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Noxious and Invasive Weed Management Plan for Salt Lake City Parks and Public Lands

Submitted to

Salt Lake City Parks and Public Lands

Prepared by

SWCA Environmental Consultants

August 2016

NOXIOUS AND INVASIVE WEED MANAGEMENT PLAN FOR SALT LAKE CITY PARKS AND PUBLIC LANDS

Submitted to

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1. INTRODUCTION

The Salt Lake City (SLC) Open Space Lands Program manages 1,452 acres of open space (Figure 1) to provide recreational and health and lifestyle benefits to the SLC community, to provide an interface with the natural areas bordering SLC, and to protect and conserve the natural environment and ecosystem services that open space provides (SLC Planning Commission 1992). This comprehensive noxious and invasive weed management plan for SLC Parks and Public Lands provides an integrated and adaptive weed management approach for treating weeds on open space owned and managed by SLC Parks and Public Lands. Noxious and invasive weeds threaten water quality, wildlife, biodiversity, and the overall ecological functioning of high-quality natural lands. For this reason, managing noxious and invasive weeds is essential to protecting Open Space Lands and critical natural areas adjacent to and near these lands, particularly lands managed by the U.S. Forest Service and SLC's Protected Watersheds. The guidance presented here considers current management conditions and emphasizes the restoration of native and desirable nonnative vegetation by cultural, mechanical, biological, and chemical weed management strategies. This plan incorporates SLC's land management goals to reduce and contain weedy plant infestations, prevent unnecessary environmental disturbance, and maintain and/or restore native ecosystem functions. SLC will continue to add information to this plan as part of an ongoing, adaptive weed management process. Specific best management practices (BMPs) and policies used by SLC's Parks and Public Lands programs can be found in Appendix A and B.

SLC Open Space Lands are divided into three management areas based on geographic location:
1) Jordan River Management Area, 2) Tributaries Management Area, and 3) Foothills Management Area.

In summer 2011, ecologists from SWCA Environmental Consultants (SWCA) mapped noxious weed populations across five Open Space Lands areas in the Jordan River, Tributaries, and Foothills Management Areas: 1) Jordan River Parkway (includes 20 parcels), 2) Parley's Historic Nature Park, 3) Wasatch Hollow Open Space, 4) H-Rock, and 5) Hidden Hollow.

In May 2016, SWCA ecologists mapped broad infestation areas for high-priority noxious weed species in additional Open Space Lands in the Foothills and Tributaries Management Areas across 21 Open Space Lands parcels: 1) Bonneville Shoreline Preserve, 2) Foothill Open Space, 3) Victory Road Natural Area, 4) Ensign Peak, 5) Ensign North, 6) City Creek Natural Area, 7) Columbus Court Natural Area, 8) Kay Rees Natural Area, 9) North Bonneville Natural Area, 10) Bonneville Drive Open Space, 11) Richland Drive, 12) Tomahawk Natural Area, 13) Perrys Hollow Natural Area, 14) Chandler Drive, 15) 921 East, 16) Popperton Park, 17) Federal Heights Detention, 18) Miller Park, 19) H-Rock, 20) Arcadia Trailhead, and 21) Cohen Property. The mapping methods used and distribution and density of noxious and invasive weed populations are presented in Section 3 of this document. The weed mapping results have been used to prioritize weed treatment and prevention areas, and detailed recommendations for specific Open Space Lands and weed treatment methods are provided as part of the site-specific weed management guidelines in this plan.

Figure 1 provides an overview map of Salt Lake City Open Space Lands surveyed in 2011 and 2016 and an index for weed survey results maps provided at the end of this document. This plan applies to all SLC Open Space Lands. This plan does not apply to other lands owned by SLC or lands managed by the SLC Department of Public Utilities, including Watershed Protection Areas.

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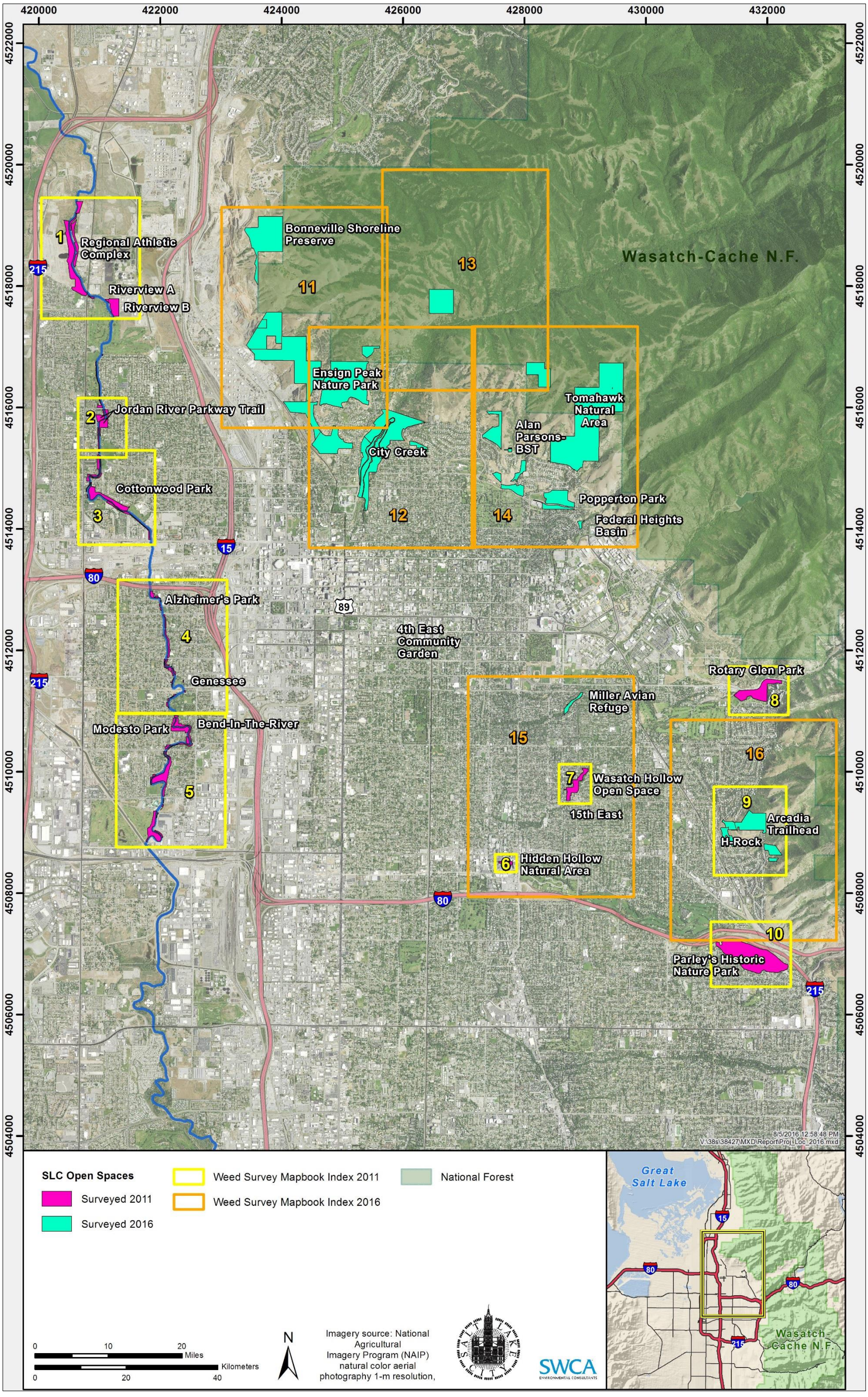

Figure 1. Salt Lake City Open Space Lands overview map.

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Utah Weed Regulatory Guidance

A weed is any plant that is not desired in a particular location and may be introduced, invasive, or noxious (Figure 2). As defined by Title 4, Chapter 17, of the Utah Noxious Weed Act (UTAH CODE 4-17), a noxious weed is "any plant the commissioner determines to be especially injurious to public health, crops, livestock, land, or other property" (UTAH CODE 4-17-2). Federal and state agencies maintain lists of specific noxious weed species that must be controlled, as required by federal and state laws and regulations. Generally, federal weed laws and regulations are geared toward preventing unwanted plants from entering the United States, whereas state laws and regulations are aimed more at the control and removal of noxious weeds (U.S. Environmental Protection Agency [EPA] 2006).

Figure 2. Weedy plant species terminology and definitions.

In recognition of the ecological and economic impacts of weeds, the Utah Noxious Weed Act requires landowners to control state-listed noxious weed species on their lands if these species are likely to encroach on neighboring lands. The act stipulates that each county and municipality in Utah must adopt a noxious weed management plan for its jurisdiction and identify the plant species in its area that it considers noxious weeds. In addition, if landowners and managers fail to control weeds on their property, the county or municipality may legally enter the property, control weeds, and charge the landowner for the cost of control work.

The State of Utah has classified 54 plant species as "noxious" weeds (Table 1). Salt Lake County's noxious weeds list includes 29 of Utah's state-listed noxious species as well as sulphur cinquefoil (*Potentilla recta*) (see Table 1). A discussion of invasive plant species, including some not found on this list (e.g., cheatgrass [*Bromus tectorum*]), is found in Appendix C.

Table 1. Utah State and Salt Lake County Noxious Weed List (Rule R68-9 as in effect on June 1, 2016)

Common Name	Scientific Name	Designation (state or county)*
Garlic mustard	*Alliaria petiolata*	State or Utah Class 1B and SLCO noxious
Jointed goatgrass	*Aegilops cylindrica*	State of Utah Class 4
Camelthorn	*Alhagi maurorum*	State of Utah Class 1B
Small bugloss	*Anchusa arvensis*	State of Utah Class 1A
Giant reed	*Arundo donax*	State of Utah Class 1B
Elongated mustard	*Brassica elongate*	State of Utah Class 1B
African mustard	*Brassica tournefortii*	State of Utah Class 1B
Hoary cress	*Cardaria draba* (*Cardaria* spp.)	State of Utah Class 3 and SLCO noxious
Plumeless thistle	*Carduus acanthoides*	State of Utah Class 1A
Musk thistle	*Carduus nutans*	State of Utah Class 3 and SLCO noxious
Purple starthistle	*Centaurea calcitrapa*	State of Utah Class 1B
Diffuse knapweed	*Centaurea diffusa*	State of Utah Class 2 and SLCO noxious
Malta starthistle	*Centaurea melitensis*	State of Utah Class 1A
Yellow starthistle	*Centaurea solstitialis*	State of Utah Class 2 and SLCO noxious
Spotted knapweed	*Centaurea stoebe* ssp. *micranthos*	State of Utah Class 2 and SLCO noxious
Squarrose knapweed	*Centaurea virgata*	State of Utah Class 2 and SLCO noxious
Canada thistle	*Cirsium arvense*	State of Utah Class 3 and SLCO noxious
Rush skeletonweed	*Chondrilla juncea*	State of Utah Class 2
Poison hemlock	*Conium maculatum*	State of Utah Class 3 and SLCO noxious
Field bindweed	*Convolvulus arvensis*	State of Utah Class 3 and SLCO noxious
Common crupina	*Crupina vulgaris*	State of Utah Class 1A
Bermudagrass	*Cynodon dactylon*	State of Utah Class 3 and SLCO noxious
Houdstounge	*Cynoglossum officinale*	State of Utah Class 3 and SLCO noxious
Scotch broom	*Cytisus scoparius*	State of Utah Class 4
Vipers bugloss	*Echium vulgare*	State of Utah Class 1B
Russian olive	*Elaeagnus angustifolia*	State of Utah Class 4
Quackgrass	*Elymus repens*	State of Utah Class 3 and SLCO noxious
Leafy spurge	*Euphorbia esula*	State of Utah Class 2 and SLCO noxious
Myrtle spurge	*Euphorbia myrsinites*	State of Utah Class 4 and SLCO noxious
Goatsrue	*Galega officinalis*	State of Utah Class 1B
Dames rocket	*Hesperis matronalis*	State of Utah Class 4
Black henbane	*Hyoscyamus niger*	State of Utah Class 2 and SLCO noxious
St. Johnswort	*Hypericum perforatum*	State of Utah Class 1B and SLCO Noxious
Cogongrass	*Imperata cylindrica*	State of Utah Class 4
Dyer's woad	*Isatis tinctoria*	State of Utah Class 2 and SLCO noxious
Perennial pepperweed	*Lepidium latifolium*	State of Utah Class 3 and SLCO noxious
Oxeye daisy	*Leucanthemum vulgare* (syn. *Chrysanthemum leucanthemum*)	State of Utah Class 1B and SLCO Noxious
Dalmatian toadflax	*Linaria dalmatica*	State of Utah Class 2 and SLCO noxious

Table 1. Utah State and Salt Lake County Noxious Weed List (Rule R68-9 as in effect on June 1, 2016)

Common Name	Scientific Name	Designation (state or county)*
Yellow toadflax	*Linaria vulgaris*	State of Utah Class 2 and SLCO noxious
Purple loosestrife	*Lythrum salicaria*	State of Utah Class 2 and SLCO noxious
Spring millet	*Milium vernale*	State of Utah Class 1A
Scotch thistle	*Onopordum acanthium*	State of Utah Class 3 and SLCO noxious
African rue	*Peganum harmala*	State of Utah Class 1A
Phragmites (common reed)	*Phragmites australis ssp.*	State of Utah Class 3
Japanese knotweed	*Polygonum cuspidatum*	State of Utah Class 1B
Sulfur cinquefoil	*Potentilla recta*	SLCO Noxious
Russian knapweed	*Rhaponticum* (*Acroptilon*) *repens*	State of Utah Class 3 and SLCO noxious
Mediterranean sage	*Salvia aethiopis*	State of Utah Class 1A
Cutleaf vipergrass	*Scorzonera lacinata*	State of Utah Class 1B
Perennial sorghum	*Sorghum halepense* (*S. almum*, *S.* spp.)	State of Utah Class 3 and SLCO noxious
Medusahead	*Taeniatherum caput-medusae*	State of Utah Class 2 and SLCO noxious
Tamarisk	*Tamarix ramosissima*	State of Utah Class 3 and SLCO noxious
Puncturevine	*Tribulus terrestris*	State of Utah Class 3 and SLCO noxious
Ventenata (North African grass)	*Ventenata dubia*	State of Utah Class 1A
Syrian beancaper	*Zygophyllum fabago*	State of Utah Class 1A

* State noxious weed data from Utah Administrative Code R68-9 (2016); Salt Lake County (SLCO) weeds data from Salt Lake County (2011). Class 1A: Early Detection Rapid Response (EDRR) Watch List; Class 1B: early Detection Rapid Response (EDRR); Class 2: Control; Class 3: Containment; Class 4: Prohibited.

Adaptive Management Strategy

Adaptive management is an effective way of addressing the complex and numerous problems that noxious weeds pose to landowners and land managers. SWCA recommends the following steps for an adaptive weed management framework for SLC Open Space Lands (Figure 3):

- Identify project areas and goals and objectives for each (objectives).
- Conduct a weed inventory and mapping of the project areas (current state).
- Identify weed species of concern and project areas for weed management (alternative actions).
- Select integrated weed management (IWM) strategies (available science and models).
- Develop a monitoring and evaluation plan (plan and implement).
- Evaluate the effectiveness of weed management actions (evaluate).

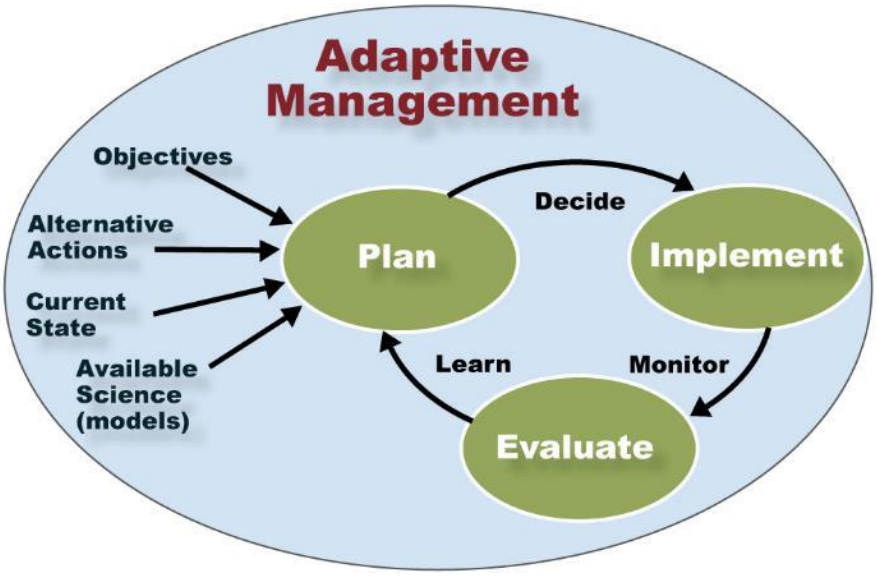

Figure 3. Adaptive management strategy (U.S. Department of the Interior 2007).

Integrated Weed Management

An important component of adaptive management is an IWM plan that uses multiple weed management techniques. IWM is a process that combines biological, chemical, mechanical, and cultural management techniques to synergistically control target weed species with minimal adverse impacts to nontarget organisms (Colorado State University [CSU] 2000). Most traditional weed management concentrates only on suppression, typically by using herbicides; however, this approach does not address the ultimate causes of weed invasion. IWM uses ecological principles of plant community establishment and persistence and integrates strategies that are practical, economical, and protective of public and environmental health (CSU 2000). By implementing multiple weed control methods, the likelihood that one of the methods will control or eliminate the target weed species is increased. SWCA recommends using an adaptive weed management process that uses the principles of IWM by meeting the following objectives:

- **Work to establish and maintain functioning native plant communities.** Disturbance—both anthropogenic and natural—is the primary factor in the degradation of native plant communities and spread of noxious weeds.
- **Implement appropriate prevention methods.** Preventing weeds from invading a site in the first place is the most effective and least costly method for controlling weeds.
- **Choose appropriate control actions.** Control strategies are a function of the biology and ecology of the target species. The appropriate strategy should also be
    - applied at the most effective time,
    - the least damaging to nontarget organisms,
    - the least hazardous to human health,
    - the least damaging to the general environment,
    - the most likely to reduce the need for weed control over the long term,
    - the most easily implemented, and
    - the most cost effective in the short term and long term.

Cooperative Weed Management Areas

Cooperative weed management areas (CWMAs) can be an effective resource in the prevention, detection, and suppression of noxious and invasive weeds. Coordinated mechanical, chemical, and biological control over large areas by multiple landowners has proven successful for a variety of weed species. These areas replace jurisdictional boundaries in favor of natural boundaries that facilitate cooperation, coordination, and implementation of effective IWM programs for listed noxious weeds. For example, CWMAs in Utah have focused on education-based projects with an early detection and rapid response component in which participants see visible improvement as the result of the treatment prescription.

The South Shore CWMA acquired the funds to develop this plan through a Pulling Together Initiative grant from the National Fish and Wildlife Foundation. The South Shore CWMA will act as the review committee for this plan and has provided input on the development of treatment and restoration strategies for SLC Open Space Lands. The Bonneville CWMA, through another National Fish and Wildlife Foundation grant, initiated an education, mapping, and control program for leafy spurge that will enable it to focus resources into control and eradication of this noxious weed. Another CWMA, the Utah-Idaho CWMA, implemented the Bag O' Woad program to educate the public about noxious weeds. In exchange for filling approved plastic bags with dyer's woad, participants receive a $10 bounty. Such projects can be implemented due to CWMA's ability to secure substantial government funding because the scope of projects includes weeds across federal, state, county, municipal, and private properties. From a plant community perspective, weeds are dispersed by vectors that very often traverse political and landownership boundaries. Collaboration at the landscape level offers incentives for individuals who might not act due to lack of resources or due to an understanding that treating weeds on a small scale is ineffectual. To prevent, detect, and suppress noxious and invasive weeds and to rehabilitate infested areas is a coordinated vision that includes SLC Open Space Lands, Salt Lake County, and adjoining municipalities and property owners. This vision is an important first step for effective and long-term weed management.

The Ecology of Plant Community Composition

Invasive plant species, including most noxious weeds, are early successional species that possess numerous adaptations for rapid colonization and spread in disturbed habitats. These adaptations include high reproductive rates, rapid germination and growth, and annual life histories in which the plant grows, flowers, sets seed, and dies in a single season. Noxious plant species may also have superior abilities to use soil and water resources, possess allelopathic mechanisms (the use of biochemicals to influence the growth, survival, and reproduction of other organisms) to suppress competing species, and have been released from their native predators and pathogens in their new environment (Coombs et al. 2004; Mack et al. 2000; Sperry et al. 2006). These factors can result in a shift in the plant community toward dominance of exotic, invasive plant species (Mack et al. 2000).

The results of the SLC Open Space Lands surveys in 2011 and 2016 show that the anthropogenic factors that appear to contribute to weed-dominated plant communities are surface disturbance associated with maintenance and construction on trails, adjacent developments, and recreation sites; movement of seeds and propagules along pedestrian and bike corridors; off-trail hiking and biking; and unauthorized recreational use such as construction of extensive bike ramps in Parley's Historic Nature Park.

Managing Plant Community Composition

One approach to adaptive or ecologically based invasive plant management is to create weed resistant plant communities using desirable, preferably native, plant species (Sheley and Mangold 2005). This is achieved by targeted removal of weedy species followed by the implementation of site-specific control mechanisms

that will eliminate or reduce the noxious weed population and provide suitable colonization sites for native plant species. Finally, it is important to select native revegetation species that will successfully compete with weedy species. Continued maintenance and monitoring for several years following weed treatments is necessary to identify problems such as new weed infestations, lack of vigor in seeded or planted native species, and additional site amendment requirements such as fertilizer/topsoil or irrigation.

2. SALT LAKE CITY OPEN SPACE PLANT COMMUNITIES

Five plant community types occur in SLC Open Space Lands: 1) sagebrush grasslands and sagebrush shrublands, 2) bigtooth maple and Gambel oak woodlands, 3) riparian woodlands and shrublands, 4) emergent marsh wetlands, and 5) managed lawns and landscaping. These four plant communities are described below. Each plant community description lists the grass, forb, shrub, and tree species that typify the community. The noxious and invasive plant species that commonly invade these community types and the ecological implications of weed invasion are also presented.

Sagebrush Grasslands and Sagebrush Shrublands

The native vegetation of the Salt Lake Valley historically consisted of bunchgrasses and desert shrub communities comprising Indian ricegrass (*Achnatherum hymenoides* [Roem. & Schult.] Barkworth), bluebunch wheatgrass (*Pseudoroegneria spicata* [Pursh] Á. Löve), mule-ears (*Wyethia amplexicaulis* [Nutt.] Nutt.), arrowleaf balsamroot (*Balsamorhiza sagittata* [Pursh] Nutt.), wild geranium (*Geranium* L. spp.), big sagebrush (*Artemisia tridentata* Nutt.), rubber rabbitbrush (*Ericameria nauseosa* [Pall. ex Pursh] G.L. Nesom & Baird), and yellow rabbitbrush (*Chrysothamnus viscidiflorus* [Hook.] Nutt. ssp. *viscidiflorus*). A list of common plant species of the sagebrush grassland and sagebrush shrubland community type is provided in Table D.1 (Appendix D). Noxious weed species documented in this community type are predominantly hoary cress, Dalmatian toadflax, myrtle spurge, dyer's woad, and yellow starthistle. Invasive weed species commonly encountered in this community include cheatgrass and mullein (*Verbascum thapsus* L.). Cheatgrass infestations are a fire hazard in this plant community. By mid- to late summer, cheatgrass has senesced, dried, and is a fire hazard where continuous infestations have created an uninterrupted fuel layer (Mack et al. 2000). Nearby native vegetation, buildings, and infrastructure can easily become engulfed in a fast-moving cheatgrass fire.

Bigtooth Maple and Gambel Oak Woodlands

This plant community type has limited weed infestations due to the low, dense canopy and vigorous native forb assemblages. Most weed infestations are found along roads, trails, and riparian corridors in this community type. Native vegetation creates a closed canopy of trees, shrubs, and forbs comprising Gambel oak (*Quercus gambelii* Nutt.), bigtooth maple (*Acer grandidentatum* Nutt.), Oregon grape (*Mahonia repens* [Lindl.] G. Don), wild geranium (*Geranium viscosissimum* Fisch. & C.A. Mey. ex C.A. Mey.), and mule-ears. A list of common plant species of the bigtooth maple and Gambel oak woodlands community type is provided in Table D.2 (see Appendix D). Noxious weed species occurring in this plant community are predominantly hoary cress, garlic mustard, yellow starthistle, myrtle spurge, dyer's woad, houndstongue, and Dalmatian toadflax. Invasive plant species include cheatgrass and burdock (*Arctium minus* Bernh.).

Riparian Woodlands and Shrublands

This plant community type occurs along large and small waterways throughout SLC Parks and Public Lands. The Jordan River Parkway is predominantly riparian habitat with managed lawns and landscaping in the surrounding uplands. This community is dominated by cottonwoods (*Populus angustifolia* [James]

and *P. fremontii* [S. Watson]), boxelder (*Acer negundo* L.), and willow (*Salix* L. spp.). Additional species include black hawthorne (*Crataegus douglasii* Lindl.), Woods rose (*Rosa woodsii* Lindl.), golden currant (*Ribes aureum* Pursh), and buffaloberry (*Shepherdia argentea* [Pursh] Nutt.). A list of common plant species of the riparian woodland and shrubland community type is provided in Table D.3 (see Appendix D). Noxious weed species that commonly occur in this community type are hoary cress, Scotch thistle, perennial pepperweed, poison hemlock, tamarisk, Russian olive, common reed, and puncturevine. Other invasive weed species include common teasel (*Dipsacus fullonum* L.), Siberian elm (*Ulmus pumila* L.), and cocklebur (*Xanthium strumarium* L.).

Emergent Marsh Wetlands

Emergent marsh wetlands in SLC Open Space Lands generally occur in small depressions or along waterways. This community type is characterized by inundation with water for most of the growing season and a predominance of hydrophytic, or water-loving, vegetation. Dominant species include bulrushes (*Schoenoplectus* [Rchb.] Palla spp.), spikerush (*Eleocharis* R. Br. spp.), cattails (*Typha* L. spp.), and forbs such as milkweed (*Asclepias speciosa* [Torr.] and *A. incarnata* [L.]). A list of common plant species of the emergent marsh wetland community type is provided in Table D.4 (see Appendix D). Noxious weed species commonly encountered in this plant community are Canada thistle, common reed, and poison hemlock. Invasive plant species such as reed canarygrass (*Phalaris arundinacea* L.), and common teasel regularly dominate this community type. A hybrid form of cattail (*T. X. glauca* Godr.) has recently invaded marshes in Great Salt Lake and may pose a problem in emergent marsh wetlands.

Managed Lawns and Landscaping

Approximately half of the SLC Parks and Public Lands inventory consists of parks with managed lawns, managed landscaping, and flower beds. These areas are dominated by horticultural grasses (*Poa* L. spp.). Noxious and invasive plant species are common in these areas because of the open environment created by regular mowing and vegetation removal. Hoary cress, field bindweed, and Scotch thistle are widespread in this plant community, whereas houndstongue and puncturevine are encountered in more isolated infestations along developed parkways and paved trails. Invasive species encountered in this plant community are mullein and burdock. Dandelions are not considered a noxious or invasive species but are managed for aesthetic value.

Because of concerns about community and environmental health, along with surface and groundwater contamination from synthetic fertilizers and pesticides, SLC is transitioning to sustainable lawn care practices on SLC Parks and Public Lands. General guidelines for the mechanical control of weeds in managed turf areas are included in Appendix A.

3. WEED MAPPING

Objectives

The objectives of the 2011 weed mapping of SLC Open Space Lands were to accurately delineate the extent and densities of current weed infestations and to identify open space that is threatened by noxious and invasive weed encroachment across five Open Space Lands areas in the Tributaries Management Area and the Jordan River Management Area. The resulting weed distribution maps establish baseline conditions and provide site-specific data that will be used to direct weed management priorities, identify high-priority weed species and areas for treatment, and evaluate weed control efforts (Weed Survey Results maps 1–10).

In May 2016, the distributions of high-priority noxious weeds were mapped in unsurveyed SLC Open Space Lands in the Tributaries and Foothills Management Areas (Weed Survey Results maps 11–16). The resulting maps and weed density data will be used to identify high-priority weed species and project areas for treatment, and to guide site-specific weed treatment methods. The methods used for the 2011 and 2016 weed mapping efforts can be repeated over time to monitor changes in the distribution of noxious weeds in SLC Open Space and to assess weed management and restoration effectiveness.

Methods

In 2011, weed mapping was conducted from May through August, with May surveys focusing on spring-flowering noxious weed species and later surveys focusing on summer and late-season flowering weed species. SLC Open Space Lands were surveyed on foot by SWCA ecologists. Weed locations were recorded using a Trimble XT global positioning system (GPS) with a noxious weed–specific data dictionary of the species, density, and size of the infestation. The resulting weed data were mapped by species, with the density and size of the infestation represented by the color and size of the map symbols, respectively. These maps were used to create weed management recommendations, as illustrated in the 2011 Weed Treatments maps 1–10, for each of the target SLC Open Space Lands.

The 2016 weed mapping surveys were conducted using the same methods, but with a focus on rapid, broad-scale mapping of the distributions of the highest priority noxious weed species in the Foothills Management Area: Dalmatian toadflax, myrtle spurge, dyer's woad, hoary cress, yellow starthistle, leafy spurge, and noxious thistle species (e.g., nodding, musk, Scotch, and Canada).

Results

The 2011 and 2016 data were compiled into weed density and distribution maps (2011 Weed Survey Results maps 1–10 and 2016 Weed Survey Results maps 10–16). The resulting weed density data for 2011 were used to identify high-priority weed species and areas for treatment for each of the parcels (2011 Weed Treatments maps 1–10), and to guide site-specific weed treatment methods. Treatment task schedules were developed for the areas surveyed in 2011 and 2016 (Appendix A, Tables A2.2–A2.4). Site-specific weed management issues and prescriptions are discussed in Section 8. An additional field map that was developed by Utah Conservation Corps is included in Appendix E.

Table 2 summarizes the total weed cover mapped in SLC Open Space Lands management areas in 2011 and 2016.

Table 2. SLC Open Space Lands Weed Cover Summary by Management Area

Management Area	Total Acres	Weed Acres	Weed Cover (%)
Foothills Management Area	1,008.8	694.7	68.9%
Jordan River Management Area	191.0	91.7	48.0%
Tributaries Management Area	107.3	29.3	27.3%
Total	**1,307.1**	**815.7**	**62.4%**

Weed cover is considerably higher in the Foothills Management Area compared to the Jordan River and Tributaries Management Areas. This is partially because of its large size and management history of the area's individual parcels. Parcels in the Jordan River and Tributaries Management Areas are more accessible, have higher visibility, and are generally small and easier to manage. Table 3 details the acres and weed cover for each parcel by management area.

Table 3. SLC Open Space Lands Weed Cover Summary by Management Area and Parcel

Management Area and Parcels	Total Acres	Weed Acres*	Weed Cover (%)†
Foothills Management Area			
921 East	10.4	4.7	45.1%
Arcadia Trailhead	8.5	4.0	46.9%
Bonneville Drive Open Space	0.2	0.1	49.6%
Bonneville Shoreline Preserve	77.4	36.9	47.7%
Chandler Drive	3.2	1.6	50.3%
City Creek Natural Area	124.5	69.6	55.9%
Cohen Property	2.0	1.5	74.2%
Columbus Court Natural Area	39.1	49.4	100.0%
Ensign North	8.0	1.3	16.7%
Ensign Peak	116.1	68.7	59.2%
Federal Heights Detention	1.8	0.6	33.7%
Foothill Open Space	122.3	126.2	100.0%
H-Rock	42.7	25.3	59.3%
Kay Rees Natural Area	5.4	7.9	100.0%
North Bonneville Natural Area	21.7	9.4	43.5%
Perrys Hollow Preserve	6.6	9.1	100.0%
Popperton Park	30.6	20.0	65.4%
Richland Drive	0.8	0.8	100.0%
Tomahawk Natural Area	249.7	122.8	49.2%
Victory Road Natural Area	137.6	134.5	97.8%
Subtotal	***1,008.8***	***694.7***	***68.9%***
Jordan River Management Area			
1700 South Restoration	7.6	6.3	83.3%
2100 South Restoration	8.7	11.3	100.0%
2200 West	17.1	–	–
9 Line Trail	13.6	0.2	1.8%
900 South Oxbow	7.0	1.0	14.3%
Alzheimer's Wildlife Grove	3.1	0.6	19.3%
Backman	6.3	3.5	55.0%
Bend in the River	15.8	4.6	29.2%
Constitution	0.8	0.5	66.1%

Table 3. SLC Open Space Lands Weed Cover Summary by Management Area and Parcel

Management Area and Parcels	Total Acres	Weed Acres*	Weed Cover (%)†
Franklin	1.1	0.4	34.1%
Gatsby Trailhead	0.5	–	–
Goshen	2.9	2.3	78.1%
Jake Garn	3.1	1.0	33.9%
Jordan River Trail	0.7	0.2	27.8%
KOA	6.5	2.1	31.7%
Neighborhood House	2.0	1.1	57.3%
North Riverside	10.2	4.6	45.2%
Northwest Recreation Center	5.3	1.8	33.4%
Peace Gardens Jordan River	0.8	1.0	100.0%
Regional Athletic Complex	53.6	40.9	76.2%
Riverview	14.4	–	–
Seven Peaks	3.0	1.0	34.8%
South Riverside	6.9	7.3	100.0%
Subtotal	***191.0***	***91.7***	***48.0%***
Tributaries Management Area			
4th East Community Garden	0.3	–	–
Blaine Natural Area	0.7	–	–
Garfield School	1.3	–	–
Hidden Hollow	3.2	0.6	19.9%
Miller Park	4.9	1.9	37.9%
Parley's Historic Nature Park	85.6	20.5	24.0%
Sugarhouse Draw	1.5	–	–
Wasatch Hollow Open Space	9.5	6.2	66.1%
Wasatch Hollow South	0.4	–	–
Subtotal	***107.3***	***29.3***	***27.3%***
Total	**1,307.1**	**815.7**	**62.4%**

* Weed mapping geospatial data were not clipped to the parcel boundary. Therefore, in some cases, the acres of weeds are larger than the parcel acres.

† Weed cover is based on the total distribution of weed species and not on actual densities.

Total weed cover by individual parcel ranges from 0% to 100%. The weed species of concern also vary widely by management area and across different parcels. Figure 4 illustrates the distribution of weed species and acres infested by SLC Open Space Lands management area.

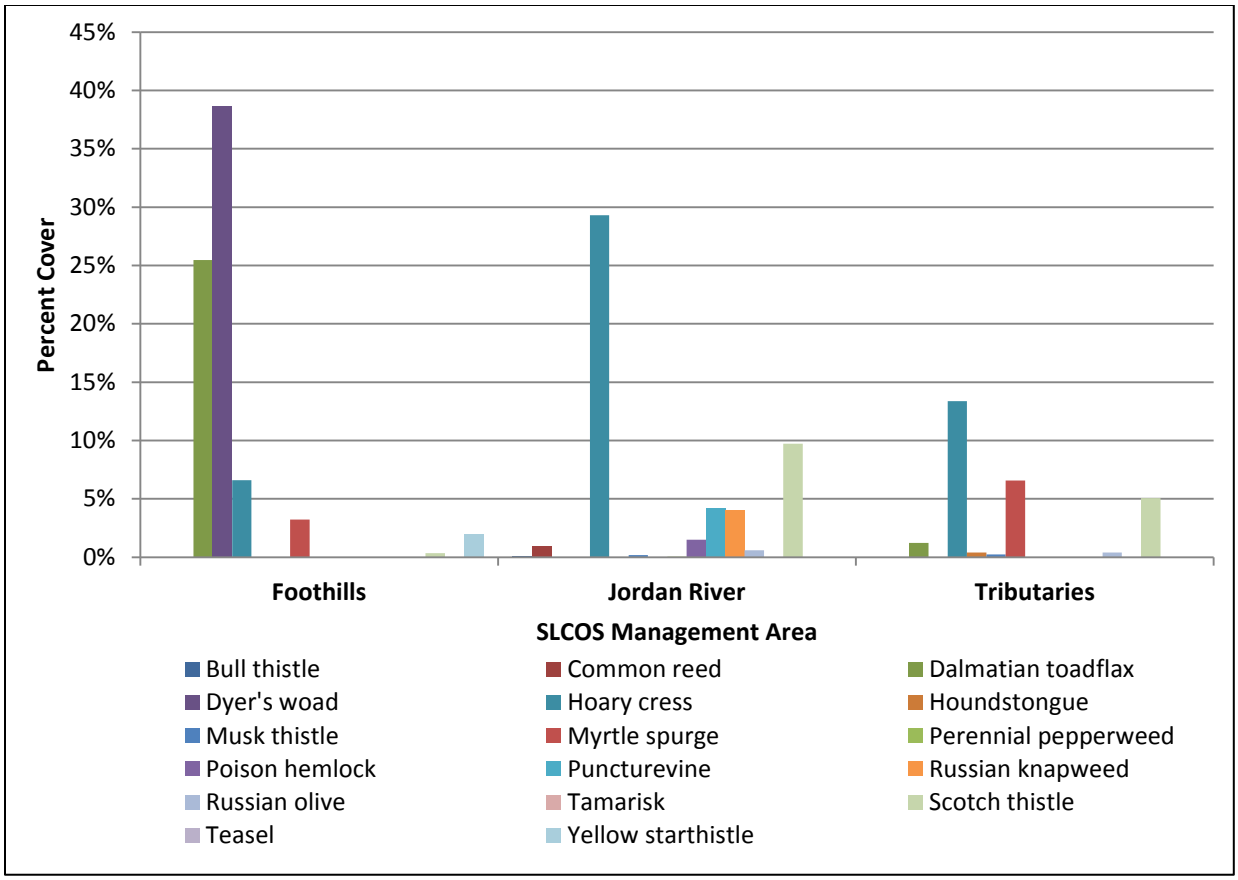

Figure 4. Acres of infestation by weed species and SLC Open Space Lands management area.

Hoary cress occurs in all three management area (Figure 5). Large scale infestations of Dyer's woad and Dalmatian toadflax are in the Foothills Management Area. Myrtle spurge is also a species of concern in the Foothills Management Area. Hoary cress and thistle species are the most widespread weed species in the Jordan River Management Area, and hoary cress and myrtle spurge are the most widespread weeds in the Tributaries Management Area. Individual weed species percentage cover is illustrated in Figure 5.

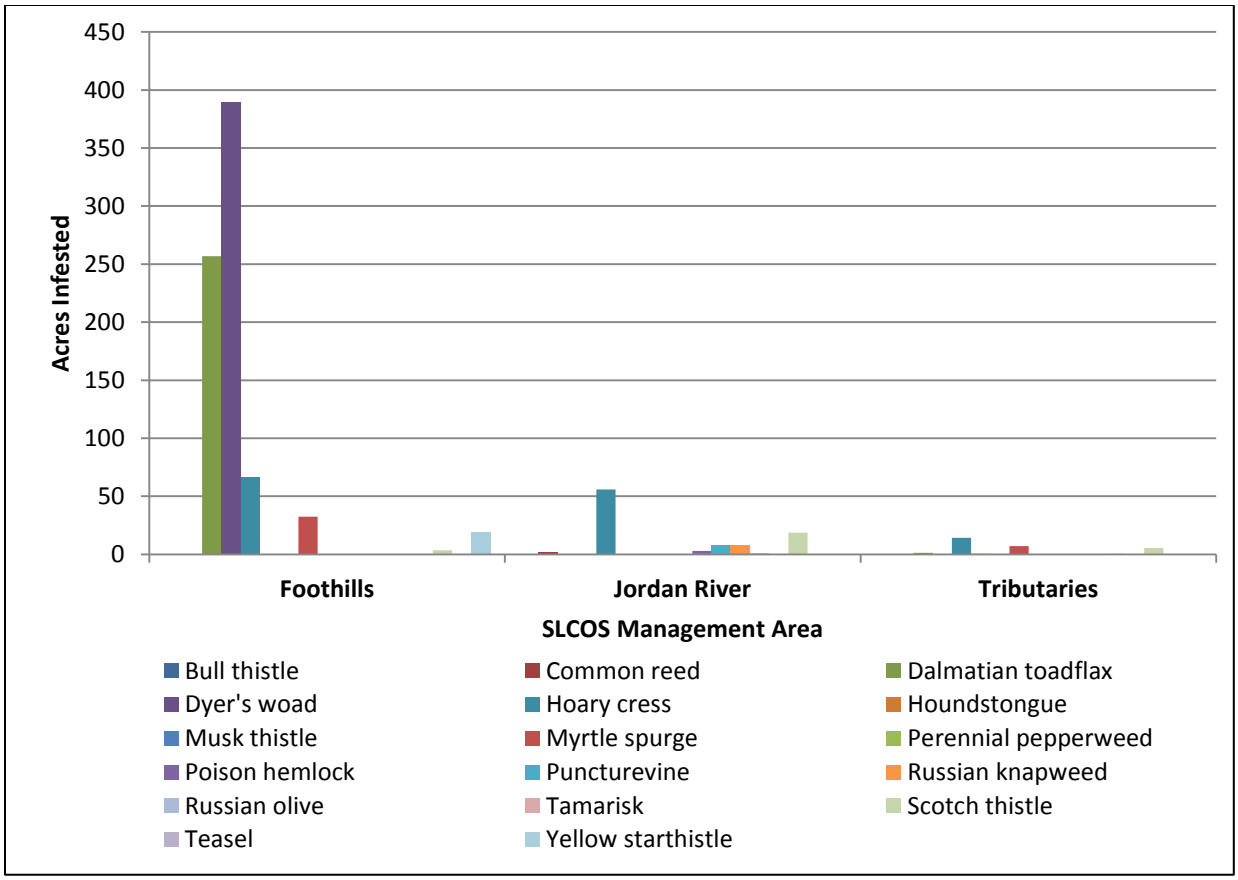

Figure 5. Percentage cover by weed species and SLC Open Space management area.

The distributions of individual weed species by acres and percentage cover for each SLC Open Space parcel are detailed in Appendix F (Tables F.1–F.3).

4. WEED MANAGEMENT GOALS AND OBJECTIVES

Preventive weed management programs should include keeping the site free of weed species that are not yet present but are known to be near the property. Project weed treatment areas should be identified to control or eliminate weeds that are established on the property, according to their actual and potential impacts on native species and communities, their visual impacts, and fire danger.

Preventing new infestations and prioritizing treatment of existing infestations are top priorities of this plan. The difficulty of control will also be considered, and infestations more receptive to available technology and resources will be given higher treatment priority.

Weed control is only part of the site management and restoration plan. The program also needs to focus on desirable plant species. The overall goal of this plan is to restore property to a mosaic of healthy, native ecosystems by reducing the negative influence of weeds on native plants and wildlife and increasing the biodiversity and abundance of desirable plant species. This goal will be accomplished by meeting the following objectives:

- Complying with existing weed control and pesticide application laws.
- Minimizing establishment of new weed species.

- Accomplishing weed control without significant adverse environmental effects.
- Revegetating weed infestations with desirable native plant species.
- Reducing impacts of weed infestations on adjacent lands.

5. WEED MANAGEMENT TECHNIQUES

Prevention

The most important weed management action is to prevent weeds from becoming established in the first place. There are two fundamental characteristics of weed species that help explain why they become established so easily.

First, weeds specialize in colonizing highly disturbed ground (Chambers 2000). They possess a number of physiological traits that allow them to inhabit disturbed sites sooner and grow faster than other plants. With these advantages, they are able to outcompete native species. To counter this characteristic of weed species, avoid large-scale disturbance or destruction of existing vegetation whenever possible. Disturbances that result in bare soil without native vegetation create ideal opportunities for weed colonization. If disturbance cannot be avoided, reseed or replant disturbed areas immediately after the disturbance has ceased.

Second, weeds tend to invade existing plant communities that have been degraded by multiple land-use activities, such as grazing or off-road driving. One of the best ways to avoid damaging native plant communities is to manage livestock grazing so it actually maintains or increases the vigor of native perennial plants, especially grasses. Encouraging vehicle operators (with training or signage) to remain on designated roads or paths will reduce the destruction to vegetation and soil. Vehicles should also avoid driving in noxious weed–infested areas and should be inspected and cleaned for weed seeds each time they work in an infested area.

A training program has also been created that addresses weed prevention BMPs and will aid in reducing the spread of existing infestations and preventing new ones. A weed prevention training module will include the following guidelines and can be reviewed by SLC staff each spring before the field season:

- Learn to identify high-priority species in the field and distinguish them from native species.
- For a cost-effective way to conduct mapping and monitoring, use field personnel to document and report new infestations of weeds.
- Inspect roadsides to detect new weed establishment on disturbed rights-of-way.
- Inspect ditches and streambanks for seeds that may be spreading by means of running water.
- Inspect gravel or fill material; weed seeds in this material can start new infestations, and bare soil provides an ideal environment for weed establishment. Cover these materials with plastic to avoid germination.
- Do not pick or transport flowering plants you cannot identify.
- Inspect all vehicles for seeds, and clean them before leaving a weed-infested area.
- Always use certified, weed-free straw, hay, or mulch.
- If you find a weed, pull it. Bag flowers or seeds.
- Stay on designated roads. Driving in established native vegetation can disturb soil and provide an opportunity for weed establishment.

Overall, the strategy for reducing the impacts of noxious and invasive weeds on natural landscapes has three main foci. These are as follows: 1) identification and elimination of vectors for transport of weed seeds and propagules, 2) containment of infestations along edges of established populations, and 3) early detection and rapid response for new and small infestations.

Engaging the public in noxious weed control and eradication efforts is also very important in creating low-maintenance natural landscapes. Education of the public about what is being done and why helps to develop buy-in and support for weed control programs. Additionally, notification of the public about herbicide use, tree removal, and biocontrol releases can help gain a broad level of support for these programs.

The following sections present potential prescriptions for treating established weed populations. Appendix C provides treatment recommendations by weed species. Appendix A provides guidance on BMPs for treatments in public places.

Biological Controls

Biological controls are some of the most efficient and cost-effective methods of combating weeds. The definition of *biological control* is the use of live, natural enemies to reduce pest population levels (Coombs et al. 2004). It is important to recognize certain requirements for and limitations of all biological control agents, including public safety, attack of nontarget plants, legal access, and measure of success. Many biological control agents have undergone extensive research and development that support the decision to import or release a natural enemy into a new ecosystem. This section will examine how natural enemies are used. Species-specific natural control agents are further examined in Appendix C.

Plant Pathogens and Insects

The use of herbivores and pathogens found in a given weed's native range can be an effective way to control that noxious weed. Pathogens that cause disease in specific plants include bacteria, fungi, nematodes, protozoa, and viruses. Generally, fungi, bacteria, and viruses are the most commonly studied plant pathogens and are therefore the best understood. Some organisms are host specific, whereas others are capable of infecting several species. Bacteria require a wound or other opening (stomata) to get into the plant, and they are spread passively by rain, moving water, or vectors such as insects. Most fungi are capable of making their own way into susceptible plants, and their spores can be blown long distances or moved in rain or running water. Viruses need a living host and require insects, nematodes, or a wound in the plant for transfer (Coombs et al. 2004).

For plant pathogens to be successful, three factors must be met: 1) the correct pathogen must be selected, 2) the target must be a susceptible host, and 3) favorable environmental conditions must be present. Infections or disease can severely damage a plant, but the pathogen will not be effective if, for example, rain washes it from the target weed's leaves. Many plant pathogens produce plant toxins or enzymes that cause cells to leak nutrients that can then be used by the invading organism, and viruses use the plant's DNA to make more of the pathogen. Some plant pathogens interact with other organisms, and the uses of known natural insect herbivores as vectors are being explored, including the flea beetle, as well as the soil-borne fungi *Rhizoctonia* and *Fusarium* (Coombs et al. 2004). A mixture of pathogens may often increase the damage incurred by the weed species.

Insects have been successfully used as biological control agents throughout the United States. They can attack the plant in both the larval and adult stages, causing damage to leaves, stems, flowers, and root systems. Releasing new insects involves the use of either a field insectary or field nursery site. These sites are weed-infested locations with conditions that optimize survival, reproduction, and growth of the insects. New agents are released at insectary sites and left relatively undisturbed. As populations increase

over 3 to 5 years, surplus agents are harvested for redistribution throughout weed-infested regions. Many factors influence the survival and success of released agents on noxious weeds, and one of the most important factors is how many agents are released and how often they are released. Larger releases are more successful because they reduce the risks of genetic effects and accommodate population shifts in highly variable environments. Therefore, it is important to create favorable release conditions, which may involve releasing 500 insects at one location, 250 at two locations, or 100 at five locations.

Federal regulatory parameters are set in place to ensure the natural enemy of the weed would not itself become a threat to the ecosystem. The international Technical Advisory Group for Biological Control Agents of Weeds (TAG) was established in 1987 with input from the U.S. Department of Agriculture (USDA) and U.S. Department of the Interior. TAG provides recommendations to the USDA Animal and Plant Health Inspection Service, Plant Protection and Quarantine (APHIS-PPQ). Currently TAG is composed of 15 government agencies representing the United States, Canada, and Mexico.

TAG reviews two types of documents: 1) noxious weed listing petitions, and 2) petitions to release a biological agent. Numerous pathogens and insects have been tested and approved by APHIS-PPQ for release against noxious weed species, and require permits for the importation, transit, domestic movement, and environmental release of the organisms that impact plants (APHIS 2006). Requirements for permits are often species specific and can change frequently.

Chemical Controls

Many types and brands of herbicides may prove useful to the reduction and eradication of noxious weeds. Because portions of SLC Open Space Lands consist of wetlands and streams, it is necessary to assess the persistence of the chemicals in these environments and their effects on nontarget plants and animals. Conversely, chemicals may remain in upland and drier areas due to the lack of water, and subsequent hydrolysis (breakdown) of the herbicide may be inhibited. Herbicides can be categorized according to how they move through a plant: downwardly mobile, upwardly mobile, and contact. Choosing the correct herbicide for the target species is important to avoid damaging desirable species, ensure effective control of the weed species, and avoid impacts to wildlife and the environment. Table 4 summarizes commonly used herbicides and their effectiveness on target species. Ratings are presented when available and were obtained largely from Dewey et al. (2006), CSU (2000), EPA Fact Sheets (2006), and specific herbicide labels. Additional information on each herbicide, guidelines for use of herbicides in publicly accessible areas, and a matrix of treatment options are included in Appendix A. Additionally, signs that can be used to notify the public about upcoming treatments and completed treatments are included in Appendix A. EPA fact sheets about the chemical characteristics and toxicity of herbicides are included in Appendix G.

A variety of application methods can be employed for herbicide treatments, such as backpack sprayers and sprayers mounted on all-terrain vehicles (ATVs), trucks, and helicopters. Any herbicide applications should be done according to herbicide labels; Pesticide Applicator Certifications and additional qualifications may be required for spraying certain agents. Applicators should always read the label and apply chemicals according to the guidelines provided with each specific constituent. It may be helpful to mix dye in with the herbicide to ensure that all areas are covered properly. Additionally, it is often necessary to mix a surfactant (sticker) with herbicides to improve the effectiveness of treatments. Only aquatic approved surfactants should be used anywhere near water. The Utah Department of Environmental Quality now requires that all municipalities obtain a pesticide permit for any work planned near waterways or open-water resources.

Table 4. Herbicide Controls for Common Noxious and Selected Invasive Weed Species

Common Name (Scientific Name)	2,4-D	Dicamba	Glyphosate	Imazapic	Imazapyr	Chlorsulfuron	Aminopyralid	Metsulfuron
Jointed goatgrass (*Aegilops cylindrica*)	P	P	E, G	–	–	–	–	–
Garlic mustard (*Alliaria petiolata* [M. Bleb.] Cavara & Grande)	F	–	F	–	–	–	–	F
Cheatgrass (*Bromus tectorum* L.)	P	P	E, G	E	–	–	–	–
Hoary cress (*Cardaria draba* [L.] Desv.)	F	G	F	G	–	E	–	E
Musk thistle (*Carduus nutans* L.)	F	G, F	G	G	–	G	E	E
Diffuse knapweed (*Centaurea diffusa* Lam.)	F	F	X	–	–	–	E	P
Yellow starthistle (*Centaurea solstitialis* L.)	G	G	–	–	–	–	E	–
Spotted knapweed (*Centaurea stoebe* L. spp. *micranthos* [Gugler] Hayek)	F	G, F	–	–	–	–	E	P
Squarrose knapweed (*Centaurea virgata* Lam.)	F	F	X	–	–	–	G	P
Canada thistle (*Cirsium arvense* [L.] Scop.)	E	F	G	–	–	G	E	–
Bull thistle (*Cirsium vulgare* [Savi] Ten.)	E	F	G	–	–	G	E	–
Poison hemlock (*Conium maculatum* L.)	G	–	E, G	–	G	–	E	–
Field bindweed (*Convolvulus arvensis* L.)	G, F	G, F	G, F	–	–	–	–	F
Bermudagrass (*Cynodon dactylon* L. Pers.)	P	P	G	–	–	–	–	–
Houndstongue (*Cynoglossum officinale* L.)	F	G	X	X	–	–	–	–
Common teasel (*Dipsacus fullonum* L.)	–	G	–	–	–	–	–	G
Russian olive (*Elaeagnus angustifolia* L.)	G	–	G	–	G	–	–	–
Quackgrass (*Elymus repens* [L.] Gould)	P	P	G	–	–	–	–	–
Leafy spurge (*Euphorbia esula* L.)	F, P	F	G, F	G	–	–	–	P
Myrtle spurge (*Euphorbia myrsinites* L.)	G	G	G	–	–	–	–	–
Dame's rocket (*Hesperis matronalis* L.)	G	P	G	G	–	–	–	–
Black henbane (*Hyoscyamus niger* L.)	G	G	G	–	–	–	–	–
St. Johnswort (*Hypericum perforatum* L.)	G	–	G	–	–	–	G	G
Dyer's woad (*Isatis tinctoria* L.)	G	E, F	G	G	–	G	–	E
Perennial pepperweed (*Lepidium latifolium* L.)	F	G	G	G	–	E	–	E
Oxeye daisy (*Leucanthemum vulgare* Lam.)	G	–	–	–	–	–	G	-
Dalmatian toadflax (*Linaria dalmatica* L. Mill.)	F, P	G, P	G	G	–	G	–	F
Yellow toadflax (*Linaria vulgaris* Mill.)	–	–	–	–	–	G	–	–
Purple loosestrife (*Lythrum salicaria* L.)	G	–	G	–	–	–	–	G
Scotch thistle (*Onopordum acanthium* L.)	F	F	–	G	–	G	G	E
Common reed (*Phragmites australis* [Cav.] Trin. Ex Steud.)	P	P	G	–	G	–	–	–
Sulphur cinquefoil (*Potentilla recta* L.)	F	–	F	–	–	–	F	F
Russian knapweed (*Rhaponticum repens* [L.] Hidalgo)	G	F	G, P	G	–	F	E	F
Johnsongrass (*Sorghum halepense* [L.] Pers.)	P	P	E, G	–	–	–	–	–

Table 4. Herbicide Controls for Common Noxious and Selected Invasive Weed Species

Common Name (Scientific Name)	2,4-D	Dicamba	Glyphosate	Imazapic	Imazapyr	Chlorsulfuron	Aminopyralid	Metsulfuron
Medusahead (*Taeniatherum caput-medusae* [L.] Nevski)	P	P	G	–	–	–	–	–
Tamarisk (*Tamarix ramosissima* Ledeb.)	–	–	X	–	G	–	–	–
Puncturevine (*Tribulus terrestris*)	G	–	–	G	–	G	G	–

Note: E = Excellent, G = Good, F = Fair, P = Poor, X = Unrated, – = Not applicable or no data.

Mechanical Controls

Mechanical plant control requires selecting the proper equipment that is adapted to the treatment site. Undesirable species that recover by root sprouting must be uprooted or chemically treated, and repeated treatment or a combination of treatments may be necessary. Annual weeds, particularly cheatgrass, recover quickly following treatment if the seeds remaining in the soil are allowed to germinate, warranting ongoing treatment for at least two to five seasons. Available equipment includes seeding and restoration equipment and mechanisms to turn the soil, sever roots, or cut or mow existing vegetation.

Disking and Plowing

Disks and plows are designed to turn over soil and surface debris, kill existing vegetation, and prepare a seedbed. They are often mounted with a three-point hitch on a tractor or dozer but should not be used on uneven, steep, and rocky terrain. The use of heavy equipment can be effective, but purchasing or renting equipment can be costly. Chains or harrows are generally pulled between two tractors to uproot trees and shrubs and can be more economical than disking or plowing. Chaining will uproot larger trees and lightly scarify soil surfaces; however, invasive trees such as tamarisk and Russian olive can re-sprout from their roots, rendering this method ineffective for weed management. Furthermore, chaining has little effect on forbs and grasses (Monsen et al. 2004). Weeds effectively controlled by disking or plowing include cheatgrass, bull thistle, and musk thistle. Disking can also be effective on hoary cress, but disking needs to be done approximately every 2 to 4 weeks throughout the growing season for 3 to 5 years. Herbicide treatment is usually required as a follow-up for areas treated with this method, but the disking typically reduces the amount of herbicide that is needed.

The drawbacks to disking or plowing include the high cost of equipment and labor, inability to access remote locations or steep slopes, root re-sprouting of rhizomatous plant species, and creation of a bare soil environment that may be invaded by other invasive plant species. These mechanical controls are often not practical to use on SLC Open Space Lands because of the presence of steep or uneven terrain, and because weeds often grow alongside native and desirable grass, shrub, and tree species.

Mowing

The ecological basis for mowing weeds is directed at the efficiency of invasive plants to take up and assimilate carbon dioxide and then alter that physiological function. Properly timed mowing can suppress invasive weeds and favor native and desirable plant species. The most effective time to mow is when the invasive weed is actively growing and the desirable species is dormant. This can prevent weed seed production, as well as stressing the plant after it has invested large amounts of energy into flowering and photosynthetic tissue. Also, repeated mowing can deplete root reserves. Effective mowing is a long-term

commitment; some weeds are stimulated by mowing, thereby increasing stand densities. However, over several years, the root reserves will become depleted and stand densities will decrease. Species that respond well to mowing are common reed, Canada thistle, Dalmatian toadflax, leafy spurge, Russian knapweed, and hoary cress (Sheley 2002).

Mowing frequency is dependent on several factors. A spring mowing may be sufficient to reduce annual or biennial species, unless summer rains or soil moisture allows the weed species to regenerate, requiring a second or even a third mowing. Rhizomatous weeds often require several mowings over a growing season to successfully control growth. Mowing is not likely to be effective alone, but it can increase effectiveness of other control efforts, such as herbicide application (Sheley 2002). Other limitations to mowing include inaccessibility to rocky or remote locations, spreading weed seeds, and high cost of equipment and labor.

Removal

Removing plants by hand to uproot the plant works well for small infestations of annual and biennial plants. Be sure the plant species do not re-sprout from residual roots. The drawbacks to hand pulling include labor costs and the necessity of obtaining workers or volunteers to perform the work. Because hand pulling is labor intensive, weed pulling should be conducted after a heavy soaking rain, when the soil is moist (CSU 2000). Pulling entire tamarisk or Russian olive trees has been effective in riparian areas and reduces the need for herbicide application. Follow-up treatments are often needed to ensure the stumps do not re-sprout, but herbicide use can be reduced to a very small amount in these sensitive areas.

Pulling does not generally remove the entire root system, and it is ineffective for killing rhizomatous weed species such as Canada thistle, field bindweed, Russian knapweed, and leafy spurge; however, it will prevent or reduce seed production. Species found on SLC Open Space Lands that are good candidates for hand pulling are Dalmatian toadflax, musk thistle, puncturevine, Scotch thistle, bull thistle, dyer's woad, and myrtle spurge. Pulling may result in soil disturbance that then stimulates germination of weed seeds present in the soil (CSU 2000); therefore, subsequent seeding with native grasses and follow-up monitoring is highly recommended. Further, hand pulling is only effective for small infestations and is not effective for large infestations . As stated above, hand pulling can also exacerbate weed infestations by creating soil disturbance that facilitates further weed seed germination and establishment.

Grazing by goats, cows, or sheep is also a good method to remove plant materials and seed in areas where other methods have failed or site conditions are difficult for mowing. Grazing can remove existing dead plants, which can help increase the effectiveness of herbicide treatments. Special care should be taken not to spread weed seeds on hooves or fur of grazing animals. A clear plan of action for unexpected changes in plant succession is also needed. Grazing can take 2 to 5 years to implement correctly, and some minor herbicide use is typically required after most of the noxious weeds have been removed. Successional seeding is also helpful to get desirable plant species established in areas where grazing is used.

Some plants produce chemicals that cause allergic reaction or dermatitis in some people. Species-specific weed management guidelines should be followed for hand pulling to prevent injury from plant structural or chemical components, such as stiff spines and toxic sap. Personal protective equipment (PPE) should always be worn (long sleeves, gloves), and areas where chemical treatments have occurred or in which other safety restrictions apply should be avoided.

Cut-Stump Treatment and Mastication

The combination of low-stump cutting and herbicide application on the stump has been very effective on controlling and eradicating invasive trees such as tamarisk and Russian olive. To be effective with this method, herbicide treatment must occur within 30 minutes of the stump cut. The tree should be cut as low

to the ground as possible, with the cutter being careful not to hit the ground with the chainsaw. Herbicide treatment can be done by painting a small amount of herbicide on the stump or by spraying it using a backpack or small pump sprayer. Vegetative material can be masticated with a grinder or chipper and piled in the restoration area. Follow-up monitoring should focus on making sure any mature seeds in the chip piles do not germinate. Monitoring for new infestations of additional species of noxious weeds in the cleared areas should be done in the first year following cut-stump treatment, and infestations should be controlled using other recommended actions. Alternately, ringing the cambium (bark) low on the tree with full-strength herbicide will also kill Russian olive and Siberian elm trees. This method has the advantage of leaving the tree standing for habitat structure. Care needs to be taken for public safety if dead trees are left standing.

6. RESTORATION

Ecosystem restoration requires containing or reducing weedy plant populations in an area while increasing the number and type of native plant species. Restoring native plant communities should include increasing native biological diversity; improving control of water flows, resulting in increased sediment and nutrient retention; and detoxifying polluted areas. Given the high cost of weed control, the benefits of restoration provide a powerful incentive for restoring native plant communities.

Research in weed management suggests that both diverse and late-successional plant communities may be relatively resistant to invasion. Diverse plant communities may use resources more completely, leaving fewer resources available for potential invaders (Tilman et al. 1997). This section outlines the considerations and actions necessary for successful ecosystem restoration. Table 5 provides BMP guidelines that can be applied to any restoration project.

Table 5. Best Management Practices Guidelines

Issue	BMP
Noxious weed establishment	• Limit access to the restoration site after the 1 foot of native soil is removed. • Put up erosion control fence to keep vehicles out. • Spray weeds that are growing in disturbed soil now. • Power wash all vehicles before they enter the restoration site.
Riverbank erosion	• Do not disturb willows growing in the bank at low water levels. • Pull soil back away from the river instead of pushing soil parallel to the bank.
Soil compaction	• Limit access to the restoration site after any native soils are disturbed. • Install fencing to keep vehicles out.
Soil cross contamination (weed seeds)	• When excavating, put soil directly into a dump truck with a front-end loader instead of stockpiling it and loading it from a central location. • Store all soil and other materials outside the restoration site.
Final grading	• Meet with all involved to answer questions about the design and to plan the final grading to minimize the spread of weeds and soil compaction. • Have SLC representative present in the field to answer any questions that arise during the final grading.

Evaluation of Ecosystem Characteristics

Plant Communities and Soils

Prior to revegetation, the soils from the restoration site and native plant communities from the surrounding area should be evaluated. Dominant tree, shrub, forb, and grass species should be identified in areas surrounding the restoration site. In addition, the percent cover of the dominant species should be estimated to determine the appropriate amount of seed for each species in the seed mix. If there is no native plant community near the restoration site, a representative native vegetation site should be chosen on the basis of having soils, elevation, slope, and aspect that are similar to the restoration site. A soil sample from the restoration site should be collected and sent to a soils lab for chemical and physical analyses to determine whether soil amendments are necessary prior to revegetation. The biggest reason that restoration projects fail is because the soils were not evaluated properly. The most common mistakes occur when soils are too salty, acidic, or alkaline and/or where the soils are too porous or not porous enough for the plants selected. General soil categories can be investigated with local soil surveys or the Web Soil Survey, but detailed site investigation is often needed due to variability in natural environments and changes in site characteristics over time.

Two general seed mixes have been developed for use on properties that contain representative species from Great Basin grasslands (Seed Mix #1) and shrubland (Seed Mix #2) communities; restoration cost estimates are included in Appendix H. These plant species are just general guidelines; more specific mixes may be required and should be based on evaluation of existing soils and site conditions.

Wildlife Considerations

Because vegetation characteristics are a primary determinant of wildlife habitat quality, an important consideration in revegetating weedy areas on property is choosing the species, planting location, and distribution of plants. For example, deer and elk should be encouraged to browse away from roads to reduce the number of vehicle-wildlife collisions. Areas within 20 feet of roads should be revegetated with low-growing native plant species that provide little forage or cover, which will discourage wildlife from using these areas. These areas should only be seeded with Seed Mix #1 (grassland). On portions of the slopes that are more than 20 feet away from roads, seeding should be done with both Seed Mix #1 and #2, and bare-root and container stock of the following species should be planted: bigtooth maple, curl-leaf mountain mahogany (*Cercocarpus ledifolius*), antelope bitterbrush (*Purshia tridentata*) , Gambel oak, and sagebrush.

In crucial wildlife habitat corridors, native shrubs should be planted where needed in the corridor. Planting antelope bitterbrush, a highly palatable species, in the center of the wildlife corridor may encourage animals to stay within the corridor as they cross through the property. In so doing, wildlife road crossings will be more predictable and thus easier to manage. Fencing may be needed during the initial establishment of shrubs and trees to reduce loss from grazing or browsing animals. Existing animal use restoration areas should be determined to improve the chances of successful plant establishment. Some additional species for evaluation of herbivory concern include voles (*Microtus* spp.) and shrews (*Sorex* spp.), Canada geese (*Branta canadensis*), deer (*Odocoileus* spp.), elk (*Cervus canadensis*), and beaver (*Castor canadensis*).

Fire Considerations

Shrubs should not be planted adjacent to roads or structures. Native FireWise grass (Dennis 2006) and forb restoration species are available for planting in these areas. Where possible, cheatgrass should be removed and areas should be restored to a more fire-resistant landscape due to the high fire potential of areas infested with cheatgrass. Special care should be taken not to create a situation where shrubs can carry fire from the ground up into trees or where they act as “ladder” fuels.

Revegetation

Site Preparation and Seeding

On slopes, the first step in site preparation is the interception of upslope runoff from snowbank melt, rainfall, and irrigation by berms and dikes. This runoff needs to be channeled away from the reclamation slopes and into native drainages. On slopes dominated by weedy plant species, appropriate weed treatments will help reduce the population of undesirable plant species without significantly impacting slope stability. Seeded slopes should be watered by truck immediately following installation of a compost blanket, straw mat, or hydromulch to aid in successful establishment. On slopes with at least 2 inches of topsoil but no significant vegetation, the soil surface should be scarified or covered in biodegradable mesh netting to help the hydromulch adhere to the slope surface. The grass and forb seed mix (see Appendix H) should be applied as part of the hydromulch. The shrub seed mix (see Appendix H) should be broadcast separately over the surface of the hydromulch. These seed mixes provide a diverse selection of locally appropriate native and desirable revegetation species. Final seed mixes should be based on these lists but modified to account for weed treatments and priority species establishment. For example, the selected seed mix can be limited to graminoid species that serve as a cultural control while broadleaf weeds are being treated.

Successful, extensive native grass and forb establishment is known to take 3 to 5 years following the initial seeding. To effectively control erosion during this time, QuickGuard sterile triticale grass or another fast-germinating grass can be included in the seed mix to provide a cover crop during the first year following seeding (Bennett 2006). Species such as yellow sweet clover (*Melilotus* spp.) should not be used as cover crops, although many seed companies will suggest these species. To reduce the establishment of undesirable, weedy plant species, liquid fertilizer should not be added to seeded slopes (USDA 2004).

Seeds can be aerial broadcast using fixed-wing aircraft or helicopters, or small areas can be hand seeded. Seeds should be covered afterward using a harrow or rake; failure to cover the seed will result in high seed predation and low germination rates. Drill seeding has the highest success rates; it involves placing seeds directly into the soil at a specified depth using specialized equipment, but it is less effective on rocky, uneven terrain. It is important that sites be correctly seeded with the appropriate seed mix; otherwise, annual grasses will quickly recover and occupy openings (Monsen et al. 2004).

Perennials must be planted on sites dominated by cheatgrass to obtain a diverse community of native plant species. One method is to use an interseeder, which is designed to seed desirable species into existing plant communities that have very little disturbance. The interseeding tractor consists of a scalper and a heavy-duty seeder (USDA 2004). An interseeder can be used on any terrain where a wheel tractor can safely travel. It is possible to use a steep-slope scarifier and seeder; however, it must be mounted to the end of a crane to operate (USDA 2004). If perennial seedlings survive the first growing season, they will usually attain dominance. After the second or third growing season, the perennials should be fully established and should mature in 6 years if properly managed.

On sites where desirable native grass and forb species are already successfully established, shrub seedlings should be planted as described below.

Shrub and Tree Planting

In areas where additional shrub cover is desired, 200 shrub seedlings should be planted per acre, resulting in approximately 10% shrub cover. A 50% mortality rate should be expected when planting most bare root and containerized shrub seedlings (USDA 2004). In the spring, bare root shrubs should be kept moist and cool throughout the planting process to avoid root desiccation. At the time of planting, organic amendment (topsoil and/or compost) should be added to the planting holes and around the base of each seedling.

Depending on the slope and size of the area to be planted, shrub seedlings can be planted by hand or with a transplanter, which is a tractor-drawn device that scalps the soil, opens a furrow, and plants a bare-root shrub. For large areas with soil at least 18 inches deep, this can be an economical planting method because transplanters consistently plant 1,000 to 1,500 plants per hour (USDA 2004).

On slopes requiring seeding and shrub installation, shrubs should be planted prior to seeding. This will help maintain the structural integrity of the hydromulch or compost blanket. The seeds/mulch should be sprayed around the newly planted shrub seedlings.

During the fall and spring plantings, shrubs should be watered by truck immediately following planting to aid in successful establishment. For spring plantings, supplemental water will be necessary to ensure seedling success. One option is to water the shrubs weekly (if there is no rain) during the first growing season using a water truck. If this method is chosen, the water truck operator should make every effort to target the shrubs rather than broadcast water over the entire slope side. This will help reduce the establishment of weedy plant species and reduce the potential for erosion. A second option is the installation of Rainbird irrigation supplements at the base of each shrub at the time of planting. These would provide time-released, targeted water to each of the shrub plantings for 30 to 90 dry days.

Seedling Protection

Follow these steps to successfully protect seedlings:

- Use mulches around the base of each shrub to retain water and protect the shrub roots from drastic changes in air temperature.
- Provide supplemental water to establish seedlings and maintain them during dry seasons.
- Use erosion control structures on the soil surface to reduce soil and water erosion. This should include a compost blanket and/or sufficient number of straw waddles to prevent slope erosion.
- Use planting stock with a good root-to-shoot ratio to avoid damage associated with extreme soil temperatures. Seedlings with excessive aboveground foliage should be pruned prior to installation to reduce stress on the root system.
- Use plant species and associations adapted to site conditions.

Seasonal Timing of Seeding/Planting Efforts

All seeding should take place in the late fall when air temperatures are lower and the chance of precipitation is high. Shrub seedlings should be installed in late fall and early spring when soil moisture content is high and the chances of precipitation are greatest (USDA 2004).

7. MONITORING

Weed Control Monitoring Objectives

Establishing a strong monitoring program that can be easily followed and repeated will greatly assist in future efforts to make appropriate management decisions. The monitoring program should include careful documentation of existing weed infestations and control agent release sites; the documentation is designed to capture changes in plant performance and plant populations. The following can provide insight into the best management techniques to combat noxious and invasive weed population: using photography and GPS technology to enhance mapping efforts and capture abiotic factors, and monitoring off-season conditions to better understand seasonal changes that may affect the biological control agents. Monitoring follows mapping and can have a variety of objectives, such as the following:

- Assessing the effect of management activities
- Detecting weeds in uninfested areas
- Assessing the impact of weeds on the ecosystem
- Assessing the effects of management activities on the ecosystem
- Evaluating weed spread

Monitoring provides feedback on the efficacy of management activities. Management plans can and should be adjusted based on feedback from monitoring. Although monitoring is often restricted to small areas or plots, weed expansion or contraction across large geographic areas can be monitored by comparing maps from different years.

Weed Monitoring Protocols

Revegetation and Treatment Area Monitoring Methods

Revegetation and treatment success should be monitored during the first three growing seasons after treatments and revegetation occur. In addition, revegetated slopes should be visited twice during summer months to obtain visual percent cover estimates by plant species and morphological class. These measurements can provide information about which grass, forb, and shrub species are most successful in various biophysical conditions (soil type, slope, aspect, etc.). Erosion should be monitored in the early spring during shrub installations and again in the summer during the vegetation evaluations. A simple point-intercept transect form is included in Appendix I. Permanent transects can be established and monitored every few years to assess plant community trajectory. A list of the noxious and invasive plant species can be found in Appendix J and a treatment tracking form is included in Appendix I.

Evaluation of Successful Revegetation

The success of slope revegetation efforts should be evaluated during each site visit. A 50% mortality rate can be expected when planting most bare root and containerized shrub seedlings (USDA 2004). This is due, in part, to the palatability of shrub seedlings for foraging wildlife species. The other major factor is transplant shock, which is likely to impact a significant percentage of the shrub seedlings. Therefore, the shrub installation should be considered a success if more than 50% of shrub seedlings survived the first 3 years following installation.

Successful, extensive native grass and forb establishment is known to take 3 to 5 years following the initial seeding. To effectively control erosion during this time, a sterile wheat/rye grass hybrid or fast-germinating native grasses can be included in the seed mix to provide a cover crop during the first year

following seeding (Bennett 2006). Each fall and spring, slopes should be examined for native growth. The seeding is considered successful if a significant increase in the number and type of native species were to occur each year, with substantial biomass and diversity after 3 years.

Contingency Measures

Possible conditions that could contribute to failure include insufficient soil nutrients, lack of erosion control measures, improper shrub installation, lack of water, extreme precipitation events, and extreme air temperatures. Of these conditions, the first four are preventable, while the latter two are not. If revegetation is not successful on certain slopes, those slopes should be carefully evaluated to determine the cause of failure. Once the cause is determined, the situation should be remedied (if, and where, possible) and the slope revegetated. Given that 50% mortality of shrub plantings is expected, only slopes exhibiting 60% or greater shrub mortality should be replanted.

8. SITE-SPECIFIC WEED MANAGEMENT

Detailed treatment and management information for common noxious weed species is provided in Table A.2.1 (Appendix A). Site-specific information on most effective treatments and timing for target weed species for each management area are provided in Table A.2.2 (Foothills Management Area), Table A.2.3 (Tributaries Management Area), and Table A.2.4 (Jordan River Management Area) in Appendix A.

Two types of areas within SLC Open Space Lands have been identified as project treatment areas based on the extent and density of noxious weeds in these areas. These areas are riparian areas and uplands. They are highlighted in the 2011 Weed Treatments maps 1–10. Riparian areas are typified by the areas directly adjacent to streams and the Jordan River, such as along the Jordan River Parkway and in Parley's Historic Nature Park. Uplands are typified by other areas away from streams but are included in the stream corridors as part of the mosaic of habitats typically found in riparian areas. Examples of upland areas are the H-Rock, Rotary Park, and other foothill properties.

Priority weed species identified from the 2011 weed mapping effort are hoary cress, Russian knapweed, Scotch thistle, myrtle spurge, houndstongue, Dalmatian toadflax, tamarisk, and puncturevine. These noxious weed species are associated with disturbed soils and pedestrian corridors throughout SLC Open Space Lands and require immediate action to prevent further spread and ecological impacts to these areas. New invaders that should be aggressively managed and mapped for changes include garlic mustard, yellow toadflax, dyer's woad, and purple loosestrife. Other invasive species that are widespread and should be controlled are common reed and Russian olive.

The project treatment areas have some similar characteristics but are managed differently to minimize chances of having pesticides enter SLC waterways. The following strategies will identify specific treatments that can be used for the different properties, including volunteer efforts, riparian corridor herbicide treatments, and upland herbicide treatments.

The numerous trails and corridors in SLC Open Space Lands are also identified as a high priority to control noxious and invasive weed species because of the high use of the areas and likelihood of spreading weed seeds. Trails can be major vectors of invasive weed seed dispersal, leading to new and expanding weed infestations. These trails are heavily infested with weeds and serve as vectors to noninvaded communities. Seeds and broken plant parts can stick to bicycle tires, clothing, and dogs' fur and can be transported to other locations. Furthermore, these weedy infestations can pose a fire risk if they are sparked and ignite dead, standing plant biomass.

The weed management goal for the trails and corridors is an example of one of the most basic principles of adaptive weed management strategy: reduce the weed vectors and drivers. Suppressing weeds using volunteer efforts, combined with biological and chemical controls, followed by revegetation with

desirable grasses and shrubs, will reduce the introduction of seeds attached to bicycle tires, hikers, and dogs' fur into new locations. Incorporating weed education into SLC's sustainable development program and public outreach is integral to help reduce the spread of these infestations and prevent future infestations. Trail corridors include Jordan River Parkway, Parley's Historic Nature Park, and the Bonneville Shoreline Trail.

Volunteer-Mediated Efforts

The most commonly observed annual and biennial corridor weed species are Scotch thistle, musk thistle, dyer's woad, and puncturevine. Scotch thistle and musk thistle are biennial plants; they develop large rosettes the first year and flower and set seed the second year. Dyer's woad and puncturevine are annual plants; they germinate in the spring and set seed in late summer to early fall. The most important aspect to controlling these species is to prevent them from flowering or from setting seed.

SLC has shown great success in using volunteers in the past. The following species are good candidates for control with volunteer efforts: musk thistle, Scotch thistle, puncturevine, dyer's woad, and houndstongue. Rosettes from all of these plant species can be mechanically removed in the spring when the soil is moist. Significant Scotch thistle and musk thistle populations occur along the Jordan River Parkway, specifically in the oxbow north of the International Peace Gardens. Puncturevine is found all along the Jordan River, and efforts are underway to eliminate this plant along most of the SLC section of the Jordan River Parkway in the next few years.

Riparian Corridors

Description

Riparian corridors are potential vectors for the spread of invasive weed seeds because of pedestrian traffic and water dispersal of seeds; as such, they have been identified as a high priority for the control of noxious and invasive weed species. Controlling noxious and invasive weeds in riparian corridors can be extremely difficult because the seed source may be coming from upstream or carried into the area by hikers, dogs, wildlife, or in floodwaters. Riparian corridors run through all plant communities and occupy small but very important sites across SLC Open Space Lands. Riparian areas attract wildlife throughout the year. The Jordan River is the major connective riparian corridor connecting Utah Lake to Great Salt Lake. Numerous tributaries, including Parley's Creek, Red Butte Creek, Emigration Creek, and City Creek, drain the Wasatch into the Jordan River. These tributaries and the Jordan River corridor are important recreation areas and are heavily infested with weed species. Due to the sensitivity of the water and wetlands, specific watershed-approved herbicides should be used.

The most commonly observed riparian weed species in the Salt Lake Valley include hoary cress, common reed, Russian olive, and houndstongue. Hoary cress is a perennial that reproduces primarily from adventitious buds on the roots but can also spread from seed. Hoary cress seeds can remain viable in the soil for up to 3 years. Houndstongue seeds are in the form of nutlets that break apart at maturity and cling to clothing or animals; reproduction is solely by seed (Belliston et al. 2004).

Strategies and Prescriptions

The following strategies are recommended to reduce the spread of noxious and invasive weeds through riparian corridors. Weed management involves a certain level of trial and error to accommodate variation between sites; therefore, modifications to the following may be necessary.

1. Strategies for reducing weed populations along riparian corridors include the following:
    - Many locations in riparian areas will require the use of targeted herbicide treatments. The most effective and least environmentally damaging methods should be used to minimize any impacts to surrounding native riparian vegetation. Herbicide application should follow the indications listed on the chemical label, and special care should be taken to provide proper signage in areas that are publicly accessible. The most effective and least damaging method that is typically used in riparian areas is spot spraying; broadcast applications should not be used unless absolutely necessary.
    - Care must be taken to select herbicides that are approved for use within the riparian zone; use EPA-approved aquatic herbicides where there is any chance of runoff into SLC waterways. Even though these herbicides are approved for aquatic use, all measures to reduce runoff of herbicides and drift should be followed. See Appendix A for BMPs related to herbicide use.
    - In April, apply watershed-approved herbicide to hoary cress at the recommended rates on the label. Target actively growing green foliage between flower bud and flowering stages. Hoary cress seeds will mature within days if plants are sprayed during the flowering stage, but some seeds may still be killed at this late growth stage.
    - If feasible, remove and bag dead biomass 30 to 60 days after herbicide application. This will remove any seeds remaining on plants, eliminate the potential fire hazard from dead, standing biomass, and allow enough time for the herbicide to be translocated from the aboveground biomass to the roots to kill the plants. Biomass removal may be difficult for smaller weed species, such as hoary cress.
    - Goat grazing can be used in targeted areas where weeds are present, and it has been used as an effective tool in riparian areas. Allowing goats to graze riparian areas in early spring reduces plant biomass and prevents seed set. Supplements of iodine are necessary to reduce the deficiency brought on by ingestion of hoary cress seeds. A goat grazing plan would require multiple years to implement and would likely need to be followed by some type of targeted herbicide application.
    - Five biological control agents that are currently being tested for use on houndstongue may become available for future use. These include a root weevil (*Mogulones cruciger*), seed weevil (*M. borreginis*), stem weevil (*M. trisignatus*), root beetle (*Longitarsus quadriguttatus*), and root fly (*Cheilosia pasquorum*).
2. Strategies for restoration of native plant diversity to riparian corridors include the following:
    - In riparian areas where no vegetation remains, bioengineered soil lifts, waddles, straw blankets, and other forms of erosion control options are available, depending on the slope, flooding frequency, and bank stabilization required.
    - Prepare seed bed by disking, tilling, or subsoiling where site conditions allow. It may not be feasible to access steep riparian with reclamation equipment.
    - Seed the weed-infested areas with a riparian seed mix 30 to 45 days after fall herbicide application. Seed mix should include native rushes, sedges, bulrushes, and spikerushes, which are dense, sod-forming species vital to streambank stability. Harrow or rake in seed where possible. Most seeds must be covered with soil for at least one winter to germinate. On slopes, hydroseeding with a bonded fiber matrix would also provide slope stability and cover for the seeds to overwinter. See Appendix H for seeding recommendations.

- Each spring for 3 years, plant native tree saplings, rushes, sedges, bulrushes, and spikerushes in small, discrete sections of the riparian corridor to retain existing plant cover, which will aid in natural recovery (Monsen et al. 2004). Transplanted trees forbs will help stabilize the streambanks and resist flooding. Yellow willow (*Salix lutea*), peachleaf willow (*S. amygdaloides*), and Fremont cottonwood (*Populus fremontii*) are appropriate species for riparian restoration; they are available for purchase in Utah as 12-inch-tall plugs. Numerous native rushes and sedges are available as 10-inch-tall plugs. Table 6 provides select native Jordan River plants.

Table 6. Select Native Jordan River Plants

Scientific Name	Common Name	Planting Zones*						Wetland Status†
		A	B	C	D	E	F	
Acer negundo L.	Box elder					X	X	FACW+
Artemisia tridentata Nutt.	Big sagebrush						X	N/A
Atriplex canescens (Pursh) Nutt.	Four-wing saltbush					X	X	UPL
Atriplex gardneri (Moq.) D. Dietr.	Gardner's saltbush					*X*	*X*	*N/A*
Carex pellita Muhl. *ex Willd.*	*Wool*ly sedge	X		X	X			OBL
*Carex nebrascensis De*wey	Nebraska sedge	X		X	X			OBL
Chrysothamnus viscidiflorus (Hook.) Nutt.	Twistedleaf rabbitbrush						X	N/A
Crataegus douglasii Lindl.	River hawthorn		X					FAC
Deschampsia cespitosa (L.) P. Beauv.	Tufted hairgrass			X		X		FACW
Distichlis spicata (L.) Greene	Inland saltgrass	X	X	X		X	X	FAC
Eleocharis palustris (L.) Roem. & Schult.	Creeping spikerush	X		X	X			OBL
Elymus trachycaulus (Link) Gould ex Shinners	Slender wheatgrass					X	X	N/A
Euthamia occidentalis Nutt.	Western goldentop			X				OBL
Juncus arcticus Willd. ssp. *littoralis* (Engelm.) Hultén	Baltic rush			X	X			FACW
Juncus torreyi Coville	Torrey's rush			X	X			FACW
Muhlenbergia wrightii Vasey ex J.M. Coult.	Spike muhly			X		X	X	FACU
Pascopyrum smithii (Rydb.) Á. Löve	Western wheatgrass					X	X	N/A
Populus fremontii Watson	Fremont cottonwood		X	X				FACW
Prunus virginiana L.	Chokecherry					X		FACU
Pseudoroegneria spicata (Pursh) Á. Löve	Bluebunch wheatgrass					X	X	N/A
Puccinellia nuttalliana (Schult.) Hitchc.	Nuttall's alkaligrass			X		X		OBL
Rhus trilobata Nutt. var. *trilobata*	Skunkbush sumac					X		N/A
Ribes aureum Pursh	Golden currant		X	X		X		FACW
Rosa woodsii Lindl.	Wood's rose		X	X		X		FAC

Table 6. Select Native Jordan River Plants

Scientific Name	Common Name	Planting Zones*						Wetland Status†
		A	B	C	D	E	F	
Salix exigua Nutt.	Sandbar willow	X						OBL
Salix amygdaloides Andersson	Peachleaf willow	X	X					FACW
Schoenoplectus maritimus (L.) Lye	Alkali bulrush	X			X			NI
Schoenoplectus pungens (Vahl) Palla	Three square bulrush	X			X			OBL
Shepherdia argentea (Pursh) Nutt.	Silver buffaloberry						X	N/A
Sporobolus airoides (Torr.) Torr.	Alkali sacaton			X		X		FAC

Note: N/A = not applicable; X = species is suitable for plantingn this zone.

* Wetland Planting Zones: A - Low Emergent Bench, B - Cottonwood/Shrub Riparian Belt, C - Open Wetland Meadow, D - Emergent Marsh/Open Water, E - Upland/Wetland Transition, F- Upland Buffer

† Wetland Status:
Obligate wetland species (OBL) occur more than 99% of the time only in wetlands.
Facultative wetland species (FACW) occur in wetlands 67%–99% of the time.
Facultative species (FAC) are tolerant of wet and dry conditions; they are as likely to occur in uplands as in wetlands and are found in wetlands 34%–66% of the time.
Facultative upland species (FACU) are flood-intolerant and usually occur in uplands (66%–99% of the time) but occasionally are found in wetlands (1%–33% of the time).
Plant species that have an indicator status of OBL, FACW, or FAC (but not FACU or UPL) are typically adapted for life in wetlands (anaerobic) soil conditions.
NI - Non Indicator (Environmental Laboratory 1987).

Monitoring

Active weed control efforts may be necessary for several years to reduce the soil seed bank. Surveys should include mapping the size of the weed infestations, species composition, photograph points, and cover estimates. This information will be helpful to determine whether a particular species is resistant to specific herbicides, whether it is increasing or decreasing in abundance, and whether new species are encroaching. The form in Appendix I can be used to collect data on point-intercept transects. These transects can be permanently marked with small PVC markers or T-posts where no mowing will occur. The following steps can be used as a general guide for establishing monitoring plots:

- Establish three to five point-intercept transects and photograph points in treated areas along riparian corridors to monitor weed control efforts, disturbance reduction success, and desirable species establishment. Record species composition, percentage cover for all plant species, and species density for weed point locations, using the GPS data dictionary as a guide. Monitor riparian plots twice per year, spring and fall, well after herbicide application to reduce chances for employee exposure. Always read label and Material Safety Data Sheet (MSDS) sheets to determine the human health risk of entering areas that have been treated with herbicide.
- Spot spray using a backpack or handheld sprayer to eliminate regrowth or newly germinated weed species after control is achieved.

Upland

Description

Much of the area surrounding the riparian corridors is classified as upland shrubland and grassland. Open Space Lands are often adjacent to weedy residential and business developments; these developments can be sources of weedy populations across property boundaries. Trail corridors that meander through the

upland areas can be vectors of seeds both into and out of SLC property. Upland areas include sections of Parley's Historic Nature Park, H-Rock, and Rotary Glen, along with other properties in the foothills such as Ensign Peak and similar landscapes. The goal of treatments and restoration in the upland areas is to create an aesthetically pleasing natural landscape free of weed species that borders the property lines and trails to stop noxious and invasive species from spreading to uninvaded areas. A secondary goal is to prevent new weed species from entering SLC properties.

Some of the most common weed species present in the upland areas are cheatgrass, Dalmatian toadflax, houndstongue, and myrtle spurge. Cheatgrass develops a continual fuel layer, increasing the probability of fire with potentially devastating effects on both the ecosystem and facilities. Cheatgrass is an annual grass that germinates in the fall, develops long roots over the winter, and flowers and sets seed in the spring. Because it is an annual, it is important not to let it flower and set seed, adding to the soil seed bank, if possible. Seeds can remain viable in the soil for up to 4 years. The dry stalk and seed heads of cheatgrass create a continuous layer that can spread fire quickly across a landscape.

Dalmatian toadflax is a perennial that reproduces mainly from seeds that can remain viable in the soil for up to 10 years, although severed roots can re-sprout. Timing is extremely important for herbicide application because the heavy waxy cuticle on the mature Dalmatian toadflax leaves prevents herbicides from the entering plant.

Houndstongue is a biennial that reproduces entirely from seed, and seeds can remain viable for up to 3 years if left on the plant, and 1 to 2 years in the soil. Therefore, the key to controlling houndstongue is to prevent it from flowering or setting seed. This species is a poor competitor with native perennials and requires disturbed or bare areas to establish.

Myrtle spurge was grown as a decorative garden plant and escaped into the foothills of the Wasatch. It is a perennial that produces new stems from the taproot each year. This plant contains toxic, milky latex, which can cause severe, blister-like burns on the skin. This plant does respond well to mechanical removal; however, if mechanically removed, care must be taken to avoid contact with the skin and eyes. The Salt Lake County Weed Program's *Purge the Spurge* campaign has been very effective, and continued coordination with this program may be an effective educational and volunteer-mediated opportunity to remove this plant species. It may also be effective to start mechanical removal as foothill areas thaw in spring. Only infestations that are small, isolated, and easily accessible should be managed with hand pulling. Large infestations should be treated with herbicide.

Strategies and Prescriptions

Strategies and prescriptions for upland areas are similar to those suggested for riparian areas. There are some different plant species that are commonly found in upland areas, and the following recommendations can be implemented as part of an adaptive management strategy.

- Use volunteers and contracted crews to remove small infestations of Dalmatian toadflax and myrtle spurge along trails and adjacent to disturbance areas. Repeated removal of these plants over 2 to 3 years has completely eliminated small infestations, and removal along trails will reduce spread by seed.
- In April, apply appropriate herbicide to hoary cress and thistle rosettes at the recommended rates on the label. Target actively growing green foliage between flower bud and flowering stages. Hoary cress seeds will mature within days if plants are sprayed during the flowering stage. Although hoary cress is being targeted, all weed species present should be thoroughly coated with herbicide.

- If feasible, remove and bag dead biomass 30 days after herbicide application. This will remove any seeds remaining on plants and eliminate the potential fire hazard from dead, standing biomass, but will allow enough time for the herbicide to be translocated to the roots to kill the plants.
- Apply appropriate herbicide at recommended rates on the label targeting Russian knapweed, Canada thistle, and field bindweed in September or October, 1 to 2 weeks following the first frost. Frost stresses the plants, making them more susceptible to herbicide application. Although Russian knapweed and field bindweed are being targeted, all weed species present should be thoroughly coated with herbicide.
- Monitor and spot treat every spring and fall to maintain weed-free pull-off locations for 3 to 5 years.
- Place weed-free barriers (use cloth barriers to allow water to infiltrate) and gravel on pad to prevent weeds from returning.
- Institute an educational program to train all authorized individuals who conduct work along the trails to identify existing and new infestations of target species.
- Supply vehicles with lists and color photographs of problem weed species.
- Where possible, provide a water tank and hose with which to remove weed seed and plant parts from vehicles before leaving weed-infested locations.
- Incorporate weed identification and BMP training into existing employee training.
- Prepare seed bed by disking or subsoiling where site conditions allow. It may not be feasible to access steep or rocky terrains with reclamation equipment.
- Seed infested areas with appropriate seed mix 30 to 45 days after fall herbicide application. Seed mix can include 10% to 20% sterile triticale or fast-germinating native grasses that will germinate quickly, stabilize soil, and compete with weeds for soil resources. See Appendix H for complete seed mix recommendations.
- Harrow or rake in seed where possible. Most seeds must be covered with soil for at least one winter to germinate. On slopes, hydroseeding with a bonded fiber matrix would also provide slope stability and protection for the seeds from predation. Seeding with perennial grasses will allow continued spot spraying with broad-leaf herbicides if necessary to maintain weed control.
- See Table 7 for shrub and tree seedling recommendations for upland areas.

Table 7. Upland Planting Recommendations

Growth Form	Common Name	Genus	Species	Notes
Trees (bare root)	Box elder	*Acer*	*negundo* var. *interior*	Probably the most valuable tree for birds, insects, and other wildlife.
Shrubs (tubelings)	Oakleaf sumac	*Rhus*	*aromatica* var. *trilobata*	Deep rooting; drought tolerant; seed spread by birds.
	Four-wing saltbush	*Atriplex*	*canescens*	Attractive gray-leaved, dioecious shrub; salt and alkali tolerant.
	Rubber rabbitbrush	*Chrysothamnus*	*nauseosus*	Common to dry lands and foothills but salt and alkali tolerant in heavy soils; currently on Utah Reclamation and Mitigation Commission historic Burgon/Greenwood property at 10500 South.
	Twistedleaf rabbitbrush	*Chrysothamnus*	*viscidiflorus*	On dry sites above the Jordan River floodplain, but not as salt and alkali tolerant as rubber rabbitbrush; local relict population 9200 South (Mumford Hill) extinct.
	Gardner's saltbush	*Atriplex*	*gardneri*	Very salt and alkali tolerant rhizomatous sub-shrub that would form a good ground cover on difficult sites; valuable for restoration; known from relict populations near the Jordan River (Corner Canyon Creek, Harrison farm, etc.)
	Big sagebrush	*Artemisia*	*tridentata* var. *tridentata*	Probably more common on uplands adjacent to the Jordan River floodplain; currently at 10500 South on Utah Reclamation and Mitigation Commission parcel (historic Greenwood/Burgon property).
	Gray horsebrush	*Tetradymia*	*canescens*	Known from Dry Creek in Dimple Dell and Mumford Hill (extinct population); drought and alkali tolerant.
Grasses (tubelings)	Alkali dropseed	*Sporobolus*	*airoides*	This deep-rooting ornamental grass would get a rapid start as a tubeling; commercial seed sources exist.
	Western wheatgrass	*Pascopyrum (Elymus, Agropyron)*	*smithii*	This rhizomatous wheatgrass will spread rapidly from tubeling transplants; commercial seed sources exist but need to be local, adapted genotypes.
	Bluebunch wheatgrass	*Pseudoroegneria (Elymus, Agropyron)*	*spicatus*	Although conventionally seeded, a fall-planted tubeling would get a successful start; local genotypes that are short-awned and semi-rhizomatous are known from the Dimple Dell/Dry Creek area; this wheatgrass has been identified from Clay Point above the Jordan River at approximately 11000 South (population now extinct due to development). Commercial seed sources exist but need to be a Utah genotype.

Table 7. Upland Planting Recommendations

Growth Form	Common Name	Genus	Species	Notes
Forbs (tubelings or seed)	Scarlet globemallow	*Sphaeralcea*	*coccinea*	This attractive, drought-tolerant, rhizomatous perennial should be planted more; it is known from heavy, clay soils along the Jordan River uplands; commercial seed sources exist, but do not confuse with the nonrhizomatous desert globemallow (*Sphaeralcea ambigua*), which is often substituted for and confused with the scarlet globemallow.
	Wild tarragon	*Artemisia*	*dracunculus*	Plants in Dimple Dell Regional Park; it used to exist on Mumford Hill, but the population is now extinct; commercial seed source unknown.
	Louisiana sagewort	*Artemisia*	*ludoviciana*	Common along Dry Creek above where it enters Jordan River; commercial seed sources exist, but it should be a Utah, low-elevation genotype.
	Lewis flax	*Linum*	*lewisii*	Known from Mumford Hill at 9800 South, east of Jordan River on sandy soil (population extinct).
	Sand puffs	*Abronia*	*fragrans*	Attractive, drought-tolerant, perennial wildflower; prefers sandy soil but would probably survive in other soil types; known from Dimple Dell Regional Park; a population existed on Mumford Hill until 1990 when it was destroyed by a golf course. Commercial seed sources exist.
	Purple Beeweed (annual)	*Cleome*	*serrulata*	Showy annual wildflower attractive for many kinds of bees; large population used to exist on Mumford Hill; now destroyed by a golf course; commercial seed sources are available.
	Pale evening primrose	*Oenothera*	*pallida*	Common in Dimple Dell Regional Park on sandy soil; could possibly survive near Jordan River, although I have never seen it there. Commercial seed sources exist.
	Low evening primrose	*Oenothera*	*caespitosa*	This wildflower occurs on sandy, well-drained soil, although it is called "gumbo lily" in the Midwest, where it occurs on heavy, textured soil; seed is commercially available.
	Longleaf phlox	*Phlox*	*longifolia*	This attractive, spring-flowering, rhizomatous perennial is known from the Jordan River uplands; associated with big sagebrush and rabbitbrush. It used to be on Mumford Hill at 9800 South, but the population is extinct; unknown seed source.

Source: Dr. Ty Harrison, Consultant, Westminster College Biology Department, June 23, 2004.

Note: These ecological assemblages are based on the personal observations of Dr. Ty Harrison of the Jordan River in south Salt Lake County over the past 40 years.

Late fall planting (October–November) of both tubelings and seed (hydroseeding) and bare-root or potted materials is recommended.

Monitoring

Active implementation of weed control efforts may be necessary for several years to reduce the soil seed bank. Surveys should include mapping the size of the weed infestations, species composition, photograph points, and cover estimates. This information will be helpful to determine whether a particular species is resistant to specific herbicides, whether it is increasing or decreasing in abundance, and whether new species are encroaching. The following list is provided as a general guideline for establishing a monitoring program.

- Establish observation points at each pull-off location; this includes the treated pull-off and adjacent vegetation around the pad. Both weed-infested and weed-free vegetation should be included to document changes in species composition. Each pull-off location should be monitored (including photographs) monthly from March through October for at least 2 years; any regrowth or newly germinating individuals should be pulled or treated. After control is achieved, monitoring can be reduced to twice per year, spring and fall.
- Establish three to five plots and photograph points in treated areas along roadsides to monitor weed control efforts and desirable species establishment. Record species composition, percentage cover for all plant species, and species density. Monitor roadside plots twice per year, spring and fall, during herbicide application.
- Spot spray using a backpack or handheld sprayer to eliminate regrowth or newly germinated weed species after control is achieved.

9. INTEGRATED PEST MANAGEMENT PLAN SUMMARY

The SLC Open Space Lands Program manages 1,452 acres of open space to provide recreational and overall health and lifestyle benefits to the SLC community, to provide an interface with the natural areas bordering SLC, and to protect and conserve the natural environment and ecosystem services that open space provides (SLC Planning Commission 1992). The purpose of this weed management plan is to provide an integrated and adaptive weed management approach for treating weeds on these ecologically and socially important open space lands owned and managed by SLC Parks and Public Lands. SLC will continue to add information to this plan as part of an ongoing, adaptive weed management process.

In 2011 and 2016, ecologists from SWCA mapped noxious weed populations across 1,307.2 acres of Open Space Lands (316.9 and 990.3 acres, respectively). The remaining 145 unsurveyed acres comprise parcels added to the SLC Open Space program in the Jordan River and Tributaries Management Areas since 2011.

Noxious weed species currently occur in large infestations in the Foothills Management Area compared to the Jordan River and Tributaries Management Areas. This is partially because of the area's large size and management history of the area's parcels. The primary weed species of concern in the Foothills Management Area are dyer's woad, Dalmatian toadflax, and hoary cress. The primary weed species of concern in the Tributaries Management Area are hoary cress, myrtle spurge, and thistle species. The weed species of concern in the Jordan River Management Area are hoary cress, knapweed, and thistle species. Puncturevine and myrtle spurge are also of concern in the Tributaries and Jordan River Management Areas.

The next step in integrated pest management planning is to prioritize the weed species and project areas for management actions. Background information and guidance for such actions are provided in the appendices that accompany this plan. Regular monitoring of treated areas is also recommended as part of any adaptive management plan to ensure that treatment strategies are effective in controlling weed infestations.

The objective of this noxious and invasive weed management plan is to identify weed infestations, prevent the establishment and spread of future weed infestations, and ultimately restore native and desirable nonnative vegetation using integrated weed management strategies. This plan reflects the land management goals of multiple city, county, and federal land management agencies to reduce and contain weedy plant infestations, prevent unnecessary environmental disturbance, and maintain and/or restore native ecosystem functions.

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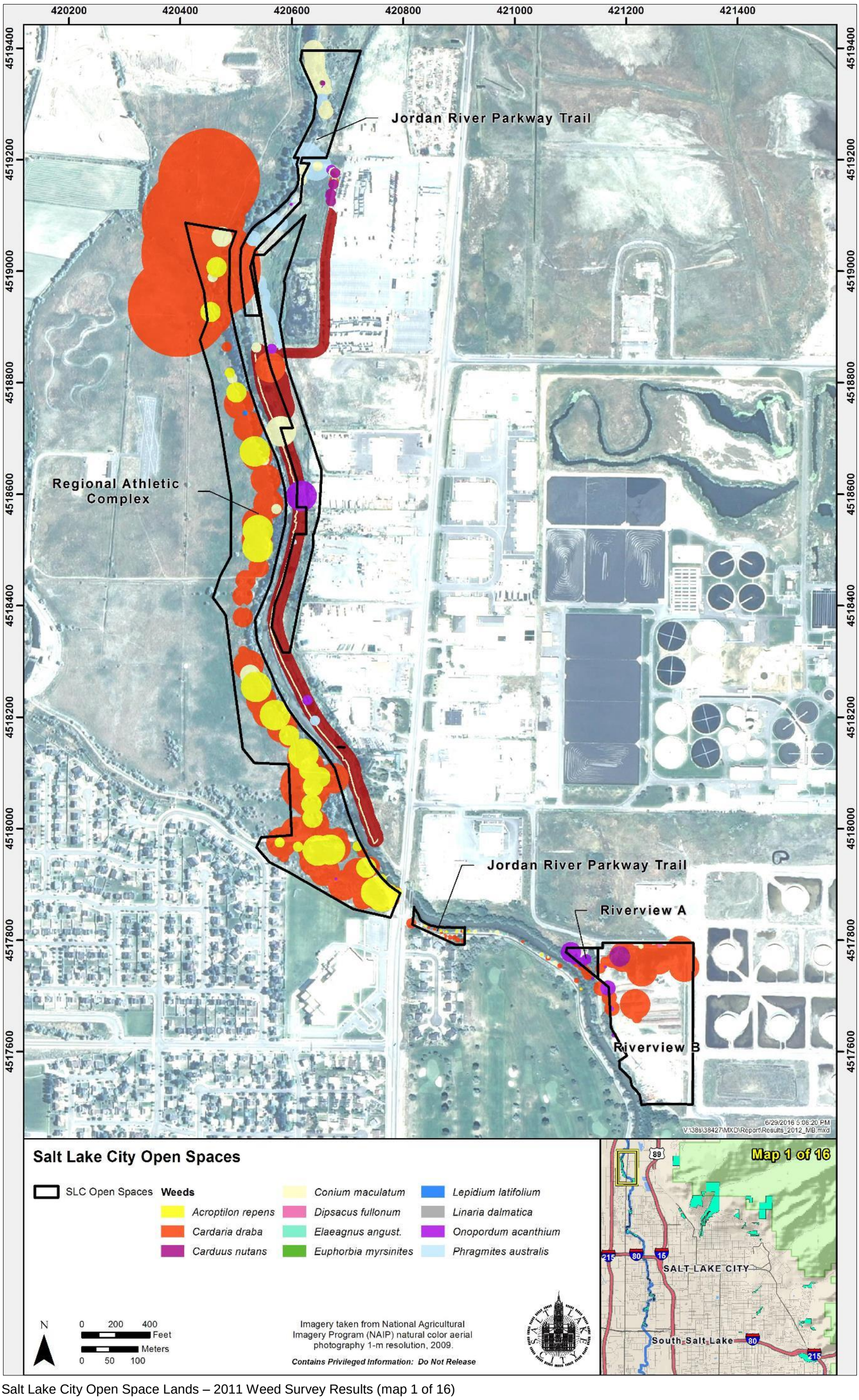
Maps

Weed Survey Results and Weed Treatment Maps for Salt Lake City Parks and Public Lands



Salt Lake City Open Space Lands – 2011 Weed Survey Results (map 1 of 16)

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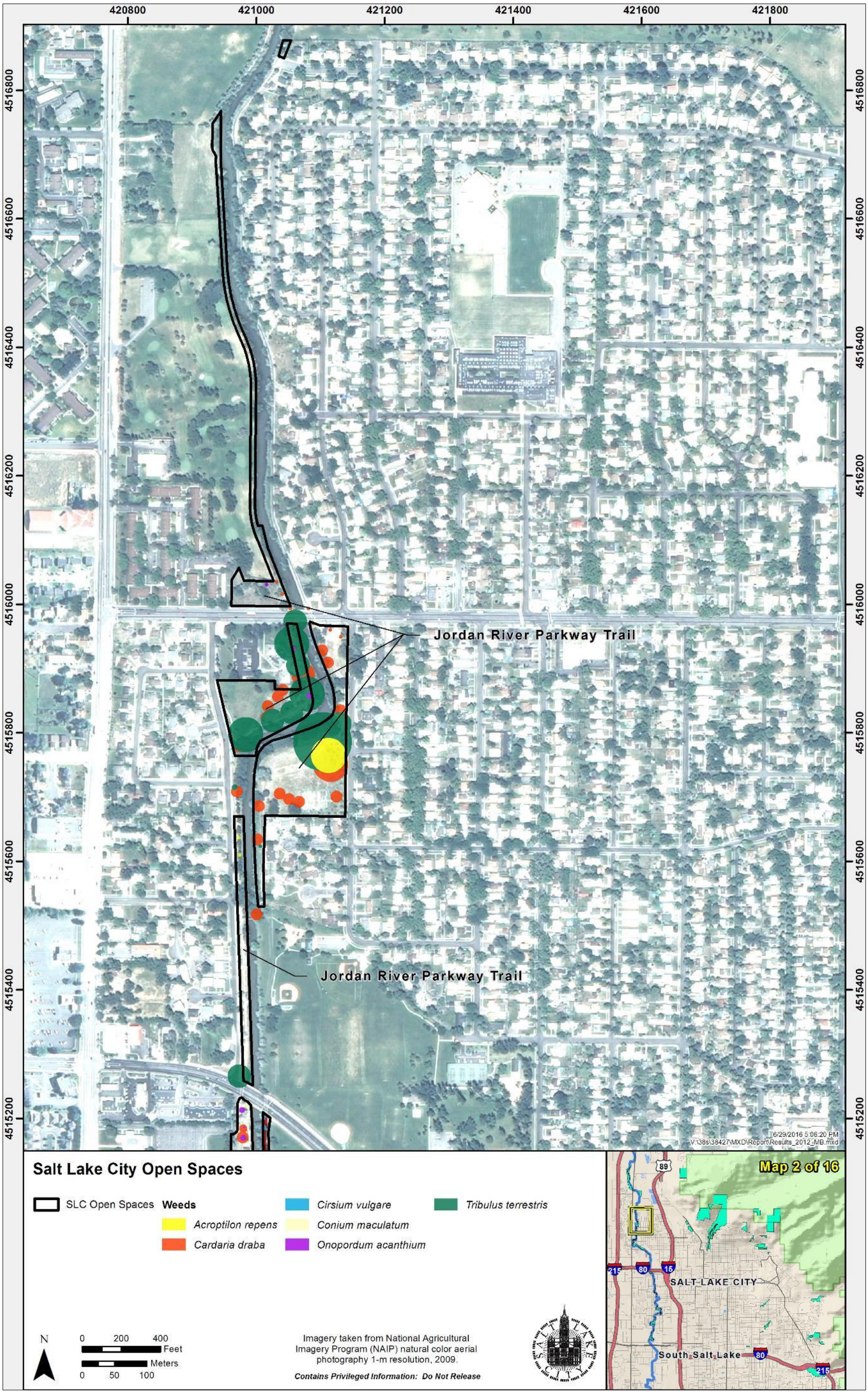

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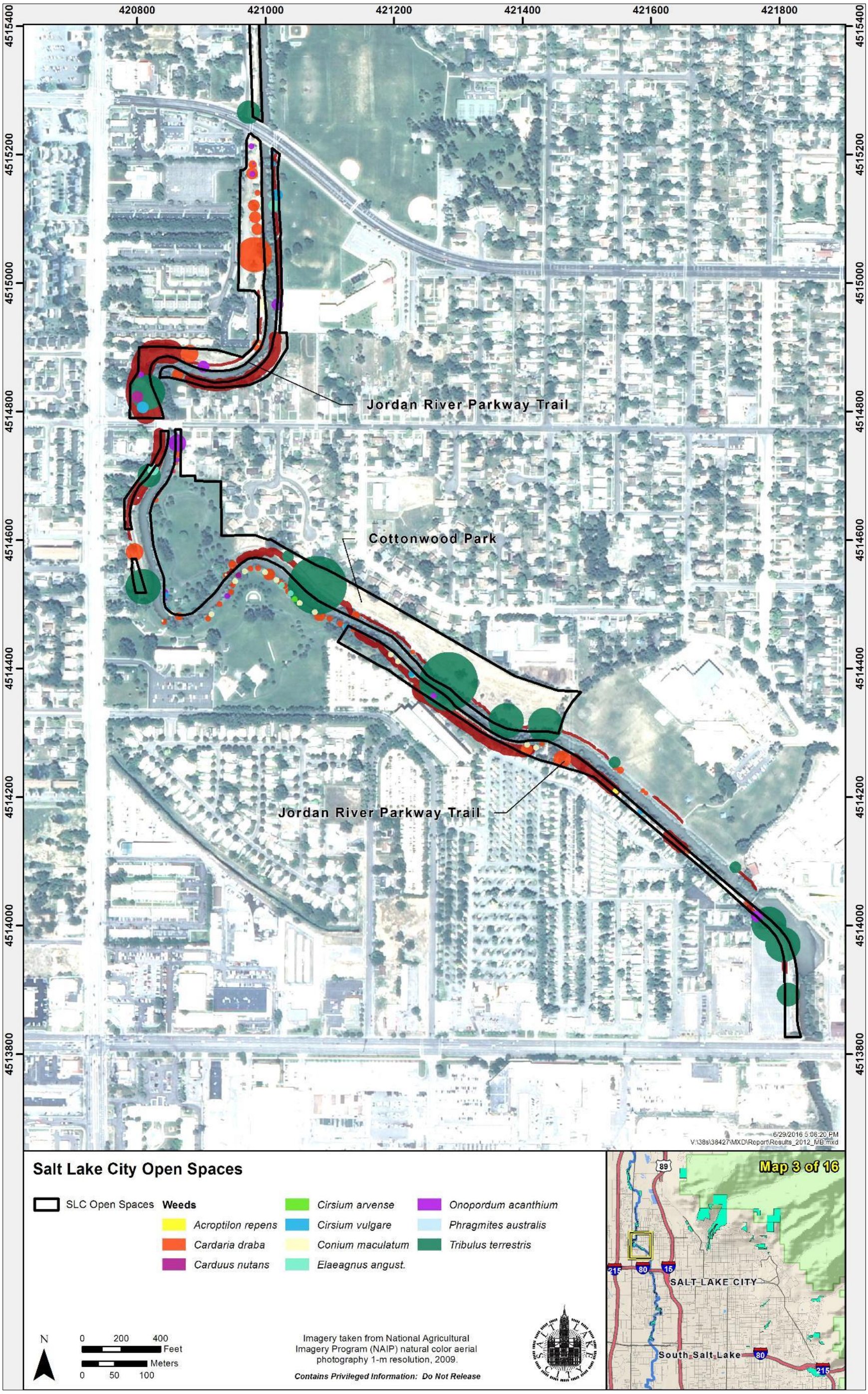

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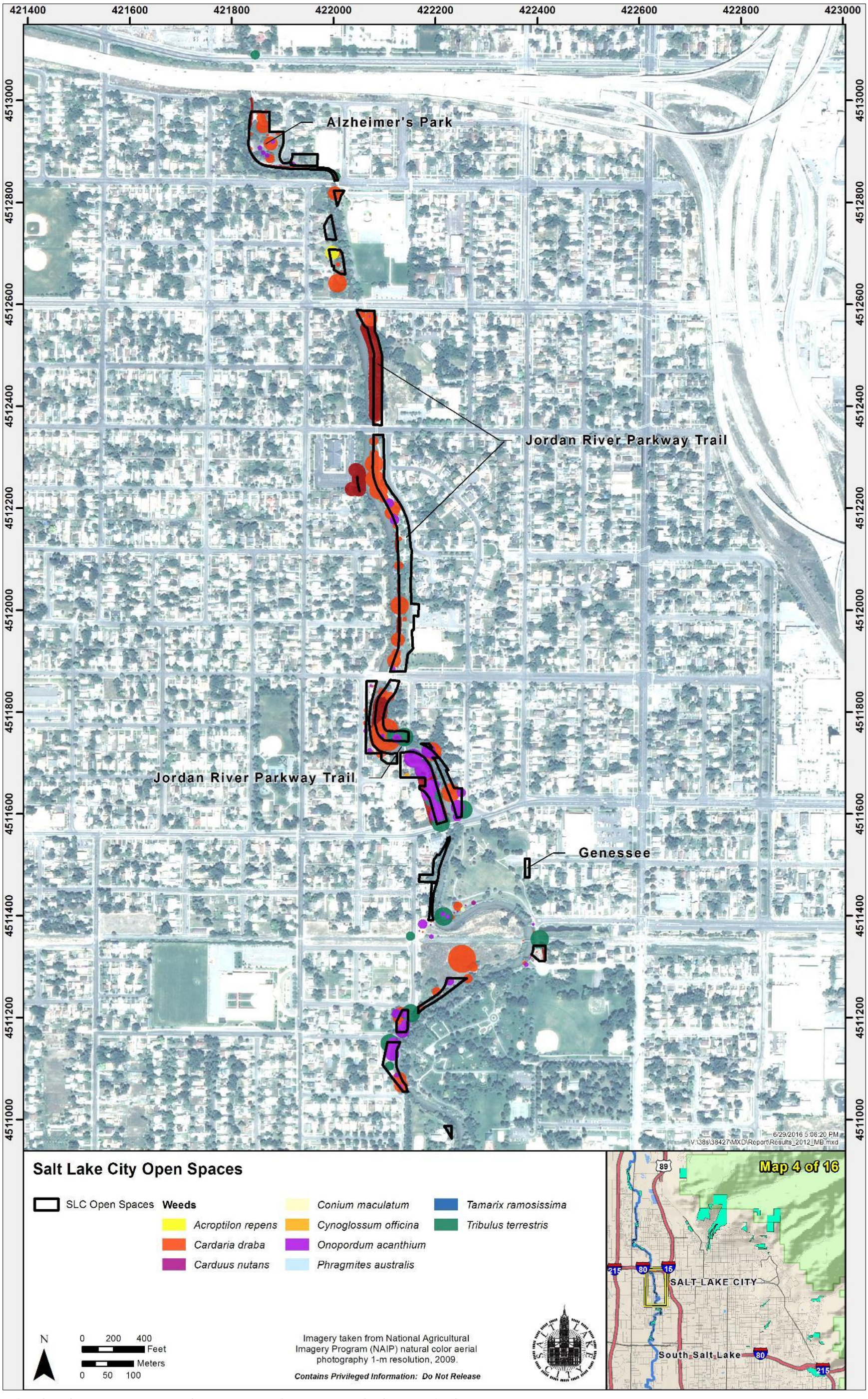

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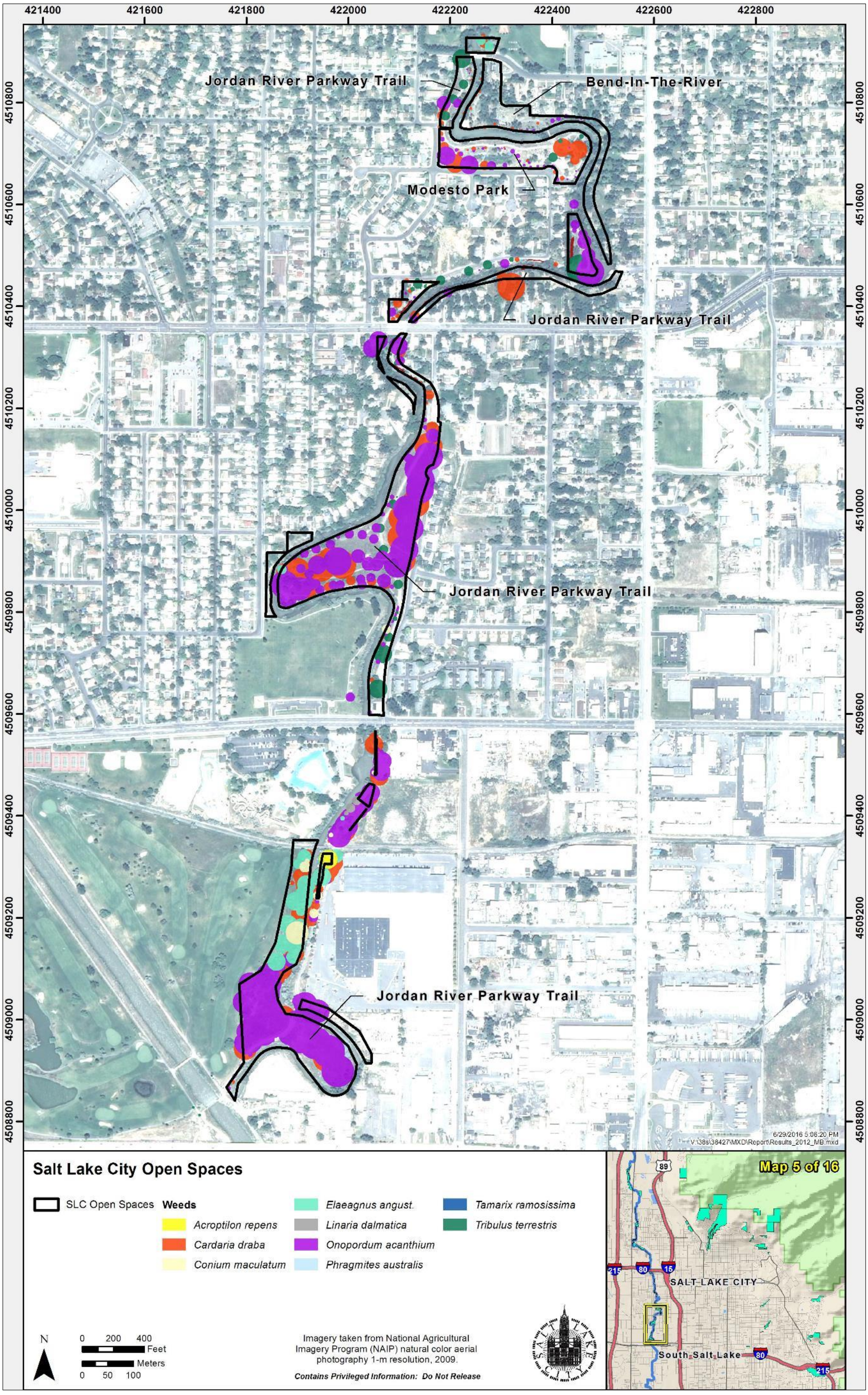

Salt Lake City Open Space Lands – 2011 Weed Survey Results (map 5 of 16)

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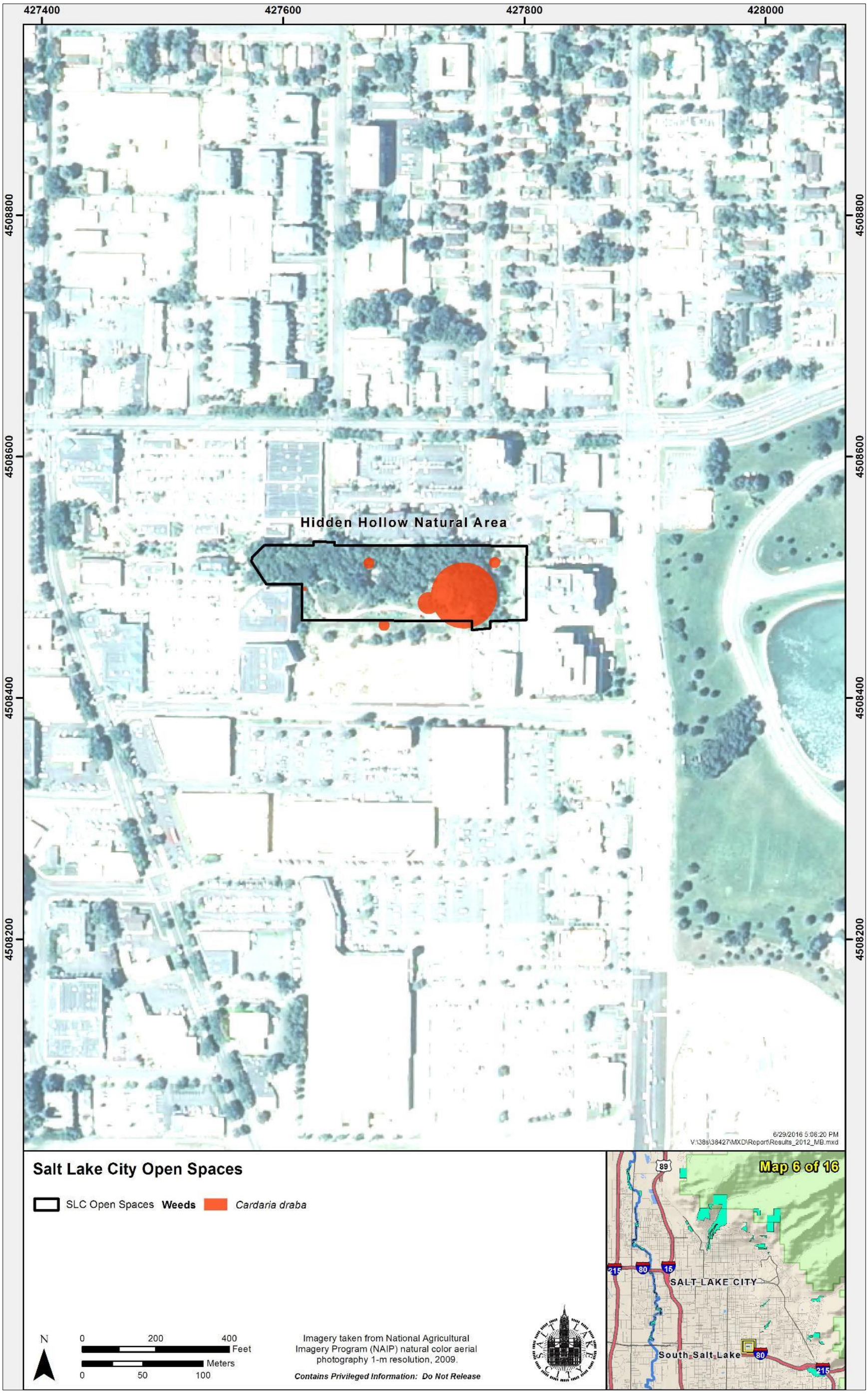

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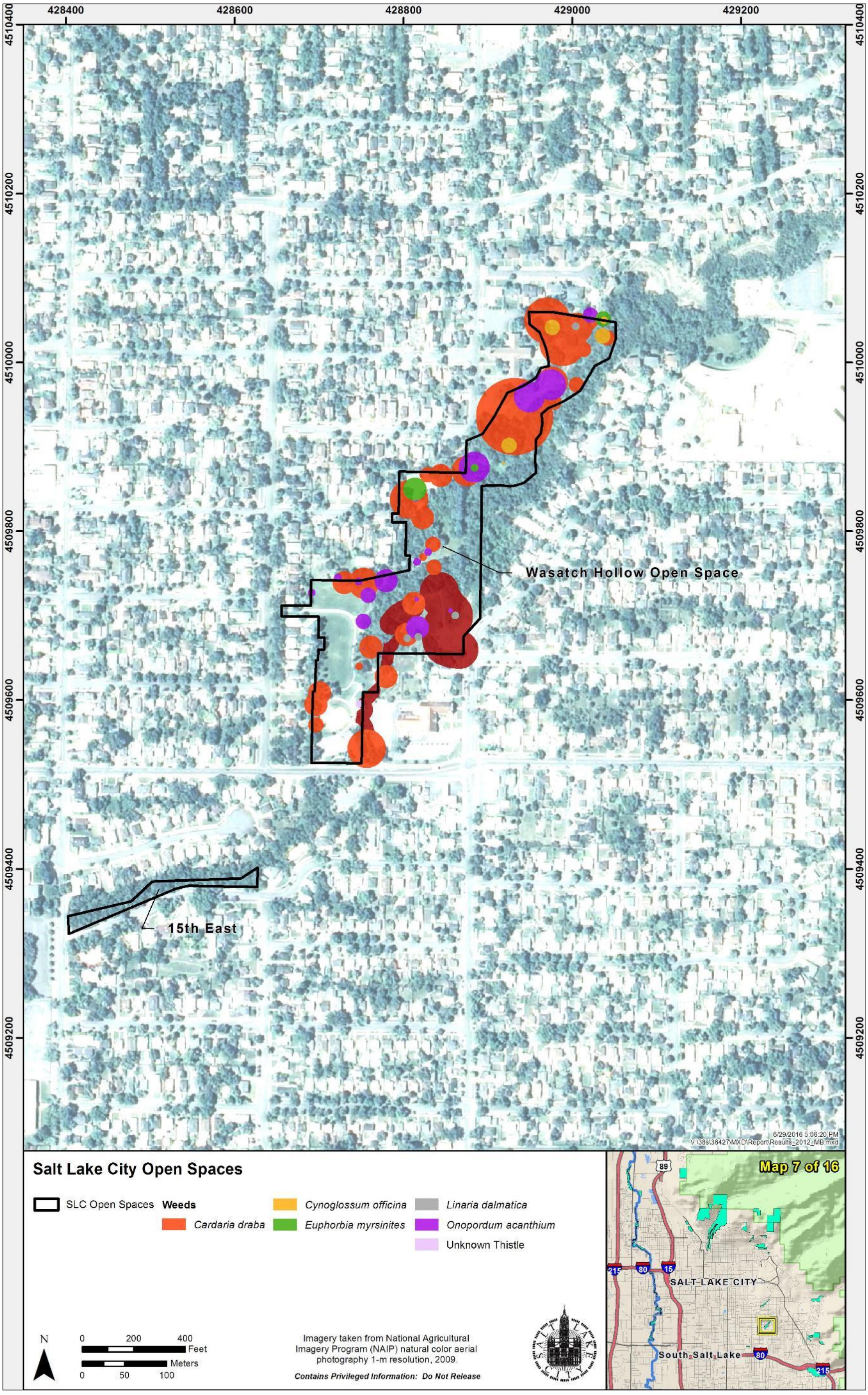

Salt Lake City Open Space Lands – 2011 Weed Survey Results (map 7 of 16)

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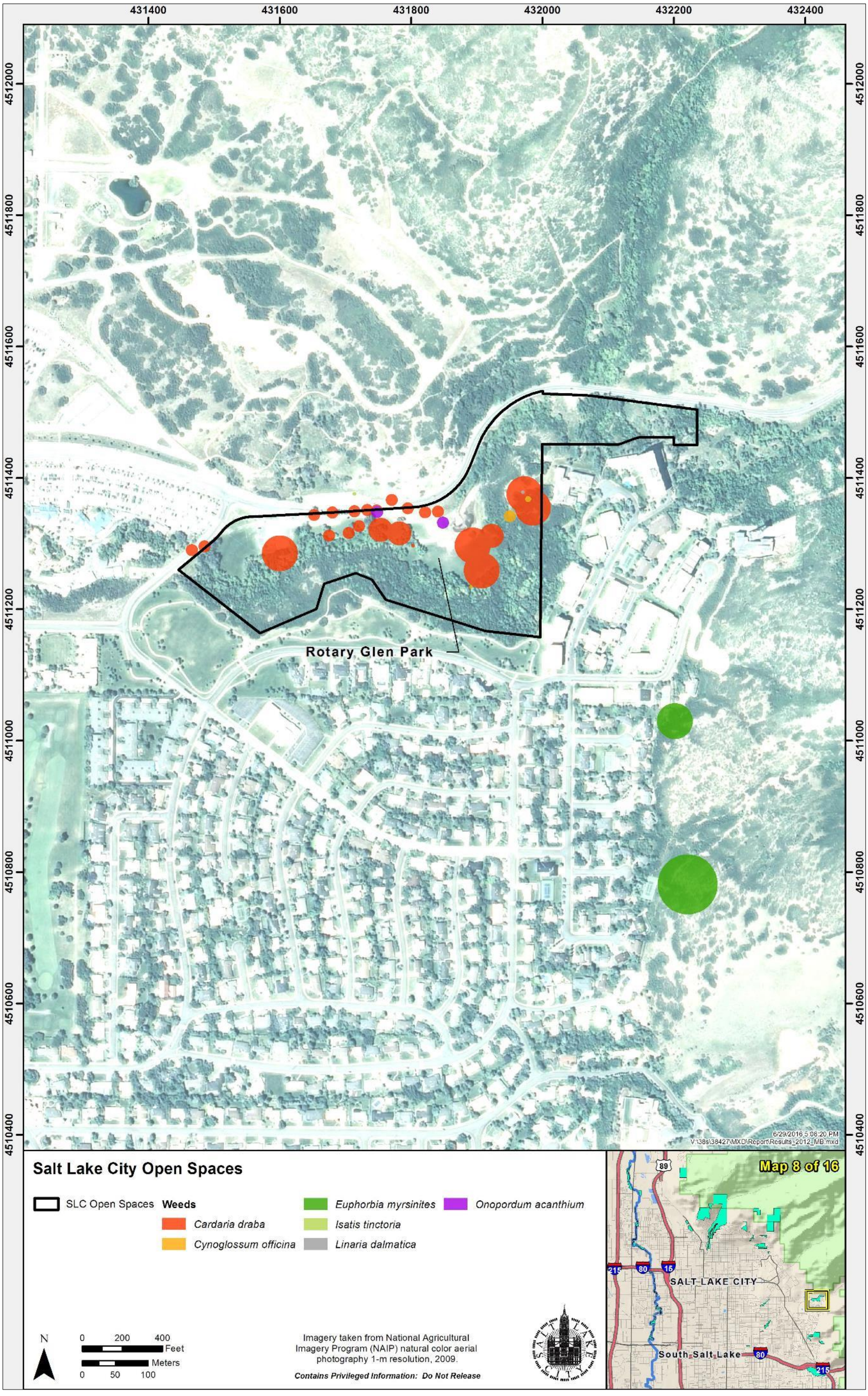

Salt Lake City Open Space Lands – 2011 Weed Survey Results (map 8 of 16)

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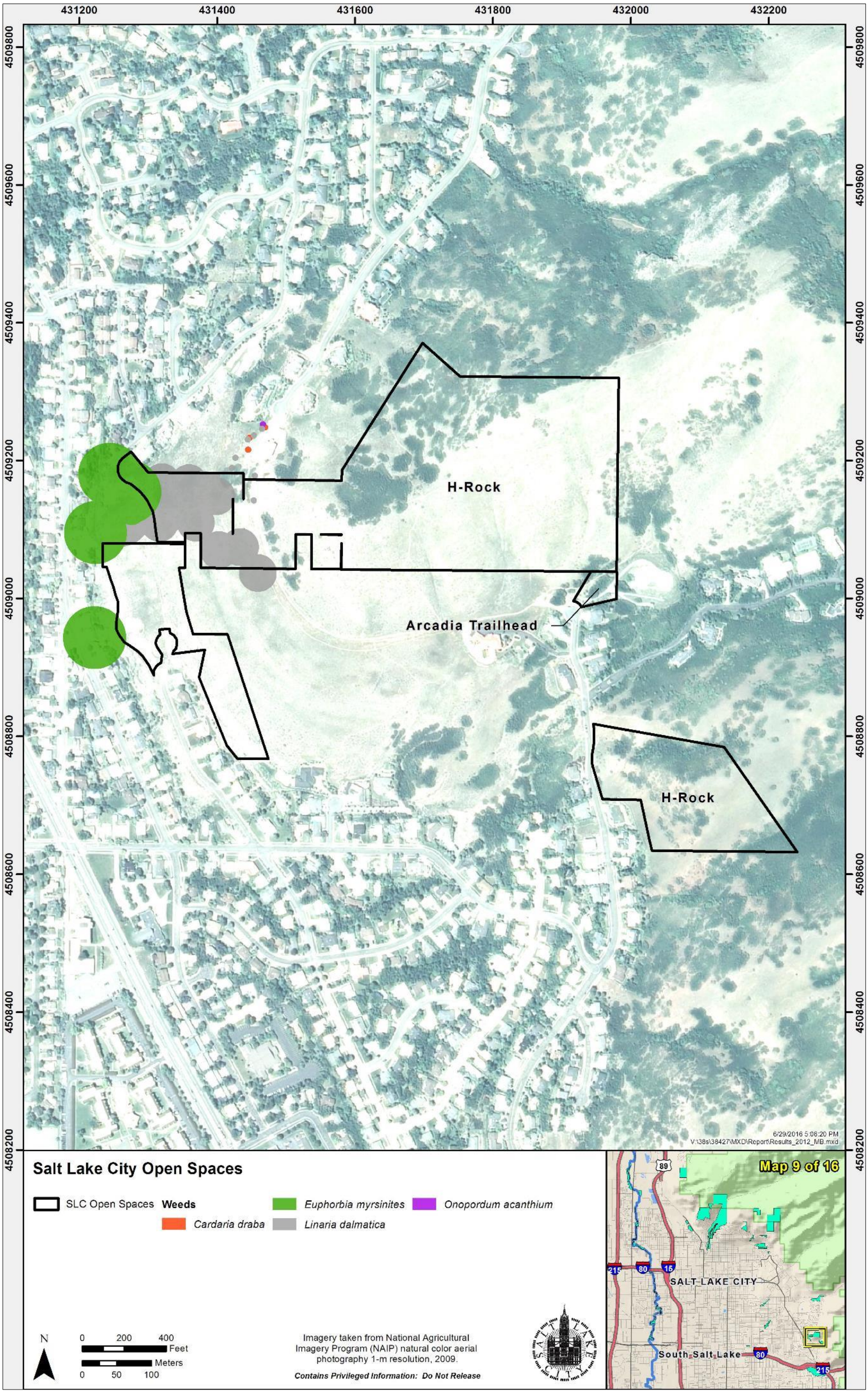

Salt Lake City Open Space Lands – 2011 Weed Survey Results (map 9 of 16)

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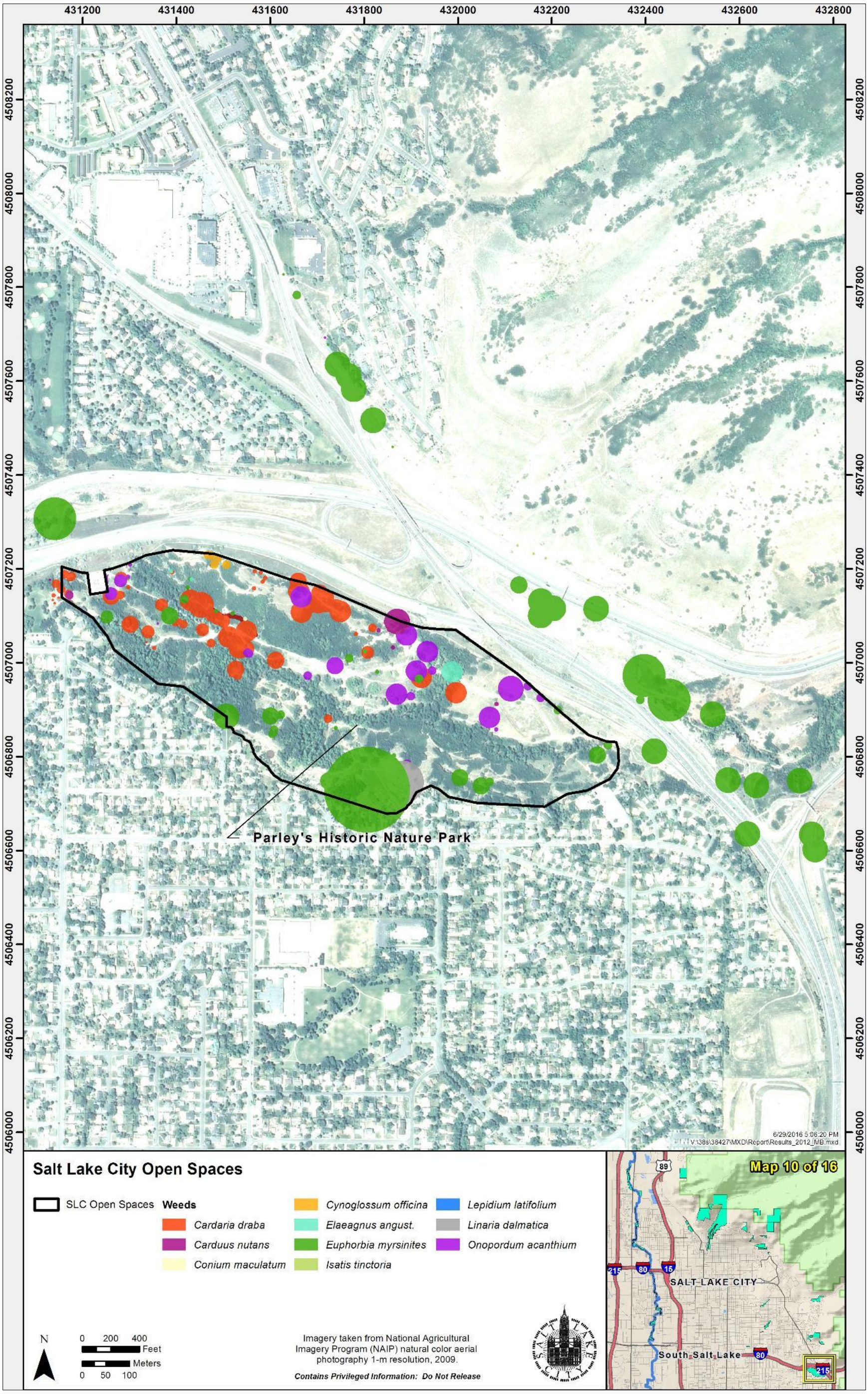

Salt Lake City Open Space Lands – 2011 Weed Survey Results (map 10 of 16)

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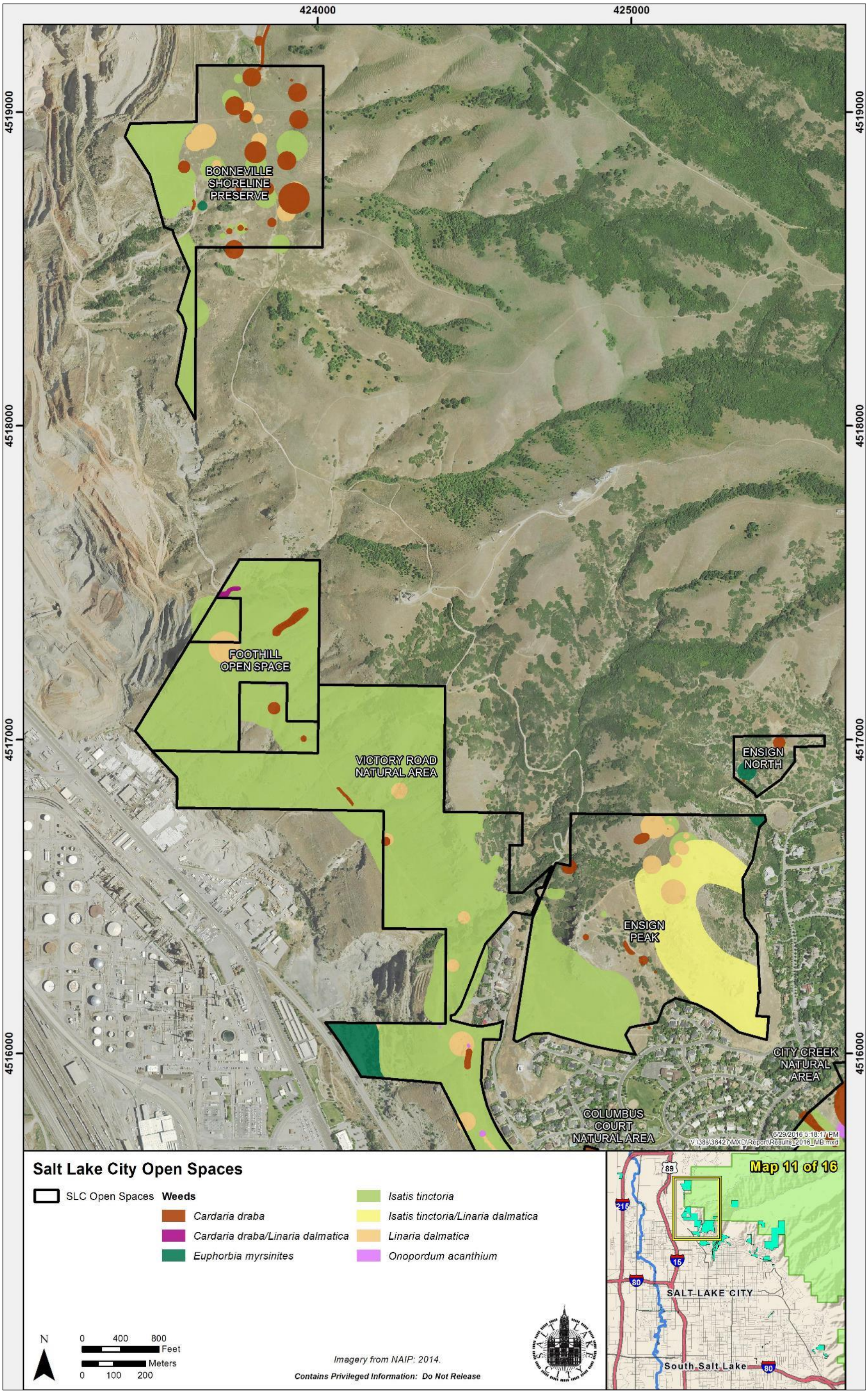

Salt Lake City Open Space Lands – 2016 Weed Survey Results (map 11 of 16)

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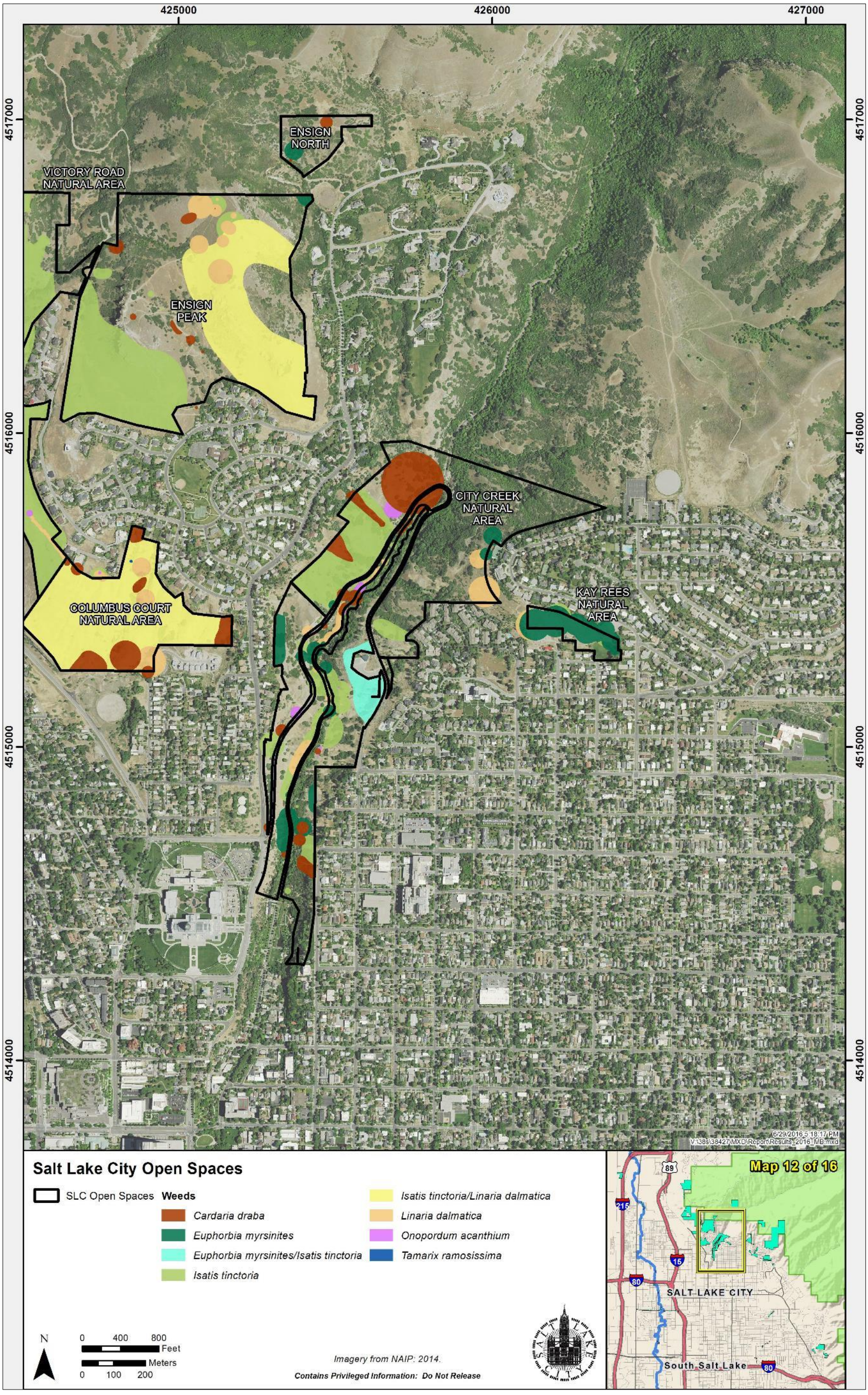

Salt Lake City Open Space Lands – 2016 Weed Survey Results (map 12 of 16)

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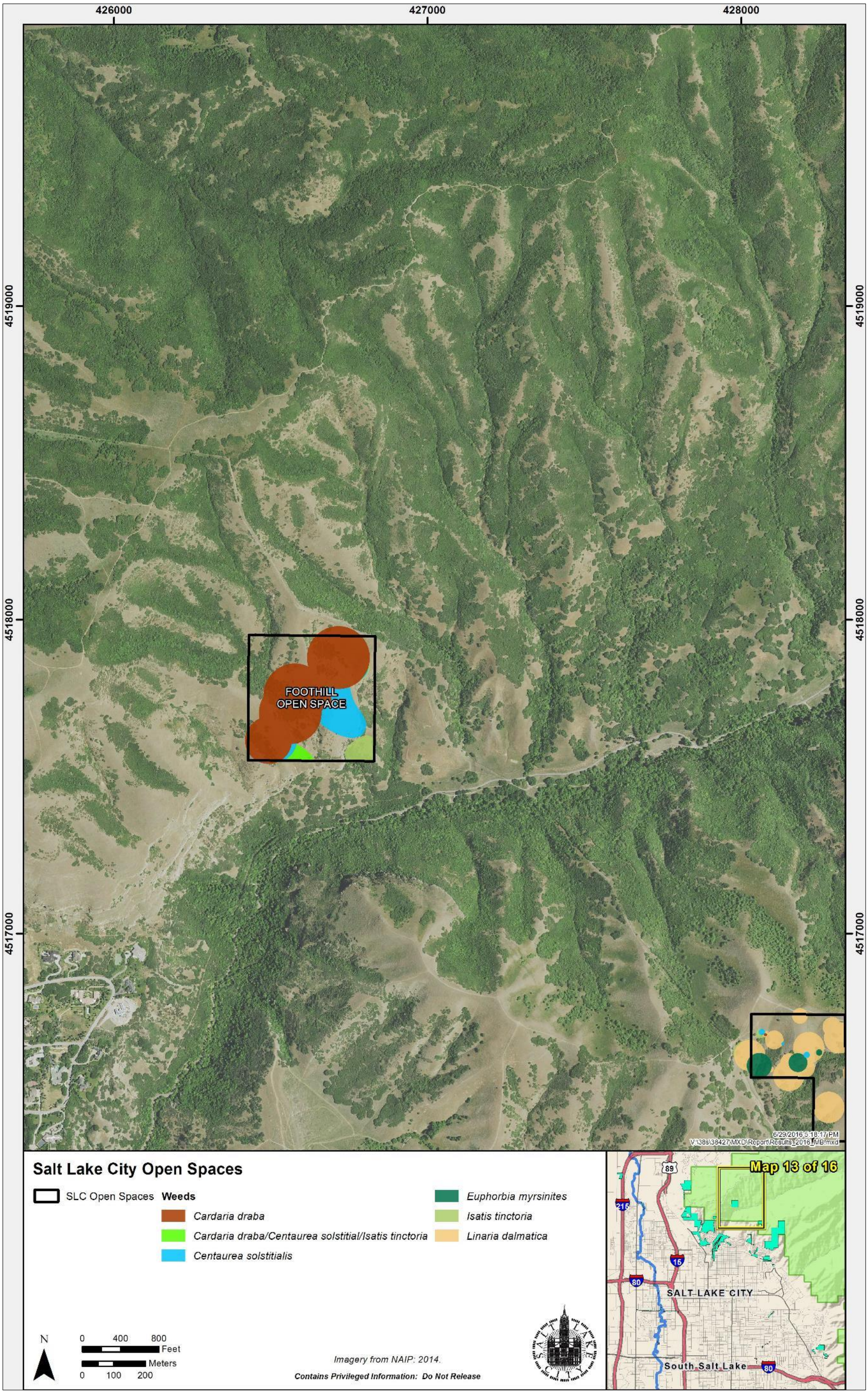

Salt Lake City Open Space Lands – 2016 Weed Survey Results (map 13 of 16)

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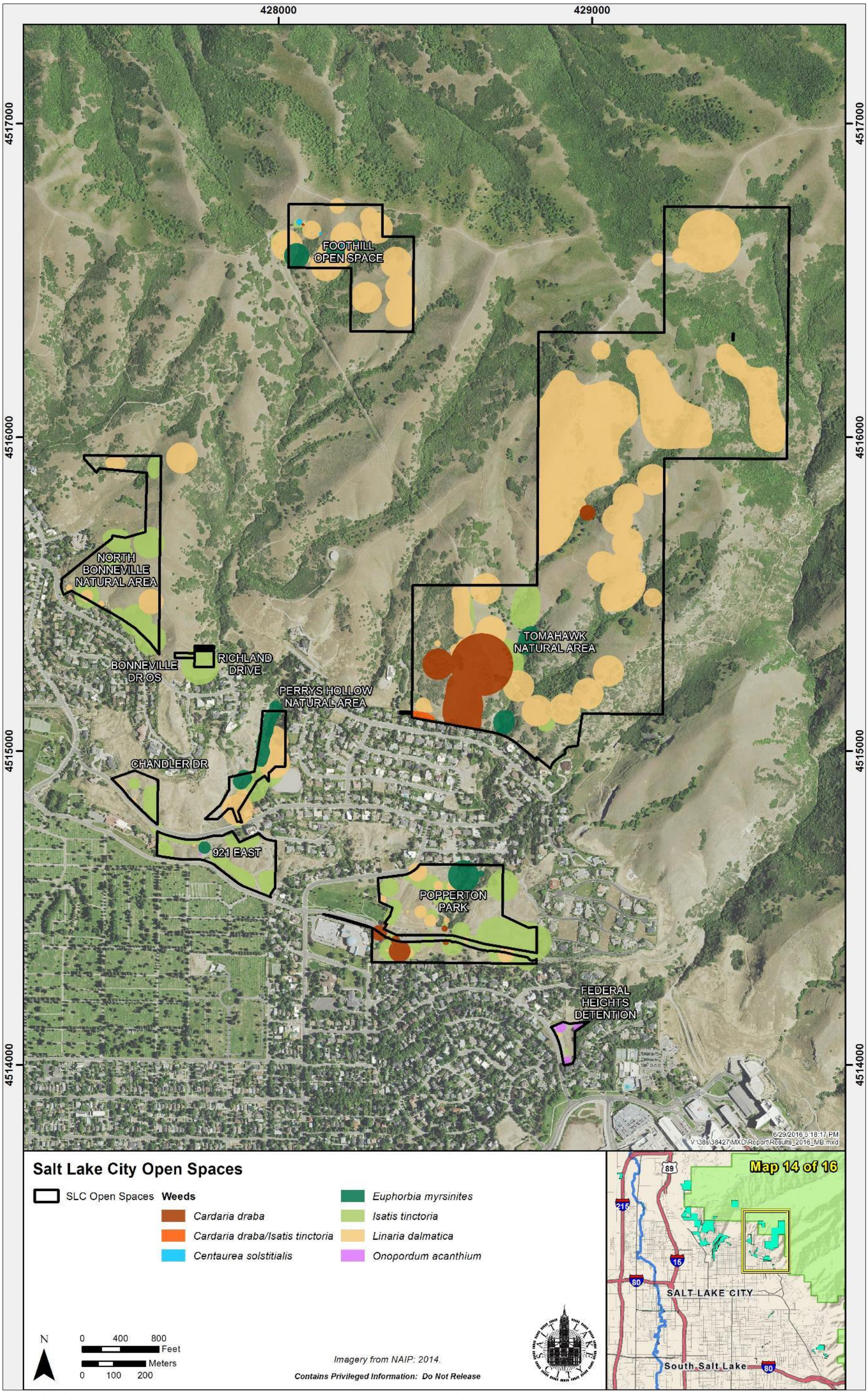

Salt Lake City Open Space Lands – 2016 Weed Survey Results (map 14 of 16)

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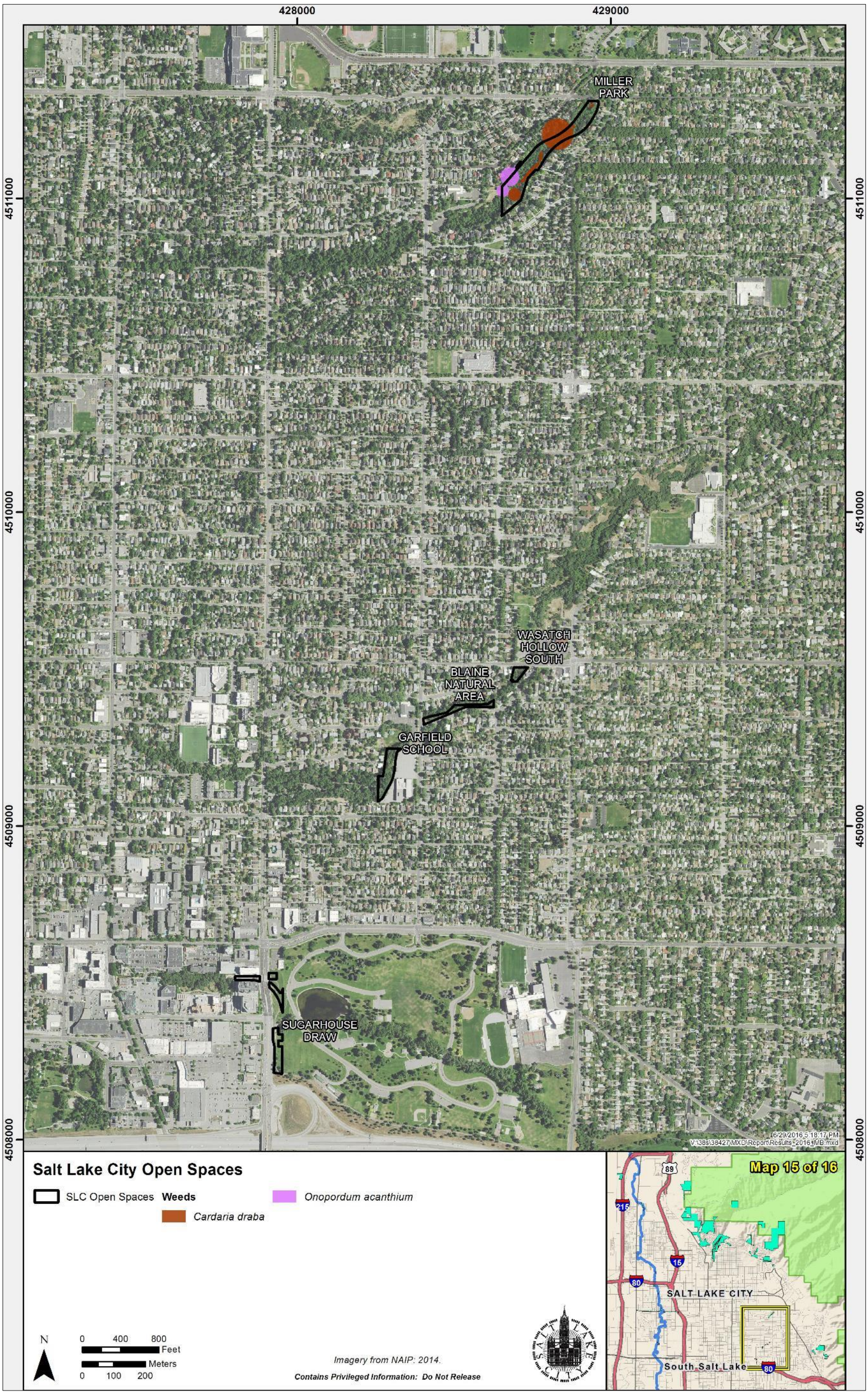

Salt Lake City Open Space Lands – 2016 Weed Survey Results (map 15 of 16)

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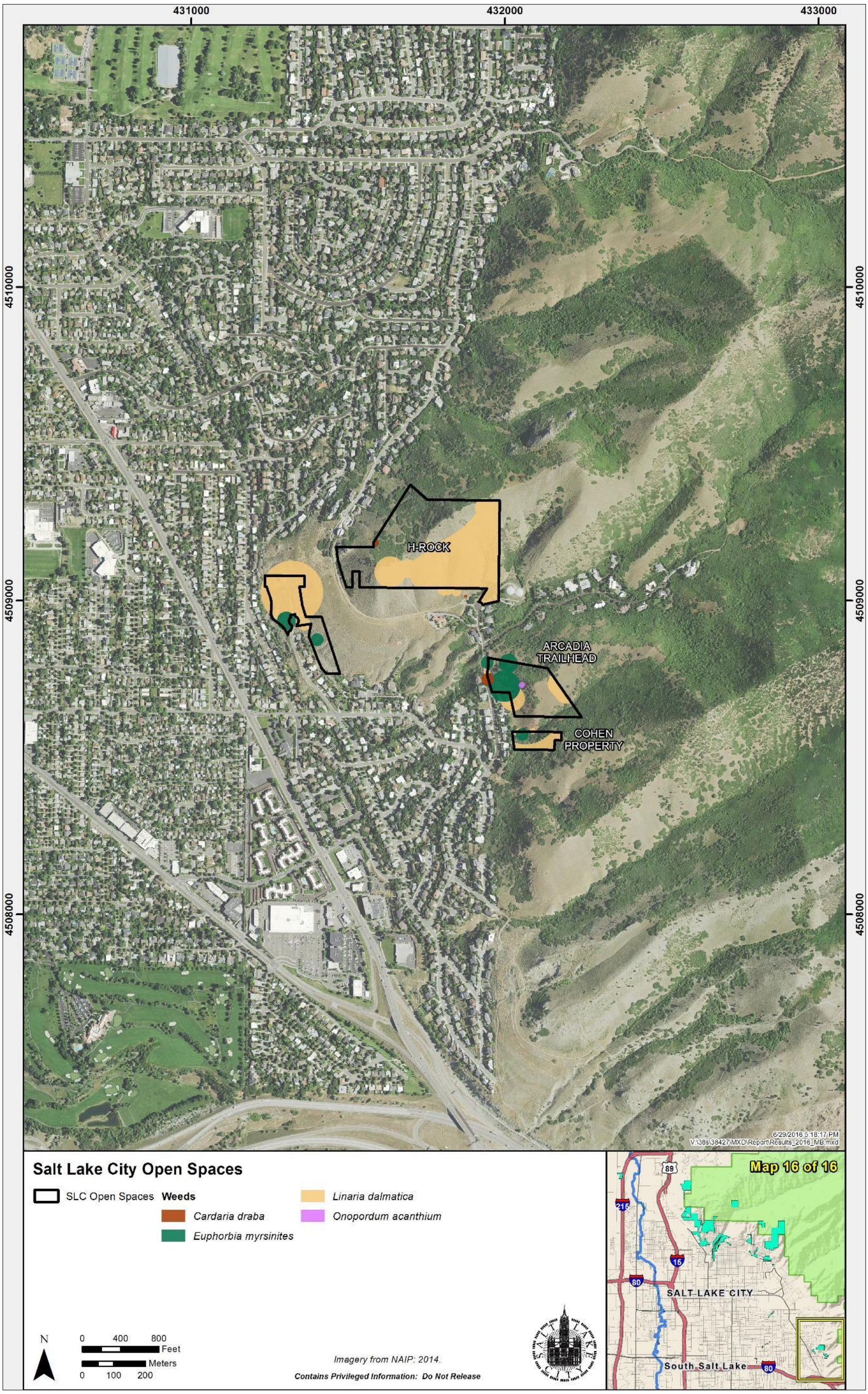

Salt Lake City Open Space Lands – 2016 Weed Survey Results (map 16 of 16)

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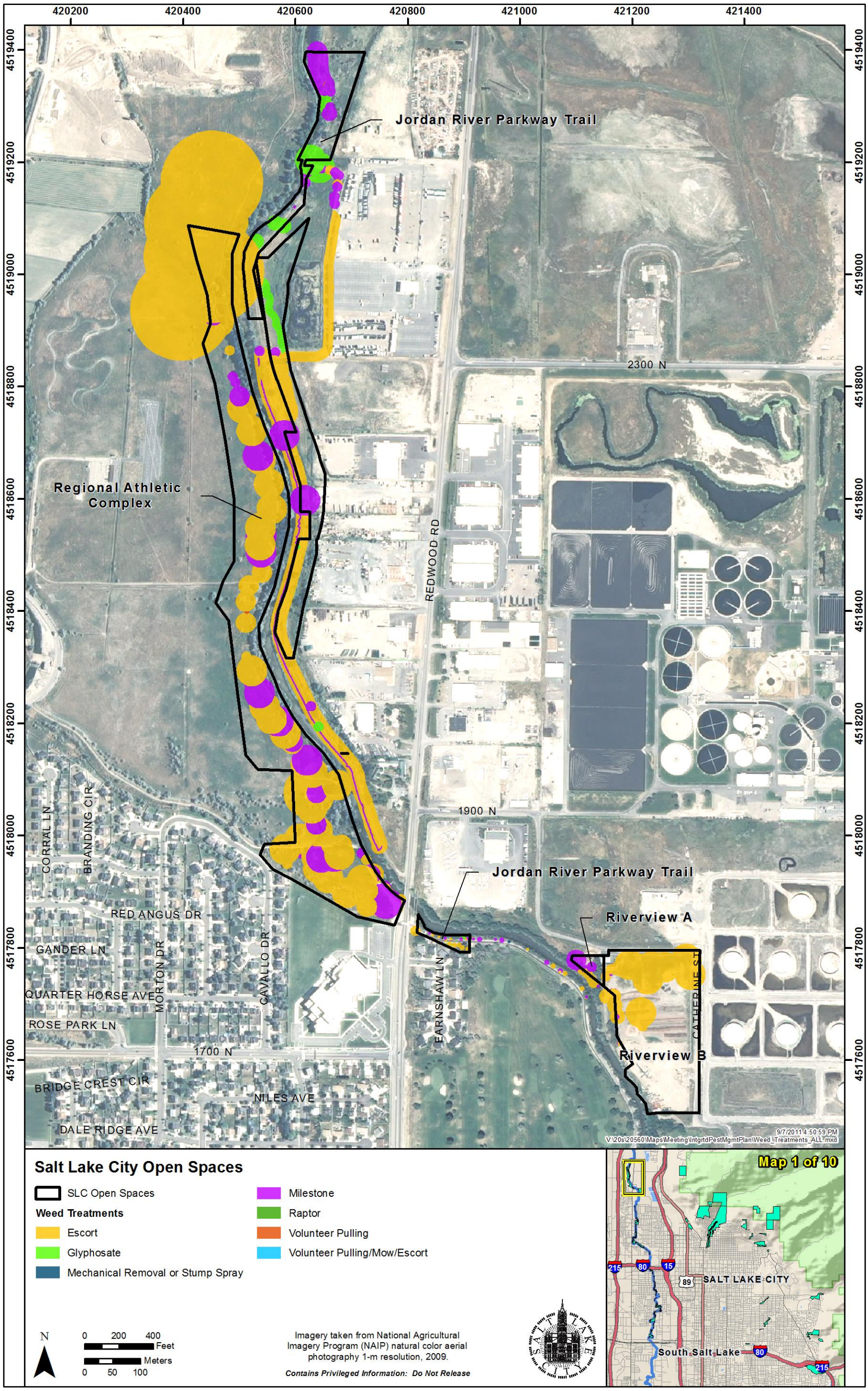

Salt Lake City Open Space Lands – 2011 Weed Treatments (map 1 of 10)

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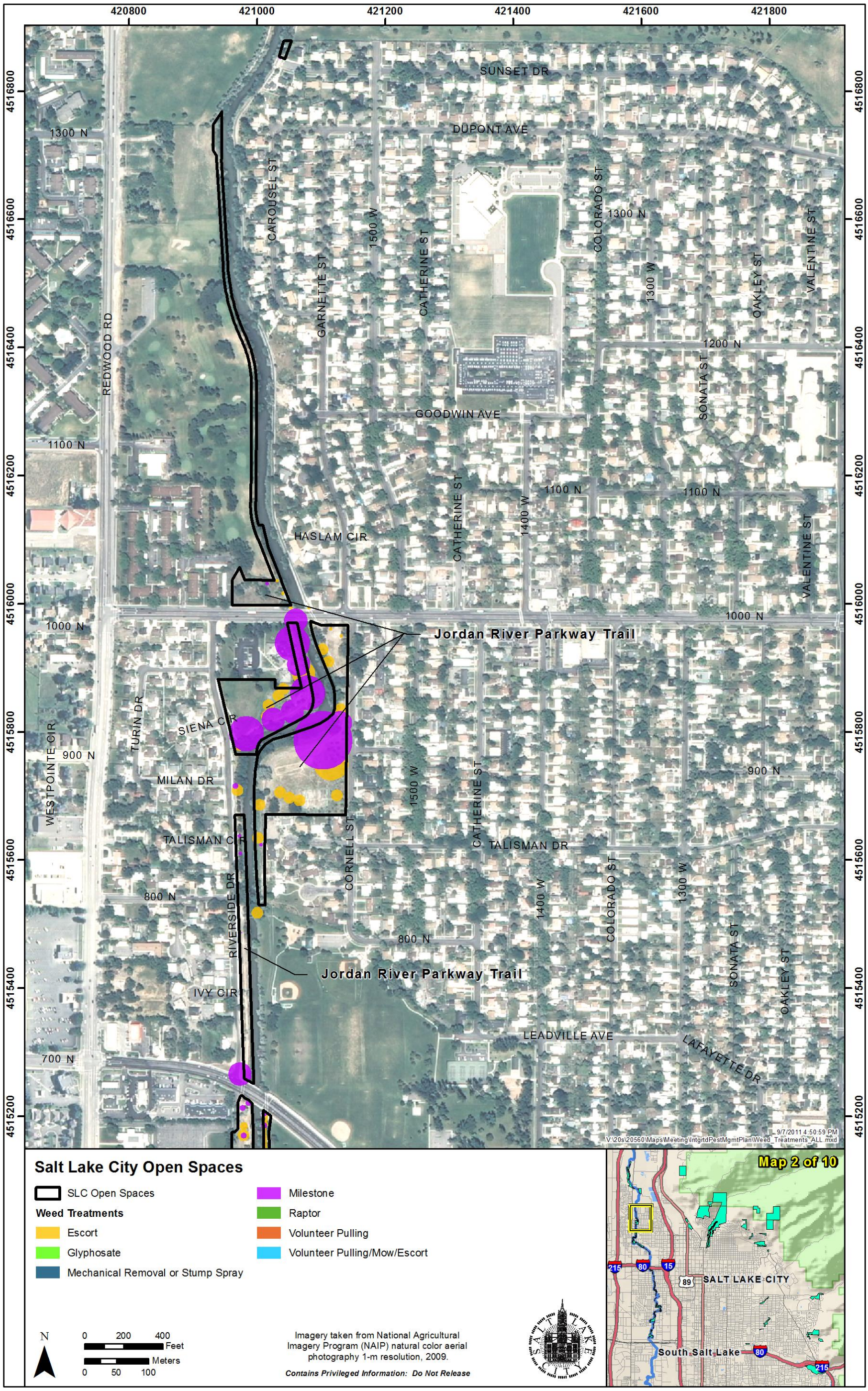

Salt Lake City Open Space Lands – 2011 Weed Treatments (map 2 of 10)

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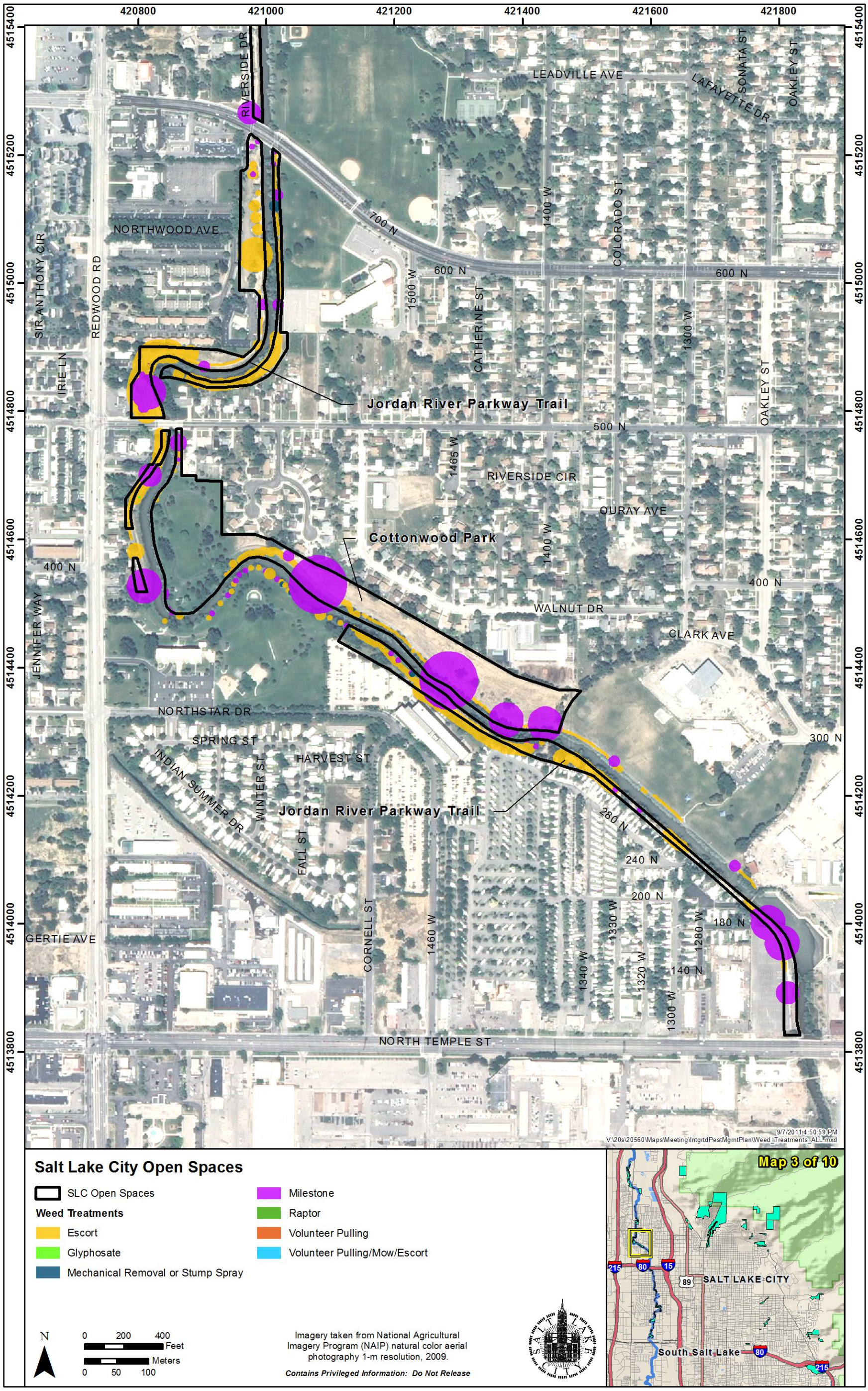

Salt Lake City Open Space Lands – 2011 Weed Treatments (map 3 of 10)

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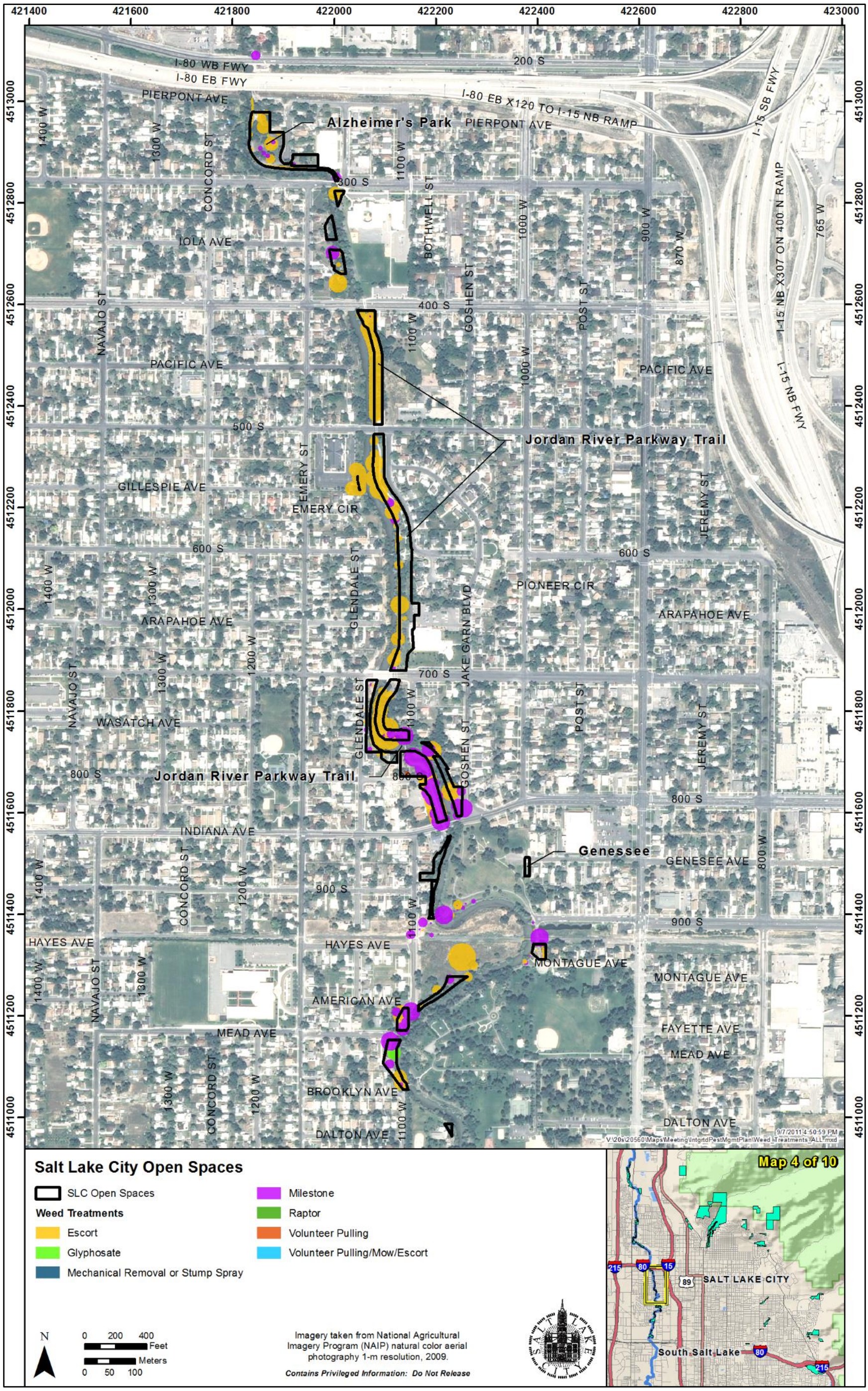

Salt Lake City Open Space Lands – 2011 Weed Treatments (map 4 of 10)

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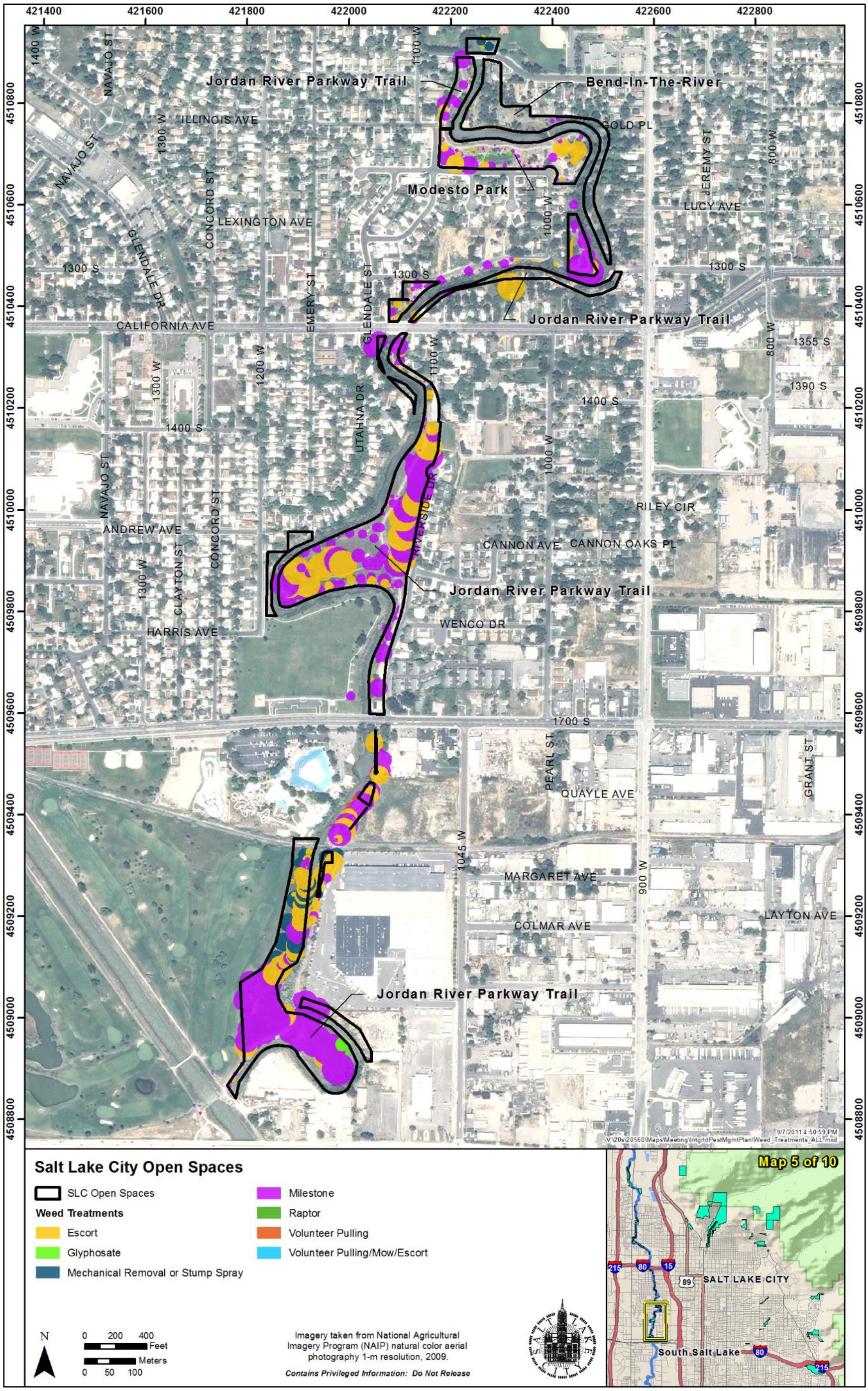

Salt Lake City Open Space Lands – 2011 Weed Treatments (map 5 of 10)

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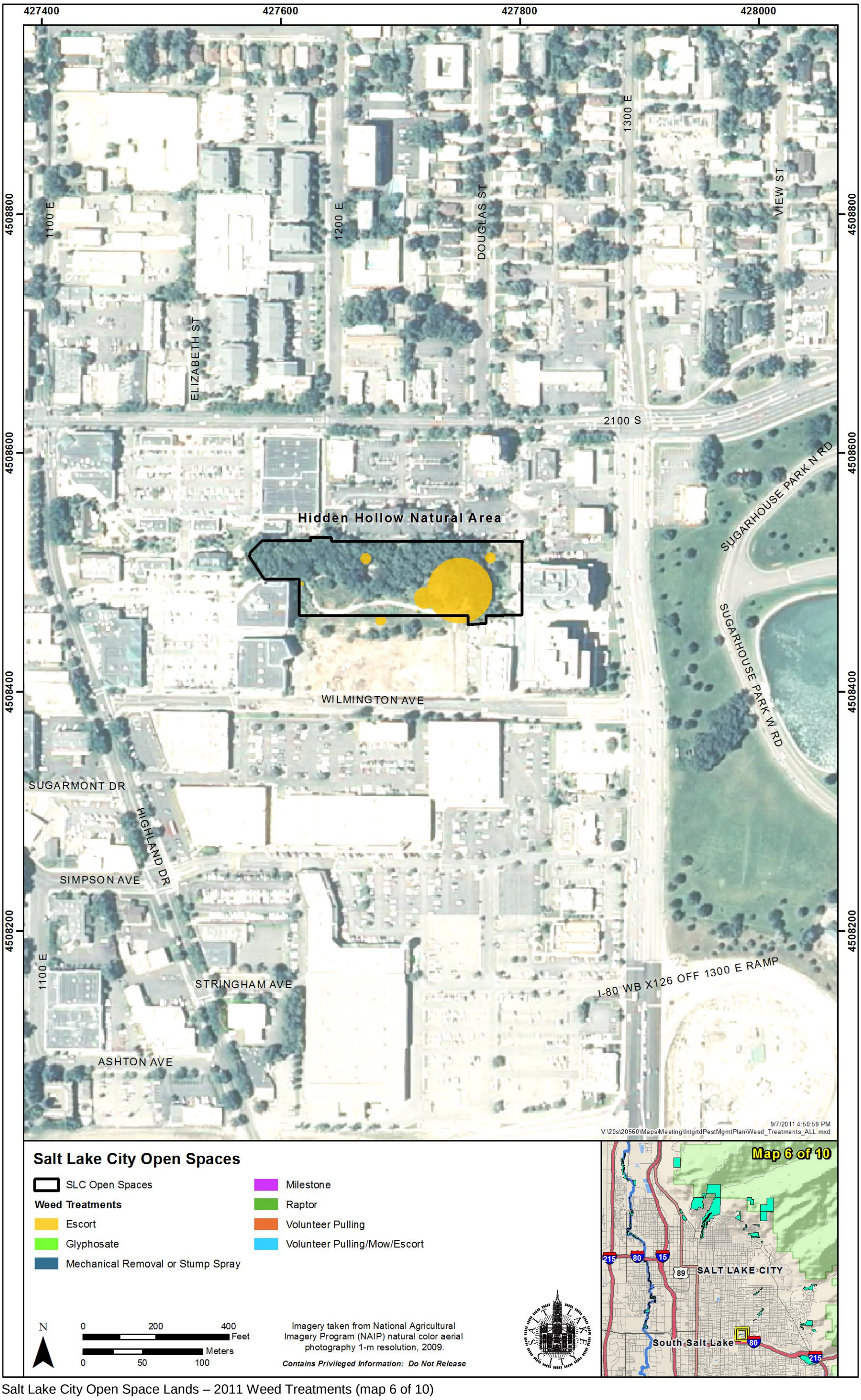

Salt Lake City Open Space Lands – 2011 Weed Treatments (map 6 of 10)

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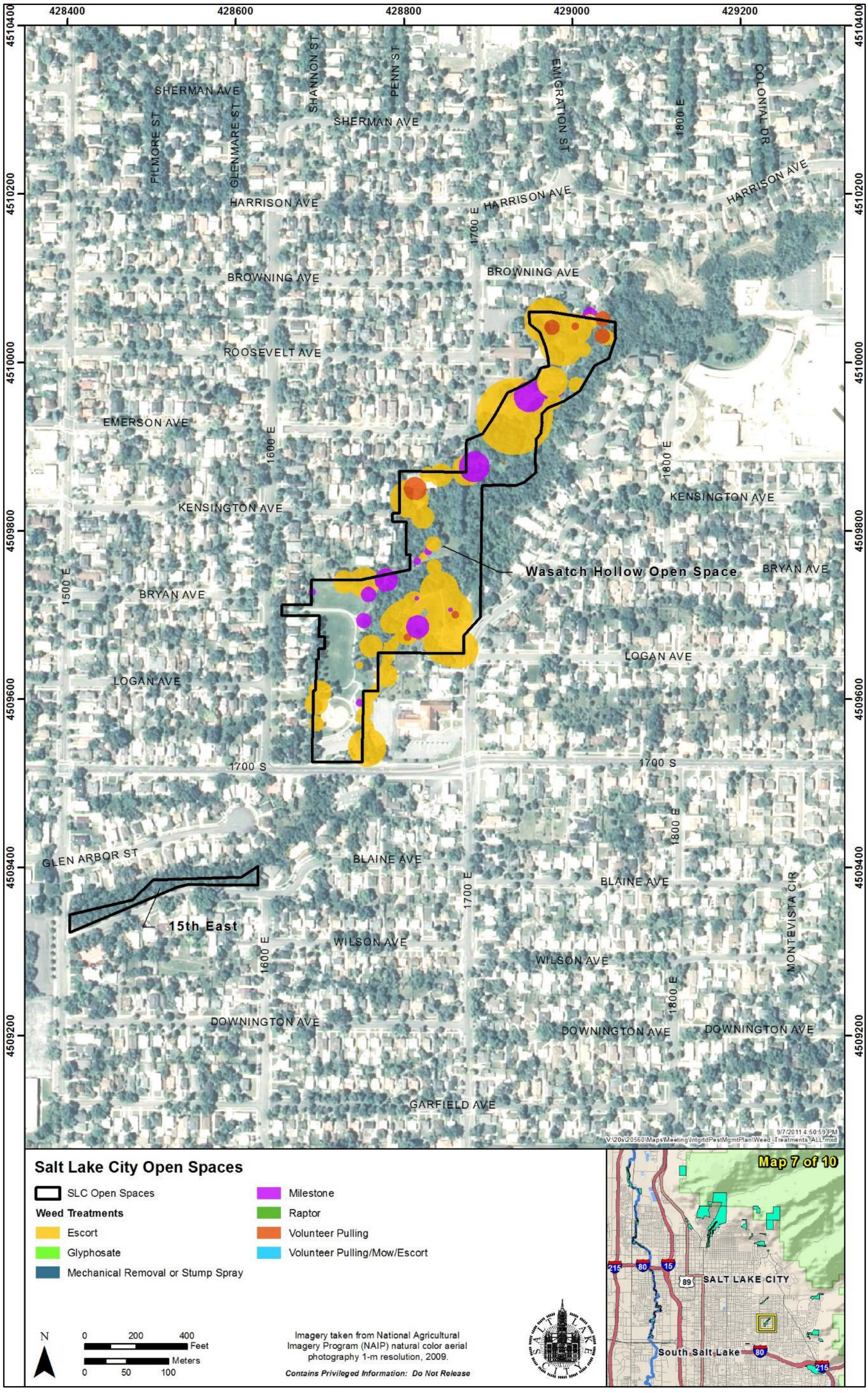

Salt Lake City Open Space Lands – 2011 Weed Treatments (map 7 of 10)

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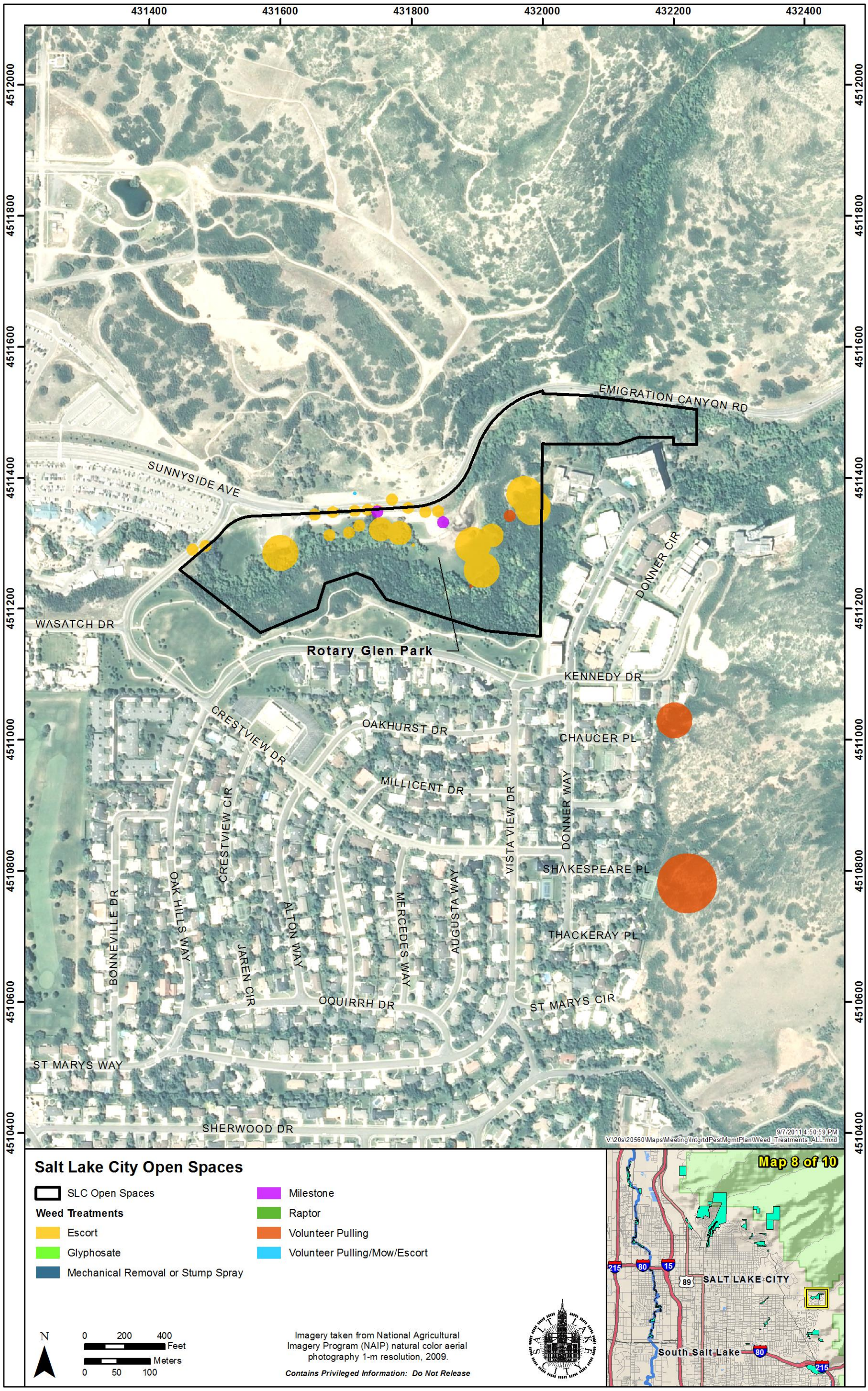

Salt Lake City Open Space Lands – 2011 Weed Treatments (map 8 of 10)

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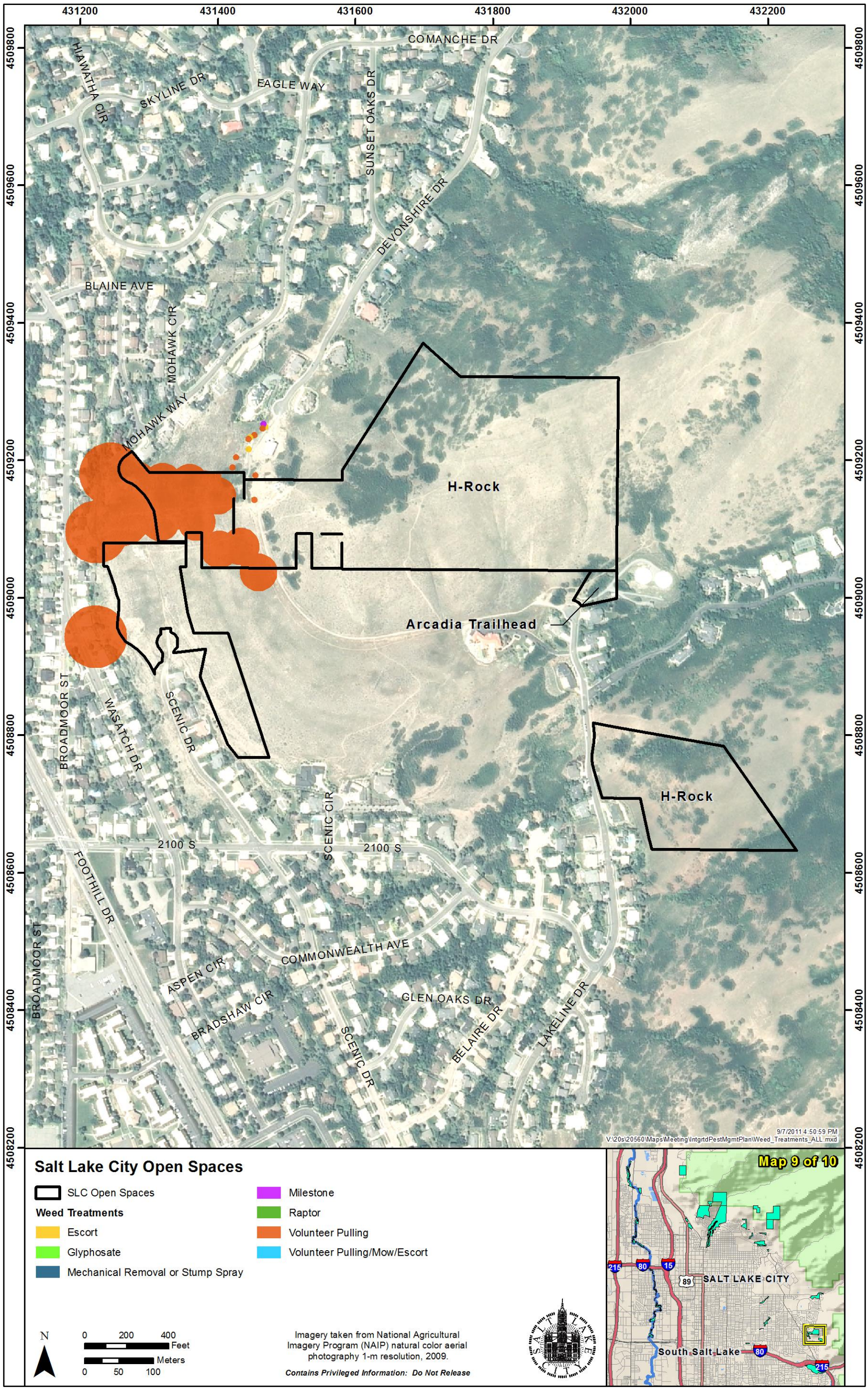

Salt Lake City Open Space Lands – 2011 Weed Treatments (map 9 of 10)

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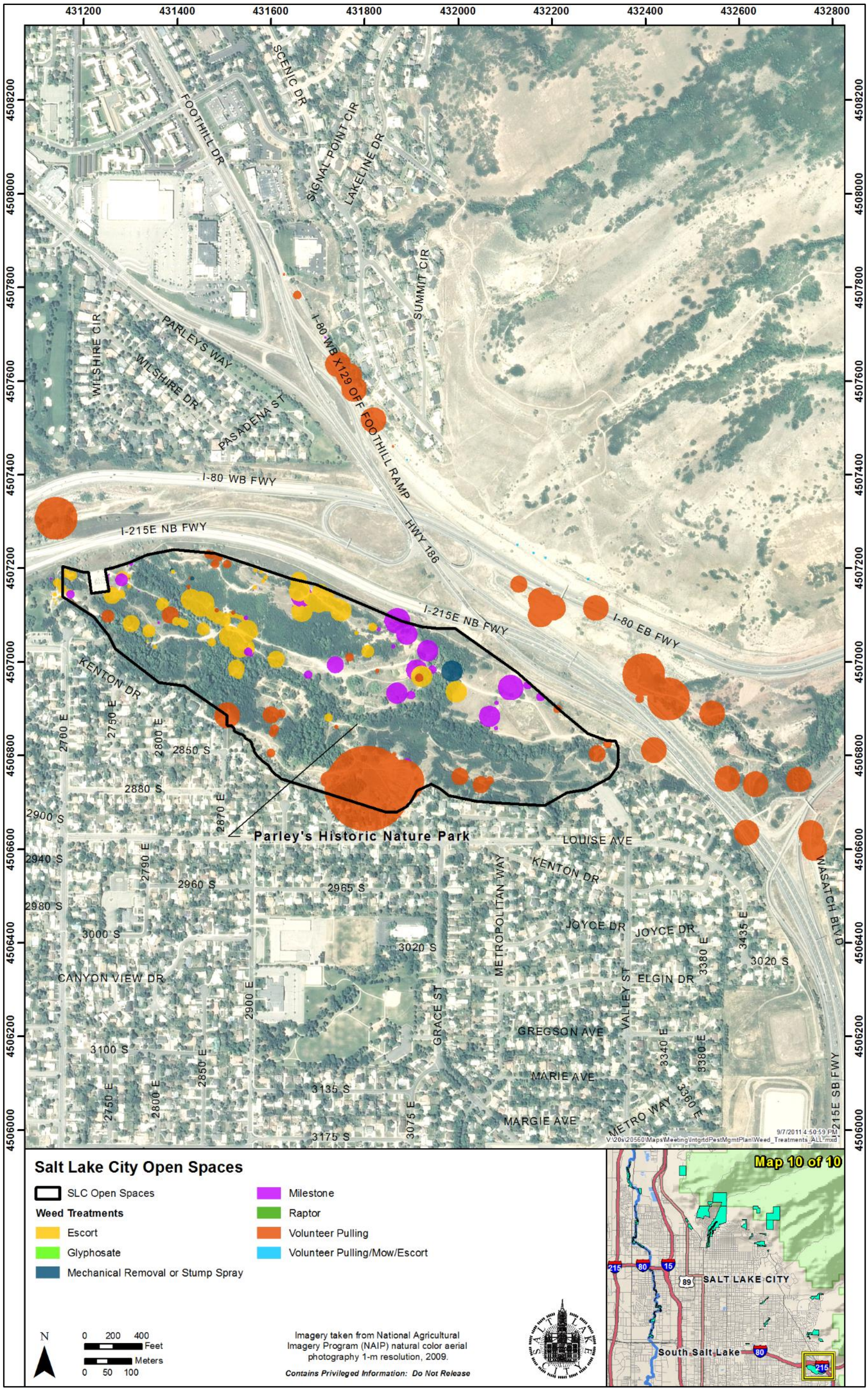

Salt Lake City Open Space Lands – 2011 Weed Treatments (map 10 of 10)

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Appendix A

Treatment Guidance

Appendix A.1.

Parks and Public Lands Staff Training and Treatment Requirements

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INTRODUCTION

In the research and development of this plan, noxious weeds on SLC public lands were identified as a priority for early detection and rapid response. The purpose of this section is to provide staff guidelines and training for the transition into an adaptive and integrated management program for and a more strategic use of chemical controls on the SLC Parks and Public Lands Division program lands: parks, natural lands, urban forests, and the City Cemetery. Due to community health and safety concerns, SLC is eliminating the use of pesticides in public parks and is currently developing an Organic Turf Management Plan.

Best Management Practice 1: Mechanical Controls

Mechanical control methods physically disrupt weed growth (Table A.1.1). Mechanical weed control is the oldest and most common method worldwide. Tilling, mowing, hand pulling, disking, mulching, and cultivation are examples of mechanical control.

- Tilling works by disturbing the root system. The objective is to dislodge or cut the root system so that the plant dies from drying out before it can reestablish its roots. Tillage easily controls small weeds and is most effective in hot, dry weather with dry soils. To effectively control noxious weeds, repeat tillage each time new shoots emerge (about every 2 weeks) for one or two growing seasons. Make sure you cut off every plant. Tillage can also kill weeds by burying them. Most annual weeds die when all growing points are buried. Burial is not effective on most established noxious weeds since their underground parts will re-sprout.
- Mowing is a suppression measure that can prevent or decrease seed head production. Mowed weeds will regrow and set seed from a reduced height, so a combined control method is necessary to be effective. Mowing causes perennial plants to weaken when forced to send up carbohydrates from underground root reserves to nourish regrowth. Mowing a perennial weed such as Canada thistle a couple of times during the summer can significantly weaken the plants, and when combined with a fall herbicide application, mowing provides excellent control.
- Hand pulling and digging are effective on some annual and biennial species. It is important to remove the upper 2 to 3 inches of taproot to prevent regrowth.
- Disking, or shallow tillage with a disk or sweep, is effective for controlling annual species. However, it can actually be counterproductive for trying to control perennial weeds such as Canada thistle, field bindweed, leafy spurge, or Russian knapweed. Perennial root systems often have meristematic buds that can set roots and produce a new plant from root segments deposited on the soil surface. Shallow tillage of perennial weeds can result in a larger, denser, and more uniform infestation than the initial patch.

Table A.1.1. Target Weed Species and Mechanical Controls

Common Name	***Scientific Name***	***Mechanical Control***
Musk thistle Scotch thistle	*Carduus nutans* *Onopordum acanthium*	Mow repeatedly to remove flowers, remove cut plants, and repeat every 4–6 weeks.
Yellow starthistle	*Centaurea solstitialis*	Cut in the summer before seed set. This will not eliminate infestation but will reduce seed production.
Diffuse knapweed Spotted knapweed Russian knapweed Squarrose knapweed	*Centaurea diffusa* *Centaurea stoebe* spp. *Micranthos* *Rhaponticum repens* *Centaurea virgata*	Pulling and mowing before seed set may reduce seed production, but roots of plants will remain viable in the soils after these treatments.

Table A.1.1. Target Weed Species and Mechanical Controls

Common Name	***Scientific Name***	***Mechanical Control***
Canada thistle Bull thistle	*Cirsium arvense* *Cirsium vulgare*	Frequent mowing will reduce root reserves, and plants will die after two or three mowings. For bull thistle, tilling or digging can cause cut roots to re-sprout if roots are cut too early. Bull thistle cannot tolerate shade, and shading can be used as a control method.
Hoary cress	*Cardaria draba*	Mow repeatedly to exhaust root system. Follow-up mowing is most effective within 10 days of re-emergence. Cut flowers can still mature into viable seed. Uprooted plants will re-sprout, increasing density; therefore, tilling must be combined with removing plants and roots.
Poison hemlock	*Conium maculatum*	Dig, pull, and remove plants before seed set to deplete the seed bank.
Dyer's woad	*Isatis tinctoria*	Hand removal April through June is the most effective form of control, followed by mowing throughout the growing season.
Perennial pepperweed	*Lepidium latifolium*	Disk in the fall to fragment roots and mow in the spring between flowerbud and flowering.

Best Management Practice 2: Chemical Controls

Numerous herbicides may prove useful to the reduction and eradication of noxious weeds and invasive weed species. Many natural areas contain ponds, wetlands, and streams, making it necessary to assess the use and persistence of the chemicals in these environments and their effects on human health, nontarget plants, and animals. It is important to choose the correct herbicide for the target species and employ BMPs when using herbicides to avoid damaging desirable species, ensure effective control of the weed species, and avoid impacts to human health, wildlife, and the environment.

General Best Management Practices for Chemical Controls

- Be familiar with existing state and federal regulations on pesticide application, certification, and weed control. Several federal and state laws control the handling, storage, application, disposal, and reporting of chemical spills. Examples include the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), the Superfund Amendments and Reauthorization Act (SARA), the Emergency Planning and Community-Right-to-Know Act (EPCRA), and Occupational Safety and Health Administration (OSHA) requirements, particularly the Hazard Communication Standard. The Utah Water Quality Control Act (25-8-601 and 25-8-606) also contains requirements for notification of the Utah Department of Environmental Quality of spills and accidental discharges and provides the department with the authority to order cleanups. It may also be necessary to file information with the local fire department based on these and other laws.
- Accurately diagnose the pest, disease, or weed and host prior to intervening with chemicals. Disease and insect symptoms can mimic each other in many plants. A fungicide will not control an insect, and an insecticide will not control a disease. For assistance in identifying pests and noxious or invasive plants, contact the Salt Lake County Extension Office at http://extension.usu.edu/saltlake, or the Utah Plant Pest Diagnostic lab at http://utahpests.usu.edu/uppdl. For weeds, you might also visit www.slcgov.com/gardenwise.
- Know your weeds. Hire a trained professional with an herbicide applicator license who can distinguish between invasive or noxious weed species and desirable plant species.
- Qualified personnel (biologists, botanists, or horticulturalists) should monitor effects on nontarget plants after application and/or monitor effectiveness of treatment. Consider pest occurrence and history when developing pest management strategies.

- Recognize that no landscape should be or can be completely pest free or weed free.
- Apply herbicides only when needed. Do not use herbicides on a regular or preventive basis.
- Only apply herbicides that have low toxicity, degrade naturally, and are non-persistent. Weeds may develop resistance to a particular herbicide over time. Use in rotation with other mechanical control methods such as hand pulling or mowing.
- Prior to use of any herbicide, read the product label. It is a violation of federal law to use any herbicide in a way that is inconsistent with the label.
- Place signs in the area 24 hours before spraying and on the day of spraying (see attachment). Upon completion of the project, remove signs and go to the next site.
- Only trained professionals with herbicide applicator licenses should apply herbicides with federally restricted uses.
- Keep up-to-date, accurate records of which herbicides were used, where they were used, and when they were used (see attached form in Appendix I.2).
- Dispose of excess herbicides properly.

Herbicide Selection

- Consider non-chemical responses to weed, pest, and disease problems, such as manual, mechanical, or biological controls, where appropriate. Visit the Utah Plant Pest Diagnostic Lab website for information regarding biological controls and beneficial insects at http://utahpests.usu.edu/uppdl.
- Select pesticides and herbicides best suited to the characteristics host plant, the site, and the particular pest or weed. Half-life, solubility, and absorption should be compared with site characteristics to determine the safest chemical. Choose the least toxic and less persistent sprays whenever possible, based on comparison of labels and associated material safety data sheets (MSDSs).
- Be aware that some pesticide formulations are not compatible with other pesticides and that combining them may result in increased potency and phytotoxicity.
- Do not apply aminopyralid-containing products at the same time as planting grass seed.
- Certain herbicides may not be used on or around water. Use herbicides that are approved by the EPA for use in wetland and aquatic areas when treating weeds that grow in or near these areas.
- Select herbicides that are best suited to the characteristics of the target site (soil texture, topography, and proximity to groundwater and surface water) and particular weed species.
- Noxious and invasive plants may develop resistance to a particular herbicide over time. Use in rotation with mechanical control methods such as hand pulling or mowing. To avoid weed resistance, do not overuse herbicides with common modes of action or herbicides that are in the same family.

Herbicide Application Requirements—Staff Field Tool

Herbicide Pre-application

Ensure that individuals applying commercial chemicals receive thorough training and proper certification prior to chemical use. Individuals and companies hired to apply pesticides must be licensed in the appropriate categories by the Utah Department of Agriculture (UDA). Limited commercial applicators

and public applicators applying restricted pesticides must register with the UDA. Only trained professionals with herbicide applicator licenses should apply restricted-use herbicides. Limited commercial applicators and public applicators not applying restricted pesticides who have submitted to the jurisdiction of the UDA must follow all record-keeping and other procedures as established by the UDA. Thoroughly complete all applicator forms, where applicable.

It is important to understand concentration and application rates specific to the herbicide being used. Apply pesticides and herbicides according to the label and follow these additional steps:

1. Be certain that the irrigation system will be shut off for the appropriate duration of application and absorption. If the site was watered, do not apply products.
2. For public or commercial sites, check that no events are scheduled to take place that will conflict with the application.
3. Because herbicides can travel outside the application area and affect nontarget plants, people, and animals, the following practices should be followed:
    a. Herbicide drift can be reduced by spraying under calm wind conditions (below 5 miles per hour) or by using a spot or wick applicator. Do not apply herbicide if wind is blowing in the direction of the waterway.
    b. The implementation of an untreated buffer zone along a river, stream, or other water ways can act as a safety zone for unanticipated herbicide spray. Streamside buffers can slow the movement of herbicide-laden runoff and allow suspended particles to settle before reaching surface waters. Buffers can be treated using a wick applicator or mechanical or other appropriate treatment (Berg 2004). Only aquatic-approved chemicals should be considered as an alternative to the preferred mechanical controls.
    c. Choose nozzles that minimize the percentage of fine- to moderate-sized droplets and maximize the percentage of larger droplets.
    d. Avoid application when wind direction is highly variable and can change suddenly.
    e. Avoid spraying in calm or no wind conditions toward evening or early morning when thermal inversions are more likely to occur. Watch for indicators of temperature inversion such as ground fog, hanging dust or smoke, and dew or frost.
    f. When using spot spraying and mowing as a combined method for turf management, spot spray at least 1 day prior to mowing (or as directed by the label) to avoid spreading the chemical by mowing.
    g. Keep fertilizer off of streets, sidewalks, and driveways to prevent water pollution. Fertilizer that inadvertently falls on impervious surfaces should be swept back onto the lawn or into the landscape.
4. Establish a site that is used exclusively for the storage and mixing of herbicides. Make sure this site is not accessible to children or animals and is not near any open water source.
5. Mix chemicals in a well-ventilated area and have a spill kit available.
6. Maintain application equipment in proper working condition and calibrate equipment frequently (see below).

SPRAYER CALIBRATION

The following step-by-step method of calibrating a backpack sprayer involves very little math or formulas. It is based on the following principal: 1 gallon = 128 fluid ounces, and your calibration area to be sprayed is 1/128 of an acre; thus, fluid ounces collected = gallons per acre.

1. Clean sprayer and nozzle thoroughly. Then, fill the spray tank with clean water. Using water only, check to see that the nozzle forms a uniform spray pattern. If the pattern is uneven, check to make sure the nozzle is clean and replace if needed. Adjustable nozzles should be set and marked to permit repeated use of the selected spray pattern.
2. Measure an area 18.5 feet by 18.5 feet, which is equal to 1/128 of an acre. If possible, this should be done in the field on which you will be spraying.
3. Time the number of seconds it takes to spray the measured area uniformly with water using a gentle, side-to side sweeping motion with the spray wand similar to spray painting a home or automobile. Record the number of seconds required to spray the area. During application, be sure to maintain a constant sprayer pressure. It will take about 4 to 6 passes through the area for complete coverage. YOU SHOULD REPEAT THIS STEP AT LEAST TWICE AND USE THE AVERAGE OF THE TWO TIMES.
4. Spray into a container for the average time calculated in step 3. Be sure to maintain constant sprayer pressure while you spray into the container.
5. Measure the number of fluid ounces of water in the bucket. The number of fluid ounces collected from the bucket is equal to the number of gallons of water per acre the sprayer is delivering. Volume sprayed in fluid ounces = gallons of water per acre (GPA).
6. Use tables to determine how much liquid herbicide to add to each amount of water (1 gallon, 20 gallons, 100 gallons). Find your spray volume in gallons per acre (GPA, calculated above) and read across the chart to determine the amount of herbicide to add to each gallon of water based on the recommended herbicide application rate.

Herbicide Application

Herbicides must be applied in conformance with the label instructions. It is illegal to apply herbicides beyond the amounts specified on the label. Only trained professionals with herbicide applicator licenses should apply restricted-use herbicides. Read and follow label safety directions and maintain appropriate MSDSs.

1. Wear the appropriate protective equipment specified on the herbicide label to minimize unnecessary exposure to herbicides.
2. Post signs notifying park users that an area has been treated with herbicide and have a spotter to inform the public of what you are doing and to stay clear of the area until dry. Signs should be posted where they are clearly visible and indicate when and where the herbicide application took place and when the area can be used again, or the re-entry interval (check herbicide label). Use the appropriate EPA Signal Word, as follows:
    a. Toxicity Class I: Danger **NOTE:** The word "POISON" and the skull and crossbones symbol are required for products classified as toxicity category I for acute oral, acute dermal, or acute inhalation toxicity studies (40 CFR 156.64(a)(1)). It is also required if inert methanol is present at 4% or more in the subject product (EPA 2011a).
    b. Toxicity Class II: Warning
    c. Toxicity Class III: Caution
    d. Toxicity Class IV: No signal word required
3. Use application techniques that allow the lowest effective labeled application rate.
4. Materials used to contain spills must be readily accessible when using herbicides.

5. Apply herbicides to target locations (spot treatments) where weeds exist; do not broadcast spray.
6. Do not apply herbicides during high temperature, windy conditions, or immediately prior to heavy rainfall or irrigation.
7. Use colorants or dyes added to the herbicide mixture to determine placement.
8. Do NOT use Milestone under leguminous trees (black or honey locust, redbud, mimosa), pinyon pine, rose, junipers, or spruce.
9. Employ application techniques that increase efficiency and allow the lowest effective application rate to adequately control the pest. Carefully calibrate application equipment and follow all label instructions. Hand-apply all chemicals when near buffer zone boundaries, and do not allow overspray from mechanical applications into buffer zones.
10. Clean up and/or contain all pesticide spills immediately and comply with state and federal regulations concerning reporting spills of hazardous materials.

Record-keeping and Disposal

1. Maintain records of all pesticides applied (both restricted and non-restricted use), including entity for whom and address where application was made, target pest, brand name, formulation, EPA registration number, amount, date and time applied, site, crop, commodity or structure treated, exact location of application, measurement of area or number of plants treated, and name of applicator. Combine and file this information with irrigation water data, crop growth records, and notes on effectiveness of alternative pest control measures to help identify and track measures to both save money and reduce pesticide usage.
2. Properly handle and dispose of containers, rinse water, unused product, and waste. Store pesticides in secured and covered areas. Never pour lawn and garden chemicals down storm drains or sanitary drains and keep off impervious surfaces during application. Check labels and MSDSs for specific instructions on disposal of the product and the product container.
3. Complete the treatment tracking form (attached in Appendix I.2) and submit for mapping and record-keeping.
4. When done spraying, always triple-rinse sprayer in a sanitary sewer as well as the containers the product came in before disposing of them.

Approved Herbicides for Natural Areas and other Open Space Lands

Table A.1.2. Turf Herbicide Toxicity Rating and Advisories

Active Ingredient	Trade Names	EPA Toxicity Category Rating					PAN Bad Actor Chemical*	Signal Word**	Restricted Entry Interval (REI)***	Groundwater Contaminant Rating	Selectivity
		Acute Oral	Acute Dermal	Acute Inhalation	Primary Eye Irritation	Primary Skin Irritation					
Chlorsulfuron	Corsair[1], Landmark XP[2], Telar XP[3]	II	II	II	III	IV	Yes	WARNING	Once dry	Potential	Yes
Glyphosate	RoundUp	III	III	III	III	IV	Not listed	CAUTION	24 hours	Potential	No
Prodiamine	Barricade	III	IV	IV	N/A	IV	Not listed	CAUTION	Once dry	N/A	Yes
2,4-D Amine (salt form)	2,4-D Amine, numerous others	II	II	III	I	IV	Yes	DANGER	Once dry	Potential	Yes
3,6-Dichloro-o-anisic acid	Dicamba[4], Banvel, Vanquish, Oracle[5]	III	IV	IV	I	IV	Yes	DANGER	Once dry	Potential	Yes

Note: N/A = not applicable.

Sources: EPA (2011a); EPA (2011b); Kegley et al (2011); DuPont (2011); Syngenta (2012); Scotts (2012); Nufarm Americas (2012).

***PAN Bad Actors** are chemicals that are one or more of the following: highly acutely toxic, cholinesterase inhibitor, known/probable carcinogen, known groundwater pollutant, or known reproductive or developmental toxicant.

**Signal word determination based on EPA Label Review Manual

***REI for uses of herbicides that are NOT within the scope of the Worker Protection Standard for agricultural pesticides.

[1]Cosair is the only formulation of Chlorsulfuron approved for lawns.

[2]Landmark XP contains Sulfometuron methyl (50%), which is not listed as an approved chemical by SLC.

[3]Telar XP approved for use in unimproved turf only. Not approved for lawns.

[4]Dicamba is not a standalone product but is used in a mix.

[5]Oracle is designated as a commercial (agricultural) herbicide and is not approved for turf use.

Herbicides that can be used in natural areas and other unmanaged Open Space Lands in SLC include the chemicals in Table A.1.2, as well as two additional herbicides that can be used to control many of the noxious and invasive weed species in SLC Open Space Lands, Milestone and Escort (Tables A.1.3 and A.1.4).

Table A.1.3. Target Weed Species Effectively Controlled by Milestone and Escort

Milestone (aminopyralid)	
Common Name	***Scientific Name***
Russian knapweed	*Acroptilon repens*
Burdock	*Arctium minus*
Musk thistle	*Carduus nutans*
Yellow starthistle	*Centaurea solstitialis*
Diffuse knapweed	*Centaurea diffusa*
Spotted knapweed	*Centaurea stoebe spp. micranthos*
Squarrose knapweed	*Centaurea virgata*
Canada thistle	*Cirsium arvense*
Bull thistle	*Cirsium vulgare*
Black henbane	*Hyoscyamus niger*
Oxeye daisy	*Leucanthemum vulgare*
Scotch thistle	*Onopordum acanthium*
Sulphur cinquefoil	*Potentilla recta*
Common dandelion	*Taraxacum officinale*
Escort (metsulfuron)	
Common Name	***Scientific Name***
Garlic mustard	*Alliaria petiolata*
Hoary cress	*Cardaria draba*
Blue mustard	*Chorispora tenella*
Poison hemlock	*Conium maculatum*
Fixweed	*Descurainia sophia*
Dyer's woad	*Isatis tinctoria*
Perennial pepperweed	*Lepidium latifolium*
Curly dock	*Rumex crispus*
Tumble mustard	*Sisymbrium altissimum*

Milestone (aminopyralid)

Noxious and invasive broadleaf species that are controlled by Milestone consist of species found in the sunflower family, including thistles, knapweeds, and oxeye daisy. There is little or no injury to desirable cool- and warm-season grasses. Labeled weeds can be controlled at rates from 4 to 7 fluid ounces per acre. Milestone does not tend to vaporize into the atmosphere from a treated surface and will be absorbed into the leaf within 2 hours following application. It can be used alone, but if additional species are to be controlled, follow the label instructions (Dow 2011).

Milestone translocates into foliage and moves quickly throughout the entire plant, accumulating in meristematic tissues, disrupting plant growth and therefore killing the entire plant. Fall foliar applications are highly effective, with the residual herbicide remaining in the soil and controlling germination and emergence of seedlings the following spring. Milestone is not expected to injure most tree species except leguminous trees, such as black locust, honey locust, and redbud. This product is not recommended for use on turf because the residual herbicide that remains in the clippings may pose a threat to untargeted plants if used as mulch or compost. Milestone has been registered under the Reduced Risk Pesticide Initiative of the EPA. This formula is safe to apply up to the water's edge (Dow 2011).

Escort (metsulfuron methyl)

Escort is registered for postemergent control of annual and perennial weeds primarily in the mustard family, including hoary cress, perennial pepperweed, and dyer's woad. Best results are achieved when flowers are budding but not yet opened. Treatment on flowering plants is less effective, and plants will still set seed. Typical application rates range from 0.5 to 2 ounces per acre (DuPont 2011).

Escort stops cell division in the shoots and roots of the plants. The EPA has classified metsulfuron methyl as Toxicity Class III: caution (low toxicity: caution). The residue is very irritating but not corrosive to the eyes, is moderately irritating to the skin, but has low to very low toxicity if ingested or inhaled. This product breaks down quickly, eliminates from the body, and does not bioaccumulate in fish. The half-life is typically 30 days, with faster breakdown in moist, warm soils. It is highly mobile and has the potential to contaminate adjacent waterways; therefore, it is advised to maintain an untreated 50-foot buffer adjacent to rivers, streams, and ponds (DuPont 2011).

Table A.1.4. Herbicides for Noxious and Invasive Weed Species Control

Common Name	Scientific Name	Open Space Approved	
		Aminopyralid (Milestone)	Metsulfuron (Escort)
Russian knapweed	*Acroptilon repens*	E	F
Jointed goatgrass	*Aegilops cylindrica*	P	-
Common burdock	*Arctium minus*	G	F
Cheatgrass	*Bromus tectorum*	P	-
Hoary cress	*Cardaria draba*	F	E
Musk thistle	*Carduus nutans*	E	F
Yellow starthistle	*Centaurea solstitialis*	E	F
Diffuse knapweed	*Centaurea diffusa*	E	F
Spotted knapweed	*Centaurea stoebe* spp. *micranthos*	E	F
Squarrose knapweed	*Centaurea virgata*	E	F
Canada thistle	*Cirsium arvense*	E	F
Bull thistle	*Cirsium vulgare*	E	F
Poison hemlock	*Conium maculatum*	F	-
Field bindweed	*Convolvulus arvensis*	F	P
Houndstongue	*Cynoglossum officinale*	F	-
Bermudagrass	*Cynodon dactylon*	P	-
Common teasel	*Dipsacus fullonum*	F	-
Russian olive	*Elaeagnus angustifolia*	F	-
Quackgrass	*Elymus repens*	P	-
Leafy spurge	*Euphorbia esula*	F, P	F
Myrtle spurge	*Euphorbia myrsinites*	F	F
Dame's rocket	*Hesperis matronalis*	-	-
Dyer's woad	*Isatis tinctoria*	F	E
Perennial pepperweed	*Lepidium latifolium*	F	E
Dalmation toadflax	*Linaria dalmatica*	F, P	-
Purple loosestrife	*Lythrum salicaria*	G	-
Scotch thistle	*Onopordum acanthium*	E	F
Common reed	*Phragmites australis*	X	-
Buffalobur	*Solanum rostratum*	P	-
Johnsongrass	*Sorghum halepense*	P	-
Tamarisk	*Tamarix ramosissima*	X	-
Medusahead	*Taeniatherum caput-medusae*	P	-
Puncturevine	*Tribulus terrestris*	F	-

Note: E = excellent, G = good, F = fair, P = poor, X = unrated, - = no information.

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Appendix A.2.

Treatment Matrix

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Table A.2.1. Treatment Matrix

Common Name (Scientific Name)	Reproduction Characteristics	Control Methods	Application Timing	Application Method	Duration of Treatment	Treatment Remarks
Russian knapweed (*Acroptilon repens*)	• Annual, biennial, short-lived perennial • Spreads primarily by adventitious shoots from widely spreading horizontal roots • Seed remains viable in soil for 2 to 8 years	• Chemical	• Spring – when plants have recently bolted • Summer – search for missed plants that have just flowered • Fall – when plants are in full bloom	• Excellent: aminopyralid • Good: glyphosate,imazapic,2,4-D • Fair: dicamba, metsulfuron, chlorsulfuron • Poor: glyphosate	• Minimum of 2 years for herbicide applications to deplete seed bank	• Aminopyralid should be applied in the fall; aminopyralid can persist in the soil for several years • Control existing infestations using a combination of methods • Reseed with desirable grasses that are unaffected by broadleaf herbicides • Glyphosate, picloram, and dicamba have shown mixed results and should be applied carefully and according to label instructions regarding application requirements and restrictions
		• Biological	• Spring – after bolting to remove flower heads	• Grazing • Competition with perennial grasses • Nematode: *Subanguina picridis*	• Graze several times annually for several years to deplete seed bank • Nematode effectiveness not consistent from year to year	• Goats prefer flowering heads but will graze green tissue • Once plants bolt, there are no more buds capable of reproduction until fall; grazing eliminates seed production but will not kill plant • Removing aboveground biomass forces them to use root reserves and stresses plant; re-emerged plants are smaller and lower in vigor • Can be outcompeted in moist locations by perennial grasses; reseed with desirable grasses • Nematode needs to be propagated and redistributed on large scale and is not cost effective with present techniques
		• Mechanical	• Spring – after bolting to remove flower heads	• Mow • Hand pulling	• Several times annually for several years • Mowing will prevent flowering and seed set from depleting soil seed bank	• Once plants bolt, there are no more buds capable of reproduction until fall • Eliminates seed production but will not kill plant • Removing aboveground biomass forces them to use root reserves and stresses plant; re-emerged plants are smaller and lower in vigor • Mow in the fall, followed immediately by picloram application to ensure herbicide reaches soil surface • Russian knapweed may contain a carcinogenic compound; use protective equipment when hand pulling
Jointed goatgrass (*Aegilops cylindrica*)	• Winter annual	• Chemical	• Spring – apply to actively growing vegetation	• Excellent: glyphosate • Good: glyphosate • Poor: 2,4-D, dicamba, picloram • Unrated: sulfometuron methyl	• Several years	• Many herbicides are broadleaf specific; read label to be sure correct formulation is used for grasses • Grass-selective herbicides may kill desirable grasses • Glyphosate has shown mixed results and should be applied carefully and according to label instructions regarding application requirements and restrictions
		• Biological	• Early spring	• Grazing	• Several years	• Cattle and goats may graze when plants are green
		• Mechanical	• Spring – after flowering and before seed set	• Mowing	• Several years	• Mowing may be required several times during the season
Cheatgrass (*Bromus tectorum*)	• Winter annual	• Chemical	• Fall – after germination • Spring – before flowering	• Excellent: imazapic, glyphosate • Good glyphosate, fluazifop • Poor: 2,4-D, dicamba, picloram	• Several years	• Check label for potential harm to desirable grasses • Glyphosate has shown mixed results and should be applied carefully and according to label instructions regarding application requirements and restrictions
		• Biological	• Spring	• Grazing	• Several years	• Grazing can help control cheatgrass if two grazing periods occur each spring for at least 2 consecutive years. First, graze just before inflorescences emerge, and then graze again before panicles emerge.
		• Mechanical	• Not recommended	• Not recommended	• Not recommended	• Cutting not recommended, as cut plants will produce new stems and seeds at cut height
Hoary cress (*Cardaria draba*)	• Perennial • Germinates in the fall • Spreads primarily from adventitious buds from lateral rhizomes • Seed remain viable in soil for 3 years	• Chemical	• Apply herbicide during bud or flowering stage (May–June) • Reapply herbicide in the fall if new growth occurs	• Excellent: metsulfuron, chlorsulfuron • Good: dicamba, imazapic, 2,4-D, metsulfuron + dicamba + 2,4-D, imazapic + glyphosate • Fair: 2,4-D, glyphosate, MCPA	• Multiyear commitment	• Control existing infestations using a combination of methods • Metsulfuron and chlorsulfuron must be applied to actively growing green tissue before flowering • Flowers will immediately set seed following herbicide application; therefore, spray at bud stage prior to flowering or foliage in the fall • May require tilling to synchronize flowering to ensure uniform herbicide application • Imazapic and 2,4-D have shown mixed results and should be applied carefully and according to label instructions regarding application requirements and restrictions
		• Biological	• Not available	• Grazing	• Not recommended	• Can cause iodine deficiency in goats • Seeds contain cyanide • Toxic to cattle and horses
		• Mechanical	• Ongoing throughout growing season	• Tilling and removal every 2 months for 3 years	• Tilling effects not evident for 2–3 years	• Till repeatedly to exhaust root system • Uprooted plants will re-sprout increasing density; therefore, tilling must be combined with removing plants and roots

Table A.2.1. Treatment Matrix

Common Name (Scientific Name)	Reproduction Characteristics	Control Methods	Application Timing	Application Method	Duration of Treatment	Treatment Remarks
Musk thistle (*Carduus nutans*) Scotch thistle (*Onopordum acanthium*)	• Musk thistle: Biennial, summer or winter annual • Musk thistle seed remains viable in soil for 10 to 15 years, and flowers produce up to 1,000 seeds per head • Scotch thistle: Biennial • Scotch thistle seeds often remain dormant in the soil up to 5 years	• Chemical	• Spring – Actively growing rosettes to early bolting • Fall – Actively growing rosettes[1]	• Excellent: aminopyralid, metsulfuron • Good: dicamba, imazapic, chlorsulfuron, clopyralid, glyphosate, dicamba + 2,4-D, • Fair: 2,4-D, dicamba, MCPA	• Multiyear commitment	• Musk and Scotch thistles can be treated together • Reseed with desirable grasses that are unaffected by broadleaf herbicides • 2,4-D and dicamba have shown mixed results and should be applied carefully and according to label instructions regarding application requirements and restrictions
		• Biological	• Spring – bud to flower	• Grazing • Musk thistle weevil (*Rhinocyllus conicus*)[5]	• Multiyear commitment	• Older male goats prefer musk thistle, compared with younger goats • Repeat grazing 4 to 7 weeks to remove new flowers • Weevil adults will feed on leaves, mate, and deposit eggs on bracts
		• Mechanical	• Early bud stage prior to flowering	• Mowing • Removal	• Multiyear commitment	• Mow repeatedly to remove flowers • Bag and burn cut plants because seeds can still mature after cutting • Repeat after 4–7 weeks as musk thistle continues flowering all summer
Yellow starthistle (*Centaurea solstitialis*)	• Annual • Germinating in the fall • Reproduces entirely by seeds that may remain viable for several years	• Chemical	• Spring – rosette to bolt • Fall – rosette[1]	• Excellent: aminopyralid • Good: dicamba, 2,4-D, clopyralid	• Several years to eliminate seed bank	• Reseed with desirable grasses that will not be affected by broadleaf herbicides
		• Biological	• Rosette to bud	• Grazing • Seedhead weevil[5]	• Multiple grazing periods per year over multiple years to eliminate seed bank	• Cattle, sheep, and goats will graze yellow starthistle before it has spines • Causes chewing disease in horses
		• Mechanical	• Summer, before seed set	• Cutting	• Several years to eliminate seed bank	• Does not eliminate infestation but will reduce seed production
Diffuse knapweed (*Centaurea diffusa*) Spotted knapweed (*Centaurea stoebe* ssp. *micranthos*)	• Diffuse knapweed: annual to short-lived perennial • Spotted knapweed: biennial to short-lived perennial • Both reproduce by seed; spotted can reproduce vegetatively • Spotted knapweed seeds remain viable for 8 years	• Chemical	• Late spring – active growth from rosette to mid-bolting stage	• Excellent: aminopyralid • Good: dicamba, clopyralid • Fair: dicamba, 2,4-D • Poor: metsulfuron	• Minimum of 2 years	• Seed area with desirable perennial native grasses; grasses will outcompete knapweed • Knapweed will reinvade if competitive grasses do not establish • Herbicides are most effective when applied to the rosette stage • 2,4-D and dicamba have shown mixed results and should be applied carefully and according to label instructions regarding application requirements and restrictions • Glyphosate may not be as effective against diffuse knapweed, compared with spotted knapweed
		• Biological	• Bud to bloom	• Goats • Fungi[5] • Weevil[5] • Seedhead flies[5] • Root beetle[5] • Moth[5]	• Several years for goats to eliminate soil seed bank • Unknown for insects and pathogens	• Goats will not eat dry seed heads • Livestock grazing twice in the spring can reduce seed set by 50% • Grazed plants may live and rebolt • Biological control agents are available, but several agents may be required to control diffuse and spotted knapweed
		• Mechanical	• Before seed set	• Mowing	• Several years, combine with herbicide treatment	• Cut plants may live and rebolt
Squarrose knapweed (*Centaurea virgata*)	• Long-lived perennial • Reproduce by seed dispersing with the head as a unit	• Chemical	• Spring – rosette to bolt stage[1]	• Excellent: picloram • Good: aminopyralid, clopyralid • Fair: dicamba, 2,4-D • Poor: metsulfuron • Unrated: glyphosate	• Minimum of 2 years	• Seed area with desirable perennial native grasses; grasses will outcompete knapweed • Knapweed will reinvade if competitive grasses do not establish • Herbicides are most effective when applied to the rosette stage
		• Biological	• Spring	• Grazing	• Several years	• Goats will graze the flower heads and buds preferentially, followed by the green photosynthetic tissue
		• Mechanical	• Spring, bolt to flower	• Mowing	• Several years	• Not recommended for mature plants as it will facilitate seed set
Canada thistle (*Cirsium arvense*) Bull thistle (*Cirsium vulgare*)	• Canada thistle spreads rapidly through creeping horizontal roots • Seeds are viable in the soil for several years • Bull thistle is a biennial forb	• Chemical	• Spring – rosette to early bloom • Fall – apply herbicide to new growth (cuticle is too thick on older leaves)[1]	• Excellent: aminopyralid, 2,4-D, glyphosate • Good: chlorsulfuron, glyphosate • Fair: dicamba	• Two-year minimum	• Monitor annually just before or during bloom period (14–18 hours of daylight) • Spreads primarily by vegetative reproduction • Combine methods of control suggested • Aminopyralid should be applied in the fall or early spring when plants are in the rosette stage • 2,4-D and glyphosate have shown mixed results and should be applied carefully and according to label instructions regarding application requirements and restrictions • 2,4-D is more effective against bull thistle than against Canada thistle
		• Biological	• Full bud before flower	• Grazing	• Not recommended	• Grazing not recommended
		• Mechanical	• After flowering before seed set	• Mowing • Shading	• Repeat in 1-month intervals throughout growing season	• Plants spend energy reproducing photosynthetic tissue, reducing root reserves, and will die after two or three mowings • If bull thistle roots are cut too early, plants will re-sprout • Bull thistle cannot tolerate shade
Poison hemlock (*Conium maculatum*)	• Biennial	• Chemical	• Spring and summer when plants are actively growing[1]	• Excellent: aminopyralid, glyphosate • Good: 2,4-D, imazapyr, glyphosate	• Several years	• Poison hemlock is often found in riparian habitats, and aquatic formulations of the herbicides are recommended • Glyphosate has shown mixed results and should be applied carefully and according to label instructions regarding application requirements and restrictions
		• Biological	• Summer	• Palearctic moth (*Agonopteris alstoemeriana*)[5]	• Several years	• The palearctic moth feeds exclusively on poison hemlock
		• Mechanical	• Before seed set	• Digging • Pulling • Burning	• Several years	• Offers good control; depletes seed bank

Table A.2.1. Treatment Matrix

Common Name (Scientific Name)	Reproduction Characteristics	Control Methods	Application Timing	Application Method	Duration of Treatment	Treatment Remarks
Field bindweed (*Convolvulus arvensis*)	• Perennial • Spreads by rhizome and seed • Seeds can be viable for up to 50 years	• Chemical	• Fall, when plants are vigorous and before seed set	• Excellent 2,4-D, dicamba • Good: 2,4-D, dicamba, picloram, glyphosate • Fair: 2,4-D, dicamba, glyphosate, metsulfuron, 2,4-D+dicamba • Poor: 2,4-D+clopyralid[1]	• Two to three years	• Herbicide can be applied any time as long as tillers are 1 foot (30 cm) tall • 2,4-D, dicamba, and glyphosate have shown mixed results and should be applied carefully and according to label instructions regarding application requirements and restrictions • The best results are achieved when 2,4-D is mixed with other herbicides: dicamba, glyphosate, or picloram • Drought reduces effectiveness of herbicide; dicamba is better than 2,4-D under drought conditions • Some biotypes are resistant to glyphosate
		• Biological	• Summer	• Grazing • Gall mite • Plant competition	• Ongoing	• Can be toxic to cattle and hogs • Goats and sheep will graze field bindweed • Mites may infest native species • Mites are susceptible to herbicides • Competition with perennial grasses reduces cover
		• Mechanical	• Before seed set	• Pulling • Digging	• Multiple years	• Tilling is not recommended without herbicide treatment; may increase number of seedlings from severed roots • Mowing encourages ground-hugging growth
Houndstongue (*Cynoglossum officinale*)	• Biennial • Reproduces entirely from seed	• Chemical	• Apply in early spring before blooms occur • Herbicide application at the rosette stage has been successful[1]	• Excellent: aminopyralid • Good: dicamba • Fair: 2,4-D • Unrated: glyphosate, imazapic	• Multiple years	• Apply according to label requirements and restrictions
		• Biological	• Not available	• Grazing	• Not recommended	• Not recommended; it is toxic to cattle and horses.
		• Mechanical	• Summer – before seed set	• Tilling	• Several years	• Flowering plants should be bagged or burned to prevent seeds from maturing
Bermudagrass (*Cynodon dactylon*)	• Mat-forming rhizomatous grass that moves along the ground and forms adventitious roots wherever a node touches the ground • Reproduces through seeds as well as rhizomes	• Chemical	• Early spring – seedling stage[1]	• Good: glyphosate, fluazifop • Poor: 2,4-D, dicamba, picloram	• Several years	• Most herbicides control broad leaf plants; selection of grass-selective herbicide is necessary • Most grass herbicides will also kill desirable native grasses; use backpack sprayer to target plants
		• Biological	• Early spring	• Grazing	• Several years	• Goats prefer forbs but will consume young shoots if nothing else is available
		• Mechanical	• Early spring – following germination	• Removal	• Several Years	• The entire plant and all runners must be removed
Common teasel (*Dipsacus fullonum*)	• Biennial or short-lived perennial • Reproduces by seed; each plant produces over 2,000 seeds • Seeds viable in soil for 2–3 years	• Chemical	• Spring to summer – when plants are bolting	• Good: metsulfuron, dicamba	• Several years	• Follow label instructions; rosettes require less concentrated herbicide than flowering plants
		• Biological	• None available	• None available	• None available	• None available
		• Mechanical	• Summer before seed set	• Mowing or cutting	• Several years	• Effective for small infestations • Exhaust seed bank after several years
Russian olive (*Elaeagnus angustifolia*)	• Perennial tree • Reproduce from seed	• Chemical	• Foliar application when leaves have fully flushed • Cut-stump application can occur year-round[1]	• Good: 2,4-D, imazapyr, triclopyr	• One to two seasons	• Apply 2,4-D when leaves are fully developed; two to three retreatments may be necessary • Apply imazapyr or triclopyr for spot foliar treatments, basal bark, or cut-stump methods; stump applications should be made as soon after cutting as possible
		• Biological	• Spring, summer	• Goats	• Limited to sprouts and low foliage	• Goats graze flowers, fruits, and leaves
		• Mechanical	• Spring	• Hand-pull seedlings and sprouts	• Several years	• Cutting or burning not recommended as they stimulate more growth
Quackgrass (*Elymus repens*)	• Propagates mainly by rhizomes but also reproduces by seed; flowers from June through August; seeds remain viable for up to 10 years	• Chemical	• Early flowering stage or new growth in the fall[1]	• Good: glyphosate, fluazifop • Poor: 2,4-D, dicamba, picloram • Unrated: sethoxydim, atrazine	• Several years	• Do not apply fluazifop to stressed quackgrass, as treatment effectiveness will be reduced
		• Biological	• Early spring	• Grazing	• Several years	• Goats prefer forbs but will graze young shoots if nothing else is available
		• Mechanical	• Before flowering	• Mowing	• Ongoing	• Will not eliminate infestation but will reduce seed set
Leafy spurge (*Euphorbia esula*)	• Primary reproduction is vegetative through lateral root system • Seeds can remain viable in the soil for 5–8 years, although 99% of the viable seeds will germinate in the first 2 years	• Chemical	• Early spring from bud to early flowering • Apply imazapic in the late fall before it loses its milky sap and after a killing frost[1]	• Good: picloram, glyphosate, imazapic • Fair: 2,4-D, dicamba, glyphosate, imazapic+glyphosate, dicamba+2,4-D • Poor: 2,4-D, 2,4-D+clopyralid, metsulfuron	• Requires repeat applications in one season	• Rapid re-establishment of treated stands often occurs after an apparently successful management effort because of the large nutrient reserve stored in the roots of leafy spurge plants • Extend herbicide 15 feet past infestation to kill lateral roots • 2,4-D and glyphosate have shown mixed results and should be applied carefully and according to label instructions regarding application requirements and restrictions
		• Biological	• Spring and summer – when plants are succulent	• Grazing	• Ongoing	• Removal of goats will result in reestablishment of leafy spurge • Goats will seek out leafy spurge
		• Mechanical	• Ongoing	• Mowing	• Several years	• Mowing will reduce seed set but not control infestation • Tilling not recommended, as cut roots will regenerate
Myrtle spurge (*Euphorbia myrsinites*)	• Perennial • Reproduces from seed, but regrowth from cut roots has been observed	• Chemical	• Spring – seedling stage	• Good: 2,4-D, dicamba, glyphosate • Fair: picloram	• Several years	• Combine herbicide and mechanical control for best results • Deplete soil seed bank
		• Biological	• None available	• None available	• None available	• Toxic to animals • Used in landscaping as a deer deterrent
		• Mechanical	• Before seed set	• Removal	• Several years	• Effective for small infestations

Table A.2.1. Treatment Matrix

Common Name (Scientific Name)	Reproduction Characteristics	Control Methods	Application Timing	Application Method	Duration of Treatment	Treatment Remarks
Dame's rocket (*Hesperis matronalis*)	• Biennail and perennial • Reproduces from seed	• Chemical	• Early spring – apply when weeds are actively growing • Late fall reapplication	• Good: 2,4-D, glyphosate, imazapic, triclopyr	• Several years to deplete seed supply in soil	• Many herbicides are broadleaf specific; read label to be sure correct formulation is used for grasses • Grass selective herbicides may kill desirable grasses • Seed area with competitive annual and perennial grasses • Minimize soil disturbance
		• Biological	• None available	• None available	• None available	• None available
		• Mechanical	• Before seed set	• Removal	• Several years	• Tilling and mowing not recommended, as cut roots and stems can re-sprout • Bag removed plants
Dyer's woad (*Isatis tinctoria*)	• Biennial • Reproduces from seed	• Chemical	• April–June, at or during first bloom when plants are vigorous and before seed set[1]	• Excellent: dicamba, metsulfuron • Good: 2,4-D, glyphosate, imazapic, chlorsulfuron • Fair: dicamba	• Several years to deplete seed supply in soil	• Prevent seedling growth • Prevent spread of weeds • Yearly summer monitoring • Do not apply during periods of intense rainfall or to soils saturated with water • Best to apply when ground is moist • Dicamba has shown mixed results and should be applied carefully and according to label instructions regarding application requirements and restrictions
		• Biological	• April–June, at or during first bloom when plants are vigorous and before seed set	• Rust fungus (*Puccinia thlaspeos*) • Grazing	• Several years to deplete seed supply in soil	• Reduce or prevent seed production • Prevent seedling growth or survival • Yearly summer monitoring • Plants regenerate from roots after leaves are removed; grazing must be repeated
		• Mechanical	• April–June, at or during first bloom when plants are vigorous and before seed set • Mowing: ongoing	• Removal • Mowing	• Several years to deplete seed supply in soil	• Removal is the simplest and most effective method of control • Bag O' Woad program organized through local CWMA to remove plants • Plants regenerate from roots after leaves are removed; mowing must be repeated throughout growing season
Perennial pepperweed (*Lepidium latifolium*)	• Perennial • Stems originate from large perennial belowground roots in early spring or late fall • Seeds lack a hard coat and do not seem to be capable of surviving long periods in the soil; thus, seed viability may be short	• Chemical	• Spring – between flowerbud and early flowering or to re-sprouted leaves after mowing • Fall, reapply after dormant roots sprout and bud	• Excellent: chlorsulfuron, metsulfuron • Good: dicamba, glyphosate, chlorsulfuron, metsulfuron, imazapic, imazapyr • Fair: 2,4-D, picloram, triclopyr	• One year with up to several years of monitoring and spot spraying if disking, mowing, and spraying	• Combine disking, mowing, and herbicide application • Disk in the fall to fragment roots • Mow between flowerbud and flowering • Apply herbicide to re-sprouted leaves 2–3 weeks after mowing • Use chlorsulfuron or metsulfuron on dry land and glyphosate or imazapyr over water • Seed exposed soil with desirable perennial plants • Monitor for recurrence in early spring and late summer for several years following treatment
		• Biological	• Spring – rosette stage	• Grazing	• Ongoing; grazing suppresses seed production but does not kill plants	• Permanent grazing will suppress plants; plants re-sprout quickly when grazing is removed • Foliate may be poisonous to cattle • Dense stands may be difficult to graze
		• Mechanical	• Fall – disk to fragment roots • Spring – mow between flowerbud and flowering • Continuous, flooding	• Disking • Mowing • Flooding • Burning	• Flooding; ongoing • One year with up to several years of monitoring and spot spraying if disking, mowing, and spraying	• Combine disking, mowing, and herbicide application • Disk in the fall to fragment roots; disking alone increases infestation by re-sprouting from fragmented roots • Mow in the spring between flowerbud and flowering; mowing alone stimulates growth • Apply herbicide to re-sprouted leaves 2–3 weeks after mowing, depending on soil moisture • Seed exposed soil with desirable perennial plants • Monitor for recurrence in early spring and late summer for several years following treatment • Burning not effective, as it does not harm roots and allows re-sprout, but it may be used to remove excessive litter buildup • Flooding for two consecutive seasons is effective by increasing competition from flood-adapted plants

Table A.2.1. Treatment Matrix

Common Name (Scientific Name)	Reproduction Characteristics	Control Methods	Application Timing	Application Method	Duration of Treatment	Treatment Remarks
Dalmation toadflax (*Linaria dalmatica*)	• Perennial • Reproduces from seed	• Chemical	• Summer – full bloom	• Good: dicamba, picloram, glyphosate, imazapic, chlorsulfuron, • Fair: metsulfuron, 2,4-D • Poor: 2,4-D, dicamba	• Several years	• Seed area with competitive annual and perennial grasses • Minimize soil disturbance • Aggressive cultivation could control an area after several seasons, but monitoring must continue for 10–15 years • Dicamba and 2,4-D have shown mixed results and should be applied carefully and according to label instructions regarding application requirements and restrictions
		• Biological	• Spring and summer	• Grazing • Toadflax flower-feeding beetle (*Brachypterolus pulicarius*) • Toadflax moth (*Calophasia lunula*) • Toadflax root-boring moth (*Eteobalea intermediella*) • Toadflax seed capsule weevil (*Gymnetron antirrhini*) • Toadflax root-galling weevil (*Gymnetron linariae*) • Toadflax stem weevil (*Mecinus janthinus*)	• Several years	• Grazing can be effective if continued to prevent rebolt and seed set • Sheep and goats prefer Dalmatian toadflax to other rangeland grasses • Many insects attack both Dalmatian toadflax and yellow toadflax
		• Mechanical	• Spring and before seed set	• Fire followed by herbicide application	• Several years	• Pulling not advised as plants develop extensive root systems (up to 2 m deep) that have dormant buds that can reproduce vegetatively
Purple loosestrife (*Lythrum salicaria*)	• Perennial • Reproduces primarily by seed, as well as creeping rootstocks and cut stems	• Chemical	• Spring – apply when weeds are actively growing	• Good: 2,4-D, metsulfuron, glyphosate	• Several years	• Purple loosestrife often grows near riparian areas, and aquatic formulations of the recommended herbicides are available
		• Biological	• Early spring – adults feed on buds	• black-margined loosestrife beetle (*Galerucella calmariensis*) • golden loosestrife beetle (*Galerucella pusilla*) • loosestrife root weevil (*Hylobius transversovittatus*)[5] • loosestrife seed weevil (*Nanophyes marmoratus*)[5]	• 2 years	• The beetles can feed on two native plants (*Decodon verticillatus* and *Lythrum alatum*) and two introduced plants (*L. hyssopifolia* and *Lagerstroemia indica*) but do not reproduce on these hosts
		• Mechanical	• Before seed set	• Removal	• Several years	• Tilling and mowing not recommended, as cut roots and stems can re-sprout • Bag or burn removed plants
Common reed (*Phragmites australis*)	• Perennial • Reproduces primarily from rhizomes • Seeds are often not viable	• Chemical	• Mid to late summer or fall – after tasseling	• Good: glyphosate, imazapyr • Poor: 2,4-D, dicamba, picloram	• Several years	• Use the aquatic formulation to avoid harm to wildlife
		• Biological	• Spring and summer	• Grazing	• Several years	• Cattle will graze common reed but do not like standing water • Goats will graze common reed, but water level must be below 4 inches
		• Mechanical	• Fall	• Burning	• Several years	• Dead common reed stands prohibit new growth of desirable plants and must be removed • Burning without herbicide treatment could result in more vigorous stands
Buffalobur (*Solanum rostratum*)	• Annual • Reproduces from seed; self-pollinates	• Chemical	• Spring – before bloom	• Unrated: 2,4-D	• Several years	• Most effective if following mowing
		• Biological	• None available	• None available	• None available	• Contains the alkaloid solanine, which is toxic to livestock • Sharp burs can damage mouth
		• Mechanical	• Spring and summer	• Pulling • Mowing	• Several Years	• This is not a very competitive species, and pulling plants offers good control as the seed bank is depleted • Mowing followed by herbicide application offers the best control
Johnsongrass (*Sorghum halepense*)	• Perennial • Colonization can occur from both rhizomes and seed, and seeds can remain viable for over 2 years in the soil	• Chemical	• Spring – apply to actively growing vegetation[1]	• Excellent: glyphosate • Good: glyphosate, fluazifop • Poor: 2,4-D, dicamba, picloram • Unrated: sulfometuron methyl	• Several years	• Many herbicides are broadleaf specific; read label to be sure correct formulation is used for grasses • Grass selective herbicides may kill desirable grasses • Glyphosate has shown mixed results and should be applied carefully and according to label instructions regarding application requirements and restrictions
		• Biological	• Early spring – before flowering	• Grazing	• Several years	• Be careful to remove grazers, as Johnsongrass becomes toxic under moisture stress
		• Mechanical	• Early spring – when soil is moist for hand pulling • Several times over the growing season	• Hand pulling • Mowing	• Several years for mowing to remove root reserves	• Be careful not to spread Johnsongrass when removing or mowing as root pieces can re-sprout

Table A.2.1. Treatment Matrix

Common Name (Scientific Name)	Reproduction Characteristics	Control Methods	Application Timing	Application Method	Duration of Treatment	Treatment Remarks
Tamarisk (*Tamarix ramosissima*)	• Perennial tree	• Chemical	• Use cut-stump method in the fall Apply herbicide to entire circumference of cambium within 1 minute of cutting • Uprooting or chaining not recommended as it may only encourage vigorous re-sprouting • Spray re-sprouted foliage 4–12 months after initial treatment[1]	• Excellent: triclopyr • Unrated: glyphosate	• One year with follow-up annual monitoring and retreatment	• Be prepared to apply herbicide immediately after cutting (works best if one person operates chain saw and a second person applies herbicide) • Wait at least 4 months before treating re-sprouted foliation • Monitor annually for success of treatment and for new areas to control • Focus on younger stands and sprouts first
		• Biological	• Best results if adults are gathered in July and allowed to lay eggs in the new location before winter	• Leaf beetle (*Diorhabda elongata*)	• Two to three seasons	• Large populations (10,000 individuals) introduced at one time reduce bird and ant predation effects
		• Mechanical	• Spring and summer	• Pulling	• One to two years	• Hand pull seedlings including tap root
Medusahead (*Taeniatherum caput-medusae*)	• Annual • Reproduces entirely from seed; up to 6,000 seeds per square foot	• Chemical	• Spring, apply to actively growing vegetation[1]	• Good: glyphosate, fluzifop • Poor: 2,4-D, dicamba, picloram • Unrated: sulfometuron methyl	• Several years	• Many herbicides are broadleaf specific; read label to be sure correct formulation is used for grasses • Grass-selective herbicides may kill desirable grasses
		• Biological	• Early spring	• Grazing	• Several years	• Cattle and goats will graze when plants are green • Seeds cause damage to eyes and mouth
		• Mechanical	• After plant senesces and before seed is disseminated	• Burning	• Several years to deplete soil seed bank	• Slow burn will destroy seeds, but other weeds may colonize after fire
Puncturevine (*Tribulus terrestris*)	• Annual • Reproduces from seed	• Chemical	• Summer – before bloom	• Good: 2,4-D, imazapic, chlorsulfuron, aminopyralid • Fair: picloram	• Several years	• Continue control to exhaust soil seed bank
		• Biological	• Spring and summer	• Seed weevil (*Microlarinus lareynii*) • Stem weevil (*Microlarinus lypriformis*)	• Several years	• The puncturevine seed weevil and stem weevil can be used seasonally during the spring and summer as they will not survive cold winter temperatures • Grazing spiny fruits can cause injury to the mouths and digestive tracts of livestock
		• Mechanical	• Spring – before seed set	• Removal	• Several years	• Remove entire plant for small infestations

Sources: CSU (2000); Lyons (2006); TNC (2006); USU (2004).

Table A.2.2. Task Schedule for the Foothills Management Area

Species	Task And Staffing	2016													2017																	
		July 25-29	August 1–5	August 8–12	August 15–19	August 22–26	August 29–September 2	September 5–9	September 12–16	September 19–23	September 26–30	October 3-7	October 10-14	October 17-21	October 24-November 4	March 20-24	March 27-31	April 3-7	April 10-14	April 17-21	April 24-28	May 1-5	May 8-12	May 15-19	May 22-26	May 29-June 2	June 5-9	June 12-16	June 19-23	June 26-30	July 3-7	July 10-14	July 17-21	July 24-28	October 23-November 3
Dalmatian Toadflax (*Linaria dalmatica*)	Collect toadflax stem boring weevil (*Mecinus janthinus*). 6 people, 1 day.																					■	■											
	Release *Mecinus janthinus* in large, dense Dalmatian toadflax infestations. 250–500 weevils per release. 4 people, 5 days.																						■	■										
	Apply chlorsulfuron to small patches of Dalmatian toadflax.* 2 people, 5 days.											■	■																					

Species	Task And Staffing	2016														2017																					
		July 25-29	August 1–5	August 8–12	August 15–19	August 22–26	August 29–September 2	September 5–9	September 12–16	September 19–23	September 26–30	October 3-7	October 10-14	October 17-21	October 24-November 4	March 20-24	March 27-31	April 3-7	April 10-14	April 17-21	April 24-28	May 1-5	May 8-12	May 15-19	May 22-26	May 29-June 2	June 5-9	June 12-16	June 19-23	June 26-30	July 3-7	July 10-14	July 17-21	July 24-28	October 23-November 3
Dyer's Woad (*Isatis tinctoria*)	Manually remove small patches of dyer's woad before seed set. 4 people, 5 days.																					■	■	■	■	■									
	Apply metsulfuron to large patches of dyer's woad before seed set.* 4 people, 5 days.																					■	■	■	■	■									
Hoary Cress (*Cardaria draba*)	Document current phenology of hoary cress where possible.															■	■																		
	Apply chlorsulfuron to hoary cress.* 4 people, 4 days.									■								■																	
	Manually remove any individuals that were missed by herbicide treatment. 4 people, 4 days.																									■									
	Seed areas where hoary cress was treated with herbicide.† 2 people, 4 days.														■																				■
Myrtle Spurge (*Euphorbia myrsinites*)	Manually remove small patches of myrtle spurge. Dig up at least 4 inches of the root. 4 people, 5 days.																	■	■	■															
	Apply glyphosate to large patches of myrtle spurge.* 4 people, 4 days.											■	■																						
Scotch Thistle (*Onopordum acanthium*)	Manually remove small patches of Scotch thistle rosettes and flowering plants. 2 people, 5 days.							■													■														
	Apply aminopyralid to actively growing rosettes in large patches of Scotch thistle.* 2 people, 4 days.											■										■													
	Seed areas where Scotch thistle was manually removed and sprayed with herbicide.† 2 people, 4 days.														■																				
Yellow Starthistle (*Centaurea solstitialis*)	Manually remove small patches of yellow starthistle before seed set. 4 people, 4 day.																									■									
	Apply aminopyralid to large patches of yellow starthistle spring rosettes through flowering stage and fall rosettes.* 2 people, 4 days.	■									■											■	■					■	■	■					
	Seed areas where yellow starthistle was manually removed.† 2 people, 1 day.														■																				■

* Any herbicide use must be conducted by a licensed applicator, and the applicator must read, understand, and adhere to the label requirements for the use, application rate, and application method of each herbicide. † See Appendix H-1 for seed mix recommended for the Foothills Management Area.

Table A.2.3. Task Schedule for the Tributaries Management Area

Species	Task And Staffing	2016														2017																			
		July 25-29	August 1–5	August 8–12	August 15–19	August 22–26	August 29–September 2	September 5–9	September 12–16	September 19–23	September 26–30	October 3-7	October 10-14	October 17-21	October 24-28	March 20-24	March 27-31	April 3-7	April 10-14	April 17-21	April 24-28	May 1-5	May 8-12	May 15-19	May 22-26	May 29-June 2	June 5-9	June 12-16	June 19-23	June 26-30	July 3-7	July 10-14	July 17-21	July 24-28	October 23-27
Dalmatian Toadflax (*Linaria dalmatica*)	Collect toadflax stem boring weevil (*Mecinus janthinus*). 6 people, 1 day.																					■	■												
	Release *Mecinus janthinus* in large, dense Dalmatian toadflax infestations. 250–500 weevils per release. 4 people, 4 days.																						■	■											
	Apply chlorsulfuron to small patches of Dalmatian toadflax.* 2 people, 5 days.											■	■																						
Dyer's Woad (*Isatis tinctoria*)	Manually remove small patches of dyer's woad before seed set. 4 people, 5 days.																					■	■	■	■	■									
	Apply metsulfuron to large patches of dyer's woad before seed set.* 4 people, 5 days.																					■	■	■	■	■									
Hoary Cress (*Cardaria draba*)	Document current phenology of hoary cress where possible.															■	■																		
	Apply chlorsulfuron to hoary cress.* 4 people, 5 days.									■								■																	
	Manually remove any individuals that were missed by herbicide treatment. 4 people, 5 days.																									■									
	Seed areas where hoary cress was treated with herbicide.† 4 people, 4 days.														■																				■
Houndstongue (*Cynoglossum officinale*)	Manually remove houndstongue using a shovel to pry up the tap root. 2 people, 4 days.			■	■	■																							■	■	■				
	Seed areas where houndstongue was manually removed.† 2 people, 2 days.														■																				■
Musk Thistle (*Carduus nutans*)	Manually remove musk thistle rosettes and flowering plants. 4 people, 4 days.									■	■										■	■													
	Seed areas where musk thistle was manually removed.† 2 people, 4 days.									■	■										■	■													

Species	Task And Staffing	2016														2017																					
		July 25-29	August 1–5	August 8–12	August 15–19	August 22–26	August 29–September 2	September 5–9	September 12–16	September 19–23	September 26–30	October 3-7	October 10-14	October 17-21	October 24-28	March 20-24	March 27-31	April 3-7	April 10-14	April 17-21	April 24-28	May 1-5	May 8-12	May 15-19	May 22-26	May 29-June 2	June 5-9	June 12-16	June 19-23	June 26-30	July 3-7	July 10-14	July 17-21	July 24-28	October 23-27
Myrtle Spurge (*Euphorbia myrsinites*)	Manually remove small patches of myrtle spurge. Dig up at least 4 inches of the root. 4 people, 4 days.																																				
	Apply glyphosate to large patches of myrtle spurge.* 4 people, 4 days.																																				
Perennial Pepperweed (*Lepidium latifolium*)	Apply chlorsulfuron to perennial pepperweed.* 4 people, 5 days.																																				
	Manually remove any individuals that were missed by herbicide treatment. 4 people, 5 days.																																				
	Seed areas where perennial pepperweed was treated with herbicide.† 4 people, 4 days.																																				
Poison Hemlock (*Conium maculatum*)	Manually mow poison hemlock before seed set using a rotary mower for large infestations or clip stems close to the ground for smaller infestations. 4 people, 4 days.																																				
Scotch Thistle (*Onopordum acanthium*)	Manually remove small patches of Scotch thistle rosettes and flowering plants. 2 people, 4 days.																																				
	Apply aminopyralid to actively growing rosettes in large patches of Scotch thistle.* 2 people, 2 days.																																				
	Seed areas where Scotch thistle was manually removed and sprayed with herbicide.† 2 people, 2 days.																																				
Yellow Starthistle (*Centaurea solstitialis*)	Manually remove yellow starthistle before seed set. 4 people, 1 day.																																				
	Apply aminopyralid to large patches of yellow starthistle spring rosettes through flowering stage and fall rosettes.* 2 people, 2 days.																																				
	Seed areas where yellow starthistle was manually removed.† 2 people, 1 day.																																				

* Any herbicide use must be conducted by a licensed applicator, and the applicator must read, understand, and adhere to the label requirements for the use, application rate, and application method of each herbicide. † See Appendix H-1 for seed mix recommended for the Tributaries Management Area.

Table A.2.4. Task Schedule for the Jordan River Management Area

Species	Task And Staffing	2016														2017																					
		July 25-29	August 1–5	August 8–12	August 15–19	August 22–26	August 29–September 2	September 5–9	September 12–16	September 19–23	September 26–30	October 3-7	October 10-14	October 17-21	October 24-November 4	March 20-24	March 27-31	April 3-7	April 10-14	April 17-21	April 24-28	May 1-5	May 8-12	May 15-19	May 22-26	May 29-June 2	June 5-9	June 12-16	June 19-23	June 26-30	July 3-7	July 10-14	July 17-21	July 24-28	October 23-November 3
Bull Thistle (*Cirsium vulgare*)	Manually remove bull thistle rosettes and flowering plants every 3 to 4 weeks throughout the growing season. 2 people, 2 days.		■				■				■							■				■				■				■				■	
	Seed areas where bull thistle was manually removed.† 2 people, 2 days.														■																				■
Canada Thistle (*Cirsium arvense*)	Manually remove Canada thistle rosettes and flowering plants every 3 to 4 weeks throughout the growing season. 2 people, 2 days.		■				■				■							■				■				■				■				■	
	Seed areas where Canada thistle was manually removed.† 2 people, 2 days.														■																				■
Common Reed (*Phragmities australis*)	Apply imazapyr to common reed. 4 people, 5 days.							■																												
	Manually cut treated stems. 4 people, 5 days.														■																		■			
	Apply glyphosate (AquaNeat®) to common reed. 4 people, 5 days.																									■									
Dalmatian Toadflax (*Linaria dalmatica*)	Collect toadflax stem boring weevil (*Mecinus janthinus*). 6 people, 1 day.																					■	■												
	Release *Mecinus janthinus* in large, dense Dalmatian toadflax infestations. 250–500 weevils per release. 2 people, 1 day.																						■	■											
	Apply chlorsulfuron to small patches of Dalmatian toadflax.* 2 people, 1 day.											■	■																						
Hoary Cress (*Cardaria draba*)	Document current phenology of hoary cress where possible.															■	■																		
	Apply chlorsulfuron to hoary cress.* 4 people, 6 days.								■	■								■	■																
	Manually remove any individuals that were missed by herbicide treatment. 4 people, 5 days.																								■	■									
	Seed areas where hoary cress was treated with herbicide.† 4 people, 5 days.																																		■

Species	Task And Staffing	2016														2017																					
		July 25-29	August 1–5	August 8–12	August 15–19	August 22–26	August 29–September 2	September 5–9	September 12–16	September 19–23	September 26–30	October 3-7	October 10-14	October 17-21	October 24-November 4	March 20-24	March 27-31	April 3-7	April 10-14	April 17-21	April 24-28	May 1-5	May 8-12	May 15-19	May 22-26	May 29-June 2	June 5-9	June 12-16	June 19-23	June 26-30	July 3-7	July 10-14	July 17-21	July 24-28	October 23-November 3
Houndstongue (*Cynoglossum officinale*)	Manually remove houndstongue using a shovel to pry up the tap root. 2 people, 4 days.			■	■	■																						■	■	■					
	Seed areas where houndstongue was manually removed.† 2 people, 2 days.														■																				■
Musk Thistle (*Carduus nutans*)	Manually remove musk thistle rosettes and flowering plants. 4 people, 3 days.									■	■										■	■														
	Seed areas where musk thistle was manually removed.† 2 people, 3 days.									■	■										■	■														
Myrtle Spurge (*Euphorbia myrsinites*)	Manually remove small patches of myrtle spurge. Dig up at least 4 inches of the root. 2 people, 1 day.																	■	■	■																
	Apply glyphosate to large patches of myrtle spurge.* 2 people, 1 day.											■	■																							
Perennial Pepperweed (*Lepidium latifolium*)	Apply chlorsulfuron to perennial pepperweed.* 4 people, 5 days.									■								■																		
	Manually remove any individuals that were missed by herbicide treatment. 4 people, 5 days.																								■											
	Seed areas where perennial pepperweed was treated with herbicide.† 4 people, 4 days.														■																				■
Poison Hemlock (*Conium maculatum*)	Manually mow poison hemlock before seed set using a rotary mower for large infestations or clip stems close to the ground for smaller infestations. 4 people, 4 days.						■													■																
Puncturevine (*Tribulus terrestris*)	Manually remove small patches of puncture vine by digging or hoeing. 4 people, 6 days.	■	■																		■	■						■	■							
	Release *Microlarinus lareynii* and *M. lypriformis* in large, dense patches of puncturevine. 2 people, 4 days.																					■	■							■	■					
	Seed areas where puncturevine was manually removed and chemically treated.† 4 people, 6 days.														■																				■

Species	Task And Staffing	2016													2017																					
		July 25-29	August 1–5	August 8–12	August 15–19	August 22–26	August 29–September 2	September 5–9	September 12–16	September 19–23	September 26–30	October 3-7	October 10-14	October 17-21	October 24-November 4	March 20-24	March 27-31	April 3-7	April 10-14	April 17-21	April 24-28	May 1-5	May 8-12	May 15-19	May 22-26	May 29-June 2	June 5-9	June 12-16	June 19-23	June 26-30	July 3-7	July 10-14	July 17-21	July 24-28	October 23-November 3
Russian Knapweed (*Acroptilon repens*)	Apply aminopyralid in the fall when plants are in full bloom. 4 people, 6 days.										■	■	■																							
Tamarisk (*Tamarix ramosissima*)	Manually remove tamarisk seedlings and saplings. 2 people, 2 days.		■																■																
	Cut larger tamarisk trees and apply triclopyr (Garlon®) to the cut stump. 2 people, 2 days.													■																					■
Scotch Thistle (*Onopordum acanthium*)	Manually remove small patches of Scotch thistle rosettes and flowering plants. 4 people, 6 days.							■	■												■	■													
	Apply aminopyralid to actively growing rosettes in large patches of Scotch thistle.* 4 people, 6 days.											■										■	■													
	Seed areas where Scotch thistle was manually removed and sprayed with herbicide.† 4 people, 5 days.																																			■

* Any herbicide use must be conducted by a licensed applicator, and the applicator must read, understand, and adhere to the label requirements for the use, application rate, and application method of each herbicide. † See Appendix H-1 for seed mix recommended for the Jordan River Management Area.

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Appendix A.3.

Signs

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CAUTION / CAUCIÓN
PESTICIDES / PESTICIDAS
KEEP OUT
NO ENTRE
Weed-control treatment area.
Treatment occurred today.
Please stay off until dry.
For more information contact Salt Lake City Parks and Public Lands at (801) 972-7800 or visit our website at www.slcgov.com/parks


DANGER / PELIGRO
PESTICIDES / PESTICIDAS
KEEP OUT
NO ENTRE
Weed-control treatment area.
Treatment occurred today.
Please keep off until dry.
For more information contact Salt Lake City Parks and Public Lands at (801) 972-7800 or visit our website at www.slcgov.com/parks


WARNING / AVISO
PESTICIDES / PESTICIDAS
KEEP OUT
NO ENTRE
Weed-control treatment area.
Treatment occurred today.
Please keep off until dry.
For more information contact Salt Lake City Parks and Public Lands at (801) 972-7800 or visit our website at www.slcgov.com/parks

NOTICE

TOMORROW
THIS AREA WILL BE CHEMICALLY TREATED FOR WEED CONTROL

TREATMENT IS WEATHER DEPENDENT

SALT LAKE CITY PARKS AND PUBLIC LANDS
WWW.SLCGOV.COM/PARKS
(801) 972-7800

Appendix B

Urban Forestry Guidance

Table B.1. Pesticide and Herbicide Application

BMP Type			
Design			
Installation			
Maintenance/Operations			X
Green Industry Relevance			
ASLA		GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGA	X
CNGA	X	GCSAA	X

Description

Apply pesticides and herbicides at dosages in accordance with the label and targeted to specific pest problems.

NOTE: Pesticide and herbicide applications within watershed areas, adjacent to riparian corridors, and within groundwater recharge zones must follow the regulations as outlined in:

1. 17.04.375: Herbicide, Pesticide, and Fertilizer Restrictions
2. 21A.34.130: Riparian Corridor Overlay District; and
3. 21A.34.060: Ground Water Source Protection Overlay District.

See the *Production Practices for Nurseries, Greenhouses and Growers* (GreenCo 2004) for more detailed guidance for these industries.

Basic Practice Guidelines

Be familiar with existing state and federal regulations on pesticide application, certification, and weed control. Several federal and state laws control the handling, storage, application, disposal, and reporting of chemical spills. Examples include the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), the Superfund Amendments and Reauthorization Act (SARA), the Emergency Planning and Community-Right-to-Know Act (EPCRA), and Occupational Safety and Health Administration (OSHA) requirements, particularly the Hazard Communication Standard. The Utah Water Quality Control Act (25-8-601 and 25-8-606) also contains requirements for notification of the Utah Department of Environmental Quality of spills and accidental discharges and provides the department with the authority to order cleanups. It may also be necessary to file information with the local fire department based on these and other laws.

Identifying and Diagnosing Problems

1. Accurately diagnose the pest, disease, or weed and host prior to intervening with chemicals. Disease and insect symptoms can mimic each other in many plants. A fungicide will not control an insect, and an insecticide will not control a disease. For assistance in identifying pests and noxious or invasive plants, contact the Salt Lake County Extension Office at http://extension.usu.edu/saltlake, or the Utah Plant Pest Diagnostic lab at http://utahpests.usu.edu/uppdl. For weeds, you might also visit www.slcgov.com/gardenwise.

Integrated Pest Management/Plant Health Care

1. Use an Integrated Pest Management (IPM)/Plant Health Care (PHC) approach, integrating a variety of management tools (e.g., scouting, monitoring, cultural practices, targeted pesticide application). The pros and cons of various tools should be weighed and used in an integrated manner to achieve pest control objectives in a safe, efficient, and cost-effective manner.
2. If pest problem is limited in scope and consequence, spot treat pests, diseases, and weeds, rather than treating the entire area.
3. Consider pest occurrence and history when developing pest management strategies.
4. Time the application of pesticides and herbicides to minimize impact to host-plant, beneficial insects, environment, and the public and to maximize pest control.
5. Rotate annual garden plants, including vegetable plants, to reduce the buildup of soil-borne pests.
6. Clean up plant litter and remove weeds before they go to seed.
7. Remove infested plant residue from the garden in the fall so that pests do not have a place to overwinter.
8. Implement cultural controls such as proper plant selection, appropriate planting time and planting method, appropriate maintenance practices, and avoid plant monocultures to reduce susceptibility to insects, pests, and diseases, thereby reducing pesticide usage. See Landscape Design and Planting BMPs (GreenCo 2004) for additional information.
9. Implement mechanical and physical controls where practical as an alternative to chemical application. Examples include a wide variety of practices such as "collars" around seedlings, mulching, solar heating, syringing, handpicking, mowing, hoeing, and traps.
10. Use biological controls where appropriate to reduce pesticide usage. For example, introduce natural enemies of pests such as lady beetles and green lacewings and increase plant diversity. NOTE: pesticides may kill these natural predators; visit http://utahpests.usu.edu/uppdl for more information on beneficial insects.
11. Consider applying environmentally friendly chemicals such as insecticidal soaps, horticultural oils, and other such measures when practical and effective. Remember, though, that these products can be harmful to the environment or to people if improperly used.

Careful scouting for pests is a key component of integrated pest management/plant health care.

Source: Denver Water.

Selecting a Treatment Methodology

1. Apply pesticides and herbicides only when needed. Do not use pesticides and herbicides on a regular or preventive basis unless preventive treatments are appropriate as interventions for anthracnose and powdery mildew.
2. Select pesticides and herbicides best suited to the characteristics host plant, the site, and the particular pest or weed. Half-life, solubility, and absorption should be compared with site characteristics to determine the safest chemical. Choose the least toxic and less persistent sprays whenever possible based on comparison of labels and associated MSDSs, unless systemics, which may be persistent and more helpful, are better to suited to controlling the pest.
3. Consider non-chemical responses to weed, pest, and disease problems, such as manual, mechanical, or biological controls, where appropriate. Visit the Utah Plant Pest Diagnostic Lab website for information regarding biological controls and beneficial insects at http://utahpests.usu.edu/uppdl.
4. Noxious and invasive plants may develop resistance to a particular herbicide over time. Use in rotation with mechanical control methods such as hand pulling or mowing.

General Guidelines for Salt Lake City Properties

1. For public or commercial sites, check that no events are scheduled to take place that will conflict with the application.
2. No spraying is allowed around public playgrounds, and it is not recommended around commercial or private playgrounds. Signs should be posted on sites that apply chemicals in the vicinity of playgrounds to warn users.
3. When spraying, sign the areas properly and never spray alone.
4. Have a spotter to inform the public that spraying is occurring and to keep the work zone safe in accordance with label directions.
5. Upon completion of project, remove signs and go to the next site.

6. Coordinate to have applicator forms submitted for mapping as project specifications may require.
7. When done spraying, always triple rinse the sprayer in a sanitary sewer as well as the containers the product came in before disposing of them. Dispose of herbicides properly.

APPLICATION PRACTICES

1. Treat for and control noxious and invasive plants or pests as needed prior to installing the landscape using an herbicide targeted to the target pests that are present and applied in accordance with the product label.
2. Be aware that some pesticide formulations are not compatible with other pesticides, and combining them may result in increased potency and phytotoxicity.
3. Prior to use of any chemical, read the product label.
4. Do not apply pesticides or herbicides during high temperatures or windy conditions or immediately prior to heavy rainfall or irrigation.
5. Mix chemicals in a well-ventilated area and have a spill kit available.
6. Apply pesticides and herbicides according to the label. It is a violation of federal law to use any herbicide or pesticide in a manner that is inconsistent with the label.
7. Apply pesticides and herbicides only when needed and use in a manner to minimize off-target effects.
8. Ensure commercial chemical applicators receive thorough training and proper certification prior to chemical use. Individuals and companies hired to apply pesticides must be licensed in the appropriate categories by the UDA. Limited commercial applicators and public applicators applying restricted pesticides must register with the UDA. Only trained professionals with herbicide applicator licenses should apply restricted-use herbicides. Limited commercial applicators and public applicators not applying restricted pesticides who have submitted to the jurisdiction of the UDA must follow all record-keeping and other procedures as established by the UDA. Thoroughly complete all applicator forms, where applicable.
9. When applying pesticides or herbicides in watershed areas, follow the procedures as noted above in BMP Description.
10. Maintain a buffer zone around wells or surface waterbodies where pesticides and herbicides are not applied to minimize pollution. SLC Ordinance Ground Water Source Protection identifies setbacks for wellheads; Riparian Corridor Overlay suggests that no pesticides, herbicides, or other chemicals be applied within 25 feet of the high-water mark. Always follow label instructions regarding water bodies.
11. Make certain the weather conditions are appropriate for application, with no wind or rain.
12. Be certain that the irrigation system will be shut off for the appropriate duration of application and absorption. If the site was watered, do not apply products.
13. For public or commercial sites, check that no events are scheduled to take place that will conflict with the application.
14. No spraying is allowed around public playgrounds, and it is not recommended around commercial or private playgrounds. Signs should be posted on sites that apply chemicals in the vicinity of playgrounds to warn users.

15. Employ application techniques that increase efficiency and allow the lowest effective application rate to adequately control the pest. Carefully calibrate application equipment and follow all label instructions. Hand-apply all chemicals when near buffer zone boundaries and do not allow overspray from mechanical applications into buffer zones.
16. Recognize that no landscape should be or can be completely pest free or weed free.

DISPOSAL AND RECORD-KEEPING

1. Maintain records of all pesticides applied (both restricted and non-restricted use), including entity for whom and address where application was made, target pest, brand name, formulation, EPA registration number, amount, date and time applied, site, crop, commodity or structure treated, exact location of application, measurement of area or number of plants treated, and name of applicator. Combine and file this information with irrigation water data, crop growth records, and notes on effectiveness of alternative pest control measures to help identify and track measures to both save money and reduce pesticide usage.
2. Properly handle and dispose of containers, rinse water, unused product, and waste. Store pesticides in secured and covered areas. Never pour lawn and garden chemicals down storm drains or sanitary drains, and keep off impervious surfaces during application. Check labels and MSDSs for specific instructions on disposal of the product and the product container.
3. For more information on disposal of hazardous materials, including garden products, from your home, visit *www.slvhealth.org* for more information. Use local recycling centers to dispose of chemicals when appropriate. See GreenCo's (2004) Pesticide, Fertilizer and Other Chemical Storage, Handling, and Disposal BMP for more information.

SOURCE WATER, STORMWATER, AND WATERWAY PROTECTION

1. Keep fertilizer off of streets, sidewalks, and driveways to prevent water pollution. Fertilizer that inadvertently falls on impervious surfaces should be swept back onto the lawn or into the landscape.
2. Maintain a buffer zone around wells or surface water bodies where fertilizers are not applied to minimize pollution. SLC Ordinance Ground Water Source Protection identifies setbacks for wellheads; Riparian Corridor Overlay suggests that no fertilizers or other chemicals be applied within 25 feet of the high-water mark. Always follow label instructions regarding water bodies.
3. In areas within groundwater recharge zones, it is particularly important to avoid overapplication of fertilizer that could leach into groundwater. These areas may be particularly well suited to slow-release fertilizer forms and conservative application rates. See SLC Ordinance 21A.34.060 Groundwater Source Protection Overlay District for map and applicability.

Resource

Utah Plant Pest Diagnostic Lab. Available at: http://utahpests.usu.edu/uppdl/.

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Appendix C

Invasive and Noxious Weed Species Accounts

All of the state-listed and Salt Lake County–listed noxious weeds, as well as other invasive plant species that are a concern to the area's native plant communities, are described below. Information regarding effective biological and/or chemical controls is also included. Species descriptions were largely obtained from the *Noxious Weed Field Guide for Utah* (Belliston et al. 2004). Full references for the literature cited in these species accounts can be found in the noxious and invasive weed management plan's literature cited section.

STATE-LISTED NOXIOUS WEED SPECIES

Jointed Goatgrass (*Aegilops cylindrical* Host)

Background: Jointed goatgrass is native to Europe and has become a serious invader of winter wheat crops spread by farm machinery in the United States. It also thrives along roadsides, in pasturelands, on rangelands, and in waste areas (Belliston et al. 2004). Jointed goatgrass is listed as a noxious weed by Tooele County and is found throughout Salt Lake County from the valley floor to midmontane habitats in dry, disturbed sites (Belliston et al. 2004; USDA, NRCS 2012d).

Description: This winter annual grows 15 to 30 inches (0.4 to 0.8 m) tall and may have one or more upright stems or tillers. Leaf blades are 0.13 to 0.25 inch (3.3 to 6.3 mm) wide, alternate, hairy, and simple and have auricles at the base. The spike is cylindrical and contains two to twelve 0.5-inch (1.2-cm) spikelets that fit into the contour of the rachis. Glumes are ribbed with a keel on one side extending into a single awn. As the seeds mature, the plant turns from green to a reddish or tan color. Flower and seed production take place from late spring to mid-summer (Whitson et al. 1999).

Control: Biocontrol is not available. Chemicals are usually effective; glyphosate at 1.5 pounds of active ingredient per acre when the plants are 12 to 18 inches (30 to 45 cm) tall or Fluzifop-P-butyl at 43 to 48 ounces per acre when seedlings are actively growing and between 2 and 8 inches (5 and 20 cm) tall. Sulfometuron methyl can be applied early post-emergence with a reapplication when regrowth begins, and it works best when applied when soils are moist to help translocate the herbicide to the root system (CSU 2000).

Garlic Mustard (*Alliaria petiolata* [M. Bleb.] Cavara & Grande)

Background: Garlic mustard is a tap-rooted, cool-season biennial introduced to North America from Europe in the 1800s. Garlic mustard can be found in disturbed areas, and along trails and roadsides. Garlic mustard reproduces only be seed, producing as many as 1,000 seeds per plant. Most seeds germinate within the first or second year, and seeds can remain viable in the soil for more than 5 years.

Description: Plants usually flower from April to May and range from 12 to 48 inches (30 to 120 cm) in height. The leaves and stems emit an onion-like odor when crushes. First-year plants consist of a cluster of three to four round, scallop-edged leaves rising 2 to 4 inches (5 to 10 cm) in a rosette. Second-year plants typically produce one to two flowering stems with numerous white flowers that have four petals. Fruits are slender capsules or siliques that produce a single row of black, oblong seeds with ridged seed coats. Stem leaves are toothed, alternate, and triangular (King County Noxious Weed Control Program 2010).

Control: Mowing is not an effective means of control unless it is repeated throughout the growing season. Plants are able to re-sprout and flower again. Remove all mowed plant material from the site.

Hand pulling can be an effective means of control. Pull the plants from April to June, after they begin to bolt until they are through flowering and while the seed pods are still green. Plants in flower or even in bud are able to form viable seeds even after they are pulled; therefore, plant pieces must be carefully

bagged and disposed of. In areas where mature plants are pulled, there are usually many small rosettes and seeds left in the soil. Carefully search the area for rosettes and dig them up carefully with a digging tool. Roots break off easily and re-sprout (King County Noxious Weed Control Program 2010).

A variety of herbicides has been used to manage garlic mustard; these include glyphosate, triclopyr, 2,4-D, metsulfuron, and oryzalin (King County Noxious Weed Control Program 2010). However, there was a significant detrimental effect on native forbs where fall herbicide treatments have been used (Herold et al. 2011).

Currently, there are no biological controls available in the United States for garlic mustard. However, in Europe, *Ceutorhynchus scrobicollis*, a root-miner, has been shown to be effective and is currently undergoing further testing in the United States (King County Noxious Weed Control Program 2010).

Hoary Cress (*Cardaria draba* [L.] Desv.)

Background: Hoary cress (whitetop) is a state-listed noxious weed introduced into North America from Eurasia in the late nineteenth century. It is now widespread throughout diverse habitats and is classified as a noxious weed in at least 24 states (Coombs et al. 2004).

Description: Hoary cress germinates in the fall, overwinters as rosettes, and blooms in May. After flowering, the plant continues to grow until the first frost. It can read a height of 2 feet (0.6 m). Leaves are blue-green and lance shaped, with the lower leaves stalked and the upper leaves having two lobes clasping the stem. Flowers are white with four petals, giving the plant a flat-topped appearance. Heart-shaped seed capsules contain two reddish brown seeds separated by a narrow partition. This species reproduces from seed and from rhizomes. Adventitious buds can develop from the lateral rhizomes with an average of 50 new buds for a total of 2 to 3 feet (0.6 to 0.9 m) of growth per year per plant. Hoary cress can overtake native plants, developing monocultures that degrade wildlife habitat and decrease biodiversity. It prefers wet, alkaline, open soils and is often found with invasive bromes and knapweeds (Belliston et al. 2004). Two other *Cardaria* species, lens-podded whitetop (*C. chalepensis*) and hairy whitetop (*C. pubescens*), are common in the western United States, with differences in seed capsules and fruit characteristics (Baldwin et al. 2002; Whitsom 1999).

Control: Control of hoary cress is very difficult, and eradication requires continual work and monitoring. Small controlled patches or the perimeter of large patches are the best option, followed by attacking any plants that expand beyond the containment area. Because of the extensive root system, removing new shoots is extremely important. Sheep and goats will consume hoary cress more readily than cattle. Cattle will consume hoary cress, but hoary cress contains glucosinolates, which may be toxic at high levels. Moreover, hoary cress may inhibit iodine absorption in goats, but this can be countered with iodine supplements. Insufficient information is currently available on the effectiveness of prescribed grazing of hoary cress. Surveys and literature disagree on the potential of controlling hoary cress with grazing because of palatability and toxicity issues. However, repeated grazing may reduce plant vigor and flower production (Zouhar 2004).

Mowing or grazing alone will not provide effective long-term control of hoary cress. Hoary cress plants can survive repeated removal of top-growth for at least one season without noticeable loss in vigor. Two consecutive years of mowing or grazing may have a more noticeable effect; however, hoary cress plants often preserve some of their vitality even after 3 years. The date of mowing or grazing influences subsequent reproductive efforts; plants mowed or grazed during flowering produced fewer viable seeds than plants mowed during bolting. Although defoliation alone is not expected to be an effective long-term control of hoary cress, properly timed aboveground biomass removal followed by herbicide application may increase mortality (Zouhar 2004).

Where physical conditions permit, hoeing or tilling at intervals of 3 to 4 weeks (depending on rate of regrowth) may be as effective as cultivation for eradication of hoary cress. Soils must remain moist between hoeing so that plants can regenerate and deplete their root reserves. Plants must be completely removed within 10 days after emergence throughout the growing season for 2 to 4 years, thereby making this method impossible for all but the smallest patches (Zouhar 2004).

Hoary cress and related *Cardaria* species are most commonly controlled with herbicides. However, multiple applications are usually needed to provide lasting control. The best time to apply herbicides is in May or June, between bud and before flowering. Metsulfuron and chlorsulfuron are the most effective herbicides as long as the plants still have green tissue. It is important to use a nonionic surfactant with the herbicide. The herbicides imazapic, 2,4-D, and glyphosate provide good to fair control when applied during the early pre-bud stage (late May through early June) (Dewey et al. 2006). Large hoary cress stands may flower at different times due to changes in microtopography; south-facing slopes and depressions will flower days to weeks before north-facing slopes. Once herbicide is sprayed, the flowering plants will immediately set viable seed. Therefore, it is imperative to apply herbicide at the bud stage, prior to flowering. To synchronize the plants, mowing or grazing may be an option in localized areas to create a phenotypic homogeneous community that can be more effectively sprayed with herbicides. It will usually take several seasons to eliminate a hoary cress patch due to both root regrowth from surviving plants and the time it takes to deplete the soil seed bank. Seeding with desirable grass species that will compete for resources but not be affected by the broadleaf herbicides is critical in the combat against hoary cress.

Musk Thistle (*Carduus nutans* L.)

Background: Musk thistle is an invasive biennial, summer, or winter annual forb. Musk thistle populations in North America exhibit almost continuous variation in characteristics such as hairiness, leaf size, spine length, flower stalk diameter, width and shape of bracts, and corolla length. Correct identification of musk thistle is important if control strategies are planned because it can be easily confused with native thistles, some of which may be threatened or endangered, and most of which fill specific ecological niches and have traits useful to humans (USDA 2006).

Description: As a biennial, musk thistle initially forms a prostrate rosette. Rosette leaves can grow up to 10 inches (25 cm) long and 4 inches (10 cm) wide, and rosettes can be 2 feet (0.6 m) or more in diameter. Musk thistle rosettes have numerous small roots in the fall and develop a large, fleshy taproot in the spring that is hollow near the soil surface. The root crown and upper root tissues contain buds, normally suppressed by apical dominance, which may sprout following damage to plants (USDA 2006).

Musk thistle may have one to seven branched stems that grow 2 to 6 feet (0.6 to 1.8 m) tall. Stem leaves are 3 to 6 inches (7.6 to 15.2 cm) long, dark green with a light greed midrib, with toothed, spiny lobes; upper leaves are much reduced. Stems have spiny wings for their full lengths except for a few inches below flower heads. Flower heads are large, often nodding, 1.5 to 3.0 inches (3.8 to 7.6 cm) in diameter, solitary, terminal, and are entirely composed of purple disc flowers. Numerous large, lance-shaped, spine-tipped bracts that resemble a pinecone subtend flowers and are a very distinctive identification feature. The fruit is an achene bearing 0.13- to 0.19-inch (0.3- to 0.5-cm) seeds with a hair-like pappus (Belliston et al. 2004; USDA 2006).

Seed production is quite variable; it is determined by habitat conditions, size of plant at flowering, and duration of flowering. The life cycle exhibited by a particular musk thistle plant also influences seed production, with biennials producing more than winter annuals, and winter annuals producing more than summer annuals. The first flower heads to emerge (terminal and topmost branch) are usually solitary; they are the largest and produce the most seeds. The number of seeds per inflorescence decreases over time

along with inflorescence size. Musk thistle can continue to produce flowers and seeds throughout the growing season if soil moisture levels are adequate. The amount of seed produced is therefore markedly affected by spring and summer rainfall patterns. Terminal flowers average about 1,000 seeds per head, whereas the last ones to bloom produce about 125 seeds or fewer per head (USDA 2006). Germination of musk thistle seeds in the field occurs over several months in the fall and spring. A dormancy period could prevent seeds from germinating all at once in response to transient summer rainfall and could allow time for some seed to become buried (USDA 2006).

Wind, water, wildlife, livestock, and human activities disperse musk thistle seed. Many musk thistle seeds fail to separate from the receptacle; therefore, fruiting heads with seeds often fall to the ground. Thus, most seeds are deposited in a dense pattern near the parent plant. This may help to explain musk thistle's slow rate of spread into favorable habitats close to existing populations. Musk thistle seeds may remain viable in the soil for 10 to 15 years or more, with seeds buried in the top 0.8 inch (2 cm) of soil surviving 3 years, and seed buried at greater depths maintaining viability for longer periods (USDA 2006).

Control: The most widely released insect for the control of musk thistle is a weevil (*Rhinocyllus conicus*). In the spring, adult weevils will feed on the leaves, mate, and deposit eggs on the bracts. When the eggs hatch, the larvae begin to bore into the flower head, reducing the ability of the plants to produce viable seed. In some cases, the weevil has reduced musk thistle populations to less than 10% pre-release levels. Seed heads that are attacked by this weevil often become tightly fixed, and although they may still germinate, competition among germinating seeds will cause high rates of intraspecific mortality. This weevil will also attack native thistles, including rare species (CSU 2000).

Repeated mowing, hand pulling, or grazing can be used to stop the spread of musk thistle. Mowing or grazing after flowering but before seed set prevents seed development and dispersal. Musk thistle appears to be a favorite of older male goats (Lamming 2001). When pulling musk thistle, it is important to completely remove the crown so that the plant does not simply re-bolt and produce seeds. Repeated, weekly visits over the 4- to 7-week flowering period are necessary when removing aboveground biomass because not all plants flower at the same time. Cut plants should be deeply buried or burned because seeds can mature and become viable after cutting.

Musk thistle is most often controlled with herbicides and can be combined with Scotch thistle treatments. The most effective chemical control occurs when musk thistle is still in the rosette stage and quickly decreases once the plant has bolted. Aminopyralid and metsulfuron offer excellent control when applied at 3 to 5 ounces per acre and 0.5 to 1.0 ounces per acre, respectively. Apply both herbicides to rosettes; fall is optimal, although spring applications are also effective. Clopyralid at 0.66 part per acre, chlorsulfuron at 0.5 to 1.0 ounces for musk thistle and 1 to 3 ounces per acre for Scotch thistle, and a combination of clopyralid and 2,4-D (Curtail®) at 1 to 2 quart per acre provide good control when applied from the late rosette stage to early bolting. Seeding with desirable grass species that will compete for resources but not be affected by the broadleaf herbicides is critical.

Diffuse Knapweed (*Centaurea diffusa* Lam.)

Background: This short-lived perennial forb was introduced from Eurasia, where it grows in the eastern Mediterranean area and in western Asia to western Germany. It is a pioneer species that can quickly invade disturbed and undisturbed grasslands, shrublands, and riparian communities. Like most knapweeds, diffuse knapweed exudes chemical substances into the soil that inhibit the growth of competing vegetation. Diffuse knapweed is found on plains, rangelands, and forested benchlands. It is generally found on light, dry, porous soils. Diffuse knapweed has been observed at elevations up to 8,500 feet (2,591 m) and grows in open habitats as well as shaded areas (CSU 2000).

Description: Diffuse knapweed is an annual or a short-lived perennial from 1 to 2 feet (0.3 to 0.6 m) tall. The flower heads are broadly urn-shaped, are less than 1 inch (2.5 cm) tall, and can be either solitary or in clusters of two to three at the ends of branches. The heads contain two types of flowers: ray flowers around the edges surrounding tubular disk flowers that bloom throughout the summer. Flowers are white, rose-purple, or lavender. Diffuse knapweed differs from other knapweeds in that the toothed flower bracts are straight and end as sharp, rigid spines rather than arched outward. Basal leaves are stalked and divided into narrow, hairy segments. Stem leaves are smaller, alternate, less divided, stalkless, and become bract-like near the flower clusters. Seedlings have finely divided leaves that are covered with short hairs (Belliston et al. 2004).

Reproduction is primarily by seed; it first forms low rosettes that may remain in this form for one to several years, depending on environmental conditions. When the rosette reaches a critical size, it bolts, flowers, and usually dies. Flower buds are formed in early June, and flowering occurs in July and August. Mature seeds are formed by mid-August. Seed dispersal is primarily by wind but can be lodged under vehicles or in animal hooves, thereby expanding their long-distance dispersal (Belliston et al. 2004).

Control: Currently, biological control agents are available, but the extent to which they effectively control diffuse knapweed populations is unclear. A combination of several insects may be required to control diffuse knapweed. Several pathogens can be quite destructive to diffuse knapweed, including two fungi: 1) *Puccinia jaceae* var. *diffusaei*, which attacks the leaves, and 2) *Sclerotinia sclerotiorum*, which attacks the crowns of both diffuse and spotted knapweed. The seed head weevil (*Larinus minutus*) has caused remarkable reductions in diffuse knapweed density in some areas of Oregon and Washington with emerging success also reported in Colorado (Coombs et al. 2004). The seed head flies (*Urophora affinis* and *U. quadrifasciata*) have been released in many Colorado Front Range counties. These insects cause plants to produce fewer viable seeds and abort terminal or lateral flowers (CSU 2006). Root-feeding insects may have a more detrimental effect on knapweed populations than seed-feeding ones. Larvae of the diffuse knapweed root beetle (*Sphenoptera jugoslavica*) feed in the roots of diffuse knapweed. Larvae of the yellow-winged knapweed moth (*Agapeta zoegana*) and the knapweed root weevil (*Cyphocleonus achates*) feed on the roots of both diffuse and spotted knapweed species (Coombs et al. 2004).

Cutting, mowing, or grazing aboveground portions of the plant before seed set may be an effective way to reduce seed production, but it will not eliminate the infestation. When a diffuse knapweed plant has been cut, the rosette may live and re-bolt. Additionally, diffuse knapweed seeds can remain dormant for several years, requiring any cutting program to be repeated several times annually (spring, summer, and fall) to be effective. Goats will not eat dry seed heads. Reduction of surface biomass, followed by a fall herbicide treatment, would be more effective than grazing or mowing alone.

Several herbicides are relatively effective at controlling both diffuse and spotted knapweed. Aminopyralid at 5 to 7 fluid ounces per acre or clopyralid at 0.33 to 1.33 parts per acre are the most widely recommended. Other less effective herbicides include imazapic, 2,4-D, and dicamba; metsulfuron is not effective against knapweeds (CSU 2000; Dewey et al. 2006). Apply herbicides during active growth with the optimum time from rosette to early bolting stage, or fall re-growth. Seeding with desirable grass species that will compete for resources but not be affected by broadleaf herbicides is critical to avoid the treated areas from returning to noxious weed communities.

Yellow Star-thistle (*Centaurea solstitialis* L.)

Background: This species was introduced from the Mediterranean region and is well established in the Pacific coast states. It appears to favor dryland conditions and will invade rangelands, pasturelands, roadsides, croplands, and wastelands. It is intolerant of shade and requires light on the soil surface for winter rosette and taproot development. Yellow star-thistle is capable of establishing on deep, well-

drained soils as well as on shallow, rocky soils that receive from 10 to 40 inches (25 to 100 cm) of annual precipitation (Whitson et al. 1999). Yellow star-thistle is a state-listed noxious weed but has only recently been identified in the Salt Lake Valley.

Description: Yellow star-thistle is a winter annual forb with yellow flower heads located singly at the ends of branches. Flower heads are distinguished by sharp, straw-colored thorns, which are up to 0.75 inches (2 cm) long. Basal leaves are deeply lobed, whereas the upper leaves are entire and sharply pointed. Mature plants are 2 to 3 feet (0.6 to 0.9 m) tall and have rigid, branching, winged stems that are covered with cottony hairs. Seedlings usually emerge in the fall, form rosettes, and begin growing a taproot. Root growth continues throughout the winter. Yellow star-thistle bolts in late spring and flowers June through August. It reproduces entirely by seeds that may remain viable for several years. Plumed seeds are dispersed by wind shortly after maturity. Plumeless seeds remain in the seed head until it disintegrates in the fall or winter.

Control: There are several biological control agents that can dramatically reduce seed production. The most commonly used biological control agent is the seed head weevil (*Bangasternus orientalis*). Larvae feed on the seeds and can destroy up to 60% of the seeds in a head. Reseeding with competitive grass species is a key part of integrated yellow star-thistle control.

Cattle and sheep will graze yellow star-thistle before it has spines, and multiple grazing periods are necessary to control it. However, yellow star-thistle causes a neurological disorder called chewing disease in horses that eat it.

Herbicides are effective when applied from the seedling to bolt stages in the spring, but they are most effective if rosettes are sprayed in the fall. Aminopyralid is the most commonly used herbicide (3 to 5 fluid ounces per acre). Seeding with desirable grass species that will compete for resources but not be affected by broadleaf herbicides is critical to avoid the treated areas from returning to noxious weed communities.

Spotted Knapweed (*Centaurea stoebe* L. spp. *micranthos* [Gugler] Hayek)

Background: Spotted knapweed is indigenous to south-central and south-eastern Europe and northwestern Asia. It arrived in the United States as a contaminant in alfalfa seed. This knapweed species infests rangelands, pasturelands, roadsides, or any disturbed soils, and it is estimated to have infested 7 million acres (3 million hectares) in the western United States, ranking as the number one weed problem in western Montana. Its early spring growth makes it competitive for soil moisture and nutrients. Like most knapweeds, spotted knapweed releases chemical substances into the soil that inhibit the growth of competing vegetation. Spotted knapweed can cause skin irritation in some people, and anyone working with spotted knapweed should wear protective gloves and avoid getting knapweed sap into cuts or abrasions (CSU 2000).

Description: Spotted knapweed is a biennial or short-lived perennial forb with solitary pinkish purple flowering heads at the ends of branches. The deeply lobed rosette leaves are up to 6 inches (15 cm) long, and the principal stem leaves are alternate, pinnately divided with smooth margins. Mature plants are 1 to 3 feet (0.3 to 0.9 m) tall, with one or more stems, and closely resembles diffuse knapweed. The flowering bracts of spotted knapweed have dark spots tipped with fringe, unlike the other knapweeds. This highly competitive weed invades disturbed as well as undisturbed areas, degrading desirable plant communities. It forms near monocultures, and it is adapted to well-drained, light- to coarse-textured soils that receive summer rainfall. It tends to inhabit somewhat moister sites than diffuse knapweed, and it is not tolerant of shade (Belliston et al. 2004).

Spotted knapweed germinates in spring or fall and develops into rosettes for at least one growing season while root growth occurs. It usually bolts for the first time in May of the second growing season and flowers August through September. Individual flowers remain in bloom for 2 to 6 days, and they can either self or cross-pollinate. Spotted knapweed reproduces entirely by seed, and seeds may remain viable in the soil for over 8 years (Belliston et al. 2004).

Control: Currently, there is no single biological control agent that effectively controls knapweed populations. Several insects are either under investigation or have been released, but researchers believe that it will take a combination of methods to reduce knapweed infestations. The fungus *Sclerotinia sclerotiorum* attacks the crowns of both diffuse and spotted knapweed. However, this fungus is being studied and is not cleared for use for biocontrol of these knapweeds or for transportation across state lines. The root insects sulfur knapweed moth (*Agapeta zoegana*) and knapweed root weevil (*Cyphocleonus achates*) are having a significant impact on spotted knapweed. The sulfur knapweed moth larva attacks the cortex of the root. Eggs are laid on the surface of stems and leaves of knapweed and other vegetation. Eggs hatch in 7 to 10 days, and the larvae migrate to the crown area, where they mine the root. The knapweed root weevil larvae mine and gall the central vascular tissue of the root, and the adults feed on the leaves. Spotted knapweed is the preferred host for knapweed root weevil, but it can also be used to attack diffuse knapweed (Coombs et al. 2004).

Goats grazing spotted knapweed at the bud to bloom stage have the greatest potential as a control tool. Grazing at the rosette to bolt stage will reduce seed count, plant count, and canopy cover, but not at the levels of bud to bloom. Grazing twice is the best method for reducing seed heads; however, this results in increased plant count, likely because grazing disturbs the seed bank, which causes quicker germination, or because the goats do not eat the dry seed heads and knock them to the ground instead (Lamming 2001).

Several herbicides are relatively effective at controlling both diffuse and spotted knapweed. Aminopyralid at 5 to 7 fluid ounces per acre is the most widely recommended. Other less effective herbicides include imazapic, 2,4-D, and dicamba; metsulfuron is not effective against knapweeds (CSU 2000; Dewey et al. 2006). Apply herbicides during active growth with the optimum time from rosette to early bolting stage or during fall regrowth.

Squarrose Knapweed (*Centaurea virgata* Lam.)

Background: Squarrose knapweed is a highly competitive weed that can displace native rangeland plants. It grows aggressively in dry, disturbed areas, particularly in sand or cinders such as roadsides or cinder pits. Like other knapweed species, squarrose knapweed releases allelopathic chemicals that inhibit the growth of other plants. Squarrose knapweed grows mainly in big sagebrush-bunchgrass rangeland, but it is also found in salt desert communities. It prefers open habitats to shaded areas, and it is not common on cultivated land or irrigated pastureland because it cannot tolerate excessive moisture (CSU 2000).

Description: Squarrose knapweed is a perennial forb with small, numerous, pink flowers, usually developing no more than three to four seeds per head. This species is often confused with diffuse knapweed, but it differs in that it is a true perennial; seed heads are highly deciduous, falling off the stems soon after seeds mature. The bracts are recurved, with the terminal spine longer than lateral spines on each bract. The lower leaves are deeply dissected, and the upper leaves are bract-like. Mature plants are typically between 1 and 2 feet (0.3 and 0.6 m) tall with highly branched stems. The root system is a deep taproot (Belliston et al. 2004).

Control: Some biocontrol insects that attack spotted knapweed also attack squarrose knapweed, including the gall-forming flies *Urophora affinis* and *U. quadrifasciata*, although they have not been quantified for effectiveness.

Cutting, mowing, or removing the aboveground portion of the plant before seed set may be an effective way to reduce seed production, but it will not eliminate the infestation; the rosette may live and re-bolt after cutting. Because re-sprouting from the crown can occur, the entire plant must be removed. Timing of mowing is critical. Rosettes are robust to mowing and generally too low to be successfully cut. A single mowing in the bud to early flower stage may be effective, but mowing more mature plants will facilitate seed dispersal and is not recommended. Goats will graze the flower heads and buds preferentially, followed by the green photosynthetic tissue (Lamming 2000). Squarrose knapweed seeds can remain dormant for several years, requiring any cutting program to be repeated annually to be effective.

Several herbicides are relatively effective at controlling knapweeds. Effective herbicides include picloram at 0.25 pound per acre, dicamba at 1 pound per acre, and clopyralid at 0.25 pound per acre. All three are most effective when applied in the spring, when plants are beginning to bolt. Picloram is the most effective treatment, followed by clopyralid and dicamba. Both clopyralid and dicamba will provide some residual control, particularly clopyralid, and retreatments may be necessary in the second, third, or fourth years. Dicamba will injure or kill most other broad leaves it contacts, including desirable species. Clopyralid is more selective but will injure legumes such as clovers. 2,4-D is the least expensive treatment but is less effective, and retreatment is required every year (CSU 2000). Seeding with desirable grass species that will compete for resources but not be affected by broadleaf herbicides is critical to avoid the treated areas from returning to noxious weed communities.

Canada Thistle (*Cirsium arvense* [L.] Scop.)

Background: This species can be confused with several other exotics. Bull thistle (*Cirsium vulgare*) has flower bracts that are somewhat tapered and covered with spines, scotch thistle (*Onopordum acanthium)* has stems that appear to have wings and floral bracts that are covered with spines, musk thistle (*Carduus nutans*) has floral bracts that are broad with spiny tips, and Russian knapweed has pointed papery tips on floral bracts. Canada thistle is an aggressive, creeping, perennial weed that infests crops, pasturelands, rangelands, roadsides, and riparian areas. Although Canada thistle mainly invades disturbed area, it does invade native plant communities, open meadows, and wetlands. Canada thistle can tolerate saline soils but does not tolerate waterlogged or poorly aerated soils.

Description: This 1- to 4-foot (0.3- to 1.2-m) perennial forb has white to purple flower heads borne in clusters of one to five per branch. Unlike other *Cirsium* species, Canada thistle is dioecious, and female flowers can be readily distinguished from male flowers by the absence of pollen and the presence of a distinct vanilla-like fragrance. It is possible for a community of male plants to maintain itself by asexual reproduction while producing no fruits. Flowering occurs from June to August, and seeds mature in October. The one-seeded fruits are straw or light brown in color and can be straight or slightly curved. The leaves are spiny, alternate, oblong or lance-shaped, with the base leaves stalkless and clasping, and rosettes have wavy leaves with spiny tips. There are two types of roots: 1) horizontal roots produce numerous shoots, and 2) vertical roots store water and nutrients in their many small branches. The overwintering root develops new underground roots and shoots in January that elongate in February. Shoots emerge between March and May forming rosettes. The plants remain near the soil surface until long days (over 14 hours of light) trigger stem elongation. It spreads rapidly through horizontal roots, which give rise to shoots, and can grow as much as 18 feet in one season. Although Canada thistle reproduces primarily vegetatively through creeping horizontal roots, seeds are viable in the soil for several years (CSU 2000).

Control: Currently, there are no biological control agents that effectively control Canada thistle. However, Canada thistle is attacked by several accidentally introduced insects, including the green tortoise beetle (*Cassida rubiginosa*), the native painted lady butterfly (*Vanessa cardui*), and the crown root weevil (*Baris subsimilis*). A rust fungus (*Puccinia carduorum*) can be found in some stands and will

kill some plants. The seed head fly (*Terellia ruficauda*) may become abundant in some areas but causes little damage. The seed head weevil (*Larinus planus*) was accidentally introduced into the United States at an unknown time. This weevil is not recorded as a pest of any economically important plant and is found to feed mainly on the foliage of *Cirsium* and *Carduus* species. It shows a preference for Canada thistle, although others, including the genera *Arctium*, *Onopordum*, and *Silybum*, are acceptable if Canada thistle is not available (Coombs et al. 2004).

Goats will eat Canada thistle, reducing biomass and stressing the plant. The most effective time to graze is when the plant is in full bud before it flowers. At this time, the plant has put all of its energy into seed reproductive structures, reducing root reserves. This can be an effective control if it is repeated in 1-month intervals throughout the growing season. Over time, the Canada thistle will spend more energy reproducing photosynthetic tissue, and after two or three grazings, root reserves will be eliminated and the plant will die (Lamming 2001).

Fall herbicide treatments are more effective because absorption is enhanced in the late summer and fall, when shoot to root translocation is the greatest. However, translocation of the herbicide is dependent on moist soil conditions and must be timed accordingly. Aminopyralid (5 to 7 ounces per acre), 2,4-D amine and glyphosate (1 quart per acre) are effective when applied in the late spring or fall. Herbicides should be applied to actively growing parts of the plant. The performance of herbicides can be improved when proceeded by two or three mowings, cuttings, or grazings under conditions when the root systems are stressed. Spring application should be timed to the rosette to bud growth stages. Chlorsulfuron and glyphosate offer good control, and dicamba is not recommended against Canada thistle (CSU 2000; Dewey et al. 2006). Seeding with desirable grass species that will compete for resources but not be affected by broadleaf herbicides is critical to avoid the treated areas from returning to noxious weed communities.

Poison Hemlock (*Conium maculatum* L.)

Background: Poison hemlock is native to Europe, and it is generally found on dry to moist soils, can tolerate poorly drained soils, and tends to be scattered in riparian areas. It is usually found along streams, roadsides, and irrigation ditches. It is often mistaken for parsley and wild carrot. All parts of the plant are toxic (CSU 2000). This species is listed by Davis, Cache, and Rich Counties as a noxious weed species, but it is found in Salt Lake County throughout riparian areas (USDA Natural Resources Conservation Service [NRCS] 2012a).

Description: Poison hemlock grows 6 to 10 feet (1.8 to 3.0 m) tall. This biennial forb has white flowers that are borne in umbrella-like clusters that are supported by a stalk. Seeds are generally light brown, ribbed, and concave. The shiny green and finely divided leaves are alternate but may be opposite above. Leaflets are segmented on short stalks, and seedling leaves have a fernlike appearance (Belliston et al. 2004).

Control: The European palearctic moth (*Agonopteris alstoemeriana*) feeds exclusively on poison hemlock and offers fair to good control. Poison hemlock can be controlled by digging, repeated mowing, or pulling or by spring and winter burns. Herbicides can offer excellent control when applied to actively growing plants between rosette and bolt stages. Tebithuron provides pre-emergent control, and chlorsulfuron and chlorsulfuron with metsulfuron provide both pre-emergent and foliar control. Aminopyralid, dicamba, and 2,4-D at 1 pound active ingredient per acre, or glyphosate at 1.5 active ingredient per acre can also be used (CSU 2000).

Field Bindweed (*Convolvulus arvensis* L.)

Background: Field bindweed is also called small-flowered morning glory, wild morning glory, creeping Jenny, and European bindweed. This European native apparently contaminated crop seed and was identified in Virginia as early as 1739. It is similar in appearance to other species in the Convolvulaceae family (Belliston et al. 2004).

Description: Field bindweed is a persistent, perennial vine that spreads by rhizome and seed. Flowers last for only 1 day and are produced late in June until conditions are no longer favorable. The extensive underground root/stem system allows some to persist through the winter, and the lateral roots can persist independently if severed from the primary root. Young plants extend a taproot deep into the soil and then form lateral roots. Initially, these lateral roots function as feeding roots for aboveground growth but later aid in vegetative reproduction. Buds may arise anywhere on the lateral roots. Eventually, the lateral roots begin growing downward, and new shoots on the root may produce aboveground growth or additional lateral roots. Lateral root growth was found to be 15 feet (4.6 m) per year but depends on the soil permeability and water table depth (The Nature Conservation [TNC] 2006).

Seedlings emerge from the soil erect and ascending, and they are often found in irrigated agricultural fields or moist locations such as riparian corridors and irrigated areas. The deep roots store carbohydrates and proteins and help field bindweed spread vegetatively by re-sprouting repeatedly following removal of aboveground growth. Seeds are extremely persistent and can lie dormant in the soil for many years. The seed coat must be exposed to adequate water, moist air, or fluctuating soil temperatures in the surface soil layers in order for a seed to germinate. New introductions of field bindweed are most likely by seed. Seeds fall near the parent plant but can be transported by water or birds. Seeds pass through the stomachs of migrating birds with little or no damage (CSU 2000).

Control: Control has been most successful when aboveground biomass is consistently removed, causing underground stores of energy to be tapped. The bindweed gall mite (*Aceria malherbae*) forms galls on the leaves, petioles, and stem tips. The folding or twisting upward along the midrib where the mites feed is visual identification that the bindweed gall mite has attacked the plant. When the stem buds are attacked, they fail to elongate and thus form compact clusters of stunted leaves. These mites stunt the plant and reduce flowering. The mite may be difficult to establish in a field under cultivation or herbicide treatment; thus, a site less aggressively managed may be a better location for release. Population of the mite are generally slow to develop and may take up to 3 years. Once established, the mite may disperse via the wind and spread rapidly. The mite could also potentially infest native species; therefore, release is not recommended for locations in which nontarget impacts may be a concern (Coombs et al. 2004).

Herbicide application is most effective when the herbicide will be translocated to the roots before the seed can be set. Control of field bindweed entails chemical applications and removal on a yearly basis. Picloram at 0.5 to 1.0 parts per acre is generally the most effective and can be applied at any time of the year when field bindweed runners are 8 to 12 inches (20 to 30 cm) long. Glyphosate, dicamba, and 2,4-D can provide some control. Early spring requires the plant to draw from its roots, and most translocation will be from below to above ground. Once aboveground growth is vigorous, translocation is primarily from the shoot to the roots, and herbicide application should be done at this stage in the fall to ensure that it is moved with the photosynthates to the roots and root buds. If the aboveground portion is continually destroyed, the root eventually starves and dies. If the aboveground portion is allowed to regenerate and feed the root system, the plant will continue to flourish. The key to implementing a successful control program is to continue treatment even after it appears that the infestations have been significantly reduced. Three to five years may be required to effectively reduce the seed source, deplete food reserves in the root system, and prevent seedling re-growth.

Burning in itself is not an effective control method but may be useful in combination with other methods. Similarly, tilling breaks up the roots and may actually increase the number of seedling or sprouts from the severed roots without herbicide application. Grazing can reduce aboveground biomass, but field bindweed can be poisonous to cattle. Hogs, sheep, and goats will graze field bindweed, but it must be in conjunction with herbicide application or the area fully recovers following grazing cessation (Lamming 2001).

Bermudagrass (*Cynodon dactylon* L. Pers.)

Background: Bermudagrass is a major turf species for sports fields, lawns, parks, golf courses, and general utility turfs in Australia, Africa, India, South America, and the southern region of the United States. It is found in over 100 countries throughout the tropical and subtropical areas of the world. It naturalized throughout the warmer regions of the United States after it was introduced during the colonial period from Africa or India. The earliest introductions are not recorded; however, bermudagrass is listed as one of the principal grasses in the southern states as early as 1807 (Duble 2006). This is a state-listed noxious weed, but it has not yet become a problem in natural areas in northern Utah.

Description: Bermuda grass is a mat-forming rhizomatous grass that moves along the ground and forms adventitious roots wherever a node touches the ground. It has a deep root system that can grow 47 to 59 inches (120 to 150 cm) deep in drought situations. Its blades are a gray-green color and are usually 1 to 4 inches (2.5 to 10.0 cm) long with rough edges. The erect stems can grow 0.3 to 1.3 feet (0.1 to 0.4 m) tall. The stems are slightly flattened, and the inflorescence is purple (Belliston et al. 2004).

Bermuda grass reproduces through seeds as well as rhizomes. The seed heads are on 1- to 3-inch (2.5- to 7.6-cm) spikes and are approximately 2 inches (5 cm) long. Bermuda grass will put out seeds about 3 months after germinating. The seeds germinate at temperatures above 68° F (20°C) and begin to grow within 2 weeks. One plant can cover an area of 3 square yards (2.7 m^2) in just 150 days after germinating. Bermuda grass can grow in poor soil, but it prefers moist and warm climates with over 16 inches (40.5 cm) of rainfall per year.

Control: Bermudagrass is a drought-tolerant grass often used as turf and ornamental groundcover. It is considered a very invasive and competitive weed, and few herbicides are effective against it. Goats prefer broadleaved plants over grasses, but will graze young shoots if nothing else is available (Lamming 2001).

Houndstongue (*Cynoglossum officinale* L.)

Background: Houndstongue was introduced from Europe in the late 1800s and was accidentally included as a contaminant in seed. It can be found in disturbed habitats, primarily in pasturelands, rangelands, and along roadsides (USDA National Invasive Species Information Center 2006). Houndstongue is listed as a noxious weed in Tooele, Wasatch, and Sanpete Counties and is known to exist throughout Salt Lake County (USDA, NRCS 2012b).

Description: Houndstongue is a biennial growing 1 to 4 feet (0.3 to 1.3 m) tall. It forms a rosette the first year and sends up a flowering stalk the second year. Leaves are alternate and range from 1 to 12 inches (2.5 to 30.0 cm) long, are rough and hairy (resembling a hounds tongue), and lack teeth or lobes. Flowers are reddish purple and bloom in early summer. The fruit is composed of four prickly nutlets. The nutlets break apart at maturity and cling to clothing or animals; reproduction is solely by seed (Belliston et al. 2004).

Control: Grazing houndstongue is not possible. It is toxic, containing pyrrolizidine alkaloids that cause liver cells to stop reproducing. Animals may survive for 6 months or longer after they have consumed a lethal amount. Horses may be especially affected when confined in a small area infested with

houndstongue and lacking desirable forage (Whitson et al. 1999). Sheep are more resistant to houndstongue poisoning than cattle or horses. Goats do not seem to be affected by ingesting this toxic plant. No other biocontrol options are available at this time. However, five biological control agents are being screened for their potential use on houndstongue. These include a root weevil (*Mogulones cruciger),* seed weevil (*M. borreginis*), stem weevil (*M. trisignatus*), root beetle (*Longitarsus quadriguttatus*), and root fly (*Cheilosia pasquorum*).

Herbicides can offer good to excellent control when applied between the rosette and bloom stages. Because this is a biennial, once it has set seed it is no longer susceptible to herbicide. The most effective chemical control is when picloram or 2,4-D is applied to the first year rosette stage, killing nearly all plants; approximately three-fourths of the plants will die when sprayed the second year after bolting and flowering. Chlorsulfuron or metsulfuron applied when bolting plants are less than 10 inches (25 cm) prevents seed production completely and are a better alternative for large stands with mixed phenological stages (USDA National Invasive Species Information Center 2006).

Tilling or digging up the roots before seed development can offer good control. Flowering plants should be removed and bagged to prevent seed dispersal.

Russian Olive (*Elaeagnus angustifolia* L.)

Background: Russian olive is originally from Europe and was used as an ornamental in the United States. The fruits can be a valuable food source, and the tree often provides habitat for birds and wildlife. It grows well in meadows and pasturelands and along waterways. Reproduction is from seed and rootstock, and thick stands can develop if left unchecked (Belliston et al. 2004). Russian olive has been identified as a noxious weed in Duchesne, Uintah, Carbon, Sevier, and Wayne Counties but is a common weedy tree throughout Salt Lake County (USDA, NRCS 2012f).

Description: Russian olive is a small, usually thorny shrub or small tree that can grow to 25 feet (7.6 m) high. Its stems, buds, and leaves have a dense covering of silvery to rusty scales. Leaves are egg- or lance-shaped, smooth margined, and alternate along the stem. Highly aromatic, the initial creamy yellow flowers are later replaced by clusters of abundant silvery fruits. The twigs are flexible and coated with a gray, scaly pubescence; they often have a short thorn at the end. The bark is thin with shallow fissures and exfoliates into long strips. It has a deep taproot and well-developed lateral root system (Invasive Species Specialist Group 2006).

Control: Adult male goats will graze the flowers, fruits, and leaves of Russian olive but are limited in their accessibility to larger and taller vegetation. The most effective combination of control efforts has been cutting trees, followed by either spraying or burning the stumps. Russian olive is sensitive to 2,4-D ester, triclopyr, 2,4-D + triclopyr, imazapyr, and glyphosate. However, effective control with these compounds almost always requires follow-up treatments for 1 to 2 years. The herbicide 2,4-D ester is applied to the foliage. It requires good coverage for acceptable results. The herbicide combination 2,4-D + triclopyr is applied either as a foliar spray or a directed spray to the basal bark of the tree. Triclopyr is applied as a directed spray to the basal bark of the tree. Basal applications require good saturation of the bark, and diesel fuel is frequently used as the carrier. Imazapyr is applied undiluted to frill cuts made in the stem. Glyphosate is also applied to frill cuts. Glyphosate has provided very good control when applied during the winter months (Invasive Species Specialist Group 2006).

Quackgrass (*Elymus repens* [L.] Gould)

Background: Originally found in the Mediterranean area, quackgrass infests crops, rangelands, pasturelands, and lawns. It adapts well to moist soils in cool temperature climates (Belliston et al. 2004).

Description: This tall (1- to 3-foot [0.3- to 0.9-m]) perennial grass has spikelets arranged in two long rows that are borne flatwise to the stem. Quackgrass leaves are often constricted near the tips, are flat, are pointed, are between 0.25 and 0.50 inches (0.6 and 1.2 cm) wide, and have small ear-like appendages at the junction of the blade and the sheath. Both leaf sheath and blade are hairless or sparsely hairy. Plant vigor is reduced when shading exceeds 50% (Belliston et al. 2004).

Quackgrass propagates mainly by rhizomes, but it also reproduces by seed. Primary rhizome growth begins in early spring and then again in September and October with the onset of fall rains and cooler temperatures. Quackgrass flowers from June through August. Cross-pollination is necessary for seed production. Seeds germinate in fall or spring; plants are capable of producing seeds more than once per season, and the seeds can remain viable for up to 10 years.

Control: No biological control methods are available at this time. Because of the ability of broken rhizome segments to grow and produce more plants, quackgrass is extremely difficult to control mechanically by tilling or ripping the soil subsurface. Mowing and raking can reduce quackgrass biomass and prevent flowering the following season. It can be effectively controlled with glyphosate, nicosulfuron, fluazifop-P-butyl, imazapyr, and princep (USDA 2006).

Leafy Spurge (*Euphorbia esula* L.)

Background: This is an aggressive, long-lived perennial weed that tends to displace all other vegetation in rangeland, pastureland, and native habitats. Leafy spurge decreases rangeland diversity, threatens native plants, and degrades wildlife habitat. It is most aggressive in semiarid areas, but can be found in xeric to subhumid and subtropic to subarctic habitats. Leafy spurge occurs most commonly on untilled, noncrop areas such as rangelands, pasturelands, woodlands, prairies, roadsides, stream and ditches, and waste sites. It grows on all kinds of soils but is most abundant in coarse-textured soils and least abundant on clay soils (CSU 2000).

People should handle the plant with caution because the latex can cause irritation, blotching, blisters, and swelling in sensitive individuals. Eye irritation can be severe. The dried latex is often very difficult to wash off, and latex gloves should be used when handling this plant (Coombs et al. 2004).

Description: Leafy spurge is a perennial forb with yellowish green flowers arranged in numerous small clusters subtended by paired heart-shaped yellow-green bracts. The leaves are alternate, and 1 to 4 inches (2.5 to 10.0 cm) long. Mature plants are up to 3 feet (0.9 m) tall, and the entire plant contains white, milky latex. Leafy spurge is one of the earliest plants to emerge in the spring, usually in mid-April to late May. The development of terminal flower clusters begins 1 to 2 weeks after stem emergence. Flower clusters have eight to 16 branches. Flowering generally ends in late June to mid-July, and growth is reduced during the hotter portion of the summer. However, if conditions are favorable, leafy spurge may produce a few lateral flowers in the summer and fall (Belliston et al. 2004; CSU 2000).

Leafy spurge produces a large number of seeds and underground shoot buds. These two reproductive techniques allow it to rapidly displace native species and form a monoculture. Rapid re-establishment of treated stands often occurs after an apparently successful management effort because of the large nutrient reserve stored in the roots of leafy spurge plants. Primary reproduction is vegetative through its extensive lateral root system. Long roots can produce shoots and can reach nearly 15 feet (5 m) laterally and approximately 30 feet (10 m) deep. Seeds can remain viable in the soil for 5 to 8 years, although 99% of the viable seeds will germinate in the first 2 years (Belliston et al. 2004; CSU 2000).

Control: Biological control is still being investigated, and successful control may require a combination of insects and long-term management. The USDA Agriculture Research Service has released 15 species

of insects in an effort to control leafy spurge. The most effective biological control agents are six species of root- and foliate-feeding beetles in the genus *Aphthona*, and a stem- and root-boring beetle, *Obera erythrocephala*.

Grazing sheep or goats has been successful, but spurge quickly returns if grazing is removed. Grazing is likely to be most effective in the spring and summer when the spurge plants are succulent. Sheep generally can be taught to feed on spurge, whereas goats will seek it out.

Herbicides can provide some control of leafy spurge; however, due to its extensive root system and general hardiness, follow-up applications are necessary. Leafy spurge has the ability to purge undesirable chemicals from its root system in approximately the top 18 inches (45 cm) of the soil, allowing the remaining portion of the root system to regenerate as soon as the effect of the chemical in the soil has dissipated (Coombs et al. 2004). Picloram is recommended for eradication of small infestations, with herbicide application extending for 10 to 15 feet (3.0 to 4.5 m) beyond the leafy spurge patches. A combination of picloram and 2,4-D can provide good results when applied in the spring when flowers emerge (CSU 2000).

Myrtle Spurge (*Euphorbia myrsinites* L.)

Background: Myrtle spurge, also known as donkey tail or creeping spurge, was introduced as a common garden plant in xeric landscapes that escaped cultivation. Its milky sap can cause significant skin and eye irritation. It does not tolerate cultivation and therefore is found in rangelands, pasturelands, and wastelands and along roadsides. It prefers well-drained, part to full sun and has been listed as a noxious weed in several states (USDA 2006).

Description: Myrtle spurge is a low-growing perennial that reaches 4 to 6 inches (10 to 15 cm) tall, with new stems originating from the taproot each spring. The stem leaves are fleshy, blue-green, and alternate, appearing spirally arranged. Inflorescences are umbels with small inconspicuous flowers subtended by yellow bracts that appear from March to May. Myrtle spurge reproduces entirely from seed.

Control: This species is not yet widespread in Utah and should be a priority for immediate eradication if found. Early detection and removal of this plant offer the most simple and cost-effective method of control for myrtle spurge, although plants must be removed for several years in a row. It is important to remove the taproot, and all flowers should be bagged or burned because the seeds can continue to mature after the plant has been cut. No known biological controls are available at this time, and there is some evidence of toxicity to cattle, although most grazers tend to avoid it.

Herbicides 2,4-D, dicamba, and glyphosate can be effective against myrtle spurge, but a surfactant must be used to ensure the herbicide adheres to the waxy cuticle. Picloram is another possible control. The seedling stage is generally the best time to apply herbicides (CSU 2000).

Dame's Rocket (*Hesperis matronalis* L.)

Background: Dame's rocket, also known as mother-of-the-evening and dame's violet, is native to Europe where it was cultivated as an ornamental. Dame's rocket was introduced to the United States around the time of European settlement. This species is now widely established in cultivated lands, particularly along irrigation canals and in open woodlands, ditches, roadsides, and other disturbed areas (Welsh et al. 2008).

Description: Dame's rocket it a biennial or short-lived perennial of the mustard family (Brassicaceae) that produces seeds prolifically. Seeds germinate and develop into a basal rosette the first year, and flowering stems are produced the second and subsequent years. The plant grows 2 to 4 feet (0.6 to 1.2 m) tall and produces one to several stems that may be simple or branched. Dame's rocket has a taproot and branching secondary roots. Flowering-stem leaves are lance-shaped or elliptical and are typically 0.78 to

6 inches (2 to 15 cm) long and 0.3 to 1.5 inches wide. Both stems and leaves are covered with fine hairs. Each flower has four petals that are pink to lavender or white. Flowers are 0.75 to 1 inch wide and form branching clusters. Dame's rocket blooms from mid-May through June. Tiny, dark brown seeds are released from siliques in late summer and early fall. Seeds can remain viable in the soil for many years (USFS 2016; Welsh et al. 2008).

Control: Hand pulling or digging small infestations or isolated plants prior to seed production can be effective as long as the entire tap root is removed. Pulling when the soil is moist increases the likelihood of removing the entire root.

Several herbicides are listed as providing control of dame's rocket, including 2,4-D (0.95 to 1.9 pounds per acre for broadcast application), glyphosate (0.75 to 1.5 pounds per acre for broadcast application), and imazapic (6 to 10 ounce per acre), when applied at the appropriate time.

Black Henbane (*Hyoscyamus niger* L.)

Background: Black henbane is an invasive weed found in meadows, sagebrush and oak-serviceberry communities, pasturelands, and along roadsides throughout the United States. Black henbane is native to northern Africa and Europe, where it was cultivated for its medicinal qualities. It was likely introduced to the United States in the seventeenth century as a medicinal and ornamental plant. This species will grow in a variety of environmental conditions and is primarily found in sandy or well-drained loam soils with moderate fertility; it does not tolerate water-logged soils (Pokorny et al. 2010; Welsh et al. 2008).

Description: Black henbane is an annual or biennial of the nightshade family (Solanaceae) that reproduces solely through seed production. Seeds germinate and develop into a rosette in late May. Black henbane has a large, whitish, branched, fleshy taproot. The plant grows 1 to 6 feet (0.3 to 1.8 m) tall. The stems of a mature plant are erect, leafy, stout, coarse, hairy, and widely branched. Leaves are large—up to 6 inches (15 cm) wide and 8 or more inches (20 cm) long. Leaves are alternate with coarsely toothed to shallowly lobed margins and are grayish green in color. Leaves are covered with fine, sticky hairs. Black henbane flowers from June to September, with peak flowering typically occurring in July. The five-lobed, funnel-shaped flowers are brownish yellow and have dark purple veins. Flowers are arranged in a long spike-like inflorescence in the upper leaves with the youngest flower at the tip. Two rows of pineapple-shaped fruits appear after flowering. Each fruit capsule contains black, pitted seeds. Black henbane produces 10,000 to 500,000 seeds per plant. Seed can remain viable in the soil for up to 5 years. This species has an unpleasant odor at all growth stages. It is poisonous to humans and livestock (Pokorny et al. 2010; Welsh et al. 2008).

Control: Management objectives for black henbane control should involve preventing seed production and periodically monitoring populations. Because seeds can remain viable in the soil for several years, it is important to control newly emerging plants for several consecutive growing seasons. Because black henbane is poisonous, grazing is not an option for control. There are no biological controls available for black henbane (Pokorny et al. 2010).

Hand pulling or digging small infestations or isolated plants prior to seed production can be effective as long as the entire tap root is removed. Pulling when the soil is moist increases the likelihood of removing the entire root. To avoid skin irritation, gloves and protective clothing are recommended when pulling plants (Pokorny et al. 2010).

Several herbicides are listed as providing control of black henbane, including Dicamba (8 to 32 ounces per acre), picloram (1 to 2 pints per acre), and metsulfuron (0.5 to 1 ounce per acre), when applied at the appropriate time. Herbicide recommendations vary by region and site. Herbicides should be applied with a nonionic surfactant at the rosette stage and prior to flowering to prevent seed production (Pokorny et al. 2010).

St. Johnswort (*Hypericum perforatum* L.)

Background: St. Johnswort is a perennial forb. It is native to Eurasia and was likely introduced to the United States in the 1700s as an ornamental. St. Johnswort can tolerate a variety of soils and environmental conditions and is commonly found in grasslands, rangelands, along roadsides, and in sagebrush, pinyon pine, white-fir, and aspen communities (Welsh et al. 2008).

Description: St. Johnswort is an erect, herbaceous perennial that grows to 2 to 5 feet (0.6 to 1.5 m) tall and has a taproot, with stolons or sometimes rhizomes. The numerous stems are woody and smooth with a rust color. Leaves are 0.6 to 0.8 inch (1.5 to 2.0 cm) long and oblong in shape. Flowers are yellow, have five petals, and have transparent black dots around the edge of each petal (Welsh et al. 2008).

Control: Hand pulling of young, isolated plants can often be an effective means of control. Be sure to remove and destroy pulled plants to prevent possible vegetative regrowth and/or seed dissemination. For larger infestations, mowing can diminish the spread of the plant if it is performed prior to seed formation. Two or more cuttings may be necessary during the growing season. Several herbicides are listed as providing control of St. Johnswort, including metsulfuron (1 ounce per acre), 2,4-D, and picloram (1 to 2 quarts per acre) when applied at the appropriate time (U.S. Geological Survey 2006).

Dyer's Woad (*Isatis tinctoria* L.)

Background: Dyer's woad's origins for human use date back over 2,000 years. In Europe, this plant was cultivated as a source of blue dye and medicinal properties. This aggressive weed infests disturbed and undisturbed sites and can spread outward into crops and rangelands. It appears to be well adapted to the physical and environmental conditions of the intermountain states and is especially well suited to dry, rocky soils common to many steep hillsides. Dyer's woad is commonly found on disturbed sites, along roadsides, in waste areas, and in rights-of-way (Belliston et al. 2004).

Description: Dyer's woad is a winter annual, biennial, or short-lived perennial forb ranging from 1 to 4 feet (0.3 to 1.3 m) tall. The flowers are bright yellow, and seedpods are black or purplish brown with a single seed. The basal rosette leaves are 3 to 4 inches (7.5 to 10 cm) long and are lance-shaped and connected to the stem with a petiole. The upper stem leaves are simple, alternate, and bluish green with a whitish nerve on the upper surface. These leaves clasp the stem with an ear-like projection and decrease in size toward the top of the stem. Mature plants have a thick taproot that may exceed 5 feet (1.5 m) long (CSU 2000).

Established dyer's woad plants begin growth early in the year. The plant has a deep taproot as well as roots near the soil surface. Early growth plus the two-tiered root system probably account for its competitive ability. It germinates in the fall or early spring and develops rosettes that produce large taproots during the first year. The following spring, new leaves grow from the crown bud in the rosette, and bolting begins. Flowering occurs in late spring, although timing is dependent on elevation. Dyer's woad reproduces mainly by seed, but seeds do not remain viable in the soil for long periods of time (Belliston et al. 2004).

Control: Removal is probably the simplest and most effective method of control, if removed after plants have bolted and begun to flower. There are several CWMAs that use local volunteers to pull Dyer's woad in Utah in the *Bag O' Woad* program. For small distinct populations, this is a valuable opportunity to eliminate the infestation, engage the community, and support education regarding this and other noxious weeds.

Dyer's woad is commonly controlled with herbicides. Metsulfuron offers excellent control at 0.33 to 2.00 ounces per acre; apply post emergence when the ground is not frozen in March or April. 2,4-D, imazapic, and chlorsulfuron offer good control at 1.75 quart per acre, 10 ounces per acre, and 1 ounce per acre, respectively. Use any of these herbicides to avoid injury to grass species (CSU 2000).

A relative of the rust fungus *Puccinia thlaspeos* is the most common biological control agent used, and it is able to prevent or reduce seed production and slow growth. The rust can enter the plant through inoculation on the leaf surface and systemically damages the plant to the roots. It can prevent or reduce seed production and may also affect the survival of seedlings, rosettes, and overwintering plants. The rust is able to complete its life cycle on Dyer's woad alone and does not seem to require a secondary host like many rusts do. Rust-infected plants will have yellowish puckered leaves with dark spots on the underside (Weber County 2006).

Perennial Pepperweed (*Lepidium latifolium L.*)

Background: Perennial pepperweed (or tall whitetop) is a highly invasive herbaceous perennial. It can invade a variety of habitats, including riparian areas, wetlands, marshes, and floodplains. Once established, this plant creates large monospecific stands that displace native plants and animals and can be very difficult to remove. Significant amounts of litter can build up in dense infestations. Old stems take several years to degrade and form a layer impenetrable to light. This deep litter layer prevents the emergence of annual plants and may reduce competition from other species. Even if perennial pepperweed is controlled, it may be necessary to remove the litter to stimulate germination and growth of desirable plant species (CSU 2000).

Description: This plant reaches 4 feet (1.2 m) in height, has lanceolate gray-green leaves, and has white dense clusters of flowers on its racemes. Deep-seated rootstocks make this weed difficult to control. Roots consist of annual, perennial, and semi-woody root crowns that creep horizontally below the soil surface, never forming dense clusters. This low root density allows soil erosion to occur more frequently along infested riverbanks. The stems originate from large perennial belowground roots and emerge in early spring/late fall. Shoots will remain in the rosette form for several weeks before stems elongate or bolt. Rosette leaves are approximately 12 inches (30 cm) long and 3 inches (8 cm) wide with serrate margins on long petioles. Stem leaves are highly reduced and tapered at the base with entire to weakly serrate margins. Shoots flower and fruit during late spring and continue throughout much of the summer; plants senesce by mid- to late summer while fruits remain on the stem. Seedlings are rarely found in the field. Seeds lack a hard coat and do not seem to be capable of surviving long periods in the soil; thus, seed viability may be short. This suggests that reinfestations from the seed bank may not be a problem once control is achieved (CSU 2000).

Control: Burning is not an effective control measure against perennial pepperweed. Although it can be efficient in removing existing and past stems, it does not appear to harm the perennial roots. Biomass of re-sprouting stems may even increase in subsequent years due to the removal of the litter layer and the addition of nutrients from the fire (CSU 2000; USDA 2006).

Cattle, sheep, and goats will graze perennial pepperweed; however, when stands are dense, it becomes very difficult for these animals (except goats) to use it as forage. Cattle will graze the rosette leaves early in the spring, but have difficulty if previous year's stems are not removed. Some reports suggest the leaves may be poisonous (Young et al. 1997).

The only nonchemical control method effective against large populations of perennial pepperweed is long-term flooding; however, it is not known whether plants will reestablish if the flooding regime is removed from these areas. The most consistent control was found with the use of herbicides applied at the flower bud to early flowering stage using chlorsulfuron with silicone-based nonionic surfactant, although this herbicide cannot be applied near or over water. Imazapyr is also effective. Mowing in the early season followed by herbicide application may lead to the translocation and accumulation of more herbicide to belowground perennial organs, thereby enhancing control. Mowing followed by the application of glyphosate in riparian or wetland areas has proven effective. The most effective time to apply herbicides is the flower bud to early flowering stage (CSU 2000).

Oxeye Daisy (*Leucanthemum vulgare* Lam.)

Background: Oxeye daisy is an invasive perennial commonly found in meadows, in pasturelands, and along roadsides throughout the United States. Conscientious management of this species is often neglected due to its showiness and beauty. Oxeye daisy, native to Europe, was introduced to North America intentionally as an ornamental and also incidentally as a contaminant of imported grain seeds and hay. This species grows in a wide range of soil textures and tends to be abundant in poor soils. Oxeye daisy can form dense stands that replace other vegetation (Mangold et al. 2009).

Description: Oxeye daisy is a perennial rhizomatous or subrhizomatous herb and a member of the Asteraceae family. Flower heads are borne individually on the tops of long, slender stems. Flowers are 1.5 to 2 inches (3.8 to 5 cm) across with yellow centers from which 20 to 30 white linear petals radiate. The petals are slightly notched or lobed at the tip. Stems grow 1 to 3 feet (0.6 to 0.9 m) tall and may be branched at the top. Leaves are dark green, smooth, and often glossy and progressively decrease in size toward the top of the stem. Basal leaves are long and linear with serrate or "toothed" margins. The upper leaves are narrow, may clasp the stem, and are alternately arranged. The plant has strong, adventitious roots and shallow, branched rhizomes. This species reproduces primarily from seed but also by rhizomes. Oxeye daisy is a prolific seed producer; each flower produces 100 to 250 seeds. Germination occurs throughout the growing season; however, most new seedlings emerge in the spring. Mature plants flower June through August. Seeds that do not germinate may remain viable for more than 6 years (Mangold et al. 2009; Welch et al. 2008).

Control: Currently, no biological control agents have been developed to control oxeye daisy. Tilling is not recommended because it is possible to spread seeds and root fragments.

Mowing may reduce oxeye daisy seed production if plants are mowed as soon as flower buds appear. Mowing may have to be repeated during a long growing season because mowing may stimulate shoot production and subsequent flowering. Mowing can be combined with nutrient treatment if used in areas infested with oxeye daisy. Mowing may improve herbicide contact with rosettes (Mangold et al. 2009).

Hand pulling may be practical for controlling small populations of oxeye daisy. Root systems are shallow, and the plant can be dug up and removed. Hand removal will have to be continued for several years because remaining roots may sprout and seedlings will continue to emerge from the soil seed bank (Mangold et al. 2009).

Spring and early summer herbicide treatments of several herbicides, including aminopyralid (4 to 6 ounces per acre), aminopyralid + 2,4-D (2 to 2.5 pints per acre), metsulfuron (0.5 to 1 ounce per acre), or picloram (1.5 pints per acre) provide effective oxeye daisy control. Oxeye daisy is moderately resistant to some 2,4-D-based herbicides except at high rates (5 pounds active ingredient per acre). Oxeye daisy is not highly competitive, and reinvasion following herbicide treatment may be slowed or prevented by establishing and maintaining a healthy desirable plant community. Glyphosate (1 to 2 quarts per acre) will control oxeye daisy where revegetation is planned (Mangold et al. 2009).

Dalmatian Toadflax (*Linaria dalmatica* L. Mill.)

Background: Dalmatian toadflax was brought to the United States from Europe, probably for ornamental purposes. It prefers rangeland and roadside habitat with sandy soils. It is very aggressive and hard to control due to its deep roots and thick waxy leaf cuticle (CSU 2000).

Description: Dalmatian toadflax can be easily identified by its bright yellow snapdragon-shaped flowers, and can be distinguished from yellow toadflax by its larger flowers and more ovate leaves. The flowers of this plant are borne in loose, elongate racemes. Fruits are egg-shaped to nearly round capsules, and seeds are sharply angular and slightly winged. Leaves are broad, ovate, and alternate. Mature plants are up to 3 feet (0.9 m) tall (CSU 2000).

Control: Sheep and goats are very effective against Dalmatian toadflax because they prefer it to other rangeland grasses. This will not kill the plant but will keep it from flowering if the grazing regime is continued over the summer.

Eight species of exotic insects have been intentionally or accidentally introduced for biocontrol of toadflax in North America. They belong to two groups: beetles (Order: Coleoptera) and moths (Order: Lepidoptera). A few of these biological control agents are available in Utah and offer fair control of Dalmatian toadflax and yellow toadflax.

Tilling can be effective if done repeatedly. The cut roots can re-sprout, resulting in a larger problem if not tilled again immediately when new sprouts are coming through the soil. This may need to be repeated three to four times per season for several years to deplete the root reserves as well as the soil seed bank (Whitson et al. 1999).

Two rangeland herbicides, picloram and chlorsulfuron, applied after a burn, have been shown to successfully reduce Dalmatian toadflax. Chlorsulfuron applied in the fall or spring or picloram applied in the spring effectively controlled Dalmatian toadflax for approximately 3 years, leaving nutrients released by fire to desirable species (Jacobs and Sheley 2005). Studies of herbicide application for perennial weed control indicate the best time for application is when carbohydrate reserves in the underground portions are lowest. Reserve carbohydrates of Dalmatian toadflax are at their highest levels in the fall at the end of the growing season and at their lowest point at the beginning of flowering in May (Invasive Species Specialist Group 2006).

Yellow Toadflax (*Linaria vulgaris* Mill.)

Background: Yellow toadflax (butter and eggs) is an invasive perennial introduced from Eurasia in the mid-1700s as an ornamental and for folk remedies. This species is commonly found in rangelands, in fields, and along roadsides. Yellow toadflax has an extensive root system, making this weed difficult to control. Yellow toadflax is able to reproduce by both seeds and roots. Yellow toadflax prefers well-drained, coarse soils in open, disturbed areas.

Description: Yellow toadflax is an erect, herbaceous perennial with long, linear, pointed leaves that are pale green and alternate in arrangement. Plants range from 1 to 3 feet (0.3 to 0.9 m) tall and are generally unbranched or sparsely branched. One plant may produce several woody stems with a reddish color at the base, becoming greener toward the top of the plant. Flowers are pale yellow snapdragon-like blossoms that are 0.8 to 1.6 inches (2–4 cm) long. The flowers form clusters at the top of the plant in groups of six to 30. The seeds are small winged discs. A single plant can produce as many as 20,000 seeds (Wilson et al. 2005).

Control: Yellow toadflax is difficult to control, and management plans should integrate multiple strategies to increase potential for success. Herbicides can be an effective means of control for yellow toadflax but typically require repeated treatments at high rates. Fall application of chlorsulfuron (1.5 to 2.0 ounces per acre) has shown to be moderately effective in controlling yellow toadflax (Beck 2009).

Eight species of exotic insects have been intentionally or accidentally introduced for biocontrol of toadflax in North America. They belong to two groups: beetles (Order: Coleoptera) and moths (Order: Lepidoptera). A few of these biological control agents are available in Utah and offer fair control of Dalmatian toadflax and yellow toadflax.

Purple Loosestrife (*Lythrum salicaria* L.)

Background: Purple loosestrife is a European plant probably introduced to the United States as an ornamental. It reproduces by both seed and creeping rootstocks. Infestations can impede water flow and replace beneficial plants and thus displace wildlife. It can be found in shallow marsh wetland areas and ditches.

Description: The purple loosestrife stems are erect, 1.5 to 8.0 or more feet (0.5 to 2.4 m) tall, four to six angled, and can be smooth or pubescent with few branches. Leaves are simple, 0.75 to 4.00 inches (2 to 10 cm) long, 0.2 to 0.5 inches (0.5 to 1.3 cm) wide, and entire and can be opposite or whorled. The most identifiable characteristic of purple loosestrife is its striking rose- to purple-colored flowers. The flowers are arranged on a spike, which can be a few inches (5 cm) to 3 feet (0.9 m) long. Each flower has five to seven petals arising from a cylindrical green tube. The plant usually flowers from early July to mid-September. The seed capsule is two celled and contains many very small seeds (1 mm long or less). The roots become thick and woody in mature plants. The aerial shoots die in the fall, and new shoots arise the following spring from buds at the top of the root crown. Although the root crown expands and produces more shoots each year, the maximum growth of the root crown diameter is limited to approximately 20 inches (50 cm). Spread of purple loosestrife is primarily by seed, but the plant can also spread vegetatively from stem cuttings (Belliston et al. 2004; USDA 2006).

Control: The purple loosestrife biocontrol project is one of the most widely implemented projects in the United States. The black-margined loosestrife beetle (*Galerucella calmariensis*) and golden loosestrife beetle (*Galerucella pusilla*) attack buds and leaves. Adult and larval feeding on the buds results in stunted plants and reduced seed production. After emerging from soil litter or from off-site in the early spring, adults feed on exposed shoots that are approximately 2 to 4 inches (5 to 10 cm) long. With heavy defoliation, the host plant becomes skeletonized and turns brown. Heavily defoliated plants may die or produce fewer shoots the following year. However, these beetles can feed on two native plants (*Decodon verticillatus* and *Lythrum alatum*) and two introduced plants (*L. hyssopifolia* and *Lagerstroemia indica*) but do not reproduce on these hosts (Coombs et al. 2004).

The loosestrife root weevil (*Hylobius transversovittatus*) larvae live in the roots while the adults feed on the foliage. The larval effects are dependent on root size, attack intensity, and duration. Small roots can be destroyed within 2 years if infested by several larvae. Larger roots may die after several consecutive years of infestation. This species increases and spreads more slowly than the leaf beetles. However, because during the growing season it feeds continuously on the root storage reserves of the plants, it is an important agent in the control of purple loosestrife. In stands of large, healthy plants, the leaf beetles may produce temporary severe defoliation, but the plants may recover after the beetles enter diapause in mid-summer. By reducing root storage reserves, the weevil limits the plant's ability to recuperate after defoliation. The combined impact of both biocontrol agents is enough to cause plants to die (Coombs et al. 2004).

The loosestrife seed weevil (*Nanophyes marmoratus*) adult and larvae attack unopened flower buds. Flower buds that are fed on by either adults or larvae usually abort and fail to produce seeds. The loosestrife seed weevil tolerates a variety of environmental conditions and possesses an excellent host-finding ability. It has successfully overwintered on exposed islands in an estuary with high tidal exchange where multiple releases of the leaf beetles have failed. The weevils can also persist where plants are scattered at low densities. Their impact is currently being overshadowed by the dramatic defoliation and plant death caused by the leaf beetles and root weevil. However, they may play an important role after loosestrife abundance declines and the other agents become less effective (Coombs et al. 2004).

Herbicide control includes the use of 2,4-D, metsulfuron, and glyphosate; dicamba offers fair control. Purple loosestrife is often found along streambanks and in riparian areas, and the aquatic formulation for these herbicides is available (Dewey et al. 2006).

Scotch Thistle (*Onopordum acanthium* L.)

Background: Scotch thistle is a native of Europe that quickly invades sunny areas that have been disturbed; however, it is suppressed when it invades a healthy system. Once established, it becomes highly competitive, often crowding out other noxious weeds, and can form stands so dense they are impenetrable to livestock. Its rapid growth and large size reduce available light for smaller plants and draw away other needed resources. Long spines intimidate animals into eating easier targets. When a Scotch thistle dies, it leaves abundant litter that can smother surrounding plants. It is best adapted to high soil moisture and is often associated with waterways in the western United States in disturbed areas where competition has been reduced. Although high soil moisture is preferred, it will occupy dry sites as well. Scotch thistle is often associated with plant communities dominated by annual weedy grasses (cheatgrass) and has been known to invade crested wheatgrass sites. It grows along roadsides, fence lines, ditch banks, open dry areas, and in pasturelands but is rarely found in gardens and areas cultivated yearly (CSU 2000).

Description: This biennial plant commonly grows 3 to 8 feet (0.9 to 2.4 m) tall, but it may grow as high as 12 feet (3.7 m). Rosettes may be 4 feet (1.2 m) wide. Large spiny leaves up to 2 feet (0.6 m) long and 1 foot (0.3 m) wide are covered with dense hair, giving a grayish blue-green coloration. The flowers are violet to reddish with spine-tipped bracts. The Scotch thistle plant blooms in mid-summer, and averages 70 to 310 flowers per plant, with 110 to 140 seeds per flowering head. Eighty to ninety percent of the seed can be dormant for approximately 5 years and are dispersed by water, wind, animals, and human activities (Belliston et al. 2004).

Control: Control of this plant must include preventing new seed dispersal for up to 6 years. Grazing young plants with sheep or goats will remove aboveground biomass and eliminate the spread of seed (CSU 2000). No other biological controls are available at this time.

Scotch thistle is most often controlled with herbicides; its control can be combined with musk thistle treatments. The most effective chemical control occurs when musk thistle is still in the rosette stage and quickly decreases once the plant has bolted. Aminopyralid and metsulfuron offer excellent control when applied at 3 to 5 ounces per acre and 0.5 to 1.0 ounces per acre, respectively. Apply both herbicides to rosettes; fall is optimal, although spring applications are also effective. Clopyralid at 0.66 part per acre, chlorsulfuron at 0.5 to 1.0 ounces for musk thistle and 1 to 3 ounces per acre for Scotch thistle, and a combination of clopyralid and 2,4-D (Curtail®) at 1 to 2 quarts per acre provide good control when applied from the late rosette stage to early bolting. Seeding with desirable grass species that will compete for resources but not be affected by the broadleaf herbicides is critical.

Common Reed (*Phragmites australis* [Cav.] Trin. Ex Steud.)

Background: Common reed is a large perennial rhizomatous grass, or reed, forming monotypic stands in wetland areas. It is common in alkaline and brackish environments and can also thrive in highly acidic wetlands. Growth is greater in fresh water but it may be outcompeted in these areas by other species. It can survive in stagnant waters where the sediments are poorly aerated by providing the underground parts of the plant with a relatively fresh supply of air from the air spaces in the aboveground stems and rhizomes. The buildup of litter from the aerial shoots within stands prevents or discourages other species from germinating and becoming established. The rhizomes and adventitious roots themselves form dense mats that discourage annual and perennial native establishment. Killing frosts may knock the plants back temporarily but can ultimately increase stand densities by stimulating bud development (CSU 2000).

Description: The plants generally flower and set seed between July and September and may produce great quantities of seed. However, some or most of the seed produced is not viable, and most reproduction results from rhizomes (TNC 2006). Individual rhizomes live for 3 to 6 years, and buds develop at the base

of the vertical tip late in the summer each year. These buds mature and typically grow about 3 feet (1 m) before terminating in an upward apex and going dormant until spring. The apex then grows upward into a vertical rhizome that in turn produces buds that will form more vertical rhizomes. Vertical rhizomes also produce horizontal rhizome buds, completing the vegetative cycle. These rhizomes provide the plant with a large, absorbent surface that brings the plant nutrients from the aquatic medium. The aerial shoots arise from the rhizomes. They are most vigorous at the periphery of a stand where they arise from horizontal rhizomes, as opposed to old vertical rhizomes. Germination is not affected by salinities below 1% but declines at higher salinities. Following seed set, nutrients are translocated down into the rhizomes, and the aboveground portions of the plant die back for the season (Belliston et al. 2004).

Control: The only biological control at this time is grazing by cattle or goats. Naturally occurring parasites have not proven to be successful control agents. Coots, nutria, and muskrats may feed on common reed but appear to have limited impacts on its populations. Burning is only successful if root burn occurs but rarely happens because a layer of soil or mud usually covers the rhizomes. Flooding can be used to control common reed when 3 feet (0.9 m) of water covers the rhizome for an extended period during the growing season, ideally for up to 4 months. However, flooding could also destroy communities of desirable plants.

Rodeo® with a surfactant that allows it to stick to and subsequently be absorbed by the plant is commonly used for common reed control. This herbicide is not, however, selective and will kill grasses and broadleaved plants alike, although it is virtually nontoxic to all aquatic animals tested (TNC 2006). Application must take place after tasseling stage in the fall when the plant is supplying nutrients to the rhizome. At this time, when Rodeo® is sprayed onto the foliage of common reed, it translocates into the roots and interferes with essential plant growth processes, causing gradual wilting, yellowing, browning, and deterioration of the plants. The dead reeds are resistant to decomposition and require physical manipulation to allow native plant species to reestablish following spraying (CSU 2000). Studies have shown that use of imazapyr is also a highly effective means to control common reed (Mozdzer et al 2008). For improved control of common reed, imazapyr should be applied earlier in June, followed by a late summer to early fall application of Rodeo®.

Russian Knapweed (*Rhaponticum repens* [L.] Hidalgo)

Background: Russian knapweed is native to Eurasia. It was probably introduced to North America as a contaminant in crop seed. It infests rangelands, field edges, pasturelands, roadsides, and other disturbed soils. It can release chemical substances into the soil that inhibit the growth of competing vegetation and can cause chewing disease in horses. It is not restricted to any particular soil, but it does especially well in clay soil. It may be outcompeted in moister locations due to competition with perennial grasses (Belliston et al. 2004).

Description: Russian knapweed can be distinguished from other knapweeds by the pointed papery tips of the floral bracts. The flower heads of Russian knapweed are urn-shaped, solitary, and composed of disk flowers only with pink or purple petals. It spreads primarily by creeping horizontal roots and does not appear to reproduce extensively from seed. Shoots emerge in early spring shortly after soil temperatures remain above freezing. All shoot development originates from root-borne stem buds. These buds arise adventitiously at irregular intervals along the horizontal roots. Plants form rosettes and bolt in late May to mid-June; once plants bolt, there are no buds capable of reproduction until fall. Russian knapweed flowers from June to October (Belliston et al. 2004; CSU 2000).

Control: The only biocontrol that has been successful at reducing infestations of Russian knapweed is the gall-inducing nematode *Subanguina picridis*, which has been introduced and established in North America. Although the nematode is effective in reducing plant biomass and flowering, infections are not

consistent from year to year because of varying moisture conditions. The nematode does not move readily; thus, it needs to be propagated and redistributed on a large scale, which is not cost effective with present techniques. For these reasons, other organisms are being considered for biological control. The seed head weevil (*Eustenopus villosus*), a biological control agent of yellow starthistle (*Centaurea solstitialis*), occasionally feeds on Russian knapweed seed heads and causes them to abort. Three fungi have been found on Russian knapweed: *Alternaria* sp. and *Puccinia acroptili*, which attack the leaves, and *Sclerotinia sclerotiorum*, which infects the roots (Coombs et al. 2004).

Cutting or grazing the aboveground portion of the plant reduces the current year's growth; it may eliminate seed production, but it will not kill Russian knapweed. Goats prefer the flowering heads, but will occasionally graze green tissue (Lamming 2001). Removing aboveground biomass several times before the plants bolt stresses Russian knapweed plants and forces them to use nutrient reserves stored in the root system. The plants that re-emerge are usually smaller in size and lower in vigor. Once plants have bolted, there are no more buds capable of reproduction (until buds begin to form again in mid-August to September).

A combination of cutting and herbicides can be used to control Russian knapweed. In the fall, apply aminopyralid to any plants that have re-emerged. This process may have to be repeated annually for several years to exhaust the soil seed bank. Picloram is widely used on Russian knapweed and is considered to be the most effective herbicide regardless of time of application, but this is a highly toxic chemical and should be used with caution. Milestone (aminopyralid) is effective when sprayed on dormant plants in the fall, if followed by reseeding the following year. Seeding with desirable grass species that will compete for resources but not be affected by the broadleaf herbicides is critical.

Johnsongrass (*Sorghum halepense* [L.] Pers.)

Background: Johnsongrass was introduced from the Mediterranean to the United States as a forage grass. However, when under frost or moisture stress, it forms hydrocyanic acid that is toxic to livestock. It aggressively crowds out native species, especially along riverbanks and ditches (Belliston et al. 2004).

Description: Johnsongrass is a hardy, warm-season perennial grass with erect stems 2 to 8 feet (0.6 to 2.4 m) tall that may be rusty red near the base. The mature flowers are large open panicles that bear many awn-tipped, shiny, reddish to purplish spikelets, with reddish brown, awned seeds. Leaf blades are flat with conspicuous midveins and are often as much as 1 inch (2.5 cm) wide. Both leaf sheath and blade are hairless, and ligules are prominent, jagged, and membranous (CSU 2000).

Johnsongrass has thick, creeping rhizomes that are usually present at an early stage. Colonization can occur from both rhizomes and seed, and seeds can remain viable for over 2 years in the soil (Belliston et al. 2004).

Control: Small infestations can be controlled by hand pulling the plants when the soil is moist. Mowing after seed head development but before flowering can be used. However, acceptable results will usually require multiple mowings per year over several growing seasons by depleting the nutrient reserves in the root system. Care should be taken not to spread rootstock pieces as they can reestablish (CSU 2000). Due to the toxicity of Johnsongrass, grazing should be carefully monitored.

Chemicals are usually effective in control of Johnsongrass; Glyphosate at 1.5 lb active ingredient per acre when the plants are 12 to 18 inches (30 to 45 cm) tall or Fluzifop-P-butyl at 43 to 48 ounces per acre when seedlings are actively growing and between 2 and 8 inches (5 and 20 cm) tall. Sulfometuron methyl can be applied early post-emergence with a reapplication when regrowth begins; it works best when applied when soils are moist to help translocate the herbicide to the root system (CSU 2000).

Medusahead (*Taeniatherum caput-medusae* [L.] Nevski)

Background: Medusahead was brought to the United States from Eurasia in the late 1880s. Medusahead is a major concern to the range livestock industry because it can suppress desirable vegetation and is unpalatable to livestock. As the plant matures, it develops long, barbed awns that can cause injury to the eyes, nose, and mouth of grazing animals. Medusahead has little to no feed value to livestock at any stage of growth, although livestock will use it when other feed is limited (Archer 2001).

Medusahead and cheatgrass overlap in distribution and habitat requirements. Each can replace other herbaceous vegetation and share dominance with the other. Cheatgrass occupies a larger geographical area than medusahead, which extends to drier areas of the semiarid western United States. Medusahead maintains its dominance on sites where native vegetation has been eliminated or severely reduced by overgrazing, cultivation, or frequent fires. It has invaded seral communities in eastern Oregon and Idaho and replaced cheatgrass as the dominant alien grass (USDA 2006).

Description: This winter annual grass ranges from 6 inches (15 cm) to 2 feet (0.6 m). The leaf blades are narrow, approximately 0.12 inch (3 mm) wide in size. The 4-inch (10-cm) seed awns become twisted as the seed matures. It is sometimes confused with foxtail barley or squirreltail, but is different in that the seed head does not break apart completely as the seeds mature (Belliston et al. 2004).

Medusahead is entirely dependent on seed production for regeneration. It is an extremely capable seeder because of its large annual production of viable seed and because its seed maintains viability in litter and soil for at least 1 year. Plants produce up to 6,000 seeds per square foot of soil, propagating dense stands in succeeding years. Medusahead is principally self-fertilizing; most of the pollen grains are dispersed within the floret, and only a moderate number of pollen grains are produced in each of the short anthers.

Control: Two smut diseases that eliminate seed production were identified by USDA Agriculture Research Service in 2002–2003 and are currently being researched (USDA 2006). Burning medusahead can destroy large amounts of seeds if the seed head has not disseminated, reducing the stand by 60% to 95% in the next growing season. A slow burn in dense medusahead stands that occur on well-developed soil profiles may reduce seed production. On less developed soil profiles where prescribed fire is not feasible, grazing livestock when plants are actively growing, herbicide treatment, reseeding, or a combination of these methods may be tried. Imazapic has been shown to be effective on medusahead.

Chemicals are usually an effective control method: glyphosate at 1.5 pounds active ingredient per acre when the plants are 12 to 18 inches (30 to 45 cm) tall or Fluzifop-P-butyl at 43 to 48 ounces per acre when seedlings are actively growing and between 2 and 8 inches (5 and 20 cm) tall. Sulfometuron methyl can be applied early post-emergence with a reapplication when regrowth begins; this works best when applied when soils are moist to help translocate the herbicide to the root system (CSU 2000).

Tamarisk (*Tamarix ramosissima* Ledeb.)

Background: Tamarisk is an aggressive, woody invasive plant that has become established over as much as 1 million acres of the western United States. Tamarisk crowds out native stands of riparian and wetland vegetation. It increases the salinity of surface soil, rendering the soil inhospitable to native plant species. Tamarisk provides generally lower wildlife habitat value than native vegetation and uses more water than comparable native plant communities. These plants can widen floodplains by clogging stream channels and can increase sediment deposition due to the abundance of tamarisk stems in dense stands (CSU 2000). This species is only listed as a noxious weed in Uintah County, although it is present in water corridors and waste areas throughout Utah.

Description: This deciduous, loosely branched shrub has whitish or pinkish flowers borne on slender racemes. The leaves are minute, appressed, and scaly. The primary root can grow as deep as 100 feet (30 m) or more, and horizontal roots can spread after reaching the water table (CSU 2000).

Control: This tamarisk leaf beetle (*Diorhabda elongata*) has had tremendous success in the Great Basin controlling tamarisk by defoliating the plant. The third instar larvae and sometimes adult may kill more foliage than they eat by scraping the bark on small twigs. Defoliated plants suffer severe stem dieback, but plants re-sprout from the base. Heavy defoliation after 2 years can kill acres of plants. When food becomes scarce, adults will fly to feed and lay eggs on nearby uninfested plants (Coombs et al. 2004). Currently, the tamarisk leaf beetle is available in Utah primarily in Delta and Moab. Best results are achieved if adult beetles are gathered in July and allowed to lay eggs in the new location before winter. Because of the massive bird and ant predation on the beetles, it is recommended that large populations (10,000 individuals) are introduced at one time (Burningham 2006). The use of the tamarisk leaf beetle to control tamarisk has had negative effects on the federally endangered southwestern willow flycatcher (*Empidonax traillii extimus*) by reducing the flycatcher's available suitable habitat (dense riparian habitats comprising cottonwood/willow and tamarisk vegetation [U.S. Fish and Wildlife Service 2016]) and by reducing nest success (Tracy et al. 2014). Because of these negative impacts, use of the tamarisk beetle may not be a viable option to control tamarisk in Utah.

A variety of herbicides has been used to manage tamarisk; these include triclopyr, imapapyr, glyphosate, and 2,4-D. These are generally applied as cut-stump treatments, although foliar, stem-sprout, root-sprout, injection, frill, and broadcast applications are used as well. When cut-stump treatments are used, the herbicide should be in a nonevaporative base so that the stump does not dry out before the chemical has entered (Invasive Species Specialist Group 2006).

Puncturevine (*Tribulus terrestris* L.)

Background: Puncturevine was first reported in California in 1903 and probably contaminated the wool of sheep imported from the Mediterranean region. This plant is widespread throughout the West and is most often found in croplands, pasturelands, corrals, and along transportation rights-of-way. The spiny burs can cause injury to the mouths and digestive tracts of livestock (Coombs et al. 2004). Puncturevine has been identified as a noxious weed in Cache, Weber, and Morgan Counties and is known throughout Salt Lake County (USDA, NRCS 2012c).

Description: Puncturevine is a prostrate, herbaceous annual. The root system of puncturevine consists of a simple taproot branching into a network of fine roots. The prostrate stems radiate out from the root crown to form a mat. The hairy stems often grow to 6 feet (1.8 m) long and are green to reddish in color. The small yellow flowers appear between June and September and are produced in the leaf axils. The spiny fruits are made up of five burs with two spines each that break apart at maturity, and each bur contains two to four seeds (Belliston et al. 2004).

Control: This plant has been controlled with biological control agents in areas without cold winters. The puncturevine seed weevil (*Microlarinus lareynii*) may produce multiple generations in warm climates. The larvae develop inside the fruits where they feed on the seeds, and the adults emerge and begin to feed on the stems, leaves, flowers, buds, and fruits. Similarly, the puncturevine stem weevil (*Microlarinus lypriformis*) may produce multiple generations in warm climates. The larvae mine the stems and root crowns of the plants, whereas the adults feed on leaves and the undersurface of the stems. Both weevils are readily available and can be collected from the soil litter beneath plants. The best control is provided when both the puncturevine seed weevil and stem weevil are used together. Damage to nontarget plants is not a problem for either species (Coombs et al.2004).

Picloram, applied as a pre-emergence spray, can give adequate but not complete control. The spraying of young plants with amitrole, cholsulfuron, or 2,4-D may also be desirable (CSU 2000).

SALT LAKE COUNTY–LISTED NOXIOUS WEED SPECIES

Sulphur Cinquefoil (*Potentilla recta* L.)

Background: Sulphur cinquefoil is native to Eurasia and was likely introduced to the United States before 1900. It is established across much of the United States. This aggressive perennial can be found in disturbed areas, meadows, pasturelands and rangelands, and shrublands and along roadsides.

Description: Sulphur cinquefoil is an erect herb that grows 1 to 2 feet (0.3 to 0.6 m) tall and has a dark tap root and branched, spreading lateral roots. The stem is woody and stout. Stem and basal leaves are palmately compound with five to seven coarsely toothed leaflets. Each stem branch terminates with a pale to yellow flower with five petals, with 20 to 40 flowers per plant. Seeds are small and ovate with narrow-winged margins. Stems and leaves have relatively sparse, long, coarse hairs (USDA NRCS 2007).

Control: Hand pulling and hoeing may be a practical method of control on small populations of sulphur cinquefoil. Pulling must remove the caudex to be effective. Mowing will reduce flowering and seed production if applied before flowers bloom.

Several herbicides are listed as providing temporary suppression of sulphur cinquefoil, including aminopyralid (5 to 7 ounces per acre), glyphosate (1 to 2 quarts per acre), metsulfuron (0.5 to 1.5 ounces per acre), and 2,4-D (1 to 2 quarts per acre) (USDA NRCS 2007).

NONLISTED INVASIVE SPECIES

Cheatgrass (*Bromus tectorum* L.)

Background: Cheatgrass can greatly alter the species composition of dry native rangeland vegetation by competitive exclusion or reproduction of native plant species and the facilitation of wildfires. Although the invasion of cheatgrass is greatest in drier environments, it is common in all lowland areas in the arid and semiarid West. Disturbance, such as heavy grazing, allows cheatgrass and other annuals to invade and proliferate. The dry stands of cheatgrass increase fire frequency, creating an environment dominated by cheatgrass (CSU 2000).

Description: Cheatgrass is a winter annual grass. The flower has loose, irregularly compound flowering parts with flowers borne on individual stalks. The panicles change color from green to purple to brown as the plant matures and eventually dries out. Branches are slender, drooping, and hairy with up to eight awned spikelets. Leaves are light green and hairy. Sheaths are fused except near the node at the bottom of each sheath. The lower sheaths are conspicuously hairy, whereas the upper sheaths are sometimes smooth. Mature plants are generally 4 to 30 inches (10 to 75 cm) tall (Belliston et al. 2004).

Control: Grazing can help control cheatgrass, and two grazing periods each spring are required for at least 2 consecutive years. Plants should first be grazed at the stage just before the inflorescences emerge and then grazed again before panicles emerge. Grazing intensity needs to be light enough to leave at least a 3-inch (7.6-cm) residual height to protect desirable grasses. Winter grazing of cheatgrass can reduce mulch, thereby hindering cheatgrass establishment and favoring perennial grass establishment in the spring (CSU 2000).

Cutting is not recommended because cut plants will produce new stems and seeds at the cut height. Burning is usually effective after the plant has dried but before the seeds have dropped; however, some seeds will survive (CSU 2000).

There are several types of herbicides that can be used alone or in combination to provide effective control. In most cases, herbicides should be applied in early spring when nontarget species are dormant. The best control is when the plants are 4 inches (10 cm) or less and growing vigorously. Spring-applied herbicides include quizalofop, fluazifop-p-butyl, sethoxydim, glyphosate, and imazapic. Fall herbicide applications should be conducted after cheatgrass seeds have germinated and are beginning to grow; these include sulfometuron methyl and metribuzin (CSU 2000).

Bull Thistle (*Cirsium vulgare* [Savi] Ten.)

Background: Bull thistle is native to Europe and now infests much of North America. It is often found in pasturelands, fields, roadsides, and disturbed sites. It is most common in lower, heavier soils and moist areas (Belliston et al. 2004). This species is only listed as a noxious weed in Beaver County; however, its distribution covers the entire state of Utah (USDA, NRCS 2012e).

Description: Bull thistle is a biennial with a short, fleshy taproot, forming a rosette the first year and bolting and flowering the second year. The stem is 2 to 5 feet (0.6 to 1.5 m) tall, bearing many spreading branches, green or brownish, sparsely hairy, with irregularly and spiny wings. Leaves are highly lobed, prickly on upper surface and cottony underneath. This is a distinguishing character for bull thistle; Canada thistle leaves are glabrous above and glabrous or hairy below. Flowers are 1 to 2 inches (2.5 to 5.0 cm) wide, pinkish purple, and clustered at the end of the branches. Involucral bracts are narrow, spine-tipped, progressively longer, and narrower from outer to inner ones. Flowering occurs between July and September. Seeds are tipped by a circle of plume like white hairs (Whitson et al. 1999).

Control: Biocontrol is available. Repeated mowing, hand pulling, or grazing can be used to stop the spread of bull thistle. Mowing or grazing after flowering but before seed set prevents seed development and dispersal. When pulling bull thistle, it is important to completely remove the crown so that the plant does not simply re-bolt and produce seeds. Repeated visits at weekly intervals over the 4- to 7-week flowering period is necessary when removing aboveground biomass because not all plants flower at the same time.

Bull thistle is most often controlled with herbicides. The most effective chemical control occurs when bull thistle is still in the rosette stage and quickly decreases once the plant has bolted. Aminopyralid offers excellent control when applied at 3 to 5 ounces per acre. Apply both herbicides to rosettes; fall is optimal, although spring applications are also effective. Clopyralid at 0.66 part per acre, chlorsulfuron at 0.5 to 1.0 ounces, and a combination of clopyralid and 2,4-D (Curtail®) at 1 to 2 quarts per acre provide good control when applied from the late rosette stage to early bolting. Seeding with desirable grass species that will compete for resources but not be affected by the broadleaf herbicides is critical.

Common Teasel (*Dipsacus fullonum* L.)

Background: Common teasel grows in open, sunny habitats that range from wet to dry. It is generally found along irrigation ditches, abandoned fields, pasturelands, waste places, and forests. It is spreading rapidly and is known to be collected and spread as an ornamental decoration for dried flower arrangements.

Description: This biennial or sometimes perennial forb has purple flowers that are subtended by spiny, awned bracts. The fruits are four-angled and each contains a single seed. The rosette leaves are conspicuously veined with stiff prickles on the lower midrib. Stem leaves are simple, opposite, and net-veined and clasp the stem. Flowering plants have large, oblong, opposite leaves that form cups that are capable of holding water. Mature plants can grow up to 6 feet (1.8 m) tall. The tap rooted stem is rigid and furrowed with rows of downward turned prickles (CSU 2000).

Control: A flea beetle, *Galeruca fuliginosa*, and the beetle *Galeruca pomonae* were found feeding on teasel in France. Both beetles are currently being tested for host specificity in field and greenhouse trials but have not been released (Coombs et al. 2004). The key to controlling common teasel is to eliminate seed production and exhaust the seed bank in the soil. Common teasel does not reproduce vegetatively and dies after seed production. Therefore, cutting the stalks of flowering plants is recommended as the best control in natural areas. Cut stalks should be bagged and burned, and it usually requires several years of control to deplete the soil seed source. Metsulfuron at 0.3 ounce of active ingredient per acre will control teasel. Dicamba at a rate of 0.25 to 0.50 pound of active ingredient per acre can be applied on teasel rosettes less than 3 inches in diameter. For rosettes greater than 3 inches, increase to 0.5 to 1.0 pound of active ingredient per acre and apply 1.0 to 1.5 pound of active ingredient per acre when teasel is bolting (CSU 2000).

Alyssum (*Alyssum simplex* Rudolphi)

Background: Plants in the *Alyssum* genus are native to Europe, Asia, northern Africa, and the Mediterranean region. They are now found throughout the globe in temperate regions.

Description: *Alyssum minus* is a short, early season annual and a member of the Brassicaceae family. It is a prolific seed producer and is capable of outcompeting other species over large areas. It prefers disturbed sites.

Control: Princep applied as a pre-emergent control is effective. Chlorsulfuron and imazapic are the most effective post-emergent herbicides for members of the Brassicaceae family.

Burdock (*Arctium minus* Bernh.)

Background: Burdock is common throughout the world but most likely originated in Europe and Asia. Its Velcro-like spines allow it to be transported on fur and clothing. It has been used for centuries for its medicinal and edible qualities, and human-introduced populations may have contributed to its wide range.

Description: Burdock is a biennial plant, having first-year basal leaves that are large (over 12 inches [30 cm] across) and second year stems that can reach 5 to 10 feet (1.5 to 3.0 m). Seed heads have long, hooked bracts that attach to fur and clothing.

Control: First-year rosettes are easily controlled using herbicides with 2,4-D. Mature plants can be controlled by manual removal before flowers and burs are formed. Efforts will most likely have to be repeated during the growing season because the plants tend to regenerate from an extensive taproot.

Buffalobur (*Solanum rostratum* Dunal)

Background: Buffalobur (Texas thistle) is native to the United States but can be very invasive, infesting disturbed areas such as corals, gardens, pasturelands, and waste areas. Although not a state-listed noxious weed, it is listed in nearby Davis County and is known to exist throughout Salt Lake County (USDA, NRCS 2012g). It grows in most soil types but prefers sandy soils. It is drought resistant, making it competitive with other less drought tolerant species, but it can also be outcompeted by many desirable species (Belliston et al. 2004).

Description: This annual grows 1 to 2 feet (0.3 to 0.6 m) tall with spines on stems, leaves, and seed heads. Leaves are heavily lobed, are 2 to 5 inches (5 to 12 cm), and have prominent veins. Flowers are yellow with five lobes that flower throughout the summer, and the black, wrinkled, and flattened seeds are enclosed in an enlarged spiny calyx. After the plant has matured, it breaks off at the stem, allowing it to blow around like a tumbleweed, spreading thousands of seeds (Arnow et al. 1980)

Control: There is no biological control at this time for buffalobur. It contains the alkaloid solanine, which is poisonous to livestock. Digging or removing this weed can provide good control, as can cutting or mowing in conjunction with herbicide application. The most effective method of control is to treat with 2,4-D after mowing or cutting before the plant blooms (Whitson et al. 1999).

Mullein (*Verbascum Thapsus* L.)

Background: There are many different species of this genus, most of which originated in Europe (particularly the Mediterranean area). It has been cultivated historically for a wide range of medicinal and other uses, and human introduction has most likely contributed to its spread.

Description: Mullein is a biennial plant that produces a rosette of gray-green leaves covered with a soft pubescence. In its second year, it sends up a flower stalk that can reach up to 6 feet (1.8 m).

Control: Mechanical removal is effective, as the plant will not regenerate from its taproot. Because mullein seedling emergence is dependent on the presence of bare ground, sowing sites with early successional native grasses or other plants may decrease seed germination and the chance of successful emergence of mullein seedlings.

Two insects are known that may have implications for biological control of mullein. The European curculionid weevil, (*Gymnaetron tetrum*), which has been determined to be specific to mullein, and the mullein moth, (*Cucullia verbasci*), have both been introduced to the United States. Larvae of the weevil mature in the seed capsules and cause significant damage to the seeds.

Herbicidal control is an effective option for situations where hand pulling of plants is not practical. Glyphosate should be applied in a 2% solution of triclopyr and water plus a nonionic surfactant.

Cocklebur (*Xanthium strumarium* L.)

Background: Cocklebur is a native to the Americas and Southeast Asia but is now found throughout the globe. Its spiny burs allowed it to be distributed by clothing and fur.

Description: Cocklebur is an annual weed species. Because seeds germinate best after having been soaked in water, it is commonly found in ephemeral ponds or along waterways. The plants are usually between 1 and 2 feet (0.3 and 0.6 m) tall, with heart-shaped leaves. A cluster of oval, prickly burs about 0.75 inch (2 cm) long occur on a terminal spike.

Control: Herbicide treatment of cocklebur is possible. Glyphosate, dicamba, or atrazine applied at post-emergence can be highly effective.

Biological control by grazing is not recommended, as several compounds found in the plant and seed tissue are highly toxic to animals.

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Appendix D

Salt Lake City Open Space Species Lists by Plant Community Type

Table D.1. Sagebrush Grassland and Shrublands Species List

Family	Scientific Name	Common name	Form
Alliaceae	*Allium acuminatum*	Tapertip onion	Forb
Anacardiaceae	*Rhus trilobata*	Skunkbush	Shrub
Apiaceae	*Cymopterus longipes*	Spring-parsley	Forb
Apiaceae	*Lomatium triternatum*	Ternate lomatium	Forb
Asteraceae	*Achillea millefolium*	Yarrow	Forb
Asteraceae	*Antennaria rosea*	Rosy pussytoes	Forb
Asteraceae	*Artemisia lucoviciana*	Louisiana wormwood	Shrub
Asteraceae	*Artemisia tridentata*	Big sagebrush	Shrub
Asteraceae	*Aster adscendens*	Aster	Forb
Asteraceae	*Balsamorhiza macrophylla*	Cutleaf balsamroot	Forb
Asteraceae	*Balsamorhiza sagittata*	Arrowleaf balsamroot	Forb
Asteraceae	*Cirsium undulatum*	Wavy-leaved thistle	Forb
Asteraceae	*Crepis acuminata*	Mountain hawksbeard	Forb
Asteraceae	*Erigeron divergens*	Spreading daisy	Forb
Asteraceae	*Gutierrezia sarothrae*	Broom snakeweed	Shrub
Asteraceae	*Heliomeris multiflora*	Showy goldeneye	Forb
Asteraceae	*Wyethia amplexicaulis*	Mule-sears	Forb
Boraginaceae	*Hackelia floribunda*	Western tickweed	Forb
Boraginaceae	*Cynoglossum officinale*	Hound’s tongue	Forb
Boraginaceae	*Cryptantha torreyana*	Torrey cryptantha	Forb
Boraginaceae	*Lithospermum sp.*	Puccoon	Forb
Brassicaceae	*Arabis holboellii*	Holboell rockcress	Forb
Fabaceae	*Hedysarum boreale*	Northern sweetvetch	Forb
Fabaceae	*Lupinus argenteus*	Silvery lupine	Forb
Hydrophyllaceae	*Phacelia linearis*	Threadleaf scorpionweed	Forb
Onagraceae	*Epilobium brachycarpum*	Autumn willowherb	Forb
Poaceae	*Aristada purpurea*	Purple threeawn	Graminoid
Poaceae	*Bromus tectorum*	Cheatgrass	Graminoid
Poaceae	*Hesperostipa comata*	Needle-and-thread grass	Graminoid
Poaceae	*Poa secunda*	Sandberg bluegrass	Graminoid
Poaceae	*Pseudoroegneria spicata*	Bluebunch wheatgrass	Graminoid
Poaceae	*Thinopyrum trachycarpum*	Slender wheatgrass	Graminoid
Polemoniaceae	*Collomia linearis*	Narrowleaf collomia	Forb
Polemoniaceae	*Microsteris gracilis*	Little polecat	Forb
Polemoniaceae	*Phlox longifolia*	Longleaf phlox	Forb
Rosaceae	*Purshia tridentata*	Bitterbrush	Shrub to Tree
Scrophulariaceae	*Comandra umbellata*	Bastard toadflax	Forb

Table D.2. Bigtooth Maple and Gambel Oak Woodlands Species List

Family	Scientific Name	Common name	Form
Aceraceae	*Acer grandidentatum*	Bigtooth maple	Tree
Apiaceae	*Lomatium dissectum*	Giant lomatium	Forb
Apocynaceae	*Apocynum androsaemifolium*	Spreading dogbane	Forb
Asteraceae	*Agoseris glauca*	Mountain dandelion	Forb
Asteraceae	*Helianthella uniflora*	One-headed sunflower	Forb
Asteraceae	*Heliomeris multiflora*	Hairy goldeneye	Forb
Asteraceae	*Machaeranthera canescens*	Hoary aster	Forb
Asteraceae	*Microseris nutans (cf. Tragopogon dubius)*	Nodding scorzonella	Forb
Asteraceae	*Senecio integerrimus*	Columbia groundsel	Forb
Berberidaceae	*Mahonia repens*	Oregon grape	Subshrub
Boraginaceae	*Mertensia brevistyla*	Wasatch bluebell	Forb
Brassicaceae	*Arabis glabra*	Tower mustard	Forb
Brassicaceae	*Descurainia pinnata*	Blue tansy mustard	Forb
Fagaceae	*Quercus gambelii*	Gambel oak	Tree
Geraniaceae	*Geranium viscosissimum*	Sticky geranium	Forb
Grossulariaceae	*Ribes aureum*	Golden currant	Shrub
Grossulariaceae	*Ribes lacustre*	Black prickly currant	Shrub
Hydrophyllaceae	*Hydrophyllum capitatum*	Ballhead waterleaf	Forb
Hydrophyllaceae	*Hydrophyllum occidentale*	Western waterleaf	Forb
Hydrophyllaceae	*Phacelia heterphylla*	Varileaf scorpionweed	Forb
Liliaceae	*Erythronium grandiflorum*	Dogtooth violet	Forb
Liliaceae	*Zigadenus paniculatus*	Deathcamas	Forb
Poaceae	*Koeleria macrantha*	Junegrass	Graminoid
Poaceae	*Leucopoa kingie*	Spike fescue	Graminoid
Poaceae	*Mountain brome*	Bromus carinatus	Graminoid
Poaceae	*Poa fendleriana*	Muttongrass	Graminoid
Poaceae	*Poa pratensis*	Kentucky bluegrass	Graminoid
Polygonaceae	*Eriogonum heracleoides*	Whorled buckwheat	Forb
Polygonaceae	*Eriogonum racemonsum*	Redroot buckwheat	Forb
Portulaceae	*Claytonia lanceolata*	Lanceleaf spring beauty	Forb
Ranunculaceae	*Delphinium nuttallianum*	Nelson larkspur	Forb
Rosaceae	*Amelanchier alnifolia*	Serviceberry	Shrub to tree
Rosaceae	*Malus sylvestris*	Apple (escaped)	Tree
Rosaceae	*Prunus virginiana*	Chokecherry	Shrub to tree
Rubiaceae	*Galium aparine*	Catchweed bedstraw	Forb
Santalaceae	*Comandra umbellata*	Bastard toadflax	Forb

Table D.3. Riparian Woodlands and Shrublands Species List

Family	Scientific name	Common name	Form
Aceraceae	*Acer grandidentatum*	Bigtooth maple	Tree
Aceraceae	*Acer negundo*	Boxelder	Tree
Apiaceae	*Osmorhiza chilensis*	Sweet cicely	Forb
Asteraceae	*Solidago canadensis*	Goldenrod	Forb
Berberidaceae	*Mahonia repens*	Oregon grape	Subshrub
Betulaceae	*Alnus incana*	Mountain alder	Shrub
Betulaceae	*Betula occidentalis*	Western water birch	Shrub to Tree
Caprifoliaceae	*Lonicera involucrata*	Bearberry honeysuckle	Vine
Cornaceae	*Cornus sericea*	Red osier dogwood	Shrub
Fagaceae	*Quercus gambelii*	Gambel oak	Tree
Grossulariaceae	*Ribes aureum*	Golden currant	Shrub
Grossulariaceae	*Ribes hudsonianum*	Western black currant	Shrub
Liliaceae	*Smilacina racemosa*	False Solomon's seal	Forb
Liliaceae	*Smilacina stellata*	Wild lily of the valley	Forb
Poaceae	*Elymus glaucus*	Blue wildrye	Graminoid
Poaceae	*Poa compressa*	Canada bluegrass	Graminoid
Poaceae	*Poa pratensis*	Kentucky bluegrass	Graminoid
Rosaceae	*Amelanchier alnifolia*	Serviceberry	Shrub
Rosaceae	*Prunus virginiana*	Chokecherry	Shrub to Tree
Rosaceae	*Rosa woodsii*	Woods rose	Shrub
Salicaceae	*Populus angustifolia*	Narrowleaf cottonwood	Tree
Salicaceae	*Populus fremontii*	Fremont cottonwood	Tree
Salicaceae	*Populus x acuminata*	Lanceleaf cottonwood	Tree

Table D.4. Emergent Marsh Wetlands Species List

Family	Scientific name	Common name	Form
Cyperaceae	*Schoenoplectus acutus*	Hardstem bulrush	Graminoid
Cyperaceae	*Schoenoplectus americanus*	Chairmaker's bulrush	Graminoid
Cyperaceae	*Schoenoplectus pungens*	Common threesquare	Graminoid
Juncaceae	*Juncus arcticus*	Arctic rush	Graminoid
Lemnaceae	*Lemna minor*	Common duckweed	Forb
Potamogetonaceae	*Stuckenia filiformis*	Fineleaf pondweed	Forb
Potamogetonaceae	*Stuckenia pectinata*	Sago pondweed	Forb
Potamogetonaceae	*Potamogeton nodosus*	Longleaf pondweed	Forb
Ruppiaceae	*Ruppia cirrhosa*	Spiral ditchgrass	Forb
Typhaceae	*Typha angustifolia*	Narrowleaf cattail	Forb
Typhaceae	*Typha latifolia*	Broadleaf cattail	Forb

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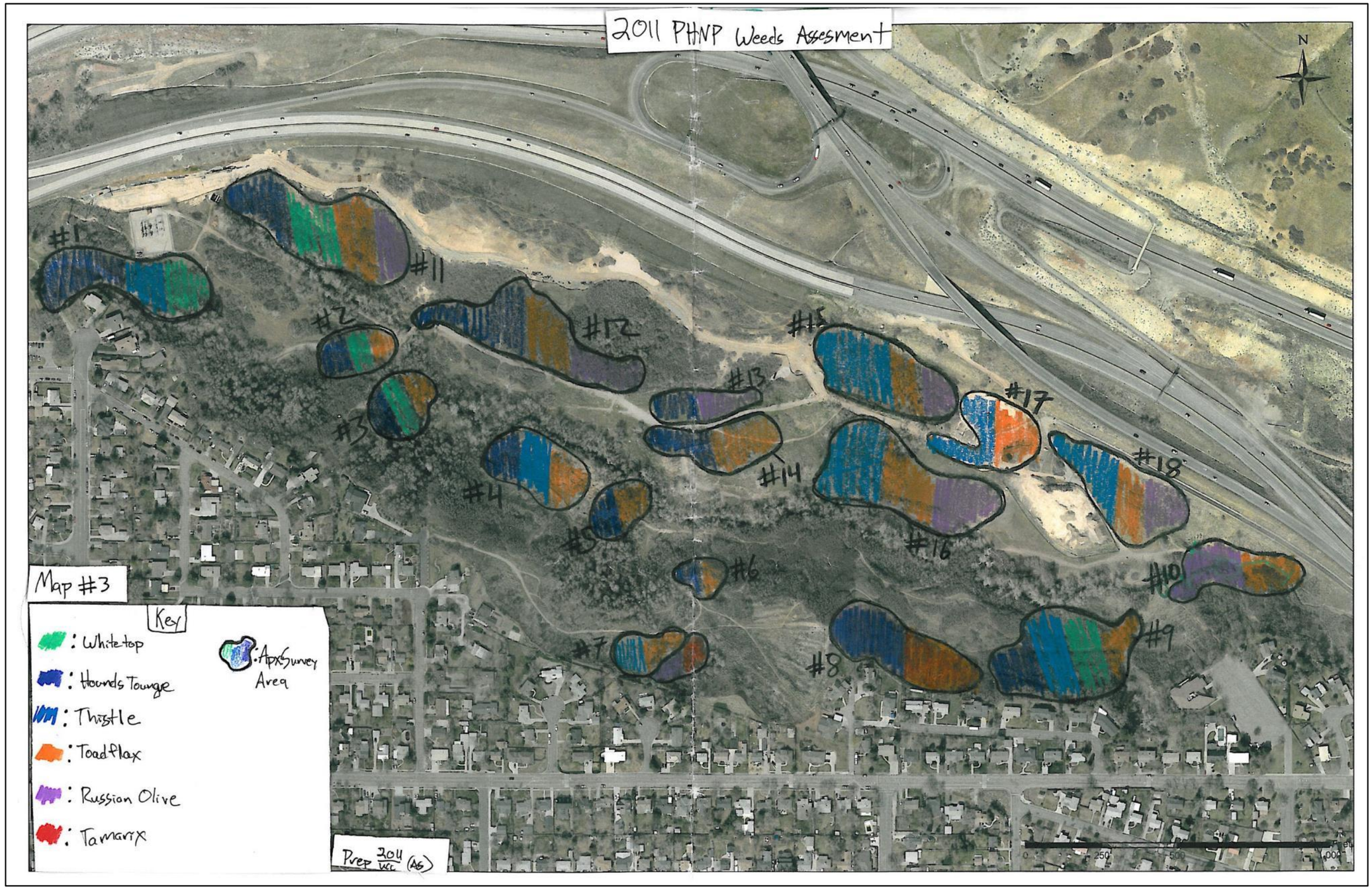
Appendix E

Utah Conservation Corps. Map of Weeds in Parley's Historic Nature Park 2011


2011 PHNP Weeds Assesment
N
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#14
#15
#16
#17
#18
Map #3
Key
: Whitetop
: Hounds Tounge
: Thistle
: Toadflax
: Russian Olive
: Tamarix
: Apx Survey Area
Prep 2011 VCC (AS)
0
250'
500'
1,000'

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Appendix F

Weed Infestations by Salt Lake City Open Space Lands and Management Area

Table F.1. Weed Infestation Acres by Salt Lake City Open Space Parcel in the Foothills Management Area

Parcel	*Cardaria draba*	*Centaurea solstitialis*	*Euphorbia myrsinites*	*Isatis tinctoria*	*Linaria dalmatica*	*Onopordum acanthium*	*Tamarix ramosissima*
921 East			0.3	4.3	0.1	<0.1	
Arcadia Trailhead	0.1		2.1		1.7	0.1	
Bonneville Drive Open Space				0.1			
Bonneville Shoreline Preserve	8.1		0.2	24.3	4.3		
Chandler Drive				1.4	0.2		
City Creek Natural Area	11.5		10.2	33.0	12.0	2.9	
Cohen Property			0.2		1.2		
Columbus Court Natural Area	5.5			41.2	41.7	<0.1	<0.1
Ensign North	0.3		0.7	0.3	<0.1		
Ensign Peak	1.2		0.4	63.0	36.9		
Federal Heights Detention	<0.1			0.1	0.0	0.5	
Foothill Open Space	23.4	19.5	1.9	61.8	23.9		
H-Rock	0.1		1.5		23.8		
Kay Rees Natural Area			3.9	2.9	1.1		
North Bonneville Natural Area				7.3	2.1		
Perrys Hollow Preserve			2.3	3.1	3.7		
Popperton Park	1.4		1.9	13.3	3.5	<0.1	
Richland Drive				0.8			
Tomahawk Natural Area	14.2		2.2	10.0	96.8		
Victory Road Natural Area	0.6		4.8	125.1	3.8	0.1	
Total	**66.6**	**19.5**	**32.5**	**391.9**	**256.8**	**3.7**	**<0.1**

Table F.2. Weed Infestation Acres by Salt Lake City Open Space Parcel in the Jordan River Management Area

Parcel	*Acroptilon repens*	*Cardaria draba*	*Carduus nutans*	*Cirsium vulgare*	*Conium maculatum*	*Cynoglossum officinale*	*Dipsacus fullonum*	*Elaeagnus angustifolia*
1700 South Restoration		2.6			<0.1			<0.1
2100 South Restoration	0.2	0.7			0.1			0.5
2200 West		3.1			0.1			0.4
9 Line Trail		<0.1						
900 South Oxbow		0.6	<0.1		<0.1			
Alzheimer's Wildlife Grove		0.5						
Backman		2.6	0.1	0.1	0.1			<0.1
Bend in the River		1.8			<0.1			0.1
Constitution		0.2						<0.1
Franklin	0.1	0.3						
Goshen		1.0				<0.1		
Jake Garn		1.0						
Jordan River Trail	<0.1	0.1			<0.1			<0.1
KOA	<0.1	1.5		<0.1	0.1			<0.1
Neighborhood House		1.1						
North Riverside	0.3	1.8						
Northwest Recreation Center		0.4						
Peace Gardens Jordan River		0.3						
Regional Athletic Complex	7.0	29.1	0.0		2.5			
Riverview	0.0	3.9	0.3		<0.1		<0.1	
Seven Peaks		0.5			<0.1			
South Riverside		2.9						
Total	**7.6**	**56.0**	**0.3**	**0.2**	**2.9**	**<0.1**	**<0.1**	**1.2**

Table F.2. Weed Infestation Acres by Salt Lake City Open Space Parcel in the Jordan River Management Area (cont.)

Parcel	*Euphorbia myrsinites*	*Lepidium latifolium*	*Linaria dalmatica*	*Onopordum acanthium*	*Phragmites australis*	*Tamarix ramosissima*	*Tribulus terrestris*
1700 South Restoration			<0.1	3.1	<0.1		0.6
2100 South Restoration				0.5			<0.1
2200 West				5.5	0.1		<0.1
9 Line Trail				<0.1			0.2
900 South Oxbow				0.2			0.2
Alzheimer's Wildlife Grove				0.1			<0.1
Backman				0.2			0.5
Bend in the River				1.6	0.1	<0.1	0.9
Constitution							0.3
Franklin							
Goshen				0.8	<0.1		0.5
Jake Garn				0.1			
Jordan River Trail					<0.1		<0.1
KOA				<0.1			0.5
Neighborhood House				<0.1			
North Riverside				<0.1			2.5
Northwest Recreation Center							1.4
Peace Gardens Jordan River				0.4	0.1		0.2
Regional Athletic Complex	<0.1	0.1	<0.1	0.7	1.4		
Riverview				0.8			
Seven Peaks			<0.1	0.6			<0.1
South Riverside				4.2			0.2
Total	**<0.1**	**0.1**	**<0.1**	**18.6**	**1.8**	**<0.1**	**8.0**

Table F.3. Weed Infestation Acres by Salt Lake City Open Space Parcel Parcel in the Tributaries Management Area

Parcel	*Cardaria draba*	*Carduus nutans*	*Conium maculatum*	*Cynoglossum officina*	*Elaeagnus angustifolia*	*Euphorbia myrsinites*	*Lepidium latifolium*	*Linaria dalmatica*	*Onopordum acanthium*
Hidden Hollow	0.6								
Miller Park	1.3								0.5
Parley's Historic Nature Park	7.4	0.2	<0.1	0.3	0.4	6.9	<0.1	1.3	4.1
Wasatch Hollow Open Space	5.0			0.2		0.2		0.1	0.8
Total	**14.3**	**0.2**	**<0.1**	**0.4**	**0.4**	**7.0**	**<0.1**	**1.3**	**5.4**

Appendix G

Herbicide Fact Sheets from EPA with Directory for DVD/CD

Table G.1. Herbicide and Pesticide Information

Name	Active Ingredients	Toxic	Non-toxic	Historic use	Current use	Related Documents
Herbicides						
2,4-D	2,4-dichlorophenoxy	X		X		MSDS, 2,4-D technical information, 2,4-D Toxicity Study 1, 2,4-D Toxicity Study 2
AquaNeat	Glyphosate N-(phosphonomethyl) glycine		X		X	MSDS
Burnout	Clove oil, Sodium Lauryl Sulfate		X		X	MSDS
Dicamba	Dimethylamine salt	X		X		MSDS & Toxicity Information
Dinoseb	2-(sec-butyl)-4,6-dinitrophenol	X		X		MSDS
Ecomazaphyr	Isopropylamine salt of imazapyr	X		X		Specimen Label & MSDS
Escort	Metsulfuron methyl		X		X	Specimen Label & MSDS
Glyphosate T&O	Glyphosate N-(phosphonomethyl) glycine		X		X	Specimen Label & MSDS
Habitat	Isopropylamine salt of imazapyr		X		X	Specimen Label & MSDS
Milestone	Triisopropanolammonium salt of 2-pyridine carboxylic acid 4-amino-3,6-dichloro-		X		X	Specimen Label & MSDS
Tordon	Picloram potassium salt	X		X		Specimen Label & MSDS
Weedmaster	2,4-dichlorophenoxy Dicamba-dimethylammonium	X				MSDS
Pesticides (Mosquito abatement)						
LI 700	Methalacetic acid, phosphatidycholine, alkyl polyoxyethylene		X	X		MSDS
Trumpet	Naled (1,2-dibromo-2,2-dichloroethyl dimethyl phosphate)	X			X	Specimen Label & MSDS
Vectolex	*Bacillus sphaericus* Serotype H5a5b	X			X	Specimen Label & MSDS

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Appendix H

Shrub and Grass Seed Mixes and Restoration Costs

Table H.1. List of Shrub and Grass Species in the Seed Mix

Species	Percentage of Mix	Broadcast Rate (Pure Live Seed lb/acre)
Shrub Species		
Mountain snowberry *Symphoricarpos oreophilus*	2.0	0.6
Antelope bitterbrush *Purshia tridentata*	5.0	1.6
Big sagebrush *Artemisia tridentata* spp. *wyomingensis*	1.0	0.3
Rubber rabbitbrush *Ericameria nauseosa* spp. *albicaulis*	2.0	0.6
Grass Species		
Bluebunch wheatgrass *Pseudoroegneria spicata* spp. *spicata*	20.0	6.4
Slender wheatgrass *Elymus trachycaulus* spp. *trachycaulus*	10.0	3.2
Bottlebrush squirreltail *Elymus elymoides*	10.0	1.6
Canby bluegrass *Poa canbyi*	5.0	0.6
Streambank wheatgrass *Elymus lanceolatus* spp. *psammophilus*	10.0	6.4
Needle and thread grass *Hesperostipa comata* spp. *comata*	5.0	3.2
Western wheatgrass *Pascopyrum smithii*	10.0	3.2
Indian ricegrass *Achnatherum hymenoides*	10.0	3.2
Forb Species		
Wasatch penstemon *Penstemon cyananthus*	4.0	0.6
California poppy *Eschscholzia californica*	1.5	0.5
Munroe globemallow *Sphaeralcea munroana*	1.0	0.3
Blue flax *Linum lewisii*	0.5	0.2
Blanket flower *Gaillardia aristata*	1.0	0.3
Western yarrow *Achillea millefolium* var. *occidentalis*	0.1	0.2
Northern sweetvetch *Hedysarum boreale*	1.5	0.5
Silky lupine *Lupinus sericeus*	0.5	0.2
Total	**90.0**	**24.3**

Note: QuickGuard Sterile Triticale cover crop would be added to the mix at 8.0 pure live seed lb/acre.

Table H.2. Foothills Management Area Recommended Seed Mix

Species	Percentage of Mix	Broadcast Rate (Pure Live Seed lb/acre)
Bluebunch wheatgrass *Pseudoroegneria spicata* spp. *spicata*	30.0	6.4
Slender wheatgrass *Elymus trachycaulus* spp. *trachycaulus*	15.0	3.2
Spike fescue *Leucopoa kingii*	15.0	3.2
Bottlebrush squirreltail *Elymus elymoides*	15.0	1.6
Sandberg bluegrass *Poa secunda*	10.0	1.0
Indian ricegrass *Achnatherum hymenoides*	10.0	3.2
Needle and thread grass *Hesperostipa comata* spp. *comata*	5.0	3.2
Total	**100.0**	**21.8**

Note: QuickGuard Sterile Triticale cover crop would be added to the mix at 8.0 pure live seed lb/acre.

Table H.3. Tributaries Management Area Recommended Seed Mix

Species	Percentage of Mix	Broadcast Rate (Pure Live Seed lb/acre)
Bluebunch wheatgrass *Pseudoroegneria spicata* spp. *spicata*	30.0	6.4
Slender wheatgrass *Elymus trachycaulus* spp. *trachycaulus*	25.0	3.2
Western wheatgrass *Pascopyrum smithii*	25.0	5.0
Bottlebrush squirreltail *Elymus elymoides*	20.0	3.2
Total	**100.0**	**17.8**

Note: QuickGuard Sterile Triticale cover crop would be added to the mix at 8.0 pure live seed lb/acre.

Table H.4. Jordan River Management Area Recommended Seed Mix

Species	Percentage of Mix	Broadcast Rate (Pure Live Seed lb/acre)
Western wheatgrass *Pascopyrum smithii*	50.0	6.4
Inland saltgrass *Distichlis spicata*	25.0	3.2
Sandberg bluegrass *Poa secunda*	25.0	1.0
Total	**100.0**	**10.6**

REVEGETATION SPECIES

Shrub Species

Big Sagebrush (Artemisia tridentata spp. *wyomingensis)*

Sagebrush individuals are generally 1.5 to 3.0 feet (0.5 to 0.9 m) tall at maturity. This species is not shade tolerant; therefore, it grows best on south to west aspects and flat areas. Sagebrush is most common on foothills, undulating terraces, slopes, and plateaus but also occurs in basins and valley bottoms (Cronquist et al. 1994). Sagebrush grows at elevations from 2,500 to 7,000 feet above sea level and requires 10 to 18 inches (25 to 45 cm) of precipitation annually (Hironaka et al. 1983; Winward and Tisdale 1977). This species is not particularly palatable to wildlife; deer will eat this sub-species of big sagebrush if nothing else is available (McArthur et al. 1978). Following disturbance, this species colonizes areas through seed dispersal. Sagebrush have mycorrhizae on roots, which allow them to succeed in nutrient poor soils. This species is easily established through broadcast seeding and bare root shrub planting (USDA 2004). This species is not inhibited by the growth of other shrub, forb, or grass species in its proximity.

Antelope Bitterbrush (Purshia tridentata)

Shrubs of this species are 3 to 13 feet (0.9 to 4.0 m) in height at maturity (Welsh et al 1987). This species is found at elevations from 200 to 11,500 feet (60 to 3500 m) above sea level (USDA 2004). Antelope bitterbrush is relatively shade tolerant; therefore, it is successful on all aspects. It is an early colonizer of disturbed sites, partially because it is a nitrogen fixer (Righetti et al. 1986). Good weed control is required following seedling transplant to ensure success. Bitterbrush requires 12 to 36 inches (30 to 90 cm) of precipitation annually (Short et al. 1966). Bitterbrush is a very palatable forage species for mule deer and a fairly good forage species for elk. It requires well-drained, coarse-textured soils to grow successfully (Martin and Driver 1983). This species re-sprouts following fire.

Rubber Rabbitbrush (Ericameria nauseosa spp. *albicaulis)*

This deciduous shrub species grow from approximately 12 to 90 inches (30 to 230 cm) high. This subspecies of rubber rabbitbrush favors sunny, open sites, foothills, and open slopes from 3,000 to 8,000 feet (900 to 2,400 m) above sea level (Institute for Land Rehabilitation 1979). Rubber rabbitbrush is excellent for soil stabilization and erosion control (Davis et al. 1985). It is also well suited for use on degraded winter ranges (Rosentreter and Jorgensen 1986). Rubber rabbitbrush has a deep root system and can establish rapidly, even on severe sites. Plants produce large quantities of leaf litter, which produces soil mulch. Seedlings are easy to establish, even on unprepared seedbeds (Monsen and Stevens 1987). Drill seeding, direct seeding, and aerial application can all be used effectively. Because it is deciduous, this species is not good winter forage for big game. Rubber rabbitbrush grows on a wide range of soil. In general, preferred soils tend to be medium- to coarse-textured and somewhat basic (Institute for Land Rehabilitation 1979). Rubber rabbitbrush is a fire-adapted species that is typically unharmed or enhanced by fire (Young 1983). Recovery time is often rapid to very rapid. Rubber rabbitbrush is generally regarded as an early seral species that rapidly invades and colonizes disturbed sites (Hegerhorst et al. 1987).

Curl-leaf Mountain Mahogany (Cercocarpus ledifolius)

This evergreen shrub grows 15 to 26 feet (4.5 to 8.0 m) tall and occurs as isolated individual shrubs or in pure, dense patches. This species has medium shade tolerance and grows well on all exposures at elevations from 2,000 to 9,000 feet (600 to 2,700 m) above sea level. It may be readily grown from seed for transplanting, although young transplants are attractive to rodents, lagomorphs, and large game. It requires 11 to 19 inches (28 to 48 cm) of precipitation annually. It is one of the few browse species that meets/exceeds protein requirements for wintering big-game species. It grows best on shallow to moderately deep soil at middle to high elevations on gentle to steep slopes, rock outcrops, and ridges (Duncan 1975). Younger, smaller curl-leaf mountain mahogany may live as understory plants for 100 years or more (Davis 1990).

Gambel Oak (Quercus gambelii)

Gambel oak is a native, broadleaf, deciduous shrub that grows from 3 to 20 feet (0.9 to 6.0 m) high, spreading through underground rhizomes. This species occurs between 4,000 and 9,000 feet (1,200 and 2,700 m) above sea level and requires 15 to 22 inches (38 to 56 cm) of precipitation annually (USDA 2004). Gambel oak requires is relatively shade tolerant; therefore, it is successful on all aspects. Gambel oak is a valuable source of food and cover for many wildlife species. This species is grazed by mule deer throughout the year.

Mountain Snowberry (Symphoricarpos oreophilus)

Mountain snowberry is a deciduous shrub species growing from 2 to 5 feet (0.6 to 1.5 m) tall. It occurs on shallow to deep soils on both slopes and flats. Mountain snowberry is known from 5,000 to 10,000 feet (1,500 to 3,000 m) above sea level (USDA 2004). It is a good wildlife forage species in the summer and fall months. Mountain snowberry is both sun and shade tolerant; therefore, it is successful on all aspects. Due to its rhizomatous nature, mountain snowberry is useful for revegetation of disturbed sites such as road cuts, landscape and recreational plantings, and wildlife habitat improvement (USDA 2004).

Grass Species

The following grass species have been chosen for their success on non-productive soils, their drought tolerance, their longevity, and their slope-stabilizing root growth:

- Bluebunch wheatgrass (*Pseudoroegneria spicata* spp. *spicata*)
- Canby bluegrass (*Poa canbyi*)
- Sheep fescue (*Festuca ovina*)
- Western wheatgrass (*Pascopyrum smithii*)
- Indian ricegrass (*Achnatherum hymenoides*)

The following grass species have been chosen for their fast growth rates and success as erosion control species:

- Slender wheatgrass (*Elymus trachycaulus* spp. *trachycaulus*)
- bottlebrush squirreltail (*Elymus elymoides*)
- Quickguard sterile triticale (a sterile cross between wheat and rye)

Forb Species

The following forb species have been chosen for their success on non-productive soils, their drought tolerance, their longevity, and their beauty:

- Wasatch penstemon (*Penstemon cyananthus*)
- Rocky Mountain penstemon (*Penstemon strictus*)
- California poppy (*Eschscholzia californica*)
- Munro globemallow (*Sphaeralcea munroana*)
- Blue flax (*Linum lewisii*)

The following forb species have been chosen for their drought tolerance and nitrogen-fixing ability:

- Silky lupine (*Lupinus sericeus*)
- Northern sweetvetch (*Hedysarum boreale*)

RESTORATION COSTS

The cost of weed management and land restoration can vary widely based on several factors, including site conditions and size of the project. Difficult site conditions (wet soils, steep slopes, rocky terrain, remote locations) can greatly increase the cost of most projects. Costs can be reduced if on-site materials are available (seed, riprap), or using available existing personnel and machinery. Costs are generally higher for small projects and less for small projects. Costs were obtained by contacting various federal and state agencies and private companies, as well as by consulting information presented by Ostler et al. (2002) in the *New Technologies to Reclaim Arid Lands Users Manual*.

Soil amendments may be necessary in areas of high chemical alteration from mining and smelting operations, and costs can vary widely. Synthetic polymers, organic materials, and fertilizers can be used to improve the soil and provide proper nutrients and water-holding capacity. Transportation of these materials can greatly influence the costs, which can be lowered by using local suppliers. Harrowing or disking in the soil amendments may be necessary and can result in very expensive projects. Fertilization is not common and is normally not recommended in arid restoration. Native perennial plants generally have low nutrient requirements while invasive plants often exploit added nutrients following fertilization (Bilbrough and Caldwell 1997).

Seeding large areas can be accomplished by drill seeding, hydroseeding, or broadcasting. If the seed is not harrowed or raked in, a higher seeding rate should be used to offset the cost of harrowing. Seed costs vary from year to year, based on the availability of seed, and are dependent on yield from the previous season and collection costs. Again, using local suppliers will decrease the cost of seed by reducing transportation costs. The condition of the soil surface, slope of project area, and availability of equipment will determine the most appropriate seeding method. Broadcast seeding can include aerial or hand seeding and often requires higher seeding rates due to the lack of harrowing. Pretreating seeds with mycorrhizae or fertilizer can greatly increase the cost of seed but increase the project success. Seeding costs are listed in Tables H.5 and H.6.

Mulch helps conserve soil moisture, adds organic matter to the soil, and reduces invasive weed infestations. Commonly used materials include straw, hay, and fiber mulch. Hay is more expensive than straw because of its alternative value as feed for livestock. These mulch types may require straw blowing

equipment and often require a wood fiber tackifier to keep straw from blowing from the site. Table H.6 reflects both straw blowing and tacking together. Straw blankets are available for steep slopes and reduce the need for specialized equipment; however, this increases labor costs, resulting in similar costs, compared with straw blowing and tacking.

Transplanting shrubs or trees provides plant material more quickly to offset erosion or weed dominance issues, in addition to increasing aesthetics in high-profile areas such as the Visitors Center and other mine-supporting infrastructure. The availability of suitable containerized trees and shrubs is often limited, so orders need to be placed 1 year in advance to ensure an adequate supply. Shrubs and trees are planted in tubes that cost approximately $1 each.

Goats seem to be better at suppressing weeds rather than eliminating them, and use of goats may need to be combined with other control methods. Generally, 250 to 300 goats are generally fenced in 1-acre patches for 24 to 48 hours, depending on the severity of the weed infestation. They require a water source within the fenced area, or the area needs to be accessible for a truck to deliver water to them. The D'Goat Ranch in Fielding, Utah owned and operated by Dee and Jason Garn, can be reached at (877) 458-3780 or (435) 452-8656. The cost of 1,000 goats is approximately $400 per acre but may need to be adjusted for transportation costs or additional supplements and water (Garn 2006).

Mechanical weed controls, combined with site preparation activities, include ripping, disking, and harrowing. Some form of site preparation is often needed prior to revegetation to reduce compaction, destroy and mulch existing vegetation, and increase moisture infiltration. Ripping or subsoiling are deep tilling operations specifically designed to break or shatter compacted soil layers. Disking can be used to ameliorate shallow compaction and remove unwanted vegetation. Harrowing is less intensive and is used to break up superficial compaction, smooth the soil surface following ripping or disking, and help cover the seeds to ensure the seed-soil contact necessary for germination. All require specialized equipment and trained personnel, adding to the overall cost of the project; costs for the various site preparation practices are listed in Table H.5.

Table H.5. Estimated Costs for Restoration

Activity	Cost Range ($/acre)
Ripping	6–65
Disking	6–50
Harrowing	5–45
Synthetic Polymers	444–744
Organic Materials	50–200
Fertilization	10–150
Broadcast Seeding	5–50
Drill Seeding	8–80
Hydroseeding	1,400–5,600
Seed	100–400
Mulch	128–450

Table H.6. Estimated Costs for Restoration

Treatment	Units	Min. Cost ($)	Max. Cost ($)
Soil			
Coconut coir log	linear feet	2.7	3.7
Erosion blanket	square feet	0.17	0.23
Riparian fencing	square feet	2.5	–
Stream slope grading to 3:1	square feet	0.5	–
Soil lifts	linear feet	75	–
Excavation	cubic yard	1.75	–
Material removal	cubic yard	5	7
Soil Import	cubic yard	5	7
Plants			
Pole plantings	each	0.5	5
Dormant cuttings 2' spacing	linear feet	3.74	–
30" deep rooted willows	linear feet	10.31	–
3"–4" tubelings or bareroot stock	each	0.79	1.49
Containerized plants – 2 gallon	each	8	15
Containerized plants – 5 gallon	each	15	39
Containerized plants – 10 gallon	each	79	159
Containerized willows – 1 gallon	each	2.79	10
Containerized willows – 5 gallon	each	7.03	–
Wetland sod	linear feet	19.05	–
Seed			
Wetland seed mix (plus installation)	acre	5,590.00	6,450.00
Riparian seed mix (plus installation)	acre	3,440.00	4,730.00
Upland seed mix (plus installation)	acre	2,580.00	4,730.00
Wetland sedge seed	acre	2,200.00	–
Wetland grass seed	acre	612	–
Upland grass seed	acre	340	–
Irrigation			
Irrigation	square feet	0.15	–

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Appendix I

Point-Intersect Transect Form and Treatment Tracking Form Examples

Appendix I.1.

Point-intercept Transect Form Example

POINT-LINE INTERCEPT

Date _____ Observer _____

Site # _____ Recorder _____

Transect 1

	Ground	Species				
	Code	Code	Code	Code	Code	Code
1m						
2m						
3m						
4m						
5m						
6m						
7m						
8m						
9m						
10m						
11m						
12m						
13m						
14m						
15m						
16m						
17m						
18m						
19m						
20m						

Transect 2

	Ground	Species				
	Code	Code	Code	Code	Code	Code
1m						
2m						
3m						
4m						
5m						
6m						
7m						
8m						
9m						
10m						
11m						
12m						
13m						
14m						
15m						
16m						
17m						
18m						
19m						
20m						

Non-tallied plant species:

TOTALS

CODE	COUNT	%

Count (transect length) X 100 = %

Appendix I.2.

Treatment tracking form Example

Salt Lake City Weed Tracking Database								
Observer	**Location**	**Observation date**	**Treatment implemented**	**Follow-up procedure**	**Habitat type**	**Area (ac)**	**Density**	**Phenology**

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Appendix J

Salt Lake County Noxious Species List

Table J.1. Salt Lake County Species List

Common Name	Species Name	Salt Lake County	Utah	Family Name
Poison hemlock	*Conium maculatum*	Noxious	Noxious	Apiaceae
Canada thistle	*Cirsium arvense*	Noxious	Noxious	Asteraceae
Diffuse knapweed	*Centaurea diffusa*	Noxious	Noxious	Asteraceae
Musk thistle	*Carduus nutans*	Noxious	Noxious	Asteraceae
Purple starthistle	*Centaurea calcitrapa*	Invasive	Noxious	Asteraceae
Russian knapweed	*Acroptilon repens*	Noxious	Noxious	Asteraceae
Scotch thistle	*Onopordum acanthium*	Noxious	Noxious	Asteraceae
Spotted knapweed	*Centaurea maculosa*	Noxious	Noxious	Asteraceae
Squarrose knapweed	*Centaurea squarrosa*	Noxious	Noxious	Asteraceae
Oxeye daisy	*Chrysanthemum leucanthemum*	Noxious	Noxious	Asteraceae
Yellow starthistle	*Centaurea solstitialis*	Noxious	Noxious	Asteraceae
Houndstongue	*Cynoglossum officinale*	Noxious	Noxious	Boraginaceae
Garlic mustard	*Alliaria petiolata*	Noxious	Noxious	Brassicaceae
Hoary cress	*Cardaria draba*	Noxious	Noxious	Brassicaceae
Perennial pepperweed	*Lepidium latifolium*	Noxious	Noxious	Brassicaceae
Dyer's woad	*Isatis tinctoria*	Noxious	Noxious	Brassicaceae
St. John's wort	*Hypericum*	Noxious	Not listed	Clusiaceae
Field bindweed	*Convolvulus arvensis*	Noxious	Noxious	Convolvulaceae
Leafy spurge	*Euphorbia esula*	Noxious	Noxious	Euphorbiaceae
Myrtle spurge	*Euphorbia myrsinites*	Noxious	Noxious	Euphorbiaceae
Purple loosestrife	*Lythrum salicaria*	Noxious	Noxious	Lythraceae
Bermuda grass	*Cynodon dactylon*	Noxious	Noxious	Poaceae
Johnson grass	*Sorghum halepense*	Noxious	Noxious	Poaceae
Medusahead	*Taeniatherum caput-medusae*	Noxious	Noxious	Poaceae
Quackgrass	*Elymus repens*	Noxious	Noxious	Poaceae
Common reed	*Phragmites australis*	Invasive	Noxious	Poaceae
Sulphur cinquefoil	*Potentilla recta*	Noxious	Not listed	Rosaceae
Dalmatian toadflax	*Linaria genistifolia*	Noxious	Noxious	Scrophulariaceae
Yellow toadflax	*Linaria vulgaris*	Noxious	Noxious	Scrophulariaceae
Black henbane	*Hysocyamus niger*	Noxious	Noxious	Solanaceae
Tamarisk	*Tamarix chinensis*	Noxious	Noxious	Tamaricaceae
Puncturevine	*Tribulus terrestris*	Noxious	Noxious	Zygophllaceae

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