COLUMBIA BASIN COOPERATIVE WEED MANAGEMENT AREA

COLUMBIA BASIN FLOWERING RUSH MANAGEMENT PLAN

A regional strategy to address *Butomus umbellatus* throughout the Columbia Basin

www.columbiabasincwma.org

Statement of Collaboration:

When possible, the partners of the Columbia Basin Cooperative Weed Management Area will strive to communicate and work collaboratively to develop a unified management effort for flowering rush throughout the Columbia Basin.

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Preface

The Columbia Basin Cooperative Weed Management Area (CBCWMA) is a regional consortium that brings together stakeholders to address noxious weed issues in the Columbia River drainage basin. The CBCWMA provides a unique opportunity for all stakeholders within the Columbia Basin to collaboratively share information, discuss strategies, and make the best use of limited resources to address shared problems. In this instance, this cooperative body has chosen to work across borders and boundaries to address flowering rush; an invasive aquatic plant that is causing numerous and widespread issues in the basin.

Flowering rush has existed in the upper Columbia River watershed for decades and is spreading downstream across state and international boundaries; cooperators saw a need to create a comprehensive strategy to address flowering rush from a basin-wide perspective. This effort has brought together various partners and diverse ideas concerning management of flowering rush. Through implementation of the identified strategic actions, cooperators will be most effective in solving shared problems.

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Executive Summary

Invasive species expand beyond jurisdictional boundaries and spread downstream over time when growing within or adjacent to rivers and streams.

The Columbia Basin Cooperative Weed Management Area, created in 2016, provides a unique opportunity for all stakeholders within the Columbia Basin to collaboratively share information, discuss strategy, and make the best use of limited resources to address shared problems. In this instance, this cooperative body has chosen to work across borders and boundaries to address the issue of the invasive species, flowering rush.

Flowering rush, *Butomus umbellatus L.*, is an aggressive freshwater invasive plant that rapidly colonizes wetlands, lakes, slow-moving rivers, canals and irrigation ditches. It is becoming an increasing problem in western North America and with no known effective control methods, is poised to become a substantial problem in many major waterways. It is capable of creating dense stands and with both emergent and submersed growth forms, can dominate from the shoreline to depths of 6 meters (20 feet). Through rhizome fragments and rhizome buds, it can quickly disperse and colonize new areas with the assistance of water movement. Flowering rush is considered an ecosystem engineer for its ability to alter habitats by sediment accretion. It affects irrigation and dam power management and recreational activities such as swimming, fishing and boating. Preliminary data suggests that native aquatic plant communities, and the fish and wildlife that depend on them, are also impacted. Specifically, flowering rush appears to provide excellent habitat for invasive northern pike which predate on native salmonid species.

In the Columbia Basin, flowering rush occurs as several distinct populations. It is extremely difficult to control once established and, with its ability to rapidly disperse, new sites are being found every year. A substantial portion of the basin remains uninfested by flowering rush, however these regions must be surveyed regularly in order to find new infestations and react quickly to eliminate them whenever possible. In regions of the basin where flowering rush is newly invading, early detection-rapid response strategies are employed to prevent its establishment through eradication techniques. In other regions where flowering rush is well-established, the focus is to reduce further spread and manage existing populations. While these efforts have been occurring throughout the basin, there has been no coordinated effort to manage flowering rush across the entire system.

The formation of the Columbia Basin Cooperative Weed Management Area was designed to bring together partners from throughout the basin to develop an integrated weed management plan for controlling flowering rush, thereby increasing the likelihood of success in managing for healthy habitats. The following plan outlines the basin-wide effort to share information and best management practices, as well as a process to identify the strategic short- and long-term actions needed to effectively and efficiently address the challenges provided by this invasive plant. The Columbia Basin Cooperative Weed Management Area intends for this plan to guide future research, policy changes, management activities, and collaboration. Through implementation of the actions identified here, those involved in flowering rush management will be most effective in solving our shared issues. The Columbia Basin Cooperative Weed Management Area thanks you for your interest in this topic and looks forward to collaborating with you to address the important issue of flowering rush.

Introduction

Scope and Purpose

Management of the non-native invasive aquatic plant flowering rush (*Butomus umbellatus* L.) in the Columbia Basin requires a collaborative approach. This document highlights the interconnectedness of aquatic systems and the capacity of individuals from different organizations to work together to control and eliminate flowering rush, where possible, and prevent further spread throughout the basin. By bringing multiple states, provinces, tribes and others together, a process to manage aquatic invasive species was created, regardless of jurisdictional boundaries.

The Columbia Basin covers over 673,397 square kilometers (260,000 square miles), from its headwaters in British Columbia, Canada to its mouth at Astoria, Oregon. The basin includes seven states, one Canadian province, and 13 federally recognized Indian reservations and their associated ceded lands (Figure 1). Over 60 major tributaries contribute to the flow and formation of the Columbia River, the primary significant tributaries include the Snake River, Willamette River, Kootenay River, and Pend Oreille River. Other significant tributaries include the Cowlitz, Spokane, Lewis, Deschutes, Yakima, Wenatchee, Okanogan, Kettle, Sand, and John Day Rivers. Through the hydrologic process, over 160 billion cubic meters (130 million acre feet) of runoff flows through the river system annually. The Columbia Basin Flowering Rush Management Plan addresses the geographic area of the Columbia Basin, focused upon the states of Idaho, Montana, Washington, and Oregon, the province British Columbia, and lands of Tribes and First Nations that fall within the Columbia Basin. Although the province of Alberta falls outside the Columbia Basin, Alberta has been highly involved in the process due to concerns over regional flowering rush infestations.

Figure 1. The Columbia Basin in Western North America

While collaboration on invasive species is something that has taken place repeatedly throughout the Columbia Basin among various entities (e.g. 100th Meridian Columbia River Basin Team, Lake Roosevelt Forum, Greater Yellowstone Coordinating Committee), the **Columbia Basin Cooperative Weed Management Area**[1] (CBCWMA) was created in 2016 to specifically work across the basin on invasive aquatic plant issues, focusing initially on flowering rush. By working together across boundaries, the CBCWMA hopes to improve regional management of flowering rush. For more information on the mission and background on the CBCWMA, see Appendix E.

The goal of the Columbia Basin Flowering Rush Management Plan (hereafter referred to as the Plan) is to provide a foundation and guide for flowering rush management and research in the Columbia Basin. The document will also provide information to assist policy and funding decisions that guide implementation. Recognizing the diversity of agencies, tribes and other stakeholders, priority areas

[1] Words in bold font are defined in the appendix.

for management and short- and long-term actions have been identified and organized by geographic regions of the basin. The Plan also recognizes that entities involved in flowering rush management are subject to diverse funding opportunities, jurisdictional and legal authorities, political and cultural realities, and various biological factors.

History of Introduction

Flowering rush was first identified in North America by Marie-Victorin circa 1897 in mudflats of the St. Lawrence River near Montreal, Canada (Countryman 1970). It has since spread or been reintroduced as an escaped garden ornamental and is currently established in parts of the northern US and southern Canada. It was first recorded in the Columbia Basin from the Snake River, Idaho in 1949 (Anderson et al. 1974) and has been a management challenge in irrigation canals in that region for many years (Steve Howser, personal communication). In 1964, it was documented in Flathead Lake, Montana (Consortium of Pacific Northwest Herbaria 2017). Within Flathead Lake, flowering rush has colonized at least 809 hectares (2,000 acres) of the littoral zone and moved downstream through the Clark Fork River into Lake Pend Oreille and the Pend Oreille River in Idaho and Washington (Parkinson et al. 2010, Jenifer Parsons, personal communication). Separate populations were found in the Yakima River in 2008, the Spokane River in 2010, and the Columbia River near Wenatchee in 2015 (Figure 2).

> *The formation of the Columbia Basin Cooperative Weed Management Area was designed to bring together partners from throughout the basin to develop an integrated weed management plan for controlling flowering rush.*

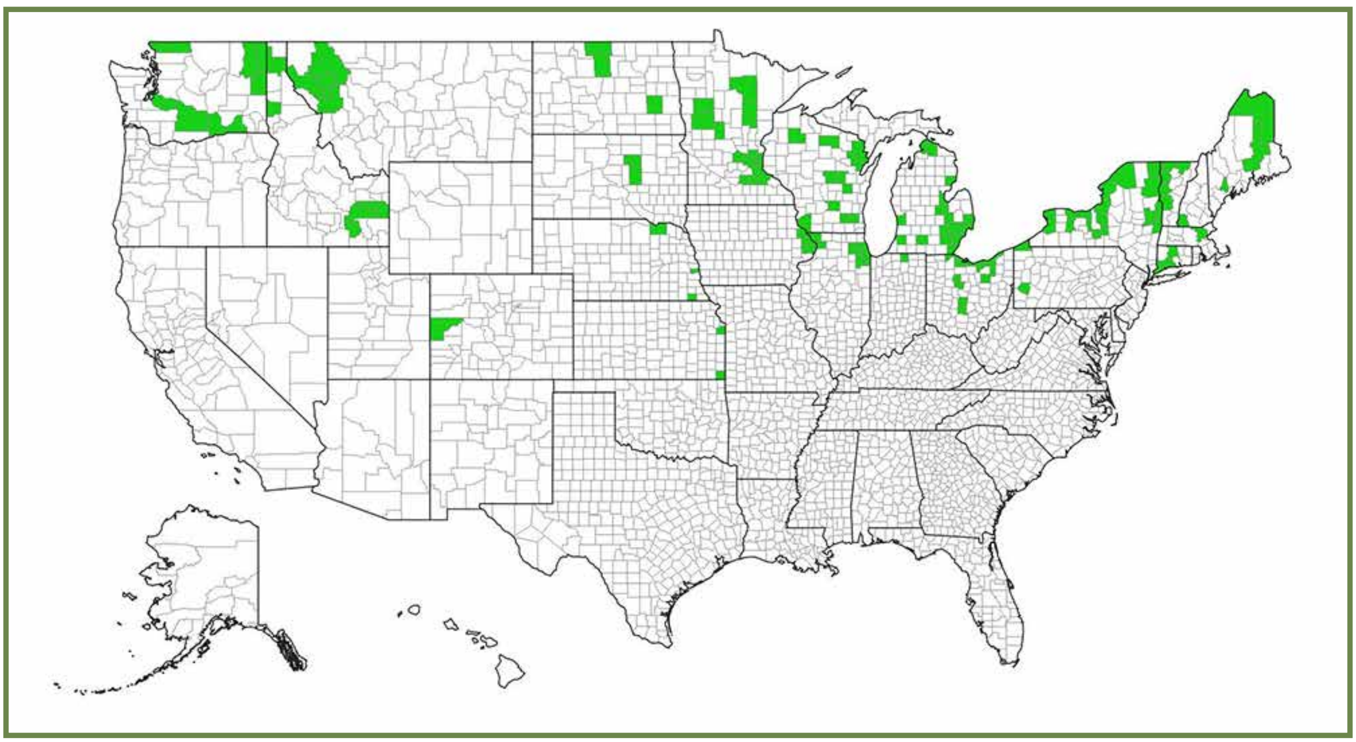

Figure 2. *National distribution of flowering rush. Citation: EDDMapS. 2019. Early Detection & Distribution Mapping System. The University of Georgia - Center for Invasive Species and Ecosystem Health. Available online at http://www.eddmaps.org/; last accessed July 9, 2019.*

Identification and Ecology of Flowering Rush

Species Classification
Order: Alismatales
Family: Butomaceae
Genus: *Butomus* L.
Species: *B. umbellatus* L.
Common names: flowering rush, grassy rush, water gladiolus

Flowering rush (*Butomus umbellatus* L.) is an herbaceous, aquatic, perennial monocot and the only species in the family Butomaceae. While it is not closely related to any other plants, it can visually resemble other aquatic and shoreline vegetation, making it hard to distinguish in the field (Figure 3). Flowering rush is indigenous to Europe and Asia, and is found sparingly in those native environments. The following description information is focused on the **triploid cytotype**, which is the dominant type found in Western North America.

Flowering rush has **rhizomes** that form numerous side branches, creating a rhizomatous mat as the plants mature. The rhizomes develop lateral buds, which are connected to the rhizome by a narrow base; thus, they

Figure 3. *Distinguishing flowering rush can be challenging, as shown here growing with other shoreline vegetation (Photo credit: A. Halpern).*

Figure 4. *The rhizomes enable the rapid spread of flowering rush through the Columbia Basin (Photo credit: J. Andreas).*

tend to break off easily (Hroudova 1989) (Figure 4). The rhizomes also become brittle with age and develop structurally weak constrictions along their length which spontaneously fragment or break readily following minor disturbance (e.g. from waves, boat wake, feeding waterfowl, human disturbance). Fragments and buds float and disperse easily on water currents to potentially start new populations elsewhere (Parkinson et al. 2010) (Figure 5). Most of the biomass of flowering rush is in the rhizomes (Marko et al. 2015), and rhizome biomass increases substantially from year to year, with an increase of 20 times over a 6-year period in one study (Hroudova 1989). The greatest increase in rhizome biomass occurs late in the growing season (Hroudova et al. 1996); however, some parts of the rhizome may remain dormant (Hroudova 1989).

The leaves emerge directly from growing points **(meristems)** along the rhizome. They are triangular in cross-section, especially at the base, tending to flatten toward the tip (Haynes 2000) (Figure 6). They are dark green, sometimes with copper-colored areas especially at the base before sometimes turning white where they join the rhizome. Leaves are typically 1 meter (3 feet)

Figure 5. A rhizome fragment floating in the waters of Flathead Lake in northwest Montana (Photo credit: P. Rice).

long when growing emerged along shorelines, but can grow up to 3 meters (10 feet) long when fully submersed (Parkinson et al. 2010). Leaves of emergent plants tend to twist (Figure 7).

The flower stalk is produced on emergent plants and is longer than the leaves. Flowers occur in a rounded cluster **(umbel)** of 20 or more light pink flowers with red or purple veins at the end of the flower stalk. The individual flowers are up to 3 centimeters (1 inch) across and have 3 petals, 3 petal-like **sepals,** 9 **stamens** and 6 **pistils** (Haynes 2000) (Figure 8). Occasionally, the **diploid** variety is reported to make bulbils in the flower cluster (Hroudova et al. 1996), which look like tiny bulbs. Triploid variety do not flower consistently from site to site or year to year. Fruits are beaked leathery follicles growing to 1 cm (0.4 inches) long and containing multiple seeds (Haynes 2000). There are up to 6 follicles per flower. The seeds are very small, 1.37 x 0.51 millimeters from diploid plants from Minnesota (Nathan Harms personal communication). Triploid flowering rush produces very little, if any, viable seed (Hroudova 1996, Lui et al. 2005) (Figure 9). However, diploid plants produced an average of 8,800 seeds per **inflorescence** (Lui et al. 2005). A range of seed viability has been reported in the literature, with a long cold stratification required for germination success (Eckert et al. 2000).

Flowering rush grows in a wide variety of water depths. In the Columbia River Basin, it grows as an emergent along shorelines, graduating out to water depths of more than 6 meters (20 feet) where it is completely submersed. It will grow in still water with muddy substrate to flowing water with rocky substrate and everything inbetween. It thrives in areas with fluctuating water levels, but also persists and spreads in stable water conditions (Hroudová 1989, Hroudová et al.

Figure 6. Flowering rush can be identified by its distinct triangular leaves (Photo credit: P. Rice).

Figure 7. The twisting leaves of an emergent flowering rush (Photo credit: J. Parsons).

1996). It will invade and dominate native plant beds (Madsen et al. 2012) and can colonize habitats previously barren of plant growth (Parkinson et al. 2010). When growing submersed, the leaves are stiff relative to other submersed plants, and thus in flowing water they are present higher in the water column (Gunderson et al. 2016).

Flowering rush exhibits a seasonal growth pattern. It is dormant in winter, and generally the leaves die back to the rhizomes. However, the collapsed dead leaves will occasionally persist through winter, or leaves can also remain upright and green. It begins growing in early spring; in Flathead Lake, Montana it has been recorded to start growing between late February and mid-April (Parkinson et al. 2010). Leaf growth is rapid, peaking in mid-summer (Gunderson et al. 2016), then **senescing**, usually in September to October.

Genetics

Genetic analysis can provide information that helps to manage plant invasions, particularly for species with a variety of **genotypes**. It can pinpoint the origins and population structure of an invasion. This information can be helpful if it is suspected that different genotypes of plants react differently to control efforts. Genetics can also inform how plants are spreading (e.g. from another invasion point or from a source such as a nursery). In addition, understanding the point of origin in the plant's native range can inform biological control agent exploration.

The genotype and ploidy (number of sets of chromosomes in a plant cell) have been studied in-depth for eastern North America populations of flowering rush, but few samples from western North America were included in those studies. The current knowledge of flowering rush genetics suggests the following: there are both diploid (26 chromosomes per cell) and triploid (39 chromosomes per cell) plants that vary in their reproductive strategies (Hroudová et al. 1996) in the North American invasion. The flowering rush in the Columbia Basin is primarily triploid (Poovey et al. 2012), and as such is expected to rarely, if ever, produce viable seed (Hroudová et al. 1996, Lui et al. 2005). Conversely, diploids produce abundant viable seed (Eckert et al. 2003). Diploids produce hundreds of bulbils and triploids usually do not produce bulbils,

Figure 8. Flowering rush's light pink flower (Photo credit: T. Miller).

Figure 9. *A dried flowering rush flower with seed pod (Photo credit: J. Parsons).*

though they clonally reproduce through rhizome fragmentation and buds (Eckert et al. 2003). Even with these reproductive differences, both diploid and triploid populations tend to contain a single clonal genotype, with rare exceptions. Therefore, reproduction by seed appears to be very uncommon in North America.

The number and diversity of genotypes have been analyzed using either Random Amplification of Polymorphic DNA (RAPDs) or Amplified Polymorphic Length Polymorphisms (AFLPs). Both methods can distinguish closely related individual plants. In Europe, Kliber and Eckert (2005) found 47 RAPD genotypes in 71 populations, and only six genotypes in North America, suggesting significantly lower genetic diversity in the introduction history (i.e. founder effect). They also found that most eastern North America plants are diploid. Seven AFLP genotypes in 72 North American populations have been identified, with most of the western North American plants being the triploid genotype 1, and only two other genotypes found at Bouchie Lake, BC (genotype 2) and Entiat Lake, WA and a pond near the town of Bonanza in Klamath County, OR (genotype 3) (John Gaskin, personal communication). Midwestern and eastern North America contain five different genotypes, with genotype 4 being most common in the St. Lawrence Riverway region (Figure 10).

Exact European origins have not been found for the common triploid genotype 1 that dominates western North America, but Kliber and Eckert (2005) suggest the closest genetic matches are from northern Germany and the Netherlands. The triploid flowering rush populations in North America are represented by four distinct but closely related genotypes; 74% of triploid populations are restricted to just one of these (Kliber and Eckert 2005). All four triploid North American genotypes are closely related to the genotypes in the Netherlands and northern Germany (Kliber and Eckert 2005). The introduction of these triploid genotypes to North America was likely facilitated by their export as horticultural plants from the Netherlands (Kliber and Eckert 2005). In a study of horticultural sources in North America, Eckert et al. (2016) determined that most nurseries sell the dominant triploid genotype. Flowering rush appears to also frequently add or delete chromosomes, resulting in a variety of chromosome numbers reported in the literature (Cahoon 2018). It is unclear if the plants with odd chromosome numbers behave more like triploids or diploids in their reproductive strategies.

Exact European origins have not been found for the common triploid genotype 1 that dominates western North America, but Kliber and Eckert (2005) suggest the closest genetic matches are from northern Germany and the Netherlands.

Figure 10. A map of the flowering rush genotypes found across the United States and Canada. Genotypes were derived from Amplified Fragment Length Polymorphism (AFLP) analysis. Seven different AFLP genotypes were identified in North America. Points on the map represent populations of one to 28 individuals, with a total of 574 individual plants genotyped from 78 populations (some populations are geographically close and overlap on the map), and an average of 7 plants per population. Color of marker indicates plant genotypes in a population. Populations contained only one genotype except for the population from Saskatchewan, which contained genotypes 1 and 6. (Photo credit: J Gaskin).

Ecological Impacts

Flowering rush is a generalist, occupying a wide range of habitats. It has been termed an ecosystem engineer for its ability to alter habitat by sediment accretion (Gunderson et al. 2016). These characteristics, along with rapid population expansion, have raised concerns about the potential impacts on habitat and water delivery if flowering rush becomes established throughout the Columbia Basin.

In Flathead Lake, the most critical environmental impact of flowering rush is the formation of dense stands in previously un-vegetated littoral zones (Figure 11). As unchecked infestations increase in size, the potential impacts increase, including changes in water temperature regimes, nutrient transfers from the hydrosoil to the water column (Van Eeckhout and Quade 1994, James et al. 2003), and altered sediment transport, deposition, and accretion rates.

Flowering rush stands provide ideal habitat for great pond snails *(Lymnaea stagnalis)*, an intermediate host for the trematode parasite (*Trichobilharzia ocellata*) that causes swimmer's itch. In one western Washington lake with dense flowering rush, swimmer's itch prevented swimming and wading until flowering rush

Figure 11. Taken from a kayak amid a flowering rush infestation at Flathead Lake (Photo credit: P. Rice).

was controlled.

There is also potential for other biotic impacts, mainly altered aquatic food webs. Of particular importance for the Pacific Northwest is the potential negative impacts on native resident and anadromous salmonids. Stands of flowering rush provide habitat for introduced fish species that spawn on vegetation, including smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*), yellow perch (*Perca flaven*), and northern pike (*Esox lucius*) (Tabor et al. 1993, Fritts and Pearson 2004, Bonar et al. 2005, Schultz 2006, Cooper et al. 2008). These vegetation-adapted piscivorous species prey upon cutthroat trout (*Oncorhynchus clarkii*), bull trout (*Salvelinus confluentus*), and juvenile anadromous salmonid (*Oncorhynchus*) species. The negative impact of introduced fish on open water native salmonids throughout the Columbia Basin is well documented (Northwest Power and Conservation Council 2008, Sanderson et al. 2009). Northern pike have been confirmed as seriously impacting cutthroat and bull trout in the Flathead Basin of Montana (Muhlfeld et al. 2008). Some of the sloughs on the upper Flathead River, Montana that are being utilized by radio tagged northern pike are heavily infested with flowering rush (Peter Rice and Virgil Dupuis, personal communication). Trapping of juvenile northern pike in a slough on the upper Flathead River has shown that at their critical early life stage, they are associated exclusively with the flowering rush infestations and not present in native vegetation or open water (Rice and Dupuis 2014). It appears that flowering rush litter from the previous year is providing spawning habitat and rearing shelter for the larval and early juvenile stages of northern pike in dam regulated systems that are at low pool in the spring. In addition, the macroinvertebrate community composition is significantly different in flowering rush stands when compared with native aquatic macrophyte stands and open water (Rice and Dupuis 2014). The macroinvertebrate functional groups occupying flowering rush infestations are less favorable prey species for native resident and anadromous salmonids.

Figure 12. *Flowering rush preventing use of a boathouse (Photo credit: P. Rice).*

Economic Impacts

The economic impacts of invasive species in the United States have been estimated at $120 billion annually (Pimental et al. 2005) and at $1.3 billion for Washington State (Community Attributes Inc. 2017). There are no publications to date that outline the economic impacts specific to flowering rush infestations, however inferences may be made from the following examples

Figure 13. *Flowering rush negatively impacts the activities of boaters and other recreationists (Photo credit: P. Rice).*

that examine other invasive aquatic species.

In some areas where dense infestations grow adjacent to the shoreline and docks (e.g. Flathead Lake, Montana), recreational use (i.e. boating, fishing and swimming) has been impaired (Figures 12 and 13). Property values have been examined where non-native invasive aquatic plants have become established. Several studies suggest that invasive aquatic plants, such as Eurasian watermilfoil (*Myriophyllum spicatum*), can significantly reduce property values and associated property taxes (Zhang and Boyle 2010, Olden and Tamayo 2014, Liao et al. 2015). The economic impact of Eurasian watermilfoil in Washington State was estimated to be $14.8 million annually (Community Attributes Inc. 2017). Presence of invasive non-native aquatic plants can also reduce shoreline development (Goodenberger and Klaiber 2016). The impact due to invasive *Elodea* spp. in Alaska has been examined and suggests that the probable economic loss to commercial fisheries and recreational floatplane pilots may be $97 million per year, with a 5% chance that combined losses exceed $456 million annually (Schwoerer 2017).

In areas of Montana's Flathead Lake where commercial marinas and homeowners have conducted control actions to prevent the growth of flowering rush, costs have ranged between $575/acre to $715/acre to implement small scale repeated chemical application (Virgil Dupuis, personal communication). In southeastern Idaho, mechanical control of flowering rush is conducted annually on nearly 322 km (200 miles) of Aberdeen-Springfield Canal Company irrigation canals near the Snake River (Figure 14). Initial costs to develop the aquatic vegetation rake to control flowering rush were $75,000/season with costs decreasing significantly once flowering rush was reduced to minimal growth (Steve Howser, personal communication).

An anecdotal exploration into potential impacts of flowering rush debris on infrastructure, such as irrigation structures and hydroelectric facilities, has yielded limited information. In some areas where there are significant infestations of flowering rush, debris that is generated from scouring events could accumulate in different areas and impede flow. In the case of irrigation structures, flowering rush debris has been observed accumulated in racks (Peter Rice, personal communication).

Figure 14. *Mechanical control using the aquatic vegetation rake (AVR) on irrigation canals near the Snake River (Photo credit: Aberdeen-Springfield Canal Company)*

Flowering rush occurs as several distinct populations in the Columbia Basin (Figure 15). The known occurrences of flowering rush in the Columbia Basin are currently being recorded and are housed online[2]. The following outlines what is understood to be the distribution at the time of document completion.

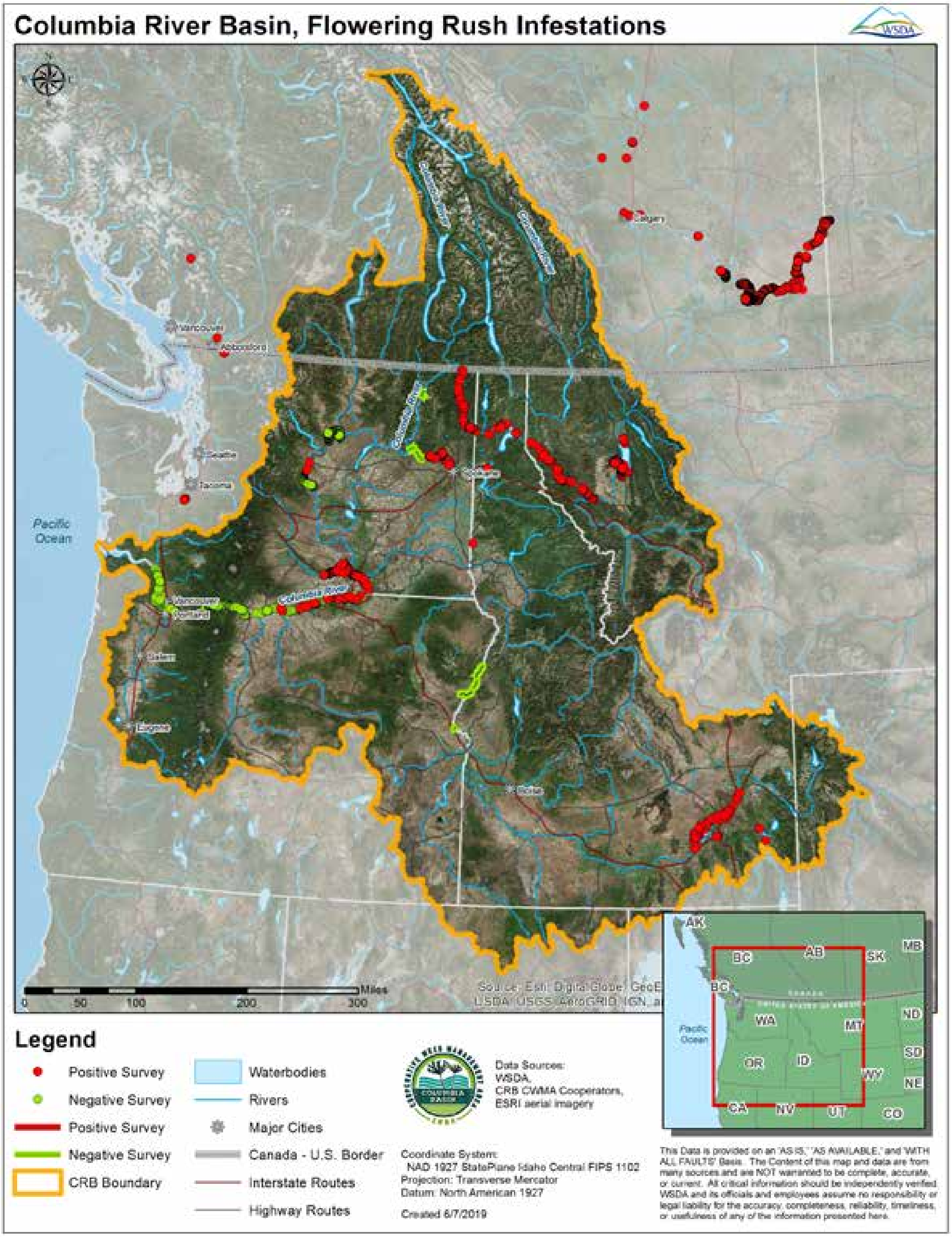

Figure 15. Distribution of flowering rush in the Columbia Basin and surrounding western region.

[2] https://wsda.maps.arcgis.com/apps/webappviewer/index.html?id=9d3b3f18dc3e4b33bb4ca9db923882e3

Tributaries to the Columbia River

Clark Fork and Pend Oreille Rivers

The upper-most population of flowering rush in the Columbia Basin is in Montana. It was discovered in Flathead Lake in 1964 (Consortium of Pacific Northwest Herbaria 2017), and as of 2008, it had infested over 809 hectares (2,000 acres) of the lake (Rice et al. 2010). It has since dispersed up the main tributary of the Flathead River. Flowering rush has spread downstream into the Clark Fork River, which feeds Lake Pend Oreille, Idaho, where it was first noticed in 2007 (US Geological Survey NAS Database). Idaho State Department of Agriculture surveys of Lake Pend Oreille from 2018 indicate that the distribution is patchy from the Clark Fork River Delta, northwest to the Pend Oreille River, and north to the Albeni Falls Dam where sparse individual plants were

> *It was discovered in Flathead Lake in 1964 (Consortium of Pacific Northwest Herbaria 2017), and as of 2008 it had infested over 809 hectares (2,000 acres) of the lake (Rice et al. 2010).*

recorded in Albeni Cove (3 kilometers [1.8 miles] east of the Washington State - British Columbia border). Dense stands (>75% cover) occurred near Clark Fork (Drift Yard), Sunnyside (Pack River Delta south of train causeway), Culver (Oden Bay), Sandpoint (Dog Beach Park, Sand Creek, Long Bridge), Dover (Dover Bay), Sagle (Swan Shores, Morton Slough, Willow Bay), Laclede (Riley Creek Recreational Area) and Priest River (Priest River Recreation Area). Other dense flowering rush areas not captured during the 2018 survey, include Kootenai Bay and Boyer Slough in Culver (Chase Youngdahl, personal communication). There is continued downstream expansion throughout the Pend Oreille River into Washington and within the waters of the Kalispel Tribe (Figure 16). Where the Pend Oreille River dips into British Columbia, Canada, there are no known populations.

Clearwater River

An approximately 0.4 hectare (1 acre) private pond in Idaho County, Idaho has a dense flowering rush population, which covers half of the pond. The infestation was first document in 2018, however the landowner described purchasing "bulbs" from a mail-order vendor about 20 years ago, and is strongly committed to working with the local natural resource management partners to resolve and eradicate the infestation (Connie Jensen-Blyth, personal communication). This isolated flowering rush population lies roughly 5 kilometers (3 miles) from the South Fork of the Clearwater River but with no fluvial connection to nearby waterways.

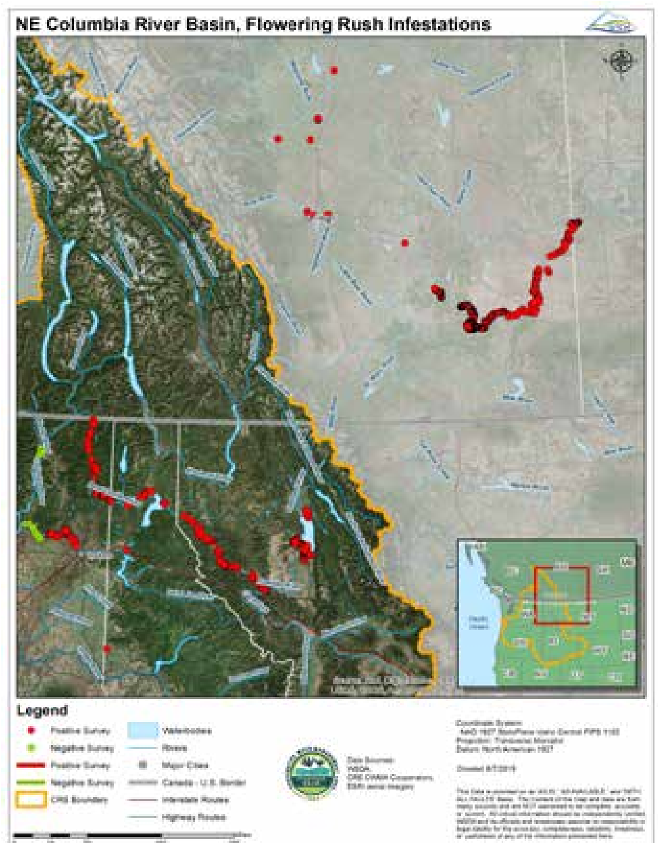

Figure 16. Detailed distribution of flowering rush in northeast portion of the Columbia Basin.

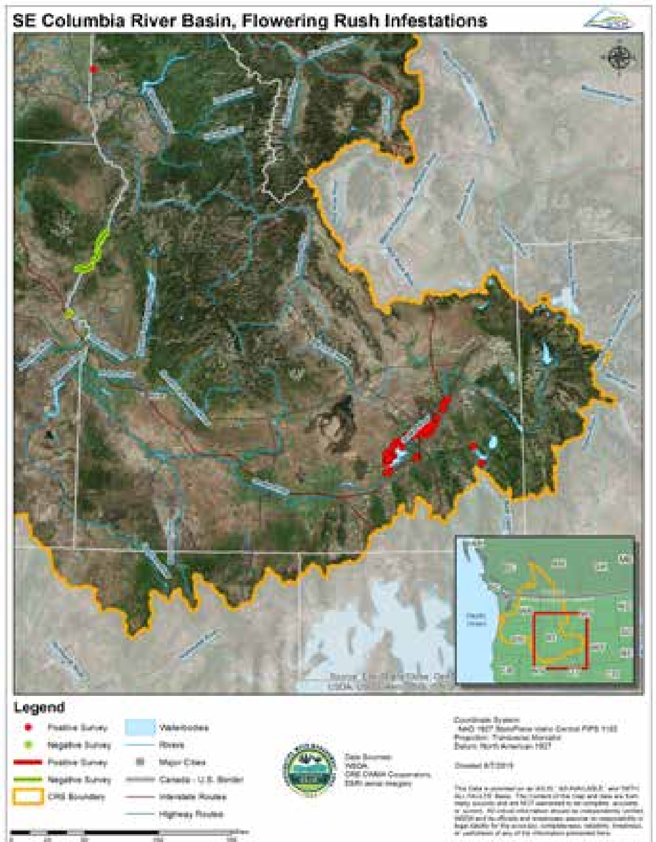

Figure 17. Detailed distribution of flowering rush in the southeast portion of the Columbia Basin.

Snake River

Flowering rush has been in the upper Snake River in southeast Idaho since at least 1949 (Anderson et al. 1974). The upper Snake River populations are found between Idaho Falls and American Reservoir (also known as the Blackfoot Reservoir) and in the associated canal system of the area (i.e. Aberdeen Springfield Canal) (Figure 17). In southwest Idaho, populations have been documented in Gem Lake Reservoir. An inventory for flowering rush on the Snake River conducted by Oregon Department of Agriculture and Portland State University's Center for Lakes and Reservoirs sampled areas between Farewell Bend and Hells Canyon Dam during 2018 and found no flowering rush.

Spokane River

The Spokane River has flowering rush populations in 9-Mile Reservoir, Lake Spokane (sometimes called Long Lake) and Little Falls Reservoir. These populations occur as scattered individual plants or small patches (Figure 18). The Spokane River flows into Lake Roosevelt after Little Falls Reservoir, and no flowering rush has been found to date in Lake Roosevelt.

Yakima River

There is a population of flowering rush in the Yakima River between the town of Prosser and the confluence with the Columbia River. These are mostly scattered emergent plants, except in the vicinity of two diversion dams where water is deeper and flowering rush grows to approximately 4 meters (12 feet) deep (Figure 19).

Mainstem of the Columbia River

While there are several known populations of flowering rush in British Columbia, none of those populations are within the Columbia River watershed of British Columbia at the time of document completion. When the Columbia River flows into Washington State from British Columbia, it becomes impounded behind Grand Coulee Dam as Lake Roosevelt. No flowering rush has been found in this reservoir to date. The first known flowering rush location down river of Lake Roosevelt is in Lake Entiat, the impoundment behind Rocky Reach Dam. There the flowering rush restricted to small groups of scattered patches near Lincoln Rock State Park and the Orondo Park boat launch[3].

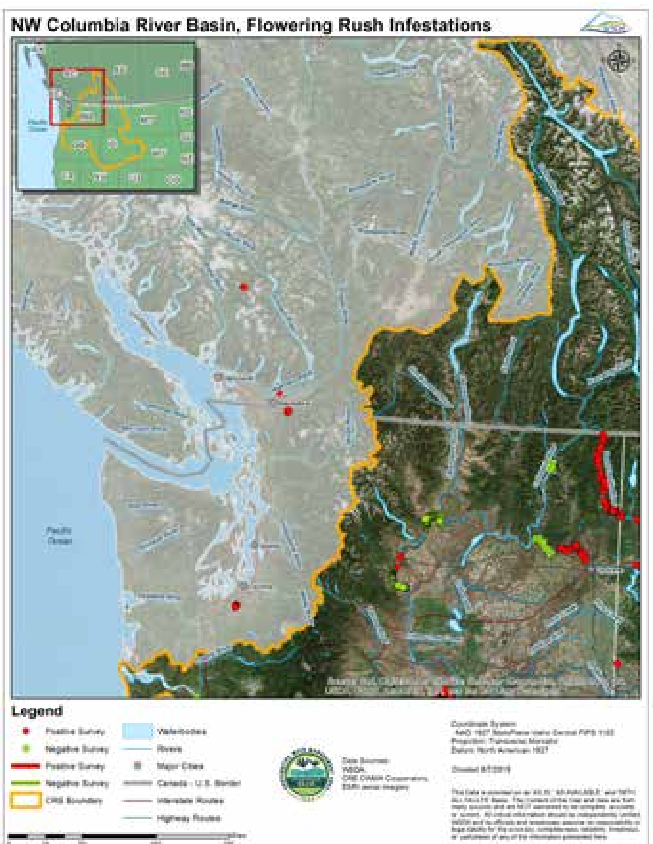

Figure 18. Detailed distribution of flowering rush in the northwest portion of the Columbia Basin.

Figure 19. Detailed distribution of flowering rush in the southwest portion of the Columbia Basin.

Downstream, the Yakima River population has spread into the Columbia River. Flowering rush is present as mostly submersed patches, some as large as 2 hectares (5 acres), in Lake Wallula behind McNary Dam. Widely scattered patches have also been found in the next lower impoundment of Lake Umatilla behind the John Day Dam (Figure 19). At the time of document completion, no flowering rush had been identified from the Columbia River below John Day Dam.

[3] This population in Lake Entiat is genetically different from the population immediately upstream from it.

Management Policies Relevant to Flowering Rush

There are various federal, state/provincial and tribal policies that guide the management of flowering rush within the Columbia Basin. The primary legislation or regulations have been identified here.

United States Federal Regulations

Archaeological Resources Protection Act

Actions to manage invasive species require consultation through the Archaeological Resource Protection Act (1979) and with local tribes due to the concern of impact to cultural and historical areas.

Executive Order 13751

"It is the policy of the United States to prevent the introduction, establishment, and spread of invasive species, as well as to eradicate and control populations of invasive species that are established. Invasive species pose threats to prosperity, security, and quality of life. They have negative impacts on the environment and natural resources, agriculture and food production systems, water resources, human, animal, and plant health, infrastructure, the economy, energy, cultural resources, and military readiness.

Executive Order 13112 of February 3, 1999 (Invasive Species), called upon executive departments and agencies to take steps to prevent the introduction and spread of invasive species, and to support efforts to eradicate and control invasive species that are established. Executive Order 13112 also created a coordinating body -- the Invasive Species Council, also referred to as the National Invasive Species Council -- to oversee implementation of the order, encourage proactive planning and action, develop recommendations for international cooperation, and take other steps to improve the Federal response to invasive species. It also directed Federal agencies to conduct, as appropriate, activities related to invasive species prevention; early detection, rapid response, and control; monitoring; restoration, research; and education. Past efforts at preventing, eradicating, and controlling invasive species demonstrated that collaboration across Federal, State, local, tribal, and territorial government; stakeholders; and the private sector is critical to minimizing the spread of invasive species and that coordinated action is necessary to protect the assets and security of the United States.

This order amends Executive Order 13112 (December 2016) and directs actions to continue coordinated Federal prevention and control efforts related to invasive species. Among other actions, the amendment incorporates considerations of human and environmental health, climate change, technological innovation, and other emerging priorities into federal efforts to address invasive species; and strengthens coordinated, cost-efficient federal action."

Endangered Species Act

The purposes of the Endangered Species Act (ESA) are to provide a means for conserving the ecosystems upon which endangered and threatened species depend and a program for the conservation of such species. The ESA directs all federal agencies to participate in conserving these species. Specifically, section 7 (a)(1) of the ESA charges federal agencies to aid in the conservation of listed species, and section 7 (a)(2) requires the agencies, through consultation with the US Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS), to ensure their activities are not likely to jeopardize the continued existence of listed species or adversely modify designated critical habitats. Section 7(a)(2) requires federal agencies to consult on actions they fund, authorize, permit, or otherwise carry out.

In the Columbia Basin aquatic system, the USFWS has primary responsibility for freshwater organisms, including bull trout, while the responsibilities of NMFS are anadromous fish, such as salmon. It is most efficient if federal agencies, applicants, and the appropriate agency engage in early coordination to develop methods of integrating proposed treatment activities with the conservation needs of listed resources before the proposed actions are fully designed.

National Environmental Policy Act (NEPA)
42 U.S.C. §4321 et seq. (1969)

The National Environmental Policy Act (NEPA) of 1969 was created to ensure federal agencies consider the environmental impacts of their actions and decisions. Federal agencies are required to systematically assess the environmental impacts of their proposed actions and consider alternative ways of accomplishing their missions, which are less damaging to and protective of the environment. All federal agencies must use a systematic interdisciplinary approach to environmental planning and evaluation of projects which may have an effect on the environment. Environmental Assessments (EA) and Environmental Impact Statements (EIS), which are assessments of the likelihood of impacts from alternative courses of action, are required from all federal agencies and are the most visible NEPA requirements.

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) 7 U.S.C. §136 et seq. (1996)

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1996 provides for federal regulation of pesticide distribution, sale, and use. All pesticides distributed or sold in the United States must be registered (licensed) by the Environmental Protection Agency (EPA).

The Federal Noxious Weed Act (FNWA)
Section 15 (1974)

Section 15 of the FNWA requires federal land management agencies to develop and establish a management program for control of undesirable plants that are classified under state or federal law as undesirable, noxious, harmful, injurious, or poisonous, on federal lands under the agency's jurisdiction (7 U.S.C. 2814(a)). FNWA also requires the federal land management agencies to enter into cooperative agreements to coordinate the management of undesirable plant species on federal lands where similar programs are being implemented on state and private lands in the same area (7 U.S.C. 2814(c)).

National Pollutant Discharge Elimination System

The National Pollutant Discharge Elimination System (NPDES) permit program, created in 1972 by the Clean Water Act, helps address water pollution by regulating point sources that discharge pollutants to waters of the United States. Under the Clean Water Act, the EPA has authorized the NPDES permit program to the States of WA, OR, and MT; and tribal, and territorial governments, enabling them to perform many of the permitting, administrative, and enforcement aspects of the NPDES program. EPA retains oversight responsibilities in these states.

With respect to NPDES permits, section 511 of the Clean Water Act establishes that only EPA-issued permits to "new sources" (dischargers subject to new source performance standards) are subject to NEPA's environmental review procedures under state law prior to permit issuance. States may have their own versions of NEPA.

Various federal and state regulations can also apply EPA NPDES Pesticide General Permit (chemical treatments), state fish and wildlife permits and potentially state departments of environmental quality or ecology permits based on locations of action being taken and based on if the state has primacy over the agency/organization taking the action.

National Historic Preservation Act (NHPA), 16 U.S.C. 470 et seq.

Section 106 of NHPA and implementing regulations (36 CFR part 800) require the EPA regional administrator, before issuing a license (permit), to adopt measures when feasible to mitigate potential adverse effects of the licensed activity and properties listed or eligible for listing in the National Register of Historic Places. This Act's requirements are to be implemented in cooperation with state historic preservation officers and upon notice to, and when appropriate, in consultation with the Advisory Council on Historic Preservation.

National Invasive Species Act

The National Invasive Species Act (NISA) was passed in 1996 amending the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990. The 1990 Act established the Aquatic Nuisance Species (ANS) Task Force to coordinate nationwide ANS activities. The ANS Task Force is co-chaired by the USFWS Assistant Director for Fisheries and Habitat Conservation and the Undersecretary of Commerce/National Oceanic Atmospheric and Administration (NOAA). NISA furthered ANS activities by calling for ballast water regulations, the development of state aquatic invasive species management plans and regional panels to combat the spread of ANS, and additional ANS outreach and research.

United States Federal Agencies

US Bureau of Reclamation

The US Bureau of Reclamation (USBR) owns and operates many water projects within the Columbia Basin, in addition to conducting noxious plant control projects. Any USBR water projects in the Columbia Basin (e.g. Grand Coulee Dam which creates Lake Roosevelt) would be subject to applicable laws and policies to conduct management of flowering rush.

US Fish and Wildlife Service

This management plan includes two regions of the USFWS; Region 6 (Montana) and Region 1 (Idaho, Washington, Oregon, Pacific Islands). Compliance with the Endangered Species Act requires consultation with the USFWS Ecological Services Programs in both Region 1 and Region 6 where management actions could affect salmonids and other native species. Invasive species management is an important component for the USFWS. Management of aquatic invasive species is one of seven core goals identified as priorities in the Strategic Plan for USFWS Fish and Aquatic Conservation Program, 2016-2020 (USFWS 2016). The plan focuses on working with tribes, states, and other partners to prevent introductions; implement an early detection and rapid response framework; prevent the spread; and manage, control, and monitor established populations of invasive species. The Refuge Program within the USFWS manages invasive species through prevention strategies, surveillance, treatment and monitoring on refuge lands. Within Region 1, USFWS has developed a regional invasive species policy to minimize the introduction of invasive species by USFWS activities. This policy also establishes minimum expectations for invasive species prevention guidelines for field activities conducted, funded, reviewed or authorized by Pacific Region employees.

There are a number of wildlife refuges and waterfowl production areas managed by the USFWS within the Columbia Basin. While many of these areas may have general management guidelines related to noxious weeds, typically none are specific to early detection or rapid response for flowering rush.

National Oceanic Atmospheric Administration

The National Oceanic Atmospheric Administration requires consultation with the NMFS to comply with Endangered Species Act requirements where management actions could affect salmonids and other native species.

National Park Service

The National Park Service's (NPS) Invasive Plant Program (IPP) leads the invasive terrestrial plant issues, as well as some aquatic and wetland plant species. The IPP provides technical assistance and policy guidance to parks and regions on matters related to invasive species prevention, containment, management, and monitoring. The Columbia Basin's Lake Roosevelt is under the management authority of NPS. Any management actions on flowering rush would follow relevant laws and policies of NPS.

US Army Corps of Engineers

The US Army Corps of Engineers (USACE) manages and administers lands and waters, for Federal Civil Works projects, and USACE lands that are utilized for grants and permits. In June 2009, a USACE policy memorandum established a USACE invasive species policy, which complemented the National Invasive Species Act, various executive orders and the National Invasive Species Management Plan, and serves as a blueprint for USACE. This nationwide policy is applied to all Civil Works project operations, planning, regulatory program, and Engineer Research and Development Center (ERDC). Measures to either prevent or reduce establishment of invasive and non-native species will be a component of all USACE Operations and Maintenance (O&M) at project sites, as well as a part of implementation of Civil Works projects.

US Department of Agriculture – Forest Service

The Forest Service works cooperatively with various stakeholders to implement appropriate regulations related to invasive species management, in many situations by working with state entities to implement their statues. Several federal regulations, including the Federal Noxious Weed Act, are applied to Forest Service invasive species management activities.

Canadian Federal Regulations

Pest Control Products Act & Regulations

Pesticides must be registered prior to use in Canada and be used according to the label directions. Pesticides are registered through Health Canada's Pest Management Regulatory Agency (PMRA).

Currently, diquat is the only registered aquatic herbicide for use in Canada. In an emergency, there is the potential to use a non-registered product.

An emergency is generally deemed to exist when both of the following criteria are met:

- An unexpected and unmanageable pest outbreak or pest situation occurs that can cause significant health, environmental, or economic problems; and
- Registered pesticides and cultural control methods or practices are insufficient to address the pest outbreak.

An Emergency Use Registration can be applied for and granted if the following criteria are met:

- Active ingredients must already be registered in Canada (e.g. a terrestrial product with the same active ingredient is registered).
- An emergency registration cannot be granted for longer than one year and may not be renewed.
- Where the pest infestation is predicted to remain an ongoing issue in future years, the PMRA expects the sponsor and registrant to prioritize the pest issue and pursue full registration of the use through normal regulatory processes as soon as possible.

Federal Fisheries Act & Aquatic Invasive Species Regulations

The aquatic invasive species regulations have designated prescribed persons to authorize the deposit of deleterious substances in the Department of Fisheries and Oceans, Parks Canada, Ontario, Nova Scotia, Manitoba, British Columbia, Saskatchewan, Alberta, and the Yukon. This allows the approval for the deposit of deleterious substances to be issued by the provinces indicated.

Deposit of Deleterious Substance for the Control of Aquatic Invasive Species, subject to section (3), states the deposit of deleterious substance (pesticides) is prohibited in water frequented by fish or in any place under any conditions where the deleterious substance or any other deleterious substance that results from the deposit of the deleterious substance may enter any such water unless authorized by the regulations.

Department of Fisheries and Oceans (DFO) Request for Review

Subject to section 35(1) activities that may cause serious harm to fish that are part of a commercial, recreational or aboriginal fishery or to fish that support such a fishery require a DFO Request for Review unless the project meets criteria within the self-assessment. Aquatic invasive species control and/or eradication activities are not listed within the self-assessment at this time.

Species at Risk Act

No permit issued. The Species at Risk Act prohibits the killing, harming, harassment, possession, capturing, or taking of a species listed as extirpated, endangered, or threatened and the damage or destruction of a residence or the destruction of any part of the critical habitat of such a listed species. The DFO self-assessment should be used to determine whether the project should be submitted for a request for review.

Migratory Breeding Birds Convention Act

Migratory Breeding Birds Conventions Act 5.1 (1) *No person or vessel shall deposit a substance that is harmful to migratory birds, or permit such a substance to be deposited, in waters or an area frequented by migratory birds or in a place from which the substance may enter such waters or such an area.*

Permits are not issued for waterbodies where migratory birds may be present. Environment Canada also does not have the authority to prescribe, recognize, or approve specific best management practices (BMPs). While BMPs do not necessarily guarantee compliance with legislation, it is the provincial government's responsibility to develop and implement appropriate preventive and mitigation measures to reduce the risk of detrimental effects of their activities to help maintain sustainable populations of migratory birds.

Navigation Protection Act

It is prohibited to construct, place, alter, repair, rebuild, remove or decommission a work in, on, over, under, through, or across any navigable water that is listed in the schedule except in accordance with this Act or any other federal Act. It is prohibited to dewater any navigable water. If invasive species control activities require the temporary or permanent shut down of a listed navigable waterbody then this Act would require approval from the Federal Minister.

Canada Federal Agencies

Fisheries and Ocean Canada

Fisheries and Oceans Canada and the Canadian Coast Guard manage Canada's fisheries and safeguard its waters. They ensure commercial vessels and recreational boaters can safely navigate our waters and are there to save lives and protect the environment when emergencies arise; sustainably manage fisheries and aquaculture and work with fishers, coastal and Indigenous communities to enable their continued prosperity from fish and seafood; and ensure that Canada's oceans and other aquatic ecosystems are protected from negative impacts. Their work is centered on four core responsibilities: fisheries, aquatic ecosystems, marine navigation and, marine operations and response.

Each responsibility calls for science-based decision-making, engagement with Canada's Indigenous Peoples and reliance on the Canadian Coast Guard fleet as a platform for on-water activities. Aquatic invasive species reports for marine species are led by Fisheries and Oceans Canada, whereas freshwater species have been deferred down to provincial or territorial governments.

Tribal Regulations

Within the Columbia Basin, there are many tribal and First Nations stakeholders which may have a role in management decisions or implementation of actions to address flowering rush. We would like to acknowledge that there are Tribes and First Nations that may not be represented here but that have a stake in management of flowering rush. The information that follows provides examples of tribal authority and response to flowering rush, but it is not a comprehensive archive of tribal and First Nation management in the Columbia Basin.

Coeur d'Alene Tribe (Idaho)

If flowering rush is discovered within the Coeur d'Alene Lake Basin or within the boundaries of the Coeur d'Alene Reservation, then the Tribe would support/implement an appropriate response using existing invasive species programs, management plans, or partnerships. Any efforts would be subject to applicable rules, regulations, or plans governing protection of natural and cultural resources.

Confederated Tribes of the Colville Nation (Washington)

The Colville Tribes follow all state and federal laws pertaining to control of noxious weeds. Flowering rush is listed as a high priority weed species in the 2016 Land Operations Integrated Weed Management Plan. A project proposal for eradication would begin immediately following any findings of flowering rush within the boundaries of the Colville Reservation and the adjacent reaches of the Okanogan and Columbia Rivers. Any management plan would follow the Tribes' project proposal process (3P) prior to applying treatments.

Confederated Salish Kootenai Tribes (Montana)

Ordinance 64a, which deals with work below the high water mark of Flathead Lake, and Ordinance 87a, which protects all other wetlands and streams within the reservation, would be implemented for flowering rush management projects. Empowered by the Environmental Protection Agency, the Confederated Salish Kootenai Tribes work to ensure adherence to the FIFRA.

Confederated Tribes and Bands of the Yakama Nation (Washington)

The Yakama Tribe adheres to all state and federal laws and regulations to conduct any noxious weed management activity. Additionally, consultation with tribal archaeologists to minimize any potential disturbances from a management action are completed. Flowering rush is listed as a "Watch" species in the 2011 *Integrated Invasive Plant Management Plan for the Yakama Reservation*. If detected within the Yakama Reservation, it would immediately be given an "A" classification and an eradication attempt would be initiated. In addition to authority for weed control within the Reservation, the Yakama Nation has broad interests in resource management within the Yakama Ceded Territories (Appendix D), as well as, a strong management presence for aquatic management throughout the Yakima River Basin. No additional tribal ordinances to address noxious weeds, including flowering rush, have been created.

Confederated Tribes of the Umatilla Indian Reservation (Oregon)

Management of flowering rush is addressed by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) in their Integrated Weed Management Plan. Within the riparian areas are priority weed management areas due to the cultural importance of the associated fish habitats for First Foods. Management objectives for riparian areas will be based on the specific invasive weeds present and will follow the species prioritization listed according to the current CTUIR Invasive Weed List. Watch List species are defined as invasive weeds that are not currently known to occur in the Integrated Weed Management Plan (IWMP) management area but have the potential to establish and become invasive. Prevention is the primary management objective for IWMP Watch List species. If any of the Watch List species are detected in the IWMP management area, the species will become a "Priority 1" species for treatment and eradication of the infestation will be attempted. Flowering rush is designated as a watch species.

Kootenai Tribe of Idaho (Idaho)

Prevention of invasive aquatic species is a primary management objective for the Kootenai Tribe of Idaho. Flowering rush is not currently known to be present in the Kootenai drainage, but if detected, the Tribe would work with other management agencies to treat and eradicate it. Flowering rush has a high priority 'Early Detection - Rapid Response' designation in Boundary County, indicating that eradication could be feasible.

> *We would like to acknowledge that there are Tribes and First Nations that may not be represented here but that have a stake in management of flowering rush.*

Kalispel Tribe of Indians (Washington)

The Invasive Aquatic Plant and Invertebrate Prevention and Control Section of the *Kalispel Natural Resources Conservation Plan* outlines appropriate control actions which are guided by the severity of the ecological threat created by the invasive species along with the level of control effort required and ecological harm created by implementation of control actions. The Kalispel Tribe has authority to enforce provisions of the Clean Water Act (CWA) and relevant management actions would be subject to the completion of a Tribal Water Quality Protection Permit and obtaining a CWA section 401 certification.

Spokane Tribe of Indians (Washington)

The Spokane Tribe of Indians adheres to all state and federal laws and regulations while conducting any noxious weed management activity. The Tribe's management activities will be guided by the Spokane Tribe of Indians Vegetation Management Plan and the Integrated Resource Management Plan for the Spokane Indian Reservation.

State and Provincial Regulations

The state and provincial regulations that may affect flowering rush management actions have been captured here.

Alberta

Prior to 2010, flowering rush was permitted in Alberta. In 2010, the Alberta Weed Control Act, within the jurisdiction of Alberta Agriculture and Forestry, listed flowering rush as a prohibited noxious weed; meaning, where found, it would need to be destroyed. Alberta Agriculture and Forestry jurisdiction lies from the land to the low water mark line. In 2015, the Alberta Fisheries Act, within the jurisdiction of Alberta Environment and Parks, was amended to include a listing of 52 fish, aquatic plants, and invertebrates that are now prohibited to import, sell, transport, or possess in Alberta. This listing includes flowering rush. Alberta Environment and Parks jurisdiction is from the high water mark line to the bed and shore. Due to the overlapping jurisdiction and legislation between Alberta Agriculture and Forestry and Alberta Environment and Parks, both ministries have been involved in control and eradication measures.

British Columbia

Flowering rush has been regulated as a Provincial Noxious Weed under the BC Weed Control Act since 2011 and will be proposed as a provincial Prohibited Noxious Weed in future legislation revisions. Under this legislation, owners or occupiers of land have a duty to control listed noxious weeds on their property and can be instructed to comply by a weed inspector. The weed inspector can detail the level of control required (e.g. preventing seed dissemination to complete eradication). Flowering rush is a candidate for eradication in BC under the Provincial Invasive Species Early Detec-

GEOGRAPHIC AREA	REGULATORY CLASSIFICATION	CLASSIFICATION AGENCY
Alberta	**Prohibited Noxious (subject to eradication) /Prohibited**	**Alberta Agriculture and Forestry Alberta Environment & Parks**
British Columbia	**Provincially Noxious**	**BC Inter-Ministry Invasive Species Working Group**
Idaho	**Containment Class (subject to reduction or elimination)**	**Idaho State Department of Agriculture**
Montana	**Priority 2A (subject to eradication or containment)**	**Montana Department of Agriculture**
Oregon	**List A (subject to control/eradication) List T (approved for control)**	**Oregon Department of Agriculture**
Washington	**Class A (subject to eradication and prevention)**	**Washington State Noxious Weed Control Board**

Table 1. Regulatory classification of flowering rush as per jurisdiction.

tion Rapid Response Plan. Natural water bodies within the province fall under the jurisdiction of the Ministry of Forests, Lands, Natural Resource Operations and Rural Development. The current land management goal for this species is containment with the ultimate goal of eradication. The sale and transport of flowering rush is not currently prohibited in BC; however, future legislation revisions will seek to change this. This species is also listed under the Community Charter - Environment and Wildlife Regulation.

Idaho

Assigned to the 'Containment' category on the Idaho State Noxious Weeds List, flowering rush management mainly consists of reduction or elimination of new and expanding populations. Under Idaho statute, management duties reside with counties, as well as, landowners and citizens with assistance from the Idaho State Department of Agriculture. In addition, cultivation, commerce, and transport of any state-listed noxious weed is prohibited. Certain counties maintain additional noxious weed priority schemes based on local distribution. As a result, flowering rush has a high priority 'Early Detection - Rapid Response' designation in some counties where absent or limited distribution, implying that eradication could be feasible (e.g. Boundary County, Idaho County).

Montana

Flowering rush is currently listed as a 2A noxious weed in Montana. A 2A weed is considered common in isolated areas of Montana. Management criteria will require eradication or containment where less abundant. Management shall be prioritized by local weed districts. Due to overlapping rules and statues, Montana Department of Agriculture, county weed districts and Montana Fish, Wildlife & Parks may work to contain, control, manage and eradicate, where feasible, aquatic invasive plant species including flowering rush. New satellite populations would be targeted for eradication and control, and containment efforts are used for established populations.

Oregon

Flowering rush is an A-rated weed in the state of Oregon. An A-rated weed is a weed of known economic importance which occurs in the state in small enough infestations to make eradication or containment possible; or is not known to occur, but its presence in neighboring states make future occurrence in Oregon seem imminent. The recommended response to an A-rated weed presence is to treat infestations with the intent of eradication or intensive control when and where found. Control of A-rated weeds is mandatory under state law. These weeds are also subject to quarantine and are not allowed to be grown, transported, or brought into the state.

Washington

Flowering rush is a Class A noxious weed on the State Noxious Weed List. Class A weeds are non-native species whose distribution in Washington State is still limited. Eradicating existing infestations and preventing new infestations are the highest priority for the State. Flowering rush is also on the Washington Department of Agriculture's quarantined list of plants. The sale or distribution of flowering rush is prohibited, including importation from other states or countries.

The strategies used to control other types of aquatic noxious weeds have been explored as tools to manage flowering rush. These include manual, mechanical, cultural, chemical, and biological control methods. Several have been examined in a variety of locations and conditions across the Columbia Basin.

Manual

Manual methods that have been utilized to control flowering rush:

- hand digging de-watered plants
- SCUBA divers using Diver Assisted Suction Harvesting (DASH)
- benthic barriers

These methods have the advantage that no chemical residues are present at a treatment site or in the water that moves downstream. When hand digging de-watered plants, simple materials such as hand tools and buckets are used to completely remove the entire plant. Hand digging can be utilized in areas where populations are exposed aerially to provide ease of access (Figure 20). Raking the leaves to remove plant material is not advised as it would disturb the shallow rhizomes and likely increase spread.

Figure 20. *It is possible to hand dig flowering rush when it is easily accessed. (Photo credit: J. Parsons)*

DASH method utilizes a snorkeler or SCUBA diver depending on depth, current and other site specific parameters. The diver uses a combination of hand-pulling, digging and suction with an underwater vacuum to remove the full plant (Figure 21). The suction is created using a water pump on a boat and hoses to create a "Venturi" effect. Removed plants are suctioned

Figure 21. *ACE diver Todd Manny with DASH suction tube and helmet camera (Photo credit: R. Benoit).*

to a holding tank on the boat and then are disposed of according to state/provincial/tribal regulations for noxious weed disposal (often on land in a dry environment which kills the plant). The application of DASH is best suited to areas with small patchy infestations due to the amount of labor and expense required. Hand digging and DASH must be done with care to remove all rhizomes and rhizome buds. Using netting to contain fragments that might be released while divers are loosening flowering rush rhizomes can be useful especially if there is any current at the site (otherwise suction is enough). Repeated treatments are usually required because it is very difficult to remove all of the rhizome fragments.

Benthic barriers can be used to suppress growth of flowering rush in the areas where they are laid down (Figure 22a and 22b). In locations such as boat slips and marinas, they can be an effective tool with proper placement and maintenance. Because plants can continue to spread and grow once covered, benthic barriers should extend well beyond the edge of the flowering rush patch and be adequately weighted to prevent further growth. Common benthic barriers are constructed of geotextile materials, which exclude light but allow gasses to

Figure 22a. Benthic barrier held down by sandbags (Photo credit: US Army Corp of Engineers).

escape. It is unclear how long a benthic mat should remain in place to kill all rhizome material underneath. One study in Idaho suggests that 16 weeks of cover was not enough to reduce the rhizome biomass (Madsen et al. 2017). In another trial in Idaho, flowering rush was viable after up to 5 years of cover (Tom Woolf, personal communication).

A combination of DASH and covering with benthic barrier has shown promise in controlling small, isolated patches of flowering rush in the Columbia River near McNary Dam. Several sites appeared free of flowering rush two years after the treatment, while other sites with larger initial patches required follow-up with additional benthic barriers to cover new plants near the initial site. Now, three years' post-treatment, some benthic barriers have plants growing around their edges (Mark Porter, personal communication).

Mechanical

Mechanical control methods such as mowing or rototilling are likely to increase the rate of flowering rush spread through root and rhizome disturbance and fragmentation (Marko et al. 2015). However, in areas where flowering rush is dense, mowing repeatedly may reduce the plant's rhizome energy reserves and eventually reduce rhizome abundance, as was demonstrated in an Alberta lake after 20 years of mowing (Cahoon 2018).

Using machines such as back-hoes to dig flowering rush also creates fragments. However, a specially designed bucket, referred to as the Aquatic Vegetation Rake[4] (AVR , see Figure 14), attached to a back-hoe has proven successful at reducing flowering rush biomass and improving water delivery in irrigation canals in southeast Idaho where chemicals cannot be used (Steve Howser, personal communication).

Cultural

Flowering rush rhizomes are not deleteriously affected by freezing, so winter drawdown to promote freezing of sediment does not provide control.

Flowering rush establishment is encouraged by fluctuating water levels (Parkinson et al. 2010). Because exposed bare or sparsely-vegetated substrates are ideal for seed, rhizome, and bulbil sprouting (Hroudová et al. 1996), maintaining stable water levels or increasing levels with flooding events have been explored as a management option. Neither type of water level manipulation has successfully suppressed flowering rush populations once the plant is established (Marko et al. 2015).

Figure 22b. Benthic barrier before it is laid over infested area (Photo credit: J. Andreas).

[4] https://maximizedwatermanagement.com

Chemical

Many herbicides have been tested on flowering rush, yet so far no chemical has been found that will provide complete control with one or a few treatments (Figure 23). In addition, chemical methods can contribute to residuals in the water that may migrate from the treatment site. There are several herbicides that will provide partial to good control, but they vary depending on the plant's growth form and treatment conditions. A summary of known herbicide trial results is presented in Table 2. Reduction of the rhizomes and rhizome buds is the most desirable outcome from any control method, since rhizomes are the key to flowering rush persistence and expansion. However, not all herbicide trials have quantified impacts to the root system. All available methods for containment within the treatment site should be utilized.

Based on the experience of the management plan authors, as well as from results of other published studies, the following recommendations are suggested with the caveat that future work may discover improved outcomes that are not reported here.

Figure 23. *Herbicide application at the East Bay of Flathead Lake (Photo credit: P. Rice).*

Emergent growth treatments: At least 0.6 meters (2 feet) of exposed leaf should be present above the water to treat. If less than that is above the water, it is better to treat submersed growth with an herbicide approved for that use-mode. A surfactant should be combined with the foliar herbicide to improve leaf absorption. Make sure the surfactant is approved for use in aquatic situations in the region where the treatment is taking place (Figure 24).

Figure 24. *Emergent growth treated with herbicide in the Columbia Basin (Photo credit: J. Parsons).*

The most promising foliar herbicides, where field trials followed plant growth for at least one-year post-treatment, are imazapyr and glyphosate. However, one-time emergent foliar treatments with imazapyr provided only 35% control one year after treatment, and imazamox provided only 23% control (Rice et al. 2009). Trials with shorter term assessment found additional potential products (Table 2), but due to the ability of flowering rush to recover from initial leaf die-back because of regrowth from the rhizomes, results from studies that follow plants for at least one-year are necessary to inform managers.

GROWTH FORM	TREATMENT TIMING	HERBICIDE	RESULTS**	SOURCE
EMERGENT*	summer	2,4-D + triclopyr	no control 12 MAT (1 ft leaf exposed and treated)	Rice et al. 2009
		glyphosate	up to 61% control of leaves 12 MAT (2+ ft of leaf exposed)	Miller 2009
		glyphosate + imazapyr	50% control of leaves 12 MAT using higher rates (4% + 0.5% respectively), 1 + ft of leaf exposed	Miller 2011
		imazamox	23% control 12 MAT (1 ft leaf exposed)	Rice et al. 2009
		imazamox + carfentrazone-ethyl	not effective if plants rooted in water > 1 ft deep	Madsen and Miskella 2018
		imazapyr	74% control 12 MAT (2+ ft of leaf exposed); 35% control (1 ft leaf exposed)	Miller 2009; Rice et al. 2009
		triclopyr	56% control 12 MAT (2+ ft of leaf exposed)	Miller 2009
	late season	2,4-D	50% control 6 WAT in mesocosms, 30 - 70 cm of leaf exposed	Wersal et al. 2014
		2,4-D + triclopyr	95% control 6 WAT in mesocosms, 30 - 70 cm of leaf exposed	Wersal et al. 2014
		aminopyralid	95% control 6 WAT in mesocosms, 30 - 70 cm of leaf exposed	Wersal et al. 2014
		glyphosate	80% control 6 WAT in mesocosms, 30 - 70 cm of leaf exposed	Wersal et al. 2014
		imazamox	95% control 6 WAT in mesocosms, 30 - 70 cm of leaf exposed	Wersal et al. 2014
		imazamox + glyphosate	95% control 6 WAT in mesocosms, 30 - 70 cm of leaf exposed	Wersal et al. 2014
		imazapyr	95% control 6 WAT in mesocosms, 30 - 70 cm of leaf exposed	Wersal et al. 2014
		imazapyr + glyphosate	100% control 6 WAT in mesocosms, 30 - 70 cm of leaf exposed	Wersal et al. 2014
		triclopyr	90% control 6 WAT in mesocosms, 30 - 70 cm of leaf exposed	Wersal et al. 2014

Table 2. A summary of herbicide treatments and herbicide type that have been examined for flowering rush control.
** surfactants approved for aquatic use were combined with the herbicide for trials on emergent growth*
***WAT=weeks after treatment, MAT=months after treatment*

GROWTH FORM	TREATMENT TIMING	HERBICIDE	RESULTS**	SOURCE
EMERGENT*	fall (Nov in Idaho) treatment of de-watered canals	diuron	not effective	Madsen and Miskella 2018
		flumioxazin	not effective	Madsen and Miskella 2018
YOUNG EMERGENT*	spring, de-watered shore	2,4-D + triclopyr	not effective (6% control 13 MAT)	Rice et al. 2009
		acetic acid	not effective	Madsen et al. 2017
		aminopyralid	not effective	Madsen et al. 2017
		copper	not effective	Turnage et al. 2017
		flumioxazin	not effective	Madsen et al. 2017
		fluridone	reduced above and below ground biomass in mesocosms, but not field trials	Madsen et al. 2017; Madsen et al. 2016
		imazamox	reduced above ground biomass in mesocosms, mixed results from field trials. Madsen et al (2017) saw no reduction, but Rice (2009) had 53% control 13 MAT with 2 qt/acre rate	Madsen et al. 2017; Rice et al. 2009
		imazapyr	reduced above ground biomass in mesocosms, mixed results from field trials. Madsen et al (2017) saw no reduction, but Rice (2009) got 87% control 13 MAT with both 2 & 3 qt/acre application rate. A second treatment the year following resulted in >95% control 1 year after second treatment	Madsen et al. 2017; Rice et al. 2009 & unpublished data
		penoxsulam	reduced above ground biomass in mesocosms	Madsen et al. 2017
		triclopyr	liquid - mixed results in mesocosms, not effective in field trial	Madsen et al. 2017
		triclopyr	granular - reduced above ground biomass in mesocosms	Turnage et al. 2017

Table 2. A summary of herbicide treatments and herbicide type that have been examined for flowering rush control.
** surfactants approved for aquatic use were combined with the herbicide for trials on emergent growth*
***WAT=weeks after treatment, MAT=months after treatment*

GROWTH FORM	TREATMENT TIMING	HERBICIDE	RESULTS**	SOURCE
SUBMERSED	summer	2,4-D	mixed results in aquaria (ester and amine), mesocosm	Poovey et al. 2013; Wersal et al. 2014
		2,4-D + tricolpyr	reduction in leaf biomass 6 WAT in aquaria, mesocosm	Poovey et al. 2013; Wersal et al. 2014
		bispyribac	not effective in aquaria	Poovey et al. 2013
		copper	not effective, mesocosm trial on young submersed plants	Turnage et al. 2017
		copper + triclopyr	not effective, mesocosm trial on young submersed plants	Turnage et al. 2017
		diquat	repeated treatments reduce above and below ground biomass in field trials > 12 MAT; year of treatment reduction in above ground biomass, mixed year of treatment results on below ground biomass	Poovey et al. 2012; Madsen et al. 2016a; Parsons et al. 2019
		endothall	reduced leaf biomass 4 WAT in aquaria	Poovey et al. 2012; Poovey et al. 2013
		flumioxazin	reduced leaf biomass 4 WAT at highest use rate, aquaria	Poovey et al. 2012; Poovey et al. 2013
		fluridone	mesocosm trial reduced above and below ground biomass 8 WAT; aquaria trial showed no reduction 5 WAT	Poovey et al. 2013; Madsen et al. 2016b
		imazamox	not effective, aquaria and mesocosm	Poovey et al. 2013; Wersal et al. 2014
		triclopyr	mixed results in aquaria, mesocosm	Poovey et al. 2013; Madsen et al. 2016b, Wersal et al. 2014; Turnage et al. 2017
		triclopyr + endothall	reduced leaf biomass 4 WAT in aquaria	Poovey et al. 2013
		triclopyr + flumioxazin	reduced leaf biomass 4 WAT in aquaria	Poovey et al. 2013

Table 2. A summary of herbicide treatments and herbicide type that have been examined for flowering rush control.
** surfactants approved for aquatic use were combined with the herbicide for trials on emergent growth*
***WAT=weeks after treatment, MAT=months after treatment*

Spring dry substrate treatments: Imazapyr and imazamox have shown high efficacy in situations where water levels are drawn down in spring, exposing the substrate; flowering rush has broken dormancy and started to grow prior to inundation. This application technique has mainly been practiced in Flathead Lake, MT and Lake Pend Oreille, ID. Treating two years in a row provided improved top growth control (Rice et al. 2019). After four and five years of sequential spraying with imazapyr or imazamox, large reductions in rhizome biomass and leaf re-sprouting has been confirmed (Rice et al. 2019).

Fall dry substrate treatments: This application scenario could use more exploration; however, few products are labeled for this use-mode. One trial of two herbicides (diuron and flumioxazin) showed no effectiveness in irrigation canals after water delivery ceased for the season (Madsen and Miskella 2018).

Submersed growth treatments: The best outcomes so far have resulted from repeated treatments with the contact herbicide diquat. Reductions in both leaf and rhizome biomass have occurred when treatments took place for at least two years (Madsen et al. 2016b, Parsons et al. 2019). Trials to determine the lowest rate that will achieve reductions have not taken place to date, so a target concentration of the maximum label rate (37 parts per billion) is recommended at this time.

Biological

A biological control research and development project was initiated for flowering rush in 2012 and the Flowering Rush Biocontrol Consortium was formed in 2013. Flowering rush is an excellent candidate for biocontrol because it is the only species within the Butomaceae family. This lack of closely related species greatly increases the likelihood of finding a host-specific insect or pathogen. Centre for Agriculture and Bioscience International (CABI) - Switzerland has taken the lead on foreign exploration for potential biocontrol agents and funding from various partners has been instrumental in this work.[5] Field surveys have been conducted in northern Germany, Czech and Slovak Republics, Poland, Hungary, Serbia, Georgia, and Kazakhstan. To date, there are no USDA-Animal and Plant Health Inspection Services (APHIS) approved biocontrol agents; however, two insects and one pathogen look very promising and are currently being investigated (Hariet

Figure 25. Biocontrol research is underway for the leaf- and rhizome-mining beetle, Bagous nodulosus. *(Photo credit: T. Haye)*

[5] Funding partners in the biocontrol project: US Army Corps of Engineers, Montana Noxious Weed Trust Fund, Montana Department of Natural Resources and Conservation, Washington State Department of Agriculture, Washington State Department of Ecology, Washington State Department of Natural Resources, British Columbia Ministry of Forests, Lands and Natural Resource Operations and Rural Development, Montana Department of Natural Resources and Conservation, Kalispel Tribe, Alberta Environment and Parks, and US Forest Service. Key partners include Jennifer Andreas, Washington State University; Peter Rice, University of Montana; John Gaskin, USDA Agriculture Resource Service Montana.

Figure 26. *A stem-mining fly shows promise as a biocontrol agent. (Photo credit: CABI)*

Hinz and Patrick Häfliger, personal communication). The leaf- and rhizome-mining beetle, *Bagous nodulosus*, is currently undergoing host-specificity testing (Figure 25). Sequential no-choice oviposition (adult egg-laying) tests were conducted in 2014-2018 on 45 test plant species to ensure non-target species are not at risk. With only one incidence of an egg being laid on a European species, *Baldellia ranunculoides*, it appears that the beetle is highly host-specific. However, it was recently discovered that *B. nodulosus* larvae can leave plant material and move to nearby plants. Given

> *Flowering rush is an excellent candidate for biocontrol because it is the only species within the Butomaceae family. This lack of closely related species greatly increases the likelihood of finding a host-specific insect or pathogen.*

the mobility of the larval stage, preliminary no-choice larval establishment tests began in 2018 using 18 test plant species. Limited larval feeding was only observed on two species so far; *Hydrocharis morsus-range* (native to Europe) and *Limnobium laevigatum* (native to South America). Studies are underway to assess the weevil's impact on flowering rush. Additional species will be tested in 2019.

A stem-mining agromyzid fly, *Phytoliriomyza ornata*, also looks promising (Figure 26). Flowering rush plants were wilted within weeks during rearing trials. Host-specificity tests and impact studies will be conducted in 2019.

A white smut fungal pathogen, *Doassansia niesslii*, was discovered in northern Germany in 2016. Initial tests indicate that it is highly host-specific and very damaging to flowering rush (Carol Ellison, personal communication) (Figure 27). The strain of rust found in northern Germany was able to kill genotype 2, the

Figure 27. *A white smut fungal pathogen is being tested as a possible biocontrol agent (Photo credit: CABI)*

genotype found in Bouchie Lake, British Columbia but did not attack genotype 1, the genotype most common to western North America. Additional surveys in the natural range of flowering rush will be required to find a match for genotype 1. Continued research on this potential biocontrol agent will take place in 2019, if funding is available.

Montana

The first report of flowering rush in Montana dated to 1964 in Peaceful Bay in the northwest corner of Flathead Lake (Rice and Dupuis 2009, Consortium of Pacific Northwest Herbaria 2007). Following the 1997 risk assessment, a shoreline survey found dense infestations along the western and southern shores of the lake, including the mouth and delta of Dayton Creek which had been an important spawning stream for adfluvial westslope cutthroat trout (Rice et al. 1997). In addition, Ducharme Fishing Access, a quay built prior to 1990 that extends several hundred yards into East Bay, is now totally obstructed by flowering rush.

In 2001 the Lake County Weed District petitioned the Montana Department of Agriculture to add flowering rush to the State Noxious Weed List. Legal designation as a noxious weed allowed the Montana Noxious Weed Trust Fund to provide some financial support to begin research on the biology, applied ecology, and management of flowering rush. Salish Kootenai College (SKC) and the University of Montana (UM) joined together to take the lead on these efforts in Montana. As SKC and UM gained preliminary knowledge on the flowering rush invasion, they were able to begin to secure numerous larger federal grants for in-depth investigations and development of management methods.

In 2008, Flathead Lake was completely mapped by satellite imagery to determine the full extent of the infestation and develop a spatial model to estimate the potential maximum area of Flathead Lake susceptible to flowering rush domination. At that time 825 hectares (2,039 acres) or 14% of the littoral zone was heavily infested. Based on remote sensing and spectral image analysis, spatial modeling of lakebed substrate exposed at low pool suggested that 4,415 hectares (10,910 acres) of the 0 to 6 meters (0 to 20 feet) littoral zone were susceptible to infestation, meaning 75% of the littoral zone (equivalent to 8.8% of the lake surface area) is at risk (Rice et al. 2010). The upper Flathead River to the north of the lake is also infested and rhizome fragments are continuously passing through Seli'š Ksanka Qlispe' Dam on the southwest corner of the lake into the lower Flathead River and on to Lake Pend Oreille.

Sequential drawdown herbicide treatments with imazapyr and imazamox were started in 2014 in the East Bay of Flathead Lake. After four years of sequential treatments, rhizome mass was reduced up to 89% with imazpyr treatments and 82% with imazamox treatments (Rice, Dupuis and McRyhew 2019).

Annual sequential treatments of flowering rush have been implemented by private landowners at three common use marinas, and by three private landowners for the past four years. SKC and the UM are providing technical assistance in developing a Flathead Lake Flowering Rush Control Project, which will implement annual sequential treatments at drawdown on flowering rush infestations supported by Montana Department of Natural Resources, USACE, and USDA-NIFA Tribal College Extension and Research Programs.

Idaho

Flowering rush was first documented in southeastern Idaho (Snake River, Idaho Falls) in 1949 and northern Idaho (Clark Fork Delta, Lake Pend Oreille) in 2007. The Idaho State Department of Agriculture (ISDA) added the species to the State Noxious Weed List under the Administrative Rule (Noxious Weed, IDAPA 02.06.22) with authority from Idaho Law (Idaho Code, Title 22, Chapter 24).

Management History

In northern Idaho, dry substrate treatments were initially explored during spring 2011 on the Lake Pend Oreille population through a collaboration of county, state and federal natural resource management partners. Treatments consisted of herbicides (i.e. imazapyr, imazamox, fluridone, triclopyr, acetic acid), mechanical removal (hand pulling, digging), and benthic barriers but with no decline in plant biomass four months' post-treatment (Woolf et al. 2011). Other flowering rush management projects include ongoing herbicide trials (imazapyr, imazamox, fluridone, diquat) at Drift Yard led by the US Army Corps of Engineers (2013-present), biannual hand pulling at Sandpoint City Beach and Dog Beach organized by the Lakes Commission (2013-2017), DASH by contractors initiated in 2018, and work by various weed control companies hired by private property owners. Complex ownership boundaries, easements and leases on Pend Oreille Lake and River, including shoreline and littoral areas, warrant extra coordination for aquatic noxious weed management.

Flowering rush was detected in Gem Lake, south of Idaho Falls and Rose Ponds, north of Blackfoot. It was also detected in Blackfoot Reservoir by ISDA. At this same time, a local irrigation company detected flowering rush in their system which originates from Gem Lake. Control trials, using imazamox, carfentrazone-ethyl and combinations of the two products, showed no positive control results. Fall bare ground trials using diuron and flumioxazin have taken place in this system, as well as in a system south of Firth. Trials of diquat and flumioxazin were attempted in Rose Ponds as an emergent control in summer (Madsen and Miskella 2018).

Infestations in Gem Lake were managed with diver dredging in conjunction with Bonneville County Search and Rescue divers. In the first year, the divers spent one day harvesting. In the second year, divers spent just a few hours harvesting, and the past two years no plants have emerged. Bonneville County coordinates with the City of Idaho Falls Power to survey the waterbody each year.

Aberdeen-Springfield Canal Company has spent considerable time and funding to manage infestations in their system since the early 1970s. This system is on the west side of the Snake River, downstream of Blackfoot, and returns into American Falls Reservoir. Surveys below American Falls Reservoir have resulted in minor detections. The early attempts to chain canals seemed to increase the spread of the weed. However, mechanical control with an aquatic vegetation rake have produced good results. The aquatic vegetation rake, developed locally by Maximized Water Management LLC in Chester, is a 5 meter (16 feet) wide tool that removes flowering rush roots and vegetative growth, but not silt. Use of the aquatic vegetation rake suggests flowering rush growth has been reduced and re-treatment is only needed every 5 years (Steve Howser, personal communication).

Fort Hall Tribes have detected flowering rush in many of their irrigation systems as all of their water originates from the Blackfoot River, flowing out of the Blackfoot Reservoir. Flowering rush has not been detected north or upstream of Gem Lake. The county weed departments along the Snake River and ISDA have prioritized monitoring in the region to prevent further spread upstream; however, funding is needed to support survey crews and coordination among county weed programs and irrigation system managers.

Alberta

Natural Systems

Lake Isle. Flowering rush was reported in 2012 by Parkland County but the full scale of the problem was not realized until 2014 when the north shore was inspected. Following detailed surveying, Lake Isle is considered the worst infestation in Alberta with over 17 linear kilometers (10 linear miles) of infested shoreline. Surveys are conducted annually to determine spread and to ensure flowering rush does not spread to the Sturgeon River and Lac Ste. Anne. Prior to 2016 and currently, mechanical harvesting takes places in Lake Isle to allow for recreational access (e.g. boating, swimming). In 2016, control trials were conducted by a University of Calgary graduate student, which included benthic barriers, mechanical harvesting, hand removal with and without native re-vegetation, and herbicides (diquat and imazapyr). In 2019, eight linear kilometers (5 linear miles) are planned to be treated with diquat.

Buffalo Creek. Flowering rush was reported in 2012 by Mountain View AgFieldmen to Red Deer County AgFieldmen. Efforts to control flowering rush have included seed head cutting in 2012 and steaming in 2013. In 2018, Buffalo Creek underwent the fourth year of herbicide applications (diquat).

Bow and South Saskatchewan Rivers. Reports of flowering rush had been made in these river system in 2015 but its extent was unknown. In 2017, a survey was conducted of both rivers from the City of Calgary to the confluence of the Bow and South Saskatchewan River and of the South Saskatchewan River into Saskatchewan. Survey results indicated extensive distribution and no effective control plan has been developed yet. No control work was conducted in 2018.

Sturgeon River (within City of St. Albert). Flowering rush was reported in 2011 by City of St. Albert. In 2017, a large hand removal project was conducted by the City of St. Albert. Hand removal continued in 2018 in addition to exploring the necessary steps to receive pesticide application approvals for the use of diquat.

Man-made Systems

Edmonton Public Schools Bennett Centre. Reported in 2017, flowering rush was successfully hand removed from two isolated educational ponds. Monitoring continued in 2018 with only one plant found. The facility has agreed to monitor for one more year before replanting with native aquatic species.

Len Thompson Trout Pond (Lacombe). Reported in 2012 by a local citizen. Hand removal took place after the initial report but no further monitoring was conducted. In mid-2018, the site was re-visited and four locations were removed. The location will be monitored for re-growth.

Chestermere Lake & Irrigation Canals. Reported in 2013 by Rocky View County. In 2017, control trials were conducted at Chestermere Lake, which included hand removal, benthic barriers, and diver assisted suction harvesting. Hand digging during draw down was completed in 2018.

Strathcona County. Reported in 2015 by a local pesticide applicator in an urban stormwater management pond. In 2018, the pond underwent its third year of herbicide applications with diquat.

Olds College. Reported in 2012 by Mountain View County. Hand removal was completed in 2018.

Calgary Zoo. Reported in 2015 by the City of Calgary. Hand removal was completed in 2018.

Sundre Golf Course. Reported in 2017 by a retired plant specialist. No control work was scheduled for 2018.

British Columbia

There are currently three confirmed sites of flowering rush in BC, but none located within the Columbia Basin. However, given the close proximity of flowering rush to the US portion of the Pend Oreille river system, the provincial government has been conducting targeted surveillance for flowering rush on the Canadian portion of the Pend Oreille annually since 2012 with no plants found.

The other three sites include Bouchie Lake in the Cariboo, Hatzic Lake in the Fraser Valley and a golf course pond in Whistler Resort Municipality on the southwest coast.

Bouchie Lake. Consists of numerous relatively small (<5meter^2) [54 feet^2]), discreet sites that have been treated via suction dredge annually since 2016. The population is declining in density and distribution. This site was confirmed by voucher collection in 2013. Site status was confirmed via extent survey in 2014 and contained using permeable weighted curtains in 2015.

Hatzic Lake. This site includes a large, continuous uniform occurrence of flowering rush along almost the entire lake margin and adjacent sloughs. Site status was confirmed via extent survey in 2012. Presence has not been confirmed downstream of the pump station in the Lower Hatzic Slough, where the lake drains into the Fraser River. Herbarium samples were first collected from the Hatzic Lake site in 1973 and periodically after that point. Samples are housed at the Royal BC Museum and the University of British Columbia. Hatzic Lake drains directly into the Fraser River and is about 24 kilometers (15 miles) from Silver Lake, WA where there are known flowering rush infestations. The drainages of Hatzic Lake and Silver Lake are not believed to be connected. Ideally permeable physical barriers would be installed to contain the infestation, in addition to treatment efforts. However, due to the size of the infestation, complexity of the site, and densely populated area, containment and treatment activities have not yet been initiated.

Whistler Pond. This site was first identified in 2006, and confirmed by voucher collection in 2015. An extent survey in 2015 confirmed that the infestation is confined to the man-made pond. Herbicide treatment using diquat was completed in 2016. Treatment was not possible in 2017 due to herbicide product shortage. Herbicide treatment occurred again in 2018.

Washington

Pend Oreille River. A single patch of flowering rush was discovered in 2010. It was covered and treated with herbicide and eliminated. Since then many additional patches have been found spanning the length of the river, presumably the result of fragments floating down from Lake Pend Oreille. In 2014, comprehensive river and shoreline surveys were initiated, including 1.8 miles (2.9 km) in Idaho below Albeni Dam. Consequently, Boundary Reservoir is on an annual eradication schedule targeting all of the infested areas utilizing herbicide on the shoreline and DASH for in-water treatments. The shoreline infestations in Box Canyon Reservoir are treated annually with herbicide, whereas in-water infestations are treated depending on available funding. The herbicide treatments are done with glyphosate at 6% with surfactant. The Kalispel Tribe has used limited barriers and DASH over the past four years to control stands along the shoreline.

Spokane River. 9-Mile, Lake Spokane and Little Falls Reservoirs – Flowering rush was first found in Lake Spokane and Little Falls Reservoir in 2010, and confirmed in 9-Mile Reservoir in 2012. Since 2011 portions of the populations in 9-Mile and Lake Spokane are hand pulled using divers annually, funded by Avista Utilities to fulfill their Federal Energy Regulatory Commission (FERC) license requirements. No control work has taken place in Little Falls Reservoir to date.

Yakima River. Emergent flowering rush has been treated in those portions of the river accessible by airboat since 2016. Glyphosate with surfactant are being used.

Columbia River at Orondo and Lake Entiat. Divers have hand pulled and covered patches in late summer each year since the presence was confirmed in 2015.

Columbia River at Lake Wallula. Tri-cities area, above McNary Dam – Flowering rush has been found between the Yakima River mouth and about 8 km (5 miles) upriver of the dam have remained untreated except for emergent plants treated near Finley.

Columbia River at Lake Wallula. Near McNary Dam and in Lake Umatilla – Flowering rush in this section of the river, which forms the border with Oregon, has been controlled in cooperation with the Oregon Department of Agriculture and US Army Corps of Engineers (USACE). Flowering rush was first found near McNary Dam on the Washington side, both upstream of the dam and downstream in Lake Umatilla, in 2014. In 2015, additional survey work farther up river located a few additional flowering rush plants. All known patches were controlled using DASH and covered in 2015. The patches were checked and re-controlled in 2016. More recent surveys, conducted by University of Washington botanists in 2017 and 2018 under contract by the USACE, have located additional flowering rush in Lake Umatilla, with isolated patches extending as far down-river as just about 13 km (8 miles) above John Day Dam. Hand pulling had taken place when possible.

Oregon

Flowering rush was first detected in August 2014 in the Columbia River during surveys conducted by Portland State University with funding provided by an Oregon State Weed Board grant. A total of six sites were discovered above McNary Dam in Umatilla County. The source of the infestation is in the Yakima River and an associated irrigation ditch. USACE and Oregon Department of Agriculture (ODA) staff placed weighted mats over the sites in January 2015 in an attempt to keep them from spreading while permits were in process for DASH treatments.

An extensive survey of McNary Pool occurred in late July of 2015, with a team from ODA, USACE, Washington State Department of Agriculture, Washington Department of Ecology and Morrow County; 24 additional sites were discovered in Oregon – an increase of 68% for the total number of sites in this area from 2014.

Mechanical treatment using DASH was completed on all sites in McNary Pool during the late summer of 2016. Follow up surveys have not been extensive but a few new sites were in close proximity to known sites. All of those sites were covered in 2017. Detailed site histories and maps have been developed to track the results of management and population trajectory between the mouth of the Snake River and the sites in the John Day Pool. No benthic mats or other treatments were done in 2018 in the McNary Pool. Some new sites were found and the initial site remained active. Some initial sites, that had been subject to DASH treatments and covered in 2015, had plants growing out from underneath the benthic barriers.

Surveys by Portland State University over the past two years have discovered multiple sites below McNary Dam, several in Oregon. The Oregon sites, upstream of Arlington, are the farthest west locations to date. These sites were hand pulled and covered in 2017 and 2018. In 2018, all sites that had any visible plants were hand pulled with the exception of the two largest sites (sites were 0.2 acres [0.08 hectares] with 50% cover, and 0.1 acres [0.04 hectares] with 20% cover). No further infestations were found in surveys targeting flowering rush in the Bonneville and Celilo pools down river of these sites.

The prevention of introduction and spread of flowering rush is of great importance to the Columbia Basin area managers and stakeholders. While it is recognized that one strategy may not fit for all individual entities involved in prevention and education, the Columbia Basin CWMA management plan team suggests the following will be instrumental in the effort on flowering rush.

Education on identifying flowering rush, what to do if you find it, and how to prevent its spread are all key components of a management plan for this invasive species. Education programs aim to gain public support while ultimately invoking changes in behavior of targeted user groups. While the relationship between education and behavior change is indirect and complex, education is an essential first step to achieve behavior change. Gaining public support for efforts for managing invasive species will result in a reduction of introductions, better mapping of the species, and maintain healthier ecosystems. The educational strategies below outline key messages and activities[6] to help protect aquatic ecosystems from flowering rush. Aligning messages across jurisdictions, through common campaigns or slogans is beneficial for sharing resources, cost savings, and resonating with the public by hearing it through multiple platforms.

There are multiple resources that have been developed by various partners, (Figure 28) including but not limited to university extension reports, posters, and videos.[7] Many of these resources may be used by others to assist in flowering rush outreach.

Learning Objectives

AWARENESS

- Target audiences are aware that invasive species exist and are a threat to healthy ecosystems.

KNOWLEDGE

- Target audiences understand the impacts of flowering rush on aquatic ecosystems.

ATTITUDE

- Target audiences gain an appreciation and concern for aquatic ecosystems that may be impacted by flowering rush and want to take action to prevent the spread.

SKILLS

- Key target audiences develop the skills required to identify flowering rush, and know who to contact to report the presence of flowering rush.

ACTION

- Key target audiences undertake recommended stewardship actions by preventing the spread of flowering rush, reporting detections to appropriate governing bodies, and actively broadcasting and sharing their knowledge with other people.

Figure 28. *An example of flowering rush outreach materials provided to the public (Photo credit: Washington State University Extension)*

[6] The strategies follow the approach created by The Campaign for Environmental Literacy http://www.fundee.org/campaigns/
[7] Online resources can be found at www.columbiabasincwma.org. A short educational video, Flowering Rush: Invasion of the Columbia Basin, can be accessed directly at https://www.youtube.com/watch?v=Ii-ZQ8QVpDs

Key Educational Messages

The following are a variety of potential messages or information that could be shared with the appropriate target audience.

1. Impacts and importance of aquatic invasive species, such as:

- Flowering rush impacts on ecosystems, human health, and the economy
- How flowering rush is spread
- What it means for the public and why they should care

2. Don't Let it Loose Campaign promotes stewardship actions & behavior change, such as:

- Plant native species
- Dispose of aquatic plants in the garbage
- Never release live plants or animals into the environment
- Report any new sightings to the appropriate governing body

3. Key legislation

- Effective legislation passed and enacted
- Enforcement of laws regulating invasive species

> *Education on identifying flowering rush, what to do if you find it, and how to prevent its spread are all key components of a management plan for this invasive species.*

EDUCATIONAL OBJECTIVE GOAL	TARGET AUDIENCE	DESCRIPTION	LEVEL OF IMPACT & INTEREST
AWARENESS, KNOWLEDGE, ATTITUDE, SKILLS, ACTION	Aquaculture Horticulturists	Horticulturists who plant aquatic plants	High
AWARENESS, KNOWLEDGE, ATTITUDE, SKILLS, ACTION	Waterfront Owners	People who own property along water bodies where flowering rush may be growing	High
AWARENESS, KNOWLEDGE, ATTITUDE	Recreationalist	People who utilize waterways for recreation (fishing, boating, swimming, etc.)	High
AWARENESS, KNOWLEDGE, ATTITUDE	Decision Makers	Planners, law makers, decision makers in communities and around water bodies	Medium to High
AWARENESS	Public	All lake and water users	Low

Table 3. Key educational objectives and target audiences in flowering rush outreach are identified. Examples of target audience outcome have been described. The level of impact of each objective is described from high to low.

Evaluating and Reporting

The prior knowledge of each target audience should be evaluated prior to starting an education plan, unless it can be reasonably assumed that people are not aware of flowering rush or its issues. After three years of implementing the entire education plan, the knowledge, attitudes, and behaviors of the target audience should be re-evaluated. Evaluation techniques include:

- Survey of awareness, attitude and actions: what they know about the issue, how they feel about it and what they have done to help
- Client satisfaction evaluations for the educational products: what are their thoughts about them? Are they meeting their needs while also affecting the general public?
- Scientific data can also help evaluate the strategy as a whole: are there more reports of flowering rush (people are aware of what it looks like, and how to report it)? Are there less introductions or new populations (people stop planting or spreading it)?

POTENTIAL TOOL & ACTIVITIES	AWARENESS	KNOWLEDGE	ATTITUDE	SKILLS	ACTIONS
1. Print	Print resources (Fact sheets, pamphlets, brochures)				
2. Online	Online resources (website, social media)			Training videos	
	Infographics		Social media campaigns	Webinars	
3. Ads	TV, radio, print press releases	TV and radio series			
	Social media ads				
	Press releases, key messages				
4. In-person	Presentations (conferences, meetings)				
	Trade shows				
	Giveaways				
5. On-site	On-site outreach				
	Regulatory signage	Educational signage			
	Posters			Tools to assist, remind of, or prompt, an action	
	Giveaways			Prizes/Incentives for action	
6. Distance		Teaching kits			
	PowerPoint slide deck, Webinars				
7. Community			Citizen science programs		
			Community stewardship initiatives		

Table 4. Potential tools and activities that can be applied in flowering rush education objectives to reach target audiences. Shaded areas in the table indicate the type of tool & activity that will affect a specific educational objective goal.

In order to address the regional management of flowering rush, strategies from multiple geographic zones (states and provinces) have been determined that identify priority areas[8], and short- and long-term actions designed specific to the issues seen in those geographic zones. For each geographic zone, multiple partners collaborated from state, federal, and tribal entities to develop these priorities and actions.

In 2018, the passage of the US Federal Water Resources Reform Development Act (H.R. 8; WRRDA) included language that addressed invasive species management, specifically for flowering rush. One million dollars was allocated for flowering rush control and projects required a 50% match from state, tribal, or local governments for eligibility. Permitting challenges have delayed allocating this funding source to specific projects. In addition, monitoring, surveillance, and biocontrol development efforts are not eligible projects. Further, the 50% match has been a challenge for state agencies with limited budgets specific to flowering rush management. The following suggestions would help CWMA partner entities accomplish the priorities and actions identified here.

Suggestions include:

- Permit the use of WRRDA funds for early detection monitoring, delimiting surveys, detailed treatment response monitoring, and research
- Reduce match requirements to 25%
- Prioritize state and local funding for flowering rush control projects to maximize opportunities for matching funds
- Restrict use of funds to Columbia Basin states
- Prioritize treatment for infestations on the downstream edge of the invasion
- Allow use of WRRDA funds for projects on federal lands and within federally managed facilities
- Work toward multi-state legislator support for funding and requisite changes to make the funding more useful
- Seek other federal and state sources of funding that might be less restrictive or more appropriate

One million dollars was allocated for flowering rush control and projects required a 50% match from state, tribal or local governments for eligibility.

Montana State Flowering Rush Priority Areas, Short-term and Long-term Actions

Developed by Tom Woolf (Montana Fish, Wildlife & Parks) and Craig McLane (Montana Fish, Wildlife & Parks).

Montana Priority Areas

1. Clark Fork River
2. Flathead Lake
3. Flathead River
4. Noxon Reservoir
5. Cabinet Gorge Reservoir
6. Thompson Falls Reservoir

MT Short-term Actions

- Evaluate listing aquatic invasive plants under Montana Fish, Wildlife & Parks Invasive Species List instead of Montana Department of Agriculture's Noxious Weed List.
- Continue early detection monitoring efforts west of the Continental Divide.

[8]In many cases the priority areas that have been identified for specific geographic areas will encompass US Fish and Wildlife Service managed refuges and waterfowl production areas.

- Respond to infestations in new waterbodies to prevent new satellite populations.
- Maintain public access at infested waters.

MT Long-term Actions

- Encourage regional efforts for research into long-term control options.
- Support the development of biocontrol options.
- Develop a biocontrol implementation plan prior to this control option becoming available.

Idaho State Flowering Rush Priority Areas, Short-term and Long-term Actions

Developed by Jeremey Varley (Idaho State Department of Agriculture).

Idaho Priority Areas

1. Lake Pend Oreille (North Idaho)
2. Blackfoot Reservoir (East Idaho)
3. Gem Lake Reservoir (East Idaho)
4. Aberdeen Springfield Canal near American Falls Reservoir (East Idaho)

ID Short-term Actions

- Survey known populations to determine a rate of spread.
- Control "leading edge" populations by diver harvesting to slow the rate of spread.
- Target large dense populations of flowering rush to receive treatments based on best management practices with efforts targeted at control, keeping the plant below detrimental thresholds.

ID Long-term Actions

- Continue the study started with Dr. John Madsen (USDA ARS/UC Davis) to determine the best treatment efficacy.
- Continue treatments to prevent spread further downstream into the Columbia River Basin.

Alberta Flowering Rush Priority Areas, Short-term and Long-term Actions

Prepared by Nicole Kimmel (Alberta Agriculture & Forestry) and Tanya Rushcall (Alberta Environment and Parks).

Alberta Priority Areas

1. Flowering rush has not been found in the Canadian portion of the Columbia River Basin

2. Lake Isle (>17 kilometer [11 miles] of shoreline)

Background: Largest infestation with width up to 10 meters (33 feet). Flowering rush is continuous in the west basin of the lake. Isolated control efforts through research have been attempted to date. Plans for 2019 include diquat application on 8 km (4.9 miles) of shoreline. Diquat is currently the only registered aquatic herbicide in Canada. Imazapyr is under review for registration.

3. Buffalo Creek (2.5 kilometers [1.5 miles])

Background: Found in isolated patches. Management complicated by bed and shore ownership by landowner through old Hudson Bay claim. Completed three years of diquat, bi-annual applications with slight biomass reductions so far. Currently exploring the potential to use imazapyr.

4. Sturgeon River (4 kilometers [2.5 miles] surveyed, more likely downstream)

Background: First documented escape for Alberta reported in 1990, with no action until 2017. The City of St. Albert hand removed plants in 2017 and expanded efforts to dig entire river infestation in 2018.

5. Bow River

a. Natural Watercourse (88 km [55 miles] of river, isolated patches to solid patches)
Background: Confirmed a few locations but extent was not fully realized until survey in 2017. Any control work approvals cannot be sought without exact knowledge of locations. Control options are limited by drinking and irrigation users.

b. Western Irrigation District Diversion (20 km [12 miles] of irrigation canal)
Background: Canal dredged mechanically starting 2015 but for silt removal, did not touch riprap sides where rush was established. Suction harvesting was attempted in 2016 on a small test section. Diver Assisted Suction Harvesting was explored in 2017.

c. Chestermere Lake, (10 km [6.2 miles] shoreline)
Background: Research trials on non-chemical control treatments occurred in 2016 and 2017. Control efforts complicated by drinking use and irrigation use. Reservoir drained from Oct-April. Flowering rush has moved past lake to areas of drainage. Hand pulling was implemented in 2018 along all shores to prevent flowering rush from gaining a major presence.

6. South Saskatchewan River

(450 km [280 miles])
Background: Infestation is very prevalent in this river. Extensively used for drinking and irrigation use makes control efforts daunting. Extent was only discovered in 2017. No plan outside of awareness for municipalities has started yet.

7. Sherwood Park storm water pond

Background: Infestation is somewhat isolated. Entering the third year of diquat application.

8. Various other storm water pond/pond/golf course water hazards/dugout locations

Background: Infestations are mostly isolated. Waiting for effective control efforts before prescribing control work in these areas. Hand removal is occurring in smaller populations (Edmonton, Calgary, Lacombe, Olds, Sundre and Taber).

Alberta Short-term Actions

Potential shovel-ready projects:

- Control activities on Lake Isle (small portion for diquat application)
  - Hand digging to continue with lake residents
  - Cutting and mechanical harvesting to continue for lake access
- Control activities at Buffalo Creek
  - Herbicide application - 4th year of diquat
- Control activities at Sturgeon River
  - Hand digging in city limit section
- Control activities in Chestermere Lake
  - Hand digging in drawdown
- Monitoring
  - Determine downstream extent of population on Sturgeon River.
- Education and promotion of citizen science
- Improve provincial approval response time and clarify process
- Clarify effective treatments for controlling flowering rush available to Alberta

Alberta Long-term Actions

- Explore extending herbicides available for aquatic use in Canada as well as extending labels for currently/pending products.
  - Currently diquat is the only registered aquatic herbicide in Canada.

  - Imazapyr is currently under review with the Pest Management Regulatory Agency for registration. Label does state it is not to be used on waters with irrigation, which is a significant portion of Alberta waters.
- Determine economic impact of flowering rush to Alberta.

British Columbia Flowering Rush Priority Areas, Short-term and Long-term Actions

Provided by Val Miller and Becky Brown (British Columbia - Ministry of Forests, Lands, Natural Resource Operations and Rural Development).

BC Priority Areas

1. **Pend Oreille River:** Flowering rush has not been confirmed in the Canadian portion of the Columbia Basin.
2. **Flowering rush populations outside the Columbia Basin occur in:**
   a. **Bouchie Lake (Cariboo)** – flows into the Fraser River Watershed
   b. **Hatzic Lake (Fraser Valley)** – flows into the Fraser River Watershed
   c. **Whistler Pond (golf course)** – flows into the Lillooet River via Green Lake and Green River

BC Short-term Actions

- Continue conducting annual detection surveys in the Pend Oreille River with the expectation that it will eventually show up from the Washington State upriver population.
- Physically contain confirmed populations using permeable barriers.
- Conduct treatments (via suction dredge and diquat herbicide) to reduce population density and distribution, with the ultimate goal of eradication.
- Educate the public in affected areas to identify flowering rush and prevent new introductions to new locations.
- Encourage nursery retailers to not sell flowering rush (sales are not a common occurrence at this time).
- Enforce the Weed Control Act to eradicate new occurrence as required.

BC Long-term Actions

- Canadian portion of Pend Oreille River is completely influenced by two dams downstream. The regular draw down may help with access and selection of treatment options in the future if/when flowering rush is discovered.
- Develop long-term strategy with Washington State.
- Revise provincial legislation to prevent the sale and transport of flowering rush and elevate species to Prohibited Noxious Weed.
- Eradicate confirmed populations.
- Support the registration of new aquatic herbicide products in Canada and label expansions to existing/pending products.
  - Diquat is the only registered aquatic herbicide for plants in Canada
  - Imazapyr is currently under review with the Pest Management Regulatory Agency for full registration

Washington State Flowering Rush Priority Areas, Short-term and Long-term Actions

Developed by Jenifer Parsons (Washington State Department of Ecology), Justin Bush (Washington Invasive Species Council), Greg Haubrich (Washington State Department of Agriculture), and Jennifer Andreas (Washington State University Extension)

Washington Priority Areas

1.Pend Oreille River (includes entire length of river in Washington State)
Background: High priority control area. Flowering rush is patchy throughout river in WA. Control has occurred since 2010.

2. Spokane River
Background: Found in three reservoirs (9-Mile, Lake Spokane, Little Falls). Past management varies by landowner. Avista Utilities funds some diver pulling and covering but not enough to control the populations. No control work has been done to date in Little Falls Reservoir; which has no public boat access.

3.Yakima River
Background: Infestation extends from Prosser to the confluence with the Columbia River. The population consists mostly of emergent plants. Past control work has been done from airboats, includes spraying, surveying and mapping. Two sections have not been controlled because it is too shallow and rocky for airboats. Nearby irrigation canals have bank populations that are not being controlled, and there is a large population in a seasonally-flooded wetland off the main river that was treated with imazapyr in 2018.

4. Mainstem Columbia River

a. Orondo (0.40 km [0.25 miles] of shoreline just downriver of the Orondo Park boat launch and near Lincoln Rock State Park in Lake Entiat above Rocky Reach Dam)
Background: Small infestations have been controlled over last 2-3 years with good results. The reservoirs upstream (Lake Pateros) and downstream (Rock Island Pool) have been surveyed with no additional plants found. This population is genetically distinct, genotype 3, from other Washington populations, which are genotype 1.

b. Mouth of the Yakima River to near Arlington, OR.
i. The mouth of the Yakima River to the mouth of the Snake River (a control and contain area)
ii. The confluence of the Snake to John Day Dam (early detection - rapid response area)
Background: Work in this section has been in partnership with Oregon Department of Agriculture (ODA), USACE Walla Walla and Portland Districts, and USFWS Mid-Columbia National Wildlife Refuge. Some flowering rush patches are fairly large (2 hectares [5 acres]) with smaller scattered patches. The flowering rush plants are mostly submerged. Control work has consisted of mostly DASH, pulling and covering. Partnership with ODA, USACE Portland District, and USFWS have supported surveys and control work conducted yearly on lower sections of the river.

Washington Short-term Actions

Potential shovel-ready projects:

- Control activities on Pend Oreille River
- Control activities Prosser to Columbia River
- Control at Little Falls area, increase control on Lake Spokane, 9-Mile reservoirs
- Control in Columbia between Arlington and Yakima River
- Control in Columbia River patches in Lake Entiat (near Orondo)
- Invite Spokane Tribe of Indians and Avista Utilities to join the CWMA
- Determine upstream extent of population on Spokane River (above 7-mile bridge)
- Develop control plan for Little Falls population
- Develop control plan for irrigation canal edges
- Coordinate site visits for stakeholders to view upstream issue
- Create economic impact analysis for impacts in Washington State
- Analyze/estimate control costs for Washington State projects. Develop a range (lowest to highest) of control costs per acre—manual, mechanical, biological, chemical
- Identify stakeholder groups that can help educate decision makers on this issue
- Create a Washington State Flowering Rush Management Plan using the regional plan as foundation

WA Long-term Actions

- Clarify management responsibilities in reservoirs
- Develop control plan for Benton County private duck pond population
- Develop monitoring strategy for Snake River in Washington
- Develop biocontrol implementation plan for flowering rush ~1-2 years before agent availability
- Convene a work group tasked with developing model FERC comments related to monitoring and treatment of Class A, B designate noxious weeds
- Ensure nursery inspectors are trained in flowering rush identification to better enforce the quarantine laws

Oregon State Flowering Rush Priority Areas, Short-term and Long-term Actions

Developed by Mark Porter (Oregon State Department of Agriculture), Mark Sytsma (Portland State University), and Tim Butler (Oregon State Department of Agriculture).

Oregon Priority Areas

1. **Main-stem Columbia River** (no other known infestations in the Columbia River Basin)

    a. Stateline to near Arlington, OR

    Background: All patches are very small but scattered between Wallula Gap and Arlington. Plants are mostly submerged. Mostly DASH, pulling and covering used for control. EDRR is ongoing. Managed by USACE Walla Walla and Portland Districts and the USFWS Mid-Columbia National Wildlife Refuge with help from the Lower Columbia Flowering Rush Working Group. This partnership is facilitated by ODA/WDOE and WSDA and includes over 70 members from multiple stakeholder groups. Partnership with ODA and USACE Portland District have supported surveys conducted yearly on lower sections. No known sites below Arlington, though surveys have been completed in likely habitats below dam.

Oregon Short-term Actions

Shovel-ready projects:

- Control in Columbia between Stateline and John Day Dam
  - EDRR inventory in likely sites of infestation. Physically mark and treat as found (DASH and cover)
  - Manual control on all new sites. Use DASH (versus pulling) where possible and cover
  - Monitor all known sites and immediate areas for any growth. Use DASH (versus pulling) where possible and cover
- John Day Pool
  - EDRR inventory in likely sites of infestation
  - Manual control on all new sites. Use DASH (versus pulling) where possible and cover
  - Monitor all know sites and immediate areas for any growth. Use DASH (versus pulling) where possible and cover
- Bonneville Pool downstream to the mouth of the Columbia
  - Continue EDRR surveys in likely areas for new sites
  - Physically mark and treat as found (DASH and cover).
  - Survey at-risk irrigation reservoirs, wildlife areas and ditches in the area (i.e. Cold Springs)
- Implement monitoring for flowering rush propagules at dam gate wells, John Day Dam and other overflows
- Facilitate ongoing coordination and implementation
- Support inventory and control work with Oregon State Weed Board Grants
- Continue to co-coordinate the Lower Columbia River Flowering Rush Working Group with WDOE,WSDA and other partners to ensure:
  - Coordinated and regional treatments are in enacted
  - All entities are apprised of best management practices
  - Proper permissions are understood and received and in place (i.e. NEPA and Consultation, Archeological clearance)
  - Support for ongoing biological control research as a long-term solution to regional infestations

Oregon Long-term Actions

- Help explore and support herbicide options or any other new methods of control (e.g. time release herbicide) and implement if effective and as approved (USACE NEPA & consultation as needed).
- Educate public and landowners on the identification, risk and control of flowering rush through:
  - Brochures and on-line information
  - Meetings and presentations with local weed control entities
  - Keep irrigation districts apprised and involved in project work
- Ensure flowering rush is not spread through recreational or other activities:
  - Support Clean, Drain, Dry messaging to incoming and outgoing recreationalists
  - Support outreach to boating community by providing education and outreach info to ODFW's boat inspection staff and stations
  - Monitor aquatic plant sales when found
- Update Oregon State Flowering Rush Management Plan to complement the regional plan
- Develop monitoring strategy for Snake River in Oregon
- Develop biocontrol implementation plan for flowering rush ~1-2 years before agent availability

- Coordinate early detection surveys with other ongoing aquatic invasive species surveys, e.g. quagga and zebra mussel surveys

Columbia Basin CWMA Actions

Short-term Regional Actions

- Define or document survey and monitoring protocols being used regionally
- Create data sharing agreement and frequency for basin states and provinces
- Increase support for biocontrol development funding
- Increase research focus on ecological impact to fisheries and salmon recovery, especially with non-native piscivorous fish in the lower Columbia River
- Initiate conversations with fisheries managers about preventing and/or monitoring northern pike movements in the Columbia River
- Develop long-term monitoring strategy and information sharing for Snake River in Oregon, Idaho, and Washington
- Develop long-term monitoring strategy and information sharing for lower Columbia Basin in both Oregon and Washington
- Reduce down-river movement of propagules

Long-term Regional Actions

- Create economic impact analysis for impacts across Columbia Basin
- Develop regional biocontrol implementation strategy

Identified Research Needs

Despite the long presence of flowering rush in North America, there is much to be learned about its biology and ecology. Better understanding of the phenology, reproduction and dispersal, impacts, and management options would facilitate control of the plant in the Columbia Basin. Flowering rush research questions were solicited at the Flowering Rush Summit in Spokane in February 2018. Additional discussion via email occurred following the meeting. Research questions that were suggested are listed below without any attempt to prioritize.

1. Flowering rush in the Columbia Basin perennates and disperses primarily via vegetative propagules (rhizomes and rhizome buds).
   - a. Do rhizome buds exhibit dormancy?
   - b. What is the most effective method to manage the rhizome bud bank in the sediments?
   - c. How does temperature and photoperiod influence the timing of sprouting of rhizome buds?
   - d. How long can rhizomes and rhizome buds survive out of water?
   - e. Does size of rhizome bud relate to establishment success in flowering rush in the Columbia Basin?
   - f. How does the buoyancy of root buds and rhizomes affect dispersal?
   - g. How and when do the root buds that are in the sediment detach from the rhizome and get to the surface to spread?
   - h. Do plants sprouted from root buds, bulbils, or rhizomes differ in ability to establish in deep water?

2. Flowering rush competes with, and can displace, native aquatic plant communities.
   - a. Does disturbance (e.g. ice scouring, wave action, boating activities, wildlife trampling and browsing, management of Eurasian watermilfoil) of submersed plant communities facilitate invasion and establishment of flowering rush?
   - b. Does allelopathy, consumptive competition, or resource preemption facilitate the invasion of flowering rush and displacement of other submersed plants?

3. Additional treatment options are desperately needed.
   - a. Can liquid or granular, low-rate treatments with triclopyr control flowering rush?
   - b. Can non-chemical treatment with UV-light effectively control the submersed growth form of flowering rush?
   - c. How does the interaction of phenological stage and treatment timing influence efficacy of treatment, and is it the same for submersed and emergent growth forms?
   - d. How does contact/exposure time influence efficacy of untested aquatic herbicides on flowering rush (e.g. penoxsulam, topramezone, bispyribac-sodium, florpyrauxifen-benzyl)?
   - e. What unregistered aquatic herbicides, adjuvants, and delivery methods can increase efficacy of flowering rush control?
   - f. Lack of efficacy below the waterline with emergent foliar herbicide application has been commonly reported. Why is this occurring and how can herbicide translocation to roots be enhanced in these treatment situations?
   - g. How would these treatments impact other organisms in the sites where flowering rush would be treated?
   - h. Explore deployment of vertical barriers around treatment sites in flowing systems to reduce dilution of herbicides and prevent downstream dispersion for maximum effectiveness.

4. Documentation of impacts of flowering rush is needed to understand the consequences of the invasion, spur interest in management, and increase potential funding for resource managers.
   a. How does flowering rush affect pH, temperature, and dissolved oxygen in water?
   b. How does flowering rush, which has a simple submersed growth form, influence invertebrate populations, epiphyte productivity, fish habitat quality, and food web dynamics?
   c. Does flowering rush invasion cause reduction in recreation and property values?
   d. What additional economic costs does flowering rush incur for irrigation districts?
   e. How do the economic impacts of flowering rush compare to impacts of other invasive aquatic plants?
   f. Does flowering rush establishment increase incidence of pond snails and presence of swimmer's itch parasites?
   g. What are the relationships and impacts on northern pike spawning and salmonid predation?
   h. Do flowering rush populations reduce water flows, displace water carrying capacity, and water quality in irrigation corridors? How does this economically affect production agriculture?
5. The genetic structure of adventive flowering rush populations in the Columbia Basin can influence management success.
   a. How do the genetic characteristics of flowering rush available in the nursery trade compare with established populations in the Columbia Basin, North America, and the native range?
   b. Does genotype affect palatability to herbivores, growth rate, and susceptibility to control techniques?
6. An effective and safe biocontrol agent is critical to long-term management of large, established populations of flowering rush in the Columbia Basin. Ongoing biocontrol research has identified some promising potential agents and should continue.
   a. How deep do root weevils travel in the water column and what depth do they prefer?
   b. Can potential biocontrol agents survive drawdown exposure in the winter?
7. Early detection and rapid response are crucial to management of the spread of flowering rush in the basin.
   a. Can outreach to the public, natural resource and irrigation district managers facilitate early detection and rapid response?
   b. How should resources be allocated to treatment of core and downstream/leading edge populations for most efficient control of flowering rush in the Columbia Basin?

Next Steps

The completion of this plan marks the beginning of an effort to regionally address flowering rush and other invasive species. By working together across the basin, the Columbia Basin CWMA hopes to improve the management and coordination to address flowering rush. Successful control of flowering rush in the Columbia Basin will require a long-term commitment to a coordinated strategy with adequate funding to protect the valuable natural and economic resources of the basin.

Key next steps include:

- Coordination among management entities in the basin through regular flowering rush updates and management plan implementation meetings and conferences.
- Working with state and federal legislators to implement this plan.
- Coordinating with other aquatic invasive species early detection and management programs in the basin to develop synergies.
- Advocating for support to address research needed to better control flowering rush.
- Widely distribute this plan through electronic distribution and presentations at relevant conferences (Pacific Northwest Economic Region Meeting, Western Regional Panel on ANS Annual Meeting, International Conference on Aquatic Invasive Species, etc.).
- Updating this plan as needed to maintain its viability and responsiveness to changing circumstances and incorporate the best available scientific information.

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Acronyms

CRTFIC – Columbia River Intertribal Fisheries Commission

CWMA – Cooperative Weed Management Area

DASH – Diver Assisted Suction Harvest

CBCWMA – Columbia Basin Cooperative Weed Management Area

EDRR – Early Detection Rapid Response

FERC – Federal Energy Regulatory Commission

IDAPA – Idaho Administrative Procedures Act

ISDA – Idaho Department of Agriculture

MFWP – Montana Fish, Wildlife & Parks

WISC – Washington Invasive Species Council

WSDA – Washington State Department of Agriculture

WDOE – Washington Department of Ecology

ODA – Oregon Department of Agriculture

USACE – US Army Corps of Engineers

USFWS – US Fish and Wildlife Service

USFS – US Forest Service

APPENDIX C

Definitions

Adventitious roots – plant roots that form from non-root tissue

Bulbils – small bulb-like vegetative reproductive structure

Columbia Basin – the entire region, including watersheds in Canada, which drains into the Columbia River

Cooperative Weed Management Area - a partnership of federal, state, provincial, and local government agencies, Native American and First Nation Tribes, non-governmental organizations, individuals, and various interested groups that manage invasive species (or weeds) within a defined area

Cytotype – refers to ploidy level

Diploid – containing two homologous sets of chromosomes; the fertile type of flowering rush

Genotype – the entire set of genes in a cell, an organism or an individual

Impoundment – a body of water confined within an enclosure, as a reservoir

Inflorescence – in a flowering plant, a cluster of flowers on a branch or a system of branches

Rhizome – a continuously growing horizontal underground stem that puts out lateral shoots and adventitious roots

Meristem – plant tissue primarily found at the growing tips of roots and shoots consisting of actively dividing cells forming new tissue

Perennates – to survive from one growing season to the next, often with a period of reduced or arrested growth between seasons

Pistil – the ovule producing part of a flower

Ploidy – the number of sets of chromosomes in a cell, or in cells of an organism

Sepal – outer parts of the flower, often green and leaf-like

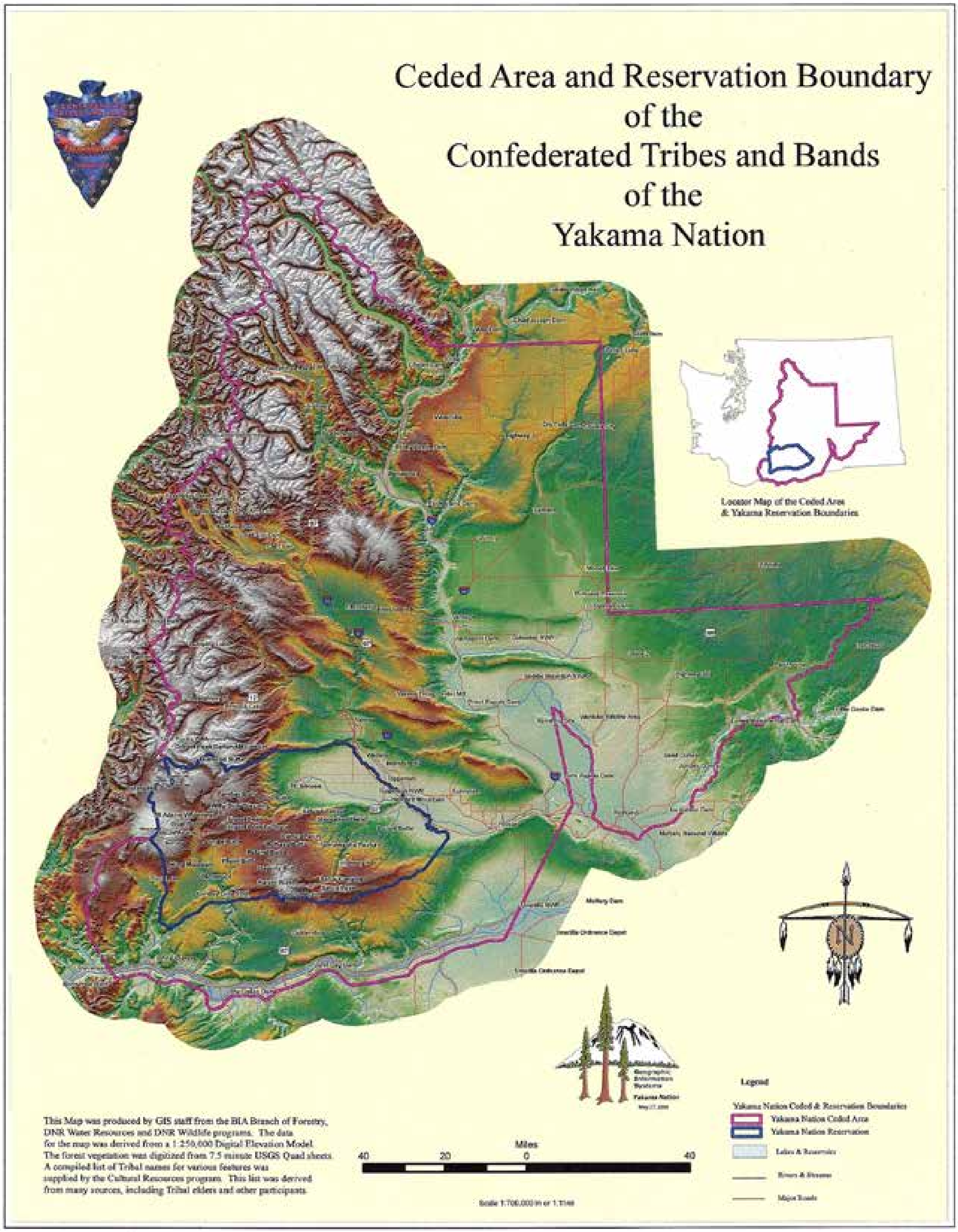
Senescence – the process by which cells irreversibly stop dividing and enter a state of permanent growth arrest without undergoing cell death

Stamen – the pollen producing part of a flower

Triploid – containing three homologous sets of chromosomes; the sterile type of flowering rush

Umbel – an inflorescence that consists of a number of short flower stalks which spread from a common point

Yakama Ceded Territories



Background on Columbia Basin Cooperative Weed Management Area

The creation of the Columbia Basin CWMA and primary actions.

Organizations across the Columbia Basin have engaged various actions to address flowering rush since first detected in 1964 in Flathead Lake. In 2014 the Northern Rockies Invasive Plant Council hosted a flowering rush regional meeting in Spokane, Washington to share information and raise awareness of the issue. In subsequent years, the issue has been reported on at various regional events, such as the 100th Meridian Initiative[9] Columbia River Basin Team meetings.

At the March 2016 Washington Invasive Species Council[10] regular meeting, the Council received a presentation on the status of flowering rush in Washington State and the Pacific Northwest region. The Washington Invasive Species Council directed staff to form an interagency work group to discuss options for responding to this issue within Washington State. Following interagency meetings between state agencies, the participants reached consensus that the issue would be best addressed at a watershed-wide level.

Following Washington Invasive Species Council research into funding opportunities for regional collaborative groups, they identified the National Fish and Wildlife Foundation, Pulling Together Initiative[11] (PTI) grant opportunity. The Pulling Together Initiative is a nationally competitive funding opportunity that is one of the only public-private partnerships to address invasive weeds nationally. PTI grants are intended to help support the creation of public-private partnerships to bring together landowners, citizen groups, and experts to develop and implement strategies for managing weed infestations on public lands, natural areas, and private working lands.

The Washington Invasive Species Council convened multiple meetings with key stakeholders from across the basin over the course of fall and winter 2016 to develop a proposal in response to the 2016 Pulling Together Initiative Request for Proposals. The National Fish and Wildlife Foundation awarded the Washington Recreation and Conservation Office $65,000 to implement the proposal submitted on behalf of the Columbia Basin stakeholders.

Following execution of an agreement between the National Fish and Wildlife Foundation and Washington Recreation and Conservation Office on January 2, 2017, staff of the Washington Invasive Species Council issued a Request for Quotations[12] on February 15, 2017 for an organization to implement the tasks of the agreement. The Invasive Species Action Network[13] (ISAN) was selected as the successful contractor by the Washington Recreation and Conservation Office who then began implementation of contracted tasks following contract execution on April 4, 2017. One of the first tasks completed by ISAN was the formation of a CWMA Steering Committee.

The Columbia Basin CWMA Steering Committee was formed in 2017 to provide long-term leadership for the CWMA in addressing flowering rush and advance the mission of the Columbia Basin CWMA. The mission of the CWMA is as follows:

[9] http://www.westernais.org/100th-meridian
[10] https://invasivespecies.wa.gov/
[11] http://www.nfwf.org/pti/Pages/home.aspx
[12] https://invasivespecies.wa.gov/documents/RFQQ-RCO1701-WISC-CRB-States-CWMA.pdf
[13] http://stopais.org/

The organization is assembled for the purposes of collaboration and cooperation on cross-jurisdictional and cross-border management of invasive species that threaten a significant portion of the Columbia Basin watershed. The initial focus of the organization shall be on the invasive aquatic plant flowering rush *(Butomus umbellatus)*, but the focus may expand based on regional need and consensus among the organization leadership.

CWMA Membership

Individuals who are interested in the management of flowering rush are invited to join the CWMA. Membership or participation in the CWMA does not preclude membership in other CWMA organizations that have a different scope or geographic footprint. The Columbia Basin CWMA includes participation from state, provincial, federal, and tribal governments, as well as regional government (i.g. county), non-profit organizations, industry and other stakeholders.

CWMA Information Sharing

The Columbia Basin CWMA hosts a website that provides general information and related products completed by the CWMA (http://www.columbiabasincwma.org). Those with an interest in the Columbia Basin CWMA may join the list serv (columbiabasincwma@lists.wsu.edu) to post or learn from information shared on this platform.

COLUMBIA BASIN CWMA STEERING COMMITTEE 2019

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COOPERATIVE WEED MANAGEMENT AREA
COLUMBIA BASIN
CWMA