Springbank Off-Stream Reservoir Project (SR1)

Noxious Weed and Invasive Species Assessment for Public Review Hearing

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TABLE OF CONTENTS

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Impartiality Statement

I am aware that it is my duty to assist the Review Panel and not to be an advocate for any party. I have made my report in conformity with that duty and if called on to give oral or written testimony, I will give that testimony in conformity with that duty.

Terry Osko

25 February 2021
Date

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1.0 Background, Context, Concerns

1.1 Weed Impacts

Weeds are an economic and ecologic concern in much of the world. Weeds can reduce yield of agricultural crops by five to eighty percent (Naylor, 2003a). Weeds can harbor diseases and pests that affect agricultural crops and livestock, can reduce crop quality, and can be toxic to livestock (Zimdahl 2018). A 1970s estimate of losses to livestock producers in U.S. Great Plain states caused by poisonous weeds was $118 million (Zimdahl 2018). Weeds are second only to habitat destruction in threats to biodiversity (Pimm and Gilpin 1989 – cited in Davies and Sheley 2007). An estimated 35 to 46% of plants and animals on the U.S. Federal Endangered Species List have been listed as a result of invasive species (Davies and Sheley, 2007). Economic costs include increased agricultural production and processing costs, increased water management costs, human health costs (allergies, skin irritations, poisonings, fire hazards), decreased land value, and decreased aesthetic value. Annual production losses due to weeds for 36 agricultural crops were estimated in 1984 to be $912 million in Canada, double the losses in 1956 (Zimdahl 2018). Chandler (1985) estimated annual agricultural losses for 64 crops to weeds in the United States at $14 billion, including $8 billion due to weed competition, $2 billion in herbicide costs, and $4 billion in equipment and labour costs. Total herbicide applied to agricultural land in the United States increased from 184 million kg of active ingredient in 1971 to 407 million kg in 1982 (Chandler, 1985). In addition to introduction of pests and diseases, weeds compete with crops for space, light, nutrients, and water (Zimdahl, 2018), thereby also altering growth and resource-capture strategies of crops (Naylor 2003a). Weeds similarly compete with native plants and introduce diseases or pests to native plant communities. Weeds impact biodiversity by altering ecosystem functions such as energy flows, water and nutrient cycling, community species composition, plant succession processes, and disturbance regimes, such as fire risk or interval (Walker and Smith 1997, Humphries 1993,). Weeds can be a threat to individual native plants or animals, as well as entire biotic communities (Grice et al., 2004). Altered plant communities in turn can alter use by wildlife due to reduction in plant palatability, nutrient value, forage production, or increased toxicity (Zimdahl, 2018). While many weeds do not cause serious environmental damage, some weeds can result in irreversible alteration of native populations and structure and function of host ecosystems (Humphries, 1993). Specifically relevant to SR1, invasive species within river systems can alter riparian ecosystems by changing hydrology and fluvial geomorphology of rivers (Richardson et al., 2007, WSSA 2011). Weeds do not stabilize soils as well as native vegetation, leading to degradation of the stream channel (Donaldson 1997). Soil and water losses increase when tap-rooted plants replace fibrous root systems, increasing surface water runoff and soil erosion, thereby decreasing water infiltration and increasing sediment production. Reduced rooting strength results in diminished capacity to withstand flood flows, leading to greater bank and bed erosion.

1.2 Weed Designation in Alberta

Regulated weeds in Alberta are designated either “Prohibited Noxious” or “Noxious.” Prohibited Noxious wweeds are species whose distribution in Alberta is presently restricted or local but which present risk of spreading and causing significant economic or ecological impact. Prohibited noxious weeds must be destroyed, which defined by the Alberta *Weed Control Act* means "to kill all growing parts, or to render reproductive mechanisms non-viable."

Noxious weeds are non-native species already widely distributed in the province that have significant ecological or economic impact, and that can spread easily from existing infestations onto adjoining properties, as well as non-native species that are relatively easily controlled when a few individuals are found but that can easily get out of hand if left uncontrolled, and can have significant impacts when abundant. Noxious weeds must be controlled, which defined by *the Act* means "to inhibit the growth or spread, or to destroy.

The province has designated 46 species Prohibited Noxious and 29 species Noxious. According to the Alberta Weed Control Regulation, municipalities may designate additional species as Prohibited Noxious or Noxious by establishing a bylaw to that effect.

1.3 Weeds and Disturbances

Disturbance is an important factor for weed invasion and establishment within native plant environments (Lonsdale, 1992). Furthermore, weeds compete more effectively on disturbed areas than desired species. Natural disturbances can include fires, floods, landslides, or overgrazing or other wildlife damage. Human-caused disturbances can also include livestock overgrazing or human-induced fires, as well as disturbances associated with development such as logging, energy exploration, construction, transportation, or cultivation. Humphries (1993) suggested vulnerability of ecosystems to weed invasion is closely associated with human-caused disturbances. Industrial and public infrastructure projects can produce large disturbances, which include not only the directly disturbed area, but also the associated infrastructure such as haul roads, access roads, maintenance yards, equipment yards, loading yards, soil stockpiles, etc. Managing weeds is increasingly difficult on such large areas of disturbance (Vasquez and Sheley, 2018). Despite efforts to quickly revegetate with desired vegetation, weeds can quickly occupy safe seedling spaces developed for desired species, become established, outcompete desired species, disperse by multiple vectors, and contribute to the soil seed bank (Vasquez and Sheley 2018, Bellairs 2006). For example, Read et al. (2000, cited in Bellairs 2006) reported weed seed content of 12 month-old topsoil stockpile increased from 377 seeds/m^2 to 4927 seeds/m^2 in just 4 months due to a 43-fold increase in weed seeds and only a 6-fold increase in native plant seeds. Increasing banks of weed seeds in the soil perpetuate weed problems into the future, increasing risk of future infestations and entrenchment of weed problems. Managing invasive species on reclaimed lands tends to be reactive, addressing weeds once they have become established, with less emphasis on prevention of weeds from infesting new areas (Vasquez and Sheley, 2018). Once entrenched, management of invasive species increases exponentially (Vasquez and Sheley, 2018), while weeds continue to spread by multiple vectors, encroaching onto non-infested neighbouring landscapes (Davis and Sheley 2007). Infestations need not be large to cause weed encroachment onto neighbouring non-infested lands. However, the likelihood of encroachment and distance of penetration by invasive species into neighbouring areas increases with the size and duration of disturbance.

1.4 Land Context and SCLG Concerns

The project development area (PDA) is situated in the County of Rocky View within the Foothills Parkland sub-region (Prairie Conservation Forum 2021) along the eastern slopes of the Rocky Mountains west of Calgary. The lands consist of foothills, grassland, forests, and wetlands and are designated as high conservation value (Prairie Conservation Forum 2021). Much of the land is used for agriculture, specifically ranching. Residents and municipalities within the sub-region share responsibility for stewardship of the land, which includes conservation of diminishing fescue grasslands.

Grasslands in Alberta provide a number of ecosystem goods and services, including forage for livestock and wildlife grazing, water purification and flood management, carbon and greenhouse gas storage, biodiversity and habitat to sustain it, pollination, and tourism (Bork 2019). Alberta's native grasslands provide forage for 1.6 million beef cows, contributing more than $2 billion in primary sales to the economy and more than $7 billion in value added sales. Native grasslands provide key habitat for pollinators, which support 80% of food crops globally. Alberta grasslands are home to 140 species of bees. Large areas of intact grasslands support more bees than fragmented grasslands. Healthy grasslands are an important component of the water cycle, capturing, storing, and slowly releasing valuable surface water, thereby managing downstream flood risk. Wetlands within grasslands comprise a small proportion of the landscape but ecosystem services provided by them are disproportionately high. Carbon stored within Alberta grasslands is 70 to 180 T/ha (Bork 2019). These values are comparable to boreal forests and rain forests. Furthermore, carbon stored in undisturbed grassland soils is stable. High biodiversity within native grasslands increases resiliency, thereby stabilizing the other services they provide. Foothills grasslands are important providers of ecosystem goods and services in particular, sequestering and storing more carbon than other types of grasslands, supporting more pollinators with their diverse wildflowers, producing more forage per hectare, and providing more scenic and diverse tourism and hunting opportunities.

Threats to native grasslands, particularly foothills fescue grasslands include:

- Industrial development
    - Oil & gas
    - Mining
- Land conversion (permanent losses)
    - Residential use
    - Industrial use
    - Transportation
    - Cultivation
- Excess or altered disturbance
    - Recreational activities
    - Severe fires, absence of fires
    - Overgrazing (becoming less common)
    - Invasive species

Land conversion eliminates the ability of grasslands to provide the listed ecosystem services, while disturbance and degradation reduce that ability. The value of present carbon stocks in Alberta grasslands is $7 to $9 billion based on a carbon valuation of $30/T. Historic carbon losses due to conversion of grasslands to cropland are estimated at up to $23 billion (Bork 2019). Unfortunately, less than 20% of Alberta's native prairie landscape remains intact as a result of transformation by agriculture, industry, and urbanization (The Alberta Prairie Conservation Forum 1995). Fescue grasslands fare worse with remaining grasslands generally estimated at 5% or less of the original area (Weins 1996). Fescue grasslands should be considered among the most threatened biogeographic regions on the Canadian plains (Wallis 1987); a consideration that underpins the stewardship motivations of area landowners.

With respect to the proposed SR1 project, the surrounding area is increasingly impacted by urban and rural residential development, recreation, and industrial development. Native vegetation cover in Rocky View County was only 36% of land cover in 2010, falling from 44% in 1990 (Prairie Conservation Forum 2019). While native vegetation cover is relatively high (76%) in the nearby Stoney and Tsuu T'ina reserves, native cover is also diminishing at these locations.

Concerns regarding weeds associated with the SR1 project centre on the risk of the project becoming a source of increased and continued noxious weed infestation onto neighbouring lands. The SR1 Concerned Landowners Group (SCLG) are concerned the proposed development will exacerbate weed problems, resulting in increased monetary and environmental costs. Specifically, costs of managing weeds will increase and become a direct cost to adjacent landowners and municipalities. Weed infestations will increase costs of weed management for local agricultural producers, as well result in production losses to local producers by reducing land and livestock productivity (e.g. reduced plant palatability, reduced nutrient value, reduced forage production, increased plant toxicity).

Noxious weeds and invasive species are of particular concern to people earning their living via agricultural enterprises, because the threats to rangeland ecology are threats to their livelihood and way of life. Grasslands degraded by invasive species are less productive. Vegetation community change also degrades soil quality, reducing the ability for native vegetation to be sustained. Severe degradation can be irreversible. Therefore the landowners, land users, and municipal administrators are exceptionally motivated to prevent, control, and manage noxious weeds and invasive species.

Costs of invasive species include the financial losses associated with land degradation as well as the costs of management. Management of invasive species requires extensive planning, surveillance, record keeping, extensive travel, specialized equipment, chemicals, and physical labour. All of these are expensive in both time and money. Alberta Transportation (AT) did not assess weed risks separately but included the influence of weeds on vegetation and wetlands. As indicated in the following section, AT expects residual vegetation effects will be restricted to the LAA. On the contrary, given the lack of foresight in AT's prescribed mitigations (see following section) the likelihood is high that the proposed SR1 development will result in emission of ecological pollutants in the form of weed seeds into the surrounding environment. While AT's prescribed mitigations may reduce weed seed emissions compared to no mitigations, the overall effect of the project will be an increase in emissions from the present case. These additional emissions will result in the imposition of additional costs to area landowners to protect a treasured public and private resource, as well as the imposition of losses to those earning their living from that resource.

2.0 Alberta Transportation Mitigations and Management Strategies

2.1 General Observations

In brief, the weed and invasive species mitigation strategy proposed for the SR1 development appears to be as follows:

1. Prevention of weed introduction sources during construction, and
2. Control of new weed infestations as they might arise.

The expectation of implementing this strategy appears to be that weeds and invasive species will be restricted to periodic temporary outbreaks on site that will easily be managed, thereby negating concern for dispersal of weeds beyond the development footprint. Confidence in this strategy belies the difficulty in actually achieving its stated outcomes. Regardless of good intentions and reasonable efforts, difficult to manage weed problems are common to projects of the magnitude proposed. Furthermore, weeds and invasive species are adapted for rapid reproduction, resistance to management, and widespread dispersal, thereby making prevention of their escape to adjacent lands equally difficult. AT has not acknowledged this difficulty in its stated mitigations. Nor has AT provided evidence to suggest they will have greater success in controlling weeds than other major projects.

2.2 Alberta Transportation Assessment of Weed Concerns and Proposed Mitigations

2.2.1 AT Problem Assessment

AT has recognized construction and dry operations have the potential to introduce and establish regulated weeds, which could result in alteration of native plant and ecological communities. AT has also acknowledged that certain weed management activities (i.e. herbicide application) could also alter native plant and ecological communities. While AT has stated that post-flood weed introduction and establishment is not quantifiable, AT has recognized that weed colonization of the post-flood environment, particularly areas buried with sediment, is likely.

AT has identified thirty-six invasive species within the PDA, including six noxious weeds. AT has stated that ten additional noxious weeds and six prohibited noxious weeds were observed historically within the RAA. AT has concluded that presence of these weeds indicates their seeds have accumulated in the soil seed bank, which are likely to be a source of weed introduction and establishment on the project development area. AT does not identify specific weed risks with specific operations, but generally attributes weed risks to areas of exposed or erodible soils, which would include areas disturbed during construction, soil piles, newly reclaimed features, and post-flood sediment deposits.

Based on proposed mitigations (see below), AT claims the geographical extent of residual effects on vegetation and wetlands (presumably including weeds) arising from construction and dry operations will be restricted to the LAA. Further, AT claims that cumulative effects of SR1 with other projects in the region will be limited or minor in terms of impacts on native vegetation and biodiversity.

2.2.2 AT Stated Mitigations

Stated preventative and post-establishment mitigation measures follow generally accepted management practices, but a comprehensive weed prevention and weed control plan was not presented.

Preventative measures include ensuring all equipment arriving on site is clean and free of any soil or vegetative debris, and quickly revegetating exposed soils. No protocol is specified for vehicle washing, where it should occur, or where/how to dispose of wash residue. However, reference is made to vehicle/equipment disinfection procedures (GOA 2020) for operations in or near water (Attachment A, Section A.2.2.5 of Volume 1: Project Description, Exhibit #20). Revegetation is to be accomplished using cover crop seed mixtures if warranted and using only Certified No. 1 seed if possible (not always possible with native plant seed). Specific revegetation prescriptions are not included for each reclaimed or post-flood feature, but the following prescriptions are to be applied as determined at the respective time of revegetation:

- Use Alberta Transportation custom native seed mix or variant thereof
- Apply soil tackifiers to wind or water-erodible soils if necessary
- Apply seed via hand, seed drill, or hydro-mulching

Weed management mitigations are similarly open-ended, stating that “operational plans for weed management have not been developed yet for the project” (Exhibit #18, PDF p. 77), “the contractor will implement appropriate weed-control measures consistent with accepted management practices” (Exhibit #66, PDF p. 18), and “control and prevention of the spread of prohibited noxious and noxious weeds will be evaluated on a site-specific basis” (Exhibit #66, PDF p. 18).

Despite the absence of a specific weed prevention and management plan, AT listed the following practices as weed management options:

- Monitor soil piles for presence of weeds.
- Mechanical control, such as mowing.

- Handpicking and disposal.
- Cultural control of weeds (i.e., seeding of competitive species).
- Application of non-residual herbicides to control small occurrences of persistent infestations that cannot be adequately controlled by other means (e.g. Canada thistle).
- Herbicide application requires contracting a licensed industrial pesticide applicator to select and apply all herbicides in compliance with the weed control plan (which does not yet exist), and the *Environmental Code of Practice for Pesticides* (ESRD 2010b).
- Herbicide application must not be within 30 m of plant species or ecological communities of management concern, wetland or water body. Regulated weeds in such areas are to be controlled by spot spraying, wicking, mowing, or hand picking.

Mitigations for weed prevention and management on post-flood accumulated sediment seem particularly indeterminate. Stated mitigations range from relatively definitive statements such as,

> "To help mitigate potential effects from sediment deposition on weeds, areas should be seeded with an Alberta Transportation custom native seed mix to promote re-establishment of native species within upland plant communities" (Exhibit #49, PDF p.26),

and

> "Areas of sediment deposition where wind erosion might be an issue will be hydroseeded with native plant species to reduce erosion potential" (Exhibit #18, PDF p.114),

to non-committal statements like,

> "exposed sediment will be monitored for weeds; revegetation, with a tackifier, if required, will be implemented as necessary" (Exhibit #18, PDF p.129),

> "do nothing, and monitor to see if certain areas require seeding" (Exhibit #66, PDF p.48),

and

> "if sediments do accumulate to more than a pre-determined depth, wait until the ground dries out and monitor to see if the vegetation recovers naturally" (Exhibit #66, PDF p.48).

2.2.3 Mitigation Ambiguity Indicates Lack of Sufficient Consideration Given to Weeds

Absence of a definitive plan, open-endedness, and inconsistency in stated mitigations suggest AT has not seriously considered the potential weed impacts resulting from the SR1 project. In addition to the ambiguous mitigation examples above, AT ironically claims that the last two alternatives presented above for weed management on post-flood sediment (Exhibit #66, PDF p.48) "are consistent with proposed end land use plan for Area B, which is tentatively designated for research on scientific research into the effects of flooding on the landscape, ecological resiliency and post-flood management options." In reality, these two wait-and-see options are antithetical to scientific research, which would instead require advance literature research to help formulate hypotheses as to what might happen post-flood, followed by designing experiments or monitoring strategies to test those hypotheses. AT did not present evidence that it has gone to this effort.

AT introduces further ambiguity to its post-flood mitigation strategies by deferring to Alberta Environment and Parks, stating,

> "AEP would have an operation and maintenance plan for the reservoir that would include sediment stabilization and debris removal" (Exhibit #18, PDF p.114).

In addition, AT gives an astonishing response to a public engagement question asking how the reservoir will be treated to control weeds and prevent fires from fuel build-up. AT's response was,

> "Fire is a naturally occurring phenomenon in grasslands. Fires will be responded to as with any other fire in the area" (Exhibit #20, PDF p.132).

This dismissive response is surprising given that the exact answer could be given in response to AT's application for SR1. That is, "Flood is a naturally occurring phenomenon in river systems. Floods will be responded to as with any other flood in the area." Such a statement would even be supported by water resources scientists (see Black 2012 for example). In any case, such thoughtless remarks and mixed messages imply AT has not seriously considered what, if anything, should be done in terms of weed prevention and management in response to post-flood conditions.

Finally, claims that weeds issues would be restricted to the LAA and would have minimal cumulative effects require either the assumption that the poorly defined weed prevention and control mitigations will be absolutely effective during each year of construction, each year of dry operations, and each year following a flood event, or the assumption that weeds do not disperse. Neither assumption is realistic. The probability that AT's mitigation plans (and those of other projects) will be absolutely effective for weed prevention and control is low. Weeds indeed disperse via numerous vectors. Therefore, the likelihood of weed dispersal beyond the LAA is considerable and could be exacerbated by weed dispersal from other projects in the region. A comprehensive weed prevention and control plan would identify potential vectors of weed dispersal and develop mechanisms to disrupt the most likely vectors. AT has not presented a comprehensive plan, examined potential weed dispersal vectors, or proposed mechanisms for disrupting them. AT does not appear prepared for addressing potential weed issues related to the SR1 development.

3.0 Weed Establishment, Dispersal, and Management Considerations

3.1 Weeds Tend to be Perpetual Problems

Weeds are colonizing species that fill in gaps in vegetative cover when soil is exposed due to disturbance. A large tract of disturbed land is a beacon for weeds to colonize it, both from seeds already existing in the soil and from propagules invading the site from outside (Iverson and Wali 1982). Controlling a weed population in one year (i.e. before development begins) will not lead to continued absence of weeds in the future (Naylor 2003b). SR1 will produce large tracts of disturbed land of some type during the three years of construction and periodically over its operational life. Continuous weed presence is likely and the risk of proliferation and dispersal to adjacent lands will always be high. Monitoring of soil stockpiles and rapid revegetation of reclaimed areas are noble intentions, but revegetation with desired species will not be achieved instantaneously. Weeds proliferating for only a short period will contribute a tremendous abundance of weed seeds to the soil seed bank, while also potentially dispersing onto adjacent lands. Typical weed seed numbers in soil are 30,000 to 80,000 seeds/m^2, but can easily be double those numbers (Naylor 2003b). By comparison, cereal crops are typically sown at 350 to 500 seeds/m^2. Weed seeds accumulated in the soil from historic weeds and new proliferations will be sources of future outbreaks any time the soil is disturbed by erosion, moved for reclamation, or by future flood disturbances. Some erosion will occur regardless of control measures. Operational or higher traffic areas such as roadsides, maintenance areas, and water management structures will be especially prone to erosion, leaving these areas subject to both weed establishment and dispersal of weed seeds to other areas. Revegetated areas, particularly slopes, will be at risk to erosion during early stages of revegetation and potentially beyond, resulting in favoured germination conditions for both seeds stored in the seed bank and seeds invading from elsewhere.

3.1.1. Industry Examples

A pair of investigative studies illustrate the difficulty in managing weeds on industrial sites. In a literature review and employee survey of weed management on oil sands operations in boreal Alberta (Small et al. 2018), thirteen species of noxious or prohibited noxious weeds were observed, five of which were described as “frequent, abundant, and prolific across sites.” Dispersal concerns for these weeds included wind, presence in the soil seed bank, and equipment and machinery. Areas identified as high risk for weed establishment and proliferation included newly reclaimed areas and sites prone to frequent re-disturbance. One interviewee commented, “Every time there is bare ground the seed bank has an opportunity to express itself. If it is full of weed seeds, weeds are the first to grow and establish.” Some management strategies expressed by companies interviewed included: continual monitoring for noxious and prohibited noxious weeds, identifying best management practices based on species and location, and assessment of risk/benefit of control. The interviewed companies reported using a total of fifteen chemicals to manage on site weeds.

The second study was a retrospective study and risk analysis of noxious weed presence and long term risk to boreal forests surrounding mined and in situ oil sands operations (Schoonmaker et al.

2018). The study summarized vegetation survey data from a number of features across sites of several companies. Features included an airstrip, a remote sump, a soil stockpile, and a base mine. Noxious weed presence was persistent over study periods of 3 to 5 years on all features. Weed ground cover was often low, but increased on all features over the respective study periods. Low ground cover over large areas can translate into numerous individuals that can produce enormous numbers of seeds, contributing to an increasing soil seed bank or dispersing to vulnerable areas.

3.1.2 Professional Experience

In twenty-seven years of industry experience I have observed that weeds remain a common issue for most large projects I have visited. Almost all major projects in Alberta use weed mitigation strategies consistent with those proposed by AT, which is evidence of a wider problem, rather than a tribute to AT. A recent example includes an interim reclamation project I completed at a major in situ oil sands facility where stockpiled topsoil and imported straw were used as reclamation materials. After the first growing season, scattered individuals of almost 30 weed species (including noxious weeds) were present in the reclaimed area. Operational staff suspected the imported straw as the source of weed seeds. However, inspection of the soil stockpile revealed that the exposed area of the stockpile, from which soil for the reclamation was removed, was completely covered by all but 1 of the weed species observed on the reclaimed area.

3.2 Weed Characteristics Contributing to Difficult Control

Below is a list of characteristics that make weeds difficult to manage and contain. Not all species will have all of these traits, but all will have some of them (adapted from Zimdahl (2018):

- Rapid seedling growth and the ability to reproduce when young. Crops (and desired rangeland species) do neither.
- Quick maturation or only a short time in the vegetative stage. Canada thistle can produce mature seed 2 weeks after flowering. Russian thistle seeds can germinate very quickly between -2 and 43°C in late spring.
- Dual modes of reproduction – by seed and vegetatively (e.g., Canada thistle, field bindweed, leafy spurge, quack grass). Some species have multiple vegetative reproductive strategies, including both aboveground runners and belowground roots (e.g. orange hawkweed).
- Many annual weeds can self-pollinate, allowing isolated plants to produce seeds.
- Capable of tolerating and growing under a wide range of climatic and soil conditions.
- Seeds resistant to detrimental environmental factors, remaining dormant for long periods in soil and germinating when conditions are most favorable for survival.
- Many have no special environmental requirements for germination.
- Weeds often produce seed the same size and shape as crop seed, which makes physical separation difficult and facilitates spread by humans.
- Some annual weeds produce seed as long as growing conditions permit rather than just once per year.
- Each generation is capable of producing a large number of seeds per plant, ensuring some seed is produced over a wide range of environmental conditions.

- Many weeds have specially adapted long- and short-range seed dispersal mechanisms.
- Roots of some weeds are able to penetrate and emerge from deep in soil. Roots and rhizomes are capable of exceptional annual growth (e.g. Canada thistle roots routinely penetrate 1 to 2 m, field bindweed roots have been recorded over 3 m deep.
- Roots and other vegetative organs of perennial weeds are vigorous with large food reserves enabling them to withstand environmental stress and intensive cultivation.
- If severed, many perennial weeds can quickly regenerate a whole plant from vegetative organs in stems or roots.
- Some weeds grow horizontal flowering stems after being cut or grazed.
- Many weeds have adaptations (e.g., spines, taste, or odor) to repel grazing.
- Weeds have great competitive ability for nutrients, light, and water and can compete by special means (e.g., rosette formation, climbing like vines, allelopathy).
- Multiple dispersal mechanisms and wide adaptation give weeds the ability to invade and colonize new areas/habitats and become widespread.
- Weeds resist control including resistance to herbicides.

3.3 Weeds WILL Disperse to Adjacent Lands

Weeds and invasive species have numerous mechanisms for dispersal, often dispersing considerable distances, none of which were considered in AT's assessment. An overview of weed dispersal and species migration is provided below, as well as brief examples of mechanisms of specific concern with SR1.

Reid's Paradox is a commonly known phenomenon that has intrigued ecologists for over a century (Clark et al. 1998, Pakeman, 2001). It refers to plant migration rates that greatly exceed distances predicted from the measured dispersal capacity of those plants. The phenomenon is named after the 19th century British ecologist who remarked that, based on their dispersal ability, the distance oaks had migrated in the 10,000 year post-glacial period could not have occurred in a million years without some outside aid (Reid, 1899). Since then, ecologists have documented this paradox for numerous species and have hypothesized a number of mechanisms by which plants achieved actual migration rates orders of magnitude above calculated expectations. The consensus among ecologists is that accelerated migration rates can be explained by long-distance dispersals, even if these are relatively rare. Plants with an average seed dispersal distance that is low because of a majority of short-distance dispersals, but which also have a sufficient number of long-distance dispersals, can have overwhelming effects on plant migration. Such plants can spread by "great leaps forward that get increasingly out of hand" (Mollison 1977, in Clark et al. 1998). Key determinants in accelerating plant migration rates are seed production and dispersal distance. The greater either of these are, the greater the migration rate (Clark et al. 1998, Higgins et al. 1999). A model simulation by Higgins et al. (1999) showed that an order of magnitude increase in predicted spread rate could be achieved if only 0.1% of seeds dispersed a distance of 1 to 10 km. A very small proportion of seeds from a prolific seed producer can still represent a large number of seeds. Keep in mind that many of the early observations of Reid's Paradox were of plants with low production of large heavy seeds that do not fall far from the parent plant, as opposed to prolific seed producing weeds with natural adaptations for long-distance dispersal. Early proposed mechanisms of long-distance dispersal included ingestion and transport of seeds within fleshy fruits by birds or mammals that could achieve the requisite distances of one to tens of kilometers. Proposed mechanisms for other seeds included tornadoes or other storms. However, recent empirical studies and simulation models have included an increasing variety of vectors that plant seeds with various adaptations (particularly weeds) can exploit for long-distance dispersal. Common vectors of dispersal include wind, water, animals, insects, humans, and vehicles (Davies and Sheley, 2007). Individual seeds can be dispersed more than once by multiple vectors, or multiple vectors can interact synergistically to greatly increase dispersal distances. Human-mediated dispersal vectors typically result in invasive plants establishing at greater distances and higher rates than natural dispersal (Hobbs and Humphries 1995).

Most of the following discussion of weed seed adaptation and dispersal vectors is summarized from descriptions in Davies and Sheley, (2007) and Zimdahl (2018), who made summaries from an extensive list of sources. Sources of additional discussion points are cited directly.

3.3.1 Wind dispersal

Small, light weed seeds can easily be dispersed large distances by wind due to their low weight to surface area. Many seeds have aerodynamic properties, such as plumed or winged appendages, that enhance the likelihood and distance of wind dispersal. Furthermore, whole plants or seed panicles can break off and be dispersed by wind. Blueweed is an example of a species identified in the project area that uses this mechanism. Grass panicles can do the same, with recorded dispersal distances in the kilometers. While severe storms or other weather events may contribute to increased seed dispersal distances, recent simulation models indicate topography and updrafts can be important contributors to long-distance dispersal. A simulation by Trakhtenbrot et al. (2014) showed that seeds released on the upwind side of hills could be transported twice as far as seeds released on flat terrain for any given wind speed. Interestingly, seeds released on the leeward side of hills were pulled by currents toward the hillcrest in the opposite direction of the prevailing wind. While innumerable other variables may influence wind dispersal, local terrain and features such as the off-stream dam may be of significance in the SR1 context because they will produce the turbulence and updrafts that increase seed dispersal distances both toward and away from the project.

3.3.2 Water dispersal

Most seeds are easily dispersed by water due to their buoyancy, small size, and continued viability after extended submersion. Even larger, heavier seeds can be moved when currents are strong. As Zimdahl (2018) noted, irrigation water deposits an estimated 296,000 seeds/ha annually on irrigated fields in Nebraska. Further, of 82 weed species found in irrigation water, 27 species germinated after 12 months – with some continuing to germinate after 60 months (Comes et al 1978). After 12 months of submersion, 22% of annuals were viable, while 75% of perennials were viable. Water dispersion can allow for very rapid species migration as the dispersed seeds germinate near the water's edge, producing more seeds, which are again transported by the water. The above processes will be enhanced at SR1 given its proximity within the Elbow River, the collection of water to be concentrated and stored off-stream, and finally released back into the Elbow River via an alternative route.

3.3.3 Animals

Ample evidence supports the notion that birds, wildlife, and domestic livestock can disperse seeds. One way is via ingestion and fecal deposition or regurgitation, as many seeds are enclosed in fleshy, edible fruits that attract consumers. Other seeds may be consumed incidentally with foliage. While not all seeds remain viable after residence in animal digestive tracts, many seeds have been found to germinate post-deposition. Weed seeds have been shown to be viable in the digestive tracts of various bird species for periods of eight to 160 hours, enabling them to be transported several thousand kilometers (Zimdahl 2018). Clark et al. (1998) listed several bird species that can disperse seeds distances ranging from one to 22 km, while Farmer et al. (2017) estimated viable weed seeds could be dispersed up 2700 km from their source by ducks. White-tailed deer were reported to deposit weed seeds in feces more than three km from the seed source. Myers et al. (2004) reported 70 species that germinated from white-tailed deer feces with an average of more that 30 seeds germinating per fecal pellet group.

Animals need not ingest seeds to transport them. Any seed may stick to the feet of animals, but many seeds also possess awned, hooked, sticky, or barbed appendages that aid in attachment to the coats of animals of all sizes. This allows for increased retention time, and thereby increased transport distance. One of the ways dispersal by adhesion to animal fur differs from fecal deposition is that attached seeds detach slowly over time, thereby distributing seeds more evenly and broadly over the area travelled by the animal (Manzano and Malo, 2006). Seed dispersal distance depends on animal behaviour and distance travelled, as well as seed and animal hair characteristics (Couvreur et al. 2004a, 2004b, Romermann et al. 2005). Smooth-haired mammals such as rabbits and mice likely contribute substantially to seed dispersal on a local scale, while animals such as sheep with longer, rougher hair might disperse seeds on a more regional scale (Couvreur et al. 2004b). Attachment of seeds to hair of deer, elk, and moose would result in dispersal distances intermediate between rabbits and sheep. Manzano and Malo (2006) experimentally attached seeds from 4 plant species to sheep and found that varying fractions of seeds remained attached after 28 days and 400 km of travel. These data not only attest to the time and distance over which seeds can be dispersed by animals, but also to the slow and steady dispersal over the distance travelled.

AT's assessment of biodiversity in and around the project area has identified numerous species of small, medium, and large mammals with varying hair coats, as well as many bird species by which seeds could be dispersed into and out of the PDA. These represent a multitude of animal vectors for long distance weed seed dispersal to and from locations both near and far from the development.

3.3.4 People

People can disperse seeds in many of the same ways that animals do, but the primary vectors are seeds sticking to footwear and clothing. A review of 21 studies found that 391 weed species attached to clothing, 58 of which were biodiversity threats (Ansong, 2015). Like animal fur, seed attachment to clothing depends on the seed adaptations and the type of fabric (Ansong, 2015). Patterns of seed dispersal from clothing are similar to seed dispersal patterns from plants in general. The majority fall near the source plant, but sufficient attachment enables carrying of some seeds over long distances. Based on an experimental study of hikers, high seed dispersal occurred within one km, moderate dispersal from one to three km, and low dispersal from three to five km (Ansong, 2015). Plant characteristics and human behaviour also affect seed dispersal distribution and distance. The more seeds produced by plants, the greater the likelihood and number of seeds will be attached to people. If and where people clean seeds off of their clothes will determine the number and distribution of seeds dispersed. Ansong (2015) reported the vast majority of seeds found attached to people tended to be weeds. Reasons suggested for this were that weeds produce large numbers of seeds, weeds dominate disturbed areas, and people often frequent disturbed areas. Pickering et al. (2011) calculated that between 1.9 and 2.4 million weed seeds could be distributed by hikers in an Australian national park over one season, but actual numbers are likely to be lower because of limited weeds at the start of hikes. Nevertheless, they concluded that weed dispersal by people was a potentially major cause of invasive weed spread. Greatest human traffic will occur during construction, coincidental with a time of major soil disturbance and exposure. Weed establishment via human dispersal is therefore most likely to occur during the construction phase.

3.3.5 Vehicles/Equipment

Farm and construction equipment are known to carry weed seeds from the soil they contact and are often cleaned specifically to reduce the spread of weeds. However, passenger vehicles have also been identified as major vectors of long-distance weed spread. A review of studies globally reported that cars transported 626 seed species, 248 of which are invasive/noxious weeds in North America (Ansong and Pickering, 2013). Weeds could be found in numerous locations on cars, including under the chassis, front and rear bumpers, wheel wells and rims, front and back mudguards, wheel wells, tires, and cabin. While the number of seeds per car can be low (1-6 seeds/car), the number of seeds moved by cars can be very high based on the number of cars in an area. For example, cars could be transporting between 490 and 980 million seeds in the United States (Ansong and Pickering, 2013). Of course, the number of seeds and distance dispersed will depend on the driving locations and distances travelled. Sludge collected from vehicle wash-down facilities located between areas of known weed infested areas and areas of less or non-infestation in Australia contained about 68,000 seeds/t of dry sludge material (Bajwa et al. 2018). This number represents the removal of about 335,000 viable seeds from vehicles per week. Seeds contained in the sludge were from 146 species, 49% of which were weeds. Weed seeds appeared in the sludge during all seasons. Ansong and Pickering (2013) reported only one study that measured the actual distance seeds were transported by cars, finding some seeds were transported 250 km. Other studies they reviewed estimated that while some species might be transported hundreds of kilometers, typical distances would likely be between 3 and 40 km.

However, a Montana study examined the retention of seeds placed experimentally on various locations on pickup trucks travelling on paved and unpaved roads in wet and dry conditions (Taylor et al. 2017). These authors reported 99% and 96% of weeds overall stayed attached on paved and unpaved roads, respectively, under dry conditions. Retention was lower (86%) within wheel wells on unpaved roads, possibly due to rocks dislodging the seeds. No seeds were retained under wheel wells and 37% of seeds were retained on the underside of pickups travelling 128 km on wet paved roads, but wheel wells and undersides retained 50% and 60% of weeds respectively on trucks travelling 256 km (max distance studied) on unpaved road. Taylor et al. also examined weed seeds collected by ATVs travelling a total of 230 km on and off trail during spring and fall. ATVs collected more seeds in fall than spring, but 98% of seeds were invasive species in spring versus 59% in fall. At 59%, weed seed collection in fall still far outnumbered weed seeds collected in spring (145/km vs 12.7/km). Seed numbers collected off trail were about two orders of magnitude greater than seeds collected on trail. Finally, these authors studied seed collection by military vehicles (Humvees, ATV's, trucks, and tanks) at National Guard training areas. All vehicles collected substantially more seeds during wet conditions than dry (e.g. Humvees = 14x, tanks = 26x). Tracked vehicles collected more seeds than non-tracked vehicles in all conditions, and seed collection numbers did not differ among non-tracked vehicles under dry conditions.

Moerkerk (2006) also presented data on an assessment of weed seeds found on a variety of vehicles and machinery, including 2WD and 4WD utility vehicles and wagons. Machinery included trucks, tractors, mowers, trailers, backhoes, graders, dozers, and excavators. Sampling did not necessarily include all locations on all items. Over 230 species were identified among the seeds collected, the most frequent of which were annuals, which was similar to the studies above. Noxious weed seeds were found on 39% of the vehicles and 25% of the machinery items. Noxious weeds were most frequently found in the cabin of vehicles, followed by the engine bay.

Since noxious weeds are already present in the SR1 area and have been for some time, a substantial load of weed seeds will exist in the soil seed bank. The project will create large disturbed areas that will expose seeds. Multiple pieces of equipment (including tracked) and vehicles will be traversing the project area under varied moisture conditions, collecting weed seeds with mud and dust. If not cleaned, any vehicle leaving the project area will be a potential vector for spreading weeds long distances from the site. The project will increase traffic to and from the project during construction, thereby increasing the probability of weed dispersal, including into adjacent areas. Finally, Highway 22 and Springbank Road traverse the project area and Highway 22 connects with Highways 1 and 8 nearby. Frequent traffic on these roads subject the project to both weed introduction to the site and dispersal from it.

3.3.6 Dispersal in Time

Dormancy is dispersal in time rather than dispersal in space. Dormancy allows seeds to exist in locations without germinating until conditions become favourable, resulting in sudden flushes of weeds where they were previously unobserved. Dormancy in seeds, as well as the inability to predict when dormancy will be broken, makes it difficult to manage weeds. Large numbers of seeds produced by weeds and their dispersal in time assures the persistence of weeds. Noxious weed species observed during the vegetation field survey include species that can produce 250 to 240,000 seeds per plant that are viable from 2 to 100 years. Every year and every plant multiplies the number of weed seeds potentially available to germinate and establish on site. Weed persistence was demonstrated by Iverson and Wali (1982), who observed that weeds initially establishing on reclaimed surface mines in North Dakota were represented by weeds coming in from adjacent areas, whereas weeds from the seed bank were represented in later years. While weeds will establish from seeds originating outside of the project area, the ample seed bank will ensure persistence of weeds present within it.

3.3.7 Multiple Vectors and Secondary Dispersal

Vectors discussed above can act together to disperse seeds more broadly than vectors acting alone. Insects can move seeds already moved by animals and vice versa. For example, rodents interacting with wind resulted in seeds being moved three and five times farther than initial dispersal distances. A windblown seed might travel up to a few hundred meters from its parent plant to a waterway that might then move it tens of kilometers further. Secondary dispersal might be considered a variant of dispersal in time mentioned above. Seed dispersed from a site may establish an infestation at a distant location, which in turn may disperse seeds to even more distant locations. For example, a water-borne seed may establish a population of weeds on the bank of a stream. That population will in turn disperse seeds by a number of vectors from that location, including the original stream. Over several generations, the weeds may penetrate deeply into the regional space adjacent to their original source.

Vectors can be multiplied by multiple land use in the vicinity of the project. Land use activity will continue directly outside the project area. Recreational activity such as designated off-road vehicle trails, hiking, and hunting will also occur nearby. Establishment of escaped of weeds into nearby areas can multiply in both magnitude and distance by local land use activities, wildlife movements, water and wind dispersal, and combinations of all of these.

3.3.8 Numerous Vectors Not Addressed by AT

The dispersal vectors described above apply to both weed seeds entering and exiting the project area, as well as within it. AT's proposed mitigations only address vectors causing weeds and invasive species to enter the project area, and ignore weeds leaving the project area. Moreover, only one mitigation against weed entry was presented. These are serious omissions. Water is an extremely likely vector to bring weed seeds into the project area, but wind, animals, people, and cars also remain excellent candidates. Further, minor weed infestations outside of the project location could cause major issues within it, given the large areas of disturbed land. Weed introductions will increase the number of species of concern, which will be multiplied on the project area. With the multi-year project schedule, weed seeds from historic and newly introduced weeds will occupy the soil seed bank. Weed seed-laden soil will be moved about the project area as topsoil is stripped, hauled to stockpiles, and then hauled again for reclamation. Much soil may be spilled as it is hauled. Of particular concern is the hauling of fill across the river for the floodplain berm. Even if soil is completely contained within truck boxes during hauling (not likely), weed seed-laden soil will be tracked into the river channel and floodplain area by truck tires. Construction and excavation equipment will traffic over the soil salvage areas, soil stockpile areas, reclamation areas, and all areas in between. Passenger vehicles transporting people around site will also traffic these areas. People will traffic some of these areas on foot. Traffic will traverse potentially weedy areas such as roadsides, storage areas, loading areas, etc. All of this traffic can collect and spread weed seeds. These processes will continue for the duration of construction and reclamation. Many pieces of equipment, vehicles, and people will leave the site after having spent time there picking up weed seeds with no apparent oversight as to where they will travel next, or by what route. AT has not presented any plans for controlling the potential transport of weeds with them.

Ignoring all of these vectors of weed introduction and spread will make weed management more difficult on the project area, while ignoring vectors for dispersal off of the project area will ensure that dispersal occurs. On the other hand, anticipating introduction and dispersal vectors and proactively disrupting them will reduce weed management difficulty and minimize dispersal. AT's wait and see, decide later approach favours the former and not the latter.

4.0 Assessment of Weed Impacts

I used the following questions to assess the potential impacts of the SR1 development on noxious weed and invasive species concerns on the project area and adjacent landscapes. I used the answers to those questions to assess selected key evaluation criteria.

1. Will noxious weeds and invasive species be persistent or exacerbated on the project area during the life of the project and after initial reclamation?
2. Is it likely that noxious weeds and invasive species will disperse from the project area?
3. What are the potential consequences of such dispersal?

Based on the review presented in section 3, the answer to the first two questions is yes.

Potential consequences to high conservation value lands within the region outside of the PDA are quite significant should noxious weeds and invasive species establish and become prevalent. Weeds and invasive species reduce grassland productivity directly by competing for space, light, water, and soil resources. Severe invasions often become irreversible as native species are "pushed out" of the community. In the case of foothills rough fescue in Alberta, there is nowhere else to go. In addition to competition, growing evidence indicates that invasive species condition soil microbes and their relationships with plant roots to favour invasive species (Endresz et al. 2013, Jordan et al. 2012, Vogelsang and Bever 2009, Pritekel et al. 2005). Moreover, such conditioning can have lasting effects even after invasive species are successfully controlled, thereby promoting future invasion by additional invasive species while suppressing native species (Jordan et al. 2012, Pritekel et al. 2005). Resulting plant community changes make conditions more and more difficult for native species to recover. Herbicide application for weed control may also affect soil microbial populations such that soil conditions further promote invasive species over native (Pritekel et al. 2005). Soil disturbance can act in the same way. Stover et al. (2018) observed that soil disturbance reduced soil microbe populations important to fescue grasslands in Alberta. Other feedback mechanisms include altering the prevalent disturbance regime to favour invasive species. For example, wildfire frequency increases as downy brome (a noxious weed identified in the project area) increases in abundance on grasslands (Knapp 1996). Frequent fires promote downy brome proliferation to the detriment of native perennials. Foothills rough fescue grasslands are prized for their superior productivity. Rough fescue cures on the stem, retaining its nutritional value in the dormant season, making it an important source of winter forage for ranchers and wildlife. Cattle wintered in the foothills routinely migrate to higher elevations during winter Chinooks to bask in the warmth and graze rough fescue on exposed slopes. Grasslands dominated by invasive species are less productive than native-dominated grasslands. In particular, invasives do not typically retain nutritional value over winter, thereby increasing winter feeding costs for ranchers. Foothills fescue grasslands are an economic, ecologic, and heritage resource. Once they're gone, they're gone. Every effort should be made to conserve them.

I selected Duration, Geographic Extent, Impact Magnitude, Irreversibility of Effects, and Project Contribution as key criteria to assess weed impacts resulting from the SR1 development.

Duration
Based on the planned mitigations, it is doubtful long-distance dispersal of weeds from the project area will be prevented. Weed infestations propagated from the release of seeds from the area will have effects lasting long after construction, exacerbated by future flood events. Duration rating is **residual**.

Geographic Extent
Based on long-distance dispersal of weeds, especially given the number of reproductive generations over the project operational life, impacts will accumulate on surrounding landscapes both numerically and spatially. Geographic extent is **regional**.

Impact Magnitude
Unmitigated establishment and proliferation of weeds in areas surrounding the PDA could cause degradation and irreversible ecologic change to high conservation value lands in the Foothills Parkland, which could in turn seriously affect social and economic parameters. The area is already subject to intense land use demands. Without comprehensive mitigation, the effects of weed invasion could tip cumulative impacts beyond what is manageable, resulting in catastrophe for specific high conservation value lands. Therefore the impact magnitude is **high**.

Irreversibility of Effects
Without comprehensive regional mitigations, impacts outside the project footprint will multiply with time. Under this scenario, weed and invasive species proliferation could exceed ecological thresholds that would allow reversibility of effects. Effects are **irreversible**.

Project Contribution

Based on the planned mitigations, long-distance dispersal of weeds from the project area resulting in potentially permanent degradation of high conservation lands is likely. Therefore the project contribution is **negative**.

Significance
With planned mitigations, the project effects are **significant**.

As noted within the rationale for each rating criteria, ratings were based on the assumption that no mitigations other than those presented AT would be employed.

5.0 Components of a Comprehensive Weed Prevention and Management Plan

Weed prevention and management is complex given the various means by which weeds can be introduced and dispersed, how quickly infestations can get out of control, how various weeds respond to control measures, and the complication of controlling weeds within sensitive areas. The mitigation measures proposed for SR1 indicate that the myriad vectors of possible weed introduction and dispersal have not been carefully considered, implying that AT has not adequately prepared for the potential weed issues that could arise from the project. A comprehensive weed prevention and management plan must address both local and regional scales because weeds are highly mobile. As discussed in previous sections it is unlikely that absolute weed control will be achieved on site and the project is exposed to many vectors of weed dispersal into the broader environment. Therefore attention must be focused beyond the boundaries of the project if prevention of both weed establishment and dispersal are to be achieved.

The following sections provide an introduction to a more comprehensive weed prevention and management strategy that addresses noxious weeds and invasive species at both project and regional scales. Strategy components can be used at both scales.

5.1 Project-Scale Prevention and Management

Most weed management strategies are reactive, focusing on controlling weed infestations as they arise rather than preventing them from occurring, but prevention is unquestionably less expensive than control. Effective mitigation will need to focus on both prevention and control.

5.1.1 Control

The backbone of control should be an Early Detection and Rapid Response (EDRR) system (Reaser et al. 2019, BC Environmental Protection and Sustainability 2020). As the name implies, an EDRR includes a system for early detection of invasive species, combined with a guided process for evaluating the threat and response options, so that rapid response can occur. An EDRR will also include a process and infrastructure for recording the location of weed occurrences and actions taken. An EDRR can be adapted to operate from local to national scales, but local systems can share data with and tie into larger databases. For example, the University of Georgia has developed a mapping system for tracking invasive species in North America called (EDDMaPs 2021). The map is searchable by species of interest and displays the number of positive identifications of a given species at the locations it was observed. Information such as when a species was observed, what actions were taken, and control results can be obtained by zooming in to individually marked locations on the map.

The EDRR for the project area should include procedures for activities as such as:

- Active weed inspections, including timing, frequency, and search strategy
- Passive weed inspections (observations during the course of regular work activities)
- Reporting – who to report weeds to and how
- Response actions, including integrated weed management strategies
- Recording and mapping
- Follow up monitoring and assessment

The response component of the EDRR should include integrated management strategies and decision making tools adapted for the cultural, biological, mechanical, and chemical control of each weed species based on their inherent life cycles and growth and reproductive strategies.

5.1.2 Prevention

The goal of the project-level weed prevention system should be to prevent means by which weeds can enter and establish on the project area and means by which weeds can escape to establish elsewhere. The foundation of this system would be a decision framework that uses weed biological characteristics, weed location, and weed dispersal vectors to develop and implement management initiatives to prevent weed seed dispersal (Davies and Sheley 2007). The framework goal is to minimize weed spread by disrupting the vectors that facilitate it. The following conceptual framework information is summarized from (Davies and Sheley 2007).

Understanding the various vectors by which each weed species can disperse and prioritization of those vectors based on the inherent risks of a site or weed location can be used to develop management initiatives that would be most effective at limiting the spread of those weeds. Management initiatives would vary according to the nature of the dispersal vectors and weed location. The framework could also be used to identify where more research into creating additional management strategies would be beneficial. Prevention efforts would be improved by strategically inserting barriers to dispersal where they would be most effective at preventing new infestations. Comprehensive prevention of invasive species would focus on identifying and managing major vectors. Management strategies would focus on creating barriers to limit dispersal by the key vectors of an invasive plant. To be most efficient, strategies would key in on the most important vectors. An example framework for identifying the most important vectors for dispersal of specific weeds would be based on plant morphology, especially the seeds, and the location of infestations relative to vector pathways. Invasive plant species could be grouped by seed traits and infestation locations to simplify or consolidate management strategies. The framework could also be used to strategically search for additional weed populations. In identifying likely vectors, search efforts could be strategically focused along those vector pathways to potentially locate additional infestations. Both the search strategies and management initiatives can plug into the ERDD to enhance detection and inform responses.

Some examples of vector pathways and disruptions include keeping weed free zones along waterways to prevent weed dispersal by water, establishing barriers such as high vegetation or windbreaks to minimize wind dispersal, and filtering seeds from discharge water. Examples of seed dispersal disruptions included in the SR1 mitigation plans include equipment cleaning and using certified seed. A dispersal disruption framework for the SR1 project would be more comprehensive than just listing these two strategies. It would flesh out the details of how cleaning vehicles and equipment would be achieved, including where to locate wash stations and how to design them, cleaning procedures, how to manage potential weed transport by commuting employees, and so on. It would identify the source of all incoming materials, the weed risk associated with them, and identify the dispersal barriers to employ. The framework would assess and prioritize all of the possible vectors by which weeds could be transported on and off the project area and identify appropriate prevention actions.

5.2. Regional-Scale Prevention and Management

Because weed management regularly focuses on a local scale, a similar adage applies to management on broader scales: Invasive plant management has traditionally focused on controlling invasive plants on already infested lands, with less importance placed on preventing invasion in un-infested areas (Davies and Sheley, 2007). However, weed prevention is the most cost-effective method of weed management (Ransom and Whitesides 2012), particularly at larger scales. Every dollar spent on early intervention was estimated to save seventeen 1993 dollars in future expenses (USDA 2011). Because costs of preventions are paid in the present but benefits do not accrue until some time in the future (Goodwin et al. 2012) many managers are reluctant to make the investment (Ransom and Whitesides 2012). Nonetheless, a growing number of cooperative/collaborative prevention systems have been demonstrating the benefits of weed prevention systems in Montana, Utah and other Great Basin states (Goodwin et al. 2012, Ransom and Whitesides 2012, USDA 2011).

Known as Weed Prevention Areas (WPAs), these cooperative systems are a community-level approach to weed management that emphasizes investment in future outcomes and concentrate on prevention efforts in the present (Ransom and Whitesides 2012). WPAs are defined as *"designated conservation areas cooperatively managed to prevent the spread of invasive weeds and minimize environmental and economic costs."*

WPAs represent an excellent partnership opportunity between AT and adjacent land jurisdictions or landowners to collaboratively manage the potential weed impacts from the SR1 development. The underlying approach is to keep weed free lands weed free and managing any newly invading weeds early (Ransom and Whitesides 2012). However, in addition to preventing invasion on weed free lands, WPAs can also be established to protect somewhat degraded land from additional invasion by the same or new species, or prevent secondary invasions on highly degraded land (Ransom and Whitesides 2012). WPAs can be adapted to a range of geographical scales or numbers of participants. Primary steps to establishing a WPA are: 1) introducing the WPA concept, 2) organizing the WPA, 3) developing an action plan, 4) implementing the action plan, and 5) evaluating the plan's success (USDA 2011). WPA's typically incorporate some form of EDRR system, as well as a decision framework for preventing dispersal (Goodwin et al. 2012). These tools would function similarly to the descriptions above, but would be scaled up appropriately for the geographic area to be managed. For example, the priority vectors of focus for weed dispersal might concentrate most on areas of human activity or traffic within the WPA, such as roads, railways, oil & gas facilities, livestock and game trails, fence lines, cattle loading or feeding areas, gravel storage areas, etc. Natural dispersal vectors such as rivers or streams would also be included. Since prevention initiatives will not be perfect in interrupting weed introductions and new invaders can spread quickly, proactive monitoring and early detection will be required to maintain weed free lands or prevent further degradation of already affected lands. The EDRR would define schedules for inventories (complete weed search) versus surveys (sampling of selected areas), prescribe search efforts and methods, and facilitate mapping and record keeping.

In addition to the EDRR and dispersal prevention systems, WPAs adopt the use of Ecologically Based Invasive Plant Management (EBIPM) (Ransom and Whitesides 2012). This management system links ecological processes that drive changes in target environments with management tools and strategies to influence those processes (James et al. 2012). The processes are based on established ecological principles or factors that mediate the relative abundance of desired and invasive plants. The objective is to bring about positive change to sites by modifying plant succession processes. Drivers include species availability (dispersal and presence of plant propagules), site availability (open or safe sites for seeds to germinate, and species performance (resources for plant establishment and growth) (James et al. 2012). Practical steps such as reducing disturbance, limiting weed seed dispersal, and favoring resource capture by desirable species can be enacted to manipulate these processes to prevent weed invasion.

Once established, producing the action plan is critical to WPA success (Ransom and Whitesides 2012). Action plan components include setting goals and objectives: identifying people and partners; and then specifying the prevention, mapping, EDRR, and EBIPM strategies to be used in achieving the objectives (USDA 2011). Record keeping and monitoring are vital to evaluating plan effectiveness and whether desired objectives are being achieved. If objectives are not being met, the action plan is scrutinized and modified to address deficiencies or select alternative strategies.

Developing education and awareness programs are also an important component of WPAs to encourage participation in activities like passive monitoring (USDA 2011). Passive monitors can include people who regularly travel through the WPA as a part of their occupations, such as oilfield workers. Hunters are excellent candidates for passive monitoring of remote areas. Education increases community awareness and participation.

Finally, but most importantly, WPAs must determine how they will be funded. Many are community funded with additional support from grants or other fund-raising activities. Of course, part of AT's commitment to WPAs could be to bear a portion of the costs in proportion to the risk posed by the development. AT's participation in a community-based weed prevention program modeled after the information above would demonstrate real leadership in environmental stewardship.

6.0 SR1 Component-Specific Risks and Mitigations

Project components vary in exposure to and interaction with various weed dispersal vectors, resulting in differential weed establishment and dispersal risks for the components. Assessing these risks, and prioritizing key vectors for disruption, will help reduce weed introduction and dispersal risks. The following is a brief assessment of risks and mitigations associated with a selection of project components as an example of how weed prevention and management for the SR1 project could be addressed.

6.1 General Prevention Controls

Any and all surface disturbances or excavations will be subject to numerous weed invasion vectors. It may be difficult to control vectors such as wind and animal movements, but other high priority vectors with substantial potential to spread weeds, such as human and equipment traffic, are manageable. For example, employee parking areas are mentioned in the SR1 Project Description, presumably indicating workers will be commuting to site in private vehicles. As discussed in Section 2.2, AT has not presented any weed management mitigations for entry and exit of private vehicles. Bussing workers to and from site would reduce the number of potentially weed-laden vehicles coming and going on and off site as well as enable control of weed-risk associated with the few vehicles that do come and go. Requiring contractor vehicles to remain on site for the duration of construction and reclamation would also minimize weed introduction and dispersal. Human-mediated weed introduction and dispersal could be managed by requiring workers to clean boots and coveralls prior to arriving or leaving site. Alternatively, boots and coveralls could be required to remain on site.

High traffic areas that remain non-vegetated such as laydown areas, staging areas, parking lots, and temporary and permanent access roads will be prone to weed establishment. While predominantly weed-free, it is not uncommon to see small infestations or individual weed plants established around the margins of such areas. These may appear non-threatening, but only a few weeds can produce an enormous number of seeds. Because vehicle traffic can easily spread weeds, such areas must be vigilantly kept free of weeds. Doing so will require a comprehensive inspection protocol and schedule, as well as an integrated weed management plan. Particular vigilance will be required along the permanent access roads because of their locations on or near weed-prone structures or near water channels. Sourcing weed-free construction materials such as gravel for running surfaces will also help reduce weed introductions.

An alternative to constructed laydown areas (i.e. strip topsoil, construct laydown pad, top with gravel – remove gravel, de-construct laydown pad, replace topsoil) would be to use a protective ground surface cover such as rig mats or other synthetic surface to produce laydown or staging areas. This would reduce the amount of weed-attracting soil disturbance and likely result in quicker and more ecologically compatible vegetation recovery once the artificial surface is removed.

6.2 Construction in or Near Water Channels

AT has committed to following the *Decontamination Protocol for Work in or Near Water* (GOA 2020) for construction of in-stream features such as the diversion structures, debris deflectors, and presumably the temporary river diversion channel. Followed correctly, doing so should also prevent introduction of weed seeds into the river for dispersal downstream. However, the river and its tributaries are major vectors of weed dispersal. Therefore, any feature in or near the river, or discharging into the river system, must be kept weed-free for as long as they exist. This includes features such as the floodplain berm, the reclaimed temporary river diversion channel, auxiliary spillway, emergency spillway, and low-level outlet. As stated in Section 1.1, invasive species within river systems can alter riparian ecosystems by changing hydrology and fluvial geomorphology of rivers (Richardson et al., 2007, WSSA 2011). It is therefore critical to control weeds and invasive species on and near such features. Items with extensive exposed earthworks such as the floodplain berm and reclaimed temporary river diversion channel need to be rapidly revegetated with ecologically appropriate species to prevent erosion and weed establishment. This may preclude use of the AT custom native seed mix. Exposed soil around concrete features must be similarly rapidly revegetated, particularly on slopes. A comprehensive weed inspection and management protocol will be required over the life of these features. The example photo of a low-level outlet channel in Figure 3-10 of the Project Description (Exhibit #20, PDF p. 79) reinforces the need for vigilance against weeds. The sloped soils draining toward the channel are primarily devoid of vegetation, exposing them to weed establishment and the leaving the channel vulnerable to weed seed deposition via eroded soils and dispersal from any establishing weeds.

Construction of the floodplain berm will be particularly problematic in terms of weed seed introduction into the Elbow River, which will in turn disperse them all along its flow path. Fill for the berm will be hauled from the permanent diversion channel excavation across the river. Therefore, the four rock-trucks will be crossing the river and floodplains carrying potentially weed seed-laden fill for extended periods. Containment of materials within the truck boxes might be achieved with tarps, but the truck bodies will be covered with soil fragments and dust, and soil will be stuck to truck tires. The trucks will deposit this material through the floodplains and into the riverbed. In addition, weed seeds contained in the fill might be blown away with the dust as material is dumped at the berm location. Granted, most of the fill for the berm will be sub-soil material, which should contain fewer weed seeds than topsoil. However, the trucks could still be traversing terrain where topsoil has been spilled and picking up weed seeds with their tires. In addition, the construction schedule (Exhibit #20, PDF p. 93) shows two periods of floodplain berm construction separated by seventeen months, both of which are coincidental with diversion channel excavation. If fill materials will be hauled during both periods, the intervening seventeen months will be plenty of time for additional weeds to be introduced (if not established) into the channel area to be picked up by the haul truck tires and deposited into the river and floodplain.

In addition to the rock trucks hauling fill over the river and floodplains, the two dozers used in constructing the floodplain berm will collect soil material in their tracks as they forward material, spread, and compact it. Weed-seed laden soil could then be spread onto the floodplain when the dozers move off of the berm footprint. The dozers could be decontaminated prior to crossing the river, but it would be impractical to decontaminate every truck loaded with fill prior to crossing. Some means of collecting material falling from the trucks over the floodplains and river is required to minimize foreign material deposit into the river. This might include some form of temporary driving surface that would collect material falling from trucks and then be cleaned regularly or after each berm construction period. An option for the dozers might be to restrict them to the berm footprint as much as possible until construction completion and then clean them again prior to crossing back over the river.

6.3 Exposed Soils (Soil Stockpiles and Borrow Areas)

Areas of prolonged soil exposure such as soil stockpiles and borrow areas will be particularly prone to weed establishment, thereby potentially multiplying the weed seeds that will eventually be applied to reclamation surfaces. As discussed in Section 1.3, weed seed numbers in soil stockpiles can increase by an order of magnitude in just a few months. Top soil stockpiles and borrow areas could be left exposed on the project for up to three years. Options for minimizing weed establishment on these areas might include interim seeding with desirable competitive vegetation to discourage weed establishment or covering topsoil piles with a seed-impermeable layer (tarps, non-woven geotextile) to prevent weed germination. The former would still require vigilant weed inspection and management protocols, while the latter could substantially reduce inspection and control practices. In the absence of either of these options, extreme vigilance would be necessary as a single season of missed weed control would substantially exacerbate weed establishment and dispersal.

6.4 Vegetated Slopes (Off-Stream Dam, Diversion Channel, Highway Modifications)

The SR1 project will result in multiple, kilometers-long features with long (20 to 120 m slopes), totaling approximately 65 ha of initially exposed sloped soil. While these areas are intended to be revegetated as quickly as possible as a weed prevention strategy, revegetation will not occur instantaneously. The slopes will be prone to weed invasion and erosion during the interim period. Erosion is expected to occur for some time even while vegetation establishes on the slopes as indicated by AT stated plans for regular inspection and repair of eroded areas until fully vegetated. Eroded soils extend weed establishment and dispersal risks in both space and time. Weed establishment and dispersal risks will remain as long as there is exposed soil caused by erosion. Ironically, erosion risk will always remain as long as there is exposed soil. The risks and proposed mitigations follow a circular tail-chasing pattern whereby an insufficient mitigation chases a repeated risk that it was supposed to address. The result is a perpetual problem that is both aesthetically displeasing and continually prone to weed invasion.

The problem derives from applying typically engineered solutions to natural phenomena rather than mimicking nature to solve such problems. The proposed slope designs, surface treatments, and revegetation strategies are typical of transportation infrastructure. When travelling Alberta's highways, particularly in hilly terrain or towards the mountains, an astute observer will notice that almost all slopes are similarly shaped, similarly vegetated, and adorned with similar erosion control devices. The observer may also notice that some slopes remain vegetated and intact with minimal erosion, while others erode consistently, are inconsistently vegetated, and erosion control devices are overloaded with sediment. Further, the observer might notice that repair attempts seem to apply more of the failed treatments rather than trying something different.

Alternatively, practices that address natural slope stabilization and revegetation processes have been adopted for reclamation of mining, energy, and other disturbances with great success in stabilizing slopes, encouraging desired native vegetation, and discouraging weeds and invasive species (Associated Environmental Consultants 2018; Polster 2020, 2011, 2009). Key approaches to success include producing a rough and loose soil surface and selecting appropriate revegetation species (Polster 2020, 2013). Long smooth slopes promote erosion by allowing water to accelerate down the slope. The longer the slope, the greater the flow velocity and erosive energy obtained by the water. A smooth track-packed surface does little to slow water velocity or encourage infiltration. Short-rooted rooted grasses have limited capability to hold soil together. On the other hand a rough and loose surface slows water flow, thereby reducing erosion and increasing infiltration. Root size, shape, and soil penetration vary in a mix of woody and herbaceous vegetation, thereby more effectively stabilizing the soil (Reubens et al. 2007). Furthermore, the rough and loose surface provides varied microhabitats and seedling safe sites to promote colonization by local native vegetation (Polster 2020, 2013, 2011).

The AT custom native seed mix is just as likely not to stabilize project component slopes as it is to stabilize them. On the other hand, should a dense stand of grass establish, it will likely prevent establishment of additional native species, leading to stagnation of ecological succession and non-integration with the surrounding environment. Furthermore, even though the mix contains "native species, " rather than nearby species integrating into the revegetated slopes, seed dispersal from a dense stand of the seed mix species could alter nearby vegetation communities. Rough fescue is notoriously difficult to establish. Therefore, even though it is in the seed mix it has low likelihood of establishing on the slopes in the presence of some of the more aggressive species. A rough and loose surface soil treatment with more strategically selected revegetation species would improve slope stability and encourage growth of a robust native plant community, thereby reducing erosion as well as weed establishment and dispersal concerns.

The off-stream dam is of particular concern because it intersects with a number of important weed dispersal vectors. First, weed dispersal distance increases with seed plant height (Thomson et al. 2011). As an elevated feature, the dam will thereby increase weed dispersal distances via wind. Secondly, there are permanent access roads on top of and below the dam on both sides. The roads serve as vectors of both weed introduction to and dispersal from the dam area. Finally, the dam is bounded by drainage ditches on both sides, which will collect runoff from the dam and discharge it out of the low-level outlet. Weed seed-laden soil washed from the dam slopes with runoff will therefore be discharged via the outlet beyond the dam to potentially establish and wreak havoc in downstream riparian ecosystems. Prevention of weed establishment and dispersal from the dam is critical. Specifically regarding soil and weed seed migration from the dam into the downstream environment via the drainage ditches, it is obvious that erosion prevention is extremely important. At least temporary erosion is expected, as per the project descriptions discussion on slope protection:

> "Established turf and proposed drainage features will provide erosion protection. Maintenance to repair water erosion channels on the slope will be required until grass is established" (Exhibit #20, PDF p. 77).

No estimate of time required for grass establishment is presented by AT. While runoff estimates have been calculated for sizing of the drainage ditches, no estimates of soil loss, and thereby weed seed loss, from slope erosion has been calculated. Moreover, as discussed above, the erosion repair – grass establishment circular routine only prolongs soil exposure and weed establishment/dispersal risks, a prolongation of unknown duration. Rough soil surfaces reduce soil erosion (Johnson et al. 1979, Lavee et al. 1995) and increase infiltration (Zhao et al. 2012), which improves soil moisture for vegetation establishment, growth, and vigour. Presumably these are desirable for rapid slope stabilization. On the other hand, increased erosion and decreased infiltration on a smooth slope will increase aridity of the site and reduce vegetation establishment, growth, and vigour. It would be wiser to prepare the slope surface such that the surface itself reduces erosion risk while reducing time required for vegetation establishment, rather than prepare a slope that requires regular erosion repair, is inconsistently revegetated, and prolongs vegetation establishment.

Some bioengineering prescriptions are presented as acceptable options in the *Alberta Transportation Erosion And Sediment Control Manual* (GOA 2011). Additionally, AT has expressed openness to modifying the composition of native seed mixes, planting trees and shrubs, and applying willow stakes, depending on operational and end land use objectives. The SR1 project would be improved with greater openness to these options, as well as and consultation with ecologists and practitioners familiar with ecological restoration and rough and loose soil practices. The rough and loose soil treatment coupled with suitable native vegetation would be particularly useful on the off-stream dam for not only practical erosion and weed prevention purposes, but also for reducing the potential eyesore the dam could become. The treatment might also be beneficial within the diversion channel. Once revegetated, the initially rough and loose side slopes stabilized with a mix of woody and herbaceous vegetation would likely slow water and help prevent erosion damage. The treatment could also be applied to the slopes on the sides of the raised section of Highway 22. A number of the shrubs identified during vegetation surveys (Exhibit #74, PDF pp. 22-24) are adapted to hill slopes. Woody vegetation could be selected for adaptation to varying edaphic conditions according to slope position and azimuth. Alternatively, by producing conditions conducive to their establishment, the appropriate native species may colonize these areas naturally. Integrating more natural solutions to slope stabilization will reduce slope erosion and weed risks while improving project aesthetics. Two additional benefits of combining rough and loose soils with more strategic revegetation are 1) more deeply rooted robust plants near the toe of dam slopes would lower the water table, which could reduce seepage concerns or otherwise improve the integrity of the dam, and 2) the costs of rough and loose soil treatments are reported to be about one third of the cost of typical hydroseeding (Polster 2011).

Following are some example photos of rough and loose application and benefits.

Rough and loose surface configurations can be made using an excavator on slopes up to 2:1 or 26°. Large areas can be treated for a cost of about $700/ha (from Polster 2013).

Erosion failure of coarse material on a reclaimed gravel pit slope (left). Even though the slope was correctly track packed – up and down the slope rather than across it (right) – the shallow-rooted grass did not provide sufficient stabilization (photos courtesy David Polster).

The hill was re-sloped (left) and then made rough and loose (right) with an excavator (photos courtesy David Polster).

2500 live poplar stakes were planted in November 2014 (left). The stakes had good survival the following year and the slope remained stable (right) (photos courtesy David Polster).

Planted poplars continued to grow over subsequent years, while additional native vegetation established naturally (left: July 2016, right: July 2018) (photos courtesy David Polster).

6.5 Sediment Deposits and Concentration of Weed Seeds (Off-Stream Dam, Diversion Channel)

All flood events triggering diversion of high water into the reservoir will deposit sediments within the reservoir and diversion channel. Local landowners expressed that sediments from the 2013 flood quickly became infested with weeds (Exhibit 18, PDF p.114), particularly Canada thistle, but also weeds not commonly occurring in the area (Mary Robinson, personal communication). The proneness of flood sediments to weed infestation is borne out in both scientific and extension literature (Donaldson 1997, Lenhart 2000, Shafroth et al. 2002, Stanley and Doyle 2003, Tickner et al. 2001, University of Nebraska 2019, USDA 2012).

Species reported by the University of Nebraska (2019) and USDA (2012) expected to establish after floods included:

- Canada thistle (*Cirsium arvense*)
- Musk thistle (*Carduus nutans*)
- Bull thistle (*Cirsium vulgare*)
- Scotch thistle (*Onopordum acanthium*)
- Plumeless thistle (*Carduus acanthoides*)
- Russian knapweed (*Acroption repens*)
- Spotted knapweed (*Centaurea maculosa*)
- Diffuse knapweed (*Centaurea diffusa*)
- Purple loosestrife (*Lythrum salicaria*)
- Phragmites (*Phragmites australis*)
- Absinth wormword (*Artemisia absinthium*)
- Sericea lespedeza (*Lespedeza cuneata*)
- Russian olive (*Elaeagnus angustifolia*)
- Eastern red cedar (Juniperus virginiana)
- Leafy spurge (*Euphorbia esula*)
- Saltcedar (*Tamarix spp.*)

Some of these species were identified within the RAA, while others are not even present in Alberta. However, some species not currently present in Alberta, such as saltcedar (*Prohibited Noxious*), are still regulated because they are spreading in nearby jurisdictions and could become a threat here. Municipalities (e.g. Calgary) also recognize the increasing threat and have developed programs to address it. Other species, like Russian olive, are not yet regulated but are common ornamental species with increasing recognition of their potential threat to natural vegetation communities. Russian olive and saltcedar are particularly damaging within riparian ecosystems.

Invasive species seeds can arrive with the flood sediments themselves. Floodwaters scour the banks of rivers and streams or spill their banks, accumulating weed seeds or plant parts from existing infestations and transporting them varied distances to previously weed-free areas (Donaldson 1997). Alternatively, wind, animals, birds, insects, or any number of other vectors can introduce invasive species to flood sediments. Bare, often nutrient rich sediments, are free of competition for water, space, and light, making them prime sites for seedlings of invasive species to germinate and become established (Shafroth et al. 2002, Stanley and Doyle 2003, Tickner et al. 2001). Many noxious weeds are capable of outcompeting native species by suppressing native recruitment, consuming water and nutrient resources, or by shading slower growing plants. Furthermore, flooding depletes soil microbes, particularly fungi (Sanchez-Rodriguez 2019), a condition that favours weedy species (Trognitz et al 2016). Invasive colonizers of flood sediments can dominate and prevent establishment of native species for indefinite periods (Lenhart 2000, Stanley and Doyle 2003), thereby impeding plant succession (Shafroth et al. 2002). Site domination by invasive species can occur despite seeding with native seed mixes (Stanley and Doyle 2003).

The off-stream reservoir will act as a concentrator of weeds seeds transported to it by floodwaters. An on-stream dam would also concentrate weed seeds, but they would likely remain inundated for periods long enough to limit viability. However, the off-stream reservoir will concentrate weed seeds with projected inundation periods short enough to retain viability. Moreover, they will be concentrated in an open, sunny, and possibly ideal, location for establishment, proliferation, and dispersal.

Given all the above, severe, difficult to control infestations are likely to occur within the reservoir after flood events. Since floodwater transport of upstream weed seeds is the vector of weed seed concentration in the reservoir, vigilant weed management along the Elbow River and its tributaries upstream of the SR1 project could reduce such concentration. This action could reduce some weed infestation, but will not address invasion by weeds arriving by other vectors. Actions that make the flood sediments less hospitable to invasive species and more hospitable to desirable species would be good preventative measures. What happens on flood sediments within the reservoir may perhaps be ultimately unknown at present, but there is enough evidence from other jurisdictions, not to mention the 2013 flood, to indicate serious weed infestations should be expected. The problem should be studied in advance to help predict several potential outcomes and develop action plans for each. Being prepared for action will help prevent a bad situation from getting beyond control. Waiting to see what happens and then seeding with a tackifier is not an example of preparedness and will likely result in disaster.

The diversion channel will similarly be a concentrator of weed seeds as sediment deposits are also expected there. The diversion channel has some additional unique challenges because sediment accumulations must be cleaned to maintain channel function. AT has not described specifically how the sediment will be cleaned and removed. An exceptional challenge will be cleaning sediment from the interstitial spaces among the riprap armour. It is not likely that all sediment will be collected and removed. The combination of sediment-borne weed seed and channel disturbance from both flood and cleanup operations will produce ideal conditions for weed establishment. In addition, the sediment will be transported off site to as yet indeterminate locations for disposal. Cleaning operations, loading, hauling, and disposal are all vectors of weed spread on site and dispersal off site. Protocols will be required for cleaning soil from trucks and equipment leaving site and to manage possible spillage of materials while hauling to disposal areas.

6.6. Weed Seed Discharge (Low-Level Outlet)

The low-level outlet will drain water accumulations within the SR1 project. As such, it is a primary vector for release and dispersal of weed seeds from the project. As discussed above, weed seeds will be concentrated within the reservoir by the floodwaters. Any seeds that have not settled out with the sediment will be released via the outlet into the un-named tributary and back into the river system. In addition, regular flow of natural drainage through the reservoir (possibly containing post-flood weed infestations) will also be a vector of dispersal via the outlet. Finally, the outlet will discharge all of the runoff collected from the dam, which by all of the vectors discussed above, will also contain weed seeds. The good news is that addressing this one vector could potentially prevent a considerable number of weed seeds from being dispersed from the project. Water discharging from the low-level outlet should be filtered to prevent weed seed dispersal from the reservoir into the downstream environment. Granted, this may not be possible during extreme flood events, but should not be difficult to accomplish during smaller floods and dry operations.

7.0 Recommended Conditions if SR1 is Approved

The most assured way to prevent the noxious weed and invasive species issues associated with the SR1 development is to deny the application. Barring that, additional mitigations are required, including protocols and prescriptions for multi-scale weed prevention and management. However, regardless of how thorough protocols and prescriptions might be, their effectiveness will be limited by compliance with them. As a simple and realistic observation of human nature, compliance may not always be perfect. A means by which to reduce non-compliance is to incorporate operational redundancy in the form of concerned party participation (e.g. SCLG, local municipalities, other concerned groups) in oversight of procedure execution. Furthermore, in order to ensure the perspectives and needs of concerned parties are included in on-site prevention and management programs, procedures, and prescriptions, one or more of these parties should participate in their development. Likewise, AT’s participation and financial support will be integral to development and execution of regional weed prevention and management programs.

The proposed SR1 weed management mitigations will not address SCLG concerns or prevent the inevitable spread of weeds and invasive species onto adjacent lands, including high conservation value landscapes. Community-based mitigations that adopt early detection and rapid response, weed dispersal prevention, ecologically based species management, and deploy these at both project-level and regional scales, are the best hope to avert potentially catastrophic ecological changes to sensitive lands and the resultant economic consequences. Similar systems have been successful in managing weeds on sensitive lands in other jurisdictions. Templates and resources are available to assist in establishing such systems and adapting them to local needs. Community engagement in AT’s weed mitigation strategies and actions will foster transparency and trust.

Therefore involving community stakeholders in the development of mitigation strategies, oversight of their execution, and participation in prescribed activities will improve both mitigation outcomes and public relations. Choosing a community-based weed management system based on the concepts presented in Sections 5 and 6, rather than the currently proposed mitigations will be a paradigm shift for weed management in association with major projects in Alberta. The result would be a better Alberta.

The following list of recommendations should be considered as conditions of SR1 project approval. This list is not exhaustive. Other conditions may arise as information develops.

1. Produce and co-fund a comprehensive weed prevention and management program that will operate on both the local project and regional scales in collaboration with SCLG, local municipalities, and other concerned groups. The program will include weed prevention and management actions both upstream and downstream of the project to minimize weed introduction into the project area and dispersal beyond it. The program will adopt Early Detection and Rapid Response principles and strategies. The program will be proactive rather than reactive. Its aim will be to keep presently weed-free lands weed-free by assessing all potential vectors of weed introduction and dispersal and implementing disruptions to circumvent those vectors. The program will enhance the ability of weed-free lands to remain so and of non-weed free lands to become so by adopting Ecologically Based Invasive Plant Management principles.

2. Develop ecologically based revegetation plans for large features such as the off-stream dam, diversion channel, floodplain berm, reclaimed temporary diversion channel, and highway modifications. Plan priorities will include weed and erosion management, ecological integration, and aesthetics, in addition to operational objectives. The plan will incorporate rough and loose soil surface treatments based on principles described by Polster (2020) to facilitate integration of a broader suite of native vegetation that includes woody species, grasses, and forbs common to the project area.

   The revegetation plans will be completed in consultation with restoration, rangeland, riparian, and/or landscape design ecologists familiar with the principles and practices indicated above. Any AT objections to adopting these principles on the basis of dam safety or integrity will be supported by empirical evidence with “real-world” examples of potential harms that could arise from adopting these principles and practices.

3. Investigate options for prevention and control of weed invasion of post-flood sediments in the off-stream reservoir and diversion channel. Options will be based on a comprehensive review of current scientific literature and consultation with relevant researchers that will help identify various potential site condition outcomes. Options will focus on proactive and pre-emptive actions to enhance native vegetation establishment and discourage weed invasion, such as planting live stakes, adjusting the sediment surface with rough and loose

soil treatments, altering drainage, applying biologicals, or any other practice that might accomplish the stated goals. The focus will be on being prepared for immediate and decisive action.

4. Provide a containment system to prevent soil-borne weed seeds from being introduced into the Elbow River channel and floodplains during hauling of fill for the floodplain berm and during construction of the berm.

5. Install a filtration system on the low-level outlet to filter weed seeds from the outlet discharge.

6. The above conditions will be implemented in consultation with SCLG.

8.0 Summary and Conclusions

Weeds will foreseeably exist on the SR1 project area for the life of the development. The project will have multiplicative effects on weed species already present at the location, as well as species introduced as development proceeds. Weeds will be introduced to and be dispersed from the project area on to adjacent lands by myriad natural and human-mediated dispersal vectors. Existence of SR1 will multiply human-mediated vectors. AT has presented no mitigations for dispersal of weeds on to adjacent lands. Adjacent lands are of high conservation, economic, and cultural value, and are already diminished and threatened by a host of other activities. Given the proposed weed mitigations, the adjacent lands, its users and administrators will be left poorer due to the impacts of the project, although it need not be so. Superior mitigations are available. The commitments made to weed and invasive species management for SR1 are typical of most major projects in Alberta. However, such commitments have been ineffective in managing invasive species. Weeds are getting out of hand in Alberta. The time has come to be proactive in addressing weed management. The Foothills Parkland sub-region is too valuable to allow it to become overrun with invasive species. Comprehensive community-based mitigations based on the concepts presented in Sections 5 and 6 of this document have proven effective in preventing spread of invasive species and increasing community engagement. Adopting such mitigation systems are an excellent opportunity for AT to be a pioneer and position itself as a leader in invasive species management in Alberta. Hopefully AT will embrace that opportunity.

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