestals.

6.2.3 Flaming

Thermal treatments can have a place in management of restored wetland prairies, especially to control thatch accumulation and treat certain weed invasions without ecological burning. However, the efficacy of this technique to control invasive plants in the West Eugene Wetlands has been generally poor. Use of the Sunburst flaming tool (see photo on page 33), a propane-fired steam-deck towed behind a tractor, resulted in re-sprouting of perennial weeds such as *Hypochaeris radicata* (hairy cat's ear). When used specifically to kill *Vulpia myuros* (rattail fescue), an annual grass, all annual seedlings were killed, including germinating natives like *Madia glomerata* (tarweed), and additional *Vulpia* seedlings emerged after the treatment. The Sunburst also performed poorly on uneven ground, required a water truck, and was challenging for operators to manage. Additional flaming techniques may become available but this technique is currently not recommended.

Tractor mowing can be an effective tool for removing woody vegetation, such as *Rubus* and other small shrubs. (Photo credit: Institute for Applied Ecology)

6.2.4 Mowing

Mowing is probably the easiest form of regular management and can be done at a relatively low cost. There are also no permitting or special weather conditions required, as there are for ecological burning. Because of this, mowing is one of the most popular and regularly used management treatments on many prairie sites. Mowing can be useful for reducing weed flowering and seed set and will help control competing shrubs, trees, and seedlings.

Frequent and sustained mowing can be used to limit woody encroachment into prairies and substantially reduce the cover of *Rubus* spp. (Himalayan blackberry) (Kaye and Benfield 2005) and limit the spread of *Cytisus scoparius* (Scotch broom). However, these reductions are often short-lived and, if mowing is ceased, significant regrowth of the undesired species can occur. A spot herbicide application that targets regrowth of these species has been shown to be effective and can be a good approach if regular mowing is not an option.

Mowing can be an effective tool to increase structural heterogeneity and enhance community diversity site-wide if used over a portion of a site or in alternating years. The timing of mowing is important. Spring mowing can be used to prevent seed set of certain species, but may impact ground nesting birds and other wildlife, as well as native wildflowers. In sites without dense grass cover, fall mowing may increase light access to the soil, and thus increase seed germination.

Compared to ecological burning, fall mowing of wetland prairie has fewer effects of less magnitude on individual species. In the study of management treatments in a remnant wetland near Eugene, Oregon (Nuckols et al. 2011), only 8 of 61 species responded in a desirable way to mowing, and seven responded negatively. Native species that responded positively to fall mowing included *Grindelia integrifolia* (gumweed), *Potentilla gracillis* (cinquefoil), *D. cespitosa*, and *J. tenuis*. Mowing had a negative effect on the native *C. quamash*, and stimulated flowering of *L. vulgare* (Nuckols et al. 2011).

Mowing is recommended as a temporary option when ecological burning or haying is not feasible and where control of woody vegetation is a high priority.

Mowing alone is generally not recommended as a method of controlling non-native grasses and forbs, limiting the dominance of native grasses such as *Deschampsia cespitosa* (tufted hairgrass), or improving native plant diversity. Routine mowing, especially in sites dominated by non-native grass, can facilitate the expansion of invasive grass species to the detriment of native grasses and forbs (Trevor Taylor, personal observation). In one study of upland prairies, mowing alone actually increased the cover of non-native perennial forbs (Stanley et al. 2010), but did little else to change the communities, unless combined with grass-specific herbicide to control invasive perennial grasses (Stanley et al. 2011). At the Coyote Prairie test plots, where there was already a relatively high native plant cover after initial site preparation, mowing as a management tool was found to lower native diversity by creating a dense thatch layer (Bois et al. 2014). In that study, repeated mowing of the dominant *Deschampsia cespitosa* resulted in heavy thatch formation, reduction of seed germination and diminished establishment of other native species that had been over-seeded. Mowing may also be detrimental to naturally occurring pedestals that provide desirable microtopographic heterogeneity in restored wetland prairies. These important features may be damaged by regular mowing with large equipment when the mower deck and tires knock over pedestals (Paul Gordon, personal observation).

In general, mowing is recommended as a temporary option when ecological burning or haying is not feasible and where control of woody vegetation is a high priority. Mowing is a useful tool if thatch removal is not a particular concern on a site, but will not generally help with invasive grass control or native diversity, even if combined with over-seeding (Bois et al. 2014).

Haying is one way to reduce thatch build-up.

6.2.4 Haying

Haying is essentially the removal of litter after a mowing treatment, either by bailing or raking. This method has been shown to reduce thatch and increase exposed soil surface, which, in theory, increases the likelihood that over-seeding will be successful. However, experiments in the West Eugene Wetlands (Bois et al. 2014) found mostly negative effects of haying. Compared to unmanipulated control plots, haying reduced native plant diversity and annual forb

Sheep grazing is an experimental tool for habitat management in wetland prairies. More research is needed to develop this tool and understand its effects on these habitats.

abundance, increased dominance of native grasses, and had little effect on other community characteristics. In addition, haying tends to be more costly and logistically challenging than mowing, but may be a good alternative if thatch removal is a management goal and ecological burning is not feasible. In general, haying is not recommended as a management tool unless combined with another management treatment to increase its effectiveness.

6.2.5 Grazing or Browsing

Grazing and browsing may be useful management techniques in wetland prairies, but recent findings suggest this treatment may have some drawbacks. Additional research and trials are needed to understand the effects of grazing in combination with other treatments. Ultimately, it may be found that grazing is a good tool for the management of low quality prairies, but less beneficial in higher quality prairies.

Sheep grazing has been tested as a habitat management technique at two sites in the West Eugene Wetlands (Coyote Prairie and Fern Ridge Natural Area). Sheep will graze on both grasses and forbs and their selectivity can be manipulated by placing them on a site during specific periods of the year. In theory, they may also help improve site microtopography and success of over-seeding by creating areas of bare ground available for plant colonization. However, a grazing treatment conducted at Coyote Prairie, which used flash grazing (20 sheep in a 0.04 acre area for 24 hours) in spring, substantially increased dominance of *D. cespitosa* and lowered native plant diversity (Bois et. al. 2014). Grazing alone in spring is currently not recommended for habitat management of restored wetland prairies.

Herbicide application may be an effective tool for managing invasive species in wetland prairies, especially when incorporated into an IPM plan.

Fall grazing/browsing by sheep and goats may hold more promise. Sheep and/or goats could be placed on a site in fall after exotics have greened up, but while most native species are still dormant. Goat browsing has long been known as an effective treatment for some forb and shrub species. Goats readily browse *Rubus* spp. and *Phalaris arundinacea* (reed canarygrass) and could be a useful tool in areas with uneven terrain or where a mower cannot access. Since goats prefer to eat immature vegetation, mowing before introducing goats to stimulate new growth may be a good strategy. Any use of livestock should ensure that seeds of non-native invasive species are not introduced by the animals themselves or their manure.

6.2.6 Herbicide

Herbicides are a useful too for large-scale habitat management to control invading species, and, if used, should be implemented as part of an Integrated Pest Management plan. Their use should follow their label restrictions and be directed at specific problem weeds and phased out over time, with continued use only for spot treatments. Also, herbicides are often most effective when applied in combination with other treatments, especially fire and hand weeding.

Chemical control of non-native species alone does not necessarily lead to increased native diversity. Once the target species have been controlled by herbicide, the treatment should be followed by planting of aggressive or desirable plants to inhibit recolonization by the same or other weed species, and increase native plant abundance and diversity.

A variety of herbicides have been used in prairie restoration and management in the Willamette Valley (Figure 6-3). These chemicals may be categorized as non-specific (or broad spectrum), grass-specific, and broadleaf specific and their type of activity can be described as systemic (absorbed and translocated throughout the plant), contact (killing only the tissues sprayed), or pre-emergent (inhibiting seed germination and seedling establishment). Glyphosate, an example of a broad spectrum, systemic herbicide, is the most widely used for weed control in natural areas in the Willamette Valley. Different weed species will be most efficiently controlled by different herbicides. Note however that some grass-specific herbicides, such as fluazifop and sethoxydim, are ineffective at controlling fine-leaved fescues like *Vulpia* spp., although clethodim may be effective on these grasses. In addition, velvet grasses (especially *Holcus mollis*) can be resistant to grass-specific herbicides.

Figure 6-3. ***Herbicides That Have Been Used for Control of Non-Native Invasive Species in WV Prairies***

Selectivity		Chemical name	Trade name	Type
Non-selective	Terrestrial	Glyphosate	Round-up/Accord	Systemic
		Nonanoic acid	Scythe	Contact
		Hexazinone	Velpar	Contact
		Oryzalin	Surflan	Pre-emergent
		Pendimethalin	Pendulum	Pre-emergent
		Imazypic	Plateau, Cadre	Systemic / Pre-emergent
	Aquatic	Glyphosate	Aquamaster	Systemic
		Imazapyr	Habitat	Systemic
Grass-specific		Sethoxydim	Poast	Systemic
		Fluazifop	Fusilade DX	Systemic
		Clethodim	Envoy/Select	Systemic
Broadleaf-specific		Aminopyralid	Milestone VM	Systemic/ Pre-emergent
		Triclopyr amine	Garlon 3A	Systemic
		Triclopyr ester	Garlon 4	Systemic
		Clopyralid	Stinger, Transline	Systemic/ Pre-emergent

Source: modified after Denehey et al. 2011

Multiple projects have found that burning, closely followed by an herbicide application, had the greatest effect on decreasing non-native invasive grass cover.

For controlling weeds and minimizing non-target effects, multiple projects have found that burning, closely followed by an herbicide application had the greatest effect. For example, a sequence of spring application of grass-specific herbicide, fall burning, followed by application of glyphosate about two weeks later achieved the greatest reduction of invasive grasses with minimal impacts to the native plant community, plus open areas for successful seeding (Stanley et al. 2011). As expected, some native grasses such as *Danthonia californica*, *Bromus carinatus*, and *Elymus glaucus* were also affected, but overall the treatment reduced non-native grass cover. It is recommended that this treatment combination be followed by seed addition when possible, particularly if native diversity is low.

Recognizing a relatively short list of high-impact, priority non-native plant species as part of a management plan helps to focus control efforts and make the task more manageable. Undertaking an annual review that combines field assessments, GPS records of species location, treatment with herbicide and/or other methods, and follow-up seeding with native plants into treated areas may be an effective means of prioritizing invasive species management on an on-going basis. The City of Eugene's 2013 Integrated Pest Management (IPM) Policy and Operations Manual (*www.eugene-or.gov*) provides detailed recommendations on herbicide types, concentration, and timing for control of specific invasive species.

Adding carbon as sugar to soils stimulates microbes that consume nitrogen, lowering soil productivity that can promote invasive weeds (Institute for Applied Ecology test plots shown above).

6.2.7 Nutrient Manipulation

Several studies have indicated that native species are more capable of tolerating low nutrient conditions than exotic species and reducing nitrogen availability through carbon addition can lower the abundance of non-native weeds, especially grasses (Alpert and Maron 2000, Blumenthal et al. 2003). Recent tests of the effects of adding sugar as a carbon source in restored upland prairies at two sites in the southern Willamette Valley indicate that adding carbon decreases overall vegetative cover, and non-native plants are reduced while natives are increased if the site is weedy (Gray 2013). At sites where natives dominate before treatment, carbon addition can disproportionately lower natives over invasives. Therefore, the effects of carbon addition on natives vs. non-natives depends on the conditions at specific sites. Although this approach is currently not practical at areas over ~0.5 hectare due to the cost of effective carbon sources (such as sugar), it may be a useful treatment to enhance native over exotic species and establish native plant populations from seed or plugs in smaller scale diversity patches where some other management treatments may not be an option. More research is needed in this area to improve our understanding of how carbon addition type (i.e., sugar, sawdust, or activated carbon), dosage rate and duration affect communities, how seeding success depends on carbon addition influences seeding success, scalability of the treatment (method vs. cost), interactions with other management treatments, and effects of initial conditions at the site on effectiveness of carbon addition.

6.2.8 Seeding

Over-seeding should be done in the fall after the management technique has been completed.

Seeding has been discussed in detail in Section 5 during the plant establishment phase of a restoration project, but periodic seed addition can also be an important technique for sustaining or enhancing diversity in an established wetland prairie. Regular seeding of remnant or restored wetland prairies has been found to increase native diversity and abundance, especially in combination with other management treatments such as burning. Seeding after management treatments may be necessary to overcome low abundance of native seed (seed limitation), especially if there are few native seed sources or low diversity of native plants in the immediate vicinity.

Seeding should be done in the fall after the management technique has been completed and is especially recommended after any treatments that disturb the soil such as weed removal and ecological burns. As noted in section 6.2.2, seeding should generally not occur until at least one to two weeks following an herbicide application and herbicide types with pre-emergent properties should be avoided if over-seeding is planned within a short timeframe. Seeding is typically done with a hand-held or tractor-pulled broadcast seeder. Harrowing after seeding is generally not necessary, especially if the thatch has been removed by the management technique and good ground-seed contact can be achieved, otherwise only light harrowing is recommended. Harrowing may also stimulate the weed seed bank that may be present in the soil, resulting in a flush of unwanted invasive species, but this will differ among sites. Seed can also be planted using a no-till seed drill into existing vegetation, which has the advantage of ensuring seed-soil contact and minimizing soil disturbance. Use of a seed drill as a management tool will be limited to sites where the soil surface is relatively flat and free of thatch. Drilling into sites with well-established *D. cespitosa* clumps is not recommended because it is difficult to run the drill equipment through this topography.

When seeding into a restored site, it is important to develop site specific seed mixes to accomplish the goals of the restoration project. See Chapter 5 for specific seed mix recommendations. The seed mix can be designed to emphasize:

- Diverse growth forms and phenologies in order to increase the competitive environment against non-native species;
- ‘‘Aggressive” native species with strong competitive abilities;
- Species that have established well at the site in previous years;
- Rare or uncommon species that are desired at the site but that may not have been included in the original restoration species mix; or
- Species of particular importance to pollinators and birds.

Research into wetland restoration has shown that there is a clear trade-off between native cover and diversity and in particular, the native bunch grass *Deschampsia cespitosa* can significantly inhibit the diversity of native plant species in Willamette Valley sites (Bois et al. 2014). Management techniques aimed at reducing the dominance of *Deschampsia cespitosa* may be necessary in order to improve the overall native diversity of a site. In addition to the obvious habitat benefits of establishing highly diverse prairies, the research has also shown a direct correlation between high native diversity and low community susceptibility to weed invasion. Increasing native diversity (over cover of single grass species) is a key factor for reducing invasibility and ultimately leads to long-term management success.

Planted strips were integrated into this upland prairie being established at The Nature Conservancy's Willow Creek Preserve to improve Fender's blue butterfly habitat. Solarization was used for site preparation followed by heavy seeding of nectar producing forbs and *Lupinus oreganus* (Kincaid's lupine) as a host plant.

6.2.9 Integrating Diversity Patches

Another planting strategy during on-going management is the creation of patches of plant diversity for specific purposes. For example, creation of 'islands' of nectar plants for pollinators such as Lepidoptera, including listed insects like Fender's blue butterfly, is an efficient approach at large sites where it may be appropriate to place key plant species strategically in smaller areas. This approach can be incorporated at the initial planting stage of the project, but some managers choose to add diversity patches during the management phase as well, often taking advantage of small scale disturbances associated with weed control events to establish groups of specialized plant species.

This approach has several advantages. It can accommodate planting different types of plant materials, including seeds and plugs, and may be more economical than planting the target plants across an entire site. Planting diversity patches can also provide an on-site seed source from which the species may disperse passively. Finally, increasing diversity at a patch-scale may help managers focus intense treatments of weeds or other issues on a narrow area to increase the likelihood of success. The following guidelines can be useful for establishing diversity patches or nectar islands:

- Control invasive species and unwanted competing vegetation prior to planting.
- Plant bulbs in the fall or late winter prior to leaf emergence.
- Plugs can be planted in the fall, late winter, or spring, or all three.
- Within the islands, plants should be placed in clumps of several individuals of each species. Spacing between plants is dependent on the species and size of the plants.
- Patches may range in size from a few tens of square meters to a few hundred square meters, as appropriate to the objective and scale of the site.
- Solarization may be a useful site preparation tool for establishing diversity patches or strips at this scale.

6.3 Knowledge Gaps Related to Long-Term Management

Our understanding of the various factors that affect successful long-term management of wetland prairies in this region is incomplete. Below, we list several significant knowledge gaps that, with further study, could lead to better long-term management results.

- *Formation and management of pedestal features.* Raised pedestals that are found in many wetland prairie sites can provide several types of microhabitats in a relatively small area and therefore higher plant species diversity. Grasses and forbs tend to thrive on the higher portions of the pedestals, while more water tolerant rushes, sedges, and annual forbs are often found in the low spaces between pedestals, which are flooded for much of the wet season (Wilson 1998). Observations suggest that the growth of mature clumps *Deschampsia cespitosa* and large ant mounds play a role in the development of these pedestals. It has been observed in restoration sites in the West Eugene Wetlands that pedestals can form naturally over time once native vegetation is established on a previously smoothed agricultural field. Further study of these features and their potential for re-establishment is needed.
- *How does small-scale heterogeneity on a site affect plant diversity?* Restored wetland prairies typically have lower diversity than high quality remnants. For example, previous work in the Willamette Valley found 30-84 plant species in remnant wetland prairie, while restored sites had over 70 species, but high quality remnants are often smaller and may have more heterogeneity than restored sites. Many of our consulting experts identified lack of heterogeneity at the small scale (microtopography) as a key factor limiting diversity in restored sites. As many wetland prairie restoration projects are located on former agricultural fields, this microtopography is lacking in restored wetland prairies. A 2012 study conducted by the University of Oregon Environmental Leadership Program suggests that variation microtopography increases native plant diversity, but recommends further research to confirm a more statistically significant relationship between microtopography and plant community composition (Logsdon et al. 2012).
- *How does seed predation by mammals, birds, and slugs effect plant establishment in restored wetland prairies?* Many studies have documented that seed predation by birds and small mammals (particularly voles) has long lasting effects on the diversity of restored prairies. Other studies have documented effects of avian and mammalian seed predators on the establishment of rare species (e.g., work by the Institute for Applied Ecology on *Lupinus oreganus* (Kincaid's lupine) and *Lomatium bradshawii* (Bradshaw's lomatium)). Seed predation may limit the number of species that establish and their abundance. Seed is one of the most costly components of restoration so reducing seed losses could lower costs and improve outcomes. A 2012 seed predation study by IAE was inconclusive, but presents recommendations for conducting the study on a larger scale and with a variety of seed mixes (Gray 2012).
- *What is the best approach for building diverse insect communities in restored wetland prairies?* Restored wetland prairies typically have lower diversity than high quality remnants and as such may provide reduced or altered habitat for native insect communities. Maintenance of native insect communities is important for a number of reasons. Insects are responsible for pollination of nearly 70% of the world's flowering plants. Insects are also an important food source for a number of rare bird and mammal species, including the streaked horned lark and Western meadowlark. Finally, many wetland prairie habitats are contiguous with upland prairies that support populations of the endangered Fender's blue butterfly. Thus, the goals of wetland prairie restoration may include providing habitat for a diverse native insect community.

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Appendices

Appendix A

Vascular Plants of the Prairies and Associated Habitats of the Willamette Valley-Puget Trough Georgia Basin Ecoregion

Appendix B

Notable Willamette Valley Wetland Prairie Sites

Appendix C

Seeding Rates

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Appendix A: Vascular Plants of the Prairies and Associated Habitats of the Willamette Valley-Puget Trough-Georgia Basin Ecoregion

Source: Ed Alverson (April 2014) with format modification for use in this appendix.

FULL SCIENTIFIC NAME	TAXONOMIC NOTES/ SYNONYMS	APG III FAMILY	APG III Number	COMMON NAME	G-Rank	Degree of fidelity to prairie habitats	Growth Form	Seasonal Wetland Prairies	Vernal Pools & Vernal Seepage	ORNHIC List
Achillea borealis Bong.	Achillea millefolium var. borealis; Achillea lanulosa	Asteraceae	F400	American yarrow	G5	M	PF	x		
Acmispon americanus (Nutt.) Rydb.	Lotus unifoliolatus var. unifoliolatus; Lotus purshianus var. purshianus	Fabaceae	F144	Spanish lotus	G5T5	M	AF	x	x	
Agoseris grandiflora (Nuttall) Greene		Asteraceae	F400	large flowered agoseris	G5	H	PF	x		
Agrostis exarata Trin. var. exarata	Agrostis longiligula; Agrostis ampla; incl. var	Poaceae	F106	spike bentgrass	G5TNR	M	GR	x	x	
Agrostis exarata Trin. var. monolepis (Torr.) A.S. Hitchc.		Poaceae	F106	awned spike bentgrass	not ranked	M	GR		x	
Agrostis microphylla Steud.		Poaceae	F106	awned spike bentgrass	G4	H	GR	x	x	
Allium amplectens Torr.		Amaryllidaceae	F074	narrowleaf wild onion	G4	H	PF	x	x	
Allium unifolium Kellogg		Amaryllidaceae	F074	One-leaved Onion	G4G5	H	PF	x		4
Alopecurus carolinianus Walt.		Poaceae	F106	Tufted Foxtail	G5	H	GR		x	
Alopecurus geniculatus L. var. geniculatus		Poaceae	F106	water foxtail	GUTU	M	GR	x	x	
Alopecurus saccatus Vasey		Poaceae	F106	Pacific foxtail	G4	H	GR		x	
Androsace filiformis Retz.		Primulaceae	F333	slender rock-jasmine	G4	H	AF	x		
Aphanes occidentalis (Nuttall) Rydb.	Aphanes arvensis, Alchemilla occidentalis	Rosaceae	F147	western lady's mantle	not ranked	M	AF		x	
Apocynum androsaemifolium L. var. androsaemifolium		Apocynaceae	F354	spreading dogbane	G5T5	M	PF	x		
Apocynum cannabinum L. var. glaberrimum DC.		Apocynaceae	F354	hemp dogbane	G5TNR	M	PF	x		
Apocynum sibiricum Jacq. var. salignum (Greene) Fernald		Apocynaceae	F354	clasping leaved dogbane	not ranked	M	PF	x		
Aristida oligantha Michaux		Poaceae	F106	prairie threeawn	G5	H	GR		x	
Asclepias fascicularis Duchesne		Apocynaceae	F354	narrowleaf milkweed	G5	H	PF	x	x	
Asclepias speciosa Torr.		Apocynaceae	F354	showy milkweed	G5	M	PF	x		
Beckmannia syzigachne (Steud.) Fernald		Poaceae	F106	sloughgrass	G5	H	GR	x	x	
Bistorta bistortoides (Pursh) Small	Polygonum bistortoides	Polygonaceae	F286	western bistort	G5	H	PF	x		
Brodiaea coronaria (Salisb.) Engl. ssp. coronaria		Asparagaceae	F075	harvest brodiaea	G4T4	H	PF	x	x	
Brodiaea elegans Hoover ssp. hooveri Niehaus		Asparagaceae	F075	elegant brodiaea	G4G5T3?	H	PF	x	x	
Callitriche heterophylla Pursh ssp. bolanderi (Hegelm.) Calder & Taylor		Plantaginaceae	F368	Bolander's water starwort	G5T3T5	M	AF		x	
Callitriche marginata Torr.		Plantaginaceae	F368	Winged Water-starwort	G4	M	AF		x	
Calochortus uniflorus Hook. & Arn.		Liliaceae	F061	large flowered startulip	G4	H	PF	x		
Camassia leichtlinii (Baker) S. Watson ssp. suksdorfii (Greenm.) Gould		Asparagaceae	F075	large camas	G4G5T4T5	H	PF	x		
Camassia quamash (Pursh) Greene ssp. intermedia Gould		Asparagaceae	F075	small camas	G5T1T3	H	PF	x		
Camassia quamash (Pursh) Greene ssp. maxima Gould		Asparagaceae	F075	small camas	G5T3T5	H	PF	x		
Cardamine penduliflora O.E. Schulz		Brassicaceae	F273	Willamette Valley bittercress	G4	M	PF	x		
Carex athrostachya Olney	Carex macloviana s.l.	Cyperaceae	F099	slenderbeak sedge	G5	M	GR	x		
Carex aurea Nuttall		Cyperaceae	F099	golden fruited sedge	G5	H	GR	x		
Carex cusickii Mack. ex Piper & Beattie		Cyperaceae	F099	Cusick's sedge	G5	M	GR	x		
Carex densa (L.H. Bailey) L.H. Bailey		Cyperaceae	F099	dense sedge	G5	H	GR	x	x	
Carex feta L.H. Bailey		Cyperaceae	F099	green sheathed sedge	G5	M	GR	x		
Carex hassei L.H. Bailey	Carex garberi	Cyperaceae	F099	false golden sedge	G4G5	H	GR	x		
Carex pachystachya Cham. ex Steud.	incl. plants identified as Carex macloviana	Cyperaceae	F099	thick headed sedge	G5	M	GR	x		
Carex scoparia Schkuhr ex Willd. var. scoparia		Cyperaceae	F099	pointed broom sedge	G5	M	GR	X		
Carex tumulicola Mack.		Cyperaceae	F099	foothill sedge	G4	H	GR	x		
Carex unilateralis Mack.		Cyperaceae	F099	one sided sedge	G5	M	GR	x	x	
Castilleja tenuis (A. Heller) T.I. Chuang & Heckard	Orthocarpus hispidus	Orobanchaceae	F376	hairy owlclover	G5	H	AF	x	x	
Centaurium muehlenbergii (Griseb.) W. Wight ex Piper		Gentianaceae	F351	Muehlenberg's centaury	G5?	H	AF	x	x	
Centunculus minimus L.	Anagalis minima	Primulaceae	F333	chaffweed	G5	M	AF	x	x	

FULL SCIENTIFIC NAME	TAXONOMIC NOTES/ SYNONYMS	APG III FAMILY	APG III Number	COMMON NAME	G-Rank	Degree of fidelity to prairie habitats	Growth Form	Seasonal Wetland Prairies	Vernal Pools & Vernal Seepage	ORNHIC List
Chamaesyce serpyllifolia (Pers.) Small ssp. serpyllifolia	Euphorbia serpyllifolia	Euphorbiaceae	F184	thyme leaved spurge	G5T5	H	AF		x	
Cicendia quadrangularis (Lam.) Griseb.	Microcala quadrangularis	Gentianaceae	F351	timwort	G4	H	AF	x	x	2
Crassula aquatica (L.) P. Schoenl.	Tillaea aquatica	Crassulaceae	F134	water pygmy weed	G5	M	AF		x	
Crocidium multicaule Hook.		Asteraceae	F400	spring gold	G5	H	AF		x	
Cuscuta pentagona Engelm. var. pentagona	Cuscuta campestris	Convolvulaceae	F357	field dodder	G5T5	M	AF	x	x	
Danthonia californica Bolander var. americana (Scribner) A.S. Hitchc.		Poaceae	F106	Umbrella Plant	not ranked	H	GR	x		
Delphinium pavonaceum Ewan	Delphinium menziesii ssp. pallidum	Ranunculaceae	F114	peacock larkspur	G1Q	H	PF	x		1
Deschampsia cespitosa (L.) P. Beauv. s.l.	Deschampsia cespitosa var. cespitosa & var. beringensis	Poaceae	F106	tufted hairgrass	G5	M	GR	x	x	
Deschampsia danthonioides (Trin.) Munro		Poaceae	F106	annual hairgrass	G5	H	GR	x	x	
Diplacus douglasii (Benth.) G.L. Nesom	Mimulus douglasii	Phrymaceae	F374	Dougla's Monkeyflower	G4G5	H	AF	x	x	
Diplacus tricolor (Hartw. ex Lindl.) G.L. Nesom	Mimulus tricolor	Phrymaceae	F374	Tricolor Monkeyflower	G4	H	AF		x	2
Dodecatheon pulchellum (Raf.) Merr. ssp. macrocarpum (A. Gray) Roy Taylor & MacBryde		Primulaceae	F333	beautiful shooting star	G5T4Q	H	PF	x		
Dodecatheon pulchellum (Raf.) Merr. ssp. monanthum (Greene) H.J. Thomps.	Dodecatheon pauciflorum var. monanthum	Primulaceae	F333	beautiful shooting star	G5T2T4	H	PF	x		
Downingia elegans (Douglas ex Lindl.) Torr. var. elegans		Campanulaceae	F391	elegant downingia	G5	H	AF	x	x	
Downingia willamettensis Peck	Downingia yina	Campanulaceae	F391	Willamette downingia	G4	H	AF	x	x	
Eleocharis acicularis (L.) Roem. & Schult. var. acicularis		Cyperaceae	F099	needle spikerush	G5T5	M	GR	x	x	
Eleocharis palustris (L.) Roem. & Schult. var. palustris	Eleocharis macrostachya	Cyperaceae	F099	creeping spikerush	G5TNR	M	GR	x	x	
Epilobium brachycarpum C. Presl	Epilobium paniculatum	Onagraceae	F220	tall annual willowherb	G5	M	AF	x	x	
Epilobium densiflorum (Lindl.) P.C. Hoch & P.H. Raven	Boisduvalia densiflora	Onagraceae	F220	close flowered boisduvalia	G5	H	AF	x	x	
Epilobium pygmaeum (Speg.) P.C. Hoch & P.H. Raven	Boisduvalia glabella	Onagraceae	F220	smooth willowherb	G5	H	AF		x	
Epilobium torreyi (S. Watson) P.C. Hoch & P.H. Raven	Boisduvalis stricta	Onagraceae	F220	Torrey's willowherb	G5	H	AF	x	x	
Equisetum palustre L.		Equisetaceae	B003	marsh horsetail	G5	M	PF	x		
Erigeron decumbens Nuttall		Asteraceae	F400	Willamette Valley daisy	G1	H	PF	x		1
Eriophyllum lanatum (Pursh) J. Forbes var. achillaeoides (DC) Jepson		Asteraceae	F400	yarrow leaved woolly sunflower	G5T3T5	H	PF	x		
Eriophyllum lanatum (Pursh) J. Forbes var. leucophyllum (DC) W.R. Carter)		Asteraceae	F400	Oregon sunshine	G5T5	H	PF	x		
Eryngium petiolatum Hook.		Apiaceae	F413	coyotethistle	G4	H	PF	x	x	
Erythranthe guttata (Fischer ex DC.) Nesom	Mimulus guttatus	Phrymaceae	F374	yellow monkeyflower	G5	M	PF	x	x	
Erythranthe nasuta (Greene) Nesom	Mimulus nasutus, Mimulus guttatus var. nasutus	Phrymaceae	F374	large-nosed monkeyflower	not ranked	H	AF		x	
Euphorbia crenulata Engelm.		Euphorbiaceae	F184	Chinese caps	G5	M	AF	x		
Euthamia occidentalis Nutt.	Solidago occidentalis	Asteraceae	F400	Western Fragrant Goldenrod	G5	M	PF	x		
Fragaria virginiana Duchesne var. platypetala (Rydb.) H.M. Hall	Fragaria virginana var. platypetala	Rosaceae	F147	prairie strawberry	G5T5?	H	PF	x		
Gamochaeta ustulata (Nutt.) G.L. Nesom	Gnaphalium purpureum L. var. ustulatum	Asteraceae	F400	purple cudweed	GNR	M	AF	x	x	
Gentiana sceptrum Griseb.		Gentianaceae	F351	king's gentian	G4	M	PF	x		
Geranium oreganum Howell		Geraniaceae	F215	western geranium	G4G5	H	PF	x		
Glyceria occidentalis (Piper) J.C. Nelson		Poaceae	F106	western mannagrass	G5	M	GR	x	x	
Gnaphalium palustre Nuttall		Asteraceae	F400	lowland cudweed	G5	M	AF	x	x	
Gratiola ebracteata Benth.		Plantaginaceae	F368	bractless hedge hyssop	G4	M	AF	x	x	
Grindelia integrifolia		Asteraceae	F400	Willamette Valley gumweed	G5TNR	H	PF	x	x	
Hemizonella minima A. Gray	Madia minima	Asteraceae	F400	least tarweed	G4	H	AF		x	
Heterocodon rariflorum Nuttall		Campanulaceae	F391	western pearlflower	G5	H	AF		x	
Heuchera chlorantha Piper		Saxifragaceae	F133	green flowered alumroot	G4G5	M	PF	x		
Hordeum brachyantherum Nevski ssp. brachyantherum		Poaceae	F106	meadow barley	G5T5	M	GR	x		
Horkelia congesta Douglas ex Hook. ssp. congesta		Rosaceae	F147	shaggy horkelia	G4T2	H	PF	x		1
Hosackia gracilis Benth.	Lotus formosissimus	Fabaceae	F144	bicolored lotus	G4	H	PF	x	x	
Hosackia pinnata (Hook.) Abrams	Lotus pinnatus	Fabaceae	F144	bog lotus	G4G5	H	PF	x	x	

FULL SCIENTIFIC NAME	TAXONOMIC NOTES/ SYNONYMS	APG III FAMILY	APG III Number	COMMON NAME	G-Rank	Degree of fidelity to prairie habitats	Growth Form	Seasonal Wetland Prairies	Vernal Pools & Vernal Seepage	ORNHIC List
Hypericum anagalloides Cham. & Schltdl.		Hypericaceae	F214	bog St. John's wort	G4	M	PF	x		
Hypericum scouleri Hook. var. scouleri	Hypericum formosum var. scouleri	Hypericaceae	F214	western St. John's wort	G5T3T5	M	PF	x		
Isoetes nuttallii A. Br.		Isoetaceae	A003	Nuttall's quillwort	G4?	H	PF	x	x	
Juncus confusus Coville		Juncaceae	F098	Colorado rush	G5	H	GR	x		
Juncus hemiendytus F.J. Herm. var. hemiendytus		Juncaceae	F098	dwarf rush	G5T5	H	GR		x	
Juncus kelloggii Engelm.		Juncaceae	F098	Kellogg's Rush	G3?	H	GR		x	3
Juncus nevadensis S. Watson var. nevadensis		Juncaceae	F098	Sierra rush	G5T4T5	H	GR	x	x	
Juncus occidentalis Wieg.	Juncus tenuis var. congestus	Juncaceae	F098	prairie rush	G5	M	GR	x		
Juncus patens E. Mey.		Juncaceae	F098	spreading rush	G5	M	GR	x		
Juncus tenuis Willd.		Juncaceae	F098	poverty rush	G5	M	GR	x		
Koeleria macrantha (Ledeb.) Schult.	Koeleria cristata	Poaceae	F106	junegrass	G5	H	GR	x		
Lactuca biennis (Moench) Fernald		Asteraceae	F400	tall blue lettuce	G5	M	AF	x		
Lasthenia glaberrima DC.		Asteraceae	F400	smooth goldfields	G5	H	AF	x	x	
Lepidium virginicum L. ssp. menziesii (DC.) Thellung		Brassicaceae	F273	hairy pepperweed	G5TNR	M	AF		x	
Leptosiphon bicolor Nuttall	Linanthus bicolor ssp. bicolor	Polemoniaceae	F327	bicolored linanthus	G5	H	AF	x	x	
Lomatium bradshawii (Rose) Mathias & Constance		Apiaceae	F413	Bradshaw's desert parsley	G2	H	PF	x		1
Lomatium dissectum (Nuttall) Mathias & Constance var. dissectum		Apiaceae	F413	fern leaved lomatium	G4T4	H	PF	x		
Lomatium nudicaule (Pursh) J.M. Coult. & Rose		Apiaceae	F413	barestem lomatium	G5	H	PF	x		
Lupinus polyphyllus Lindl.	s.l., incl. Lupinus polyphyllus var. pallidipes	Fabaceae	F144	large leaved lupine	G5	M	PF	x		
Luzula comosa E. Mey.	Luzula campestris var. congesta	Juncaceae	F098	Pacific woodrush	G4G5	M	GR	x		
Madia elegans D. Don ex Lindl. ssp. elegans		Asteraceae	F400	showy tarweed	GNRTNR	H	AF	x		
Madia glomerata Hook.		Asteraceae	F400	mountain tarweed	G5	H	AF	x	x	
Madia sativa Molina	sensu lato	Asteraceae	F400	coast tarweed	G5	M	AF	x		
Mentha canadensis L.	Mentha arvensis var. canadensis	Lamiaceae	F373	field mint	G5	M	PF	x		
Micranthes oregana (Howell) Small in N. L. Britton	Saxifraga oregana var. oregana	Saxifragaceae	F133	Oregon saxifrage	G4G5	H	PF	x		
Micropus californicus Fisch. & C.A. Mey. var. californicus		Asteraceae	F400	slender cottonweed	G5T5	H	AF	x		
Microseris laciniata (Hook.) Sch. Bip. ssp. laciniata		Asteraceae	F400	cutleaf silverpuffs	G4T4	H	PF	x		
Microsteris gracilis (Hook.) Greene	Phlox gracilis	Polemoniaceae	F327	pink annual phlox	G5T5	H	AF	x	x	
Montia fontana L. var. tenerrima (Gray) Fern. & Wieg.		Montiaceae	F309	water chickweed	G5TNR	M	AF	x	x	
Montia howellii S. Watson		Montiaceae	F309	Howell's montia	G3G4	M	AF	x		4
Montia linearis (Douglas ex Hook.) Greene		Montiaceae	F309	narrowleaf montia	G5	M	AF	x	x	
Myosurus minimus L.		Ranunculaceae	F114	least mousetail	G5	H	AF		x	
Navarretia intertexta (Benth.) Hook. ssp. intertexta		Polemoniaceae	F327	needle leaved navarretia	G5TNR	H	AF	x	x	
Navarretia leucocephala Benth. ssp. leucocephala		Polemoniaceae	F327	white flowered navarretia	G4T4?	H	AF		x	4
Navarretia squarrosa (Eschsch.) Hook. & Arn.		Polemoniaceae	F327	skunkweed	G5	M	AF		x	
Navarretia willamettensis S.C. Spencer		Polemoniaceae	F327	Willamette navarretia	G1	H	AF		x	1
Orthocarpus bracteosus Benth.		Orobanchaceae	F376	rosy owlclover	G3?	H	AF	x	x	
Panicum acuminatum Sw. ssp. fasciculatum (Torr.) Freckman & Lelong	Panicum occidentale; Dichanthelium acuminatum var. fasciculatum	Poaceae	F106	western witchgrass	G5T5	H	GR	x	x	
Panicum capillare L. var. occidentale Rydb.	Panicum barbipulvinatum	Poaceae	F106	witchgrass	G5TNR	M	GR		x	
Perideridia montana (Blank.) Dorn	Perideridia gairdneri ssp. borealis	Apiaceae	F413	mountain yampah	G5	H	PF	x		
Perideridia oregana (S. Watson) Mathias		Apiaceae	F413	Oregon yampah	G4G5	H	PF	x		
Piperia elegans (Lindl.) Rydb. ssp. elegans	Habenaria elegans	Orchidaceae	F062	elegant rein orchid	G4T4	M	PF	x		
Plagiobothrys figuratus (Piper) I.M. Johnst. ssp. figuratus		Boraginaceae	F356	fragrant popcorn flower	G4T4	H	AF	x	x	
Plagiobothrys scouleri (Hook. & Arn.) I.M. Johnst. var. hispidulus (Greene) Dorn		Boraginaceae	F356	sleeping popcornflower	G5T5	M	AF	x		
Plagiobothrys scouleri (Hook. & Arn.) I.M. Johnst. var. scouleri		Boraginaceae	F356	Scouler's popcorn flower	G5TNR	M	AF	x	x	

FULL SCIENTIFIC NAME	TAXONOMIC NOTES/ SYNONYMS	APG III FAMILY	APG III Number	COMMON NAME	G-Rank	Degree of fidelity to prairie habitats	Growth Form	Seasonal Wetland Prairies	Vernal Pools & Vernal Seepage	ORNHIC List
Plectritis congesta (Lindl.) DC. var. congesta		Caprifoliaceae	F406	rosy plectritis	G5T5?	H	AF	x		
Poa secunda J. Presl	incl. Poa scabrella, Poa juncifolia	Poaceae	F106	sandberg bluegrass	G5	H	GR	x	x	
Polygonum polygaloides ssp. confertiflorum	Polygonum confertiflorum	Polygonaceae	F286	close flowered knotweed	G4G5T3T4	H	AF		x	
Polygonum spergulariaeforme Meisn.	Polygonum douglasii ssp. spergulariforme	Polygonaceae	F286	fall knotweed	G5T4?	H	AF	x		
Potentilla gracilis Douglas ex Hook. var. gracilis		Rosaceae	F147	graceful cinquefoil	G5T5	H	PF	x		
Prunella vulgaris L. var. lanceolata (W.P.C. Barton) Fernald	Prunella vulgaris var. atropurpurea	Lamiaceae	F373	native self heal	G5T5	M	PF	x		
Psilocarphus elatior (A. Gray) A. Gray		Asteraceae	F400	tall woollyheads	G4Q	M	AF	x	x	
Psilocarphus oregonus Nuttall		Asteraceae	F400	Oregon Woollyheads	G4	M	AF	x	x	
Psilocarphus tenellus Nuttall var. tenellus		Asteraceae	F400	slender woollyheads	G4T4	H	AF		x	
Pyrrocoma racemosa (Nuttall) Torr. & A. Gray var. racemosa	Haplopappus racemosus	Asteraceae	F400	racemed goldenweed	G5T3T4	H	PF	x		2
Ranunculus alismifolius Geyer ex Bentham var. alismifolius		Ranunculaceae	F114	plantain leaved buttercup	G5T5	H	PF	x	x	
Ranunculus lobbii (Hiern) A. Gray		Ranunculaceae	F114	Lobb's water buttercup	G4	H	AF		x	
Ranunculus occidentalis Nuttall var. occidentalis		Ranunculaceae	F114	western buttercup	G5T5	H	PF	x		
Ranunculus orthorhynchus Hook. var. orthorhynchus		Ranunculaceae	F114	straightbeak buttercup	G5T5	H	PF	x		
Ranunculus orthorhynchus Hook. var. platyphyllus A. Gray		Ranunculaceae	F114	broadleaved buttercup	not ranked	H	PF	x		
Rorippa curvisiliqua (Hook.) Bessey ex Britton		Brassicaceae	F273	western yellowcress	G5	M	AF		x	
Rotala ramosior (L.) Koehne		Lythraceae	F219	Toothcup	G5	M	AF		x	2
Rudbeckia occidentalis Nuttall var. occidentalis		Asteraceae	F400	western coneflower	G5TNR	M	PF	x		
Rumex salicifolius Weinm. var. salicifolius	Rumex transitorius Rech. f.	Polygonaceae	F286	willow dock	G5TNR	M	PF	x	x	
Sanguisorba annua (Nuttall ex Hook.) Torr. & A. Gray	Sanguisorba occidentalis	Rosaceae	F147	western burnet	G4	M	AF		x	
Sclerolinon digynum (A. Gray) C.M. Rogers	Linum digynum	Linaceae	F208	northwestern yellowflax	G5	H	AF	x	x	3
Sericocarpus rigidus Lindl.	Aster curtus	Asteraceae	F400	rigid white topped aster	G3	H	PF	x		1
Sidalcea campestris Greene		Malvaceae	F250	meadow checkermallow	G4	H	PF	x		4
Sidalcea cusickii Piper	includes ssp. purpurea	Malvaceae	F250	Cusick's checkermallow	G4	H	PF	x		4
Sidalcea nelsoniana Piper		Malvaceae	F250	Nelson's Sidalcea	G2G3	H	PF	x		1
Sisyrinchium bellum S. Watson		Iridaceae	F071	beautiful blue-eyed-grass	G4G5	H	PF	x		
Sisyrinchium hitchcockii D.M. Hend.		Iridaceae	F071	Hitchcock's blue-eyed-grass	G2	H	PF	x		1
Sisyrinchium idahoense E.P. Bicknell var. idahoense		Iridaceae	F071	Idaho blue-eyed-grass	G5T4	H	PF	x		
Spiranthes porrifolia Lindl.		Orchidaceae	F062	western ladies' tresses	G4	H	PF		x	
Spiranthes romanzoffiana Cham.		Orchidaceae	F062	hooded ladies' tresses	G5	H	PF	x	x	
Symphyotrichum hallii (A. Gray) G.L. Nesom	Aster hallii	Asteraceae	F400	Hall's aster	G4	H	PF	x		
Symphyotrichum subspicatum (Nees) G.L. Nesom	Aster subspicatus	Asteraceae	F400	Douglas' aster	G5	M	PF	x		
Thalictrum polycarpum (Torr.) S. Watson	Thalictrum fendleri var. polycarpum	Ranunculaceae	F114	tall western meadowrue	not ranked	M	PF	x		
Toxicoscordion venenosum (S. Watson) Rydberg var. venenosum	Zigadenus venenosus var. venenosus	Melanthiaceae	F053	meadow deathcamas	G5T5	H	PF	x		
Trichostema lanceolatum Benth.		Lamiaceae	F373	vinegar weed	G5	H	AF	x	x	
Trichostema oblongum Benth.		Lamiaceae	F373	downy blue curls	G5	H	AF	x	x	
Trifolium longipes Nuttall ssp. longipes		Fabaceae	F144	longstalk clover	G5T3T4	H	PF	x		
Trifolium oliganthum Steud.		Fabaceae	F144	few flowered clover	G5	H	AF	x		
Triodanis biflora (Ruíz & Pav.) Greene	Triodanis perfoliata var. biflora	Campanulaceae	F391	small Venus' lookingglass	G5	H	AF	x		
Triphysaria pusilla (Benth.) Chuang & Heckard	Orthocarpus pusillus	Orobanchaceae	F376	dwarf owlclover	G5	M	AF	x		
Triteleia hyacinthina (Lindl.) Greene	Brodiaea hyacinthina	Asparagaceae	F075	hyacinth triteleia	G4G5	H	PF	x	x	
Veronica peregrina L. var. xalapensis (Kunth) H. St. John & F.A. Warren		Plantaginaceae	F368	hairy purslane speedwell	G5T5	M	AF	x	x	
Veronica scutellata L.		Plantaginaceae	F368	marsh speedwell	G5	M	PF	x	x	
Vicia americana Muhl. ex Willd. var. americana		Fabaceae	F144	American vetch	G5T5	M	PF	x		
Viola hallii A. Gray		Violaceae	F202	Hall's violet	G4	H	PF	x		
Wyethia angustifolia (DC.) Nuttall		Asteraceae	F400	narrowleaf mule's ears	G4	H	PF	x		

Definitions, Acronyms, and Data Sources

APG III FAMILY: Angiosperm Phylogeny Group III system of flowering plant classification is a mostly molecular-based system of plant taxonomy.

G-Rank: NatureServe and its member programs and collaborators use a suite of factors to assess the conservation status of plant, animal, and fungal species, as well as ecosystems. For species, these ranks provide an estimate of extinction risk, while ecosystems they provide an estimate of the risk of elimination. For more detailed information about conservation status ranks visit NatureServe Publications. Conservation status ranks are based on a one to five scale, ranging from critically imperiled (G1) to demonstrably secure (G5). Status is assessed and documented at three distinct geographic scales-global (G), national (N), and state/province (S).

Degree of Fidelity to Prairie Habitats:

This is a generalization for the species across the ecoregion.

H = high fidelity to native prairie and related habitats; usually when this species is observed it is in a prairie remnant or fragment of historic native prairie.

Note: this category may include native weeds that historically occurred primarily in prairies but have spread into other disturbed areas.

M = moderate fidelity to native prairie habitats; may occur occasionally in conifer forest, wetland, riparian forest, or other habitats.

Growth Form:

PF = Perennial Forb
AF = Annual Forb
GR = Graminoid

ORNHIC List: Oregon Threatened or Endangered Field Guide (http://orbic.pdx.edu/plants/view_plants2.php)

List 1: Contains taxa that are threatened with extinction or presumed to be extinct throughout their entire range.
List 2: Contains taxa that are threatened with extirpation or presumed to be extirpated from the state of Oregon.
List 3: Contains taxa for which more information is needed before status con be determined, but which may be threatened or endangered in Oregon or throughout their range.
List 4: Contains taxa which are of conservation concern but are not currently threatened or endangered.

Sections of the WPG ecoregion abd acronyms/codes for data sources:

GB = Georgia Basin section. Includes SE Vancouver Island and adj. Gulf Islands, San Juan Islands, and rain shadow portions of Island, Clallam, and Jefferson Counties.

IFBC = Illustrated Flora of British Columbia, vol. 8, Douglas et al., 2002
SJ = Wild Plants of the San Juan Islands, Atkinson & Sharpe, 2nd. Ed, 1993
UBC = University of British Columbia Herbarium
VI = Flora of the Saanich Peninsula, Szczawinski & Harrison 1972
VP=Vascular Plants of the Pacific Northwest, Hitchcock et al. 1955-1969
WE = Wayne Erickson data

PT = Puget Trough section. Includes mainland BC portions of the ecoregion, plus Puget Trough outside of the Olympic Rain shadow, south through Thurston County WA.

BH = Bald Hill NAP, Thurston Co. WA, Ed Alverson 1988
CB =
FL = Fort Lewis plant list, Fort Lewis Staff, 1992-1995
GM = Grass Manual on the Web, http://herbarium.usu.edu/webmanual/default.htm
FRV = F. Lomer 2011, "Rare Plants of the Fraser Valley in the Lowland Zone", BEN #432-43*
PI = Piper 1906, Flora of Washington
PE= Peter & Shebitz, "Beargrass savannas of SE OP", Restoration Ecology 14(4):605-615
PP = Glacial Outwash Prairies, Thurston and Pierce Cos., WA
RP = Rocky Prairie, TNC list
SC = Scatter Creek wildlife area, Thurston Co. WA, Jim Barrett 1979
TH = list of vascular Plants of Thurston Co. WA, Jim Barrett et al.
WH = "The Flora of Whatcom County", W.C. Meunscher, 1941

LC = Lower Columbia section. Includes immediate vicinity of the Columbia River from about Cape Horn downstream to below Longview, and from Lewis County WA south to Washington County OR and most of Clackamas County	BI = Blackwater Island RNA, Clark Co. WA CO = Cooper Mountain Metro Greenspace, Washington Co., OR CP = TNC Camassia Preserve, Clackamas Co. OR EA = Plants of the Lewis County prairies, Ed Alverson, 1986 LM = Lacamas Meadows/Green Mtn. Resort easement, Clark Co. WA OSC = Oregon State University Herbarium data base OPA = Oregon Flora Plant Atlas PDX = Flora of Portland, Christy and Kimpo, NPSO Occasional Paper #2 PD = Phil Gaddis VP=Vascular Plants of the Pacific Northwest, Hitchcock et al. 1955-1969 WN = Willamette Narrows, Clackamas Co. OR
WV = Willamette Valley section. From the Molalla River and Chehalem Mountains south to Lane County, OR.	BH = Bald Hill Park, Corvallis, Benton Co. EA = Ed Alverson observation FR = Finley National Wildlife Refuge, Benton Co. LA = Vascular Plants of Lane County Oregon, 2002 MP = Howard Buford Recreation Area (Mt. Pisgah), Lane Co. OSC = Oregon State University Herbarium data base OPA = Oregon Flora Plant Atlas VP=Vascular Plants of the Pacific Northwest, Hitchcock et al. 1955-1969 WC = Willow Creek Natural Area, Lane Co. WEW= West Eugene Wetlands, Lane Co. unless otherwise noted, data taken mostly from WV flora focus list, Native Seed Network.

Sources of Herbarium Label Data:

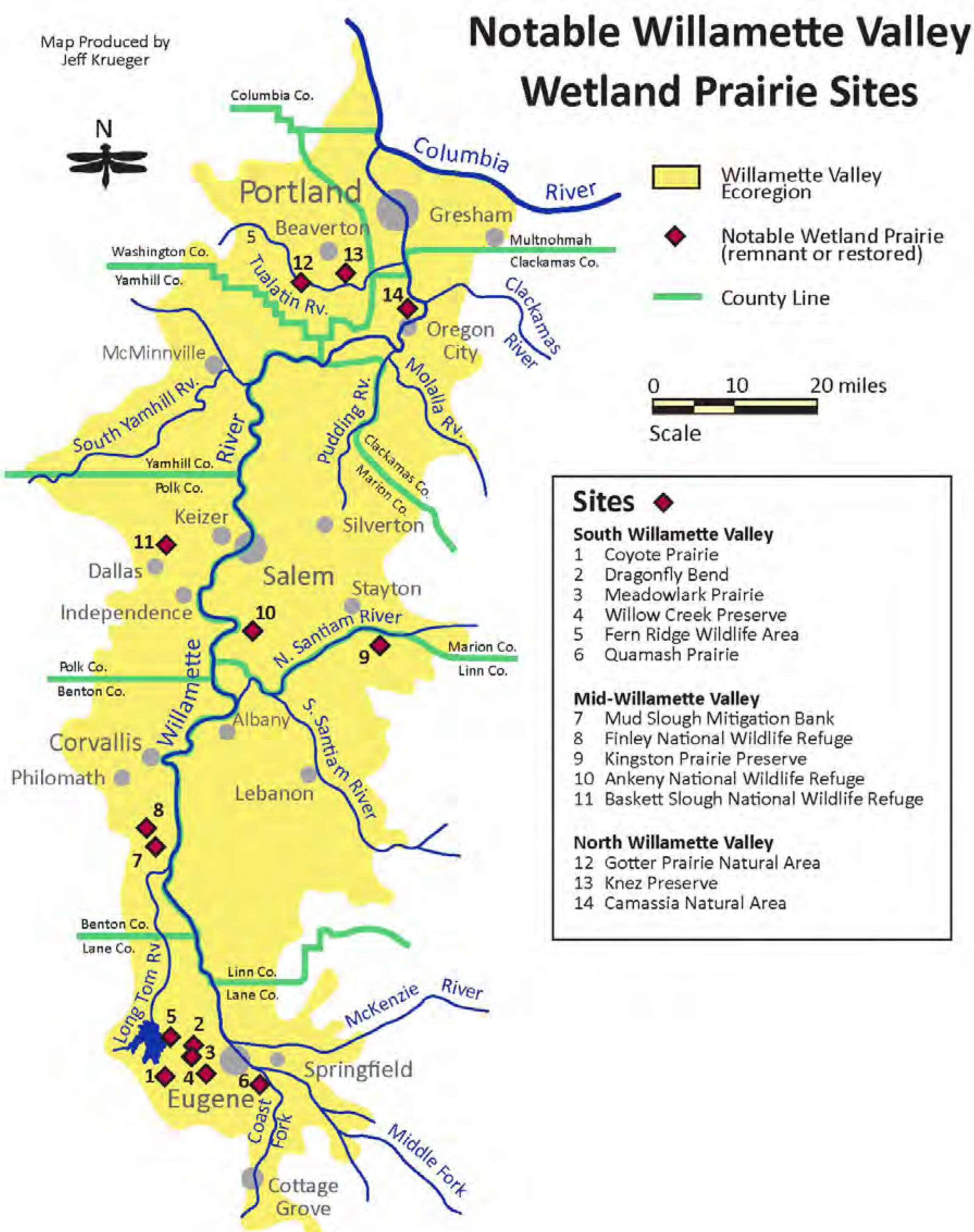
WTU = University of Washington herbarium
OSC = Oregon State University Herbariumn
WS = Marion Ownbey Herbarium, Washington State University

Ecological Systems:

Oak woodland and forest:	Habitats with oak as a dominant or co-dominant in the overstory (canopy closure >ca. 60%), with low shrubs and herbs in the understory.
Savanna:	Scattered canopy trees (canopy closure from 5% to 60%) with herb-dominated understory
Herbaceous Balds and rock Outcrops:	Areas of bedrock exposure that are relatively open and herbaceus dominated, plus rock crevices and open talus sopes.
Upland Prairies:	Prairies on deep, well drained, soils dominated by grasses and forbs; moisture levels ranging from mesic to xeric depnding upon soil texture. Includes coastal meadows above the immediate wave-influecned zone.
Seasonal Wet Prairies:	Prairies on poorly drained soils or otherwise with a seasonally high water table, but also characterized by seasonal (late summer) drought.
Vernal Pools and Vernal Seepage:	Localized depressions within a prairie landscape that are seasonally inundated but excessively dry in the summer, as well as floristically similar depressions or flats on bedrock outcrops that are seasonally inundated or constantly saturated.

Appendix B: Willamette Valley Wetland Prairie Sites

Several notable concentrations of remnant, or recently restored, wetland prairies can be found in the Willamette Valley. These sites are extremely important from the perspective of preserving associated plant species and creating viable habitat blocks for dependent wildlife. In addition, many also function as reference sites that can be used to guide future wetland prairie restoration efforts. The section below highlights some of the more significant sites found within the Willamette Valley.



Southern Willamette Valley Sites

1. Coyote Prairie (City of Eugene)	
Category	Restoration
Location	Located near Coyote Creek to the west of Eugene
Size	240 acres. The site is a component of the much broader West Eugene Wetlands complex which covers approximately 3,000 acres.
Overview	Coyote Prairie is a City of Eugene owned wetland mitigation site located near Coyote Creek, approximately one and a half miles to the west of Eugene. The site is bordered to the north by Cantrell Road and has been in agricultural production for grass seed since the 1970s. The property is now in the process of being restored to wetland prairie in phases by the City's wetland mitigation bank. The first phase of the project began in 2006, with the restoration of 23 acres of wetland prairie, plus an additional two acres of vernal pool and one acre of upland prairie. The following year, work was begun on 38 additional acres of wetland prairie, and in 2009, the most recent phase of wetland prairie restoration was begun on an additional 84 acres of land. The third phase also included the integration of several vernal pools and native tree and shrub patches to help increase habitat diversity. The final phase of restoration is scheduled to being in 2014 on the remaining 80 acres, which are currently being maintained under a temporary agricultural contract or are being utilized for the research test plots.
Management	The site's native vegetation is establishing well, including in the vernal pools where native annual plant species thrive. Monitoring of the newly created vernal pools in the latest phase of the project also revealed that all pools supported aquatic invertebrates and many supported breeding Pacific chorus frogs (*Pseudacris regilla*). Intensive vegetation management to control invasive species is occurring during the first several years of the restoration process. When the restoration project is considered complete, the site will continue to be managed for natural resource values, with long-term management actions directed at maintaining diversity and addressing woody encroachment and invasion by non-native plants. Management will include periodic ecological burns and mowing along with spot herbicide application as needed.
Access and Contact:	The site is open to the public, but there are currently no facilities or formal parking. For information on how to visit Coyote Prairie, contact the City of Eugene Parks and Open Space Division at 541-682-4800.

2. Dragonfly Bend (City of Eugene)	
Category	Restoration
Location	Located in west Eugene to the north of Royal Avenue, adjacent to Amazon Creek.
Size	77 acres. The site is a component of the much broader West Eugene Wetlands complex which covers approximately 3,000 acres.
Overview	Dragonfly Bend was historically a wetland prairie, converted in the 1930s to agricultural use. It was farmed for *Lolium multiflorum* (annual ryegrass) production when purchased by the City of Eugene in 2002 for use as a wetland mitigation site. The wetland restoration project was initiated in 2005 and is now considered complete. The project included restoration of approximately 32 acres of wetland prairie, 16 acres of vernal pools, 4 acres of upland prairie, and a one-acre ash swale. In addition, approximately 3,000 lineal feet of riparian restoration was implemented on the adjacent Amazon Creek. The restoration effort was considered highly successful with monitoring results showing the establishment of 97%-99% relative cover of natives in the first phase of the project.
Management	Ongoing management actions are directed at maintaining diversity and addressing woody encroachment and invasion by non-native vegetation. Management will include periodic ecological burns and mowing along with spot treatment of emerging invasive species.
Access and Contact:	The site is open to the public, although no formal facilities are present. Public parking is available at the adjacent Checkermallow Access (on Meadowlark Prairie) located on the south side of Royal Avenue. To access Dragonfly bend, carefully cross to the north side of Royal Avenue and access the site via the gate on the west side of Amazon Creek. For more information, contact the City of Eugene Parks and Open Space Division at 541-682-4800.

3. Meadowlark Prairie	
Category	Restoration
Location	Located in west Eugene to the south of Royal Avenue and east of Greenhill Road
Size	398 acres (BLM and City of Eugene ownership). The site is a component of the much broader West Eugene Wetlands complex which covers approximately 3,000 acres.
Overview	Meadowlark Prairie is the site of a major Corps of Engineers floodplain restoration project that was completed in 2001. This project included relocation of several miles of flood control levee that lined Amazon Creek and the Amazon Diversion Channel. This reconnected the floodplain of the creek to the adjacent wetlands has allowed more frequent flooding to occur. The Corps, BLM, and West Eugene Wetlands Mitigation Bank then partnered to restore and enhance nearly 300 acres of wetland prairie on the site over the next several years. Much of the restoration area was previously used for agriculture and pasture and had been slated for industrial development prior to the discovery of significant wetlands and subsequent public acquisition.
Management	The site is managed jointly by the BLM and City of Eugene for habitat and passive recreational uses. Typical management actions at Meadowlark Prairie include regular rough mowing and/or ecological burning to limit colonization by woody vegetation and invasive species control as needed. Western pond turtle habitat enhancements on the site included installation of improved nesting areas and basking logs. Bicycle and pedestrian use of the Fern Ridge Path, which runs along the perimeter of the site, is very popular. Meadowlark Prairie is an excellent spot for viewing raptors including Red-shouldered Hawk (*Buteo lineatus*), Bald Eagle (*Haliaeetus leucocephalus*), Peregrine Falcon (*Falco peregrinus*), White-tailed Kite (*Elanus leucurus*), and Northern Harrier. Prairie dependent species such as Western meadowlark and short-eared owl are known to nest here.
Access and Contact:	Meadowlark Prairie can be accessed by foot or bicycle from the paved Fern Ridge Path and by vehicle at the Checkermallow Access on Royal Avenue and the Meadowlark Prairie Overlook on Greenhill Road. For more information, contact the City of Eugene Parks and Open Space Division at 541-682-4800 or go to http://www.eugene-or.gov/index.aspx?NID=628 to view the site web cam.

4. Willow Creek Preserve (The Nature Conservancy)	
Category	Remnant and enhancement
Location	Located south of 18th Avenue in west Eugene
Size	519 acres. The site is a component of the much broader West Eugene Wetlands complex which covers approximately 3,000 acres.
Overview	The Nature Conservancy began managing parts of this site in cooperation with the private landowners as early as 1981 and took ownership of the core of the preserve in the early 1990s. Additional parcels were purchased or donated since the initial acquisition, bringing the total size to 519 acres. The preserve contains a mix of upland and wetland prairie, forested wetland, riparian forest, and oak woodland. The wetland prairie on the preserve is considered to be one of the best remaining examples of this habitat in the Willamette Valley and is often utilized as a reference site for restoration projects. Although the wetland prairie had been grazed prior to acquisition, it was never tilled or drained for agriculture, so contains a high diversity of native species, unaltered hydrology, and topography with mounds, hummocks, and vernal pools.
Management	When TNC began managing the prairie, encroachment by woody vegetation was a significant issue. Beginning in 1986, TNC began using ecological burning as a management tool, and has continued this practice on a regular basis since that time. This regular burning has reduced the encroachment of woody vegetation and has also benefited native species like *Lomatium bradshawii*, which has increased significantly in burned areas. Scientists have been monitoring vegetation, reptiles, amphibians, and butterflies on the site for nearly three decades to gain a better understanding of how Willamette Valley prairies function. More than 200 native plants, 100 birds, and 25 butterfly species have been recorded on the preserve. Volunteers have been utilized on a regular basis to help eradicate invasive species such as *Cytisus scoparius* (Scotch broom), *Hedera helix* (English ivy), and *Rubus* spp. (blackberry).
Access and	The site is open to the public, but facilities are limited to a single loop trail accessed from 18th

Contact:	Avenue. For more information about the site, contact The Nature Conservancy at 541-343-1010.

5. Fern Ridge Wildlife Area (U.S. Army Corps of Engineers)	
Category	Remnant and enhancement
Location	Located approximately two miles west of Eugene along the banks of Fern Ridge Reservoir
Size	5,010 acres of mixed habitats including significant areas of wetland prairie
Overview	The Fern Ridge Wildlife Area was designated in 1957 following the construction of the Fern Ridge Reservoir under an agreement between the U.S Army Corps of Engineers (Corps) and Oregon Department of Fish & Wildlife (ODFW), which allowed the State to manage the wildlife resources on a 5,010 acre portion of the lands surrounding the reservoir. Emphasis for this management was placed primarily on waterfowl and wetland species. The site includes approximately 2,000 acres of marshland, 800 acres of mixed woodland, 1,800 acres of open water, and 400 acres of upland and wetland prairie. The site contains several areas of high quality remnant prairie and recently enhanced prairie.
Management	In a cooperative agreement between The Nature Conservancy, University of Oregon, ODFW, and the Corps, hundreds of acres within the Fern Ridge Wildlife Area have been designated as *Research Natural Areas* to protect the sensitive prairies. These areas are being managed to with a goal of protecting established native species and increasing native diversity. Ecological burns along with mowing and selective herbicide application area common management tools.
Access and Contact:	Access points are located around the perimeter of the reservoir. For more information on wetland prairie locations contact the Corps at 541-935-2591or go to http://www.dfw.state.or.us/resources/visitors/fern_ridge_wildlife_area/.

6. Quamash Prairie (Lane County Waste Management)	
Category	Restoration
Location	Located approximately two miles south of Eugene, adjacent to I-5 and the Lane County Short Mountain Landfill, near the Coast Fork of the Willamette River
Size	Approximately 100 acres of restored wetland prairie adjacent to a mix of other habitats
Overview	The site had been used for agricultural purposes (*Lolium multiflorum* production) until purchased by the Lane County Waste Management Division to serve as a site to mitigation wetland impacts occurring on the adjacent landfill. Restoration was begun in 2008 and included areas of significant grading. Site preparation occurred in 2009-2010, and planting in 2011 to present. The project included major transplant of approximately 100,000 *Camassia* spp. bulbs harvested from the impacted landfill area.
Management	Following certification of mitigation credits, Lane County Waste Management will continue to manage the site at a low level to maintain diversity and address woody encroachment and invasion by non-native vegetation. Ecological burns are unlikely on this site due to proximity to the highway. They will consider haying as a method of reducing thatch build-up.
Access and Contact:	There is currently no formal public access onto the site, but tours are occasionally offered. Contact Lane County Waste Management at 541-687-4120

Mid-Willamette Valley Sites

7. Mud Slough Mitigation Bank (privately owned with conservation easement held by the Wetlands Conservancy)	
Category	Restoration
Location	Near Rickreall, Oregon
Size	550 acres
Overview	The site was farmed by the Knaupp family for grass seed production until 1993 when the family put a voluntary easement on 320 acres of their property through the Wetland Reserve Program. Through this program they received technical and financial assistance to restore the agricultural land into wetland. By 1996, 400 acres of farmland had been restored to wetland including significant areas of wetland prairie. The Knaupp family later turned portions of the site into a wetland mitigation bank beginning in 2000. In 2005, the Knaupp family approached the Wetlands Conservancy, asking them to hold a conservation easement on the property for perpetuity. Since 1996 the land has made a great recovery and hosts a large number of native plant and animal

	species. The mitigation bank is now completing the fourth phase of restoration and is having good success with increasing forb diversity in the latest phase.
Management	The site contains a mix of shallow water habitats, willow patches, and wetland prairie.
Access and Contact:	No public access. For information, contact The Wetlands Conservancy at 503-227-0778.

8. William L. Finley National Wildlife Refuge (U.S. Fish & Wildlife Service)	
Category	Preservation, enhancement, and restoration
Location	Finley National Wildlife Refuge is situated along the foothills of the Coast Range on the western edge of the Willamette Valley, approximately 10 miles south of Corvallis.
Size	The refuge covers a total of 5,791 acres, comprised of cropland (managed for goose forage), oak savanna, mixed forests, and prairie. The refuge includes a total of 366 acres of land classified as wetland prairie.
Overview	The wetland prairie in Finley NWR is considered to be the largest contiguous tract of historic (remnant) wetland prairie habitat remaining within the Willamette Valley. This area was grazed until 1966, but was never tilled. As a result, this wetland prairie contains a high diversity of native species, unaltered hydrology, and topography with mounds, hummocks, and vernal pools (USFWS, 2011). The refuge has over 12 miles of hiking trails and observation platforms for the public viewing and a tour route for cars.
Management	Grazing of the wetland prairie area occurred until it was established as a Research Natural Area (RNA) in 1966, at which time prescribed burning became the preferred management treatment to maintain the prairie habitat structure. Fire was used sparingly until 1990, when a structured prescribed fire plan was implemented and burning increased. Selective mowing and brush cutting with chain saws have also been utilized as methods for controlling woody vegetation. All mechanical work, including mowing and removal of felled trees/shrubs, is done using a low ground pressure skid-steer tractor. The preferred fire interval on the wetland prairie management units is 2-4 years. Active wetland prairie restoration was begun in 1999 on approximately 130 acres of retired agricultural fields within the NWR. Typical restoration in these areas has involved herbicide treatments for two successive growing seasons, often with prescribed fire in one or both seasons depending on herbaceous cover, and no-till drilling of native wet prairie grasses and forbs in the second fall. The first year follow-up treatment may involve late spring mowing to reduce seed set of non-native annuals, spot herbicide treatment of invasive plants that may impact native establishment, and supplemental seeding to increase species diversity.
Access and Contact:	Public access is permitted, but some areas are off limits to the public during winter months. For additional information, call 541-757-7236, or go to http://www.fws.gov/willamettevalley/ankeny/.

9. Kingston Prairie Preserve (The Nature Conservancy)	
Category	Preservation and enhancement
Location	Three miles southeast of Stayton, Oregon near the Santiam River
Size	152 acres
Overview	Due to the presence of shallow soils and basalt bedrock outcrops, this site was never used for agriculture and has retained much of its original prairie vegetation. Kinston Prairie Preserve is now owned and managed by The Nature Conservancy. The site has both dry upland areas and wet meadows and serves as a prime example of the ecosystem that once dominated much of the Willamette Valley. The wet meadows are dominated by the native *Deschampsia cespitosa* along with a diversity of native species including *camassia* and *Lomatium bradshawii*.
Management	The Nature Conservancy has been using controlled burns to limit invasion by woody vegetation, preserve plant diversity, and help restore nutrients to the soil. Volunteers have been utilized to remove invasive species like *Cytisus scoparius* and the *Rubus* spp. from the prairie. Ecologists have been monitoring the native species and plan to restore disturbed areas around the perimeter of the site. Wildlife biologists have used the preserve to study habitat needs of the Western Meadowlark and other songbirds known to be declining in the Willamette Valley.
Access and Contact:	The Kingston Prairie Preserve is located 1.7 miles eastbound on Kingston-Lyons Drive outside of Stayton. There are a few trails open to the public. Dogs are not allowed. Contact The Nature

	Conservancy at 541-343-1010 for more information.

10. Ankeny National Wildlife Refuge (U.S. Fish & Wildlife Service)	
Category	Preservation and enhancement
Location	The Refuge is situated near the confluence of the Santiam and Willamette rivers, approximately 12 miles south of Salem.
Size	The Refuge totals 2,814 acres, and contains approximately 1,765 acres of cropland managed to provide forage for wintering geese, 600 acres of riparian forests, and 500 acres of shallow water seasonal wetlands, of which a 40-acre block is classified as wetland prairie.
Overview	Many of the wetlands found at Ankeny occur naturally, although some were artificially created with a network of dikes and levees. A 2001 survey of the 40-acre wetland prairie area at Ankeny NWR (conducted by TNC) indicated that the site supported a low diversity of native wetland species and had significant woody vegetation encroachment.
Management	Woody vegetation was significantly cleared from the wetland prairie between 2003 and 2005 and the site was burned in 2007, resulting in increased herbaceous cover. Management applications currently include late summer mowing and/or prescribed fire on a 3-4 year interval. In 2001, approximately 12 acres of land adjacent to managed wetlands were seeded with wetland prairie plant species in an attempt to shift formerly weedy sites along the fringes to native grassland species. However, these sites are not currently classified as wet prairie habitat because they are small isolated strips and are primarily dominated by tufted hairgrass with minimal diversity. An additional site on the refuge, Eagle Marsh Prairie, is currently under restoration, but the emphasis is on establishing a viable population of Nelson's checkermallow (*Sidalcea nelsoniana*) prior to adding a diversity of wet prairie species (USFWS, 2011).
Access and Contact:	Public access is permitted, but some areas are off limits to the public during winter months. For additional information, call 541-757-7236, or go to http://www.fws.gov/willamettevalley/ankeny/

11. Baskett Slough National Wildlife Refuge (U.S. Fish & Wildlife Service)	
Category	Preservation, restoration, and enhancement
Location	Approximately 10 miles west of Salem
Size	2,522 acres including approximately 10 acres of wetland prairie
Overview	Baskett Slough NWR was established in 1965. The refuge consists of over 1,700 acres of cropland managed for geese forage along with approximately 550 acres of grassland, 500 acres of shallow seasonal wetland, and 35 acres of permanent open water. Baskett Slough has several small tracts of wet prairie, including a six-acre area on the slopes below Baskett Butte and a two-acre patch east of Morgan Reservoir. These wetland prairie sites have adequate hydrology, but low native plant diversity and had previously been disturbed for agricultural use. An additional nine acres was planted with wetland prairie species in 2001.
Management	Existing management of wet prairie habitat at Baskett Slough includes mowing and prescribed fire. Restoration of additional wetland prairie from agricultural fields is in progress.
Access and Contact:	Access from Coville Road via Highway 22 just west of Rickreall. Public access to some paths in the refuge is limited during winter months. 541-757-7236. http://www.fws.gov/WillametteValley/baskett/.

Northern Willamette Valley Sites

12. Gotter Prairie Natural Area (Metro)	
Category	Restoration
Location	Located along the Tualatin River at the confluence of Baker and McFee creeks in Hillsboro
Size	120 acres (including approximately 20 acres of wetland prairie)
Overview	This floodplain site was first put into agricultural use in the 1930s by the Gotter family and was used for growing a variety of crops and grazed until it was purchased by Metro in 1994 for habitat restoration. Since the purchase, Metro's natural resources team has been working to restore the agricultural lands to historic native floodplain habitats. The land had most recently been used to grow potatoes. Metro has partnered on this restoration effort with the Tualatin Riverkeepers who have helped bring hundreds of volunteers to the site. In all, six plant communities are being

	restored on the property based on assessment of historic conditions. These include wetland prairie (20 acres), wetland scrub (15 acres), forested wetland (13 acres), oak savanna (22 acres), riparian woodland (23 acres), and emergent wetland (18 acres). The restoration process in the wetland prairie area has included removal of drainage ditches and tiles to restore wetland hydrology followed by site preparation work that included disking and spot herbicide application. Native seed was then broadcast onto the site. *Sidalcea nelsoniana* was thought to have disappeared from the Tualatin River watershed until botanists discovered it at the Gotter Prairie Natural Area. Following the discovery, Metro's Native Plant Center volunteers and staff collected seed from the site and grew more than 500 plants. The next spring, approximately 200 of these checkermallow plants were planted in the site's wetland prairie.
Management	The wetland prairie area is being managed on an ongoing basis to maintain diversity and control weed invasion. Regular flooding from the Tualatin River carries seed from non-native plants onto the site on a regular basis, which are controlled with spot herbicide applications as needed. Tufted hairgrass had initially become dominant in the wetland prairie area, but has been knocked back through a series of ecological burns and prolonged flooding of the area. This management approach has reduced tufted hairgrass cover and resulted in a much greater diversity of native species within the prairie. Metro scientists and local farmers have partnered to study grazing of the native grasses on the property, using cows to replicate what elk might have historically done. Metro hopes to acquire over 200 additional acres of adjacent land to expand the preserve.
Access and Contact:	For more information about the preserve, contact the Metro Natural Areas Program at 503-797-1545 or naturalareas@oregonmetro.gov.

13. Knez Preserve (The Wetlands Conservancy)	
Category	Restoration
Location	Located between Red Rock Creek and Highway 217 in Tiagard, Oregon
Size	1.9 acres
Overview	The Knez Preserve is one of just a handful of wetland prairie sites remaining in the Portland metro area. Historically, the area around what is today the Knez Preserve contained an extensive wetland system that was associated with Red Rock Creek. When the site was acquired by The Wetlands Conservancy, the expanse of wetland had been reduced to 1.9 acres. The wetland restoration effort began in December 2005, starting from a condition that was originally a monoculture of *Phalaris arundinacea*. The goals of the restoration effort were to increase stream shading and vegetation, create greater wildlife habitat, increase native biodiversity, and to filter run off.
Management	In order to establish native species, the monoculture of *Phalaris arundinacea* was mowed to the ground and then covered by a solarization plastic. Native wetland prairie species including tufted hairgrass were used to establish native cover following the site preparation. The Wetlands Conservancy partnered with the Metro Native Plant Nursery to propagate additional native species such as checkermallow, slender cinquefoil, sedges, and rushes, which were used to increase the site's diversity. Knez Preserve is managed by the Wetlands Conservancy and volunteers. Because the wetland is located close to Highway 217 ecological burning is not a viable management option on the site.
Access and Contact:	For more information, contact the Wetlands Conservancy at 503-227-0778 or go to http://oregonwetlands.net/index.php/land-conservvation/our-preserves/metro/knez-wetland.

14. Camassia Natural Area (The Nature Conservancy)	
Category	Preservation and enhancement
Location	Near the confluence of the Clackamas and Willamette Rivers in West Linn, Oregon
Size	27 acres
Overview	Purchased in 1962, the site was the first TNC preserve in Oregon and includes a mix of woodland, savanna, and prairie. The area was sculpted by prehistoric floods (Ice Age Floods) and includes a rocky plateau with a host of extraordinary floral diversity including rare plants and uncommon wetland and grassland communities. At the time of acquisition, the site's prairies were dominated by mature *Cytisus scoparius* and the forested areas were overrun by *Hedera helix* and *Rubus* spp. Today, the West Linn High School uses the preserve as an outdoor classroom and TNC volunteers offer guided hikes to educate the public about this unique property.

Management	TNC and volunteers have worked for many years to control *Pseudotsuga menziesii* (Douglas-fir), *Hedera Helix*, *rubus* spp., and *Cytisus scoparius* across the site. Researchers regularly monitor the rare plant populations and water quality. Controlling *Hedera helix*, which heavily covered ten acres of the site, became a management priority starting in 2001. *Hedera helix* was removed through a combination of hand pulling and herbicide application (winter applications) and is now largely under control. Similar methods of hand cutting and follow-up herbicide application have been used to control *rubus* spp. Proximity to urban development prevents ecological burning from being used as a management tool.
Access and Contact:	A series of boardwalks and trails provide access to the site. Access from the end of Walnut Street in West Linn. For more information call 503-802-8100 or go to http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/oregon/placesweprotect/camassia-natural-area.xml.

Appendix C: Seeding Rates

Table C-1: An Example of Single-Year Seed Mixes and Seeding Rates Successful in the WEW

Association / Species	Recent synonym	Seeds/lb	Gm/acre	Seeds/ft^2	SE G	SE F	Unk
Wet Prairie							
Achillea millefolium		1,418,947	20	1.4			
Acmispon americanus	*Lotus unifoliolatus* var. *unifoliolatus*	71,812	30	0.1		x	
Carex densa		507,750	40	1.0	x		
Carex feta		2,000,000	15	1.5			
Carex stipata		1,152,250	30	1.7			
Carex tumilicola		267,763	20	0.3			x
Carex unilateralis		988,644	40	2.0	x		
Castilleja tenuis		7,559,833	3	1.1			
Epilobium densiflorum		850,694	30	1.3		x	
Eriophyllum lanatum var. *leucophyllum*		1,169,047	70	4.1			
Galium trifidum		500,000	30	0.8			
Grindelia integrifolia		127,508	80	0.5		x	
Hosackia gracilis	*Lotus formosissimus*	264,638	15	0.2			
Juncus effusus var pacificus		18,000,000	2	1.8			
Juncus occidentalis		26,068,391	1	1.3	x		
Lomatium nudicaule		39,557	250	0.5			
Lupinus polyphyllus		21,598	100	0.1			
Lupinus rivularis		23,000	50	0.1		x	
Luzula comosa		944,979	30	1.4			
Madia elegans		43,014	30	0.1			
Madia glomerata		175,000	10	0.1		x	
Madia sativa		185,720	5	0.0		x	
Micranthes oregana	*Saxafraga oregana*	14,057,541	2	1.4			
Microseris laciniata		316,753	120	1.9			
Microsteris gracilis	*Phlox gracilis*	416,392	20	0.4			
Montia linearis		353,766	20	0.4			
Orthocarpus bracteosus		859,072	20	0.9			
Perideridia montana	*Perideridia gairdneri*	877,928	40	1.8			x
Perideridia oregana		279,304	60	0.8			x
Plagiobothrys figuratus ssp. *figuratus*		881,553	120	5.4			
Plectritis congesta var. congesta		1,005,743	30	1.5			

Association / Species	Recent synonym	Seeds/lb	Gm/acre	Seeds/ft^2	SE G	SE F	Unk
Potentilla gracilis var. *gracilis*		1,417,469	50	3.6		x	
Prunella vulgaris var. *lanceolata*		400,228	70	1.4			
Ranunculus occidentalis var. *occidentalis*		153,568	40	0.3			
Ranunculus orthorhynchus		141,924	50	0.4			
Rorippa curvisiliqua		15,896,846	3	2.4			
Rumex salicifolius var. *salicifolius*		296,593	30	0.5			
Sidalcea cusickii		175,810	110	1.0			
Sisyrinchium bellum		380,000	60	1.2			x
Sisyrinchium idahoensis		380,000	60	1.2			x
Symphiotrichum hallii		1,799,960	120	10.9			
Veronica peregrina var. *xalapensis*		11,894,843	20	12.0			
TOTAL			1946.0	71.0			
Vernal pool							
Alisma triviale		1,056,000	20	1.1			
Downingia elegans		1,995,129	100	10.1			
Downingia yina		1,995,129	100	10.1			
Eleocharis obtusa		2,834,953	110	15.8			
Eleocharis palustris		755,983	110	4.2	x		
Eryngium petiolatum		127,900	300	1.9			
Gratiola ebracteata		19,467,381	20	19.7			
Juncus accuminatus		32,000,000	2	3.2			x
Juncus bolanderi		26,000,000	2	2.6			x
Juncus ensifolius		26,000,000	2	2.6			x
Juncus oxymeris		26,000,000	2	2.6			x
Juncus patens		26,000,000	2	2.6			
Lasthenia glaberrima		1,677,891	120	10.2			
Myosotis laxa		1,343,572	30	2.0			x
Navarretia intertexta ssp. intertexta		1,121,637	160	9.1			
Ranunculus alismifolius var. *alismifolius*		25,000	150	0.2			x
Veronica scutellata		15,000,000	20	15.2			
TOTAL			1250.0	113.4			

Association / Species	Recent synonym	Seeds/lb	Gm/acre	Seeds/ft^2	SE G	SE F	Unk
Grasses (drilled rate)							
Agrostis exarata		5,600,000	80	22.7	x		
Beckmania syzigachne		533,217	800	21.6			
Danthonia californica var. americana		91,523	1800	8.3			
Deschampsia cespitosa		1,659,478	40	3.4	x		
Deschampsia danthoniodes		900,000	60	2.7			
Dichanthelium acuminatum		1,049,977	400	21.3			x
Hordeum brachyantherum ssp. brachyantherum		67,432	600	2.0			
TOTAL			3380.0	60.7			
Slow-growing[1]							
Allium amplectens		351,529	800	14.2			
Asclepias speciosa		85,000	3000	12.9			x
Brodiea elegans ssp. hooveri		302,667	1200	18.4			x
Calochortus tolmiei		240,000	2000	24.3			x
Camassia leichtlinii var. *suksdorfii*		41,754	6000	12.7			x
Camassia quamash var. *maxima*		100,057	2500	12.7			
Triteleia hyacinthina		261,543	1000	13.2			x
Toxicoscordion venenosum	*Zigadenus venenosus*	160,468	3000	24.4			x
Wyethia angustifolia		47,546	4000	9.6			x

Note: These rates reflect a single year of forb, sedge, and rush broadcast seeding. Typically, a similar mix of forbs, sedges, and rushes, is broadcast a second year, after reducing the rates of those species identified during field assessments as establishing particularly well.

Grass seeding rates reflect seed that has been drilled over a portion of the restoration site.

Several species in the wet prairie mix (e.g., *Achillea millefolium* (*A. borealis*), *Eriophyllum lanatum* spp. *leucophyllum*, and *Plectritis congesta*) establish only on dryer locations within wet prairie. These are identified in Appendix A (Unpublished data) as occurring in wet prairie, but not vernal pool habitats.

Column explanations:

SE G: Strong Establisher - Graminoid.

SE F: Strong Establisher - Forb

U: Unknowns related to Establishment - Establishment of these species in West Eugene Wetland restorations has been infrequent, varied substantially between restoration sites, or limited seed

availability has provided few opportunities to test seed rates.
[1] **Slow-growing:** Species that typically take 4 or more years to reach reproductive size.

Table C-2: Number of Seeds per Pound for Plant Species Used in Restorations in the WEW

Species	Seeds/lb (midpoint if range given)	Source[1]
Achillea millefolium	1,418,947	Guerrant 1995
Acmispon americanus	71,812	Guerrant 1995
Agoseris grandiflora	274,000	USDA NRCS Plant Guide or Fact Sheet
Agrostis exarata	5,600,000	USDA NRCS Plant Guide or Fact Sheet
Alisma triviale	1,056,000	Western Native Seeds
Allium amplectens	351,529	Guerrant 1995
Asclepias speciosa	85,000	USDA NRCS Plant Guide or Fact Sheet
Beckmania syzigachne	533,217	Guerrant 1995
Brodiea elegans ssp. *hooveri*	302,667	*B. coronaria* in Heritage Seedlings, Inc.
Camassia leichtlinii var. *suksdorfii*	41,754	Guerrant 1995
Camassia quamash var. *maxima*	100,057	Guerrant 1995
Carex densa	507,750	Guerrant 1995
Carex feta	2,000,000	River Refuge Seed
Carex leporina	599,669	Guerrant 1995
Carex obnupta	567,000	Western Native Seeds
Carex stipata	1,152,250	Western Native Seeds
Carex tumilicola	267,763	Guerrant 1995
Carex unilateralis	988,644	Guerrant 1995
Castilleja tenuis	7,559,833	Guerrant 1995
Danthonia californica var. *americana*	91,523	Guerrant 1995
Deschampsia cespitosa	1,659,478	Guerrant 1995
Deschampsia danthoniodes	900,000	USDA NRCS Plant Guide or Fact Sheet
Dichanthelium acuminatum	1,049,977	Guerrant 1995
Downingia elegans	1,995,129	Guerrant 1995
Downingia yina	1,995,129	*D. elegans*
Eleocharis obtusa	2,834,953	USDA NRCS Plant Guide or Fact Sheet
Eleocharis palustris	755,983	Guerrant 1995
Epilobium brachycarpum	1,429,981	Guerrant 1995
Epilobium densiflorum	850,694	Guerrant 1995
Eriophyllum lanatum var. *leucophyllum*	1,169,047	Guerrant 1995
Eryngium petiolatum	127,900	*E. yuccifolium* in Henderson 1998
Galium trifidum	500,000	USDA NRCS Plant Guide or Fact Sheet

Species	Seeds/lb (midpoint if range given)	Source[1]
Geum macrophyllum	793,706	USDA NRCS Plant Guide or Fact Sheet
Gratiola ebracteata		unknown
Grindelia integrifolia	127,508	Guerrant 1995
Hordeum brachyantherum ssp. *brachyantherum*	67,432	Guerrant 1995
Juncus accuminatus	32,000,000	Agrecol
Juncus bolanderi	26,068,391	*J. occidentalis*
Juncus effusus var. *pacificus*	18,000,000	USDA NRCS Plant Guide or Fact Sheet
Juncus ensifolius	26,068,391	*J. occidentalis*
Juncus occidentalis	26,068,391	Guerrant 1995
Juncus oxymeris	26,068,391	*J. occidentalis*
Juncus patens	26,068,391	*J. occidentalis*
Lasthenia glaberrima	1,677,891	Guerrant 1995
Lomatium nudicaule	39,557	Guerrant 1995
Lotus formosissimus	264,638	Guerrant 1995
Lupinus polyphyllus	21,598	Guerrant 1995
Lupinus rivularis	23,000	USDA NRCS Plant Guide or Fact Sheet
Luzula comosa	944,979	*L. campestris* in Guerrant 1995
Madia elegans	43,014	Guerrant 1995
Madia glomerata	175,000	USDA NRCS Plant Guide or Fact Sheet
Madia sativa	185,720	Guerrant 1995
Microseris laciniata	316,753	Guerrant 1995
Microsteris gracilis	416,392	Guerrant 1995
Montia linearis	353,766	Heritage Seedlings, Inc.
Myosotis laxa	1,343,572	Guerrant 1995
Navarretia intertexta ssp. *intertexta*	1,121,637	Guerrant 1995
Orthocarpus bracteosus	859,072	Guerrant 1995
Perideridia montana	877,928	Guerrant 1995
Perideridia oregana	279,304	Guerrant 1995
Plagiobothrys figuratus ssp. figuratus	881,553	Heritage Seedlings, Inc.
Plectritis congesta	1,005,743	Guerrant 1995
Poa scabrella	1,200,000	USDA NRCS Plant Guide or Fact Sheet
Potentilla gracilis var. *gracilis*	1,417,469	Guerrant 1995
Prunella vulgaris var. *lanceolata*	400,228	Guerrant 1995
Pyrrocoma racemosa var. racemosa	112,368	Guerrant 1995
Ranunculus alismifolius var. *alismifolius*	25,000	USDA NRCS Plant Guide or Fact Sheet
Ranunculus occidentalis var.	153,568	Guerrant 1995

Species	Seeds/lb (midpoint if range given)	Source[1]
occidentalis		
Ranunculus orthorhynchus	141,924	Guerrant 1995
Rorippa curvisiliqua	15,896,846	Guerrant 1995
Rumex salicifolius var. salicifolius	296,593	Guerrant 1995
Saxafraga oregana	14,057,541	Guerrant 1995
Sidalcea cusickii	175,810	Guerrant 1995
Sisyrinchium bellum	380,000	*Sisyrinchium idahoensis*
Sisyrinchium hitchcockii	279,545	Guerrant 1995
Sisyrinchium idahoensis	380,000	USDA NRCS Plant Guide or Fact Sheet
Symphiotrichum hallii	1,799,960	Guerrant 1995
Toxicoscordion venenosum var. *venenosum*	160,468	Guerrant 1995
Triteleia hyacinthina	261,543	Guerrant 1995
Veronica peregrina var. *xalapensis*	11,894,843	*V. americana* in Guerrant 1995
Veronica scutellata	11,894,843	*V. americana* in Guerrant 1995
Wyethia angustifolia	47,546	Guerrant 1995

[1] Sources with a date are listed in the References section of this guide.
A plant name in this column indicates that the seed weight of a surrogate species was used, because the target species seed weight was unavailable.
The following are nurseries that provide seed weight information on their websites (as of May 2014):

- Agrecol
- Heritage Seedlings, Inc.
- Oregon Wholesale Seed Co. via OregonFlowerSeed.com
- River Refuge Seed
- Western Native Seed

USDA NRCS Plant Guides and Fact Sheets are available on the USDA NRCS Plants Database website.