# Invasive Plant Species Inventory and Management Plan for the Hanford Reach National Monument

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# Contents

## List of Tables



## List of Figures

# I. Introduction

The Hanford Reach National Monument covers approximately 195,000 acres on both sides of the Columbia River in south-central Washington. The Monument is comprised of lands originally acquired by the federal government in 1943 for the Department of Defense's Manhattan Project. All of the land within the Monument is currently under the ownership of the U.S. Department of Energy (DOE) as part of the 360,000-acre Hanford Site. Monument lands consist primarily of parts of the Hanford Site that were considered safety and security buffers during the weapons production period of the site's history. Monument lands are located primarily in Benton, Grant, and Franklin Counties, with the northeast corner of the Monument extending a short distance into Adams County. Most of the Monument is managed jointly by DOE and the U.S. Fish and Wildlife Service (USFWS), with a small tract under management of the Washington Department of Fish and Wildlife (WDFW).

The protected status of the Hanford Site since 1943 has resulted in its becoming a refuge for native plants, animals, and biological communities that were once far more common in the surrounding landscape. The Hanford Reach National Monument was established by Presidential Proclamation in June 2000 to protect the only free-flowing, non-tidal stretch of the Columbia River remaining in the United States along with the largest remnant of the shrub-steppe ecosystem that dominated the Columbia Basin prior to European settlement. The Reach itself is home to the most important salmonid spawning grounds on the Columbia River. The surrounding uplands contain some of the best remaining large-scale examples of the shrub-steppe vegetation type in the Pacific Northwest, habitat for many species of native wildlife (including shrub-steppe obligate species), a diverse array of native plant communities (including many threatened and endangered taxa) and cryptogams, and a unique invertebrate fauna that is still being catalogued (Soll et al. 1999, Evans et al. 2003).

The Monument lies within the Columbia Basin, the hottest, driest region of Washington state (Franklin and Dyrness 1973). Environmental characteristics are summarized in Soll et al. (1999), and Rickard et al. (1988). Elevations range from below 400 ft. (122 m) a.s.l. along the Columbia River shoreline to more than 3500 ft. (1067m) at the summit of Rattlesnake Mountain near the western boundary of the site. Annual precipitation varies with elevation, from as little as 16 cm at the lowest elevations up to 35 cm along the crest of Rattlesnake Mountain.

## Management Units

The Monument is divided into six administrative units (Fig. 1). Land ownership for the entire Monument resides with the U.S. Department of Energy (DOE). However, the U.S. Fish and Wildlife Service (USFWS) exercises direct management over 165,000 acres of Monument lands, while the Washington Department of Fish and Wildlife (WDFW) manages a small recreational access area. The administrative management units are as follows.

**The Fitzner-Eberhardt Arid Lands Ecology (ALE) Reserve.** The 77,000-acre ALE Reserve lies within the southwest portion of the Hanford Site, in Benton County. The Reserve was officially recognized as a valuable site for scientific study in 1967 due to the rich and relatively undisturbed character of its native shrub-steppe ecosystem. The Reserve was subsequently designated a federal Research Natural Area in 1971. The area, managed by USFWS since 1997, is closed to public access but is open by special use permit for scientific research and educational purposes.

**The McGee Ranch–Riverlands Unit.** This 9100-acre unit to the north of the ALE Reserve is managed directly by DOE. The unit lies entirely within Benton County and contains the biologically diverse Umtanum Ridge area and extensive native grasslands and shrublands, as well as powerline corridors and highly degraded former agricultural lands, homesteads, and townsites. Public access is limited to the Riverlands area north of the Midway Substation Road.

**The Vernita Bridge Recreation Area.** This small area (approx. 800 acres) on the Columbia River just north of the Vernita Bridge has been managed by WDFW since 1971, primarily to provide river access for fishing and boating.

**Saddle Mountain National Wildlife Refuge/ Saddle Mountain Unit.** This 32,000-acre unit borders the north shore of the Columbia River and is located entirely within Grant County. This unit of the Monument, managed by USFWS since 1971, contains sagebrush stands and important rare plant habitats, along with heavily disturbed former agricultural lands and the Saddle Mountain Lakes, a large area of irrigation wasteway impoundments. The unit is bisected by State Route 24 but is otherwise closed to public access.

**Wahluke Unit.** The 57,000-acre Wahluke Unit, located primarily in Grant and Franklin counties, is open to the public. This unit, managed by USFWS since 1999, includes most of the Monument's signature geologic feature, the White Bluffs, as well as significant shrub-steppe plant communities and rare plant habitats. The unit includes the Wahluke Branch Wasteway and associated impoundments, in particular the WB10 Ponds.

**River Corridor Unit.** This 25,000-acre unit of the Monument includes the Hanford Reach of the Columbia River along with the Columbia River islands and a one-quarter-mile-corridor strip along the south and west shore of the river. The unit also contains the Hanford Dunes, reportedly the only active dunefield within Washington state. Management of this unit is multijurisdictional, involving DOE, USFWS, the U.S. Bureau of Land Management, and state and county agencies.

## Impacts of Invasive Plant Species

Invasive alien plant species pose one of the most serious threats to the native biodiversity, wildlife habitat, and scenic values which the Hanford Reach National Monument was declared to protect, and for which the entire Hanford Site is well known (Soll et al. 1999). At Hanford, as elsewhere in western North America, invasive and noxious alien plant species compete against and reduce habitat available for rare plant taxa and native plant species in general. Weeds alter ecosystem structure and function, disrupt food chains and other ecosystem characteristics vital to wildlife (including rare and endangered species), and can dramatically alter key ecosystem processes such as hydrology, productivity, nutrient cycling, and fire regime (Randall 2001, Brooks and Pyke 2001, Mack et al. 2000).

Fig. 1. Management units of the Hanford Reach National Monument.

Invasive species can be seemingly restricted to the margins of major plant communities for a time, even many years, before acquiring some poorly understood critical mass or the timely coincidence of favorable environmental conditions that allow them to explode onto the broader landscape (Brooks and Pyke 2001). Conditions created by wildfire favor the spread of many noxious weed species (Brooks and Pyke 2001, Grace et al. 2001, Bushey 1995).

The deleterious effects of invasive plant species are not limited to natural areas but may also severely impact local economies. Invasive weeds compete with agricultural crops for light, moisture, and nutrients, clog irrigation systems, and reduce livestock forage values in pastures and rangelands (Mack et al. 2000, Bridges 1994). Degradation of agricultural lands resulting from invasive species infestations may drastically reduce land values (TCWPP 2003, Weiser 1997).

## Management Setting

Shrub-steppe ecosystems such as that represented on the Hanford Reach National Monument are highly susceptible to infestation by invasive plant species, especially when disturbed (DiTomaso 2000). The Monument's large size (195,000 acres) and the large number of documented or potential invasive plant species present significant challenges to the stewards of biological resources. Past and present land use practices such as farming and ranching; military activities, road building and quarrying, and riverflow management have helped to create conditions favorable for the establishment of many invasive plant species on Monument lands and throughout the Columbia Basin.

The introduction and spread of invasive plant species is enhanced by the existence of disturbed lands and corridors (Mack et al. 2000). Potential corridors for the migration of invasive species into and within the Hanford Reach National Monument include (HRNM 2003):

- Forty-four miles of the Columbia River, including 15 islands.
- Eleven miles of active irrigation canals and wasteways, and more than 1000 acres of associated impoundments.
- More than 50 miles of state highway, and more than 180 miles of paved and unpaved secondary roads in widely varying condition.
- More than 20 miles of powerline corridors and associated access roads.

Certain trends may make invasive species even more of a problem in the future than they are at present. New weeds may be expected to arrive within the coming years as technology and commerce continue to reduce barriers to plant migrations (McNeely 2001, Mack et al. 2000). At the same time, recurrent wildfires, powerline development and maintenance, the slumping of the White Bluffs, and other disturbances continually create new habitats for invasive species to colonize.

# II. Management Program Overview

## Conservation Targets

An invasive species control program must be based on the overall conservation and management goals of the area for which it is designed. Long-term conservation planning for the Hanford Reach National Monument is underway; however, the process has not been completed as of this writing. In light of guidance included in the Presidential Proclamation (Clinton 2000), current management practices, and preliminary results of the Comprehensive Conservation Planning process (USFWS and CBSG 2003, 2002), the following generalizations have been made regarding Monument conservation goals as a basis for this weed management plan:

- Fully functioning shrub-steppe habitats and the processes that characterize and maintain them, including their full array of native species.
- Natural spring and stream habitats with their full complement of associated native vegetation and wildlife.
- Healthy aquatic and riparian habitats of the Hanford Reach of the Columbia River.

When the final version of a long-term Comprehensive Conservation Plan (CCP) for the Monument is adopted, weed planning documents should be reviewed to ensure full compatibility with the goals and objectives outlined in the CCP.

While weed management practices vary, the most successful programs adopt an adaptive, integrated management approach with emphasis on the following points (adapted from Tu and Meyers-Rice 2002, USFWS 2001, DiTomaso 2000, Zamora and Thill 1999, Randall 1996, S. Johnson pers. comm.).

## Resource-Based Management

Managers should address invasive species issues within the context of Monument conservation goals. A particular focus on establishing or reestablishing desired vegetation in place of the invasive weeds at a site rather than on simply eliminating the weeds themselves is recommended.

Restoration of native vegetation is a desireable end goal for most, but not necessarily all, infested sites. In some cases, non-invasive non-native species may be used as competitive plantings or place holders in treatment areas.

## Prevention

The most effective method of control for invasive plant species is to prevent their establishment. Measures to minimize the introduction of potentially invasive species onto Monument lands may include administrative control of access to sites, limiting access to designated entry points (as along a single, carefully monitored road), inspection and decontamination of vehicles, cooperative agreements with contractors and other parties that need regular access to the site, educational programs, and other measures. Different measures may be applied to different management units or subunits within the Monument, reflecting different levels of biological value and condition, and different management goals for particular units. Strong preventive measures are recommended for the ALE Reserve and the Umtanum Ridge area of the McGee Ranch-Riverlands Unit.

## Early Detection and Rapid Response

Weed populations are dynamic, and occasional new introductions may be expected even when rigorous preventive measures are in place. Next to prevention, the most effective method for control of invasive plant species is to detect and treat infestations as soon after establishment as possible. Provision for extensive, ongoing surveys to detect new occurrences of invasive plant species is an essential component in successful weed management plans (Snyder-Conn 2001).

In order to realize the full benefits of early detection, detection must be linked to the timely initiation of a treatment program for the newly detected invasive species occurrence. An aggressive program of early detection and rapid treatment response is one of the most cost-effective strategies that can be applied in weed management.

This is critically important in an era where funding for natural resources management is in decline. Early detection of invasive species occurrences makes it possible for treatment to be applied before a spot infestation can spread more extensively across the landscape. Timely intervention increases treatment effectiveness while reducing treatment duration (Belnap and Phillips 2001, Moody and Mack 1988), thus reducing expenditures for staff time and materials, and minimizing chemical inputs to the environment, which in turn reduces the potential for treatment impacts to non-target resources such as native plants, wildlife, and aquatic resources.

## Inventory and Monitoring

Ongoing monitoring of weed occurrences is necessary in order to assess the status of invasive plant populations and to evaluate the effectiveness of integrated treatment methodologies. Documented occurrences of high priority target species (Priorities 1 and 2, described below) must be visited and assessed at least annually. See Inventory Methods (Section III, this volume) for a list of basic inventory information to be collected at each site. For each site receiving treatment, a precise record of the treatment history and the effects of treatment upon the target species must be compiled. The treatment data must include precise information regarding all methods used, including herbicide and adjuvant concentrations, dates of applications, and pretreatments or integrated measures, along with quantitative measures of the target species' response to the treatment(s). Weed responses may be assessed using infestation size and abundance (percent aerial cover or, for very small infestations, stem density) of the invasive species. All sites (Priorities 1, 2, and 3) that are undergoing active treatment should be assessed at least two times per year: in the spring, and in the fall following the end of the drought period but before the onset of dormancy. Some successful programs monitor even more often. A monitoring schedule should be flexible enough to allow the timing of monitoring visits to fit the phenology of the target species.

## Prioritization of Species and Sites

Thirty-six species of invasive weeds have been identified as target species for the Hanford Reach National Monument weed management program (Table 1). Twenty-three of these species have been documented as presently occurring on the Monument. In a large landscape with numerous target weed species and where infestations vary from a single plant to hundreds of acres or larger in size, a prioritization strategy for control and elimination of invasive plant species is essential to effectively allocate limited management resources. This plan combines species-based criteria with site-based criteria to prioritize specific weed occurrence sites for treatment. Resources can then be directed to infestations with the highest priority. The following factors are

Table 1. Target list of invasive plant species for the Hanford Reach National Monument: a) species that occur primarily in uplands; b) species that occur primarily in wetlands and riparian areas; c) species of concern that are already widespread. Scientific names are from Kartesz (1999). Boldface indicates nomenclatural changes since Hitchcock and Cronquist (1973). Letter codes in the right-hand column indicate weed regulatory status in Washington state (Appendix B), including Monitor (M) and species not listed (NL; NWCB 2003a).

**a. Upland Species: Active List**

| Scientific name | Hitchcock & Cronquist (1973) | Common name | Weed Class |
|---|---|---|---|
| ***Acroptilon repens*** | *Centaurea repensa* | Russian knapweed | B |
| ***Alhagi maurorum*** | No record | camelthorn | B |
| ***Bassia scoparia*** | *Kochia scoparia* | kochia | B |
| *Cardaria draba* | *Cardaria draba* | white top | C |
| *Centaurea diffusa* | *Centaurea diffusa* | diffuse knapweed | B |
| *Centaurea solstitialis* | *Centaurea solstitialis* | yellow starthistle | B |
| ***Chondrilla juncea*** | No record | rush skeletonweed | B |
| *Cirsium arvense* | *Cirsium arvense* | Canada thistle | C |
| *Cirsium vulgare* | *Cirsium vulgare* | bull thistle | C |
| *Convolvulus arvensis* | *Convolvulus arvensis* | field bindweed | C |
| *Gypsophila paniculata* | *Gypsophila paniculata* | baby's breath | C |
| *Lepidium latifolium* | *Lepidium latifolium* | perennial pepperweed | B |
| *Linaria dalmatica* | *Linaria dalmatica* | dalmatian toadflax | B |
| *Onopordum acanthium* | *Onopordum acanthium* | Scotch thistle | B |
| *Secale cereale* | *Secale cereale* | winter rye | C |
| ***Sphaerophysa salsula*** | No record | swainsonpea | B |
| *Tribulus terrestris* | *Tribulus terrestris* | puncturevine | B |

**a. Upland Species: Watch List**

| Scientific name | Hitchcock & Cronquist (1973) | Common name | Weed Class |
|---|---|---|---|
| ***Abutilon theophrasti*** | No record | velvetleaf | A |
| ***Anthriscus sylvestris*** | No record | wild chervil | B |
| *Carduus nutans* | *Carduus nutans* | musk thistle | B |
| *Cenchrus longispinus* | *Cenchrus longispinus* | sandbur | B |
| ***Centaurea biebersteinii*** | *Centaurea maculosa* | spotted knapweed | B |
| *Euphorbia esula* | *Euphorbia esula* | leafy spurge | B |
| *Sorghum halepense* | *Sorghum halepense* | johnsongrass | A |
| ***Taeniatherum caput-medusae*** | *Elymus caput-medusae* | medusahead wildrye | NL |

Table 1 (continued).

### b. Wetland and Riparian Species: Active List

| Scientific name | Hitchcock & Cronquist (1973) | Common name | Weed Class |
|---|---|---|---|
| *Eleagnus angustifolia* | *Eleagnus angustifolia* | Russian olive | NL |
| *Lythrum salicaria* | *Lythrum salicaria* | purple loosestrife | B |
| *Myriophyllum spicatum* | *Myriophyllum spicatum* | Eurasian watermilfoil | B |
| *Phragmites australis* | *Phragmites communis* | common reed | C |
| *Sonchus arvensis* ssp. *arvensis* | *Sonchus arvensis* ssp. *arvensis* | perennial sowthistle | B |
| *Tamarix parviflora* | *Tamarix parviflora* | saltcedar, tamarisk | NL |
| ***Tamarix ramosissima*** | No record | saltcedar, tamarisk | A |

### b. Wetland and Riparian Species: Watch List

| Scientific name | Hitchcock & Cronquist (1973) | Common name | Weed Class |
|---|---|---|---|
| ***Amorpha fruticosa*** | No record | indigobush | B |
| *Cyperus esculentus* | *Cyperus esculentus* | yellow nutsedge | B |
| ***Epilobium hirsutum*** | No record | hairy willow-herb | M |
| ***Myriophyllum aquaticum*** | *Myriophyllum brasiliense* | parrotfeather | B |

### c. Species of Concern Which Are Already Widely Established

| Scientific name | Hitchcock & Cronquist (1973) | Common name | Weed Class |
|---|---|---|---|
| Upland | | | |
| *Bromus tectorum* | *Bromus tectorum* | cheatgrass, downy brome | NL |
| ***Salsola tragus*** | *Salsola kali* | Russian thistle, tumbleweed | NL |
| Wetland and Riparian | | | |
| *Phalaris arundinacea* | *Phalaris arundinacea* | reed canarygrass | C |

among the key criteria considered in the prioritization of sites for treatment:

- Invasive potential of the weed species.
- Ecological impacts of the weed species on native species and communities (especially in relation to specific conservation targets).
- The size of the infestation.
- Proximity of the infestation to valuable biological resources.
- Susceptibility of the invasive species to treatment.
- Potential impacts of treatment upon non-target species.

Legal obligations under Washington state weed law, and neighboring land management practices, such as agriculture, will also help guide site prioritization.

The following section outlines prioritization guidelines based on attributes of the affected site as well as those of the targeted invasive species (adapted from Tu and Meyers-Rice 2002). Relative priority values are ranked from the highest priority (1) to the lowest priority (4).

I. **Current extent of the infestation.** Priority values regarding infestation size are based on the following hierarchy of program objectives: 1) to prevent the establishment of new weed species; 2) to eliminate small infestations, especially those that are rapidly growing; 3) to prevent large infestations from expanding; and 4) to reduce or eliminate large infestations.

   a. Species not yet on the site but which are present nearby.

   b. Species present as new populations or small outliers of larger infestations, especially if they are expanding rapidly.

   c. Species present in large infestations that continue to expand.

   d. Species present in large infestations that are not expanding, or are expanding very slowly.

II. **Current and potential impacts of the invasive species.**

   a. Species that alter ecosystem processes such as fire frequency, sedimentation, nutrient cycling, or other ecosystem processes.

   b. Species that outcompete natives and dominate otherwise undisturbed native communities.

   c. Species that do not outcompete established, dominant natives but:

      i. prevent or depress recruitment or regeneration of native species; OR

      ii. reduce or eliminate resources (e.g., food, cover, nesting sites) used by native animals; OR

      iii. promote populations of invasive non-native animals by providing them with resources otherwise unavailable in the area.

   d. Species that overtake and exclude natives following fires or other disturbances, thereby altering succession, or that interfere with the restoration of natural communities. Species of this type should be assigned higher priority in areas subject to repeated disturbances.

**III. Value of the infested habitats or areas and surrounding or adjacent areas.**

a. Infestations that occur in or near the most highly valued special habitats or resource areas of the site—especially areas that contain rare or highly valued species or communities and areas that provide vital resources.

b. Infestations that occur in or near high-quality native plant communities, or that occur along corridors that may facilitate the spread of the species to conservation target areas.

c. Infestations that occur in less highly valued portions of the site. Areas already badly infested with invasive plant species may be given low priority unless the species in question will make the situation significantly worse or represent a clear threat to disperse into highly valued resource areas.

**IV. Effectiveness of available control technologies.**

a. Infestations likely to be controlled or eliminated with available technology and resources and that desirable native species will replace with little further input. In some cases, such as where satellite colonies of highly noxious invasive plant species are beginning to colonize non-native annual grassland, allowing less undesirable non-native species to replace the highly undesirable target species may be an acceptable short-term outcome. In some cases (e.g., weed species growing through road surfaces), vegetation replacement may not be a relevant criterion.

b. Infestations likely to be controlled with available technology and resources but not likely to be replaced by desirable natives without an active restoration program.

c. Infestations difficult to control with available technology and resources and/or whose control will likely result in substantial damage to other, desirable species.

d. Infestations unlikely to be controlled with available technology and resources.

Invasive species that are fast growing, exhibit high reproductive rates, are highly disruptive to conservation targets, that occur along pathways of spread, or that are otherwise highly mobile on the landscape must be given priority consideration. High priority is also assigned to small, incipient, isolated or satellite infestations, since these are the primary loci of population spread and at the same time are the sites where control and eradication efforts are most likely to be successful (Moody and Mack 1988). Difficulty of control must also be considered. Infestations where control efforts using available technology and resources are likely to yield positive results receive higher priority than those where available methods are likely to have little effect.

Invasive species whose populations are decreasing and/or those that colonize only disturbed areas and don't move into undisturbed habitats and do not impact recovery from the disturbance are assigned the lowest priorities.

Target invasive plant species for the Hanford Reach National Monument are divided into an active list of species documented as occurring on the Monument and a watch list of species not yet documented on the Monument (Table 1). Active list species are further divided into groups for prioritization of treatment activities (Table 2).

Priority 1 species (Table 2a) are perceived as the greatest and most immediate threats to the biological resources of the Hanford Reach National Monument. Priority 1 species are annual, biennial, and perennial species that are, in general, prolific seed producers, highly mobile on the landscape, aggressive competitors, and tenaciously persistent when established.

The Priority 1 rank includes invasive species such as diffuse knapweed and saltcedar, which are among the most abundant on the Monument. It also includes several species, such as dalmatian toadflax and camelthorn, which are known from only one or a few locations on the Monument and may, because of the small size of the

Table 2. Invasive plant species treatment priorities, Hanford Reach National Monument, 2002–2003: a) Priority 1 species; b) Priority 2 species; c) Priority 3 species.

**a. Priority 1 Species**

| Common Name | Scientific Name |
|---|---|
| camelthorn | *Alhagi maurorum* |
| diffuse knapweed | *Centaurea diffusa* |
| yellow starthistle | *Centaurea solstitialis* |
| rush skeletonweed | *Chondrilla juncea* |
| baby's breath | *Gypsophila paniculata* |
| dalmatian toadflax | *Linaria dalmatica* |
| Scotch thistle | *Onopordum acanthium* |
| saltcedar | *Tamarix ramosissimus, T. parviflora* |
| puncturevine | *Tribulus terrestris* |

**b. Priority 2 Species**

| Common Name | Scientific Name |
|---|---|
| Russian knapweed | *Acroptilon repens* |
| whitetop | *Cardaria draba* |
| Canada thistle | *Cirsium arvense* |
| Russian olive | *Eleagnus angustifolia* |

**c. Priority 3 Species**

| Common Name | Scientific Name |
|---|---|
| **kochia** | *Bassia scoparia* |
| bull thistle | *Cirsium vulgare* |
| field bindweed | *Convolvulus arvensis* |
| perennial peppererweed | *Lepidium latifolium* |
| purple loosestrife | *Lythrum salicaria* |
| Eurasian watermilfoil | *Myriophyllum spicatum* |
| common reed | *Phragmites australis* |
| winter rye | *Secale cereale* |
| swainsonpea | Sphaerophysa salsula |

colonies, be amenable to early eradication. Ideally, all populations of Priority 1 species should be attacked aggressively with the goal of eradicating small infestations within a few years, and gradually reducing larger infestations. In practical terms, some infestations of diffuse knapweed and saltcedar in low-quality areas cannot be eradicated in the short term without taking critical resources away from areas where high-quality resources must be protected. In the short term, treatment must concentrate on Priority 1 species where infestations are small and/or in areas of high biological value, while larger infestations in low-quality areas must be monitored and contained until resources permit aggressive control of all infestations of these species.

Priority 2 species (Table 2b) pose somewhat less of an immediate threat to Monument resources than do Priority 1 species, but are still invasive species of great concern. The principal characteristic distinguishing the two ranks is one of reproductive biology: Priority 2 species do not spread as rapidly by seed as Priority 1 species. Priority 2 species are perennial species that spread primarily by vegetative means, although new colonies are initiated from time to time from seed. This plan offers recommendations for treating infestations of Priority 2 species in specific sites wherever small, isolated populations occur and where Priority 2 species threaten high-quality natural areas, rare species, or other biological resources.

Priority 3 species (Table 2c) include all other active list invasive species. Priority 3 species are perceived as less likely to increase, spread, or otherwise threaten Monument resources and specific conservation targets than Priority 1 and Priority 2 species, but are still invasive species of concern. This plan offers recommendations for treatment of Priority 3 species in specific sites, especially where these species occur in isolated or satellite populations, or where they threaten high-quality natural areas, rare species, or other biological resources.

## Integrated Treatment Program for Priority Species and Sites

The U.S. Fish and Wildlife Service will utilize an Integrated Pest Management (IPM) approach to treat targeted invasive plant species on the Hanford Reach National Monument. Manual, mechanical, biological, cultural (e.g., prescribed fire, competitive plantings), and chemical treatment methods will be utilized to achieve prioritized weed control objectives. Invasive species managers will draw upon the full range of appropriate control technologies to develop integrated treatment plans for target species at selected priority sites. Treatment methodologies will be based upon the best information available from weed management literature and professional experience, tailored to the characteristics of the particular species and site.

Section IV of this document provides a profile of the ecology, reproductive characteristics, and impacts of each target invasive plant species, and includes a discussion of IPM treatment options based upon invasive species literature (TNC 2003, NWCB 2003b, William et al. 2002, Bossard et al. 2000, CNAP 2000, Sheley and Petroff 1999, and other sources) and discussions with local professionals.

The most appropriate treatment for an infestation typically depends on the scale of the infestation and on the morphology and ecology of the target species (Youtie 1997, S. Johnson pers. comm.). Manual pulling or digging may effectively control small infestations of invasive species with minimum impact to surrounding resources. Manual methods are labor-intensive, however, and are not effective against larger infestations or against deep-rooted perennials. Mechanical methods vary in their effectiveness but can be highly disruptive to soils and microbiotic crusts. Biological controls are rarely effective by themselves, are lacking for many species, and are typically not effective for small-scale infestations. Chemical control may be the most practical and effective option for small- to moderate-scale infestations of perennial plant species but must be applied so as to minimize impacts on non-target plant species as well as other organisms and systems. In practice, effective treatment for many weed infestations will require a long-term integrated approach utilizing all methods that are available. For example, pulling, mowing, or burning at the most favorable time of year or plant developmental stage may enhance the effectiveness of later chemical treatments, thus reducing the chemical inputs required for eradication of a species or for a target level of control (Renz 2000).

Prescribed fire may be used as part of an integrated program to control selected invasive plant species or to prepare sites for restoration to native plant species. Given the deleterious effects of too-frequent, uncontrolled wildfire within shrub-steppe ecosystems, however, a great deal of care must be used when implementing any treatment program involving fire.

Treatment success is greatly enhanced by aggressive early intervention at newly discovered, isolated satellite weed occurrences. As mentioned above, timely intervention may reduce or, in some cases, even eliminate the need for chemical inputs, reducing potential non-target impacts to desireable native species and to the surrounding environment.

Treatment of an uninfested buffer zone around the perimeter of existing infestations is recommended when control of spread is the management goal for large infestations. If the target species' seed dispersal characteristics are well known, the area of this perimeter can be estimated by the formula

$$a = \pi d2 (2y\text{-}1)$$

where $d$ is the maximum distance to which 95% of the infesting species' seeds disperse, and $y$ is the years of spread (Auld and Coote 1980). While information on dispersal distances may be lacking or not readily available, this principle should be held in mind. When reduction of the infestation is the goal, the treatment area should be incrementally extended into the infestation itself.

With many invasive plant species, successful control of even small infestations requires several years of treatment, often utilizing multiple treatments per year. A long-term perspective is particularly important for established populations of deep-rooted perennials, such as rush skeletonweed, Russian knapweed, and others, and for species that are long-lived in the soil seed bank, such as yellow starthistle, field bindweed, and others. In some cases, total eradication is not a realistic short-term goal. Treatment success depends as much upon long-term diligence as it does upon the methods used (Mack et al. 2000, Snyder-Conn 2001). The duration of treatment required for a successful outcome is generally reduced by early detection and timely treatment.

The removal of invasive species is one step in a process of ecological restoration of a site. Reintroduction of native plant species will inhibit recolonization of treated sites by invasive species (Brooks and Pyke 2001). However, where the natural physical and biological processes of sites are not restored, sites will remain vulnerable to reinfestation by invasive plant species.

## Adaptive Management

The ongoing monitoring of weed populations and of the results of control programs is a critical component of an adaptive management approach to Integrated Pest Management. Information provided by the monitoring component of this management plan will be used by IPM managers to evaluate the effectiveness of treatment methods in light of site conservation goals. Managers will use this information to adjust priorities and objectives, to modify treatment methodologies for greater effectiveness, and to improve precision in budgeting and planning preocesses. The modification of weed control objectives begins a new round of treatment, monitoring, and assessment.

## Building Partnerships

Invasive plant species have impacts that ignore ownership and cross management boundaries. Effective weed control efforts in one area can be nullified if similar measures are not taken simultaneously on neighboring properties. Monument co-managers USFWS and DOE should coordinate weed control efforts closely. Partnerships between other local and regional management entities can also greatly increase efficiency in education, detection, and treatment.

Monument co-managers already participate in valuable partnerships through the Noxious Weed Task Force, an organization that originally formed around efforts to control saltcedar. Task Force members include federal and state agencies (USFWS, DOE, WDFW, U.S. Bureau of Reclamation) along with local jurisdictions such as county and district weed boards and public utility and irrigation districts. The Task Force has already achieved important gains in outreach, detection, and treatment of saltcedar in the mid-Columbia region and fostered a spirit of cooperative partnership among members (Hill 2003). These partnerships should be maintained or expanded, and cooperative partnerships should be explored wherever opportunities are available.

## Education, Outreach, and Training

Education and outreach regarding noxious weed identification and the ecological and economic impacts of invasive species enhances the long-term success of weed management programs (Svejcar 1999). Educational programs should reach out to partners, landowners, public and private schools, user groups, and the public at large. Increasing public awareness can lead to assistance in the prevention and early detection of weed occurrences. Avenues for educational outreach can include workshops, brochures, interpretive displays at visitor centers, along roadsides, and at community fairs and similar events.

Adequate training for all staff with weed management responsibilities is critical. When inventory and treatment responsibilities are performed by different persons, treatment staff must be as skilled as inventory staff in the field identification of target invasive plant species and their look-alikes.

All monument staff should receive training in invasive species impacts to Monument resources and in recognition of common species. Preventive measures of weed control often rely upon conscientious attention to detail by non-biological personnel such as maintenance staff, law enforcement professionals, fire crew, and others. Adequate training of staff at all levels will improve understanding of the threats posed by invasive species to Monument resources, motivate compliance with management directives, expand the Monument's early detection capacity, and represents one step towards spreading invasive species awareness throughout the mid-Columbia community.

## Fire Management

The unique role of wildfire in invasive species behavior in arid lands deserves mention. At Hanford as throughout the arid West, the increase in both the frequency and extent of wildfires over the last half-century is attributable in large part to invasive species and has created conditions that favor invasive plant species and communities over native ones (Grace et al. 2001, Bushey 1995, Young and Evans 1985). Implementation of a fire management plan aimed at maintaining fire frequencies at appropriate intervals for the perpetuation of intact native vegetation will be a critical tool in limiting the spread and abundance of invasive plant species on the Hanford Reach National Monument.

## Minimum Staffing Requirements

In order to carry out the provisions of an effective monitoring and treatment program for invasive plant species on the Hanford Reach National Monument, well-trained staff must be maintained at adequate levels to attend to the detailed elements of this plan throughout the year. While some degree of staff turnover is inevitable in any position, maintaining continuity of personnel experienced in invasive species monitoring and management should also be a very high priority for the Monument. Dedication of a full-time, year-round IPM coordinator, assisted by a qualified crew leader/assistant in a term position and a seasonal crew of 3–4 persons is strongly recommended as minimum staffing for USFWS-managed portions of the Monument. Additional assistance from other USFWS personnel, seasonal staff, volunteers, and, under some circumstances, paid contractors, will be required at times and insofar as posible should be made available when needed.

# III. Invasive Plant Species Inventory, 2002–2003

## Introduction

In order to assess the current status of invasive plant species on the Hanford Reach National Monument, an inventory of noxious weeds in Monument management areas was conducted by personnel from The Nature Conservancy's Washington Field Office and staff of the Hanford Reach National Monument in 2002 and 2003.

## Methods

A preliminary target list of actual and potential invasive plant species for the Monument (Table 1) was developed during Winter 2002 after consulting ecological literature (TNC 2003, Sackschewsky and Downs 2001, CNAP 2000, Mitchell 2000, Mullins et al. 2000, PNEPPC 1997), Washington State weed law (NWCB 2003a), staff of the Hanford Reach National Monument, personnel from the Hanford Integrated Biological Control Program, and local professionals. Species selected for inventory (hereafter referred to as "target species") were those which met the following criteria: 1) a demonstrated ability to outcompete native plant species and to change the structure and function of natural ecosystems in the Columbia Basin and/or elsewhere in the arid and semiarid West, and 2) ranges that currently include the Lower Columbia Basin or nearby areas or that can be reasonably expected to migrate into the Columbia Basin within the relatively near future. This working list of target weeds is intended to be a flexible tool that can be expanded or reduced as new information about plant migrations and ecological effects becomes available.

The list of target invasive plant species is divided into upland and riparian habitat types. Species that may occur in either habitat type were placed into the type where they were most likely to be encountered, but surveys for that species were not necessarily limited to that habitat type. The list of species for each habitat type is further divided into species that have been confirmed to occur on Monument Lands (Active List) and species that have not yet been documented on Monument lands (Watch List). An additional category identifies invasive plant species that display considerable ecological impacts on infested lands, but which are already so widespread on the Monument that control is feasible only in selected areas for particular management purposes (Table 1c). Since they are already ubiquitous throughout all or most of their suitable habitats, these widespread species of concern were not inventoried during the surveys.

Surveys for target invasive plant species were performed between April 1 and October 10, 2002, and between April 15 and July 3, 2003. For each invasive species occurrence, the following information was documented:

Scientific name: genus, species, and any other nomenclature required for positive identification of a taxon.

Infestation size (length x width).

Phenology: seedling; rosette; bolting; flowering, seed (ripening/dispersing); mature; dead.

Percent cover of the invasive species within the infested area. Percent cover was estimated using the following cover classes: < 1%, 1–10%, 11–25%, 26–50%, 51–100%.

*(Continued)*

Management unit name.

County name.

USGS 7.5′ quadrangle name.

Specific location information.

Disturbance type, if known.

Associated vegetation.

Field data was recorded using hand-held microprocessors (Handspring Visor Platinum) linked to a desktop invasive species database (Microsoft Access 97) under development by The Nature Conservancy's Oregon Field Office and the U.S. Bureau of Land Management. Geographic locations of weed occurrences were recorded as either points, lines, or polgons using portable GPS units. Three types of GPS unit were used during the course of the inventory: a Magellan *Companion* plug-in for a hand-held microprocessor; a Trimble Geoexplorer III, and a Garmin *etrex*. Coordinates were recorded in UTM NAD27 or were converted to this datum in the GIS lab.

All GPS coordinates were imported into GIS layers. Weed occurrences were also drawn in the field on USGS 7.5′ topographic maps. Some large polygons in degraded, low-quality areas were recorded only on topographic maps and were digitized from these hand-drawn records. A few large polygons were approximated from existing vegetation maps (*Secale cereale*), from aerial imagery (*Eleagnus angustifolia*), or from direct expert accounts (*Myriophyllum spicatum*).

**Search areas and strategies.** Inventory staff searched well over 20,000 acres (>8000 ha) of the Monument for targeted invasive plant species (Fig. 2). Inventories focused on areas where noxious weeds had been previously reported, on special habitats (e.g., springs or riparian areas) where certain target species are expected to occur, and in disturbed lands and corridors. Most non-native plant species establish most readily in areas such as roadsides, gravel pits, abandoned agricultural fields, and other disturbed lands. Roads and watercourses, in particular, can behave as corridors for weed transport and migration into new areas. Detection of weeds along corridors prompted systematic searches of surrounding areas. Searches of target areas such as these have a high likelihood of turning up many noxious weed occurrences (Zamora and Thill, 1999). Some noxious weed species are highly mobile and capable of establishing in undisturbed habitats, necessitating systematic overland searches. Such overland searches were limited by time constraints for this inventory, but were conducted in areas of particular biological importance such as Umtanum Ridge on the McGee Ranch-Riverlands Unit, the White Bluffs, and portions of the Arid Lands Ecology (ALE) Reserve. Inventory staff also searched for noxious weeds while traversing expansive areas of the ALE Reserve in the course of a concurrent vegetation-monitoring project.

The inventory was conducted primarily on shrub-steppe uplands and around natural springs. Aquatic environments associated with irrigation wasteways and artificial impoundments on the North Slope were not included in the survey. Riparian habitats surrounding these features were only partially surveyed, and invasive species associated with these habitats are undoubtedly substantially underreported here. Aquatic and shoreline habitats of the Columbia River were surveyed on five different days during July and October 2002 and July 2003 and were undoubtedly undersampled. Hydrophytic weeds and other invasive species that occur between the high- and low-water marks of the river appeared to be widespread to ubiquitous along the length of the river shore and were not mapped.

Fig. 2. Search areas for invasive plant species, Hanford Reach National Monument, 2002–2003.

## Results and Discussion

Noxious weed surveys in 2002 and 2003 confirmed the presence of 23 invasive plant species on the Hanford Reach National Monument (Table 1), including three species that had not been previously documented on Monument lands. Overall, the inventory recorded 401 occurrences of invasive plant species, infesting more than 9000 acres (> 3600 ha) over all management units of the National Monument (Table 3, Fig. 3).Diffuse knapweed (*Centaurea diffusa*) infested more than 3600 acres (> 1400 ha), more than 40% of the total area occupied by target invasive plant species on the Monument. Diffuse knapweed infestations were mostly along roads, but also occurred in riparian areas, in old fields, and, most noteworthy, in some shrublands. Diffuse knapweed appears to be ubiquitous along the shoreline of the Hanford Reach between the high- and low-water marks. This acreage has not been mapped or included in area figures, so that the total acreage of diffuse knapweed infestations reported here is clearly an underestimation.

Table 3. Occurrences and areas infested by target invasive plant species, Hanford Reach National Monument 2002–2003.

| Common name | Scientific Name | Total Occurrences | Area (Hectares) | Area (Acres) |
|---|---|---|---|---|
| Russian knapweed | *Acroptilon repens* | 48 | 381.6 | 943.1 |
| camelthorn | *Alhagi maurorum* | 1 | < 0.1 | < 0.1 |
| whitetop | *Cardaria draba* | 63 | 201.2 | 497.1 |
| diffuse knapweed | *Centaurea diffusa* | 88 | 1488.9 | 3679.1 |
| yellow starthistle | *Centaurea solstitialis* | 29 | 126.5 | 312.7 |
| rush skeletonweed | *Chondrilla juncea* | 31 | 280.0 | 692.0 |
| Canada thistle | *Cirsium arvense* | 24 | 6.1 | 15.1 |
| bull thistle | *Cirsium vulgare* | 3 | < 0.1 | < 0.1 |
| field bindweed | *Convolvulus arvensis* | 29 | 33.7 | 83.3 |
| Russian olive | *Eleagnus angustifolia* | 8 | 234.3 | 579.0 |
| baby's breath | *Gypsophila paniculata* | 1 | < 0.1 | < 0.1 |
| kochia | *Kochia scoparia* | 8 | 17.3 | 42.7 |
| perennial pepperweed | *Lepidium latifolium* | 13 | 122.7 | 303.1 |
| dalmatian toadflax | *Linaria dalmatica* | 2 | < 0.1 | < 0.1 |
| purple loosestrife | *Lythrum salicaria* | 3 | 0.8 | 2.0 |
| Eurasian watermilfoil | *Myriophyllum spicatum* | 2 | 9.4 | 23.1 |
| Scotch thistle | *Onopordum acanthium* | 3 | 0.1 | 0.2 |
| common reed | *Phragmites australis* | 11 | 36.1 | 89.3 |
| winter rye | *Secale cereale* | 3 | 192.6 | 475.8 |
| perennial sowthistle | *Sonchus arvensis* | 1 | area unknown | |
| swainsonpea | *Sphaerophysa salsula* | 10 | 15.0 | 37.1 |
| saltcedar | *Tamarix ramosissima, T. Parviflora* | 19 | 519.5 | 1283.8 |
| puncturevine, tackweed | *Tribulus terrestris* | 1 | 0.1 | 0.2 |
| | **Totals** | 401 | 3665.8 | 9058.6 |

Clonal colonies of Russian knapweed (*Acroptilon repens*; 943 acres/381 ha) and whitetop (*Cardaria draba*) dominated considerable acreage in riparian areas, former agricultural lands, and other disturbed areas. Whitetop (63 occurrences, 497 acres/201 ha) in particular was present at nearly every spring, seep, well, or other area where soil moisture may have been closer to the surface than in the surrounding landscape.

Rush skeletonweed (*Chondrilla juncea*; 692 acres/280 ha) and yellow starthistle (*Centaurea solstitialis*; 312 acres/126 ha) both formed large patches in highly disturbed areas. However, these highly mobile species appeared in lightly to moderately disturbed grasslands and shrublands as well. Occurrences of both of these species continued to be discovered by personnel from USFWS and The Nature Conservancy (TNC) through the spring and early summer of 2003, suggesting that additional infestations of both of these composite species remain to be found.

Saltcedar (*Tamarix* spp.; 1284 acres/ 520 ha) was the second most common taxon in the inventory, comprising more than 14% of the total area occupied by target invasive plant species on the Monument. Saltcedar was common on or near seeps along the face of the White Bluffs as well as along irrigation wasteways and impoundments on the North Slope, where it was often codominant with Russian olive (*Eleagnus angustifolia*; 579 acres/234 ha). With the exception of these woody species, the artificial wetlands and riparian areas associated with wasteway impoundments were considered low priorities for inventory purposes. Species such as purple loosestrife (*Lythrum salicaria*) and common reed (*Phragmites communis*) were consequently undersampled in these habitats and along the Columbia River shoreline, and the results presented here are poor indicators of these species' abundance on the Monument.

Three invasive plant species were documented for the first time on the Hanford Reach National Monument. A single individual of dalmatian toadflax (*Linaria dalmatica*) was observed along the west side of the White Bluffs Road in the Wahluke Unit. A small infestation was also observed on a USFWS island just outside the Monument's boundary by USFWS personnel. Three small clusters of Scotch thistle (*Onopordum acanthium*) where recorded in the lower Cold Creek Valley. Perennial sowthistle (*Sonchus arvensis* ssp. *arvensis*) was identified from a specimen collected in a riparian area associated with the WB 10 Ponds, where it appeared to be somewhat abundant. The species may have been present in this area for some time without notice.

## CHARACTERIZATION OF INFESTATIONS BY MANAGEMENT AREA

**The Arid Lands Ecology (ALE) Reserve.** While ALE contains many of the highest quality native plant communities on the Monument, invasive species are a mounting concern. Riparian vegetation at important spring systems (Rattlesnake, Snively, and Benson/Bobcat) is highly degraded and increasingly dominated by invasive species such as Russian knapweed, whitetop, and Canada thistle. Whitetop is common also at many seeps along the middle slopes of the Rattlesnake Hills. Russian knapweed and whitetop are common and probably spreading in highly disturbed lands along the length of Cold Creek. Diffuse knapweed is widespread along many of the Reserve's roadways, including those at higher elevations and in remote locations, and in the dry creekbed of upper Cold Creek. The species has not yet been documented colonizing in natural areas surrounding these corridors and is a high priority for treatment to prevent this colonization. Rush skeletonweed is established in the lower Cold Creek Valley and has recently been discovered in Iowa Flats and other areas on the low slopes of Rattlesnake Mountain. There is great concern over this mobile species' ability to move further into quality natural areas, making all occurrences high priorities for treatment on ALE (see Section IV, this volume). The recent fire history of the ALE Reserve has favored the increase and spread of many of these invasive species, along with cheatgrass (*Bromus tectorum*) and Russian thistle (*Salsola tragus*; Evans et al. 2003).

*(Continued)*

Fig. 3. Areas infested by invasive plant species, Hanford Reach National Monument, 2002–2003.

**The McGee Ranch–Riverlands Unit.** Portions of this unit are extremely weedy. Diffuse knapweed, Russian knapweed, whitetop, perennial pepperweed (*Lepidium latifolium*), and other invasive species infest large areas of the McGee Ranch area north of SR 24. Diffuse knapweed is common along roads and other disturbed sites throughout the unit. It is notable that diffuse knapweed has escaped from gravel roads and infested sagebrush shrublands at the west end of the site along with some abandoned agricultural fields. The Riverlands area hosts a number of large infestations of Russian knapweed, most notably in the vicinity of the old Midway townsite and at China Bar. China Bar also hosts the unit's only documented occurrence of saltcedar (*Tamarix* spp). Fortunately, biologically rich Umtanum Ridge appears to be largely free of noxious weeds at this time, except for small infestations of diffuse knapweed and Russian knapweed on unpaved roads through the area. These isolated occurrences should be high priorities for treatment (see Section IV, this volume).

**The Vernita Bridge Recreation Area.** Diffuse knapweed, which is common along the Columbia River shorelines up and down the length of the Hanford Reach, is scattered throughout this unit, particularly on roadways and in parking and boat launch areas. While these areas will undoubtedly continue to receive diffuse knapweed propagules brought in by automobiles and, possibly, by boats, control activities in these areas will minimize the spread of diffuse knapweed from these locations to other portions of the Monument and surrounding areas. Two small borrow pits in the eastern section of the site support riparian vegetation including patches of Canada thistle and common reed small enough for eradication to be a reasonable objective.

**Saddle Mountain Unit.** Large areas of this unit between SR 24 and the Columbia River are lightly to heavily infested with noxious weeds. Diffuse knapweed occupies extensive former agricultural lands in the flats along the shore of the Columbia. Abandoned quarries host saltcedar, rush skeletonweed, and Russian knapweed. The Saddle Mountain Wasteway and its impoundments, including Saddle Mountain Lake, host populations of many riparian weed species, including saltcedar, Russian olive, common reed , purple loosestrife, and perennial pepperweed. Isolated infestations of saltcedar and yellow starthistle are priorities for treatment on this unit (see Section IV, this volume).

**Wahluke Unit.** The riparian areas surrounding the WB10 Ponds are dominated by Russian olive and host many other riparian weed species. Saltcedar is abundant in places, particularly in slumping areas along the White Bluffs. Yellow starthistle is well established in the lowlands and bluffs of the southern portion of this unit. All infestations of this mobile annual are high priorities for treatment, especially where they threaten the population of White Bluffs bladderpod (*Lesquerella tuplashensis*; see Section IV, this volume). Extensive patches of Russian knapweed and a number of other invasive species occupy extensive areas along the Ringold Road.

**River Corridor Unit.** The dynamism of the great river, the wide daily fluctuations in riverflow owing to upriver hydroelectric generation, and the steady supply of alien propagules borne by the river make this corridor a fertile ground for hydrophytic weeds and other invasive plant species and complicate plans to control or contain invasive species. Hydrophytic weeds such as purple loosestrife and reed canarygrass (*Phalaris arundinacea*) are common between the high- and low-water marks along the length of the Hanford Reach. Diffuse knapweed colonizes this same disturbed elevational zone and is the most abundant and widespread weed along the river. A large clonal stand of common reed can be observed upstream from the Wahluke ferry landing. Eurasian watermilfoil (*Millefolium spicatum*) occurs in several persistent patches south of the White Bluffs boat launch.

Island uplands are subject to infestations similar to mainland uplands with Russian knapweed, diffuse knapweed, Canada thistle, yellow starthistle, and rush skeletonweed the most widespread and abundant of invasive species in these areas. The later two highly mobile species, positioned, as they are, upwind of natural areas on the Wahluke Unit, are high priorities for treatment.

## Conclusions and Recommendations

There are more species of noxious weeds infesting larger land areas of the Hanford Reach National Monument than had previously been reported. While this inventory represents a concerted effort to provide a detailed picture of the extent of invasive plant species on the Monument, it is far from a complete picture. Due to inevitable time limitations, large areas of the Monument remain unexplored by inventory personnel, so that the numbers of species and infested areas that are reported here must be taken as minimum estimates for invasive plant species on the Monument.

A biological inventory represents only a snapshot in time. Invasive plant populations are dynamic and will require monitoring annually or more often to accurately apprise management of patterns of abundance and threats to biological resources. Invasive species can be seemingly restricted to the margins of major plant communities for many years before acquiring some poorly understood critical mass, or the timely coincidence of favorable environmental conditions, that allows them to explode onto the broader landscape (Brooks and Pyke 2001). Conditions created by wildfire favor the spread of many noxious weed species (Grace et al. 2001, Bushey 1995). Invasive species that have not yet been recorded on the Monument occur in as close proximity to its boundaries as in Central Hanford or in the nearby Tri-Cities area (Rice 2002, R. Roos pers. comm.). In the years ahead new species of non-native plants will continue to arrive from near and far (McNeely 2001, Mack et al. 2000).

The ongoing monitoring of weed populations and their responses to control programs is also necessary in order to evaluate the effectiveness of integrated treatment methods applied by invasive species management personnel. Managers must have this information in order to adjust treatment priorities and objectives in a changing landscape, to modify treatment protocols to maximize effectiveness, and to enable greater precision in budgeting and planning processes.

Managers of the Hanford Reach National Monument will continue to require timely information regarding the distribution and abundance of invasive plant species and the effectiveness of weed control efforts in order to adequately protect the biodiversity of the Hanford Site. Establishing and maintaining a well-staffed and trained, year-round invasive plant species monitoring program as part of an overall Integrated Pest Management Plan must be a high priority for the Hanford Reach National Monument.

**Further inventories.** Herbaceous weeds of artificial riparian areas associated with irrigation wasteway impoundments on the Wahluke and Saddle Mountain Units were considered low priorities for inventory activities and were, as a result, considerably undersampled. A more accurate estimate of the abundance and distribution of these invasive species can be obtained only by a thorough inventory of these areas as well as the irrigation canals and wasteways themselves, should resources permit.

**Access and security.** Weed inventory personnel were unable to gain access to the southern portion of the McGee Ranch area through Gates 121 (from SR 240) and 121B (from Cold Creek County Rd.). Keys to padlocks on these gates did not work. Hanford Biological Control Program personnel mentioned that their keys to these gates had stopped working some time ago. Although the area can be accessed via a rough track through sagebrush from the Umtanum Ridge Road, this route may not be appropriate for all kinds of transport and may represent a potential fire hazard during the dry months. Repair or replacement of the Gate 121 and 121B locks would greatly facilitate inventory and control efforts in this portion of the McGee Ranch-Riverlands Unit.

A rudimentary gate in sagelands along a powerline access road at the southwest boundary of the McGee Riverlands Unit is secured only by loops of barbed wire. This gate, in a remote part of the Monument and near habitats of high biological value, was found open during a survey in 2002. Installation of a standard security gate with padlock should help to reduce ocasional incidences of trespass, which are reported in this area. Trespassing individuals or livestock represent an avenue of invasive species introductions that can be controlled by this simple security measure.

**Changes to the target list.** Wide-ranging surveys during 2002–2003 suggest that bull thistle (*Cirsium vulgare*) is present only as scattered individuals and does not appear to pose a significant threat to Monument resources. Given the large number and widespread nature of many other invasive species on the Monument, this non-native thistle should be removed from the list of target species in order to concentrate resources on species that demonstrate more significant impacts on Monument resources.

The extent of dense, persistent patches of black locust (*Robinia pseudo-acacia*) along the Ringold Road warrant attention. The species clearly reproduces vegetatively and spreads aggresively under the right conditions (pers. obs.). Monitoring around extant patches and along the Columbia River shoreline upstream of Ringold to determine if sexual reproduction is occurring in this potentially invasive species is recommended (M. Tu pers. comm.).

# IV. Invasive Plant Species Profiles

## Introduction

This section presents brief profiles of current target invasive plant species for the Hanford Reach National Monument. Each profile includes a summary of the following information for each species:

- Biology and ecological impacts.
- Legal status in Washington. Definitions of Washington state noxious weed classes are presented in Appendix B.
- Distribution on the Monument, if applicable. A distribution map is furnished for all active species.
- Priority sites for treatment activities.
- Treatment methods.

Target invasive plant species are presented in two groups. Active List species are presented first, and Watch List species follow. Species are presented in alphabetical order by scientific name within groups.

Common terms and abbreviations used in the text are given below. Definitions are from Hager and Sprague (2000) and Senese (2002).

**A** – acres

**a.i**. – active ingredient. The component of a chemical herbicide that is responsible for its toxic effect upon a target species.

**a.e.** – acid equivalents. The herbicidally active portion of the active ingredient in an herbicide formulation; a method of comparing the actual amount of herbicidally active material between different formulations of the same herbicide. This term is not synonymous with the term 'active ingredient.' Different formulations of an herbicide may contain different amounts of active material, even when the amount of active ingredient is the same. See Appendix C or Hager and Sprague (2000) for a more complete explanation.

**amine** – A formulation of an herbicide with enhanced water solubility. Amine formulations may be recommended when the aim is for the herbicide to move freely through the soil solution for uptake by the target's roots.

**ester** – A formulation of an herbicide with enhanced lipid (fats and oils) solubility. Ester formulations enhance an herbicide's ability to penetrate the waxy leaf cuticles developed by some plant species (e.g., dalmatian toadflax).

**v/v** – volume-to-volume. A calculation of the volume of a solute to be added to the total volume of a solution to produce a desired concentration. See Appendix C or Senese (2002) for a more complete explanation.

# Active List

## RUSSIAN KNAPWEED *ACROPTILON REPENS (CENTAUREA REPENS)*

Russian knapweed is a long-lived perennial forb in the composite family (Asteraceae) characterized by an extensive, spreading root system and low seed production (Carpenter and Murray 1998a).

Russian knapweed is a strong competitor and can form dense colonies in disturbed areas. The plant spreads primarily through a system of creeping horizontal roots. The roots of Russian knapweed can extend to a depth of more than 7 meters with as much as 2.5 meters of growth occurring the first year (Zimmerman 1996). A single plant can cover an area of 12 $m^2$ within two years (Watson 1980).

Russian knapweed's dense vegetative growth allows the species to quickly colonize and dominate new sites, forming dense single-species stands. Russian knapweed produces an allelopathic compound which may inhibit root growth of neighboring plants (Watson 1980, Stevens 1986), furthering the species' competitive advantage.

Russian knapweed invades open, disturbed areas, roadsides, agricultural areas, and rangelands. Russian knapweed appears to thrive in riparian areas where soil moisture is somewhat higher than normal; however, recent evidence suggests it is expanding slowly into even the driest habitats (Young and Clements 2002). Russian knapweed infestations crowd out native plant species, reduce forage value for wildlife and range stock, and increase precipitation runoff and soil erosion (Carpenter and Murray 1998a, Roché and Roché 1988). The species can be extremely long-lived and persistent, with clonal stands reported as old as 75-100 years (Carpenter and Murray 1998a).

Russian knapweed is classified as a Class B Non-Designate noxious weed in Regions 6 and 9. State law calls for containment, gradual reduction, and prevention of further spread of Class B Non-Designate noxious weeds (NWCB 2003a).

### Current Status and Treatment Priorities on the Monument

Russian knapweed is a Priority 2 species on the Hanford Reach National Monument. Russian knapweed is known to infest more than 940 acres (> 380 ha) on the Monument, with multiple large concentrations occurring on every management unit of the Monument (Fig. 4). Occurrences at the White Bluffs boat launch and potential habitats in the vicinities of most irrigation wasteways and impoundments were not surveyed, so that Russian knapweed is certainly underreported here.

Priority treatment sites for Russian knapweed include 2 isolated individuals in roadways on Umtanum Ridge, a small isolated stand amid sagebrush in the west end of the McGee Ranch area, an isolated stand in Bobcat Canyon near Benson Spring, an isolated stand near an unnamed artesian well in the McGee Ranch area, and a stand along the gate 118 Rd on ALE (Table 4). These sites should be treated aggressively with the aim of eradication within 3 years for the two small Umtanum Ridge sites, and within 5 years for the other sites. Picloram (Tordon) applied during late spring is the most effective herbicide for use against Russian knapweed (see below). Clopyralid (Transline) applied during spring and fall has also been effective. Small, isolated infestations may be controlled by covering with securely anchored landscape fabric for three or more years.

Table 4. Priority Sites for treatment of Russian knapweed.

| Unit | Location | East (NAD 27) | North (NAD 27) |
|---|---|---|---|
| McGee-Riverlands | Umtanum Ridge | 287367 | 5165422 |
| | | 286772 | 5165279 |
| | McGee Ranch (west) | 286612 | 5161819 |
| | | 287881 | 5162729 |
| ALE | Rattlesnake Mt., Wooden Powerline Rd. | 303884 | 5140517 |
| | Benson Spring | 295865 | 5147223 |
| | Gate 118 Rd | 292639 | 5153468 |

Fig. 4. Occurrences of Russian knapweed (*Acroptilon repens*) mapped during the 2002–2003 invasive plant species inventory, Hanford Reach National Monument.

The perimeters of larger infestations, especially those around Rattlesnake Spring, should be treated to contain or gradually reduce the infestations as resources permit.

## Control

Russian knapweed is extremely persistent. An integrated program of mechanical, chemical, and biological control, combined with frequent monitoring, is needed to control and eradicate an established population.

*Manual and Mechanical Methods*

Manual and mechanical methods can be used to reduce an infestation, but used alone will not eliminate a stand of Russian knapweed.

Repeated pulling can reduce plant vigor and may be a practical control for small populations. Pullers should try to remove as much of the plant's root as possible.

CAUTION: An single account has anecdotally linked sap from diffuse knapweed, and perhaps related knapweed species, with a form of cancer. Anyone working with diffuse knapweed or other knapweed species should wear protective gloves and avoid getting knapweed sap into open cuts or abrasions (Carpenter and Murray 1998b).

Mowing may be used to prevent or postpone flowering and seed production, but provides little stress to overall plant vigor unless repeated consistently at short intervals. In low-quality areas disking or plowing (to a depth of at least 30 cm) can provide effective control if the practice is continued for at least 3 years (Carpenter and Murray 1998a).

*Biological Methods*

*Subanguina picridis*, a gall-forming nematode, has been introduced in Washington, but failed to establish (Coombs et al. 2002). Where established, its affect on Russian knapweed populations has been largely unnoticeable.

Sheep and goats will graze Russian knapweed if confined to an area where alternative forage is unavailable. Repeated grazing will weaken plant reserves and make plants more susceptible to herbicide treatments (BIRC 2000). Carefully controlled grazing could be an effective part of an integrated treatment plan for dense infestations of Russian knapweed such as those along Ringold Flat, or in the lower Cold Creek Valley.

*Chemical Methods*

**Picloram** (Tordon, Grazon) is cited as the most effective herbicide on Russian knapweed by Duncan (1994, cited in Carpenter and Murray 1998a). William et al. (2002) recommend 0.25 – 0.5 lb. a.e./A applied in late spring. Repeated applications are required for thorough control. However, application of Tordon 22K has yielded unsatisfactory results on Russian knapweed elsewhere in Washington (D. Wilderman pers. comm.).

**Clopyralid** (Transline, Stinger) applied at 1.3 pints product/A during bud-growth stage and in fall controlled Russian knapweed by 96 and 100% respectively (Duncan 1994, cited in Carpenter and Murray 1998a). Second year control was not quite as high (88%). Clopyralid is more selective than Picloram but can still damage or kill members of the composite (Asteraceae), legume (Fabaceae) and buckwheat (Polygonaceae) families.

Curtail is a formulation of clopyralid and 2,4-D which is effective against a wider range of broadleaf plants than clopyralid alone. Curtail applied at 3 qts. product/A provided somewhat less control of Russian knapweed than Clopyralid alone in field tests (Duncan 1994, cited in Carpenter and Murray 1998a). The Washington Natural Areas Program has had variable success using Curtail in the treatment of Russian knapweed (D. Wilderman pers. comm.). Curtail will damage most perennial broad-leaved plants and so should be applied carefully to minimize the damage to non-target plants.

Redeem R&P is a combination of clopyralid and triclopyr. This formulation, may be applied at 2.5-4.0 pts. product/A during the early bud to early flower stage to control Russian knapweed. The formulation should be applied with a nonionic surfactant in at least 10 gal. of water/A (William et al. 2002).

**Imazapyr** (Plateau) applied at 8 oz. product/A has provided excellent control of Russian knapweed (Snyder-Conn 2001). Imazapyr is most effective applied in late fall (J. Rodriguez pers. comm.).

**2,4-D** at 4.0-8.0 lb. a.e./A applied early during the bolting stage will control plants emerged at the time of spraying but delivers no residual control (William et al. 2002).

**Glyphosate** (Roundup, Roundup Ultra, Rodeo, Accord) applied at 1 qt. product/A during the bud-growth stage can be used to control the topgrowth of Russian knapweed (Beck 1996, Watson 1980). Abundant regrowth from the root systems may occur the following year and additional applications will be necessary. A 10% concentration of Roundup applied during the late bolt to flower bud stage has resulted in 80-90% mortality in Washington (D. Wilderman pers. comm.).

**CAMELTHORN** ***ALHAGI MAURORUM (ALHAGI PSEUDALHAGI)***

Camelthorn is a deep-rooted, rhizomatous, perennial Eurasian shrub in the legume (Fabaceae) family. Camelthorn's spiny, intricately-branched stems reach 1.5 to four feet in height, while roots can extend six to seven feet in depth. Seedling establishment is sporadic, but the species spreads aggresively by vegetative means (O'Connell and Hoshovsky 2000). The spreading root system can produce aerial shoots up to 25 feet away from the parent plant (NWCB 2003b).

Camelthorn is unpalatable and may be injurious to some animals. Because of its deep root system, camelthorn grows successfully in dry, rocky, and saline soils, as well as in deeper, moister soils. The plant is especially abundant along riverbanks, canals, and irrigation ditches (NWCB 2003b).

Camelthorn was first reported in 1956 along the lower Crab Creek drainage in Grant County, WA., and has since spread eastward. Part of the infestation borders on a major state highway, which raises concerns for its potential to spread rapidly to other areas (NWCB 2003b).

Camelthorn is classified as a Class B Designate noxious weed in Region 9. State law requires prevention of seed production and spread of Class B Designate weeds. Camelthorn is classified as a Class B Non-Designate noxious weed in all other jurisdictions that include the Monument . State law calls for containment, gradual reduction, and prevention of further spread of Class B Non-Designate noxious weeds (NWCB 2003a).

## Current Status and Treatment Priorities on the Monument

Because of its limited distribution, camelthorn is a Priority 1 species on the Hanford Reach National Monument. At present camelthorn is known only as a population of a few plants (or stems of a single plant) at a single location on the Monument, the former dog trial area on the Wahluke Unit (Table 5, Fig. 5). Despite the species' resistance to treatment, eradication of this small population is highly achievable within 3-5 years. Repeated mowing or clipping to remove top growth, along with cut-stem application of picloram (Tordon) once or twice per year is recommended. Density measurement (stem counts) is the most appropriate abundance measure for evaluating treatment success with this small infestation.

The proximity of the Monument to the center of camelthorn's distribution in Washington state suggests that staff should be on the lookout for future occurrences of this invasive species on Monument Lands in the future, especially along highway corridors or primary access points.

Table 5. Priority Sites for treatment of camelthorn.

| Unit | Location | East (NAD 27) | North (NAD 27) |
|---|---|---|---|
| Wahluke | dog trial area | 314692 | 5179230 |

## Control

*Manual and Mechanical Methods*

Camelthorn's deep taproot makes the species difficult to remove manually. Cutting stimulates growth from subsurface buds, while disking and deep plowing create root fragments that reestablish readily (O'Connell and Hoshovsky 2000). Persistent, long-term removal of topgrowth may help to deplete the extensive underground resources and make the infestation more susceptible to chemical treatment (CNAP 2000).

*Biological Methods*

No effective biological control agents are currently available.

*Chemical Methods*

**Picloram** (Tordon) at 1.0 lb. a.i./A. and **glyphosate** (Roundup) at 1.5 lb.a.i./A may be used to control camelthorn (CNAP 2000). Columbia National Wildlife Refuge has used Tordon in cut-stem applications with success (R. Hill pers. comm.). **2,4-D** has also been used (NWCB 2003b).

Fig. 5. Occurrences of camelthorn (*Alhagi maurorum*) mapped during the 2002–2003 invasive plant species inventory, Hanford Reach National Monument.

## KOCHIA — *BASSIA SCOPARIA (KOCHIA SCOPARIA)*

Kochia is a robust Eurasian summer annual in the goosefoot (Chenopodiaceae) family. It has a deep taproot (to 16 feet), is very drought tolerant, and can spread rapidly in arid lands. Kochia has a wide tolerance of soil types and is even adapted to salty soils. Kochia invades rangeland, roadsides, and agricultural areas (NWCB 2003b).

Reproduction is entirely by seed; kochia may produce more than 14,000 seeds per plant. Seeds are spread by tumbling. Seeds likely retain their viability no more than a year or two in the soil (NWCB 2003b).

Kochia is classified as a Class B Non-Designate noxious weed in Regions 6 and 9. State law calls for containment, gradual reduction, and prevention of further spread of Class B Non-Designate noxious weeds (NWCB 2003a).

### Current Status and Treatment Priorities on the Monument

Kochia is a Priority 3 species on the Hanford Reach National Monument. No attempt to systematically map populations of kochia was made during this project, so that the landscape distribution of this species is greatly underreported here (Fig. 6). Kochia is widespread along roads in and around the Monument, especially in the Ringold and Midway areas, and along state highways. Kochia has not yet been observed invading natural areas at the Monument. No priority sites are designated for treatment, but infestations along SR 240 and the Gate 106 Rd. are a concern due to the risk of spread along roads via vehicular traffic. Kochia should be treated as part of general roadside vegetation management in these areas.

### Control

*Manual and Mechanical Methods*

Since kochia reproduces only by seeds which have relatively short-term viability in the soil seed bank, manual and mechanical techniques have a role to play in an effective integrated management scheme. Hand pulling may control small infestations. Early tillage in the spring gives good control of emerging seedlings. Mowing or slashing the plants before flowering can reduce, but will not eliminate, seed production (NWCB 2003b, CNAP 2000).

*Biological Methods*

No effective biological control agents are currently available.

*Chemical Methods*

Kochia exhibits repeated germination events following rainfall. A pre-emergent herbicide, or multiple applications of post-emergence herbicides, are necessary for control (D. Wilderman pers. comm.). **Glyphosate** (Roundup) at 1.5 lb. a.i./A is effective on post-emergent growth. **Dicamba** (Banvel) at 1 lb. a.i./A used alone, or in combination with metsulfuron may be effective for pre-emergent control. Dicamba should not be used in diverse natural areas, as it has a tendency to eliminate all broadleaved species (Carpenter and Murray 1998b).

Some biotypes of kochia have been found to have developed resistance to herbicides, particularly 2,4-D and triazine. Rotating herbicides will reduce the chance of encouraging the development of resistance (NWCB 2003b, CNAP 2000).

Fig. 6. Occurrences of kochia (*Bassia scoparia*) mapped during the 2002–2003 invasive plant species inventory, Hanford Reach National Monument.

**WHITETOP, HOARY CRESS** ***CARDARIA DRABA***

Whitetop is a hardy Eurasian perennial forb in the mustard family (Brassicaceae). The species grows in a variety of habitats, but thrives in disturbed areas where soil moisture is at or near the surface for some part of the growing season. Whitetop's dense clonal growth excludes native species and reduces forage quality for wildlife(Lyons 1998a, Chipping and Bossard 2000).

Whitetop possesses a deep, long-lived taproot that enables plants to spread rapidly, outcompete native vegetation, and resist control efforts. Roots are fast growing and penetrate at least several meters into the soil. Even small fragments of damaged roots left behind after control efforts will resprout (Lyons 1998a).

Whitetop is classified as a Class C noxious weed in Washington. Under Washington's weed law, control measures are a local option for Class C noxious weeds(NWCB 2003a). No control measures are required for this species by local jurisdictions within the Hanford Reach National Monument area.

## Current Status and Treatment Priorities on the Monument

Whitetop is a Priority 2 species on the Hanford Reach National Monument. At present whitetop infests nearly 500 acres (> 200 ha) of the Monument, with most of the records occurring south of the Columbia River, on the McGee Ranch-Riverlands and ALE units (Fig. 7). In the Columbia Basin, whitetop is typically associated with springs, seeps, and riparian areas, and with deep soils in the upper Cold Creek Valley. Great Basin wildrye (*Elymus cinereus*) is a common associate and conspicuous indicator of the soil moisture whitetop favors.

The highest priority sites for treatment of whitetop on the Hanford Reach National Monument are associated with ephemeral springs and seeps on the lower slopes of the Rattlesnake Hills on the ALE Reserve (Table 6). Several infestations on roadways are also high priorities, because of the opportunity these sites create for long-distance dispersal on vehicles.

Table 6. Priority Sites for treatment of whitetop.

<table>
<tr><th>Unit</th><th>Location</th><th>East (NAD 27)</th><th>North (NAD 27)</th></tr>
<tr><td rowspan="17">ALE</td><td>Jct. Of 117 and 1200' Rds.</td><td>296188</td><td>5148679</td></tr>
<tr><td>Gate 120 Rd.</td><td>292006</td><td>5159451</td></tr>
<tr><td>Bobcat Rd. 60m up road from its junction w/ the 1200' Rd.</td><td>296766</td><td>5147694</td></tr>
<tr><td>Knob on hillside 50m W of 1200' Rd.</td><td>297278</td><td>5147482</td></tr>
<tr><td>Spring in small canyon SE of Bobcat Canyon</td><td>297324</td><td>5147256</td></tr>
<tr><td>Mouth of spring canyon SE of Bobcat Canyon</td><td>297389</td><td>5147390</td></tr>
<tr><td>Seep in small canyon W of 1200' Rd. between spring canyon and Doke Spring.</td><td>297694</td><td>5147087</td></tr>
<tr><td rowspan="2">Doke Spring, near its mouth, W of the 1200' Rd.</td><td>298135</td><td>5146272</td></tr>
<tr><td>298110</td><td>5146234</td></tr>
<tr><td>Doke Spring, up canyon from the previous 2 sites.</td><td>298014</td><td>5146215</td></tr>
<tr><td>Benson Spring</td><td>295865</td><td>5147223</td></tr>
<tr><td rowspan="3">Gate 111 Rd.</td><td>303856</td><td>5142935</td></tr>
<tr><td>304419</td><td>5143307</td></tr>
<tr><td>305203</td><td>5143941</td></tr>
<tr><td rowspan="2">Gate 106 Rd.</td><td>308420</td><td>5138432</td></tr>
<tr><td>311366</td><td>5138416</td></tr>
</table>

The resistance of whitetop to treatment advocates for aggressive, integrated measures to control small infestations before they expand. Herbicides may be applied in the spring during the bud to flower stages, as well as in the fall. Chemical control is enhanced when integrated with a mowing program. Competitive plantings using nursery-grown Great Basin wildrye (*Elymus cinereus*) should be tried on an experimental scale, and implemented more widely if results appear favorable after 2-3 years. In order to accomplish this, efforts to collect wildrye seed from local stocks should begin at the earliest opportunity.

## Control

Whitetop is able to readily regenerate from its extensive root system after incomplete eradication measures. Therefore, control must be persistent, and requires at least 2-3 years of follow-up work (Lyons 1998a). Successful control efforts integrate herbicide treatments and physical removal with competitive plantings. Great Basin wildrye (*Elymus cinereus*) show promise as a species that may compete succesfully against whitetop as dense plantings of nursery-grown stock (H. Newsome pers. comm.).

*Manual and Mechanical Methods*

Cutting is somewhat effective in controlling whitetop, if properly timed. A combination of mowing and chemical herbicide application has provided 50% control at a preserve maintained by The Nature Conservancy (Lyons 1998a). A single cutting is not effective. Cutting when plants are in full flower produces smaller, less vigorous plants and lower seed production, and may be combined with grazing to increase stress on plants (McInnis et al., 1990).

Whitetop root systems can be exhausted through repeated cultivation, resulting in complete elimination if the follow-up occurs diligently within ten days of weed reemergence for 2-4 years (Sheley and Stivers 1999, Miller & Callihan, 1991). Cultivation is more successful when combined with a competitive planting (Lyons 1998a). Cultivation machinery can spread whitetop infestations, so all root fragments should be removed from machinery before it is moved to uninfested areas.

*Biological Methods*

No effective biological control agents are currently available.

Sheep will eat *C. draba*, and especially like seedlings (Lyons 1998a). Sheep grazing may be worth exploring experimentally for management of whitetop populations in degraded areas of the Cold Creek drainage on the ALE Reserve. A grazing flock would have to be managed carefully to prevent straying into higher quality areas and to ensure that seeds of undesireable species are not introduced.

*Chemical Methods*

Whitetop displays some resistance to chemical treatment (Lyons 1998a). Herbicide treatment for whitetop can be effective, but in most cases a multi-year commitment is required: whitetop can re-establish rapidly if control measures are stopped too soon (Sheley and Stivers 1999, Lyons 1998a).

The timing of herbicide application is important. Chemicals provide the most effective control when applied at the early bud or flowering stage, when carbohydrates are moving from above to below ground and herbicides are more likely to be transported to the roots.

**2,4-D** LV ester or amine may be applied at 2-3 lb.a.e./A (2.3-3.4kg a.e./ha) for broadcast treatment and at 1.0 lb. a.e./A (1.1kg a.e./ha) for selective treatment. Apply in spring before or just at the bud stage (William et al. 2002). Ester formulations should be sprayed only when the temperature is low, since they can evaporate at temperatures as low as 21ºC (70ºF) and harm non-target plants (Lyons 1998a).

Mowing flowering plants followed by 2,4-D application using a backpack sprayer, repeated several times during the growing season resulted in approximately a 50% control rate (O’Brien & O’Brien 1994, cited in Lyons 1998a).

*(Continued)*

Fig. 7. Occurrences of whitetop (*Cardaria draba*.) mapped during the 2002–2003 invasive plant species inventory, Hanford Reach National Monument.

**Amitrol (Amitrol-T)** at 3.0 lb a.i./ 50 gal. (0.7kg a.i./100 liters) water is effective for spot treatment when applied before first flowers open (William et al. 2002). Foliage must be wet thoroughly.

**Chlorsulfuron (Telar)** is effective if applied at the pre-bloom to bloom growth stage, or to rosettes in the fall at 0.75 oz. a.i./A [ 1.0 oz./A of the 75% a.i. Telar] (26-53gm a.i./ha; with an 80% a.i. surfactant (William et al. 2002). Chlorsulfuron at 0.5 – 2.0 oz./ A has been used succesfully along roadsides in California Cipping and Bossard 2000).

**Metsulfuron (Escort)** is effective if applied at the pre-bloom to bloom growth stage, or to rosettes in the fall at 0.6 oz. a.i./A [1 oz./A of the 60% a.i. Escort] (21-42gm a.i./ha). A non-ionic or silicone surfactant will increase effectiveness (William et al. 2002). Application of 0.03 oz./ gal. has been moderately successful in Washington, slowly reducing a small population over a period of several years (D. Wilderman pers. comm.).

**Glyphosate** (Roundup, Rodeo) applied at 1.0 pt./ A at bud stage has yielded 80% control (Chipping and Bossard 2000).

## DIFFUSE KNAPWEED *CENTAUREA DIFFUSA*

Diffuse knapweed is a highly competitive annual to short-lived perennial forb of the composite family (Asteraceae). Young plants first form low rosettes with deep taproots and may remain in this stage for one to several years. At maturity plants bolt, flower, set seed, then die. Diffuse knapweed may produce as many as 146,000 seeds $m^2$ (Schirman 1981). Seeds are spread in tumbleweed fashion and seed-bearing stems are spread long distances attached to undercarriages of vehicles; waterborne seeds are carried along streams and irrigation ditches (Roché and Roché 1999). Seeds may remain dormant in the soil for several years.

Diffuse knapweed has infested more than one million acres of grassland, shrubland, and riparian communities in the western United States, and the area infested is increasing rapidly (Roché and Roché 1999). Disturbed or overgrazed lands are prime candidates for colonization, but diffuse knapweed will also invade undisturbed areas (Zimmerman 1997, Sheley et al. 1997, R. Leonard pers. comm.). Diffuse knapweed outcompetes desirable native species and is capable of forming dense stands which reduce biodiversity, degrade wildlife forage quality, and increase surface runoff and soil erosion (Roché and Roché 1999, 1988). Diffuse knapweed leaves contain an allelopathic chemical which may contribute to the species' competitive advantage (Watson and Renney 1974).

Diffuse knapweed is classified as a Class B Designate noxious weed in the following portions of the Hanford Reach National Monument: Grant County portions of the Monument lying in Townships 13 through 16 North, Ranges 25 through 27 East (about 2 miles east of the Venita Bridge and north to the Monument boundary); Adams County portions of the Monument; and in Franklin County portions of the Monument (region 9). State law requires prevention of seed production and spread of Class B Designate weeds (NWCB 2003a).

Diffuse knapweed is classified as a Class B Non-Designate noxious weed in other jurisdictions included within the Monument. State law calls for containment, gradual reduction, and prevention of further spread of Class B Non-Designate noxious weeds (NWCB 2003a).

### Current Status and Treatment Priorities on the Monument

Diffuse knapweed is a Priority 1 species on the Hanford Reach National Monument. At present diffuse knapweed infests more than 3600 acres (>1450 ha) of Monument lands. Diffuse knapweed is also nearly ubiquitous between the low and high water marks along the Columbia River shoreline, where it was not surveyed, so that the actual size of the overall infestation is considerably larger than what is reported here.

Much of the upland acreage occupied by diffuse knapweed lies along unpaved roads (Fig. 8). However, infestations have moved into sagebrush stands in the McGee Ranch area and show signs of beginning to move into natural areas on Umtanum Ridge, and the species is also widespread in old ranchland along the north shore of the Columbia River in the Saddle Mountain Unit.

Ideally, all infestations of diffuse knapweed on the Monument should be attacked aggressively. In practice, the infestation of old agricultural fields on the Saddle Mountain Unit is too large to readily control over the short term, and the infested area is of very low quality. The short-term goal for this infestation should be containment. Treatments along the Columbia River shore will be difficult and unlikely to achieve great success due to the steady influx of riverborne seeds. Management's immediate objective should be eradication of diffuse knapweed from all other roadways, corridors, and natural areas. Given diffuse knapweeds mobility and widespread distribution on the landscape, complete eradication fof this species over large areas of the Monument is unlikely. However, diffuse knapweed occurrences should become rare in controlled access areas of the Monument within 5-10 years, and should become rare along public access ways within 10-15 years.

While all diffuse knapweed occurrences represent threats to the Monument's biological resources, several occurrences are especially threatening to conservation targets. Several small, distinct occurrences on roads on Umtanum Ridge (Table 7) could be hand-pulled by two persons in ½ day or less. The infestations in sagebrush in the McGee Ranch area and along the Cold Creek creekbed are larger and may be treated by hand-pulling or spot application of herbicides. Aggressive treatment, along with continued monitoring and retreatment in these areas for at least 3-5 years until seedbanks are exhausted is critical to successfully controlling diffuse knapweed in these areas.

More continuous infestations along unpaved roadways in the McGee Ranch-Riverlands Unit, on the ALE Reserve, and at the Vernita Bridge Recreation Area's boat launch areas must be treated effectively to reduce the potential for infestations to advance into natural areas or to be transported by vehicular traffic. Glyphosate (Roundup), applied after plants have bolted, should be effective along most roadways (see below). These areas, especially those with public access, are likely to require continuing treatment as seedlings emerge from existing seedbanks and new propagules continue to be transported into the sites. A pre-emergent herbicide may be the best choice for isolated occurrences in roadways.

Anecdotal evidence suggests that *Larinus minutus*, the lesser knapweed flower weevil, can significantly reduce diffuse knapweed populations in Washington (G.L. Piper pers. comm.). The abundance and distribution of this biocontrol species on the Monument should be assessed, and the population augmented if necessary, especially in the vicinity of large knapweed infestations.

Table 7. Priority Sites for treatment of diffuse knapweed. Roads and corridors not listed here (see text) are also high priorities.

| Unit | General Location | Specific Location | East (NAD 27) | North (NAD 27) |
|---|---|---|---|---|
| McGee-Riverlands | Umtanum Ridge | BPA access Rd. | 286832 | 5165444 |
| | | | 286740 | 5165240 |
| | | | 286157 | 5164070 |
| | | Umtanum Ridge Rd. | 285971 | 5165479 |
| | | | 286456 | 5165469 |
| | McGee Ranch | Near vinyards | 286473 | 5161941 |
| | Upper Cold Creek | Cold Creek creekbed | 286268 | 5161073 |
| ALE | Upper Cold Creek | Cold Creek creekbed | 291304 | 5159575 |

Fig. 8. Occurrences of diffuse knapweed (*Centaurea diffusa*) mapped during the 2002–2003 invasive plant species inventory, Hanford Reach National Monument.

## Control

Since diffuse knapweed reproduces entirely by seed, the key to controlling existing infestations is to eliminate new seed production and deplete the existing seed bank (Carpenter and Murray 1998b).

### Manual, Mechanical, and Cultural Methods

Hand pulling before seed set is an effective method of control for small or widely scattered , low-density infestations, but is very labor intensive (Roché and Roché 1999, D. Wilderman pers. comm). Hand-pulling can be most effective where a strong, committed pool of volunteer laborers is available (Tu 2001). The labor required to maintain control should decrease over the years. Hand-pulling can also be used to maintain or further reduce low knapweed densities brought about by herbicide treatments (Youtie 1997). Areas to be hand pulled should be treated three times annually: 1) during spring when moist soil allows maximum taproot extraction; 2) during late spring/ early summer when remaining plants have bolted; 3) in mid-late summer before overlooked plants have dipersed seed. Plants with seeds remaining in capsules should be bagged to keep the seeds from spreading (Youtie and Soll 1994, cited in Roché and Roché 1999).

CAUTION: An single account has anecdotally linked sap from diffuse knapweed, and perhaps related knapweed species, with a form of cancer. Anyone working with diffuse knapweed or other knapweed species should wear protective gloves and avoid getting knapweed sap into open cuts or abrasions (Carpenter and Murray 1998b).

Hand pulling programs should be repeated annually for as long as diffuse knapweed is a problem in the surrounding area. Seeds in the soil may remain dormant for several years and an area can become quickly reinfested. Monitoring of a site should continue for at least five years after an infestation has apparently been eradicated. A few knapweed plants can quickly destroy years of hard work if left undetected (Carpenter and Murray 1998b).

Cutting or mowing will not eliminate diffuse knapweed but can reduce seed production, and can be used to prolong the rosette season at which herbicide treatment is most effective (Roché and Roché 1999). Mowing actually increased populations of diffuse knapweed in at least one study (Zimmerman 1997).

Deep plowing may be an effective control on highly disturbed lands as diffuse knapweed seeds do not germinate below 3 cm of soil (Zimmerman 1997, Watson and Renney 1974). However, shallow plowing actually increased the amounts of diffuse knapweed in test plots (Zimmerman 1997, Watson and Renney 1974).

*Biological Methods*

Biocontrol agents may prove useful in integrated control programs by weakening the plants and/or reducing seed output enough to make the plants more susceptible to herbicides, prescribed fires or other techniques Carpenter and Murray 1998b). Numerous biological control agents for diffuse knapweed have been released in Washington. Although many of these agents sharply reduce seed production or inhibit root and shoot growth, none of them has been shown to significantly reduce diffuse knapweed densities.

*Urophora affinis* (banded gall fly) and *Urophora quadrifasciata* (knapweed seed head fly) are seed head feeding flies native to Eurasia. These species are widely distributed throughout Washington and can reduce seed production by up to 95% (Coombs et al. 2002, Rees et al. 1996).

*Larinus minutus* (lesser knapweed flower weevil), a weevil native to Greece, also preys upon diffuse knapweed seeds. Anecdotal evidence suggests that this weevil can significantly reduce diffuse knapweed populations in Washington (G.L. Piper pers. comm.). Collections of this species were released during each summer from 2000-2003 on the Saddle Mountain Unit of the Monument, along the Columbia River downstream from the Vernita Bridge, and at several wasteway ponds (H. Newsome pers. comm.). The abundance and distribution of this biocontrol species on the Monument should be assessed, and the population augmented if necessary, especially in the vicinity of large knapweed infestations.

*Cyphocleonus achates* (knapweed root weevil) is a European root weevil. Larvae can severely damage knapweed roots (Carpenter and Murray 1998b). Excellent control has been observed in Washington, but the species is limited in its distribution (Coombs et al. 2002). Coombs et al. (2002) and Carpenter and Murray (1998b) list other biocontrols for diffuse knapweed.

Sheep and goats will graze diffuse knapweed if confined to an area where alternative forage is unavailable. Repeated grazing will weaken plant reserves and make plants more susceptible to herbicide treatments (BIRC 2000).

*Chemical Methods*

Roché and Roché (1999) cite the rosette stage in spring or fall as the most favorable stage for effective herbicide application. On Natural Area Preserves in Eastern Washington, however, observations suggest that mortality is highest when herbicides are applied after plants have bolted (D. Wilderman pers. comm).

**Glyphosate** (Roundup, Roundup Ultra, Rodeo, Accord) is a non-selective contact herbicide that kills both broad-leaved plants and grasses. Glyphosate can be applied directly to the leaves of diffuse knapweed with a hand-held sprayer or wick applicator. William et al. (2002) recommend 3.0 lb. a.e./A (3.36 kg a.e./ha). Glyphosate will only provide control during the year of application, and will not kill seeds or inhibit germination the following season.

**Clopyralid** (Stinger, Transline) 0.25 – 0.5 lb. a.e./A (0.28 – 0.56 kg a.e./ha) [0.66 – 1.33 pts. product/A] is recommended for application from the rosette stage up to the to bud stage (William et al. 2002). Clopyralid + 2,4-D (Curtail) at 2.0 – 5.0 qts. Product/A and clopyralid + triclopyr (Redeem R&P) at 1.5 – 2.0 pts. product /A may also be used (William et al. 2002).

**2,4-D** is a selective, auxin-type herbicide that can be used to control many types of broad-leaved plants. 2,4-D at 1.0 – 2.0 lb. a.e./A (1.12 – 2.24 kg a.e./ha) may kill mature diffuse knapweed but will have no effect on the seedbank (William et al. 2002). A combination of 2,4-D and dicamba may reduce infestations enough so that control of survivors can be achieved by hand pulling (Youtie 1997).

**Picloram** (Tordon) applied at a rate of 0.25 - 0.5 lb.a.i. /A (0.28 - 0.56 kg a.i./ha) of [0.5 - 1.0 qt. product/A] is recommended for the control of diffuse knapweed (William et al. 2002, Roché and Roché 1999, A. Johnson, pers. comm.). Picloram may provide residual control of diffuse knapweed for 3 to 4 years on semi-arid rangeland sites (Watson and Renney 1974). Application of 1.5 pts./ A Tordon applied in late spring, before the last of the spring rains, has been very effective on diffuse knapweed on Central Hanford (R. Roos pers. comm.).

**Dicamba** (Banvel, Clarity, Vanquish, Veteran) applied at rates of 0.5 to 1.0 lb./acre (0.5 to 1.0 qt. product/acre) provides effective control of diffuse knapweed (Beck 1997). Dicamba can also be mixed with 2,4-D for spot treatments of diffuse knapweed (Beck 1997, Youtie 1997). Dicamba should not be used in diverse natural areas, as it has a tendency to eliminate all broadleaved species (Carpenter and Murray 1998b).

**Combinations**. Several of these herbicides can be combined to treat diffuse knapweed (Beck 1997). Tank-mixes of picloram and dicamba (0.25 to 0.5 lb./acre + 0.125 to 0.25 lb./acre), picloram plus 2,4-D (0.188 lb./acre + 1.0 lb./acre), and dicamba plus 2,4-D (0.5 lb./acre + 1.0 lb./acre) all have been used to control diffuse knapweed (Beck 1997, Youtie 1997).

**YELLOW STARTHISTLE** ***CENTAUREA SOLSTITIALIS***

Yellow starthistle is an erect winter annual or occasionally biennial European forb in the composite family (Asteraceae). Yellow starthistle infests more than 15 million acres (6 million ha) in the western U.S. where it can form dense stands in natural areas, rangelands, and elsewhere. Yellow starthistle disperses seeds both in the summer (plumed seeds) and in early winter (non-plumed seeds; Larson and Shelley 1994). Mature plants are capable of producing as many as 75,000 seeds, which may remain viable in soil for up to 10 years (DiTomaso and Gerlach 1999). Taproots grow vigorously early in the season to soil depths of 1 m or more, giving plants access to deep soil moisture during the dry months of summer and early fall (DiTomaso 2001, Larson and Shelley 1994).

Yellow starthistle infestations can reduce wildlife habitat and forage, displace native plants, and reduce native plant and animal diversity (Sheley and Larson 1994). Yellow starthistle significantly depletes soil moisture reserves in both annual and perennial grasslands. Its high water usage threatens human economic interests as well as native ecosystems (DiTomaso 2001).

Yellow starthistle is able to invade and coexist within cheatgrass-dominated annual grasslands, further complicating restoration efforts (Sheley and Larson 1994).

Yellow starthistle is classified as a Class B Designate noxious weed thoughout Region 6 and in all of Region 9 included in and adjacent to the Monument . State law requires prevention of seed production and spread of Class B Designate weeds (NWCB 2003a).

## Current Status and Treatment Priorities on the Monument

Yellow starthistle is a Priority 1 species on the Hanford Reach National Monument. At present yellow starthistle is known to infest more than 310 acres ( > 125 ha) on the Monument. All recorded infestations are from the North Slope, primarily on the Wahluke Unit, and from the Columbia River islands (Fig. 9). At least four small point occurrences of yellow starthistle occur in close proximity to a portion of the population of White Bluffs bladderpod (*Lesquerella tuplashensis*). White Bluffs bladderpod is a Candidate species for listing by the U.S. Fish and Wildlife Service under the Endangered Species Act, and is listed as Threatened in Washington (Washington Natural Heritage Program 1997).

Because of its mobility on the landscape, all infestations of yellow starthistle on the Monument should be treated aggressively and persistently with the aim of eradicating all infestations of 0.5 acres (0.2 ha; Table 8) or less within 5 years and all larger infestations within 10-15 years. Small infestations can be pulled by hand prior to seed set. Picloram (Tordon) is effective on rosettes during autumn and spring, while glyphosate (Roundup) is effective on plants that have bolted later in spring (see below). Yellow starthistle's longevity in the seedbank will require treatment and monitoring measures to be persistent through a 5-15 year time period and perhaps beyond. Treatment sites must be monitored for at least 10 years following apparent eradication to ensure that the seed bank is exhausted. Coordination of efforts between USFWS and DOE personnel will be critical in the control of this invasive species that readily crosses management boundaries.

Table 8. Selected priority sites (< 0.5 A/ 0.2 ha) for treatment of yellow starthistle.

| Unit | General Location | Specific Location | East (NAD 27) | North (NAD 27) |
|---|---|---|---|---|
| Saddle Mt. Unit | "T" road | N of SR 24 | 306869 | 5180014 |
| | | | 306874 | 5179608 |
| | | | 307041 | 5180002 |
| Wahluke Unit | White Bluffs | | 318954 | 5162859 |
| | | | 318984 | 5162972 |
| | | | 319068 | 5162998 |
| | | | 320412 | 5162344 |
| | | Crest of bluffs, just NW of wooden transmision line. W/ White Bluffs bladderpod | 318428 | 5163896 |
| | | | 318482 | 5163896 |
| | | | 318494 | 5163816 |
| | | | 318497 | 5163780 |
| | | Ringold – White Bluffs Rd. | 321327 | 5160134 |
| | | | 318157 | 5162551 |
| | | | 318306 | 5162485 |
| | | | 318890 | 5161815 |
| | | | 318434 | 5162481 |
| | Flats above White Bluffs | Along or in vicinity of wooden transmission line | 319479 | 5162424 |
| | | | 319566 | 5164951 |
| | | | 319645 | 5165048 |
| | | | 319928 | 5165456 |

Fig. 9. Occurrences of yellow starthistle (*Centaurea solstitialis*) mapped during the 2002–2003 invasive plant species inventory, Hanford Reach National Monument.

## Control

Control of yellow starthistle cannot be accomplished with a single treatment or in a single year. Effective control requires suppression of seed production. An integrated approach using several methods is the best for long-term management of *C. solstitialis* (DiTomaso 2001).

### Manual, Mechanical and Cultural Methods

Hand pulling may be effective for individuals or small colonies of yellow starthistle (Snyder-Conn 2001). Mowing can be used for starthistle control provided it is well timed and used on plants with a high-branching growth form. Mowing should take place when the first plants in a population are beginning to flower, and must cut plants below the lowest branches. Tillage of young plants prior to flowering may also be effective (DiTomaso and Gerlach 1999). Repeated mechanical treatments will be necessary to exhaust the seedbank accumulated by established infestations.

CAUTION: An single account has anecdotally linked sap from diffuse knapweed, and perhaps related knapweed species, with a form of cancer. Anyone working with diffuse knapweed or other knapweed species should wear protective gloves and avoid getting knapweed sap into open cuts or abrasions (Carpenter and Murray 1998b).

Prescribed burning may be part of an integrated plan for controlling yellow starthistle. Burning should be performed when flowers first appear. Yellow starthistle will be green at this time and will require desiccated surrounding vegetation in order to burn (DiTomaso 2001).

*Biological Methods*

The hairy weevil (*Eustenopus villosus*), and the peacock seed head fly (*Chaetorellia australis*) have significant impacts on reproduction of yellow starthistle, reducing seed production by 43 to 76% when used in combination (DiTomaso 2001). These species, along with another seed head fly (*Chaetorellia* succinea) and a seed head weevil (*Eustenopsis villosus*) are widely established in Washington and provide good control (Coombs et al. 2002). While not adequate for long-term control, these agents can be an important component of an integrated management approach.

Sheep, goats or cattle are effective in reducing *C. solstitialis* seed production when grazed after plants have bolted but before spines form on the plant. Goats will continue to graze Yellow starthistle even in the spiny stage and can be an effective part of an integrated, multi-strategy plan for controlling small to moderately sized infestations (DiTomaso 2001, Thomsen et al. 1993).

*Chemical Methods*

**Clopyralid** (Transline, Stinger) is a very selective herbicide that does not injure grasses or most broadleaf species. Clopyralid gives excellent control (effective for one season) of yellow starthistle at 1.5 to 6.0 oz a.e./A (0.1- 0.42 kg a.e./ha; William et al. 2002). The best time to apply is during the early rosette stage prior to bud formation. Clopyralid is also effective on plants in the bolting and bud stage, but higher rates are required (DiTomaso 2001). Applications made after the bud stage will not prevent the development of viable seed (DiTomaso 2001). When treating older plants or plants exposed to moderate levels of drought stress, surfactants can enhance the activity of the herbicide. A combination of clopyralid and 2,4-D amine (Curtail) can be used at 1 – 5 qts. product/A after the majority of *C. solstitialis* rosettes have emerged but before bud formation (William et al. 2002).

**Glyphosate** (Roundup) is also effective on yellow starthistle. It will control bolted plants at 1.0 – 2.0 lb a.e./acre [0.33 – 0.66 gal product/A] (1.12 – 2.24 kg a.e./ha [9.4 – 18.8 liters product/ha]), or 1% solution and can be used as a late season spot treatment on small infestations or escaped plants. Good coverage, clean water, and actively growing yellow starthistle plants are all essential for adequate control (DiTomaso 2001)

**Picloram** (Tordon) acts much like clopyralid, but gives a broader spectrum of control and has much longer soil residual activity (2-3 years; DiTomaso 2001). Picloram is applied (usually with a surfactant) at a rate between 0.25 lb and 0.375 lb a.e./acre (0.28-0.42 kg a.e./ha) in late winter to spring when plants are still in the rosette through bud formation stages (William et al. 2002). This treatment can provide effective residual control for 2-3 years. Tordon applied at 1.5 pts./ A in late spring, before the last of the spring rains, has been very effective for yellow starthistle on Central Hanford (R. Roos pers. comm.).

**Other Compounds**. Postemergence herbicides such as **2,4-D** (0.5 to 0.75 lb a.e./acre; 0.56-0.84 kg a.e./ha), **dicamba** (Banvel, Vanquish; 0.25 to 1.0 lb a.e./acre; 0.28-1.1 kg a.e./ha), and **triclopyr** (Garlon 3A, Garlon 4, Remedy; 0.5 or 1.5 lb a.e./acre; 0.56-1.7 kg a.e./ha ) can be effectively used to spot-treat escaped plants or to eradicate small populations in the rosette stage or in late season when starthistle is easily visible but has yet to produce viable seed. These herbicides have no soil residual activity and will not control plants germinating after application (DiTomaso 2001). Amine forms are as effective as ester forms at the small rosette growth stage, but amine forms reduce the chance of off-target movement. In late season treatments a surfactant should be added to amine formulations (DiTomaso 2001). Dicamba should not be used in diverse natural areas, as it has a tendency to eliminate all broadleaved species (Carpenter and Murray 1998b).

### RUSH SKELETONWEED — *CHONDRILLA JUNCEA*

Rush skeletonweed is a tall, deep-rooted perennial Eurasian forb of the composite family (Asteraceae). Mature plants have a taproot reaching down seven feet or more and can produce more than 20,000 seeds each (Sheley et al. 1999). Seeds are capable of long distance dispersal via wind or automobiles but do not remain viable in the seed bank for more than 1-2 years (Sheley et al. 1999). In sandy and gravely soils lateral roots can branch from the tap root and can spread several feet, producing daughter rosettes from buds (NWCB 2003b). Small root fragments can develop into new plants, even when buried deeply (Sheley et al. 1999).

Rush skeletonweed invades disturbed rangelands and agricultural lands of the Columbia Basin. In rangeland rush skeletonweed crowds out native plant species and reduces wildlife forage production (Sheley et al. 1999).

Three biotypes of rush skeletonweed occur in the Pacific Northwest (NWCB 2003b). The tall, late flowering Spokane, Washington biotype can reach 50 inches tall, is sparsely branched, and flowers in August. The short, early flowering Post Falls, Idaho biotype ranges from 25 to 35 inches tall, with extensive branching, and flowers in mid-July. The short Banks, Idaho biotype is very similar in appearance and flowering times to the Post Falls biotype.

Rush skeletonweed is classified as a Class B Designate noxious weed thoughout Region 9 and in all portions of Grant County included in and adjacent to the Monument. State law requires prevention of seed production and spread of Class B Designate weeds (NWCB 2003a).

## Current Status and Treatment Priorities on the Monument

Rush skeletonweed is a Priority 1 species on the Hanford Reach National Monument. At present rush skeletonweed is known to infest more than 690 acres (> 280 ha) on the Monument, primarily in the lower Cold Creek Valley and the low slopes of Rattlesnake Mountain on the ALE Reserve, as well as on some Columbia River islands (Fig. 10).

Because of it's mobility on the landscape, all infestations of rush skeletonweed on the Monument should be treated aggressively and persistently with the aim of eradicating all infestations of 0.5 acres (0.2 ha; Table 9) or less within 5 years and all larger infestations within 10-15 years. Both clopyralid (Transline) and picloram (Tordon) applied in late fall to early spring (picloram even into mid-summer) have been successful in Washington (see below). Rush skeletonweed's deep root system and longevity in the seedbank will require treatment and monitoring measures to be persistent through these time periods and perhaps beyond. Coordination of efforts between USFWS and DOE personnel will be critical in the control of this mobile invasive species that readily crosses management boundaries.

Table 9. Selected priority sites (< 0.5 A/ 0.2 ha) for treatment of rush skeletonweed.

| Unit | General Location | Specific Location | East (NAD 27) | North (NAD 27) |
|---|---|---|---|---|
| ALE | Snively Basin | Upper Snively Basin Rd. | 289998 | 5145983 |
| | Iowa Flats | | 310004 | 5138331 |
| | | | 310178 | 5138690 |
| | Lower Slopes | | 300221 | 5146550 |
| | | | 300243 | 5148084 |
| | | | 300210 | 5148164 |
| | | | 300467 | 5148505 |
| | | | 300547 | 5148443 |
| | | | 301102 | 5144613 |
| | | | 301092 | 5144598 |
| | | | 301069 | 5144614 |
| | | | 301110 | 5144627 |
| Wahluke Unit | Ringold | Bluffs above road. | 326877 | 5148980 |
| | | Near Parking Lot #8 | 318162 | 5162566 |
| | | Along Ringold-White Bluffs Rd. | 317575 | 5163279 |
| | | | 317929 | 5162878 |
| | | | 320356 | 5160980 |
| | White Bluffs | South of wooden transmission line | 315318 | 5171925 |
| | Flats aboveWhite Bluffs | Vicinity of wooden transmission line | 319927 | 5165453 |
| River Corridor | Island # 12 | South end of island | 326382 | 5150684 |
| | | | 326504 | 5150956 |
| Columbia River Islands | Island # 14 (Wooded Island) | South end of island | 325908 | 5142942 |
| | | Center of island | 325961 | 5143739 |
| | | | 325964 | 5143869 |

Fig. 10. Occurrences of rush skeletonweed (*Chondrilla juncea*) mapped during the 2002–2003 invasive plant species inventory, Hanford Reach National Monument.

## Control

Successful control of rush skeletonweed will require an integrated approach and sustained effort for many years (Sheley et al. 1999).

*Manual and Mechanical Methods*

Hand pulling can be used to control very small infestations of rush skeletonweed, but must be performed diligently 2-3 times/ year for 6 – 10 years to be effective (Sheley et al. 1999). Cultivation can be considered on seedlings less than 36 days old, as they are unable to develop new shoots from root fragments (Old 1981 cited in NWCB 2003b), but mechanical damage to mature plants stimulates new growth, often resulting in satellite plants (NWCB 2003b). Frequent mowing of rush skeletonweed plants infested with and impacted by the gall mite (*Eriophyes chondrillae*) may decrease the rate of spread of this plant (McLellan 1991 cited in NWCB 2003b).

*Biological Methods*

Biological control agents by themselves will not control rush skeletonweed, but can be a contributing element of an integrated control program. Several biological control agents for rush skeletonweed are widely established in the Pacific Northwest (Coombs et al. 2002).

A gall mite (*Eriophyes chondrillae*) is considered the most effective biological control agent available to date (NWCB 2003b). The mite is effective against all biotypes of rush skeletonweed. The visible impacts to flowering buds are leaf-like galls, up to two inches in diameter, which can reduce or prevent seed production. The gall mite also affects root carbohydrate reserves, preventing the formation of satellite plants. The seedlings and satellite plants often die. However, bud production is stimulated by the feeding mites (Prather 1993 cited in NWCB 2003b). Soil disturbance associated with cultivation in croplands interferes with the life cycle of the mite, and as a result, there is a reduction in the persistence of gall mite infestations on rush skeletonweed (Rees et al. 1996). Rush skeletonweed often remains the dominant species in gall infested populations.

The gall midge (*Cystiphora schmidti*) impacts the rosette and flowering stems of all biotypes in our region, and affected stands are often a noticeable purple to reddish color (Martin 1996; Rees et al. 1996).

Some biological control agents for rush skeletonweed are very specific to biotype. The rust fungus *Puccinia chondrillina,* introduced to Washington in 1978, is effective on the Banks, Idaho biotype (NWCB 2003b). However, the Post Falls biotype is resistant to this rust (Rees et al. 1996).

*Chemical Methods*

Rush skeletonweed's deep root system is resistant to herbicide treatments and different biotypes may exhibit different susceptibilities to different rates of herbicides (Sheley et al. 1999). Young plants less than five years old are more susceptible to herbicide treatment than older plants (NWCB 2003b). Control with herbicides requires an aggressive follow-up program with repeated applications. Herbicides are most effective when combined with biological control programs (Sheley et al. 1999).

**Picloram** (Tordon), applied at 1.0 lb a.e./A to rosettes just prior to or during bolting, is the most effective herbicide treatment available for rush skeletonweed control (William et al. 2002). Although treatment from late fall to early spring is usually recommended, mid-summer (July) treatment has proven successful at Hanford (R. Roos pers. comm.). Repeated treatments are necessary for long-term control.

**Clopyralid** (Transline, Stinger) at 0.25 lb. – 0.375 lb. a.e./A (0.66 – 1.0 pt. Product/A) applied to rosettes in late fall (November – December; R. Roos pers. comm.) or up to early bolting stage in spring (William et al. 2002). Treatment with Transline produced a 95 percent effective control rate. However, plants did show up three to five years later (NWCB 2003b). Transline at 1.0 oz./ gal. has been used effectively for spot treatments on rush skeletonweed in Eastern Washington (D. Wilderman pers. comm.).

Curtail is a formulation of Clopyralid and 2,4-D which is effective against a wider range of broadleaf plants than clopyralid alone. Curtail (2.5 oz./gal.) has been used with success against rush skeletonweed by the Washington Deparent of Natural resources on the Kahlotus Ridgetop Natural Area Preserve, but this formulation has been somewhat less effective than Transline (D. Wilderman pers. comm.). Curtail will damage most perennial broad-leaved plants and so should be applied carefully to minimize the damage to non-target plants.

**2,4-D** applied at 2.0 lb. a.e./A at the rosette or bolting stages in the spring may control aboveground growth but will not kill rush skeletonweed roots (William et al. 2002). Repeated treatments will be necessary.

## CANADA THISTLE *CIRSIUM ARVENSE*

Canada thistle is an erect rhizomatous perennial forb in the composite (Asteraceae) family. This Mediterranean species is distinguished from all other thistles by a spreading horizontal root system and dense clonal growth, and by small dioecious (male and female flowers on separate plants) flowerheads (Nuzzo 1997).

Canada thistle is an aggressive invader of distrubed grasslands and riparian areas across the Intermountain West. Canada thistle threatens natural communities by directly competing with and displacing native vegetation, decreasing species diversity, and changing the structure and composition of plant communities. Canada thistle invades new sites via airborne or waterborne dispersal of plummed seeds. Subsequent spread is primarily through the aggressive expansion of spreading rhizomes (Morashita 1999, Nuzzo 1997).

In addition to its impacts on natural areas Canada thistle presents an economic threat to farmers and ranchers by reducing crop yield, interfering with harvest, and by hosting invertebrate pest species (Nuzzo 1997).

On Hanford Reach National Monument Canada thistle appears to be most common near springs and riparian areas, often in association with Russian knapweed, whitetop, and other invasive species. It also occurs at some higher elevation sites on Rattlesnake Mountian and in the Rattlesnake Hills.

Canada thistle is classified as a Class C noxious weed in Washington. Under Washington's weed law, control measures are a local option for Class C noxious weeds (NWCB 2003a). No control measures are required for this species by local jurisdictions within the Hanford Reach National Monument area.

### Current Status and Treatment Priorities on the Monument

Canada thistle is a Priority 2 species on the Hanford Reach National Monument. Canada thistle is recorded on only 15.1 acres (6.1 ha) of the Monument (Fig. 11). However, large areas of suitable habitat along irrigation wasteways and impoundments on the North Slope, and occurrences along the Columbia River shoreline, and in irrigation-seep wetlands along the Ringold Road were not surveyed, so that this species is greatly underreported here.

Priority treatment sites are all small, isolated occurrences (Table 10). An exception is the Bobcat Canyon site, where a more widespread infestation degrades the riparian area along Benson Spring, perhaps the highest-quality natural spring system on the Monument.

Clopyralid plus 2,4-D amine (Curtail) appears to provide the best chemical control of Canada thistle, although results can be variable (see below). Covering with well-secured black landscape fabric for 3-5 years is recommended for trial on remote, isolated infestations such as on the upper Bobcat Road and the Rattlesnake Mountain, mid slopes infestation.

Table 10. Priority sites for treatment of Canada thistle.

| Unit | Location | East (NAD 27) | North (NAD 27) |
|---|---|---|---|
| ALE | Rattlesnake Mt. summit ridge | 299929 | 5141563 |
| | Bobcat Rd. near western boundary | 294641 | 5144489 |
| | Rattlesnake Mt., mid slopes | 300353 | 5143832 |
| | Bobcat Canyon | 295865 | 5147223 |
| | Spring in small canyon SE of Bobcat Canyon | 297311 | 5147212 |
| | Seep in small canyon W of 1200' Rd. between spring canyon and Dokes Spring | 297694 | 5147087 |
| Vernita | Borrow pit | 290674 | 5169211 |
| | Borrow pit | 290746 | 5169175 |

## Control

Canada thistle has numerous ecotypes that respond differently to management activities. Some infestations may be completely controlled by one technique, while others will only be partially controlled because two or more ecotypes are present within the population. Additionally, Canada thistle responds differently to management under different weather conditions. Therefore an integrated control program including careful monitoring is recommended (Morashita 1999, Nuzzo 1997).

Since Canada thistle is dioecious, some control of seed production is possible by targeting female clones for treatment. However, most of the spread of established clones is by vegetative means.

*Mechanical and Cultural Methods*

Mowing temporarily reduces above-ground biomass, but does not kill Canada thistle unless repeated at 7-28 day intervals for up to 4 years. Mowing just twice a year may reduce or contain Canada thistle. Stems must be mown before the flowers open or immediately thereafter (flowers that have been open 8-10 days can develop viable seeds after cutting (Nuzzo 1997). When the primary stem is removed, rootbuds are stimulated to produce new shoots, so mowing should be done high enough to leave > 9 leaves/stem, or >20 cm of bare stem tissue. Mowing enhances control following applications of picloram, picloram + 2,4-D, clopyralid + 2,4-D, and dicamba (Morashita 1999).

Tilling can reduce or eliminate Canada thistle, if conducted repeatedly for several years (Nuzzo 1997, Morashita 1999). Tilling is only appropriate for highly disturbed areas, but may be an effective strategy for small infestations if done manually. Care must be taken not to spread root fragments which can regenerate. Cultivation may also increase the effectiveness of subsequent herbicide applications (Nuzzo 1997).

Covering small infestations with black landscape fabric such as Mirafi or other light-impervious materials can kill Canada thistle plants. Materials can be secured using 10” gutter nails or tree anchors (M. Tu pers. comm.). It is necessary to prevent shoot growth for at least two years to deplete roots and kill Canada thistle.

Fire is generally not effective in controlling Canada thistle (root systems resprout) and burning may promote the species at the expense of native vegetation (Nuzzo 1997, Bushey 1995).

*Biological Methods*

Available biological control agents have provided little control of Canada thistle populations, according to Nuzzo (1997). Adults of the crown and root weevil *Ceutorhynchus litura* eat young thistle shoots, but do little damage. The stem gall fly, *Urophora cardui* lays its eggs in the terminal buds; galls develop which divert nutrients and stress the plant; however, the distribution and availability of this species in Washington is limited. The seed head weevils *Larinus planus* and *Rhinocyllus conicus* are well-established in Washington and reportedly offer good control (Coombs et al. 2002, NWCB 2003b). However, *Larinus planus* has been reported to feed upon at least one species of native thistle in Colorado, reducing seed production of that non-target species by more than 50% (Jensen 2001). Introduction of this biocontrol agent is NOT recommended, unless further research indicates a high degree of assurance that this species will not generalize onto the native thistle *Cirsium undulatum*. In order to determine whether or not there is a current threat from *L. planus*, native and non-native thistles on the Monument should be surveyed for the presence of this species and, if present, the effect of *L. planus* on native thistles should be evaluated.

*(Continued)*

Fig. 11. Occurrences of Canada thistle (*Cirsium arvense*) mapped during the 2002–2003 invasive plant species inventory, Hanford Reach National Monument.

*Chemical Methods*

The following factors should be considered when using herbicides against Canada thistle (Nuzzo 1997):

Canada thistle's deep, well-developed root system makes it resistant to herbicides. Herbicide effectiveness depends upon Canada thistle growth stage, environment, ecotype, and genotype.

Not all shoots and roots in a clone remain physically connected. Because of aggressive clonal growth it is necessary to kill all Canada thistle plants within a site to achieve control.

For all herbicides except 2,4-D, two or more applications per year give better control than a single application, regardless of seasonal sequence.

Canada thistle's absorption of herbicide is greatest in late summer and fall. Treatment may also be applied during spring at the flowerbud stage, when root reserves are lowest.

Chemical control efforts will likely require multiple (at least 2) annual applications over a period of several years to achieve success.

Herbicide effect is enhanced when Canada thistle roots are weakened during the growing season by previous herbicide treatment, crop competition, frequent mowing or tilling, and when new shoots are stimulated to grow. Herbicides should be applied to new growth when leaves are green. Avoid applying herbicide to old leaves (thick cuticle limits absorption) or to drought-stressed leaves (Nuzzo 1997).

**Clopyralid** (Stinger, Transline) is a relatively selective post-emergence herbicide that kills many broadleaf weeds and woody plants but does little harm to grasses and other monocots. Fall application of clopyralid at 560 – 840 g/ha delayed shoot emergence of Canada thistle and reduced shoot density the following summer, with the higher concentration producing the most pronounced effect (Donald 1993).

Clopyralid plus 2,4-D amine (Curtail) has provided the best and most consistent control of Canada thistle in agricultural areas (Nuzzo 1997). Annual applications in early June at 70 g a.i./acre clopyralid +280 g a.i./acre 2,4-D resulted in elimination or near-elimination of all Canada thistle roots in the top 50 cm of soil after 2-4 years. In Eastern Washington, Curtail at 2.5 oz./ gal. or 5.0% concentration has provided excellent control on many of the state's Natural Area Preserves (D. Wilderman pers. comm.).

**Glyphosate** (Roundup, Rodeo) is a non-selective systemic herbicide with little or no residual effect in soil. Apply at 1.5 – 2.25 lb. a.e./A for broadcast applications. For spot treatment use a 2.0% solution (William et al. 2002). For optimal results apply glyphosate under warm conditions in fall well before the first killing frost and when soil moisture is good, or after plants have adjusted to colder weather (Nuzzo 1997)

**Picloram** (Tordon) will act on most broadleaf species and may persist for up to 3 years in the soil (Nuzzo 1997). It is relatively soluble and thus is likely to migrate into groundwater. Two to three annual fall applications of picloram at 280 g/ha gradually reduced Canada thistle density, and both one and three consecutive annual fall applications at 560 g/ha essentially eliminated Canada thistle (Donald 1993). William et al. (2002) recommend 1 lb. a.e./A mixed in 100 gal. water applied prior to the bud stage.

**Chlorsulfuron** (Telar) is a post-emergent herbicide that primarily suppresses regrowth of Canada thistle, and secondarily reduces the number of root buds and plant weight (Peterson 1983). Application of 1.125 oz. a.i./A (a.5 oz. product/A) to Canada thistle in bloom stage or to fall rosettes is recommended (William et al. 2002).

**Amitrole** (Amitrol-T) may be applied to growing thistles at 0.5 lb. a.i./12 gal. water for spot treatments, or at 4.0 lb. a.i./A for broadcast application (William et al. 2002). Canada thistle should be at least 6 inches tall but prior to bud stage. Foliage should be thoroughly wetted.

## BULL THISTLE *CIRSIUM VULGARE*

Bull thistle is a Eurasian biennial in the composite (Asteraceae) family. Reproduction is only via seeds, which are produced prolifically (up to 4,000/ plant) and which are relatively short-lived (1-3 years) in the soil seed bank . Plumed seeds can be transported long distances by wind or birds (CNAP 2000, Beck 1999a).

Bull thistle colonizes disturbed areas but is rarely troublesome in undisturbed places. Dense infestations can crowd out native species, reduce forage, and restrict wildlife movement (CNAP 2000, Beck 1999a).

Bull thistle is classified as a Class C noxious weed in Washington. Control measures are not required by state law, but are a local option (NWCB 2003a). No control measures are required by local jurisdictions within the Monument area.

### Current Status and Treatment Priorities on the Monument

Bull thistle is a Priority 3 species on the Hanford Reach National Monument. Bull thistle appeared to be limited to isolated individuals scattered about the Monument. These scattered individuals can be best controlled by manual removal when encountered. No sites are designated for priority treatment.

### Control

*Manual and Mechanical Methods*

Severing the taproot below the soil surface will kill these biennials. Hand-pulling can eliminate isolated individuals and small infestations. Cutting or mowing just before seed set will eliminate the current year's seed production. Cutting or mowing should be done after plants have bolted but before flowering has occurred. Asynchronous bolting may require more than one mowing per year to be effective. Persistence with these methods over several years will exhaust the seed bank and eliminate an infestation (CNAP 2000, Beck 1999a).

*Biological Methods*

The bull thistle seedhead gall fly (*Urophora stylata*) has a limited distribution in Washington and provides only fair control (Coombs et al. 2002). Bull thistle populations observed on the Hanford Reach National Monument are too small and scattered to support species-specific biocontrol agents.

*Chemical Methods*

**Glyphosate** (1.5 lb. a.i./A), **clopyralid** (0.13-0.5 lb. a.i./A) , **2,4-D** (1.5-2.0 lb. a.i./A), clopyralid (0.2-0.3 lb. a.i./A) plus 2,4-D (1.0-1.5 lb. a.i./A), **dicamba** (0.5 – 1.0 lb. a.i./A), and 2,4-D (1.0 lb. a.i./A) plus dicamba (0.5 lb. a.i./A) are all effective when applied to rosettes in spring or following mowing. **Picloram** (0.13-0.5 lb. a.i./A) can also be applied to rosettes in spring, or in the fall (CNAP 2000, Beck 1999a). Dicamba should not be used in diverse natural areas, as it has a tendency to eliminate all broadleaved species (Carpenter and Murray 1998b).

**FIELD BINDWEED** ***CONVOLVULUS ARVENSIS***

Field bindweed is a prostrate perennial vine of the morning-glory family (Convolvulaceae). Because of its wide distribution, abundance and economic impact, this warm season Eurasian species is considered one of the world's ten worst weeds (Holm et al., 1980). Field bindweed's extensive root system can penetrate as deeply as 10 feet (3.0 m) into the soil (Whitson et al. 1996). Many roots perish at the end of the season, but enough persist through the winter to produce the next year's growth (Lyons 1998b). Shallow rhizomes help the plant spread along the surface, forming tangled mats (Lyons 1998b). Field bindweed also produces large numbers of seeds which can remain viable in the soil for decades (Whitson et al. 1996). Seedlings grow rapidly following germination.

Field bindweed invades cropland, abandoned fields, and moist locations such as riparian areas. Bindweed excludes native species through aggressive competition for soil moisture and other resources (Weaver & Riley 1982) reducing biodiversity and lowering wildlife habitat value.

Field bindweed is classified as a Class C noxious weed in Washington. Control measures are not required by state law, but are a local option (NWCB 2003a). No control measures are required for this species by local jurisdictions within the Hanford Reach National Monument area.

## Current Status and Treatment Priorities on the Monument

Field bindweed is a Priority 3 species on the Hanford Reach National Monument. Field bindweed is widespread on the Monument (Fig. 12), but is generally limited to old agricultural sites and other disturbed places. Three small infestations, all on the ALE Reserve, are designated for priority treatment (Table 11). Each of these sites, two on roadways, the third in an occasionally-flooded creekbed, represent points from which the infestations are likely to spread further along these corridors and from there, potentially, into natural areas. These occurrences are among the few records of field bindweed on ALE, and the only ones located along dispersal corridord. The infestations are very treatable, each infestation being less than 1.0 $m^2$ in size at present. These sites should be treated aggressively and persistently, with the aim of preventing reproduction and eliminating the infestations within 3 years. Dicamba (Banvel, Clarity) is recommended for aggressive treatment of these small infstations. because of the longevity of this species in the soil seed bank, pains should be taken to prevent or remove annual sed prodction, and these sites should be monitored for at least 10 years after apparent control has been achieved.

Table 11. Priority sites for treatment of field bindweed.

| Unit | Location | East (NAD 27) | North (NAD 27) |
|---|---|---|---|
| ALE | 1200 Ft. Rd. | 303281 | 5142690 |
| | Gate 120 Rd. | 292006 | 5159451 |
| | Cold Creek creekbed, No. of Gate 120 Rd. | 291593 | 5159401 |

Fig. 12. Occurrences of field bindweed (*Convolvulus arvensis*) mapped during the 2002–2003 invasive plant species inventory, Hanford Reach National Monument.

## Control

Field bindweed must be managed for several years to bring it under control. Alcock *et al.* (1974, cited in Lyons 1998b) suggest the following as general objectives in the control program for field bindweed: 1) reduce seed in soil; 2) prevent seedling growth, 3) deplete root system reserves, and 4) prevent spread. With diligence the roots can be removed leaving only the seedlings, however, even with intensive management field bindweed will persist as seed for several years. A minimum of three to five growing seasons are required in agricultural settings to eliminate all seedlings (Callihan *et al.,* 1990).

*Manual and Mechanical Methods*

Hand-pulling may help to control small infestations of field bindweed but must be done frequently through the growing season. Neither mowing nor burning provide effective control (Callihan *et al*., 1990). Repeated cultivation (to at least 15 cm depth) can help to control field bindweed, but must be repeated as often as weekly or bi-weekly to be effective when used alone (Lyons 1998b). . Tilling may be performed with hand tools in very small sites. Smothering plants with light impervious landscape fabric for several years may be effective in controlling small infestations where other methods cannot be applied successfully.

Manual or mechanical methods may enhance the performance of chemical treatments when used as part of an integrated control program.

*Biological Methods*

*Aceria malherbae* is a gall forming mite whose larvae and adults feed on buds and leaves of field bindweed. Its distribution in Washington is limited and its effectiveness in the Northwest is unknown (Coombs et al. 2002).

*Chemical Methods*

Herbicides should be applied to mature leaves during first bloom when the root carbohydrates are at their lowest (Lyons 1998b). Drought may decrease the effectiveness of herbicides (Wiese *et al.* 1996). Repeated use of the same or similar herbicides can result in the development of herbicide resistance (Lyons 1998b).

**Glyphosate** (Rodeo, Roundup, Accord) alone does not provide consistent control of field bindweed (Callihan et al., 1990). Some biotypes are resistant to glyphosate, and drought conditions lessen the effectiveness for all biotypes (Lyons 1998b).

Glyphosate at 3.0 – 3.75 lb. a.e./A (3.4 - 4.2kg a.e./A) applied at full bloom or early seed stage is effective in the Pacific Northwest, especially if the area is tilled 2-3 weeks after treatment (William et al. 2002). Repeated treatments, and application to fall regrowth may be necessary for complete control. The adjuvants MON0818 and Tween 20 at 0.5%w/v improve control (Sherrick et al. 1986).

William et al. (2002) also recommend using Landmaster BW (a mix of 2,4-D and glyphosate) at 0.378 lb. a.e./A (0.43 to 0.75 kg a.e./ha0 [54 oz. product/A] when bindweed runners are at least 25cm long. A 1% solution can be used for spot treatments. Tilling 2-3 weeks after treatments improves control.

**2,4-D** is a selective herbicide that will not damage most grasses and other monocots. Rates of 2.0 – 3.0 lb a.e./A (2.24 –3.4 kg/ha) are advised for treatment of field bindweed (William et al. 2002). 2,4-D may be more cost effective than dicamba in some cases (Lyons 1998b). Use of 2,4-D in combination with other herbicides and/or mechanical methods may increase the effectiveness of control (Lyons 1998b).

Applications of 2,4-D in amine form at 2-3 lb a.e./A (2.25-3.4kg a.e./ha) at bud growth stage or in early August reduces field bindweed 60-80% and helps prevent seedling establishment. Applications must be repeated annually or more often until the infestation is eradicated, or bindweed will recover (William *et al.,* 2002).

**Picloram** (Tordon) provides residual control for a number of years (Lyons 1998b, William et al. 2002). William et al. (2002) recommend 1.0 lb a.e./A (1.12 kg a.e./ha) picloram applied at early bud stage to full bloom.

**Dicamba** (Banvel, Clarity) can be more effective than 2,4-D and picloram against field bindweed, but it generally is more expensive and can persist in soil and damage other plant species (Callihan *et al.,* 1990). 1.0 – 2.0 lb a.e./ A (2.24 – 4.48 kg/ha) provides control (William et al. 2002). The best time for application is during the post-flowering stage. Dicamba is more effective under drier conditions than 2,4-D, while 2,4-D is more effective under wetter conditions (Lyons 1998b). Dicamba should not be used in diverse natural areas, as it has a tendency to eliminate all broadleaved species (Carpenter and Murray 1998b).

## RUSSIAN OLIVE *ELEAGNUS ANGUSTIFOLIA*

Russian olive is a small tree or large shrub (10-25 ft.) in the oleaster family (Eleagnaceae). Long-lived and fast-growing, this deep-rooted European native has been planted widely as an ornamental. The large fruits are readily dispersed by birds. Seeds germinate readily from fall through spring and may remain viable in the soil for up to three years (Shafroth et al. 1995, Howe and Knopf 1991).

Russian olive invades both disturbed and undisturbed moist pastures, irrigation overflows, wetlands, and riparian areas, often forming dense, monospecific stands (Whitson et al. 1996, Tu 2003). In natural areas it can reduce biodiversity by outcompeting and displacing native species and altering stand structure. Dominance by this species alters key ecosystem processes such as nutrient cycling, sediment deposition, and hydrology (Tu 2003). Although Russian olive woodlands are used by many bird and mammal species, species richness is typically reduced compared to communities dominated by native species (Knopf and Olson 1984).

Russian olive is not classified as a noxious weed in Washington state (NWCB 2003a).

### Current Status and Treatment Priorities on the Monument

Russian olive is a Priority 2 species on the Hanford Reach National Monument. Russian olive occurs in dense infestations around the WB10 Ponds as well as in other wasteway-associated riparian areas in the Wahluke Unit, as well as around Saddle Mountain Lake (Fig. 13). Russian olive has been recorded on 579 acres (234.3 ha) of Monument lands, but has been underreported around Saddle mountain Lake and elsewhere. Because of the large, dense acreages already ocupied by this species, the primary emphasis for management on the North Slope is to detect and control new infestations and isolated occurrences. Additional detailed surveys must be done before specfic sites can be designated for treatment. It is recommended such surveys be done during late summer or early fall, a time when many other weed inventory and management activities are at low ebb while the Russian olive trees remain easily recognizable.

Isolated seedlings of Russian olive may be hand pulled. Glyphosate (Roundup, Rodeo), or 2,4-D may be applied to foliage of seedlings or saplings when fully leafed out. Frill cut or cut stem methods are recommended for mature individuals (see below).

Russian olive has not been recorded on Monument lands south of the Columbia River. A high priority should be placed on early detection and aggressive control of infestations that may be discovered in these areas, particularly in any of the spring systems of the ALE Reserve.

### Control

*Manual and Mechanical Methods*

Small seedlings of Russian olive can be hand pulled when soil is moist. Cutting or mowing can provide control but must be repeated conscientiously and is very labor intensive. A single cutting, mowing, or burning alone stimulates regrowth from roots and can result in a denser infestation. Cutting, mowing, or burning may be effective elements of integrated control plans (Tu 2003).

*Biological Methods*

No effective biological control agents are currently available (Tu 2003).

*Chemical Methods*

Russian olive's deep root system confers some resistance to chemical herbicide treatment. Multiple herbicide applications over several years may be required to achieve control, regardless of the herbicide formulation used or the method of delivery (William et al. 2002). Cut stump methods have proven most effective in a number of cases, provided herbicide is applied to the cambium within a few minutes after it is exposed (Tu 2003, R. Leonard pers. comm.). Other methods of delivering herbicide to the cambium such as frill cuts or root injection are also effective (Tue 2003).

**2,4-D** LV ester at 2.0 lb. a.e./A applied as an aerial spray when leaves are fully developed may control Russian olive. **2,4-D + triclopyr** (Crossbow) in 1.5% spray solution, applied during active growth, when leaves are fully developed is also effective. The latter formulation may also be applied as dormant cut-stem and basal bark applications (Tu, in prep.).

A formulation of 2,4-D and picloram (Pathway) applied to cut stumps at full concentration is reported to kill Russian olive without resprouts (Tu 2003).

**Triclopyr** (Garlon 4, Remedy) is effective as a basal bark application for stems with smooth bark. The product is applied to the bottom 60 cm or 2 feet of each stem, and must wet the entire circumference of the stem. Treatment of larger individuals with furrowed bark must extend farther up the stem to areas of smooth bark, and is generally less effective. Treatment should be applied to actively growing plants (Parker and Williamson 1996, cited in Tu 2003). A 5% solutiuon of Garlon 4 ester may also be applied to cut stems or in frill cuts of larger trees with furrowed bark, or via root injection (Tu 2003, R. Leonard pers. comm.).

**Glyphosate** (Roundup, Rodeo) applied undiluted to frill cuts in bark at 2 cc (ml) of product / inch of trunk diameter, or applied to foliage as a 5.0% solution when trees are fully leafed out (William et al. 2002).

**Imazapyr** (Arsenal, Contain) applied undiluted to frill cuts in bark at 2 cc (ml) of product / inch of trunk diameter, or applied to foliage as a 0.75% solution of 2.0 lb. a.i./gal. product when trees are fully leafed out (William et al. 2002).

*Integrated Treatments*

Parker and Williamson (1996, cited in Tu 2003) report that burning is an effective pre-treatment of Russian olive stands prior to basal bark applications of herbicides to regrowth.

Fig. 13. Occurrences of Russian olive (*Eleagnus angustifolia*) mapped during the 2002–2003 invasive plant species inventory, Hanford Reach National Monument.

**BABY'S BREATH** ***GYPSOPHILA PANICULATA***

Baby's breath is a tall (up to 0.75m in height), branching Eurasian perennial forb in the pink (Caryophyllaceae) family. Mature plants have a thick, deep and persistent root system extending up to 4m in depth. Flowers, which do not appear until the third year of growth, produce abundant seeds. A single plant can produce over 13,000 seeds/ year. Seeds exhibit little dormancy and are short-lived in the seed bank. Most seeds fall near the parent plant, but seed-bearing plants can break off at the base and tumble across the landscape as well (Darwent 1975, NPWRC 2003, CDFA 2003a).

Baby's breath invades roadsides, waste areas, and disturbed grasslands, particularly where soils are sandy or coarse. It is capable of forming dense stands that crowd out native plant species and reduce wildlife forage (Darwent 1975, NPWRC 2003).

Baby's breath is classified as a Class C noxious weed in Washington. Control measures are not required by state law, but are a local option (NWCB 2003a). No control measures are required for this species by local jurisdictions within the Hanford Reach National Monument area.

## Current Status and Treatment Priorities on the Monument

Due to it's extremely limited distribution, Baby's breath is a Priority 1 species on the Hanford Reach National Monument. At present the only documented occurrence of this species on the Monument is that of a single individual on the ALE Reserve (Table 12, Fig. 14). The individual was removed manually in 2003 (J. Meisel pers. comm.). This site must be resurveyed 1-2 times / year for at least 3 years to ensure that treatment was fully effective. If necessary manual control should be repeated annually during spring (May) before flowers are produced. If manual methods are ineffective the cut stem method described below should be applied.

Dense infestations in a few locations within the region call for continued vigilance for this species along roadways and other suitable habitats.

## Control

*Manual and Mechanical Methods*

Severing the crown of the plant by hand cutting or cultivation to a minimum depth of 6-12" (deeper if possible) will reportedly kill baby's breath (CDFA 2003a, D. Wilderman pers. comm.). To be most effective, manual control must be performed before seeds are produced. Roots are hardy and robust, however, and plants will frequently regenerate following this treatment (R.Roos pers. comm.).

The plants vigor is little reduced by mowing or clipping or by light or infrequent grazing (NWCB 2003b).

*Biological Methods*

No effective biological control agents are currently available.

*Chemical Methods*

Treatment with **glyphosate** will stress plants and reduce or eliminate baby's breath's annual seed production, but is unlikely to kill the plant (CDFA 2003a). Baby's breath is susceptible to **picloram** at 1.12 kg a.i./ha or more and to **dicamba** at 2.24 kg a.i./ha or more (NWCB 2003b). A cut stem treatment using these herbicides may be effective on isolated individuals or small stands (R. Leonard pers. comm.).

Baby's breath is also sensitive to **Imazapyr** (Arsenal, Contain) and **metsulfuron** (Escort) applied during the full bloom stage (J. Rodriguez pers. comm.)

Table 12. Priority sites for treatment of baby's breath.

| Unit | Location | East (NAD 27) | North (NAD 27) |
|---|---|---|---|
| ALE | Gate 111 Rd. | 304358 | 5143288 |

Fig. 14. Occurrences of baby's breath (*Gypsophila paniculata*) mapped during the 2002–2003 invasive plant species inventory, Hanford Reach National Monument.

## PERENNIAL PEPPERWEED *LEPIDIUM LATIFOLIUM*

Perennial pepperweed is a tall, Eurasian forb in the mustard family (Brassicaceae). This deep-rooted (to 3 m) perennial produces seeds prolifically, although seeds remain viable only for a short time (Miller et al., 1986). Seeds may be spread rapidly along streams and irrigation channels. Perennial pepperweed also spreads via an extensive creeping root system and can rapidly form dense stands that crowd out native vegetation (NWCB 2003b).

Perennial pepperweed invades a wide range of habitats including irrigation systems, wetlands and riparian areas, and rangelands where the water table is within a few meters of the surface. Perennial pepperweed appears to thrive in areas where soil moisture is higher than normal; however, recent evidence suggests it is expanding slowly into even the driest habitats (Young and Clements 2002). Perennial pepperweed crowds out native plant species, reduces wildlife forage value, and degrades bird nesting habitat (Renz 2000, NWCB 2003b). Perennial pepperweed plants extract salt ions from deep soils and deposit them near the surface, altering plant habitat, community composition, and diversity (Blank and Young 1997). The species also produces dense, persistent litter which can smother competing plants (Renz 2000).

Perennial pepperweed is classified as a Class B Non-Designate noxious weed in Regions 6 and 9. State law calls for containment, gradual reduction, and prevention of further spread of Class B Non-Designate noxious weeds (NWCB 2003a).

### Current Status and Treatment Priorities on the Monument

Perennial pepperweed is a Priority 3 species on the Hanford Reach National Monument. At present is documented on more than 300 acres (> 120 ha) on the Monument (Fig. 15). The species is common in upper Cold Creek on the ALE Reserve and in the McGee Ranch area. Large areas of suitable habitat along irrigation wasteways and impoundments on the North Slope were not surveyed, suggesting that this species may be greatly underreported.

No priority sites are designated for treatment. Program emphasis is on detection and treatment of new occurrences, especially along spring streams on the ALE Reserve, where perennial pepperweed has not yet been detected.

### Control

Perennial pepperweed can be very dificult to control. A carefully planned, integrated approach that combines multiple strategies is recommended (Renz 2000). Because perennial pepperweed is so resistant to control measures, prevention of new infestations, containment of existing infestations (including control of seed production) along with early detection and eradication of newly established infestations is extremely important (NWCB 2003b).

*Mechanical Methods*

Hand pulling is a labor-intensive but effective way to remove small infestations so long as the treatment is repeated conscientiously until the infestation is eradicated. Perennial pepperweed can regenerate from tiny fragments of its root system, so as much of the root as possible must be removed at each pull (Renz 2000).

Mowing or cutting alone is not an effective control strategy and can actually lead to increased biomass production in perennial pepperweed However, an early season mowing prior to herbicide treatment may dramatically increase the contact of herbicides with lower leaves, enhancing herbicide transport into below ground rhizomes (Renz 2000).

Disking fragments perennial roots and may increase the density of infestations. Disking may contribute to management when followed by herbicide treatment, however (Renz 2000).

Fire does not harm the roots of perennial pepperweed and may stimulate an increase in production in subsequent years (Renz 2000).

*Biological Methods*

No biological control agents have been introduced to control perennial pepperweed. Grazing by sheep reduced flower production by 98% in one study (Kilbride et al. 1997).

*Chemical Methods*

The best time to apply systemic herbicides to perennial pepperweed is at the flowerbud to early flowering stage (Young et al., 1998). Due to the dormancy of perennial roots, monitoring and spot spraying are necessary over several years to eliminate this weed.

**Triclopyr** (Garlon 3A, Garlon 4A) ) is a selective herbicide active on broadleaf plants. Application of commercial concentrations (Garlon 3A, 3 lbs. a.e./gal; Garlon 4A, 4 lbs. a.e./gal) at 2.25 lbs. a.e./A (2.52 kg a.e./ha = 0.75 gal Garlon 3A/A) with surfactant (non-ionic at 0.25% or silicone based surfactants at 0.1%) removes 13-70% of above ground growth without harming grass species, but provides poor long-term (i.e. longer than 1 year) control. Triclopyr may be registered for use near water (Renz 2000).

**2,4-D** applied at 4.0 lbs. a.e./A may provide short-term control (William 2002). Multiple treatments will likely be required (Renz 2000).

**Glyphosate** (Roundup Pro, Rodeo) is ineffective in controlling perennial pepperweed without integrating other control methods. Formulations of Glyphosate combined with 2,4-D (Landmaster; 0.9 lbs. a.e. glyphosate/gal and 1.5 lbs. a.e. 2,4-D/gal) (Campaign; 0.9 lbs. a.e. glyphosate/gal and 1.5 lbs. a.e. 2,4-D/gal) offer up to 72% control one year after applications (Renz 2000).

**Imazapyr** (Arsenal) applied at 4-6 oz a.e./A (0.28-0.42 kg a.e./ha) [16-24 oz. product/A with 0.1% silicone surfactant] gave 95-98% biomass reduction and 88-89% reduction in stem density 1 year after applications. However, treatment areas have little to no vegetation reestablishing 1 year after applications (Renz 2000).

**Chlorsulfuron** (Telar) at 1.5 oz. a.i./A (0.052 kg a.i./ha) [2 oz. product/A with 0.1% silicone based or 0.25% nonionic surfactant] controls perennial pepperweed (William et al. 2002, Young et al., 1998). Chlorsulfuron at lower rates, 0.75 oz/A (0.026 kg /ha)[1.0 oz. product/A with 0.25% nonionic surfactant] has been effective in controlling perennial pepperweed in some areas but inconsistent control has been observed in other studies (Renz 2000). Kilbride et al. (1997) used higher concentrations of Telar (3.0 oz. product/A) to achieve 97% control over 2 years.

**Metsulfuron** (Escort) at 0.6 oz. a.i./A (0.5-1.0 oz. product/A) [42 g a.i./ha]with a 0.25% nonionic surfactant] can provide good control one year after applications (Reid et al., 1999, William et al. 2002). One researcher found enhanced control (97%) with a fall application (Beck 1999b cited in Renz 2000).

*Integrated Treatments*

Integrated control strategies consisting of mowing and/or disking followed by herbicide applications to resprouting shoots have exhibited better control than chemical treatments alone (Renz 2000).

Mowing plants at the flowerbud stage, followed by an herbicide application to resprouting stems when they return to the flowerbud stage, increased the effectiveness of nearly all herbicides 1 year after treatment and reduced the quantities of herbicide required for equivalent levels of control (Renz & DiTomaso, 1998 a & b). Following mowing, herbicide applications are delayed to allow for shoots to resprout and return to the flowerbud stage (Renz 2000).

*(Continued)*

Fig. 15. Occurrences of perennial pepperweed (*Lepidium latifolium*) mapped during the 2002–2003 invasive plant species inventory, Hanford Reach National Monument.

**Glyphosate** (3.0 lbs. a.e./A [3.3 kg a.e./ ha]; Roundup 1 gal. product/A), which is registered for use in/near water (Rodeo Pro 0.75 gal. product/A) and has no residual soil activity, showed a high level of control in some areas following mowing and allowed for increased plant diversity in treated areas compared to other treatments (Renz 2000).

**Chlorsulfuron** at 0.75 oz. a.i./A (0.026 kg /ha) [Telar at 1 oz. product/A with 0.1% silicone based or 0.25% nonionic surfactant] provided near complete control after one year. This was one half the rate needed for this level of control in areas not mowed.

**Imazapyr** at 1.5 –6.0 oz. a.i./A (0.053-0.105 kg a.i./ha) [Arsenal (2 lbs a.e./gal; 6-24 oz. product/ A] also had a high level of control (Renz 2000). Revegetation of treated sites is suppressed as a result of residual herbicide activity in the soil for both of these treatments.

In addition to breaking up rhizomes and depleting the energy available to any individual plant, disking appears to stimulate germination of seeds from the seedbank, exposing them to treatment effects (Renz 2000). A combination of fall disking followed by spring mowing at the flowerbud stage and by applications of herbicides to resprouting stems at the flowerbud stage following the mow greatly enhanced control of perennial pepperweed over mowing plus herbicides and herbicides alone. Excellent one year control with **glyphosate** may be obtained following application at the rates specified above. **2,4-D, triclopyr**, and **imazapyr** may also be applied following mechanical treatments at the rates specified above (Renz 2000).

**DALMATIAN TOADFLAX** ***LINARIA DALMATICA* SSP. *DALMATICA***

Dalmatian toadflax is a tall (0.8 to 1.5 m), short-lived, cool season perennial Eurasian forb in the figwort family (Scrophulariaceae). A mature plant can produce up to 500,00 seeds, which are primarily dispersed by wind and may remain viable for up to ten years in the soil (Robocker 1970). Seeds are also dispersed by water and by automobile traffic (M. Stairet pers. comm.). Established infestations spread aggressively via horizontal or creeping rootstocks as well as by seed.

Dalmatian toadflax is an aggressive invader of rangelands, agricultural areas, roadsides, and waste areas, especially where soils are sandy or gravelly (Lajeunesse 1999).

Mature plants are strongly competitive and can displace native plant communities, reduce wildlife forage value, increase soil erosion, and cause economic losses to farmers (Lajeunesse 1999) .

Dalmatian toadflax is classified as a Class B Designate noxious weed throughout Region 9, and in Adams County portions of Region 6. State law requires prevention of seed production and spread of Class B Designate weeds. Dalmatian toadflax is classified as a Class B Non-Designate noxious weed elsewhere in Region 6. State law calls for containment, gradual reduction, and prevention of further spread of Class B Non-Designate noxious weeds (NWCB 2003a).

## Current Status and Treatment Priorities on the Monument

Dalmatian toadflax is a Priority 1 species on the Hanford Reach National Monument. At present dalmatian toadflax is known from only one location on the Monument, as well as from a neighboring island under the jurisdiction of USFWS (Table 13, Fig. 16). Each occurrence consists of only one to a few plants. It is critical to eliminate seed production and to eradicate these incipient infestations before this dangerous weed can spread. Despite the species' resistance to treatment, eradication of these small infestations is very achievable within a few years using either the hand-pulling or cut stem herbicide treatments described below, alone or in combination.

Table 13. Priority sites for treatment of dalmatian toadflax.

| Unit | Location | East (NAD 27) | North (NAD 27) |
|---|---|---|---|
| Wahluke | White Bluffs Rd. | 314782 | 5176895 |
| Columbia River Islands (USFWS) | Johnson Island | 325732 | 5140053 |

Fig. 16. Occurrences of dalmatian toadflax (*Linaria dalmatica*) mapped during the 2002–2003 invasive plant species inventory, Hanford Reach National Monument.

## Control

*Manual and Mechanical Methods*

A persistent, long-term hand-pulling effort may control small infestations of dalmatian toadflax if annual seed production is eliminated (Lajeunesse 1999, CNAP 2000). Pullers should try to follow lateral roots to their ends to remove the most root possible. Pulling may be easier in spring when soils are moist, or in sandy soils. Pulling annually for 5-6 years is often necessary to achieve control (Lajeunesse 1999).

Intensive cultivation for two or more years can effectively control Dalmatian toadflax. Eight - ten cultivations at 7-10 day intervals during the first year , followed by 4 - 5 cultivations in the second year is recommended (Morishita 1991). Dalmatian toadflax seedlings do not compete well against established vegetation; control efforts should include attempting to establish and manage desirable species that will compete with toadflax throughout the year (Lajeunesse 1999).

*Biological Control*

*Calophasia lunula,* a defoliating moth, is well-established in Washington and reportedly provides good control. A stem-boring weevil, *Mecinus janthinus*, has also been released but is limited in its distribution in Washington (NWCB 2003b, Coombs et al. 2002).

*Chemical Methods*

The waxy cuticle on leaves of mature plants makes dalmatian toadflax resistant to chemical treatments. Herbicides must be applied to plants early in spring before the cuticle matures for greatest effectiveness; applications during and after flowering have no effect (D. Wilderman pers. comm.).

**Glyphosate** (Roundup) was applied via a cut-stem method by TNC in Moses Coulee in 2002 with good results (R. Leonard pers. comm.). Stems were clipped to 3” above the ground and treated with a 10% solution of Roundup. Small spray bottles, or sponge-type paint brushes may be used to apply the herbicide.

**Picloram** (Tordon) at 1.0 lb. a.e./A applied as a spot treatment in spring before flowering, or in the fall, is effective on small infestations of toadflax and will not damage associated perennial grasses (William et al. 2002). Picloram (Tordon 22K) + 2,4-D may be applied at 0.5 lb. a.e./A picloram + 1.5 lb. a.e./A 2,4-D as a broadcast treatment (William et al. 2002).

**Clopyralid** + 2,4-D (Curtail ) at 2.5 oz./gal. has been used with some success against dalmatian toadflax by the Washington Deparent of Natural Resources on their Natural Area Preserve system in Eastern Washington. A surfactant is necessary to help the herbicide penetrate the leaf’s waxy cuticle (D. Wilderman pers. comm.). Curtail will damage most perennial broad-leaved plants and so should be applied carefully to minimize the damage to non-target plants.

**Dicamba** (Banvel, Clarity) may be applied at 4.0 to 6.0 lb.a.e./A prior to the bloom stage. Repeated applications of dicamba may be necessary to achieve complete control (William et al. 2002). Dicamba should not be used in diverse natural areas, as it has a tendency to eliminate all broadleaved species (Carpenter and Murray 1998b).

**PURPLE LOOSESTRIFE** ***LYTHRUM SALICARIA***

Purple loosestrife is a perennial emergent aquatic forb in the loosestrife family (Lythraceae). Mature plants possess a thick, woody taproot and spreading lateral roots.

Purple loosestrife, an obligate wetland species, invades both freshwater and brackish wetlands and riverbanks, especially where distrubed. Purple loosestrife outcompetes native vegetation to form long-lived, dense, monotypic stands that crowd out native plants and provide unsuitable habitat for native wildlife. Waterfowl, mammals, and birds vacate wetland habitat when they lose their food sources, nesting material, and ground cover due to native vegetation loss and replacement. Purple loosestrife impacts agricultural communities where it clogs irrigation systems and invades wet pastures (NWCB 2003b, Bender 1987).

Expansion in a wetland can be extensive and sudden due to the abundance of seeds produced and the rapid growth of seedlings. High seed viability and prolific seed production can build up a seed bank of massive proportions. A mature purple loosestrife plant can produce more than 2 million tiny seeds which remain viable for several years. Dispersal of seeds is primarily by water (which can also spread newly germinated seedlings) and by wind, but waterfowl and other vectors contribute to the spread of this species. Purple loosestrife also has the ability to spread vegetatively by resprouting from cut stems and regenerating from fragments of rootstock (NWCB 2003b, Bender 1987).

Purple loosestrife is classified as a Class B Designate noxious weed in the following portions of the Hanford Reach National Monument: most of region 6 including portions of Grant County included in the Monument; Franklin County portions of region 9, but not in Benton County. State law requires prevention of seed production and spread of Class B Designate weeds. Purple loosestrife is classified as a Class B Non-Designate noxious weed in all other jurisdictions that include the Monument. State law calls for containment, gradual reduction, and prevention of further spread of Class B Non-Designate noxious weeds (NWCB 2003a).

## Current Status and Treatment Priorities on the Monument

Purple loosestrife is a Priority 3 species on the Hanford Reach National Monument. Purple loosestrife's primary habitat within the Monument is the Columbia River shoreline, where it is widespread. Large areas of potential habitat occur along irrigation wasteways and impoundments on the North Slope as well. These areas were not mapped in detail; consequently, purple loosestrife is substantially underreported by this inventory.

Several small, isolated occurrences of purple loosestrife are recommended for treatment should resources permit (Table 14, Fig. 17). Purple loosestrife has not been recorded in any of the spring systems of the ALE Reserve thus far, and a high priority should be placed on early detection and aggressive control of infestations that may be discovered in these systems.

The status and effectiveness of biological control agents released on the Monument in 2000 should be assessed (see below). Spot or wick applications of glyphosate (Rodeo) are recommended for small infestations.

Table 14. Priority sites for treatment of purple loosestrife.

| Unit | Location | East (NAD 27) | North (NAD 27) |
|---|---|---|---|
| Saddle Mt. | Borrow pit east of Vernita Bridge | 290919 | 5169256 |
| | WB10 Wasteway | 316275 | 5171362 |

Fig. 17. Occurrences of purple loosestrife (*Lythrum salicaria*) mapped during the 2002–2003 invasive plant species inventory, Hanford Reach National Monument.

## Control

*Mechanical Methods*

Hand-removal is recommended for small populations and isolated stems. Ideally, the plants should be pulled out before they have set seed. The entire rootstock must be removed since regeneration from root fragments is possible. Minimization of disturbance to the soil and native vegetative cover is highly desireable. Uprooted plants and broken stems must be removed from the area since the broken stems can resprout (Bender 1987).

Shoots and adventitious roots will develop following cutting alone. Cutting as part of an integrated control program may enhance the effectiveness of herbicide treatments. Cutting late in the season reduces shoot production more than mid summer cutting (NWCB 2003b).

*Biological Methods*

Biological control agents provide hope for success in controlling Purple loosestrife. *Galerucella calmariensis* and *G. pusilla* are both leaf-feeding chrysomelids which defoliate plants and attack terminal buds, drastically reducing seed production. The mortality rate of seedlings infested with these biocontrols is high (NWCB 2003b). Both beetles are widely established in Washington and are available for mass collections (Coombs et al. 2002). *G. calmariensis* was released on the Hanford Reach National Monument at locations along the north shore of the Columbia River during July, 2000, 2002, and 2003, including locations near the Vernita Bridge, near the White Bluffs boat launch, and at Savage Island (H. Newsome pers. comm.).

Other potential biological controls include *Hylobius transversovittatus*, a root-mining weevil that also eats leaves. *H. transversovittatus* larvae deplete plant carbohydrate reserves by severing xylem and phloem in the root, reducing plant size and reproductive capacity. *Nanophyes marmoratus*, a seed eating beetle, is another biocontrol option (NWCB 2003b). The efficacy of control offered by either of these two species is limited, however, and neither is widely established nor readily available in Washington (Coombs et al. 2002).

*Chemical Methods*

**Glyphosate** (Roundup, Rodeo) provides good control when spot-applied to foliage as a 1.0 – 1.5% solution to actively growing plants from flower initiation through peak bloom. Seedlings may be effectively treated early in the season after a fall application to mature plants. Rodeo should be applied with a 0.5% v/v nonionic surfactant. Thoroughly wet foliage but avoid runoff (Benefield 1999, William et al. 2002). Another method of applying glyphosate to purple loosestrife is to cut off all stems at about 6 inches and then paint or drip onto the cut surface a 20-30% solution (Bender 1987).

**Triclopyr** (Garlon 4 or Garlon 3A) is effective at 1.5 to 2% concentration for spot applications when plant is in the mid- to full-bloom stage, or on seedlings in early spring (William et al. 2002).

**Metsulfuron** (Escort) is also effective when applied at 0.6 oz a.i./A (1 oz product/A) to actively growing plants. Using a nonionic or silicone surfactant increases effectiveness (William et al. 2002).

## EURASIAN WATERMILFOIL *MYRIOPHYLLUM SPICATUM*

Eurasian watermilfoil is a submersed perennial aquatic forb in the water-milfoil family (Haloragaceae). The species grows in a wide range of water depths and is tolerant of a wide range of environmental conditions (NWCB 2003b).

Eurasian watermilfoil may spread rapidly. Milfoil produces a large number of highly germinable and long-lived seeds. However, vegetative spread is the major method of reproduction. During the growing season, the plant undergoes autofragmentation. Fragments readily take root in new substrates and may even develop roots before separating from the parent plants. Fragments are also produced by wind and wave action and boating activities (NWCB 2003b, Bossard 2000).

Eurasian watermilfoil colonizes freshwater lakes and ponds, and waterways with slow moving water, especially where nutrients are plentiful. Eurasian watermilfoil adversely impacts aquatic ecosystems by forming dense floating canopies that shade out native vegetation. Monospecific stands of Eurasian watermilfoil provide poor habitat for waterfowl, fish, and other wildlife. Eurasian watermilfoil infestations alter ecosystem production, biomass accumulation, decomposition, and nutrient regimes. Dense mats alter water quality by raising pH, decreasing dissolved oxygen, and increasing water temperatures (NWCB 2003b, Bossard 2000).

Eurasian watermilfoil also impacts human activities. Infestations clog intake pipes of hydroelectric dams and irrigation systems and milfoil mats interfere with recreational activities. Stagnant water created by Eurasian watermilfoil mats provides good breeding grounds for mosquitoes (NWCB 2003b).

Eurasian watermilfoil is classified as a Class B Designate noxious weed throughout Region 9, and in Adams County. State law requires prevention of seed production and spread of Class B Designate weeds. Eurasian watermilfoil is classified as a Class B Non-Designate noxious weed in Grant County. State law calls for containment, gradual reduction, and prevention of further spread of Class B Non-Designate noxious weeds (NWCB 2003a).

### Current Status and Treatment Priorities on the Monument

Eurasian watermilfoil is a Priority 3 species on the Hanford Reach National Monument. At present, Eurasian watermilfoil has been recorded only from sites along the Columbia River (Fig. 18). Potential habitat for this species occurs in wasteway impoundments of the North Slope which were not surveyed extensively. Thus the species may be underreported here.

No priority sites are designated for treatment of Eurasian watermilfoil. Available treatments are not likely to be effective on populations along the main stem of the Columbia River. The development of biological controls may provide an effective means of treatment for Eurasian watermilfoil in these habitats in the future (see below).

Fig. 18. Occurrences of Eurasian watermilfoil (*Myriophyllum spicatum*) mapped during the 2002–2003 invasive plant species inventory, Hanford Reach National Monument.

## Control

*Mechanical and Cultural Methods*

Where practical, water level drawdowns can be effective at reducing Eurasian watermilfoil. A drawdown of about 2 meters is effective in reducing excessive populations. Short-term dewatering for 2-3 days during a period of freezing temperatures has been effective, but multiple exposures may improve control. The success of a drawdown on Eurasian watermilfoil is dependent on several factors such as degree of desiccation, the composition of substrate (sand vs. clay), air temperature (the exposed sediments need to freeze down to 8-12 inches), and presence of snow (NWCB 2003b).

Cutting and harvesting provide little control unless performed multiple times during the growing season. Because this species spreads readily through fragmentation, mechanical controls such as cutting, harvesting, and tilling should be used only when the infestation has occupied all available niches. Using mechanical controls while the plant is still invading, will tend to enhance its rate of spread. Washington law requires that cut plants be removed from the water (NWCB 2003b).

*Biological Methods*

The North American weevil, *Euhyrchiopsis lecontei* has been found associated with declining populations of Eurasian watermilfoil in northeastern North America. *Euhrychiopsis lecontei* has been found in Washington state feeding on both Eurasian watermilfoil and northern milfoil (*Myriophyllum sibericum*) plants. Studies have shown that this native weevil appears to be a milfoil specialist and will not feed on other macrophyte species. It can be easily raised in the laboratory and laboratory-reared weevils could be used to augment natural populations, as is being tried in Vermont. Weevil augmentation studies for Eurasian watermilfoil management have been proposed for Washington State (Creed and Sheldon 1993, 1994).

*Chemical Methods*

Excellent control of Eurasian watermilfoil is reported with 2,4-D, diquat, diquat + complexed copper, endothall dipotassium salt, and endothall + complexed copper. Good control is also reported with use of fluridone. (Westerdahl and Getsinger 1988). In Washington, fluridone (Sonar) has been successfully used to eradicate Eurasian watermilfoil in Long Lake, Thurston County and in other western Washington lakes, although some eradication attempts with fluridone have had mixed success in Washington. To be effective, fluridone concentrations of 10-15 ppb must be maintained in the water column for 10 to 12 weeks. Follow-up diver surveillance and hand-pulling of surviving plants is essential to the success of this technique (NWCB 2003b).

**Triclopyr** holds promise for Eurasian watermilfoil control. Triclopyr requires a short contact time (18 to 48 hours) and will selectively control Eurasian watermilfoil while leaving many native aquatic plants relatively unaffected. Triclopyr is not currently registered for use in aquatic systems in Washington (NWCB 2003b).

Endothall, fluridone, and copper are permitted for aquatic use in Washington waters, but copper is generally permitted only as an algicide (NWCB 2003b).

## SCOTCH THISTLE *ONOPORDUM ACANTHIUM*

Scotch thistle is a robust, taprooted Eurasian biennial (or sometimes annual) in the composite (Asteraceae) family. The species often grows 8 feet or more in height and 6 feet in width. Healthy plants may produce 5,000 up to as many as 50,000 seeds which may remain viable in soil for 5 years or more (Beck 1999a, Joley et al. 1998). Seeds are dispersed by wind, water, wildlife, livestock, and agricultural activities (Beck 1999a).

Scotch thistle infests waste places, roadsides, riparian areas, pastures and arid rangelands dominated by cheatgrass (Beck 1999a, Whitson et al. 1996). Scotch thistle is found in most Washington counties east of the Cascades. Scotch thistle infestations crowd out native species, reduce forage, and restrict movement of wildlife, and result in significant economic losses for farmers and ranchers (NWCB 2003b).

Scotch thistle is classified as a Class B Designate noxious weed throughout regions 6 and 9 . State law requires prevention of seed production and spread of Class B Designate weeds (NWCB 2003a).

### Current Status and Treatment Priorities on the Monument

Scotch thistle is a Priority 1 species on the Hanford Reach National Monument. At present Scotch thistle is recorded as only one to a few plants at two locations in the lower Cold Creek Valley (Table 15, Fig. 19). Eradication of these small infestations of biennial plants is very achievable within one to a few years (depending on the species presence in the seed bank) using manual methods described below. Monitoring of sites will be necessary for at least 5 years after plants are eliminated, to ensure that seedbanks are exhausted.

### Control

*Manual and Mechanical Methods*

Manual and mechanical methods are effective alone or in combination with herbicide treatments (CNAP 2000). Small areas can be eradicated by digging or hand pulling. Manual removal must take place prior to flowering and seed production and plant roots must be severed below the soil surface (Beck 1999a).

Mowing has limited effectiveness for controlling Scotch thistle. It can prevent seed production if performed within 2 days following full bloom of the terminal cluster, but if performed earlier or later plants will recover or detached infloresences will still produce seed (Beck 1999a). Only a small percentage of potential seed production needs to become viable to perpetuate Scotch thistle stocking levels.

*Biological Methods*

No biological controls are currently available in the United States (NWCB 2003b). Goats will graze Scotch thistle, reducing plant numbers and preventing seed production (Sindel 1991).

*Chemical Methods*

Herbicides are most effective when applied in the spring before Scotch thistle bolts, or in the fall to new rosettes (William et al. 2002, Beck 1999a). The following herbicides may be used, among others:

**Clopyralid** (Stinger, Transline) at 0.1 – 0.375 lb. a.e./A (0.25 – 1.0 pt. product/A); Clopyralid + 2,4-D amine (Curtail) at 1 – 5 qts. product/A; **picloram** (Tordon) at 0.25lb.a.e./A; **2,4-D** applied at 1.5 – 2.0 lb. a.e./A. **Dicamba** (Banvel, Clarity) at 0.5 – 1.0 lb. a.e./A and **Metsulfuron** (Escort) at 0.6 oz. a.i./A (1.0 oz. product/A) with an anionic or silicone surfactant, have also been effective (William et al. 2002).

Table 15. Priority sites for treatment of Scotch thistle.

| Unit | Location | East (NAD 27) | North (NAD 27) |
|---|---|---|---|
| ALE | Lower Cold Creek | 311800 | 5140691 |
| | Gate 109 quarry | 311483 | 5141855 |

Fig. 19. Occurrences of Scotch thistle (*Onopordum acanthium*) mapped during the 2002–2003 invasive plant species inventory, Hanford Reach National Monument.

**COMMON REED** ***PHRAGMITES AUSTRALIS***

Common reed is a large perennial rhizomatous grass of worldwide distribution. These emergent wetland plants may produce great quantities of seed. New sites are colonized by waterborne seed or rhizome fragments. The thick rhizomes form dense mats and can reach almost 2 meters below ground. Roots penetrate even more deeply, allowing the plant access to receding water tables (Haslam 1970).

Common reed is an aggressive invader of freshwater and brackish wetlands. Rapid clonal growth and thick litter accumulations crowd out native species and produce dense, monotypic stands, reducing biodiversity, wildlife forage, and overall habitat value. Disturbance and increased nutrients from agricultural runoff and other sources may contribute to common reed dominance, but the species is capable of invading pristine wetlands as well (Marks et al. 1993).

While the species is native to North America, one or more new, more invasive genotypes appear to have been introduced from the Old World (Hauber et al. 1991). Native populations may be difficult to distinguish from invasive populations, but rapidly spreading stands, especially where they occur on disturbed sites, generally indicate the invasive genotype. Stands of common reed on the Hanford Reach National Monument appear to fit this profile. The Washington State Department of Agriculture is currently engaged in mapping and genetic testing of common reed populations within the state, and genetic tests of Hanford genotypes may take place in the near future (G. Haubrich pers. comm.).

The non-native genotype of common reed is classified as a Class C noxious weed in Washington. Under Washington's weed law, control measures are a local option for Class C noxious weeds(NWCB 2003a). No control measures are required for this species by local jurisdictions within the Hanford Reach National monument area.

## Current Status and Treatment Priorities on the Monument

Common reed is a Priority 3 species on the Hanford Reach National Monument. Common reed has been recorded on 89.3 acres (36.1 ha) of the Monument. The primary habitat for common reed on the Monument appears to be impoundments associated with the Saddle Mountain Wasteway (Fig. 20). Similar habitats occur in the WB 10 ponds. These areas were not mapped in detail; consequently, the extent of infestations of common reed may be substantially underreported by this inventory.

Common reed has not been recorded in any of the spring systems of the ALE Reserve thus far, and a high priority should be placed on early detection and aggressive control of infestations that may be discovered in these systems.

Three current sites are recommended for treatment of common reed, should resources permit (Table 16). The two borrow pit sites on the Saddle Mountain Unit are small, isolated clones in seasonally dry areas that should be relatively amenable to treatment. The site along the rivershore may be difficult to treat due both to its large size and to its proximity to the river. However, this site represents the only documented site along the Columbia River shoreline within the Monument. The annual mowing or cut-stem herbicide methods described below should be effective treatments for these infestations.

Table 16. Priority Sites for treatment of common reed.

| Unit | Location | East (NAD 27) | North (NAD 27) |
|---|---|---|---|
| Vernita Bridge Recreation Area | Borrow pit West of Vernita Bridge | 290674 | 5169210 |
| Saddle Mt. | Borrow pit East of Vernita Bridge | 290918 | 5169257 |
| River Corridor | North shore, Columbia River. Adjacent to Saddle Mt. NWR | 302100 | 5171441 |

## Control

*Manual and Mechanical Methods*

Hand pulling can be effective in controlling common reed, especially in sandy soils, but is very labor intensive and is practical only for small infestations (Marks et al. 1993).

Mowing has been used successfully to control common reed. Cutting aerial shoots at the base near the end of the growing season and before the onset of dormancy reduces the plant's vigor. A gas-powered trimmer fitted with a circular blade is most effective, or hand tools may be used. This regime may eliminate a colony if carried out annually for several years When applied at the perimeter of large stands cutting may be useful in preventing spread (Marks et al. 1993). Cut shoots should be removed from moist areas to prevent their sprouting and forming stolons (Osterbrock 1984). Cutting may also be used in combination with herbicide treatments (see below).

Fire does little to reduce common reed's vigor under most conditions, and may even promote increases in density and production (Marks et al. 1993).

*Biological Methods*

No effective biological control agents are currently available.

*Chemical Methods*

**Glyphosate** (Rodeo) is the herbicide most commonly used for control of common reed. Application rates may vary; effective control of *Phragmites* in a Delaware marsh was achieved with 4 pints/acre of concentrate. Application of Rodeo must take place after most plants are in the tasseling stage when the plant is supplying nutrients to the rhizome. In dense stands, smaller plants are protected by the tall, thick canopy and thus may not receive adequate herbicide coverage. For these reasons, touch up work will be necessary. Glyphosate can be applied aerially to large areas or to smaller areas with a backpack sprayer or wick applicator (Marks et al. 1993).

The Nature Conservancy reports successful control using a method combining cutting and herbicide application to the cut stems (Martin 2001a). Stems are cut at chest height during late summer, when common reed is flowering but before seed set. Immediately following cutting, the hollow reed stems were filled with undiluted Rodeo herbicide.

Fig. 20. Occurrences of common reed (*Phragmites australis*) mapped during the 2002–2003 invasive plant species inventory, Hanford Reach National Monument.

### WINTER RYE, FERAL RYE — *SECALE CEREALE*

Winter rye is a domesticated winter annual or biennial grass. Reproduction is strictly by seed. Mature plants can produce more than 700 seeds each. Less than 1% of seed remains viable a year after dispersal. Roots may reach as deeply as 6 feet (Trainor and Bussan 2001). Winter rye produces allelopathic chemicals which help to suppress competitors (Stumbaugh 2002).

Winter rye volunteers freely and can persist for many years in abandoned fields (pers. obs.) and spreads along roadsides and into waste places and rangelands (Trainor and Bussan 2001, Whitson et al. 1996).

Winter rye is classified as a Class C noxious weed in Washington. Control measures are not required by state law, but are a local option (NWCB 2003a). No control measures are required for this species by local jurisdictions within the Hanford Reach National monument area.

## Current Status and Treatment Priorities on the Monument

Winter rye is a Priority 3 species on the Hanford Reach National Monument. Winter rye currently occupies nearly 500 acres within the Monument, with the predominant infestation occurring in upper Snively Basin (Fig. 21), where it has persisted in old agricultural fields since the 1930s (Rice 2002). This large infestation is visible from certain vantage points many miles away and has been mapped as a vegetation unit (PNNL 2002). Winter rye has spread along roadsides in the area and appears to be spreading to a small degree into nearby natural areas, possibly via an animal vector. A smaller infestation occurs along the Ringold Flats Road.

No winter rye sites are designated for priority treatment at this time. However, control of roadside plants is recommended, and a seasonal quarantine of infested roadways should be considered to prevent the spread of this species into new areas.

## Control

The tall stems and disarticulating seedheads of winter rye are readily dispersed by vehicles along roads (pers. obs.). Roadsides should be kept clear of winter rye to minimize its spread.

*Manual and Mechanical Methods*

Individuals or small stands of winter rye may be removed by hand pulling prior to seed maturation. When pulling, the entire crown of the plant must be removed (Trainor and Bussan 2001, R. Leonard pers. comm.).

The Boardman Conservation Area in North Central Oregon plans to mow large infestations during flowering, but before fertilization and seed production begin. Cut material should be removed after mowing or allelopathic chemicals may suppress non-target species (Stumbaugh 2002).

*Biological Methods*

No effective biological control agents are currently available.

*Chemical Methods*

**Glyphosate** (Roundup) may be applied at 6.0 oz. product/A. Because winter rye is taller then most native perennials at bloom, an agricultural wicker / wiper such as those used in wheat fields may be effective for large infestations. For small stands use 0.5% solution of Roundup sprayed to cover (R. Leonard pers. comm.).

Trainor and Bussan (2001) recommend higher concentrations (12.0 oz. product/A) of glyphosate for control of winter rye. Plants should be treated when they are only 1-6” tall.

Fig. 21. Occurrences of winter rye (*Secale cereale*) mapped during the 2002–2003 invasive plant species inventory, Hanford Reach National Monument.

## PERENNIAL SOWTHISTLE *SONCHUS ARVENSIS* SSP. *ARVENSIS*

Perennial sowthistle is a deep-rooted perennial Eurasian forb in the composite family (Asteraceae). Perennial sowthistle reproduces by seeds and creeping horizontal roots. Seeds are generally wind-dispersed, but the seeds' pappus hairs have hooked cells that allow them to stick to clothes, fur, vehicles, and farm implements. The seeds are also sometimes moved as commercial seed or hay contaminants (Lemna and Messersmith 1990).

Perennial sowthistle invades disturbed areas, roadsides,and riparian areas where it displaces native species. It is a serious weed in agricultural areas where it reduce crop yields and hosts plant pests (Lemna and Messersmith 1990).

Perennial sowthistle is classified as a Class B Designate noxious weed throughout Region 9 and in Adams County. State law requires prevention of seed production and spread of Class B Designate weeds (NWCB 2003a). Perennial sowthistle is classified as a Class B Non-Designate noxious weed throughout the remainder of Region 6. State law calls for containment, gradual reduction, and prevention of further spread of Class B noxious weeds.

### Current Status and Treatment Priorities on the Monument

Perennial sowthistle is a Priority 3 species on the Hanford Reach National Monument. *Sonchus arvensis* ssp. *arvensis* was identified from a specimen collected in the riparian zone on the south margin of the WB 10 ponds. Due to time constraints, the full extent of the infestation could not be mapped.

The WB 10 ponds and similar habitats associated with the Saddle Mountain Wasteway were not mapped in detail; consequently, the extent of perennial sowthistle infestations may be underreported by this inventory.

No priority sites are designated for treatment of perennial sowthistle. Further inventory work should seek to confirm the identification of this species and map the extent of its infestation.

### Control

*Mechanical Methods*

Tillage at the seven to nine leaf rosette stage can be effective in reducing the reproductive vigor of the roots. Depth of burial and amount of root breakage determine the effectiveness of tillage. Root fragments left on the soil surface die from desiccation, and those buried 30 cm or more are unlikely to resprout. However, roots buried at intermediate depths will produce new shoots. Smaller root fragments produce fewer, less vigorous shoots (Lemna and Messersmith 1990).

*Biological Control*

No effective biological control agents are currently available.

*Chemical Methods*

Perennial sowthistle is relatively resistant to many common broadleaf herbicides. Herbicide performance is enhanced when combined with other control methods (NWCB 2003b). The following herbicides are recommended (Williams et al. 2002):

**2,4-D** at 2.0 lb. a.e./A applied when plants are in the bud stage, and on 8-10" tall regrowth. Repeat treatments are required to achieve control.

**Clopyralid + 2,4-D amine** (Curtail) at 1 – 5 qts. product/A, applied to rosettes prior to entering the bud stage. The higher rates are more appropriate for rangeland applications, over established grass only.

**Dicamba**, **Amitrole** (Amitrol-T) and other herbicides have also been used, with varying results (NWCB 2003b, William et al. 2002). Dicamba should not be used in diverse natural areas, as it has a tendency to eliminate all broadleaved species (Carpenter and Murray 1998b).

**SWAINSONPEA** ***SPHAEROPHYSA SALSULA***

Swainsonpea is a long-lived rhizomatous, taprooted perennial of Asian origin in the legume (Fabaceae) family. Swainsonpea reproduces by seeds and by aggressive creeping rhizomes. Seeds may remain viable in soil for many years (CDFA 2003b, Whitson et al. 1996).

Swainsonpea invades roadsides and other disturbed areas, riparian areas, and agricultural fields (CDFA 2003b). Swainsonpea was collected at Rattlesnake Spring on the Arid Lands Ecology Reserve in 1971 (Rice 2002). The small population there today suggests that this species is not moving very fast.

Swainsonpea is classified as a Class B Designate noxious weed in Franklin County and in Adams County of Region 6. State law requires prevention of seed production and spread of Class B Designate weeds. Swainsonpea is classified as a Class B Non-Designate noxious weed in all other jurisdictions that include the Monument. State law calls for containment, gradual reduction, and prevention of further spread of Class B Non-Designate noxious weeds (NWCB 2003a).

## Current Status and Treatment Priorities on the Monument

Swainsonpea is a Priority 3 species on the Hanford Reach National Monument. Swainsonpea was recorded on 37 acres (15 ha) of the Monument during 2002–2003. Swainsonpea also appears to be abundant in some areas around the WB 10 ponds. Time constraints prohibited a systematic mapping of these occurrences, hence the species is underreported here. Of more concern are infestations associated with perennial springs and roadways on the ALE Reserve (Table 17, Fig. 22). At present these infestations are relatively small, but seeds may be transported by water or vehicles to new locations.

Table 17. Priority sites for treatment of swainsonpea

| Unit | Location | East (NAD 27) | North (NAD 27) |
|---|---|---|---|
| ALE | Rattlesnake Spring | 293024 | 5153813 |
| | | 293030 | 5153783 |
| | Lower Snively Spring | 291125 | 5148937 |

## Control

*Mechanical Methods*

Mowing may reduce seed production of swainsonpea but is unlikely to provide long term control. Tillage may be ineffective due to the extensive creeping root system developed by mature plants. Care must be taken to avoid spreading root fragments with equipment (CDFA 2003b).

*Biological Methods*

No effective biological control agents are currently available.

*Chemical Methods*

**2,4-D LV ester** at 2.0 lb. a.e./A applied during the early bloom stage can be used to control swainsonpea. Repeated treatments may be required (William et al. 2002). Herbicides active on the legume family, such as **clopryralid** (Transline) and clopyralid + 2,4-D (Curtail) may also be effective (R. Hill pers. comm.).

Fig. 22. Occurrences of swainsonpea (*Sphaerophysa salsula*) mapped during the 2002–2003 invasive plant species inventory, Hanford Reach National Monument.

**SALTCEDAR, TAMARISK** ***TAMARIX RAMOSISSIMA, TAMARIX PARVIFLORA***

Saltcedar is a deep-rooted shrub or small tree (5-20 feet tall) in the tamarisk family (Tamaricaceae). Representatives of this Old World genus on the Hanford Site include *Tamarix ramosissima* (which has flower parts in 5's) and *T. parviflora* (which has flower parts in 4's). *Tamarix ramosissima* is highly invasive in Washington, while *T. parviflora* is less so (NWCB 2003b). Plants of both species are characterized by numerous slender, spreading branches and scale-like deciduous leaves. Some individuals or populations of saltcedar in the northwest may represent hybrids between *T. ramosissima* and other, morphologically similar *Tamarix* species (Gaskin and Schall 2002).

A single mature saltcedar may produce hundreds of thousands of tiny seeds which are readily dispersed by wind and water. Seed dispersal may occur throughout the spring and summer months. Seedling growth is very rapid. The species can resprout vigorously from buried, submerged, or damaged stems and mature plants spread vegetatively as well (Sudbrock 1993). Once established, even dramatic changes in soil moisture will not eliminate saltcedar, as long as abundant ground water is available (Frasier and Johnsen 1991, Brotherson and Field 1987).

Aggressive and long-lived, saltcedar has colonized more than one million acres of floodplains, riparian areas, and wetlands throughout the arid west. Saltcedar outcompetes and crowds out native vegetation and alters patterns of sediment deposition (Tallent-Halsell and Walker 2002, Carpenter 1999, Sudbrock 1993). Saltcedar uses more water than comparable native plant communities and alters local hydrology by lowering the water table (Hoddenbach 1987 cited in Carpenter 1999). The stems and leaves of mature plants secrete salt, increasing soil salinity and further excluding many native plant species (Sudbrock 1993).

Infestations also have detrimental impacts on wildlife. Saltcedar is not favored habitat for most bird species. Saltcedar seeds have almost no protein and are too small to be eaten by most granivores, and the scale-like leaves offer little suitable forage for browsing animals (Anderson et al. 1977). Stands of saltcedar are associated with lower diversity of aquatic invertebrates (Bailey et al. 2001).

Saltcedar-dominated communities experience higher fire frequencies than native cottonwood-willow communities, eventually eliminating the fire-sensitive natives (Busch 1995, Busch and Smith 1993).

Formerly a Class A noxious weed throughout the state of Washington, *Tamarix ramosissima* was recently reclassified as a Class B Non-Designate noxious weed in the four county area encompassing the Monument (S. McGonigal pers. comm. 7/10/2003). State law calls for containment, gradual reduction, and prevention of further spread of Class B Non-Designate noxious weeds (NWCB 2003a). *Tamarix parviflora* is not classified as a noxious weed in Washington state.

## Current Status and Treatment Priorities on the Monument

Saltcedar is a Priority 1 species on the Hanford Reach National Monument. Saltcedar has been recorded on more than 1200 acres (> 500 ha) of the Monument. Infestations are concentrated on the North Slope, in riparian areas associated with irrigation wasteway systems and on the White Bluffs (Fig. 23). Integrated treatments begun by the USFWS are underway in several polygons and should continue. Because of the large acreages already occupied by this species, the emphasis for additional management on the Wahluke and Saddle Mountain units is to detect and control new infestations, or those which are isolated.

A single small saltcedar was reported from near the center of Homestead Island in the River Corridor Unit by a reliable observer (P. Camp pers. comm.). The plant could not be relocated by a surveyor with limited time. This incipient infestation merits a thorough search of the island's center, and aggressive action to eliminate the individual within three years once found.

Saltcedar has only been recorded in one small, isolated infestation on Monument lands south of the Columbia River (Table 18). This infestation, a robust individual near China Bar on the McGee Ranch-Riverlands Unit, should be treated aggresively, with the goal of eradicating the species from this site within five years. Excavation of the root of this small infestation should be considered as a way of weakening the infestation, in combination with herbicide treatments, if the infestation resists chemical treatment alone. Saltcedar has not been recorded in any of the spring systems of the ALE Reserve thus far, and a high priority should be placed on early detection and aggressive control of infestations that may be discovered in these systems.

It is recommended that additional inventories for saltcedar be conducted during late spring and summer when the flowering plants are most easily observed. Cut stem control methods using glyphosate (Roundup, Rodeo) or triclopyr (Garlon 3A, Garlon 4) may be applied during late fall when plants are actively translocating materials to their roots (see below).

## Control

Effective control programs for saltcedar require integration of manual, mechanical and chemical control methods. Saltcedar can be controlled by five principal methods: 1) applying herbicide to foliage of intact plants; 2) removing aboveground stems by burning or mechanical means followed by foliar application of herbicide; 3) cutting stems close to the ground followed by application of herbicide to the cut stems; 4) spraying basal bark with herbicide; and 5) digging or pulling plants (Carpenter 1999).

Control of saltcedar often involves considerable cash and labor resources, which may exceed those available from any one source. Partnerships such as the Saltcedar Task Force (Hill 2003) have been able to solicit cash grants and in-kind contributions from a variety of partners to accomplish projects that a single agency would not be able to complete alone (Carpenter 1999). Volunteers may also be a valuable resource in saltcedar control projects (Barrows 1993).

## Manual, Mechanical, and Cultural Methods

Manual, mechanical, or cultural methods alone will rarely control saltcedar infestations. However, cutting, mowing , and other mechanical or cultural methods can be used to reduce the volume and vigor of saltcedar stands prior to herbicide treatment (Carpenter 1999).

Root plowing can be effective in large, dense stands that have little or no native vegetation if the plow cuts the saltcedar root crowns well below (0.3 to 1.0 m) the soil surface (Frasier and Johnsen 1991). Root plowing works best during hot, dry conditions that help dry the cut roots. Root fragments left in the ground after plowing will often resprout, necessitating follow-up treatment (Carpenter 1999).

Hand pulling can be used effectively to control young saltcedar plants after the larger plants have been killed.

Draining or other activities that lead to local declines in water table depth could promote saltcedar at the expense of desirable native plants.

*(Continued)*

Table 18. Priority Sites for treatment of saltcedar.

| Unit | Location | East (NAD 27) | North (NAD 27) |
|---|---|---|---|
| McGee-Riverlands | China Bar area | 289678 | 5167784 |
| River Corridor | Homestead Island | unknown | unknown |
| Saddle Mt. | Borrow pits, Wahluke Ferry Rd. | 305676 | 5176712 |

Fig. 23. Occurrences of saltcedar, tamarisk (*Tamarix parviflora, T. ramosissima*) mapped during the 2002–2003 invasive plant species inventory, Hanford Reach National Monument.

Although saltcedar typically resprouts vigorously after fire, burning followed by herbicide application to the resprouts can achieve control in monotypic stands. Wildfires may present an opportunity to begin saltcedar control. Burning during the hottest part of the summer, when plants experience the greatest water stress, is likely to yield the best results. Burning is not recommended for control of saltcedar where it occurs as a component of native communities (Carpenter 1999).

*Biological Methods*

Research has indicated approximately a dozen insect species that might be used to fight saltcedar. The USDA has tested and proposed the release of two species of insects for saltcedar biocontrol but releases have not yet been permitted (Carpenter 1999).

*Chemical Methods*

**Imazapyr** (Arsenal) alone or in combination with **glyphosate** (Roundup, Rodeo), applied to foliage aerially or with surface equipment, is effective and practical for controlling large, dense stands of saltcedar, particularly where little on no native vegetation is present (Duncan 1994). A mixture of 0.5% (v/v) imazapyr and 0.5% glyphosate (v/v) plus 0.25% (v/v) nonionic surfactant gives satisfactory results (Duncan and McDaniel 1996 cited in Carpenter 1999). Younger, smaller plants are easier to kill than larger, mature ones.

*Cut-Stump Method*

**Triclopyr** (Garlon4, PathfinderII) has been used to successfully control small (< 2 ha) saltcedar infestations via cut-stump applications (Sudbrock 1993, Carpenter 1999, Martin 2001b). Garlon4 is diluted 1:3 (v/v) in the field with cheap vegetable oil while PathfinderII is sold already mixed and diluted with vegetable oil. PathfinderII also contains a dye, which makes it easier to distinguish stumps that have been treated from those that have not. Dyes such as colorfast purple, colorfast red and basoil red can be added to Garlon4. Stems of saltcedar should be cut within 5 cm of the ground surface and herbicide applied immediately to the entire circumference of the stem cambium (Sudbrock 1993). Any resprouted foliage should be retreated between 4 to 12 months after the initial treatment. Sudbrock (1993) used **glyphosate** (Roundup, Rodeo) and triclopyr (Garlon 3A, Garlon 4) diluted 1:1 with deisel oil or with water and applied as above. The best time for treatment is in late fall and early winter when saltcedar is entering dormancy and translocating carbohydrates to the roots (Sudbrock 1993).

Imazapyr (Arsenal) may also be used in cut stem applications (H. Newsome pers. comm.). Regardless of the herbicide used, it is important to re-treat saltcedar that is not killed by initial treatment. It is essential to continue to monitor and control saltcedar indefinitely because saltcedar is likely to re-invade treated areas. However, follow-up control is likely to require much less labor and materials than the initial control efforts (Carpenter 1999).

**PUNCTUREVINE, TACKWEED** ***TRIBULUS TERRESTRIS***

Puncturevine is a prostrate summer annual Mediterranean forb in the caltrop (Zygophyllaceae) family. The fruit is a notorious burr with sharp, rigid spines. Puncturevine invades pastures, roadsides, waste places, and cultivated fields. The spines of the fruit can injure the feet and mouths of animals.

Puncturevine reproduces completely by seeds, which may germinate throughout the growing season (R. Leonard pers. comm.). Seeds spread by attaching to animals, people, and vehicles and may remain dormant and viable in soil for 4-5 years (Whitson et al. 1996).

Puncturevine is classified as a Class B Designate noxious weed in Adams County. State law requires prevention of seed production and spread of Class B Designate weeds. Puncturevine is classified as a Class B Non-Designate noxious weed in all other jurisdictions that include the Monument . State law calls for containment, gradual reduction, and prevention of further spread of Class B Non-Designate noxious weeds (NWCB 2003a).

## Current Status and Treatment Priorities on the Monument

Puncturevine is a Priority 1 species on the Hanford Reach National Monument. The distribution of puncturevine on the Monument is limited at present. During this inventory, puncturevine was recorded only from a single location on the Monument's North Slope (Fig. 24). Since the completion of the inventory, two additional infestations have been discovered by Monument personnel (Table 19). These infestations should be treated aggressively before seed can spread to new locations. The key to controlling puncturevine is to prevent seed production and exhaust the seedbank. To be effective, treatments must be applied before seeds can be produced. Since the infestations occur largely within cracked asphalt or packed gravel substrates, mechanical methods are unlikely to be effective. Treatment with glyphosate (Roundup) is recommended (see below).

Vehicle traffic through the infested areas should be restricted as much as possible, and recreational and non-essential vehicle traffic should be prohibited until the infestation is eliminated. Due to seedbank longevity, the site must be monitored for at least 5 years following apparent eradication before it can be declared clean and restrictions lifted. Sites should be monitored periodically through the growing season to capture opportunistic germinations.

Puncturevine is not uncommon in the Tri-Cities area and elsewhere in the landscape surounding the Monument, and new infestations are likely to continue to be found along roadsides within the Monument. Continuing inventory work, and staff education in recognizing this species will assist in controlling puncturevine within the Monument.

Table 19. Priority Sites for treatment of puncture vine.

| Unit | Location | East (NAD 27) | North (NAD 27) |
|---|---|---|---|
| Wahluke | dog trial area | 314608 | 5179210 |
| | Ringold-White Bluffs Rd. | Coordinates not available | |
| ALE | 1200 Ft. Rd. | Coordinates not available | |

Fig. 24. Occurrences of puncturevine (*Tribulus terrestris*) mapped during the 2002–2003 invasive plant species inventory, Hanford Reach National Monument.

## Control

The key to controlling puncturevine, as with all annual species, is to prevent seed production and gradually exhaust the seedbank. Puncturevine will germinate from mid-June until frost, so treatments must be repeated several times through the growing season (R. Leonard pers. comm.). Due to seedbank longevity, the site must be monitored for 5 years following apparent eradication before it can be declared clean and restrictions lifted.

Because of puncturevine's ability to spread via vehicles (at all seasons), infested areas should be quarantined. Vehicle traffic through infested areas should be restricted as much as possible, and recreational and non-essential vehicle traffic should be prohibited until the infestation is eliminated.

*Manual and Mechanical Methods*

Pulling, digging or tilling prior to flower and seed production is effective in controlling new infestations (CNAP 2000). Several years' cultivation may be required to exhaust the seedbank in established infestations (NWCB 2003b).

*Biological Methods*

Two weevils, *Microlarinus lareynii* and *M. lypriformis*, have been introduced into the United States as biocontrol agents. The larvae attack the seed and stems and have reportedly provided reasonably good results. (NWCB 2003b).

*Chemical Methods*

**Glyphosate** at 1.5 lb. a.i./A or **picloram** at 0.25a.i./A may be used for control of seedlings. **2,4-D** in either amine or LV ester form, or **amitrole** (Amitrol-T) at 1.0 – 2.0 lb. a.i./A in 10-20 gal. of water is effective for spot treatments. **Dicamba** at 0.25a.i./A, may also be used for control of seedlings (William et al. 2002, CNAP 2000). Dicamba should not be used in diverse natural areas, as it has a tendency to eliminate all broadleaved species (Carpenter and Murray 1998b).

# Watch List

**VELVETLEAF** ***ABUTILON THEOPHRASTI***

Velvetleaf is a taprooted summer annual forb in the mallow family (Malvaceae). This vigorous and fast-growing Asian species may produce thousands of seeds per plant, and seeds may remain viable in the soil seed bank for as long as 50 years. Seeds germinate throughout the growing season, and will ripen even after the parent plant is uprooted. The species is a strong competitor and may have allelopathic effects upon competitors (NWCB 2003b, Roeth et al. 1983).

Velvetleaf invades disturbed areas, especially rich soils and agricultural areas, but may be restricted to irrigated fields and other mesic sites in the Columbia Basin due to high evapotranspiration (Warwick and Black 1988).

Velvetleaf is classified as a Class A noxious weed in Washington. State law requires eradication of Class A weeds (NWCB 2003a).

## Control

Due to the long-term viability of seeds it is critical to detect infestations early and eliminate seed production. Multiple control methods are required to control established populations (Roeth et al. 1983).

*Mechanical Methods*

Small populations and young plants may be controlled by hand pulling before flowers are produced. Cutting or mowing plants after they begin to flower but before seed set will eliminate the current year's seed crop. Plants should be removed from the site and burned following manual or mechanical control (Roeth et al. 1983).

*Biological Methods*

The Washington State Noxious Weed Control Board discusses potential agents of biological control for velvetleaf (NWCB 2003b). As of 2002, no biocontrols for velvetleaf have been released in Washington (Coombs et al. 2002).

*Chemical Methods*

Herbicides should be applied to young plants early in the growing period for greatest effect. Because velvetleaf seeds germinate throughout the warm season, this will require multiple treatments throughout the growing season (Roeth et al. 1983).

**Glyphosate** at 1.5 lb. a.i./A, 2,4-D at 1.0 lb. a.i./A, **picloram** at 0.5 lb. a.i./A, and **dicamba** at 1.0 lb. a.i./A applied post-emergence and before seed set may be used to control velvetleaf (CNAP 2000). Dicamba should not be used in diverse natural areas, as it has a tendency to eliminate all broadleaved species (Carpenter and Murray 1998b). Data is lacking on the efficiency of chemical controls in the Pacific Northwest (William et al. 2002).

Some velvetleaf populations have demonstrated resistance to atrazine and other agricultural herbicides (Heap 2003).

**INDIGOBUSH** ***AMORPHA FRUTICOSA***

Indigobush is a large deciduous shrub in the legume family (Fabaceae) native to the southeastern and midwestern U.S. Reproduction is primarily by seed (Roché and Halse 1992). In Washington and Oregon indigobush grows in riparian areas, especially in the upper fluctuation zone of reservoirs in the Columbia and Snake rivers (Glad and Halse 1993). Since its introduction to the Northwest, indigobush has spread widely along these rivers, forming dense stands that crowd out native riparian vegetation, slow river currents, and alter such river processes such as long-term patterns of erosion and sediment accumulation. Currently these processes support federally threatened fall chinook salmon by providing spawning and rearing habitat. In the lower Columbia River, indigobush impacts habitat for persistentsepal yellowcress (*Rorippa columbiae*), a State Threatened plant species and federal Species of Concern, by altering the vegetative structure and composition and ecosystem dynamics of its habitat (L. Cornelius pers. comm). This strongly suggests that it may also be a threat to the Columbia yellowcress (*Rorippa columbiae*) population along the Hanford Reach. Columbia yellowcress is listed as a Species of Concern with the USFWS and is considered Threatened in Washington (WNHP 1997). Indigobush occurs on the Snake River and on the Columbia River downstream from its confluence with the Snake River but does not appear to be moving upriver from this area (M. Stairet pers. comm.).

Indigobush is classified as a Class B Designate noxious weed throughout Region 9, except within 200 feet of the Columbia River. State law requires prevention of seed production and spread of Class B Designate weeds. Indigobush is classified as a Class B Non-Designate noxious weed throughout Region 6. State law calls for containment, gradual reduction, and prevention of further spread of Class B Non-Designate noxious weeds (NWCB 2003a).

## Current Status and Distribution on the Monument

Indigobush has not been reported recently on lands currently comprising the Hanford Reach National Monument. However, the species was reported from the Columbia River shoreline in southern Benton County, from the lower Snake River, and even from the Hanford Reach in Franklin and Benton Counties during the early 1990s (Rice 2002). Monument staff should continue to be on the lookout for this species along the southern shores of the Reach, where it is likely to spread first from concentrations on the Snake and lower Columbia rivers.

## Control

Once established, indigobush is difficult to control. Early detection and timely removal of new infestations is highly recommended (Roché and Halse 1992).

### *Manual and Mechanical Methods*

A single cutting of indigobush stimulates mutiple stem resprouts from lateral buds and may result in a denser infestation (Lapin and Nothnagle 1995). Repeated cutting may suppress growth and reproduction but is unlikely to kill indigobush plants (Roché and Halse 1992, L. Cornelius pers. comm.).

### *Biological Methods*

No effective biological control agents are currently available.

### *Chemical Methods*

**Glyphosate**. Foliar application of glyphosphate (Roundup) at 18% concentration by volume accounted for more than 99% mortality of indigobush plants treated (Lapin and Nothnagle 1995). Cut stem applications of the same concentration provide greater target selectivity near water and in other sensitive areas, but killed only 60-70% of treated stems. More complete control or eradication of established stands would probably require multiple treatments over several years. Only the Rodeo formulation of glyphosate should be used where the chemical may get into water. Washington State Parks Deparent is currently experimenting with cut stem and basal bark applications of glyphosate, triclopyr, and chlopyralid (L. Cornelius pers. comm).

**WILD CHERVIL** ***ANTHRISCUS SYLVESTRIS***

Wild chervil is a tall biennial to short-lived perennial Eurasian forb in the parsley family (Apiaceae). Wild chervil has a deep taproot which can extend to depths greater than 6 feet. Seeds may be spread by birds, water, and human activity (BCMA 2003).

Wild chervil is spreading rapidly along roadways, fencelines and pastures in British Columbia. Northwest infestations may be traceable to commercial wildflower mixes. Wild chervil may compete strongly against native plants and reduce forage for wildlife. The species is host for several agricultural pathogens as well (BCMA 2003).

Wild chervil is classified as a Class B Designate noxious weed throughout Regions 6 and 9. State law requires prevention of seed production and spread of Class B Designate weeds (NWCB 2003a).

## Control

Wild chervil may be difficult to control due to the deep taproot of mature plants, along with a displayed resistance to some herbicides. Early identification and removal of young plants is the best management strategy known at this time (BCMA 2003).

*Manual and Mechanical Methods*

Very young plants may be hand dug. Mature plants must be severed below the root crown for removal to be effective (BCMA 2003).

*Biological Methods*

No effective biological control agents are currently available.

*Chemical Methods*

No information on chemical controls is available. The species is reportedly tolerant of 2,4-D (William et al. 2002).

**MUSK THISTLE** ***CARDUUS NUTANS***

Musk thistle is a tall (up to 1.5 m) Eurasian biennial or winter annual forb in the composite family (Asteraceae). Musk thistle spreads rapidly over short distances via wind-dispersed seed. Seed production can be as great as 11,000 seeds per plant (McCarty 1982). The bulk of the seeds fall near the parent plant with less than 1% being carried further. Seeds have been reported to remain viable in the soil for periods as long as ten years (Burnside et. al. 1981).

Musk thistle invades disturbed roadsides and agricultural areas, and rangelands, where it can form dense stands, outcompete native vegetation, and reduce forage value and restrict wildlife movement(Beck 1999a, Heidel 1987).

Musk thistle is classified as a Class B Designate noxious weed throughout regions 6 and 9 . State law requires prevention of seed production and spread of Class B Designate weeds (NWCB 2003a).

## Control

*Manual and Mechanical Methods*

Small infestations of musk thistle may be hand pulled or grubbed out (Beck 1999a).

Hand-cutting , chopping, or mowing can provide control if repeated over a period of years. Effective control is obtained when cutting is done with a sharpened shovel at ground level at the base of the bud and the top of the root crown. If only the terminal bud is destroyed, the side buds can develop into leaders and set seed. Hand-chopping may also be performed just before anthesis, at the onset of blooming. Treatment before plants are fully bolted results in regrowth (Heidel 1987).

Repeated visits at weekly intervals over the 4 to 7 week blooming period provide most effective control because not all plants bloom simultaneously and it is important to cut them after first anthesis but before seed set (Heidel 1987).

*Biological Methods*

Larvae of the European seed head weevil *Rhinocyllus conicusus* (Coleoptera: Cuculionidae) feed on the immature heads of musk thistle, reducing seed output (Heidel 1987, NWCB 2003b). This species is widely available and has provided excellent control in Washington (Coombs et al. 2002).

A second European introduction, the crown weevil *Trichosirocalus horridus* (= *Ceuthorhynchidus horridus*) weakens Carduus plants by infesting the crown tissues of the rosettes. This species is established in Idaho where it provides good control, but is not established in Washington. The species may not be suitable for release near agricultural areas because it damages lettuce and artichokes (Heidel 1987).

When used together, the crown and seedhead weevils may provide fair to good control, but will not eliminate musk thistle.

*Chemical Methods*

Chemical control methods are similar to those for Scotch thistle. Herbicide treatment is most effective during the rosette stage in the spring before musk thistle bolts, or in the fall after new rosettes have formed (William et al. 2002, Beck 1999a).

**Glyphosate + 2,4-D** (Campaign) 16 – 32 fl. oz. product /A for broadcast applications, or in 1-2% solution for spot treatments is recommended for musk thistle control and may be applied at the rosette stage during spring or fall. 2,4-D at 1.5 – 2.0 lb. a.e./A may also be used (William et al. 2002).

**Picloram** (Tordon) at 0.25lb.a.e./A (William et al. 2002). Picloram alone or in combination with either 2,4-D or dicamba gives the best control under cool, dry late-season conditions (Heidel 1987).

**Dicamba** (Banvel, Clarity) at 0.5 – 1.0 lb. a.e./A (William et al. 2002). This rate will not harm surrounding grasses. Dicamba may be effective earlier in the season than 2,4-D (Heidel 1987). Dicamba should not be used in diverse natural areas, as it has a tendency to eliminate all broadleaved species (Carpenter and Murray 1998b).

**Clopyralid** (Stinger, Transline) at 0.1 – 0.375 lb. a.e./A (0.25 – 1.0 pt. Product/A) may be applied up to the bud stage. Clopyralid + 2,4-D amine (Curtail) may also be used at 1 – 5 qts. product/A (William et al. 2002).

**Metsulfuron** (Escort) at 0.6 oz. a.i./A (1.0 oz. product/A) with anionic or silicone surfactant (William et al. 2002).

**LONGSPINE SANDBUR** ***CENCHRUS LONGISPINUS***

Longspine sandbur is a warm season annual grass of European origin. Sandbur invades disturbed areas, especially those with sandy soils, and can form extensive spreading mats (Whitson et al. 1996).

Longspine sandbur was reported from "the Hanford area, sandy shores of the Columbia River (Rice 2002)" as early as 1930.

Longspine sandbur is classified as a Class B Designate noxious weed in Adams County. State law requires prevention of seed production and spread of Class B Designate weeds. Longspine sandbur is classified as a Class B Non-Designate noxious weed in all other jurisdictions that include the Monument . State law calls for containment, gradual reduction, and prevention of further spread of Class B Non-Designate noxious weeds (NWCB 2003a).

## Control

The key to controlling this species, as with all annuals, is the elimination of seed production.

*Mechanical Methods*

Physical removal may be effective for small infestations.

*Biological Methods*

No effective biological control agents are currently available.

*Chemical Methods*

**Glyphosate** at 0.75 lb. a.e./A for young, small plants (< 6.0" tall or long) and at 1.5 lb. a.e./A for larger plants (> 6.0") has been used to control longspine sandbur (William et al. 2002).

**Fluazifop** (Fusilade DX at 0.19 – 0.375 lb. a.i./A (0.75-1.5 pts. product/A) with a 1.0% v/v oil surfactant or 0.25% v/v non-ionic surfactant may also be used. Apply when plants are small (2"-8"). Fluazifop acts slowly and results will take several weeks to become apparent (William et al. 2002).

**SPOTTED KNAPWEED** ***CENTAUREA BIEBERSTEINII (CENTAUREA MACULOSA)***

Spotted Knapweed is a taprooted European biennial or short-lived perennial in the composite family (Asteraceae). Overwintering rosettes bolt in early summer, producing multi-stemmed adults. Lateral root-sprouting in spotted knapweed may result in rosettes that may remain attached to the parent for an indefinite length of time; however, expansion of a colony is primarily dependent upon seed production (Tyser and Key 1988), which has been estimated at up to 90,000 seeds/$m^2$ (Schirman 1981). Unaided dispersal generally covers only short distances (3-4'). Movement over greater distances requires transport by rodents, livestock, vehicles, or hay or commercial seed (Roché et al. 1986). Schirman (1981) estimated that survival of only about .1% of seed production is required to maintain stands at observed plant densities in highly disturbed areas.

Spotted knapweed is an aggressive invader that has infested more than 1.5 million ha of pasture and rangeland in the western U.S. and Canada (Harris and Cranston 1979). In 1988 spotted knapweed rated third among Washington state's knapweeds, with four percent of the total acreage. It was reported in 19 counties, with a total area of 10,777 ha. Ninety-two percent of the spotted knapweed was found in three northeastern counties (Roché and Roché 1988). Spotted knapweed grew primarily on industrial lands, gravel pits, roads and other corridors, and on pasture and rangeland (Roché and Roché 1988). In the counties that reported few infestations, the plants were almost exclusively along roads or in urban areas. In central Washington, spotted knapweed often occurred in association with irrigation systems and areas of high available moisture, including areas of deep soil with threetip sagebrush/fescue and roadsides receiving runoff (Roché et al. 1986).

Spotted knapweed infestations impact ranch and agricultural lands, degrade the quality of range forage and wildlife habitat, reduce native plant diversity, increase runoff and soil erosion rates, decrease the visual quality and appeal of recreational lands, and pose wildfire hazards (NWCB 2003b, Sheley et al. 1999, Maurer 1987). Spotted knapweed is unpalatable and of low value to most stock and wildlife.

Spotted knapweed readily invades disturbed areas. Once established, however, it can invade adjacent areas that are relatively undisturbed or in good condition (Tyser and Key 1988, Lacey et al. 1990). Spotted knapweed is highly adept at capturing available moisture and nutrients, and it quickly chokes out other vegetation (Roché et al. 1986).

Spotted knapweed is classified as a Class B Designate noxious weed throughout regions 6 and 9 . State law requires prevention of seed production and spread of Class B Designate weeds (NWCB 2003a).

Spotted knapweed has not been recorded on the Hanford Reach National Monument. However, infestations are present at the Hanford Townsite and at the Energy Northwest powerplant site on Central Hanford (R. Roos pers. comm.).

## Control

*Manual, Mechanical, and Cultural Methods*

Persistent hand pulling or clipping over several years may be effective for new or very small infestations. Hand pulling must remove entire plants before seed is dispersed. The best time for pulling is in spring when soil is moist (Sheley et al. 1999). The recommended time for clipping is after flowers have formed but before seeds have matured. All stems and seed heads must be removed from the site (Morisawa 1999).

Mowing may be a way to control populations of spotted knapweed but will likely not lead to eradication. Mowing during the early flowering stage usually results in regrowth and plants are able to produce abundant late season seeds. Mowing when most flowering has ended but before seeds have matured may greatly reduce that year's seed set. However, the seed bank in well-established infestations can probably overcome many years of such treatment (Maurer 1987). Long-term effects of mowing on spotted knapweed densities are unknown (Sheley et al. 1999).

Cultivation may reduce spotted knapweed biomass, but must be done to at least 7-8” depth (Sheley et al. 1999).

Repeated, very hot fires may reduce dense infestations of spotted knapweed. However, single, low-severity burns will not prevent resprouting or seed germination and the infestation will quickly recover (Morisawa 1999).

*Biological Methods*

Ten biocontrol agents have been released on spotted knapweed in Washington. The seed head weevil *Larinus minutus*, two seed head gall flies (*Urophora affinis*, and *Urophora quadrifasciata*) and a seedhead moth (*Metzneria paucipunctella*) attack seed heads and are available for mass collections (Coombs et al. 2002).

Sheep and goats will graze spotted knapweed if confined to an area where alternative forage is unavailable. Repeated grazing will weaken plant reserves and make plants more susceptible to herbicide treatments (BIRC 2000).

*Chemical Methods*

For all chemical applications the treated area should include a 3.0-4.5 meter buffer around the infestation. Follow-up treatments are extremely important for the continual control of spotted knapweed (Morisawa 1999).

**Clopyralid** (Transline) applied at 0.25 – 0.5 lb. ae/A (0.66 – 1.33 pts. product/A) will control spotted knapweed with little soil residual activity. Apply to rosettes and bolted plants up to the flower bud stage. Clopyralid + 2,4-D amine (Curtail) applied at 2.0 – 5.0 qts. product/A (the lower rate is for agricultural applications) also provides control. Apply Curtail in spray volume sufficient to ensure good coverage. Apply to rosettes prior to bolting (William et al. 2002).

**Triclopyr** + clopyralid (Redeem R&P) may be applied at 1.5 – 2.0 pts. product/A in at least 10 gal./A of water to actively growing rosettes and plants in early bolt stage. A non-ionic surfactant is recommended (William et al. 2002).

**Glyphosate** may be applied at 3.0 lb. a.e./A to actively growing plants at the flower bud stage. Annual reapplications are necessary to exhaust the seed bank since glyphosate has no residual effect in soil (William et al. 2002). Glyphosate will kill perennial grasses and other desireable vegetation within the treatment area.

**2,4-D** may be applied at 1.0 – 2.0 lb. a.e./A at the beginning of bolting. Annual reapplications are necessary to exhaust the seed bank since 2,4-D has no residual effect in soil (William et al. 2002).

**Picloram** (Tordon) at 0.25 – 0.5 lb. a.e./A can control spotted knapweed without harming most perennial grasses. However, there is a long residual and the herbicide is costly (as is dicamba - listed below). Apply during the rosette growth stage in the fall or in late spring before or during bolting. Picloram can not be used near water or in porous substrata overlying ground water. Picloram does not affect grasses, but long term affects have been observed from it on shrubs and trees, possibly due to leaching into ground water (William et al. 2002, Morisawa 1999).

**Dicamba** (Banvel) will also provide control of plants and shorter residual control of seedlings at a rate of 1.0 – 2.0 lbs. a.e./A (0.18-0.37 kg/ha). A follow-up treatment of 2,4-D at 0.18 kg/ha (1 lb/acre) annually may be needed to prevent reinfestation (Morisawa 1999). Dicamba should not be used in diverse natural areas, as it has a tendency to eliminate all broadleaved species (Carpenter and Murray 1998b).

## YELLOW NUTSEDGE (GOLDEN NUTSEDGE) ***CYPERUS ESCULENTUS***

Yellow nutsedge is a fibrous-rooted perennial in the sedge family (Cyperaceae) which reproduces by seeds, creeping rootstocks, or by underground nutlets or tubers (Whitson et al. 1996). Yellow nutsedge generally occurs in disturbed habitats, but can tolerate a wide range of soil types. The species grows along seasonally flooded margins of lakes, rivers, streams, and marshes, and in irrigated fields (NWCB 2003b).

Yellow nutsedge is considered one of the world's worst weeds (Bayer 1987; Holm et al. 1980; Mulligan and Junkins 1976). Well-adapted to irrigated agriculture, yellow nutsedge competes aggressively for water, light, and nutrients, thereby reducing crop yield (Torrell et al. 1993; Mulligan and Junkins 1976). There has been some suggestion of allelopathic effects on other plants and crops (Torrell et al. 1993).

Yellow nutsedge is classified as a Class B Designate noxious weed in all portions of regions 6 and 9 that are included within the Hanford Reach National Monument. State law requires prevention of seed production and spread of Class B Designate weeds (NWCB 2003a).

### Current Status on the Monument

Yellow nutsedge was not recorded during the course of this project's inventories. However, after final field work had been completed, an herbarium record was discovered locating this species at the southern end of Savage Island, in the Wahluke Unit (WTU 2003). Future surveys should attempt to relocate this occurrence and document the species' current status at this site.

### Control

*Mechanical Methods*

Tillage at four week intervals will deplete the energy reserves of tubers. However, cultivation alone takes at least two years to eliminate yellow nutsedge (Lanini 1987). Cultivation should be carried out throughout the growing season, as long as tubers are sprouting. This strategy will ensure that no new tubers are formed. Fall cultivation, when tubers are dormant, is not an effective control method (Mulligan and Junkins 1976).

*Biological Methods*

No effective biological control agents are currently available.

*Chemical Methods*

Yellow nutsedge is resistant to many herbicides and may increase rapidly when other weeds are controlled by herbicides (Mulligan and Junkins 1976). Most herbicides used affect only the shoots and/or roots and do not kill the tubers (Bayer 1987).

Effective herbicide treatments must outlast the tubers' ability to resprout - i.e. the chemical must remain active for 10 to 12 weeks (Lanini 1987).

**Glyphosate** (Roundup, Rodeo) may be broadcast at 2.25 lb. a.e./A or applied as 1.0% solution for spot treatments. Treatments should be applied to actively growing plants (William et al. 2002). This treatment is unlikely to be effective unless repeated frequently during the course of the growing season.

Atrazine, bromacil, bentazon, amitrole, and other herbicides have also been used with varying results on yellow nutsedge (William et al. 2002, Lanini 1987).

### HAIRY WILLOW-HERB *EPILOBIUM HIRSUTUM*

Hairy willow-herb is a tall, semi-aquatic perennial European forb in the evening primrose family (Onagraceae). Mature plants may produce more than 70,000 seeds which remain viable for several years. Plumed seeds are dispersed on the wind. The species also spreads by creeping stolons that can reach lengths of 0.5 m . Seedlings germinating in the fall may overwinter as basal rosettes (Shamsi and Whitehead 1974, 1977). Hairy willow-herb has the ability to outcompete aggressive competitors such as purple loosestrife (*Lythrum salicaria*) where nutrients are not limiting (Shamsi and Whitehead 1977).

Hairy willow-herb colonizes moist soils, wetlands, ditches, stream banks, low fields, and pastures, forming persistent, monospecific stands that exclude other species (Shamsi and Whitehead 1974). A recent arrival in Washington, hairy willow-herb has displayed an ability to spread rapidly. (NWCB 2003b). Hairy willow-herb occurs in Benton County near Finley and in Kennewick as well as in Franklin County, but has not been reported from the Hanford Reach National Monument to date (Rice 2002, M. Stairet pers. comm.).

Hairy willow-herb is listed as a monitor species by Washington state. Control measures are not required at this time (NWCB 2003a). Hairy willow herb has not been reported on the Hanford Reach National Monument, but has been reported as recently as 2000 in nearby Kennewick as well as in Franklin County. Monument staff should be on the lookout for this species particularly in the irrigation seeps along the Ringold Road.

## Control

Control methods for hairy willow-herb have not been investigated and are not known at this time.

*Manual and Mechanical Methods*

Effective manual and mechanical methods are not known at this time.

*Biological Methods*

No effective biological control agents are currently available.

*Chemical Methods*

If the site can be dried down, **2,4-D** will control hairy willow-herb. In aquatic situations, **glyphosate** (Rodeo) will stress or kill above-ground portions of plants, but plants will recover (M. Stairet pers. comm.).

### LEAFY SPURGE *EUPHORBIA ESULA*

Leafy spurge is an erect perennial Eurasian forb in the spurge family (Euphorbiaceae). Long-lived and aggressive, leafy spurge reproduces both by seeds, which can be shot 20 or more feet when the capsule ripens and explodes, and by vegetative growth. Numerous buds are produced along the thick roots. These buds can initiate growth when broken into small segments by tillage (NWCB 2003b).

Leafy spurge produces large numbers (> 10,000/ $m^2$) of highly germinable seeds, and is capable of vigorous vegetative spread as well. Seeds may remain dormant for 5-8 years (Bowes and Thomas 1978). Seeds spread by explosive dehisence, and by floating along watercourses. Once established, the species will spread very rapidly, crowding out and shading desireable species. Early spring emergence contributes to leafy spurge's competitive advantage. There is some evidence of allelopathy as well (Biesboer 1996).

Leafy spurge invades both disturbed and undisturbed rangelands where it can form dense, monotypic stands that displace native vegetation and reduce biodiversity. It also colonizes waste places and agricultural areas, where it is a serious economic threat. Leafy spurge is toxic to some animals and unpalatable to most, so it thrives in areas where competitive plants are heavily grazed (NWCB 2003b, Biesboer 1996).

Leafy spurge is classified as a Class B Designate noxious weed throughout regions 6 and 9. State law requires prevention of seed production and spread of Class B Designate weeds (NWCB 2003a).

## Control

Leafy spurge cannot be controlled by a single treatment of any kind. The deep and extensive root system resists control efforts. New infestations that are detected early through an aggressive monitoring program may be eradicated. Only an expensive long-term effort, including annual or semi-annual herbicide treatments over 5-10 years or longer can hope to control large, established colonies (NWCB 2003b, Biesboer 1996).

*Mechanical Methods*

Cultivation of spurge plants can actually cause a net increase in the density of an infestation. Fire effects only the top growth of leafy spurge and, like cultivation, may promote leafy spurge at the expense of native species when used alone. Integrated approaches employing mowing or prescribed burning followed by herbicide application can provide better control of leafy spurge than herbicides alone (Biesboer 1996).

*Biological Methods*

A number of biological control agents have been released for control of leafy spurge in the Pacific Northwest. So far, all are of limited distribution in Washington state (Coomb et al. 2002).

Sheep or goats will graze leafy spurge. Three or more years of continuous grazing can significantly reduce the density of established leafy spurge growth.

*Chemical Methods*

Leafy spurge is sensitive to the timing of herbicide applications. Control is most effective when herbicide is applied during flowering and seed development, and during fall regrowth from treatment, when spurge regrowth is 4-6" high (NWCB 2003b, Biesboer 1996). Infestations should be retreated annually or more often to control resprouts and new plants emerging from the seedbank (Biesboer 1996).

**Picloram** (Tordon) is one of the most frequently recommended herbicides for leafy spurge control. Picloram may be applied at 0.5 – 1.0 lb a.e./A during the growing season (William et al. 2002). Lower rates in the range are recommended for use near water. Biesboer (1996) recommends higher rates, to 2 lb. a.e./A, especially for areas which are difficult to retreat. Combining picloram with 2,4-D may provide a more effective and more economical control than picloram alone (Lym and Messersmith 1987). Biesboer (1996) used picloram and 2,4-D at 0.25 lb and 1.0 lb a.e./A respectively.

**Glyphosate** (Roundup, Rodeo) can be effective against leafy spurge when applied at 0.38 lb. a.e./A (applied June 1st, July 1st, and August 1st) to 0.75 lb. a.e./A (applied June 1st and July 1st). The lower concentration allows some perennial grasses to survive the effects of the non-selective herbicide (William et al. 2002).

**Landmaster BW** is a formulation of glyphosate and 2,4-D. 54 oz. product/A in 3 – 10 gal. water can be effective when applied in late summer or fall (William et al. 2002).

**2,4-D LV ester** may be used at varying concentrations for different purposes. 1.0 lb a.e./A helps prevent seed formation, while 6 lb. a.e./A helps control the infestation itself (William et al. 2002). Some sources question the effectiveness of 2,4-D alone or in combination with other herbicides for leafy spurge control (Biesboer 1996).

**Forsamine** (Krenites) is a selective herbicide that can be effective on leafy spurge when applied at 2 gal. product/ 100 gal. water at the flowering stage (William et al. 2002).

**Dicamba** (Banvel, Clarity) may be applied at 4.0 – 8.0 lb. a.e./A during spring or early summer (William et al. 2002). Dicamba is generally less expensive than picloram, but does not have the long-term residual effects of the latter herbicide. Dicamba should not be used in diverse natural areas, as it has a tendency to eliminate all broadleaved species (Carpenter and Murray 1998b).

**PARROTFEATHER** ***MYRIOPHYLLUM AQUATICUM***

Parrotfeather is a rhizomatous South American aquatic perennial in the water-milfoil family (Haloragaceae). Parrot feather has both submersed and emergent leaves, with the submersed form being easily mistaken for Eurasian watermilfoil (*Myriophyllum spicatum*), a close relative. The emergent stems and leaves are the most distinctive trait of parrotfeather. Parrotfeather grows best when rooted in shallow water, but has been known to occur as a floating plant in some lakes. The species is well adapted to moderate water level fluctuations. All parrotfeather plants in North America are female, so no seeds are produced; the species spreads exclusively by plant fragments outside of its native range. Fragments root readily, and the tough rhizomes can be transported long distances on boat trailers (NWCB 2003b).

Parrotfeather has colonized freshwater lakes, ponds, streams, and canals and thrives in high nutrient environments. The species colonizes slowly moving or still water, forming dense mats and crowding out native species. Parrotfeather's dense mats of floating rhizomes and emergent stems shade the water column and reduce the density of phytoplankton. These stands also lower the dissolved oxygen and increase acidity in aquatic systems. Overall, these changes degrade habitat values for fish and other aquatic organisms. In addition, the plant provides choice mosquito larvae habitat (Systma 2003, Godfrey 2000). Parrotfeather also restricts recreational opportunities in infested waters (WAPMS 2003).

The species is becoming an increasing problem in irrigation and drainage canals. The Longview, Washington Diking District spends many thousands of dollars per year on parrotfeather control in drainage ditches (NWCB 2003a). Washington's parrotfeather infestations appear to be largely limited to coastal lakes and streams, and the southwest Washington portion of the Columbia River, but a recent infestation has turned up in Yakima County (M. Stairet pers. comm).

Parrotfeather is classified as a Class B Designate noxious weed throughout regions 6 and 9. State law requires prevention of seed production and spread of Class B Designate weeds (NWCB 2003a).

## Control

*Mechanical Methods*

Because this plant can spread readily through fragmentation of rhizomes, using mechanical controls may accelerate its spread. Mechanical controls such as cutting, and tilling should be used only when the extent of the infestation is such that all available niches have been filled. Parrotfeather populations can be successfully harvested, but the dense tough rhizomes are very heavy and the plant regrows rapidly (NWCB 2003b, Godfrey 2000).

*Biological Control*

Most grazers find parrotfeather unpalatable. Potential agents exist, but are not presently available (NWCB 2003b).

*Chemical Methods*

Herbicide treatments have exhibited little success controlling parrotfeather (NWCB 2003b). The waxy cuticle on parrotfeather stems and the species aquatic habitat make parrotfeather difficult to control by chemical means. The Monsanto Company suggested that applying a 1.75% solution of glyphosate (Rodeo) with surfactant to plants in the summer or fall when water levels are low would give about 95 percent control of the plants. In practice, however, this method is likely to kill emergent stems but leave submersed portions of the plant unaffected (Godfrey 2000). Treatment with triclopyr has also proven to be ineffective.

Westerdahl and Getsinger (1988) reported excellent control of parrotfeather with 2,4-D, diquat, diquat and complexed copper, endothall dipotassium salt, and endothall and complexed copper. Control of parrotfeather may be achieved with low-volatility ester of 2,4-D at 4.4-8.9 kg ha, sprayed onto the emergent foliage of young, actively growing plants. The granular formulation of 2,4-D was needed to control parrot feather for periods greater than 12 months.

Endothall, glyphosate, and copper are permitted for aquatic use in Washington waters, but copper is generally permitted only as an algicide (NWCB 2003b).

## JOHNSON GRASS *SORGHUM HALEPENSE*

Johnson grass is a tall (to 3 m) perennial Mediterranean grass considered to be one of the world's worst weeds (Holm et al. 1980). Johnson grass is an invasive and tenacious weed that thrives in disturbed soils where moisture is present. It can be a problem in agricultural fields, irrigation ditches and riverbanks (CNAP 2000). Prolific seed production coupled with extended viability in the seedbank, a massive rhizome system, sprouting ability of fragmented rhizomes, and ability to grow in a wide range of environments make Johnson grass difficult to control (McWhorter 1981).

Johnson grass is classified as a Class A noxious weed in Washington. State law requires eradication of Class A weeds (NWCB 2003a).

### Control

The best time to implement control techniques is during the first two weeks of growth in spring when new rhizome development has not yet begun and when the carbohydrate supply is at its lowest concentration. During the fall the rhizome carbohydrate levels are again low, due to the formation of over-wintering rhizomes, making this also an appropriate time for herbicide application. A combination of mowing, tilling, and herbicide applications may provide adequate control of Johnson grass and may produce better effects than just one technique alone (Newman 1990).

*Mechanical Methods*

Frequent mowing of Johnson grass over several seasons depletes carbohydrate storage and reduces rhizome growth, making plants more susceptible to herbicide treatment. Mowing should be conducted after inflorescences have developed but before flowers have opened. (CNAP 2000). Recommendations for the optimum height at which to cut johnson grass in order to starve the rhizomes vary from 8 – 15 inches (Newman 1990).

Hand pulling or hoeing may be effective for controlling small infestations. Hand hoeing is practical only where the concentration of Johnson grass is low. Shallow cultivation using sharp hoes, shovels, knives or hand pulling will remove the plants and the rhizomes from the upper portion of the soil without dividing or pulling up deep rhizomes (Newman 1990).

Plowing breaks up and dessicates rhizomes that are brought to the surface (McWhorter 1981). A 99% reduction in rhizome production resulted from six thorough tillings at two week intervals (Warwick and Black 1983). Cultivation may also be effective in late fall or early spring, since Johnson grass rhizomes are sensitive to cold (CNAP 2000). Plowing could spread the rhizomes and increase the problem if contaminated machinery is used in uninfested areas.

*Biological Methods*

No effective biological control agents are currently available.

*Chemical Methods*

Herbicides alone will not successfully eradicate Johnson grass but can be effective when combined with mechanical methods (Newman 1990). William et al. (2002) presents a number of chemical altenatives including the following:

**Glyphosate** is a non-selective, foliar herbicide that has been effective in controlling Johnson grass in natural, non-agricultural sites. The recommended concentration is 2.25 lb. a.e./ A (William et al. 2002) applied when plants are 12-18 inches tall (CNAP 2000). Multiple applications for several years will be required.

**Fluazifop** (Fusillade) may also be effective at 0.25 – 0.375 lb. a.i./A (32-48 oz. product/ A) when plants are 8-18 inches tall and actively growing. A 1.0% v/v crop oil concentrate or 0.25% v/v nonionic surfactant is recommended (William et al. 2002).

**MEDUSAHEAD WILDRYE** ***TAENIATHERUM CAPUT-MEDUSAE***

Medusahead is a winter annual grass native to the Mediterranean region. Medusahead grows in relatively temperate regions of the arid west, especially on soils with high clay content (Dahl and Tisdale 1975). It is best adapted to areas with 25-50 cm of annual precipitation. The species matures later than other annual grasses and may require clay soils for their high water-holding capacity (Young and Evans 1970).

Medusahead produces large quantities of highly germinable seed. Seeds remain viable for three years or longer. Roots grow rapidly during the winter, reaching depths as great as 1 meter and depleting soil moisture before seedlings of native species can access it. These characteristics allow medusahead to outcompete native perennials and to even displace cheatgrass on mesic sites (Miller et al. 1999, Hironaka 1994, Harris 1977).

Medusahead establishes in intact, diverse communities of native perennials as well as in disturbed sites (Miller et al. 1999). Medusahead forms dense stands that exclude native species and provide low-quality forage for wildlife. Like cheatgrass, medusahead stands develop continuous litter mats which decompose slowly, smother microbiotic crusts, alter soil nutrient regimes, and contribute to increases in the severity, frequency, and extent of wildfires (Miller et al. 1999, Maurer 1988). The litter mat enhances medusahead germination and may help to exclude cheatgrass (Maurer 1988, Evans and Young 1970). After wildfire, medusahead recovers to or exceeds pre-fire abundance within a few years (Hironaka 1994, Young et al. 1972).

Medusahead has not been reported on the Hanford Reach National Monument but was recently discovered growing in the 200 West area on Central Hanford (R. Roos, H. Newsome pers. comm.). Medusahead is not classified as a noxious weed in Washington state (NWCB 2003a).

## Control

*Mechanical and Cultural Methods*

Plowing or disking, alone or in combination, provide some control. The effectiveness of these methods is much greater when combined with burning or with chemical herbicide treatments (Miller et al. 1999).

Burning medusahead prior to seed dissemination can reduce stands by 60-95% for the next growing season. Burning also removes the litter mat and enhances the establishment of desireable vegetation. Burning should be conducted in late spring or early summer before seed release, even while seeds are immature. Treatment the following spring with glyphosate herbicide (see below) increases control (Miller et al. 1999).

Medusahead is unpalatable to both wildlife and livestock due to its high silica content and long, rigid awns which can injure eyes and mouths (Miller et al. 1999).

*Biological Methods*

No biological agents are currently available for medusahead. The USDA Agricultural Research Service is investigating a crown rot fungus (*Fusarium culmorum*) for possible biological control (Miller et al. 1999).

*Chemical Methods*

**Glyphosate** has been effective at controlling medusahead when applied at 0.375 lb./A (0.41 kg/ha) early in spring before seedheads appear. This is a low rate that may allow native perennials to survive the treatment. Effectiveness is increased by prior burning, as described in the previous section, or by a second glyphosate application one month after the first. **Atrazine**, **bromacil**, and other compounds, alone or in combination, have also been used (Miller et al. 1999)

# V. Conclusions

This document presents a detailed plan for the management of invasive plant species that pose critical threats to the biological resources of the Hanford Reach National Monument. The U.S. Fish and Wildlife Service will utilize an Integrated Pest Management (IPM) approach to identify and treat targeted invasive plant species on the Hanford Reach National Monument. Manual, mechanical, biological, cultural (e.g., prescribed fire, competitive plantings), and chemical treatment methods will be utilized to achieve prioritized weed control objectives. Invasive species managers will draw upon the full range of appropriate control technologies to develop integrated treatment plans for target species at selected priority sites. Treatment methodologies will be based upon the best information available from weed management literature and professional experience, tailored to the characteristics of the particular species and site. Treatment success will be carefully monitored and management plans will be modified based upon evaluation of these findings. This approach is recommended to other comanagers of Monument lands as well.

The provisions in this plan can and should grow and change in response to changes in invasive species populations, new information concerning either invasive species autecology or biological resources, advances in weed management technologies, and clarification of Monument conservation goals.

Weed laws, personnel, conservation goals, and even the invasive species of greatest concern may change over time, but invasive plant species will remain a relatively constant threat to native biodiversity in the Columbia Basin. Effective management and control of invasive plant species on the Hanford Reach National Monument will require a dedicated, persistent, and long-term effort. Careful planning must be coupled with sufficient resources to sustain determined and long-term inventory and control efforts in the field. In a large landscape like the Columbia Basin and the Hanford Site, where noxious weeds are established, costs of control efforts can be substantial. However, the consequences of failing to meet the challenges of invasive species will be the decline of irreplaceable biological resources. Overall program costs should decline as control objectives are gradually met.

This inventory and management plan dealt only with invasive vascular plant species. However, some species of non-native insects, mollusks, fish, birds, reptiles, amphibians, and mammals are likely to have important impacts on the native biodiversity of the Hanford Site, now or in the future. Inventories of all taxa likely to have deleterious effects upon conservation targets are strongly recommended.

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Robert Leonard. Moses Coulee/Beazly Hills Weed Coordinator. The Nature Conservancy, Wenatchee, WA.

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# Appendices

# APPENDIX A

Emergency Contact Information
Hanford Reach National Monument and Vicinity

ALL EMERGENCIES: 911

**Hospitals:**

| | | |
|---|---|---|
| Kadlec General Hospital | 888 Swift Blvd, Richland | 509-946-4611 |
| Kennewick General Hospital | 900 S. Auburn Ave, Kennewick | 509-586-6111 |
| Our Lady of Lourdes | 520 N. 4th St, Pasco | 509-547-7704 |
| Othello Community Hospital | 315 N. 14th St, Othello | 509-488-2636 |

**County EMS:**

Adams ........ 509-488-2061
Benton ........ 509-628-2600
Franklin ........ 509-545-3546

**Law Enforcement:**

Adams County ........ 509-488-2061
Benton County ........ 509-628-0333
Franklin County ........ 509-545-3510
Grant County ........ 509-762-1160
Washington State Patrol ........ 509-765-9171
Hanford Patrol ........ 509-373-3800
Poison Control Center ........ 800-732-6985
Hanford Dispatch ........ 509-373-3856

**Hanford Reach National Monument** ........ 509-371-1801

# APPENDIX B

## Washington State Weed Law: Noxious Weed Classes and Regions

### 1. Washington State Noxious Weed Classification (NWCB 2003a)

#### Class A

Class A noxious weeds are non-native species with a limited distribution within the state. State law requires eradication of Class A weeds.

#### Class B

Class B noxious weeds are non-native species that are established in some regions of Washington, but are of limited distribution or not present in other regions of the state. Because of differences in distribution, treatment of Class B weeds varies between regions of the state. In regions where a Class B noxious weed is unrecorded or of limited distribution, the species is classified as a 'Class B Designate': prevention of seed production is required. In regions where a Class B species is already abundant or widespread, control is a local option. In these areas the species is a 'Class B Non-designate'; containment, gradual reduction, and prevention of further spread are the chief goals.

#### Class C

Class C noxious weeds are non-native species that are already widely established within the state. Control measures are not required by state law, but are a local option.

#### Monitor List

The Monitor List is maintained for non-native species that may be invasive in Washington or which exists in an adjacent state or province or occurs on an adjacent state or province's noxious weed list and is not known from Washington. Additional information is needed on distribution, abundance or biology.

**2. Washington State Noxious Weed Management Regions in and around the Hanford Reach National Monument**

**Region 6**

a. All lands lying within the boundaries of Kittitas and Grant Counties.
b. All lands lying within the boundaries of Chelan and Douglas Counties and south of Highway 2.
c. All lands lying within the boundaries of Yakima County and north of Highway 12 from the Yakima-Lewis County line to Yakima and north of Highway 82 from Yakima to the Yakima-Kittitas County line.
d. All lands lying within the boundaries of Range 28E, 29E and 30E of Adams County.

**Region 9**

a. All lands lying within the boundaries of Benton and Klickitat Counties.
b. All lands lying within the boundaries of Yakima County and south of Highway 12 from the Yakima-Lewis County line to Yakima and south of Highway 82 from Yakima to the Yakima-Kittitas County line.
c. All lands lying within the boundaries of Franklin County and west of Highway 395.

# APPENDIX C

## Explanations of Selected Chemical Terms

### 1. Herbicide Formulations and Calculations: Active Ingredient or Acid Equivalent?

Aaron Hager and Christy Sprague. 2000. Tables and figures not included: See http://www.ag.uiuc.edu/cespubs/pest/articles/20002j.html.

Most people who routinely use pesticides are familiar with the term active ingredient. The active ingredient of a pesticide formulation is the component responsible for its toxicity (phytotoxicity for herbicides) or ability to control the target pest. The active ingredient is always identified on the pesticide label, either by common name (atrazine or bentazon, for example) or chemical name (2,4-dichlorphenoxy acetic acid or diglycolamine salt of 3,6-dichlor-o-anisic acid, for example). The active ingredient statement may also include information about how the product is formulated and the amount of active ingredient contained in a gallon or pound of formulated product. For example, the Basagran label indicates the active ingredient (bentazon) is formulated as the sodium salt, and one gallon of Basagran contains 4 pounds of active ingredient.

Usually when an herbicide trade name is followed by a number and letter designation (4L, 75DF, 7EC, etc.), the number indicates how many pounds of active ingredient are in a gallon (for liquid formulations) or pound (for dry formulations) of the formulated product. The formulation designations for Basagran 4L, AAtrex 90DF, and Prowl 3.3EC indicate Basagran 4L contains 4 pounds of active ingredient (bentazon) per gallon of formulated product, AAtrex 90DF contains 0.90 pound of active ingredient (atrazine) per pound of formulated product, and Prowl 3.3EC contains 3.3 pounds of active ingredient (pendimethalin) per gallon of formulated product, respectively.

Some herbicides (atrazine, for example) have specific maximum-per-year application rates that cannot be exceeded. These maximum-per-year application rates are generally presented in terms of the total amount of active ingredient that can be applied per year. How would you calculate the pounds of active ingredient applied at a given product use rate? There are several calculations that can be used to determine the amount of active ingredient applied at a given product use rate. One of the easiest calculations is

lbs. active ingredient (a.i.) per acre = gallons or lbs. product applied/ acre x lbs. a.i./ gallons or lbs. product

Using this equation, we can calculate the amount of active ingredient (bentazon) that is applied when we apply 2 pints (0.25 gallon) per acre of Basagran 4L:

Sometimes, however, the numbers preceding the formulation designation (L, EC, DF, etc.) do not indicate pounds active ingredient per gallon or pound but rather the acid equivalent per gallon or pound. The term acid equivalent is one that many people are less familiar with. Acid equivalent may be defined as that portion of a formulation (as in the case of 2,4-D ester, for example) that theoretically could be converted back to the corresponding or parent acid. Another definition of acid equivalent is the theoretical yield of parent acid from a pesticide active ingredient that has been formulated as a derivative (esters, salts, and amines are examples of derivatives). For instance, the acid equivalent of the isooctyl ester of 2,4-D is 66 percent of the ester formulation but 88 percent of the ethyl acetate ester formulation. Why would an herbicide (one that has the acid as the parent molecule) be formulated as a derivative (ester, salt, amine, etc.) of the parent acid?

An herbicide molecule may sometimes be altered to impart some property other than herbicidal activity. Herbicidal activity refers to the ability of a particular herbicide to effectively bind to a target site within the plant and exert some type of lethal effect (i.e., you apply the herbicide to the plant and the plant eventually dies). Such alterations are possible with herbicide molecules that are acids (for example, molecules that have a carboxyl group as part of their structure). The acidic carboxyl hydrogen is replaced by the desired ions to form a salt or reacted with an alcohol to form an ester. Why would this be done? For example, due to the chemical characteristics of a particular herbicide molecule, the parent acid may not be readily absorbed into a plant, because it's not able to effectively penetrate the waxy cuticle covering the leaf. Somehow altering the parent acid may increase the ability of the herbicide to penetrate through the leaf much more effectively. For some postemergence herbicides, formulating the parent acid as an ester or salt is frequently done to facilitate absorption through the leaf. Other formulations or derivatives of the parent acid may increase the water solubility of the herbicide. 2,4-D (2,4-dichlorphenoxy acetic acid) is commonly formulated as an ester or amine. The ester formulation increases the lipid solubility of the herbicide, which allows it to more easily penetrate the waxy cuticle of the plant leaf. The amine formulation greatly increases the water solubility of the herbicide, which may be desirable if the product needs to be moved into the soil solution for root uptake (brush control, for example).

If an herbicide is formulated as a derivative of the parent acid, it is important to remember that the parent acid is the herbicidally active portion of the formulation. The parent acid is what binds to the herbicide target site within the plant and causes plant death. The salt or ester portion of the formulated product may allow for greater absorption into the plant but plays no role in binding to the herbicide target site. For example, when an ester herbicide penetrates the cuticle, enzymes convert the ester back to the parent acid, so following absorption, the ester part of the formulation plays no role in herbicidal activity. Modification of the parent acid (formulation as a salt, ester, or amine) may increase the amount of active ingredient in a formulation, because the amount of active ingredient listed on a product label includes both the weight of the parent acid and the weight of the salt or ester. Modification does not always, however, increase the amount of acid (herbicidally active portion) in the formulation. The acid equivalent represents the original acid portion of the molecule and is used for "apples-to-apples" comparisons of different formulations containing the same acid. Another example will hopefully alleviate some the confusion.

2,4-D can be formulated as various esters. The chain length of the ester can be varied but is most commonly eight carbon atoms long (isooctyl ester). Let's assume we have two ester formulations of 2,4-D: the first has only two carbon atoms forming the ester, and the second has eight carbons forming the ester. The parent acid is the same in these two formulations; the only difference is the length of the ester. These can be visualized in the following diagrams.

The structure on the left is the parent acid of 2,4-D. The second diagram is the parent acid, formulated with a 2-carbon side chain (the two added carbons are in bold text), and the third diagram is the parent acid, formulated with an 8-carbon side chain (again, the added carbon atoms are in bold text). While these added carbon atoms may modify some aspect of herbicide performance (the isooctyl ester is the most commonly used ester formulation of 2,4-D), it is the parent acid (the one depicted in the left diagram) that acts at the target site within the plant. The added carbon atoms of the esters add weight to the formulation and may increase the amount of active ingredient of a formulation, but they do not increase the amount of parent acid in the formulation. If these two formulations were commercially available, and someone wanted to know how much of the parent acid each formulation contained, the calculation to use would be based on the acid equivalent of the formulations, not the active ingredient of the formulations.

Let's assume that both the 2,4-D 2-carbon ester formulation and the 8-carbon ester formulation were commercially available and each contains 4 pounds of active ingredient per gallon. The application rate on the label is 1 pint per acre of either formulation. Since the application rates and the pounds of active ingredient per gallon are identical for each formulation, the amount of active ingredient applied would be the same for each formulation. If you doubt this, plug in the appropriate numbers for each formulation in the formula given previously for calculating the amount of active ingredient applied. Even though the amount of active ingredient applied is the same for each formulation, the amount of acid applied is not the same. Remember that it is the parent acid that binds to the target site to control the weed; the ester portion of the formulation is not involved in binding to the target site. How would we calculate the amount of acid applied?

The first step is to determine the amount of acid equivalent contained in a gallon of formulated product. Some labels indicate both the amount of active ingredient and acid equivalent contained in the formulation, while others list only active ingredient. If the pounds acid equivalent is specified on the product label, all you need to do to determine the pounds acid equivalent applied per acre is substitute pounds acid equivalent for pounds active ingredient in the equation presented previously for calculating the pounds active ingredient applied. For this example, however, let's assume that neither of these 2,4-D ester formulation labels indicates the amount of acid equivalent.

The formula that can be used to calculate the amount of acid equivalent contained in a gallon of formulated product is acid equivalent (a.e.) = molecular weight of the acid/ molecular weight of the salt or ester x 100

We now need to provide some molecular weights (i.e., how much the molecule weighs) to complete these calculations. The molecular weight of the parent 2,4-D acid is 221.04. The molecular weight of the 2-carbon ester formulation is 29.02 (weight of the two carbons and five hydrogens) + 221.04 (weight of the parent acid) = 250.06. The molecular weight of the 8-carbon ester formulation is 333.25.

The acid equivalent of the 2-carbon ester formulation is

acid equivalent = 221.04 – 1/ 250.06 x 100 – 88%

So the amount of acid equivalent in 1 gallon of formulated product is

88% a.e. x 4 lbs. active ingredient (a.i.)/ gallon = 3.52 lbs. a.i.

The acid equivalent of the 8-carbon ester formulation is:

a.i. = 221.04 – 1/ 333.25 x 100 – 66%

So the amount of acid equivalent in 1 gallon of formulated product is:

66% a.e. x 4 lbs. a.i./ gallon = 2.64 lbs. a.i.

Again we applied 1 pint (0.125 gallon) per acre of each formulation, and because they both contain 4 pounds active ingredient per gallon, the amount of active ingredient applied is equal. The amount of acid applied (that part of the formulation that actually controls the weed) for each formulation is not equal.

The amount of acid applied per acre with the 2-carbon ester formulation is:

0.125 gallons of product applied/ Acre x 3.52 lbs. per acre/ gallon of product – 0.44 lbs. applied per acre

The amount of acid applied per acre with the 8-carbon formulation is:

0.125 gallons of product applied/ Acre x 2.64 lbs. per acre/ gallon of product – 0.33 lbs. applied per acre

This example demonstrates that there was more acid applied with the 2-carbon ester formulation than with the 8-carbon formulation. In practical terms, more of the part of the formulation that actually controls the weeds was applied with the 2-carbon ester formulation. To compare the herbicidally active portion of two ester, salt, or amine formulations, product equivalents should be based on the acid equivalent of a salt or ester formulation.

This exercise was done to illustrate that, to calculate equivalent rates of salt or ester formulations, the acid equivalent calculation should be used. If there is only one formulation of a salt or ester product commercially available, it wouldn't really matter if you calculated active ingredient or acid equivalent. For example, Pursuit is formulated as the ammonium salt of imazethapyr, but currently only one manufacturer markets Pursuit. There are, however, several commercial formulations of 2,4-D and glyphosate. Referring to Table 5, you can see there are over 30 different commercial formulations of glyphosate available today, and more will likely be available in the future. Not all these formulations contain the same amount of acid equivalent, so if you want to determine equivalent rates of two glyphosate-containing formulations with respect to how many molecules of glyphosate are applied, you must calculate these rates based on acid equivalent. Table 6 lists some calculations of acid equivalents, based on an application rate of 1 pound active ingredient per acre. This table illustrates that, when calculations are based on equivalent active ingredient, the amount of acid applied may not always be equal. It is the acid portion of a salt formulation that binds at the target site.

The purpose of this article is to illustrate how to calculate differences in formulations based on either active ingredient or acid equivalent. Will differences in the amount of acid equivalent applied between two formulations result in weed-control differences? You might argue that, if the difference in amount of acid applied is large enough, differences in weed control might result and might be noticed on weeds against which the herbicide is "marginal." However, it is difficult to make an all-inclusive statement that weed-control differences will always result if differing amounts of acid are applied, especially when the difference in amount of acid applied is small. Labeled application rates are established by herbicide manufacturers based on product testing. It does not seem likely that a herbicide manufacturer would market an herbicide at an application rate that would consistently result in reduced weed control compared to a competitive formulation.

## 2. How are percentages by volume calculated?

Fred Senese. 2002. Available online at: http://antoine.frostburg.edu/chem/senese/101/solutions/faq/percentage-by-volume.shtml

Volume-to-volume (vol/vol) percentage is calculated as:

$$\text{Volume \%} = \frac{\text{volume of substance}}{\text{volume of total solution}} \times 100\%$$

For example, to prepare 100 ml of 5% (v/v) solution of ethanol, pipette 5 ml of ethanol into the bottom of a 100 ml flask and dilute to the mark with water. Careful, though. The denominator specifically says volume of total solution and NOT volume of solvent. This makes a difference, because volumes are not additive. 5 ml ethanol plus 95 ml of water does NOT equal 100 ml of solution!

# APPENDIX D

Invasive Plant Species Occurrence Form

**Weed Occurrence Report** **Date:** ____________________

**Management Unit:** ______________ Recorder(s):______________________ USGS Quadrangle: ______________________

| Species (#) | UTM NAD27 | | Map Type | Size | | | | Associated Vegetation | Location | Markers | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | East | North | | L (m) | W (m) | % Cvr | Phenology | | | Type | Color |
| | | | | | | | | | | | |
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| | | | | | | | | | | | |

**Weed Occurrence Report** **Date: ______________________**

INSTRUCTIONS

**Species (#)** – Species name or code. Numbers may be attached to codes to temporarily distinguish between occurrences.

**UTM NAD27** -- All coordinates are recorded in UTM datum NAD27.

**Map Type --** Occurrences are recorded as points (PT) lines (L) or polygons (POLY).

**Size –** Length and width of invasive species occurrence, in meters.

**Phenology –** Phenological stages are as follows: seedling; rosette; bolt; flowering, seed (i.e., maturing seeds are on the plant, ready to disperse); mature (plant is past the seeding stage; seeds are all, or nearly all, dispersed); dead.

**Associated Vegetation –** Name of community type or names of dominant plant species in the vicinity.

**Location** – Information to help treatment crew accurately relocate the site. Use landmarks where possible.

**Markers –** Where appropriate, occurrence boundaries or individual plants are marked using flagging tape (T) or wire flags (WF).

# APPENDIX E

## Comprehensive List of Invasive Plant Species Occurrences

**Dimensions.** Length and width are entered for point and line occurrences only. Perimeter length is entered for polygon occurrences only.

**Coordinates.** All coordinates are in UTM datum NAD27. For occurrences mapped as polygons, the coordinates given are the centroids of the polygons. Two sets of coordinates -- the start point and the end point -- are displayed for line occurrences only.

**Management Units.** ALE = Arid Lands Ecology Reserve Unit; CR = Columbia River Corridor Unit; MR = McGee Ranch - Riverlands Unit; SM = Saddle Mountain unit; VB = Vernita Bridge Unit; W = Wahluke Unit.

Priority treatment sites are displayed in **bold**.

| Weed Name | Species Priority | Year Recorded | Mgmt. Unit | Occurrence type | Coordinates | | Coordinates | | Dimensions | | | Area (m2) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | E | N | E | N | Length (m) | Width (m) | Perimeter | |
| **Acroptilon repens** | **2** | **2003** | **MR** | **Point** | **286612** | **5161819** | | | **8** | **8** | | **64** |
| **Acroptilon repens** | **2** | **2003** | **MR** | **Point** | **286772** | **5165279** | | | **0.1** | **0.1** | | **0.01** |
| **Acroptilon repens** | **2** | **2003** | **MR** | **Point** | **287367** | **5165422** | | | **0.5** | **0.5** | | **0.25** |
| **Acroptilon repens** | **2** | **2003** | **MR** | **Point** | **287881** | **5162729** | | | **25** | **25** | | **625** |
| **Acroptilon repens** | **2** | **2002** | **ALE** | **Polygon** | **292639.37** | **5153468.09** | | | | | **177.46** | **2499.93** |
| **Acroptilon repens** | **2** | **2002** | **ALE** | **Polygon** | **295864.64** | **5147222.79** | | | | | **157.5** | **1663.48** |
| **Acroptilon repens** | **2** | **2002** | **ALE** | **Point** | **303884.33** | **5140517.47** | | | **0.01** | **0.01** | | **0.0001** |
| Acroptilon repens | 2 | 2003 | MR | Polygon | 285756.74 | 5166684.09 | | | | | 420.15 | 8935.83 |
| Acroptilon repens | 2 | 2002 | MR | Point | 287454.78 | 5165836.5 | | | 10 | 10 | | 100 |
| Acroptilon repens | 2 | 2002 | MR | Polygon | 287467.83 | 5165858.5 | | | | | 144.17 | 1649.95 |
| Acroptilon repens | 2 | 2003 | MR | Polygon | 287583.99 | 5166227.05 | | | | | 248.84 | 1886.54 |
| Acroptilon repens | 2 | 2003 | MR | Polygon | 287741.92 | 5166529.01 | | | | | 254.34 | 1474.47 |
| Acroptilon repens | 2 | 2003 | MR | Point | 288385 | 5166232 | | | 5 | 25 | | 125 |
| Acroptilon repens | 2 | 2003 | MR | Point | 288686 | 5166221 | | | 3 | 25 | | 75 |
| Acroptilon repens | 2 | 2002 | MR | Polygon | 289511.39 | 5167719.84 | | | | | 2431.47 | 153767.01 |
| Acroptilon repens | 2 | 2002 | MR | Polygon | 289557.41 | 5167426.08 | | | | | 685.57 | 35195.57 |
| Acroptilon repens | 2 | 2002 | MR | Polygon | 289931.16 | 5167610.3 | | | | | 981 | 70644.63 |
| Acroptilon repens | 2 | 2002 | MR | Polygon | 290636.81 | 5162585.91 | | | | | 4428.68 | 1121003.82 |
| Acroptilon repens | 2 | 2002 | ALE | Point | 291403.28 | 5148099.5 | | | 15.24 | 6.09 | | 92.9 |
| Acroptilon repens | 2 | 2002 | ALE | Point | 292668.03 | 5159377.5 | | | 2 | 1 | | 2 |
| Acroptilon repens | 2 | 2002 | ALE | Polygon | 293015.23 | 5153806.24 | | | | | 393.84 | 11555.8 |
| Acroptilon repens | 2 | 2002 | ALE | Polygon | 293052.15 | 5153697.54 | | | | | 125.5 | 1250.23 |
| Acroptilon repens | 2 | 2002 | ALE | Point | 294519.71 | 5152825 | | | 10 | 10 | | 100 |
| Acroptilon repens | 2 | 2002 | ALE | Polygon | 295510.29 | 5152789.74 | | | | | 3566.87 | 401889.54 |
| Acroptilon repens | 2 | 2002 | ALE | Point | 295918.09 | 5147255 | | | 15 | 15 | | 225 |
| Acroptilon repens | 2 | 2002 | ALE | Point | 296057.87 | 5152330.5 | | | 30 | 30 | | 900 |

| | Species | Year | Mgmt. | Occurrence | Coordinates | | Coordinates | | | Dimensions | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weed Name | Priority | Recorded | Unit | Type | E | N | E | N | Length (m) | Width (m) | Perimeter | Area (m2) |
| Acroptilon repens | 2 | 2002 | ALE | Polygon | 296185.71 | 5152367.01 | | | | | 501.95 | 19999.48 |
| Acroptilon repens | 2 | 2002 | ALE | Polygon | 302020.77 | 5150873.03 | | | | | 1732.26 | 117577.45 |
| Acroptilon repens | 2 | 2002 | ALE | Polygon | 303085.7 | 5150055.52 | | | | | 1186.66 | 64690.65 |
| Acroptilon repens | 2 | 2002 | SM | Polygon | 305759.32 | 5176464.81 | | | | | 972.03 | 74998.05 |
| Acroptilon repens | 2 | 2002 | CR | Polygon | 310835.75 | 5176113.1 | | | | | 319.6 | 7273.3 |
| Acroptilon repens | 2 | 2002 | CR | Polygon | 311405.3 | 5175451.83 | | | | | 543.19 | 12262.6 |
| Acroptilon repens | 2 | 2002 | W | Point | 314719.75 | 5179164.5 | | | 30 | 10 | | 300 |
| Acroptilon repens | 2 | 2003 | W | Line | 318092 | 5162638 | 326410.31 | 5153781.94 | 13411.34 | 50 | | 670567.07 |
| Acroptilon repens | 2 | 2003 | W | Point | 318442 | 5162446 | | | 25 | 10 | | 250 |
| Acroptilon repens | 2 | 2003 | W | Polygon | 318576.05 | 5162462.02 | | | | | 303.71 | 6585.26 |
| Acroptilon repens | 2 | 2002 | W | Point | 318924.25 | 5162972 | | | 25 | 32 | | 800 |
| Acroptilon repens | 2 | 2003 | W | Point | 318972 | 5161897 | | | 3 | 3 | | 9 |
| Acroptilon repens | 2 | 2003 | W | Polygon | 318988.4 | 5161698.39 | | | | | 3043.63 | 175771.81 |
| Acroptilon repens | 2 | 2002 | W | Point | 319241.68 | 5171284 | | | 0.01 | 0.01 | | 0.0001 |
| Acroptilon repens | 2 | 2002 | W | Polygon | 319829.42 | 5170687.2 | | | | | 2345.17 | 98241.91 |
| Acroptilon repens | 2 | 2002 | W | Polygon | 320630.96 | 5168823.62 | | | | | 931.52 | 41354.07 |
| Acroptilon repens | 2 | 2003 | W | Polygon | 321425.76 | 5159723.84 | | | | | 3051.4 | 176038.55 |
| Acroptilon repens | 2 | 2003 | W | Polygon | 323267.99 | 5159326.98 | | | | | 371.98 | 6669.58 |
| Acroptilon repens | 2 | 2003 | W | Polygon | 324356.01 | 5157916.59 | | | | | 2158.76 | 333557.06 |
| Acroptilon repens | 2 | 2002 | CR | Polygon | 325948.46 | 5143615.46 | | | | | 1632.83 | 150005.23 |
| Acroptilon repens | 2 | 2002 | CR | Polygon | 326184.38 | 5144317.61 | | | | | 1142 | 40281.15 |
| Acroptilon repens | 2 | 2002 | CR | Polygon | 326871.71 | 5148898.41 | | | | | 339.73 | 3380.06 |
| **Alhagi maurorum** | **1** | **2002** | **W** | **Point** | **314692.03** | **5179230.5** | | | **10** | **3** | | **30** |
| **Cardaria draba** | **2** | **2003** | **ALE** | **Point** | **292006** | **5159451** | | | **100** | **5** | | **500** |
| **Cardaria draba** | **2** | **2002** | **ALE** | **Polygon** | **295864.46** | **5147245.13** | | | | | **323.2** | **5847.49** |
| **Cardaria draba** | **2** | **2003** | **ALE** | **Point** | **296188** | **5148679** | | | **15** | **15** | | **225** |
| **Cardaria draba** | **2** | **2003** | **ALE** | **Point** | **296766** | **5147694** | | | **15** | **15** | | **225** |
| **Cardaria draba** | **2** | **2002** | **ALE** | **Polygon** | **297281.57** | **5147479.19** | | | | | **223.22** | **2321.15** |
| **Cardaria draba** | **2** | **2003** | **ALE** | **Polygon** | **297323.99** | **5147255.99** | | | | | **243** | **2266.6** |
| **Cardaria draba** | **2** | **2003** | **ALE** | **Point** | **297389** | **5147390** | | | **15** | **5** | | **75** |
| **Cardaria draba** | **2** | **2003** | **ALE** | **Point** | **297694** | **5147087** | | | **45** | **15** | | **675** |
| **Cardaria draba** | **2** | **2003** | **ALE** | **Polygon** | **298014.01** | **5146214.96** | | | | | **102.31** | **823.99** |
| **Cardaria draba** | **2** | **2003** | **ALE** | **Point** | **298110** | **5146234** | | | **20** | **25** | | **500** |
| **Cardaria draba** | **2** | **2003** | **ALE** | **Point** | **298135** | **5146272** | | | **25** | **25** | | **625** |
| **Cardaria draba** | **2** | **2002** | **ALE** | **Point** | **303856.46** | **5142935** | | | **0.01** | **0.01** | | **0.0001** |
| **Cardaria draba** | **2** | **2002** | **ALE** | **Point** | **304418.96** | **5143306.5** | | | **0.01** | **0.01** | | **0.0001** |
| **Cardaria draba** | **2** | **2002** | **ALE** | **Point** | **305203.43** | **5143941** | | | **0.01** | **0.01** | | **0.0001** |
| **Cardaria draba** | **2** | **2002** | **ALE** | **Point** | **308420.37** | **5138431.5** | | | **0.1** | **0.1** | | **0.01** |
| **Cardaria draba** | **2** | **2002** | **ALE** | **Point** | **311366.37** | **5138415.5** | | | **0.01** | **0.01** | | **0.0001** |
| Cardaria draba | 2 | 2003 | MR | Point | 286283 | 5161040 | | | 15 | 8 | | 120 |
| Cardaria draba | 2 | 2003 | MR | Point | 287091 | 5162730 | | | 22 | 15 | | 330 |
| Cardaria draba | 2 | 2003 | MR | Point | 287547 | 5166572 | | | 5 | 20 | | 100 |
| Cardaria draba | 2 | 2003 | MR | Point | 287836 | 5162516 | | | 12 | 4 | | 48 |
| Cardaria draba | 2 | 2003 | MR | Point | 287895 | 5162754 | | | 13 | 11 | | 143 |
| Cardaria draba | 2 | 2003 | MR | Polygon | 287901.99 | 5163131.99 | | | | | 157.07 | 1962.71 |

| | Species | Year | Mgmt. | Occurrence | Coordinates | | Coordinates | | | Dimensions | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weed Name | Priority | Recorded | Unit | Type | E | N | E | N | Length (m) | Width (m) | Perimeter | Area (m2) |
| Cardaria draba | 2 | 2003 | MR | Point | 287907 | 5162513 | | | 14 | 7 | | 98 |
| Cardaria draba | 2 | 2003 | MR | Point | 287909 | 5162651 | | | 25 | 10 | | 250 |
| Cardaria draba | 2 | 2003 | MR | Polygon | 288044.97 | 5163193.96 | | | | | 214.02 | 3453.72 |
| Cardaria draba | 2 | 2003 | MR | Polygon | 288091.02 | 5163143.98 | | | | | 185.03 | 2357.9 |
| Cardaria draba | 2 | 2003 | MR | Point | 288097 | 5162451 | | | 5 | 5 | | 25 |
| Cardaria draba | 2 | 2003 | MR | Polygon | 288143.01 | 5162391.04 | | | | | 160.85 | 1787.42 |
| Cardaria draba | 2 | 2003 | ALE | Point | 288610 | 5159949 | | | 35 | 25 | | 875 |
| Cardaria draba | 2 | 2003 | ALE | Point | 290201 | 5159732 | | | 30 | 30 | | 900 |
| Cardaria draba | 2 | 2002 | MR | Point | 290349.9 | 5162606 | | | 25 | 30 | | 750 |
| Cardaria draba | 2 | 2002 | MR | Polygon | 290400.04 | 5162234.53 | | | | | 580.13 | 25917.53 |
| Cardaria draba | 2 | 2003 | MR | Point | 290414 | 5162459 | | | 15 | 15 | | 225 |
| Cardaria draba | 2 | 2002 | MR | Polygon | 290424.57 | 5162607.92 | | | | | 743.36 | 42514.54 |
| Cardaria draba | 2 | 2003 | MR | Point | 290514 | 5162760 | | | 7 | 5 | | 35 |
| Cardaria draba | 2 | 2003 | MR | Polygon | 290577 | 5162457.96 | | | | | 141.95 | 1571.35 |
| Cardaria draba | 2 | 2003 | MR | Point | 290612 | 5162829 | | | 5 | 5 | | 25 |
| Cardaria draba | 2 | 2003 | MR | Point | 290638 | 5162805 | | | 15 | 15 | | 225 |
| Cardaria draba | 2 | 2003 | MR | Point | 290643 | 5162700 | | | 7 | 6 | | 42 |
| Cardaria draba | 2 | 2003 | ALE | Point | 291073 | 5149655 | | | 25 | 5 | | 125 |
| Cardaria draba | 2 | 2003 | ALE | Point | 291234 | 5159644 | | | 20 | 17 | | 340 |
| Cardaria draba | 2 | 2003 | ALE | Point | 291674 | 5159446 | | | 20 | 20 | | 400 |
| Cardaria draba | 2 | 2003 | ALE | Point | 292514 | 5153460 | | | 20 | 20 | | 400 |
| Cardaria draba | 2 | 2002 | ALE | Polygon | 292633.63 | 5158793.46 | | | | | 5010.45 | 1476496.32 |
| Cardaria draba | 2 | 2002 | ALE | Polygon | 293032.62 | 5153705.8 | | | | | 371.51 | 8068.68 |
| Cardaria draba | 2 | 2002 | ALE | Line | 293258.55 | 5153719.59 | 292655.63 | 5153751.08 | 644.14 | 5 | | 3220.73 |
| Cardaria draba | 2 | 2002 | ALE | Point | 295108.84 | 5152551.5 | | | 10 | 5 | | 50 |
| Cardaria draba | 2 | 2002 | ALE | Polygon | 295510.29 | 5152789.74 | | | | | 3566.87 | 401889.5 |
| Cardaria draba | 2 | 2002 | ALE | Line | 295867.66 | 5146962.46 | 295888.87 | 5147144.69 | 190.71 | 5 | | 953.55 |
| Cardaria draba | 2 | 2003 | ALE | Point | 295955 | 5147200 | | | 30 | 30 | | 900 |
| Cardaria draba | 2 | 2003 | ALE | Polygon | 296089.95 | 5148531.97 | | | | | 302.25 | 6783.12 |
| Cardaria draba | 2 | 2003 | ALE | Polygon | 296163.01 | 5148017.01 | | | | | 207.12 | 3140.98 |
| Cardaria draba | 2 | 2002 | ALE | Point | 296185.62 | 5148687 | | | 7 | 11 | | 77 |
| Cardaria draba | 2 | 2003 | ALE | Point | 296214 | 5148638 | | | 15 | 10 | | 150 |
| Cardaria draba | 2 | 2002 | ALE | Point | 296769.37 | 5147697.5 | | | 13 | 12 | | 156 |
| Cardaria draba | 2 | 2002 | ALE | Polygon | 301796.86 | 5150867.51 | | | | | 115.21 | 1053.62 |
| Cardaria draba | 2 | 2002 | ALE | Point | 302014.81 | 5150900.5 | | | 15 | 15 | | 225 |
| Cardaria draba | 2 | 2002 | ALE | Point | 302918.93 | 5149880.5 | | | 5 | 5 | | 25 |
| Cardaria draba | 2 | 2002 | ALE | Point | 303090.43 | 5150070.5 | | | 20 | 20 | | 400 |
| Cardaria draba | 2 | 2002 | ALE | Point | 303263.5 | 5150056.5 | | | 0.01 | 0.01 | | 0.0001 |
| Cardaria draba | 2 | 2003 | W | Polygon | 318345.04 | 5162337.95 | | | | | 314.35 | 7841.13 |
| Cardaria draba | 2 | 2002 | CR | Point | 325861.21 | 5143865 | | | 30 | 20 | | 600 |
| Cardaria draba | 2 | 2002 | CR | Polygon | 325981.15 | 5143473.91 | | | | | 224.9 | 879.51 |
| **Centaurea diffusa** | **1** | **2003** | **MR** | **Line** | **285971** | **5165479** | **286563** | **5165469** | **598.2** | **4** | | **2392.83** |
| **Centaurea diffusa** | **1** | **2002** | **MR** | **Point** | **286148.87** | **5164075** | | | **10** | **5** | | **50** |
| **Centaurea diffusa** | **1** | **2003** | **ALE & MR** | **Line** | **286268** | **5161063.73** | **291711.14** | **5159323.02** | **6315.64** | **20** | | **126312.95** |
| **Centaurea diffusa** | **1** | **2003** | **MR** | **Polygon** | **286476.38** | **5161931.11** | | | | | **1729.46** | **180376** |

| | Species | Year | Mgmt. | Occurrence | Coordinates | | Coordinates | | | Dimensions | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weed Name | Priority | Recorded | Unit | Type | E | N | E | N | Length (m) | Width (m) | Perimeter | Area (m2) |
| **Centaurea diffusa** | **1** | **2002** | **MR** | **Point** | **286512.93** | **5161879.5** | | | **0.01** | **0.01** | | **0.0001** |
| **Centaurea diffusa** | **1** | **2002** | **MR** | **Point** | **286747.09** | **5165258.5** | | | **5** | **2** | | **10** |
| **Centaurea diffusa** | **1** | **2002** | **MR** | **Point** | **286836.56** | **5165440** | | | **2** | **1** | | **2** |
| **Centaurea diffusa** | **1** | **2003** | **MR** | **Point** | **287670** | **5165389** | | | **15** | **3** | | **45** |
| Centaurea diffusa | 1 | 2003 | MR | Line | 285663 | 5166747 | 291334.64 | 5166504.38 | 5698.44 | 10 | | 56984.41 |
| Centaurea diffusa | 1 | 2002 | MR | Line | 286188.81 | 5161701.02 | 286182.67 | 5161085.88 | 615.17 | 5 | | 3075.85 |
| Centaurea diffusa | 1 | 2003 | MR | Line | 286203 | 5161767 | 290803 | 5162419.52 | 5345.7 | 5 | | 26728.51 |
| Centaurea diffusa | 1 | 2003 | MR | Line | 286251 | 5162763 | 286203 | 5161764 | 1000.15 | 5 | | 5000.76 |
| Centaurea diffusa | 1 | 2002 | MR | Polygon | 286691.64 | 5167405.08 | | | | | 2695.05 | 225995.02 |
| Centaurea diffusa | 1 | 2002 | MR | Point | 286736.99 | 5166001 | | | 0.01 | 0.01 | | 0.0001 |
| Centaurea diffusa | 1 | 2002 | ALE | Point | 286787.25 | 5150008 | | | 10 | 3 | | 30 |
| Centaurea diffusa | 1 | 2002 | MR | Line | 286805.67 | 5166071.15 | 287577.84 | 5165852 | 971.04 | 5 | | 4855.21 |
| Centaurea diffusa | 1 | 2003 | MR | Polygon | 286824.85 | 5162714.54 | | | | | 1257.78 | 125736.04 |
| Centaurea diffusa | 1 | 2002 | MR | Point | 287068.56 | 5165748 | | | 10 | 5 | | 50 |
| Centaurea diffusa | 1 | 2003 | MR | Line | 287801 | 5161992 | 287834 | 5162664 | 672.8 | 5 | | 3364.04 |
| Centaurea diffusa | 1 | 2002 | MR | Line | 288091.08 | 5167012.99 | 288077.28 | 5166620 | 394.02 | 5 | | 1970.11 |
| Centaurea diffusa | 1 | 2002 | VB | Line | 289063.54 | 5168316.62 | 289784.53 | 5169037.98 | 1830.4 | 5 | | 9152 |
| Centaurea diffusa | 1 | 2002 | ALE | Point | 289176.87 | 5149504 | | | 10 | 10 | | 100 |
| Centaurea diffusa | 1 | 2003 | MR | Point | 289345 | 5166148 | | | 60 | 10 | | 600 |
| Centaurea diffusa | 1 | 2002 | ALE | Line | 290009.27 | 5145988.83 | 290015.77 | 5146117.42 | 131.89 | 5 | | 659.47 |
| Centaurea diffusa | 1 | 2002 | VB | Line | 290009.28 | 5169047.99 | 290618.13 | 5169055.72 | 618.06 | 5 | | 3090.31 |
| Centaurea diffusa | 1 | 2002 | VB | Line | 290105.33 | 5168610.97 | 290673.69 | 5168949.89 | 663.01 | 5 | | 3315.05 |
| Centaurea diffusa | 1 | 2003 | MR | Point | 290292 | 5161630 | | | 0.01 | 0.01 | | 0.0001 |
| Centaurea diffusa | 1 | 2002 | VB | Polygon | 290726.5 | 5169038.33 | | | | | 643.13 | 25657.3 |
| Centaurea diffusa | 1 | 2002 | SM | Polygon | 290897.82 | 5169273.13 | | | | | 709.87 | 39998.96 |
| Centaurea diffusa | 1 | 2002 | ALE | Point | 291024.87 | 5149781 | | | 0.01 | 0.01 | | 0.0001 |
| Centaurea diffusa | 1 | 2002 | MR | Line | 291055.24 | 5168589.55 | 290982.62 | 5168538.09 | 89.21 | 5 | | 446.09 |
| Centaurea diffusa | 1 | 2002 | ALE | Point | 291060.81 | 5148493 | | | 4.57 | 6.09 | | 27.87 |
| Centaurea diffusa | 1 | 2002 | ALE | Line | 291201.95 | 5149591.88 | 296207.29 | 5148686.91 | 5469.96 | 5 | | 27349.8 |
| Centaurea diffusa | 1 | 2002 | ALE | Line | 291310.9 | 5147248 | 291609.67 | 5147637.6 | 498.2 | 5 | | 2491 |
| Centaurea diffusa | 1 | 2003 | MR | Line | 291334.64 | 5166482.63 | 285713.11 | 5167490.11 | 6461.29 | 10 | | 64612.92 |
| Centaurea diffusa | 1 | 2002 | ALE | Line | 291585.31 | 5147571 | 291395.14 | 5146256.8 | 1455.1 | 5 | | 7275.5 |
| Centaurea diffusa | 1 | 2002 | ALE | Line | 291632.68 | 5147724 | 291419.28 | 5148056.2 | 405.98 | 3 | | 1217.95 |
| Centaurea diffusa | 1 | 2002 | ALE | Point | 294501.75 | 5152795.5 | | | 3 | 1 | | 3 |
| Centaurea diffusa | 1 | 2002 | SM | Line | 294706.31 | 5171509.42 | 294852.03 | 5169468 | 2483.29 | 5 | | 12416.45 |
| Centaurea diffusa | 1 | 2002 | SM | Line | 295092.71 | 5171050 | 303082.84 | 5172847.18 | 8927.64 | 5 | | 44638.22 |
| Centaurea diffusa | 1 | 2002 | old Creek borr | Point | 296135.09 | 5153318 | | | 1.52 | 0.3 | | 0.46 |
| Centaurea diffusa | 1 | 2002 | ALE | Line | 296222.48 | 5148702.11 | 296070.27 | 5148710.2 | 153.32 | 3 | | 459.97 |
| Centaurea diffusa | 1 | 2002 | ALE | Line | 296266.4 | 5151599 | 291112.85 | 5149747 | 8663.35 | 1 | | 8663.35 |
| Centaurea diffusa | 1 | 2002 | ALE | Point | 296438.15 | 5149757 | | | 0.01 | 0.01 | | 0.0001 |
| Centaurea diffusa | 1 | 2002 | SM | Line | 297192.59 | 5174980 | 295738.12 | 5176004 | 1782.7 | 5 | | 8913.54 |
| Centaurea diffusa | 1 | 2002 | ALE | Line | 298272.17 | 5146446.71 | 298304.19 | 5146267.7 | 199.52 | 4 | | 798.08 |
| Centaurea diffusa | 1 | 2002 | ALE | Line | 299159.43 | 5142576 | 299361.44 | 5142135.33 | 571.22 | 10 | | 5712.26 |
| Centaurea diffusa | 1 | 2002 | ALE | Line | 299371.62 | 5142124 | 300351.19 | 5141189.27 | 1373.25 | 3 | | 4119.76 |
| Centaurea diffusa | 1 | 2002 | ALE | Line | 299725.9 | 5142327 | 299163.65 | 5142573.42 | 1116.66 | 3 | | 3349.98 |

| | Species | Year | Mgmt. | Occurrence | Coordinates | | Coordinates | | | Dimensions | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Weed Name** | **Priority** | **Recorded** | **Unit** | **Type** | **E** | **N** | **E** | **N** | **Length (m)** | **Width (m)** | **Perimeter** | **Area (m2)** |
| Centaurea diffusa | 1 | 2002 | SM | Polygon | 299768.38 | 5170983.98 | | | | | 30874.21 | 12540869.73 |
| Centaurea diffusa | 1 | 2002 | ALE | Polygon | 300540.54 | 5140960.03 | | | | | 137.48 | 1500.42 |
| Centaurea diffusa | 1 | 2002 | ALE | Line | 300543.33 | 5140955.69 | 300539.32 | 5140893.87 | 61.94 | 1 | | 61.94 |
| Centaurea diffusa | 1 | 2002 | ALE | Line | 300706.84 | 5141029.9 | 301272.91 | 5140939.61 | 573.25 | 4 | | 2293.03 |
| Centaurea diffusa | 1 | 2002 | ALE | Point | 300933.56 | 5140473.5 | | | 0.01 | 0.01 | | 0.0001 |
| Centaurea diffusa | 1 | 2002 | ALE | Line | 301132.06 | 5140022 | 301347.51 | 5140037.25 | 243.52 | 5 | | 1217.62 |
| Centaurea diffusa | 1 | 2002 | ALE | Point | 302408.61 | 5140757.59 | | | 0.01 | 0.01 | | 0.0001 |
| Centaurea diffusa | 1 | 2002 | SM | Line | 302991.3 | 5173601.82 | 302024.5 | 5173779.07 | 1641.62 | 5 | | 8208.1 |
| Centaurea diffusa | 1 | 2002 | ALE | Point | 303133.16 | 5140641.15 | | | 0.01 | 0.01 | | 0.0001 |
| Centaurea diffusa | 1 | 2002 | ALE | Line | 303737.44 | 5142893.54 | 305145.61 | 5143198.73 | 2688.91 | 3 | | 8066.74 |
| Centaurea diffusa | 1 | 2002 | ALE | Line | 304403.92 | 5140430.49 | 304677.88 | 5140387.2 | 277.46 | 5 | | 1387.32 |
| Centaurea diffusa | 1 | 2002 | SM | Line | 304638.68 | 5178327 | 304555.78 | 5178818 | 552.43 | 5 | | 2762.18 |
| Centaurea diffusa | 1 | 2002 | CR | Polygon | 306127.45 | 5175283.36 | | | | | 958.83 | 40907.56 |
| Centaurea diffusa | 1 | 2002 | W | Line | 306813.33 | 5179225.1 | 306808.92 | 5179125 | 100.19 | 3 | | 300.58 |
| Centaurea diffusa | 1 | 2002 | CR | Polygon | 307165.54 | 5177513.88 | | | | | 1248.02 | 59762.7 |
| Centaurea diffusa | 1 | 2002 | CR | Polygon | 308354.96 | 5177120.6 | | | | | 5002.78 | 502002.43 |
| Centaurea diffusa | 1 | 2002 | CR | Polygon | 310347.06 | 5176431.48 | | | | | 1588.77 | 89804.4 |
| Centaurea diffusa | 1 | 2002 | W | Line | 310680.19 | 5185237.13 | 313250.83 | 5184810.99 | 2701.19 | 5 | | 13505.95 |
| Centaurea diffusa | 1 | 2002 | CR | Polygon | 310730.61 | 5176177.07 | | | | | 1041.64 | 58841.64 |
| Centaurea diffusa | 1 | 2002 | CR | Polygon | 311122.95 | 5175708.9 | | | | | 2542.25 | 225557.56 |
| Centaurea diffusa | 1 | 2002 | W | Polygon | 311540.59 | 5184620.9 | | | | | 660.51 | 33784.66 |
| Centaurea diffusa | 1 | 2002 | W | Line | 311565.06 | 5184463.6 | 312030.61 | 5184131 | 591.01 | 5 | | 2955.09 |
| Centaurea diffusa | 1 | 2002 | W | Polygon | 313348.97 | 5184767.67 | | | | | 693.69 | 37145.54 |
| Centaurea diffusa | 1 | 2002 | W | Line | 314675.5 | 5179224.4 | 314692.4 | 5179198 | 31.34 | 1 | | 31.34 |
| Centaurea diffusa | 1 | 2003 | W & CR | Polygon | 318091.41 | 5162535.87 | | | | | 198.27 | 2901.46 |
| Centaurea diffusa | 1 | 2003 | W | Polygon | 318194.2 | 5162638.16 | | | | | 668.83 | 23560.54 |
| Centaurea diffusa | 1 | 2002 | W | Line | 318268.36 | 5162545.96 | 318217.06 | 5162489 | 77.48 | 5 | | 387.4 |
| Centaurea diffusa | 1 | 2003 | W | Point | 318349 | 5162411 | | | 1 | 1 | | 1 |
| Centaurea diffusa | 1 | 2002 | W | Line | 318931.68 | 5162151 | 318735.31 | 5161649 | 618.02 | 5 | | 3090.14 |
| Centaurea diffusa | 1 | 2002 | W | Line | 319183.21 | 5161887 | 318777 | 5161679 | 543.11 | 5 | | 2715.59 |
| Centaurea diffusa | 1 | 2002 | W | Line | 319252.11 | 5161774.56 | 319124.09 | 5161827 | 158.53 | 5 | | 792.69 |
| Centaurea diffusa | 1 | 2002 | W | Polygon | 320325.56 | 5161223.48 | | | | | 1654.83 | 125444.95 |
| Centaurea diffusa | 1 | 2002 | W | Polygon | 321327.69 | 5160075.77 | | | | | 501.95 | 19999.48 |
| Centaurea diffusa | 1 | 2002 | W | Line | 321433.5 | 5159698 | 321433.5 | 5159698 | 82.09 | 5 | | 410.47 |
| Centaurea diffusa | 1 | 2002 | W | Line | 321475.81 | 5159955 | 321433.5 | 5159698 | 279.28 | 5 | | 1396.44 |
| Centaurea diffusa | 1 | 2002 | W | Line | 324223.38 | 5158179.02 | 318176.37 | 5162599.15 | 7734.86 | 5 | | 38674.3 |
| Centaurea diffusa | 1 | 2002 | CR | Point | 325834.65 | 5144247.5 | | | 3 | 3 | | 9 |
| Centaurea diffusa | 1 | 2002 | CR | Point | 325931.68 | 5144010.5 | | | 5 | 5 | | 25 |
| Centaurea diffusa | 1 | 2002 | CR | Point | 326399.46 | 5150572 | | | 12 | 5 | | 60 |
| **Centaurea solstitialis** | **1** | **2002** | **W** | **Point** | **306868.65** | **5180014** | | | **40** | **10** | | **400** |
| **Centaurea solstitialis** | **1** | **2002** | **W** | **Point** | **306873.68** | **5179608** | | | **20** | **3** | | **60** |
| **Centaurea solstitialis** | **1** | **2002** | **W** | **Point** | **307041.4** | **5180002** | | | **0.01** | **0.01** | | **0.0001** |
| **Centaurea solstitialis** | **1** | **2003** | **W** | **Point** | **318127** | **5162551** | | | **10** | **10** | | **100** |
| **Centaurea solstitialis** | **1** | **2003** | **W** | **Point** | **318306** | **5162485** | | | **3** | **3** | | **9** |
| **Centaurea solstitialis** | **1** | **2003** | **W** | **Point** | **318428** | **5163896** | | | **10** | **5** | | **50** |

| | Species | Year | Mgmt. | Occurrence | Coordinates | | Coordinates | | | Dimensions | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weed Name | Priority | Recorded | Unit | Type | E | N | E | N | Length (m) | Width (m) | Perimeter | Area (m2) |
| **Centaurea solstitialis** | **1** | **2003** | **W** | **Point** | **318482** | **5163896** | | | **2** | **2** | | **4** |
| **Centaurea solstitialis** | **1** | **2003** | **W** | **Point** | **318494** | **5163816** | | | **7** | **1** | | **7** |
| **Centaurea solstitialis** | **1** | **2003** | **W** | **Point** | **318497** | **5163780** | | | **0.01** | **0.01** | | **0.0001** |
| **Centaurea solstitialis** | **1** | **2003** | **W** | **Point** | **318890** | **5161815** | | | **2** | **2** | | **4** |
| **Centaurea solstitialis** | **1** | **2002** | **W** | **Point** | **318953.62** | **5162858.5** | | | **5** | **2** | | **10** |
| **Centaurea solstitialis** | **1** | **2002** | **W** | **Point** | **318984.46** | **5162971.5** | | | **0.01** | **0.01** | | **0.0001** |
| **Centaurea solstitialis** | **1** | **2002** | **W** | **Point** | **319067.71** | **5162997.5** | | | **4** | **4** | | **16** |
| **Centaurea solstitialis** | **1** | **2002** | **W** | **Point** | **319478.68** | **5162424** | | | **60** | **12** | | **720** |
| **Centaurea solstitialis** | **1** | **2002** | **W** | **Point** | **319566.31** | **5164950.5** | | | **0.01** | **0.01** | | **0.0001** |
| **Centaurea solstitialis** | **1** | **2002** | **W** | **Point** | **319645.12** | **5165047.5** | | | **0.01** | **0.01** | | **0.0001** |
| **Centaurea solstitialis** | **1** | **2002** | **W** | **Point** | **319927.96** | **5165455.5** | | | **0.01** | **0.01** | | **0.0001** |
| **Centaurea solstitialis** | **1** | **2002** | **W** | **Point** | **320412.15** | **5162343.5** | | | **1** | **1** | | **1** |
| **Centaurea solstitialis** | **1** | **2002** | **W** | **Polygon** | **321326.93** | **5160133.71** | | | | | **131.23** | **752.69** |
| Centaurea solstitialis | 1 | 2002 | W | Polygon | 317926.77 | 5162883.65 | | | | | 352.45 | 7131.96 |
| Centaurea solstitialis | 1 | 2003 | W | Polygon | 318356.14 | 5162462.99 | | | | | 680.96 | 35379.6 |
| Centaurea solstitialis | 1 | 2002 | W | Polygon | 318938.6 | 5162425.29 | | | | | 974.45 | 45219.14 |
| Centaurea solstitialis | 1 | 2002 | W | Polygon | 319201.65 | 5162802.4 | | | | | 7110.01 | 916116.15 |
| Centaurea solstitialis | 1 | 2003 | W | Polygon | 319765.7 | 5164974.83 | | | | | 539.85 | 17758.88 |
| Centaurea solstitialis | 1 | 2003 | W | Polygon | 319768.24 | 5165302.1 | | | | | 289.57 | 4629.6 |
| Centaurea solstitialis | 1 | 2002 | W | Line | 319859.28 | 5162456.95 | 319537.79 | 5162542.49 | 580.38 | 2 | | 1160.77 |
| Centaurea solstitialis | 1 | 2003 | W | Polygon | 319874.31 | 5165229.77 | | | | | 229.42 | 3030.65 |
| Centaurea solstitialis | 1 | 2003 | W | Polygon | 319935.09 | 5164708.65 | | | | | 2077.74 | 107416.85 |
| Centaurea solstitialis | 1 | 2002 | W | Polygon | 320325.53 | 5161223.53 | | | | | 1654.86 | 125471.08 |
| **Chondrilla juncea** | **1** | **2002** | **ALE** | **Point** | **289997.93** | **5145982.5** | | | **0.01** | **0.01** | | **0.0001** |
| **Chondrilla juncea** | **1** | **2002** | **ALE** | **Point** | **300220.71** | **5146550** | | | **0.01** | **0.01** | | **0.0001** |
| **Chondrilla juncea** | **1** | **2002** | **ALE** | **Point** | **301090.55** | **5144612.99** | | | **15** | **15** | | **225** |
| **Chondrilla juncea** | **1** | **2002** | **ALE** | **Point** | **310004** | **5138830.99** | | | **20** | **20** | | **400** |
| **Chondrilla juncea** | **1** | **2002** | **ALE** | **Point** | **310178.03** | **5138690** | | | **10** | **8** | | **80** |
| **Chondrilla juncea** | **1** | **2002** | **W** | **Point** | **315317.59** | **5171925** | | | **0.1** | **0.1** | | **0.01** |
| **Chondrilla juncea** | **1** | **2002** | **W** | **Point** | **317575.46** | **5163278.5** | | | **0.3** | **0.3** | | **0.09** |
| **Chondrilla juncea** | **1** | **2002** | **W** | **Point** | **317928.9** | **5162878** | | | **0.3** | **0.3** | | **0.09** |
| **Chondrilla juncea** | **1** | **2002** | **W** | **Point** | **318162** | **5162566** | | | **1** | **1** | | **1** |
| **Chondrilla juncea** | **1** | **2002** | **W** | **Point** | **319927.37** | **5165452.5** | | | **0.01** | **0.01** | | **0.0001** |
| **Chondrilla juncea** | **1** | **2002** | **W** | **Point** | **320356.06** | **5160979.5** | | | **0.01** | **0.01** | | **0.0001** |
| **Chondrilla juncea** | **1** | **2002** | **CR** | **Point** | **325908.09** | **5142942** | | | **0.01** | **0.01** | | **0.0001** |
| **Chondrilla juncea** | **1** | **2002** | **CR** | **Point** | **325960.87** | **5143739.5** | | | **4** | **4** | | **16** |
| **Chondrilla juncea** | **1** | **2002** | **CR** | **Point** | **325964** | **5143869** | | | **0.02** | **0.02** | | **0.0004** |
| **Chondrilla juncea** | **1** | **2002** | **CR** | **Point** | **326381.59** | **5150684** | | | **0.3** | **0.3** | | **0.09** |
| **Chondrilla juncea** | **1** | **2002** | **CR** | **Point** | **326504.21** | **5150956** | | | **5** | **5** | | **25** |
| **Chondrilla juncea** | **1** | **2002** | **CR** | **Point** | **326877.25** | **5148979.5** | | | **5** | **3** | | **15** |
| Chondrilla juncea | 1 | 2003 | ALE | Polygon | 300373.98 | 5148306.72 | | | | | 1085.17 | 39690.5 |
| Chondrilla juncea | 1 | 2002 | ALE | Line | 304231.99 | 5138027.47 | 305814.77 | 5138800.08 | 1902.67 | 3 | | 5708.02 |
| Chondrilla juncea | 1 | 2002 | SM | Polygon | 305635.92 | 5176511.23 | | | | | 283.94 | 6399.83 |
| Chondrilla juncea | 1 | 2002 | ALE | Line | 307158.66 | 5139071.52 | 311941.51 | 5138072.38 | 5307.24 | 5 | | 26536.21 |
| Chondrilla juncea | 1 | 2002 | CR | Polygon | 307985.29 | 5177188.82 | | | | | 303.36 | 7047.9 |

| | Species | Year | Mgmt. | Occurrence | Coordinates | | Coordinates | | | Dimensions | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weed Name | Priority | Recorded | Unit | Type | E | N | E | N | Length (m) | Width (m) | Perimeter | Area (m2) |
| Chondrilla juncea | 1 | 2002 | CR | Polygon | 308282.11 | 5177308.12 | | | | | 286.26 | 6289.36 |
| Chondrilla juncea | 1 | 2002 | ALE | Polygon | 312215.78 | 5140617.47 | | | | | 9676.29 | 2614645.11 |
| Chondrilla juncea | 1 | 2003 | W | Polygon | 319889.53 | 5165305.6 | | | | | 175.72 | 1453.47 |
| Chondrilla juncea | 1 | 2002 | CR | Polygon | 325644.44 | 5154225.14 | | | | | 172.27 | 2128.64 |
| Chondrilla juncea | 1 | 2002 | CR | Polygon | 325674.14 | 5154277.45 | | | | | 169.82 | 2067.92 |
| Chondrilla juncea | 1 | 2002 | CR | Polygon | 325790.66 | 5153953.91 | | | | | 604.29 | 16329.21 |
| Chondrilla juncea | 1 | 2002 | CR | Polygon | 325879.83 | 5153680.89 | | | | | 154.3 | 1716.34 |
| Chondrilla juncea | 1 | 2002 | CR | Polygon | 326125.07 | 5144558.89 | | | | | 541.16 | 19447.95 |
| Chondrilla juncea | 1 | 2002 | CR | Polygon | 326839.95 | 5149294.42 | | | | | 1093.12 | 50185.93 |
| **Cirsium arvense** | **2** | **2002** | **VB** | **Point** | **290673.78** | **5169210.5** | | | **0.01** | **0.01** | | **0.0001** |
| **Cirsium arvense** | **2** | **2002** | **VB** | **Point** | **290745.63** | **5169174.53** | | | **0.01** | **0.01** | | **0.0001** |
| **Cirsium arvense** | **2** | **2002** | **ALE** | **Point** | **294640.75** | **5144489** | | | **8** | **8** | | **64** |
| **Cirsium arvense** | **2** | **2002** | **ALE** | **Line** | **295834.44** | **5146913.47** | **296001.32** | **5147351.07** | **533.35** | **5** | | **2666.76** |
| **Cirsium arvense** | **2** | **2003** | **ALE** | **Line** | **297294.37** | **5147147.37** | **297326.69** | **5147266.47** | **129.99** | **5** | | **649.97** |
| **Cirsium arvense** | **2** | **2003** | **ALE** | **Polygon** | **297693.98** | **5147086.88** | | | | | **99.38** | **518.48** |
| **Cirsium arvense** | **2** | **2002** | **ALE** | **Point** | **299928.62** | **5141562.5** | | | **20** | **12** | | **240** |
| **Cirsium arvense** | **2** | **2003** | **ALE** | **Point** | **300353** | **5143832** | | | **20** | **20** | | **400** |
| Cirsium arvense | 2 | 2002 | ALE | Point | 291332.25 | 5148183.5 | | | 9.14 | 4.57 | | 41.8 |
| Cirsium arvense | 2 | 2002 | ALE | Point | 292666.87 | 5153741 | | | 80 | 5 | | 400 |
| Cirsium arvense | 2 | 2002 | ALE | Line | 292677.48 | 5153754.17 | 293441.86 | 5153743.8 | 838.21 | 5 | | 4191.06 |
| Cirsium arvense | 2 | 2002 | ALE | Point | 295166.81 | 5154713.5 | | | 0.01 | 0.01 | | 0.0001 |
| Cirsium arvense | 2 | 2002 | SM | Point | 305667.84 | 5176722.5 | | | 15 | 25 | | 375 |
| Cirsium arvense | 2 | 2002 | CR | Polygon | 310380.39 | 5176447.6 | | | | | 265 | 5428.54 |
| Cirsium arvense | 2 | 2002 | W | Point | 311279.43 | 5181937 | | | 2 | 1 | | 2 |
| Cirsium arvense | 2 | 2003 | W | Polygon | 323327.66 | 5159418.83 | | | | | 199.39 | 2797.72 |
| Cirsium arvense | 2 | 2003 | W | Polygon | 324371.48 | 5158021.12 | | | | | 225.93 | 3156.56 |
| Cirsium arvense | 2 | 2003 | W | Polygon | 325706.65 | 5155701.9 | | | | | 1850.37 | 27137.94 |
| Cirsium arvense | 2 | 2002 | CR | Point | 325835.78 | 5142835 | | | 0.01 | 0.01 | | 0.0001 |
| Cirsium arvense | 2 | 2002 | CR | Polygon | 325842.71 | 5144583.25 | | | | | 335.87 | 6436.35 |
| Cirsium arvense | 2 | 2002 | CR | Point | 325899.62 | 5143020 | | | 0.01 | 0.01 | | 0.0001 |
| Cirsium arvense | 2 | 2002 | CR | Point | 325910.87 | 5143571.5 | | | 50 | 15 | | 750 |
| Cirsium arvense | 2 | 2002 | CR | Polygon | 325910.98 | 5143002.45 | | | | | 158.73 | 1999.94 |
| Cirsium arvense | 2 | 2002 | CR | Polygon | 326774.49 | 5148808.81 | | | | | 224.48 | 3999.89 |
| Cirsium vulgare | 3 | 2002 | ALE | Point | 305187.18 | 5140530 | | | 0.01 | 0.01 | | 0.0001 |
| Cirsium vulgare | 3 | 2002 | ALE | Point | 311821.56 | 5140711 | | | 0.01 | 0.01 | | 0.0001 |
| **Convolvulus arvensis** | **3** | **2003** | **ALE** | **Point** | **291593** | **5159401** | | | **1** | **1** | | **1** |
| **Convolvulus arvensis** | **3** | **2003** | **ALE** | **Point** | **292006** | **5159451** | | | **1** | **1** | | **1** |
| **Convolvulus arvensis** | **3** | **2003** | **ALE** | **Point** | **303281** | **5142690** | | | **1** | **10** | | **10** |
| Convolvulus arvensis | 3 | 2002 | MR | Line | 286189.98 | 5161700.98 | 286179.73 | 5161088.03 | 613.46 | 5 | | 3067.31 |
| Convolvulus arvensis | 3 | 2003 | MR | Point | 286314 | 5161844 | | | 1 | 0.02 | | 0.02 |
| Convolvulus arvensis | 3 | 2003 | MR | Point | 286502 | 5162006 | | | 0.1 | 0.02 | | 0.0020 |
| Convolvulus arvensis | 3 | 2002 | MR | Polygon | 286537.56 | 5167464.46 | | | | | 1382.5 | 138951.77 |
| Convolvulus arvensis | 3 | 2003 | ALE | Point | 286780 | 5160779 | | | 2 | 2 | | 4 |
| Convolvulus arvensis | 3 | 2003 | MR | Point | 287030 | 5162653 | | | 10 | 10 | | 100 |
| Convolvulus arvensis | 3 | 2003 | MR | Polygon | 287318 | 5162675 | | | | | 1207.4 | 25056 |

| | Species | Year | Mgmt. | Occurrence | Coordinates | | Coordinates | | | Dimensions | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weed Name | Priority | Recorded | Unit | Type | E | N | E | N | Length (m) | Width (m) | Perimeter | Area (m2) |
| Convolvulus arvensis | 3 | 2003 | MR | Point | 287862 | 5162984 | | | 7 | 5 | | 35 |
| Convolvulus arvensis | 3 | 2003 | MR | Polygon | 287870.5 | 5163214 | | | | | 292.26 | 4800 |
| Convolvulus arvensis | 3 | 2003 | MR | Point | 287894 | 5162748 | | | 6 | 5 | | 30 |
| Convolvulus arvensis | 3 | 2003 | MR | Polygon | 287946 | 5163140 | | | | | 140 | 1000 |
| Convolvulus arvensis | 3 | 2003 | MR | Point | 287968 | 5162774 | | | 90 | 10 | | 900 |
| Convolvulus arvensis | 3 | 2002 | MR | Line | 288980.75 | 5167582 | 289734.69 | 5167737.99 | 808.23 | 5 | | 4041.17 |
| Convolvulus arvensis | 3 | 2002 | MR | Line | 289709.31 | 5167852.01 | 289734.69 | 5167737.99 | 116.9 | 5 | | 584.52 |
| Convolvulus arvensis | 3 | 2002 | MR | Line | 289734.69 | 5167737.99 | 289976.7 | 5167877.86 | 286.75 | 5 | | 1433.79 |
| Convolvulus arvensis | 3 | 2002 | MR | Line | 289734.69 | 5167737.99 | 289737.64 | 5167700.88 | 37.29 | 5 | | 186.46 |
| Convolvulus arvensis | 3 | 2002 | MR | Line | 290269.37 | 5162498.7 | 290267.03 | 5162463.3 | 35.48 | 5 | | 177.4 |
| Convolvulus arvensis | 3 | 2002 | MR | Point | 290274.81 | 5162567.5 | | | 15 | 25 | | 375 |
| Convolvulus arvensis | 3 | 2002 | MR | Polygon | 290421.54 | 5162281 | | | | | 1603.54 | 143751.78 |
| Convolvulus arvensis | 3 | 2002 | ALE | Polygon | 291412.78 | 5146300.44 | | | | | 466.74 | 10953.65 |
| Convolvulus arvensis | 3 | 2002 | ALE | Line | 291709.31 | 5146768 | 291583.92 | 5147040.09 | 302.35 | 3 | | 907.07 |
| Convolvulus arvensis | 3 | 2003 | ALE | Point | 303281 | 5142690 | | | 1 | 1 | | 1 |
| Convolvulus arvensis | 3 | 2002 | SM | Line | 306265.93 | 5176083.97 | 306208.25 | 5175981.03 | 118 | 4 | | 472 |
| Convolvulus arvensis | 3 | 2002 | CR | Point | 325852.06 | 5142932 | | | 0.01 | 0.01 | | 0.0001 |
| Convolvulus arvensis | 3 | 2002 | CR | Point | 326499.06 | 5150960 | | | 15 | 10 | | 150 |
| Convolvulus arvensis | 3 | 2002 | CR | Point | 326636.28 | 5148977 | | | 6 | 6 | | 36 |
| Eleagnus angustifolia | 2 | 2002 | W | Polygon | 319517.31 | 5169838.15 | | | | | 41500.94 | 2322936.6 |
| Eleagnus angustifolia | 2 | 2002 | W | Polygon | 319608.15 | 5169923.38 | | | | | 176.03 | 2035.54 |
| Eleagnus angustifolia | 2 | 2002 | W | Polygon | 319632.5 | 5170226.92 | | | | | 256.84 | 4277.12 |
| Eleagnus angustifolia | 2 | 2002 | W | Polygon | 319669.63 | 5169952.46 | | | | | 103.56 | 678.67 |
| Eleagnus angustifolia | 2 | 2002 | W | Polygon | 319759.39 | 5170257.2 | | | | | 331.37 | 7279.19 |
| Eleagnus angustifolia | 2 | 2002 | W | Polygon | 319848.85 | 5170049.96 | | | | | 251.89 | 2340.38 |
| Eleagnus angustifolia | 2 | 2002 | W | Polygon | 319857.3 | 5170171.19 | | | | | 211.86 | 2476.23 |
| Eleagnus angustifolia | 2 | 2002 | W | Polygon | 319970.13 | 5170151.54 | | | | | 133.88 | 1028.59 |
| **Gypsophila paniculata** | **1** | **2002** | **ALE** | **Point** | **304357.75** | **5143288** | | | **0.01** | **0.01** | | **0.0001** |
| Kochia scoparia | 3 | 2002 | MR | Line | 286183.58 | 5160905.7 | 286182.63 | 5161325.7 | 420.7 | 5 | | 2103.52 |
| Kochia scoparia | 3 | 2002 | MR | Polygon | 287479.51 | 5166645.15 | | | | | 2583.06 | 148146.41 |
| Kochia scoparia | 3 | 2002 | ALE | Line | 308685.29 | 5138359.95 | 310854.28 | 5138264 | 2171.55 | 5 | | 10857.78 |
| Kochia scoparia | 3 | 2002 | ALE | Point | 311952.71 | 5138069.24 | | | 0.01 | 0.01 | | 0.0001 |
| Kochia scoparia | 3 | 2002 | W | Polygon | 319331.88 | 5171234.21 | | | | | 329.07 | 8103.61 |
| Kochia scoparia | 3 | 2002 | W | Polygon | 320051.95 | 5170665.06 | | | | | 190.35 | 2778 |
| Kochia scoparia | 3 | 2003 | W | Point | 324772 | 5157136 | | | 100 | 3 | | 300 |
| Kochia scoparia | 3 | 2003 | W | Point | 324772 | 5157136 | | | 100 | 3 | | 300 |
| Lepidium latifolium | 3 | 2002 | MR | Line | 286179.71 | 5161086.72 | 286180.6 | 5161159.24 | 72.52 | 5 | | 362.62 |
| Lepidium latifolium | 3 | 2003 | ALE & MR | Line | 286180 | 5161110.67 | 291711.14 | 5159323.02 | 6416.12 | 20 | | 128322.55 |
| Lepidium latifolium | 3 | 2003 | MR | Polygon | 287079 | 5162713 | | | | | 232 | 2340 |
| Lepidium latifolium | 3 | 2003 | MR | Polygon | 288172.25 | 5162562.52 | | | | | 1378.2 | 48205 |
| Lepidium latifolium | 3 | 2002 | MR | Polygon | 290286.46 | 5162508.07 | | | | | 611.86 | 14849.33 |
| Lepidium latifolium | 3 | 2003 | MR | Polygon | 290426.98 | 5162808.01 | | | | | 157.29 | 1964.77 |
| Lepidium latifolium | 3 | 2002 | ALE | Polygon | 292486.64 | 5159039.86 | | | | | 4688.28 | 627552.7 |
| Lepidium latifolium | 3 | 2002 | ALE | Polygon | 295510.29 | 5152789.74 | | | | | 3566.87 | 401889.51 |
| Lepidium latifolium | 3 | 2002 | SM | Point | 305670.81 | 5176723.5 | | | 5 | 5 | | 25 |

| | Species | Year | Mgmt. | Occurrence | Coordinates | | Coordinates | | | Dimensions | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weed Name | Priority | Recorded | Unit | Type | E | N | E | N | Length (m) | Width (m) | Perimeter | Area (m2) |
| Lepidium latifolium | 3 | 2002 | W | Point | 311187.53 | 5180109.5 | | | 15 | 5 | | 75 |
| Lepidium latifolium | 3 | 2002 | W | Point | 311278.78 | 5181935 | | | 1 | 1 | | 1 |
| Lepidium latifolium | 3 | 2002 | W | Point | 314418.68 | 5179690 | | | 0.01 | 0.01 | | 0.0001 |
| Lepidium latifolium | 3 | 2002 | W | Point | 314728.87 | 5179120 | | | 30 | 30 | | 900 |
| **Linaria dalmatica** | **1** | **2002** | **W** | **Point** | **314782.18** | **5176895** | | | **0.01** | **0.01** | | **0.0001** |
| **Linaria dalmatica** | **1** | **2002** | **nbia River is** | **Point** | **325732.24** | **5140053.19** | | | **0.01** | **0.01** | | **0.0001** |
| Lythrum salicaria | 3 | 2002 | W | Point | 316275.15 | 5171362.5 | | | 25 | 4 | | 100 |
| Lythrum salicaria | 3 | 2002 | SM | Point | 290918.84 | 5169256 | | | 30 | 30 | | 900 |
| Lythrum salicaria | 3 | 2002 | CR | Line | 286425.72 | 5167694.73 | 286781.45 | 5167734.33 | 361.68 | 20 | | 7233.77 |
| Myriophyllum spicatum | 3 | 2002 | CR | Polygon | 317286.98 | 5163618.37 | | | | | 1284.18 | 63673.06 |
| Myriophyllum spicatum | 3 | 2002 | CR | Polygon | 326261.15 | 5147987.57 | | | | | 926.84 | 30049.2 |
| **Onopordum acanthium** | **1** | **2002** | **ALE** | **Point** | **311483.09** | **5141855.5** | | | **10** | **10** | | **100** |
| **Onopordum acanthium** | **1** | **2002** | **ALE** | **Point** | **311800.37** | **5140691** | | | **0.01** | **0.01** | | **0.0001** |
| **Phragmites australis** | **3** | **2002** | **VB** | **Point** | **290673.78** | **5169210.5** | | | **0.01** | **0.01** | | **0.0001** |
| **Phragmites australis** | **3** | **2002** | **SM** | **Point** | **290918.28** | **5169256.5** | | | **10** | **10** | | **100** |
| **Phragmites australis** | **3** | **2003** | **CR** | **Line** | **302100** | **5171441** | **302321** | **5171640** | **297.39** | **30** | | **8921.75** |
| Phragmites australis | 3 | 2003 | SM | Polygon | 299797.16 | 5175278.68 | | | | | 315.17 | 6984.67 |
| Phragmites australis | 3 | 2003 | SM | Polygon | 300392.17 | 5175507.08 | | | | | 970.86 | 55053.74 |
| Phragmites australis | 3 | 2003 | SM | Polygon | 301009.89 | 5174905.85 | | | | | 215.29 | 3323.01 |
| Phragmites australis | 3 | 2003 | SM | Polygon | 301627.9 | 5174353.98 | | | | | 281.19 | 5957.83 |
| Phragmites australis | 3 | 2003 | SM | Polygon | 301849.82 | 5174142.26 | | | | | 243.09 | 4175.07 |
| Phragmites australis | 3 | 2003 | SM | Polygon | 302003.08 | 5173274.86 | | | | | 439.86 | 14279.58 |
| Phragmites australis | 3 | 2003 | SM | Polygon | 302404.63 | 5171742.74 | | | | | 447.18 | 10128.54 |
| Phragmites australis | 3 | 2003 | SM | Polygon | 302981.97 | 5173173.43 | | | | | 5172.54 | 252510.1 |
| Secale cereale | 3 | 2003 | ALE | Polygon | 290851.84 | 5147048.49 | | | | | 3471.54 | 486059.58 |
| Secale cereale | 3 | 2003 | ALE | Polygon | 291264.57 | 5146166.71 | | | | | 7564.88 | 1422819.9 |
| Secale cereale | 3 | 2003 | W | Line | 322271 | 5159744 | 321627 | 5159919 | 667.35 | 25 | | 16683.84 |
| **Sphaerophysa salsula** | **3** | **2002** | **ALE** | **Polygon** | **291125.92** | **5148937.86** | | | | | **350.04** | **9452.23** |
| **Sphaerophysa salsula** | **3** | **2002** | **ALE** | **Point** | **293024.46** | **5153813** | | | **50** | **5** | | **250** |
| **Sphaerophysa salsula** | **3** | **2002** | **ALE** | **Point** | **293030.27** | **5153783** | | | **0.01** | **0.01** | | **0.0001** |
| Sphaerophysa salsula | 3 | 2002 | W | Point | 318757.62 | 5170301.5 | | | 30 | 15 | | 450 |
| Sphaerophysa salsula | 3 | 2002 | W | Point | 318909.84 | 5170332 | | | 15 | 10 | | 150 |
| Sphaerophysa salsula | 3 | 2002 | W | Point | 318909.9 | 5170262.5 | | | 0.01 | 0.01 | | 0.0001 |
| Sphaerophysa salsula | 3 | 2002 | W | Point | 318999.59 | 5169995 | | | 0.01 | 0.01 | | 0.0001 |
| Sphaerophysa salsula | 3 | 2002 | W | Point | 319014 | 5170118.5 | | | 0.01 | 0.01 | | 0.0001 |
| Sphaerophysa salsula | 3 | 2002 | W | Polygon | 319829.22 | 5170687.49 | | | | | 2344.44 | 98312.09 |
| Sphaerophysa salsula | 3 | 2002 | W | Polygon | 320631.04 | 5168823.58 | | | | | 931.32 | 41299.2 |
| **Tamarix sp.** | **1** | **2002** | **MR** | **Point** | **289669.87** | **5167743.5** | | | **1** | **1** | | **1.0000** |
| **Tamarix sp.** | **1** | **2002** | **SM** | **Polygon** | **305675.68** | **5176711.92** | | | | | **250.97** | **4999.87** |
| **Tamarix sp.** | **1** | **2002** | **CR** | **Point** | **Coordinates not available** | | | | **0.1** | **0.1** | | **0.01** |
| Tamarix sp. | 1 | 2002 | SM | Polygon | 298086.48 | 5174560.67 | | | | | 2269.59 | 81508.82 |
| Tamarix sp. | 1 | 2002 | SM | Polygon | 299758.95 | 5174444.23 | | | | | 4058.86 | 631354.01 |
| Tamarix sp. | 1 | 2002 | SM | Polygon | 301949.92 | 5172069.62 | | | | | 1988.82 | 222313.91 |
| Tamarix sp. | 1 | 2002 | SM | Polygon | 302808.08 | 5174131.51 | | | | | 6074.17 | 615643.79 |
| Tamarix sp. | 1 | 2002 | SM | Polygon | 303168.31 | 5173369.7 | | | | | 3143.64 | 647243.77 |

| | Species | Year | Mgmt. | Occurrence | Coordinates | | Coordinates | | | Dimensions | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Weed Name** | **Priority** | **Recorded** | **Unit** | **Type** | **E** | **N** | **E** | **N** | **Length (m)** | **Width (m)** | **Perimeter** | **Area (m2)** |
| Tamarix sp. | 1 | 2002 | W & CR | Polygon | 312276.92 | 5175127.56 | | | | | 5625.18 | 603742.02 |
| Tamarix sp. | 1 | 2002 | W & CR | Polygon | 312826.96 | 5171971.93 | | | | | 2259.01 | 75682.17 |
| Tamarix sp. | 1 | 2002 | W | Polygon | 313973.18 | 5175874.39 | | | | | 5430.1 | 1564395.41 |
| Tamarix sp. | 1 | 2002 | W & CR | Polygon | 314997.96 | 5170218.25 | | | | | 4531.7 | 671481.54 |
| Tamarix sp. | 1 | 2002 | W | Point | 316477.46 | 5171408 | | | 0.5 | 0.5 | | 0.25 |
| Tamarix sp. | 1 | 2002 | W | Point | 319001.18 | 5170203 | | | 0.5 | 0.5 | | 0.25 |
| Tamarix sp. | 1 | 2002 | W | Point | 319969.4 | 5170664 | | | 0.01 | 0.01 | | 0.0001 |
| Tamarix sp. | 1 | 2002 | W | Point | 320164.68 | 5168868.5 | | | 3 | 3 | | 9 |
| Tamarix sp. | 1 | 2002 | W | Point | 320196.43 | 5168856 | | | 5 | 4 | | 20 |
| Tamarix sp. | 1 | 2002 | W | Point | 320247.68 | 5168928 | | | 15 | 15 | | 225 |
| Tamarix sp. | 1 | 2002 | W | Polygon | 322037.1 | 5160520.48 | | | | | 1092.04 | 76807.94 |
| Tamarix sp. | 1 | 2002 | CR | Point | 326838.93 | 5149325.5 | | | 0.01 | 0.01 | | 0.0001 |
| **Tribulus terrestris** | **1** | **2002** | **W** | **Point** | **314608** | **5179210.5** | | | **30** | **30** | | **900** |

# APPENDIX F

## Invasive Plant Species Operating Plan, 2003–2004

This appendix provides a summary of priority species and treatment sites as recommended in the invasive species management plan, along with general recommendations for treatment methods and time of year to apply treatments. Ideally, treatment options should be selected based on infestation size, phenological development of the target species, and other seasonal and site-specific factors. See Species Profiles [Section IV] for more extended discussions on treatment options and recommendations for each species.

**All coordinates are in UTM datum NAD27.**

### PRIORITY 1 SPECIES

**camelthorn** — *Alhagi maurorum (Alhagi pseudalhagi)*

| Unit | Location | East | North | Control measures |
|---|---|---|---|---|
| Wahluke | dog trial area | 314692 | 5179230 | Picloram cut-stem method (spring and fall) |

**diffuse knapweed** — *Centaurea diffusa*

| Unit | Location | East | North | Control measures |
|---|---|---|---|---|
| McGee-Riverlands | Umtanum Ridge, BPA access rd. | 286832 | 5165444 | Maintain/ enhance biocontrol |
| McGee-Riverlands | Umtanum Ridge, BPA access rd. | 286740 | 5165240 | (knapweed flower weevil |
| McGee-Riverlands | Umtanum Ridge, BPA access rd. | 286157 | 5164070 | Larinus minutus). |
| McGee-Riverlands | Umtanum Ridge, Umtanum Ridge Rd. | 285971 | 5165479 | Glyphosate (spring and fall; |
| McGee-Riverlands | Umtanum Ridge, Umtanum Ridge Rd. | 286456 | 5165469 | Fig. F1). |
| McGee-Riverlands | McGee Ranch, near vinyards | 286473 | 5161941 | Small infestations may be hand- |
| McGee-Riverlands | Upper Cold Creek, Cold Creek creekbed | 286268 | 5161073 | pulled. Avoid sap contact w/ |
| ALE | Upper Cold Creek, Cold Creek creekbed | 291304 | 5159575 | open wounds. |
| ALE | 1200 Ft. Rd. and other roads throughout | | | |

**yellow starthistle** *Centaurea solstitialis*

| Unit | Location | East | North | Control measures |
|---|---|---|---|---|
| Saddle Mt. | "T" road north of SR 24 | 306869 | 5180014 | Clopyralid applied at rosette stage or early bolt (late winter, spring). Small infestations may be hand-pulled prior to seed set. Avoid sap contact w/ open wounds. |
| Saddle Mt. | "T" road north of SR 25 | 306874 | 5179608 | |
| Saddle Mt. | "T" road north of SR 26 | 307041 | 5180002 | |
| Wahluke | White Bluffs | 318954 | 5162859 | |
| Wahluke | White Bluffs | 318984 | 5162972 | |
| Wahluke | White Bluffs | 319068 | 5162998 | |
| Wahluke | White Bluffs | 320412 | 5162344 | |
| Wahluke | Crest of White Bluffs, just NW of wooden transmision line. W/ White Bluffs bladderpod. | 318428 | 5163896 | |
| Wahluke | White Bluffs | 318482 | 5163896 | |
| Wahluke | White Bluffs | 318494 | 5163816 | |
| Wahluke | White Bluffs | 318497 | 5163780 | |
| Wahluke | Ringold – White Bluffs Rd. | 321327 | 5160134 | |
| Wahluke | Ringold – White Bluffs Rd. | 318157 | 5162551 | |
| Wahluke | Ringold – White Bluffs Rd. | 318306 | 5162485 | |
| Wahluke | Ringold – White Bluffs Rd. | 318890 | 5161815 | |
| Wahluke | Ringold – White Bluffs Rd. | 318434 | 5162481 | |
| Wahluke | Flats above White Bluffs, along or in vicinity of wooden transmission line | 319479 | 5162424 | |
| Wahluke | Flats above White Bluffs, along or in vicinity of wooden transmission line | 319566 | 5164951 | |
| Wahluke | Flats above White Bluffs, along or in vicinity of wooden transmission line | 319645 | 5165048 | |
| Wahluke | Flats above White Bluffs, along or in vicinity of wooden transmission line | 319928 | 5165456 | |

**rush skeletonweed** *Chondrilla juncea*

| Unit | Location | East | North | Control measures |
|---|---|---|---|---|
| ALE | Snively Basin, Upper Snively Basin Rd. | 289998 | 5145983 | Picloram or clopyralid applied at rosette to early bolt stage (fall through spring; Fig. F1). |
| ALE | Iowa Flats | 310004 | 5138331 | |
| ALE | Iowa Flats | 310178 | 5138690 | |
| ALE | Lower Slopes | 300221 | 5146550 | |
| ALE | Lower Slopes | 300243 | 5148084 | |
| ALE | Lower Slopes | 300210 | 5148164 | |
| ALE | Lower Slopes | 300467 | 5148505 | |
| ALE | Lower Slopes | 300547 | 5148443 | |
| ALE | Lower Slopes | 301102 | 5144613 | |
| ALE | Lower Slopes | 301092 | 5144598 | |
| ALE | Lower Slopes | 301069 | 5144614 | |
| ALE | Lower Slopes | 301110 | 5144627 | |
| Wahluke | Ringold, bluffs above road. | 326877 | 5148980 | |
| Wahluke | Near Parking Lot #8 | 318162 | 5162566 | |
| Wahluke | Along Ringold-White Bluffs Rd. | 317575 | 5163279 | |
| Wahluke | Along Ringold-White Bluffs Rd. | 320356 | 5160980 | |
| Wahluke | White Bluffs south of wooden transmission line | 315318 | 5171925 | |
| Wahluke | Flats above White Bluffs in vicinity of wooden transmission line | 319927 | 5165453 | |
| River Corridor | Island # 12: south end of island | 326382 | 5150684 | |
| River Corridor | Island # 12: south end of island | 326504 | 5150956 | |
| Columbia River Islands | Island # 14 (Wooded Island): south end | 325908 | 5142942 | |
| Columbia River Islands | Island # 14 (Wooded Island): ctr. of island | 325961 | 5143739 | |
| Columbia River Islands | Island # 14 (Wooded Island): ctr. of island | 325964 | 5143869 | |

**baby's breath** *Gypsophila paniculata*

| Unit | Location | East | North | Control measures |
|---|---|---|---|---|
| ALE | Gate 111 Rd. | 304358 | 5143288 | Sever crown at 12" depth or deeper. Picloram via cut-stem method if manual methods fail. |

**dalmatian toadflax** *Linaria dalmatica*

| Unit | Location | East | North | Control measures |
|---|---|---|---|---|
| Wahluke | White Bluffs Rd. | 314782 | 5176895 | Clopyralid + 2,4-D (Curtail). |
| Columbia River Islands ( | Johnson Island | 325732 | 5140053 | Small infestations may be hand-pulled prior to seed set. |

**Scotch thistle.** *Onopordum acanthium*

| Unit | Location | East | North | Control measures |
|---|---|---|---|---|
| ALE | Lower Cold Creek | 311800 | 5140691 | Sever root manually below crown. |
| ALE | Gate 109 quarry | 311483 | 5141855 | |

**saltcedar** *Tamarix ramosissima, T. parviflora*

| Unit | Location | East | North | Control measures |
|---|---|---|---|---|
| McGee-Riverlands | China Bar area | 289678 | 5167784 | Triclopyr or glyphosate for cut-stem treatments. |
| River Corridor | Homestead Island | unknown | unknown | |
| Saddle Mt. | Borrow pits, Wahluke ferry rd. | 305676 | 5176712 | Imazapyr + glyphosate foliar spray, for small individuals. |

**puncture vine** *Tribulus terrestris*

| Unit | Location | East | North | Control measures |
|---|---|---|---|---|
| Wahluke | dog trial area | 314608 | 5179210 | Glyphosate or manual methods. |
| Wahluke | Ringold-White Bluffs Rd. | dinates not available | | |
| ALE | 1200 Ft. Rd. | dinates not available | | |

**PRIORITY 2 SPECIES**

**Russian knapweed** *Acroptilon repens (Centaurea repens)*

| Unit | Location | East | North | Control measures |
|---|---|---|---|---|
| McGee-Riverlands | Umtanum Ridge | 287367 | 5165422 | Picloram (spring), or clopyralid |
| McGee-Riverlands | Umtanum Ridge | 286772 | 5165279 | (spring and fall; Fig. F1) |
| McGee-Riverlands | McGee Ranch (west) | 286612 | 5161819 | Small infestations may be |
| McGee-Riverlands | McGee Ranch (west) | 287881 | 5162729 | covered with light-impermeable |
| ALE | Rattlesnake Mt., Wooden Powerline Rd. | 303884 | 5140517 | landscape fabric for 2-3 years |
| ALE | Benson Spring | 295865 | 5147223 | |
| ALE | Gate 118 Rd. | 292639 | 5153468 | |

**whitetop** *Cardaria draba*

| Unit | Location | East | North | Control measures |
|---|---|---|---|---|
| ALE | Jct. of 117 & 1200' Rds. | 296188 | 5148679 | Metsulfuron (spring and fall). |
| ALE | Gate 120 Rd. | 292006 | 5159451 | Integrate herbicide treatment |
| ALE | Bobcat Rd. 60m up road from its junction w/ the 1200’ Rd. | 296766 | 5147694 | with mowing. Carefully controlled grazing by goats or |
| ALE | Knob on hillside 50m W of 1200' Rd. | 297278 | 5147482 | sheep will help reduce large |
| ALE | Spring in small canyon SE of Bobcat Canyon | 297324 | 5147256 | colonies. |
| ALE | Mouth of spring canyon SE of Bobcat Canyon | 297389 | 5147390 | |

| | | | | |
|---|---|---|---|---|
| ALE | Seep in small canyon W of 1200' Rd. between spring canyon & Doke Spring. | 297694 | 5147087 | |
| ALE | Doke Spring, near its mouth, west of the 1200’ Rd. | 298135 | 5146272 | |
| ALE | Doke Spring, near its mouth, west of the 1200’ Rd. | 298110 | 5146234 | |
| ALE | Doke Spring, up canyon from the previous 2 sites. | 298014 | 5146215 | |
| ALE | Benson Spring | 295865 | 5147223 | |
| ALE | Gate 111 Rd. | 303856 | 5142935 | |
| ALE | Gate 111 Rd. | 304419 | 5143307 | |
| ALE | Gate 111 Rd. | 305203 | 5143941 | |
| ALE | Gate 106 Rd. | 308420 | 5138432 | |
| ALE | Gate 106 Rd. | 311366 | 5138416 | |

**Canada thistle**

*Canada thistle*

| Unit | Location | East | North | Control measures |
|---|---|---|---|---|
| ALE | Rattlesnake Mt. summit ridge | 299929 | 5141563 | Clopyralid plus 2,4-D amine (Curtail): spring or late spring. Covering with well-secured black landscape fabric for 3-5 years is recommended for trial on remote infestations such as on the upper Bobcat Road and the Rattlesnake Mountain mid-slopes infestation. |
| ALE | Bobcat Rd. near western boundary | 294641 | 5144489 | |
| ALE | Rattlesnake Mt., mid-slopes | 300353 | 5143832 | |
| ALE | Bobcat Canyon | 295865 | 5147223 | |
| ALE | Spring in small canyon SE of Bobcat Canyon | 297311 | 5147212 | |
| ALE | Seep in small canyon W of 1200' Rd. between spring canyon & Dokes Spring. | 297694 | 5147087 | |
| Vernita | Borrow pit | 290674 | 5169211 | |
| Vernita | Borrow pit | 290746 | 5169175 | |

## PRIORITY 3 SPECIES

**kochia** — *Bassia (= Kochia) scoparia*

| Unit | Location | East | North | Control measures |
|---|---|---|---|---|
| All units | Along roadsides | | | Treat as part of integrated roadside maintenance. |

**field bindweed** — *Convolvulus arvensis*

| Unit | Location | East | North | Control measures |
|---|---|---|---|---|
| ALE | 1200 Ft. Rd. | 303281 | 5142690 | Dicamba (mid-late spring, summer; Fig. F1). |
| ALE | Gate 120 Rd. | 292006 | 5159451 | |
| ALE | Cold Creek creekbed, No. of Gate 120 Rd. | 291593 | 5159401 | |

**purple loosestrife** — *Lythrum salicaria*

| Unit | Location | East | North | Control measures |
|---|---|---|---|---|
| Saddle Mt. | Borrow pit east of Vernita Bridge | 290919 | 5169256 | Glyphosate or hand-pulling for small infestations. Biocontrols effective on larger colonies. |
| Saddle Mt. | WB10 Wasteway | 316275 | 5171362 | |

**common reed** — *Phragmites australis*

| Unit | Location | East | North | Control measures |
|---|---|---|---|---|
| Vernita Bridge | Borrow pit west of Vernita Bridge | 290674 | 5169210 | Cut-stem treatment w/ glyphosate (Rodeo) for smaller infestations. Annual mowing for river shore infestation. |
| Saddle Mt. | Borrow pit east of Vernita Bridge | 290918 | 5169257 | |
| River Corridor | North shore, Columbia River. Adjacent to Saddle Mt. NWR | 302100 | 5171441 | |

**swainsonpea** *Sphaerophysa salsula*

| Unit | Location | East | North | Control measures |
|---|---|---|---|---|
| ALE | Rattlesnake Spring | 293024 | 5153813 | 2,4-D |
| ALE | Rattlesnake Spring | 293030 | 5153783 | |
| ALE | Lower Snively Spring | 291125 | 5148937 | |