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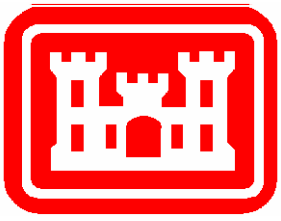
OVERVIEW OF NATIVE PLANT SPECIES WITH REMEDIATION POTENTIAL THAT HAVE APPLICABILITY TO LAND REHABILITATION OBJECTIVES



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OVERVIEW OF NATIVE PLANT SPECIES WITH REMEDIATION POTENTIAL THAT HAVE APPLICABILITY TO LAND REHABILITATION OBJECTIVES

1. Purpose.

a. This Public Works Technical Bulletin (PWTB) provides an overview of native plants that possess both remediation potential and land rehabilitation value to address military land management objectives. These species can allow land managers to passively address soil contamination by selecting species that not only fit land rehabilitation objectives, but have proven abilities to reduce the offsite migration of soil contaminants commonly found on training lands. Species can be selected by contaminant, vegetation type, and geographical region.

b. All PWTBs are available electronically (in Adobe Acrobat portable document format) through the World Wide Web (WWW) at the National Institute of Building Sciences' Whole Building Design Guide web page, which is accessible through URL:

http://www.wbdg.org/ccb/browse_cat.php?o=31&c=215

2. Applicability. This PWTB applies to all continental U.S. Army facilities.

3. References.

a. Army Regulation (AR) 200-1: *Environmental Protection and Enhancement*, 21 February 1997.

b. AR 350-4: *Integrated Training Area Management*, 8 May 1998.

c. Clean Water Act of 1977 (Public Law 95-217, U.S. Code, Title 33, Part 1251).

d. Executive Order 13112: Invasive Species, 3 February 1999.

e. Additional references contained in Appendix H.

4. Discussion.

a. The Clean Water Act established standards for water quality in the United States and limits contaminant discharges, including those on and around military lands. To comply with this and other regulations, Army Regulation 200-1 states that the Army will plan and conduct peacetime mission activities to minimize adverse impacts on the environment. Further, Army Regulation 350-4 provides for the repair and rehabilitation of training lands, including protection of natural resources, compliance with statutory regulations, prevention of future pollution, and reduction of hazardous waste and toxic releases. To prevent introduction and spread of invasive species, Executive Order 13112 requires federal agencies to provide for restoration of native species. Numerous regulatory requirements regarding environmental stewardship on military lands result in limited options for successful land management.

b. This bulletin provides an overview of native plant species that have been shown to provide some level of improvement in soil contaminant persistence and/or mobility through previous phytoremediation investigations. These studies investigated phytotransformation, or plant uptake whereby the contaminant is degraded or chemically reduced to a less toxic substance; phytostabilization, in which plant processes cause the contaminant to become less mobile and increase soil retention; or phytostimulation, in which the plant supports degradation or stabilization of the contaminant through stimulation of soil microbial communities around its roots.

c. The contaminants investigated include heavy metals (arsenic, cadmium, copper, lead, and zinc), explosives (HMX, RDX, and TNT), and petroleum-based fuels, oils, and lubricants. These contaminants were chosen because they have all been documented as potential contaminants on military lands and because enough research has been conducted on them to provide a minimal level of plant species for consideration.

d. Nativity of plant species with positive results was determined and the native species were further investigated for geographic range, growth requirements, commercial availability, and utilization importance. Species that were selected were then grouped by contaminant and separated based on geographical regions.

e. Appendix A contains background information for each contaminant, including natural occurrence, sources, and how they enter soil.

f. Appendix B contains native plant species with remediation capacity adapted to the Pacific Coast Region, which includes CA, OR, and WA.

g. Appendix C contains native plant species with remediation capacity adapted to the Western Mountain Region, which includes AZ, CO, ID, MT, NM, NV, UT, and WY.

h. Appendix D contains native plant species with remediation capacity adapted to the Central Plains Region, which includes IA, IL, IN, KS, MI, MN, MO, ND, NE, OH, OK, SD, TX, and WI.

i. Appendix E contains native plant species with remediation capacity adapted to the Southeast Region, which includes AL, AR, DE, FL, GA, KY, LA, MD, MS, NC, SC, TN, VA, and WV.

j. Appendix F contains native plant species with remediation capacity adapted to the Northeast Region, which includes CT, MA, ME, NH, NJ, NY, PA, RI, and VT.

k. Appendix G contains general characteristics and growth requirements for native plant species with remediation capacity that are documented in Appendices B-F. These characteristics include scientific and common name, functional type, height, rate of vegetative spread, shade tolerance, minimum consecutive frost free days, tolerance to soil texture type, soil pH range, precipitation range, moisture use, drought tolerance, salinity tolerance, and fire tolerance.

5. Points of Contact (POCs).

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APPENDIX A: OVERVIEW OF CONTAMINANTS

Introduction

Military training and testing create unique problems for sustainable land management, such as creating disturbances that affect the functioning of training ecosystems, which can result in contamination of the environment. Many sources of contamination are very small and do not result in adverse effects. However, due to the size of military installations and training activities, the cumulative impact of multiple contaminant locations can be a potential source of problems if the contaminants are carried in runoff or leaching and end up concentrated in water that moves off site. The most important aspect of managing soil contamination is to first keep it from entering surface and ground water supplies, and then focus on remediating the contamination.

Because many of these small disturbances occur in areas where physical disturbance requires land rehabilitation, the opportunity exists to remedy contaminated areas without adding additional costs or manpower requirements. Land rehabilitation can include selection of plant species with proven contaminant remediation properties to complement already existing range seed mixes. This not only provides desirable vegetative cover for soil stabilization and wildlife habitat, but also provides a means to passively reduce the availability of soil contaminants that might exist in these locations as well.

This bulletin provides an overview of such plant species. These plants have been shown in scientific literature to possess qualities favorable for reducing the availability of specific soil contaminants, either through degradation or stabilization. Species possessing these traits were reduced to include only those species native to the continental United States with wide geographic ranges, broad growth requirements, commercial availability, and potential for success when used in land rehabilitation plantings. Many of these species are already components of widespread range seed mixes. However, all of the species in this bulletin have the potential to improve training land sustainability.

The following sections provide an overview of the different contaminants that were researched (heavy metals,

explosives, and petroleum products), including sources of contamination. likely contaminated areas on military training lands, and environmental effects of contamination. Appendices B–F provide specific information for the selected plant species, including potential species for each geographic region by contaminant and vegetation type. Appendix G provides an overview of growth requirements for all plant species presented in this bulletin.

Heavy Metals

Heavy metals are naturally occurring minerals in the Earth's crust. They cannot be broken down by natural processes, so once an area is contaminated it is very difficult to remove the heavy metals. Many sources of heavy metal contamination on military lands are primarily from vehicle operation. This is a result of normal wear and tear of moving metal parts (e.g., copper and zinc in brake pads, cadmium in nuts and bolts, lead in bearings). The heavy metals presented here are arsenic, cadmium, copper, lead, and zinc. For low-level contamination, the best method is to decrease the available (reactive) ions. Most heavy metals will bind to soil organic matter, where they are less prone to offsite migration.

Arsenic: Arsenic (As) is a constituent of pesticides, wood preservatives, chemical weapons, and munitions. Likely areas for As contamination include railroads, former and current agricultural land, unexploded ordnance (UXO) sites, impact areas, and former chemical weapons storage areas. Arsenic-containing compounds can be attacked microbially, which can increase water solubility. Arsenic contamination of water is common worldwide. Since As is toxic to plants, hyperaccumulation is rare and tolerance is the best way to achieve vegetative cover. Phosphorous fertilization can alleviate plant As toxicity as both share a pathway for uptake.

Cadmium: Cadmium (Cd) is a constituent of Ni-Cad batteries, paints, fertilizers, fasteners (e.g., nuts, bolts, and screws), rubber tires, munitions, and fuels. It is accumulated by tobacco in relatively high concentrations and is a component of cigarette butts. Likely areas for Cd contamination include former and current agricultural land, UXO sites, impact areas, roadsides, bivouac sites, maneuver areas, vehicle maintenance facilities, and assembly areas. Cadmium mobility is closely related to the pH of the soil,

with acidic soils generally having much higher mobility. Most plant species will accumulate Cd in their tissues, but concentrations are generally low, with toxicity being more of a problem in herbivores than in vegetation.

Copper: Copper (Cu) is a constituent of pesticides, munitions, brake pads, radiators, and alloys. Likely areas for Cu contamination include former and current agricultural land, small arms ranges, UXO sites, impact areas, roadsides, bivouac sites, maneuver areas, vehicle maintenance facilities, and assembly areas. Copper is an essential micronutrient to both plants and animals in small concentrations. It is quite immobile in soils and is concentrated in the surface layers, but in soils with a pH below neutral, Cu mobility increases. Under Cu enrichment, many plant species can increase concentrations in their roots, which is more effective in decreasing availability than in leaves and other aerial structures.

Lead: Lead (Pb) is a constituent of paints, munitions, tires, alloys, and was formerly an additive in gasoline, which has resulted in Pb contamination of most roadways. Likely areas for Pb contamination include small arms ranges, UXO sites, impact areas, roadsides, bivouac sites, maneuver areas, vehicle maintenance facilities, and assembly areas. Lead is the least mobile of the heavy metals and concentrates in the soil surface layers. Liming soils can greatly decrease mobility of Pb by increasing the soil pH, which leads to formation of phosphates, carbonates, and binding to organic matter. Plant roots can also lead to Pb immobilization through promotion of rhizosphere processes causing pyromorphite crystals to form. Lead occurs naturally in all plants, and its uptake is generally a reflection of the Pb concentration of the soil in which a plant grows. However, some plant species can accumulate large quantities of Pb in their roots, reducing its availability for offsite migration.

Zinc: Zinc (Zn) is a constituent of munitions, pesticides, rubber tires, brakes, grease, alloys, and batteries. Likely areas for Zn contamination include former and current agricultural land, small arms ranges, UXO sites, impact areas, roadsides, bivouac sites, maneuver areas, vehicle maintenance facilities, and assembly areas. Zinc is easily adsorbed to both mineral and organic soil compounds and accumulates in surface soil layers. However, Zn has higher mobility than Pb and Cu. As with other heavy metals, Zn

uptake by plants appears to be closely related to the soil concentration, and plants can accumulate high concentrations in their roots, which decreases its mobility.

Explosives

Explosives are generally a military-unique environmental contaminant. The three primary explosives are HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine), RDX (1,3,5-trinitro-1,3,5-triazine), and TNT (2,4,6-trinitrotoluene). As primary constituents in numerous rockets, bombs, and other weapons, their widespread manufacture and utilization has resulted in contamination of multiple, easily identified areas. All three are slow to degrade under most natural conditions and are mobile in the environment to varying degrees, with TNT being the least mobile and RDX being the most water soluble. Due to this water mobility as well as wind deposition, areas adjacent to impact areas and UXO sites can also be prone to low-level contamination. Remediation of these areas is much simpler than in areas with UXO. Research has shown that these contaminants can be degraded by biological processes, although some degradation results in creation of compounds that are more mobile and/or more toxic.

HMX: HMX is water soluble and prone to leaching through the soil profile. Although evidence of HMX degradation by plants has not been demonstrated, plant species have been shown to accumulate HMX, which keeps it from entering groundwater.

RDX: RDX is highly water soluble and has high soil leaching potential. RDX is readily taken up by plants and has been shown to be vulnerable to degradation by plant metabolic processes.

TNT: TNT has the lowest leaching potential of the three explosives, but still has the capacity to end up in groundwater. TNT can be taken up and metabolized by plants.

Petroleum-Based Fuels, Oils, and Lubricants

Petroleum products are complex mixtures consisting of scores of hydrocarbon molecules of varying toxicity. Because these fuels, oils, and lubricants are so closely related and complex, it is difficult to separate them based on environmental effects, and they are commonly grouped as

POL (petroleum, oils, and lubricants). Because almost all petroleum contamination on military lands is related to vehicles, different petroleum compounds often occur together in the soil. Many of these hydrocarbon molecules have been shown to succumb to degradation in soil through microbial attack. Since plant roots support such high concentrations of microbial populations relative to bulk soil, plant root systems play a very important role in increasing the rate of degradation. For this report, results from studies of crude oil, diesel fuel, heavy oil, and mixtures of polycyclic aromatic hydrocarbons have been combined to provide an overall guidance for general petroleum contamination (Table 1).

Table 1. Summary of likely areas for contamination on military training areas.

	Heavy Metals					Explosives			
	As	Cd	Cu	Pb	Zn	HMX	RDX	TNT	POL
Impact areas (and adjacent lands)	x	x	x	x	x	x	x	x	
UXO sites (and adjacent lands)	x	x	x	x		x	x	x	
Small arms ranges			x	x	x				
Roadsides		x	x	x	x				x
Bivouac sites		x	x	x	x				x
Maneuver areas		x	x	x	x				x
Assembly areas		x	x	x	x				x
Vehicle maintenance facilites		x	x	x	x				x
Agricultural fields (current and former)	x	x	x	x	x				
Railroads	x								
Former chemical weapons storage areas	x								

Conclusions

Although this investigation of the literature has shown that a great deal of research has been conducted in the area of phytoremediation, many plant species still have not been investigated. Thus, the species lists in the following appendices are by no means exhaustive. A future research focus on native plant species with value to other aspects of land management would provide a significant advantage to military land management over work that uses crop species or other vegetation with little inherent value to field applications.

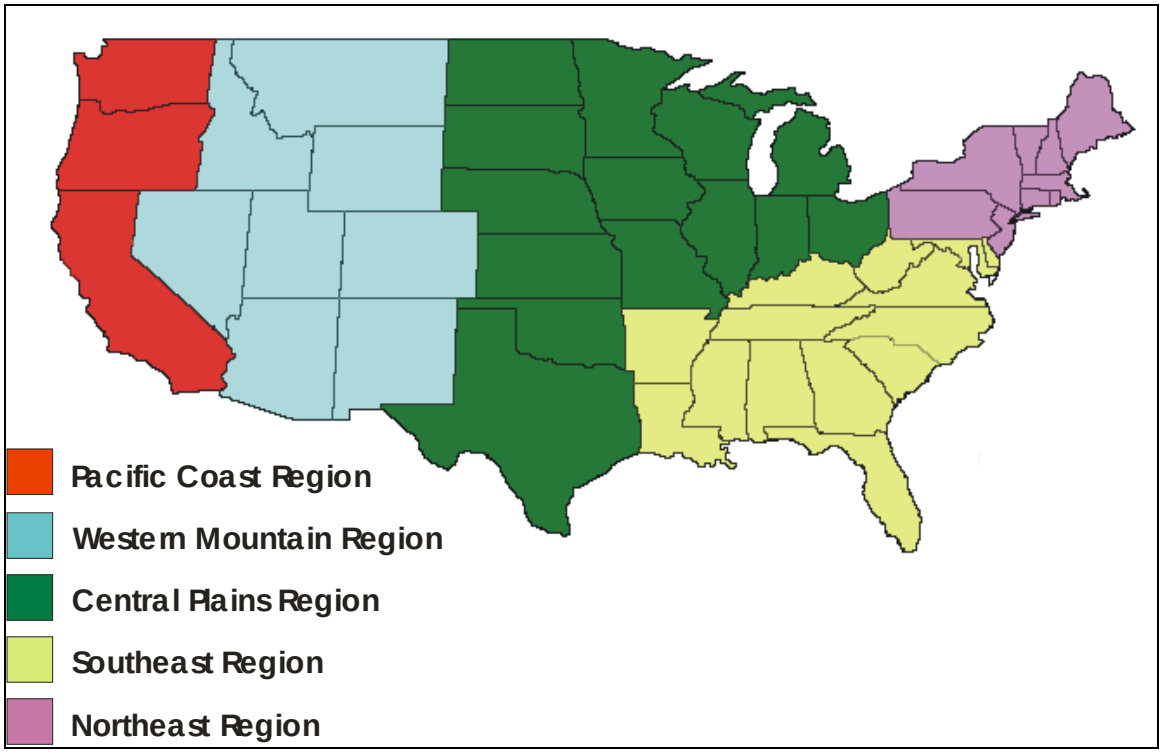

Figure A-1. Plant regions referred to in Appendices B–F.

APPENDIX B: NATIVE PLANT SPECIES WITH REMEDIATION CAPACITY ADAPTED TO PACIFIC COAST REGION

Appendix B. Native plant species with remediation capacity adapted to Pacific Coast Region.

Contaminant	Vegetation Type: Grasses	Forbs	Shrubs	Trees
Heavy Metals				
As	*Pseudoroegneria spicata*	*Achillea millefolium*		
Cd	*Pseudoroegneria spicata*	*Achillea millefolium*	*Vaccinium uliginosum*	*Alnus incana* *Robinia pseudoacacia*
Cu	*Deschampsia caespitosa* *Elymus trachycaulus* *Leymus cinereus* *Poa secunda* *Pseudoroegneria spicata*	*Achillea millefolium* *Phyla nodiflora*		*Alnus incana* *Robinia pseudoacacia*
Pb	*Festuca rubra* *Pseudoroegneria spicata*	*Achillea millefolium*		
Zn	*Elymus trachycaulus* *Festuca rubra* *Leymus cinereus*	*Phyla nodiflora*	*Vaccinium uliginosum*	*Alnus incana* *Robinia pseudoacacia*
Explosives				
HMX	*Pascopyrum smithii*	*Monarda fistulosa*	*Artemisia ludoviciana* *Symphoricarpos albus*	
RDX	*Phalaris arundinacea*	*Helianthus nuttalli* *Polygonum pensylvanicum* *Solidago canadensis*		*Robinia pseudoacacia*
TNT	*Festuca rubra* *Phalaris arundinacea*			*Robinia pseudoacacia*

Appendix B (continued). Native plant species with remediation capacity adapted to Pacific Coast Region.

Vegetation Type			
Grasses	**Forbs**	**Shrubs**	**Trees**
Petroleum-Based Fuels, Oils, and Lubricants			
Bouteloua curtipendula *Bromus carinatus* *Distichlis stricta* *Elymus canadensis* *Elymus trachycaulus* *Festuca rubra* *Leymus triticoides* *Pascopyrum smithii* *Poa secunda*		*Artemisia frigida*	

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APPENDIX C: NATIVE PLANT SPECIES WITH REMEDIATION CAPACITY ADAPTED TO ROCKY MOUNTAIN REGION

Appendix C. Native plant species with remediation capacity adapted to Rocky Mountain Region.

Contaminant	Vegetation Type			
	Grasses	**Forbs**	**Shrubs**	**Trees**
	Heavy Metals			
As	*Pseudoroegneria spicata*	*Achillea millefolium*		
Cd	*Pseudoroegneria spicata*	*Achillea millefolium*	*Vaccinium uliginosum*	*Alnus incana* *Robinia pseudoacacia*
Cu	*Deschampsia caespitosa* *Elymus trachycaulus* *Leymus cinereus* *Poa secunda* *Pseudoroegneria spicata*	*Achillea millefolium* *Phyla nodiflora*		*Alnus incana* *Robinia pseudoacacia*
Pb	*Festuca rubra* *Pseudoroegneria spicata*	*Achillea millefolium*		
Zn	*Elymus trachycaulus* *Festuca rubra* *Leymus cinereus*	*Penstemon palmeri*	*Vaccinium uliginosum*	*Alnus incana* *Robinia pseudoacacia*
	Explosives			
HMX	*Pascopyrum smithii*	*Monarda fistulosa*	*Artemisia ludoviciana* *Symphoricarpos albus*	
RDX	*Phalaris arundinacea*	*Helianthus nuttalli* *Polygonum pensylvanicum* *Solidago canadensis*		*Robinia pseudoacacia*
TNT	*Festuca rubra* *Panicum virgatum* *Phalaris arundinacea*			*Robinia pseudoacacia*

Appendix C (cont'd). Native plant species with remediation capacity adapted to Rocky Mountain Region.

Vegetation Type			
Grasses	**Forbs**	**Shrubs**	**Trees**
Petroleum-Based Fuels, Oils, and Lubricants			
Andropogon gerardii *Bouteloua curtipendula* *Bouteloua gracilis* *Distichlis stricta* *Elymus canadensis* *Elymus trachycaulus* *Festuca rubra* *Leymus triticoides* *Panicum virgatum* *Pascopyrum smithii* *Poa secunda* *Schizachyrium scoparium* *Sorghastrum nutans*	*Aster ericoides* *Grindelia squarrosa*	*Artemisia frigida*	

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APPENDIX D. NATIVE PLANT SPECIES WITH REMEDIATION CAPACITY ADAPTED TO CENTRAL PLAINS REGION

Appendix D. Native Plant Species with Remediation Capacity Adapted to Central Plains Region

Contaminant	Vegetation Type: Grasses	Forbs	Shrubs	Trees
	Heavy Metals			
As	*Pseudoroegneria spicata*	*Achillea millefolium*		
Cd	*Pseudoroegneria spicata*	*Achillea millefolium*		*Alnus incana* *Robinia pseudoacacia*
Cu	*Deschampsia caespitosa* *Elymus trachycaulus* *Poa secunda* *Pseudoroegneria spicata*	*Achillea millefolium* *Phyla nodiflora*		*Alnus incana* *Robinia pseudoacacia*
Pb	*Festuca rubra* *Pseudoroegneria spicata*	*Achillea millefolium*		
Zn	*Elymus trachycaulus* *Festuca rubra*	*Phyla nodiflora*		*Alnus incana* *Robinia pseudoacacia*
	Explosives			
HMX	*Pascopyrum smithii*	*Monarda fistulosa*	*Artemisia ludoviciana* *Symphoricarpos albus*	
RDX	*Phalaris arundinacea*	*Asclepias syriaca* *Polygonum pensylvanicum* *Solidago canadensis* *Helianthus nuttalli*		*Juniperus virginiana* *Robinia pseudoacacia*
TNT	*Festuca rubra* *Panicum virgatum* *Phalaris arundinacea*			*Robinia pseudoacacia*

Appendix D (cont'd). Native plant species with remediation capacity adapted to Central Plains Region.

Vegetation Type			
Grasses	**Forbs**	**Shrubs**	**Trees**
Petroleum-Based Fuels, Oils, and Lubricants			
Andropogon gerardii *Bouteloua curtipendula* *Bouteloua gracilis* *Distichlis stricta* *Elymus canadensis* *Elymus trachycaulus* *Festuca rubra* *Panicum virgatum* *Pascopyrum smithii* *Poa secunda* *Schizachyrium scoparium* *Sorghastrum nutans*	*Aster ericoides* *Grindelia squarrosa* *Pediomelum esculentum*	*Artemisia frigida*	

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APPENDIX E: NATIVE PLANT SPECIES WITH REMEDIATION CAPACITY ADAPTED TO SOUTHEAST REGION

Appendix E. Native plant species with remediation capacity adapted to Southeast Region.

Contaminant	Vegetation Type: Grasses	Forbs	Shrubs	Trees
Heavy Metals				
As		*Achillea millefolium*		
Cd		*Achillea millefolium*		*Robinia pseudoacacia*
Cu		*Achillea millefolium* *Phyla nodiflora*		*Robinia pseudoacacia*
Pb	*Festuca rubra*	*Achillea millefolium*		
Zn	*Festuca rubra*	*Phyla nodiflora*		*Robinia pseudoacacia*
Explosives				
HMX	*Pascopyrum smithii*	*Monarda fistulosa*	*Artemisia ludoviciana*	
RDX	*Phalaris arundinacea*	*Asclepias syriaca* *Polygonum pensylvanicum* *Solidago canadensis*		*Juniperus virginiana* *Robinia pseudoacacia*
TNT	*Festuca rubra* *Panicum virgatum* *Phalaris arundinacea*			*Robinia pseudoacacia*

Appendix E (cont'd). Native plant species with remediation capacity adapted to Southeast Region.

Vegetation Type			
Grasses	**Forbs**	**Shrubs**	**Trees**
Petroleum-Based Fuels, Oils, and Lubricants			
Andropogon gerardii *Bouteloua curtipendula* *Distichlis stricta* *Festuca rubra* *Panicum virgatum* *Schizachyrium scoparium*	*Aeschynomene americana* *Aster ericoides*		

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APPENDIX F: NATIVE PLANT SPECIES WITH REMEDIATION CAPACITY ADAPTED TO NORTHEAST REGION

Appendix F. Native Plant Species with Remediation Capacity Adapted to Northeast Region.

Contaminant	Vegetation Type			
	Grasses	Forbs	Shrubs	Trees
	Heavy Metals			
As		*Achillea millefolium*		
Cd		*Achillea millefolium*	*Vaccinium uliginosum*	*Alnus incana* *Robinia pseudoacacia*
Cu	*Deschampsia caespitosa* *Elymus trachycaulus*	*Achillea millefolium*		*Alnus incana* *Robinia pseudoacacia*
Pb	*Festuca rubra*	*Achillea millefolium*		
Zn	*Elymus trachycaulus* *Festuca rubra*		*Vaccinium uliginosum*	*Alnus incana* *Robinia pseudoacacia*
	Explosives			
HMX	*Pascopyrum smithii*	*Monarda fistulosa*	*Artemisia ludoviciana* *Symphoricarpos albus*	
RDX	*Phalaris arundinacea*	*Asclepias syriaca* *Polygonum pensylvanicum* *Solidago canadensis*		*Juniperus virginiana* *Robinia pseudoacacia*
TNT	*Festuca rubra* *Panicum virgatum* *Phalaris arundinacea*			*Robinia pseudoacacia*

Appendix F (cont'd). Native plant species with remediation capacity adapted to Northeast Region.

Vegetation Type			
Grasses	**Forbs**	**Shrubs**	**Trees**
Petroleum-Based Fuels, Oils, and Lubricants			
Andropogon gerardii *Bouteloua curtipendula* *Distichlis stricta* *Elymus canadensis* *Elymus trachycaulus* *Festuca rubra* *Panicum virgatum* *Pascopyrum smithii* *Schizachyrium scoparium* *Sorghastrum nutans*	*Aster ericoides* *Grindelia squarrosa*	*Artemisia frigida*	

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APPENDIX G: GENERAL CHARACTERISTICS AND GROWTH REQUIREMENTS FOR NATIVE PLANT SPECIES WITH REMEDIATION CAPACITY

Appendix G. General characteristics and growth requirements for native plant species with remediation capacity.

Species	Common Name	Type	Ht	Vegetative Spread	Shade Tolerance	Frost Free Days	Soil Texture Type	Soil pH	Precipitation Range	Moisture Use	Drought Tolerance	Salinity Tolerance	Fire Tolerance
Achillea millefolium v. occidentalis	western yarrow	forb	3'	Yes	Medium	100	Coarse, Medium, No Fine	6-8	8-26"	Medium	Medium	Low	High
Aeschynomene americana	jointvetch	forb	6'		Low		Fine, Medium, No Coarse	5.5-6.5			None		
Asclepias syriaca	common milkweed	forb	6'	Yes	Medium		All Soils	5.5-7.5	15-50"		High		High
Aster ericoides	white heath aster	forb	3'	Yes	Medium	110	Coarse, Medium, No Fine	5.5-7	28-50"	Medium	High		High
Grindelia squarrosa	gumweed	forb	3'	Yes			Coarse, Medium, No Fine				High	Medium	Low
Helianthus nuttalli	Nutall sunflower	forb	10'	Yes	None	120	Fine, Medium, No Coarse	5.9-7.5	12-20"	Medium	Low	None	Medium
Monarda fistulosa	wild bergamont	forb	5'	Yes	Medium	150	Fine, Medium, No Coarse	6-8	20-60"	High	Low	Low	None
Pediomelum esculentum	breadroot	forb	1'	No	None		Coarse, Medium, No Fine				Low		
Penstemon palmeri	Palmer penstemon	forb	3.5'	No	None	140	Coarse, Medium, No Fine	6-8	6-14"	Low	High	None	High
Phyla nodiflora	turkey tangle fogruit	forb	.5'	Yes	Medium	110	All Soils	6-8.5	10-40"	Low	Medium	Medium	None
Polygonum pensylvanicum	Pennsylvania smartweed	forb	4'	No	None	95	All Soils	4-8.5	12-60"	Medium	Medium	Low	High
Solidago canadensis	Canada goldenrod	forb	3.5'	Yes	None	80	All Soils	5-7.5	16-60"	Medium	Medium	None	High
Artemisia frigida	fringed sagebrush	shrub	2'	Yes	Medium	90	All Soils	7-9	10-40"	Low	High	Medium	High
Artemisia ludoviciana	white sagebrush	shrub	3'	Yes			Coarse, Medium, No Fine				Medium	Low	Medium
Symphoricarpos albus	snowberry	shrub	3'	Yes	None	150	All Soils	6-8	12-45"	Medium	High	None	High
Vaccinium uliginosum	bog blueberry	shrub	2'	Yes	Medium	90	Medium Soils Only	4.5-5.7	18-45"	Medium	Low	None	High
Alnus incana	gray alder	tree	25'	Yes	Medium	100	All Soils	5-7	32-60"	High	Low	None	High
Juniperus virginiana	eastern redcedar	tree	50'	No	Medium	140	All Soils	4.7-8	15-68"	Low	High	Low	Low
Robinia pseudoacacia	black locust	tree	80'	Yes	None	90	All Soils	4.6-8.2	16-65"	Medium	High	Low	High

Appendix G (cont'd). General characteristics and growth requirements for native plant species with remediation capacity.

Species	Common Name	Type	Ht	Vegetative Spread	Shade Tolerance	Frost Free Days	Soil Texture Type	Soil pH	Precipitation Range	Moisture Use	Drought Tolerance	Salinity Tolerance	Fire Tolerance
Andropogon gerardii	big bluestem	grass	6'	Yes	None	155	All Soils	5-7.5	12-55"	Low	High	Medium	High
Bouteloua curtipendula	sideoats grama	grass	3'	Yes	None	150	All Soils	5.5-8.5	6-25"	Medium	Medium	Low	Low
Bouteloua gracilis	blue grama	grass	1'	No	None	145	All Soils	6.5-8.5	8-22"	Medium	High	Medium	High
Bromus carinatus	California brome	grass	4'	No	None	150	Coarse, Medium, No Fine	5.5-8	8-20"	Low	Medium	Medium	Low
Deschampsia caespitosa	tufted hairgrass	grass	3.5'	No	None	100	All Soils	5-7	14-24"	Low	Low	Low	High
Distichlis stricta	inland saltgrass	grass	1.5'	Yes	None	80	Fine, Medium, No Coarse	6.5-10.5	5-70"	Medium	Medium	High	High
Elymus canadensis	Canada wildrye	grass	3'	No	Medium	90	All Soils	5-8	20-45"	Medium	Medium	Medium	Low
Elymus trachycaulus	slender wheatgrass	grass	3'	Yes	None	90	Fine, Medium, No Coarse	5.6-9	8-25"	Low	High	High	High
Festuca rubra	red fescue	grass	2'	Yes	Low	90	Fine, Medium, No Coarse	5-7.5	30-70"	Medium	Medium	Low	High
Leymus cinereus	basin wildrye	grass	5'	Yes	None	90	All Soils	5.5-9	8-20"	High	Medium	High	High
Leymus triticoides	beardless wildrye	grass	3'	Yes	None	110	Fine, Medium, No Coarse	6-9	7-60"	High	High	Medium	High
Panicum virgatum	switchgrass	grass	5'	Yes	None	120	All Soils	4.5-8	12-60"	Medium	Medium	Medium	High
Pascopyrum smithii	western wheatgrass	grass	2'	Yes	None	90	Fine, Medium, No Coarse	4.5-9	8-36"	Medium	High	High	High
Phalaris arundinacea	reed canarygrass	grass	5'	Yes	None	120	Fine, Medium, No Coarse	5.5-8	30-65"	High	Low	Medium	High
Poa secunda	Sandberg bluegrass	grass	1.5'	No	Medium	90	Coarse, Medium, No Fine	6-8	8-16"	Low	High	Low	Medium
Pseudoroegneria spicata	bluebunch wheatgrass	grass	3'	No	Medium	90	All Soils	6.6-8.4	8-35"	Low	High	Low	High
Schizachyrium scoparium	little bluestem	grass	3'	No	None	100	All Soils	5-8.5	12-45"	Low	High	None	Medium
Sorghastrum nutans	indiangrass	grass	6'	Yes	None	120	All Soils	5-8	11-45"	Medium	Medium	Medium	High

Appendix H: References

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