COTTONWOOD CONSULTANTS LTD.
615 Deercroft Way S.E.
Calgary, AB T2J 5V4   CANADA
phone and fax: (403) 271-1408
email: deercroft@shaw.ca

February 26, 2021

Ms. Ifeoma Okoye
Mr. Richard Secord
Ackroyd LLP
1500 First Edmonton Place, 10665 Jasper Avenue
Edmonton AB Canada T5J 3S9

Dear Ms. Okoye and Mr. Secord:

RE: Statement of Independent Review—Springbank SR1

The following paragraph is missing from the Introduction to my report on the Springbank SR1 Project and should be part of the record:

> *"I acknowledge that I have been engaged to be an independent witness to give opinion evidence on issues within my area of expertise and acknowledge that as such I have a duty to provide evidence to that is fair, objective and non-partisan."*

Respectfully submitted,

Cliff Wallis, P. Biol.
President, Cottonwood Consultants Ltd.

Environmental Considerations for the Springbank SR1 Off-Stream Reservoir Project

CLIFF WALLIS P. BIOL.

Prepared for Ackroyd LLP on behalf of the SR1 Concerned Landowners Group (SCLG)

February 2021

Cottonwood Consultants Ltd.
615 Deercroft Way SE
Calgary, AB   T2J 5V4
Telephone: (403) 271-1408
email: cottonwood@shaw.ca

EXECUTIVE SUMMARY

The proposed Springbank Off-Stream Reservoir SR1 Project will be located in the Parkland Natural Region near Calgary, Alberta. Parkland is one of the most heavily impacted natural regions in Alberta.

The project lies in the South Saskatchewan Regional Plan (SSRP) area. The vision for the SSRP has a clear focus on sustainability and conservation.

In my professional opinion, key biodiversity issues include:

- much of the Springbank SR1 Project boundary is located in one or more landscapes of conservation significance (High Value Landscape, Environmentally Significant Areas, Areas of High Wildlife Sensitivity, Key Wildlife and Biodiversity Area, High Sensitivity Watershed).
- in contravention of guidance in the South Saskatchewan Regional Plan (SSRP), portions of the project will be developed on lands mapped as intact native grasslands in the SSRP.
- in contravention of the avoidance direction of Alberta's Wetland Policy, wetlands and streams will be permanently lost.
- cumulative effects are not being addressed adequately due the lack of consideration of the degree to which the Foothills Parkland Natural Subregion has already been modified.
- a lack of attention to the ecological effects of capture of all flood events over 160 m^3/s on downstream riparian habitats and ecological functions of major flood events is a significant omission.

To summarize:

Mitigation will not eliminate all the effects of the project--there will be significant residual adverse effects.

The project will have significant adverse effects on biodiversity during construction and operation (inside and outside of flood events).

The instream nature of some of the components, the capture of the most significant flood events, the degradation of upland and wetland habitats from sedimentation during flood events, and the destruction of habitats in various permanent components of the project all weigh against project approval.

There will be impacts on native habitats in landscapes of environmental significance and related potential impacts on wildlife both in the dry reservoir area as well as downstream on the Elbow River.

Some of the adverse effects are in contravention of the spirit and intent found in provincial guidance, especially Alberta's Wetland Policy and the guidance on intact native grasslands in the South Saskatchewan Regional Plan.

<u>Recommendations:</u>

My professional recommendation is that the project not be approved in its current configuration and operating mode which captures all floods above 160 m^3/s.

If the project is approved, consideration should be given for allowing larger flood events to pass.

If the project is approved, immediate sediment removal following floods should not be a condition of approval.

1. INTRODUCTION

Cottonwood Consultants Ltd. was retained by Ackroyd LLP on behalf of the SR1 Concerned Landowners Group (SCLG) to evaluate the proposed Springbank Off-Stream Reservoir SR1 Project, located just west of the City of Calgary in the vicinity of the Elbow River.

I was requested to provide an assessment of some of the biodiversity considerations of the project and an evaluation of the potential residual impacts of the project on biodiversity.

I am personally familiar with the lands in question since my involvement with the first environmentally significant areas study conducted in Alberta in the Calgary Region (Lamoureux 1983) and subsequent field visits through the area and surrounding lands. My most recent visit was in November 2020.

Rather than do an in-depth review of the extensive hearing documentation, I have focused on a few key issues that might help in the panel's work and whether to approve or deny the Springbank SR1 project as currently proposed, with or without conditions.

I have undertaken this approach since the area is situated in the Foothills Parkland Natural Subregion (Alberta Environment and Parks 2016a) and most of the area falls under one or more designations as a landscape of conservation significance (High Value Landscapes, Environmentally Significant Areas, Areas of High Wildlife Sensitivity, Key Wildlife and Biodiversity Areas – Lamoureux 1983; Fiera 2011 and 2014; Alberta Environment and Sustainable Resource Development 2015; and Alberta Environment and Parks 2018 and 2021).

I have undertaken a review mostly of components related to vegetation and wildlife as well as portions of the hydrology studies that discuss downstream effects in riparian lands.

If the project is approved, the mitigations proposed by Alberta will help reduce residual or long-term effects for many biodiversity components. However, they will not prevent immediate and lasting damage to an area of environmental significance. There will be residual and long-term adverse effects on components of conservation concern where there is clear provincial guidance, including wetlands and intact native grassland.

In my professional opinion, the key terrestrial biodiversity issues are:

- much of the Springbank SR1 Project boundary is located in one or more landscapes of conservation significance (High Value Landscape, Environmentally Significant Areas, Areas of High Wildlife Sensitivity, Key Wildlife and Biodiversity Area, High Sensitivity Watershed).
- in contravention of guidance in the South Saskatchewan Regional Plan (SSRP), portions of the project will be developed on lands mapped as intact native grasslands in the SSRP.
- in contravention of the avoidance direction of Alberta's Wetland Policy, wetlands and streams will be permanently lost.
- cumulative effects are not being addressed adequately due to the lack of consideration of the degree to which the Foothills Parkland Natural Subregion has already been modified.

- a lack of attention to the ecological effects of capture of all flood events over 160 m^3/s on downstream riparian habitats and ecological functions of major flood events is a significant omission.

Alberta Transportation (2021, Exhibit 219, pdf pages 22, 25 and 27) describes the key project activities in the site preparation and construction phases as well as the conditions for opening the diversion inlet gates and the residual effects of the project:

> *"The site preparation phase and construction phase would involve the construction and installation of all of the components such as: diversion inlet, service spillway, and debris deflector deflection barrier; floodplain berm; diversion channel; off-stream reservoir; and off-stream dam, and low-level outlet; the upper side walls of the diversion channel; the dam embankment; side slopes and back slopes of new roads; and modification and construction of the roads and bridge.*
>
> *Additionally, it would involve the construction of temporary areas that will be reclaimed post construction, including: the river cofferdam; the south (non-river) side of the floodplain berm; the upper side walls of the diversion channel; the dam embankment; contractor laydown areas; borrow areas; spoil areas; side slopes and back slopes of new roads; areas disturbed by utility construction; temporary construction access roads that have been decommissioned; the decommissioned portion of Highway 22; the temporary channel used for the diversion of the Elbow River; and all other areas disturbed by construction that are not required for operation and maintenance."*
>
> *. . .*
>
> *"Flood operations would occur when flows in the Elbow River meet or exceed 160 cubic metres per second. The service spillway gates would be raised to create a backwater upstream of the diversion structure, and the diversion inlet gates would be raised to allow flows through the diversion channel for storage in the off-stream reservoir. Once the off-stream reservoir has been filled, the diversion inlet gates would be closed and the auxiliary service spillway gates lowered. The diverted floodwaters would be retained in the off-stream reservoir until the flood event has subsided."*
>
> *. . .*
>
> *"The EIA assessed an early and late release scenario to cover the range of operational scenarios. The early release scenario is the operational rule and has the reservoir release when flows in the Elbow River drop below 160 cubic metres per second. The late release scenario was based on keeping flows in Elbow River at or below bankfull flow rates (47 cubic metres per second)."*
>
> *. . .*
>
> *"Residual effects on vegetation and wetlands during construction and dry operations would be of long-term duration."*
>
> *. . .*
>
> *"Sedimentation will result in some temporary loss of upland communities and potentially permanent loss of wetlands."*
>
> *. . .*
>
> *"The Proponent estimated 70.3 hectares of wetland within the reservoir will be inundated during a design flood."*
>
> *. . .*

"The majority of nesting habitat flooded during a design flood would be tame pasture (373 ha)."

While there is extensive documentation, its breadth should not be seen as completeness and assurance of limited environmental impact.

The Springbank Community Association (2021b, Exhibit 194) raised some general questions and concerns on the subject of design changes which have merit. Some of the more significant changes that could affect biodiversity include:

1. *"Doubling of the diversion channel (2016) and, accordingly, storage volumes.*
4. *Shifting of dam toe by 100M (2019 - using 2016 report) due to slope stability.*
5. *Moving of the Low-Level Outlet (LLOW) 190 meters to the south west (2020) resulting from apparent concerns of foundation material.*
7. *Creation of new 500M channel within reservoir from the unnamed creek to the new LLOW (2020).*
8. *Creation of a new 700M channel on the exterior of the reservoir back to the unnamed creek (2020).*
9. *Erosion protection along the complete length of the unnamed creek back to the Elbow River (2020)."*

Stantec (2020c, Exhibit 218, pdf page 19) notes:

"Given this release model, clarity for draw down times for each flood scenario (1:10, 1:100, design flood) and on analysis of potential effects to VC are needed in order to determine changes to sediment deposition, potential effects to water quality and quantity, and potential effects to fish and fish habitat. Additionally, it was discussed in the February 2020 Technical Advisory Group Meeting that it is still unclear how the capacity of the low-level outlet 27 m^3/s was determined."

This information is relevant to the downstream effects, although it goes mostly to degree, not to whether or not there will be a significant downstream effect.

2. FOOTHILLS PARKLAND CONTEXT

Alberta has adopted the natural regions landscape classification system to describe environmental diversity and provide the scientific framework for the protected areas network (Alberta Environment and Parks 2016a). Each natural region contains a mix of similar vegetation, geology, soils, and landscape features. Alberta recognizes six natural regions including the Aspen Parkland (Figure 1) that are again subdivided into 21 natural subregions, including the Foothills Parkland in which lands affected by the proposed project are located.

Protected area targets have not been met in some Natural Subregions, e.g., Foothills Parkland, where the targets are already extremely low--even by older protected areas standards (Figure 2). Just 2% of this subregion has been protected (Alberta Environment and Parks 2018). For the Foothills Parkland Subregion, Alberta Environment and Parks (2016b) notes “Foothills Parkland is among the most poorly represented Subregions in the parks system. Only slightly more than 40% of the Natural Landscape Type targets have been achieved." Any remnant natural habitats in the Aspen Parkland are considered significant for biodiversity conservation whether on public or private land.

Alberta Environment and Parks (2016a) notes: “Wetlands are uncommon, covering about 4% of the total area, but seepage on lower slopes is a common phenomenon.”

Alberta Environmental Protection (1997) notes: “The Parkland is one of the most heavily impacted Natural Regions in Alberta. It has changed dramatically over the last 75 to 100 years under the cumulative effects of roadways, urbanization, cultivation, livestock grazing, petroleum and natural gas development, mining, hydroelectric dams, irrigation developments, electrical transmission lines and other developments.”

The ongoing fragmentation and loss of native Aspen Parkland and associated wetland habitats strongly suggests that project developers should exhibit a higher standard of care when conducting activities in this region. Cumulative effects assessment for a project like Springbank SR1 should consider all losses of native Aspen Parkland habitat as significant.

Natural Foothills Parkland habitats occupy a significant portion of the project area. Stantec (2016, Exhibit 2, pdf page 72) notes:

> *“Fescue grasslands are important ecologically as a climax community providing habitat and winter forage for wildlife. . . . Because of the decline of fescue grassland communities in Alberta and the difficulty of re-establishing them, numerous fescue dominated communities are tracked and watched by the Alberta Conservation Information Management System (2014) . . . Areas of native prairie within the Project Area have the potential to include fescue grassland. Some of these areas of native prairie would be removed during the construction of the project components and increase the fragmentation of the grassland in the Project Area.”*

Stantec (2020c, Exhibit 218, pdf page 83) notes:

“Most of the sediment deposition is expected to range from 10 cm to 100 cm deep in the reservoir (319.03 ha. 39.07% for early release: 337.36 ha. 41.32% for late release). Sediment ranging from 3 cm to 10 cm deep will cover 15.22% to 18.96% of the reservoir for early release and late release, respectively. Sediment greater than 100 cm deep will cover 0.63% to 0.69% (Table 1-10), respectively.”

. . .

“sediment deposition between 10 cm and 100 cm is expected to result in mortality of plants in the herb and short shrub strata.”

. . .

“most effects for early release and late release will be to agricultural land, 368.90 ha. (98.72% of baseline area in the reservoir); followed by grassland, 119.21 ha (88.13% of baseline area in the reservoir) and shrubland, 78.17 ha (90.35% of baseline area in the reservoir).”

. . .

“Portions of existing native grassland in the reservoir will also be affected in areas of greater than 3 cm of sediment deposition for early and late release. Most of the baseline native grassland area, 57.99% to 62.78%; however, will receive less than 3 cm of sediment deposition and is not expected to be affected.”

This implies that a significant portion of the baseline native grassland will be affected in addition to loss from permanent works and construction areas. Stantec (2020c, Exhibit 218, pdf 87) identifies 78.53 ha as the baseline condition for rough fescue grassland—about 4.22 ha or 5.37% will be negatively affected by sediment deposition in the design flood in the most favorable early release scenario. About 22.5% of all grassland types will be negatively affected by sediment deposition in the design flood in the most favorable early release scenario. Note that the totals for all unaffected and affected areas did not add up to the baseline numbers in Stantec’s (2020c, Exhibit 218, pdf page 87) Table 1-10 but these figures should still be a good approximation. A significant percentage of grasslands will be negatively affected.

A significant portion of the baseline wetlands and open water will be affected in addition to loss from permanent works and construction areas. Stantec (2020c, Exhibit 218, pdf page 87) identifies 70.1 ha as the baseline condition for all wetland types and 61.15 ha for open water—about 32.9 ha (46.9%) of wetland and 85 ha (64.7%) of open water and wetlands will be negatively affected by sediment deposition in the design flood in the most favorable early release scenario. Note that the totals for all unaffected and affected areas did not add up to the baseline numbers in Stantec’s (2020c, Exhibit 218, pdf page 87) Table 1-10 but this should still be a good approximation. A significant percentage of wetlands will be negatively affected.

Stantec (2019a, Exhibit 217, pdf page 24) notes:

“Wetland ecological function (i.e., wildlife habitat and plant diversity) would be altered due to vegetation clearing for permanent components. Dry operations would result in the loss of 16% (8 ha) of the estimated high value wetland area and 36.1 % (13 ha) of moderate value wetland area.”

Stantec (2019b, Exhibit 94, pdf page 116) states:

> *"deposition of sediment is likely to alter wetland topography, resulting in changes to surface flow and alteration of wetland basin shape and depth. Together, these changes could result in the total permanent loss of up to 12.0 ha of wetland following a design flood. It is possible that some areas of wetlands will no longer function as wetlands and will shift to upland habitat. It is also possible that some upland habitat could shift to wetland habitat due to altered topography and drainage patterns, or wetland basins could have altered shape and depth as a result of sediment deposition."*

Lastly, soils would be impacted significantly. This is based on a response that includes a correction to the significance conclusion (Stantec 2019b, Exhibit 94, pdf page 16):

> *"construction of the Project would result in a significant effect on soil because there will be a change in soil quality or quantity resulting in a reduction in agricultural land capability that cannot be offset through mitigation or compensation measures (this occurs in the off-stream reservoir)."*

The significant degradation of soil quality (agricultural land capability) for the design flood is shown in Figures 9-3 to 9-5 of Stantec (2018b, Exhibit 48, pdf pages 22 to 24). This loss of productivity due to soil degradation will be felt in native and non-native upland and wetland habitats. Some of these effects will be minor where sediment deposition is infrequent or shallow but significant in areas of frequent sediment deposition (e.g., every 5-10 years) or where sediment deposition is deep (greater than 10 cm).

Grasslands are discussed further in the South Saskatchewan Regional Plan section.

To summarize, there will be residual negative biodiversity impacts of the project on these scarce natural parkland habitats, including wetlands and intact native grassland through direct habitat loss under project components and sediment deposition during flood events and activities to remove sediment following floods.

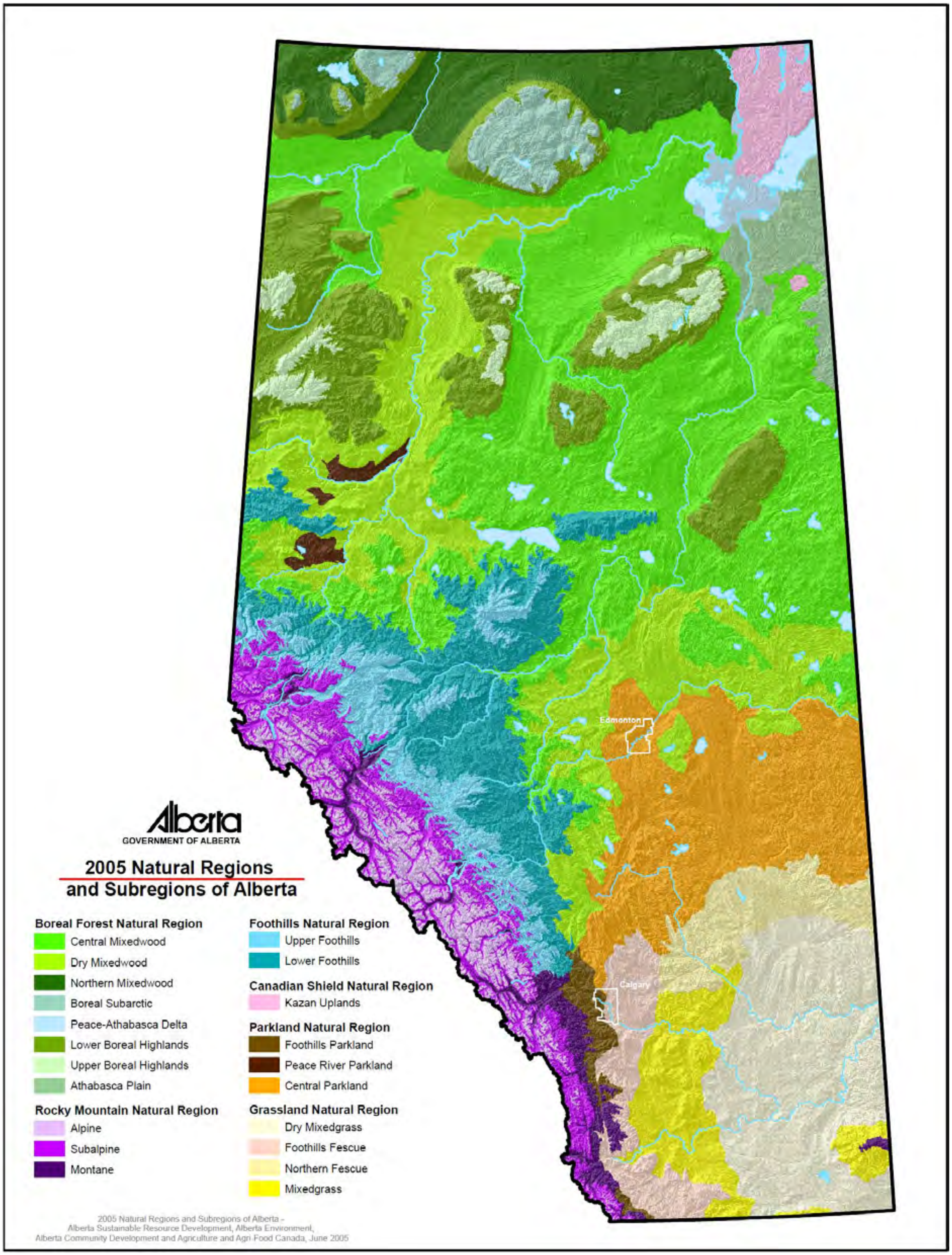


Figure 1. Alberta Natural Regions and Subregions (Alberta Environment and Parks 2016a)

Figure 2. Theme Targets for Protection by Natural Region

Progress Summary of Ecological Representation (Natural Landscape Types) by Natural Region and Subregion within Protected Areas in Alberta

updated: July 4, 2018

					Representation Targets			PROGRESS[1]				
Natural Region	Subregion	Subregion size (km²)	Total # Parks and Protected Areas	Total Area in Parks and Protected Areas (km²)	# Natural Landscape Targets	Total Area of Targets (km²)	Target as % of Subregion	# Representation Targets Completed	# Gaps	# Protected Areas Contributing	Average % Progress Towards Targets	% of Subregion in IUCN /CARTS Protected Areas
Rocky Mountains	Montane	8,768	84	2,647	9	410	5%	7	2	33	88%	30.0%
	Subalpine	25,218	53	14,068	8	1,241	5%	8	0	33	100%	55.8%
	Alpine	15,084	22	12,862	5	751	5%	5	0	22	100%	85.3%
	Subtotal	***49,070***		***29,577***	***22***	***2,403***	***5%***	***20***	***2***			***60.2%***
Foothills	Lower Foothills	44,899	58	339	14	2,227	5%	1	13	24	31%	0.7%
	Upper Foothills	21,537	54	605	11	1,056	5%	3	8	20	56%	2.7%
	Subtotal	***66,436***		***944***	***25***	***3,284***	***5%***	***4***	***21***			***1.4%***
Grassland	Mixedgrass	20,072	13	205	11	984	5%	0	11	4	15%	0.9%
	Northern Fescue	14,933	10	200	12	731	5%	1	11	6	20%	1.3%
	Foothills Fescue	13,623	13	83	9	658	5%	0	9	5	8%	0.4%
	Dry Mixedgrass	46,937	12	769	11	2,326	5%	2	9	9	36%	1.6%
	Subtotal	***95,565***		***1,257***	***43***	***4,699***	***5%***	***3***	***40***			***1.25%***
Parkland	Central Parkland	53,706	31	467	13	2,678	5%	2	11	23	30%	0.9%
	Foothills Parkland	3,921	14	82	7	198	5%	1	6	12	40%	2.1%
	Peace River Parkland	3,120	5	21	8	162	5%	0	8	5	27%	0.7%
	Subtotal	***60,747***		***570***	***28***	***3,038***	***5%***	***3***	***25***			***0.9%***
Boreal Forest	Central Mixedwood	167,856	63	22,316	13	8,355	5%	11	2	44	93%	13.3%
	Dry Mixedwood	82,321	97	1,372	13	4,203	5%	1	12	65	38%	1.5%
	Northern Mixedwood	29,513	3	13,236	10	1,464	5%	9	1	3	90%	44.8%
	Lower Boreal Highlands	55,615	16	4,607	10	2,742	5%	7	3	8	89%	8.3%
	Upper Boreal Highlands	11,858	5	2,090	9	588	5%	7	2	4	80%	17.6%
	Peace-Athabasca Delta	5,535	3	5,193	5	256	5%	5	0	3	100%	93.8%
	Boreal Subarctic	11,823	2	5,838	9	587	5%	8	1	2	91%	49.4%
	Athabasca Plain	13,525	7	3,733	10	669	5%	10	0	7	100%	27.6%
	Subtotal	***378,046***		***58,384***	***79***	***18,863***	***5%***	***58***	***21***			***15.4%***
Canadian Shield	Kazan Uplands	9,719	5	7,130	7	481	5%	7	0	5	100%	73.4%
	Subtotal	***9,719***		***7,130***	***7***	***481***	***5%***	***7***	***0***			***73.4%***
ALL	TOTAL	659,583		97,863	204	32,767		95	109			14.6%

1 - only those sites in Alberta meeting the IUCN definition of "protected area" and reported to the Canadian Conservation Areas Reporting and Tracking System (CARTS) are measured against targets (note that all governance types (ie. federal, provincial, municipal, private, community or Indigenous) are included)
2 - Target 1 of the Canadian Biodiversity 2020 Targets and Aichi Target 11 under the UN Convention on Biological Diversity (CBD) stipulates a target of ensuring at least 17% in terrestrial networks by 2020

Figure 2. Progress Towards Targets for Protection by Natural Region
Central Parkland highlighted in red (Alberta Environment and Parks 2018)

3. SOUTH SASKATCHEWAN REGIONAL PLAN CONTEXT

The South Saskatchewan Region Regional Plan (SSRP) (Government of Alberta 2018, pdf pages 29 and 44) expresses the following vision:

> *"Southern Alberta is a diverse, healthy, vibrant and prosperous region where the natural beauty of the region is managed so that citizens feel connected to the land and its history. Albertans, industry, governments, and aboriginal peoples work together to share responsibility for stewardship of the land and resources in a way that ensures current needs are met without compromising opportunities for future generations. Aboriginal peoples, through their traditional knowledge, share their intimate understanding of the region's natural environment and ecosystems."*

> *"The South Saskatchewan Region supports a diverse and growing population. Economic diversification supports employment and contributes to a prosperous future. Agriculture is a significant renewable resource industry demonstrating environmental stewardship while pursuing growth and diversification opportunities. There are continued opportunities for oil and natural gas production and renewable energy will become increasingly significant. Forests are managed with watershed management and headwaters protection as the highest priority and healthy forests continue to contribute to the province's timber supply. The region has unique landscapes that form the basis of a popular tourism and recreation destination which continues to grow."*

> *"Air, water, land and biodiversity are sustained with healthy functioning ecosystems. The headwaters in the region supply vital regional freshwater quality. Conservation strategies help many species at risk in the South Saskatchewan Region recover, while also preserving the diversity and splendor of Alberta's natural regions with various parks and conservation areas providing Albertans with improved health and inspiration to value nature."*

The vision has a clear focus on sustainability and conservation as well as non-renewable resource production centred on oil and natural gas. The SSRP describes the importance of the region:

> *"A wide range of fish, wildlife and plant species exist in the region, including: 17 sport fish species; over 700 vascular plant species; numerous songbirds, hawks, owls, waterfowl and grouse; and mammals such as moose, deer, pronghorn, wolves, grizzly bears, cougars and lynx. The region also serves as breeding grounds and staging areas for birds during migration and overwintering periods. The South Saskatchewan Region has more than 80 per cent of the province's species at risk as listed under the federal Species at Risk Act and the provincial Wildlife Act. Factors contributing to this high proportion include human settlement, disturbance from industrial, recreational and other uses, fragmentation, environmental contaminants and the introduction of invasive species."*

> *"The range of species and diversity of ecosystems across the region reflects the biodiversity found here and means there is a broad range of ecosystem services provided. Biodiversity represents the assortment of life – including the variety of genetics and species and the habitats in which they occur – all shaped by natural processes of change and adaptation. Biodiversity and ecosystem services are not the same thing but they are interdependent.*

Ecosystem services are the benefits humans, communities and society as a whole receive from healthy, functioning ecosystems and the biodiversity within them. Biodiversity underpins the supply of ecosystem services, so changes in biodiversity will affect the type and amount of those services available to humans."

"All ecosystem services contribute to sustaining a healthy and prosperous way of life for all Albertans. Fish, wildlife, traditional medicinal plants, berries and less-developed spaces are also important for the cultural practices of First Nations peoples."

3.1 South Saskatchewan Regional Plan -- Intact Native Grassland

The Alberta Land Stewardship Act provides direction for decision-making bodies in section 21(1):

"21(1) *When a regional plan is made, every decision-making body affected by the regional plan must*
(a) review its regulatory instruments, and
(b) decide what, if any, new regulatory instruments or changes to regulatory instruments are required for compliance with the regional plan."

"(2) *Every decision-making body affected by the regional plan must, within the time set in or under, or in accordance with, the regional plan,*
(a) make any necessary changes or implement new initiatives to comply with the regional plan, and
(b) file a statutory declaration with the secretariat that the review required by this section is complete and that the decision-making body is in compliance with the regional plan."

The South Saskatchewan Regional Plan (Government of Alberta 2018, pdf pages 76 and 141) provides guidance with respect to intact native grasslands (Figures 4 and 5):

"Implement guidelines to ***avoid conversion and maintain intact native grasslands on public land*** *(see Appendix G - Grasslands).*

- *Species at risk habitat – No conversion permitted as habitat needs to be sustained as part of government programs for species recovery (as required under federal and provincial legislation)."*

. . .
"Areas with high biodiversity value such as areas important for connectivity and areas that are "intact" and would benefit from remaining in a less disturbed condition such as intact native grasslands."

Alberta Transportation (2021 – Exhibit 219, pdf page 4) notes its land use priorities:

"Alberta Transportation's land use priorities in the LUA are presented in the Updated Draft Guiding Principles and Directions for Future Land Use document as follows:

- *The primary and overarching use of the Crown land within the Project footprint is for flood mitigation."*

Stantec (2018a, Exhibit 80, pdf page 99) notes:

"Time required for upland native communities to re-establish following the design flood will vary depending on community type, sediment depths, plant characteristics and climatic conditions. Areas of complete burial and full loss of existing species (i.e., 10 cm to greater than 100 cm) will likely take the longest to revegetate. Most of the dominant grasses (e.g., bluejoint [Calamagrostis canadensis], Kentucky bluegrass [Poa pratensis], slender wheat grass [Elymus trachycaulus]), dominant shrubs (e.g., rose [Rosa sp.] and buckbrush [Symphoricarpos occidentalis]), and trees of inundated areas (trembling aspen [Populous tremuloides] and balsam popular [Populus balsamifera]), have rapid growth and are capable of moderate to rapid vegetative spread (USDA 2018). These species should quickly colonize flooded areas following water drawdown. However, potentially more than 10 years, may be required for conditions to resemble baseline."

On average, floods of sufficient size to be captured by the project may occur every 5-10 years (although intervals may be longer). This means that there is little likelihood of re-establishment of diverse native vegetation in the frequently inundated area. I believe that, for conditions to resemble baseline in native habitats, significantly more than 10 years will be needed, especially for upland sites. More than likely, non-native, and pioneering native species will dominate for quite some time given the large presence of non-native species in the surrounding environment.

Stantec (2020b, Exhibit 138, pdf page 451) indicates the relative values of grassland habitats, both native and tame:

"The statement in the EIA, Volume 3A, Section 11.4.2.3, is intended to indicate that tame pasture provides relatively higher suitability wildlife habitat compared to crop and hayland—not relative to native plant communities. Tame pasture provides relatively lower habitat suitability compared to native plant communities for most wildlife species; however, tame pasture can provide suitable habitat for some wildlife species, such as deer or elk, as well as grassland bird species that are habitat generalists (e.g., vesper sparrow, savannah sparrow). It is expected that after reclamation, tame pasture will increase wildlife habitat suitability compared to crop and hayland, based on the reclamation seed mix, which will provide potential food sources and plant cover for various grassland-dependent wildlife species."

"The Project residual effects on change in habitat were considered in the determination of significance (see Volume 3A, Section 11.5), which states that with the application of mitigation and environmental protection measures, the residual environmental effects on wildlife are predicted to be not significant (i.e., the residual effects on change in habitat is unlikely to pose a long-term risk to the persistence or viability of a wildlife species in the RAA)."

While I agree with the relative values for wildlife and the superiority of diverse native plant communities for wildlife compared to tame pastures with a few highly productive species, the last statement is not supported. The continuing destruction of native grassland habitats in the Foothills Parkland Natural Subregion is a serious concern and is one of the reasons why temperate grasslands, including the Northern Great Plains ecoregion, in which the project is located, has been identified as a global priority for conservation and protection as one of the World Wildlife Fund's (2009) Global 200 ecoregions. Temperate grasslands represent one of the biomes most at risk in the world and are now the target of international conservation efforts. Birds that nest in temperate grasslands are the most rapidly declining group of birds in North America (North American Bird Conservation Initiative Canada 2019--Figure 3). This project will add to the cumulative impacts on those species.

Stantec (2019b, Exhibit 94, pdf page 150) indicates that the existing area of native fescue grassland is expected to be reduced by 8.9 ha following construction.

Alberta Transportation (2021 – Exhibit 219, pdf page 12) notes that native vegetation cannot be left undisturbed in all cases:

> *"The Proponent shall give preference to the use of existing access roads and disturbed areas for temporary workspaces and transportation activities over building new access roads and temporary workspace in undisturbed areas, and shall not remove native vegetation when building temporary workspace**, where practical. Where native vegetation is removed for temporary workspaces, these areas will be revegetated**."*
>
> *"Recommending modified wording as it is not practical that native vegetation can be maintained at all temporary workspaces."*

To summarize, in contravention of the SSRP guidance to maintain intact native grasslands, portions of the project footprint are located on what will be public land inside areas mapped as intact native grasslands in the SSRP (Figures 4 and 5).

<u>3.1.1 Reclamation of Rough Fescue Communities</u>

Stantec (2020b, Exhibit 138, pdf pages 459 and 464), notes:

> *"The assessment does acknowledge that during construction the Project will result in the alteration and loss of habitat including native grassland (see EIA, Volume 3A, Section 10.4.3; Volume 3B, Section 10.2.2; Volume 3A, Section 11.4.2.3, and Volume 3B, Section 11.3.2). The permanent and long-term loss of habitat, such as native grassland, will occur where there is overlap with permanent Project structures (e.g., diversion channel). However, reclamation of the construction area will result in changes that will vary. Grasslands are expected to re-establish within three years but resemble early seral communities for 12 years or more beyond construction."*
>
> *. . .*
>
> *"A return of pre-disturbance communities is not expected; however, communities dominated by native plants will occur and these communities are expected to provide suitable habitat for wildlife."*

This contrasts to a more rosy assessment in Stantec (2019b, Exhibit 94, pdf page 150):

> *"This area will be native grassland following re-vegetation, and the overall area of native grassland will increase by 90.6 ha during dry operations."*
>
> *"Species composition and productivity may be altered in flooded grassland areas and areas of sediment deposition (in the off-stream reservoir), but no reduction in native grassland area is expected following flooding."*

I have considerable difficulty with Stantec's (2019b) characterization of the area as native grassland following re-vegetation. The difficulties of restoring native grasslands are well known. While there may be some native species dominating in revegetated sites, they do not have the full functionality and productivity for native plants and wildlife, including invertebrate populations.

The following is a brief discussion of the difficulties of restoring foothills grasslands, focusing on rough fescue, which the proponent has acknowledged will be lost and not restored.

Bradley and Neville (2010) indicate that successful restoration of foothills fescue grasslands has not been documented. Revegetation success is hampered by invasive non-native species such as smooth brome, Kentucky bluegrass and timothy. They state that for industrial projects in foothills fescue grasslands "*avoidance is the preferred strategy*." Alberta Sustainable Resource Development (2010) also recognized the values of foothills grasslands and the difficulties of re-establishing them -- they also recommended avoidance as the key guidance:

> *"Foothills fescue grasslands contribute ecological goods and services important to the economy and public interests of Alberta. The value of retaining the ecological health and function of these grasslands is acknowledged by the ranching community, government agencies, stewardship groups and through conservation easements on freehold lands. Of increasing value to Albertans is the role foothills fescue grasslands play in maintaining surface and groundwater resources. Also, there is an increasing awareness of their role in capturing and storing carbon. It is recognized that fragmentation of these remaining fescue grasslands jeopardizes their ecological health, function and operability."*
> *. . .*
> *"Unlike many native prairie ecosystems, natural recovery has failed to restore foothills fescue plant communities as the native plants simply cannot compete with invasive non-native species. Disturbed sites seeded with native plant cultivars have resulted in limited success in reducing non-native species invasion. Long term restoration success has yet to be demonstrated and documented on industrial sites subjected to the full range of production and operational disturbance related activities."*

While Lancaster et al. (2016, pdf pages 19 and 48) provide a good overview of issues related to the benefits of native grasslands and the difficulties of reclamation in Alberta's foothills, the reclamation "successes" described relate primarily to one site (Lewis Ranch) where the soil layer was not disturbed:

> *"Relative to each unique ecological site, intact native grasslands possess a rich diversity of native grasses, forbs and shrubs that produce a characteristic plant community structure, facilitating optimal use of moisture, nutrients and available sunlight.* ***To the extent possible, reclamation practices aim to restore the native plant community so that ecological health and function, and the related ecological services are maintained. In the Alberta Grassland Natural Region, recovery of native plant communities can be more readily achieved in drier prairie environments while mesic foothill environments are much more challenging, primarily due to the greater competitiveness of agronomic grasses and weeds in the moister growing environment. Ecological health, function and***

associated ecological services will be diminished when plant communities are modified by non-native species (my emphasis).”

. . .

“On the post-2000 wellsites some hopeful expressions of native species infilling and recruitment were evident including a very strong re-establishment of rough fescue on the Lewis wellsite where the surface topsoil had not been stripped.”

3.2 Riparian Lands and Wetlands

The SSRP recognizes the value of riparian lands and wetlands:

> ***“****Riparian lands are important as they are highly productive, rich and resilient parts of the landscape.”*
>
> *. . .*
>
> *“Wetlands are highly diverse and complex ecosystems and have long been recognized for the contributions they make to human and ecosystem health. They provide benefits that contribute to resiliency to drought and flood conditions, water purification, groundwater recharge and recreational opportunities and they are centres of high biodiversity.”*

In the strategies for enhanced integrated watershed management, the SSRP recommends:

> ***“****4.9 Encourage decision-makers and land managers to use the available* ***planning information****, including: riparian and wetland mapping and inventories, environmentally significant areas mapping and groundwater vulnerability mapping.*

The SSRP continues:

> **“**As work continues to complete this planning for all of the public land in the region, the criteria will be considered to identify further priority areas:”

- *“Areas of important ecosystem function such as key headwaters areas, high value wetlands and riparian lands*
- *Areas of sensitive terrestrial and aquatic habitat such as habitat of species at risk and habitat identified in provincial species recovery plans*
- *Areas with high biodiversity value such as areas important for connectivity and areas that are “intact” and would benefit from remaining in a less disturbed condition such as intact native grasslands”*

The following sections will explore such landscapes of conservation significance.

3.3 Recommendation

For the reasons outlined in this section (difficulty of restoring intact native grassland and SSRP guidance against disturbing intact native grassland), I recommend that the Springbank SR1 project not be approved in its current configuration.

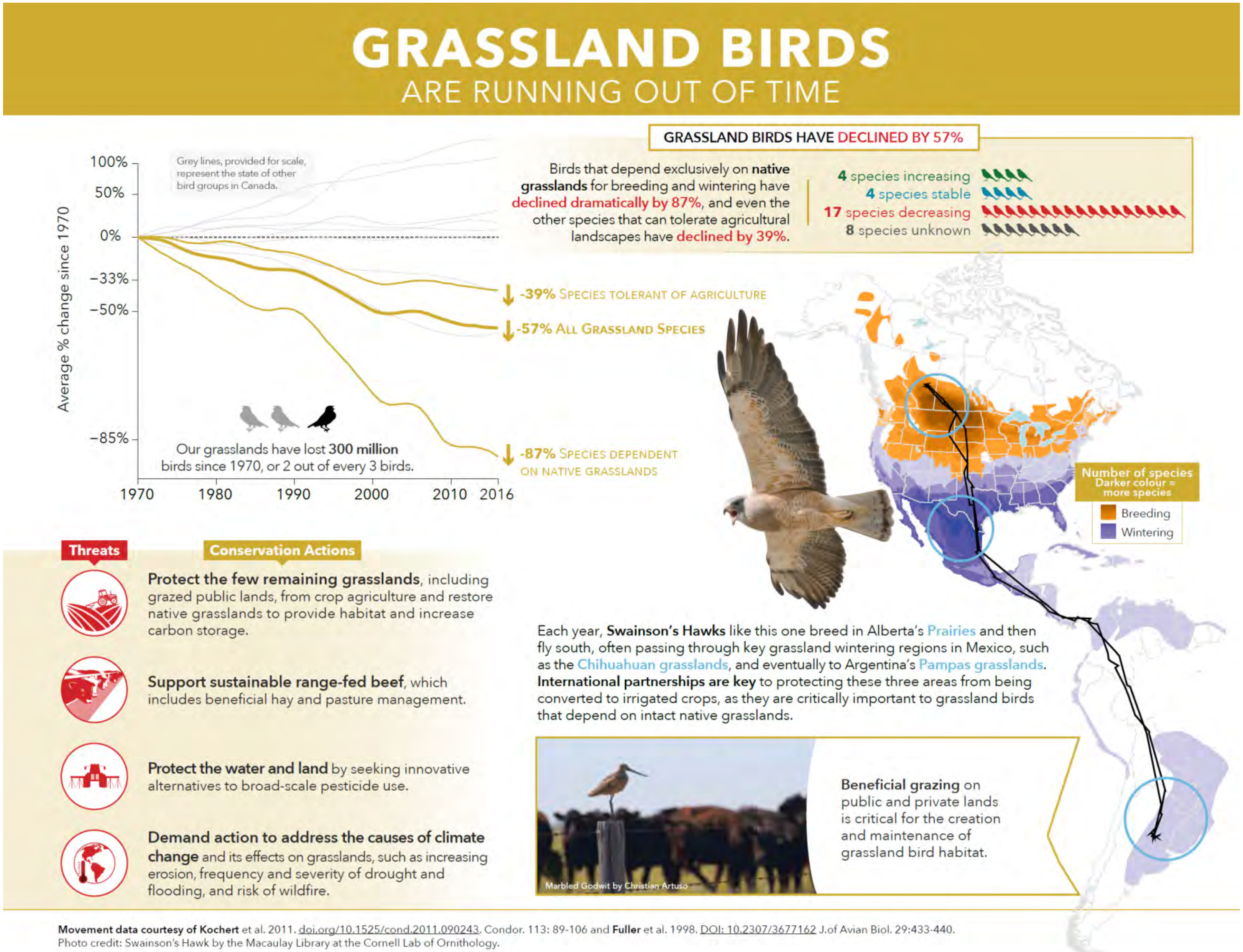


Figure 3. North American Bird Conservation Initiative Canada (2019) – showing overall grassland bird decline

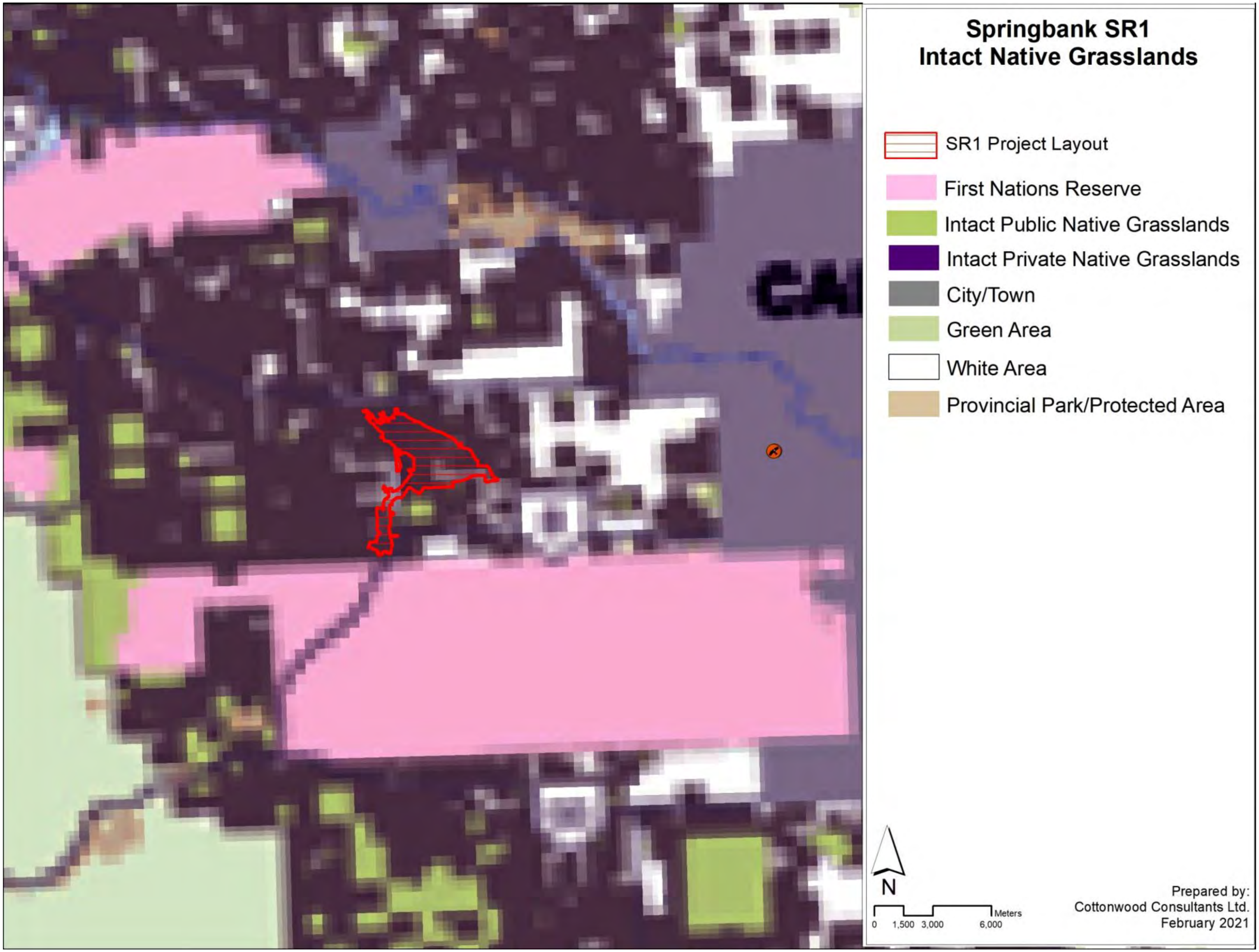


Figure 4. Intact Private and Public Native Grasslands (Government of Alberta 2018)

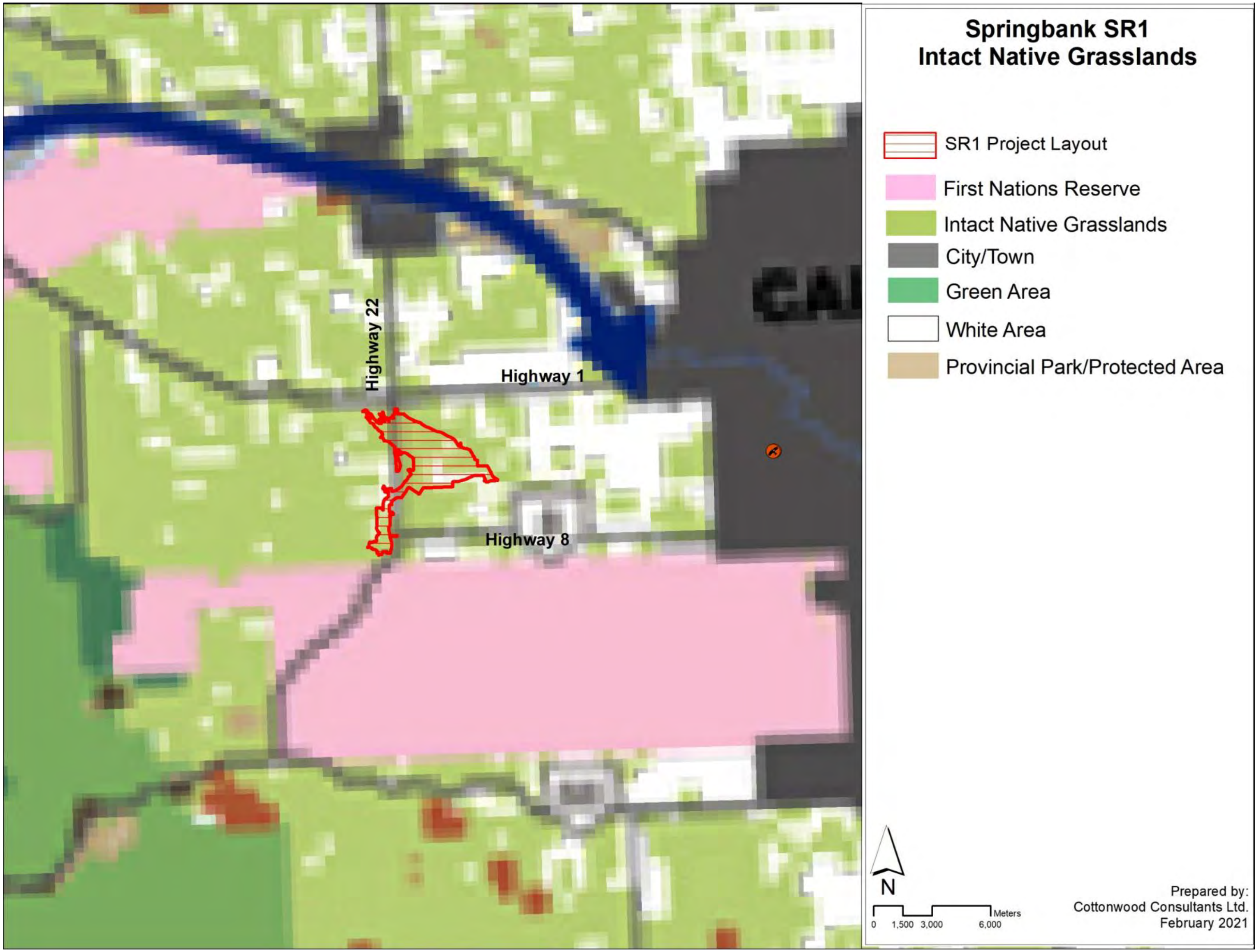


Figure 5. Intact Native Grasslands (Government of Alberta 2018)

4. LANDSCAPES OF CONSERVATION SIGNIFICANCE

Several mapping exercises have been done since the early 1980s to identify landscapes of conservation significance. Most recently this has included high value landscape mapping by the Prairie Conservation Forum (2016 and 2021). The first Environmentally Significant Area (ESA) study conducted in Alberta (Lamoureux 1983) was undertaken in the Calgary region, including the project area. Subsequent studies on ESAs have been done at a provincial level of significance or higher (Fiera 2011, 2014). The Alberta Government has also produced "Key Wildlife and Biodiversity" mapping (Alberta Environment and Sustainable Resource Development 2015**)** as well as a high risk/sensitivity mapping for renewable resource development (Alberta Environment and Parks 2017). The Bow River Basin Council (2012) has mapped high sensitivity watersheds.

4.1 High Value Landscapes

The Prairie Conservation Forum (2016 and 2021) mapped what they referred to as "high value landscapes" (Figure 6). They note that "some landscapes have higher native biodiversity than other areas" and that their map "was prepared by compiling four different map layers including native vegetation, species at risk, ecosystem services and environmentally significant areas". The Prairie Conservation Forum identifies that their map of high value landscapes provides an appropriate scale to initiate a dialogue around maintaining large landscapes and conserving connecting corridors.

The entire project area falls within a "high value landscape" mapped by the Prairie Conservation Forum (2016 and 2021).

4.2. Environmentally Significant Areas (ESAs)

Environmentally Significant Areas (ESAs) are areas that have been identified as being of ecological, hydrological, or geological importance based on representativeness, diversity, naturalness, and ecological integrity. In Alberta, ESAs include areas that meet any of the following criteria (Sweetgrass Consultants 1997):

"1. areas that provide an important linking function and permit the movement of wildlife over considerable distances, including migration corridors and migratory stopover points;
2. areas that perform a vital environmental, ecological, or hydrological function such as aquifer recharge;
3. areas that contain rare or unique geological or physiographic features;
4. areas that contain significant, rare, or endangered plant or animal species;
5. areas that are unique habitats with limited representation in the region or are a small remnant of once large habitats that have virtually disappeared;
6. areas that contain an unusual diversity of plant and/or animal communities due to a variety of geomorphological features and microclimatic effects;
7. areas that contain large and relatively undisturbed habitats and provide sheltered habitat for species that are intolerant of human disturbance;

8. *areas that are excellent representatives of one or more ecosystems or landscapes that characterize a natural region;*
9. *areas with intrinsic appeal due to widespread community interest or the presence of highly valued features or species such as game species or sport fish; and*
10. *areas with lengthy histories of scientific research."*

These criteria were simplified by Fiera (2009) to:

"1. Areas that contain elements of conservation concern.
2. Areas that contain rare or unique landforms.
3. Areas that contain habitat for focal species.
4. Areas that contain important wildlife habitat.
5. Riparian areas.
6. Large natural areas.
7. Sites of recognized significance."

Fiera (2009) states

> *"Environmentally Significant Areas (ESAs) are defined as areas that are vital to the long term maintenance of biological diversity, physical landscape features and/or other natural processes at multiple spatial scales. Identifying these areas using scientifically rigorous, defendable, and relevant methodology is the first step toward the successful integration of ecological values into provincial planning and management. The early recognition of ESAs is essential to help identify and prioritize areas that may be important to conserve, or that require special management consideration, thus supporting land-use planning processes. For example, areas of environmental importance are commonly used to prioritize environmental management toward areas that represent under-protected or vulnerable resources or resources that are highly unique (naturally rare) or "irreplaceable". Identifying ESAs using credible, broadly supported methods enables decision makers to rapidly progress through the planning process where informed trade-offs can be discussed, priorities set and clear policy direction achieved."*

Most ESAs have been assigned a significance level: local, regional, provincial, national, or international. Many regionally or locally important ESA have only been identified in the various regional ESA studies (e.g., Lamoureux et al. 1983) but they are not recognized in the readily available provincial online database. This regional and local ESA information should also be accessed when considering the environmental effects of projects.

Alberta has compiled ESA information for the entire province. ESAs may contain rare or unique biodiversity or are areas that may require special management consideration due to biodiversity conservation needs. ESAs currently have no policy context and are only intended to be an information tool to help inform land use planning and policy at local, regional, and provincial scales.

Representativeness, diversity, naturalness, and ecological integrity all play a role in delineating ESAs (Fiera 2009, 2011, 2014).

Much of the project area has been identified as a regional ESA (Lamoureux et al. 1983), an aquatic ESA (Fiera 2011), or as a regional or provincial ESA (Fiera 2014).

4.2.1 ESAs—Fiera 2014

The Government has updated ESAs for the province (Fiera 2014) but has provided it in a format that is somewhat challenging to use as it is only a quarter-section method with no named/numbered natural area boundaries, being based strictly on a numerical threshold. Each quarter section is ascribed a ranking based on a summation of various criteria. Fiera states: "Ultimately, professional judgment was used to determine a cutoff value of >0.189 for designating quarter sections as Environmentally Significant Areas in the province." From experience, this is a relatively arbitrary cutoff number and must be used with historical ESA information and current field studies to refine ESA boundaries. Limitations are recognized by the authors themselves:

> *"It should be recognized that there may be environmentally significant areas that have not been identified in this assessment, and these omissions may be due to a lack of inventory and data that documents their location and/or significance. Further, it's important to note that all ecosystems in Alberta, including those that fall outside of designated ESAs, should be considered in planning exercises that involve objective setting for environmental and land use criteria. This is of particular importance when considering coarse-filter biodiversity at a landscape scale. For example, habitat connectivity and locations that provide diverse habitat for a variety of species are important considerations in addition to ESAs . . . It is important to note that this project focused on identifying ESAs at the provincial scale. There are many regionally and locally significant sites that are not included in this compilation, but should be identified and considered during finer scale planning."*
>
> *. . .*
>
> *"This ESA product does not replace other indicator-specific mapping and planning tools, such as wetland inventories, caribou range maps, and species at risk recovery plans. These more detailed information sources must be consulted when planning for projects that may impact specific environmental resources, particularly when dealing with regulatory requirements. ESAs are not intended to be used in the regulatory context."*
>
> *. . .*
>
> *"there has been no systematic measurement of the aerial extent of intact riparian habitat in Alberta."*
>
> *. . .*
>
> *"the provincial wetland inventory consists of a compilation of different inventories that were produced using a variety of methods and mapping techniques. The result is an inventory with inconsistent accuracy across different regions of the province . . . As a result, any indicator that required a wetland inventory was removed. Given the environmental importance of wetlands, the inability to reliably identify wetlands in Alberta was considered a major gap in this assessment."*
>
> *. . .*
>
> *"ESAs were identified at a very coarse scale (provincial) using the quarter-section as the unit of analysis. As such, this model provides a coarse-scale assessment of environmental values in the province, and the resulting ESA map highlights general*

areas that contain environmentally significant elements. Finer-scale planning processes are required if the objective is to identify and delineate specific areas of environmental significance at scales finer than the quarter section (e.g., a single wetland or a tree stand). Further, the identification of ESAs at finer scales allows for region-specific prioritization and weighting of criteria and indicators. "

. . .

"Several of the indicators used to identify ESAs relied on species observation and occurrence records, which represents "presence only" data. The use of presence only data can be problematic because there is no reliable information about where a particular species is not found, and these types of data often exhibit strong spatial bias related to survey effort."

Since Fiera follows quarter section boundaries and not natural boundaries, non-significant lands are often included in those quarter-section boundaries and more detailed mapping is required to identify key components contributing to that significance.

Nevertheless, Fiera (2014) provides insights into concentrations of significant features and is an additional tool that, with appropriate context, can be used in planning work.

Fiera (2014) maps 13 of the 46 quarter sections occurring (in part or in whole) in the project area as provincially significant and 17 as regionally significant* (Figure 8).

**Note: I have inferred "regional significance" to the next threshold tier below the provincial or higher significance threshold of >0.189 in Fiera's scoring system. This approach comports reasonably well with previous field-based ESA studies done through the late 1980s and 1990s for the Government of Alberta.*

<u>4.2.2 ESAs, pre-2014</u>

ESAs not utilized by the proponents in their evaluations include ESAs identified for the Calgary Region (Lamoureux et al. 1983) and provincially for aquatic ESAs (Fiera 2011) (Figure 7).

The entire Elbow River riparian area has been identified as environmentally significant regionally (Lamoureux et al. 1983). Lamoureux et al. characterize the ESA along the Elbow River upstream of the Glenmore Reservoir as a significant natural landscape and also an environmental priority area:

"The Elbow River, upstream of Glenmore Reservoir, {#2119) is the only remaining natural link between the City of Calgary and the natural foothill and mountain landscapes of Kananaskis Country (Bow-Crow Forest Reserve) to the west. As such it is a unique and irreplaceable environmental resource."

. . .

"The Elbow River Valley (R-17) provides an important natural environment corridor between the semi-wilderness of the Forest Reserve and the City of Calgary. It is an important refuge."

. . .

"It seems clear that the future interests of the Region will be best served by maintaining a virtually uninterrupted natural riparian vegetation zone along the full length of the river. This will preserve the river's function as a wildlife corridor and will facilitate future development of a trail system along the river."

In 2011, Alberta identified criteria for Aquatic Environmentally Significant Areas to support land use planning (Fiera 2011). The following criteria were used to identify and define Aquatic ESAs based on recommendations developed by the Alberta Water Council:

- Presence of aquatic focal species, species groups, or their habitat
- Presence of species of conservation concern
- Presence of rare or unique aquatic ecosystems
- Key areas that contribute to water quality
- Key areas of biological connectivity
- Key areas of intact complexity and/or biodiversity
- Key areas that contribute to water quantity.

The Elbow River upstream of Glenmore Reservoir and its smaller tributary streams are mapped as Aquatic ESAs (Figure 7).

Since Fiera follows quarter section boundaries and not natural boundaries, non-significant lands are often included in those quarter-section boundaries and more detailed mapping is required to identify key components contributing to that significance.

4.3 Areas of Wildlife Sensitivity

Alberta Environment and Parks (2017) maps areas of wildlife sensitivity for renewable energy developments. The interpretation document states:

"Projects that are sited to avoid important wildlife habitats decrease wildlife mortality, disturbance and habitat loss as well as reduce the need for further mitigation measures or costs to the project proponent. The AEP Wildlife Directive for Alberta Wind Energy Projects and AEP Interim Solar Guidelines (the Directives) identify areas or zones that should be avoided or minimized to limit the negative impact of a renewable energy development on wildlife and wildlife habitat."

While directed to renewable energy projects, the mapping highlights the importance of areas for wildlife. Areas mapped as high or moderate risk (high or moderate sensitivity) carry the recommendations:

*"**High Risk**: Several Wildlife Sensitivity Layers are ranked as High Risk since these areas are likely used by one or more species at risk or priority management species. The Directives recommend avoiding areas ranked as high risk."*

***"Moderate Risk**: These wildlife habitat areas are considered to be at a moderate risk since species at risk or priority management species can likely inhabit these areas. Due to the close proximity to native grasslands and the potential of habitat values existing for multiple* *species in these areas, there will likely be risks that could require mitigation considerations and potentially added costs to siting renewable energy projects in these areas."*

Specific guidance for the Parkland Natural Region sets desired outcomes of the use of the wildlife sensitivity mapping as:

1. *"Reduce human caused wildlife mortality.*
2. *Recover and conserve habitat for species at risk.*
3. *Recover and conserve populations of species at risk.*
4. *Reduce increased predation associated with anthropogenic features.*
5. *Conserve and protect critical habitat.*
6. *Maintain the ecological conditions necessary for naturally sustainable wildlife populations to exist throughout Alberta, and conserve the habitat that they require.*
   a. *Maintain unique and/or important wildlife habitat sites.*
   b. *Avoid or minimize development within key habitats (local and landscape scales) and key seasons.*
   c. *Maintain habitat intactness, connectivity, and allow for wildlife use, breeding and passage throughout areas by minimizing habitat loss and fragmentation.*
7. *Minimize potential adverse effects of land use activities on wildlife population health.*
8. *Reduce the potential for species avoidance of anthropogenic features.*
9. *Decrease potential for sensory disturbance and displacement of wildlife."*

The rationale for allocating a high risk ranking to native habitat in the Parkland Natural Region is:

"The Grassland and Parkland Natural Region has undergone significant habitat changes since European settlement in the late 1800's. This has resulted in only 30% of the region remaining under native grassland cover (The Alberta Prairie Conservation Forum, 2016). The significant habitat alterations have had a direct impact on the wildlife populations in the region; consequently, the region is home to 75% of Alberta's species at risk."

. . .

"Industrial scale developments in these sensitive areas may result in negative impacts to these wildlife species and their associated habitat features. This includes, but is not limited to, direct mortality of species at risk, reduced productivity, and habitat loss/fragmentation, disturbance to the population or individuals and habitat avoidance/abandonment. The Directives identifies that avoidance of native grassland and parkland habitat as the first strategy to mitigating the potential negative impacts of development on species at risk."

"As per the Directives, all areas ranked as High risk should be avoided for renewable developments. Areas identified as Moderate may require increased pre-assessment work, mitigation and project constraints due to the risk to specific species at risk in the area. The primary strategy identified in the Directives is to avoid development in these areas. Where avoidance is not possible specific mitigation strategies must be adhered to."

Much of the project area has been identified as an area of high risk/sensitivity for wildlife (Alberta Environment and Parks 2017) (Figure 9). 39 of the 46 quarter sections occurring

(in part or in whole) in the project area are mapped as high risk/sensitivity while 7 are mapped as moderate risk/sensitivity.

4.4 Key Wildlife and Biodiversity Areas

For Key Wildlife and Biodiversity Zones (Alberta Environment and Parks (2017), desired outcomes include:

1. *"Protect the integrity of ungulate winter ranges, river corridors and biodiversity areas where species tend to concentrate.*
2. *Protect locally and regionally-significant wildlife movement corridors, including bird and bat migration corridors.*
3. *Protect areas with rich habitat diversity and regionally-significant habitat types and habitat diversity.*
4. *Protect hiding and thermal cover.*
5. *Protect the complex biological structure and processes of identified riparian areas.*
6. *Reduce excessive mortality of wildlife from all sources.*
7. *Protect ungulate energy reserves, body condition and reproductive potential."*

The rationale for allocating a high risk ranking to Key Wildlife and Biodiversity Zones under Areas of Wildlife Sensitivity noted in section 4.3 above is:

> *"The Key Wildlife and Biodiversity Zone is a combination of key wildlife habitat from both uplands and major watercourse valleys. The basis of this zone was determined using major river corridors, valley topography, valley slope breaks, bird and bat migration corridors and ungulate winter densities. The Key Wildlife and Biodiversity Zone is intended to prevent loss and fragmentation of habitat; maintain migration corridors, prevent short and long-term all-weather public vehicle access; prevent sensory disturbance during periods of thermal or nutritional stress on wildlife; and prevent the development of barriers to wildlife corridors (e.g., stream crossings). No new roads and no new development within the valley breaks for renewable activities are consistent with the management intent of the area."*

While the high-risk designation does permit development by working with Alberta Environment and Parks biologists on mitigation -- that is not the intent. The prime directive is for major developments to avoid high risk/sensitivity areas.

Alberta Environment and Sustainable Resource Development (2015) notes that:

> *"Key Wildlife and Biodiversity Wildlife Zones are considered to be a combination of key winter ungulate habitat and higher habitat potential for biodiversity. In some areas this zone consists of important riparian vegetation complexes that are important for biodiversity, while in other areas it indicates important winter ranges for ungulates."*
>
> *. . .*
>
> *"Key Wildlife and Biodiversity Zones play a disproportionately large role in the landscape given their localized size and distribution, in maintaining the overall productivity of regional*

ungulate populations and source of biodiversity. These zones ensure that a significant proportion of the breeding population survives to the next year."

The Key Wildlife and Biodiversity Zone is intended to:

- *"protect the long-term integrity and productivity of key ungulate winter ranges and river corridors where ungulates concentrate.*
- *protect locally and regionally-significant wildlife movement corridors.*
- *protect areas with rich habitat diversity and regionally-significant habitat types.*
- *protect key hiding and thermal cover for wildlife."*

The main approaches for protecting Key Wildlife and Biodiversity Zones are:

a. *"Protect vegetation from being cleared by minimizing all industrial activity. (This forest growth is essential for providing food and thermal protection for ungulates, and protecting the slopes from erosion and other degradation.)*
b. *Minimize activity during winter months to avoid displacing wildlife.*
c. *Reduce access and/or do not create new access.*
d. *Follow general timing restrictions."*

The entire Elbow River riparian area has been identified as a Key Wildlife and Biodiversity Area (Alberta Environment and Sustainable Resource Development 2015).

Stantec (2020b, Exhibit 138, pdf 249) acknowledges some of the importance of the area for wildlife as it still has occasional Grizzly Bear occupancy.

"Alberta Transportation's response to Round 1 AEP IR415 suggested that historical sightings and occurrences in the Enforcement Occurrence Records (ENFOR) database indicate grizzly bear use is known to be greater than reported wildlife assessment in the EIA."

4.5 High Sensitivity Watersheds

The Bow River Basin Council (2012, pdf page 26) mapped the Elbow River as a "High Sensitivity Watershed".

4.6 Summary

Several cautionary red flags for the project area are evidenced by the multiple designations as "environmentally significant": High Value Landscape, Environmentally Significant Area, Key Wildlife and Biodiversity Zone, Wildlife Habitat Sensitivity and High Sensitivity Watershed.

There will be residual adverse and negative biodiversity impacts of the project on an area that has been mapped in whole or in part as an area of environmentally significance. This will include direct loss of an area of environmental significance under project components, sediment deposition during flood events in the dry dam reservoir, activities to remove sediment following floods, and, downstream, through modification of stream

flows, channel migration, and sediment deposition during major and minor flooding events.

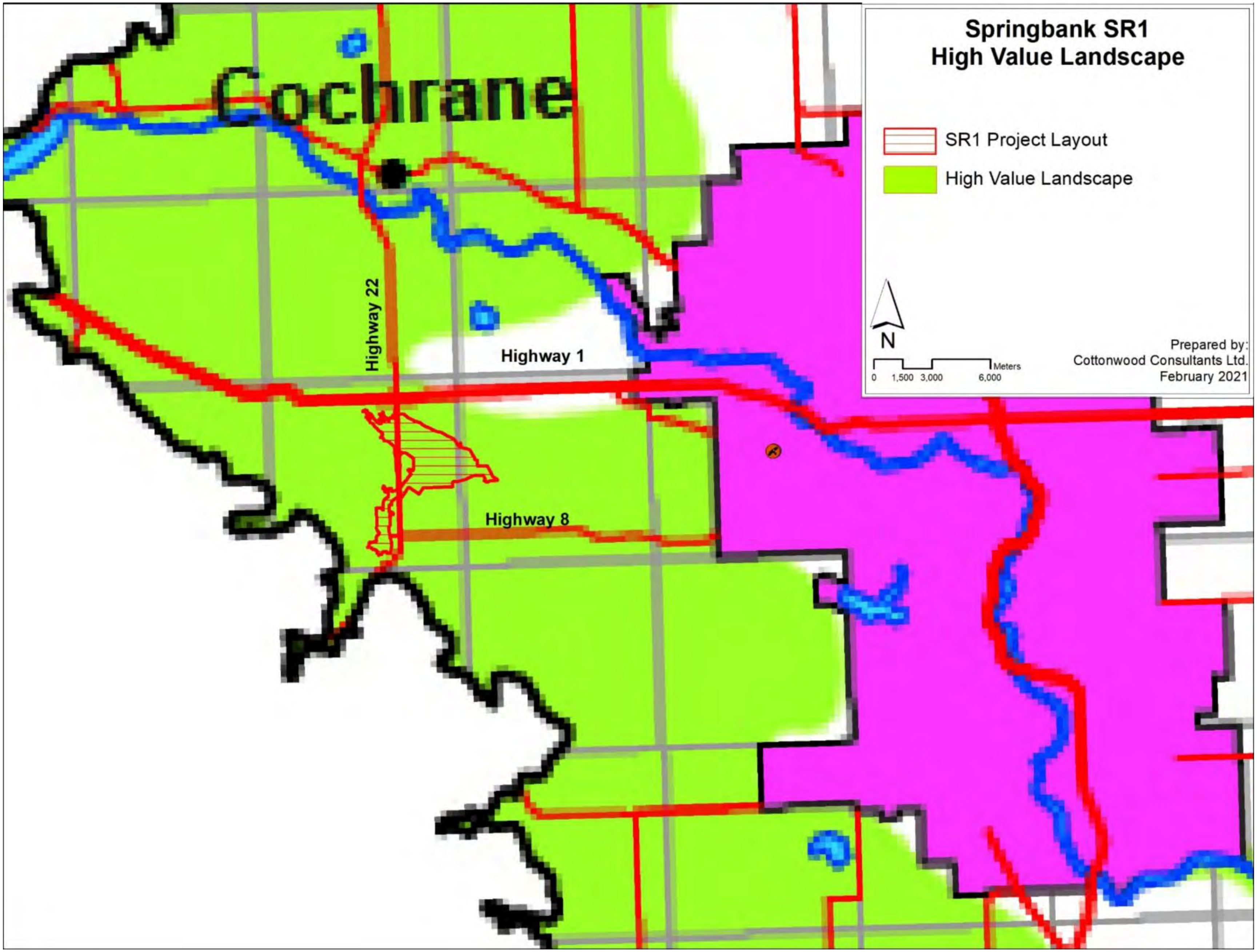


Figure 6. High Value Landscape (Prairie Conservation Forum 2021)

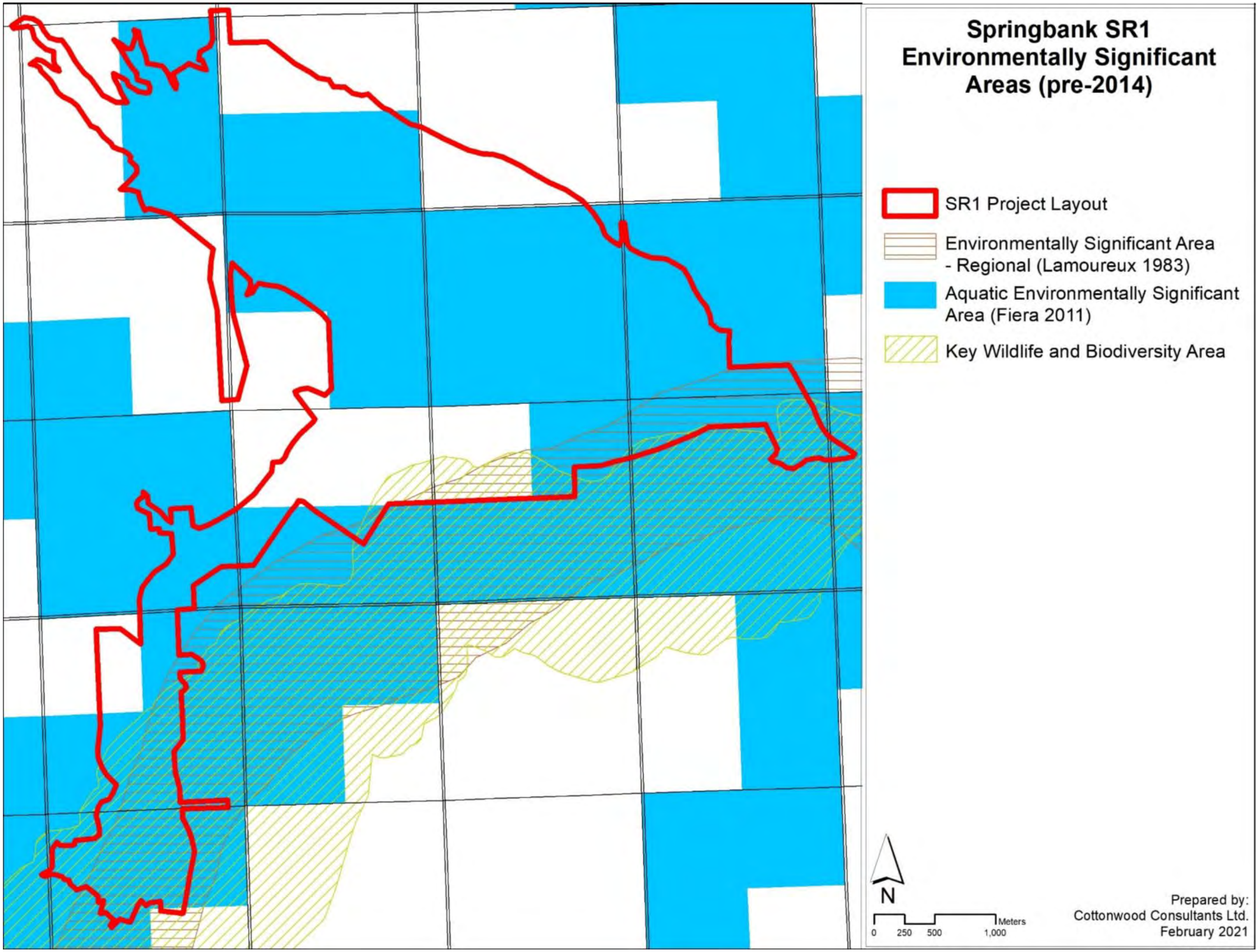


Figure 7. Environmentally Significant Areas delineated prior to 2014 and Key Wildlife and Biodiversity Area

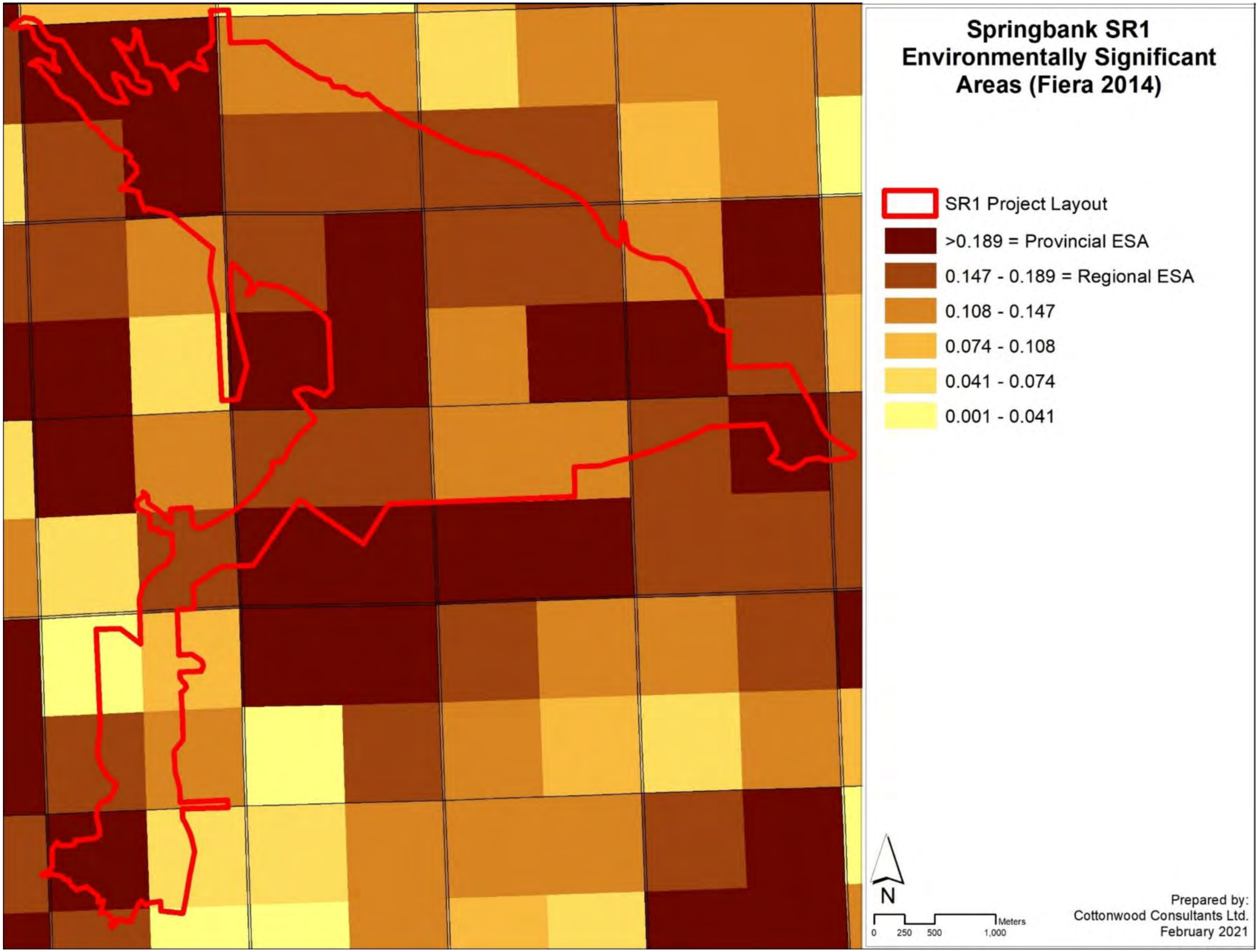


Figure 8. Environmentally Significant Areas (Fiera 2014); regional ESAs are inferred

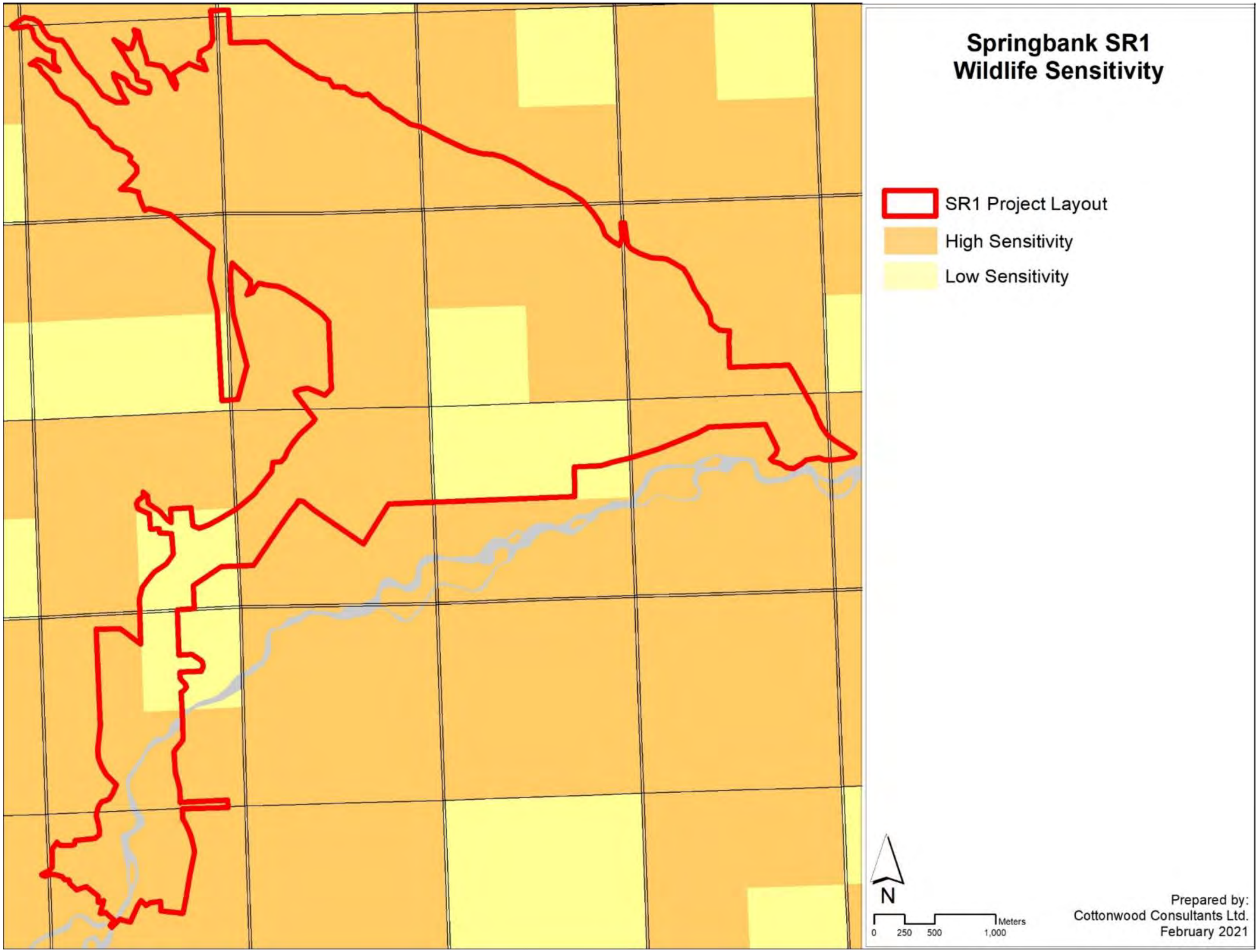


Figure 9. Areas of Wildlife Sensitivity (Alberta Environment and Parks 2017 data)

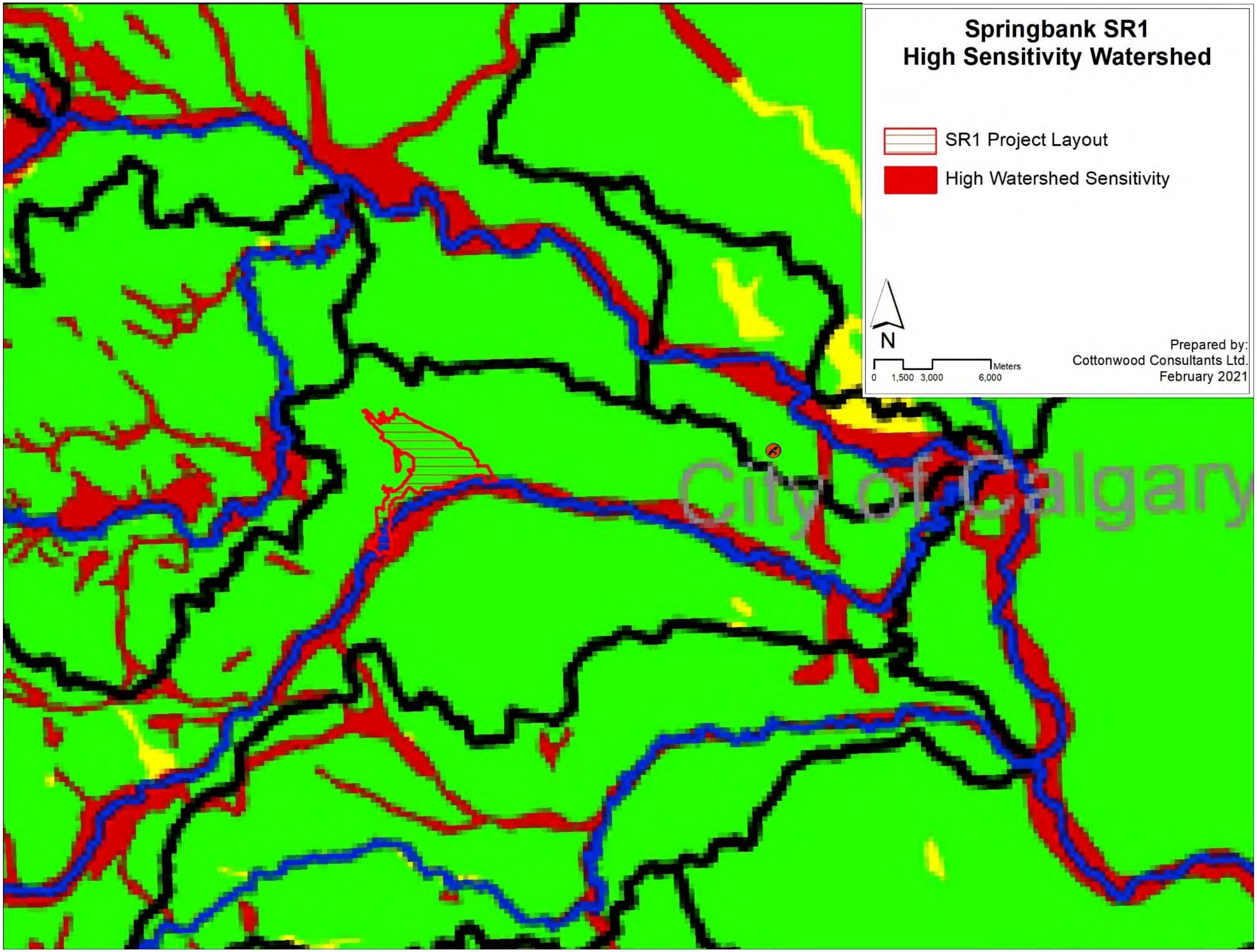


Figure 10. High Sensitivity Watershed Areas (Bow River Basin Council 2012)

5. WETLANDS AND RIPARIAN LANDS

5.1 Wetlands

The Government of Alberta (Alberta Environment and Sustainable Resource Development 2013) Wetland Policy for Alberta states:

"Several key concepts and mechanisms are crucial to the successful implementation of a provincial wetland management system under the Alberta Wetland Policy:

1. Relative Wetland Value
2. Wetland Mitigation
a. Avoidance
b. Minimization
c. Replacement
3. Knowledge and Information Systems
4. Performance Measures, Monitoring, and Reporting
5. Wetland Stewardship in Alberta"

The Alberta Wetland Policy outlines a valuation approach that will be used:

"Based on the sum total of all metrics, wetlands will be assigned to one of four relative wetland value categories (A [highest] through D [lowest]). These categories will reflect the relative importance of a wetland on the landscape, from an ecological and human perspective. In applying this approach, the Alberta Wetland Policy will focus first on the avoidance and minimization of impacts on all wetlands, regardless of their relative wetland value category.

"

The policy outlines a hierarchical approach that will be used to protect wetlands:

"Alberta's Wetland Mitigation Hierarchy can best be described as follows:

1. Avoidance – The primary and preferred response is to avoid impacts on wetlands.
2. Minimization – Where avoidance is not possible, proponents are expected to minimize impacts on wetlands.
3. Replacement – As a last resort, and where avoidance and minimization efforts are not feasible or prove ineffective, wetland replacement is required."

The Alberta Wetland Policy (Alberta Environment and Sustainable Resource Development 2013) states:

> “Under the wetland mitigation hierarchy, the primary and preferred response is to avoid all impacts on wetlands. **Avoidance is the most efficient and effective mitigation strategy**, as it eliminates the potential risks and inherent uncertainty of other mitigation practices. Since avoidance prevents direct wetland impacts, it is typically the most desired form of wetland mitigation.”

The Guiding Principles of the Wetland Avoidance System (Alberta Wetland Policy, page 16 item 3.) places the responsibility on the proponent to show that use of this particular project site is unavoidable.

> “In cases where avoidance is deemed not practicable, it is the responsibility of the proponent to adequately demonstrate that alternative projects, project designs, and/or project sites have been thoroughly considered and ruled out for justifiable reasons.”

The Bow River Basin Council (2012, pdf pages 23 and 36)) outlines several outcomes related to riparian areas and wetlands, including those in the Elbow River watershed. For riparian areas these include:

- *“Existing riparian land including associated upland areas are kept intact or restored, ecologically functional, appreciated and valued.*
- *Core ecological functions of healthy riparian lands are maintained (e.g., water quality protection, water storage and flood conveyance, bank stability, biodiversity, soil health, etc.).”*

Measurable objectives include:

- *“No net loss of area of functioning riparian lands.*
- *Restoration of degraded riparian lands to functioning riparian lands.”*

For wetlands, the Bow River Basin Council’s outcomes include:

- *“Impacts to existing wetlands should be avoided wherever possible.*
- *Existing wetland complexes including associated upland areas and ephemeral wetlands are kept intact or restored, ecologically functional, appreciated and valued.*
- *Core ecological functions of healthy wetlands are maintained (e.g., water quality protection, water storage and flood protection, biodiversity, habitat, etc.).*

- *Invasive plant species are reduced, especially in riparian lands adjacent to watercourses and water bodies."*

Measurable objectives include:

- *"No net loss of area of wetland area.*
- *No further loss of wetland number."*

Stantec (2020b, Exhibit 138, pdf page 467) states:

"Sediment depths greater than 10 cm are expected to result in the loss of grasses, forbs and short shrubs. Grasses, sedges, forbs and shrubs are expected to re-establish in less than 10 years, provided post-flood topography supports wetland conditions, but cover may be lower than areas of shallower sediment."

The Impact Assessment Agency of Canada (2021, Exhibit 164, pdf page 3) outlines benefits and values of wetlands in its definition of "wetland functions":

"1.35 Wetland functions means the natural processes and derivation of benefits and values associated with wetland ecosystems, including economic production, fish and wildlife habitat, organic carbon storage, water supply and purification (e.g. groundwater recharge, flood control, maintenance of flow regimes, shoreline erosion buffering), and soil and water conservation, as well as tourism, heritage, recreational, educational, scientific, and aesthetic opportunities."

The Impact Assessment Agency of Canada (2021—Exhibit 164, pdf page 13) proposes several conditions for wetlands including:

"5.6 The Proponent shall mitigate the adverse environmental effects of the Designated Project on wetland functions by avoiding the loss of wetlands and wetland functions when feasible. When avoidance is not feasible, the Proponent shall minimize adverse effects on wetlands, and shall compensate any permanent loss of wetlands or wetland function, taking into account Alberta Wetland Policy."

Stantec (2019b, Exhibit 94, pdf page 114) notes that there will be permanent diversion of five small tributary streams intersected by the diversion channel.

To summarize, despite proposed and suggested mitigation, there will be residual negative biodiversity impacts of the project on valuable wetlands and streams (Figures 11 and 12) through sediment deposition during flood events and activities to remove sediment following floods, as well as modification of stream flow or outright loss of these features under project components.

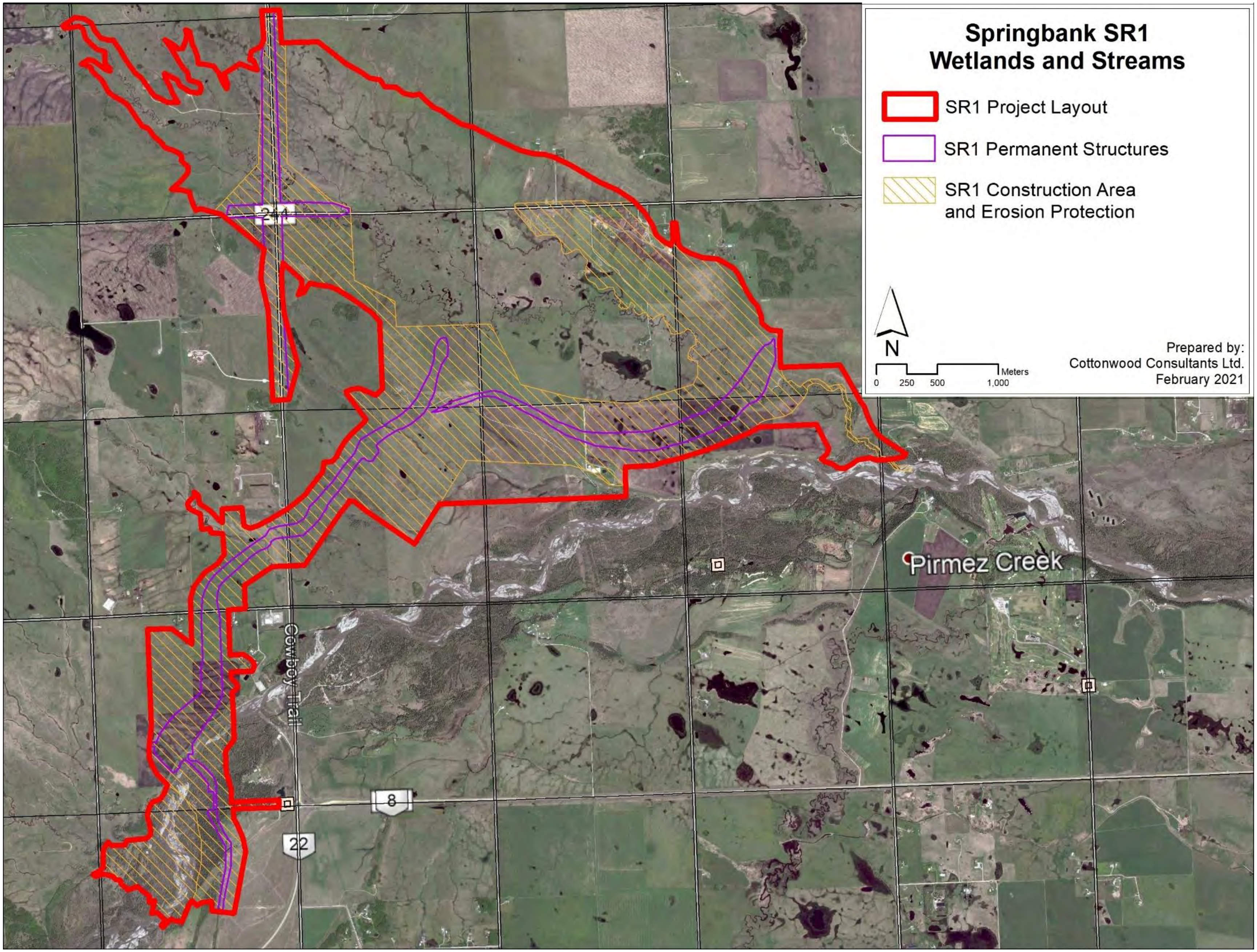


Figure 11. Project areas showing concentration of wetlands and streams (June 2011 Google Earth photo base)—see detail in Figure 5

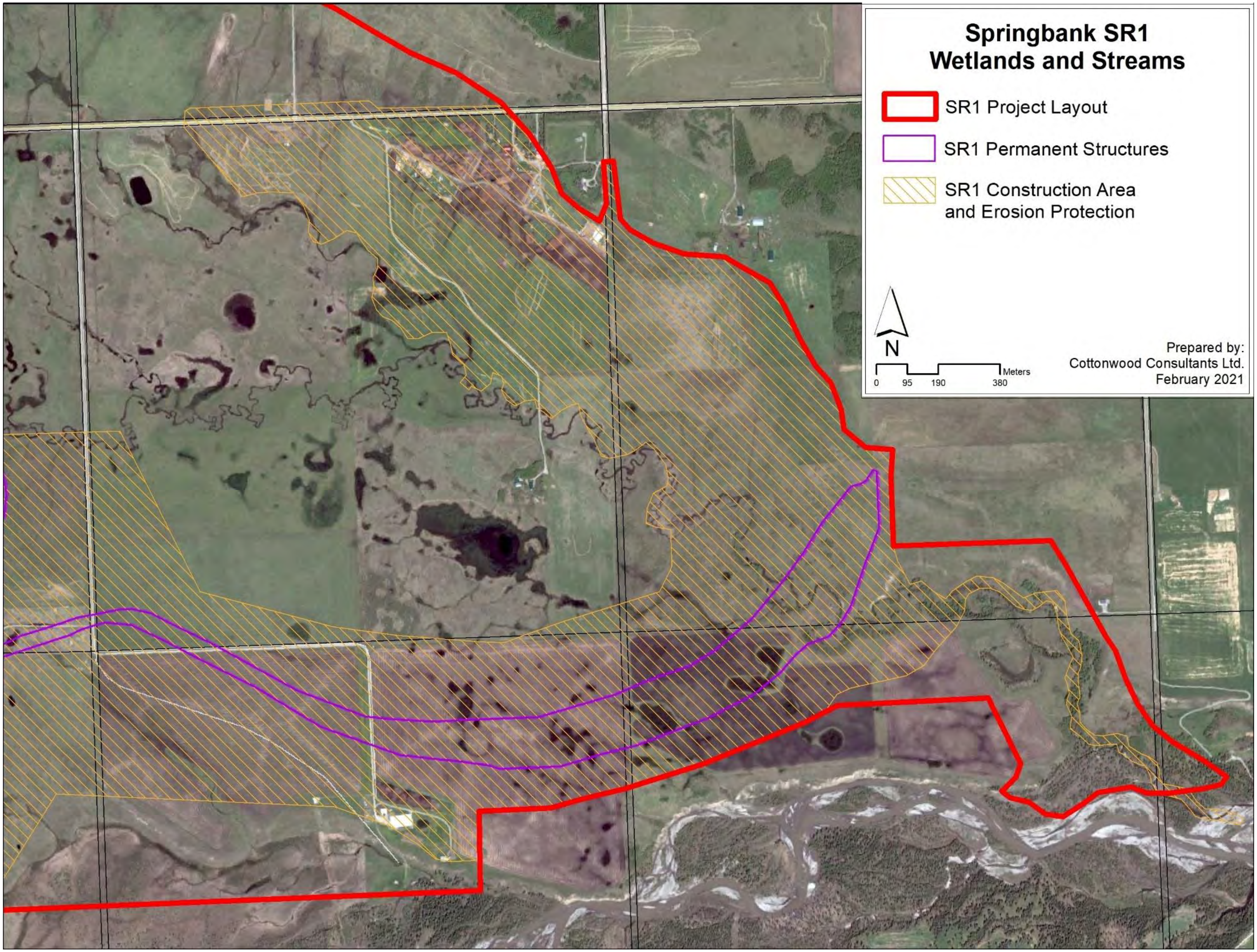


Figure 12. Detail of concentration of wetlands and streams; also impact on stream at Low Level Outlet (June 2011 Google Earth photo base)

5.2 Floods and Riparian Vegetation

White spruce and balsam poplar dominate the Elbow River floodplain forests in the vicinity of the project and downstream to the Glenmore Reservoir. The Alberta Water Council (2013, pdf page 50) notes *"floods are essential to maintain long-term riparian function because, among other things, they scour channels, clean sediments from fish spawning gravel, and add coarse woody debris to the riparian system."*

O2 (2013, pdf page 44) indicates that "*loss of upstream wetlands, riparian areas, and pervious cover types tends to have cascading impacts on water quantity, water quality, and downstream riparian and stream health*."

Stantec (2020b, Exhibit 138, pdf page 475) acknowledges some of the impacts of regulated flow:

> *"Regulated river flows such as those that occur on dammed rivers can affect riparian cottonwood forests by reducing the magnitude of peak flows that create newly exposed sediment necessary for seedling establishment and by releasing very low flows later in the summer, which can result in drought stress and potential mortality of mature cottonwood trees."*

Nevertheless, Stantec (2018d, Exhibit 35, pdf 69) states:

> *"the Project would not eliminate flooding and scouring of Elbow River; the off-stream reservoir would only divert water from Elbow River that cannot be handled by the Glenmore Reservoir during larger floods. Therefore, this has not been further analyzed as a potential Project pathway for TLRU."*

Stantec (2019b, Exhibit 94, pdf 154) states:

> *"Retention of water in the off-stream reservoir during diverted floods will reduce peak flows but will not reduce the occurrence of floods. This might reduce the rate and magnitude of change to downstream habitats (e.g., scour or change in stream bank morphology), but changes to the hydrological regime due to diversion are unlikely to modify the long-term median flow values in a meaningful way."*
>
> *"Long-term changes in habitat conditions, such as scouring, plant cover, woody debris, supporting habitat functions (e.g., food sources, shelter), and health in downstream habitat are therefore also not expected to change in a meaningful way."*

Despite this, Stantec (2019c, Exhibit 93, pdf 122) shows in Table IR287-1 that there will be a change in river channel morphology (long-term) with adverse direction, neutral to moderate magnitude (changed from high), long-term duration and irreversible.

The above paragraphs from Stantec (2018b and d; and 2019b) are misleading and the lack of meaningful analysis of the impacts on the downstream riparian lands is an omission from the assessment. The importance of large magnitude floods is discussed in the following sections. Median flows are not the only major ecosystem shapers in this riparian environment.

Stantec (2020b, Exhibit 138, pdf 79-86) shines some light on this subject and at least acknowledges some of the ecologically important processes and ecological values of high magnitude floods:

"The overall effect on ecological and geomorphic processes of reducing the flood peak, for extreme floods, to 160 m^3/s for flows up to 760 m^3/s (thereby, reducing flows by up to 600 m^3/s) is neutral, although effects on some individual processes could be adverse. Within the regional assessment area (RAA) downstream of the Project, the ecological and geomorphic process in Elbow River have already been subjected to substantial change, primarily through the creation of Glenmore Reservoir."

"There are five ecologically important geomorphic processes that may be incrementally altered by decreasing peak flood flows in Elbow River: (1) overbank deposition, (2) bank erosion rates, (3) channel morphology, (4) scour and maintenance of large pools, and (5) maintenance and formation of side channels."

. . .

"Large floods add nutrients to the floodplain from suspended sediment deposits. These floods benefit the ecosystem and occur in rural and natural environments. In urban environments, like the City of Calgary, these ecological benefits from flooding are not readily realized. Flooding has an adverse effect on the environment by introducing contaminants and other anthropogenic materials found in most urban environments from the floodplain to the river.

. . .

"The Project will maintain some overbank deposition on the floodplain and in riparian areas, but at a reduced spatial extent and severity."

. . .

"However, the reduction of the largest flows will decrease sediment transport rates during floods when the Project is operational, compared to existing conditions. Over time, this may result in a narrowing and simplification of the channel."

. . .

"Wandering gravel bed rivers, such as Elbow River, have side channels that provide important ecological value. These side channels are reactivated and enlarged during large flows. Hydraulic modelling has shown that the floodplain becomes inundated during flows of 160 m^3/s, activating many of the side channels, particularly in the lower floodplain (see Figure 14-1 and Figure 14-2). Figure 14-1 shows that most of the existing side channels in the lower floodplain are inundated during a 160 m^3/s flow. The depth of flow in the side channel is lower than at 760 m^3/s, but there should be sufficient flow to maintain the existing channel as long as upstream connectivity to the mainstem remains."

*"**With the reduction of peak flows, the geomorphology of Elbow River between the Project and the Glenmore Dam will be simplified because the creation of new side channels or the activation of abandoned channels within the floodplain will be reduced (my emphasis).** Also, large floods trigger avulsions that create side channels that provide important fish habitat. These floods also have high sediment transport rates that create large bars and produce heterogeneous bed sediment patterns. The frequency and*

magnitude of overbank deposition will be reduced as inundation of the floodplain decreases. The magnitude of the change to the geomorphology of Elbow River is moderate, the duration is long term, and the overall direction of the change is neutral."

. . .

"The operational target of 160 m³/s that the Project uses honours this design objective but is selected because it coincides with the maximum discharge capacity of Glenmore Reservoir's low-level outlet. ***The discharge was not chosen to maintain river processes and does not represent a geomorphic or ecological threshold (my emphasis)****. It does, however, coincide with a one in seven-year flood and does allow some inundation of riparian areas and channel maintenance processes downstream of the Project and upstream of Glenmore Reservoir."*

. . .

*"****Changes to ecological function associated with limiting flows in Elbow River to 160 m³/s cannot be mitigated (my emphasis);*** *however, changes can be offset through the Fisheries Act authorization process that is being undertaken for the Project."*

In this overview above, Stantec mixes some effects on the human environment with ecological and geological processes. The second paragraph quoted above identifies the five important processes that will be altered and affect biodiversity and the third from last paragraph quoted above understates the importance of this effect in relation to biodiversity (Figure 14). Stantec (2020b, Exhibit 138, pdf page 85) defines "direction-neutral" as "*no net change in measurable parameters for hydrology relative to existing conditions*."

Further on, Stantec (2020b, Exhibit 138, pdf page 211) intimates that the neutral ranking is related to the infrequent nature of the reduction of peak flows. I submit that it is during those peak flows that the hydrology does much of the reshaping of the riparian environment. The occurrences may be infrequent but the change to hydrology is dramatic and the impacts on ecological processes significant. Stantec (2019c, Exhibit 93, pdf page 108) acknowledges in its Table IR279-1 "Project Interactions with Hydrology", that **there will potentially be changes in channel morphology, hydrological regime, and suspended sediment transport** for several project components and activities.

Stantec (2020b, Exhibit 138, pdf page 475) further muddies the waters with their characterization of the effects on cottonwood recruitment:

"A flow of 160 m³/s is approximately a one in seven-year flood. Natural cottonwood recruitment appears to be associated with a one in five to one in ten-year flood (Mahoney and Rood 1998). Many of the key hydrological processes that maintain riparian health along Elbow River, while altered, will continue to occur."

Stantec goes on to compare impacts, with and without diversion, for flow rates between 160 m³/s and 300 m³/s. These do not reflect the large magnitude floods that support large riparian areas and are inappropriate for evaluating the effects of the loss of such large floods. Compare the figures in Stantec (2020b, Exhibit 138, pdf page 481) with the same area shown in Stantec (2020b, Exhibit 138, pdf 84) (Figure 14 in my report) which shows comparisons with 760 m³/s and smaller floods.

Maintaining some riparian habitat is not the same as maintaining the environmentally significant, extensive, and diverse riparian areas downstream of the project. As discussed later in my report, the impact of flow regulation could have significant effects on riparian habitats downstream. These cannot all be dealt with in a Fisheries Act authorization process.

To add further to the confusion, Stantec (2019c, Exhibit 93, pdf page 109) states:

> *"the Project reduces (compared to without the Project) the design flood peak by about 50% (1,150 m³/s to 550 m³/s), the 1:100 year flood peak by about 80% (760 m³/s to 160 m³/s) and the 1:10 year flood peak by about 20% (200 m³/s to 160 m³/s)."*
>
> *"These effects are positive in direction (reduction in ecological and economic damages) and moderate to high in magnitude (as stated in Volume 3A, Table 6-2). Because the effect is positive to reduce flood peaks, no mitigation for effects on hydrology is required."*

The effects of flow regulation on the ecological side cannot be seen as positive. The project will be significantly modifying an important riparian habitat shaping process—large magnitude floods. These ecosystems evolved with floods of varying sizes.

If we took Stantec's argument (that reducing large magnitude floods is ecologically positive) to its illogical conclusion, then one would recommend flood control on all streams. This would not only be costly but would significantly degrade naturally functioning riparian ecosystems, as that approach already has in other areas of Alberta and the world.

The Task Force on the Natural and Beneficial Functions of the Floodplain (2002, pdf pages 22-23 and 31-33) provides a summary of those impacts and the direction that floodplain management should be heading:

> *"Although the Task Force recognizes that many flood control and other water resource structures provide valuable benefits to society in the form of flood control, water supply, power, and recreation, these structures can have significant impacts on the natural floodplain and on natural and beneficial floodplain functions including reducing flood velocities and peak flows. Less intrusive solutions can sometimes achieve these same benefits without the loss of floodplain resources and functions."*
> *. . .*
> *"Dams and reservoirs can impede the flow of rivers, reduce or eliminate the beneficial periodic inundation of natural floodplains, and block or slow the passage and migration of aquatic organisms. Dams can result in the long-term loss of diversity, and adversely impact stream habitat, aquatic resources and other functions. This in turn affects food chains associated with floodplain functions, and alters the size and diversity of wildlife populations."*
> *. . .*
> *"While floodplain management programs and practices have improved significantly since the 1960s, there is a continuing loss of natural and beneficial floodplain functions. In large part*

this is due to a lack of explicit goals, insufficient technical data, inadequate coordination and a failure to use watershed-based approaches to managing our land and water resources."
. . .
"Protecting and restoring natural and beneficial functions is not the primary consideration in the aftermath of a crisis."
. . .
"All response and recovery efforts should include floodplain restoration and protection as a key component of project planning."
. . .
"In the past, limited consideration was given to non-structural alternatives in formulating flood loss reduction plans. Evaluation procedures, including those used to determine benefit/cost ratios were focused on structural flood control measures and often do not work as well for non-structural approaches. Today, non-structural solutions are gaining greater attention and through their success, these methods are proving their worth."

The US Army Corps of Engineers (1991, pdf page 285) provides a summary of potential impacts of "dry" dams:

"Because "dry" dams are specifically designed to substantially reduce the downstream peak flow characteristics, substantial changes in the streamside communities below the dam typically result. Specifically, the width of the riparian and scour zones becomes narrowed because of the attenuation of flushing and scouring flows (Taylor 1981). The riparian zone at the upland interface typically reverts to dry land habitat and at the water interface, woody riparian species expand into the former scour zone and increase along the waters edge especially at sand bars and shoals. Species composition (terrestrial and aquatic, as well as plant and animal) within the riparian zone inevitably changes from those characteristic of a highly dynamic fluvial/riparian system to those more indicative of a relatively constant and narrower less variable flow system. The extent of these effects within a given system undoubtedly depends upon the change in magnitude of the peak flow conditions."

There will be direct impact/loss of riparian habitats from permanent structures and erosion protection at the Low Level Outlet (Figures 11 to 13) as well as from downstream effects on the Elbow River floodplain from flow modification.

For the Low Level Outlet (LLOW) Stantec (2020c, Exhibit 218, pdf page 6) notes:

"*The previous location was aligned with the unnamed creek and required limited intake and exit channels to connect with the existing unnamed creek stream channel. The revised location is located upland from the unnamed creek and requires the construction of channels from the unnamed creek (in the reservoir) to the LLOW and from the LLOW back to the unnamed creek (outside the reservoir).*

Figure 12 shows there will also be disturbance to the natural unnamed creek system with this change. An additional 4.8 ha is required in a construction area at the downstream end of the unnamed creek compared to what was identified in the EIA (Stantec 2020c, Exhibit 218, pdf page 6).

Figure 13. Looking NE towards diversion structure, west of Highway 22 (Stantec 2020e – Exhibit 159, pdf page 20) – note there will be permanent loss of riparian shrubbery and white spruce-dominated riparian forest at this location.

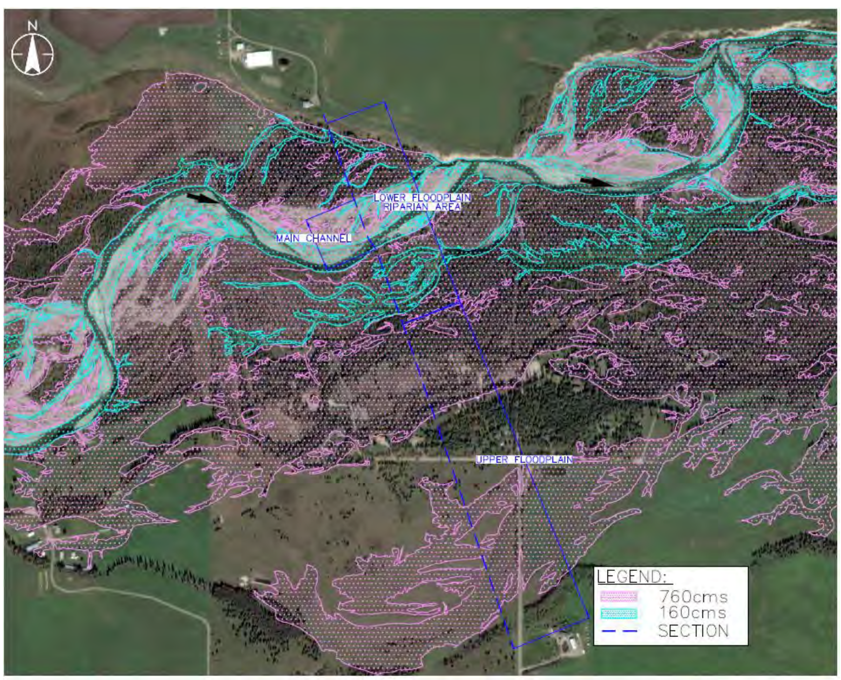


Figure 14. Example cross-section view of Elbow River Showing Differences in Flood Inundation at 160 m^3/s and 760 m^3/s Flows (Stantec 2020b – Exhibit 138, pdf 84) – note the extensive area that is inundated by a large magnitude flood compared to the much smaller area that is inundated in a flow regulated situation with the project operational. This impact is not “neutral” in direction as indicated by Stantec (2020b), not for hydrology and certainly not for biodiversity and ecological processes of the riparian environment.

5.1.1 Importance of Flooding to Riparian Balsam Poplar and White Spruce

Bradley et al. (1991, pdf pages 3, 16, 18, 19, 24, 26, 27) note the importance of floods to riparian cottonwoods, including balsam poplar:

> *"Successful replenishment occurs infrequently and appears to be correlated with high spring flood events during the time of seed dispersal followed by gradually receding water levels and moist conditions in late summer.* ***Two forms of replenishment are recognized - 'general replenishment' across much of the floodplain attributed to very large, infrequent floods; and 'fringe replenishment' along existing channels attributed to smaller, more frequent floods (my emphasis)."***
>
> *. . .*
>
> *"Numerous studies have documented a decline in poplar forests along rivers in the plains of western North America and have attributed it to man's activities. Altered river regimes downstream of dams is implicated as the major factor responsible."*
>
> *. . .*
>
> *"The reasons for the differing ranges of the three riparian poplar species is not well understood. It may be an artifact of the rate of species range expansion following deglaciation or it may be a function of differing environmental tolerances, such as climate. As well, there are a number of notable differences in the general characteristics of rivers that flow through the foothills compared to those that flow through the prairies; and the different species may be preferentially adapted for the different regimes and floodplain characteristics."*
>
> *"**Balsam poplar is found along foothill rivers, which generally have steep gradients, coarse beds, low suspended sediment loads and braided or straight channels (my emphasis)**."*
>
> *. . .*
>
> *"Poplar seedlings require barren sites for successful establishment since they are poor competitors (Read, 1958). Ideal sites are clear of other vegetation to allow abundant sunlight, and remain constantly moist for the first few weeks. Even under these conditions, many more seedlings germinate than survive the first year. A common reason for losses of seed viability and small seedlings in the first season is drying of seed beds."*
>
> *. . .*
>
> *"middle-aged trees of balsam poplar commonly produce new individuals by suckering from lateral roots."*
>
> *"Suckering is promoted when flooding or ice scouring removes bank materials and shears poplar roots (Williams and Wolman, 1984). The severed roots then form dense new growth. These events are probably important components of natural riparian forest cycling where balsam poplar dominates."*
>
> *. . .*
>
> *"Most major southern Alberta rivers fluctuate annually with peak flows in late spring following snow melt in the Rocky Mountains. Overbank flooding may occur when heavy spring rains augment the rapid melting of deep snow packs (Johnston 1987; Gildart 1984). The highest*

flows normally last for just a few days in early to mid-June although annual peaks range between April 25 and June 30 for some rivers (Environment Canada, 1985). These floods shift the course of river channels and carry large sediment loads which they deposit adjacent to the channel or in low-lying areas of the floodplain (Williams, 1989). As well, existing stream.banks and bars are scoured and new sand and gravel bars are deposited (Colby, 1964; Everitt, 1968; Wolman and Leopold, 1957). These barren sites of fresh sediment, sand and gravel are favourable locations for poplar seedling establishment (Behan, 1981; Johnson et al., 1976; Noble, 1979)."

. . .

"Fringe replenishment, replenishment of poplars along the edges of channels, is highly dependent on spring flood events."

. . .

"Field surveys of braided reaches of the Oldman Basin (Mahoney and Rood, pers. comm.) and the lower Red Deer River in and near Dinosaur Park (Marken, pers. comm.) found large tracts of evenly aged trees across much of the floodplain suggesting a second model of poplar replenishment, termed general replenishment. Along these reaches, poplar replenishment may be linked with major overbank flood events rather than incremental point bar aggradation. These major flood events may occur about every 30-50 years instead of every five, and encourage replenishment of large areas across the full width of the floodplain rather than only on the tips of point bars. Marken (pers. comm.) observed that a significant proportion of the poplar woodlands, occurring on large expanses of the lower Red Deer River floodplain, were established 75 to 85 years ago, Establishment of these woodlands coincided with record high spring flood events occurring in generally wet years."

. . .

"In summary, for both fringe and general replenishment, spring flooding serves two essential functions. Firstly flooding prepares sites suitable for successful poplar seedling establishment through scouring and deposition. Secondly it recharges the riparian water table and inundates the floodplain including new barren sites. In addition, the emergence of new shoots from the roots or buried stems of existing trees may help replenish balsam poplar by filling in gaps in the forest and forming new age classes, although this has not been noted for riparian poplar species other than balsam poplar."

There is much less information available on the importance of flooding for white spruce establishment on floodplains but what is known could have relevance to the Elbow River situation. Landhäusser (2000, pdf page 2) notes how white spruce is able to adapt to significant flood events and silt deposition:

"To counteract the negative effects of silt deposits, white spruce is able to produce adventitious roots further up the buried stem, creating multi-layered root systems (Jeffrey 1959). The ability to grow roots, helps to avoid the less optimal condition in the deeper portions of the soil by replacing the dying or only partially functioning elements of the roots system in the deeper soil layers (Strong and La Roi 1983, Gill 1975)."

Landhäusser (2000, pdf page 6) notes, in the Mackenzie Delta area where there is a frequent flood regime, that there is an uneven aged stand structure. He postulates that white spruce establishment in the delta probably occurs in waves, which coincide with major flooding events.

His view is that flood deposits create favourable seedbeds for white spruce. When flooding coincides with good seed production in adjacent mature spruce stands, they will result in periods of spruce establishment (referring also to Jeffrey 1961 and Wagg 1964). Although there is risk to established seedlings from large amounts of silt that could get deposited in subsequent major flood events, the extensive occurrence of white spruce on the floodplain means that enough white spruce seedlings achieve sufficient growth to overtop silt deposits from the flooding events. This would also seem to be the case with white spruce on the Elbow River floodplain.

5.1.2 Impacts of Flow Regulation on Poplars

Bradley et al. (1991) note:

> *"Rood and Heinze-Milne (1989) studied the downstream impacts of river damming on riparian poplars in southwestern Alberta. Three parallel rivers were analyzed with air photos to ascertain the decline of poplars along the rivers. The unique arrangement of dammed rivers, the St. Mary and Waterton, flowing on either side of a relatively uncontrolled river, the Belly, through generally undeveloped regions permitted a controlled, replicated study of the downstream forest declines. The analysis showed declines in forest abundance of 48% and 23% between 1961 and 1981 downstream from the St. Mary and Waterton River Dams, respectively. Forest declines upstream from the dams were only 5% and 6% respectively. Little change (0-5% decline) in forest abundance was observed along the middle, undammed Belly River.* ***These results support a causal relationship between river damming and downstream forest decline." (my emphasis)***
>
> *. . .*
>
> *"The· river systems of southern Alberta are naturally very dynamic. Periodic overbank flooding shifts channels and drives the meandering process. The movement of the river channel within the river valley constantly exposes or builds new sites suitable for poplar establishment.* ***Trapping spring floods or releasing a constant flow downstream from impoundment structures alters the hydrological pattern and creates a more stable regime. Stabilized flows contribute to degradation of the streambed, less floodplain deposition, and less lateral movement of the channel (my emphasis)*** *(Williams and Wolman, 1984). Downgrading eliminates broad sand and gravel bars and forms steeper embankments that are less suitable for poplar establishment (Everitt, 1968; Johnson et al., 1976; and Bradley and Smith, 1986)."*
>
> *"The characteristics of the river and normal sediment load determines the extent of the silt shadow (Williams and Wolman, 1984). Clean, steep-gradient rivers with coarse textured beds recover silt loads quickly while shallow-gradient rivers with sand and silt beds recover much more slowly. Up to 300 km may be required for meandering prairie rivers to recover the pre-dam sediment load (Williams and Wolman, 1984).* ***The sediment-depleted river below a dam scours the river bend and bank to replenish the sediment load. This action removes sediment from the riparian system so that the formation of sites suitable for poplar seedling establishment is reduced (my emphasis)."***

Table 1 summarizes the impacts of altered flow regime on riparian poplar (from Bradley et al. (1991).

Table 1. Altered River Regime Factors Contributing to Decline of Riparian Poplar

Proposed Cause	Comment	References
Hydrological Changes		
Reduced flooding	Spring flooding is essential to create moist seed beds for seedling establishment	Johnson et al. (1976) Brown et al. (1977) Fenner et al. (1985)
Reduced downstream flows	Diversion of water offstream creates a water deficit downstream, resulting in drought stress and enhanced mortality	Brown et al. (1977) Rood et al. (1989)
Geomorphological Changes Resulting From Hydrological Alterations		
Reduced meandering	With reduced flooding, channel migration is reduced and suitable seed beds are reduced	Johnson et (1976) Bradley and Smith (1986)
Sediment depletion	The water impoundments lead to settling of suspended silt loads and downstream reaches are impoverished of the sediment	Bradley and Smith (1986)

Rood and Bradley (2015) note for the Bow River downstream of Calgary:

> *"The cottonwoods are primarily balsam poplars (Populus balsamifera), trees that are able to reproduce both sexually through seedlings and asexually by suckering, the production of new shoots from existing roots. Probably as a result of river flow stabilization, and the attenuation of flooding that has followed the installation of ten dams upstream, the Bow River channel has become somewhat entrenched and the development of lateral and point bars has apparently been reduced. This may have been compounded by a decreased frequency of overbank floods in the Bow River basin since the 1930's due to climatic conditions. The lack of flooding and subsequent geomorphological changes has resulted in a lack of suitable sites for cottonwood regeneration by seedlings or by suckers. Recent regeneration does not appear to be sufficient to replace existing stands and if conditions do not change, a progressive decline in cottonwood forests may be expected over the next century "*
>
> . . .
>
> *"According to Kellerhals et al. (1972), the Bow River near Calgary is a predominantly gravel bed river with a partly entrenched and frequently confined channel. Banks are of sand and gravel and the channel is sinuous with frequent islands, mid-channel bars and diagonal bars. The river apparently experiences only slight lateral migration, a characteristic that differs from undammed rivers with more dynamic river channels along which cottonwood forests have been studied."*
>
> . . .
>
> *"Cottonwood reproduction through seedlings appeared to be sparse, or nonexistent, along the Bow River reach. This apparent lack of seedlings can probably be attributed to a lack of suitable sites and conditions for seedling establishment.* ***Creation of suitable sites***

depends on flooding prior to seed dispersal, dynamic channel migration and bar formation *(**my emphasis**), none of which appeared abundant along the Bow River study reach."*

. . .

"The effect of the altered river regime and these geomorphological consequences would be fewer sites available for cottonwood seedling establishment. Cottonwood seeds require saturated and barren sites for imbibition, germination and initial seedling growth. As well, suckering might also be retarded since this process may normally follow disturbance events which produce barren areas and stimulates the roots of mature trees to send up shoots. Cottonwood regeneration is well adapted to, and dependent upon, the natural disturbances which occur on the river floodplain. Conversely, with attenuated flooding, sites suitable for seedlings will become scarce and suckering might be deficient. Additionally, mature trees are less likely to be toppled following bank undercutting which erodes their anchoring substrates away. Thus, the dynamic population cycling that is characteristic of riparian cottonwood forests is retarded."

"Additionally, attenuated flooding also alters the suitability of the river banks for other vegetation and this can also impede cottonwood recruitment. Cottonwoods and willows are very flood-tolerant and thus able to survive along shallow river banks and bars that are inundated for one or more weeks during the normal period of high flows in late spring. Conversely, grasses and many shrubs are restricted to higher elevations away from the river's edge since those plants are less able to withstand the anaerobic periods of spring flooding."

. . .

"Thus, due directly to reduced flooding and indirectly through geomorphological changes and change in vegetation patterns, the attenuation of spring flooding will likely lead to a deficiency or elimination of cottonwood seedling regeneration along the Bow River downstream from Calgary. Similar deficiencies of regeneration have been observed downstream from other flood control dams, particularly in the southwestern United States (see review by: Rood and Mahoney, 1990). While flooding might intuitively seem like an undesirable feature of the river valley, it is a natural and essential component for the long-term sustenance of the riparian ecosystem."

. . .

"Although built primarily for hydroelectric power generation, the dams upstream of Calgary are able to attenuate moderate but not extreme floods. The perceived security from flooding has led to extensive urban and industrial developments in the floodplain of the Bow River and probably especially along the Elbow River through Calgary. It is very unlikely that operation of the upstream dams would be altered to enable overbank flooding. However, there may be opportunity for minor changes to upstream dam operation which would encourage some channel migration, bar formation, and cottonwood establishment. This would require a better understanding of the age structure of the floodplain forests and the events which led to their establishment."

*"Even with the dams installed, mayor (*sic*) floods would overwhelm the control capabilities and cause costly flood through Calgary, as occurred in 2013. Although such a flood would be very destructive to the urban developments along the Bow River floodplain, it might*

enable a major recruitment event for cottonwoods. Recognizing the probable property damage that would follow such an event, we do not promote such a flood, but rather, ***recognize that recruitment of cottonwood forests may be partially dependent on rare, very large floods that are beyond human control." (my emphasis)***

. . .

"Impacts of dams on riparian ecosystems extend downstream as far as the river flow is altered, distances of tens or hundreds of kilometers (Williams and Wolman, 1984). Consequently, environmental impact assessments for any project proposed on the Highwood must consider influences downstream as far as the hydrological pattern is altered."

There have been at least 10 flood events since 1950 on the Elbow River (based on measurements above and below the Glenmore Dam—Stantec (2020d) which the proposed project would potentially have captured (Table 2).

Stantec (2020a, Exhibit 137, pdf page 94) states that over *"the last 105 years, Elbow River flows Elbow River flows exceeded 160 m*^{3}*/s approximately 10 times, which averages to once every 10 years.*" If I am interpreting this correctly, it appears to be contradictory to information presented in Stantec (2020d, Exhibit 173, pdf pages 47-51) which shows 20 years with instantaneous flows exceeding 160 m^{3}/s. That would translate to about once every 5 years.

Every river system is different and responds uniquely to alterations caused by flow regulation but the causes of change are similar: peak flow reduction and reduction in sediment. The other major lesson from many studies is that the effects take time to develop and fully show up in the ecosystem. Johnson et al (2012, pdf page 12) strike a cautionary note from long-term research on the Missouri River floodplain:

"The major lesson from this long-term research is that a second, more insidious wave of impacts of damming follows the initial acute impacts associated with the filling of large reservoirs. The second wave affects the remnant forests that survived downstream of the dams or in gaps between the reservoirs. ***These slow-to-develop environmental changes, such as channel incision, bank stabilization, and delta formation, are the product of flow and sediment alteration (my emphasis).*** *Other impacts not directly associated with damming can be as serious as physical environmental changes in influencing ecological processes and biodiversity, such as the expansion of invasive plants, agricultural and urban expansion, and the introduction of insect pests and diseases. What started out 40 years ago as predominantly a cottonwood-regeneration problem on the Missouri River floodplain has expanded into a potential riparian-forest catastrophe with increasingly daunting prospects for recovery."*

Table 2. Maximum Instantaneous Discharge (m3/s) (Elbow River) – events over 160 m^3/s (Stantec 2020d)

ID	Year	Month-Day	m^3/s
05BJ001	1908	06-02	217.5
05BJ001	1912	06-16	161.1
05BJ001	1915	06-26	379.4
05BJ001	1916	06-29	196.5
05BJ001	1917	06-03	198.8
05BJ001	1923	06-01	402.1
05BJ001	1929	06-03	433.2
05BJ001	1932	06-03	713.6
05BJ005	1942	05-11	226.5
05BJ005	1948	05-23	259.1
05BJ005	1951	08-31	170.8
05BJ005	1953	06-04	166.8
05BJ005	1963	06—30	178.7
05BJ005	1967	05--31	279.2
05BJ005	1969	06—30	165.1
05BJ005	1995	06—17	293
05BJ005	2005	06—18	338
05BJ005	2008	05—25	220
05BJ005	2011	05--27	215
05BJ005	2013	06--21	1240

5.1.3 Importance of Riparian Habitats

Bradley et al. (1991) note the importance of riparian habitats in southern Alberta:

"Today, many southern Albertans preferentially choose riparian poplar stands as outdoor recreation environments. It is noteworthy that four provincial parks - Dinosaur, Woolford, Writing-on-Stone and Dry Island - as well as major urban parks in Calgary, Lethbridge and Medicine Hat and several parks in smaller centres are located in riparian poplar forests. It also is not surprising that local parks or picnic areas have been developed at several locations where riparian poplar forests occur near river crossings."

"More importantly, the riparian ecosystem is probably the single most productive type of wildlife habitat in the semi-arid Great Plains (Bottorff, 1974; Hubbard, 1977; Rhodes, 1991). Similarly, riparian habitats in the semi-arid regions of southeastern Oregon are used more than any other type of habitat by 82% of the terrestrial species (Thomas et all, 1979)."
1
Many bird species in the prairies are dependent on riparian poplar forests. In Alberta, Savoy (1991) reported that 72% of the bird species found in the riparian poplar forests of Dinosaur Provincial Park on the Red Deer River use that habitat exclusively. Breeding bird densities range from 550-706 pairs per 40 ha., among the highest densities in Canada. Savoy

concluded that disappearance of riparian poplar forests would result in a dramatic reduction of bird species and numbers in prairie regions. For example, studies in Fish Creek Provincial Park found that American kestrels nest almost exclusively in riparian poplars (Greg Wagner, pers. comm.). Furthermore, great blue heron rookeries are restricted to riparian poplar woodlands in the prairies and eagles use poplar groves in valleys for night roosting. Other highly visible bird species using riparian poplar habitats in the prairies include Swainsons and red-tailed hawks, tree-nesting common mergansers and Canada geese, and ring-necked pheasants, who concentrate in the understories."

"Virtually all of the forests found in the river valleys of southern Alberta constitute critical habitat for deer (Fitch, pers. comm.). Critical habitat refers to winter range and breeding areas, because these are the habitat components in shortest supply . Both mule deer and whitetail deer use riparian forests."

5.2 Recommendations

Given the impacts on native wetland and riparian habitats in landscapes of environmental significance both in the dry reservoir area as well as downstream on the Elbow River, I recommend that the project not be approved in its current configuration and operating mode.

If the project is approved, consideration should be given for allowing larger flood events to pass.

6. WILDLIFE

The submissions by the Springbank Community Association (2021a and c, Exhibits 195 and 196) identify a number of issues related to wildlife for which there are many unanswered questions or doubt about the effectiveness or practicality of some mitigation strategies. In my professional opinion, key concerns include:

1. impacts on migratory birds of floodwaters in the dry dam area during dry conditions as well as flood events; and
2. impacts of floods, sediment and sediment removal on wildlife habitat in the dry dam area.

Stantec (2020b, Exhibit 138, pdf page 461) identifies several long-term irreversible and adverse residual effects on wildlife and biodiversity. These include change in habitat, change in movement, and change in mortality risk. While there may not be much change in species richness, there will be a general degradation of habitat which will lower the productivity of the habitats for a variety of species.

Stantec (2019d, Exhibit 125, pdf pages 20-21) identifies potential impacts to wildlife:

> *"Construction, dry operations, flood and post-flood operations have the potential to affect wildlife and wildlife habitat through direct habitat loss or alteration, including residences of SAR species."*
>
> *. . .*
>
> *"The Project is predicted to increase wildlife mortality risk in the off-stream reservoir during a flood. Whether the risk is low or moderate depends on the species and magnitude of the flood. Most of the flooded area would encompass wetlands and reclaimed vegetation that might be suitable breeding habitat for amphibians and ground-nesting migratory birds, respectively. Rising flood waters in the off-stream reservoir would remove migratory bird residences (e.g., nests) and young (e.g., eggs, nestlings, or fledglings), change the conditions required for amphibian larvae to develop, and introduce predatory fish that can prey on amphibians (e.g., eggs, larvae, or adults). For large mammals (e.g., elk and grizzly bear), mortality risk would be less because of their mobility to avoid floods."*

Stantec (2019b, Exhibit 94, pdf page 198) indicates:

> *"Volume 3A, Section 11.4.5.3 specifically addresses Project residual effects on biodiversity, which acknowledges potential Project effects on wildlife species dependent on upland communities including bird species richness. As stated in Volume 3A, Section 11.4.5.3, "Shrubland and grassland would be reduced by up to 20.8% and 21.1% in the local wildlife LAA, respectively during construction (see Table 11-12). Reclamation of disturbed native upland and shrub habitat types will be reclaimed using an Alberta Transportation native custom seed mix (see Volume 3A, Section 10.3.1, Table 3-10). Reclamation would result in an additional 91 ha of grassland habitat in the LAA during dry operations, a 21% increase from existing conditions."*

This is misleading. As noted in the South Saskatchewan Regional Plan section dealing with native grasslands, this reclaimed grassland cannot be considered native grassland habitat with all the functionality and species richness of native plant and animal species, including invertebrate populations.

The Impact Assessment Agency of Canada (2021, Exhibit 164, pdf pages 11 and 12) proposes several conditions:

> *"4.1 The Proponent shall carry out the Designated Project in a manner that protects migratory birds and avoids harming, killing or disturbing migratory birds or destroying, disturbing or taking their nests or eggs. In this regard, the Proponent shall take into account Environment and Climate Change Canada's Guidelines to reduce risk to migratory birds."*
>
> *. . .*
>
> *"4.6 The Proponent shall remove sediment and debris in the off-stream reservoir within seven days after the draining of the reservoir. If it is not technically feasible for the Proponent to remove sediment and debris within seven days after the draining of the reservoir, the Proponent shall develop and implement additional mitigation measures, in consultation with relevant authorities, to avoid harm to migratory birds and their nests or eggs."*
>
> *. . .*
>
> *"4.8 The Proponent shall develop and implement, in consultation with Indigenous groups and relevant authorities, a protocol to prevent harm to migratory birds, including migratory birds species at risk identified in Table 7.2-1 of the draft environmental assessment report, within the reservoir footprint. The Proponent shall develop the protocol prior to construction and implement it prior to flood operation. The protocol shall include:*
>
> *4.8.1 flood forecasting undertaken prior to inventories conducted in accordance with condition 4.9; and*
>
> *4.8.2 measures to rescue migratory birds chicks and eggs."*

Stantec (2020c, Exhibit 218, pdf pages 100-105) provides a fairly in-depth discussion by Stantec of the approach proposed to be in compliance with the approach outlined in Alberta Transportation's (2021, Exhibit 219, pdf page 13) revised wording in feedback on draft potential conditions under CEAA, i.e.:

> ***"the Proponent shall follow the proposed approach outlined in IR4-03, submitted in the Response to Information Request Round 2 Package 4-01 to -04 (Canadian Impact Assessment Registry Reference Number 80123, Document Number 1311.***

With regards to moving or "clearing" wildlife to get them out of harm's way during a flood event, I have no confidence that there could be sufficient effort to remove a significant number of species of conservation concern, let alone all the migratory birds that may be at peak nesting period during a major flood event. In addition to human safety concerns, the rapidity with which such flood events develop and the problem of where to house and care for "rescued" wildlife caution against attempting such mitigation.

On the subject of sediment. It has already been determined that sediment deposition will degrade natural and non-native agricultural lands. Sediment removal will also have negative impacts. It is not clear where sediment could be moved to and what the impacts of that removal would be. Impacts could include a sharp increase in human activity in the sediment area and on roads between the project area and the sediment disposal site.

The questions and concerns on this topic raised by the Springbank Community Association (2021a, Exhibit 195 and 2021c, Exhibit 196) are appropriate.

The proponent has gone about as far as it can with mitigation approaches for wildlife and that will help reduce impacts but not eliminate them.

In addition to the intractable problems related to sediment (leaving in place or removal) and wildlife "clearing" during flood events, mitigation cannot deal effectively with outstanding issues related to loss of intact and diverse native grasslands and wetlands as well as the downstream effects on the extent of riparian habitat and its quality. All these issues will have long-term and adverse effects on the wildlife using these habitats. While I agree that most, if not all, wildlife species will continue to use the area, populations for many species currently using the area will be reduced due to varying degrees of degradation in upland, wetland, and riparian habitat quality and diversity.

6.1 Recommendations

Given the impacts on native habitats in landscapes of environmental significance and the related potential impacts on wildlife both in the dry reservoir area as well as downstream on the Elbow River, I recommend that the project not be approved in its current configuration and operating mode.

If the project is approved, immediate sediment removal following floods should not be a condition of approval.

7. LITERATURE CITED

Alberta Environmental Protection. 1997. The Parkland Natural Region of Alberta. Natural Resources Service, Recreation and Protected Areas Division, Natural Heritage Planning and Evaluation Branch, Edmonton. Website: https://ia800305.us.archive.org/15/items/parklandnaturalr00albe/parklandnaturalr00albe.pdf

Alberta Environment and Parks. 2016a. Managing Parks and Protected Areas: Scientific Framework. Alberta Tourism Parks and Recreation, Edmonton. Website: http://www.albertaparks.ca/albertaparksca/management-land-use/building-the-parks-system/scientific-framework.aspx.

Alberta Environment and Parks. 2016b. Management and Land Use--Parkland. http://www.albertaparks.ca/albertaparksca/management-land-use/current-parks-system/parkland.aspx

Alberta Environment and Parks. 2017. Areas of Wildlife Sensitivity. Alberta Environment and Parks, Edmonton. Website: https://open.alberta.ca/publications/areas-of-wildlife-habitat-sensitivity and https://open.alberta.ca/dataset/838630df-f943-4456-a938-f5e21e426c52/resource/0a98d9c5-f9e0-4ff3-813a-7822512cf240/download/interpretingwildlifehabitatsensitivitymap-aug-2017.pdf

Alberta Environment and Parks. 2018. Progress Summary of Natural Landscape Type Representation by Natural Region and Subregion within Protected Areas in Alberta. Website: https://www.albertaparks.ca/media/6262166/alberta-s-network-of-protected-areas-progress-toward-achieving-natural-landscape-targets.pdf

Alberta Environment and Parks. 2021. Key Wildlife and Biodiversity Zones (dataset). Website: https://extranet.gov.ab.ca/srd/geodiscover/srd_pub/LAT/FWDSensitivity/KeyWildlifeAndBiodiversityZones.zip

Alberta Environment and Sustainable Resource Development. 2013. Alberta Wetland Policy. Government of Alberta, Edmonton. Website: https://open.alberta.ca/dataset/5250f98b-2e1e-43e7-947f-62c14747e3b3/resource/43677a60-3503-4509-acfd-6918e8b8ec0a/download/6249018-2013-alberta-wetland-policy-2013-09.pdf

Alberta Environment and Sustainable Resource Development. 2015. Recommended Land Use Guidelines: Key Wildlife and Biodiversity Zones. Alberta Environment and Sustainable Resource Development, Edmonton. Website: https://open.alberta.ca/dataset/5c6e2826-50ab-4d2a-a673-9d703d6b5c52/resource/d8d1b2e9-3a72-471d-9479-56db5ee68210/download/KeyWildlifeBiodiversityZones-Apr08-2015.pdf

Alberta Sustainable Resource Development. 2010. Industrial Activity in Foothills Fescue Grasslands — *Guidelines for Minimizing Surface Disturbance.* Prepared by Alberta Sustainable Resource Development, Lands Division. Edmonton, AB. Website: https://open.alberta.ca/dataset/572ff6d5-807e-40ee-a4d8-117ae4cfd23e/resource/88217c9c-b413-4d98-a1cf-e2cb326d6149/download/2010-grassland-minimizingsurfacedisturbance.pdf

Alberta Transportation. 2021. Springbank Off-Stream Reservoir Project – Public Comment on the Draft Environmental Assessment Report and Draft Potential Conditions. February 3, 2021. Exhibit 219 of this process. Alberta Transportation, Edmonton. Website: https://www.alberta.ca/assets/documents/trans-springbank-at-response-iaac-20210203.pdf or https://www.nrcb.ca/download_document/2/83/10754/20210203-at-corr-to-agency-re-comments-on-draft-ea-report-andpotential-conditions

Alberta Water Council. 2013. Riparian Land Conservation and Management Report and Recommendations. Alberta Water Council, Edmonton. Website: https://www.awchome.ca/_projectdocs/?file=e807bf3e2ed51423

Behan, M., 1981. The Missouri's stately cottonwoods: How can we save them? Montana Magazine September, p76- 77.

Bow River Basin Council. 2012. Bow Basin Watershed Management Plan: Land Use, Headwaters, Wetlands, Riparian Lands, Water Quality. Bow River Basin Council, Calgary. Website: https://brbc.ab.ca/our-activities/bow-basin-watershed-management-plan

Bradley, C., and M. Neville. 2010. Minimizing Surface Disturbance of Alberta's Native Prairie--Background to Development of Guidelines for the Wind Energy Industry. Foothills Restoration Forum and Prairie Conservation Forum. Website: http://www.albertapcf.org/rsu_docs/wind-energy-background-final-december-2010.pdf

Bradley, C., F. Reintjes, and J. M. Mahoney. 1991. The Biology and Status of Riparian Poplars in Southern Alberta. World Wildlife Fund Canada, Toronto, and Alberta Forestry, Lands & Wildlife, Edmonton. Website: http://www.albertapcf.org/rsu_docs/biology-and-status-feb-1991.pdf

Bradley, C., and D. Smith. 1986. Plains Cottonwood Recruitment and Survival on a Prairie Meandering River Floodplain, Milk River, Southern Alberta and Northern Montana, Canadian Journal of Botany, 64:1433-1442. Website: https://cdnsciencepub.com/doi/pdf/10.1139/b86-195

Brown, D.E., C.H. Lowe & J.F. Hausler, 1977. Southwestern riparian communities: Their biotic importance and management in Arizona, in: Importance, Preservation and Management of Riparian Habitat: A symposium, R.R. Johnson & D.A. Jones eds. Tucson, Arizona, July 9, 1977. pages 201-211. USDA Forest Service General Technical Report RM-43. Website: https://www.fs.fed.us/rm/pubs_rm/rm_gtr043.pdf

Colby, B.R., 1964. Scour and fill in sand-bed streams, US Department of Interior, USGS professional paper 462-D. Washington. Website: https://pubs.usgs.gov/pp/0462d/report.pdf

Environment Canada, 1985. Historical streamflow summary: Alberta to 1984, Inland Waters Directorate, Ottawa. 527 pp.

Everitt, B., 1968. Use of the cottonwood in an investigation of the recent history of a flood plain. American Journal of Science 266:417-439.

Fenner, P., W. Brady & D. Patton, 1985. Effects of regulated water flows on regeneration of Fremont Cottonwood. Journal of Range Management, 38(2):135-138. Website: https://www.semanticscholar.org/paper/Effects-of-regulated-water-flows-on-regeneration-of-Fenner-Brady/1343ad5f106350188c96aa55111008cbfc9c737c

Fiera Biological Consulting. 2009. Environmentally Significant Areas Update. Prepared for Alberta Tourism Parks and Recreation, Edmonton. Website: https://albertaparks.ca/albertaparksca/library/environmentally-significant-areas-report/

Fiera Biological Consulting. 2011. Aquatic Environmentally Significant Areas in Alberta. Prepared for Alberta Environment and Alberta Sustainable Resource Development, Edmonton. Website: https://open.alberta.ca/dataset/aquatic-environmentally-significant-areas-in-alberta

Fiera Biological Consulting. 2014. Environmentally Significant Areas, 2014 Update. Prepared for Government of Alberta, Edmonton, Alberta. Fiera Biological Consulting Report Number 1305. Website: http://www.albertaparks.ca/media/5425575/2014-esa-final-report-april-2014.pdf

Gildart, R.C., 1984. Montana's Missouri River, Montana Geographic Series Number 8. Montana Magazine Inc, Helena. 104pp.

Gill, D. 1975. Influence of white spruce trees on permafrost table microtopography, Mackenzie River Delta. Canadian Journal of Earth Sciences 12: 263-272. Website: https://cdnsciencepub.com/doi/pdf/10.1139/e75-023

Government of Alberta. 2018 (amended). South Saskatchewan Regional Plan, 2014-2024, an Alberta Land-use Framework Integrated Plan. Government of Alberta, Edmonton. Website: https://open.alberta.ca/dataset/13ccde6d-34c9-45e4-8c67-6a251225ad33/resource/e643d015-3e53-4950-99e6-beb49c71b368/download/south-saskatchewan-regional-plan-2014-2024-may-2018.pdf

Impact Assessment Agency of Canada. 2021. Potential conditions under the *Canadian Environmental Assessment Act, 2012.* Impact Assessment Agency of Canada, Ottawa. Exhibit 164 of this process. Website: https://www.nrcb.ca/download_document/2/83/10672/20210104-agency-eia-to-at-re-draft-ea-report-potential-conditions

Jeffrey, W.W. 1959. White spruce rooting modifications on the fluvial deposits of the lower Peace River. Forestry Chronicle 35: 305-311. Website: https://pubs.cif-ifc.org/doi/pdf/10.5558/tfc35305-4

Jeffrey, W.W. 1961. Origin and structure of some white spruce stands on the lower Peace River. Technical Note No. 103, Forest Research Branch, Canada Department of Forestry. 20 pp. Website: https://d1ied5g1xfgpx8.cloudfront.net/pdfs/31368.pdf

Johnson, W., R. Burgess & W. Keammerer, 1976. Forest overstory vegetation and environment on the Missouri River Floodplains in North Dakota. Ecological Monographs 46(1):59-84. Website: https://doi.org/10.2307/1942394

Johnson, W. Carter, Mark D. Dixon, Michael L. Scott, Lisa Rabbe, Gary Larson, Malia Volke, and Brett Werner. 2012. Forty Years of Vegetation Change on the Missouri River Floodplain. Bioscience 62(2): 123-135. Website: https://www.semanticscholar.org/paper/Forty-Years-of-Vegetation-Change-on-the-Missouri-Johnson-Dixon/50ad4decfebfb073e07408c7d6b1f6611efeb132

Johnston, A, 1987. History of floods in the Oldman River Valley at Lethbridge, Lethbridge Historical Society, Lethbridge, Alberta. 19pp.

Kellerhals R., C.R. Neill, and D.I. Bray. 1972. Hydraulic and Geomorphic Characteristics of Rivers in Alberta. Research Council of Alberta Report 72-1.

Lamoureux, R. G. Chow and B. Reeves. 1983. Environmentally significant areas of the Calgary region, Phase Two Report. Prepared by Lamoureux and Associates, Calgary for Calgary Regional Planning Commission, Calgary. Website: https://www.calgary.ca/CSPS/Parks/Documents/Planning-and-Operations/Environmentally-Significant-Areas-1983.pdf

Lancaster, J., R. Adams, B. Adams, and P. Desserud. 2016. Long-term Revegetation Success of Industry Reclamation Techniques for Native Grasslands: Foothills Fescue, Foothills Parkland, and Montane Natural Subregions; Phase 1-Literature Review and Case Studies-2014. Prepared for: Land and Forestry Policy Branch, Alberta Environment and Sustainable Resource Development. Website: https://open.alberta.ca/dataset/d9006d18-bcf6-441c-90f2-a9469aa8c624/resource/61ae5f43-0a62-443a-9d4b-263321786ab7/download/ff-fp-m-2014-phase1-lit-review-monitoring-report-2015-11-16.pdf

Landhäusser, S. 2000. How old are white spruce trees in the Mackenzie Delta really? Inuvik Region Final Report 2000. Department of Renewable Resources, University of Alberta, Edmonton, AB. 7 pp. Website: http://www.grrb.nt.ca/pdf/forestry/HowOldrWSpruce2000.pdf

Noble, M.G., 1979. The origin of *Populus deltoides* and *Salix interior* zones on point bars along the Minnesota River. American Midland Naturalist, 102(1):59-67. Website: https://www.jstor.org/stable/2425066?seq=1

North American Bird Conservation Initiative Canada. 2019a. The State of Canada's Birds, 2019. Environment and Climate Change Canada, Ottawa, Canada. 12 pages. Website: www.stateofcanadasbirds.org

O2. 2013. Riparian Areas Mapping Project - Phase 1 Technical Report Current Conditions Maps. Prepared for City of Calgary Water Resources, Calgary by O2, Calgary. Website: https://www.calgary.ca/content/dam/www/uep/water/documents/water-documents/riparian-areas-mapping-technical-report.pdf

Prairie Conservation Forum. 2016. Alberta Prairie Conservation Action Plan: 2016-2020. Published by the Prairie Conservation Forum, Lethbridge, Alberta. 30 pages. Website: https://www.albertapcf.org/rsu_docs/pcap-2016-2020--small-.pdf

Prairie Conservation Forum. 2021. Alberta Prairie Conservation Action Plan: 2021-2025. Published by the Prairie Conservation Forum, Lethbridge, Alberta. 30 pages. Website: https://www.albertapcf.org/wp-content/uploads/2021/02/PCAP-2021-web.pdf

Read, R., 1958. Silvical characteristics of plains cottonwood, USDA Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Station Paper No. 33, 18pp. Website: https://archive.org/details/silvicalcharacte33read/page/n1/mode/2up

Rood, S., and C. Bradley. 2015. Assessment of riparian cottonwoods along the Bow River downstream from Calgary, Alberta. Website: https://www.researchgate.net/publication/292128886_Assessment_of_Riparian_Cottonwoods_along_the_Bow_River_Downstream_from_Calgary_Alberta

Rood, S.B. & S. Heinze-Milne, 1989. Abrupt riparian forest decline following river damming in southern Alberta. Canadian Journal of Botany, 67:1744-1749. Website: https://cdnsciencepub.com/doi/pdf/10.1139/b89-221

Rood, S., and J.M. Mahoney. 1990. The Collapse of River Valley Forests Downstream from Dams in the Western Prairies: Probable causes and prospects for mitigation, Environmental Management. 14:451-464. Website: https://www.researchgate.net/publication/225370385_Collapse_of_Riparian_Poplar_Forests_Downstream_From_Dams_in_Western_Prairies_Probable_Causes_and_Prospects_for_Mitigation

Springbank Community Association. 2021a. SR1 Project and Wildlife (CEAA Conditions Section 5). Letter from K. Hunter, Springbank Community Association to Impact Assessment Agency of Canada and Natural Resources Conservation Board, February 14, 2021. Exhibit 195 of this process. Website: https://www.nrcb.ca/download_document/2/83/10742/20210214-springbankcomassoc-sub-to-nrcb-re-4-wildlife-andbiodiversity

Springbank Community Association. 2021b. SR1 Project General Comments. Letter from K. Hunter, Springbank Community Association to Impact Assessment Agency of Canada and Natural Resources Conservation Board, February 14, 2021. Exhibit 194 to this process. Website: https://www.nrcb.ca/download_document/2/83/10743/20210214-springbankcomassoc-sub-to-nrcb-re-1-general-comments

Springbank Community Association. 2021c. SR1 Project and Migratory Birds (CEAA Conditions Section 4). Letter from K. Hunter, Springbank Community Association to Impact Assessment Agency of Canada and Natural Resources Conservation Board, February 14, 2021. Exhibit 196 to this process. Website: https://www.nrcb.ca/download_document/2/83/10741/20210215-springbankcomassoc-sub-to-nrcb-re-3-migratory-birds

Stantec. 2016. Springbank Off-Stream Reservoir Project, *Canada Environmental Assessment Act*, 2012. Project Description April 18, 2016 Prepared for Alberta Transportation by: Stantec Consulting Ltd., Calgary. Exhibit 2 of this process. Website: https://www.nrcb.ca/download_document/2/83/8604/20160418-at-eia-to-nrcb-re-project-description

Stantec. 2018a. Springbank Off-Stream Reservoir Project, Annex 2, May 2019. Prepared for Alberta Transportation, Edmonton by Stantec Consulting Ltd., Calgary. Exhibit 80 of this process. Website: https://www.nrcb.ca/download_document/2/83/8830/20180511-at-eia-to-nrcb-re-annex-2

Stantec. 2018b. Springbank Off-Stream Reservoir Project, Environmental Impact Assessment, Volume 3B: Effects Assessment (Flood and Post-Flood Operations), Assessment of Potential Effects on Terrain and Soils. March 2018. Prepared for Alberta Transportation, Edmonton by Stantec Consulting Ltd., Calgary. Exhibit 48 of this process. Website: https://www.nrcb.ca/download_document/2/83/8732/20180326-at-eia-to-nrcb-re-vol-3b-s09-terrain-and-soils

Stantec. 2018c. Springbank Off-Stream Reservoir Project, Environmental Impact Assessment, Volume 3A: Effects Assessment (Construction and Dry Operations), Assessment of Potential Effects on Traditional Land and Resource Use. March 2018. Prepared for Alberta Transportation, Edmonton by Stantec Consulting Ltd., Calgary. Exhibit 48 of this process. Website: https://www.nrcb.ca/download_document/2/83/8724/20180326-at-eia-to-nrcb-re-vol-3a-s14-tlru

Stantec. 2019a. Springbank Off-Stream Reservoir Project, May 2019. Response to CEAA Information Request Package 2 – August 20, 2018, Appendix IR19-1 Draft Vegetation and Wetland Mitigation, Monitoring and Revegetation Plan. Prepared for Alberta Transportation, Edmonton by Stantec Consulting Ltd., Calgary. Exhibit 217 of this process. Website: https://www.nrcb.ca/natural-resource-projects/natural-resource-projects-listing/83/springbank-off-stream-reservoir-project/documents/9088/20190614-at-eia-to-nrcb-re-ceaa-ir-response-package-2-appendix-ir19-1

Stantec. 2019b. Springbank Off-Stream Reservoir Project, May 2019. Response to NRCB and AEP Supplemental Information Request 1 – July 28, 2018-Terrestrial. Prepared for Alberta Transportation, Edmonton by Stantec Consulting Ltd., Calgary. Exhibit 94 of this process. Website: https://www.nrcb.ca/download_document/2/83/9200/20190614-at-sir-to-nrcb-re-sir1-response-sec-6-terrestrial

Stantec. 2019c. Springbank Off-Stream Reservoir Project, May 2019. Response to NRCB and AEP Supplemental Information Request 1 – July 28, 2018-Water. Prepared for Alberta Transportation, Edmonton by Stantec Consulting Ltd., Calgary. Exhibit 93 of this process. Website: https://www.nrcb.ca/download_document/2/83/9206/20190614-at-sir-to-nrcb-re-sir1-response-sec-5-water

Stantec. 2019d. Springbank Off-Stream Reservoir Project, May 2019. Response to NRCB and AEP Supplemental Information Request 1 – July 28, 2018. Appendix IR425-1, Draft Wildlife Mitigation and Monitoring Plan. Prepared for Alberta Transportation, Edmonton by Stantec

Consulting Ltd., Calgary. Exhibit 125 of this process. Website: https://www.nrcb.ca/download_document/2/83/9180/20190614-at-sir-to-nrcb-re-sir1-response-appendix-ir425-1

Stantec. 2020a. Springbank Off-Stream Reservoir Project, April 2020 (Second Submission). Response to NRCB and AEP Supplemental Information Request 2 -- November 18, 2019. Prepared for Alberta Transportation, Edmonton by Stantec Consulting Ltd., Calgary. Exhibit 137 of this process. Website: https://www.nrcb.ca/download_document/2/83/10063/20200515-at-sir-to-aep-re-sir2-responses-second-submission

Stantec. 2020b. Springbank Off-Stream Reservoir Project, June 2020. Response to NRCB and AEP Supplemental Information Request 2 – November 18, 2019. Prepared for Alberta Transportation, Edmonton by Stantec Consulting Ltd., Calgary. Exhibit 138 of this process. Website: https://www.nrcb.ca/download_document/2/83/10218/20200623-at-sir-to-aep-re-sir2-response

Stantec. 2020c. Springbank Off-Stream Reservoir Project, June 2020. Response to Impact Assessment Agency of Canada Information Request package 4 – Technical Review Round 2, March 23, 2020. Prepared for Alberta Transportation, Edmonton by Stantec Consulting Ltd., Calgary. Exhibit 218 to the process. Website: https://www.nrcb.ca/download_document/2/83/10293/20200716-at-sir-to-agency-re-ir-response-package-4-round-2unsecured

Stantec. 2020d. Springbank Off-Stream Storage Project, Preliminary Design Report, Appendix B--Hydrology, September 25, 2020. Prepared for Alberta Transportation, Edmonton by Stantec Consulting Ltd., Calgary. Exhibit 173 of this process. Website: https://www.nrcb.ca/download_document/2/83/10696/20210201-at-eia-to-nrcb-re-preliminarydesignreport-appendix-bhydrology-rev0-20200925

Stantec. 2020e. Springbank Off-Stream Storage Project, Preliminary Design Report, December 8, 2020. Prepared for Alberta Transportation, Edmonton by Stantec Consulting Ltd., Calgary. Exhibit 159 of this process. Website: https://www.nrcb.ca/download_document/2/83/10664/20201218-at-sir-to-nrcb-re-preliminary-design-report

Strong, W.L. and La Roi, G.H. 1983. Root-system morphology of common boreal forest trees in Alberta, Canada. Canadian Journal of Forest Research 13: 1164-1173. Website: https://cdnsciencepub.com/doi/10.1139/x83-155

Sweetgrass Consultants Ltd. 1997. Environmentally Significant Areas of Alberta. Volumes 1, 2 and 3. Prepared by Sweetgrass Consultants Ltd., Calgary, AB for Resource Data Division, Alberta Environmental Protection, Edmonton, Alberta. Website: https://open.alberta.ca/publications/2073237

Task Force on the Natural and Beneficial Functions of the Floodplain. 2002. The natural and beneficial functions of floodplains: reducing flood losses by protecting and restoring the floodplain environment: a report for Congress, Federal Emergency Management Agency. Website: https://www.hud.gov/sites/documents/DOC_14217.PDF

Taylor, G.G. 1981. Stream Alterations: an introduction. U.S.F.W.S., Office of Biological Services, Eastern Energy and Land Use Team. Kearneysville, WV. 19 pp.

US Army Corps of Engineers. 1991. American River watershed investigation, California, Volume 6, Appendix S, Part 1. US Army Corps of Engineers, Sacramento District, South Pacific Division. Website: https://apps.dtic.mil/dtic/tr/fulltext/u2/a436970.pdf

Wagg, J.W.B. 1964. White spruce regeneration on the Peace and Slave River lowlands. Publication 1069, Research Branch, Canada Department of Forestry, Ottawa. 35 pp.

Williams, G.P., 1989. Sediment concentration versus water discharge during single hydrologic events in rivers. Journal of Hydrology 111:89-106. Website: https://www.sciencedirect.com/science/article/abs/pii/0022169489902540

Williams, G. & M. Wolman, 1984. Downstream effects of dams on alluvial rivers, US Department of the Interior, USGS Professional Paper 1286, 83pp. Website: https://pubs.usgs.gov/pp/1286/report.pdf

Wolman, M.G. & L.B. Leopold, 1957. River flood plains: some observations on their formation. US Department of Interior, USGS Professional Paper 282-C. Washington. p.87-107. Website: https://pubs.usgs.gov/pp/0282c/report.pdf

World Wildlife Fund. 2009. Ecoregions: WWF's Global 200. Website: http://worldwildlife.org/publications/global-200

8. APPENDICES

Excerpts from Documents in Literature Cited.

APPENDIX 1

Alberta Environmental Protection. 1997. The Parkland Natural Region of Alberta. Natural Resources Service, Recreation and Protected Areas Division, Natural Heritage Planning and Evaluation Branch, Edmonton. Website: https://ia800305.us.archive.org/15/items/parklandnaturalr00albe/parklandnaturalr00albe.pdf

The Parkland Natural Region of Alberta

One of a series of reports prepared for the Special Places 2000 Provincial Coordinating Committee

by

Alberta Environmental Protection
Natural Resources Service
Recreation & Protected Areas Division
Natural Heritage Planning and Evaluation Branch

November 1997

Chapter 1.1 Purpose of Report

1.1.1 Purpose

This report is one of a series dealing with the province's Natural Regions and Subregions and was prepared, in part, for the Special Places Provincial Coordinating Committee (PCC). The purpose of this report is to provide the PCC with an analysis of the Parkland Natural Region from a landscape protection/biodiversity conservation perspective. This analysis will assist members of the PCC in evaluating and ranking candidate Special Places sites nominated by Albertans.

1.1.2 Overview of Report Contents

This report discusses the Parkland Natural Region and focuses on crown land. Chapter 1.1 provides background information on the reasons why this report was prepared. Chapter 1.2 presents a brief biophysical perspective of the Parkland biome in North America and in Canada, with more detailed information for Alberta. Chapter 1.3 provides an historical perspective and Chapter 1.4 discusses the resulting amount of Parkland remaining. Detailed information on ongoing fragmentation of Parkland ecosystems through linear disturbances is presented in Chapter 1.5. Chapters 1.6 and 1.7 review the results of historical trends on Parkland species.

The Parkland is one of the most heavily impacted Natural Regions in Alberta. It has changed dramatically over the last 75 to 100 years under the cumulative effects of roadways, urbanization, cultivation, livestock grazing, petroleum and natural gas development, mining, hydroelectric dams, irrigation developments, electrical transmission lines and other developments. These are all a necessary part of modern society and help to support the social and economic needs and other demands of its human population — locally, nationally and internationally. Human activity, however, has altered species, landscapes and the natural ecological processes of the Parkland.

Many individuals, organizations, agencies and industries recognize the value of restoring, reclaiming and rehabilitating damaged or degraded Parkland features, ecosystems and landscapes. Considerable effort and funds are devoted to this cause and progress has been made. Some aspects that are being considered in the task of conserving and restoring native Parkland are discussed in Chapter 1.8.

Along with restoration of damaged or degraded areas, there is a need to protect examples of Parkland ecosystems. This is dealt with in considerable detail in Part 2. The philosophy behind designing a protected area's network on provincial crown lands for the Parkland of Alberta is presented in Chapter 2.1. Chapter 2.2 outlines where gaps occur in the system of protected lands in the three Parkland Subregions in the province. Chapter 2.3 describes the process used to help focus on provincial crown lands that have the potential to fill identified gaps. The final three chapters (2.4 to 2.6) deal with each of the Subregions in the Parkland Natural Region and the locations of the best candidate areas to be considered for protection.

APPENDIX 2

Alberta Environment and Parks. 2017. Areas of Wildlife Sensitivity. Alberta Environment and Parks, Edmonton. Website: https://open.alberta.ca/publications/areas-of-wildlife-habitat-sensitivity and https://open.alberta.ca/dataset/838630df-f943-4456-a938-f5e21e426c52/resource/0a98d9c5-f9e0-4ff3-813a-7822512cf240/download/interpretingwildlifehabitatsensitivitymap-aug-2017.pdf

August 2, 2017

Interpreting the Areas of Wildlife Habitat Sensitivity Map: A support document to use in association with the *Wildlife Directive for Alberta Wind Energy Projects* and the *Wildlife Directive for Alberta Solar Energy Projects*.

Introduction

The Alberta Government has developed a Climate Leadership Plan (http://www.alberta.ca/documents/climate/climate-leadership-report-to-minister-executive-summary.pdf) and a key piece of this plan will be reducing Alberta's dependency on coal electricity generation and moving to renewable energy sources such as wind and solar. Even though wind and solar provide a reliable source of clean and renewable energy, the related infrastructure has direct and indirect effects on wildlife, particularly birds and bats (Baerwald and Barclay 2011; Drewitt and Langston 2008; Erickson et al., 2001, Kaegan 2015, Walston et al. 2015). A role of Government of Alberta's Ministry of Environment and Parks, specifically Wildlife Management (GOA-Wildlife) is to ensure that development of wind and solar power projects includes appropriate considerations and mitigation of potential effects on wildlife and wildlife habitat.

Appropriate site selection is the first and most critical factor in preventing significant negative effects on wildlife (Drewitt and Langston 2008). Projects that are sited to avoid important wildlife habitats decrease wildlife mortality, disturbance and habitat loss as well as reduce the need for further mitigation measures or costs to the project proponent. The AEP *Wildlife Directive for Alberta Wind Energy Projects* and AEP *Interim Solar Guidelines* (the Directives) identify areas or zones that should be avoided or minimized to limit the negative impact of a renewable energy development on wildlife and wildlife habitat.

This document is organized by descriptions of the layers incorporated into the Areas of Wildlife Habitat Sensitivity Map (available at: http://aep.alberta.ca/fish-wildlife/wildlife-land-use-guidelines). For each layer, background information is provided, along with a sensitivity ranking for renewable energy operations. To facilitate this process, zones and habitat features identified within the Directives have been ranked as follows:

- **Critical Wildlife Zone**: Areas included in this category are either designated as protected areas or identified as critical importance for one or more wildlife species of conservation concern. These areas must be avoided by renewable energy projects.

- **High Risk**: Several Wildlife Sensitivity Layers are ranked as High Risk since these areas are likely used by one or more species at risk or priority management species. The Directives recommend avoiding areas ranked as high risk.

- **Moderate Risk**: These wildlife habitat areas are considered to be at a moderate risk since species at risk or priority management species can likely inhabit these areas. Due to the close proximity to native grasslands and the potential of habitat values existing for multiple species in these areas, there will likely be risks that could require mitigation considerations and potentially added costs to siting renewable energy projects in these areas.

- **Lower Risk**: The remaining areas of wildlife habitat of the province are considered to be at lower risk since the chance of a species at risk or priority management species occurring in these areas is less likely than the other ranked areas. The lower risk areas are typically between 500-1000 meters from native grassland. However, there is still the potential of these areas possessing quality wildlife habitat. If a species at risk feature is identified, mitigation is required as per the Directives which may impact the overall project costs, siting and operations.

The following sections outline the justification and GOA policy support for the map layers used to develop the *Areas of Wildlife Habitat Sensitivity Map***.**

Methods

The renewable energy risk datasets were created using a combination of different wildlife sensitivity data, parks and protected areas, and native grassland landcover data (i.e., Grassland Vegetation Inventory, ABMI Landcover). The data were divided into four categories: 1) The Critical Wildlife Zone consists of all provincial parks and protected areas, trumpeter swan, mountain goat and sheep, greater sage-grouse, woodland caribou, and piping plover areas; 2) The “High Risk” category includes key wildlife and biodiversity zones, grizzly bear core habitat, native grassland and a 1000 meter buffer around all named lakes. 3) The “Moderate Risk” category consists of areas within 500 meters of all native grassland; and 4) the “Lower Risk” category consists of special access zones, grizzly bear support habitat, and areas 500-1000 meters from native grassland. All data were rasterized to 100 meter cells and the cell statistics tool was used to extract the highest value when multiple layers overlapped. The zonal statistics tool was then used to downscale the data by determining the majority risk value within a quarter-section, and that value was extrapolated to the entire quarter section and assigned to a risk category.

1.0 Greater Sage-Grouse (*Centrocercus urophasianus urophasianus*) **Range:**

Desired Outcomes:

1. Conserve and protect greater sage-grouse critical habitat and range.
    a. Maintain integrity of remaining leks and allow for reoccupation of historical lek sites
    b. Maintain habitat connectivity between lek sites and nesting/brood rearing habitat
    c. Maintain key winter and nesting/brood rearing habitat
    d. No new sensory disturbance
    e. Maintain greater sage-grouse lek attendance

Digital Layers available:

- Greater Sage-Grouse Range (existing Wildlife Sensitivity Layer in LAT) populations due to reproductive stress over time. Renewable energy operations are not compatible with ensuring populations of these important alpine species remain. Additionally, alpine habitat within mountain goat and sheep areas is more difficult to reclaim. The Directives require renewable development to avoid activities in the mountain goat and sheep zones.

5.0 Piping Plover (*Charadrius melodus)* Waterbodies:

Desired Outcomes:

1. Maintain piping plover waterbodies including identified habitat areas.
2. Decrease mortalities, nest abandonment, and nest depredation, off road vehicles and cattle.

Digital Layers available:

Piping Plover Waterbodies (existing Wildlife Sensitivity Layer in LAT)

Risk Ranking: Critical Wildlife Zone

Rational for Risk Ranking:
The piping plover is designated as *Endangered* in Alberta. Shoreline protection is identified as a key habitat management objective to ensure the long term persistence of this species in Alberta. Implementation of setbacks from the shoreline of identified water bodies will ensure renewable energy operations do not impact shorelines for breeding and foraging, or contribute to degradation of habitat required to recover this endangered species. The Directives requires avoidance of all lakes designated as Critical Habitat for piping plovers as identified by Environment Canada (Government of Canada 2007).

6.0 Native Grassland and Parkland Natural Region

Desired Outcomes

1. Reduce human caused wildlife mortality.
2. Recover and conserve habitat for species at risk.
3. Recover and conserve populations of species at risk.
4. Reduce increased predation associated with anthropogenic features.
5. Conserve and protect critical habitat.
6. Maintain the ecological conditions necessary for naturally sustainable wildlife populations to exist throughout Alberta, and conserve the habitat that they require.
   a. Maintain unique and/or important wildlife habitat sites.
   b. Avoid or minimize development within key habitats (local and landscape scales) and key seasons.
   c. Maintain habitat intactness, connectivity, and allow for wildlife use, breeding and passage

throughout areas by minimizing habitat loss and fragmentation.

7. Minimize potential adverse effects of land use activities on wildlife population health.
8. Reduce the potential for species avoidance of anthropogenic features.
9. Decrease potential for sensory disturbance and displacement of wildlife.

Digital Layers

- Grassland Vegetation Inventory (GVI)
- Alberta Biodiversity Monitoring Inventory Native Landcover 2010 Grassland Habitat
    - Note this layer will only be used in areas within the Grassland Natural Region for which GVI is not available. Once GVI or relative substitute (Parkland Vegetation Inventory, PVI) is fully available this layer will no longer be necessary.

Risk Ranking: To assist in industrial project preplanning, all areas of remaining native grassland in Alberta have been mapped. Quarter sections identified as native grassland within the Alberta GVI have been ranked as High, Moderate and Lower risk.

- **High**: Areas of native grasslands are ranked as High risk as they are likely habitat for one or more species at risk.
- **Moderate**: Areas within 500 meters of native grassland have been ranked as Moderate Risk.
- **Lower:** Areas between 500 - 1000 meters from native grassland are ranked as Lower Risk.

Rational for Risk Ranking:

The Grassland and Parkland Natural Region has undergone significant habitat changes since European settlement in the late 1800's. This has resulted in only 30% of the region remaining under native grassland cover (The Alberta Prairie Conservation Forum, 2016). The significant habitat alterations have had a direct impact on the wildlife populations in the region; consequently, the region is home to 75% of Alberta's species at risk. Species at risk found in the Grassland and Parkland Natural Region include, but are not limited to: ferruginous hawk (*Buteo regalis*), burrowing owl (*Athene cunicularia*), sharp-tailed grouse (*Tympanuchus phasianellus*), eastern short-horned lizard (*Phrynosoma herandesi*), prairie rattlesnake (*Crotalus viridis viridis*), northern leopard frog (*Lithobates pipens*), Great Plains toad (*Anaxyrus cognatus*), plains spadefoot toad (*Spea bombifrons*), mountain plover (*Charadrius montanus*), Sprague's pipit (*Anthus spragueii*), chestnut-collared longspur (*Calcarius ornatus*), Ord's kangaroo rat (*Dipodomys ordii*) and swift fox (*Vulpes velox*).

Industrial scale developments in these sensitive areas may result in negative impacts to these wildlife species and their associated habitat features. This includes, but is not limited to, direct mortality of species at risk, reduced productivity, and habitat loss/fragmentation, disturbance to the population or individuals and habitat avoidance/abandonment. The Directives identifies that avoidance of native grassland and parkland habitat as the first strategy to mitigating the potential negative impacts of development on species at risk.

As per the Directives, all areas ranked as *High* risk should be avoided for renewable developments. Areas identified as *Moderate* may require increased pre-assessment work, mitigation and project constraints due to the risk to specific species at risk in the area. The primary strategy identified in the Directives is to avoid development in these areas. Where avoidance is not possible specific mitigation strategies must be adhered to.

7.0 Grizzly Bear (*Ursus arctos horribilis)* Zone

Desired Outcomes:

1. Reduce all sources of human-caused mortality.
2. Reduce human-bear conflicts.
3. Avoid development within key habitats (local and landscape scales) and key seasons.
   a. Maintain high value and low mortality risk habitat areas.
   b. Avoid development of grizzly bear attractants (all sources).

Digital Layers available:

- Grizzly Bear Zone (existing Wildlife Sensitivity Layer in LAT)

Risk Ranking: Grizzly Bear Core Zones: High risk

Grizzly Bear Support Zones: Moderate

Rational for Risk Ranking:

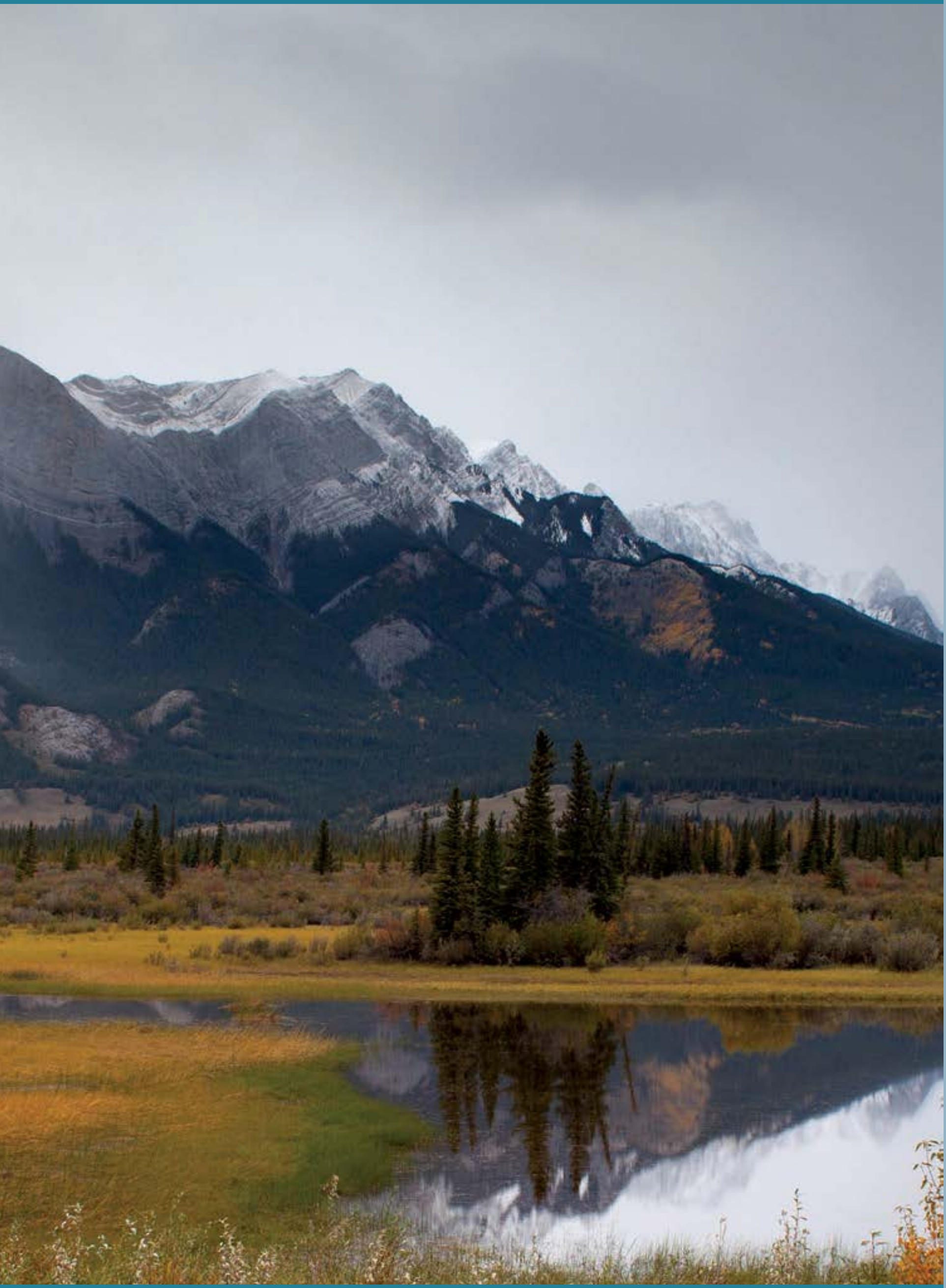
The grizzly bear is listed as a *Threatened* species under the Alberta *Wildlife Act*. The Alberta recovery plan has identified *Habitat Needed to Support Recovery* for the species (Government of Alberta, 2016). Human caused mortality (both direct and indirect) resulting from human access on roads is identified as the number one threat to grizzly bear populations in Alberta. Recommendations coming out of the *Grizzly Bear Recovery Plan for Alberta* suggest prioritising use of existing roads and minimizing increasing road footprint within the grizzly bear zone. This includes necessary breeding, overwintering, foraging habitat as well as movement corridors. These areas have been identified as areas of Moderate and High risk for future developments. The primary strategy identified in the Directives is to avoid development in these areas. Where avoidance is not possible specific mitigation strategies must be adhered to.

8.0 Key Wildlife and Biodiversity Zones

APPENDIX 3

Alberta Environment and Sustainable Resource Development. 2013. Alberta Wetland Policy. Government of Alberta, Edmonton. Website: https://open.alberta.ca/dataset/5250f98b-2e1e-43e7-947f-62c14747e3b3/resource/43677a60-3503-4509-acfd-6918e8b8ec0a/download/6249018-2013-alberta-wetland-policy-2013-09.pdf

Alberta Wetland Policy



Alberta Government

Wetland Management System

Several key concepts and mechanisms are crucial to the successful implementation of a provincial wetland management system under the Alberta Wetland Policy:

>>

1. Relative Wetland Value
2. Wetland Mitigation
   a. Avoidance
   b. Minimization
   c. Replacement
3. Knowledge and Information Systems
4. Performance Measures, Monitoring, and Reporting
5. Wetland Stewardship in Alberta

1. Relative Wetland Value

Alberta's wetlands are highly diverse in form, function, use, and distribution across the province; they are not all of equal value. The Alberta Wetland Policy addresses this diversity through the concept of 'relative wetland value', which acknowledges the relative contribution of an individual wetland to water quality improvement, hydrology, biodiversity, and various human uses. The approach is one of cumulative effects management, enabling planners and decision makers to consider the broader importance of an individual wetland on the landscape. In this way, knowledge and understanding of Alberta's vast wetland diversity is incorporated into the execution of informed management decisions.

The relative wetland value approach is based on the understanding that some wetlands provide more

Wetland Value Functional Groups

Biodiversity & Ecological Health
Wetlands are dynamic, complex habitats that contribute to biodiversity and other ecological functions.

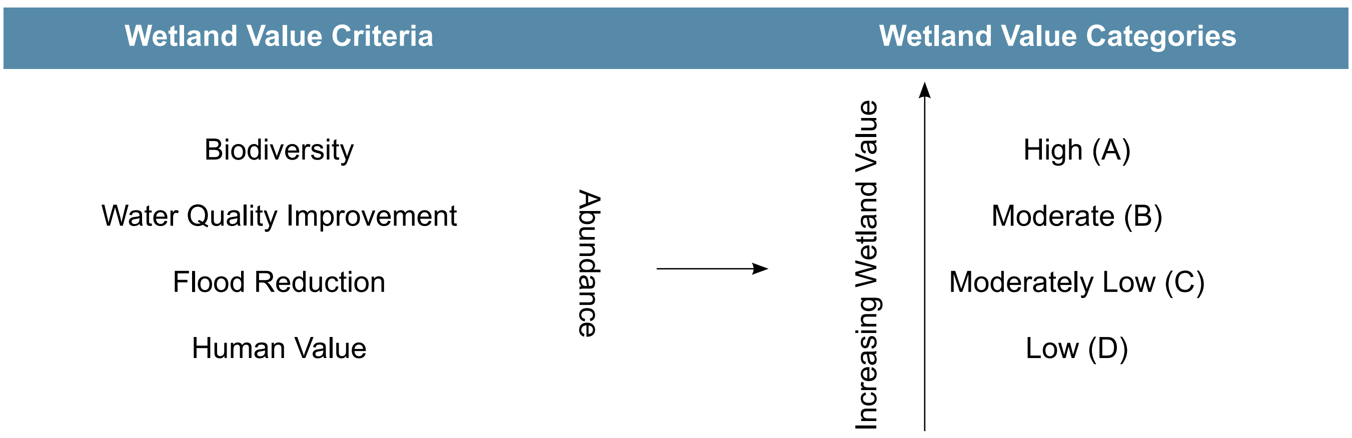
Water Quality Improvement
W

Hydrologic Function
W f and slowing its downstream release. They are also important as areas of groundwater recharge and discharge.

Human Uses
Wetlands support multiple human activities (e.g., recreation, and education) and have varying

Relative Abundance
The relative abundance of wetlands in an area strongly affects the sensitivity of an area to the effects of further wetland loss.

Based on the sum total of all metrics, wetlands will be assigned to one of four relative wetland value categories (A [highest] through D [lowest]).
wetland on the landscape, from an ecological and human perspective. In applying this approach, the Alberta W
regardless of their relative wetland value category.



The relative wetland value approach will ensure informed and strategic wetland management by taking into account numerous characteristics of a wetland. It will consider a wetland within a broader context, including the landscape upon which the wetland is found, the environmental functions it performs,
This will allow the importance of individual wetlands to be acknowledged, their contribution to the ecosystem to be better understood, and informed wetland management decisions to be made.

In keeping with a comprehensive and informed approach to wetland management, the ‘relative abundance’ component of the system incorporates aspects of current abundance/density and historical loss into the value assessment. In areas of low current abundance and high historical loss, the approach will place additional value on existing wetlands and promote both conservation and restoration as wetland management priorities. In areas of high abundance and low historical loss, the system will continue to acknowledge and promote the importance of wetlands and wetland values on the landscape. At the same time, it will facilitate a considered approach to wetland management, balancing environmental, social, and economic priorities in the execution of management decisions.

A wetland management system based on relative wetland value will help ensure that land use planners,

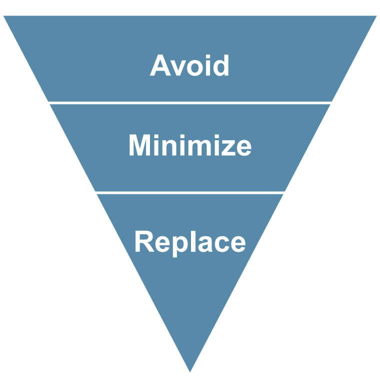
of their decisions at early stages in the planning process. At the same time, knowledge and understanding of relative wetland value will reinforce the wetland mitigation hierarchy (avoid, minimize, replace), providing sound rationale for decisions that may require avoidance or minimization of negative wetland impacts.

2. Wetland Mitigation

Under the Alberta Wetland Policy, mitigation refers to management activities undertaken to avoid and minimize negative impacts on wetlands, and to replace lost wetlands, where necessary. The term 'Wetland Mitigation Hierarchy' refers to a three stage approach toward achievement of wetland management objectives and/or goals. The three stages, listed in order of descending priority, are: 1) avoidance of negative wetland impacts, 2) minimization of negative wetland impacts, and 3) wetland replacement to account for negative wetland impacts that could not be avoided or minimized.

As part of the regulatory approval process, the mitigation hierarchy is intended to guide management actions for the mitigation of negative impacts on wetlands. Use of the hierarchy will be informed by relative wetland value, which will provide the rationale for wetland management decisions. It will be further supported by a decision-making framework, as well as codes of practice and standard operating procedures for some commonly occurring activities.

Alberta's Wetland Mitigation Hierarchy can best be described as follows:



1. Avoidance – The primary and preferred response is to avoid impacts on wetlands.
2. Minimization – Where avoidance is not possible, proponents are expected to minimize impacts on wetlands.
3. Replacement – As a last resort, and where avoidance and minimization efforts are not feasible or prove ineffective, wetland replacement is required.

Where achievable, wetlands will be replaced type-for-type; where this is not achievable, wetland replacement will seek to replace wetland value. Additionally, it is preferred that replacement take place in the area of original wetland loss.

Alberta's wetland mitigation system will be guided by ten overarching principles.

Guiding Principles of the Wetland Mitigation System

1. The primary focus of the wetland mitigation system is to sustain the full range of wetland
2. The mitigation hierarchy will encompass consistent and predictable processes. It will begin with (and place the greatest emphasis on) wetland avoidance, proceed through minimization only if avoidance is not practicable, and consider wetland replacement only as a last resort.
3. Mitigation is one component of a broader policy approach to wetland management that includes planning, education and awareness, and voluntary stewardship programs.
4. The wetland mitigation system will support cumulative effects management on a landscape

   considering place-based economic, social, and environmental priorities.
5. The wetland mitigation process will be considered in all stages of a project; from land or lease purchase, planning, siting, and design, through implementation and monitoring.
6. fective, predictable, fair, easily understood, and publicly accessible.
7. No one group will be expected to bear the entire burden of wetland tradeoff decisions. There must be some consideration of what constitutes an equitable sharing of environmental, social, and economic costs between all groups involved, including society at large.
8. Monitoring is an essential component of an adaptive management approach. In cases where a

   Government of Alberta will be responsible for monitoring and evaluation of the broader wetland mitigation system.
9. The wetland mitigation system will be adaptable, acknowledging and incorporating new information, as wetland science and public policy continue to evolve.
10. A comprehensive record-keeping system will be developed and used to maintain an administrative link between a development activity, the management decision, wetland impacts or losses incurred, and any resulting mitigation activities.

2a. Avoidance

Under the wetland mitigation hierarchy, the primary and preferred response is to avoid all impacts on wetlands. A fective mitigation strategy, as it eliminates the potential risks and inherent uncertainty of other mitigation practices. Since avoidance prevents direct wetland impacts, it is typically the most desired form of wetland mitigation.

To ensure feasibility and practicality, avoidance must be enabled at an early stage in the planning process. The Alberta Wetland Policy will facilitate this through provision of a relative wetland value map, which establishes the relative value of all wetlands in the province. This map, in conjunction with a ground-level assessment tool and operational guidance manual, will support the execution of informed wetland planning and management decisions. Although the mitigation hierarchy, as presented here, is discussed in the context of the *Water Act* approval process, avoidance will also be informed by a broader regional context for wetland management.

Wetland avoidance under the Alberta Wetland Policy will be achieved on the basis of the following four key criteria.

Guiding Principles of the Wetland Avoidance System

1. Avoidance should always be the primary considerations for any activity that could have adverse effects, regardless of wetland value.
2. In cases where avoidance is deemed impracticable and a negative wetland impact is likely to occur, wetlands of higher relative value should require stronger evidence of effort to avoid than lower value wetlands.
3. In cases where avoidance is deemed not practicable, it is the responsibility of the proponent to adequately demonstrate that alternative projects, project designs, and/or project sites have been
4. The process for evaluating feasible project alternatives must be fair should take into account environmental, social, and economic considerations.

2b. Minimization

Minimization is the second step in the wetland mitigation hierarchy. It is only applied once avoidance

The intent of minimization is to reduce negative impacts on wetlands to the smallest practicable degree. This is meant to be achievable during any stage of development, including planning, design, construction, and operation, as well as during the execution of activities that could harm wetlands.

Minimization of wetland impacts can be achieved through a number of different mechanisms. The minimization mechanism chosen or required will depend on several different factors, including the type and relative value of wetland, the development activity, and the desired outcome. Much like wetland avoidance, minimization will be informed by the relative wetland value map, a ground-level value assessment tool, and an operation guidance manual.

The minimization of wetland impacts under Alberta's wetland mitigation system will be guided by the following eight overarching criteria.

Guiding Principles of the Wetland Minimization System

1. Minimization of adverse effects to a wetland refers to both direct and indirect effects on the physical area of the wetland, the relative value of the wetland, or a combination of both.
2. Minimization procedures and techniques should be based on sound ecological principles and best available science and technology.
3. Minimization is usually accomplished through the use of proven measures and approaches for
4. Where minimization is to be accomplished through new and experimental approaches, activities should be carried out on a pilot basis and monitored to assess effectiveness. Proponents should not be penalized if a new or experimental approach does not achieve intended outcomes.
5. Minimization procedures should be based on continuous improvement, using an iterative or adaptive approach to advance the state of knowledge and science over time.
6. Minimization measures should remain functional as long as the project has reasonable potential for adverse effects on the wetland.
7. Monitoring may be required to evaluate the outcome of minimization activities. The cost of monitoring should be factored into any minimization process and is the responsibility of the proponent.
8. Efforts to minimize adverse effects to wetlands do not relieve the proponent of wetland replacement requirements; in the event of permanent wetland loss, despite minimization efforts, wetland replacement will be required.

2c. Replacement

Where avoidance and minimization efforts are not feasible or prove ineffective, wetland replacement is acknowledged as the last resort in the mitigation process. It will only be considered for residual impacts that were impractical to minimize or avoid and will not apply to temporary wetland impacts. If, after all practicable avoidance and minimization measures have been exercised, permanent loss of a wetland, or portion thereof, is incurred, wetland replacement will be required for the portion that is lost. Replacement requirements will be established on the basis of a) wetland area lost and b) the relative value of that area. In cases where development that results in wetland loss is subject to a reclamation plan, replacement requirements will be adjusted accordingly, taking into account the area and value of both wetlands lost and wetlands constructed under the reclamation plan.

Wetland replacement will fall into one of two overarching categories:

- **Restorative Replacement** refers to replacement activities that attempt to make up for the permanent loss of a wetland through the restoration, enhancement, or construction of another wetland.
- **Non-restorative Replacement** refers to a variety of alternatives that must support the maintenance of wetland value, by advancing the state of wetland science and wetland management. Acceptable non-restorative replacement measures include:
  -
  - Provincial level monitoring of wetlands
  -
  -
  - Public education and outreach programs
  - Wetland securement for the purposes of long term conservation

Replacement can be further divided into two subcategories. *in-lieu* fee payment, These funds will

guidance documents. The second subcategory is permittee-responsible replacement, whereby the approval holder may choose to actively engage in restorative replacement, in accordance with criteria and guidance put forth by the Government of Alberta.

A comprehensive decision making framework, including a sound wetland research strategy, will guide the application of replacement measures. Additional criteria will direct the inclusion of constructed wetlands as an element of restorative replacement, as well as the proportion of non-restorative replacement measures that are permitted as part of a replacement package.

Replacement requirements will be established on the basis of replacement ratios. A replacement ratio determines how many hectares of replacement wetland are required per hectare of permanently lost wetland. The ratio system has been developed on the basis of relative wetland value, taking into account both the relative value of the impacted wetland and that of the replacement wetland.

The suite of replacement ratios developed by the Government of Alberta is established around a midpoint of 3:1. This ratio, which is the basis for Alberta's interim wetland policy, is broadly recognized throughout North America. It is based on three key considerations:

1. A restored wetland is unlikely to achieve the same level of function as the natural wetland it replaces.
2. A , between the moment a wetland is lost and the point a restored wetland achieves a reasonable level of function.
3. Some proportion of restored wetlands is expected to fail over time.

As the midpoint for the range of core replacement ratios (blue in the following table), the 3:1 ratio will help support the overarching goal of the Alberta Wetland Policy – to *conserve, restore, protect, and manage* Alberta' s they provide to the environment, society, and economy. At the upper end, the 8:1 replacement ratio will help incent avoidance of high value wetlands, thereby supporting Outcome #1 of the Alberta Wetland Policy – wetlands of the highest value are Albertans.

The Wetland Replacement Matrix

		Value of Replacement Wetland			
		D	C	B	A
Value of Lost Wetland	A	8:1	4:1	2:1	1:1
	B	4:1	2:1	1:1	0.5:1
	C	2:1	1:1	0.5:1	0.25:1
	D	1:1	0.5:1	0.25:1	0.125:1

*Ratios are expressed as hectares of wetland

The core replacement scheme established by the Alberta Wetland Policy
column in the preceding table, is expressed in terms of low value, or 'D', wetlands. This core scheme will apply to all cases of *in-lieu* fee payment. For example:

1. If the loss of a one-hectare 'B' value wetland is approved, the approval holder will be expected to pay wetland replacement at a rate of 4:1, or four hectares of 'D' wetland.
2. If an approved development project results in the loss of 8 hectares of 'C' value wetland, the approval holder will be required to replace at a rate of 2:1, or 16 hectares of 'D' wetland.

In the case of permittee-responsible replacement, the Alberta Wetland Policy seeks to encourage innovation and continuous improvement in wetland restoration and construction. It does so by acknowledging efforts to restore a wetland to a higher value. For example:

1. As part of its *Water Act* approval, Company X is permitted to develop one hectare of 'B' value wetland. Normally, this would require four hectares of 'D' value wetland as replacement (4:1). However, Company X has decided to engage in permittee-responsible replacement and, through the investment of additional effort and resources, is able to demonstrably restore a 'C' value wetland. Hence, the replacement requirement will be reduced to 2:1, or two hectares.
2. Company Y has received approval to remove four hectares of 'D' value wetland in the course of developing an industrial park. Normally, this would require four hectares of 'D' value wetland as replacement (1:1). In pursuing permittee-responsible replacement on an adjacent property, Company Y is demonstrably able to restore a 'C' value wetland. The replacement requirement is therefore reduced to two hectares (0.5:1) of 'C' value wetland.

The cost of *in-lieu* fee payment for wetland replacement will be established on the basis of four key factors:

1. The average cost of wetland restoration work [established provincially].
2. The cost of monitoring restoration success over the long term [established provincially].
3. An administrative fee [established provincially].
4. The average value of land within the area of original wetland loss [established locally].

Payment of wetland replacement under the Alberta Wetland Policy will not exempt the applicant from other requirements that may be enacted under the provincial *Public Lands Act*, as it pertains to the acquisition of beds and shores of water bodies titled to the Crown.

APPENDIX 4

Alberta Environment and Sustainable Resource Development. 2015. Recommended Land Use Guidelines: Key Wildlife and Biodiversity Zones. Alberta Environment and Sustainable Resource Development, Edmonton. Website: https://open.alberta.ca/dataset/5c6e2826-50ab-4d2a-a673-9d703d6b5c52/resource/d8d1b2e9-3a72-471d-9479-56db5ee68210/download/KeyWildlifeBiodiversityZones-Apr08-2015.pdf

Recommended Land Use Guidelines: Key Wildlife and Biodiversity Zones

Wildlife Land Use Guidelines

The Key Wildlife and Biodiversity Zone will function in the same manner as Key Wildlife and Watercourse Areas or Ungulate Winter Areas or Moose zones, found on earlier versions of Area Wildlife Referral maps.

Rationale for Special Protection of Key Wildlife and Biodiversity Zones

The Key Wildlife and Biodiversity Wildlife Zones are considered to be a combination of key winter ungulate habitat and higher habitat potential for biodiversity. In some areas this zone consists of important riparian vegetation complexes that are important for biodiversity, while in other areas it indicates important winter ranges for ungulates. In North America, particularly at more northern latitudes, wildlife may enter a negative energy balance during the late fall and winter season. This is the result of lower quality and less accessible food resources combined with harsher environmental conditions, such as cold temperatures and deep or crusted snow. Drought and high wind chill may be compounding factors, particularly in the Montane Natural Regions of southern Alberta. This negative energy balance usually lasts until spring green-up when new plant growth becomes available.

The basic strategy for the majority of wildlife during the winter season is to minimize energy expenditures and use stored body fat reserves to supplement winter food resources of limited quantity and quality. Behavioral adaptations include:

- Selection of localized and familiar habitats that provide relatively high quality and abundant winter food resources in proximity to good thermal and security cover.
- Reduced movement, with increased amounts of time spent resting in locations that minimize body heat loss and energy expenditure.

Typically, Key Wildlife and Biodiversity Zones occur along major river valleys. These landforms contain the topographic variation and site productivity conditions that provide increased levels of biodiversity and good winter browse conditions in proximity to forest and topographic cover. Additionally, south-facing valley slopes have relatively lowers now accumulations and warmer resting sites for ungulate species. The valley landform itself provides protection from high wind chills.

Key Wildlife and Biodiversity Zones play a disproportionately large role in the landscape given their localized size and distribution, in maintaining the overall productivity of regional ungulate populations and source of biodiversity. These zones ensure that a significant proportion of the breeding population survives to the next year.

Industrial activity within and adjacent to Key Wildlife and Biodiversity Zones adds stress and increases energy drain for animals. Wildlife may be forced to move about more than normal and even relocate to less favorable habitat. This becomes an increasingly significant factor as winter progresses. Industrial activity may also create temporary and permanent access that exposes animals to additional non-industrial disturbances and to greater pressure from predators.

In the interest of maintaining areas of biodiversity and productive ungulate populations in Alberta, industrial land use guidelines must reflect an understanding of the wildlife biology and the importance of key winter ranges for ungulates. The Key Wildlife and Biodiversity Zone is intended to:

- protect the long term integrity and productivity of key ungulate winter ranges and river corridors where ungulates concentrate.
- protect locally and regionally-significant wildlife movement corridors.

- protect areas with rich habitat diversity and regionally-significant habitat types.
- protect key hiding and thermal cover for wildlife.

Primary strategies for protection in these zones are as follows:

a) Protect vegetation from being cleared by minimizing all industrial activity. (This forest growth is essential for providing food and thermal protection for ungulates, and protecting the slopes from erosion and other degradation.)

b) Minimize activity during winter months to avoid displacing wildlife.

c) Reduce access and/or do not create new access.

d) Follow general timing restrictions

The areas where these conditions apply will be illustrated as “Key Wildlife and Biodiversity Zones” within the Wildlife Sensitivity Layers that are consistent with the Landscape Analysis Tool and available at: http://esrd.alberta.ca/forms-maps-services/maps/wildlife-sensitivity-maps/default.aspx

Guidelines

1. New permanent access development is not recommended. Where permanent access is essential, an access management plan and associated approval will be required to address the need to minimize disturbance to wildlife and degradation of associated habitat. Access control will be required to minimize public vehicle traffic on these roads. The highest priority should be to develop the option that uses temporary access and strives to access resources from outside the zone (e.g. directional drill, remote production)

2. Where temporary access is required, it should be designed and managed to minimize disturbance to wildlife and degradation of associated habitat.

3. The applicable timing restrictions on industrial activities are applicable and required for all upgraded access and/or seismic activity due to the impacts on wildlife. Timing restrictions (no activity) apply to activities occurring within Key Wildlife and Biodiversity Zones:

   i. All areas identified as Key Wildlife and Biodiversity zones that are North of HWY #1; no construction between January 15th and April 30th

   ii. All areas identified as Key Wildlife and Biodiversity zones that are South of HWY #1 and west of HWY #2; no construction between December 15th and April 30th

4. Guidelines will be applied in an equitable fashion for all industrial sectors within a region, recognizing that some flexibility is required for site/area-specific conditions and particular land use activities. The expectation is that all winter activities are planned to be completed prior to the timing restrictions. Relaxation from the timing restriction requires approval and is based on extenuating circumstance. For example,

   i. Timing restrictions may be adjusted in exceptional and localized situations if other considerations are applied that still protect the wildlife resource.

   ii. Where localized temporary valley crossings are required to access adjacent tableland areas outside of the Key Wildlife and Biodiversity Zones.

APPENDIX 5

Alberta Sustainable Resource Development. 2010. Industrial Activity in Foothills Fescue Grasslands — *Guidelines for Minimizing Surface Disturbance.* Prepared by Alberta Sustainable Resource Development, Lands Division. Edmonton, AB. Website: https://open.alberta.ca/dataset/572ff6d5-807e-40ee-a4d8-117ae4cfd23e/resource/88217c9c-b413-4d98-a1cf-e2cb326d6149/download/2010-grassland-minimizingsurfacedisturbance.pdf

Industrial Activity in Foothills Fescue Grasslands — *Guidelines for Minimizing Surface Disturbance*

Prepared By

Alberta Sustainable Resource Development,

Lands Division

March 2010

Government of Alberta

Industrial Activity in Foothills Fescue Grasslands — Guidelines for Minimizing Surface Disturbance

Introduction

This background document has been prepared to supplement Information Letter 2009-04, ***Foothills Fescue Grassland Information Letter- Principles for Minimizing Surface Disturbance.***

The importance of foothills fescue grasslands has been recognized through the designation of foothills rough fescue (*Festuca campestris*) as our provincial grass. Extensive tracts of foothills fescue grassland within the landscape of south western Alberta have been lost due to agricultural crop production, industrial development, urban and rural infrastructure. Alberta Sustainable Resource Development (SRD) has placed Protective Notations (PNT) on specified public lands known to include foothills fescue grassland. The purpose of the PNT is not to restrict development but to alert industry to the environmental and economic risk. The Information Letter supporting the PNT identifies the expectations for planning and development standards.

Foothills fescue grasslands contribute ecological goods and services important to the economy and public interests of Alberta. The value of retaining the ecological health and function of these grasslands is acknowledged by the ranching community, government agencies, stewardship groups and through conservation easements on freehold lands. Of increasing value to Albertans is the role foothills fescue grasslands play in maintaining surface and groundwater resources. Also there is an increasing awareness of their role in capturing and storing carbon. It is recognized that fragmentation of these remaining fescue grasslands jeopardizes their ecological health, function and operability.

The Spatial Distribution of Foothills Fescue Grasslands

Foothills rough fescue grasslands occur as the dominant native plant communities in the Foothills Fescue Natural Subregion and are co-dominant with forest and shrub communities in the Foothills Parkland Natural Subregion. These grasslands may also occur in open valley bottoms and on south facing slopes, ridges, or as patches in the Montane and Sub-alpine function and operability of fescue grasslands. Winter forage, critical for sustaining important wildlife species such as elk, is reduced. Forage production for livestock is less stable and forage quality is diminished. Biodiversity, critical to ecological health and function, is diminished. The important hydrologic function that rough fescue grasslands provide is reduced, accelerating surface runoff, and soil erosion. This in turn affects both water quantity and quality for downstream users.

Factors Limiting Restoration Potential

Unlike many native prairie ecosystems, natural recovery has failed to restore foothills fescue plant communities as the native plants simply cannot compete with invasive non-native species. Disturbed sites seeded with native plant cultivars have resulted in limited success in reducing non-native species invasion. Long term restoration success has yet to be demonstrated and documented on industrial sites subjected to the full range of production and operational disturbance related activities.

Efforts and research to develop methods to successfully restore native rough fescue plant communities are ongoing and these efforts are encouraged. To date, commercially available rough fescue seed is available only through wild harvest collection. Many factors have prohibited the native seed industry from providing a reliable source of wild harvested rough fescue seed from the Natural Subregions of Alberta. Research projects and reclamation trials are ongoing regarding the use of nursery raised rough fescue grass plugs, forbs and shrubs. Wild harvested native seed has been used on a trial basis and research is currently being conducted regarding the use of wild harvested hay. These projects, while encouraging in the initial stages, have not been completed, nor subjected to a full range of environmental and climatic conditions.

APPENDIX 6

Alberta Water Council. 2013. Riparian Land Conservation and Management Report and Recommendations. Alberta Water Council, Edmonton. Website: https://www.awchome.ca/_projectdocs/?file=e807bf3e2ed51423

ALBERTA WATER COUNCIL

NOVEMBER 2013

Riparian Land Conservation and Management Report and Recommendations

Figure 7: Examples of riparian land mapping

Riparian Map Upper Wildhay 100,000ha

Photo Credit: Hinton Wood Products

Riparian Map Orthophoto

Photo Credit: Hinton Wood Products

7.2 Methods for Riparian Health Assessment

Healthy riparian lands can help deliver a full range of ecological goods and services — clean water, flood protection, pollutant filtering, biodiversity, and other elements. Because riparian functions can be impaired due to natural and human causes, recognizing the dynamic nature of these areas in planning, management and monitoring is important. For example, after a flood event riparian lands may be impaired. However, floods are essential to maintain long-term riparian function because, among other things, they scour channels, clean sediments from fish spawning gravel, and add coarse woody debris to the riparian system. Assessment efforts also need to incorporate or account for land use variability, and plan for overall, long-term health and function.

The Fiera report defined riparian health as "*the ability of an ecosystem to perform a number of key ecological functions.*" There are many ways to evaluate and define what we mean by riparian health, although a basic method, championed by Cows and Fish, is widely used and accepted in Alberta.[38]

Riparian health assessments define baseline conditions or outline areas where health has changed, including where it has been degraded and should be restored. Riparian health assessment data has been collected mostly at the local watershed and site level and may not always be publicly available. Some sectors require provincial scale information to inform decision-making efforts, and sampling at finer scales may not provide the type of information required unless it is structured to be representative. A lack of systematic data gathering for riparian health information has limited our ability to quantify riparian health at some scales. In addition, lack of comprehensive data limits our ability to understand connectivity of riparian lands. Although the health assessment methods themselves would not necessarily require

38 Cows and Fish. 2013. Online at: www.cowsandfish.org/riparian/health.html. Accessed March 2013.

APPENDIX 7

Bow River Basin Council. 2012. Bow Basin Watershed Management Plan: Land Use, Headwaters, Wetlands, Riparian Lands, Water Quality. Bow River Basin Council, Calgary. Website: https://brbc.ab.ca/our-activities/bow-basin-watershed-management-plan

Bow River Basin Council

Bow Basin Watershed Management Plan 2012

Land Use, Headwaters,
Wetlands, Riparian Lands, Water Quality

ISBN: 978-0-9737429-2-3

The BRBC would like to thank the ENMAX Corporation and the Government of Alberta for their generous financial contributions towards the production of the Bow Basin Water Management Plan 2012.

This report is available and may be freely downloaded from the BRBC website at www.brbc.ab.ca.

Cover Photo: Quirk Creek, courtesy of Jamie Dixon

COPYRIGHT AND TERMS OF USE

PERMISSION STATEMENT

DISCLAIMER

CONTACT US

To learn more about the Bow Basin Watershed Management Plan 2012, please contact Mark Bennett, BRBC Executive Director at (403) 268-4596 or via e-mail at Mark.Bennett@calgary.ca.

OUTCOMES

	BOW BASIN SCALE
9.2 Water Quality	• Surface water quality is improved. – Maintain or enhance surface water quality (and linked alluvial aquifers) for human consumption. – Surface water quality that is appropriate for irrigation of crops. – Surface water quality that is appropriate for livestock watering. – Surface water quality that protects water withdrawal systems from high levels of algae and/or macrophytes. – Surface water quality that maintains the existing cold-water and/or cool-water aquatic functionality. – Surface water quality where body contact recreation is safe. • Rivers and streams are free of "nuisance" growth of aquatic vegetation.
9.3 Water Quantity	• Recognition that high and low flow periods are essential to aquatic and riparian ecosystems. • Significant groundwater recharge and discharge areas are identified and protected to sustain surface and groundwater supply. • Alluvial aquifers and floodplains are identified and protected as shallow water reservoirs for sustaining instream flows during low flow periods. • Efficient water use through improved urban, rural residential, agricultural, and industrial conservation practices. • Appropriate instream flow needs year-round to enhance a functioning ecosystem. • As opportunities present, enhanced flows for recreational opportunities.
9.4 Land Use	• Lands are managed with source water protection as a high priority. • Hydrologically significant lands are identified, conserved and managed to sustain their functionality. • Cumulative effects management principles are applied to all land management decisions. • Integrated landscape management principles are applied to all land management decisions. • Landscapes support healthy ecosystems with an abundance of economic, aesthetic and recreational opportunities. • Land conserved and/or managed for multiple uses with minimal impact on water-related natural, cultural and historical assets in order to protect the ecological integrity of the area. • Invasive plant species are reduced, especially in riparian lands adjacent to watercourses and water bodies. • Restoration of indigenous upland plant communities where opportunities exist. • Enhanced knowledge and understanding of: – the spatial connectivity of structural and functional terrestrial and aquatic landscape features, inter-relationships and processes that produce ecosystem services at a regional scale; – ecosystem services provided by soils, vegetation and landscapes and methods to quantify the value of these ecosystems services; – how uplands can have direct and indirect influences on water quality and quantity.
9.5 Riparian Lands	• Existing riparian land including associated upland areas are kept intact or restored, ecologically functional, appreciated and valued. • Core ecological functions of healthy riparian lands are maintained (e.g., water quality protection, water storage and flood conveyance, bank stability, biodiversity, soil health, etc.). • Invasive plant species are reduced, especially in riparian lands adjacent to watercourses and water bodies. • Enhanced knowledge and understanding of: – the importance of the composition, structure and health of the upland area to the health of riparian lands; – the functions provided by riparian land and how to conserve and manage for those functions.
9.6 Wetlands	• Impacts to existing wetlands should be avoided wherever possible. • Existing wetland complexes including associated upland areas and ephemeral wetlands are kept intact or restored, ecologically functional, appreciated and valued. • Core ecological functions of healthy wetlands are maintained (e.g., water quality protection, water storage and flood protection, biodiversity, habitat, etc.). • Invasive plant species are reduced, especially in riparian lands adjacent to watercourses and water bodies. • Enhanced knowledge and understanding of: – the role wetlands play in supporting healthy watersheds through water capture and storage, groundwater recharge and/or discharge, and water purification; the importance of connectivity of wetlands to the continued functionality of wetlands.
Headwaters and Other Hydrologically Significant Areas	• Headwaters are managed with source water protection as the highest priority. • Headwaters are managed to provide a continuous supply of clean water to meet the needs of the environment, and the residents of the Bow Basin and those who depend on its water, now and in the future. • Enhanced knowledge and understanding of the key ecosystem services provided by headwaters.

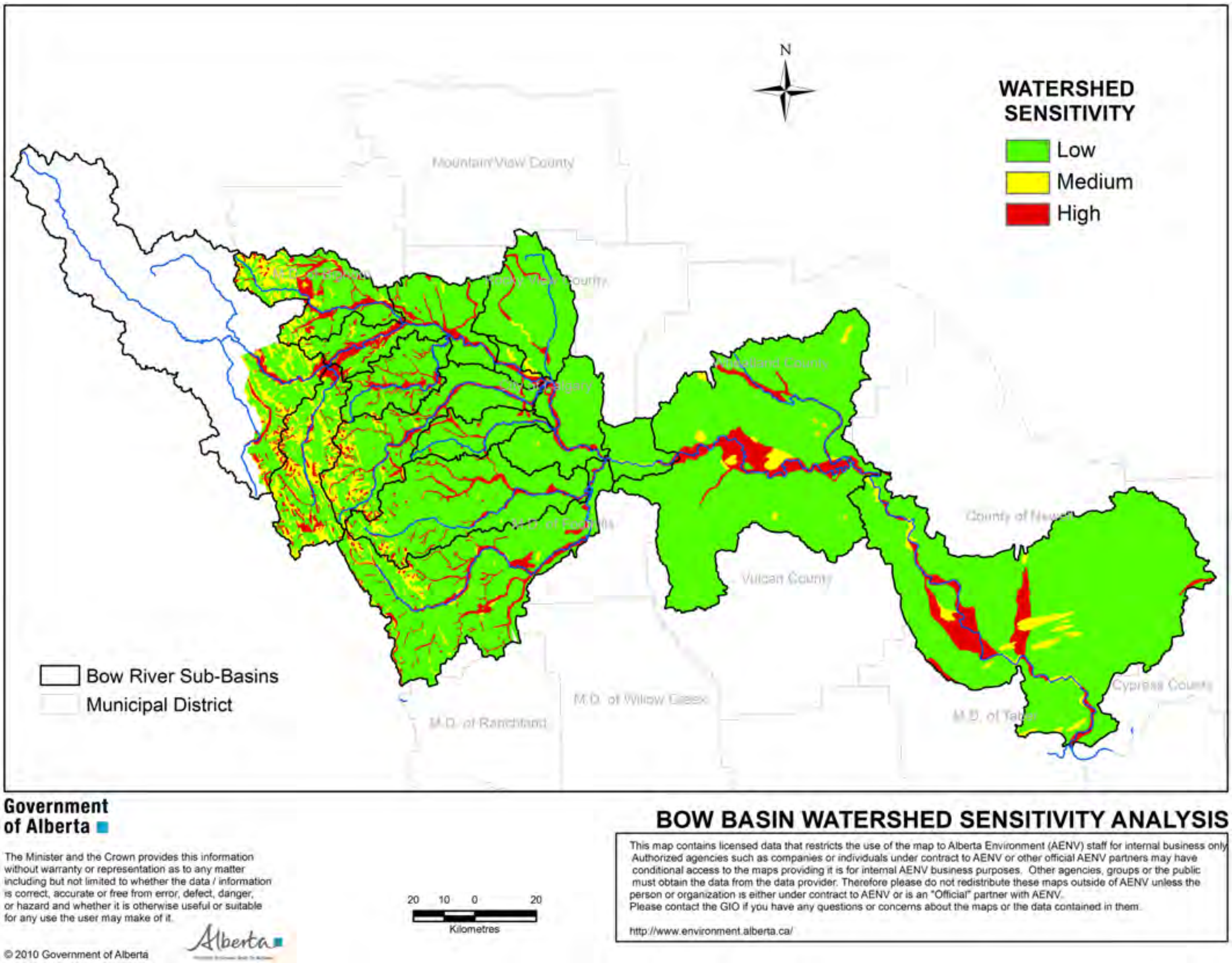


Figure 6: Bow Basin Watershed Sensitivity Analysis[53, 54]

- Land conserved and/or managed for multiple uses with minimal impact on water-related natural, cultural and historical assets in order to protect the ecological integrity of the area.
- Invasive plant species are reduced, especially in riparian lands adjacent to watercourses and water bodies.
- Restoration of indigenous upland plant communities where opportunities exist.
- Enhanced knowledge and understanding of:
  - the spatial connectivity of structural and functional terrestrial and aquatic landscape features, interrelationships and processes that produce ecosystem services at a regional scale;
  - ecosystem services provided by soils, vegetation and landscapes and methods to quantify the value of these ecosystems services;

[53] This map was developed by AEW using a Geographic Information System (GIS) based overlay analysis that highlights areas within the Bow River sub-basin and selected watersheds that have high cultural, environmental, or social value and can potentially be affected by management decisions. The groups of features selected to be included covered three main themes: groundwater, land and surface water. One of the main criterions used in selecting the individual parameters was that digital data that could be used within a GIS had to be available for the entire Bow River sub-basin to allow comparisons between different areas and sub-watersheds. Many of the provincial datasets do not extend into the headwaters portion located in Banff National Park, hence its exclusion. The analysis work assigns each of the features with a sensitivity or value ranking from a value of one, the lowest sensitivity/value, to a maximum of three for the highest sensitivity/value. Map algebra was then used to sum all the layers to find the areas of the highest sensitivity or value in the basin. The full text for the map disclaimer is located in Footnote 43.

[54] For a complete description of how this map was developed, please refer to *Future Planning Priorities for the Bow River Basin Council,* http://www.brbc.ab.ca/pdfs/SWATMaterials/SWAT_May_6_2009_Final_Report.pdf

2.2.6 INDICATORS AND THRESHOLDS

INDICATOR	TRIGGERS, LIMITS AND TARGETS[66]	PRIORITY & TIMELINE
Area of functioning riparian lands	Target: No net loss of area of functioning riparian lands. This target "may" be achieved through 1) avoidance of negative impacts, 2) the development of new policies and bylaws, 3) the application of best management practices (e.g., fencing and off-stream watering allowing some riparian areas to recover), and 4) through restoration of degraded riparian lands (with the understanding that restored riparian lands will take substantial time to recover their original function) and 5) changes to river management (i.e., flow changes). Other tools may also be used.	Long-Term by End 2017
Restoration of riparian lands identified as degraded as a result of human activity	Target: Riparian lands identified as degraded have a plan in place to address the recovery or restoration of riparian function. This target for restoration can be captured by the indicators immediately above and below.	Medium-Term by End 2015
Condition of riparian land health as indicated using the *Cows and Fish Riparian Health Inventory Rating System* or alternative methodologies	Target: Riparian land health is one level higher than initial conditions measured using the Cows and Fish Riparian Health Inventory rating system (Fitch and Ambrose 2003) (e.g., "unhealthy"➔"healthy with problems"➔"healthy"). If the river and/or reach previously rated as "healthy", the target remained as "healthy". In all cases, the long-term goal is "healthy". See table below. Alternative methodologies could include aerial surveys, float evaluations, etc.). The chosen method of evaluation should be carefully considered depending on the location and characteristics of the area (e.g., rural versus urban).	Very Long-Term by 2030
Percentage of Bow Basin Municipalities with riparian conservation and setback guidelines and/or policies for future development and redevelopment	Target: 100% of Bow Basin Municipalities with riparian conservation, restoration and management guidelines, policies and/or bylaws for future development and redevelopment based on no further loss or impairment of riparian lands.	Short-Term by End 2013

THEORETICAL EXAMPLE OF RIPARIAN HEALTH STATUS OF SAMPLED SITES DURING IDENTIFIED TIME PERIODS			
RIPARIAN HEALTH CATEGORY	2001-2005	2006-2010	2011-2015
Healthy	36% (4/11)	36% (5/14)	38% (5/13)
Healthy with Problems	36% (4/11)	43% (6/14)	46% (6/13)
Unhealthy	27% (3/11)	21% (3/14)	15% (2/13)

[66] Limits represent levels at which the risk of adverse effects on environmental quality is becoming unacceptable. Triggers are set in advance of limits as early warning signals. Limits and triggers consider current science, and are meaningful and future-focused. Targets are an indicator value that reflects a desirable environmental outcome.

APPENDIX 8

Bradley, C., and M. Neville. 2010. Minimizing Surface Disturbance of Alberta's Native Prairie--Background to Development of Guidelines for the Wind Energy Industry. Foothills Restoration Forum and Prairie Conservation Forum. Website: http://www.albertapcf.org/rsu_docs/wind-energy-background-final-december-2010.pdf

Minimizing Surface Disturbance of Alberta's Native Prairie

Background to Development of Guidelines for the Wind Energy Industry

December 2010

Authors:

Cheryl Bradley M.Sc., P. Biol.

and

Marilyn Neville
Coordinator, Foothills Restoration Forum

Foothills Restoration Forum

PRAIRIE CONSERVATION FORUM

Site operation involves:

- Regular visits (weekly) for routine maintenance of turbines (e.g. oil changes), power lines and all-weather access routes over the life of the project. Turbine life is estimated to be about 25 years. Maintenance may require temporary work space of large equipment.
- Repowering may be undertaken which is replacing existing turbines with new technology and extending the lifetime of the project to several decades.

Site decommissioning involves:

- Removal of turbines and other equipment including power cables and transformer stations.
- Partial excavation and removal of cement tower base to depth >1.5 meters.
- Reclamation of disturbed areas, including access routes if required by the landholder.

Estimates of direct surface disturbance per turbine vary depending on terrain and turbine size and type. The Bureau of Land Management (BLM 2005) estimates the surface disturbance per turbine to be approximately 0.5-1.5 ha (1-3 acres). For recent Alberta wind projects, the area of permanent surface disturbance over the lifetime of the project for a 1.5 - 2 MW turbine 80m in height and with 90m blade diameter is estimated to be .06 ha (25 m x 25 m) (Golder 2009, Nexen 2010, West WindEau Inc. 2007). The area of temporary surface disturbance during construction for each turbine is 1 ha (100 m x 100 m). In addition there is surface disturbance for an access route and a power cable trench to each turbine, the area of disturbance varying according to the project site.

A wind energy project may have several to dozens of turbines. Large turbines in a row are spaced 250 m apart and rows of turbines are spaced 500 m apart (five to ten turbine diameters of spacing). Given this spacing, the project area encompassing a dozen 2 MW towers (25-megawatt wind project) may be between 100 ha (250 ac), if all in a row, and 250 ha (about 1 section, 625 ac) if in three rows. As well each project requires access routes, power cable trenches and one or more transformer stations (1-2 ha each). The area of direct disturbance of native vegetation for all activities related to a wind energy project, is conservatively estimated to be 5 to 10% of the total project area (BLM 2005, National Research Council 2007, Canadian Wind Energy Association 2010). Additional vegetation disturbance results through compaction by heavy equipment and introduction of invasive non-native species.

There are approximately 5500-6000 MW of wind generation projects that have applied for connection to the Alberta transmission system as of Spring 2010 with projections of 11,000 to 12,000 MW of potential wind generation in future (Alberta Energy 2009, Southern Alberta Alternative Energy Partnership 2009). Approximately 1100 - 5500 turbines could be installed over the next few decades in southern and central Alberta, estimating 2-5 MW of power generated per turbine. Given that surface disturbance per turbine is 0.5 – 1.5 ha, a total direct surface disturbance footprint of 550 - 8250 ha can be anticipated that would increase with indirect impacts such as introduction and spread of non-native species into native vegetation. This footprint distributed across the remaining native prairie can potentially have significant negative impact.

5.0 Challenges in Prairie Restoration

Very little information is available on decommissioning and reclamation of wind power projects since very few have been decommissioned in the prairies. We can however learn from the results of reclamation efforts related to other types of activities.

An analysis by Gramineae Services Ltd. (2007) of revegetation strategies for industrial disturbances on native prairie sites in Alberta contains the following key findings:

- Mixed Grasslands – Natural recovery of dry mixed grasslands does occur if fragmentation is minimal, disturbance is minimized and grazing is managed to benefit restoration of native vegetation. Moist mixed grasslands are more fragmented than dry mixed grasslands and more susceptible to invasion by invasive non-native species such as smooth brome and crested wheat grass. For both dry and moist mixed grasslands a recommended strategy is avoidance. If avoidance is not possible, then minimize disturbance and use natural recovery.

- Rough Fescue Grasslands – Successful restoration of rough fescue grasslands has not been documented. Climate in regions supporting rough fescue grasslands presents numerous challenges for industrial development. Revegetation success is hampered by invasive non-native species such as smooth brome, Kentucky bluegrass and timothy. Avoidance is the preferred strategy.

In 2006 the Foothills Restoration Forum came together to accomplish the restoration of the native grassland ecosystems of southwestern Alberta. Focus has been on fostering research and filling critical gaps in our knowledge base regarding restoration of rough fescue grasslands (see www.foothillsrestorationforum.com).

6.0 Information Letters, Principles and Guidelines for Minimizing Native Prairie Disturbance

In 1996 the Energy Resources Conservation Board issued an Information Letter (ERCB IL 96-9) alerting all oil, gas and pipeline operators to the environmental and economic risk of developing native prairie and parkland environments. Concern about loss and fragmentation of native prairie from petroleum industry activity and a desire to improve industry practices prompted the provincial government to develop this initial set of guidelines for minimizing disturbance. Several documents have since been produced regarding minimizing surface disturbance of native prairie by the petroleum industry. The following provide valuable lessons that can, with some modification, be applied to the wind energy industry.

- *Energy Resources Conservation Board Information Letter 2002-1 Principles for Minimizing Surface Disturbance in Native Prairie and Parkland Areas*.
  EUB IL 2002-1 supersedes ERCB IL 96-9 and is a set of principles reflecting continuing improvement in industry practices and understanding of native prairie and parkland environments. Principles were developed and endorsed by a team of representatives from government agencies having jurisdiction over petroleum industry activities - Alberta Energy, Alberta Environment, Alberta Sustainable Resource Development and the Special Areas Board. IL 2002-1 states that although the principles were developed specifically for the petroleum industry, they are applicable to any other activities proposed for an area of native prairie or parkland. Their implementation is encouraged for development on both public and private land.

- *Petroleum Industry Activity in Native Prairie and Parkland Areas: Guidelines for Minimizing Surface Disturbance* (Native Prairie Guidelines Working Group 2001)
  The Guidelines are intended to be a planning tool for project applicants and operators and serve as the best practices needed to achieve the principles of minimal disturbance identified in EUB IL 2002-1. They detail how oil and natural gas exploration, development, production, and pipeline activities should be conducted in areas of native prairie and parkland in Alberta. Although the guidelines were developed specifically for the petroleum industry, there is an explicit statement that the principles and practices should be applied to any other activities

APPENDIX 9

Bradley, C., F. Reintjes, and J. M. Mahoney. 1991. The Biology and Status of Riparian Poplars in Southern Alberta. World Wildlife Fund Canada, Toronto, and Alberta Forestry, Lands & Wildlife, Edmonton. Website: http://www.albertapcf.org/rsu_docs/biology-and-status-feb-1991.pdf

THE BIOLOGY AND STATUS OF RIPARIAN POPLARS IN SOUTHERN ALBERTA

Mahoney

ALBERTA SOCIETY of Professional Biologists
John M. Mahoney
572
PROFESSIONAL BIOLOGIST

WWF

World Wildlife Fund Canada

and

Forestry, Lands & Wildlife,
Fish & Wildlife Division

THE BIOLOGY AND STATUS OF RIPARIAN POPLARS IN SOUTHERN ALBERTA

prepared by:

Cheryl Bradley and Frances Reintjes
Western Environmental and Social Trends Inc.
and
John Mahoney
University of Lethbridge

FEBRUARY 1991

100% RECYCLED PAPER

EXECUTIVE SUMMARY

World Wildlife Fund and Alberta Fish and Wildlife Division commissioned this study to summarize existing information relevant to the conservation biology of riparian poplars and to determine the distribution and status of riparian poplars in southern Alberta.

Poplar forests along rivers in the grasslands of southern Alberta are very important for wildlife and recreation as well as being of considerable cultural significance to indigenous peoples. They also provide agricultural and water quality benefits. Three poplar species - balsam poplar, plains cottonwood and narrowleaf cottonwood - converge and hybridize in southern Alberta, each with differing physiological and ecological characteristics. All, however, are adapted to regenerate and survive under the naturally dynamic river regimes of southern Alberta rivers.

Successful replenishment occurs infrequently and appears to be correlated with high spring flood events during the time of seed dispersal followed by gradually receding water levels and moist conditions in late summer. Two forms of replenishment are recognized - 'general replenishment' across much of the floodplain attributed to very large, infrequent floods; and 'fringe replenishment' along existing channels attributed to smaller, more frequent floods. Prolonged drought causes increased mortality.

Numerous studies have documented a decline in poplar forests along rivers in the plains of western North America and have attributed it to man's activities. Altered river regimes downstream of dams is implicated as the major factor responsible. Other factors are livestock grazing, harvesting and floodplain developments. In Alberta two studies have documented decline in riparian poplars, one on the St. Mary and Waterton rivers, where decline is attributed to dams, and the other on the Milk River, where decline is attributed to fire. Concerns have been raised about the impacts of the Oldman Dam on extensive stands of riparian poplars immediately downstream on the Oldman River.

As part of this study, the distribution and density of riparian poplars along major rivers in southern Alberta were mapped using 1980s aerial photography. Of about 2000 km of river investigated, 1500 km support riparian poplars and of this, about 1000 km support stands considered moderate, dense or very dense. The total aereal extent of riparian poplar forests is less that 500 km2. Six reaches were determined as particularly significant for riparian poplars: Bow River (Carseland - Cluny), Oldman River (Brocket - Lethbridge), Belly River (Glenwood - Waterton River), Red Deer River (Finnegan - Empress), Milk River (through Milk River Canyon) and Sheep River (near Okotoks).

Comparison of 1980s distribution of riparian poplars with 1880s mapping by Dawson and 1950s air photo analysis suggests no general decline of riparian poplars in southern Alberta in the last century. In fact, there are apparent increases along some reaches of the Red Deer, Bow, and South Saskatchewan Rivers. However, declines are apparent along the St. Mary and Waterton Rivers below dams and along two reaches of the Oldman River where clearing for cultivation is a probable factor. Before a reliable assessment of the status of riparian poplars in Southern Alberta can be made, verification that mortality does not exceed replenishment, through age-class analysis of representative stands, is required. As well further investigations into those aspects of riparian poplar ecology and physiology which will assist in management planning are recommended as are socio-economic assessments of the value of riparian poplar forests.

TABLE OF CONTENTS

MAPS:

FIGURES:

TABLES:

APPENDIX A:

Summary of Reach Characteristics, and Description of Reaches:

THE BIOLOGY AND STATUS OF RIPARIAN POPLARS IN SOUTHERN ALBERTA

1.0 INTRODUCTION

Over the past few decades there has been growing recognition of the importance of poplar stands along rivers in southern Alberta for wildlife, and increased concerns for their health and survival. In response to these concerns, World Wildlife Fund Canada and Alberta Forestry, Lands and Wildlife, Fish and Wildlife Division have identified the need:

- to determine the present distribution and density of riparian poplars along rivers in southern Alberta;
- to assess changes in distribution and density using historical maps and aerial photography; and
- to summarize existing information relevant to the conservation biology of riparian poplars.

Western Environmental and Social Trends (W.E.S.T.) was contracted to do this work.

This report represents the first step in setting management objectives for riparian poplars in southern Alberta. It provides an information base to assist decision making about appropriate management actions and what additional research may be required to assist in future management of riparian poplars. World Wildlife Fund and the Fish and Wildlife Division recognize that decisions about the management of riparian poplars will involve a broad spectrum of stakeholders, including provincial government agencies, municipal government agencies, native organizations, environmental groups, grazing leaseholders, private landowners and other interested individuals. It is hoped that this report will be a useful information base for all these interests.

Furthermore, World Wildlife Fund and the Fish and Wildlife Division recognize that many of the management decisions regarding riparian poplars will have implications for other riparian habitats such as wetlands and shrub communities. It is assumed that a conservation strategy for riparian poplars will not negatively affect, and in fact will hopefully benefit, a whole suite of riparian habitats and the wildlife dependent on them.

2.0 METHODOLOGY

Present distribution and density of riparian poplars in southern Alberta was determined through analysis of recent air photos. A preliminary assessment of status was accomplished by comparing this information with that from analysis of 1950s photos and with Dominion Survey maps by Dawson from the 1880s. Results are presented in Section 8.0 of this report.

A review of the extensive literature relevant to conservation biology of riparian poplars was completed and key points are summarized in Sections 3.0 to 7.0. To ensure accuracy and completeness of the summary, the first draft of these sections was circulated to several individuals knowledgeable in the field. Thoughtful comments and suggestions were provided by Ron Bjorge and Steve Brechtel (Alberta Fish and Wildlife Division), Ian Dyson (Alberta Regional Co-ordination Services), Lorne Fitch (Alberta Fish and Wildlife Division), Joyce Gould (World Wildlife Fund), Maureen Hills-Urbat (University of Calgary), Sandra Marken (University of Calgary), Ron Middleton (Alberta Public Works, Supply and Services), David Reid (Hardy BBT), Dr. Stewart Rood (University of Lethbridge), Eric Vuori (Alberta Fish and Wildlife Division), Greg Wagner and Gordon Walder (Alberta Environment), and Cliff Wallis (Cottonwood Consultants).

3.0 SIGNIFICANCE OF RIPARIAN POPLAR FORESTS

On the western prairies of North America, the ribbons of floodplain forests that border rivers provide welcome relief from the wind and sun in a generally treeless grassland. However, the benefits derived from these productive riparian areas extend beyond the shelter they provide.

For centuries, indigenous peoples on the prairies have lived and hunted in riparian poplar forests. The importance of these environments to indigenous cultures is reflected in the fact that three major Indian Reserves in Southern Alberta - the Blackfoot, Blood and Peigan - are located along river valleys which contain extensive stands of riparian poplars.

Today, many southern Albertans preferentially choose riparian poplar stands as outdoor recreation environments. It is noteworthy that four provincial parks - Dinosaur, Woolford, Writing-on-Stone and Dry Island - as well as major urban parks in Calgary, Letbbridge and Medicine Hat and several parks in smaller centres are located in riparian poplar forests. It also is not surprising that local parks or picnic areas have been developed at several locations where riparian poplar forests occur near river crossings.

More importantly, the riparian ecosystem is probably the single most productive type of wildlife habitat in the semi-arid Great Plains (Bottorff, 1974; Hubbard, 1977; Rhodes, 1991). Similarly riparian habitats in the semi-arid regions of southeastern Oregon are used more than any other type of habitat by 82% of the terrestrial species (Thomas et all, 1979).

Many bird species in the prairies are dependent on riparian poplar forests. In Alberta, Savoy (1991) reported that 72% of the bird species found in the riparian poplar forests of Dinosaur Provincial Park on the Red Deer River use that habitat exclusively. Breeding bird densities range from 550-706 pairs per 40 ha., among the highest densities in Canada. Savoy concluded that disappearance of riparian poplar forests would result in a dramatic reduction of bird species and numbers in prairie regions. For example, studies in Fish Creek Provincial Park found that American kestrels nest almost exclusively in riparian poplars (Greg Wagner, pers. comm.). Furthermore, great blue heron rookeries are restricted to riparian poplar woodlands in the prairies and eagles use poplar groves in valleys for night roosting. Other highly visible bird species using riparian poplar habitats in the prairies include Swainsons and red-tailed hawks, tree-nesting common mergansers and Canada geese, and ring-necked pheasants, who concentrate in the understories.

Virtually all of the forests found in the river valleys of southern Alberta constitute critical habitat for deer (Fitch, pers. comm.). Critical habitat refers to winter range and breeding areas, because these are the habitat components in shortest supply . Both mule deer and whitetail deer use riparian forests. During Spring, 1988 and 1989 researchers of plains cottonwood forests along the lower Red Deer River observed four to eight mule and white-tailed deer fawns along each 700 to 1200 m transect (Sandra Marken, pers. comm.). A survey by the Fish and Wildlife Division along the Oldman River has shown that areas of healthy, continuous poplar forest support about four times more deer ($11.2/km^{2)}$ than areas with discontinuous forest ($3.1/km^{2)}$ (Fitch, pers. comm.).

Aerial surveys for deer in southern Alberta are flown almost exclusively over riparian habitats as deer are virtually absent elsewhere. In January 1982, an aerial survey which included the Belly River, St. Mary River, Waterton River and the Oldman River from Pincher Creek to Lethbridge found 725 mule deer, 1565 whitetail deer, 94 coyotes, seven foxes, 123 pheasants, 268 sharptail grouse, 60 grey partridge, seven prairie falcons, 11 bald eagles, ten golden eagles and 500 waterfowl (Fitch, pers. comm.).

The same characteristics that make riparian poplar stands attractive to wildlife make them attractive for livestock production. Livestock use these forests for shelter, water and bedding or resting. It is interesting to note that forage species for cattle in riparian habitats are generally not as high in nutrient content as upland forage species. However because density of forage is usually higher in the riparian zone the overall nutrients available to livestock generally is comparable to upland habitats (Roath and Krueger, 1982; Kauffmann and Krueger, 1984).

As importantly, riparian vegetation benefits fluvial systems. By stabilizing river banks and providing protection from ice scouring, flooding and erosion, sediment loads are reduced and water quality is improved (Schlosser and Kerr, 1981). Vegetation cover also slows runoff from the prairie upland and by so doing may help reduce pollution of rivers from agricultural chemicals (Lowrance, 1985). Shade provided by overhanging trees and embankments stabilized by root systems reduce water temperatures and help to increase the oxygen levels of smaller rivers (Meehan et al., 1977). These overhangs also provide important cover for fish populations (Marcusson, 1977, Rhodes, 1991). In addition, debris entering the fluvial system from the riparian zone accounts for most of the organic material necessary to support aquatic communities (Kennedy, 1977).

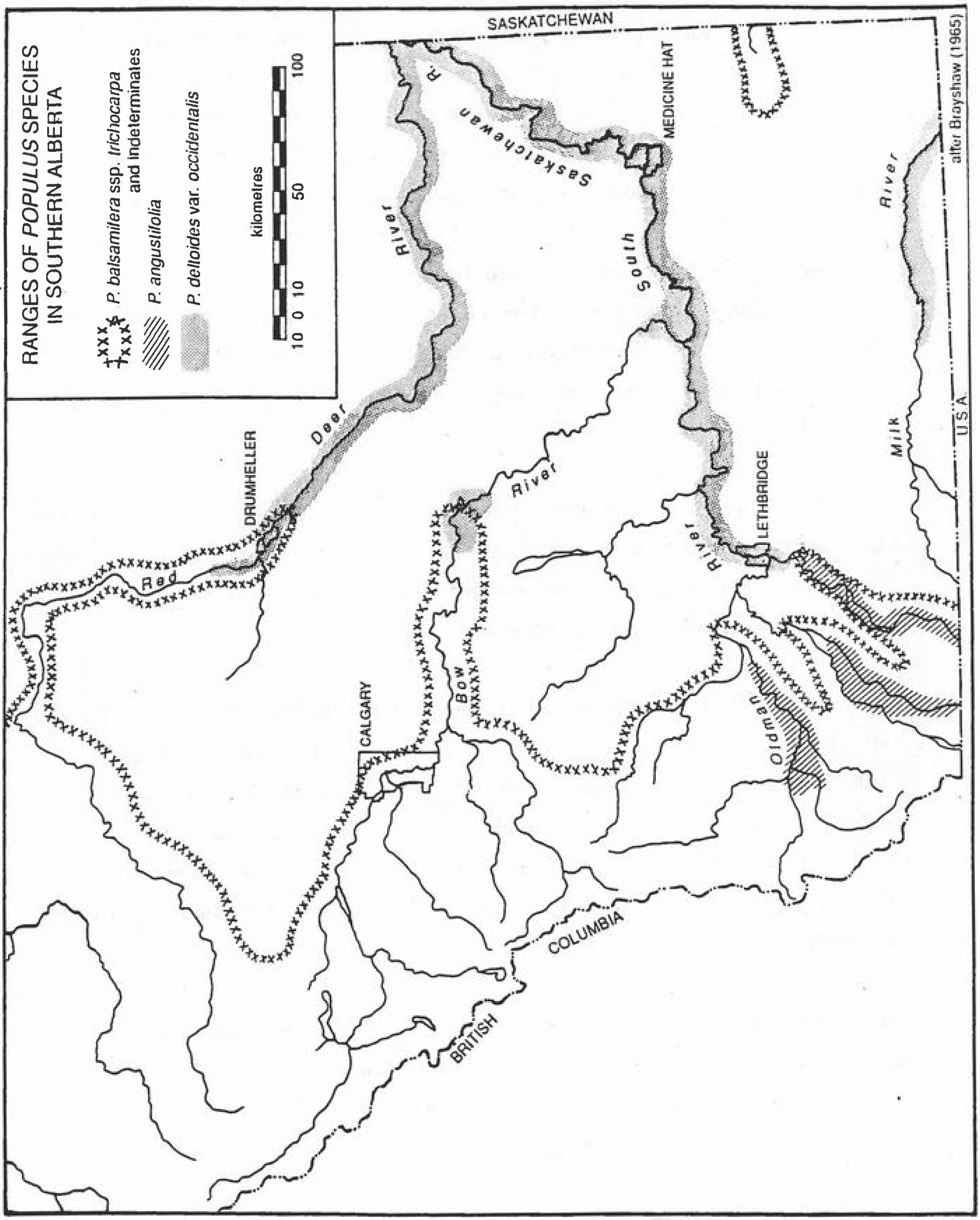
Riparian forests of the western prairies (specifically along a corridor east of the Rocky Mountains ranging from Alberta south through Montana, Wyoming, Colorado, Utah, New Mexico and Arizona) differ fundamentally from those of eastern prairie regions. Along rivers in the eastern prairies, poplars are a pioneer species, being replaced by other tree species as the forest matures. On the other hand, along western rivers poplars are generally the dominant or sole tree species. Thus, riparian stands in the western prairies are often considered to be in a perpetual seral condition and dependent on the predictable instability of the fluvial system for renewal (Brayshaw, 1965; Rood and Mahoney, 1990). Loss of flooding and channel shifting can lead to overwhelming loss of riparian forests. This in turn leads to loss of understory communities. As well, loss of productive riparian wetland and shrub communities can be expected. As the riparian habitats decline, so does the wildlife that depends on them and likewise the other irreplaceable benefits they provide.

4.0 POPLARS OF SOUTHERN ALBERTA

A survey of the poplars of southern Alberta by Brayshaw (1965) found that three poplar species - balsam poplar (*Populus balsamifera* subs. *balsamifera* and *P. balsamifera* subs. *trichocarpa*), plains cottonwood, (*P. deltoides*), and narrowleaf cottonwood (*P. angustifolia*) - are at the limits of their ranges in this area (Figure 1). Trembling aspen (*P. tremuloides*) is also found in the upland areas of southwestern Alberta, but is not a riparian species and is therefore omitted from this discussion. Balsam poplar approaches from the north and west, plains cottonwood from the east and southeast, and the narrowleaf cottonwood from the south along the foothills into Alberta via the St. Mary, Belly and Waterton rivers.

Plains cottonwood in southern Alberta is found east of a line running approximately between Lethbridge and Drumheller. The Red Deer River represents the most northerly extension of plains cottonwood in North America. Populations also are found east of Alberta, in Saskatchewan, Manitoba and Ontario. Narrowleaf cottonwoods are limited to the southwest corner of Alberta extending only as far northeast as Lethbridge (Brayshaw, 1965). Like plains cottonwood the Alberta population of narrowleaf cottonwood represents the most northerly extension of this species. Noteworthy is that Alberta is the only province in Canada in which narrowleaf cottonwood occurs. With respect to balsam poplar, its distribution in Southern Alberta is limited to the foothills but extending eastward and southward to Drumheller along the Red Deer River.

Figure 1: Ranges of Riparian Poplar Species in Southern Alberta



Brayshaw (1965) noted that interspecific crosses are possihle between the three parent poplar species. Hybrid forms occur readily where the ranges overlap. Balsam poplar (*Populus balsamifera*) and narrowleaf cottonwood (*P. angustifolia*) are both in the Tacamahaca Section and hence, very close; they freely interbreed in many locations. Plains cottonwood (*Populus deltoides*) is in the Aigeros Section. The Tacamahaca x Aigeros hybrids are a little more unusual and these receive the names *P. x jackii* (*P.deltoides x balsamifera*), and *P. x acuminata* (*P. deltoides x P. angustifolia*). Rood et al. (1986) found a continuous hybrid swarm generated by the three parent species with a unique trispecific population found in the Lethbridge area. Biochemical analysis (Greenway et al., 1990; Vanende, 1991) supports the conclusions of Rood et al. (1986) in differentiating between the hyhrid crosses.

It is noteworthy that in the vicinity of Drumheller, older poplar trees (120-140 years) are *P. x jackii* crosses whereas younger trees (less than 80 years old) are pure plains cottonwood (*P. deltoides)*. This suggests a recent westward extension of plains cottonwood along the Red Deer River (Marken, pers. comm.).

The reasons for the differing ranges of the three riparian poplar species is not well understood. It may be an artifact of the rate of species range expansion following deglaciation or it may be a function of differing environmental tolerances, such as climate. As well, there are a number of notable differences in the general characteristics of rivers that flow through the foothills compared to those that flow through the prairies; and the different species may he preferentially adapted for the different regimes and floodplain characteristics.

Balsam poplar is found along foothill rivers, which generally have steep gradients, coarse beds, low suspended sediment loads and braided or straight channels. Plains cottonwood occurs along prairie rivers which generally have low gradients, sand beds, high suspended sediment loads and freely meandering (unless confined by bedrock) or braided channels.

Narrowleaf cottonwood and the natural hybrids are found in the transition zone between the foothills and prairies (Brayshaw, 1965; Eckenwalder, 1984b; Rood et al. 1986).

The remainder of this report will discuss poplars in general, noting differences in the species when known. Most studies on poplar biology have dealt with a single species, usually of silvicultural significance. Few studies examine the differences in species physiology or ecology. Although there is little evidence to suggest that poplars cannot be discussed together, reason dictates that differences in species physiology and ecology may be adequate to necessitate different management approaches. Caution should be used before applying the general conclusions to a specific situation.

5.0 THE POPLAR LIFECYCLE

5.1 Sexual Reproduction

A single mature poplar produces tens of millions of small, light seeds annually (Bessey, 1904). The seeds are attached to cottony enclosures (hence the common name of "cottonwood") that aid in wind dispersal. Generally, release of seeds occurs every spring to early summer when normal river flows are high (Everitt, 1968; Ware and Penfound, 1949). The synchronization of seed release and high flows ensures that new, moist sand and silt beds are available for successful seed imbibition and establishment. Lack of seed production can occur in some years, such as when severe frosts occurring in late spring cause damage to catkin buds (Marken, pers. comm.).

Seed viability usually lasts only two to four weeks (Fenner et al., 1984; McComb and Lovestead, 1954; Moss, 1938; Ware and Penfound, 1949). Viability varies with humidity, temperature and photoperiod (Hellum, 1948; Hosner, 1957; Farmer and Bonner, 1967;

Fenner et al., 1984) but germination must occur during this time if seeds are to establish in any given year.

Poplar seedlings require barren sites for successful establishment since they are poor competitors (Read, 1958). Ideal sites are clear of other vegetation to allow abundant sunlight, and remain constantly moist for the first few weeks. Even under these conditions, many more seedlings germinate than survive the first year. A common reason for losses of seed viability and small seedlings in the first season is drying of seed beds (Engstrom, 1948; Moss, 1938; Read, 1958; Farmer and Bonner, 1967).

The uncertain timing of annual peak flows means the hydrologic conditions essential for successful seed germination and establishment occur irregularly (Barnes, 1985). Bradley and Smith (1986) suggest that about a two to ten year interval, with an average interval of five years, may be expected between successful regeneration events along the meandering reaches of the Milk River. Analysis of age-class distribution of plains cottonwoods along the lower Red Deer River shows much less frequent regeneration events (Sandra Marken, pers. comm.). A significant proportion of the present woodlands were established between 40 and 80 years ago. Trees aged 75-85 years old are found over large expanses of floodplain, their establishment coinciding with record high spring flood events occurring in generally very wet years. This age group is found mainly along braided sections, which comprise 70% of the river length. Trees at both ends of the age spectrum cover relatively small areas, although there is a surge in representation of 135 to 140 year old trees. Marken (pers. comm.) suggests that trees in the 0 to 10 year old age class are extremely limited due to decreased flow resulting from decreased precipitation and the Dixon Dam, and from local water removal.

As well as point bars, abandoned channels are important sites for plains cottonwood establishment along the Milk and Lower Red Deer Rivers (Dave Reid, pers. comm.; Maureen Hills-Urbat, pers. comm.; Sandra Marken, pers. comm.). Other observations specifically along the Red Deer River in Dinosaur Provincial Park suggest that in some instances plains cottonwood seedings establish under stands of young willows that have been recently flooded (Maureen Hills-Urbat, pers. comm.).

5.2 Asexual Reproduction

All three species of riparian poplar are known to propagate asexually through suckering (sprouting from roots), coppicing (sprouting from stems) or cladoptosis (sprouting from branch tips). In nature some forms of asexual reproduction are more common in some poplar species than in others (Dickmann and Stuart, 1983).

Field observations in southern Alberta suggest that suckering seldom occurs in plains cottonwood. Bradley (1982) and Dave Reid (pers. comm.) observed no suckering of plains cottonwood along the Milk River. Sandra Marken (pers. comm.) observed suckering of plains cottonwood only twice along the Red Deer River; both times this occurred in young saplings (3 years), in backwater areas characterised by high clay content and standing water. Narrowleaf cottonwood and its hybrids produce suckers very infrequently, according to observations by Dave Reid (pers. comm.) along the St. Mary, Belly and Waterton Rivers. However, further investigation of this is required. On the other hand, middle-aged trees of balsam poplar commonly produce new individuals by suckering from lateral roots.

Suckering is promoted when flooding or ice scouring removes bank materials and shears poplar roots (Williams and Wolman, 1984). The severed roots then form dense new growth. These events are probably important components of natural riparian forest cycling where balsam poplar dominates (Ashton, 1979; McBride and Strahan, 1984). However, the relative contribution of suckering as opposed to reproduction from seeds to natural forest regeneration in southern Alberta is difficult to assess. Preliminary work using root excavation has been attempted along southwest Alberta rivers, but is inconclusive since root grafting may link neighbouring trees (Rood and Mahoney, 1991a). Isoenzyme or flavonoid analysis may permit more confident analyses of the extent of suckering in riparian poplars in the future (Vanende, 1991).

Coppice growth, the production of shoots from stems of young to middle aged trees occurs in all three species of riparian poplars in southern Alberta. Coppicing generally occurs following damage to trunks by fire, beavers, flooding or ice scouring. The large established root system supports regrowth that is often much more rapid than the rates seen in seedlings (Dickmann and Stuart, 1983). This form of propagation declines in older trees (Read, 1958). For example, sprouting from old plains cottonwood trunks damaged by a recent fire were noted in 1982 (Bradley, 1982), but by 1989 these new sprouts had died (Reid, pers. comm.).

As well, coppicing can occur through flood training (Everitt, 1968). In this process pliable saplings are bent over and covered by sediment. New shoots may then emerge from the buried stems creating a clonal group progressing downstream from the original sapling. This form of asexual reproduction has been observed on the Belly River and Bow River (Reid, pers. comm.) and at two sites on the Red Deer River related to ice scour events (Sandra Marken, pers. comm.). At one site on the Red Deer River, an entire large stand was affected, and stand density was estimated to have increased four to six times because of it.

Cladoptosis, the rooting of branch tips that are broken off and land on suitable sites has been observed occasionally in riparian poplars in southern Alberta (Shaw, 1976; Bradley, 1982). However, this form of asexual reproduction is much more significant for balsam poplar in the wetter Pacific Northwest (Galloway and Worrall, 1979).

Silvicultural techniques have been developed to exploit the tendency for asexual reproduction in poplars (Fege, 1983; Strong, 1989). The most common technique used in establishing poplar plantations is through sprouting from shoot tissues, (cladoptosis) (Phipps et al., 1977). Coppicing also is used in short rotation poplar silviculture to maintain high productivity (Dickmann and Stuart, 1983).

5.3 Growth and Longevity

Poplars obtain water primarily from groundwater sources, which is characteristic of most deep-rooted trees and results in them being termed phreatophytes. Thus, the depth of the water table determines the availability of water and the severity of drought stress during the growing season. Precipitation may provide a small amount of moisture for poplars through their extensive shallow root system, but does not appear to contribute to the long term growth success (Reily and Johnson, 1982). Since root growth must be rapid enough to maintain contact with the riparian water table as it recedes following spring flooding, the limits of root growth may determine the initial success of the seedlings. If water supply recedes more rapidly than the ability of the roots to grow to maintain contact, seedlings will dry out and die.

Plains cottonwood (*P. deltoides*) seedlings can grow 50 cm in their first year in Oklahoma and roots may extend a similar distance (Ware and Penfound, 1949). Along the Milk River, first year growth of shoots and roots seldom measured more then 30 cm (Bradley, 1982). In the greenhouse, the seedling roots of a closely related species, Fremont cottonwood (*P. fremontii*), have been reported to grow about 6 mm per day although higher rates were observed in some soils (Fenner et al., 1984). Fenner et al. (1984) also found that Fremont cottonwood seedling roots reached 72 cm by the end of the first summer in the field. Again, final depth varied with genotype and substrate composition (Fenner et al., 1984).

The small size and correspondingly small root systems of seedlings keep them vulnerable to drought-induced mortality in the year following establishment. Through the second year, growth is more rapid than that of the first year and at the end of two years, roots may extend almost three meters in length (Ware and Penfound, 1949). The longer roots help plants exploit more stable, deeper water sources (Pezeshki and Hinckley, 1988).

In contrast to their intolerance of drought, poplar seedlings are quite tolerant of flooding. Hosner (1957) found that nearly half the seedlings tested survived 30 days of inundation. This characteristic is useful in helping seedlings survive flooding in subsequent years. However, high flows can scour seedlings away or bury them with sediment. For example, along the Red Deer River seedlings established in June, 1989 which were in densities of up to $500/m^2$ and 2 to 6 cm tall were scoured away by high August flows (Sandra Marken, pers. comm.).

Poplar saplings become more tolerant of flooding and drought stress after the first two years as the root system develops (Pezeshki and Hinckley, 1988). This permits accelerated growth so that three to five year-old trees can grow more than a meter in height annually (Dickmann and Stuart, 1983). Growth rates slow down after the first five years and remain relatively constant for the next few decades. Flowering first occurs after approximately seven years depending on the genotype (Rood, unpublished).

Changes in the rate of poplar growth are readily evaluated by measuring tree ring increments from stem cores or discs. Albertson and Weaver (1945) found that annual growth increments were reduced in poplars of the western prairies during the drought of the 1930s. Growth increments were also reduced in riparian species following damming of the Missouri River in North Dakota (Reily and Johnson, 1982). These researchers concluded the reduced growth was probably related to reduced early-season downstream flows.

Poplar longevity is influenced by a number of environmental factors, especially drought stress (Reily and Johnson, 1984). During the extensive drought of the 1930s on the western prairies, older poplars were observed to be especially vulnerable (Albertson and Weaver, 1945). Riparian poplars that have survived a number of dry periods often appear very ragged due to the death of some upper branches. When the volume of water transpired cannot be replaced through the xylem, a break in the water column occurs. This effectively shuts off the water supply to the branch, thereby reducing the shoot mass and leaf area to a level that can be supported by the root system with the water available.

Although poplars can live for over 200 years, most trees in Alberta die before the end of their first century (Shaw, 1976; Cordes, 1991; Marken, 1991). On the Milk River in southeastern Alberta, few plains cottonwood were found over 100 years of age (Bradley and Smith, 1986; Hardy, 1990). However, Marken (pers. comm.) has found several trees aged at 135 to 140 years along the Red Deer River. It should be noted that precise aging of poplars is difficult due to burial of the lower portions of stems by floodplain sedimentation and heartwood rot in older trees.

6.0 NATURAL FACTORS AFFECTING REPLENISHMENT AND SURVIVAL OF RIPARIAN POPLAR FORESTS

6.1 Replenishment vs Mortality

The status of a poplar forest is determined by the relative rates of replenishment and mortality. The rate of replenishment will depend on the frequency at which events suitable for seed germination and seedling establishment, or suckering (in balsam poplar), occur. The rate of mortality will depend on species longevity as well as several factors including severe drought, flood, winds, beaver, fire and disease. Generally, replenishment of the younger age classes must exceed mortality of the middle to older age classes if the forest is to increase or even maintain equilibrium. If mortality exceeds replenishment the stand will decline. An analysis of the age-class composition of a forest helps to determine if a forest is increasing, in equilibrium or declining. Since the reasons for increased or decreased replenishment are somewhat different from those causing increased or decreased mortality, an age-class analysis is essential in determining the factors underlying general forest trends. Factors affecting replenishment and mortality are discussed in detail in the following sections.

6.2 River Regime

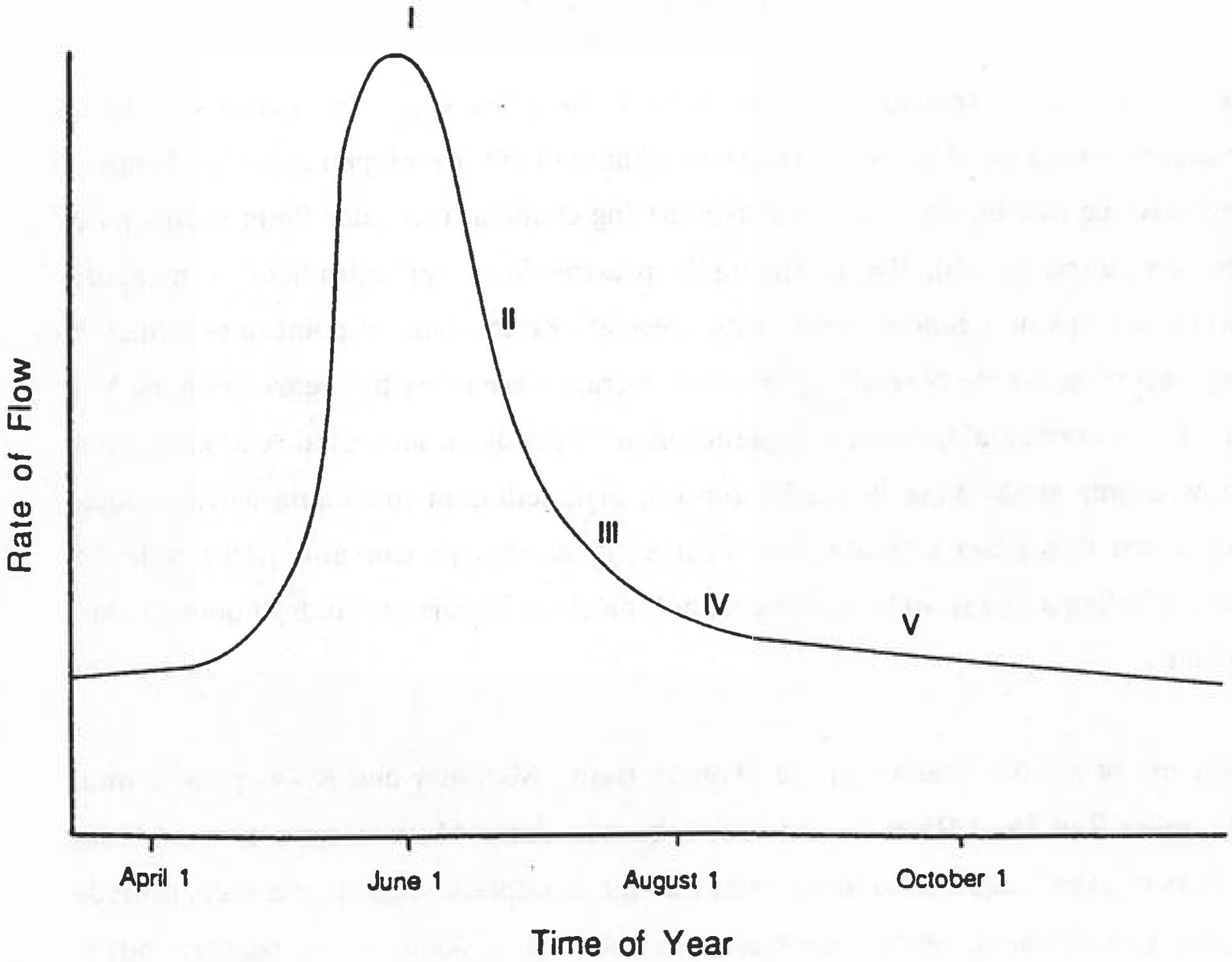
Riparian ecosystems in southern Alberta are adapted to, and may even depend on, the dynamic flow regimes which are characteristic of rivers in the region. However, the unpredictable variation in the range and timing of parameters such as flooding and seed dispersal also means establishment is successful only at irregular intervals.

Figure 2 presents a river flow pattern typical of an unmodified river in southern Alberta. A discussion of the contribution of five characteristics of river flows that influence poplar forest survival and replenishment noted on Figure 2 follows.

6.2.1 Spring Flooding/Fringe and General Replenishment

Most major southern Alberta rivers fluctuate annually with peak flows in late spring following snow melt in the Rocky Mountains. Overbank flooding may occur when heavy spring rains augment the rapid melting of deep snow packs (Johnston, 1987; Gildart, 1984). The highest flows normally last for just a few days in early to mid-June although annual peaks range between April 25 and June 30 for some rivers (Environment Canada, 1985). These floods shift the course of river channels and carry large sediment loads which they deposit adjacent to the channel or in low-lying areas of the floodplain (Williams, 1989). As well, existing streambanks and bars are scoured and new sand and gravel bars are deposited (Colby, 1964; Everitt, 1968; Wolman and Leopold, 1957). These barren sites of fresh sediment, sand and gravel are favourable locations for poplar seedling establishment (Behan, 1981; Johnson et al., 1976; Noble, 1979).

Figure 2: Typical Discharge Hydrograph Showing Elements Important in Riparian Poplar Survival



I	SPRING FLOOD LEVELS
II	FALLING RIVER FLOWS DURING POPLAR SEED RELEASE
III	GRADUAL TAPERING OF RIVER FLOWS
IV	MINIMUM SUMMER FLOWS
V	AUTUMN FLOW LEVELS

The newly formed seed beds are saturated by the floods so that poplar seeds released immediately after the flood and landing on those barren, moist sites are likely to survive. The surface moisture is necessary to support the seedlings until the roots penetrate to the water table. Once seedling roots contact the water table, root growth must be adequate to follow the water table as it declines over the growing season.

Fringe replenishment, replenishment of poplars along the edges of channels, is highly dependent on spring flood events. Bradley and Smith (1986) developed a model (Figure 3) relating seedling establishment along a meandering channel to regular flood events based on their work along the Milk River. The model presents forest replenishment as an ongoing process on the tips of meander lobes. New trees are established on point bars formed by flooding occurring at time of seed dispersal (on average once every five years along the Milk River). This incremental method of replenishment depends on successful seed production, high flow events at the time of seed dispersal, high sediment loads and active channel migration and floodplain aggradation. Fringe replenishment can also occur following overbank flooding along straight, stable channels resulting in narrow bands of poplars along the channel.

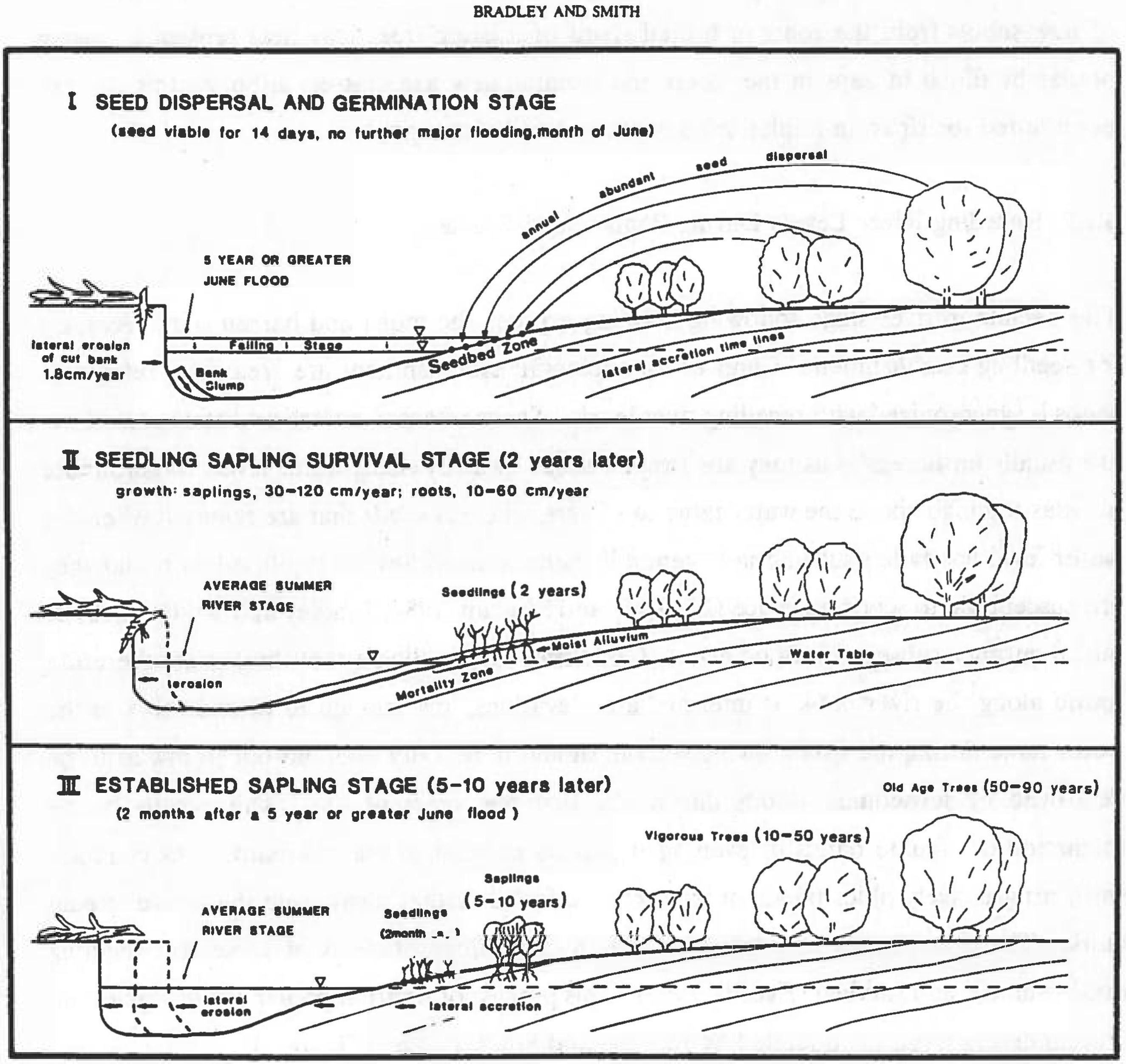
Field surveys of braided reaches of the Oldman Basin (Mahoney and Rood, pers. comm.) and the lower Red Deer River in and near Dinosaur Park (Marken, pers. comm.) found large tracts of evenly aged trees across much of the floodplain suggesting a second model of poplar replenishment, termed general replenishment. Along these reaches, poplar replenishment may be linked with major overbank flood events rather than incremental point bar aggradation. These major flood events may occur about every 30-50 years instead of every five, and encourage replenishment of large areas across the full width of the floodplain rather than only on the tips of point bars. Marken (pers. comm.) observed that a significant proportion of the poplar woodlands, occurring on large expanses of the lower Red Deer River floodplain, were established 75 to 85 years ago. Establishment of these woodlands coincided with record high spring flood events occurring in generally wet years.

In summary, for both fringe and general replenishment, spring flooding serves two essential functions. Firstly flooding prepares sites suitable for successful poplar seedling establishment through scouring and deposition. Secondly it recharges the riparian water table and inundates the floodplain including new barren sites. In addition, the emergence of new shoots from the roots or buried stems of existing trees may help replenish balsam poplar by filling in gaps in the forest and forming new age classes, although this has not been noted for riparian poplar species other than balsam poplar.

6.2.2 Receding River Levels During Poplar Seed Release

The decline in river stage following flooding exposes the moist and barren sites necessary for seedling establishment. Chances for successful establishment are greatest if release of seeds is synchronized with receding river levels. Seeds released before or during peak flows are usually unsuccessful as they are either washed away by rising water levels or germinate on sites too high above the water table to survive, whereas seeds that are released when the water level has fallen substantially generally germinate so low on the floodplain that they are susceptible to scouring by ice (McBride and Strahan, 1984; Bradley and Smith, 1986) or burial during a subsequent flood event. Good sites for seedling establishment are therefore found along the river bank at intermediate elevations, low enough to extend roots to the water table during the first growing season, should it be a dry one, but not so low as to be destroyed by subsequent floods during the first few years of life. This results in the formation of arcuate bands of even aged poplars parallel to the riverbank. As channels shift, progressively older bands of trees can be found further away from the active stream bank. The older bands of poplars provide a chronology of years of successful seedling establishment and survival (Everitt, 1968). This process of riparian poplar establishment on a meandering river, as modelled by Bradley and Smith (1986) (Figure 3).

Figure 3: A Proposed Conceptual Model Showing an Association Between Cottonwood Establishment and River Flooding and Sedimentation



6.2.3 Tapering River Flows After Seed Germination

Since poplars exploit ground water reserves as their main source of moisture, seedling root growth must be rapid enough to maintain contact with the riparian water table as it drops in concert with declining river flows. The natural decline of the water table following peak flows is usually relatively gradual, and poplar seedlings are able to maintain the root link with the water supply. Abrupt drops in water table, such as those associated with artificial reductions in river flows due to reduced releases from dams or increased diversion, can be lethal to poplars. Research has shown that rates of water table decline exceeding 4 cm/day has serious effects on poplar seedling growth and survival (Mahoney and Rood, 1991a).

As well as seedlings and saplings, mature trees also are susceptible to drought stress induced by rapidly falling water tables especially if this is preceded by a prolonged period of inundation. When inundated for periods of 8 days or longer root absorption declines and within 32 days roots die (Hosner, 1958; 1962). The zone of active absorption is limited to the roots above the level of inundation. As the water table declines, the non-functioning portion of the root must be reactivated to maintain effective water absorption. If the water table declines at a rate faster than the roots can be reactivated, drought stress and mortality may occur (Mahoney and Rood, 1991a). Very old trees are expected to be especially susceptible to this stress.

6.2.4 Minimum Summer Flows

The lowest river flows during the growing season normally occur in the late summer months. This is also the time when hot, dry weather causes high water demand for plant survival. Low flows and a related deep water table during July and August when water demand is high may cause drought stress in seedlings and saplings, especially for those established high on the floodplain or far back from the channel. This is substantiated by observations along the Red Deer River which suggest that a wet August followed by several wet years are required to insure seedling survival on sites far back from the river after a general replenishment event (Sandra Marken, pers. comm.). However, Bradley (1982) found that summer flows were not the most critical factor governing successful replenishment along the Milk River. Even though there were high summer flows both upstream and downstream of the Fresno Dam, seedlings below the dam did not survive.

Mature trees usually have deep root systems and will probably be noticeably impacted only when extremely low summer flows occur over a period of several years, such as occurs during prolonged drought or on rivers where substantial withdrawals are made annually for irrigation purposes.

6.2.5 Autumn Flows

River flows remain low in the fall, however cooler temperatures and shorter days lower the water requirements of the trees so that overall drought stress is decreased.

Overwintering survival of riparian poplars in southern Alberta is probably dependent on a healthy water status in the autumn. Stored moisture helps poplars survive winter freezing and the drying effects of Chinook winds. Both processes remove moisture from shoot tissues. Since water cannot be transported by the roots through the zone of frozen soil, a water deficit results leaving the trees in a weakened condition in the spring. Thus, trees entering the winter with a healthy moisture balance have greater moisture reserves and improved tolerance to winter stresses.

6.3 Drought

The weather of the Great Plains, including southern Alberta, is extremely variable with dramatic seasonal and annual fluctuations in precipitation and temperature. Longer term fluctuations, such as the extended drought of the 1930s are also apparent. Ellison and

Woolfolk (1937), Weaver and Albertson (1936) and Albertson and Weaver (1945) documented widespread drought-induced mortality of poplars in many regions of the North American prairies during the 1930s and 1940s. They related the extensive mortality of riparian poplars to the general lowering of the riparian water table due to deficient precipitation and a resultant reduced stream flow. The shallowness of root systems of seedlings and saplings were identified as the probable reason for the high drought-induced mortality of this age class. Older trees (greater than 30 years) were also more susceptible to drought.

At sites where the water table declined rapidly, Albertson and Weaver (1945) observed the death of riparian trees within a few months. This mortality was apparently the result of a specific drought event. At other sites, mortality progressed over the period of continued drought. Albertson and Weaver (1945) proposed that the effects of loss of tree vigour and viability were cumulative at these sites. Growth rates of leaf area, branches, and radial increments of the trunks were all reduced and extensive leaf senescence, leaf abscission, and death of branches was often observed prior to whole tree mortality (Albertson and Weaver, 1945). Reid (pers. comm.) has observed widespread evidence of drought stress during 1984-87, a series of dry years, along rivers throughout southern Alberta. He speculates that cottonwoods along the Milk River are an exception to this due to the fact that summer flows are enhanced by a diversion into the headwaters.

6.4 Cumulative Hydrological Factors

The replenishment and survival of riparian poplar forests is probably most dependent on a combination of flow regime and climate factors. The patterns of precipitation and temperature, locally or upstream in the headwaters, may compound the effects of altered river regime. An indication of the hydrological component responsible for a decline can be determined by noting the age of the trees that are affected. A forest with few seedlings might indicate changes in the volume or the timing of peak flows. These changes would be expected to limit seedling replenishment while older trees would probably be less influenced. Rapidly declining flows following flooding and low minimum summer or autumn flows, would probably increase drought stress on both young seedlings and older trees which have reduced vigour. The loss of these age groups may indicate drought-induced mortality. In general, seedlings and young saplings are expected to be the most vulnerable age groups to environmental stresses followed by the older trees. Middle aged poplars are expected to be least affected.

In summary riparian poplars are highly sensitive to drought stress in their first few years of growth, become fairly resistant once their roots have reached water table, and then become sensitized again as they approach old age. Mature poplars appear to be able to survive single stress events, but it is reasonable to assume that they are less likely to survive through sequential and cumulative stresses. Natural hydrological stresses, compounded by other stresses including those imposed by man's activities can lead to a major decline of all age classes. This decline may occur dramatically over a few years or it may not be readily apparent for a period of several years.

7.0 MAN'S IMPACT ON REPLENISHMENT AND SURVIVAL OF RIPARIAN POPLAR FORESTS

Numerous researchers have documented a decline in poplar forests along rivers in the western prairies of North America (Figure 4, Table 1) and have attributed it to man. The majority of these studies have focused on the downstream impacts of dams and diversions as the principle factor affecting replenishment and survival (Table 2). Livestock grazing is also cited as a major factor contributing to poplar decline. Other factors include harvest by man and beavers and localised floodplain developments. The following section is a review of these studies and following that are sections analyzing the key factors attributed to man which contribute to riparian poplar decline.

Figure 4: Locations of Studies Documenting Decline of Riparian Poplars in Western North America

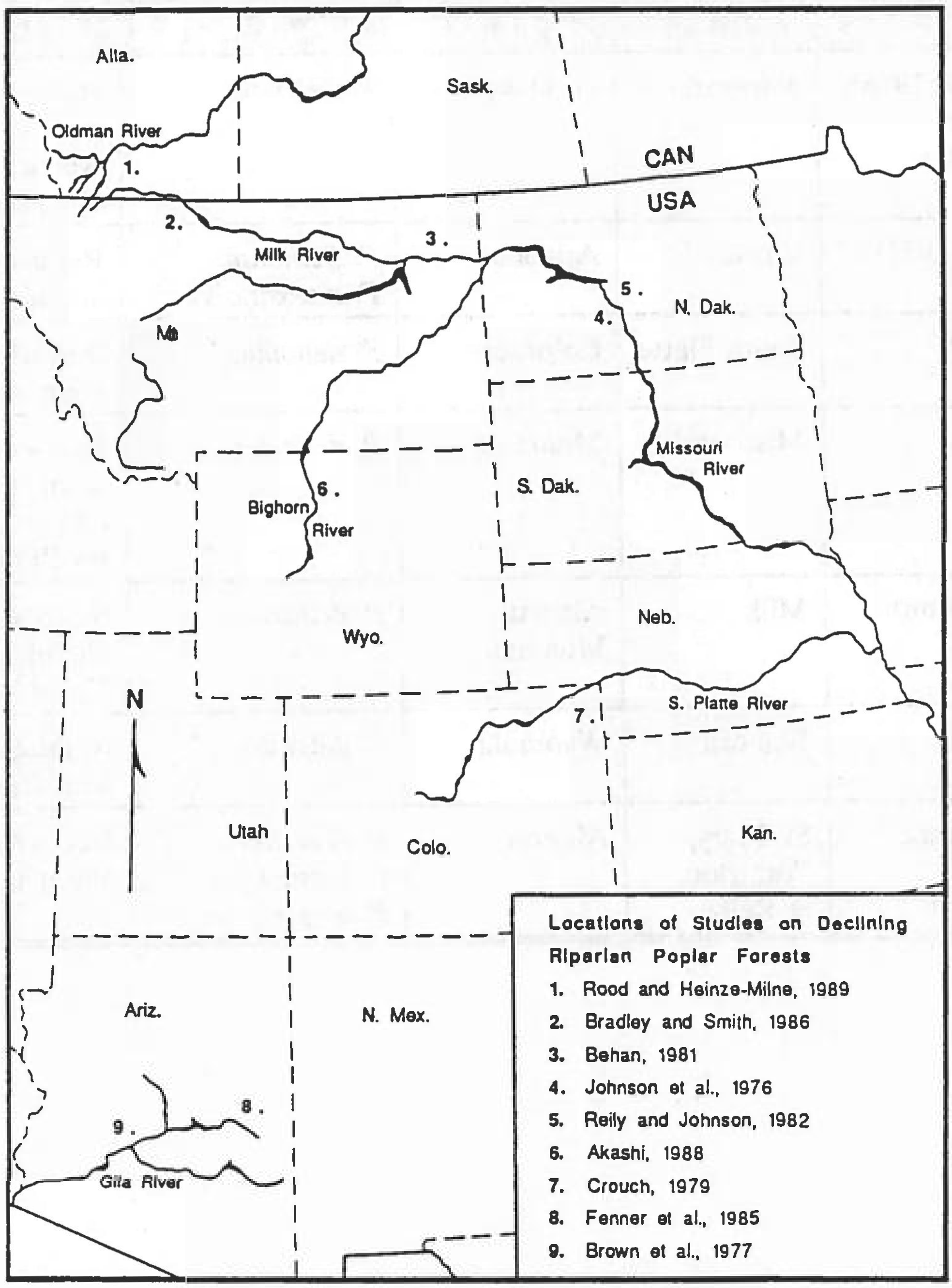


Table 1: Summary of Principal Studies Documenting Decline of Riparian Poplars

Author (Date)	River	Region	*Populus*	Impacts
Johnson et al (1976), and Reily and Johnson (1982)	Missouri	N. Dakota	*P. deltoides*	Reduced tree growth Reduced seedling abundance
Brown et al (1977)	various	Arizona	*P. fremontii*, *P. angustifolia*	Reduced forest abundance
Crouch (1979)	South Platte	Colorado	*P. deltoides*	Reduced forest abundance
Behan (1981)	Missouri	Montana	*P. deltoides*	Reduced forest abundance Absence of seedlings
Bradley and Smith (1986)	Milk	Alberta/ Montana	*P. deltoides*	Reduced forest abundance Fewer saplings
Akashi (1988)	Bighorn	Wyoming	*P. deltoides*	Reduced forest abundance
Rood and Heinze-Milne (1989)	St. Mary, Waterton, & Belly	Alberta	*P. deltoides*, *P. balsamifera*, *P. angustifolia*	Reduced forest abundance

Table 2: Altered River Regime Factors Contributing to Decline of Riparian Poplar

Proposed Cause	Comments	References
1. Hydrological changes:		
A. Reduced flooding	Spring flooding is essential to create moist seed beds for seedling establishment	Johnson et al. (1979) Brown et al. (1977) Fenner et al. (1985)
B. Reduced downstream flows	Diversion of water offstream creates a water deficit downstream, resulting in drought stress and enhanced mortality	Brown et al. (1977) Rood et al. (1989)
II. Geomorphological changes resulting from hydrological alterations:		
A. Reduced meandering	With reduced flooding, channel migration is reduced and suitable seed beds are reduced	Johnson et al. (1979) Bradley and Smith (1986)
B. Sediment depletion	The water impoundments lead to settling of suspended silt loads and downstream reaches are impoverished of the sediment	Bradley and Smith (1986)

FROM ROOD AND MAHONEY (1990A)

7.1 Review of Relevant Studies

Johnson et al. (1976) were the first to report reduced plains cottonwood (*Populus deltoides*) abundance, downstream from the Garrison Dam on the Missouri River in North Dakota. The population structure observed by Johnson et al. (1976) suggested that either a recent increase in seedling mortality or a decrease in seed production was causing a decline in the contribution of cottonwoods to the riparian forest. They concluded that the operation of the dam for downstream flood protection was causing a number of vegetation changes in the riparian zone. Although Johnson et al (1976) noted that cottonwood abundance was highly variable, they did not compare poplar abundance upstream and downstream from the dam to determine the dam's causative effect. However in 1982, Reily and Johnson, by comparing downstream riparian sites with an upland site and a site on an undammed river, concluded that flow control by the Garrison Dam caused reduced river meandering resulting in reduced production of satisfactory seed beds. This led to lower seedling establishment.

Brown et al. (1977) studied riparian communities of Fremont cottonwood (*P. fremontii*) and narrowleaf cottonwood (*P. angustifolia*) in western Arizona. They compared the present forest abundance to historical reports and found a significant decrease. The losses were attributed primarily to reduced stream flow following damming. Grazing pressure from livestock was cited as another factor causing decline. Problems of increased water salinity and ground water pumping were also noted to have contributed to the decline of riparian poplars in this area. Brown et al. (1977) recognized the vital role of spring flooding for creating seedling establishment sites. Their results showed that decadent stands were found along reaches with stabilized flows. They also noted that unregulated rivers with high spring run-off still generated considerable seedling replenishment.

Crouch (1979a) reported variations in poplar forest abundance along the South Platte River in Colorado over the past century. He found that in the late 1800s, during the first explorations of the region, few trees were present however they increased in numbers until the mid-1900s. The reasons for this are unknown. However, following the mid-1900s riparian poplars declined. Sites along grazed and ungrazed reaches of the South Platte River were assessed in 1961 and 1978 to measure changes in poplar abundance and health (Crouch, 1979b). This analysis permitted comparisons both between sites and within sites over 17 years. Declines in abundance and vitality were noted on both types of sites with greater losses on the grazed sites due to grazing of seedlings. However, Crouch (1979b) also suggested that grazing improved some sites for poplar by clearing the understory of competition. Harvesting by beavers was another factor cited as contributing to the poplar decline on this reach. Additionally, flow alterations due to upstream damming were cited as the cause for a failure of seedling replenishment at both types of sites in 1978.

The Missouri River in central Montana has twenty-seven dams that moderate spring flooding along the reach described in a study by Behan (1981). He found that young plains cottonwood (*P.deltoides)* are often absent along this portion of the Missouri River and that most of the trees are mature or over-mature. He suggested the upstream dams reduce spring flooding and slow the rate of river meandering to limit the formation of sites suitable for seedling establishment. Behan (1981) also noted that cattle grazing contributed to poplar decline by removing small seedlings. He recommended fencing cattle from poplar stands.

The hydrology of the Salt River in Arizona is altered by the Stewart Mountain Dam (Fenner et al., 1985). Typically, the spring flood is trapped and high, steady summer flows are released. These authors compared pre-dam stream flows and poplar abundance with post-dam stream flows and present abundance. They concluded, based on their knowledge of the relationship between river flow and poplar establishment requirements, that the change in flow regime (which included loss of peak spring flows and augmented summer flows) is unsuitable for Fremont cottonwood (*P. fremontii*) replenishment.

The operation of the Fresno Dam on the Milk River in Montana has led to reduced flood magnitude and frequency, reduced sedimentation and reduced rates of meander migration downstream (Bradley and Smith, 1984). Although this does not appear to affect the recruitment of plains cottonwood seedlings, based on upstream and downstream comparisons of seedling densities, it has resulted in decreased survival of seedlings past two years of age and a decrease in the overall abundance of poplars (Bradley, 1982; Bradley and Smith, 1986). By comparing forest age structure from transects upstream and downstream of the Fresno Dam, Bradley and Smith (1986) were able to attribute changes in the downstream forest to the influence of the dam. The data collected from the upstream reach is an important control in the study since both the upstream and downstream reaches are exposed to similar environmental conditions, including constant mid-summer flows, winter grazing and local harvest by beavers.

Another study along the Milk River in southeastern Alberta, reported a 16% decline in the area of plains cottonwood (*P. deltoides*) forest between 1951 and 1989 (Hardy BBT, 1990). This loss was attributed primarily to the effects of a fire that removed over 100 hectares of riparian forest. Although alterations to flows since 1917, winter grazing by livestock, harvesting by beaver, and browsing by deer have all occurred continually along this reach, there is no evidence that they have affected the long term establishment and survival patterns of the cottonwoods (Bradley and Smith, 1986; Hardy BBT, 1990).

A historical distribution of poplars along the Bighorn River downstream from the Boysen Dam in Wyoming was compiled by Akashi (1988). The loss of poplars over the past 50 years in this area was attributed to land clearing, increased occurrence of fires, and changes in the rates of channel migration and sedimentation (Akashi, 1988). Akashi (1988) also reported that poplar seedling replenishment was reduced following river damming due to the alteration of flow regime. This reduced replenishment contributed to the observed downstream forest decline.

Rood and Heinze-Milne (1989) studied the downstream impacts of river damming on riparian poplars in southwestern Alberta. Three parallel rivers were analyzed with air photos to ascertain the decline of poplars along the rivers. The unique arrangement of dammed rivers, the St. Mary and Waterton, flowing on either side of a relatively uncontrolled river, the Belly, through generally undeveloped regions permitted a controlled, replicated study of the downstream forest declines. The analysis showed declines in forest abundance of 48% and 23% between 1961 and 1981 downstream from the St. Mary and Waterton River Dams, respectively. Forest declines upstream from the dams were only 5% and 6% respectively. Little change (0-5% decline) in forest abundance was observed along the middle, undammed Belly River. These results support a causal relationship between river damming and downstream forest decline.
Further to this, Reid (pers. comm.) has compared present distribution of cottonwoods along the St. Mary, Waterton and Belly Rivers with maps developed by Dawson and McConnel in the 1880s and has concluded that poplar distribution today is very similar as 100 years ago except for obvious declines below dams on the St. Mary and Waterton Rivers.

Plains cottonwood (*P. deltoides*) has been found to suffer localized, drought-induced mortality along the South Saskatchewan River (Reid, 1991). At Police Point Park in Medicine Hat, cottonwoods died in the immediate vicinity of three high capacity water wells shortly after they were drilled. In these areas, mature poplars were unable to extend the root system rapidly enough to maintain contact with the altered water table. These trees consequently succumbed to drought stress.

7.2 Ongoing Studies in Alberta

Studies on riparian poplars presently being conducted in Alberta as of Fall, 1990 are listed in Table 3.

Table 3: Current (Fall 1990) Studies on Riparian Poplars in Southern Alberta

Researcher	Affiliation	Rivers	Purpose
Larry Cordes	University of Calgary	Lower Bow	On-going investigation of the biogeography and distribution of poplars in the area
Maureen Hills-Urbat	University of Calgary	Red Deer	Master's thesis to investigate regeneration and survival of cottonwoods in Dinosaur Provincial Park
Sandra Marken	University of Calgary	Red Deer	Master's thesis to relate riparian vegetation and cottonwood age-class distribution to hydrologic regime and land use
David Reid	Hardy BBT	Oldman, Waterton, St. Mary, Belly, Milk	Inventory of riparian vegetation to develop instream flow needs for these streams
Stewart Rood John Mahoney	University of Lethbridge	Oldman, Waterton, St. Mary, Belly	Inventory of riparian poplars to assess the operation of the Oldman Dam and determine instream flow and other mitigation requirements
Tony Yarranton	Concord Scientific	Highwood	Inventory of riparian vegetation to assess impacts of Highwood water diversion project and establish instream flow requirements
Tony Yarranton	Concord Scientific	Willow Creek	Inventory of riparian vegetation to assess impacts of a proposed offstream storage reservoir and to establish instream flow requirements

7.3 Reduced Seedling Establishment due to Dams

As discussed above, spring flooding is essential to the riparian ecosystem and must persist for forest replenishment. The operation of flow control structures to trap spring floods has a serious ecological impact on the riparian ecosystem downstream. The prevention of downstream flooding, or storage of water for municipal, industrial, or hydroelectric needs (Harris et al., 1987) may be desirable, but it also eliminates one, or all, of the conditions necessary for seedling establishment. Although many impoundments in southern Alberta do not have the capacity to significantly alter peak flows, some reservoirs may. Moreover, as more dams are constructed, the cumulative effect within a basin may become significant.

The river systems of southern Alberta are naturally very dynamic. Periodic overbank flooding shifts channels and drives the meandering process. The movement of the river channel within the river valley constantly exposes or builds new sites suitable for poplar establishment. Trapping spring floods or releasing a constant flow downstream from impoundment structures alters the hydrological pattern and creates a more stable regime. Stabilized flows contribute to degradation of the streambed, less floodplain deposition, and less lateral movement of the channel (Williams and Wolman, 1984). Downgrading eliminates broad sand and gravel bars and forms steeper embankments that are less suitable for poplar establishment (Everitt, 1968; Johnson et al., 1976; and Bradley and Smith, 1986).

The model of poplar establishment presented by Bradley and Smith (1986) (Figure 3) depends on a constant supply of sediment for deposition and formation of new point bars. The loss of this material will inhibit the formation of the bars essential for poplar regeneration. The placement of large reservoirs on rivers causes the formation of a silt shadow where river sediment is depleted for some distance downstream (Williams and Wolman, 1984). The loss of the sediment load downstream from dams is a critical element contributing to the decline of riparian poplar forests downstream from dams (Johnson et al., 1977; Crouch, 1979b; Behan, 1981; Bradley and Smith, 1986; Akashi, 1988).

The characteristics of the river and normal sediment load determines the extent of the silt shadow (Williams and Wolman, 1984). Clean, steep-gradient rivers with coarse textured beds recover silt loads quickly while shallow-gradient rivers with sand and silt beds recover much more slowly. Up to 300 km may be required for meandering prairie rivers to recover the pre-dam sediment load (Williams and Wolman, 1984). The sediment-depleted river below a dam scours the river bend and bank to replenish the sediment load. This action removes sediment from the riparian system so that the formation of sites suitable for poplar seedling establishment is reduced.

If poplar forest decline is closely related to sediment depletion, the forest decline should be limited to the zone of depletion. The poplar forest should recover as the river regains its sediment load and deposition of sediments forming suitable establishment sites reoccurs. No studies have been completed in southern Alberta on the actual extent of sediment load changes downstream from dams. However, preliminary work (Mahoney and Rood, pers. comm.) below the St. Mary and Waterton dams suggests that pre-dam sediment loads may be regained within 15 km of the dams. Since no forest recovery is found within 40 km of these dams (Rood and Heinze-Milne, 1989), it is postulated there are other factors besides the silt shadow contributing to the downstream forest decline along these rivers.

With respect to other dams on southern Alberta Rivers, the silt shadow created by the Dixon Dam on the upper Red Deer River probably is not affecting cottonwood replenishment along the lower Red Deer River since there are major sources of sediment, including tributary streams and badlands, downstream of the dam (Marken, pers. comm.). The silt shadow below the Bearspaw Dam on the Bow River may not to be affecting riparian poplar replenishment in the Blackfoot Indian Reserve due to an influx of sediment from the Highwood River, which is not dammed. However these predictions need verification.

As a general conclusion, however, the silt shadow appears to be an important factor in riparian poplar decline on high sediment rivers where there are few new sediment sources for considerable distances downstream of dams.

7.4 Drought Stress due to Dams and Diversions

Seedling survival is a limiting factor of the poplar forest cycle in southern Alberta. An increase in drought stress would likely decrease seedling survival and further exaggerate this limitation to forest replenishment. Changes in the flow regime that reduce flow during the hot, dry summer probably increase the rate of substrate drying and the level of drought stress.

Under natural conditions, slow flow reduction provides poplars with an interval for hardening. During this period plant tolerance to drought stress gradually increases. An abrupt reduction in downstream flow eliminates this hardening interval and is likely to be particularly stressful (Crouch, 1979b; Rood and Heinze-Milne, 1989). Preliminary work (Mahoney and Rood, pers. comm.) indicates that riparian water table levels closely match river stage. Rapid stage decline is therefore indicative of rapid water table decline. If root growth is inadequate to maintain contact with the falling water table, drought stress and, possibly, mortality will result. This is most likely to occur in sites with a gravel on the surface or with a gravel substrate below fluvially deposited sands and silts. Seedlings have limited root systems to cope with a sudden change in water availability throughout their first year. If the water table declines abruptly during the first year, desiccation and mortality is very likely. Marken (pers. comm.) noted that plains cottonwoods in the 30 to 40 year age class have significantly smaller diameters where they grow on sites which have gravel substrates compared to those that do not. Albertson and Weaver (1945) noted that older, less vigorous trees are less drought resistant than middle-aged trees so that an abrupt water cut-off could be fatal to these trees as well. In Alberta, this was observed in Police Point

Park on the South Saskatchewan River in the vicinity of high capacity water wells (Reid, 1991).

The ability of poplars to resist drought stress varies with the species (Pallardy and Kozlowski, 1981). For example, plains cottonwood was found to respond more slowly to drought stress than balsam poplar hybrids by taking longer to close leaf stomata and longer to reopen them as well. These researchers did not investigate narrowleaf cottonwood. However, a decline of all species may occur over large areas if severe drought conditions occur.

7.5 Livestock Production

River valleys are used extensively for livestock production. The forest provides protection from poor weather, the river provides ready access to water, and the generally abundant vegetation provides forage. It is noteworthy that the nutrient value of forage species in riparian poplar stands is generally low compared to that of the adjacent grasslands. However, this is often compensated for by increased biomass production.

Light grazing is probably not detrimental to riparian poplar forests. It can clear the understory and add nutrients to the riparian zone. Unfortunately, livestock overuse is often the case and this can seriously degrade the riparian ecosystem and contribute to riparian poplar decline (Behan, 1981; Crouch, 1979a; Kauffmann and Krueger, 1984; Kellogg and Swan, 1986; Shaw, 1976). Cattle prefer the young poplar seedlings and saplings as a food source (Behan, 1981). In addition, they often congregate on point bars near the river's edge to obtain access to water which can lead to trampling of young seedlings. These losses limit poplar replenishment in grazed areas. Marlow and Pogacnik (1985) report that in late summer when water is scarce, up to 80% of the forage may be derived from the 4% of pasture acreage that is in the riparian zone in Colorado. Marken (pers. comm.) suggests that one of the major causes of lack of poplar replenishment along the Red Deer River is grazing by cattle. As well, overgrazing can alter the quantities of dead and live stems (Knopff and Connor, 1982) and reduce shrub cover by 92% and canopy cover by 55% (Marcusson, 1977).

The effects of cattle grazing are illustrated by the recovery or survival of forests along river reaches that have been protected by fencing (Behan, 1981; Crouch 1979b). Protection from grazing promotes rapid recovery of poplars and understories (Davis, 1977; Elmore, 1989; Kauffman and Krueger, 1984; Hansen, 1985; Reichard, 1989; Smith, 1989). Protection during the hot summer months appears to be especially important (Marcusson, 1977; Platts et al., 1987), although studies on the effectiveness of various grazing systems to reduce negative effects on poplars have so far been inconsistent and inconclusive (Hansen, 1985).

7.6 Harvest by Man and Beavers

Historically, the river forests were important sources of wood since the uplands of the western plains support few trees. Although poplar has poor construction characteristics, it was often pressed into service as the only material available. River poplars were used to build homes, forts and other structures both in the river valley and on the prairie (Shaw, 1976).

Poplar was also used extensively as fuel for cooking and heating. Gildart (1984) reports that harvesting of poplar to power steamboats also had a considerable impact. The removal of 250,000 cords of poplar between the Yellowstone River and Fort Benton on the Missouri River over a period of 20 years must have seriously reduced the riparian forest along that reach (Gildart, 1984). Marken (pers. comm.) suspects that a lack of trees in the 80 to 120 year age class along the Red Deer River may be due to a large influx of settlers to the region just before and at the turn of the century.

Riparian poplar forests have been cleared to open areas for crop cultivation and urban expansion. The alignment of transportation routes and the development of recreation areas has also resulted in the clearing of poplar forests. Removal of these forests has led to a concentration of wildlife in the remaining stands. This may cause species such as beaver, which preferentially select young poplars over willow, to increase harvesting in limited areas in an attempt to survive in the smaller forest (Barnes, 1985; Crouch, 1979b). If the balance of beavers and poplars is further distorted due to a reduction in beaver predators around developed areas, an increased loss of riparian poplars can result.

Removal of trees by beaver has been suggested as a threat to limited stands of riparian poplars along the lower Bow River (Cordes, 1991) and the Red Deer River in Dinosaur Provincial Park (Maureen Hills-Urbat, pers. comm.).

7.7 Developments on Floodplains

Several developments on floodplains affect riparian poplar replenishment and survival in relatively localized areas, but the cumulative effect may have a significant impact in southern Alberta, especially when they lead to demands for flood control. These developments include:

Rural Acreage Development - This is a relatively new and incremental encroachment which can result in permanent removal of riparian vegetation, intensive grazing pressure and pumping of groundwater. More importantly it can lead to demands for flood control. Municipal zoning to prevent building in floodplains can be used to address this problem.

Agriculture - Besides the cultivation of flood plains, these areas are attractive for feedlot operations and as farm building locations. As well, it is suspected that competition from introduced agricultural species such as sweet clover (*Melilotus* sp.), may hinder poplar replenishment on newly formed bars. Irrigation activities and application of fertilizers, which can lead to salinization of soils in river valleys, are another threat. Herbicide drift from aerial spraying of agricultural lands has been postulated as another agricultural factor which may affect survival of riparian poplars (Middleton, pers. comm.).

Golf Courses - These and other recreational developments result in removal of riparian vegetation and negative impacts on riparian forests with pumping from groundwater sources, herbicide drift and, possibly, fertilizer use.

Gravel Mining - This activity can result in temporary, sometimes permanent removal of forests and impacts on ground water.

Industrial Activities - Primarily including oil and gas exploration, development and transportation, this can result in clearing of forests.

Onstream Reservoirs - While much of this report discusses downstream effects of reservoirs, direct loss of riparian poplars can occur behind dams when river valleys are flooded out.

8.0 RIPARIAN POPLAR DISTRIBUTION AND DENSITY IN SOUTHERN ALBERTA

As part of this overall assessment of the biology and status of riparian poplars in southern Alberta, a project was undertaken to determine the present distribution and density of riparian poplars along rivers in southern Alberta through interpretation of recent air photos. Comparisons were made of distribution and density of riparian poplars interpreted from air photos from the early 1950s to determine if any changes were apparent over a 30-year period along the Bow, Oldman, Red Deer and South Saskatchewan Rivers. The present distribution of riparian poplars also was compared to the mapped distribution of wooded river valleys in the early 1880s to identify reaches that have changed since that time.

8.1 Methods

Poplars were mapped using air photo interpretation along major river valleys and their major tributaries within the grasslands of southern Alberta (Map 2). More specifically, mapping of the major rivers was completed upstream to a point where balsam poplar, aspens and conifers were found in large numbers in the coulees and the main valley. This generally included those portions of the rivers occurring in the Mixed Grassland, Fescue Grassland and outer fringe of the Aspen Parkland Natural Regions. Mapping of major tributaries to these rivers was completed up to a point where riparian poplars no longer occurred.

Rivers and their major tributaries investigated were:

- Red Deer River - Threehills Creek, Kneehills Creek, Rosebud River
- Bow River
- Oldman River - Pincher Creek, Willow Creek (to Hwy 2), Little Bow River
- Belly River
- St. Mary River - Lee Creek
- Waterton River - Drywood Creek, Foothills Creek
- South Saskatchewan River - Bullshead Creek
- Milk River

Poplars could be detected on photos at scale of 1:40,000 or greater using a mirror stereoscope at three times magnification. Mapping was first done from photos dating to the early 1980s to determine present distribution and then from photos dating to the early 1950s, the earliest available photography, to determine if any changes in distribution or density could be detected. Air photography flown by the federal government in the 1920s also was examined but did not cover areas pertinent to this study. In total over 1300 photos were interpreted. Table 4 provides a summary of photos used for the 1980s mapping. A more complete listing of photos used for both the 80s and 50s is filed with Alberta Forestry, Lands and Wildlife - Fish & Wildlife Division in Lethbridge. Only four rivers were considered in the 1950s mapping - Bow, Red Deer, South Saskatchewan and Oldman - as changes in distribution and abundance along the Milk River (Hardy BBT, 1990) and the Belly, Waterton, and St. Mary Rivers (Rood and Heinze-Milne, 1989) have been completed by other researchers.

The location and density of riparian poplars was mapped onto 1:50,000 NTS map sheets. A colour-coded system representing four density categories was used; stands were mapped as greater or less than 50 m wide, and as sparse or dense. Areas undergoing cultivation were also delineated. The original colour-coded maps are on file with the Alberta Forestry, Lands and Wildlife, Fish and Wildlife Division in Lethbridge, Alberta.

Table 4: 1980s Air Photography Used to Determine Riparian Poplar Distribution and Density

River	Year	Scale	Type
Red Deer	1986	1:40,000	b/w
Bow	1981 1983 1985	1:30,000 1:30,000 1:30,000	b/w b/w b/w
Highwood	1983	1:40,000	b/w
Oldman	1985	1:30,000	b/w
Belly	1985	1:30,000	b/w
St. Mary	1985	1:30,000	b/w
Waterton	1985	1:30,000	b/w
South Saskatchewan	1980 1985 1985 1986	1:30,000 1:30,000 1:30,000 1:40,000	b/w b/w false colour infrared b/w
Milk	1984	1:30,000	false colour infrared

Data from the 1:50,000 scale maps was summarized for presentation on a 1:1 000 000 map by dividing each river into fairly homogeneous reaches based on riparian poplar distribution and density, and geomorphology. The divisions are somewhat subjective since in nature changes in riparian poplar density are often gradual rather than abrupt. Map 2 shows reaches identified by a river letter and reach number (e.g. R1, BL3).

For each reach an overall assessment was made of poplar density - none/negligible, sparse, moderate, dense and very dense. The river length in each density category was measured using a computer coordinating planimeter. Although it might have been more desirable to planimeter areas of stands in each density category, this would have required working again from the original air photos, which time and resources did not permit. For each reach notes were also made of channel character (freely meandering, confined meandering, straight and braided), floodplain width, disturbance and special features.

Although there is a great deal of confidence in the results, mention should be made of certain limitations inherent in air photo interpretation. One very important limitation is that young age classes of poplars (under 2m) could not be differentiated from shrubs, therefore they are not mapped. And, photos taken very early in the season before leaves appear or very late after leaf senescence may result in underestimation of density. As well, some photos are over- or under-exposed resulting in loss of contrast and thus detail. These difficulties are accentuated with older photography. Furthermore, changes in the cultural landscape (ie roads) and in the physical landscape (ie river course) can inhibit accurate transfer of air photo information onto map sheets. And of course less detail is evident with smaller scale photography. One final point is that groundtruthing, which allows for verification of the interpretation, was not undertaken as part of this project.

The distribution of wooded areas in river valleys for most of the present study area was mapped in the 1880s as part of the Dominion Survey (Dawson, 1885). In this survey, Dawson identified river valleys that were treeless, valleys with small isolated groves, or wooded river valleys. By relating these three categories to those used in the present study, it is possible to qualitatively compare the historic distribution with the present distribution. Dawson (1885) did not use the same categories as those used in the present study, nor did he use density as a weighting factor. For comparison between the two data sets, it was assumed that the density of forest along reaches left unmarked by Dawson were equivalent to the density of forest along reaches rated none/negligible in the present study. Reaches noted to have only isolated groves in Dawson's report were assumed to be equivalent to reaches with sparse forests in the present study. The wooded river valleys identified by Dawson were estimated to be equivalent to those rated as moderate, dense or very dense in the present study. Reach boundaries used for airphoto analysis were easily located on the 1885 map for the purposes of comparison.

Statistical analysis of the data was not undertaken as much of the interpretation is qualitative rather than quantitative.

8.2 Present Distribution and Density

Distribution and density of riparian poplars in southern Alberta as determined from 1980s air photos is presented in Map 1. Table 5 provides information on the length of each river in each density category, in kilometres and by percent.

Of the 2075 km of river length investigated, 30 percent (625 km) has sparse density of poplars; 23 percent (470 km) has no or negligible density; 22 percent (465 km) has moderate density, 15 percent (320 km) is considered dense and nine percent (195 km) very dense (Figure 5).

Figure 5: 1980's Riparian Poplar Density Distribution in Southern Alberta (percent river length per density class)

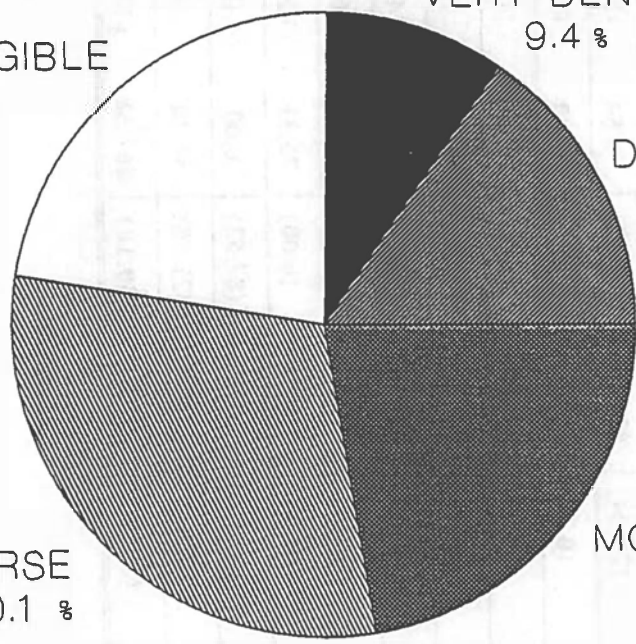


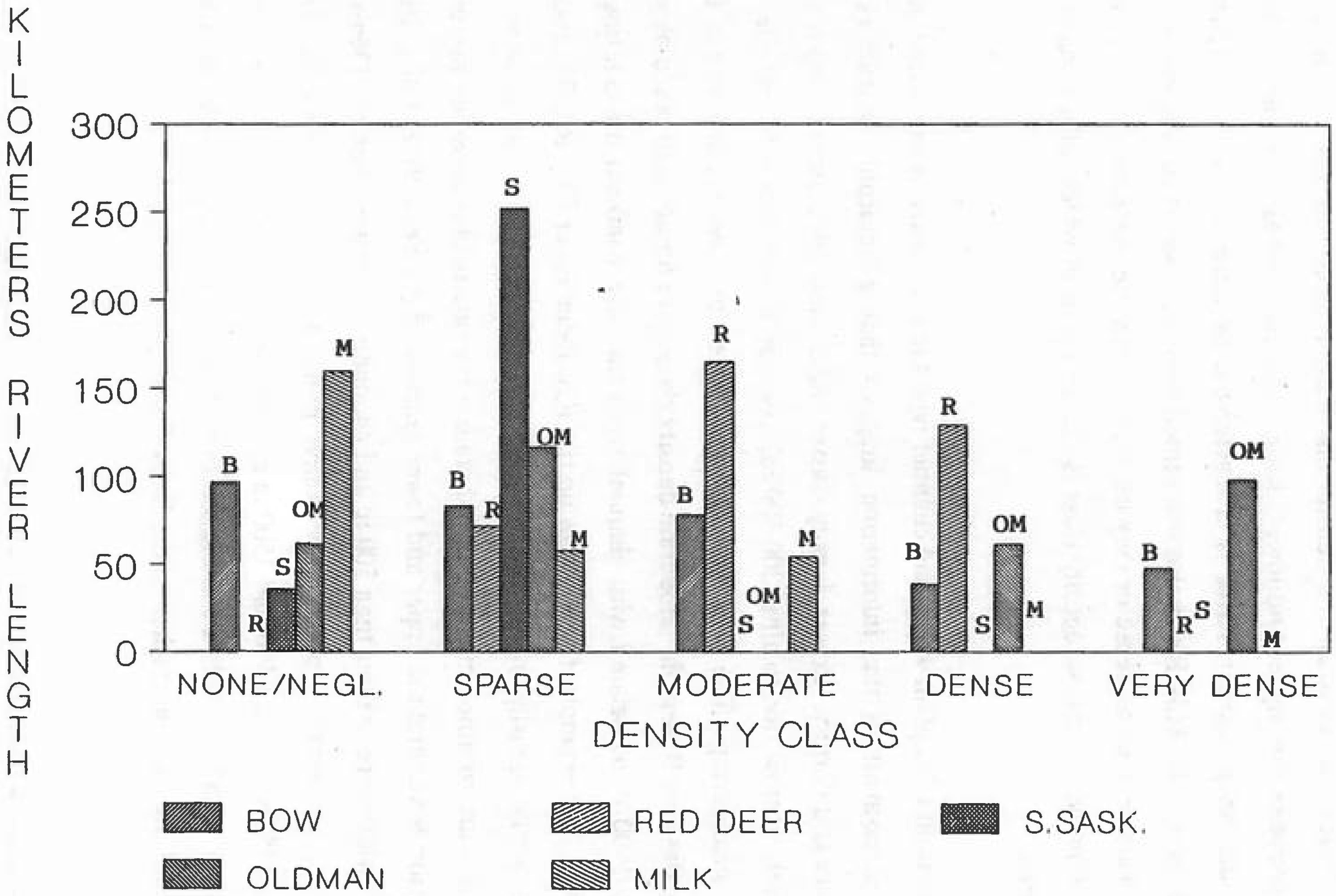
Table 5: 1980s Density Distribution Along Rivers in Southern Alberta

River	Length (Km)		KM/DENSITY CLASS (% INDIVIDUAL RIVER LENGTH)									
			1 None/Negligible		2 Sparse		3 Moderate		4 Dense		5 Very Dense	
Red Deer	366.65		0.00	(0.00)	72.04	(19.65)	165.05	(45.02)	129.56	(35.34)	0.00	(0.00)
Bow	346.62		97.18	(28.04)	83.60	(24.12)	78.84	(22.75)	38.86	(11.21)	48.14	(13.89)
Highwood	69.18		0.00	(0.00)	41.76	(60.30)	27.42	(39.64)	0.00	(0.00)	0.00	(0.00)
Sheep	25.93		0.00	(0.00)	0.00	(0.00)	0.00	(0.00)	25.93	(100.00)	0.00	(0.00)
Oldman	340.01		62.08	(18.26)	117.18	(34.46)	0.00	(0.00)	61.93	(18.21)	98.82	(29.06)
Belly	149.96		0.00	(0.00)	0.00	(0.00)	63.56	(42.38)	37.59	(25.07)	48.81	(32.55)
St. Mary	140.91		115.51	(81.94)	0.00	(0.00)	0.00	(0.00)	25.40	(18.03)	0.00	(0.00)
Waterton	75.31		0.00	(0.00)	0.00	(0.00)	75.31	(100.00)	0.00	(0.00)	0.00	(0.00)
South Saskatchewan	288.04		35.95	(12.48)	252.09	(87.52)	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)
Milk	272.32		159.96	(58.74)	57.96	(31.20)	54.40	(19.98)	0.00	(0.00)	0.00	(0.00)
Total (% Total)	**2,074.93**	**(100)**	**470.68**	**(22.68)**	**624.63**	**(30.10)**	**464.58**	**(22.39)**	**319.27**	**(15.39)**	**195.77**	**(9.44)**

Some general aspects of riparian poplar distribution along the major rivers are worth noting (Figure 6). The Bow River is the only river which has reaches in all density classes. Density of riparian poplars along the Red Deer River is clustered within the three middle density categories (sparse, moderate, dense); no reaches were at either extreme (none/negligible or very dense). By contrast the density distribution along the Oldman River is equally divided between the higher and lower classes with no reaches of moderate density. The entire South Saskatchewan River is characterized by none/negligible or sparse riparian poplar density. The Milk River also is oriented towards lower density distribution, with no reaches characterized as dense or very dense, and only the easternmost reach of moderate density. Finally, the sparse density class is the only one in which all the major rivers are represented.

Information on floodplain width and channel type for each reach is presented in Appendix A. An assessment of this information suggests that geomorphic characters influence distribution and density. Lower density classes (none/negligible and sparse) tend to occur on relatively narrow floodplains (200-500 m) associated with channels that are straight or confined meandering. The best examples of this are the lower reaches of the Bow River below the Bassano Reservoir. Moderate density classes are found on floodplains with widths of 300 to 1000 m associated with channel types that are confined meandering or freely meandering. For example, four reaches on the Red Deer River (R1, R3, R5, and R9) have moderate poplar density along floodplains which are less than 500 m wide and have channels that are confined meandering; whereas moderate poplar densities also occur along the Waterton River and the upper and lower reaches of the Belly River (BL1, BL4) where floodplain widths are greater than 500 m and channels freely meandering. Dense and very dense classes of riparian poplars are found predominantly along reaches which have floodplain widths between 500 and 1500 m and channel types which are freely meandering or braided. Examples of this are along the Bow River within the Blackfoot Indian Reserve (B2, B3) and the middle reaches of the Belly River (BL2, BL3).

Figure 6: 1980's Riparian Poplar Density Distribution Along Five Major Rivers in Southern Alberta (river length per density class) (Reference to Table 5.)



8.3 Comparison with 1950s Distribution

Table 6 and Figure 7 present riparian poplar distribution and density on the Red Deer, Bow, Oldman and South Saskatchewan Rivers during 1950-52 compared to that of the 1980s. Overall there appears that little or no change in distribution and density of riparian poplars along these four rivers in the last thirty to thirty-five years. In fact, the data suggests a slight increase in density along some reaches. Analysis of Table 6 reveals that one reach on the Red Deer (R8) shifted from moderate in the 1950s to dense in the 1980s and one reach on the Bow River (B3) shifted from dense (1950s) to very dense (1980s). No major changes in density along the Oldman River were determined. The easternmost reach of the South Saskatchewan River (S3) shifted from none/negligible (1950s) to sparse (1980s).

Caution must be exercised when interpreting these results due to the arbitrary nature of the reach divisions and the necessity of generalizing density within each reach. As a result, localized changes in density may be masked.

8.3.1 Cultivation

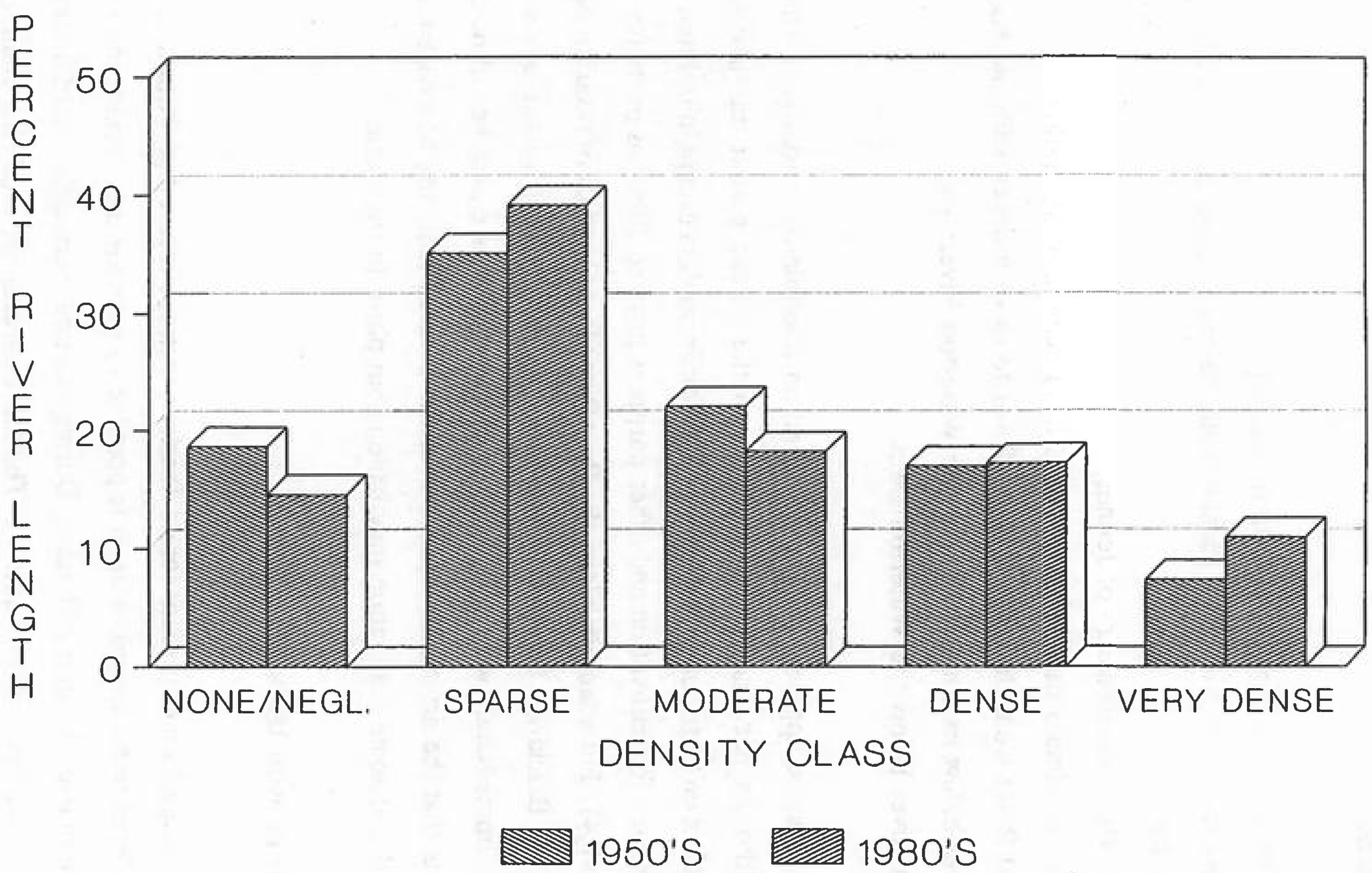
According to interpretation of the 1980s air photos, cultivation is present in 31 of the 44 river reaches (Appendix A). Areas of cultivation are outlined on the 1:50,000 maps which are on file with Alberta Forestry, Lands and Wildlife, Fish and Wildlife Division in Lethbridge, Alberta.

Table 6: 1950s and 1980s Riparian Poplar Density Distribution Along Four Major Rivers in Southern Alberta

River	Length (Km)		KM/DENSITY CLASS (% INDIVIDUAL RIVER LENGTH)									
			1 None/Negligible		2 Sparse		3 Moderate		4 Dense		5 Very Dense	
Red Deer	366.65	1950s	*0.00	(0.00)	72.04	(19.65)	216.38	(59.00)	78.23	(21.34)	0.00	(0.00)
		1980s	**0.00	(0.00)	72.04	(19.65)	165.05	(45.02)	129.56	(35.34)	0.00	(0.00)
Bow	346.62		97.18	(28.04)	83.60	(24.12)	78.84	(22.75)	87.00	(25.10)	0.00	(0.00)
			97.18	(28.04)	83.60	(24.12)	78.84	(22.75)	38.86	(11.21)	48.14	(13.89)
Oldman	340.01		62.08	(18.26)	117.18	(34.40)	0.00	(0.00)	61.93	(18.21)	98.82	(29.00)
			62.08	(18.26)	117.18	(34.46)	0.00	(0.00)	61.93	(18.21)	98.82	(29.06)
South Saskatchewan	288.04		90.84	(31.54)	197.20	(68.46)	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)
			35.95	(12.48)	252.09	(87.52)	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)
Tutal (% Tutal)	1,341.32		250.10	(18.66)	470.02	(35.04)	295.22	(22.04)	227.16	(16.94)	98.82	(7.37)
			195.21	(14.57)	524.91	(39.13)	243.89	(18.14)	230.35	(17.17)	146.96	(10.96)

* 1950s Density
** 1980s Density

Figure 7: **1950s and 1980s Riparian Poplar Density Distribution Along Four Major Rivers in Southern Alberta (percent river length per density class) (Refer to Table 6)**



According to the 1980s air photo analysis, cultivation of floodplains is prevalent along the following reaches:

- Oldman River from Fort McLeod to its mouth;
- South Saskatchewan River for considerable distances upstream and downstream of Medicine Hat;
- Red Deer River downstream of Jenner;
- Bow River floodplain near Carseland and from Scandia to its mouth;
- Highwood River from the town of High River to its confluence with the Sheep River;
- Belly River below its confluence with the Waterton River; and
- Waterton River below the Waterton Dam.

Generally, cultivation appears to have increased on floodplains in southern Alberta since the 1950s, although not dramatically and not to the extent that it has had an overall measurable effect on distribution and density of riparian poplars except in isolated locations. Clearing of poplars for cultivation and other purposes prior to 1950 has probably had some effect (section 8.4). For example, along the Bow River larger stands of riparian poplars are found within the Blackfoot Indian Reserve where there is no cultivation as compared to smaller stands immediately west of the Reserve where there is extensive cultivation. One further point is that the air photos upon which the present mapping was based are now 5 to 10 years old and some cultivation may have taken place in that time.

8.4 Comparison with 1880s Distribution

Although the comparison of present forest densities with the forest distribution of the 1880s must be considered to be approximate, it is possible to estimate a general trend in riparian forest distribution over the past 100 years. During this time period the riparian forest along most reaches has changed little (Table 7). The most uncertainty regarding changes in river valley forests since the 1880s is with those which were mapped as wooded by Dawson compared to those mapped as moderate, dense or very dense in the 1980s. For the purposes of this study they have been considered equivalent since the generality of Dawson's "wooded" category does not allow for a more refined assessment.

Reaches of the Red Deer River show the most consistent change over 100 years. From the 1880s to the 1980s, four reaches show increases in riparian poplars from negligible/none or sparse to moderate or dense. None of the reaches investigated along the Red Deer River showed a decline in this period. A tributary of the Red Deer, the Rosebud River, did show a decline from moderate-very dense to sparse over this interval.

There is no discernable change along the Bow River between the time of these two surveys with the exception of an increase from none-negligible to sparse along the reach from Bassano to Bow City (B5). The lower portion of the Highwood River is unchanged, but riparian forests above High River (H1) appear to show an increase from sparse to moderate. However, this may be due to an overlap between the boundaries of the limit of wooded river valley noted by Dawson and the upstream boundary of the H1 reach. The Sheep River near Okotoks has increased from a few isolated groves to a more densely wooded stream along the reach surveyed.

Two reaches of the Oldman River show a change since the 1880s. Reach OM3, immediately upstream of the Belly River confluence, shows a decrease in the riparian forest from dense to sparse between the 1880s and the 1980s, the largest apparent decline of any major river in the study area. Reach OM6, just upstream of the mouth of the Oldman River, shows a decline from sparse to negligible. The reasons for these declines are unclear, although cultivation may be a factor.

Table 7: Changes in Riparian Forest Distribution 1880s to 1980s

Reach		Dawson *	1980s	Change
Red Deer:	R3	Negligible	Moderate	increase
	R4	Sparse	Sparse	no change
	R5	Sparse	Moderate	increase
	R6	Moderate - Very Dense	Dense	no change
	R7	Negligible	Moderate	increase
	R8	Sparse	Dense	increase
Rosebud River		Moderate - Very Dense	Sparse	decrease
Bow:	B1	Moderate - Very Dense	Moderate	no change
	B2	Moderate - Very Dense	Dense	no change
	B3	Moderate - Very Dense	Very Dense	no change
	B4	Moderate - Very Dense	Moderate	no change
	B5	Negligible	Sparse	increase
	B6	Negligible	Negligible	no change
	B7	Negligible	Negligible	no change
	B8	Sparse	Sparse	no change
Highwood:	H1	Sparse	Moderate	increase
	H2/3	Sparse	Sparse	no change
Sheep:	SH1	Sparse	Dense	increase
Oldman:	OM1	Moderate - Very Dense	Moderate	no change
	OM2	Moderate - Very Dense	Very Dense	no change
	OM3	Moderate - Very Dense	Sparse	decrease
	OM4	Moderate - Very Dense	Dense	no change
	OM5	Sparse	Sparse	no change
	OM6	Sparse	Negligible	decrease
Belly:	BL1	Moderate - Very Dense	Moderate	no change
	BL2	Sparse	Very Dense	increase
	BL3	Moderate - Very Dense	Dense	no change
	BL4	Moderate - Very Dense	Moderate	no change
St Mary:	SM1	Moderate - Very Dense	Dense	no change
	SM2	Sparse	Negligible	decrease
Waterton:	W1	Moderate - Very Dense	Moderate	no change
South Saskatchewan:	S1	Sparse	Sparse	no change
Milk:	M1	Negligible	Negligible	no change
	M2	Negligible	Negligible	no change
	M3	Negligible	Negligible	no change
	M4	Sparse	Sparse	no change
	M5	Negligible	Negligible	no change
	M6	Sparse	Sparse	no change
	M7	Moderate - Very Dense	Moderate	no change

* Distribution categories used by Dawson (1880s) have been translated for the purpose of comparison with the present study as:

Present 1980s:	**Dawson 1880s:**
None/Negligible	treeless
Sparse	small isolated groves
Moderate	-
Dense	wooded river valleys
Very Dense	-

Along the Belly River all but one reach have remain unchanged since the 1880s. Reach BL2, immediately upstream of the confluence with the Waterton River shows an increase in forest density from sparse to very dense over the past 100 years. This is a dramatic change considering the lack of change along the other rivers studied. Again, the reasons for this are unclear. On the other hand, the St. Mary River below the St. Mary Reservoir (SM2) shows a decrease in riparian forest distribution from sparse to none/negligible. The Waterton River shows no apparent change.

The South Saskatchewan River to Medicine Hat (S1) shows no change during the past 100 years, riparian poplars being rated as sparse both in Dawson's 1880s maps and in the 1980s air photo interpretation. Dawson's maps do not extend beyond Medicine Hat so comparison of the lower reaches is not possible.

All reaches of the Milk River show no change. However it is noteworthy that Dawson mapped Reach M4 above Verdigris Coulee as treeless and below Verdigris Coulee as a wooded river valley. The 1980s maps show the whole reach as sparse, with an annotation that riparian poplar distribution is generally patchy and sparse except for two dense concentrations.

8.5 Significant Reaches

Based on the results of this study, six river reaches stand out as particularly significant for riparian poplars in southern Alberta. Criteria used to assess significance are 1) density, 2) species diversity and position in range of species and 3) amount of disturbance. The river reaches assessed as significant are:

- Bow River, Carseland - Cluny (B2-3) (87 km)
  - poplar stands broad and dense to very dense
  - composed of balsam poplar, plains cottonwood and hybrids; at limit of ranges of both balsam poplar and plains cottonwood
  - relatively undisturbed, particularly in Blackfoot Indian Reserve; cultivation west of the Blackfoot Indian Reserve and eastern portion of reach influenced by Bassano Reservoir
  - floodplain broad (up to 2500m wide) with freely meandering and braided channel

- Oldman River, Brocket - below Lethbridge (OM2-4) (182 km)
  - poplar stands broad and dense to very dense
  - composed of narrowleaf cottonwood and balsam poplar and their hybrids including trispecific hybrids with plains cottonwood; part of very restricted range of narrowleaf cottonwood in Canada
  - relatively undisturbed, particularly in Peigan Indian Reserve; cultivation along lower portion of reach
  - floodplain broad (up to 2000m wide) with freely meandering and braided channel; channel has changed course in several places over 30 years; 20 km reach (OM3) has narrow, straight valley with confined channel and sparse poplar density

- Belly River, Glenwood - below Waterton confluence (BL2-3) (86 km)
  - poplar stands narrow and dense to very dense
  - composed of narrowleaf cottonwood, balsam poplar and their hybrids; part of restricted range of narrowleaf cottonwood in Canada
  - relatively undisturbed particularly through Blood Indian Reserve
  - 500 to 1500 m wide floodplain with freely meandering and braided channel

- Red Deer River, Finnegan - Empress (R5-10) (240 km)
  - poplar stands generally elongated in form but with a particularly diverse mosaic of stand sizes upstream of and extending into Dinosaur Provincial Park and moderate to dense
  - composed of plains cottonwood; at northern and western limit of range of plains cottonwood in North America
  - relatively undisturbed; some cultivation on floodplain below Jenner
  - floodplain consistently 500 m wide with confined meandering, freely meandering and braided channel

- Milk River, through Milk River Canyon (M7) (54 km)
  - poplar stands medium-sized and sparse with localised dense patches
  - composed of plains cottonwood; at western limit and near northern limit of range of plains cottonwood in North America
  - isolated and undisturbed except for a fire that killed trees in a 10 km reach in 1973
  - floodplain 500-750 m wide with confined and freely meandering channel

- Sheep River near Okotoks (SH1) (26km)
  - poplar stands medium-sized and very dense
  - composed of balsam poplar and hybrids with narrowleaf cottonwood
  - disturbance includes residential development in and near Okotoks and cultivation at confluence with Highwood River
  - 500 m wide floodplain with freely meandering channel

8.6 Status of Riparian Poplars in Southern Alberta

Over 50% of total river length in southern Alberta is characterized by none or sparse riparian poplar density. The 980 km of river valleys that do contain relatively continuous stands of poplars therefore represent a very restricted habitat, less that 500 km2 in total area. Because these habitats have such disproportionately large importance to wildlife relative to the total area they occupy on the prairies, loss of even a small portion of the riparian poplar forests, and in particular of those reaches assessed as significant in the previous section, could have major implications for prairie wildlife.

It is encouraging that there appears to have been no general decrease in riparian poplars along rivers in southern Alberta since the 1880s. In fact comparison of the 1980s mapping with that for the 1950s and 1880s suggests slight increases in distribution and density along some reaches of the Red Deer, Bow and South Saskatchewan Rivers. As well, the Belly River above its confluence with the Waterton River and the lower Sheep River show notable increases in riparian poplars since the 1880s.

However some reaches have experienced notable declines. A study by Rood and Heinze-Milne (1989) documented a decline of riparian poplars along the St. Mary and Waterton Rivers below dams since the 1950s. A decline on the St. Mary River also is apparent when 1980s mapping is compared with 1880s mapping. As well, two reaches on the Oldman River, one immediately upstream of the confluence with the Belly and the other downstream of Taber, and the lower Rosebud River show declines since the 1880s. Clearing for cultivation is a probable factor in these declines.

Concerns have been expressed about the impacts of the nearly-completed Oldman Dam on significant tracts of riparian forest in the Oldman River valley below that dam (Cliff Wallis, pers. comm.). The legitimacy of these concerns is substantiated not only by the results of this study and that of Rood and Heinze-Milne (1989) in Alberta, but also by the results of several studies of riparian poplar forests below dams in the United States (Johnson et al., 1976; Brown et al., 1977; Crouch, 1979; Behan, 1981; Reily and Johnson, 1982; Bradley and Smith, 1986; Akashi, 1988).

Furthermore, determination of age structures of riparian poplar stands through field surveys will be required before any conclusion about the status of riparian poplars in southern Alberta can be clearly ascertained. If such studies find that, in general, replenishment is not keeping up with mortality, then there will be cause for even greater concern about the long-term survival of riparian poplar forests in southern Alberta.

9.0 RESEARCH AND MANAGEMENT NEEDS

The understanding of the extent and reasons for the decline of riparian poplar forests along several rivers in the western prairies has increased rapidly through the 1980s. However, there is further information required on the status of riparian poplars, the ecology of these forests, and the physiology of the species involved to assist in developing effective management plans.

9.1 Determining Status and Trends

Several studies have reported decline of riparian poplars in the Great Plains of North America including two from Alberta. Significant decline was noted on the St.Mary and Waterton Rivers below dams and on the Milk River over a 30-year period (Hardy BBT, 1990). However, only a very slight decline was noted on the Belly River and on the St. Mary and Waterton Rivers above dams over a 20-year interval 1961-1981. Furthermore, as part of this study, air photo analysis at a 1:40,000 scale of the Red Deer, Bow, Oldman and South Saskatchewan Rivers suggests no significant decline of riparian poplars along these rivers over a 30-year period, 1950s-1980s.

These general observations need to be verified through more detailed inventories, particularly focused on significant reaches identified in this report. These inventories need to include air photo interpretation and mapping at a scale of 1:20,000 or larger to serve as a baseline for monitoring trends over the long term, field checks to confirm mapping units, and age-class analysis to determine if regeneration is occurring at a rate which matches or exceeds mortality of older trees.

Preliminary work on determination of age structures has been conducted along the Milk River (Bradley, 1982; Hardy BBT, 1990) and the lower Red Deer River (Sandra Marken, pers. comm.; Maureen Hills-Urbat, pers. comm.), but an assessment of long-term survival of these stands has not been undertaken.

In order to more accurately determine the effects of dams on riparian poplars downstream, measurements need to be made of altered river regime. These measurements would include changes in peak flows, mid-summer flows, sediment load, channel movement, and floodplain building.

While the effect of damming on downstream poplar forests is most prominent in the literature as causing poplar decline, other causative agents have been identified as well. These factors, such as livestock grazing, increased beaver activity and floodplain developments, may not have the widespread impact of reduced river flows, but can have significant local impacts. Thus, surveys to locate sites where these other factors are working will help managers target areas where specific intensive management programs can be quickly implemented. This data will also help researchers determine the relative contribution of these factors in riparian forest decline. In particular, specific studies are needed to determine the impacts of livestock production and beaver on replenishment and survival of riparian poplars in southern Alberta. The results of such research will help determine where controlling livestock access to riparian zones through fencing is appropriate and if beaver control programs are needed.

9.2 Riparian Poplar Forest Ecology

The riparian poplar forests of southern Alberta occur along two distinct types of rivers. Reports in the literature refer almost exclusively to the prairie type situation dominated by plains cottonwood. Since some 30% to 50% of the riparian poplars in Alberta are found along foothills type rivers where narrowleaf cottonwood, balsam poplar and hybrids dominate, it is necessary to clarify the differences between these two types of forests and their relationships with the river. Management plans may need to be developed that address the differences found in each zone.

Related to the two river types found in Alberta, is the mechanism of forest regeneration that occurs in each. The general replenishment model proposed for foothill rivers is only in the preliminary stages of development and requires more work. A population survey and construction of an age class profile is needed before this model can be completed. Some researchers have suggested that survival of poplars along foothills rivers may be more tenuous than along prairie rivers due to fewer sites being available for establishment, greater potential for drought stress due to coarser substrates, and dependence on higher, less frequent floods for major regeneration events.

Much of the ecology of poplar forests is based on an understanding of their age class profile. These profiles are normally generated by analysis of increment cores. Such analyses often make basic assumptions on the number of years required to grow to the sampled height. Recent field observations indicate that it may be unreasonable to make some of these assumptions. A study to validate the procedure currently used to age riparian poplars, or develop a modified procedure is necessary to strengthen age class profiles for further analysis.

In addition, little is known about other floodplain species, their interrelationships and requirements for successful establishment. For example, given that the extensive shallow root system of riparian poplars greatly deplete soil moisture (McQueen and Miller, 1966), how is the composition of understories in riparian poplar stands and the vigour of component species affected during times of drought stress? What is the synergistic effect of reduced flooding and drought stress on poplar stands and other riparian habitats, such as wetlands? There is a suggestion that requirements for replenishment of riparian shrubs such as water birch (*Betula occidentalis*) and buffalo berry (*Shepherdia canadensis*) are even more stringent than for riparian poplars (Marken, pers. comm.). Answers to these and other questions could contribute to instream flow needs assessments for riparian habitats and development of models of flow rates and channel dynamics (including sedimentation) required to optimize or maintain these habitats.

9.3 Poplar Physiology

Although the discussion in this report has dealt with poplars in general, the three species found in the riparian areas of southern Alberta are known to react to various stimuli differently. The ability to tolerate flooding, resist drought, and grow roots, shoots, or leaves all vary between species under different pressures. Studies to determine whether these differences are significant is important for management purposes. If the differences are not significant, general management guidelines can be formed; whereas if the differences are significant, specific plans would need to be developed for each species.

In particular, studies on the factors limiting seedling establishment and survival and encouraging asexual reproduction need to be investigated. Seedling establishment and survival is known to limit poplar forest cycling. Availability of seedbeds and water supply have been identified as an important factor contributing to seedling establishment and survival. Other environmental parameters are almost certainly contributing as well and need to be identified. The effects of over-wintering and growth in the second year warrant special attention at this time.

To date, seedling establishment has been assumed to be the overriding mechanism in riparian poplar forest regeneration. However, asexual reproduction may also contribute to the maintenance of the poplar forest through coppicing and suckering. The relative importance of each form of reproduction needs to be clarified as do the conditions that encourage each of these.

Finally, much of the information on poplar physiology presently available is based on laboratory or greenhouse experimentation under controlled conditions. Experimentation in the field or nursery setting will help determine the rate of growth or recovery of riparian poplar forests that might be expected following the implementation of management plans.

9.4 Socio-economic Assessments

As the status of riparian poplars becomes better understood, it will be possible to estimate the significance of any change on related resources. The loss of riparian forests is expected to cause a reduction or loss in wildlife populations, water quality, recreational use and agricultural value. Studies are required to determine how great a loss each of these resources may suffer depending on future trends in the status of riparian forests. This information will help put more accurate values on the costs and benefits of development proposals which affect riparian poplars. It will also help identify the stakeholders most affected by further forest declines, and indicate the resources in greatest need of mitigation measures or protection.

10.0 LITERATURE CITED AND RELATED WORKS

Akashi, Y., 1988. Riparian vegetation dynamics along the Bighorn River, Wyoming, M.Sc Thesis, University of Wyoming, Laramie, 245p.

Albertson, F. & J. Weaver, 1945. Injury and death or recovery of trees in prairie climate, Ecological Monographs, 15(4):395-433.

Anderson, B.W. & R.D. Ohmart, 1979. Riparian revegetation: An approach to mitigating for a disappearing habitat in the southwest, in: The Mitigation Symposium: A National Workshop on Mitigating Losses of Fish and Wildlife Habitats July 16-20, G.A. Swanson (ed). USDA Forest Service General Technical Report RM-65, Fort Collins, Colorado. p481-487.

Ashton, G.D., 1979. River ice, American Scientist 67:38-45.

Asplund, K.K. & M.T. Gooch, 1988. Geomorphology and the distributional ecology of Fremont cottonwood (*Populus fremontii*) in a desert riparian canyon, Desert Plants, 9(1):17-27.

Baker, W.L., 1988. Size-class structure of contiguous riparian woodlands along a Rocky Mountain river, Physical Geography, 9(1):1-14.

Baker, W.L., 1989. Macro- and micro-scale influences on riparian vegetation in western Colorado, Annals of the Association of American Geographers, 79(1):65-78.

Baker, W.L., 1990. Climatic hydrologic effects on the regeneration of *Populus angustifolia* James along the Animas River, Colorado, Journal of Biogeography, 17:59-73.

Barnes, W., 1985. Population dynamics of woody plants on a river island, Canadian Journal of Botany, 63:647-655.

Batson, F.T., P.E. Cuplin & W.A. Crisco, 1987. The use of aerial photography to inventory and monitor riparian areas, US Department of Interior, Bureau of Land Management Technical Reference 1737-2, Denver, Colorado. 13pp.

Behan, M., 1981. The Missouri's stately cottonwoods: How can we save them?, Montana Magazine,September, p76-77.

Bell, 1974. Tree stratum composition and distribution in the streamside forest, American Midland Naturalist, 92:35-44.

Bessey, D.E., 1904. The number and weight of cottonwood seeds, Science, 20:118-119.

Boggs, K.W., 1984. Succession in Riparian Communities of the Lower Yellowstone River, Montana·, MSc Thesis, Montana State University, Bozeman. 106pp.

Botorff, R.L., 1974. Cottonwood habitat for birds in Colorado. American Birds, 28(6):975-979.

Bradley, C.E., 1982. Modified Meandering River Regimes - Effects on Plains Cottonwood Regeneration, MSc Thesis, University of Calgary, Alberta. 138pp.

Bradley, C.E., 1987. Disappearing cottonwoods: The social challenge, Alberta Department of Culture. Provincial Museum Occasional Paper No. 9. p119-121.

Bradley, C. & D. Smith, 1984. Meandering channel response to altered flow regime: Milk River, Alberta and Montana, Water Resources Research, 20(12):1913-1920.

Bradley, C. & D. Smith, 1986. Plains cottonwood recruitment and survival on a prairie meandering river floodplain, Milk River, Southern Alberta and Northern Montana, Canadian Journal of Botany, 64:1433-1442.

Brayshaw, T.C., 1965a. Native Poplars of Southern Alberta and Their Hybrids Department of Forestry Publication No. 1109, Ottawa. 40pp.

Brayshaw, T.C., 1965b. The status of the black cottonwood *Populus trichocarpa* Torrey and Gary. Canadian Field Naturalists 79: 91-95.

Brown, D.E., C.H. Lowe & J.F. Hausler, 1977. Southwestern riparian communities: Their biotic importance and management in Arizona, in: Importance, Preservation and Management of Riparian Habitat: A symposium, R.R. Johnson & D.A. Jones eds. Tucson, Arizona, July 9, 1977. p. 201-211.

Bryon, K., 1928. Changes in plant associations by change in groundwater level, Ecology, 9:474-478.

Campbell, C.J., 1970. Ecological implications of riparian vegetation management, Journal of Soil and Water Conservation, 25:49-52.

Campbell, C.J. & W.A. Dick-Peddic, 1964. Comparison of phreatophyte communities on the Rio Grande in New Mexico, Ecology, 45(3):492-502.

Campbell, C.J. & W. Green, 1968. Perpetual succession of stream-channel vegetation in a semiarid region, Arizona Academy of Science, 5(2):86-98.

Ceulemans, R., I. Impens & V. Steenackers, 1984. Stomatal and anatomical leaf characteristics of 10 *Populus* clones, Canadian Journal of Botany, 62(3):513-518.

Chia-chi, H., T. Crovello & R. Sokal, 1985. The numerical taxonomy of some species of *Populus* based only on vegetative characters, Taxon, 34(2):197-206.

Ciesla, W.M., 1989. Aerial photos for assessment of forest decline - A multinational overview, Journal of Forestry 87(2):37-41.

Clary, W.P. & B.F. Webster, 1989. Managing grazing of riparian areas in the intermountain region, USDA Forest Service General Technical Report INT-263, Ogden, Utah. 11pp.

Colby, B.R., 1964. Scour and fill in sand-bed streams, US Department of Interior, USGS professional paper 462-D, Washington.

Cole, D.N. & J.L. Marion, 1988. Recreation impacts in some riparian forests of the eastern United States, Environmental Management, 12(1):99-107.

Cordes, L.D., 1991. The distribution and age structure of cottonwood stands along the lower Bow River, Alberta, In; The Biology and Management of Southern Alberta's Cottonwoods, Eds, S.B. Rood and J.M. Mahoney. May 3,4, University of Lethbridge.

Critchfield, W., 1960. Leaf dimorphism in *Populus trichocarpa*, American Journal of Botany,47(8):699-711.

Crouch, G., 1979a. Changes in the vegetation complex of a cottonwood ecosystem on the South Platte River, Great Plains Agricultural Council Publication, 91:19-22.

Crouch, G., 1979b. Long-term Changes in Cottonwoods on a grazed and an ungrazed plains bottomland in northeastern Colorado, USDA Forest Service Research Note RM-370, Fort Collins, Colorado. 4pp.

Davidson, W., 1983. Hybrid poplars for reclamation, In: Better Reclamation with Trees Conference, Terre Haute Indiana, pp. 99-106.

Davis, G.A., 1977. Management Alternatives for the Riparian Habitat in the Southwest, In: R.R. Johnson, and D.A. Jones (Tech Coords), Importance, Preservation and Management of Riparian Habitat: A symposium. Tucson, Arizona. USDA Forest Service General Technical Report RM-43. 218p.

Dawson, G.M., 1885. Map showing wooded and prairie districts, etc., in the region in the vicinity of the Bow and Belly Rivers. In maps, etc. to accompany Report of Progress for 1882-83-84, Geological and Natural History Survey and Museum of Canada. Dawson Bros. (Montreal).

DeBano, L. & B. Heede, 1987. Enhancement of riparian ecosystems with channel structures, Water Resources Bulletin 23(3):463-470.

DeBano, L.F. & L.J. Schmidt, 1989. Improving southwestern riparian areas through watershed management, USDA Forest Service, General Technical Report RM-182:1-33, Fort Collins Colorado.

Dickmann, D.I., 1979. Physiological determinants of poplar growth under intensive culture, in: Poplar Research, Management and Utilization in Canada, D. Fayle, L. Zsuffa and H. Anderson eds. Ontario Ministry of Natural Resources Information Paper No. 102, 12pp.

Dickmann, D., H. Phipps & D. Netzer, 1980. Cutting diameter influences early survival and growth of several *Populus* clones, USDA Forest Service Research note NC-261, St. Paul, Minnesota. 4pp.

Dickmann, D.I. & K.W. Stuart, 1983. The culture of poplars in eastern North America, Department of Forestry, Michigan State University, East Lansing.

Eckenwalder, J., 1984a. Natural intersectional hybridization between North American species of *Populus* (*Salicacae*) in sections Sigeiros and Tacamahaca I: Population studies of *P.x Parryi*, Canadian Journal of Botany, 62(2):317-324.

Eckenwalder, J., 1984b. Natural intersectional hybridization between North American species of *Populus* (*Salicacae*) in sections Sigeiros and Tacamahaca II: Taxonomy, Canadian Journal of Botany, 62(2):325-335.

Eckenwalder, J., 1984c. Natural intersectional hybridization between North American species of *Populus* (*Salicacae* in sections Sigeiros and Tacamahaca III: Palaeobotany and evolution, Canadian Journal of Botany, 62(2):336-342.

Eliasson, L., 1968. Dependence of root growth on photosynthesis in *Populus tremula*, Physiologia Plantarum, 21:806-810.

Eliasson, L., 1971. Adverse effect of shoot growth on root growth in rooted cuttings of aspen, Physiologia Plantarum, 25:268-272.

Eliasson, L. & L. Brune, 1980. Light effects on root formation in aspen and willow cuttings, Physiologia Plantarum, 48:261-265.

Elliott, Joe C., 1987. Riparian vegetation of the Oldman River - possible impacts of the Oldman River dam. 36 pp. and Appendices. Report prepared for Peigan Resource Development, Peigan Nation.

Ellison, L. & E.J. Woolfolk, 1937. Effects of drought on vegetation near Miles City, Montana, Ecology, 18:329-336.

Elmore, W., 1989. Rangeland Riparian Systems, in: Abell, D.T. (Tech Coord), Proceedings of the California Riparian Systems Conference. Davis, California. USDA Forest Service General Tecnhical Report PSW-110. 544p.

Engstrom, A., 1948. Growing cottonwood from seed, Journal of Forestry, 46:130-132.

Environment Canada, 1985. Historical streamflow summary: Alberta to 1984, Inland Waters Directorate, Ottawa. 527pp.

Everitt, B., 1968. Use of the cottonwood in an investigation of the recent history of a flood plain, American Journal of Science, 266:417-439.

Farmer, R. & F. Bonner, 1967. Germination and initial growth of eastern cottonwood as influenced by moisture stress, temperature, and storage, Botanical Gazette, 128(3-4):215-218.

Fege, A., 1983. The practice and physiological basis of collecting, storing, and planting *Populus* hardwood cuttings, USDA Forest Service General Technical Report NC-91, St. Paul, Minnesota. 11pp.

Fege, A. & H. Phipps, 1984. Effect of collection date and storage conditions on field performance of *Populus* hardwood cuttings, Canadian Journal of Forest Research, 14:119-123.

Fenner, P., W. Brady & D. Patton, 1984. Observations on seeds and seedlings of Fremont Cottonwood, Journal of Desert Plants, 6:55-58.

Fenner, P., W. Brady & D. Patton, 1985. Effects of regulated water flows on regeneration of Fremont Cottonwood, Journal of Range Management, 38(2):135-138.

Fernet, D. & S. Matkowski, 1986. Oldman River Dam environmental mitigation/ opportunities plan phase II: fish distribution, abundance, critical habitats and relationships with streamflow downstream of the Oldman River damsite, Environmental Management Associates, Calgary, 132 pp.

Fonda, R.W., 1984. Forest Succession in relation to river terrace development in Olympic National Park, Washington, Ecology, 55:927-942.

Francis, J.K., 1985. The roots of plantation cottonwood: their characteristics and properties, USDA Forest Service Research Note So-314. New Orleans. p. 1-4.

Franz, E. & F. Bazzaz, 1977. Simulation of vegetation responses to modified hydrologic regimes: A probabilistic model based on niche differentiation in a floodplain forest, ecology, 58:176-183.

Fritts, H., 1976. Tree rings and climate, Academic Press, New York, 367pp.

Galloway, G. & J. Worrall, 1979. Cladoptosis: a reproductive strategy in black cottonwood, Canadian Journal of Forest Research, 9(1):122-125.

Gecy, J.L. & M.V. Wilson, 1990. Initial establishment of riparian vegetation after disturbance by debris flows in Oregon, American Midland Naturalist, 123:282-291.

Gildart, R.C., 1984. Montana's Missouri River, Montana Geographic Series Number 8. Montana Magazine Inc, Helena. 104pp.

Gill, C.J., 1977. Some aspects of the design and management of reservoir margins for multiple use, Applied Biology, 2:129-182.

Glinsky, R.L., 1977. Regeneration and distribution of sycamore and cottonwood trees along Sonora Creek, Santa Cruz Co., Arizona. In Johnson R.R. and D. Jones (eds): Importance, preservation and management of riparian habitat, p116. USDA Forest Service General Technical Report RM-43, 217 pp.

Graf, W.L., 1988. Fluvial processes in dryland rivers, Springer Verlag, New York. 346pp.

Green, W., 1947. Effect of water impoundment on tree mortality and growth, Journal of Forestry, 45:118-121.

Greenaway, W., S. English, F.R. Whatley, and S.B. Rood, 1990. Interrelationships of poplars in a hybrid swarm as studied by gas chromatography-mass spectrometry. Canadian Journal of Botany (in press).

Hall, R.S., 1973. Vegetation and river regime of the South Saskatchewan River near Saskatoon, Msc Thesis, University of Saskatchewan, Saskatoon. 171pp.

Hallgren, S.W., 1989. Growth response of populus hybrids to flooding, Annals of Scientific Forestry, 46:361-372.

Hansen, P., K. Boggs, R. Pfister, & J. Joy, 1990. Classification and Management of riparian and wetland sites in central and easter Montana, Montana Riparian Association, University of Montana, Missoula. 279p.

Hansen, P.L., 1985. An ecological study of the vegetation of the Grand River/Cedar River, Sioux and Ashland Districts of the Custer National Forest, PhD Thesis, South Dakota State University, Brookings. 257pp.

Hansen, P.L., 1989. Inventory, classification, and management of riparian sites along the Upper Missouri National Wild and Scenic River, Montana Riparian Association, University of Montana, Missoula. 213pp.

Hansen, P.L., S.W. Chadde & R.D. Pfister, 1988. Riparian dominance types of Montana, Montana Riparian Association, University of Montana, Missoula. Miscellaneous Publication No. 49, 411pp.

Hardy Associates, 1986. Vegetation inventory - Oldman River Dam, Alberta Environment Planning Division, 86pp.

Hardy BBT Limited, 1988. Cottonwood mortality assessment - Police Point Park, Prepared for the City of Medicine Hat, Alberta. 21pp.

Hardy BBT Limited, 1990. Western cottonwood (*Populus deltoides*) communities of the Milk River Valley, Alberta, Volume 1.

Harris, R., C. Fox & R. Risser, 1987. Impacts of hydroelectric development on riparian vegetation in the Sierra Nevada Region, California, USA, Environmental Management, 11(4):519-527.

Hefly, H.M., 1937. Ecological studies on the Canadian river floodplain in Cleveland County, Oklahoma, Ecological Monographs, 7:345-402.

Hellum, A., 1948. Seed storage and germination of Black Poplar, Canadian Journal of Plant Science, 53:227-228.

Hook & Brown, 1973. Root adaptation and relative flood tolerance of five hardwood species, Forest Science, 19(3):225-229.

Hills-Urbat, M., (in press). Regeneration and survival of cottonwoods in Dinosaur Provincial Park. Preliminary report for Alberta Recreation and Parks.

Hosner, J., 1957. Effects of water upon the seed germination of bottomland trees, Forest Science, 3(1):67-70.

Hosner, J., 1958. The effects of complete inundation seedlings of six bottomland tree species, Ecology, 39(2):371-373.

Hosner, J., 1960. Relative tolerance to complete inundation of fourteen bottomland tree species, Forest Science, 6(3):246-251.

Hosner, J. & S. Boyce, 1962. Tolerance to water saturated soil of various bottomland hardwoods, Forest Science, 8:180-186.

Hubbard, J.P., 1977. Importance of riparian ecosystems: biotic considerations in: importance, preservation and management of riparian habitat, USDA Forest Service General Technical Report RM-43, Fort Collins, Colorado. p.14-18.

Hunter, W.C., B.W. Anderson, & R.E. Tollefson, 1989. Bird use of natural and recently revegetated cottonwood-willow habitats of the Kern River, In: Proceedings of the California Riparian Systems Conference protection, management and restoration for the 1990s, Tech Coord, D.L. Abell, Sept 22-24, 1988, Davis California. USDA Forest Service General Technical Report PSW-110. pp. 332-338.

Johnson, R.R., & D.A. Jones, (Tech coords) 1977. Importance, preservation and management of riparian habitat: A symposium, USDA Forest Service General Technical Report RM-43. 218 pp.

Johnson, W., R. Burgess & W. Keammerer, 1976. Forest overstory vegetation and environment on the Missouri River Floodplains in North Dakota, Ecological Monographs, 46(1):59-84.

Johnston, A., 1987. History of floods in the Oldman River Valley at Lethbridge, Lethbridge Historical Society, Lethbridge, Alberta. 19pp.

Kapustka, L.A., 1972. Germination and establishment of *Populus deltoides* in eastern Nebraska, PhD. Thesis, University of Nebraska, Lincoln. 72p.

Kauffman, J.B. & W.C. Krueger, 1984. Livestock impacts on riparian ecosystems and streamside management implications: A review, Journal of Range Management, 37(5):430-438.

Kelliher, F., M. Kirkham & C. Tauer, 1980. Stomatal resistance, transpiration, and growth of drought-stressed eastern cottonwood, Canadian Journal of Forest Research, 10(4):447-451.

Kellogg, R. & E. Swan, 1986. Physical properties of black cottonwood and balsam poplar, Canadian Journal of Forest Research, 16:491-496.

Kennedy, C.E., 1977. Wildlife conflicts in riparian management in: Importance, Preservation and Management of Riparian Habitat, USDA Forest Service General Technical Report RM-43, Fort Collins, Colorado. p. 52-58.

Knopf, F.L. & R.W. Cannon, 1982. Structural resilience of a willow riparian community to changes in grazing practises, in: Wildlife-Livestock Relationships Symposium: Proceedings 10. Forest, Wildlife, and Range Experiment Station, Moscow, Idaho. p. 198-209.

Kocsis, M., J.M. Mahoney & S.B. Rood, 1991. Effect of substrate and rate of water table decline on growth, transpiration and survival of three poplar species, in; The Biology and Management of Southern Alberta's Cottonwoods, Eds, S.B. Rood and J.M. Mahoney. May 3,4, University of Lethbridge.

Kondolf, G., J. Webb, M. Sale & T. Felando, 1987. Basic hydrologic studies for assessing impacts of flow diversions on riparian vegetation: examples from streams of the eastern Sierra Nevada, California, USA, Environmental Management 11(6):757-769.

Krasny, M.E., J.C. Zasada & K.A. Vogt, 1988. Adventitious rooting of four *Salicaceae* species in response to a flooding event, Canadian Journal of Botany, 66:2597-2598.

Lee, C., S. Heinze-Milne, J.M. Mahoney & S.B. Rood, 1991. Recent and present poplar forests along the St. Mary, Belly and Waterton Rivers, Alberta, In; The Biology and Management of Southern Alberta's Cottonwoods, Eds, S.B. Rood and J.M. Mahoney. May 3,4, University of Lethbridge.

Lee, M., 1945. An ecological study of the flood plain forest along the White River system of Indiana, Butler University Botanical Studies, 7:155-165.

Leighton, J.P. & R.J. Risser, 1989. A riparian vegetation ecophysiological response model, in: Proceedings of the California Riparian Systems Conference protection, management and restoration for the 1990s, Tech Coord, D.L. Abell, Sept 22-24, 1988, Davis California. USDA Forest Service General Technical Report PSW-110. pp. 370-374.

Lowrance, R., R. Leonard & J. Sheridan, 1985. Managing riparian ecosystems to control nonpoint pollution, Journal of Soil and Water Conservation, 40:87-91.

Mahoney, J. M. & P. Koegler, 1991. The accuracy of tree ring analysis for estimating the age of riparian poplars, in; The Biology and Management of Southern Alberta's Cottonwoods, Eds, S.B. Rood and J.M. Mahoney. May 3,4, University of Lethbridge.

Mahoney, J.M. & S.B. Rood, 1991a. A device for studying the influence of declining water table on plant growth and survival, Tree Physiology, In Press.

Mahoney, J.M. & S.B. Rood, 1991b. A model for assessing the impact of altered river flows on riparian poplars in southwestern Alberta, in; The Biology and Management of Southern Alberta's Cottonwoods, Eds, S.B. Rood and J.M. Mahoney. May 3,4, University of Lethbridge.

Maini, J. & R. Copland, 1964. A simple technique for age determination in trembling aspen, Forestry Chronicle, 40:219-220.

Malanson, G.P. & D.R. Butler, 1990. Woody debris, sediment and riparian vegetation of a sub-alpine river, Montana, US, Arctic and Alpine Research, 22(2):183-194.

Marcusson, P.E., 1977. The effect of cattle grazing on brown trout in Rock Creek, Montana, Montana Department of Fish and Game, Special Report F-20-R-21-11a, Helena. 23pp.

Marken, S., 1991. Plains cottonwoods and riparian vegetation on the Lower Red Deer River, in; The Biology and Management of Southern Alberta's Cottonwoods, Eds, S.B. Rood and J.M. Mahoney. May 3,4, University of Lethbridge.

Marlow, C.B. & T.M. Pogacnik, 1985. Time of grazing and cattle-induced damage to streambanks, in: Riparian Ecosystems, and Their Management: Reconciling conflicting uses, Tech. Coords., R.R. Johnson, C.D. Ziebell, D.R. Patton, P.F. Ffolliott and R.D.Hamre. USDA General Technical Report RM-120, Fort Collins, Colorado. 523pp.

Mazzoleni, S. & D. Dickmann, 1988. Differential physiological and morphological responses of two hybrid *Populus* clones to water stress, tree physiology, 4:61-70.

McBride, J. & J. Strahan, 1984. Establishment and survival of woody riparian species on gravel bars of an intermittent stream, The American Midland Naturalist, 112(2):235-245.

McComb, A.L. & H.S. Lovestead, 1954. Viability of cottonwood seeds in relation to storage temperatures and humidities, USDA Forest Service Tree Planters Notes, 17:9-11.

McQueen, I.S. & R.F. Miller, Soil moisture and energy relationships associated with riparian vegetation near San Carlos, Arizona, Gila River Phreatophyte Project, E1.

Meehan, W.R., F.J. Swanson & J.R. Sedell, 1977. Influences of riparian vegetation on the aquatic ecosystem with particular reference to salmonid fishes and their food supply, in: Importance, Preservation and Management of Riparian Habitat, USDA Forest Service General Technical Report RM-43, Fort Collins, Colorado. p. 137-173.

Michael, D.A., J.G. Isebrands, D.I. Dickman & N.D. Nelson, 1988. Growth and development during the establishment year of two *Populus* clones with contrasting morphology and phenology, Tree Physiology, 4:139-152.

Middleton, R. & C. Brodie, 1991. Riparian vegetation and water management: issues, questions, answers, in; The Biology and Management of Southern Alberta's Cottonwoods, Eds, S.B. Rood and J.M. Mahoney. May 3,4, University of Lethbridge.

Mohn, C. & W. Randall, 1973. Interaction of cottonwood clones with site and planting year, Canadian Journal of Forest Research, 3(3):329-332.

Moss, E., 1932. The vegetation of Alberta: IV. The poplar association and related vegetation of central Alberta, Journal of Ecology, 20:380-415.

Moss, E., 1938. Longevity of seed and establishment of seedlings in species of *Populus*, Botanical Gazette, 99(3): 529-542.

Mueller-Dombois, D., 1964. Effect of depth to water table on height growth of tree seedlings in a greenhouse, Forest Science, 10:306-316.

Mueller-Dombois, D. & H. Ellenberg, 1974. Aims and methods of vegetation ecology, Wiley & Sons, Toronto. 547pp.

Murtha, P.A., 1972. A guide to air photo interpretation of forest damage in Canada, Canadian Forestry Services, Ottawa. 62pp.

Nanson, G. & H. Beach, 1977. Forest succession and sedimentation on a meandering-river floodplain, Northeast British Columbia, Canada, Journal of Biogeography, 4:229-251.

Netzer, D., 1984. Hybrid poplar plantations outgrow deer browsing effects, USDA Forest Service Research Note NC-325, St. Paul, Minnesota. 3pp.

Nillson, C., 1984. Effects of stream vegetation on reparian vegetation in: Regulated Rivers (edited by A. Ullehammer and S.J. Saltvat) Oslo University Press, Oslo. pp 93-106.

Noble, M.G., 1979. The origin of *Populus deltoides* and *Salix interior* zones on point bars along the Minnesota River, American Midland Naturalist, 102(1):59-67.

Oglesby, R., C. Carlson & J. McCann (eds), 1972. River ecology and man, Academic Press, New York. 465pp.

Padgett, W.G., 1982. Ecology of riparian communities in Southern Malheur Forest, MSc Thesis, Oregon State University, Corvallis. 143pp.

Pallardy, S. & T.T. Kozlowski, 1979a. Early root and shoot growth of *Populus* clones, Silvae Genetica 24(4):153-156.

Pallardy, S. & T.T. Kozlowski, 1979b. Stomatal response of *Populus* clones to light intensity and vapour pressure deficit, Plant Physiology, 64:112-114.

Pallardy, S. & T. Kozlowski, 1981. Water relations of *Populus* clones, Ecology, 62(1):159-169.

Parker, J., 1980. Great blue herons (Ardea herodias) in northwestern Montana: Nesting habitat use and the effects of human disturbance, MSc Thesis, University of Montana Missoula. 82pp.

Pearson, G.A., 1936. Why the prairies are treeless, Journal of Forestry, 34:405-408.

Pereira, J. & T. Kozlowski, 1977. Variations among woody angiosperms in response to flooding, Physiologia Plantarum, 41:184-192.

Pezeshki, R. & T. Hinckley, 1988. Water relations characteristics of *Alnus rubra* and *Populus trichocarpa*: responses to field drought, Canadian Journal of Forest Research, 18(9):1159-1166.

Pfister, R.D. & R.F. Batchelor, 1984. Montana riparian vegetation types. Western Wildlands 9(4):19-23.

Phinney, R., 1982. Flood of June 1975 in the Oldman River Basin, Alberta, Environment Canada, Inland Waters Directorate, Western and Northern Region, 79pp.

Phipps, H. & D. Netzer, 1981. The influence of collection time and storage temperature on *Populus* hardwood cutting development, Tree Planters' Notes, 32(4):33-36.

Phipps, H.M., D.A. Belton & D.A. Netzer, 1977. Propagating cuttings of some *Populus* clones for tree planting, The Plant Propagator, 23(4). 3pp.

Pieters, G., 1983. Growth of *Populus euramericana*, Physiologica Plantarum, 57:455-462.

Platts, W.S., C. Armour, G.D. Booth. M. Bryant, J.L. bufford, P. Culpin, S. Jensen, G.W. Lienkaemper, G.W. Minshall, S.B. Monsen, R.L. Nelson, J.R. Sedell & J.S. Tuhy, 1987. Methods for evaluating riparian habitats with applications to management, USDA General Technical Report INT-221. Ogden, Utah. 187pp.

Read, R., 1958. Silvical characteristics of plains cottonwood, USDA Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Station Paper No. 33, 18pp.

Regeher, D., F. Bazzaz & W. Boggess, 1975. Photosynthesis, transpiration and leaf conductance of *Populus deltoides* in relation to flooding and drought, Photosynthetica, 9(1):52-61.

Reich, P., 1984a. Leaf stomatal density and diffusive conductance in three amphistomatus hybrid poplar cultivars, New Phytologist, 98:231-239.

Reich, P., 1984b. Oscillations in stomatal conductance of hybrid poplar leaves in the light and dark, Physiologica Plantarum, 61:541-548.

Reichard, N., 1989. Restoring and Maintaining Riparian Habitat on Private Pastureland, in: Abell, D.T. (Tech Coord), Proceedings of the California Riparian Systems Conference. Davis, California. USDA Forest Service General Technical Report PSW-110. 544p.

Reid, D., 1991, Cottonwood mortality assessment at Police Point Park, Alberta, In; Biology and Management of Southern Alberta's Cottonwoods, Eds, S.B. Rood and J.M. Mahoney. May 3,4, University of Lethbridge.

Reily, P. & W. Johnson, 1982. The effects of altered hydrologic regime on tree growth along the Missouri River in North Dakota, Canadian Journal of Botany, 60:2410-2423.

Rhodes, T., 1991. The importance of riparian cottonwoods to wildlife: a fish and wildlife division perspective, in; Proceedings of the Biology and Management of Southern Alberta's Cottonwoods Conference, Eds, S.B. Rood and J.M. Mahoney. May 3,4, U. Lethbridge.

Rice, E., 1965. Bottomland forests of north central Oklahoma, Ecology, 46(5):708-714.

Richards, J. & P. Larson, 1981. Morphology and development of *Populus deltoides* branches in different environments, Botanical Gazette, 142(3):382-393.

Roath, L.R. & W.C. Krueger, 1982. Cattle grazing influence on a mountain riparian zone, Journal of Range Management, 35:100-104.

Robertson, D., G. Weaver & J. Cavanaugh, 1978. Vegetation and tree species patterns near the northern terminus of the south floodplain forest, Ecological Monographs, 48:249-267.

Rood, S.B., 1985. Clarifying the status of poplars in southern Alberta University of Lethbridge Research Note. 13pp.

Rood, S.B., 1988. Potential impact of the Oldman River dam on downstream vegetation, in: Economic and Social Aspects of the Oldman River Dam Project, S.B. Rood & F.J. Jankunis (eds.) University of Lethbridge. p. 137-144.

Rood, S.B., 1990. The parched Oldman: vanishing rivers in southern Alberta in: Flowing to the Future, Alberta's Rivers Conference, C. Bradley, A. Einsiedel, T. Pyrch & K. VanTighem (eds.). The University of Alberta. p. 131-144.

Rood, S., J. Campbell & T. Despins, 1986. Natural poplar hybrids from Southern Alberta: I. Continuous variation for foliar characteristics, Canadian Journal of Botany, 64:1382-1388.

Rood, S., G. Daicos & T. Blake, 1984. Gibberellic acid induced growth acceleration in *Populus* hybrids, Canadian Journal of Forest Research, 14:850-854.

Rood, S.B. & S. Heinze-Milne, 1989. Abrupt riparian forest decline following river damming in southern Alberta, Canadian Journal of Botany, 67:1744-1749.

Rood, S.B. & F.J. Jankunis (eds), 1988. Economic, environmental, and social aspects of the Oldman River dam project, Proceedings of the Oldman River Dam Forum, University of Lethbridge, Alberta, March 4, 5. 211pp.

Rood, S. & J.M. Mahoney, 1990a. Collapse of river valley forests downstream from dams in western Prairies: probable causes and prospects for mitigation, Environmental Management 14: 451-464

Rood, S.B. & J.M. Mahoney, 1990b. The collapse of river valley forests downstream from dams in the Rocky Mountain Foothills, in; Collection Environment et Geologie, Eds. C.E. Delisle and M.A. Bouchard. Canadian Society of Environmental Biologists, Montreal. 9(21):417-430.

Rood, S.B. & J.M. Mahoney, 1990c. The effects of river damming on cottonwood forests of southern Alberta, proceedings of the irrigation research and development in the 1990's conference, July 17-20, Water Resources Institute, Lethbridge.

Rood, S.B. & J.M. Mahoney, 1991a. The importance and extent of cottonwood forests decline downstream from dams, In; The Biology and Management of Southern Alberta's Cottonwoods, Eds, S.B. Rood and J.M. Mahoney. May 3,4, University of Lethbridge.

Rood, S.B. & J.M. Mahoney, 1991b. Influence of substrate texture on responses of poplar to declining water table, Tree Physiology, under review.

Rydberg, P.A., 1893. On the American black cottonwood, Bulletin of the Torrey Botanical Club, 20:46-52.

Savoy, E., 1991. The importance of riparian forests to prairie birds: A case study - Dinosaur Provincial Park, Alberta, In; The Biology and Management of Southern Alberta's Cottonwoods, Eds, S.B. Rood and J.M. Mahoney. May 3,4, University of Lethbridge.

Schier, G. & R. Campbell, 1976. Differences among *Populus* species in ability to form adventitious shoots and roots, Canadian Journal of Forest Research, 6(3):253-261.

Schlosser,I.J. & J.R. Kerr, 1981. Riparian vegetation and channel morphology impact on spatial patterns of water quality in agricultural watersheds, Environmental Management, 5:233-243.

Schulz, T.T. & W.C. Leininger, 1990. Differences in riparian vegetation structure between grazed areas and exclosures, Journal of Range Management, 43(4):295-299.

Sedell, J. & J. Froggatt, 1984. Importance of streamside forests to large rivers: the isolation of the Willamette River, Oregon, U.S.A., from its floodplain by snagging and streamside forest removal, Verh. Internat. Verein. Limnol. December, 1984, 22:1828-1833.

Sedgewick, J.A. & F.L. Knopf, 1986. Cavity nesting birds and the cavity-tree resource in plains cottonwood bottomland, Journal of Wildlife Management, 509(2):247-252.

Sedgewick, J.A. & F.L. Knopf, 1989. Demography, regeneration and future projections for a bottomland cottonwood community, in: Freshwater Wetlands and Wildlife, R.R. Sharitz & J.W. Gibbons (eds.). DOE Symposium series No. 61, Oakridge, Tennessee. p. 249-266.

Sedgewick, J.A. & F.L. Knopf, 1990. Habitat relationships and nest site characteristics of cavity nesting birds in cottonwood floodplains, Journal of Wildlife Management, 54(1):112-124.

Shaw, R.K., 1974. A Taxonomic and ecologic study of the riverbottom forest on St. Mary River, Lee Creek, and Belly River in southwestern Alberta, Canada, The Great Basin Naturalist, 36(3):243-271.

Shaw, R.K., 1976. A taxonomic and ecologic study of the riverbottom forest on St. Mary River, Lee Creek, and Belly River in Southwestern Alberta, Canada, PhD Thesis, Brigham Young University, Utah. 242pp.

Shaw, R.K., 1991. Ecology of the riverbottom forest on St. Mary River, Lee Creek and Belly River in Southwestern Alberta, In; The Biology and Management of Southern Alberta's Cottonwoods, Eds, S.B. Rood and J.M. Mahoney. May 3,4, University of Lethbridge.

Shull, C.A., 1944. Observations of general vegetational changes on a river island in the Mississippi River, American Midland Naturalist, 32:771-776.

Simmons, D., 1979. Effects of stream regulation on channel morphology, in: The Ecology of Regulated Streams, J. Ward & J. Stanford eds. Plenum Press, NY, p.95-111.

Skoglund, S.J., 1990. Seed dispersing agents in two regularly flooded river sites, Canadian Journal of Botany, 68(4):754-760.

Smith, J.J., 1989. Recovery of riparian vegetation on an intermittent stream following removal of cattle, in: Proceedings of the California Riparian Systems Conference protection, management and restoration for the 1990s, Tech Coord, D.L. Abell, Sept 22-24, 1988, Davis California. USDA Forest Service General Technical Report PSW-110. pp. 217-221.

Smith, S.D., J.L. Nachlinger, A.B. Wellington, & C.A. Fox, 1989. Water relations of obligate riparian plants as a function of streamflow diversion on the Bishop Creek watershed in: Proceedings of the California Riparian Systems Conference protection, management and restoration for the 1990s, Tech Coord, D.L. Abell, Sept 22-24, 1988, Davis California. USDA Forest Service General Technical Report PSW-110. pp360-365.

Sorg, C.F. & J.B. Loomis, 1984. Empirical estimates of amenity forest values: A comparative review, USDA Forest Service General Technical Report RM-107.

Stobbs, K., A. Corbiere, J.M. Mahoney & S.B. Rood, 1991. The influence of rate of water table decline on establishment and survival of hybrid poplar seedlings, in; The Biology and Management of Southern Alberta's Cottonwoods, Eds, S.B. Rood and J.M. Mahoney. May 3,4, University of Lethbridge.

Stockton, C., 1975. Long-term stream flow records reconstructed from tree rings, papers of the laboratory of tree-ring research #5, The University of Arizona Press, Tucson. 111pp.

Stokes, M. & T. Smiley, 1968. An Introduction to tree-ring dating, University of Chicago Press, Chicago. 73pp.

Stromberg, J.C. & D.T. Patten, 1989. Early recovery of an eastern Sierra Nevada riparian system after 40 years of stream diversion, in: Proceedings of the California Riparian Systems Conference protection, management and restoration for the 1990s, Tech Coord, D.L. Abell, Sept 22-24, 1988, Davis California. USDA Forest Service General Technical Report PSW-110. pp. 399-404.

Stromberg, J.C. & D.T. Patten, 1990. Riparian vegetation instream flow requirements: a case study from a diverted stream in the eastern Sierra Nevada, California, USA, Environmental Management, 14(2):185-194.

Szaro, R.C., 1990. Southwestern riparian plant communities: Site characteristics, tree species distributions, and size-class structures, Forest Ecology and Management, 33/34:315-334.

Szaro, R.C. & L.F. DeBano, 1985. The effects of streamflow modification on the development of a riparian ecosystem, in: Riparian Ecosystems and their Management: Reconciling conflicting uses. First North American Riparian Conference, Tucson, Arizona. p. 211-215.

Szaro, R.C. & J.N. Rinne, 1988. Ecosystem approach to management of southwestern riparian communities. Transactions of the 53rd North American Wildlife and Natural Resources Conference. p. 502-511.

Thomas, J.W., C. Maser & J.E. Rodiek, 1979. Wildlife habitat in managed rangelands - the great basin of southeastern Oregon, USDA Forest Service General Technical Report PNW-80, Portland, Oregon. 18pp.

VanSlycken, J. & H. Vereecken, 1990. Water supply from the groundwater table and the growth of poplar: A case study, Agricultural and Forest Meteorology, 50:65-74.

Vanende, A., 1991. Analysis of gene flow in *Populus* species using flavonoids and isoenzyme markers, in; The Biology and Management of Southern Alberta's Cottonwoods, Eds, S.B. Rood and J.M. Mahoney. May 3,4, University of Lethbridge.

Virginillo, M., J.M. Mahoney & S.B. Rood, 1991. Establishment and survival of poplar seedlings along the Oldman River, Southern Alberta, In; The Biology and Management of Southern Alberta's Cottonwoods, Eds, S.B. Rood and J.M. Mahoney. May 3,4, University of Lethbridge.

Ware, G. & W. Penfound, 1949. The vegetation of the lower levels of the floodplain of the South Canadian River in Central Oklahoma, Ecology, 30(4):478-484.

Waring, R.H., 1985. Imbalanced forest ecosystems: assessments and consequences, Forest Ecology and Management, 12:93-112.

Waring, R.H. & B.D. Cleary, 1967. Plant moisture stress: evaluation by pressure bomb, Science, 155:1248-1254.

Weaver, J., 1960. Flood plain vegetation of the Central Missouri Valley and Contacts of Woodland with Prairie, Ecological Monographs, 30(1):37-64.

Weaver, J.E. & F.W. Albertson, 1936. Effects of the great drought on the prairies of Iowa, Nebraska, and Kansas, Ecology 17:567-639.

Weaver, J.E., H.C. Hanson & J.M. Aikman, 1925. Transect method of studying woodland vegetation along streams, Botanical Gazette, 80:168-187.

White, W.W., 1951. Native cottonwoods of Montana, Proceedings of the Montana Academy of Sciences, 9:33-39.

Williams, J.G., 1989. Interpreting physiological data from riparian vegetation: Cautions and complications, in: Proceedings of the California Riparian Systems Conference: protection, management and restoration for the 1990s, Tech Coord, D.L. Abell, Sept 22-24, 1988, Davis California. USDA Forest Service General Technical Report PSW-110. 381-386.

Williams, G.P., 1989. Sediment concentration versus water discharge during single hydrologic events in rivers, Journal of Hydrology, 111:89-106.

Williams, G. & M. Wolman, 1984. Downstream effects of dams on alluvial rivers, US Department of the Interior, USGS Professional Paper 1286, 83pp.

Wilson, R., 1970. Succession in stands of populus deltoides along the Missouri River in southeastern South Dakota, The American Midland Naturalist, 83(2):330-342.

Wolman, M.G. & L.B. Leopold, 1957. River flood plains: some observations on their formation, US Department of Interior, USGS Professional Paper 282-C, Washington. p.87-107.

Zasada, J. & R. Densmore, 1979. A trap to measure *Populus* and *Salix* seedfall, The Canadian Field Naturalist, 93(1):77-79.

Zsuffa, L., 1976. Vegetative propagation of cottonwood by rooting cuttings, Cottonwood Symposium, Greenville, Mississippi, Sept 28-Oct2. 10pp.

Zube E.H. & D.E. Simcox, 1987. Arid lands, riparian landscapes, and management conflicts, Environmental Management, 11(4):529-535.

11.0 PERSONAL COMMUNICATION (PERS.COMM.)

Lorne Fitch
Head, Habitat, Southern Region
Alberta Forestry, Lands and Wildlife
Fish and Wildlife Division
Lethbridge, Alberta

Maureen Hills-Urbat
Department of Geography
University of Calgary
Calgary, Alberta

Sandra Marken
Department of Geography
University of Calgary
Calgary, Alberta

Ron Middleton
Reservoir Development Division
Alberta Public Works
Supply and Services
Edmonton, Alberta

David E. Reid
Hardy BBT Limited
Calgary, Alberta

Dr. Stewart Rood
Biological Sciences
University of Lethbridge
Lethbridge, Alberta

Greg Wagner
Planning Division
Alberta Environment
Edmonton, Alberta

Cliff Wallis
Cottonwood Consultants
Calgary, Alberta

APPENDIX 10

Government of Alberta. 2018 (amended). South Saskatchewan Regional Plan, 2014-2024, an Alberta Land-use Framework Integrated Plan. Government of Alberta, Edmonton. Website: https://open.alberta.ca/dataset/13ccde6d-34c9-45e4-8c67-6a251225ad33/resource/e643d015-3e53-4950-99e6-beb49c71b368/download/south-saskatchewan-regional-plan-2014-2024-may-2018.pdf

environmental • social • economic

An Alberta Land-use Framework Integrated Plan

South Saskatchewan Regional Plan

2014 - 2024

Amended May 2018

Alberta Government

Landscapes and Biodiversity

The South Saskatchewan Region contains diverse landforms, vegetation and species. The region spans four of Alberta's six Natural Regions including the Grassland, Parkland, Foothills and Rocky Mountains. The Grasslands are dominated by a diverse and unique native prairie, extensive riparian cottonwood forests and broad plateaus within the Cypress Hills and Milk River Ridge. The Parkland region in the north represents the transition area between grasslands and forests. A small portion of the Foothills lies within the South Saskatchewan Region along the eastern edge of the Rocky Mountains. The Rocky Mountain region that runs along the Continental Divide is characterized by grasslands, shrubs, forests and alpine areas above the tree line.

A wide range of wildlife and plant species exist in the region, including: 17 sport species; over 700 vascular plant species; numerous songbirds, hawks, owls, waterfowl and grouse; and mammals such as moose, deer, pronghorn, wolves, grizzly bears, cougars and lynx. The region also serves as breeding grounds and staging areas for birds during migration and over-wintering periods. The South Saskatchewan Region has more than 80 per cent of the province's species at risk as listed under the federal *Species at Risk Act* and the provincial *Wildlife Act*. Factors contributing to this high proportion include human settlement, disturbance from industrial, recreational and other uses, fragmentation, environmental contaminants and the introduction of invasive species.

The range of species and diversity of ecosystems across the region the biodiversity found here and means there is a broad range of ecosystem services provided. Biodiversity represents the assortment of life – including the variety of genetics and species and the habitats in which they occur – all shaped by natural processes of change and adaptation. Biodiversity and ecosystem services are not the same thing but they are interdependent. Ecosystem services are the humans, communities and society as a whole receive from healthy, functioning ecosystems and the biodiversity within them. Biodiversity underpins the supply of ecosystem services, so changes in biodiversity will affect the type and amount of those services available to humans.

All ecosystem services contribute to sustaining a healthy and prosperous way of life for all Albertans. Fish, wildlife, traditional medicinal plants, berries and less-developed spaces are also important for the cultural practices of First Nations peoples.

Biodiversity

The Land-use Framework defines biodiversity as "The assortment of life on earth – the variety of genetic material in all living things, the variety of species on earth and the different kinds of living communities and the environments in which they occur".

Ecosystem Services

The following are examples of ecosystem services, the benefits that come from healthy functioning ecosystems and the biodiversity found in them:

- food, fiber, fresh water ("provisioning" services)
- flood control, water and air purification ("regulating" services)
- spiritual, recreational, cultural benefits ("cultural" services)
- nutrient cycling, soil formation ("supporting" services)

Vision, Outcomes and Strategic Directions for the Region

The SSRP establishes a regional vision that describes the desired future state of the South Saskatchewan Region in a manner that adheres to the guiding principles of the Land-use Framework and is aligned, consistent and supportive of the framework's provincial vision and outcomes.

To support the achievement of the regional vision, the SSRP establishes outcomes at the regional level, as well as a set of strategic directions to further specify the priority areas of focus for the region. The vision for the South Saskatchewan Region the Land-use Framework's vision of Albertans working together to respect and care for the land as the foundation of our economic, environmental and social well-being.

Vision for the South Saskatchewan Region

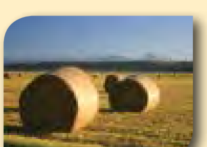
Southern Alberta is a diverse, healthy, vibrant and prosperous region where the natural beauty of the region is managed so that citizens feel connected to the land and its history. Albertans, industry, governments and aboriginal peoples work together to share responsibility for stewardship of the land and resources in a way that ensures current needs are met without compromising opportunities for future generations. Aboriginal peoples, through their traditional knowledge, share their intimate understanding of the region's natural environment and ecosystems.

The South Saskatchewan Region supports a diverse and growing population. Economic supports employment and contributes to a prosperous future. Agriculture is a renewable resource industry demonstrating environmental stewardship while pursuing growth and opportunities. There are continued opportunities for oil and natural gas production and renewable energy will become increasingly Forests are managed with watershed management and headwaters protection as the highest priority and healthy forests continue to contribute to the province's timber supply. The region has unique landscapes that form the basis of a popular tourism and recreation destination which continues to grow.

Air, water, land and biodiversity are sustained with healthy functioning ecosystems. The headwaters in the region supply vital regional fresh water quality. Conservation strategies help many species at risk in the South Saskatchewan Region recover, while also preserving the diversity and splendor of Alberta's natural regions with various parks and conservation areas providing Albertans with improved health and inspiration to value nature.

Land-use Framework - Provincial Outcomes

- Healthy economy supported by our land and natural resources;
- Healthy ecosystems and environment; and
- People-friendly communities with ample recreational and cultural opportunities.



3.6. Complete the **Majorville Guidelines for Land and Resource Management** by the end of 2015.

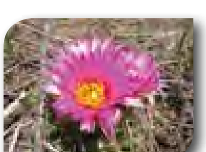
This collaborative initiative with external partners supports an area that is recognized for its heritage values, First Nations traditional use and unique native prairie biodiversity within existing agricultural and industrial developments. The guidelines will provide direction for managing public land and natural resources at Majorville – an area which contains a large number of historic resource sites and areas that have cultural for Alberta's three Blackfoot Tribes. The guidelines will direct future land use while ensuring that the cultural heritage of First Nations is protected and that the unique prairie landscape, its heritage and its biodiversity values are maintained.

3.7. Implement guidelines to **avoid conversion and maintain intact native grasslands on public land** (see Appendix G - Grasslands).

- Species at risk habitat – No conversion permitted as habitat needs to be sustained as part of government programs for species recovery (as required under federal and provincial legislation).
- Intact native grasslands – No conversion permitted where no or poor irrigation suitability exists according to the map Irrigation Suitability on Intact Native Grasslands (see Map 14) and on-site assessments.
- Intact native grasslands – Where irrigation suitability exists, land will be considered on a case-by-case basis for conversion to irrigation development as long as an alternative equivalent area of intact private grassland with low or no irrigation suitability is for a land exchange as part of the development proposal. Other criteria the government will consider in such proposals include water availability and adjacency to existing irrigation operations where applicable. A land exchange under the Government of Alberta Land Exchange Program is preferred (see Appendix G - Grasslands). The alternative area for the land exchange must be continuous and have connectivity with other intact native grasslands.
- Non-intact native grasslands – Regardless of irrigation suitability, lands will be considered on a case-by-case basis for a land exchange. In such cases, a land exchange under the Government of Alberta Land Exchange Program is preferred.

3.8. Implement a policy to allow for increased **grazing tenure terms**, from 10 years to 20 years, to continue to sustain intact native grasslands.

This policy allows for increased grazing tenure terms, from 10 years to 20 years, for leaseholders who uphold high stewardship management standards on public land outside of heritage rangelands. To support



- Areas with high biodiversity value such as areas important for connectivity and areas that are "intact" and would from remaining in a less disturbed condition such as intact native grasslands;
- Areas of land cover that have declined in area substantially and are to restore such as the Foothills Fescue Natural Subregion;
- Areas experiencing higher pressures from development and areas experiencing off-highway vehicle use; and
- Areas which have "legacy" land disturbance and areas with a high potential for restoration such as abandoned well-sites, decommissioned forestry roads and seismic areas no longer in use.

In the Pekisko area, a heritage rangeland and a Special Management Area on adjacent lands will be established. The Special Management Area will complement the heritage rangeland and will be linked to the existing Public Land Use Zones. This area is a priority for development of **a management plan for both the Pekisko Heritage Rangeland and the Pekisko Special Management Area**.

Existing **Integrated Resource Plans** will also be reviewed. The results of this work will be incorporated into, or be aligned with the subregional planning.

Governance

The Government of Alberta will provide leadership in the development of these plans. This includes coordinated involvement of other governments, aboriginal peoples, stakeholders, partners and the public. This collaboration will also require connecting to different planning initiatives within the government and with multi-stakeholder groups within the planning areas. It will be important to maintain and leverage these collaborative relationships and partnerships through implementation, monitoring and review to ensure success and alignment with regional outcomes and objectives.

The governance and process for planning will be coordinated where planning initiatives overlap and will include clear roles and responsibilities. It will build on and leverage work that has already been done by government, partners and other stakeholders, including the existing Integrated Resource Plans. Recognizing and incorporating existing planning and research by partners and stakeholders will increase and integration of the plans. As well, identifying interest and opportunities for involvement at different scales subregional, regional) and in different ways will make the most effective use of participant's time. For example, some may be most interested in the planning for trails in areas they use most, while others may be interested in the broader recreation system.

APPENDIX 11

Johnson, W. Carter, Mark D. Dixon, Michael L. Scott, Lisa Rabbe, Gary Larson, Malia Volke, and Brett Werner. 2012. Forty Years of Vegetation Change on the Missouri River Floodplain. Bioscience 62(2): 123-135. Website: https://www.semanticscholar.org/paper/Forty-Years-of-Vegetation-Change-on-the-Missouri-Johnson-Dixon/50ad4decfebfb073e07408c7d6b1f6611efeb132

Forty Years of Vegetation Change on the Missouri River Floodplain

W. CARTER JOHNSON, MARK D. DIXON, MICHAEL L. SCOTT, LISA RABBE, GARY LARSON, MALIA VOLKE, AND BRETT WERNER

Comparative inventories in 1969 and 1970 and in 2008 of vegetation from 30 forest stands downstream of Garrison Dam on the Missouri River in central North Dakota showed (a) a sharp decline in cottonwood regeneration; (b) a strong compositional shift toward dominance by green ash; and (c) large increases in invasive understory species, such as smooth brome, reed canary grass, and Canada thistle. These changes, and others discovered during remeasurement, have been caused by a complex of factors, some related to damming (altered hydrologic and sediment regimes, delta formation, and associated wet–dry cycles) and some not (diseases and expansion of invasive plants). Dominance of green ash, however, may be short lived, given the likelihood that the emerald ash borer will arrive in the Dakotas in 5–10 years, with potentially devastating effects. The prospects for recovery of this valuable ecosystem, rich in ecosystem goods and services and in American history, are daunting.

Keywords: riparian, cottonwood, deltas, restoration, reservoirs

Although dam building continues globally, the era of dam building in North America is over (Graf 1999). The ecological effects of dams, however, will continue apace for decades or even centuries unless those dams are removed or reregulated or their effects are mitigated by extensive and expensive restoration projects (e.g., planting trees, stocking fish, constructing nesting islands; see, e.g., Gore and Shields 1995, Galat et al. 1998, NRC 2002). Some 75,000 dams have been built in the continental United States; all watersheds in the nation larger than about 2000 square kilometers have one or more dams altering water flow (Dynesius and Nilsson 1994, Graf 1999). The most rapid increases in reservoir storage occurred between the late 1950s and the late 1970s (Graf 1999). The Great Plains and Rocky Mountain regions have some of the highest ratios of reservoir storage capacity to annual runoff in North America; these dammed regions have therefore experienced the greatest changes in river discharge (Graf 2006).

The holistic science of large-river ecology that developed during the last few decades of the twentieth century followed (and, to a considerable extent, was stimulated by) the dam-building era on the world's waterways (e.g., Ward and Stanford 1979, Vannote et al. 1980, Nilsson 1981, Williams and Wolman 1984, Power et al. 1988, Junk et al. 1989, Bayley 1991, Scott et al. 1996, Stanford et al. 1996, Poff et al. 1997, Galat et al. 1998, Sparks et al. 1998, Osterkamp and Hupp 2010). Therefore, most of what we have learned about the natural functioning of river ecosystems, and especially about complex land and water interactions, has been learned out of necessity from the study of ecologically impaired rivers. The scarcity of unregulated rivers—such as the Fiume Tagliamento, a reference river for the European Alps (Ward et al. 1999)—that could serve as experimental references or as restoration targets, has made predictions of regulated-river behavior in most regions less certain. Because of the lack of such large reference rivers in the Great Plains, it is necessary to conduct long-term studies and monitoring to test predictions about rivers in this region. Our science would benefit from periodic checks on the concepts and theories of river-ecosystem behavior that have developed from these predictions. In the present study, we attempted to accomplish this by resampling riparian forests studied 40 years ago and by evaluating the accuracy of the hypotheses made at that time.

One of the first studies in which the long-term effects of dams on riparian vegetation in the drylands of North America were predicted (Johnson et al. 1976) was conducted in 1969 and 1970, within a 166-kilometer (km)–long remnant floodplain reach of the heavily regulated Missouri River in North Dakota, between Garrison Dam (closed in 1953), which formed Lake Sakakawea, and Oahe Reservoir (filled about 1960), which was formed by Oahe Dam, downstream in South Dakota (figure 1). The six mainstem dams on the Missouri River operated by the Corps of Engineers can store up to 90.5 cubic kilometers of water, more capacity than any other river system in the United States.

Riparian forests in drylands are especially valued for their high biodiversity; these forests may cover only 1% of

BioScience 62: 123–135. ISSN 0006-3568, electronic ISSN 1525-3244. doi:10.1525/bio.2012.62.2.6

Figure 1. Map of the Missouri River (in dark blue) and watershed in central North America. The enlarged map of North Dakota shows the Garrison Reach of the Missouri River flanked by Lake Sakakawea and Oahe Reservoir. Source: US Army Corps of Engineers.

the landscape area but support—for example—more bird species than all other vegetation types combined (Ohmart 1994). Hibbard (1972) found that riparian forests in the Garrison Reach provided nesting habitat for a wide range of bird species, from open-country birds in the youngest, post-flood cottonwood–willow communities, to shrub-loving bird species in middle-aged cottonwood communities, to forest-dwelling birds in the most-mature forests. Some bird species, such as cavity-nesting woodpeckers, are reliant on cottonwood trees, specifically because of their large size and hollow trunks and branches (Sedgwick and Knopf 1992). About half of the species of birds that nest in the middle Missouri River forests are Neotropical migrants (Liknes et al. 1994). Riparian forests also function as corridors and habitat connectors, facilitating the mobility of organisms across landscapes and sustaining biodiversity (Hilty et al. 2006).

Dams and riparian vegetation: Initial hypotheses

Two specific hypotheses about the long-term effects of dams on riparian vegetation on the Missouri River floodplain were made by Johnson and colleagues (1976).

Hypothesis 1. The lack of cottonwood regeneration downstream of dams on the Missouri River is caused by major reductions in peak flows and channel dynamics (meandering and widening), after which the river ceases to create sandbars necessary for seedling establishment. Johnson and colleagues (1976) forecast a rather bleak future for the tree species *Populus deltoides* Bartr. ex Marsh. and its minor associate, the peach-leaf willow (*Salix amygdaloides* Anderss.). Large storage dams were seen as an ecological "game changer" because they cut peak flows and reduced the formation of flood-deposited point bars downriver that are needed to regenerate cottonwood and other pioneering species that initiate forest succession on floodplains. The Missouri River dams were predicted to sharply reduce cottonwood forest area, changing it from the historically dominant community occupying three-quarters of the floodplain area into a minor community relegated to small patches in river-marginal locations. Cottonwood is well adapted for success on active floodplains. Its many adaptations included voluminous seed dispersal by wind and water, timed with receding flows and exposure of fresh alluvium; rapid seed germination and root and height growth that enable tolerance to flooding, drought, and sedimentation; tolerance to low soil fertility on sandbars; and the ability to reproduce vegetatively after physical damage (Braatne et al. 1996).

A shortage of sandbar habitat for cottonwood regeneration would be less serious if cottonwood could maintain itself in established stands. Johnson and colleagues (1976) and others observed, however, that established cottonwood communities appeared not to be self-maintaining; cottonwood seedlings were absent in cottonwood-forest understories, probably because of reduced light levels and the negative effect of leaf-litter buildup on seed germination. A sharp decline in reproduction, as was forecast for a species that cannot maintain itself in established stands, is indeed a recipe for a slow death.

Identification of a cottonwood problem on regulated rivers by Johnson and colleagues (1976) spawned a plethora of similar ecological studies on the numerous cottonwood-dominated rivers in central and western North America. The assessments for the future of forests on dammed rivers from many of these studies were more dire than were those for the Missouri River. Descriptors like *imminent decline* (Howe and

Knopf 1991), *collapse* (Rood and Mahoney 1990), *survival… in jeopardy* (Bradley and Smith 1986), and *abrupt forest decline* (Rood and Heinze-Milne 1989) were used to characterize the status of cottonwood on other rivers. Therefore, the cottonwood problem, apparently first detected on the Missouri River, has now been suspected or confirmed on dozens of dammed, meandering-type rivers in the drylands of North America. Some dammed, braided-type rivers in the American West, however, have undergone channel narrowing and short-term cottonwood forest expansion (Johnson 1994, 1998, Friedman et al. 1998).

Hypothesis 2. Evidence of declining reproduction of box elder and American elm, coupled with high reproduction densities of green ash, suggests declining diversity in late-successional forest stands. Johnson and colleagues (1976) observed that the short-lived cottonwood forests were likely to be replaced by combinations of four late-successional species—green ash, *Fraxinus pennsylvanica* var. *lanceolata* (Borkh.) Sarg.; box elder, *Acer negundo* L.; American elm, *Ulmus americana* L.; and bur oak, *Quercus macrocarpa* Michx.—that all (except bur oak) reproduce abundantly in the understory of cottonwood forests. Because of a dynamic, meandering channel and natural successional processes, the preregulation floodplain was a mosaic of forests of different ages and species mixes, ranging from young, thick stands of cottonwood to forests older than 100 years that had lost the cottonwood component and were populated by late-successional tree species.

Johnson and colleagues (1976) thought that the cessation of channel meandering caused by Garrison Dam would shift the floodplain-forest composition over time away from cottonwood and toward these late-successional species. But as hypothesis 2 suggests, there were indications from field data that in the postdam environment, two of the four late-successional species—elm and box elder—showed signs of low survival of reproduction, possibly caused by the cessation of spring moisture recharge from overbank flooding. An increased rate of mortality of established trees from disease, flooding, or drought (discussed later) was not forecast. Ultimately, as the hypothesis suggests, chronic reproductive failure of elm and box elder would favor green ash, the only late-successional species that at the time exhibited a balanced population structure. The demise of elm and box elder would produce a decline in biodiversity across the floodplain, especially in cottonwood forests midway through succession, a period when all tree species grow together—cottonwood in the overstory and the late-successional species in the understory.

The Garrison Reach study area

Major changes have occurred in the broader physical and biological environment of the Garrison Reach study area since dam construction. Hydrology, channel structure, land and water cover, and delta formation top the list.

Hydrologic and sediment regime. The filling of Lake Sakakawea behind Garrison Dam began in the fall of 1953. The reservoir eliminated approximately 23,000 hectares each of riparian forests and of cropland. The river below the dam was subjected to a controlled-release regimen and began to adjust to this major alteration of sediment and flow. The average daily flow of the Missouri River was nearly identical before and after the dam's construction at the US Geological Survey gauging station in Bismarck: The flow in the predam period (1928–1952) was 623.2 cubic meters (m^3) per second, and it was 624.2 m^3 per second in the postdam period (1953–2010). The flow regime, however, changed markedly after the dam's construction. During the predam period, approximately two-thirds of the annual peaks were greater than 2500 m^3 per second (figure 2). The instantaneous annual peak of record occurred in 1952 (14,150 m^3

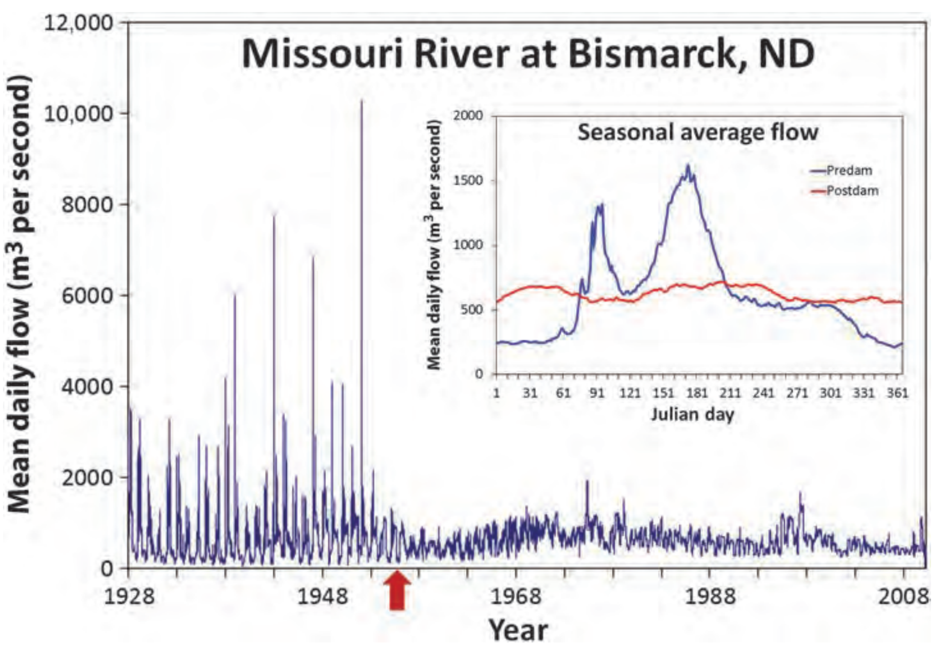


Figure 2. Daily hydrograph for the period of record for the Bismarck, North Dakota, gauge (no. 06342500) on the Missouri River. The insert is streamflow for the same data set averaged for each Julian day (1 January–31 December). The red arrow points to the year in which Lake Sakakawea was filled for the first time. Source: US Geological Survey National Weather Information System. Abbreviation: m^3, cubic meters.

per second) just before the dam's closure. No postdam peak of record has exceeded 2500 m^3 per second; the highest was 1951 m^3 per second in 1975.

The seasonal flow patterns changed markedly after the dam's construction. For example, the large peak flows between April and July in the predam period disappeared in the postdam period (inset in figure 2). Over the period of record, the relatively flat postdam hydrograph showed higher winter flows but generally lower summer flows than during the predam period.

Virtually all of the sediment that enters Lake Sakakawea remains there. The annual suspended-sediment load transported by the Missouri River past Bismarck declined by almost an order of magnitude following the closure of Garrison Dam (USACE 1951, 1957, 1965, 1970, 1976). Postdam sources of sediment for the Garrison Reach are primarily from tributaries and erosion of the riverbed and banks of the Missouri itself.

Riverbed elevation. The shape of the longitudinal curve of riverbed elevation (using water-surface elevation as a proxy) through the Garrison Reach has changed since Garrison Dam's construction. When the reservoir was filled (1954), riverbed elevation throughout the reach had assumed a relatively straight line, indicating a uniform slope (figure 3). Postdam sampling (in 1975 and 1995) showed a pronounced downcutting of the river channel below the dam, caused by sediment-hungry, clear-water releases. This effect attenuated with distance until at the midpoint of the reach, downcutting was negligible. From midreach downstream, however, the riverbed has aggraded such that the river current has slowed, and sediment has dropped out at the confluence with Oahe Reservoir. The slope in the reservoir-delta region eventually approached zero (figure 3). The riverbed below the dam (river mile 1388) has degraded 2.6 meters (m) in 40 years, whereas it has aggraded near Oahe Reservoir (river mile 1289) by 2.5 m. The rate of degradation has slowed, probably because of a coarsening of the riverbed (Livesey 1963, Williams and Wolman 1984).

Overall, the upper section of the curve has flattened out from channel incision, whereas the lower section has aggraded and flattened out through sedimentation. Channel incision is known to reduce channel meandering and to lower floodplain groundwater levels, whereas channel aggradation generally raises the water table, reduces flow conveyance, and increases flooding (Schumm 2005). Therefore, only the middle section of the reach (the hinge point in the stream gradient) has retained its predam elevation. Alteration of the channel slope by dams bordering remnant riverine reaches negatively impacts their underlying physical environment and ecological function (Ligon et al. 1995, Graf 2006).

Historic land- and water-cover changes. The Garrison Reach was mapped at three points in time using ArcGIS (Esri, Redlands, California) to compare pre- and postdam land-cover

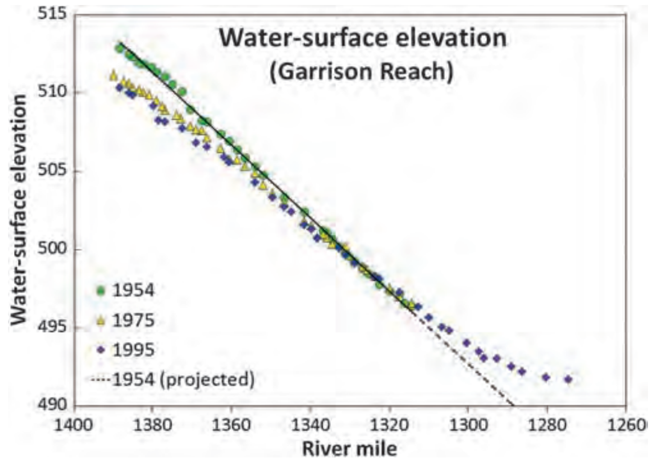


Figure 3. Elevation (in meters) above mean sea level of the river surface under steady flow (1050 cubic meters per second) through the Garrison Reach of the Missouri River in North Dakota. Water-surface elevation is used as a proxy for riverbed elevation. Elevation downstream of river mile 1315 in 1954 was estimated by linear regression of upstream observations. Source: data from Paul Boyd, US Army Corps of Engineers.

conditions. Digital, georeferenced images of the 1892 Missouri River Commission maps, including their vegetation-type designations, were obtained from the US Army Corps of Engineers. Geographic information system (GIS) maps for the 1950s (1955 and 1956) were produced from black-and-white aerial photographs at 1:20,000 scale obtained from the US Department of Agriculture (USDA) Aerial Photography Field Office. The mid-1950s maps were considered to be predam snapshots, given the short time interval between the filling of the reservoir (1954) and the photography dates. Land-cover maps for 2006 were based on county mosaic orthophotography (in true color) from the National Agricultural Imagery Project, obtained from the USDA National Resources Conservation Service Geospatial Data Gateway. Details of the procedures used in mapping land cover are available in Dixon and colleagues (2010).

A time series of GIS maps revealed changes since 1892. Two sets of maps—one for a relatively narrow floodplain section (figure 4) and a second for a relatively wide floodplain section (figure 5)—reflect the range of conditions in the Garrison Reach. Both river sections exhibit a loss of channel complexity, a decrease in active channel width, and a decrease in the number of open sandbars between the pre- and postdam maps; they also exhibited a conversion of most of the natural upland grassland and about a quarter of the forest on the floodplain to agriculture during the predam period, as well as an expansion of grassland (especially visible in figure 5) and development of wooded islands from sandbars between the pre- and postdam dates of the snapshots. The narrow section shows little channel meandering across the time series, whereas major differences

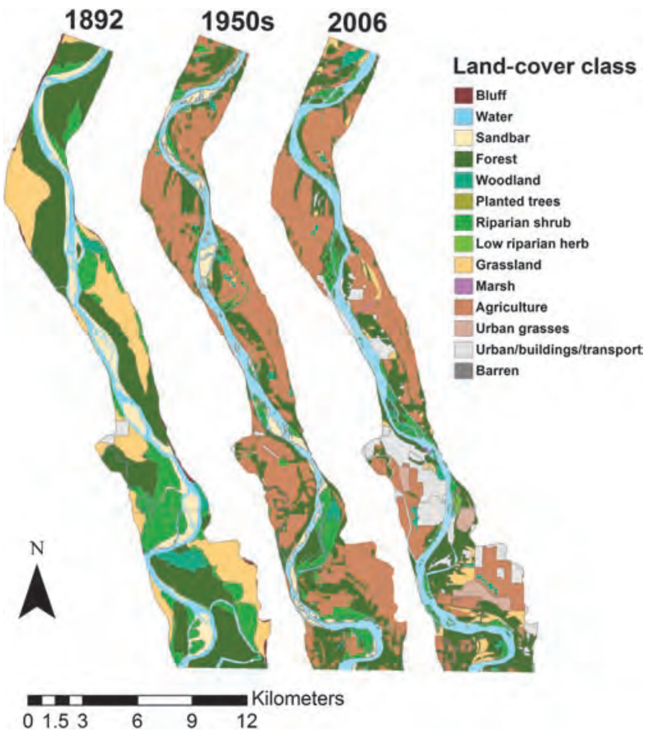


Figure 4. Geographic information system maps of land and water cover for a relatively narrow floodplain reach of the Missouri River at three points in time.

are visible in the channel's location in the wide floodplain section between the two predam maps but not between the postdam-period maps. Flood protection enabled the expansion of urban land near Bismarck and Mandan (figure 4) during the postdam period.

The areal extent of forest types on the floodplain also shifted during the 1892–2006 period. The cottonwood forests that had established before Garrison Dam was built were considerably more extensive than were the postdam cottonwood forests in 2006 (figure 6). The postdam cottonwood forests were, for the most part, located near the main river channel, in contrast to the predam cottonwoods, which were more widely distributed across the floodplain. Dixon and colleagues (2010) found that the rate of cottonwood establishment has slowed during the postdam period.

Reservoir delta. Potential impacts of a delta forming south of Bismarck were neither forecast nor discussed by Johnson and colleagues (1976). Sedimentation (aggradation) occurs wherever flowing water that is transporting sediment contacts the still water of the reservoir margin. The point of confluence frequently shifts from near the South and North Dakota state line during the low-reservoir stage to as much as 70 river km upstream, near the Burleigh–Emmons county line when the reservoir is full (figure 7). The river deposits sediment sporadically along this 70-km reach, depending on the reservoir stage. The aerial image in figure 7 shows splays of sediment scattered throughout this reach; however, because the reservoir is most often maintained near full pool

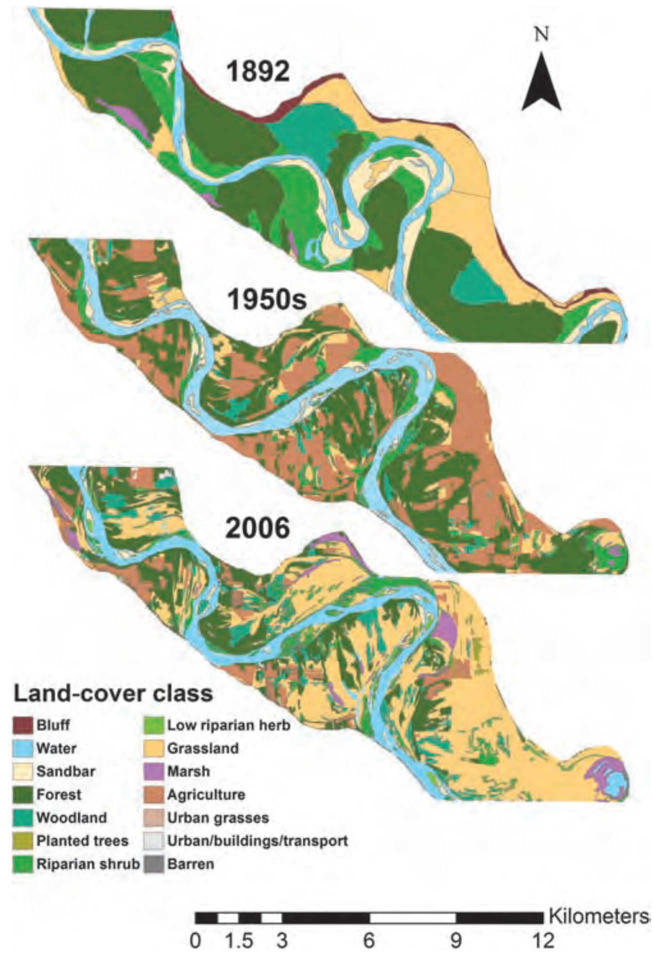


Figure 5. Geographic information system maps of land and water cover for a relatively wide floodplain reach of the Missouri River at three points in time.

to create maximum head for power generation, the delta is best developed near the Burleigh–Emmons county line.

Reservoir deltas have been termed "novel" riverine habitats because on unregulated rivers, deltas are transient features associated with tributary confluences (Stevens et al. 2001, Johnson 2002). They are highly dynamic and ecologically complex, but they are poorly studied. The areas of natural river upstream of the reservoir at full pool were thought to be largely outside the influence of the reservoir. However, we have learned with time from the Garrison Reach and from other rivers (Schumm 2005) of three types of physical changes upstream of reservoirs: channel aggradation, reduced channel conveyance, and rising river and groundwater levels. The first two of these cause the third. Aggradation occurs when sediment accumulates in the channel and raises the riverbed elevation at the river–reservoir confluence. As the slope of the channel flattens out and flow velocity drops, a backup effect causes the river stage to rise and sediment deposition to occur farther upstream. When high flows occur in river sections with restricted conveyance, especially during cold winters with heavy ice buildup

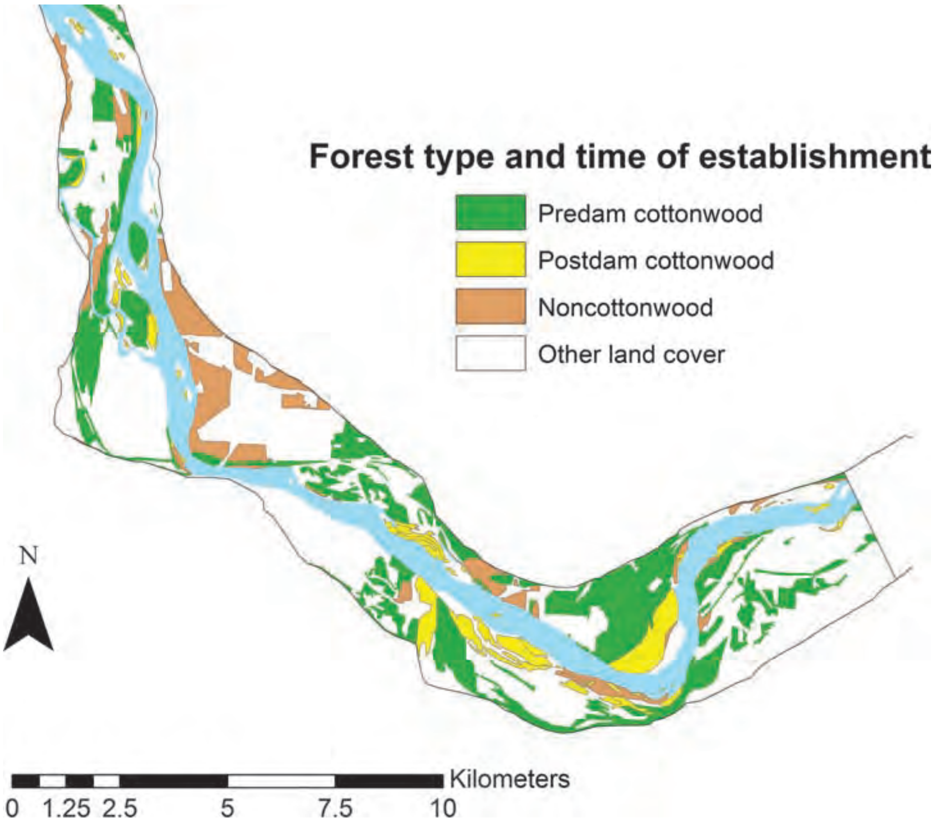


Figure 6. Forest age classes and the period of establishment for a typical section of the Garrison Reach of the Missouri River in North Dakota.

and jams, backup can be severe and can cause considerable property damage many kilometers upstream, as occurred near Bismarck in March 2010. The net effect of sedimentation and backup is hydration of the floodplain well upstream of the predelta, full-pool reservoir margin.

Forty years of vegetation change

The best test of hypotheses 1 and 2 are the remeasurement data from the 34 stands of forest in the Garrison Reach.

Field sampling of riparian vegetation. Stands 1–10 were sampled in the summer of 1969, whereas Stands 11–34 were sampled in the summer of 1970. The method used to sample vegetation in 2008 was identical to those of Johnson and colleagues (1976) and Keammerer (1972), except that tree-seedling density was not estimated in 2008 and that four more herbaceous-layer plots were sampled for each stand in 2008.

Thirty of the 34 stands were resampled in the summer of 2008. One of the four unsampled stands (Stand 31, near Bismarck) had been converted to suburban land use. Permission was not granted to resample the three other stands (Stands 9, 18, and 22); however, they had remained forested.

Forest population structure. The results from the remeasured stands confirmed a key observation about cottonwood: It does not reproduce successfully in its own forests. The population structure of a young cottonwood stand (Stand 28) in 1970 assumed a negative exponential form, typical of a balanced population (Meyer 1952) that could be self-maintaining over time (figure 8 insert). Forty years later, however, the size structure of the population had shifted strongly to a normal distribution, with the peak numbers of trees in larger size classes. A sizable gap in the smallest size classes indicated no population ingrowth. The mean diameter of cottonwood trees during the period nearly doubled from 15.5 centimeters (cm) diameter at breast height (DBH) to 31.5 cm DBH; the largest cottonwood tree sampled in Stand 28 in 1970 was 30 cm DBH, whereas the DBH of the largest cottonwood sampled in 2008 was 70 cm. The same shift in cottonwood size structure was evident when the size classes of all 22 remeasured stands in which cottonwood was present were averaged at both sampling dates (figure 8). The mean DBH in these stands was 32.8 cm in 1969 and 1970 and 48.2 cm in 2008. Cottonwood is slowly but certainly on the way out in established stands on the Missouri River floodplain.

Late-successional species exhibited widely varying trends in basal area (cross-sectional area of trees at 1.3 m above the ground expressed on a unit area basis) over the remeasurement period. American elm underwent the largest change within the group of late-successional species (figure 9). Elm was historically a major canopy tree on the floodplain; Johnson and colleagues (1976) found elm basal area to have been second only to that of cottonwood. Because of Dutch elm disease (*Ophiostoma ulmi* [Buisman] Nannf.), however, elm has been nearly eliminated as a member of the mature forest community (figure 9). Forests that were once dominated by elm have now, at best, a few large trees remaining.

The decline of box elder dominance was less dramatic than that of elm (figure 9). The basal area of box elder declined in the large majority of stands; small increases were largely confined to young cottonwood stands. The largest declines occurred in middle-aged forests in which late-successional species would be expected to be increasing, not decreasing, as cottonwoods undergo natural thinning.

Green ash basal area increased in most stands, including young cottonwood stands, whereas only a few stands experienced modest to large decreases (figure 9). Overall, the postcottonwood forest community has been reduced to a

Figure 7. Aerial photograph of the Missouri River mainstem delta south of Bismarck, North Dakota. The horizontal yellow line corresponds to the border between Burleigh and Emmons Counties and the approximate northern boundary of the full pool of Oahe Reservoir. Photograph: US Department of Agriculture, National Agriculture Imagery Program.

green-ash dominated community with box elder as a waning codominant.

Forest succession in real time. The successional trajectories of the large majority of the remeasured stands with cottonwood present were, as was expected, toward increasing proportions of late-successional species. The *rate of succession* is defined here as the proportional increase in the importance value of late-successional species. *Importance value* is the sum of the relative values of frequency, density, and dominance (basal area) (Curtis and McIntosh 1951) and is a measure of the relative ecological importance of species in a plant community.

Stands that experienced slow rates of succession (the shortest arrows in figure 10) generally occurred near the ends of the stand gradient. For example, 40 years was insufficient for late-successional species to colonize and grow to tree size (i.e., more than 10 cm DBH) in the nutrient-poor, young cottonwood stands. Among the older stands, the last few giant cottonwood trees (1–2 m DBH) mostly survived through the remeasurement period, despite broken branches and tops.

The most rapid succession rates (the longest arrows in figure 10) occurred in middle-aged forests (the middle portion of figure 10). The stands with abundant elm and box elder in 1969 and 1970 (Stands 2 and 7) exhibited slow succession because of the high mortality of these species during the remeasurement period. In contrast, Stands 12 and 17, in which ash was the dominant late-successional species and in which elm was absent or uncommon in 1969 and 1970, exhibited the highest rates of succession. The decline of elm in all stands and box elder in many stands had the effect of slowing the natural shift in relative importance from pioneer to late-successional species and to delay the time at which late-successional species would dominate cottonwood compositionally. The expectations during succession that late-successional species should increase and that pioneer species should decrease with time were not observed in many of the remeasured stands.

Five stands (marked in red in figure 10) experienced *reverse succession*, defined as a decrease in the importance of late-successional species. Three of these (Stands 3, 6, and 8) experienced high mortality in the Oahe delta region caused by rising groundwater. Two of the five stands (Stands 14 and 32) had been managed for wildlife by cutting the smaller trees, most often of late-successional species more desirable for firewood.

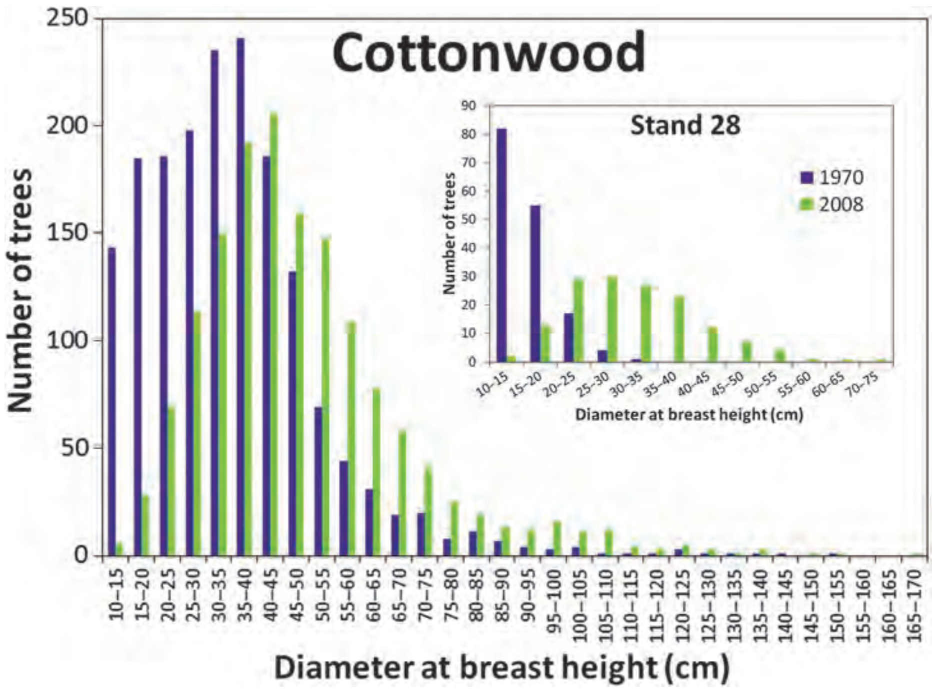


Figure 8. Size structure changes of cottonwood between the measurement in 1969 and 1970 and that in 2008, averaged for all resampled stands. The insert is the size structure of cottonwood trees for a single remeasured stand (Stand 28).

Overall, a complex pattern of succession has developed in Missouri River forests of predam origin. Flooding from reservoir backup and exotic plant diseases have altered the normal development of late-successional species by reducing their regeneration, growth rates, and survival.

Trends in tree reproduction. The mean seedling density across all stands in 1969 and 1970 was approximately 1 seedling per square meter (m^2) for box elder and 6 seedlings per m^2 for ash and elm (table 1). These seedling densities were several orders of magnitude greater than the tree densities in the same stands. Box elder and elm sapling densities were a fourth of that for ash (table 1).

The reproduction of late-successional species has decreased sharply since the 1969 and 1970 measurement. Box elder and elm seedling ubiquity dropped from 31 to 6 stands and from 22 to 15 stands, respectively (table 1). Ash ubiquity declined less, from 33 to 25 stands. Box elder sapling density declined from 1596 saplings per hectare to 250 saplings per hectare (table 1). Elm sapling reductions were even greater. Ash experienced major reductions in seedling presence and sapling density but still remained at much higher densities than box elder and elm.

Changes in herbaceous vegetation. The most-striking changes in the herbaceous layer involved three invasive species. Smooth brome (*Bromus inermis* Leyss), of Eurasian origin (Vogl et al. 1996), was present in about half of the stands in 1969 and 1970; its relative cover was low, averaging 5.4% in occupied stands (figure 9). By 2008, smooth brome was present in all but one remeasured stand, and its average relative cover had risen to 34.4%. In 10 of the 30 stands, relative cover by smooth brome exceeded 50% (figure 9).

Canada thistle (*Cirsium arvense* [L.] Scop.) and reed canary grass (*Phalaris arundinacea* L.) were more restricted geographically than the ubiquitous smooth brome. Canada thistle, also of Eurasian origin, is a noxious weed in many Great Plains states (Stubbendieck et al. 2003) but was not sampled in the large majority of stands in 1969 and 1970. Where it did occur, it exhibited relative cover values less than 5% (figure 9). By 2008, it had spread to nearly all stands and had reached cover values up to 25%. It also exhibited a strong longitudinal pattern of occurrence, with low cover values nearer the dam and high cover values associated with the Oahe delta (figure 9).

Reed canary grass is a hybrid between North American and Eurasian genotypes (Reinhardt-Adams and Galatowitsch 2005). It has expanded rapidly in shallow wetlands throughout the northern Great Plains, displacing many native wetland plants. It was absent from riparian forests in 1969 and 1970 but is now quite abundant and concentrated in the Oahe delta region. Cover values ranged widely, from several percent to 75% (figure 9).

1969 and 1970 hypotheses: Right or wrong?

New data from the Garrison Reach generally support hypothesis 1. GIS maps clearly show that the river channel has moved very little in the nearly 60 years since Garrison Dam's construction. This contrasts sharply with the extensive channel meandering mapped in the predam period (figure 5). The expansive swaths of early-successional forests mapped in 1892 cannot be sustained by a fixed channel and the low postdam regeneration rate observed. Cottonwood communities of postdam origin have been mostly confined to comparatively small patches near the main river channel highly vulnerable to erosion.

Reduced peak flows in the Garrison Reach following damming triggered the near-channel expansion of cottonwood reproduction (figure 4). Channel narrowing is a well-known mechanism of forest regeneration on confined sections of meandering rivers during periods of low flow, when banks and islands are exposed (Friedman et al. 1996). Without channel movement or further narrowing in the future, similar

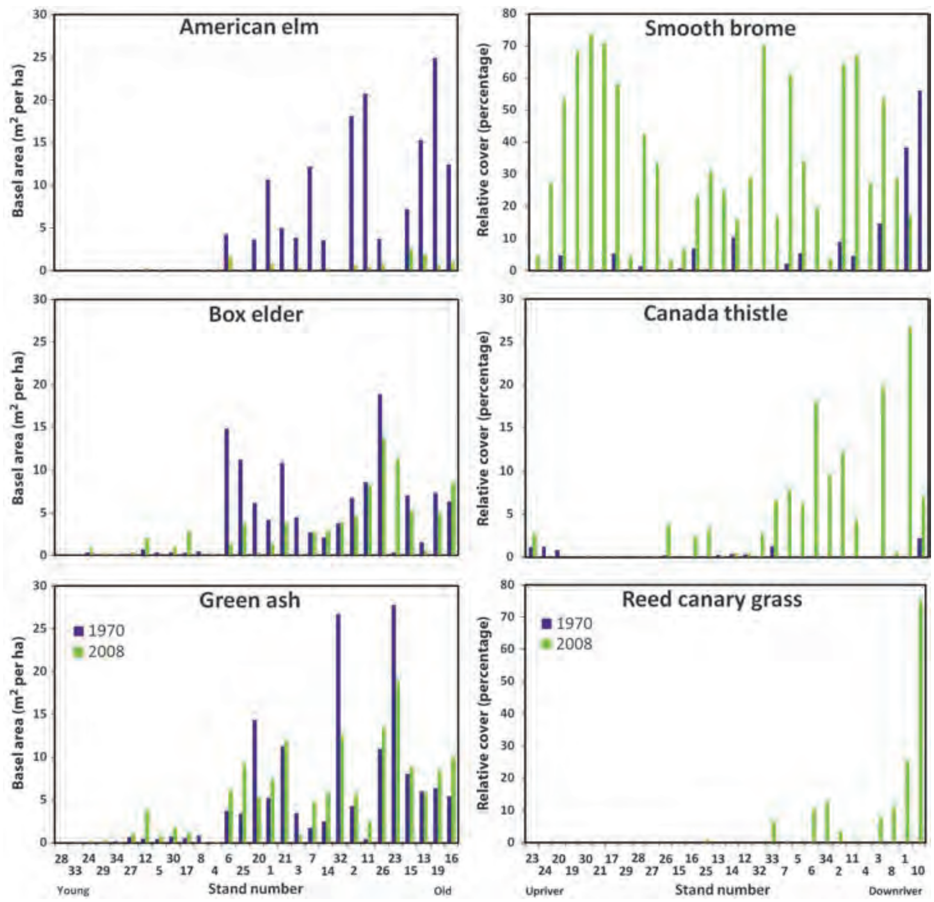


Figure 9. Changes in basal area for three late-successional tree species (left column) and changes in cover for three invasive herbaceous species (right column) over a 40-year period in the Garrison Reach of the Missouri River floodplain. Abbreviations: ha, hectares; m², square meters.

sapling category (hypothesis 2) was only a short-term bottleneck or was a chronic recruitment problem that would eventually slow the successional advance of box elder and elm. The remeasurement data show that the unbalanced age structure has continued, leading to our acceptance of hypothesis 2—that biodiversity in successionally mature stands will continue to decline. Neither species appears able to maintain its predam prominence on the floodplain in the postdam environment but for very different reasons, as is discussed below.

Green ash has emerged as the dominant late-successional species, as was predicted by Johnson and colleagues (1976). Major declines in all size classes of American elm and box elder foretell their greatly reduced roles in the future floodplain forests. Elm will eventually be extirpated in the region by Dutch elm disease unless resistant trees are found and propagated. Johnson and colleagues (1976) did not discuss the potential effects of the disease because none were apparent in natural forests at the time of their study; however, some street trees in Bismarck had succumbed to the disease by 1969. The loss of elm from the ecosystem will have long-term consequences for the biodiversity, productivity, and resilience of late-successional forests on this and other floodplains (e.g., Hale et al. 2008).

The cause of box elder decline is less obvious. Johnson and colleagues (1976) hypothesized that overbank flooding may have periodically provided essential moisture and nutrient-rich silt to enable the roots of late-successional species to reach the capillary fringe of the water table in the semiarid climate. Xerification of the floodplain now that floods have ceased could be lowering the survivorship of all but the larger and more deeply rooted box elder trees. Browsing by cattle and deer is a second likely factor reducing recruitment into box elder populations. Deer and cattle are both numerous on the floodplain; other studies have shown browsing to be a major factor affecting the composition and structure of riparian forests (e.g., Scott and Auble 2002).

In summary, the two hypotheses of Johnson and colleagues (1976) have been largely borne out by the remeasurement data—that is, a sharp decline in cottonwood regeneration caused by the cessation of flooding and a

pulses of cottonwood regeneration are unlikely to be repeated. The rate of cottonwood regeneration has declined in recent decades (Dixon et al. 2010). The proximity of these river-marginal patches to the main channel also makes them more vulnerable to erosion from ice and high flows than would have been the case for predam patches that established on the inside of dynamic river bends. Stabilization of riverbanks is common in the Garrison Reach, which further limits channel movement, point bar formation, and forest regeneration (Florsheim et al. 2008). Fifty-two percent of the banks have been stabilized in the urban areas of the reach, whereas 21% have been stabilized in rural areas (Angradi et al. 2004).

The remeasurement data clearly show the void of reproduction within established stands, steadily increasing tree size, and aging population structure of cottonwood. The remeasured stands and the historic land- and water-cover mapping together provide strong evidence that cottonwood is indeed a fugitive species on the Missouri River floodplain that is dependent on cut-and-fill alluviation during high flows to form new recruitment sites.

It could not have been known from a single measurement in 1969 and 1970 whether the low recruitment into the depauperization of the late-successional forest community and floodplain landscape.

Surprises

Although ash appears to be the current winner on the successional racetrack, its dominant position may be short lived, given the appearance and westward movement of a "great equalizer": the emerald ash borer (*Agrilus planipennis* Fairmaire). This Asian insect was first found in Detroit, Michigan, and Windsor, Ontario, in 2002, associated with urban trees (Poland and McCullough 2006). To date, tens of millions of ash trees have been killed as the pest outbreak has expanded from the Detroit area west to Minnesota, east to Maryland, and south to West Virginia (Moser et al. 2009). The borer often attacks stressed trees first, but when beetle populations are high, even the healthiest ash trees are killed. All North American species of ash are susceptible to mortality by the insect. Foresters are not sanguine about the prospects for containment because of the widespread nature of ash and the potential for inadvertent transport of the pest via firewood.

A second surprise after 40 years was the rapid formation and impact of the Oahe delta. Groundwater has been rising in the affected area, causing considerable mortality of established trees. Of the six native tree species on the floodplain, only peach-leaf willow can withstand chronic flooding. Even cottonwood, which is remarkably well adapted to life along rivers, rarely survives flooding throughout the growing season. Field notes from the 2008 remeasurement show a high mortality rate of trees in most stands (Stands 1, 2, 3, 6, 8, and 10) south of Bismarck in the affected area. There was no evidence of abnormal rates of tree mortality in the 1969 and 1970 survey of the same stands. Sedimentation in the delta area will continue, and unless streamflow and groundwater backup are relieved by channelization or flood-scale releases from Garrison Dam, such as those that occurred in summer 2011, water tables are likely to increase further or stabilize at high levels during high-reservoir stages.

The survival prospects for these forests are poor. The complete replacement of some forests that were well developed in 1969 by grassland had already occurred in 2008 (e.g., Stand 10;

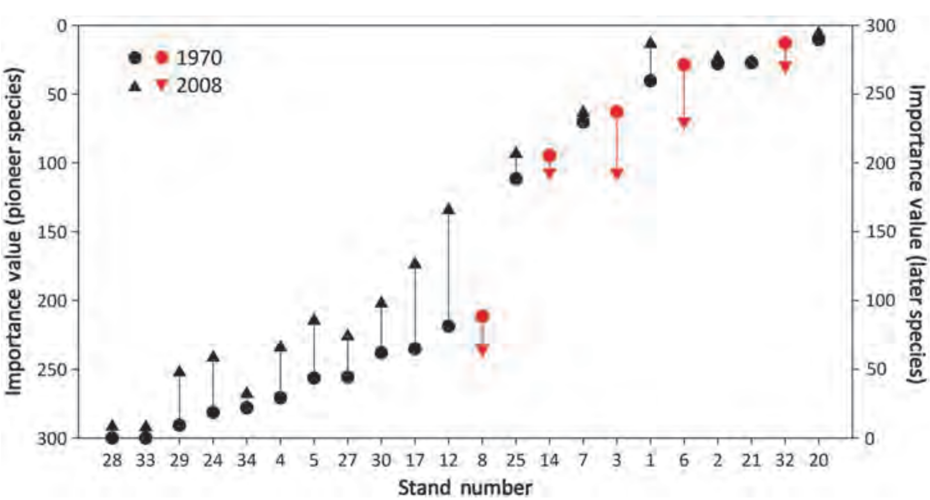


Figure 10. Successional trajectories for all remeasured stands over a 40-year period (stands with cottonwood present in 1969 and 1970). The circles represent the 1969 and 1970 importance values for pioneer species (cottonwood, left ordinate) and late-successional species (elm, ash, and box elder; right ordinate). The triangles represent the importance values for each group of species in 2008. The red color signifies reverse succession (increased importance values for pioneer species over time) and the black signifies forward (normal) succession (decreased importance values of pioneer species over time). The stands are arranged by decreasing importance value of cottonwood and willow in 1969 and 1970. The ordinates of the graph are scaled differently.

Table 1. Density of reproduction of late-successional tree species in occupied stands at two time periods on the Missouri River floodplain.

	Seedlings				Saplings			
	1969–1970[a]		2008		1969–1970[a]		2008	
Species	Number per square meter	Number of occupied stands	Number per square meter	Number of occupied stands	Number per hectare	Number of occupied stands	Number per hectare	Number of occupied stands
Green ash	6.6	33		25	6043	33	163	9
Box elder	1.0	31		6	1596	33	250	3
American elm	6.4	22		15	1405	27	73	4

Note: Seedling density was not estimated in 2008. Thirty-four stands were sampled in 1969 and 1970, and 30 of those were resampled in 2008.
[a]From Johnson (1971).

figure 11). The conversion process is accelerated by wildfires, which are primarily caused accidentally by recreationists, that occur commonly now because more grassland has been planted in the Oahe Game Management Area. Most of the cropland within the boundary of the management area has been planted with various mixtures of native, warm-season grasses (Jeb Williams, North Dakota Game and Fish Department, personal communication, 9 August 2011). Many wetter sites, some of which were forested in 1969 and 1970 within the boundary, have also converted naturally—assisted by fire—to mixtures of reed canary grass and prairie cordgrass (figure 11).

The future vegetation of the area south of Bismarck affected by the delta will be dominated by wet grassland, not forest and agriculture as it was in 1969 and 1970. The high water table and increased flooding during high-reservoir stages and fires during low-reservoir stages will open the forest canopy, facilitating grassland establishment and heavy weed growth, except on some of the higher ground that currently supports midsuccessional, high-diversity cottonwood forests.

At the opposite (northern) end of the Garrison Reach, channel degradation, not aggradation, has occurred. Any ecological effects of degradation, such as increased tree mortality from a lowered water table, were not apparent from the remeasurement data. However, other measurements should be taken to determine whether more-subtle effects, such as tree growth decline, a lowering of floodplain lake and wetland levels, and restricted lateral movement of the incised channel, are detectable, as they have been found to be on the lower Missouri River (NRC 2002).

Conclusions

The changes on the Missouri River floodplain over the past 40 years follow a century and a half of substantial human influences, the most important of these being the extensive clearing of timber for agriculture; the cutting of massive volumes of timber for steamboat fuel; the removal of snags; channelization and levee construction; bank stabilization; and, most recently, the building of large dams (Schneiders 1999). Concern in the United States over the declining health of this river system is evidenced by two major reports by the National Research Council in the last decade in which the collective impacts and approaches needed for ecosystem recovery were reviewed (NRC 2002, 2011). The new findings from the Garrison Reach describe both the continuing and other, unforeseen stressors on what remains of the ecological legacy in remnant reaches confined between reservoirs. River

Figure 11. Conversion of a successionally mature riparian forest to a grassland dominated by reed canary grass. The forest was killed by reservoir backup during high-reservoir stages and by wildfire during low-reservoir stages. The left photograph is of Carter Johnson in Stand 10 in 1969. Photograph: Janet Johnson. The right photograph is of Carter Johnson in same stand in 2008. Photograph: Michael L. Scott.

engineering, agriculture, and urbanization are not the only causes of the declining health of riparian forests. Diseases and insect pests imported from around the world have been (and may continue to be) an important cause of the decline of the trees that naturally replace short-lived cottonwoods and contribute so much to forest biodiversity.

Perhaps the most surprising consequence of the dams has turned out to be the areal extent and the impacts of deltas in the contact zone between river and reservoir. Almost a quarter of the Garrison Reach's floodplain forests—once thought to be safe from permanent flooding—are now dead or dying as a result of rising groundwater. The environmental benefits of this novel delta ecosystem dominated by low-diversity grassland—much of it planted—pale in comparison to those of the high-diversity riparian forests being lost. As the world's reservoir systems age, the effects of delta formation and expansion will become more evident and problematic, as they have in the Garrison Reach. Studies are needed in order to identify problems and to find solutions that will minimize the effects of deltas on the riparian ecosystems associated with most dammed river systems worldwide (Johnson 2002).

Mounting, cumulative impacts make the restoration of the riparian ecosystems of the Missouri River doubtful. More and more cards are stacked against the natural river ecosystem as impacts diversify and magnify. Although some of these impacts were predictable, others—largely stochastic in nature (pest invasions and tree diseases)—were not. If ash and elm are functionally extirpated, true restoration will be impossible; however, reactivating key ecological processes, such as flooding and cut-and-fill alluviation, in the reach could recover much of the biodiversity and function of the cottonwood community (see Rood et al. 2003) that historically dominated the floodplain.

The major lesson from this long-term research is that a second, more insidious wave of impacts of damming follows the initial acute impacts associated with the filling of large reservoirs. The second wave affects the remnant forests that survived downstream of the dams or in gaps between the reservoirs. These slow-to-develop environmental changes, such as channel incision, bank stabilization, and delta formation, are the product of flow and sediment alteration. Other impacts not directly associated with damming can be as serious as physical environmental changes in influencing ecological processes and biodiversity, such as the expansion of invasive plants, agricultural and urban expansion, and the introduction of insect pests and diseases. What started out 40 years ago as predominantly a cottonwood-regeneration problem on the Missouri River floodplain has expanded into a potential riparian-forest catastrophe with increasingly daunting prospects for recovery.

Postscript. During the publication phase of this article, unprecedented moisture in the upper Missouri River basin triggered record-breaking flow releases from the US Army Corps of Engineers dams. The extent to which these flows will rejuvenate the impaired elements of the river ecosystem discussed in this article are as yet unknown but should be a high priority for study when the flood waters have receded.

Acknowledgments

Funding for this research was provided by the US Army Corps of Engineers, Kansas City Office. Warren Keammerer and Deborah Keammerer collected the forest understory data in 1969 and 1970. Dale Kohlmetz, Jennifer Young, Brittany A. Hummel, Keir A. Morse, and Tara L. Kline collected all field data in 2008. We also thank the many riparian landowners who allowed us to access their property and to sample their forests (some of them twice). We thank Waite Osterkamp for reviewing an early draft of the manuscript and for making helpful suggestions. This article is dedicated to the late Robert L. Burgess, whose foresight to investigate the ecological effects of dams on the newly impounded Missouri River made this long-term study possible.

References cited

Angradi TR, Schweiger EW, Bologrien DW, Ismert P, Selle T. 2004. Bank stabilization, riparian land use and the distribution of large woody debris in a regulated reach of the upper Missouri River, North Dakota, USA. River Research and Applications 20: 829–846.

Bayley PB. 1991. The flood pulse advantage and the restoration of river-floodplain systems. Regulated Rivers: Research and Management 6: 75–86.

Braatne JH, Rood SB, Heilman PE. 1996. Life history, ecology, and conservation of riparian cottonwoods in North America. Pages 57–85 in Stetler RF, Bradshaw FA, Heilman PE, Hinckley TM, eds. Biology of *Populus* and Its Implications for Management and Conservation. NRC Research Press.

Bradley CE, Smith DG. 1986. Plains cottonwood recruitment and survival on a prairie meandering river floodplain, Milk River, southern Alberta and northern Montana. Canadian Journal of Botany 64: 1433–1442.

Curtis JT, McIntosh RP. 1951. An upland forest continuum in the prairie–forest border region of Wisconsin. Ecology 32: 476–496.

Dixon MD, Johnson WC, Scott ML, Bowen D. 2010. Status and Trend of Cottonwood Forests along the Missouri River. US Army Corps of Engineers, Omaha District. Report no. 78.

Dynesius M, Nilsson C. 1994. Fragmentation and flow regulation of river systems in the northern third of the world. Science 266: 753–762.

Florsheim JL, Mount JF, Chin A. 2008. Bank erosion as a desirable attribute of rivers. BioScience 58: 519–529.

Friedman JM, Osterkamp WR, Lewis WM Jr. 1996. Channel narrowing and vegetation development following a Great Plains flood. Ecology 77: 2167–2181.

Friedman JM, Osterkamp WR, Scott ML, Auble GT. 1998. Downstream effects of dams on channel geometry and bottomland vegetation: Regional patterns in the Great Plains. Wetlands 18: 619–633.

Galat DL, et al. 1998. Flooding to restore connectivity of regulated, large-river wetlands: Natural and controlled flooding as complementary processes along the lower Missouri River. BioScience 48: 721–732.

Gore JA, Shields FD Jr. 1995. Can large rivers be restored? BioScience 45: 142–152.

Graf WL. 1999. Dam nation: A geographic census of American dams and their large-scale hydrologic impacts. Water Resources Research 35: 1305–1311.

———. 2006. Downstream hydrologic and geomorphic effects of large dams on American rivers. Geomorphology 79: 336–360.

Hale BW, Alsum EM, Adams MS. 2008. Changes in the floodplain forest vegetation of the lower Wisconsin River over the last fifty years. American Midland Naturalist 160: 454–476.

Hibbard EA. 1972. Vertebrate Ecology and Zoogeography of the Missouri River Valley in North Dakota. PhD dissertation. North Dakota State University, Fargo.

Hilty JA, Lidicker WZ Jr, Merenlender AM. 2006. Corridor Ecology: The Science and Practice of Linking Landscapes for Biodiversity Conservation. Island Press.

Howe WH, Knopf FL. 1991. On the imminent decline of Rio Grande cottonwoods in central New Mexico. Southwestern Naturalist 36: 218–224.

Johnson WC. 1971. The Forest Overstory Vegetation on the Missouri River Floodplain in North Dakota. PhD dissertation. North Dakota State University, Fargo.

———. 1994. Woodland expansion in the Platte River, Nebraska: Patterns and causes. Ecological Monographs 64: 45–84.

———. 1998. Adjustment of riparian vegetation to river regulation in the Great Plains, USA. Wetlands 18: 608–618.

———. 2002. Riparian vegetation diversity along regulated rivers: Contribution of novel and relict habitats. Freshwater Biology 47: 749–759.

Johnson WC, Burgess RL, Keammerer WR. 1976. Forest overstory vegetation and environment on the Missouri River floodplain in North Dakota. Ecological Monographs 46: 59–84.

Junk WJ, Bayley PB, Sparks RE. 1989. The flood pulse concept in river-floodplain systems. Canadian Special Publication of Fisheries and Aquatic Sciences 106: 110–127.

Keammerer WR. 1972. The Understory Vegetation of the Bottomland Forests of the Missouri River in North Dakota. PhD dissertation. North Dakota State University, Fargo.

Ligon FK, Dietrich WE, Trush WJ. 1995. Downstream ecological effects of dams: A geomorphic perspective. BioScience 45: 183–192.

Liknes ET, Dean KL, Swanson DL. 1994. Avian diversity, density, and breeding status in a riparian community in southeastern South Dakota. Proceedings of the South Dakota Academy of Science 73: 83–100.

Livesey RH. 1963. Channel Armoring below Fort Randall Dam. US Department of Agriculture Publication no. 970.

Meyer HA. 1952. Structure, growth, and drain in balanced uneven-aged forests. Journal of Forestry 50: 85–92.

Moser WK, et al. 2009. Impacts of nonnative invasive species on US forests and recommendations for policy and management. Journal of Forestry 107: 320–327.

Nilsson C. 1981. Dynamics of the shore vegetation of a north Swedish hydroelectric reservoir during a 5-year period. Acta Phytogeographica Suecica 69: 1–96.

[NRC] National Research Council. 2002. The Missouri River Ecosystem: Exploring the Prospects for Recovery. National Academies Press. 175 pp.

———. 2011. Missouri River Planning: Recognizing and Incorporating Sediment Management. National Academies Press. 152 pp.

Ohmart RD. 1994. The effects of human-induced changes on the avifauna of western riparian habitats. Studies in Avian Biology 15: 273–285.

Osterkamp WR, Hupp CR. 2010. Fluvial processes and vegetation-glimpses of the past, the present, and perhaps the future. Geomorphology 116: 274–285.

Poff LN, Allan JD, Bain MB, Karr JR, Prestegaard KI, Richter BD, Sparks RE, Stromberg JC. 1997. The natural flow regime: A paradigm for river conservation and restoration. BioScience 47: 769–784.

Poland TM, McCullough DG. 2006. Emerald ash borer: Invasion of the urban forest and the threat to North America's ash resource. Journal of Forestry 104: 118–124.

Power ME, Stout RJ, Cushing CE, Harper PP, Hauer FR, Matthews WJ, Moyle PB, Statzner B, Wais De Badgen IR. 1988. Biotic and abiotic controls in river and stream communities. Journal of the North American Benthological Society 7: 456–479.

Reinhardt-Adams C, Galatowitsch SM. 2005. *Phalaris arundinacea* (reed canary grass): Rapid growth and growth pattern in conditions approximating newly restored wetlands. Ecoscience 12: 569–573.

Rood SB, Heinze-Milne S. 1989. Abrupt downstream forest decline following river damming in southern Alberta. Canadian Journal of Botany 67: 1744–1749.

Rood SB, Mahoney JM. 1990. Collapse of riparian poplar forests downstream from dams in western prairies: Probable causes and prospects for mitigation. Environmental Management 14: 451–464.

Rood SB, Gourley CR, Ammon EM, Heki LG, Klotz JR, Morrison ML, Mosley D, Scoppettone GG, Swanson S, Wagner PL. 2003. Flows for floodplain forests: A successful riparian restoration. BioScience 53: 647–656.

Schneiders RK. 1999. Unruly River: Two Centuries of Change along the Missouri. University Press of Kansas.

Schumm SA. 2005. River Variability and Complexity. Cambridge University Press.

Scott ML, Auble GT. 2002. Conservation and restoration of semiarid riparian forests: A case study from the upper Missouri River, Montana. Pages 145–190 in Middleton BA, ed. Flood Pulsing in Wetlands: Restoring the Natural Hydrological Balance. Wiley.

Scott ML, Friedman JM, Auble GT. 1996. Fluvial process and the establishment of bottomland trees. Geomorphology 14: 327–339.

Sedgwick JA, Knopf FL. 1992. Cavity turnover and equilibrium cavity densities in a cottonwood bottomland. Journal of Wildlife Management 56: 477–484.

Sparks RE, Nelson JC, Yin Y. 1998. Naturalization of the flood regime in regulated rivers: The case of the upper Mississippi River. BioScience 48: 706–720.

Stanford JA, Ward JV, Liss WJ, Frissell CA, Williams RN, Lichatowich JA, Coutant CC. 1996. A general protocol for restoration of regulated rivers. Regulated Rivers: Research and Management 12: 391–413.

Stevens LE, et al. 2001. Planned flooding and Colorado River riparian trade-offs downstream from Glen Canyon Dam, Arizona. Ecological Applications 11: 701–710.

Stubbendieck J, Coffin MJ, Landholt LM. 2003. Weeds of the Great Plains. Nebraska Department of Agriculture.

[USACE] US Army Corps of Engineers. 1951. Suspended Sediment in the Missouri River: Daily Record for Water Years 1937–1948. US Army Corps of Engineers, Missouri River Division.

———. 1957. Suspended Sediment in the Missouri River: Daily Record for Water Years 1949–1954. US Army Corps of Engineers, Missouri River Division.

———. 1965. Suspended Sediment in the Missouri River: Daily Record for Water Years 1955–1959. US Army Corps of Engineers, Missouri River Division.

———. 1970. Suspended Sediment in the Missouri River: Daily Record for Water Years 1960–1964. US Army Corps of Engineers, Missouri River Division.

———. 1976. Suspended Sediment in the Missouri River: Daily Record for Water Years 1970–1974. US Army Corps of Engineers, Kansas City Division.

Vannote RL, Minshall GW, Cummins KW, Sedell JR, Cushing CE. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37: 130–137.

Vogl KP, Moore KJ, Moser LE. 1996. Bromegrasses. Pages 535–567 in Moser LE, Buxton DR, Casler MD, eds. Cool-season Forage Grasses. American Society of Agronomy, Crop Science of America, and Soil Science Society of America.

Ward JV, Stanford JA, eds. 1979. The ecology of regulated streams. Plenum Press.

Ward JV, Tockner K, Edwards PJ, Kollmann J, Bretschko G, Gurnell AM, Petts GE, Rossaro B. 1999. A reference river system for the Alps: The 'Fiume Tagliamento.' Regulated Rivers: Research and Management 15: 63–75.

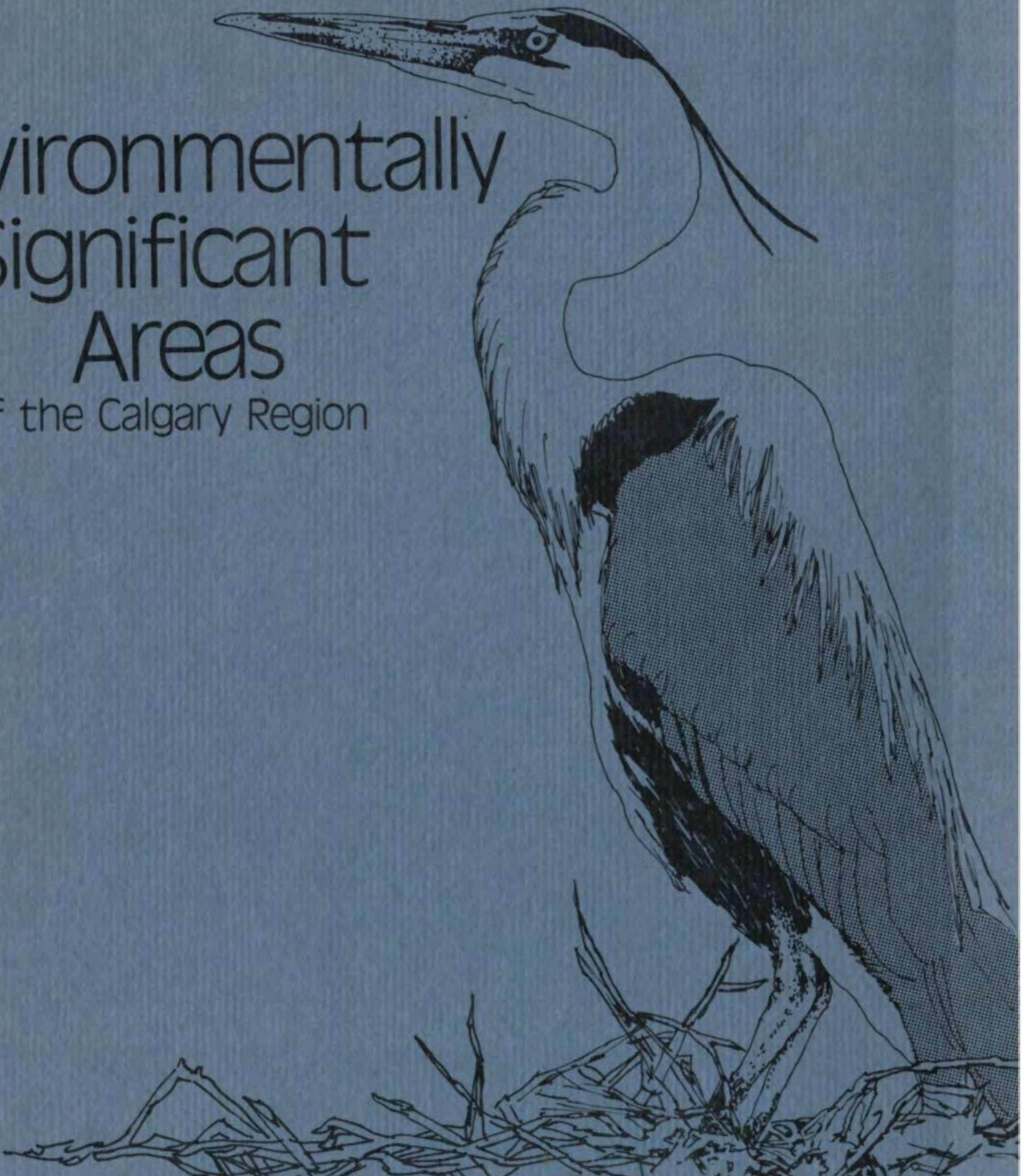
Williams GP, Wolman MG. 1984. Downstream effects of dams on alluvial rivers. U. S. Geological Survey Professional Paper no. 1286. US Government Printing Office.

W. Carter Johnson (carter.johnson@sdstate.edu), Gary Larson, Malia Volke, and Brett Werner are affiliated with the Department of Natural Resource Management at South Dakota State University in Brookings. Mark D. Dixon is affiliated with the Department of Biology at the University of South Dakota in Vermillion. Michael L. Scott is affiliated with the US Geological Survey, in Fort Collins, Colorado. Lisa Rabbe is affiliated with the Army Corps of Engineers, in Kansas City, Missouri.

APPENDIX 12

Lamoureux, R. G. Chow and B. Reeves. 1983. Environmentally significant areas of the Calgary region, Phase Two Report. Prepared by Lamoureux and Associates, Calgary for Calgary Regional Planning Commission, Calgary. Website: https://www.calgary.ca/CSPS/Parks/Documents/Planning-and-Operations/Environmentally-Significant-Areas-1983.pdf

Environmentally Significant Areas
of the Calgary Region



CALGARY REGIONAL PLANNING COMMISSION 8 83 38

In addition to the above river valley lands, the complex river valley slopes (#2113) at the confluence of the Ghost and Bow Rivers remain in a relatively natural state.

South of the Bow River and west of Highway 22 is an extensive area devoted mainly to ranching. To the north of the Trans-Canada Highway the area is primarily grassland while to the south it is largely forested. To an observer proceeding west along the Trans-Canada Highway, the dominant topographic feature of this area is Copithorne Ridge (#2116) a true foot-hill supporting grassland vegetation. Limber Pine are reputed to grow on exposed sites on this ridge, but we did not have the opportunity to verify their presence during the reconnais-sance program. Jumpingpound Creek (#2117) is the most signi-ficant river valley feature of this area. Its banks are rela-tively natural through most of its length except in the vici-nity of a gas plant located near the north end of Copithorne Ridge. The area between Jumpingpound Creek and Bragg Creek, adjacent to the Forest Reserve Boundary (#2118), is an exten-sive wetland zone which has been identified as being of ecolo-gical importance by the Calgary Field Naturalist's Society. Logan Ridge, a forested foothill, has been included within this unit to obtain representation of the full range of foot-hill environments found in this part of the region. The Jumpingpound Creek Valley, Copithorne Ridge and the Jumpingpound/Bragg Creek Wetland area together form a complex which captures much of the ecological diversity of the Jumpingpound area.

The Elbow River, upstream of Glenmore Reservoir, (#2119) is the only remaining natural link between the City of Calgary and the natural foothill and mountain landscapes of Kananaskis Country (Bow-Crow Forest Reserve) to the west. As such it is a unique and irreplacable environmental resource. Its importance is further enhanced by the fact that it is the major source of drinking water for the City of Calgary.

(see Section 5.4). The environment of the creek valley also has exceptionally good aesthetic qualities.

The wetlands south of Jumpingpound Creek (R-15) represent some 60 to 70 percent of the high quality moose habitat found within the M.D. of Rocky View (see Section 5.3), and is hence a high priority conservation area. Logan Ridge, a forested foothill, has also been included within this unit in order to encompass the full range of foothills environments found within the western portion of the District of Rocky View.

The diversity of habits represented by the linear complex comprising Units R-12, R-13 and R-15 is exceptional. Terrain ranges from low-lying wetland to exposed ridge tops and vegetation from dry grassland to foothills forest.

Norman Lake (R-14) is one of the few good waterbird lakes in the western part of the M.D. of Rocky View, and thus merits special status.

Bragg Creek (R-16) is undoubtedly the best Eastern Brook Trout system in the M.D. of Rocky View. It is also a potentially important link between the natural environments of the Jumpingpound Creek and Elbow River Drainages. For both of these reasons planning policies should favour the maximum feasible level of conservation of natural riparian vegetation.

The Elbow River Valley (R-17) provides an important natural environment corridor between the semi-wilderness of the Forest Reserve and the City of Calgary. It is an important refuge for a wide variety of wildlife species, including White-tailed Deer and Mule Deer (see Section 5.4). It also provides important spawning habitat for Eastern Brook Trout (see Section 5.6). Although it currently receives only limited recreational use, it will become a resource of critical importance for recreation as the population of the Region expands. Its importance as the water supply for much of the City of Calgary will also continue into the foreseeable future. It seems clear that the future interests of the Region will be best served by maintaining a virtually uninterrupted natural riparian vegetation zone along the full length of the river. This will preserve the river's function as a wildlife corridor and will facilitate future development of a trail system along the river. It should be noted that portions of the River Valley lie within the Sarcee Indian Reserve, resulting in the need for a co-operative approach in environmental planning matters.

Camp Sarcee (R-18) is one of the last large areas of natural parkland environment in the Calgary Region. The area has considerable conservation and recreation potential. However, any future disposition of the site is a matter between the Sarcee Indian Band and the Federal Government.

The portion of the Fish Creek Valley within the Sarcee Indian Reserve (R-19) is also a potentially valuable natural area with characteristics comparable to those of Fish Creek Provincial Park. The decision on the best use of these lands rests with the Band Council of the Sarcee Indian Reserve.

In examining the priority natural environments in the M.D. of Rocky View south of the Bow River and west of the City of Calgary, it should be noted that they form a continuous linear system linking the Weaselhead area of the City of Calgary's river valley parks system with the Bow River Valley at the community of Cochrane. It would be quite feasible to develop a trail system through these natural environments. This trail system could be linked back, via a trail system through the Bow Valley, to the existing and proposed Bow Valley trail system, to create a circle route.

APPENDIX 13

Lancaster, J., R. Adams, B. Adams, and P. Desserud. 2016. Long-term Revegetation Success of Industry Reclamation Techniques for Native Grasslands: Foothills Fescue, Foothills Parkland, and Montane Natural Subregions; Phase 1-Literature Review and Case Studies-2014. Prepared for: Land and Forestry Policy Branch, Alberta Environment and Sustainable Resource Development. Website: https://open.alberta.ca/dataset/d9006d18-bcf6-441c-90f2-a9469aa8c624/resource/61ae5f43-0a62-443a-9d4b-263321786ab7/download/ff-fp-m-2014-phase1-lit-review-monitoring-report-2015-11-16.pdf

Long-term Revegetation Success of Industry Reclamation Techniques for Native Grassland:

Foothills Fescue Foothills Parkland and Montane Natural Subregions

April 2015

Phase 1
Literature Review and Case Studies
2014

Prepared by:

J. Lancaster, R. Adams, B. Adams and P. Desserud

Cover Photos

Pekisko Rangelands, Courtesy of Jane Lancaster, Kestrel Research Inc.

Rough Fescue, Courtesy of Donna Watt, CorPirate Services

Executive Summary Photos

Foothills Fescue, Courtesy of Donna Watt, CorPirate Services

Example Monitoring Frame, Courtesy of Jane Lancaster, Kestrel Research Inc.

2.1.3 Montane Natural Subregion

In terms of elevation, the Montane Natural Subregion occurs below the Subalpine NSR in the mountains and above the Foothills Fescue and Foothills Parkland NSRs in southern Alberta. It occurs along lower slopes and valley bottoms in the front ranges, along the base of the Porcupine Hills and at higher elevations in the Cypress Hills. Chinooks are frequent along the Front Ranges, and winters are warm with much greater winter snowfall than the Foothills Fescue NSR and lower amounts than the adjoining Subalpine and Alpine Natural Subregions. The Montane has the warmest winter temperatures of any forested region in Alberta because of chinook activity and reduced influence of Arctic air (Strong and Leggat 1992). Yearly precipitation ranges 308 mm to 1279 mm with two precipitation peaks occurring in May-June and again in August-September (Strong and Leggat 1992). Summer monthly temperatures average about 12ºC and are 2ºC warmer than the Subalpine and 2ºC colder than the Foothills Fescue Natural Subregions.

Terrain is complex, soils are variable and vegetation cover also reflects this diversity of slopes, aspects, substrates and moisture regimes (Natural Regions Committee 2006). The Montane is distinguished from the other subregions by the presence of Douglas fir, limber pine (*Pinus flexilis*) and lodgepole pine (*Pinus contorta*). Dominant upland soils associated with forest cover are well drained, medium to fine textured Luvisolic and Brunisolic types. Grasslands associated with the Montane NSR are similar to those found in the Foothills Fescue and Foothills Parklands NSRs. Particularly well-defined vegetation patterns such as the grassland/forest mosaics of the Whaleback Ridge and the Porcupine Hills reflect the often abrupt nature of topographically controlled moisture and temperature gradients. Grasslands are common on moderately dry south- and west-facing aspects and include Foothills rough fescue, Idaho fescue and Parry's oat grass on well to moderately well drained Chernozemic soils.

2.2 Cumulative Effects Management and Fragmentation

Cumulative effects are the combined effects of past, present and reasonably foreseeable future land use activities on the environment. Surface disturbance in grasslands can be grouped in a number of measurable categories that help in the understanding and management of cumulative impacts of land use practices to Alberta's native grasslands. These include:

1) **Permanent conversion to non-native cover types:** Over the past century, extensive tracts of Foothills Fescue, Foothills Parkland and Montane grasslands have been permanently converted to non-native cover types primarily for agricultural cropping, transportation and energy infrastructure, and urban and country residential development. Incremental losses through these processes continue.

2) **Reclamation success and plant community integrity:** Relative to each unique ecological site, intact native grasslands possess a rich diversity of native grasses, forbs and shrubs that produce a characteristic plant community structure, facilitating optimal use of moisture, nutrients and available sunlight. To the extent possible, reclamation practices aim to restore the native plant community so that ecological health and function, and the related ecological services are maintained. In the Alberta Grassland Natural Region, recovery of native plant communities can be more readily achieved in drier prairie environments while mesic foothill environments are much more challenging, primarily due to the greater competitiveness of agronomic grasses and weeds in the moister growing environment. Ecological health, function and associated ecological services will be diminished when plant communities are modified by non-native species.

Pre-disturbance (or adjacent) Plant Community

The pre-disturbance plant communities at all wellsites were native in character but had a significant component of invasive agronomic species including awnless brome, Kentucky bluegrass and timothy. In addition to these species, the MFC and Cross ranch sites included a minor cover of Parry's oat grass or rough fescue plus a significant component of native forbs and graminoids. The Lewis ranch site had the highest proportion of rough fescue which was co-dominant with Kentucky bluegrass.

Reclamation Plant Community

Of all the wellsites evaluated in this initial review of Foothills wellsites, these treatments provided some of the best examples of native species re-establishment with improved practices. Native infilling species ranged from 15 to 33 % depending on site and treatment. The complicating factor in interpreting these results is the profound influence of above average moisture levels in the region extending back to the time of the last drought year which was 2001. As such, even the most healthy plant communities show elevated levels of invasive agronomic species. It will be interesting to see how sites like these evolve through periods of dry or drought conditions when native species are normally much more competitive.

Site Stability

All of the wellsites showed stable site conditions with no evidence of soil erosion or increased human caused bare ground. All sites had abundant vegetation cover with very limited cover of bare soil. Trace to minor amounts of moss were recorded on Lewis, Cross and Cross – Gravel pit sites.

Range Health

Range health scores on disturbed wellsites ranged from 41 to 73% and overall were much higher than for disturbed sites reported in the earlier time categories. It's important to note that the control sites were in the mid to upper range of the 'healthy with problems' class, overall, largely due to the presence of invasive agronomic species, strongly influenced by a series of years with above average precipitation.

Infill

Looking across all reclamation treatments, the percentage of cover from infilling native species including rough fescue, Idaho fescue, native wheat grasses, native forbs and graminoids, ranged from 15 to 33% cover. The highest percentage cover of native infilling species was on the second MFC wellsite and the non-stripped Lewis wellsite location.

Succession of Disturbance Plant Communities Over Time

On the pre-2000 wellsites succession was primarily to non-native species with limited infilling of natives, or were sharply influenced by the cultivar seed mix of the day (e.g. Cicer milk vetch, Sheep fescue etc.) On the post-2000 wellsites some hopeful expressions of native species infilling and recruitment were evident including a very strong re-establishment of rough fescue on the Lewis wellsite where the surface topsoil had not been stripped.

APPENDIX 14

Landhäusser, S. 2000. How old are white spruce trees in the Mackenzie Delta really? Inuvik Region Final Report 2000. Department of Renewable Resources, University of Alberta, Edmonton, AB. 7 pp. Website: http://www.grrb.nt.ca/pdf/forestry/HowOldrWSpruce2000.pdf

Inuvik Region Final Report 2000

How old are white spruce trees in the Mackenzie Delta really?

SIMON LANDHÄUSSER
RESEARCH ASSISTANT PROFESSOR
DEPARTMENT OF RENEWABLE RESOURCES
4-42 EARTH SCIENCES BUILDING
UNIVERSITY OF ALBERTA
EDMONTON, ALBERTA
T6G 2E3

How old are white spruce trees in the Mackenzie Delta really?

SIMON LANDHÄUSSER

Introduction

Soils in the Mackenzie Delta are characterised by fluvial deposits along the channels of the Mackenzie River. Alluvial deposits are very fine particles and produce fine textured soils. In contrast to upland sites, these fluvial soils can support a productive forest cover of white spruce (*Picea glauca* (Moench) Voss) and balsam poplar (*Populus balsamifera* L.). This is largely due to generally warmer soil temperatures during the growing season, which results in deeper active layers. Forests of the delta are mostly dominated by riverine disturbances, such as flooding, erosion, and fluvial deposits. In addition, these sites have longer fire return intervals than upland sites, which allows trees to become very old. In the southern part of the delta, forests can produce impressive trees >40 cm diameter at breast height (1.3m). In some instances coring or cutting these trees (30 cm above ground) revealed that the trees were only about 100 to 200 years old (pers. observation, Mackenzie Delta Forest Inventory 1997). Therefore the productivity and growth of these trees should be comparable with sites in the more southern regions of the boreal forest.

Since white spruce in the Mackenzie Delta establish under the flooding regime of the Mackenzie River, stems of seedlings and saplings get partially buried by silt deposits after each flooding event. Gill (1975) found that silt deposits are larger close to the stems of existing trees due to the obstruction of flow and the formation of eddies. The increased deposits will not only lead to a burial of the stem but also to lower soil temperatures and soil oxygen concentrations surrounding the tree. Decreased soil temperature and oxygen level lead to less root growth and reduced root activity resulting in decreased water and nutrient uptake (Grossnickle 1987). To counteract the negative effects of silt deposits, white spruce is able to produce adventitious roots further up the buried stem, creating multi-layered root systems (Jeffrey 1959). The ability to grow roots, helps to avoid the less optimal condition in the deeper portions of the soil by replacing the dying or only partially functioning elements of the roots system in the deeper soil layers (Strong and La Roi 1983, Gill 1975). Therefore the buried stem of these trees can easily be mistaken as a tap root; however, tap rooted white spruce has only been reported for sandy soils in northern Ontario (Jeffrey 1959; Wagg 1967).

In the case of a stem buried by fluvial deposits, the evidence of the true age of a tree is also buried with the stem under ground; therefore, age measurements taken above-ground or at ground level are potentially incorrect and could let us believe that the trees are significantly younger than they really are (DesRochers and Gagnon 1997). It is thought that even-aged stands on fluvial deposit landtypes are generally the result of a catastrophic event such as fire (Jeffrey 1961). Many of the white spruce stands in the Mackenzie Delta appear to be even-aged due to similar heights and diameters; however, especially stem diameter is not a good indicator of tree age (Smith et al. 1997).

The objective of this study was to determine the true age of buried white spruce trees excavated near the arctic tree by Inuvik and to determine radial growth rates over the last two centuries.

Methods

In the summer of 1999, 5 white spruce trees were selected along a cutbank on the east channel about 2 km north of the town site of Inuvik. Trees were excavated using a portable high-pressure WAJAX fire pump (Figure 1a). Stem discs were also taken at breast height (BH) and at ground level. The stumps and discs were transported to Edmonton for further examination. Three of the excavated tree stems were up to one meter buried in the ground, while the other two were buried to about 0.5m (Figure 1b).

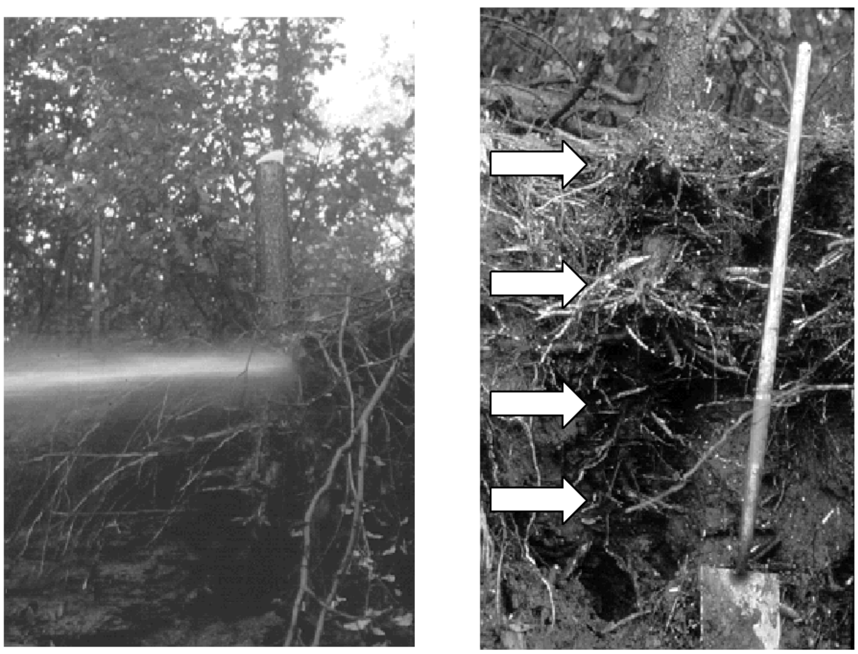


Figure 1a and b: a) Water excavation of trees and **b)** the stump after excavation showing several layers of major adventitious roots (arrows)

The stumps were cut into 2.5 cm thick discs and sanded up to 400 grit (Figure 2 and 3). Rings were counted under a stereo dissecting scope. Using a sharp razor blade and chalk for increased contrast of the vascular cells, the tight tree rings were highlighted and counted (Figure 3 and 4). If possible, the root collar was determined by the transition from the pith to a central vascular cylinder (Esau 1960). The radial sections were then cross-dated using the skeleton plot method

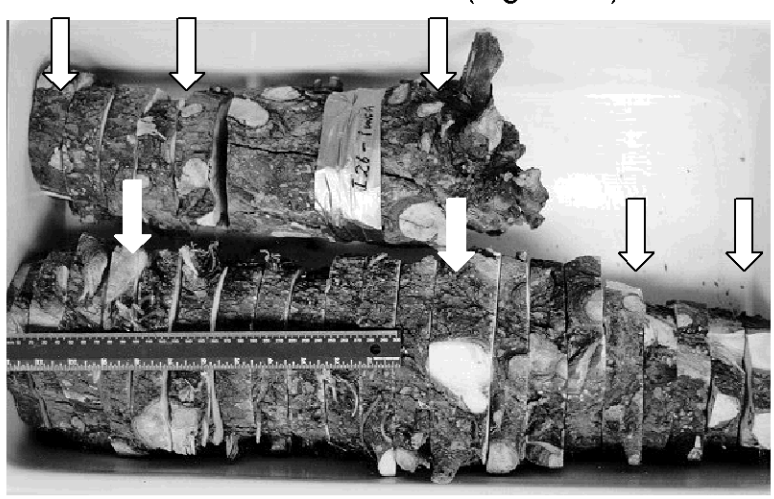


Figure 2: Tree #3 total length 79cm. Arrows indicate the establishment (layers) of major adventitious roots.

(Schweingruber 1989). Relative ring width, compression wood, false rings and other specific characteristics were used in the crossdating.

Ring width measurements were also taken on discs cut at ground level to describe the radial growth rates during that period of growth.

Figure 3: Discs of tree #3

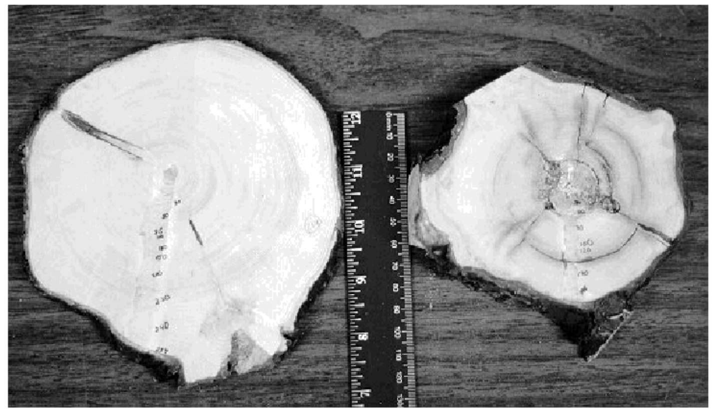


Figure 4: Discs of tree #3 from base and last measurable disc of buried stem at 64 cm.

Results

The 5 selected trees had an average age at breast height (BH) of 213 years. The ages ranged from 176 to 245 years (Table 1). The age at current ground level was between 209 and 317 years, which resulted in an average difference of 44 years between BH age and ground level age. All of the tree stumps had a rotten or missing central part of the stem therefore the transition from pith to central vascular cylinder could not be determined. As a result the precise total age of the tree could not be determined. The portions, which could be crossdated, added an average of 36 years to the age of the tree at ground level (Table 1).

Table 1: Dendrochronological analyses of 5 white spruce trees collected near Inuvik in 1999.

Tree	Age at BH (1.3m) (years)	Age at base (years)	Cross-dated Age (years)	Remaining stump length (cm)	Conservative estimate of total age (years)
1	176	209	236	65	261
2	224	262	300	6	303
3	224	254	278	15	286
4	198	242	258	20	268
5	245	317	391	6	400
AVG	213	257	293		304

There were, however, remaining lower portions of the stems, which could not be crossdated (Table 1). Conservative estimates of the age of the remaining portions were made and added to the total age of the tree. The age was estimated by assuming an average height growth of 3 cm. The average height growth was derived from the age difference between the breast height age (1.3m) and the ground level age. Therefore the estimated total age of these three trees was determined to be between 261 and 400 years (Table 1).

On average there were 47 years buried with the stem in the fluvial deposits. However, the number of years ranged from a minimum of 26 years to a maximum of 83 years. It is very likely that these numbers are still an underestimation of the true age, since all trees were missing stem sections below the excavated stem (see blunt end of stem in Figure 2).

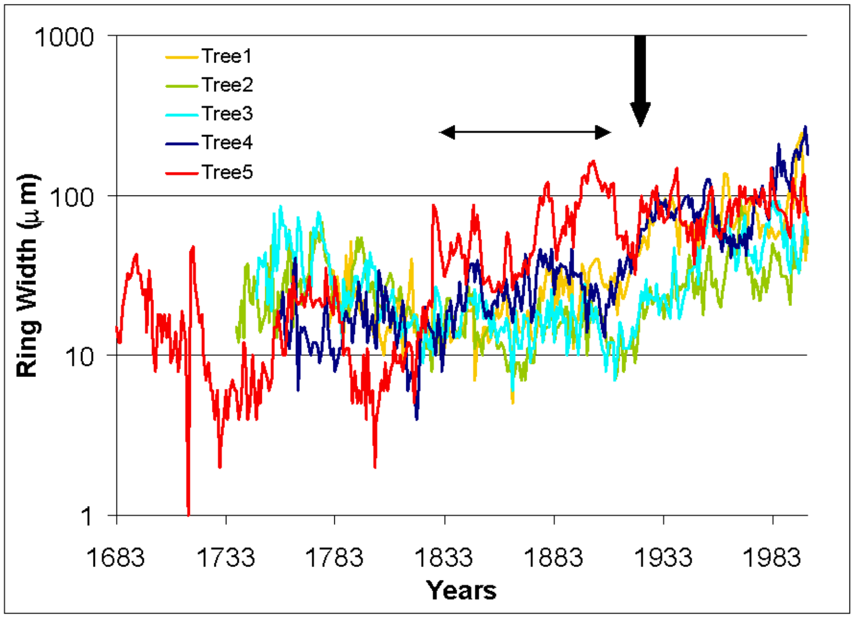


Figure 5: Tree ring width at ground level of five trees collected near Inuvik in 1999.

Measuring the ring width at ground level of all five trees revealed that ring width has been increasing by ten fold from 10μm to 100μm (notice logarithmic scale of y-axis) since the turn of the century (vertical arrow) (Figure 5). Only tree number 5 showed an earlier increase in ring width (horizontal arrow). This increase is largely due to the presence of reaction wood. Reaction wood is the preferential allocation of wood towards parts of the stem or branches to compensate for stresses such as leaning or bending. In the case of conifers, compression wood is put down on that side the tree is leaning towards. This results in the production of larger rings in that particular region to support the leaning trunk. Due to difficulties (rot) on the opposite side of the stem, the tree ring widths in the compression wood had to be used for the measurements, artificially increasing the ring width.

Discussion

A significant amount of growth of the white spruce tree in the Mackenzie Delta is concealed due to past and present flooding events depositing substrate around the stems of the trees. This study determined that an average of 47 years of growth was hidden under ground. The length of the buried stem did not appear to be a good indicator of the number of years, which need to be added to the tree age. For instance, tree number 5 had about 50cm of its stem buried, this length represented about 83 years of growth. This stays in contrast to tree number 3, where 76 cm of the stem was buried. This represented 32 years of growth. Generally these results have to be carefully interpreted. This study looked only at a limited number of stems and can be seen as an exploratory study producing more questions than answers. The determination of the true age of these trees and the amount of stem buried in the fluvial deposits are likely an underestimation. Even the careful excavation of the trees from the cutbanks of the river did not allow for a full recovery of the stems. Therefore it is not known, how much of the bottom end of the stems is actually missing. To avoid these problems it would be probably better to extract trees further away from the edge of the river, since the bottom parts of the stems might be preserved in the higher permafrost table (Gill 1975).

The establishment of white spruce in this selected stand north of Inuvik, as determined by the five trees, did not to occur at the same time, resulting in an uneven-aged stand structure. This suggests that white spruce establishment in the delta probably occurs in waves, which coincide with major flooding events rather than catastrophic events such as fires (Jeffrey 1961). However this line of inquiry needs further testing. These fluvial deposits create favourable seedbeds and when coincide with good seed crops in nearby mature stands they will result in periods of spruce establishment (Jeffrey 1961; Wagg 1964). Once the seedlings have established, major flooding events, which deposits large amounts of silt will be detrimental to the growth and survival of these newly established seedlings. The establishing seedlings must have sufficient height growth to be able to out-grow subsequent silt deposits from the succeeding flooding events.

Tree discs at ground level of all five trees showed a substantial increase in ring width of about 10 fold from 10μm to 100μm since the turn of the last century. It can, however, only be speculated whether the response is due to climatic or flooding factors or both. However, data like these could give the opportunity to correlate radial growth with existing climatic and flooding data over the last fifty or so years which might be available for the region. Additionally, the small size of rings during earlier growth raises another important issue. During various periods, the five trees in this study showed remarkable narrow growth rings therefore accurate age determination in the field seems impossible. The chronological data clearly show that in the case of these five collected trees, up to 200 years are represented in rings, which are between 10 and 50μm wide. This could lead to gross mistakes in determining ages at either breast height or ground level.

As indicated earlier, this study presents the opportunity to use the buried stems as an indicator for past and present climate or flooding regimes. If it was possible to find deeply buried stems of earlier white spruce stands preserved in the permafrost, ring width data could be crossdated with current tree data and extended into the past over longer time periods. These growth data could then be correlated to past and present climate and/or flooding regimes.

The pattern of adventitious root development is an interesting area in the autecology of flood plain white spruce (Jeffrey 1959; Wagg 1964) which has not been addressed in detail. The pattern of rooting is most likely the response to soil temperature and soil oxygen minima. As the thickness of the fluvial deposit layer increases new adventitious roots are produced to keep the tree alive. By crossdating the initiation of the roots in each layer with the main stem, fluvial deposit patterns could be determined and projected into the future. Research in this area could lead to a better understanding of white spruce autecology in response to flooding and soil temperature regimes. This information is pertinent for the prediction of establishment and growth of white spruce in flood plains and will assist in the future regeneration and maintenance of northern riparian forest stands.

Acknowledgements

I thank Annie DesRochers for her help in the crossdating and age determination of the white spruce stems. I also thank the Gwich'in Renewable Resource Board and the First Nations Forestry Program of Inuvik for their financial support. In particular, I thank Robert Charlie, Peter Clarkson, Jennifer Walker-Larson, Shannon Haszard, and Donald Andre. In addition, I acknowledge the generous in kind support from the G.N.W.T. Dept. Resources, Wildlife and Economic Development through Mike Gravel and Johnny Charlie. I thank Les Kutny, Barbara Sander, Jessika Schoplick, Jim Weber, and Jennifer Dober for their help in the field. The study was supported by an NCE-SFM grant to David Anderson and Ross Wein.

Literature cited

DesRochers, A. and Gagnon, R. 1998 Is ring count at ground level a good estimation of black spruce age? Can. J. For. Res. 27: 1263-1267.

Esau, K. 1960. Anatomy of seed plants. John Wiley & Sons, Inc., New York.

Gill, D. 1975. Influence of white spruce trees on permafrost table microtopography, Mackenzie River Delta. Can. J. Earth Sci. 12: 263-272.

Grossnickle, S.C. 1987. Influence of flooding and soil temperature on the water relations and morphological development of cold-stored black spruce and white spruce seedlings. Can. J. For. Res. 17: 821-828.

Jeffrey, W.W. 1959. White spruce rooting modifications on the fluvial deposits of the lower Peace River. For. Chron. 35: 304-311.

Jeffrey, W.W. 1961. Origin and structure of some white spruce stands on the lower Peace River. Forest Res. Branch Tech. Note No. 103. 20pp.

Schweingruber, F.H. 1989. Tree rings: basics and applications of dendrochronology. Kluwer Academic Publishers Group, Dordrecht, The Netherlands.

Smith, D.M., Larson, B.C., Kelty, M.J., and Ashton, P.M. 1997. The practice of silviculture: Applied forest ecology. John Wiley & Sons, Inc., New York.

Strong, W.L. and La Roi, G.H. 1983. Root-system morphology of common boreal forest trees in Alberta, Canada. Can. J. For. Res. 13: 1164-1173.

Wagg, J.W.B. 1964. White spruce regeneration on the Peace and Slave River lowlands. Department of Forestry Publication 1069. 35pp.

Wagg, J.W.B. 1967. Origin and development of white spruce root forms. Min. Forestry and Rural Development. Departmental Publication 1192. 45pp.

APPENDIX 15

Prairie Conservation Forum. 2021. Alberta Prairie Conservation Action Plan: 2021-2025. Published by the Prairie Conservation Forum, Lethbridge, Alberta. 30 pages. Website: https://www.albertapcf.org/wp-content/uploads/2021/02/PCAP-2021-web.pdf

PRAIRIE CONSERVATION FORUM

alberta prairie conservation

[2021 - 2025]

ACTION PLAN

The Prairie Conservation Forum wishes to thank:

- Members of the Prairie Conservation Forum for the photos used in this document.
- The core PCAP team: Brandy Downey, Ian Dyson, Nolan Ball, Brian Peers, Peg Strankman, and Katheryn Taylor.
- All those who provided review of the PCAP with a special thanks to Norine Ambrose and Ron McNeil.
- All Prairie Conservation Forum members for your continued support in managing and implementing the PCAP over the past 30 years. Including in-kind support, financial support and fundraising through participation in the casino nights.

This report may be cited as:

Prairie Conservation Forum. January 2021. Alberta Prairie Conservation Action Plan: 2021-2025. Published by the Prairie Conservation Forum, Lethbridge, Alberta. 30 pages.

Copies of this report may be obtained from:

Prairie Conservation Forum
2nd Floor, Provincial Building
200 – 5th Avenue South
LETHBRIDGE, Alberta
T1J 4L1

This report may be viewed on the Internet at:

http://www.albertapcf.org

ISBN No. 978-1-7774877-0-6 (printed)
ISBN No. 978-1-7774877-1-3 (on-line)

Executive Summary

Alberta's grassland and parkland natural regions are part of a much larger grassland ecosystem called the North American Great Plains that extends from Alberta south through the United States and into Northern Mexico. The Alberta grassland and parkland natural regions are rich in biodiversity and provide ecological, cultural and economic benefits for all Albertans. As such, multiple competing demands are prevalent within the region, including conversion of native landscapes for agriculture, urban expansion, and industrial land uses. Intensive use of land and water can change the health, integrity, capacity and resilience of the ecosystem to maintain the services critical to our current and future society. The Prairie Conservation Forum (PCF) recognizes the need for different activities to occur on the landscape and collaborates with many different stakeholders to improve management and conserve native prairie landscapes while still benefiting from the prairie's resources.

The PCF is continuing our collaborative efforts with our 7th Prairie Conservation Action Plan (PCAP) and is working towards achieving our identified strategies and outcomes. The goal of these five-year plans is to use collaborative approaches among our diverse member stakeholders and partners to initiate and sustain prairie-wide efforts to conserve and manage native prairie species, communities, and habitats. Our vision is that the biological diversity of native prairie and parkland ecosystems is secure under the mindful and committed stewardship of all Albertans. The 2021-2025 PCAP builds on our work from previous PCAPs and continues to provide an ongoing profile for prairie and parkland conservation initiatives.

PCAP 2021-2025 recognizes the need to focus activities (that the PCF has the capacity to achieve, either alone or in partnership) around three primary strategies: to complete, or further, inventories and assessments of native biodiversity in Alberta; to share knowledge and foster a dialogue around prairie conservation; and to promote stewardship of native prairie and parkland ecosystems. Three important long-term environmental outcomes are also necessary to bring the PCAP vision to reality: maintain large native prairie and parkland landscapes; conserve connecting corridors for biodiversity; and protect isolated native habitats. These outcomes require close linkage to management and planning decisions by all levels of government and private landowners. Our engagement approach to achieving all outcomes includes educational and awareness programming as well as providing web-based access to prairie conservation information.

The PCF takes a coordinating and advisory role, respecting the individual mandates and interests of its members. We recognize that the success of achieving our vision relies upon PCF members to implement PCF programs and activities in their respective organizations. Implementation of the PCAP requires an involved and active membership and Board of Directors. Additionally, successfully achieving our outcomes relies heavily upon the capacity of its member organizations and individuals. The PCF welcomes you to join us on this journey.

Contents

Figures

ALBERTA
ENVIRONMENT AND PARKS

Office of the Minister
Government House Leader
MLA, Rimbey-Rocky Mountain House-Sundre

Message from the Honourable Jason Nixon
Minister of Environment and Parks

Alberta's grasslands offer opportunity for all Albertans. Working together, we can find ways to keep Alberta's native habitats strong and healthy, while ensuring Albertans can sustainably enjoy our natural heritage.

The grasslands of Alberta are a diverse and dynamic working landscape. Home to many native plant and wildlife species, our grasslands are also where we work, live and recreate.

Since 1989, the Prairie Conservation Forum has contributed to the environmental guidelines that establish best management practices for sustainable economic development. The Forum itself consists of more than 50 organizations and individuals that are dedicated to the implementation of conservation initiatives of the prairie and parkland landscapes in Alberta. These organizations and individuals, including federal and provincial agencies, industry, landholders, agricultural and environmental groups, municipalities, and academia, have been informing and facilitating conversations and partnerships centered on prairie conservation for more than two decades.

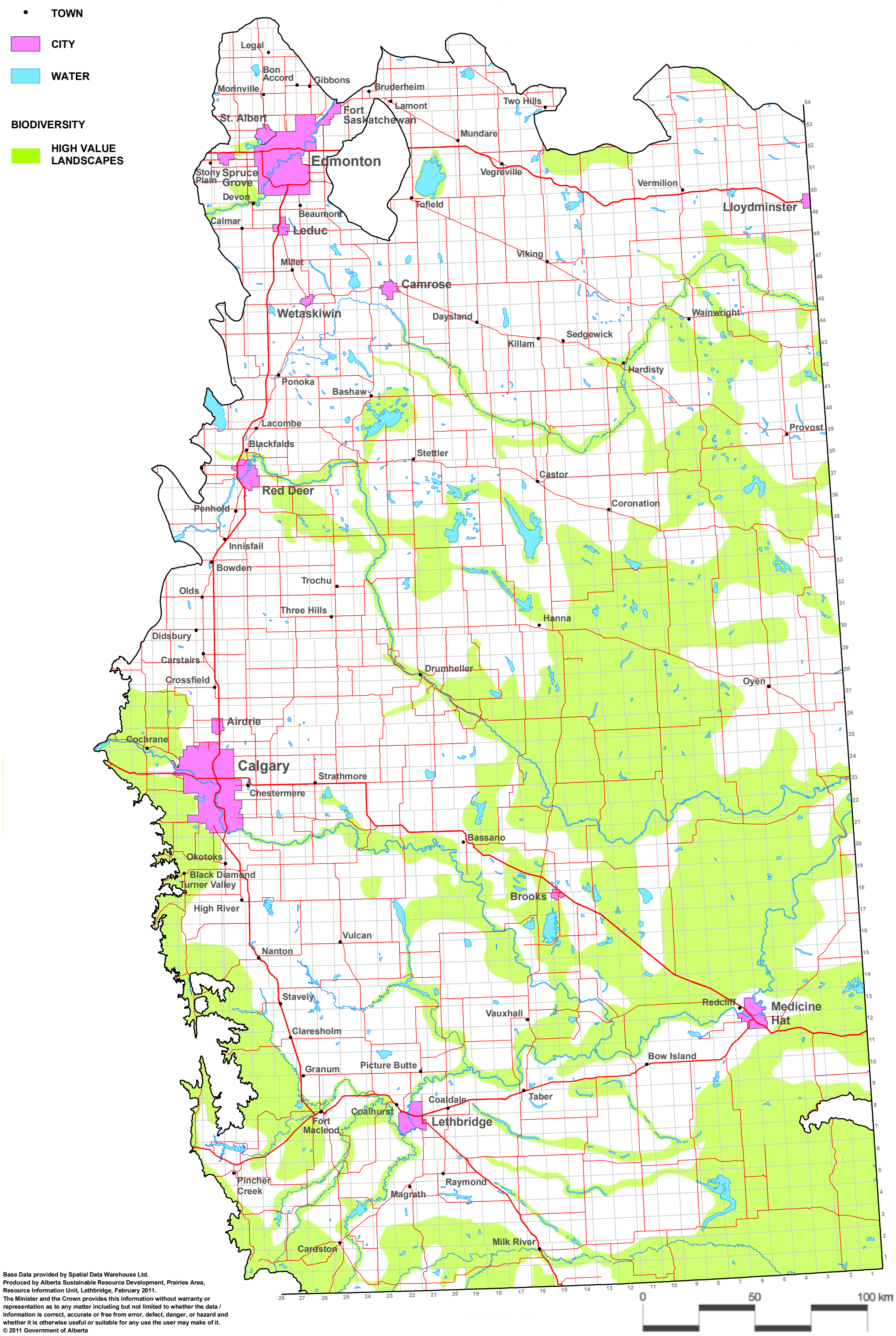
Today, the Forum continues to promote stewardship of native grasslands through the use of many different tools, and the guidelines for managing environmental impacts originating from human activity on native prairie grass. In addition, the 2021-2025 Prairie Conservation Action Plan is a blueprint that will enable continued stewardship in our province through the Prairie Conservation Forum. This and many other successes of the Forum illustrate what can be done when Albertans from a variety of sectors work together to conserve the prairie and parkland legacy we have inherited.

Thank you to the Prairie Conservation Forum for its enduring commitment to the conservation of Alberta's native prairie and parkland environments, its inclusive approach of involving all interests, and for aligning this renewed action plan to support opportunities for the people of Alberta. The western heritage that Albertans pride ourselves in was founded in Alberta's prairie landscapes and continues to shape who we are today.

Sincerely,

Jason Nixon
Minister of Environment and Parks

Figure 4:
Native Biodiversity: High Value Landscapes in Prairie and Parkland Alberta



APPENDIX 16

Rood, S. and C. Bradley. 2015. Assessment of riparian cottonwoods along the Bow River downstream from Calgary, Alberta. Website: https://www.researchgate.net/publication/292128886_Assessment_of_Riparian_Cottonwoods_along_the_Bow_River_Downstream_from_Calgary_Alberta

Assessment of Riparian Cottonwoods along the Bow River Downstream from Calgary, Alberta

Stewart B. Rood and Cheryl Bradley
Department of Biological Sciences, University of Lethbridge, Alberta

Photo: This downstream (easterly) view from the coulee top near McKinnon Flats shows the cottonwood (balsam poplar) forests limited to the floodplain, and in the distance on the right coulee, groves of white spruce and quaking aspen.
(photo reference #107, all photos by S. Rood)

This report was initially developed March 1993 following concern by biologists with the Calgary chapter of Trout Unlimited Canada. The report was slightly revised and color photos were added in March 2015, for the Calgary Rivers Morphology Study.

Contents

Summary

Despite its proximity to Alberta's largest city, the Bow River valley downstream from Calgary remains a relatively natural landscape. The river valley contains abundant riparian (floodplain) cottonwood groves and the existing trees appear relatively healthy. The cottonwoods generally don't presently display severe branch or crown die-back or other drought symptoms that are apparent downstream from dams on some other rivers in the South Saskatchewan River Basin.

The cottonwoods are primarily balsam poplars *(Populus balsamifera)*, trees that are able to reproduce both sexually through seedlings and asexually by suckering, the production of new shoots from existing roots. Probably as a result of river flow stabilization, and the attenuation of flooding that has followed the installation of ten dams upstream, the Bow River channel has become somewhat entrenched and the development of lateral and point bars has apparently been reduced. This may have been compounded by a decreased frequency of overbank floods in the Bow River basin since the 1930's due to climatic conditions. The lack of flooding and subsequent geomorphological changes has resulted in a lack of suitable sites for cottonwood regeneration by seedlings or by suckers. Recent regeneration does not appear to be sufficient to replace existing stands and if conditions do not change, a progressive decline in cottonwood forests may be expected over the next century.

It is important to gather further information on the age structure of the cottonwood forests along the study reach as well as information clarifying the factors associated with major cottonwood recruitment events along the Bow River. This information will help to determine future water and land use management strategies. Such strategies might include altering the operation of dams and diversions upstream to reestablish more dynamic river flows. Proposed dams or diversion on the Highwood River will affect riparian ecosystems of the Bow River below the Highwood inflow. Thus, water management projects for the Highwood as well as the Bow River must be cautiously considered.

While river flow management is important, probably the most significant and widespread current impact on the Bow River cottonwoods is from cattle grazing. Heavy use by cattle clears the forest understory and retards the recruitment of new cottonwoods since seedlings and saplings are grazed or trampled. There is a need to evaluate the grazing management patterns currently in use along the study reach and to consider alternate grazing strategies. Coordinated efforts between landholders and other interested parties are essential to determine appropriate land uses, including grazing strategies.

According to Kellerhals et al. (1972), the Bow River near Calgary is a predominantly gravel bed river with a partly entrenched and frequently confined channel. Banks are of sand and gravel and the channel is sinuous with frequent islands, mid-channel bars and diagonal bars. The river apparently experiences only slight lateral migration, a characteristic that differs from undammed rivers with more dynamic river channels along which cottonwood forests have been studied.

With respect to Alberta rivers, the Bow's coarse substrate, low sediment load, and relatively steep gradient, provides it with characteristics similar to other foothills rivers such as the middle Oldman River, the Belly and Waterton Rivers, and the upper St. Mary River (Rood and Heinze-Milne, 1989; Rood and Mahoney, 1992). Conversely, the study reach is less like the prairie reaches of the lower Bow River (Cordes, 1991), the Milk River (Bradley and Smith, 1986), the lower Red Deer (Marken, 1991), or the South Saskatchewan River (Reid, 1991). In analyzing the biology of riparian cottonwoods, there are differences between the forest ecology along foothills versus prairie rivers and these differences prevent direct comparisons across the two river types. As a simplistic but useful means of discriminating the river types, foothills rivers are trout streams whereas the prairie rivers are characterized by warm water fish. Additionally, balsam poplars are prevalent along the foothills rivers whereas the prairie rivers support prairie cottonwoods. Thus, the Bow River reach of the present study is classed as a foothills type river.

regrowth from existing stumps is referred to as coppicing and can result in extremely fast sapling growth rates and the production of characteristically large leaves. Like suckering, copping is an asexual form of regeneration, but unlike suckering, coppice shoots are limited to areas immediately adjacent to the parental trees, since the coppice shoots originate from parental trunks rather than roots.

It is difficult to discriminate suckering, the formation of new shoots from existing roots, from coppicing, the production of new shoots from existing shoots. Even if shoots originate from below the soil surface, they may still represent coppice growth from shoots which have been knocked down by ice blocks or flood flows and subsequently covered by sediment. This latter process is referred to as flood training and results in rows of coppice shoots projecting from toppled parental trees. Only careful and destructive excavation can discriminate suckers from coppice shoots, and both of those from seedlings. Thus, analyses of reproductive biology of cottonwood forests are particularly complex.

Cottonwood reproduction through seedlings appeared to be sparse, or nonexistent, along the Bow River reach. This apparent lack of seedlings can probably be attributed to a lack of suitable sites and conditions for seedling establishment. Creation of suitable sites depends on flooding prior to seed dispersal, dynamic channel migration and bar formation, none of which appeared abundant along the Bow River study reach. It is predicted that any seedling recruitment that is occurring is most likely below the Highwood Rivers confluence, where the river appeared to be a more dynamic. However, the apparent lack of seedlings should be confirmed by more thorough excavation of study sites. For this and other goals, research transects should be established to enable long-term studies of cottonwood recruitment and ecology.

It is assumed that the existing forests along the Bow River established during a few major recruitment events.. Currently however, it appears that asexual replenishment through suckering may be the primary or even exclusive method of reproduction of the riparian cottonwoods along the Bow River. Should this apparent change in recruitment pattern continue, it could result in decreased forest abundance and diminished biodiversity, since clonal reproduction by suckering does not introduce genetic diversity.

It is uncertain what long-term ecological consequences would result from the transition from a seedling- to suckering-based forest. A reduction in the amount of regeneration and

Table 2. Mean June flows of the Bow River at Calgary and Carseland and predicted (estimated) flows if no dams occurred upstream (data from Alberta Environment, (no date)).

	Mean June Flow at	
Period	Calgary	Carseland
1911-1928	291 cms*	
1929-1986 (predicted natural, without dams)	279 cms	385 cms
1929-1986 (actual, with dams)	213 cms	269 cms
Reduction (natural vs. actual)	24 %	30 %

* Flows in cubic meters per second (cms) = 35.3 cubic feet per second (cfs).

Because June is the month when peak discharges for the year usually occur on the Bow River, it is also usually the time when erosional and sedimentation processes are at their peak. Historically there probably was considerable flooding, channel shifting overbank deposition and bar formation at this time of year. However, with significantly reduced mean and peak flows the river is less competent to move sediment. As well, there is a loss of some sediment that settles in the slow moving water behind the upstream dams. The result, particularly from attenuated flooding, would very probably be stabilization and entrenchment of the river channel (Photographs 8, 22, 27, and 30) and a reduction in overbank sedimentation and point and lateral bar formation.

The effect of the altered river regime and these geomorphological consequences would be fewer sites available for cottonwood seedling establishment. Cottonwood seeds require saturated and barren sites for imbibition, germination and initial seedling growth. As well, suckering might also be retarded since this process may normally follow disturbance events which produce barren areas and stimulates the roots of mature trees to send up shoots. Cottonwood regeneration is well adapted to, and dependent upon, the natural disturbances which occur on the river floodplain. Conversely, with attenuated flooding, sites suitable for seedlings will become scarce and suckering might be deficient. Additionally, mature trees are less likely to be toppled following bank undercutting which erodes their anchoring substrates away. Thus, the dynamic population cycling that is characteristic of riparian cottonwood forests is retarded.

Additionally, attenuated flooding also alters the suitability of the river banks for other vegetation and this can also impede cottonwood recruitment. Cottonwoods and willows are very flood-tolerant and thus able to survive along shallow river banks and bars that are inundated for one or more weeks during the normal period of high flows in late spring. Conversely, grasses and many shrubs are restricted to higher elevations away from the river's edge since those plants are less able to withstand the anaerobic periods of spring flooding. This difference in tolerable hydroperiod normally results in stratified floodplain vegetation, with willows and cottonwood seedlings occurring adjacent to the river’s edge and grasses and various herbs and shrubs being restricted to slightly higher zones. However, with attenuated flooding, perennial grasses and shrubs are able to grow right down to the river's edge (Photographs 6, 31 and 34). Cottonwood or willow seedlings are not competitive with the grasses and shrubs and hence, the new cottonwood seedlings may not germinate or survive. This further retards the recruitment of cottonwood and willow seedlings, compounding problems created by a relatively static river channel with a lack of new lateral and point bar formation.

The occurrence of dense perennial vegetation right to river's edge may also provide some stabilization of the river banks. Thus, the dense areas of grasses, herbs, and shrubs probably act as a biological armoring that further resists dynamic channel meandering. This would even further reduce the formation of new barren point and lateral bars that are essential for cottonwood and willow seedling recruitment.

Thus, due directly to reduced flooding and indirectly through geomorphological changes and change in vegetation patterns, the attenuation of spring flooding will likely lead to a deficiency or elimination of cottonwood seedling regeneration along the Bow River downstream from Calgary. Similar deficiencies of regeneration have been observed downstream from other flood control dams, particularly in the southwestern United States (see review by: Rood and Mahoney, 1990). While flooding might intuitively seem like an undesirable feature of the river valley, it is a natural and essential component for the long-term sustenance of the riparian ecosystem.

5. Opportunities for Enhancing Cottonwoods Recruitment

5. 1 Population Analysis

A more precise analysis of the age structure of the cottonwood population should be conducted. Investigations of the natural factors including floods that enable recruitment would be useful to understand the status and prospects of the cottonwood forests in the short- and long-term. Population analysis would involve systematic tree coring and correlation with flow records. As well, some DNA (deoxyribonucleic acid) analyses would be useful to investigate the extent of historical recruitment that was by seedlings (sexual reproduction) versus suckering (asexual reproduction).

If flood flow events which lead to recruitment are determined to be relatively minor, it may be possible to simulate these conditions by managing upstream flow regulation structures. However, if recruitment is dependent on major flood events artificial means for perpetuating the population may be required, such as transplanting saplings or scarification to promote suckering (see Section 5.6).

5. 2 River Flow Management

Although built primarily for hydroelectric power generation, the dams upstream of Calgary are able to attenuate moderate but not extreme floods. The perceived security from flooding has led to extensive urban and industrial developments in the floodplain of the Bow River and probably especially along the Elbow River through Calgary. It is very unlikely that operation of the upstream dams would be altered to enable overbank flooding. However, there may be opportunity for minor changes to upstream dam operation which would encourage some channel migration, bar formation, and cottonwood establishment. This would require a better understanding of the age structure of the floodplain forests and the events which led to their establishment (see Section 5.1).

Even with the dams installed, mayor floods would overwhelm the control capabilities and cause costly flood through Calgary, as occurred in 2013. Although such a flood would be very destructive to the urban developments along the Bow River floodplain, it might enable a major recruitment event for cottonwoods. Recognizing the probable property damage that would follow such an event, we do not promote such a flood, but rather, recognize that recruitment of cottonwood forests may be partially dependent on rare, very large floods that are beyond human control.

The installation of a dam or increased diversion of water from the Highwood River could have substantial impacts on the forests of the lower Bow River. Impacts of dams on riparian ecosystems extend downstream as far as the river flow is altered, distances of tens or hundreds of kilometers (Williams and Wolman, 1984). Consequently, environmental impact assessments for any project proposed on the Highwood must consider influences downstream as far as the hydrological pattern is altered. In the case of the Bow River, the existing Carseland weir and particularly, the Bassano Dam dramatically alter the flow of the Bow past Scandia to the Oldman River junction, as well as the flow of the South Saskatchewan downstream through Medicine Hat. Environmental studies regarding a possible diversion of the Highwood River, should consider impacts on the Bow River from the Highwood junction downstream at least to the Bassano Dam.

Hopefully, any policy of river flow management will be multiple-use based, considering the full range of environmental and economic aspects of the Bow River flow. Flow regulation patterns need to consider municipal, hydroelectric and irrigation demands as well as aesthetic importance, recreational use and environmental aspects such as fisheries.

The provision of instream flows that are adequate for riparian ecosystems and for fisheries will also contribute favorably to water quality and will provide flows that enable recreational use and contribute to aesthetic value. Although it is extremely difficult to quantify the financial benefit from these non-consumptive uses, the combined value of the flowing river as an environmental, recreational, health, and aesthetic resource is clearly substantial. All of Alberta's cities and most elsewhere in Canada are situated along rivers. Although their initial location may have been prompted by the importance of the rivers as transportation corridors, it is clear that the rivers provide a richness that is appreciated in numerous ways by most residents. Rivers are a central feature of Alberta's landscape and Albertans' lifestyle and river preservation is certainly deserved.

APPENDIX 17

Task Force on the Natural and Beneficial Functions of the Floodplain. 2002. The natural and beneficial functions of floodplains: reducing flood losses by protecting and restoring the floodplain environment: a report for Congress, Federal Emergency Management Agency. Website: https://www.hud.gov/sites/documents/DOC_14217.PDF

The Natural & Beneficial Functions Of Floodplains

Reducing Flood Losses By Protecting And Restoring The Floodplain Environment

June 2002

A Report For Congress By The Task Force On The Natural And Beneficial Functions Of The Floodplain

The Natural And Beneficial Functions Of Floodplains

Reducing Flood Losses By Protecting And Restoring The Floodplain Environment

June 2002

A Report For Congress By The Task Force On The
Natural And Beneficial Functions Of The Floodplain

Section Three
THE IMPACT OF HUMAN ACTIVITIES ON FLOODPLAINS

Humans have always been attracted to floodplains because of their many sustaining attributes: fresh waters, rich diversity of fish and game resources, fertile soils, level terrain and their proximity to waterways. Activities such as agriculture, forestry, and industrial, commercial and residential development have historically thrived in floodplains. These activities have altered the landscape and adversely impacted the natural functions of floodplains. Only recently have we begun to understand the adverse effects that years of human development and industrialization have had upon floodplains. These adverse effects include decreases in water quality, loss of wildlife habitats, and an increase in the frequency and severity of catastrophic flood losses. Through an understanding of our impacts upon floodplains and of the economic and environmental benefits of floodplains, can we formulate better floodplain management approaches that will better protect the floodplain's natural and beneficial functions.

3.1 Impacts of Flood Control and Other Water Resources Structures

Although the Task Force recognizes that many flood control and other water resources structures provide valuable benefits to society in the form of flood control, water supply, power, and recreation, these structures can have significant impacts on the natural floodplain and on natural and beneficial floodplain functions including reducing flood velocities and peak flows. Less intrusive solutions can sometimes achieve these same benefits without the loss of floodplain resources and functions.

Channelization and Diversions

Channelization is the process of deepening, straightening, and/or widening a waterway for the purpose of moving high water flows quickly downstream to prevent over bank flooding of adjacent lands. Channel deepening and straightening is also done to improve navigation. Channelization can reduce flooding in the immediate area of the channel, but can also aggravate flood heights and velocities, and erosion downstream. Channelization can also eliminate or reduce floodplain functions by lowering water levels, effectively disconnecting the floodplain from the stream, reducing the retention of water in wetlands, decreasing habitat diversity, and destroying riparian vegetation. Construction usually requires the clearing of vegetation to allow access for equipment to excavate and maintain the channel.


USFWS

Channelizing streams can reduce flooding in the immediate area of the channel, but it often increases flood heights and erosion downstream. Stream channelization also degrades water quality, destroys habitats for fish and wildlife, and adversely impacts the natural functioning of the stream and its floodplain.

Diversions, which are particularly common in the West, are open or closed channels used to transfer water from a water body to a new location for use in industry, agriculture, or for domestic consumption. Many state policies on agricultural diversion practices require that specified amounts of flow be maintained in the channel or that the diverted water be returned to the stream or river after use in order to prevent the destruction of instream and floodplain habitat. This process can help preserve floodplain functions that depend on the timing and quantity of water diverted (e.g., waterfowl habitat, fisheries, and water recreation).

Dams and Reservoirs

Dams create impoundments of water for use in the generation of hydroelectric power, irrigation, water supply, and flood damage reduction. Well-sited and properly managed dams can limit flood losses and some of the adverse impacts on the functions of floodplains. Dams can store and release water in reservoirs on a controlled basis, thus limiting the occurrence of downstream flooding and minimizing erosion over that which may have occurred during high flows before the dam was constructed. Reservoirs can also provide additional benefits, such as recreation and warm water fisheries.

Dams can adversely impact floodplain natural resources and functions by inundating floodplains and by changing downstream flow regimes.

However, dams can have dramatic impacts on river systems. Stream and terrestrial habitat and associated resources are lost due to inundation by the impoundment. Dams and reservoirs can impede the flow of rivers, reduce or eliminate the beneficial periodic inundation of natural floodplains, and block or slow the passage and migration of aquatic organisms. Dams can result in the long-term loss of diversity, and adversely impact stream habitat, aquatic resources and other functions. This in turn affects food chains associated with floodplain functions, and alters the size and diversity of wildlife populations. Dams can also alter water quality by changing the normal temperature of the body of water, consequently affecting the biological conditions necessary for feeding or reproduction.

Dams can block sediment transport which affects the volume and water quality in the reservoir and can cause scouring downstream until an equilibrium bed load is reestablished (Interagency Stream Restoration Working Group, 1998). This can also reduce the sand supply in coastal systems increasing coastal erosion and resulting storm damages. Finally, dams can create a false sense of security from flooding that leads to increased development below the dam.

Levees, Dikes and Floodwalls

Levees, dikes and floodwalls can provide flood protection from seasonal or sporadic flooding, and are often used in conjunction with other types of channel modifications. Construction usually requires the clearing of vegetation to allow earth-moving equipment access for excavation and placement of the embankment. After construction, side slopes are often seeded or sodded, and vegetation is maintained to avoid conditions that might endanger the levee's structural integrity during flood events.

Levees, dikes and floodwalls often have similar impacts on the floodplain as channelization. Levee systems create drier conditions on the protected floodplain, which may have adverse impacts on the spawning success of many fish species, and contributes to the loss of wetlands. Levees also typically raise the water surface elevation on the riverward side during flood conditions, causing further inundation that can lead to soil, vegetation and habitat loss (*USACE,* lands mapped or designated by the community. *(See Case Study - Integrated Watershed Management Program, Baltimore County, Maryland.)*

4.2 The Challenges in Floodplain Management for Policy Makers

While floodplain management programs and practices have improved significantly since the 1960s, there is a continuing loss of natural and beneficial floodplain functions. In large part this is due to a lack of explicit goals, insufficient technical data, inadequate coordination and a failure to use watershed-based approaches to managing our land and water resources. While the nation has a clearer understanding of the benefits of floodplains and has accepted the concept that floodplains should be preserved, many challenges lie ahead before we can turn the idea of preserving floodplains into measurable actions towards improved, restored, or protected floodplain values and functions. These challenges, which necessitate floodplain management actions by local, state, and Federal governments, are discussed below.

Clear Guidance on Considering the Natural and Beneficial Functions of Floodplains

Without a clear and specific mandate to consider natural and beneficial floodplain functions, elected officials and other policymakers and personnel involved in flood loss reduction at all levels of government may not properly assess or consider these functions in their planning and implementation efforts. Comprehensive and concise program guidance is needed on effective methods for floodplain management that protect and restore natural and beneficial floodplain functions that provide for a unified effort by all levels of government.

Communities participating in the National Flood Insurance Program (NFIP) have adopted floodplain regulations to prevent fill and other obstructions in floodway areas, and that require elevation or other protection for new structures to above the "100-year" flood elevation. While some states and communities have established additional regulations that guide local floodplain development, they generally have not established specific policies that protect and restore the natural and beneficial functions of floodplains. However, additional efforts to outline floodplain resources nationally must be combined with the establishment of national standards for protecting the natural and beneficial functions of floodplains. This approach would provide the framework to support a unified, national approach to managing floodplain resources.

Post-Disaster Opportunities

Often the most practicable opportunities for protecting and restoring natural floodplain functions occur after flood disasters as part of the response and recovery operations. Opportunities arise to relocate structures, create greenways, acquire easements or fee title to property, restore stream banks and wetlands, reconstruct roads, bridges, dikes and levees, and to repair or redesign sewer and water systems in ways that benefit floodplain functions. There may also be opportunities to change attitudes toward development in the floodplain. However, protecting and restoring natural and beneficial functions is not the primary consideration in the aftermath of a crisis. During response and recovery efforts, technical assistance should be provided on long-term floodplain management approaches to both Federal emergency management agencies and to planners at the state and municipal levels. Information should be targeted to beneficial approaches to the management of sensitive areas and the techniques to restore such areas. All response and recovery efforts should include floodplain restoration and protection as a key component of project planning.

Watershed Approaches

Floodplain functions are not confined to larger rivers and streams – the focus of many floodplain management efforts. The floodplains of lakes and estuaries and smaller rivers, streams and creeks play significant roles in flood storage and conveyance, erosion control and habitat functions. The beneficial functions of both smaller and larger streams are dependent upon the overall hydrologic and ecological regimes of the watershed in which they are located. Activities throughout the watershed area, such as urbanization, land management practices, and non-point source pollution, can affect these natural and beneficial floodplain functions. A watershed-based approach incorporates these smaller yet vital waterways and the processes and activities taking place in the watershed.

In recent years, many Federal agencies have begun to use a watershed or ecosystem approach to resource protection when evaluating their actions. They recognize that preserving and restoring the natural and beneficial functions and resources of floodplains requires that they consider the characteristics of the entire watershed, not just the floodplains themselves. For example, efforts to restore eroded stream banks may fail if development has increased the impervious surface in the watershed, altering the hydrology of the watershed and the flow regime of the stream. Watershed and ecosystem approaches also allow agencies to identify and evaluate the critical resources in a watershed and focus limited resources on the primary issues and resources of concern.

Interagency Coordination

Limited coordination between agencies administering emergency management, water resources management, and ecosystem-based programs can hinder their overall effectiveness as well as their ability to protect natural floodplain functions. Improved interagency communications, in addition to specified and shared objectives between various levels of government, are instrumental in creating a unified support system for successfully managing resources. Effective interagency coordination prevents the duplication of actions or creation of conflicts that can occur between agency efforts in both pre-flood and post-flood contexts, and ensures that multi-objective approaches are not overlooked. Strong coordination also results in a more efficient use of government funds and agency personnel, allowing the leveraging of funds from several sources to implement an action that a single agency may not have the resources or authorities to fund individually.

Partnerships

Effective multi-objective and multi-level partnerships are essential to protecting and restoring the natural and beneficial functions of floodplains. Scientific and regulatory standards alone are not enough; there must be a willingness among floodplain stakeholders to work together to develop programs to achieve this goal. Involvement of a wide variety of stakeholders and leveraging of limited Federal funds and resources with those of state and local government and the private sector can result in plans and projects in floodplains that more fully account for natural and beneficial functions while at the same time reducing flood losses.

Non-Structural Solutions

National Archives, Still Picture Branch

Non-structural solutions to reducing flood losses, such as relocating buildings out of the floodplain, are gaining greater attention and proving their worth.

In the past, limited consideration was given to non-structural alternatives in formulating flood loss reduction plans. Evaluation procedures, including those used to determine benefit/cost ratios were focused on structural flood control measures and often do not work as well for non-structural approaches. Today, non-structural solutions are gaining greater attention and through their success, these methods are proving their worth. Comprehensive non-structural approaches to flood damage reduction also preserve and promote the restoration of the natural resources of floodplains as well as the benefits that they provide.

Government Subsidies

Some government programs continue to subsidize or encourage public and private development and reconstruction within floodplains regardless of the risk of flooding. These programs are often the unintended consequences of other well-meaning programs and do not consider the natural and beneficial functions of floodplains. This has been particularly true for post-disaster recovery programs. However, the focus today appears to be shifting from flood recovery to flood damage prevention. Government subsidized programs must be limited in the type of development and recovery or reconstruction assistance they provide within floodplain environments so that they do not inadvertently encourage actions that damage the natural and beneficial functions of floodplains or increase flood damages.

Technical Expertise

Agencies involved in flood loss reduction and emergency management at all levels of government must have staff with the scientific expertise necessary to identify and protect the natural and beneficial functions of floodplains. They

APPENDIX 18

US Army Corps of Engineers. 1991. American River watershed investigation, California, Volume 6, Appendix S, Part 1. US Army Corps of Engineers, Sacramento District, South Pacific Division. Website: https://apps.dtic.mil/dtic/tr/fulltext/u2/a436970.pdf

Feasibility Report Appendixes

December 1991

American River Watershed Investigation, California

VOLUME 6 – APPENDIX S PART 1

US Army Corps
of Engineers

Sacramento District
South Pacific Division

American River Watershed Investigation, California

FEASIBILITY REPORT

LIST OF APPENDIXES

INTRODUCTION AND BACKGROUND

Construction and operation of a proposed "dry" dam flood control reservoir at the Auburn Dam site would result in periodic inundation of substantial portions of the American River Canyon near Auburn. Inundation would adversely affect several miles of both the north and middle forks. In an effort to describe, predict and evaluate the effects of such a dam on the biotic communities of the American River canyon, our analysis necessarily depended heavily upon project design and hypothetical operation information provided by the Corps of Engineers as well as field data (both quantitative and observational) gathered by the Service during HEP sampling in the canyons. We also conducted brief examinations of sites in California with similar vegetation that also are subject to periodic inundation, such as the upper zones of several small multipurpose reservoirs and the area below Keswick dam on the upper Sacramento River (at the suggestion of Dr. Andrew Leiser, Univ. Calif. Davis). In addition, we reviewed available literature on similar existing flood control structures and on the flood tolerance of species indigenous to California and the American River Canyons. This was supplemented by computer searches of information available from libraries and the Service's Wildlife Review database in Fort Collins Colorado. We also contacted researchers knowledgeable in plant tolerance to flooding and the effects of flooding on plant and animal communities.

THE "DRY" DAM CONCEPT

The concept of a peak flow detention dam, "dry" dam or "dry" bed dam to reduce the flood potential to downstream areas is a relatively new approach to large scale flood control efforts, at least in the arid west. In contrast to a typical large multipurpose reservoir, which not only provides some level of flood control, but also stores water for other uses, a peak flow detention dam impounds water only during periods when runoff from the upstream watershed exceeds the dam outlet capacity (Taylor 1981). The frequency, duration, elevation, and areal extent of inundation behind a particular "dry" dam depend on several factors such as: 1) the size, hydrologic and geomorphic characteristics of the watershed in which the dam is placed 2) the vegetative communities within the watershed; 3) characteristics of individual storms, which, at least conceptually, are a function of the climatic regime in which the watershed exists; and, of course; 4) the specific design of the dam.

The outlet structure of a peak flow detention faciltiy, which is typically an ungated opening through the dam, is specifically designed and sized to allow unrestricted passage of specific stream-flow volumes (usually normal or lower flow volumes). Flow volumes exceeding the outlet design capacity are passively detained and back-up behind the dam, temporarily inundating the upstream channel and adjoining terrestrial habitats.

LITERATURE REVIEW

Impacts to Vegetation and Wildlife

Although peak flow detention dams (in comparison to similar sized multipurpose reservoirs), typically inundate a smaller area for relatively brief periods, they nonetheless effect profound changes in stream-edge and upland communities above and below the impoundments (Taylor 1981). In relatively undisturbed watersheds, such as the American River Canyon, both the terrestrial and aquatic environments generally exist in a dynamic equilibrium (Karr and Schlosser 1977). Human modifications to relatively intact, natural watersheds and stream systems introduces completely new physical influences that disrupt the existing or developing dynamic equilibrium of the system. The ensuing extent of disequilibrium (Karr and Schlosser 1977) varies with the location, areal extent, and types of modifications made and the former condition of the system. Despite the existing uses and human influences present in the canyon, the American River canyon remains one of the largest, relatively natural river systems in California.

In most cases studied, river impoundments, in general, result in substantial loss of biological diversity in both the terrestrial and aquatic portions of the system above and below the impoundment. This has been attributed to reduction in the spatial and temporal heterogeneity within the systems (Ward and Stanford 1979). Another forseeable result is the obvious fundamental alteration of the basic nature and frequency of the former habitat patch dynamics (Pickett and White 1977). Of particular concern are terrestrial processes and cycles such as fire regimes, various population cycles (such as insect and vertebrate density fluctuations), that serve to maintain the long-term dynamic equilibrium in the terrestrial communities. Even relatively rare inundation events have the potential to substantially, if not completely, alter these processes.

Interestingly, despite the obvious ecological alterations that occur with peak flow detention dams, little attention has been given to research on the effects on the wildlife communities probably because most dry dams are very small, inundating relatively small acreages and/or occur in mostly lowland areas where increased inundation can be managed to enhance already existing wetland values (USFWS 1981). Review of available literature found virtually no information or data on the impacts to terrestrial wildlife for "dry" dam types of flood control structures. Consequently, the following discussions focus largely on impacts to the vegetation and habitats for wildlife rather that actual effects on wildlife populations.

GENERAL DOWNSTREAM IMPACTS

Because "dry" dams are specifically designed to substantially reduce the downstream peak flow characteristics, substantial changes in the streamside communities below the dam typically result. Specifically, the width of the riparian and scour zones becomes narrowed because of the attenuation of flushing and scouring flows (Taylor 1981). The riparian zone at the upland interface typically reverts to dry land habitat and at the water interface, woody riparian species expand into the former scour zone and increase along the waters edge especially at sand bars and shoals. Species composition (terrestrial and aquatic, as well as plant and animal) within the riparian zone inevitably changes from those characteristic of a highly dynamic fluvial/riparian system to those more indicative of a relatively constant and narrower less variable flow system. The extent of these effects within a given system undoubtedly depends upon the change in magnitude of the peak flow conditions.

GENERAL UPSTREAM IMPACTS

Conceptually, in comparison to a permanent multipurpose reservoir, a peak flow detention dam would fill for relatively brief periods of time and most inundations cover much less than the maximal land area behind the dam. Consequently, losses of vegetation and wildlife habitat are expected to be less than a comparable multipurpose reservoir since a proportion of the vegetation (and supportive habitat for wildlife) would remain alive and productive within the temporary reservoir pool area. Actual impacts of a "dry" dam on the local wildlife populations, however, are expected to be severely disruptive, since most terrestrial wildlife species cannot breathe under water even for a few minutes.

Wildlife

Most of the highly vagile wildlife in the canyons will be forced out of the area as the water rises. Birds will obviously be able to fly to new areas and many of the larger ground dwelling mammals that are active during the flood periods will move out also. However, subterranean species, those aestivating or hibernating will drown. This comprises a large biomass and significant component of the wildlife trophic support level. Many highly significant trophic groups such as reptiles, amphibians, and slow moving rodents likely will be eliminated. Other very important trophic components such as the invertebrates will also decline enormously. Even those animals capable of moving to new areas will be severely stressed and many will die because food and cover resources will not be sufficient to sustain the abnormally higher populations in the escape areas.