Invasive Plant Management Guidance
Nixon Fork Mine, Alaska

Report prepared by Casey Greenstein & Helen Cortés-Burns

Alaska Natural Heritage Program
UNIVERSITY of ALASKA ANCHORAGE

The Alaska Natural Heritage Program – University of Alaska Anchorage
707 A Street
Anchorage, Alaska 99501

Prepared for

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Bureau of Land Management
Anchorage Field Office
4700 BLM Road
Anchorage, AK 99507-2599

February 25, 2013

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Cover photo: Taken from the pond at Nixon Fork Mine, Laurie Thorpe (BLM)

Acknowledgements

The Bureau of Land Management, Anchorage Field Office funded this project. Laurie Thorpe (BLM) in particular was instrumental in mobilizing this effort and has supplied valuable input throughout. I would also like to thank the Nixon Fork staff, particularly Josh Bishoff, for their help while preparing and conducting this invasive plant study. Matt Carlson (Alaska Natural Heritage Program, UAA) assisted in development of previous drafts.

Introduction

The establishment, growth, and persistence of non-native[11] plant species pose a serious threat to native ecosystems. Even though not all non-native species cause significant economic or ecological harm, a smaller proportion of these plants may be invasive[2] and may significantly alter community composition, successional pathways, nutrient cycling, hydrology, and fire regimes, as well as to reduce or eliminate threatened and endangered native species populations (U.S. Congress 1993, Busch 1995, Myers 1997, Brooks 1999, Stein et al. 2000).

While invasive plants constitute a major problem in the lower 48 states (Randall 1996), Alaska has remained much less affected. However, over the last ten years there has been a marked acceleration in the rate of introduction of non-native plants to the state, probably driven by increases in population, commerce, development, gardening, and outdoor recreation activities (Carlson and Shephard 2007). Invasive species have become costly in Alaska, with an annual average of $5.8 million spent between 2007 and 2011 (Schwörer et al. 2012).

The susceptibility of native plant communities to invasion is largely a function of the degree of natural or anthropogenic disturbance (Hobbs and Huenneke 1992). In Alaska, non-native plant occurrence is most strongly correlated with high-use, and therefore highly disturbed, areas such as urban centers and transportation routes. Invasive plants establish in these types of areas because there are more opportunities for introduction, less competition from native plants, and plenty of disturbed substrates on which invasive species (hereafter also referred to as weeds) thrive. However, in some cases invasive weeds have been documented moving off the human footprint into natural ecosystems. In interior boreal Alaska, these species include, but are not limited to, *Caragana arborescens, Crepis tectorum, Hieracium umbellatum, Melilotus albus,* and *Vicia cracca* (Lapina et al. 2007; Cortés-Burns et al. 2007, 2008; Conn et al. 2008; Villano and Mulder 2008).

In addition to direct anthropogenic factors, climate change may also affect non-native plant establishment. At higher latitudes climate change is more pronounced (Holland and Bitz 2003), which may lead to a higher rate of non-native species establishment and accelerated population growth in the future. Non-native species are often more adaptable and better competitors (Prentis et al. 2008) relative to native species, so they may be at an advantage with changing weather and temperature patterns. Native species have slower migration rates (Malcolm et al. 2002, van Grunsven et al. 2007) and thus are likely to lag behind invasive species in their response to environmental changes. The compounding impacts of climate change on invasive species augments the need to prevent and manage non-native species in Alaska.

In Alaska's boreal forests – as delineated by Nowacki et al. (2003) - in which Nixon Fork Mine is situated, 169 non-native plant species were present as of 2013. Many native species of the boreal forest are stress tolerant, including bryophytes, lichens, and ericoid shrubs, but are difficult to reestablish once they are removed (Grime 1979, Haeussler et al 2002); if eliminated from an area (e.g. by fire, clear cut logging, roads, resource extraction, pipelines) habitats are opened up for more opportunistic species. Thus, as the frequency and scale of these types of disturbances increase, so does the chance that invasive species will be introduced and successfully establish (Byers 2002).

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[1] Invasive plants are non-native plants that produce viable offspring in large numbers and have the potential to establish and spread in natural areas (AKEPIC 2005). Some invasive plants have strong negative impacts on native ecosystems, cause important economic losses, or can be detrimental to human health.

Some specific examples of the deleterious effects non-native plants have on boreal forests are included in Appendix I. Moreover, a large number of non-native species currently inhabiting boreal forests were intentionally introduced in conjunction with revegetation aimed at preventing erosion and stabilizing soil after disturbance. Roadside reseeding is responsible for the introduction of several non-native species in remote areas. For these reasons, prevention, risk assessment, and proper restoration approaches should be a top priority in areas undergoing development (Sanderson et al. 2012).

Mines in remote locations are of particular concern because they provide opportunities for weeds to spread from urban centers to remote locations, facilitating their establishment in natural ecosystems. Additionally, mines inherently have a high rate of substrate disturbance, further aiding non-native plants in establishing self-perpetuating populations.

Background information and objectives

Nixon Fork mine is located in west central Alaska, approximately 13 kilometers (eight miles) north of Medfra and 51 kilometers (32 miles) northeast of McGrath (Figure 1). The elevation of the mine ranges from 282 meters (925 feet) to 419 meters (1375 feet) above sea level.

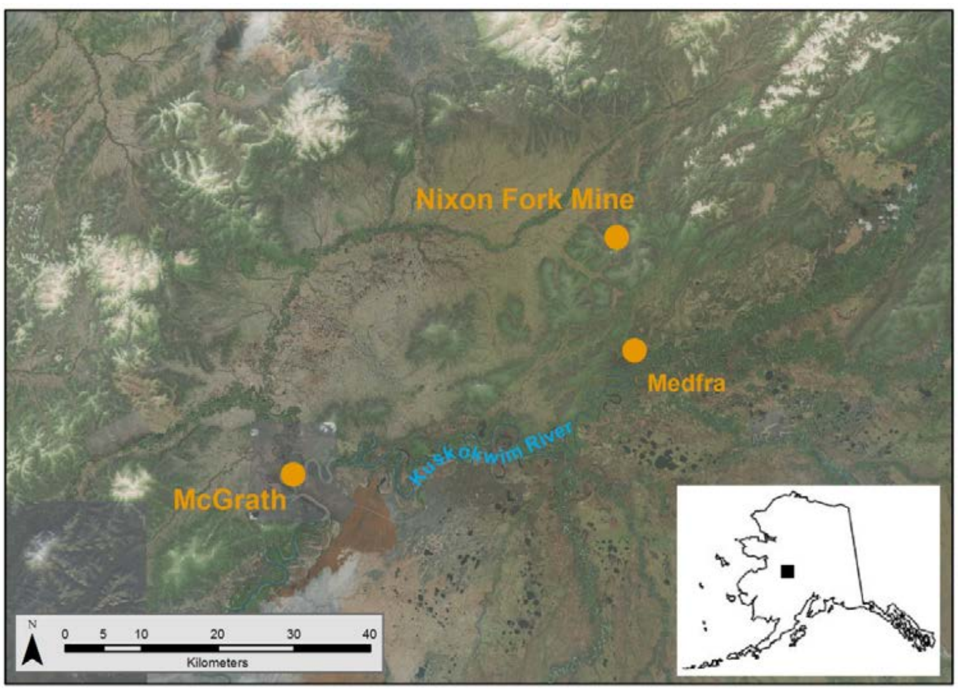

Figure 1. Location of Nixon Fork Mine within Alaska

Nixon Fork Mine is an underground gold mine first staked in 1917 and has been actively mined sporadically between then and the 1950s. Most vegetation was cleared from the site in the 1920s, but has since regenerated. After several decades of disuse it was permitted and active from 1995 to 1999, at which time a number of features were developed, including a 4200-foot airstrip, road system, shop, mill, tailings impoundment, water supply system, utility system, 50-person camp, and offices. The Mine was re-opened by Mystery Creek Resources, Inc. in 2003 to resume mining, clean up the site, maintain facilities, and conduct further mineral exploration (ADNR undated).

The historical access route for the site is a Department of Transportation 13-mile road from the town of Medfra; this route is still used in the winter but is impassible in the summer except by four-wheeler. In the future, this road may be improved, so that materials and equipment can be sent by barge up the Kuskokwim River to Medfra and driven to the site (Josh Bishoff, pers. comm., Dec 11, 2012; Mystery Creek Resources, Inc. 2005). Presently, the Mine is accessible only by charter plane, with flights originating out of McGrath, Fairbanks or Anchorage (Travis/Peterson Environmental Consulting, Inc. 2011).

As of 2005 approximately 90 acres were disturbed at the site, reflecting development and deforestation occurring primarily in the 1990s. With the mine now active, it is estimated that an additional 10 acres per year may be cleared for surface exploration. Through the 1970s to date, exploration has cleared multiple areas, and there is an established trail system throughout the region for accessing exploration sites (Mystery Creek Resources, Inc. 2005).

The mine is found in a mixed spruce-birch forest. The area supports common interior boreal tree species, including white spruce, black spruce, quaking aspen, balsam poplar (cottonwood), and paper birch (Viereck and Little 1972). White spruce is dominant on well drained, higher slopes, and black spruce dominates wetter lowland areas. Riparian areas primarily host willows and alders. The understory is composed of common boreal shrub and herb species, including dwarf birch, Labrador tea, bunchberry, high and low-bush cranberry, crowberry, bog blueberry, leatherleaf, cloudberry, horsetail, willow, prickly rose, fireweed, and Canada bluejoint; wetter areas have a ground cover of moss, and dry slopes are populated by grasses (Selkregg 1975). Historic and recent mining activities have resulted in roads and other disturbed areas with sparse vegetation. At these sites both native and non-native ruderal species are found, including native fireweed, salmonberry, and alder, and non-native dandelion (Mystery Creek Resources, Inc. 2005). For a more detailed description of forest type variation throughout the site, see the Nixon Fork Mine Environmental Assessment (Mystery Creek Resources, Inc. 2005).

The Bureau of Land Management Anchorage Field Office (BLM-AFO) administers the Nixon Fork Mine region and requires the establishment of an invasive plant management plan for the site. In support of this future plan, the BLM-AFO entered in to an agreement with the Alaska Natural Heritage Program (AKNHP) to conduct a non-native plant inventory of disturbed sites throughout Nixon Fork Mine and to establish best management practices to address existing populations, potential future infestations, and to limit new introductions and spread. Ecological degradation due to invasive plants has been a costly problem for mines in the lower 48 states, and early implementation of invasive plant management plans in Alaska may help the state avoid similar impacts.

This report describes the findings from the 2012 Nixon Fork Mine non-native plant study, outlines best management practices (BMPs) and early detection rapid response (EDRR) measures, prioritizes sites for monitoring and control, and explains control methods to manage and limit future unwanted introductions.

2012 Weed survey results

On August 19, 2012, AKNHP conducted an invasive plant survey at Nixon Fork Mine, targeting areas of high traffic and human disturbance. These areas were selected based on conversations with mine staff. Observations of native and non-native plant species were also made while moving between the target areas. No new or highly-invasive species were encountered between sites. The following describes the location and taxonomic identity of non-native species were found at, each site[2]. Figure 2 shows the locations of each plot within the Nixon Fork Mine area. Table 1 provides a summary of all non-native plants found across all sites.

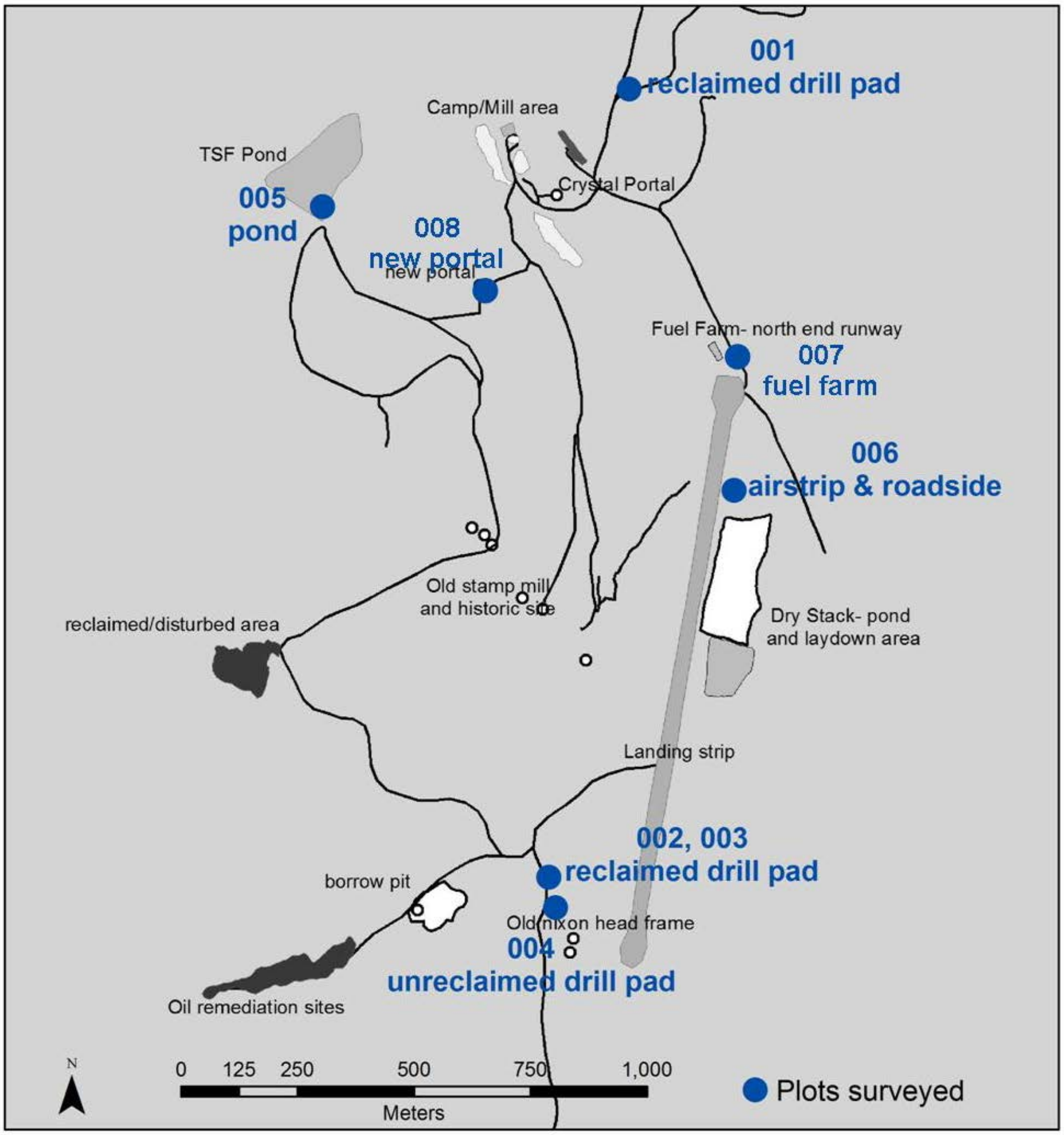

Figure 2. Locations of plots surveyed for non-native plants at the Nixon Fork Mine, Alaska.

[2] Plots 001-006 were read by AKNHP on August 19, 2012. Plants were collected at plots 007 and 008 by the BLM on June 18, 2012 and were subsequently identified by AKNHP. For detailed site descriptions see Appendix II.

Table 1. Overview of all non-native plants found.

Scientific name	Common name	Invasiveness Rank[3]	001	002	003	004	005	006	007	008
Crepis tectorum	narrowleaf hawksbeard	56						0.1	x	
Descurainia sp.[†]	tansy mustard	41							x	
*Hordeum jubatum**	foxtail barley	63			0.001		0.1	0.1		
Matricaria discoidea	pineappleweed	32					0.01			
Plantago major	common plantain	44			0.001		0.01			
Taraxacum officinale	common dandelion	58	0.001		0.001	0.01	0.1			
Trifolium hybridum	alsike clover	57					0.1			
Trifolium repens	white clover	59								x

Numbers 0.001-0.1 indicate size of infestation in acres. Cells marked with an "x" indicate presence, but infestation size was not documented.
**Hordeum jubatum* appears to be native to the eastern and central interior of Alaska, but has expanded its range dramatically in the last few decades and can cause health concerns for dogs and wildlife.
[†] *Descurainia* sp. at the site is either native *D. sophioides* or non-native *D. sophia*. The specimen collected for identification was too young to be positively identified.

Weed management at Nixon Fork Mine

Presently, Nixon Fork Mine harbors only a few non-native plant species, many of which are considered to represent a minor threat to the local ecosystems (i.e. relatively low Invasiveness Rank[3]). *Taraxacum officinale* was present at the most sites; *Hordeum jubatum* occupied the greatest acreage; and Site 5 (the Pond) was the most infested, harboring five species and greatest area of recorded infestation. However, it should be noted that *Crepis tectorum* has become a major problem in other parts of Alaska (e.g. Campbell Tract in Anchorage), and may warrant top priority for control.

For the most part, the present weed populations are found along roads and at disturbed sites, growing among native ruderal species, such as fireweed, salmonberry, and alder saplings and do not yet appear to be moving into undisturbed, natural areas. However, it is worth noting that invasive plants often have a lag time between their establishment and spread, so these incipient populations may exhibit more aggressive

[3] Invasiveness Rank is calculated based on a species' ecological impacts, biological attributes, distribution, and response to control measures. The ranks are scaled from 0 to 100, with 0 representing a plant that poses no threat to natural ecosystems and 100 representing a species that poses a major threat to natual ecosystems (see Carlson et al. 2008 for more information).

behavior in the future.

Many of the less-invasive species (such as *Plantago major*) found at the Mine are widespread throughout Alaska and are strongly associated with roadside habitats; they are often introduced to sites through contaminated heavy equipment and/or imported fill. These small populations pose little threat to ecosystem structure and function and the likelihood of reintroduction from people, vehicles, and equipment is high. For these reasons, we recommend that efforts should be placed first on preventing the introduction of new, more aggressive species to the site and second on controlling the ruderal non-native species currently present.

Minimizing the introduction and spread of non-native species and populations can be accomplished by following best management practices (BMPs) and early detection and rapid response (EDRR) measures, and by monitoring known and susceptible areas of infestation, as well as involving Mine staff in weed management.

Best management practices (BMPs)

In order to minimize impacts to natural resources, construction, maintenance, or mineral extraction projects should assess risks associated with weeds in the planning stage, including the likelihood of spread into the project area, and the potential effects of weed establishment in the area. Similarly, maintenance operations should also evaluate the potential impact of weeds. If a risk or threat is identified in the planning stages, weed prevention practices should be developed. Not all weed management actions are appropriate for all sites; management plans need to be site-specific. Prevention practices should be evaluated to ensure they meet project-specific goals and stipulations, can be feasibly implemented, and are cost-effective. The latter should compare the costs associated with implementing a project, versus the cost associated with doing nothing and dealing with the consequent ecological damage (USDA Forest Service 2001).

Furthermore, the Nixon Fork Mine Reclamation Plan Approval (DNR 2012) includes the following stipulation regarding invasive plant management at the Mine:

> "Mystery Creek Resources shall inspect revegetated areas to identify invasive plant species and eradicate these species to the extent practicable. If invasive plant species are identified, Mystery Creek Resources shall notify the Authorized Officer. If equipment is brought into the area from regions with known populations of invasive plant species or noxious weeds, prior to transport to Nixon Fork Mine, that equipment should be inspected and thoroughly cleaned to remove soil, plant and seed contaminants prior to use at the mine site. If a population of noxious weeds is found at the mine site, equipment should be inspected and thoroughly cleaned to remove soil, plant and seed contaminants prior to use at another area at the mine site."

Indeed, the most effective, economical, and ecologically sound approach to managing invasive plants is to prevent their introduction. It is recommended that those responsible for environmental compliance at the Mine implement the following BMPs, which are central to actively preventing the introduction of weeds into Nixon Fork Mine as well as managing infestations (modified from USFS 2001):

Ground disturbing activities and maintenance projects

- Incorporate weed prevention and management into project design, evaluation, and decisions.
    - Assess the risks of possible introduction and spread, analyze treatment options for high-risk sites, and identify prevention practices.
    - Determine necessary actions to control weeds at the start of project planning (e.g. determine how to obtain herbicide permits, if needed).
    - Manage sources of weed propagules and seeds to prevent and limit their spread.
- Prior to ground-disturbing actions, inventory weed populations at the project site and along access routes, and prioritize populations for control. Take control actions where necessary.
    - Start projects in areas not infested, or minimally infested with weeds, then move into weed-infested areas later, as necessary.
    - Use staging areas that are weed-free. Restrict or minimize travel through weed-infested areas, or move through these areas only when propagules and seeds are not likely to spread (e.g. before plants begin to flower and produce seed).
    - Identify sites for equipment cleaning. Plant parts, mud, and dirt should be removed from equipment before moving into the project area, when exiting the project area if the site has weeds, or traveling to weed-free sites. Where practical, seeds and plant parts should be incinerated.
    - Consider closing off access to sensitive areas to allow native vegetation to reestablish.
- Clean equipment and gear
    - Workers should inspect their clothing, boots, tool bags, and other gear. These should be free of plant parts, seeds, and mud; debris should be removed and double bagged for later incineration.
    - Inspect and clean equipment, vehicles, machinery, and other gear. When cleaning equipment, areas to target include the insides of bumpers, wheel wells, undercarriages, belly plates, excavating blades, buckets, tracks, rollers, drills, buckets, shovels, and any digging tools. High pressure washing is recommended to clean heavy equipment and vehicles.
    - Cleaning gear is particularly important when moving from a site infested with non-native plants to a weed-free site. Attention should be paid when vehicles and gear are moved from outside regions that have high non-native plant densities and diversity (e.g. Anchorage, Fairbanks, Mat-Su, and Kenai). Heavy equipment, pallets, and other materials should be inspected and cleaned prior to transport to the mine to prevent new introductions.
- Prevent weed introduction and dispersal via gravel, sand, or other fill materials.
    - Maintain stores of materials in weed-free condition. Regularly inspect material source areas for weeds. As necessary, treat these sites and strip off contaminated material before use of pit material. Do not use any materials contaminated with weeds.

    - During construction activities, do not dump invasive plant-contaminated waste on established, desired vegetation; instead, dispose of waste and invasive plant contaminated soil at a designated disposal site.
    - Where soil has been disturbed and/or where weed treatment takes place, continue monitoring and control actions for at least five years after project completion.
- Minimize sources of non-native plant seed along roadsides to limit transportation to other areas.
    - Roads and right-of-ways should be inspected periodically for weeds. Inventory, document, and schedule treatment for infestations.
    - Ensure proper equipment cleaning, as mentioned above.
    - If acquiring water for dust abatement during road construction projects requires travel through weed-infested areas, alternative sources should be used.
    - When decommissioning a road, treat weeds on the road before they become impassible. Monitor and do follow-up treatments as necessary.
    - Consult a professional before pulling or cutting weeds to ensure effective methods are used. Schedule treatment for when propagules and seeds are least viable and likely to be spread. Work from areas with fewer weeds to areas more densely infested. Minimize soil disturbance. Properly dispose of weed waste or keep it contained on-site.
- Maintain intact ecosystems as much as possible.
    - In areas with a naturally dense canopy cover, maintain this cover as much as possible in inhibit the establishment of weeds. Keep as much native vegetation as possible in and around the project area.
    - Minimize soil disturbance as much as possible to avoid causing conditions in which weeds thrive.

Revegetation

- Revegetation can include planting, seeding, mulching, fertilizing, liming, and topsoil replacement.
    - Restore disturbed sites in a timely manner. Site reclamation should take place immediately after a soil-disturbing project is completed.
    - Revegetate sites in a site-specific manner.
    - Where practical, set aside sod and/or topsoil before projects commence on weed-free sites, and use the sod or topsoil to restore disturbed ground.
    - Where sod and/or topsoil are not set aside for site restoration, reseed with weed-free perennial grasses and forbs that are quick to establish; this encourages the growth of native species and provides competition for non-native species.
    - All revegetation projects should use certified weed-free products; weed-free, locally sourced material is recommended. Use of locally-produced certified weed-free straw and plant materials will decrease the potential for seed contaminants. More information about sources of these materials and planting guidelines can be found at the Alaska Plant Materials Center website (see Appendix III).

Education

- Raise awareness among staff and visitors regarding non-native plants. A particular emphasis should be placed on measures to prevent introduction from off-site sources.
    - Provide training and educational materials regarding plant identification, impacts, and preventative actions to Mine staff.
    - Designate at least one weed management expert on staff.
    - Create incentives for workers to look out for new weeds.
    - Post educational displays, including prevention practices, at housing facilities and offices.
- Lead by example. Prevent and treat weeds around administrative sites.

Early detection and rapid response (EDRR)

Early detection and rapid response (EDRR) is the process of locating, assessing, and eliminating invasive species populations before they have a chance to spread to unmanageable levels. Invasive plant populations often exhibit a lag time before they begin to spread. EDRR enables land managers to find incipient populations of invasive plants and eradicate or contain them during this lag period, consequently reducing environmental and economic impacts.

This strategy includes surveys for monitoring, assessment and control of new and emerging non-native species. Early detection of new infestations requires vigilance and regular monitoring of the managed area and surrounding ecosystem. EDRR efforts at Nixon Fork Mine should focus on areas of high traffic and disturbance (e.g. construction sites, roads, and trails), which should be surveyed at least once a year, preferably in July when most plants have flowered but not yet set seed; unfamiliar species should be identified. Populations identified through EDRR should be submitted to the Alaska Exotic Plants Information Clearinghouse[4] (AKEPIC) database at the Alaska Natural Heritage Program to augment the knowledge base of new infestations and movements of known populations within Alaska. A comprehensive picture of the distribution of non-native species and infestations is important for the development and adaptation of effective management strategies.

The species listed in Table 2 are recommended for EDRR based on their likelihood to become established if introduced to the Mine and their potential to alter the structure and function of ecosystems.
The species listed on the EDRR watch list are included for different reasons. *Phalaris arundinacea* and *Lythrum salicaria* pose threats to riparian areas can have significant negative impacts along rivers and wetlands. *Melilotus* spp. and *Vicia cracca* thrive in the interior boreal forest and are difficult to remove once they have become established. *Hieracium aurantiacum* is also extremely difficult to eradicate, requiring the use of herbicides; this species does well in organic soil and does not require human disturbance to establish. *Elodea* sp. grows in slow-moving freshwater and can clog up waterways, destroying fish habitat and limiting recreational use of rivers and wetlands. These species all have a high likelihood of introduction as

[4] The Alaska Exotic Plants Information Clearinghouse (AKEPIC) is a database and mapping application that provides geospatial information for non-native plant species in Alaska and the Yukon Territory. Available at http://aknhp.uaa.alaska.edu/botany/akepic/.

infestations are known from Anchorage and Fairbanks International airports and/or seaplane bases. For more details about species' impacts visit the Alaska Natural Heritage Program's website, listed in Appendix III.

Table 2. EDRR watch list

Scientific name	Common name	Invasiveness Rank
Elodea sp.*	waterweed	79
Hieracium aurantiacum	orange hawkweed	79
Lythrum salicaria	purple loosestrife	84
Melilotus albus	white sweetclover	81
Melilotus officinalis	yellow sweetclover	69
Phalaris arundinacea	reed canarygrass	83
Vicia cracca	bird vetch	73

*Both *Elodea nuttallii* and *E. canadensis* have been known to form fertile hybrids, which exhibit morphologically intermediate vegetative characteristics and are only distinguishable by their floral structures, which are rarely found. In the absence of floral structures, genetic techniques are necessary to determine taxonomic identity. Both species share geographic ranges. To date, a determination of the species found in Alaska has not been made.

Prioritizing infestations for control work

Infestations should be prioritized for control work based on their distributions and abundance, known or perceived risk to natural ecosystems, and government mandates for control (e.g. presence on the State of Alaska Noxious Weed List, which can be found in Appendix IV). General tools for prioritizing populations for control can be found AKEPIC (2005) and in Cortés-Burns et al. (2012).

Control of invasive species that are locally uncommon should take precedence over invasive species that are widespread on regional and local scales. Control of such incipient populations should take place regardless of perceived invasiveness. Similarly, populations that are small and disjunct, or that are actively invading – or capable of invading – undisturbed native vegetation, should be prioritized over populations that are continuous and large, or that tend to remain restricted to anthropogenically disturbed habitats.

When prioritizing species with similar distributions and abundances, control first those species present on the State of Alaska Noxious Weed List, with higher Invasiveness Ranks, or demonstrated aggressiveness. In general, species with invasiveness ranks of >50 represent species considered modestly to extremely invasive (Carlson et al. 2008) and are reasonable targets for control in areas with low levels of infestation and non-native plant diversity, such as Nixon Fork Mine.

Although top priority at the Mine is preventing the introduction of new, more aggressive species, it is recommended that removing populations of *Taraxacum officinale* (common dandelion) and *Crepis tectorum* (narrowleaf hawksbeard) be a secondary priority. These species are ranked as modestly invasive and could move off the human footprint into surrounding areas; they are not likely to cause any great ecosystem disruption, but the mine should not be a source for weed introduction into surrounding environments. Control options for common dandelion include digging plants out (including the entire root), springtime burning, or herbicides. Narrowleaf hawksbeard can be treated by hand pulling or with herbicides. Where time and money allow, all infestations of non-native plants should be treated. For more details about species' growth habits and treatment option visit the Alaska Natural Heritage Program's website listed in Appendix III.

Inventory and monitoring

Monitoring involves periodic observation and documentation. It is an ongoing and dynamic process and is an integral part of a successful weed control program. Monitoring includes gathering information to gauge the effectiveness of management actions in meeting predetermined objectives. A monitoring program can elucidate objectives that are not being met, actions that need to be modified, and actions that are not working and should be stopped. The inventory and monitoring plan should be evaluated annually, if possible, or at least every three years, so that its efficacy can be assessed, and modifications can be implemented where appropriate to increase the plan's success.

Non-native plant surveys at Nixon Fork Mine should be conducted once a year, in July when most non-native plant species are easily identifiable but have not yet produced seed. Identifying and prioritizing infestations before seed set will decrease the risk of inadvertently spreading plant propagules and thereby improve the efficiency of control measures. Ideally, some member(s) of mine staff should be continuously on the lookout for new or unfamiliar plants.

Sources and dispersal vectors to prioritize for monitoring

Areas that should be top priority for monitoring include potential points of introduction, dispersal corridors, material source areas, material storage sites, and other high-use or high-disturbance locations. Specific sites for survey work include:

- Airstrip and unloading zone
- Roadsides and trails, including the 13 mile road from Medfra to the Mine, if the road is re-opened in the future, and the network of trails surrounding the Mine
- Gravel quarries
- Snow and soil storage sites
- Spoil piles
- Natural aquatic habitats; these are often more susceptible to invasive plant introductions and spread than terrestrial habitats

There are plans to bring in materials by road from Medfra (and by barge to Medfra from McGrath). If this happens in the future, additional locations will need to be monitored and managed. Specifically, the dock at Medfra, the 13 kilometers (8 miles) of road leading to the mine, and where the road enters Nixon Fork Mine. We recommend a survey protocol that begins with a coarse-scale survey with plots read approximately every mile (e.g. each mile marker), as well as at each turnoff, and at each sensitive area (e.g. where the road crosses or comes near a waterway). If problematic infestations are detected during the initial surveys, a finer-scale survey could be conducted to delineate the extent of infestations. It should be emphasized that while conducting the initial coarse-scale survey that observers should be on the lookout for infestations between surveyed plots.

Control methods

Effective control relies on a number of factors. For one, it is essential to clearly establish treatment goals (e.g. does a species need to be eradicated or just contained?). It is also necessary to understand the biology of the target species (e.g. whether it reproduces vegetatively or sexually or by both plant propagules and seed). It is important to recognize the pathways associated with a species' introduction and to understand the ecosystem that has been invaded. It is also critical to know which control methods are effective for which species, as there is no single panacea for treating all infestations and the most effective control often combines manual, mechanical, chemical and biological techniques over several years. To learn more about the control methods discussed below, see additional resources in Appendix III.

Integrated weed management

A single technique is rarely adequate for successful control of multiple species or infestations; under an integrated approach, all control methods are considered and often applied in combination. Specific treatment prescriptions are determined by the biology of the particular plant species, site characteristics, management objectives, and resources available. Management techniques fall into three categories:

- **Manual/Mechanical:** Hand pulling, mowing, tilling, and burning are commonly used to physically destroy weeds or interfere with their reproduction and can be used on small infestations of annual or biennial species. To be most effective, treatment should take place before seed production. Plants that have flowered must be removed from the site and destroyed. Plants can be double bagged and transported to a designated disposal site; if possible, they should be incinerated. Repeated mowing or tilling during the growing season can effectively control or contain many weed species. Generally, manual/mechanical methods are not recommended as the sole approach for control of species that spread vegetatively.

- **Chemical:** Herbicides are likely to be the best option for larger infestations and for perennial species that do not respond well to manual and mechanical methods. The particular herbicide used and its rate of application depend on specific site characteristics, target plants, non-target vegetation, and land use. Herbicides are a particularly important method of treatment when complete eradication of a population is the management objective. Treatment at the earliest stage of invasion will greatly reduce the future need for additional herbicide applications. Herbicides often provide the only effective and feasible control of rhizomatous species, and species for which hand pulling or cutting is not effective. If applied in a specific manner and according to the label, herbicides can be extremely efficient in selectively removing weeds that are mixed in with native vegetation. This approach can reduce the amount of revegetation needed after the treatment is complete.

- **Biological:** This method involves the use of herbivores and pathogens that are known to attack or eat the non-native species of interest in its native range. Introduced biological control species often have few natural enemies and consequently have the potential to become invasive themselves and attack non-target species. Permitting release of biological control agents requires many years of host specificity testing and evaluation by the U.S. Department of Agriculture's Animal and Plant Health

Inspection Service. This type of control is only used on very large infestations (big enough to support the insect or pathogen population) and to date, has not been implemented in Alaska.

Education and outreach

Developing active awareness regarding threats posed by invasive species through educational programs and outreach activities helps promote effective weed management. We recommend that at least one Nixon Fork Mine environmental compliance official should attend a non-native plant identification workshop. These are often jointly hosted in the spring by the BLM and AKNHP in Anchorage and other locations. To raise awareness among Mine staff, educational materials covering topics such as threats posed by, and diagnostic characteristics of, EDRR species could be shared with the staff and posted in common areas. Incentives could be offered, providing a reward for being the first to spot a new plant invader on the premises to encourage involvement and foster stewardship of the natural resources at the Mine.

Conclusion

The invasive plant survey at Nixon Fork Mine highlights three main findings. First, those species presently found at the mine that were unintentionally introduced are of low Invasiveness Rank and pose little threat to the surrounding ecosystem. Second, although these are not very aggressive species, it is recommended that an effort be made to control and eliminate populations to the extent practicable. Third, areas with much human traffic and soil disturbance are at high risk for the establishment of more aggressive and potentially damaging invasive species that have not yet been reported from the area. These points illustrate the need for increased education and outreach among Mine staff, or at least among environmental compliance officers. Enacting comprehensive weed monitoring and management measures as soon as possible is the best way to avoid future financial expenditures and to defend against long-term degradation of native plant communities.

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Appendix I – Examples of non-native plant effects on boreal forests

Species	Invasiveness Rank	Effect on boreal forests
Caragana arborescens (Siberian peashrub)	74	fixes nitrogen, forms dense stands, is highly competitive, shades and smothers native plants (Cortes Burns et al. 2007, Carlson et al. 2008)
Centaurea stoebe (spotted knapweed)	86	allelopathic; interferes with native plant germination and growth (Bais et al. 2003)
Cirsium arvense (Canada thistle)	76	may be allelopathic; reduces seedling emergence and performance of fir trees (*Abies* spp.) (Humber and Hermanutz 2011)
Cirsium vulgare (bull thistle)	61	can out-compete conifer seedlings in clear-cuts (Randall and Rejmanek 1993)
Crepis tectorum (narrowleaf hawksbeard)	56	inhibits native species reestablishment after fire (Villano 2008)
Lonicera tatarica (Tatarian honeysuckle)	66	interferes with forest succession and limits tree regeneration (Batcher and Stiles 2000)
Senecio jacobaea (tansy ragwort)	63	invades clearcuts but does not extend into undisturbed forests (Carlson et al. 2008)
Trifolium pratense (red clover)	53	invades clearcuts but does not extend into undisturbed forests (Carlson et al. 2008)
Vicia cracca (bird vetch)	73	can smother young conifers, causing branch dieback and inhibiting regeneration (Buchholdt et al. 2010)

Developed from Sanderson et al. 2012

Appendix II – site descriptions and non-native species presence

Plot 1: NXF12-001

Drill pad reclamation site toward the north end of the mine. This site is being actively reclaimed.

Scientific name	Common name	Invasiveness Rank
Taraxacum officinale	common dandelion	58

Plot 2: NXF12-002

Drill pad reclamation site toward the south end of the mine. Last active in 2010.

No non-native plants found

Plot 3: NXF12-003

Drill pad reclamation site toward the south end of the mine. On the opposite side of the road from drill pad at Plot 2.

Scientific name	Common name	Invasiveness Rank
Taraxacum officinale	common dandelion	58
Plantago major	common plantain	44
Hordeum jubatum	foxtail barley	63

Plot 4: NXF12-004

Unreclaimed drill pad toward south end of mine. Nearby reclaimed drill pads Plots 1 and 2.

Scientific name	Common name	Invasiveness Rank
Taraxacum officinale	common dandelion	58

Plot 5: NXF12-005

Pond in northwest region of mine site; built in 1995. The pond is surrounded by disturbed margins with several weedy species.

Top three and bottom right photo by Laurie Thorpe

Scientific name	Common name	Invasiveness Rank
Taraxacum officinale	common dandelion	58
Plantago major	common plantain	44
Hordeum jubatum	foxtail barley	63
Trifolium hybridum	alsike clover	57
Matricaria discoidea	pineappleweed	32

Plot 6: NXF12-006
Airstrip and surrounding roads, along east end of mine site.

Photo by Laurie Thorpe

Scientific name	Common name	Invasiveness Rank
Hordeum jubatum	foxtail barley	63
Crepis tectorum	narrowleaf hawksbeard	56

The following collections were made on a separate visit to the Mine by Laurie Thorpe (BLM) on June 18, 2012 and species were subsequently identified by AKNHP.

Plot 7: NXF12-007
Fuel farm, located at the north end of the airstrip, and adjacent to the road leading to the mill works from the airstrip. This site is a fuel storage and containment facility to service the mine works, mill site, vehicles, and other fuel-consumptive needs at the mine.

Photo by Laurie Thorpe

Scientific name	Common name	Invasiveness Rank
Crepis tectorum	narrowleaf hawksbeard	56
Descurainia sp.[†]	tansy mustard	41

[†] *Descurainia* sp. at the site is either native *D. sophioides* or non-native *D. sophia*. The specimen collected for identification was too young to be positively identified.

Plot 8: NXF12-008
New portal, located east of the pond (Plot 5). The proposed new portal would provide alternative access to underground mineral resources and would be developed and utilized in a similar fashion as the existing Chrystal and Mystery portals. Mining equipment, gear, and people would be transported via this to the underground, and ore would be transported back out for processing at the mill site.

No photos available

Scientific name	**Common name**	**Invasiveness Rank**
Trifolium repens	white clover	59

Appendix III – Additional resources

University of Alaska Cooperative Extension Service (CES)
http://www.uaf.edu/ces/

General information and links
http://www.uaf.edu/ces/pests/plants/

Integrated Pest Management (IPM) and reporting portal
http://www.uaf.edu/ces/ipm/

Alaska Invasive Species Working Group (AISWG)
http://www.uaf.edu/ces/pests/aiswg/

Committee for Noxious and Invasive Plants Management (CNIPM)
http://www.uaf.edu/ces/pests/cnipm/
1-877-520-5211

Alaska Natural Heritage Program (AKNHP)
Alaska Exotic Plants Information Clearinghouse (AKEPIC), link to submit invasive plant data, and link to AKEPIC data portal
http://aknhp.uaa.alaska.edu/botany/akepic/

Alaska non-native plant species list, ranks, and biographies
http://aknhp.uaa.alaska.edu/botany/akepic/non-native-plant-species-biographies/

Alaska Department of Fish and Game toll-free hotline for invasive species reporting
1-877-INVASIV (1-877-468-2748)

Appendix IV – Prohibited and restricted noxious weeds in Alaska

Provided by the Alaska Department of Natural Resources, Division of Agriculture
Available at http://plants.alaska.gov/invasives/noxious-weeds.php
A new, updated list will be released in 2013; check this website for future revisions.

Convolvulus arvensis (field bindweed)
Rorippa austriaca (Austrian fieldcress)
Galensoga parviflora (galensoga)
Galeopsis tetrahit (hempnettle)
Solanum carolinense (horsenettle)
Acroptilon repens (Russian knapweed)
Lactuca pulchella (blue-flowering lettuce)
Elymus repens (quackgrass)
Sonchus arvensis (perennial sowthistle)
Euphorbia esula (leafy spurge)
Cirsium arvense (creeping thistle, Canada thistle)
Cardaria draba, Cardaria pubescens, Lepidium latifolium (whitetops and its varieties)
Lythrum salicaria (purple loosestrife)
Hieracium aurantiacum (orange hawkweed)

Appendix V – Percent frequency and total infested acres

This table does not include species found at plots 7 (fuel farm) and 8 (new portal), as these plants were noted on a separate visit to the mine in which infested area was not noted.

Scientific name	Common name	Percent frequency	Total infested acres
Crepis tectorum	narrowleaf hawksbeard	8.33	0.10
Hordeum jubatum	foxtail barley	25.00	0.20
Matricaria discoidea	pineappleweed	8.33	0.01
Plantago major	common plantain	16.67	0.01
Taraxacum officinale	common dandelion	33.33	0.11
Trifolium hybridum	alsike clover	8.33	0.10
Total		100	0.53