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Information in support of a recovery potential assessment of Bull Trout (*Salvelinus confluentus*) (Saskatchewan – Nelson rivers populations) in Alberta

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

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ABSTRACT

In November 2012, a meeting of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) recommended that Bull Trout, *Salvelinus confluentus*, (Saskatchewan – Nelson rivers, Designatable Unit [DU] 4) be designated Threatened. The reason given for this designation is that, “Historical range contractions now limit the populations to the foothills and east slopes of the Rocky Mountains, likely in response to habitat deterioration and reduced habitat connectivity through damming of the larger rivers. No populations are abundant and more than half show evidence of decline” (COSEWIC 2012). Furthermore, due to the threats faced by these populations “an aggregate decline in abundance of ≥ 30% over the next three generations is projected” (COSEWIC 2012). This was the first assessment of Bull Trout by COSEWIC and it has not yet been listed under the *Species at Risk Act* (SARA).

The Recovery Potential Assessment (RPA) was developed by Fisheries and Oceans Canada (DFO) to provide information and scientific advice needed to fulfill various requirements of the SARA, including informing both scientific and socio-economic elements of the listing decision and permitting activities that would otherwise violate SARA prohibitions, and the development of recovery strategies. This Research Document describes the current state of knowledge of the biology, ecology, distribution, population trends, habitat requirements and threats to Bull Trout in DU 4. Mitigation measures and alternative activities related to identified threats, which can be used to protect the species, are also presented. The RPA information may be used to inform the development of recovery documents and for assessing permits, agreements and related conditions, as per sections 73, 74, 75, 77, 78 and 83(4) of the SARA and to prepare for the reporting requirements of SARA section 55. The scientific information from the RPA also serves as advice to the DFO Minister regarding the listing of the species under the SARA. This assessment updates and consolidates the available scientific data pertaining to the recovery of Bull Trout (DU 4) in Alberta .

Données et renseignements nécessaires à l'évaluation du potentiel de rétablissement de l'omble à tête plate (*Salvelinus confluentus*) (populations de la rivière Saskatchewan et du fleuve Nelson) en Alberta

RÉSUMÉ

Une réunion du Comité sur la situation des espèces en péril au Canada (COSEPAC) tenue en novembre 2012 a débouché sur la recommandation de désigner l'omble à tête plate *Salvelinus confluentus* de la rivière Saskatchewan et du fleuve Nelson (unité désignable [UD] 4) comme espèce menacée. Le motif donné pour cette désignation est le suivant : « Les contractions de l'aire de répartition historique limitent maintenant les populations aux contreforts et aux versants est des montagnes Rocheuses, probablement en réaction à une détérioration de l'habitat et à une connectivité réduite des habitats en raison des barrages érigés sur les plus grandes rivières. Aucune population n’est abondante et plus de la moitié des populations montrent des signes de déclin (COSEPAC 2012). » De plus, compte tenu des menaces auxquelles ces populations sont exposées, « un déclin total de l'abondance de plus de 30 % au cours des trois prochaines générations est prévu (COSEPAC 2012). » Il s'agit de la première évaluation de l'omble à tête plate ayant été réalisée par le COSEPAC. L'espèce n'a pas encore été inscrite en vertu de la *Loi sur les espèces en péril* (LEP).

Pêches et Océans Canada (le MPO) a préparé une évaluation du potentiel de rétablissement (EPR), afin de fournir les renseignements et les avis scientifiques nécessaires pour répondre aux diverses exigences de la LEP. Cette évaluation permet notamment d'éclairer les aspects scientifiques et socioéconomiques de la décision relative à l'inscription, de réaliser des activités qui autrement enfreindraient les interdictions de la LEP, et d'élaborer des programmes de rétablissement. Ce document de recherche décrit les connaissances actuelles au chapitre de la biologie, de l’écologie, de la répartition, de l’état des populations, des besoins en habitats et des menaces de l'omble à tête plate de l'UD 4. On y présente également les mesures d'atténuation et les autres activités associées aux menaces déterminées, que l'on peut utiliser afin de protéger l'espèce. Les renseignements de l'EPR peuvent aussi être utilisés pour guider l'élaboration de documents sur le rétablissement, et l'évaluation des permis, des ententes et des conditions connexes, conformément aux articles 73, 74, 75, 77, 78 et le paragraphe 83 (4) de la LEP. Enfin, ils peuvent servir à préparer les rapports exigés en vertu de l'article 55 de la même loi. L'information scientifique contenue dans l'EPR peut être utilisée comme avis à l'intention du ministre du MPO concernant l'inscription de l'espèce en vertu de la LEP. Cette évaluation permet d'actualiser et de regrouper les données scientifiques relatives au rétablissement de l'omble à tête plate (UD 4) en Alberta.

SPECIES INFORMATION

Scientific Name – *Salvelinus confluentus*

Common Name – Bull Trout (Saskatchewan – Nelson rivers populations)

Range in Canada – Alberta

Current COSEWIC Status (Year of Designation) – Threatened (2012)

COSEWIC Reason for Designation – This freshwater fish is broadly distributed east of the Rocky Mountains. It is a slow-growing, late maturing species that thrives in cold, pristine waters and often requires long, unimpeded migratory routes joining spawning to adult habitat. Historical range contractions now limit the populations to the foothills and east slopes of the Rocky Mountains, likely in response to habitat deterioration and reduced habitat connectivity through damming of the larger rivers. No populations are abundant and more than half show evidence of decline. The primary and persistent threats to these populations include competition and hybridization with introduced Brook Trout (*S. fontinalis*) and climate-induced increases in water temperature. Although legal harvest has been eliminated, this species is highly catchable and is therefore likely susceptible to catch and release mortality in many areas that are accessible to recreational anglers. Consequently, an aggregate decline in abundance of ≥ 30% over the next 3 generations is projected (COSEWIC 2012).

Canada *Species at Risk Act* – New Species, No Schedule, No Status

Alberta *The Wildlife Act* – Sensitive

BACKGROUND

Bull Trout (*Salvelinus confluentus*) is a large freshwater char belonging to the Salmonidae family. This species is native to western Canada and the Pacific Northwest region of the United States. The first assessment of this species by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was conducted in 2012. Based on COSEWIC's guidelines for recognizing Designatable Units (DUs) (COSEWIC 2009), Bull Trout in Canada were split into five DUs (Figure 1):

- South Coast British Columbia populations (DU 1),
- Western Arctic populations (DU 2),
- Upper Yukon Watershed populations (DU 3),
- Saskatchewan – Nelson rivers populations (DU 4), and
- Pacific populations (DU 5).

The rationale for this decision is outlined in COSEWIC (2012). The South Coast British Columbia and Western Arctic populations were ranked Special Concern, the Upper Yukon Watershed populations were ranked Data Deficient, the Saskatchewan – Nelson rivers populations were ranked Threatened, and the Pacific populations were ranked Data Deficient. As such, the Saskatchewan – Nelson rivers populations (DU 4) are now being considered for listing under the Species at Risk Act (SARA). This document provides biological information to be used in evaluating the potential for recovery of Bull Trout (DU 4) in Alberta.

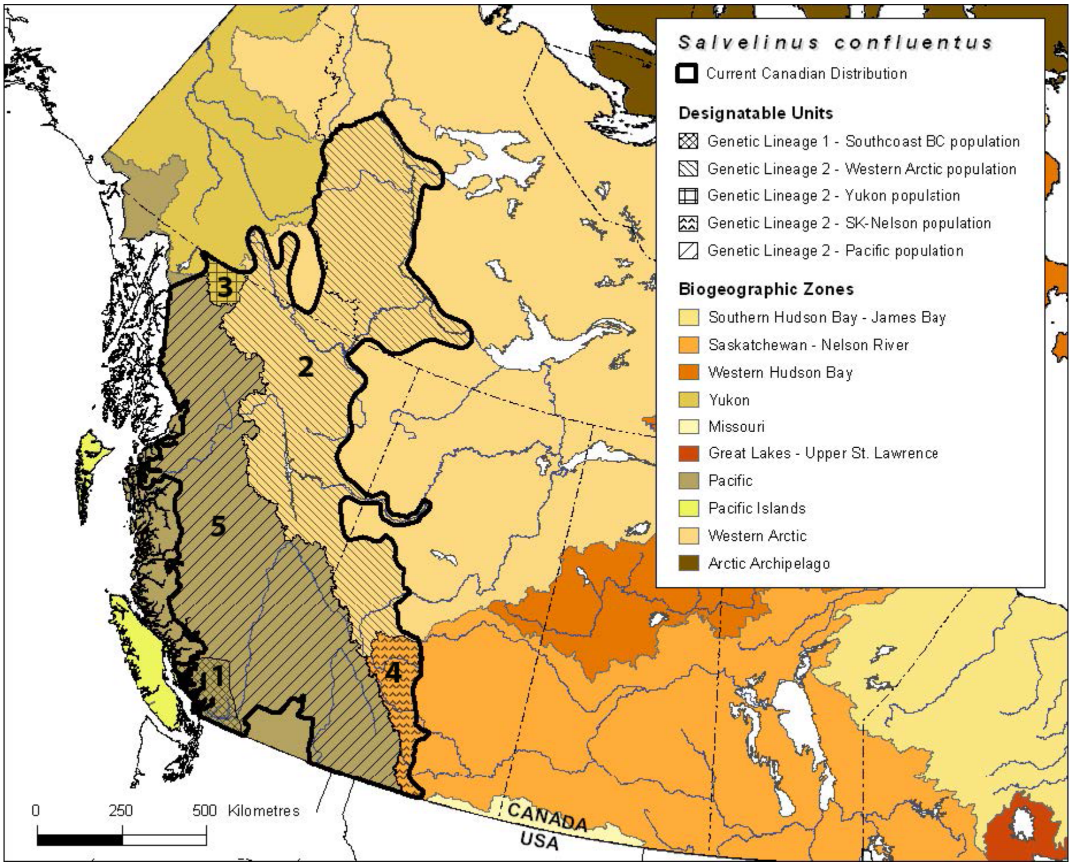

Figure 1. Designatable units of Bull Trout in Canada (from COSEWIC 2012).

SPECIES DESCRIPTION

Bull Trout is a long and slender salmonid with a relatively large head and jaws (Figure 2), hence its common name. Physical characteristics are summarized in Nelson and Paetz (1992) and include:

- an upper jaw which extends past the posterior edge of the eye in fish greater than approximately 8 cm,
- a relatively pointed anterior tip of the dorsal fin, a moderately forked caudal fin,
- 105–142 pored scales along the lateral line,
- 13–16 dorsal fin rays, 11–15 anal fin rays,
- 13–22 gillrakers, 20–40 pyloric caeca,
- 25–30 branchiostegal rays (total for both sides), and
- 62–67 vertebrae.

Three life history strategies are exhibited in Alberta; resident, fluvial and adfluvial (see Life History Diversity) (AESRD and ACA 2009). Body size at maturity varies by life history type with the resident form having an average size at maturity of 250 mm fork length (FL) (range: 150–300 mm FL), fluvial > 400 mm FL (range: 240–730 mm FL), and adfluvial > 400 mm FL (range: 330–900+ mm FL) (AESRD and ACA 2009).

Body colour is olive-green to blue-gray dorsally with silvery colouration laterally and pale yellow, orange or red round spots on their backs and sides. The pelvic and anal fins often have white leading edges not followed with black. They have pale bellies which may turn red or orange on spawning males (Nelson and Paetz 1992). The pale, round spots on their back and sides and the absence of black markings on their dorsal fin are primary features distinguishing Bull Trout from co-occurring salmonids such as Rainbow Trout (*Oncorhynchus mykiss*), Cutthroat Trout (*O. clarkii*), Brown Trout (*Salmo trutta*), and Brook Trout (*S. fontinalis*) (AESRD and ACA 2009).

Hybridization with Brook Trout occurs in Alberta with hybrids having marking, colouration and body shapes intermediate between the two species (Fredenberg et al. 2007). Popowich et al. (2011) found dorsal fin markings to be the most reliable distinguishing feature of hybrids for fish 125 mm or longer, with Brook Trout having distinct black markings on their dorsal fins, Bull Trout having no markings and presumed hybrids having pale spots on most of the dorsal fin. Larval Bull Trout may be distinguished from other larval char by the presence of a prominent fleshy ridge underneath the chin (Gould 1987). Sexual dimorphism is exhibited during the spawning season when males often develop large kypes (hooked lower jaw) and become more brightly coloured than females (Baxter 1997a). Males also usually have larger adipose fins than females of the same size (McPhail 2007).

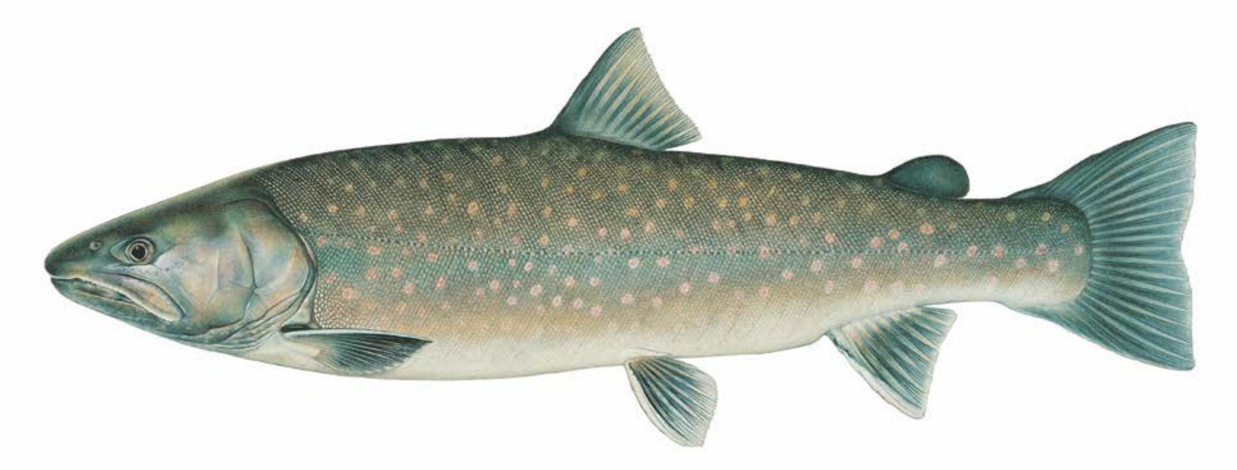

*Figure 2. Bull Trout (*S. confluentus*). Illustration by Joe Tomelleri, reproduced with permission.*

TAXONOMY

Bull Trout, once considered geographic variants within the Arctic Char (*S. alpinus*) species complex, were shown to be distinct from Arctic Char through morphological analyses (McPhail 1961), but for many years were still believed to be members of the Dolly Varden (*S. malma*) species complex. Cavender (1978) was the first to describe Bull Trout as a species distinct from Dolly Varden. This was later confirmed through morphological (Haas and McPhail 1991) and genetic (Phillips et al. 1995) analyses. In Alberta, however, these two species are not sympatric. Dolly Varden are not native to the province, but were successfully introduced into Chester Lake in the Kananaskis River drainage in 1974 (Nelson and Paetz 1992); Bull Trout are not present in Chester Lake.

LIFE HISTORY DIVERSITY

Within Alberta, Bull Trout exhibit three life history strategies; stream resident, fluvial and adfluvial (AESRD and ACA 2009). Stream residents are non-migratory and spend their entire lives in small streams and rivers. They rarely exceed 300 mm FL (McPhail and Baxter 1996).

They are often isolated by physical (e.g., waterfalls, dams), physiological (e.g., water temperature) or biological (e.g., non-native competitors) barriers (COSEWIC 2012). Fluvial Bull Trout rear in headwater streams and migrate to large tributaries and mainstem rivers at approximately age 2, mature, and overwinter, returning to natal streams to spawn, sometimes in alternate years, at approximately age 5 (Fraley and Shepard 1989, McPhail and Baxter 1996, Warnock 2008). Adfluvial Bull Trout rear in headwater streams and migrate into lakes to mature, returning to their natal streams to spawn at approximately age 5, usually every year if habitat productivity allows (Stelfox 1997, Warnock 2008). Anadromous Bull Trout, which migrate between freshwater and the ocean, are restricted to southwestern British Columbia and northwestern Washington (COSEWIC 2012). There is no evidence of genetic differentiation between life history types (Homel et al. 2008), and offspring may exhibit a different life history type than their parents, indicating plasticity in this trait (Brenkman et al. 2007, Dodson et al. 2013). Migratory and resident life history types may occur in sympatry or residents may be isolated by barriers (McPhail and Baxter 1996, Nelson et al. 2002).

REPRODUCTION

The following information is summarized in COSEWIC (2012) unless otherwise indicated. Bull Trout typically reach sexual maturity between age 5–7 (range: 3–8 years). Ages up to 24 years have been documented, but maximum age is unknown. Generation time has been estimated at approximately 7 years in mixed life history populations in British Columbia. The sex ratio of populations is typically 1:1. Fecundity is related to body size (Goetz 1989, Johnston and Post 2009); small, resident females produce approximately 500 eggs and larger, migratory females produce 2,000–5,000 eggs (Berry 1994, AESRD and ACA 2009). Egg diameter ranges from 4.8–6.2 mm (Allan 1980, AESRD and ACA 2009).

Spawning occurs from mid-August to late October. Resident Bull Trout spawn locally, but migratory forms may migrate over 200 km to spawn (McPhail and Baxter 1996, Shepard et al. 1984) and generally exhibit homing to natal streams (McPhail and Baxter 1996, Swanberg 1997, Bahr and Shrimpton 2004, Warnock 2008), but straying within localized areas has been documented (AESRD and ACA 2009). Spawning migrations begin between late May and August depending on distance to be travelled, with movements generally occurring at night (AESRD and ACA 2009). Younger Bull Trout may enter the spawning streams first, finish gamete development within the stream and then spawn at the same time as older fish. Spawning usually occurs during the day but may occur at night in disturbed systems and has been documented to occur at temperatures below 10 °C and is suspended below approximately 5 °C.

Females excavate a spawning site, or redd, in gravel substrate typically in association with groundwater upwelling. A dominant male is usually found alongside each spawning female. The male defends the female from other males (satellite males) who try to compete for fertilization. In some populations, small males termed jacks or ‘sneakers’ rush in when the female releases her eggs and are often successful at fertilizing some of them. The fertilized eggs incubate over the winter in the substrate and hatch in March–April. At emergence, the length range of fry is 21–33 mm (Allan 1980, Ratcliff et al. 1996, Reiser et al. 1997, AESRD and ACA 2009).

Bull Trout are iteroparous but many spawn in alternate years. Johnston and Post (2009) found that alternate-year spawning in Lower Kananaskis Lake, Alberta increased with increasing density; annual spawning was more frequent when Bull Trout density was low. In cold systems with lower productivity, a resting period between spawning events is likely necessary to replenish the energy required for spawning (AESRD and ACA 2009).

DIET AND GROWTH

Bull Trout are opportunistic predators, consuming a variety of vertebrate and invertebrate prey, altering their diet based on prey availability (Stewart et al. 2007). Prey species vary across their range, but the general taxonomic groups that make up their diet are similar and include annelids, molluscs, crustaceans, insects, fish, amphibians, birds and small mammals (COSEWIC 2012; Figure 3).

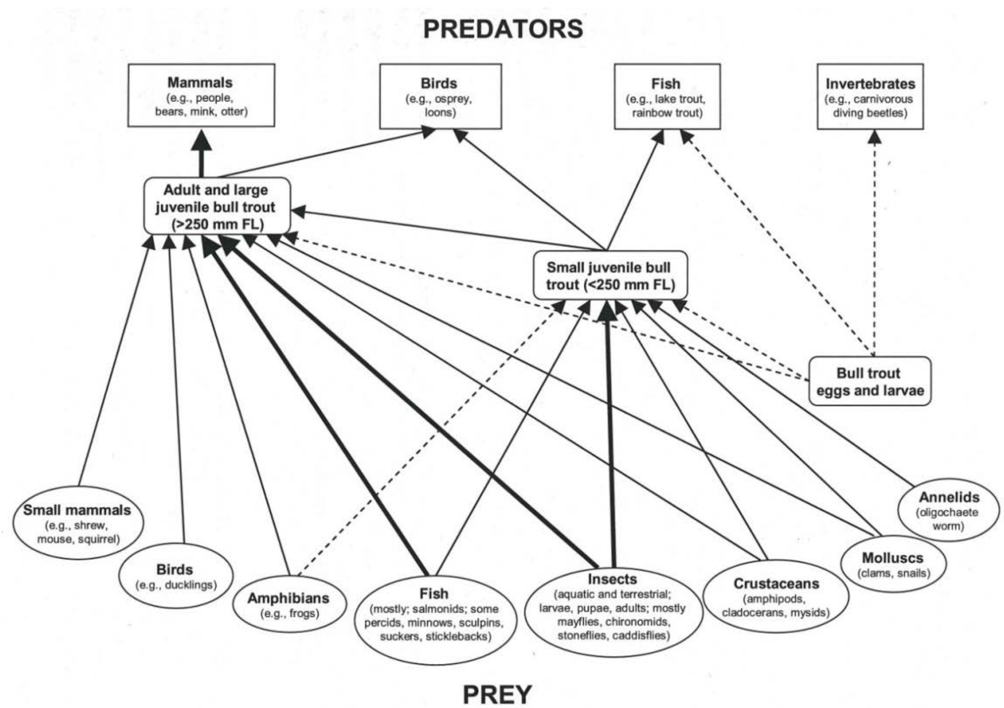

Figure 3. Generalized food web for Bull Trout showing the direction of energy flow. Bold lines indicate major food pathways in comparison to thinner lines; solid lines indicate demonstrated, and dashed lines putative, pathways (from Stewart et al. 2007).

Juveniles forage on drift during the day and benthic organisms at night, rarely if ever feeding at the surface (Nakano et al. 1992, Bonneau and Scarnecchia 1998, Hagen and Taylor 2001, Stewart et al. 2007). Their diet consists of a variety of macroinvertebrates with mayflies, midges, stoneflies and caddisflies forming the bulk of the diet in both lakes and streams during the summer (Hagen and Baxter 1992, Nakano et al. 1992, Underwood et al. 1995, Stewart et al. 2007). Cold temperatures, low productivities and insect-based diets often result in low juvenile growth rates (Berry 1994).

As juveniles grow larger, they begin preying on fish. This shift to piscivory usually occurs once they have reached 100–200 mm in length (Goetz 1997a, Stewart et al. 1982, Boag 1987, Hagen and Baxter 1992, Pratt 1992, Stewart et al. 2007). Invertebrates are included in the adult diet, but as size increases, other fishes are more heavily preyed on when available (COSEWIC 2012). In the Elbow River, Alberta adult Bull Trout fed almost exclusively on fish including Brook Trout, Cutthroat Trout, Mountain Whitefish (*Prosopium williamsoni*), Rainbow Trout and juvenile Bull Trout (Popowich 2005). Cannibalism has also been documented in other populations (e.g., Cavender 1978, Leathe and Graham 1981, Wilhelm et al. 1999, Mochnacz et al. 2004). The diet of larger Bull Trout may also include frogs, snakes, ducklings and small mammals (e.g., squirrels, shrews, mice) if the opportunity presents (Brown 1971, Cavender 1978, Goetz 1989). Smaller Bull Trout eat primarily benthos and amphipods (Connor et al. 1997). Dietary differences between resident and migratory forms are likely related to prey availability in habitats occupied (Boag 1987). This is one reason resident Bull Trout are much smaller than fluvial fish, which in turn, are smaller than adfluvial fish (Berry 1994, Ratcliff et al. 1996).

In Alberta streams, Bull Trout grow an estimated 30–40 mm per year in the first several years of life (Paul et al. 2000, Paul et al. 2003). In the Kakwa River basin, Alberta Bull Trout were found to grow approximately 30 mm per year (Hvenegaard and Fairless 1998) while in Pinto Lake, Alberta where Bull Trout is the only fish species in the lake, they grew 10 mm per year (Herman 1997, AESRD and ACA 2009). In Lower Kananaskis Lake, growth of adults was inversely related to abundance and fish length, females grew slower than males, and growth of larger fish approached zero at high density (approximately 2.3 fish/hectare) (Johnston and Post 2009).

PHYSIOLOGY

The physiological requirements of Bull Trout, most notably water temperature, limit its distribution (Rieman and McIntyre 1993, Dunham et al. 2003a). A narrow range of cold temperatures is required for reproduction and survival. Adults generally occur in water below 18 °C, but are more common at temperatures below 12 °C (Dunham et al. 2003a). Colder temperatures are especially important during incubation and juvenile rearing. The lower dissolved oxygen levels at higher water temperatures increase the rate of yolk absorption resulting in smaller fry (COSEWIC 2012). The optimal incubation temperature range is 2–4 °C with survival declining rapidly at temperatures above 8 °C. Groundwater inflows are important in maintaining stable temperatures during egg incubation (Baxter and McPhail 1999). These cooler temperatures result in lower growth rates, but they also exclude species with higher temperature requirements from entering the habitat and competing with Bull Trout (COSEWIC 2012).

Although cold temperatures are important for survival, Bull Trout do exhibit a high degree of behavioural thermoregulation and are able to forage in waters with higher than preferred temperatures (USFWS 2000, Stewart et al. 2007). For example, in Idaho streams, Bull Trout were found in water above 20 °C where they remained for several hours on hot summer days, although they were more commonly found at temperatures between 2 and 12 °C (Adams 1994).

INTERSPECIFIC INTERACTIONS

Life history characteristics of Bull Trout (e.g., late maturity, variable spawning frequency, and slow growth) make them vulnerable to competition with other species. Much of the research on Bull Trout's interspecific interactions has therefore focused on potential competition with other native and non-native salmonids (COSEWIC 2012). Within Alberta, research has focused on the following species whose ranges overlap with that of Bull Trout; Rainbow Trout (native [Athabasca River drainage] and introduced), Cutthroat Trout (native [Bow and Saskatchewan River drainages] and introduced), Lake Trout (*S. namaycush*; native), Brown Trout (introduced) and Brook Trout (introduced) (Nelson and Paetz 1992).

When Bull Trout co-occur with Rainbow Trout or Cutthroat Trout, it may be beneficial to Bull Trout in that these species are a source of high quality food (Beauchamp and VanTassel 2001, COSEWIC 2012). In studies examining interactions between Bull Trout and Cutthroat Trout, resource partitioning was found to be an important mechanism enabling their co-existence (Nakano et al. 1992, Jakober et al. 2000). When *Oncorhynchus* species (i.e., Cutthroat Trout and Rainbow Trout) are introduced into Bull Trout waters, the impact on Bull Trout appears to be less pronounced than when other *Salvelinus* species are introduced (Donald and Stelfox 1997, AESRD and ACA 2009). However, competition may still occur through negative changes to the ecosystem and/or reduced growth and survival of Bull Trout (AESRD and ACA 2009).

Lake Trout is native to Alberta and its range overlaps with that of Bull Trout, but the species are separated spatially. Native Lake Trout occur mainly in lakes of 1,032–1,500 m elevation and Bull Trout in lakes between 1,500–2,200 m, although Bull Trout are typically present in the tributaries or outlet streams of lower elevation lakes containing Lake Trout (Donald and Alger 1993). Their distributions were not found to be limited by either environmental or habitat-specific characteristics. When Lake Trout was introduced into higher elevation lakes containing Bull Trout, the Bull Trout were extirpated from those lakes (Donald and Alger 1993). Donald and Alger (1993) found evidence that Lake Trout was the dominant species in these lakes and that competition resulting from the significant niche overlap in food resources and growth may be one factor contributing to their spatial separation.

Brown Trout, Brook Trout and Rainbow Trout are the most widely introduced salmonids in western North America (Fuller et al. 1999). Introduction of species such as Brown Trout and Brook Trout into Bull Trout waters has likely contributed to the decline of Bull Trout in Alberta (Berry 1994, Fitch 1997, McCart 1997, AESRD and ACA 2009). Brown Trout may disturb Bull Trout redds, as they spawn later in the season than Bull Trout (Rhude and Stelfox 1997). In one system where Brown Trout was the only introduced species, extirpation of Bull Trout did not occur, but when both Brook Trout and Brown Trout were present, Bull Trout were extirpated (Fitch 1997). Brook Trout have similar spawning requirements to Bull Trout, thus these species compete for spawning habitat and have a higher risk of hybridization (Berry 1994, Ratcliff et al. 1996, AESRD and ACA 2009). These hybrids are believed to be sterile (Berry 1994), but Buktenica (1997) and Popowich et al. (2011) found evidence of reproduction (AESRD and ACA 2009). Brook Trout may also exhibit sneaking behaviour during Bull Trout spawning events, further increasing hybridization and decreasing Bull Trout spawning success (Ratcliff et al. 1996, Bellerud et al. 1997, Paul 2000, Post and Paul 2000, AESRD and ACA 2009). In a study in eastern Oregon, habitat partitioning between Bull Trout and introduced Brook Trout was not observed (Gunckel 2000). In regions of southwestern Alberta where Brook Trout have been introduced, approximately 70% of the Bull Trout populations have been, or are thought to have been, extirpated (Fitch 1997). Further information can be found in the Threats section.

SPECIAL SIGNIFICANCE

Despite its wide distribution in North America, Bull Trout has been declining in abundance over the past century, particularly near its southern distributional limits in the U.S.A. (Haas and McPhail 1991). Human impacts on populations and habitats are believed to be the cause for the decline. In the 1920s, Bull Trout were considered 'junk' fish and were culled in an attempt to increase sport fish populations such as Rainbow Trout, Brook Trout and Brown Trout (Colpitts 1997). COSEWIC (2012) notes that the Canadian range is considered Bull Trout's stronghold. Bull Trout is the only native char to historically occupy all the drainages of the eastern slopes of Alberta, and is the only native stream-dwelling char species in the North Saskatchewan and Red Deer River basins (Berry 1994, Nelson and Paetz 1992, AESRD and ACA 2009). In November 1999, Bull Trout was listed as Threatened throughout its range in the U.S.A. under the *Endangered Species Act* (USFWS 1999). In Alberta it is ranked as Sensitive under *The Wildlife Act*.

As voracious piscivores, Bull Trout may influence community structure, and energy and nutrient flows within the ecosystem as has been shown for other char species including, for example, Dolly Varden (Nakano et al. 1999, Baxter et al. 2004) and Brook Trout (Bechara et al. 1992) (COSEWIC 2012). In addition, fluvial and adfluvial Bull Trout link food webs and the flow of energy and nutrients between different habitats (e.g., lakes and rivers) (Holmlund and Hammer 1999, Dunham et al. 2008, COSEWIC 2012).

ASSESSMENT

HISTORIC AND CURRENT DISTRIBUTION TRENDS

Bull Trout are endemic to northwestern North America where they occupy a large geographic range (Figure 4). They are distributed from the Oregon-California border and northern Nevada (42°N) to southern Yukon and southwestern Northwest Territories (65°N; Haas and McPhail 1991, Mochnacz et al. 2009, COSEWIC 2012). Their distribution extends from the Pacific Coast in southwestern British Columbia and northwestern Washington (~ 113°W) in the west (Cavender 1978, Haas and McPhail 1991), to the eastern slope of the continental divide in western Montana and Alberta and the Northwest Territories (Haas and McPhail 1991, Reist et al. 2002) in the east (COSEWIC 2012).Their range has declined over the past century, particularly in southern regions (Figure 4). In recent decades, Bull Trout's distribution has also declined in eastern parts of its range in Alberta (AESRD and ACA 2009).

Approximately 80% of its global range is within western Canada (British Columbia, Alberta, Yukon and Northwest Territories; Rieman et al. 1997). Within Alberta, Bull Trout's range includes all of the major east slope river drainages; Peace, Athabasca, South Saskatchewan and North Saskatchewan (Figure 4; Nelson and Paetz 1992, Haas and McPhail 2001, AESRD and ACA 2009). Historically, Bull Trout were more widely distributed in Alberta. Once occupying reaches further downstream, they are now restricted to upstream reaches with the exception of the northern Peace and Athabasca drainages where they occur in low abundance (Berry 1994, COSEWIC 2012).

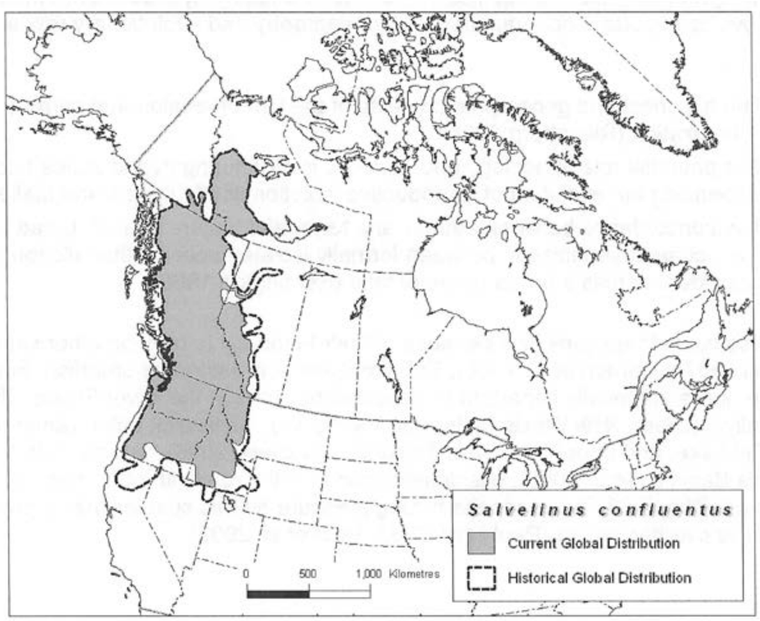

Figure 4. Approximate current and historical global range of Bull Trout. Distribution is not continuous throughout range (from COSEWIC 2012).

Two DUs occur within Alberta; DU 2 (Western Arctic populations) and DU 4 (Saskatchewan – Nelson rivers populations) (COSEWIC 2012). The distribution of Bull Trout in the latter DU extends from the North Saskatchewan River south to the Canada–USA border (Figure 5). The extent of occurrence is estimated to be greater than 20,000 km^2 and the index of area of occupancy greater than 2,000 km^2 calculated using a 2 km x 2 km grid (COSEWIC 2012).

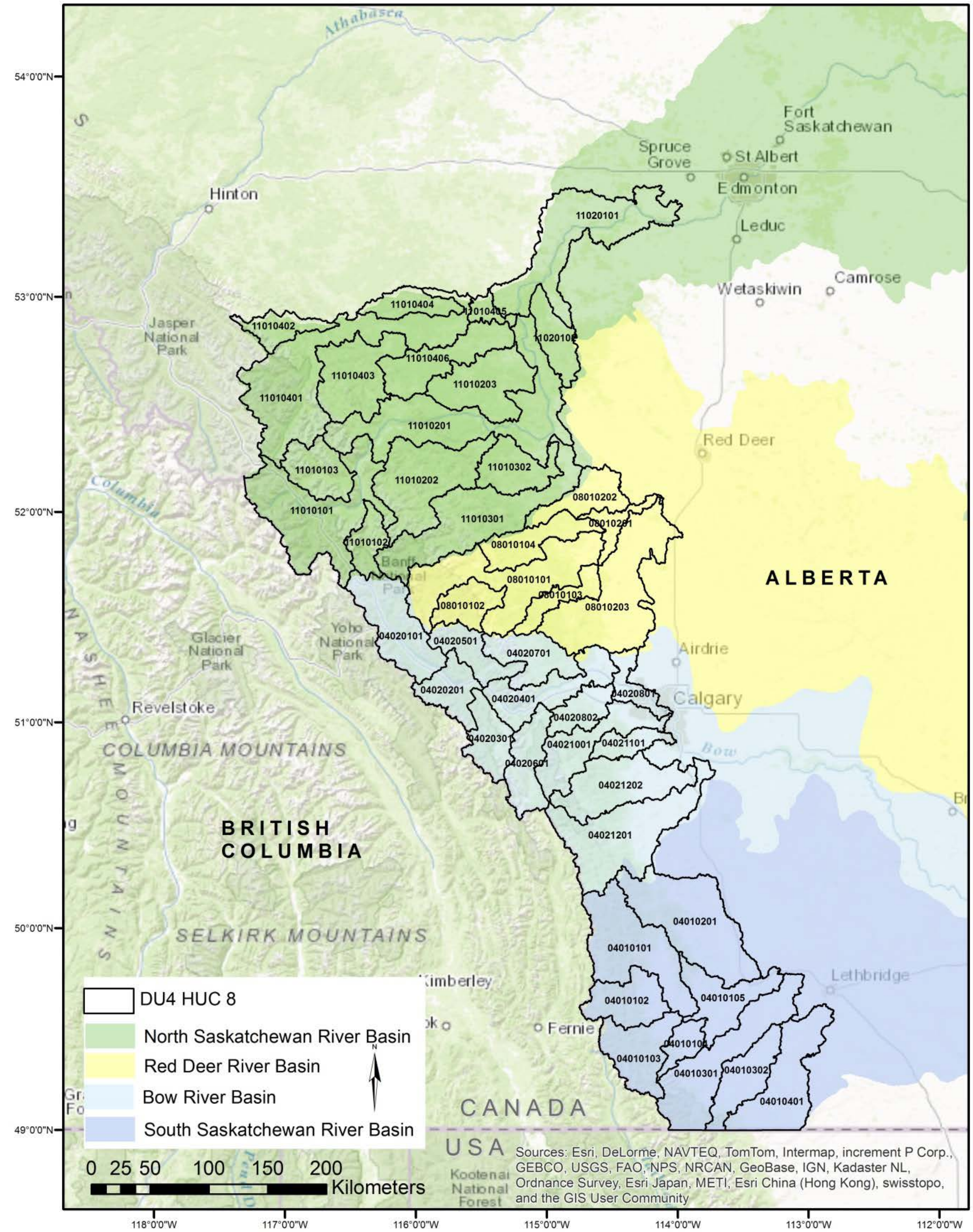

Figure 5. Distribution of Bull Trout in DU 4 showing HUC8s for the North Saskatchewan, Red Deer, Bow and South Saskatchewan River Basins. HUC8 data were obtained from Alberta Environment and Sustainable Resource Development and are based on AESRD (2014).

HISTORIC AND CURRENT ABUNDANCE AND TRENDS

Many Bull Trout populations in Alberta have been declining over the past century. In the Bow River, for example, large decreases in abundance were reported as early as the late 1930s and recent studies have confirmed a continuing decline (Brewin 1996, AESRD and ACA 2009). Bull Trout are no longer found in large areas of the Oldman River drainage and the Red Deer River system (Brewin and Brewin 1997, AESRD and ACA 2009). Once abundant in the North Saskatchewan River near Edmonton, they have not been documented there since the late 1950s (Brewin 1994b, AESRD and ACA 2009).

To assess the status of Bull Trout populations in Alberta, the Fisheries Management Branch of Alberta Sustainable Resource Development applied the Alberta Fish Sustainability Index (FSI). The three major components of this assessment process are:

1) organizing stocks into spatial units;
2) assessing the stock(s) within the spatial unit; and
3) combining those assessments into a province-level strategic information system (Coombs and MacPherson 2013).

The spatial units used were 8-digit Hydrological Unit Codes (HUC8). HUCs are “successively smaller hydrologic units that nest within larger hydrologic units, creating a hierarchical watershed boundary dataset” (AESRD 2014). This system is used by the USGS (USGS and USDA 2012), and the same guidelines were followed for delineating HUCs with a few modifications (AESRD 2014). A total of 88 Bull Trout HUC8s were delineated within Alberta; DU 4 encompasses 45 of these HUC8s. Several metrics were examined to assess the stocks within the HUC8s, including metrics of population integrity, productive potential and threat mitigation (Coombs and MacPherson 2013).

Prior to adopting the HUC approach, Bull Trout within Alberta were assessed by core area following a modification of the Natural Heritage Network ranking methodology using NatureServe Conservation Status Assessment Criteria (Fredenberg et al. 2005). Using this method, 51 core areas were identified in Alberta (AESRD and ACA 2009); 36 of these occurred within DU 4 (COSEWIC 2012). Core areas are analogous to metapopulations and are defined as “habitat areas in watersheds that contain one or more closely linked Bull Trout subpopulations that form a population unit” (AESRD and ACA 2009, p. 21). Within DU 4, Bull Trout occur in four river basins; the Oldman, Bow, Red Deer and North Saskatchewan - and have an estimated adult abundance of 10,218 (range: 6,359–21,700) (AESRD and ACA 2009). Population size estimates range from 10 in the Middle Bow and Little Red Deer rivers to 1,275 in the Brazeau River (Table 1). The Bull Trout populations in the Upper Crowsnest River, Willow Creek and Lower Bow River were identified as extirpated. This is likely an underestimation of the number of extirpated popualtions, as populations were extirpated earlier in the century prior to data being available to identify core areas (AESRD and ACA 2009). Information required for the assessment was not available for the Upper Bow River (AESRD and ACA 2009).

Table 1. Abundance and occupancy estimates for the Saskatchewan – Nelson rivers (DU 4) populations of Bull Trout in Alberta. Assessment was completed by the Fish and Wildlife Division of Alberta Sustainable Resource Development. Estimated adult population abundance (using quantitative data and/or expert opinion) are accompanied by appropriate NatureServe Range Categories in parentheses. Core areas currently occupied by Bull Trout were the focus, thus this is not a comprehensive list of extirpated core areas. Modified from AESRD and ACA (2009), COSEWIC (2012) and AESRD (2012).

Oldman River Basin

Waterbody (Core Area)	HUC8	Life History Types	Estimated Abundance (Adults)	Occupancy (stream km)
Belly River	04010302	Fluvial Resident	250 (250–1,000)	4–40
St. Mary River	04010401	Fluvial Resident	550 (250–1,000)	40–200
Upper Crowsnest River	04010102	–	–	–
Castle River and Oldman Reservoir	04010102, 04010103	Fluvial Adfluvial Resident	310 (250–1,000)	200–1,000
Upper Oldman River	04010101	Fluvial Resident	410 (250–1,000)	40–200
Upper Livingstone River	04010101	Resident	280 (250–1,000)	4–40
Lower Oldman River	04010105	Fluvial Resident	60 (50–250)	40–200
Waterton River	04010301	Resident	40 (1–50)	4–40
Drywood Creek	04010301	Resident	40 (1–50)	4–40
Willow Creek	04010201	–	–	–

Bow River Basin

Waterbody (Core Area)	HUC8	Life History Types	Estimated Abundance (Adults)	Occupancy (stream km)
Lower Bow River	04020801	–	–	–
Highwood River	04021201	Fluvial Resident	190 (50–250)	40–200
Flat Creek	04020601	Resident	40 (1–50)	4–40
Sheep River	04021202	Fluvial Resident	445 (250–1,000)	40–200
Lower Elbow River	04021001	Fluvial Resident	105 (50–250)	40–200
Canyon Creek	04021001	Resident	20 (1–50)	4–40
Upper Elbow River	04021001	Resident	115 (50–250)	40–200
Jumpingpound Creek	04020802	Resident Fluvial	15 (1–50)	4–40

Waterbody (Core Area)	HUC8	Life History Types	Estimated Abundance (Adults)	Occupancy (stream km)
Ghost River	04020701	Resident Fluvial	385 (250–1,000)	40–200
Middle Bow River	04020301, 04020501	Incidental	10 (1–50)	< 4
Middle Kananaskis River	04020601	Resident	Unknown	4–40
Upper Kananaskis River (Kananaskis Lakes)	04020601	Adfluvial	1200 (1,000–2,500)	40–200
Upper Spray River	04020301	Resident	40 (1–50)	4–40
Lake Minnewanka	04020501	Resident	58 (50–250)	4–40
Upper Bow River	04020101, 04020201	Resident Fluvial?	Unknown	Unknown

Red Deer River Basin

Waterbody (Core Area)	HUC8	Life History Types	Estimated Abundance (Adults)	Occupancy (stream km)
Red Deer River	08010101, 08010102, 08010104, 08010201, 08010202	Fluvial Resident	530 (250–1,000)	200–1,000
Little Red Deer River	08010203	Resident	10 (1–50)	4–40

North Saskatchewan River Basin

Waterbody (Core Area)	HUC8	Life History Types	Estimated Abundance (Adults)	Occupancy (stream km)
Brazeau River	11010401, 11010402, 11010404, 11010405	Fluvial Resident	1275 (1,000–2,500)	200–1,000
Blackstone River	11010403	Fluvial Resident	720 (250-1,000)	200–1,000
Nordegg River	11010401, 11010406	Fluvial	105 (50–250)	40–200
Baptiste River	11010203	Resident	50 (1–50)	40–200
Upper North Saskatchewan River	11010101, 11010102, 11010201	Fluvial	950 (250–1,000)	40–200
Pinto Lake and Cline River	11010103	Adfluvial Fluvial	1150 (1,000–2,500)	40–200
Middle North Saskatchewan River	11010201, 11010202	Fluvial	400 (250–1,000)	40–200

Waterbody (Core Area)	HUC8	Life History Types	Estimated Abundance (Adults)	Occupancy (stream km)
Lower North Saskatchewan River	11020101	Fluvial	75 (50–250)	40–200
Clearwater River	11010301, 11010302	Fluvial Resident	390 (250–1,000)	40–200
Total			10,218 (6,359–21,700)	

Long-term data for Alberta Bull Trout populations are rare and are summarized in AESRD and ACA (2009) and AESRD (2012) (Table 2). The Lower Kananaskis Lake (Bow River basin) dataset is the most comprehensive dataset available and it documents the effect of protection from angler harvest on a heavily exploited adfluvial population. In 1954, Bull Trout comprised 11% of the reservoir's fish population, by 1986 they made up only 2% (Stelfox 1997) and by 1992 they had decreased to only 60 spawning adults (Figure 6). Restrictive angling measures, including a zero-bag limit, were implemented in 1992 (three years before the province-wide zero-bag limit was implemented [Hvenegaard and Fairless 1998]). By 2000, the adult population estimate had increased to more than 1,650 individuals (Johnston et al. 2007). The increased density resulted in delayed maturation and an increased frequency of skipped spawning events; the population is thought to have reached its carrying capacity (Johnston and Post 2009). The adfluvial populations in Harrison Lake (Red Deer River basin) (Parker et al. 2007), and in Jacques Lake (Sullivan et al. 2005 unpubl. rep) and Pinto Lake (Herman 1997) in DU 2 also appear to be increasing.

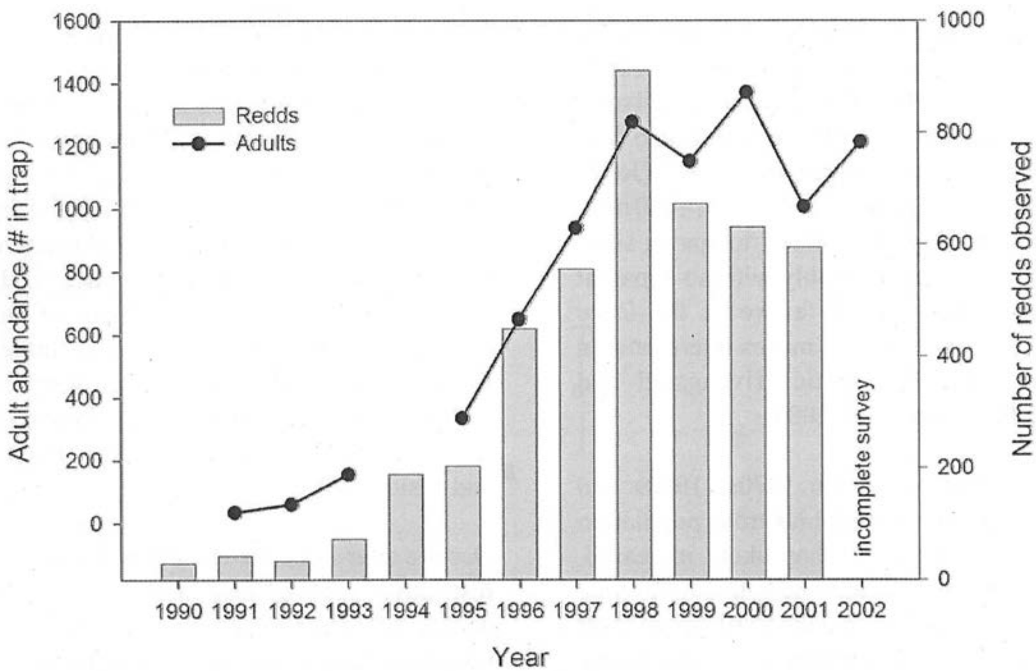

Figure 6. Bull Trout population trend in Lower Kananaskis Lake, 1990-2002. A zero-bag limit for Bull Trout was implemented in 1992. Bars indicate the number of redds observed in Smith-Dorrien Creek. Points indicate the number of spawning adults that were caught in a trap. Trapping began in May–August and ended in October of each year. Adult abundance in 2001 is estimated (see Johnston et al. 2007 for explantation; F. Johnston unpubl. data). Figure from AESRD and ACA (2009).

Table 2. Summary of Bull Trout surveys and population trends for selected watercourses within the Oldman, Bow and North Saskatchewan River basins, Alberta (modified from AESRD 2012). AESRD (2012) provides the references for these data.

Oldman River Basin

Drainage	Waterbody	Survey Years	Sampling Method	Bull Trout Population Trend[1]	Confidence in Trend Result[2]
Castle	West Castle River	Multiple years between 1990 and 2000, 2008	Electrofishing and redd surveys	Stable	Low
Upper Oldman	Hidden Creek	1995–1998, 2008	Redd surveys	Stable (upper) Declining (lower)	Medium

Bow River Basin

Drainage	Waterbody	Survey Years	Sampling Method	Bull Trout Population Trend[1]	Confidence in Trend Result[2]
Elbow	Canyon Creek	1996, 2005	Electrofishing	Stable	Medium
	Quirk Creek	Multiple years between 1997 and 2007	Electrofishing	Stable (after multiple years of Brook Trout removal)	High
	Elbow River	2002, 2003, 2006, 2007, 2009	Redd surveys	Fluctuating	Medium
Kananaskis	Smith-Dorrien Creek	Multiple years between 1991 and 2002	Redd surveys and fish traps	Increasing	High
Kananaskis	Pocaterra Creek	1982, 1985, 2002, 2006	Electrofishing	Declining (marginal population)	Low
	Spotted Wolf Creek	1982, 1985, 2006, 2008	Electrofishing	Fluctuating (marginal population)	Low
Highwood	Highwood River	Multiple years between 1994 and 2009	Redd surveys	Stable	Medium
	Sheep River	1996, 2003, 2006, 2008	Redd surveys	Increasing	Medium
	Flat Creek	1980, 2006	Electrofishing	Insufficient data	Low

North Saskatchewan River Basin

Drainage	Waterbody	Survey Years	Sampling Method	Bull Trout Population Trend[1]	Confidence in Trend Result[2]
Clearwater	Elk Creek	1979, 1985, 1987, 1998, 2003, 2008	Electrofishing	Increasing	High
	Clearwater River	1975, 1977, 1987, 1992, 1993, 2004	Electrofishing	Insufficient data for population estimates	Medium
	Cutoff, Forbidden and Rocky creeks	1992, 1993, 2004	Electrofishing	Appears stable at very low levels	Low
	Peppers and Seven Mile creeks	1992, 1993, 2004	Electrofishing	Extirpated	Low
	Timber Creek, Sawmill Spring and 40-Mile Spring	Multiple years between 1974 and 2004	Redd surveys	Fluctuating (marginal population)	Medium
Nordegg	Nordegg River	1979, 1999, 2006	Electrofishing	Insufficient data for population estimates	Medium
Cline	Pinto Lake and outlet	1987–88, 1993–94, 2003–04	Electrofishing and fish traps	Fluctuating	High

1. Stable does not imply that the population is healthy, rather that there has been no change in survey results over time.

2. High: high level of confidence in comparing the data over time (i.e., consistent methodologies and habitat conditions),
Medium: medium level of confidence in comparing the data over time (i.e., partially consistent methodologies and habitat conditions),
Low: low level of confidence in comparing data over time (i.e., inconsistent methodologies and habitat conditions)

The restrictive angling regulations have had a less consistent impact on fluvial and resident populations. The fluvial population in Clearwater River (North Saskatchewan River basin) has likely increased, although the data may not be reliable due to changes in study design and the long time-period between assessments (> 10 years) (Rodtka 2005). Abundance estimates in Elk Creek, a tributary of the Clearwater River, declined from 80 Bull Trout/km in 1966 to 13 Bull Trout/km in 1979, then increased to 151 Bull Trout/km in 1998 and appear to have remained stable (S. Herman pers. comm. cited in AESRD and ACA 2009).

Redd counts conducted periodically on the Elbow and Highwood rivers (Bow River basin) have revealed little change in numbers of fluvial Bull Trout redds, while in the Sheep River (Bow River basin) redds increased from 51 in 1996 to 243 in 2006 (although the length of reach surveyed was shorter in 1996) (Popowich and Eisler 2008). Paul et al. (2003) reported that despite significant efforts (e.g., active suppression of non-native Brook Trout, zero-bag limit (1995) and designation of the stream as catch-and-release only (1998), the Bull Trout population of Quirk Creek (tributary of Elbow River) does not appear to be increasing. Bull Trout have made up 10% or less of the electrofishing catch in two stream reaches since the 1990s and their relative abundance has shown wide fluctuations with no apparent trend (Figure 7; Earle et al. 2007). Natural fluctuations, however, are not uncommon. Hunt et al. (1997) documented wide natural fluctuations (2 orders of magnitude in 15 years) in juvenile abundance in Eunice Creek, Alberta (DU 2). This watershed is relatively undisturbed and has been closed to angling for over 20 years. The natural fluctuations in this creek were attributed to competition and cannibalism (Paul et al. 2000).

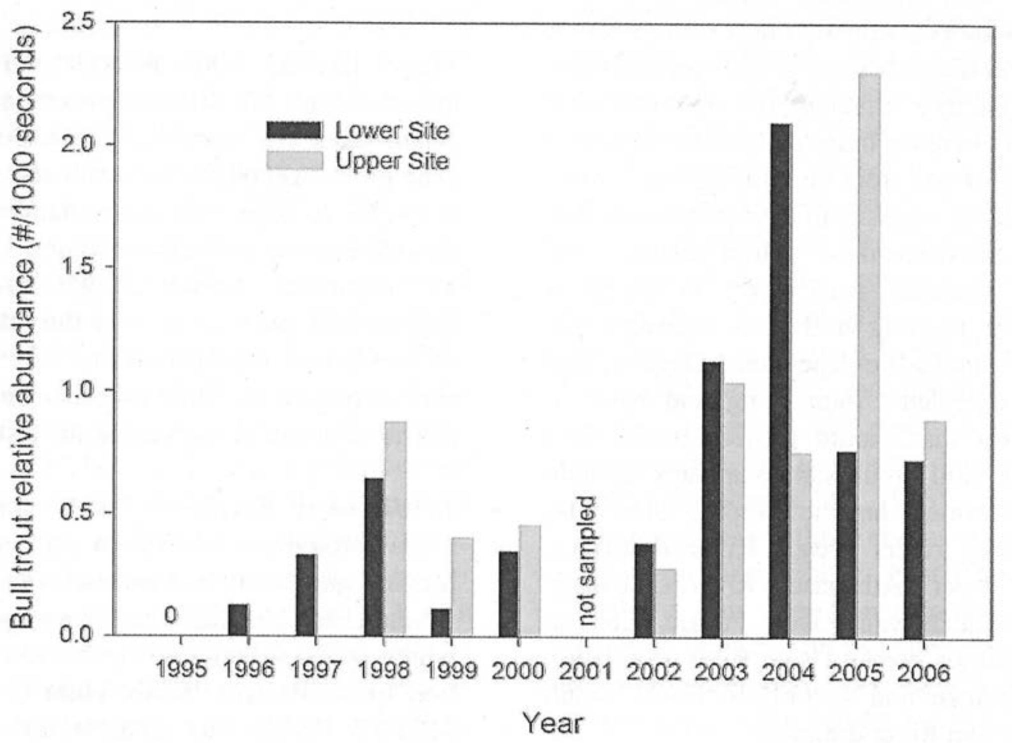

Figure 7. Relative abundance (#/1,000 seconds) of Bull Trout in electrofishing catch at two permanent sample sites established on Quirk Creek, in August to September of 1995–2006. The upper site was not established until 1998; neither site was surveyed in 2001. Catch at the upper site in 2005 likely includes young Brook Trout x Bull Trout hybrids misidentified as Bull Trout. Figure from Earle et al. (2007) and AESRD and ACA (2009).

Population Status Assessment

To assess the population status of Bull Trout in DU 4, the populations were ranked in terms of their abundance (Relative Abundance Index) and trajectory (Population Trajectory) (Table 3). The Relative Abundance Index was assigned as Extirpated, Low, Medium, High or Unknown. The Fish Sustainability Index (Alberta Environment and Parks [AEP] 2013) was used to assess the Bull Trout populations. The population trajectory was assessed as Increasing (an increase in abundance over time), Stable (no change in abundance over time), Decreasing (a decrease in abundance over time) or Unknown.

Table 3. Relative Abundance Index and Population Trajectory of Bull Trout for HUC8s within DU 4. The Relative Abundance Index is based on Alberta Fish Sustainability Index (AEP 2013)

Oldman River Basin

HUC8	HUC Name	Relative Abundance Index	Population Trajectory
04010101	Upper Oldman River	Low	Decreasing
04010102	Crowsnest River	Low	Decreasing
04010103	Castle River	Medium	Decreasing
04010104	Pincher Creek	Low	Stable
04010105	Oldman River below reservoir	Low	Decreasing
04010201	Willow Creek	Extirpated	n/a
04010301	Belly River	Low	Decreasing
04010302	Waterton River	Low	Decreasing
04010401	St. Mary River	Low	Decreasing

Bow River Basin

HUC8	HUC Name	Relative Abundance Index	Population Trajectory
04020101	Upper Bow River	Medium	Decreasing
04020201	Brewster Creek	Low	Decreasing
04020301	Spray Lakes River	Low	Decreasing
04020501	Cascade River	High	Stable
04020401	Bow River and Ghost Reservoir	Low	Decreasing
04020601	Kananaskis River	Low	Decreasing
04020701	Ghost River	Medium	Stable

HUC8	HUC Name	Relative Abundance Index	Population Trajectory
04020801	Bow River and Bighill Creek	Extirpated	n/a
04020802	Jumpingpound Creek	Low	Decreasing
04021001	Elbow River	Low	Decreasing
04021101	Fish Creek	Extirpated	n/a
04021201	Highwood River	Low	Decreasing
04021202	Sheep River	Low	Decreasing

Red Deer River Basin

HUC8	HUC Name	Relative Abundance Index	Population Trajectory
08010101	Upper Red Deer River	Low	Decreasing
08010102	Panther River	Low	Decreasing
08010103	Fallentimber Creek	Low	Decreasing
08010104	James River	Low	Decreasing
08010201	Red Deer River and Gleniffer Lake	Low	Decreasing
08010202	Raven River	Extirpated	n/a
08010203	Little Red Deer River	Low	Decreasing

North Saskatchewan River Basin

HUC8	HUC Name	Relative Abundance Index	Population Trajectory
11010101	North Saskatchewan above Abraham	High	Stable
11010102	Siffleur River	Medium	Stable
11010103	Cline River	High	Stable
11010201	North Saskatchewan below Abraham	Low	Decreasing
11010202	Ram River	Medium	Stable
11010203	Baptiste River	Low	Decreasing
11010301	Clearwater River	Medium	Decreasing

HUC8	HUC Name	Relative Abundance Index	Population Trajectory
11010302	Prairie Creek	Low	Decreasing
11010401	Brazeau River	Medium	Decreasing
11010402	Cardinal River	Low	Decreasing
11010403	Blackstone River	Medium	Decreasing
11010404	Elk River	Low	Decreasing
11010405	Brazeau Canal	Extirpated	n/a
11010406	Nordegg River	Medium	Decreasing
11020101	North Saskatchewan above Wabamun	Extirpated	n/a
11020102	Wolf Creek	Extirpated	n/a

The Relative Abundance Index and Population Trajectory values were then combined in the Population Status Matrix (Table 4) to determine the Population Status (Poor, Fair, Good, Unknown or Extirpated) (Table 5). The certainty of the Population Status is reflective of the certainty associated with the initial parameters, determined using quantitative data and/or expert opinion. Twenty-five populations were rated Poor, three were rated Fair, three were rated Good, two Unknown and three Extirpated.

Table 4. The Population Status Matrix combines the Relative Abundance Index and Population Trajectory rankings to establish the Population Status of Bull Trout for HUC8s in DU 4. The resulting Population Status has been categorized as Poor, Fair, Good, Unknown or Extirpated.

		Population Trajectory			
		Increasing	Stable	Decreasing	Unknown
Relative Abundance Index	Low	Poor	Poor	Poor	Poor
	Medium	Fair	Fair	Poor	Poor
	High	Good	Good	Fair	Fair
	Unknown	Unknown	Unknown	Unknown	Unknown
	Extirpated	Extirpated	Extirpated	Extirpated	Extirpated

Table 5. Population Status of Bull Trout for HUC8s within DU 4, resulting from an analysis of both the Relative Abundance Index and Population Trajectory.

Oldman River Basin

HUC8 Population	Population Status
04010101 (Upper Oldman River)	**Poor**
04010102 (Crowsnest River)	**Poor**
04010103 (Castle River)	**Poor**
04010104 (Pincher Creek)	**Poor**
04010105 (Oldman River below Oldman Reservoir)	**Poor**
04010201 (Willow Creek)	**Extirpated**
04010301 (Belly River)	**Poor**
04010302 (Waterton River)	**Poor**
04010401 (St. Mary River)	**Poor**

Bow River Basin

HUC8 Population	Population Status
04020101 (Upper Bow River)	**Poor**
04020201 (Brewster Creek)	**Poor**
04020301 (Spray Lakes River)	**Poor**
04020501 (Cascade River)	**Good**
04020401 (Bow River and Ghost Reservoir)	**Poor**
04020601 (Kananaskis River)	**Poor**
04020701 (Ghost River)	**Fair**
04020801 (Bow River and Bighill Creek)	**Extirpated**
04020802 (Jumpingpound Creek)	**Poor**
04021001 (Elbow River)	**Poor**
04021101 (Fish Creek)	**Extirpated**
04021201 (Highwood River)	**Poor**
04021202 (Sheep River)	**Poor**

Red Deer River Basin

HUC8 Population	Population Status
08010101 (Upper Red Deer River)	Poor
08010102 (Panther River)	Poor
08010103 (Fallentimber Creek)	Poor
08010104 (James River)	Poor
08010201 (Red Deer River and Gleniffer Lake)	Poor
08010202 (Raven River)	Extirpated
08010203 (Little Red Deer River)	Poor

North Saskatchewan River Basin

HUC8 Population	Population Status
11010101 (North Saskatchewan above Abraham)	Good
11010102 (Siffleur River)	Fair
11010103 (Cline River)	Good
11010201 (North Saskatchewan below Abraham)	Poor
11010202 (Ram River)	Fair
11010203 (Baptiste River)	Poor
11010301 (Clearwater River)	Poor
11010302 (Prairie Creek)	Poor
11010401 (Brazeau River)	Poor
11010402 (Cardinal River)	Poor
11010403 (Blackstone River)	Poor
11010404 (Elk River)	Poor
11010405 (Brazeau Canal)	Extirpated
11010406 (Nordegg River)	Poor
11020101 (North Saskatchewan above Wabamun)	Extirpated
11020102 (Wolf Creek)	Extirpated

HABITAT REQUIREMENTS

The habitat requirements of Bull Trout are specific and are often characterized by the “Four Cs”; cold, clean, complex and connected (USFWS 2000). General habitat requirements of stream resident, fluvial and adfluvial Bull Trout are summarized in Stewart et al. (2007) and AESRD (2012). Life history types present in waters occupied by Bull Trout in DU 4 are shown in Table 1.

Stream Resident

These fish live permanently in the small, cold spawning tributary streams and often spawn and overwinter within a 2 km section of river (Jakober et al. 1998, Chandler et al. 2001). They are strongly associated with pool habitat and instream and overhead cover. They may be connected to migrant populations or be fully or partially isolated by natural barriers. In the West Castle River (Oldman River basin), resident juveniles and adults overwinter in small, shallow pools with a maximum depth of 0.4–1.5 m. These pools are isolated from one another, provide little cover and receive flow from groundwater springs (Boag and Hvenegaard 1997). Seasonal and perennial groundwater upwellings are an important component of Bull Trout habitat for all life history types. Seasonal upwellings provide residents with cold-water refugia in summer and perennial upwellings provide warm-water refugia in winter (Baxter and Hauer 2000). Stream resident Bull Trout are active during the night throughout the winter on or above the substrate, even during extreme temperature and ice conditions (Jakober 1995, Jakober et al. 2000). Small fish (< 200 mm) seek cover in large substrates and large woody debris.

Fluvial

Fluvial populations occupy rivers and major tributaries and move into high gradient smaller rivers and tributary streams to spawn (Bahr and Shrimpton 2004). In addition to spawning habitat, these smaller rivers and streams provide rearing habitat for young-of-the-year and young juveniles. Spawning in the mainstems of the rivers and major tributaries occupied by older juveniles and adults has not been documented although suitable spawning habitat may exist and spawning could be possible in these rivers.

Fluvial adults may undertake extensive seasonal migrations, typically upstream to spawning tributaries in May to August and downstream to overwintering areas by late September to early October (Pattenden et al. 1991, McLeod and Clayton 1993, 1997, Fernet and O’Neil 1997, Swanberg 1997, Burrows et al. 2001, Hemmingsen et al. 2001, Bahr and Shrimpton 2004, Pillipow and Williamson 2004, Hurkett and Blackburn 2015). These migrations may be lengthy (up to 500 km) and demonstrate the spatial scale and habitat diversity required by fluvial populations (Swanberg 1997), the importance of high quality spawning habitat (Pillipow and Williamson 2004) and the importance of stream connectivity (USFWS 2000, Muhlfeld and Marotz 2005, Stewart et al. 2007). In a study conducted in the upper North Saskatchewan River area, Bull Trout were found to begin spawning migrations as early as mid-June in 2003 and July in 2002 (Fontana et al. 2006). As found in other Bull Trout movement studies (Fraley and Shepard 1989, McLeod and Clayton 1997, Swanberg 1997, Hvenegaard and Fairless 1998), the majority of Bull Trout entered spawning tributaries before the end of August. Early initiation of spawning migrations has also been observed in the Peace River (DU 2; R.L. and L. 1992), the upper Athabasca River (DU 2; McLeod and Clayton 1997) and the Blackfoot River (Montana; Swanberg 1997). Spawning migrations in the North Saskatchewan River area in 2002 and 2003 were initiated earlier than has been documented in the Clearwater River and the Kakwa River (DU 2; Hvenegaard and Fairless 1998) drainages (Fontana et al. 2006).

It has been suggested that the onset of spawning migrations is triggered by declining water temperature and shortening day lengths (Swanberg 1997). McPhail and Murray (1979 cited in

Stewart et al. 2007) found migrations peaked at water temperatures of 10–12 °C, but this varies among rivers. Fish that migrate longer distances and gain elevation or that migrate through systems with a higher seasonal decline in flow following the spring freshet (Thiesfeld et al. 1996) or are in unfavourable temperature conditions (Swanberg 1997) may begin the spawning migration earlier in the season (Stewart et al. 2007). In the upper North Saskatchewan River area, return migrations to overwintering areas occurred from September to the end of October and were completed by early December (Fontana et al. 2006). Return migrations may be triggered by declining water temperature (Jakober et al. 1998) and low stream flows (Swanberg 1997). In some systems, fluvial Bull Trout exhibit a strong fidelity to spawning tributaries and overwintering areas (Bahr and Shrimpton 2004), but in others they change spawning locations over time (Pratt 1992). Movements during the winter are typically minimal (McLeod and Clayton 1997, Hvenegaard and Fairless 1998, Chandler et al. 2001, Fontana et al. 2006).

Adfluvial

Adfluvial Bull Trout reside in lakes and move into high gradient small rivers and tributary streams to spawn (Fraley and Shepard 1989, Ratcliff et al. 1996, Olmsted et al. 2001). Spawning within lakes has not been documented. Juvenile rearing begins in the spawning stream. They eventually move downstream into large rivers or lakes to feed, mature and overwinter. Larger adults more often feed and overwinter in lakes (Connor et al. 1997). Spawning migration distance varies depending on the availability and location of suitable spawning habitat. In high, isolated oligotrophic lakes (e.g., Pinto and Harrison lakes, Alberta), spawning habitat is usually located a short distance upstream in the lake inlet or downstream in the outlet (Herman 1997, Wilhelm et al. 1999). Habitat use within lakes shifts with the season and changing water temperatures (MBTSG 1998). Bull Trout are generally more evenly distributed under isothermal conditions, but seek cool, deep water in the summer. They typically rest near the substrate during the day and forage in the littoral zone at night.

Spawning and Incubation Habitat

High quality spawning habitat and access to it (i.e., connectivity) is essential for maintaining healthy populations of Bull Trout. Successful incubation depends upon temperature, gravel composition, permeability and surface flow (COSEWIC 2012). Spawning streams are typically high elevation, structurally complex, shallow headwater or tributary streams with stable channels (Burrows et al. 2001, Ripley et al. 2005, Decker and Hagen 2008, COSEWIC 2012). The structural complexity ensures habitat for both spawning adults and rearing juveniles. Adults undergo a behavioural shift in habitat use once in the natal stream (after migration for fluvial and adfluvial Bull Trout) towards a pattern of seeking cover during the day in woody debris and substrate crevices and emerging at night (Jakober et al. 2000). They spawn in flowing water in coarse gravel–cobble substrates with low levels of fine sediment (AESRD 2012). In experimental studies, hatching success was found to be inversely related to percent fine material (< 6.35 mm); survival to emergence ranged from 49–69% in substrates with 10% fines to 0–4% in substrates with 50% fines (Weaver and White 1985, Weaver and Fraley 1991, Stewart et al. 2007).

Redds are typically constructed at sites associated with perennial groundwater upwellings. These upwellings are a very important component of Bull Trout spawning habitat. Eggs incubate over the winter, thus are vulnerable to sediment accumulation, anchor ice accumulations, scouring, low flows and freezing (AESRD 2012, COSEWIC 2012). Groundwater upwellings stabilise temperatures through the winter, provide stable flows and prevent anchor and frazil ice formation (Bonneau and Scarnecchia 1998). Within these areas of upwelling, they often select localized spots of strong downwelling and high intergravel flows, increasing aeration of eggs

(Baxter and Hauer 2000, COSEWIC 2012). Water above the redds and in the interstitial spaces is well oxygenated (e.g., 10–11.5 mg/L and 8–12 mg/L, respectively) (Weaver and White 1985, Fairless et al. 1994). Hatching of eggs incubated at 5 mg/L was minimally delayed and post-hatch alevins were smaller and therefore less likely to survive (Chambers et al. 2000b). Water velocities at spawning sites range from 2–92 cm/s and depths from 0.07–0.93 m (Fernet and Bjornson 1997, James and Sexauer 1997, Baxter and McPhail 1999, Stewart et al. 2007). The area disturbed by redd construction varies from 0.5–3.72 m^2 (Goetz 1989). Larger female spawners can bury eggs deeper (DeVries 1997) in coarser substrates, closer to the center of the channel reducing the likelihood of freezing or dessication from low flows (Berry 1994, Fairless et al. 1994, AESRD 2012). In Dutch Creek (Oldman River drainage), the majority of redds were located in gravel substrate under woody debris, overhanging vegetation or undercut banks (Hurkett et al. 2011). Overhead cover has been found to be important in other regions as well, for example Craig (1997) observed higher redd densities in areas with > 54% overhead cover in the Yakima River basin, Washington.

Fry and Young Juvenile Rearing Habitat

Eggs hatch in late spring and yolk absorption takes 65 to 90 days (Shepard et al. 1984). Neutral buoyancy is attained three weeks after yolk absorption is complete (McPhail and Murray 1979 cited in Stewart et al. 2007). Negative buoyancy at emergence makes feeding difficult but allows fry to maintain their position within the stream (Stewart et al. 2007). At this stage, fry are typically found in shallow, low-velocity stream margins with an abundance of cover and coarse cobble-boulder substrate (Fraley and Shepard 1989, Baxter 1997a,b, Pollard and Down 2001, Spangler and Scarnecchia 2001, Cope et al. 2002). Once they are neutrally buoyant, fry exhibit diel habitat shifts; the majority are generally out of cover from late morning to early evening and return to cover about 2 hours before dusk (Goetz 1997a).

As they grow they typically move to deeper, faster-flowing water and prefer pools over riffles (Bonneau and Scarnecchia 1998, Pollard and Down 2001, Spangler and Scarnecchia 2001). Microhabitat use of young juveniles shifts daily and seasonally. They remain near cover during the day, dispersing at night. This pattern is common during all seasons but is particularly evident in winter (Bonneau and Scarnecchia 1998, Jakober et al. 2000). In laboratory studies, age-1 Bull Trout preferred cobble and boulder substrate during the day and silt and gravel at night, shallower, lower velocity water was also preferred during the day (Baxter and McPhail 1997). Similar habitat use has been observed in the wild (Goetz 1997a). In fall, young juveniles generally move to deeper, low velocity areas with coarse substrates where they remain near the substrate and close to cover (Bonneau and Scarnecchia 1998, Spangler and Scarnecchia 2001). Shade, undercut banks and large woody debris are used for cover where available. These habitat features are less common at higher latitudes and/or elevations so pocket pools, rootwads, cobbles, boulders and overhanging vegetation are used instead (Mochnacz et al. 2004). In the West Castle River drainage, young-of-the-year overwinter within and upstream of the spawning area in interstitial sub-surface flow under the dry channel bed (Boag and Hvenegaard 1997).

Older Juvenile and Adult Foraging and Overwintering Habitat

Juveniles move out of rearing streams into larger rivers generally by age 3–4 (Fraley and Shepard 1989), but in Alberta they may stay in rearing areas for up to six years (Allan 1980). As they grow larger than 100 mm total length (TL), juveniles become less associated with the substrate but remain near cover (Fraley and Shepard 1989). In rivers, older juveniles and adults prefer low-velocity water, are often associated with the tail-outs of pools and remain near cover (Clayton 1999, Popowich 2005, McPhail 2007). Perrenial groundwater upwellings and overhead and/or instream cover are important components of overwintering habitat (Goetz 1997b). In lakes, Bull Trout are generally more abundant in deeper, cooler water (Connor et al. 1997, MBTSG 1998, MBTRT 2000). They typically rest on the bottom during the day and move into the littoral zone to forage at night (Connor et al. 1997, McPhail 2007).

Habitat Availability

The spatial extent of spawning, rearing, foraging and overwintering habitat has not been quantified for Bull Trout in DU 4. Waterbodies for which spawning and/or overwintering habitat has been identified are summarized below (this list is not exhaustive). Redds are often concentrated in specific areas even though larger areas of suitable habitat appear to be available. This can be so pronounced in some systems that a high degree of redd superimposition occurs (Baxter and McPhail 1996).

Oldman River Basin

Redds have been located in nine watercourses within the Castle River drainage – South Castle River, West Castle River, Carbondale River, and Mill, Gardiner, Whitney, South Lost, North Lost and Lost creeks (Figure 8 a-d; Hurkett et al. 2012, 2013, 2014, Hurkett and Blackburn 2015). In total, 68 km of spawning habitat has been identified and characterized in the Castle River drainage (Hurkett and Blackburn 2015). Suitable spawning habitat was also observed in Scarpe and Gladstone creeks; however, evidence of spawning activity was not observed at these sites (Hurkett and Blackburn 2015). Spawning habitat in each sub-drainage is described in Hurkett and Blackburn (2015). In general, spawning occurred in run-type reaches in low gradient and flood plain sections with groundwater influence (either upwellings or bank seeps) with fine to moderate-sized gravel substrate and an average depth of 30 cm. In the South Castle River, Bull Trout spawning activity in a main spawning area was relocated to a new channel in 2012 when the river re-channelized (Hurkett and Blackburn 2015). In the West Castle River, spawning activity was observed within a 50 m section of river that contained groundwater input and juveniles and adults overwintered in shallow isolated pools associated with groundwater upwellings with little overhead cover (Boag and Hvenegaard 1997). Overwintering pools were separated by lengths of channel with no visible surface flow. Suitable overwintering habitat has also been documented in Mill Creek; Carbondale River and Gardiner, North Lost, South Lost and Lost creeks provide minimal overwintering habitat (Hurkett and Blackburn 2015). Bull Trout populations in Carbondale and South Castle rivers and Mill Creek are primarily migratory and smaller numbers of resident Bull Trout are present in South Castle River and Mill Creek (Hurkett and Blackburn 2015). Bull Trout in West Castle River are primarily resident and a small number are migratory (RL&L 1992b, Warnock 2008, Hurkett and Blackburn 2015). Data from Hurkett and Blackburn (2015) and other tagging studies (Hurkett et al. 2011, Matt Coombs, ESRD, pers. comm. in Hurkett and Blackburn 2015) identified an extensive Bull Trout migratory network between the Castle River drainage and the Crowsnest River and Upper Oldman River drainages. Bull Trout from the Carbondale River had the most extensive migratory network and all migratory Bull Trout were found to exhibit high stream fidelity (Hurkett and Blackburn 2015).

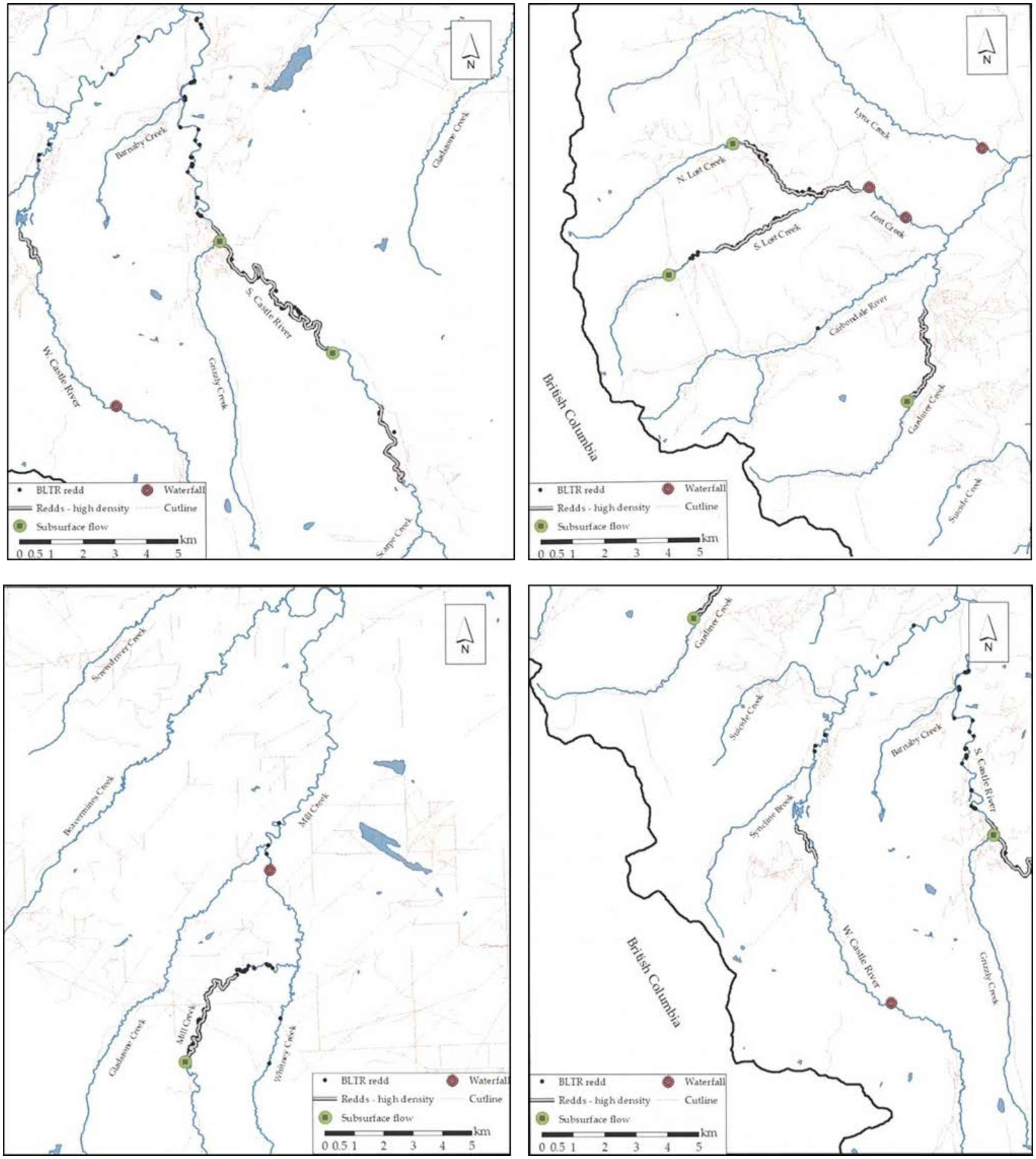

Figure 8. Location of BullTrout redds observed in the Castle River drainage, 2011–2014 (from Hurkett and Blackburn 2015). A) South Castle River, B) Carbondale River sub-drainage, C) Mill Creek sub-drainage, D) West Castle River.

In the Upper Oldman River drainage, spawning habitat has been documented in seven watercourses and overwintering habitat in four (Hurkett et al. 2011). Hidden Creek contains the largest migratory Bull Trout population in the Oldman River drainage (there are a few stream-residents present, but the majority are migratory) (Hurkett et al. 2011). Hidden Creek Falls are a seasonal barrier. The highest density of Bull Trout redds in Hidden Creek was observed in a

100 m reach of stream approximately 200 m downstream of the falls (Figure 9). Between 2008 and 2009, redd size ranged from 40–330 cm in length and 20–150 cm in width. Between 2007 and 2010, spawning activity peaked between the last week of August and mid-September.

Locations where redds were observed in the Livingstone River are indicated in Figure 9. Hurkett et al. (2011) found redds upstream of the falls, indicating stream-resident Bull Trout are present and confirming the observations of Warnock (2008). Most redds were found along the river margins in association with overhanging vegetation and/or large woody debris. Redds were also observed in the center of the channel under woody debris or in deep water and along the upstream end of an active beaver dam approximately 30 m upstream from the Isolation Creek bridge crossing (Hurkett et al. 2011). Between 2008 and 2010, redd size ranged from 40–280 cm in length and 25–100 cm in width. The lower reach of Livingstone River has many large deep pools which are used as overwintering habitat for adult Bull Trout from Hidden, Racehorse and Dutch creeks (Hurkett et al. 2011).

Racehorse Creek contains migratory and likely stream resident (South Racehorse Creek above the falls located 2 km upstream from the mouth) Bull Trout. In Racehorse Creek, five redds were found in 2010 downstream of a major logjam that was likely a barrier (Figure 9). The redds were located beneath vegetation or large woody debris in gravel substrate; high flows in 2010 washed out 2 of the 5 redds (Hurkett et al. 2011). In South Racehorse Creek, redds were located in run sections without cover in gravel substrate (Hurkett et al. 2011). In 2009 and 2010, redd size ranged from 40–320 cm in length and 15–70 cm in width. North Racehorse Creek was historically documented as a Bull Trout spawning reach (Gerrand and Watmough 1996, Gerrand and DeRosa 1997, both cited in Hurkett et al. 2011) but redds were not detected by Hurkett et al. (2011). The stream channel was observed to be relatively shallow with many logjams and silty substrates and is likely no longer suitable Bull Trout spawning habitat. Racehorse Creek also likely provides overwintering habitat for post-spawn migratory Bull Trout from Hidden Creek (Hurkett et al. 2011).

Dutch Creek contains migratory and stream resident Bull Trout. A large logjam on the creek has likely blocked migration and created an isolated population – however, relatively large Bull Trout (> 400 mm) were observed spawning upstream of this barrier and it was uncertain whether these were isolated migratory fish or stream resident fish (Hurkett et al. 2011). Between 2008 and 2010, spawning occurred throughout September. Redds were located in areas with groundwater upwellings in gravel substrate and under woody debris, overhanging vegetation or undercut banks (Figure 9; Hurkett et al. 2011). The highest density of redds was observed directly upstream of the Atlas Road bridge crossing where groundwater input and sub-surface flow were consistent. Redd size in Dutch Creek between 2008 and 2010 ranged from 50–350 cm in length and 25–200 cm in width.

In the upper Oldman River, Bull Trout were observed spawning during the first half of September. Most redds were located along the river margins in areas lacking cover with medium-sized gravel substrate that was clear of algae and silt throughout the fall (Figure 9; Hurkett et al. 2011). Redd size in 2009 and 2010 ranged from 60–190 cm in length and 30–150 cm in width. Redds were also documented in a 1.5 km reach of Savanna Creek (Figure 9) and a 5 km reach (from the mouth, upstream) of Daisy Creek (Figure 9). Redds were not detected in surveys of Mean Creek and Isolation Creek conducted in 2009 (Hurkett et al. 2011).

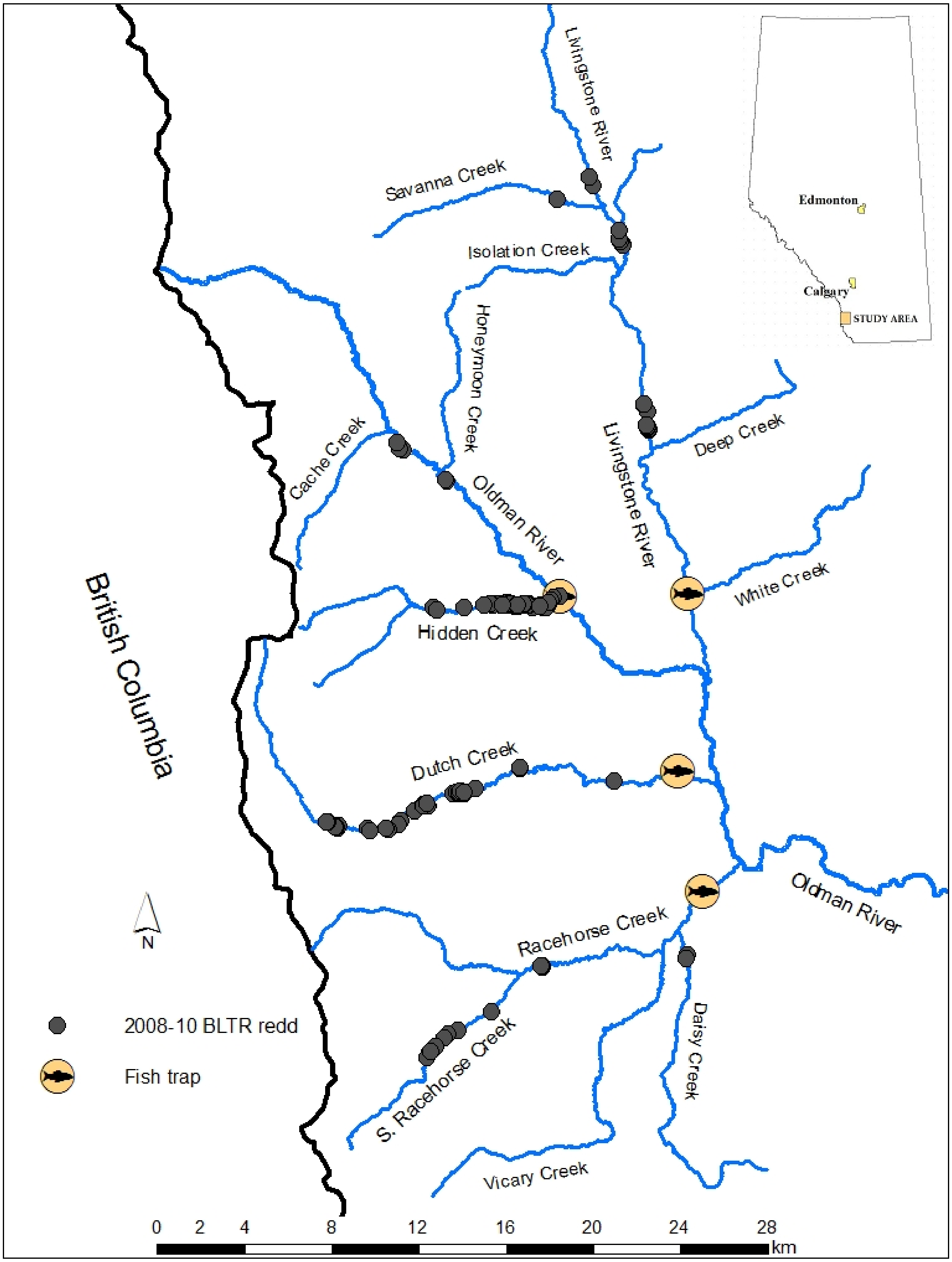

Figure 9. Location of Bull Trout redds observed in the upper Oldman River and tributaries 2008–2010 (from Hurkett et al. 2011).

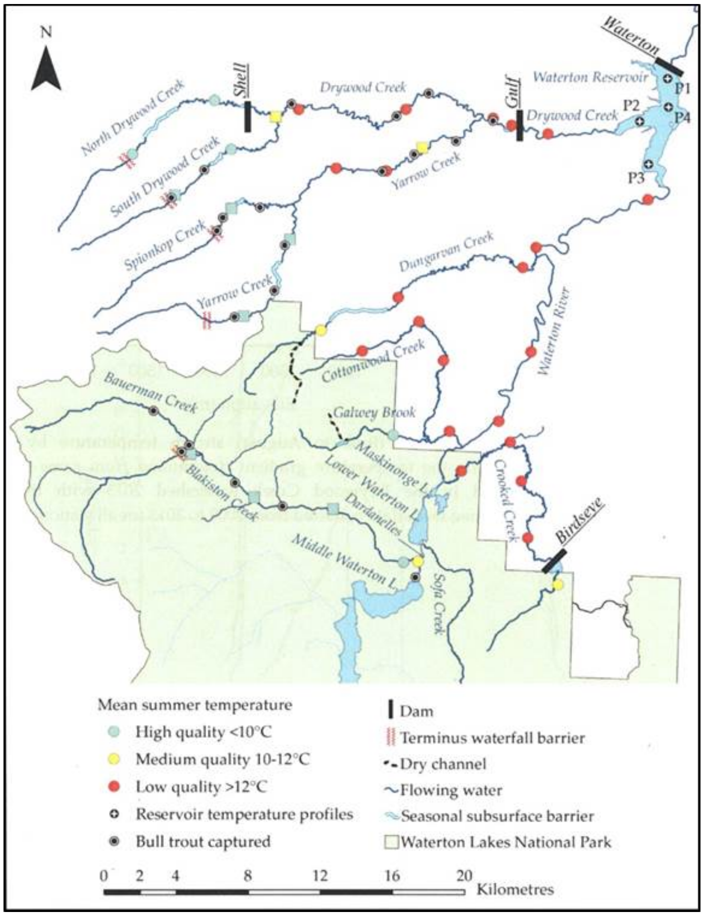

Figure 10. Bull Trout capture sites and thermal habitat quality in the Waterton River watershed study area of Blackburn et al. (2014). Circles represent temperature data collected by ACA in 2012 and 2013; squares represent temperature data collected by the University of Lethbridge from 2009 to 2011 (Warnock 2012). From Blackburn et al. (2014).

In the Waterton River drainage, six high quality thermal habitat areas (mean summer temperature < 10 °C; see Isaak et al. 2009) were identified by Blackburn et al. (2014). These included North Drywood, South Drywood, Spionkop, Yarrow, upper Galwey and Blackiston creeks (Figure 10). Galwey and North Drywood creeks are fragmented by migration barriers, thus Bull Trout were not captured in these locations.

Bow River Basin

Redds have been located in the Elbow (Figure 11), Sheep (Figure 12) and Highwood (Figure 13) rivers and in Storm (Figure 13) and Canyon creeks (Figure 14) (Buchwald et al. 2006 cited in Popowich and Eisler 2008, Popowich and Eisler 2008). The adfluvial population in Kananaskis Lakes spawns in Smith-Dorrien Creek (Stelfox 1997). The majority of spawning occurs during the first three weeks of September in a 2 km section of the creek between James Walker Creek and the first impassable beaver dam (Stelfox 1997). Overwintering habitat in the Bow River Basin has not been documented.

Red Deer River Basin

Spawning and rearing habitat has been documented in four watercourses in the Upper Red Deer River basin – Pinto Creek and an unnamed tributary to Pinto Creek (Figure 15) and Sheep and North Burnt Timber creeks (Fitzsimmons et al. 2010, 2012).

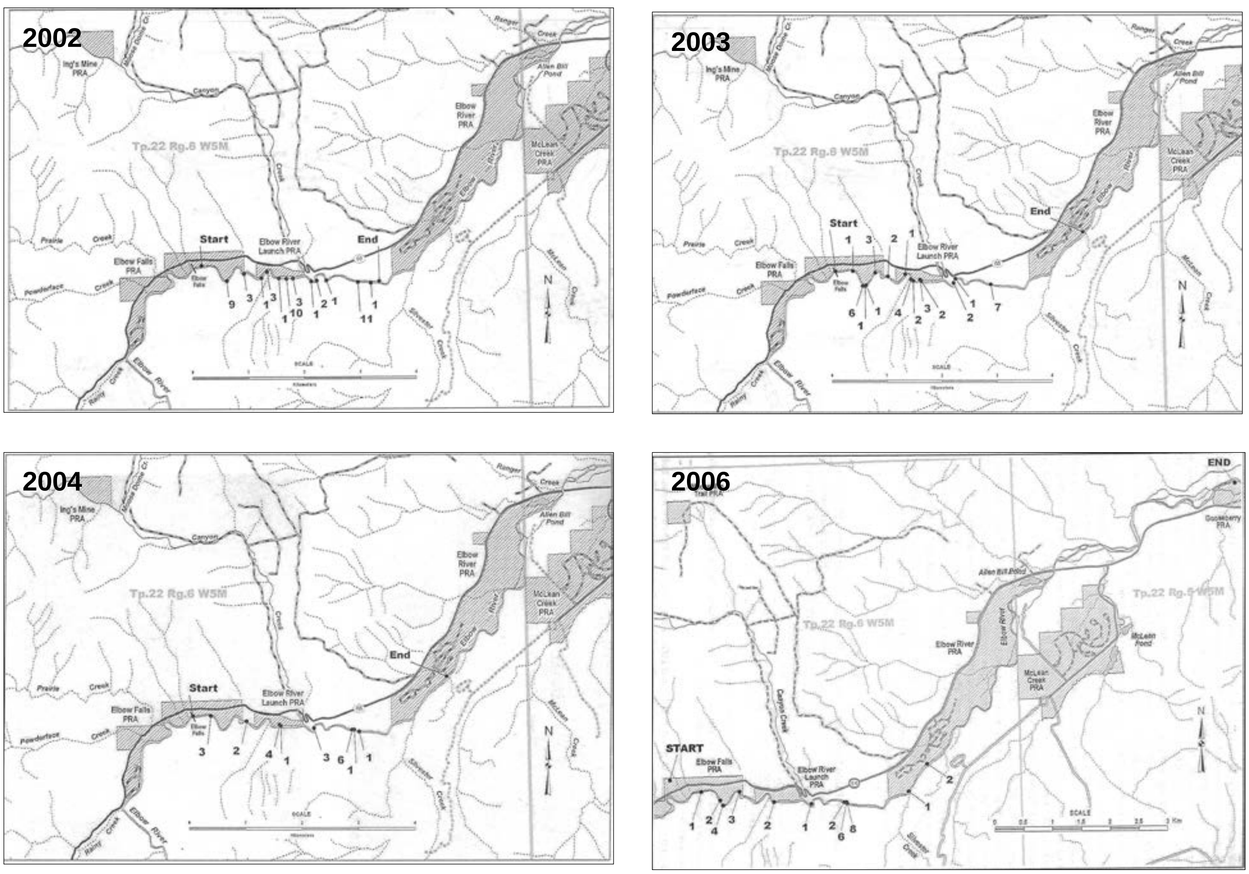

Figure 11. Location and number of Bull Trout redds observed in the Elbow River in 2002, 2003, 2004 and 2006 (from Popowich and Eisler 2008).

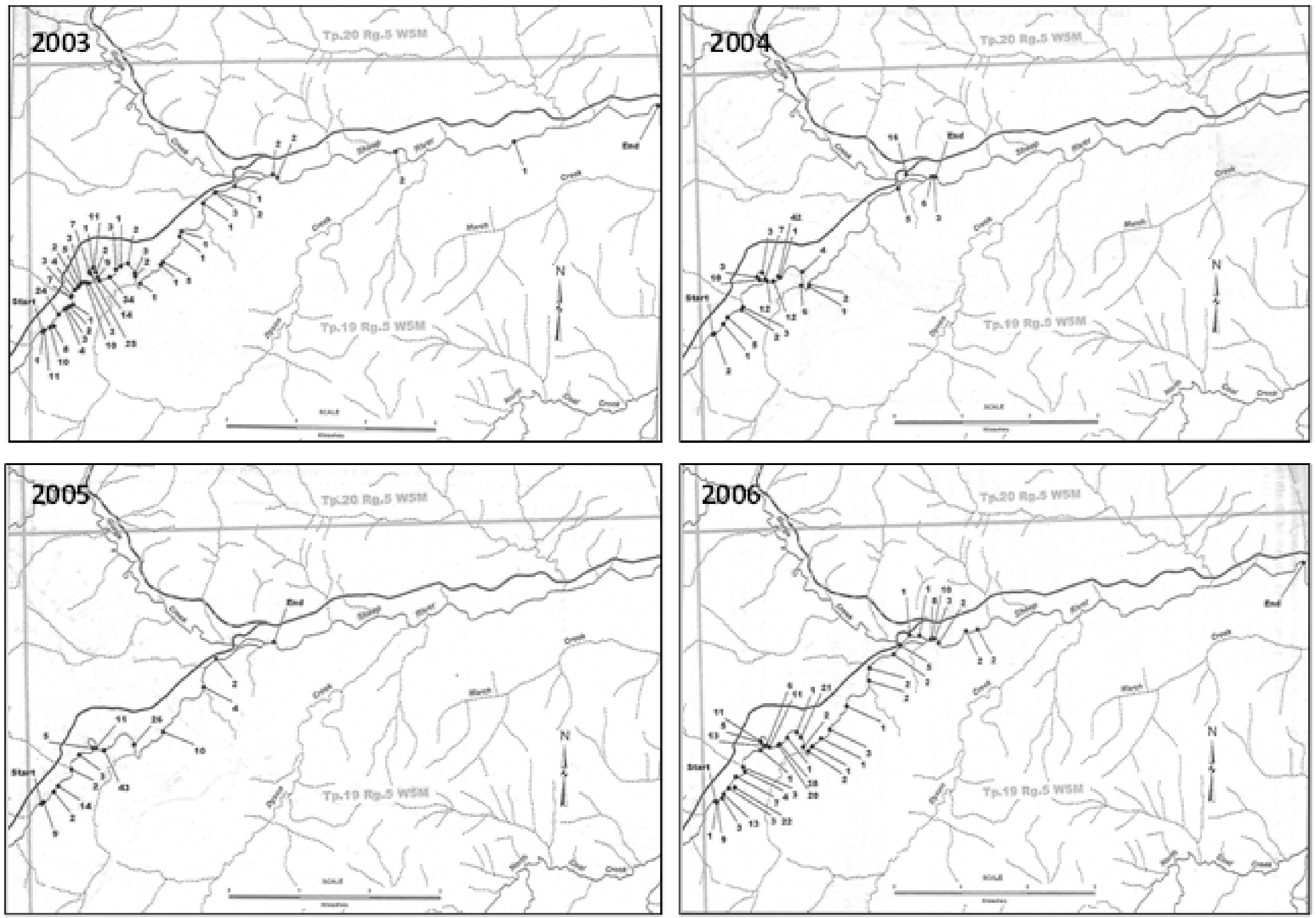

Figure 12. Location and number of Bull Trout redds observed in Sheep Creek, 2003–2006 (from Popowich and Eisler 2008).

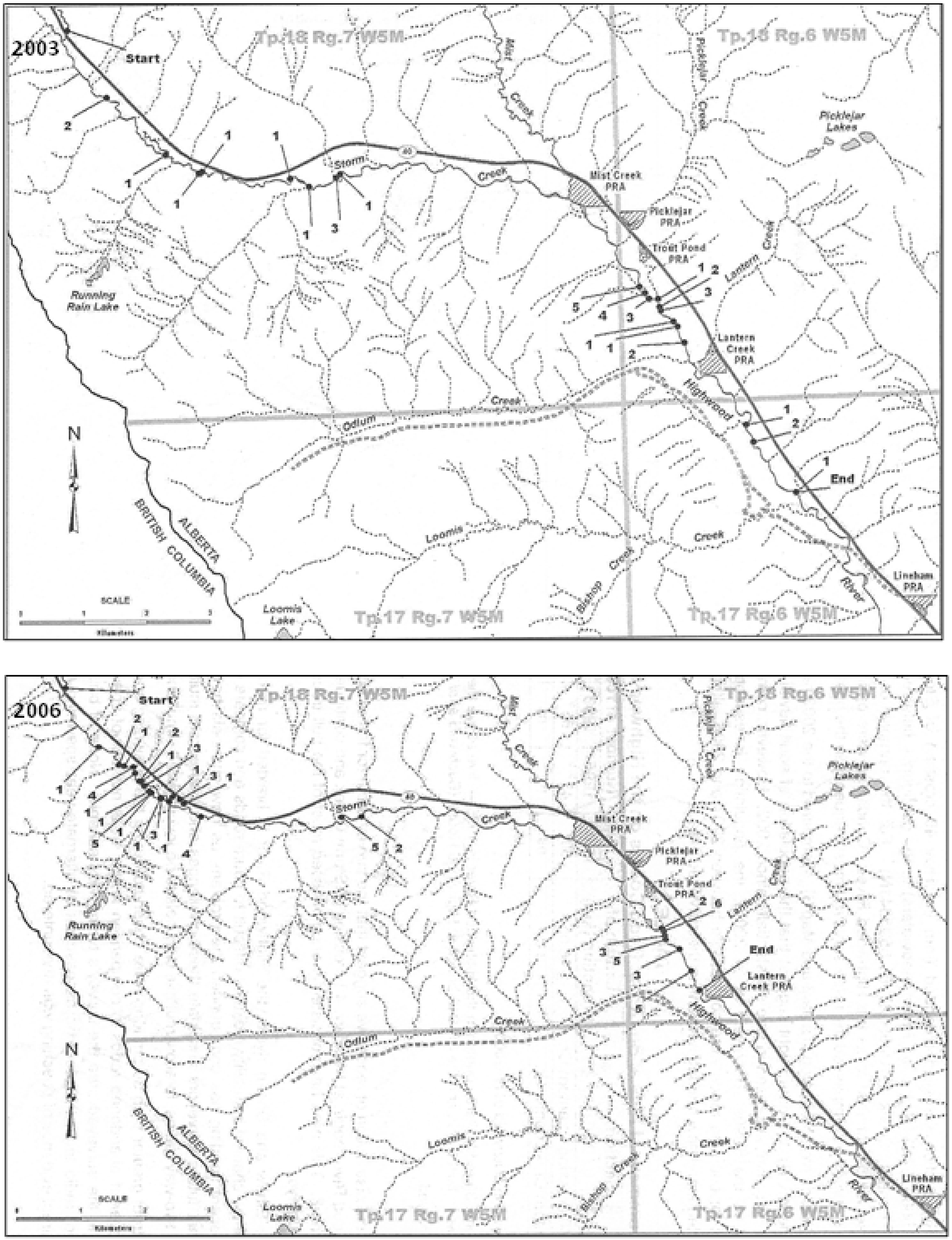

Figure 13. Location and number of Bull Trout redds observed in the Highwood River and Storm Creek in 2003 and 2006 (from Popowich and Eisler 2008).

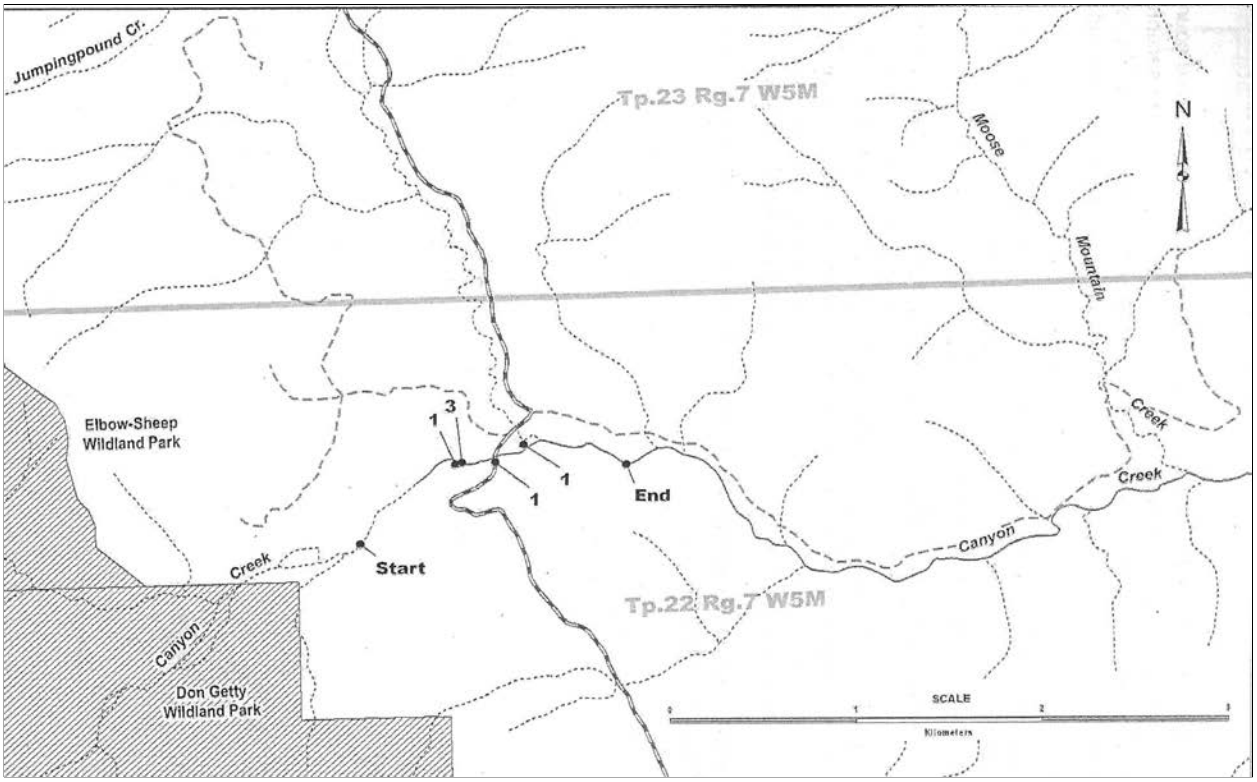

Figure 14. Location and number of Bull Trout redds observed in Canyon Creek in 2006 (from Popowich and Eisler 2008).

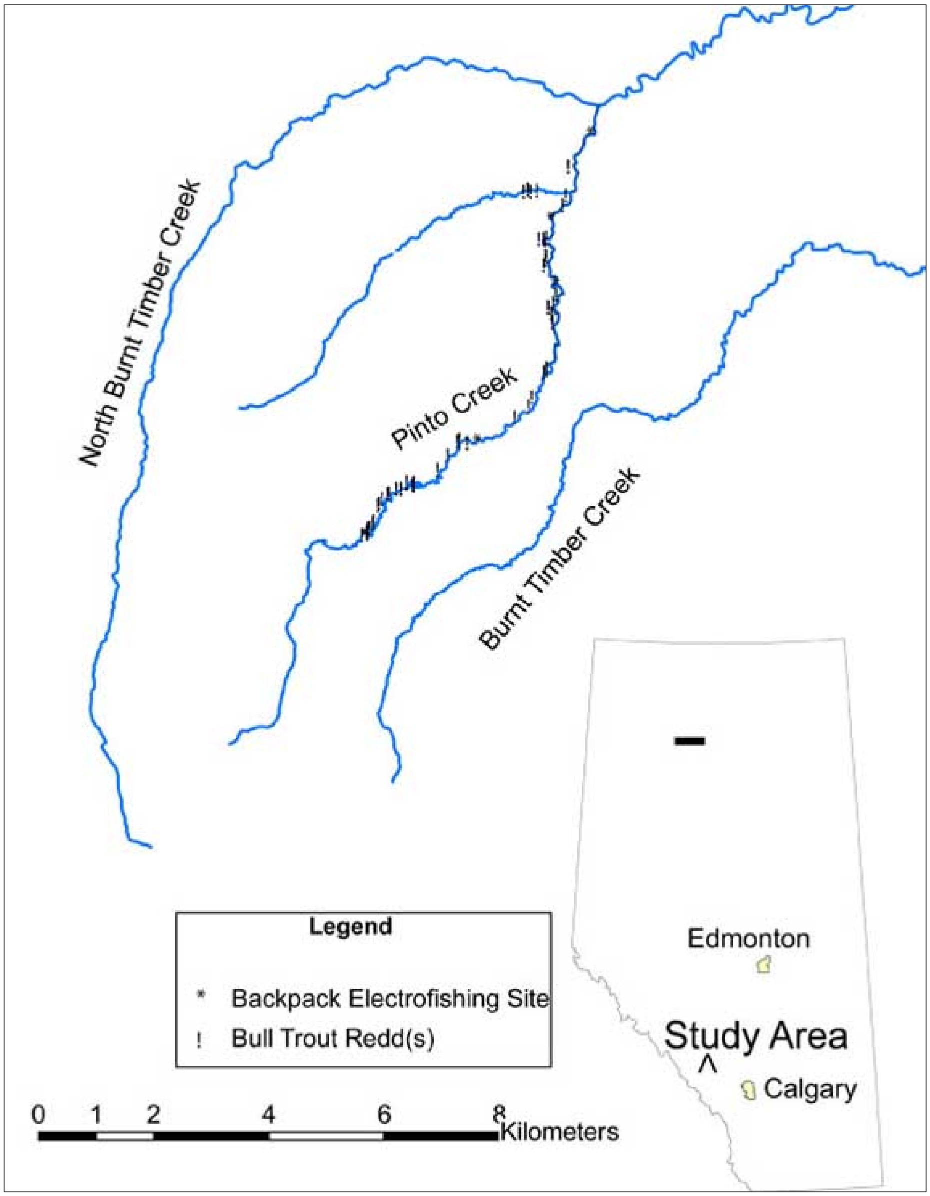

Figure 15. Location of Bull Trout redds observed in Pinto Creek in 2009 (from Fitzsimmons et al. 2010).

North Saskatchewan River Basin

Spawning and overwintering habitat have been documented in several watercourses within this basin. In Fall Creek, the majority of redds were located within the uppermost 1.5 km of stream that was accessible to Bull Trout (i.e., stream km 6.0–7.5) (Rodtka et al. 2010). A spawning population was identified through microsatellite DNA analysis in the Ram River drainage, but spawning locations are unknown (Rodtka et al. 2010). Overwintering habitat was identified in the Clearwater, North Saskatchewan and Ram rivers (Figure 16; Rodtka et al. 2010).

In the upper North Saskatchewan drainage, spawning habitat was identified in Unnamed Creek #22932 (tributary to Howse River) and in Owen Creek (Figure 17; Fontana et al. 2006). Based on captures in summer and fall, spawning habitat may also be present in Loudon, Spreading, Tershishner and Whitegoat creeks and in several unnamed tributaries (see Gardiner et al. 2001, Rodtka 2002). The majority (94%) of the adfluvial population in Pinto Lake spawn in the

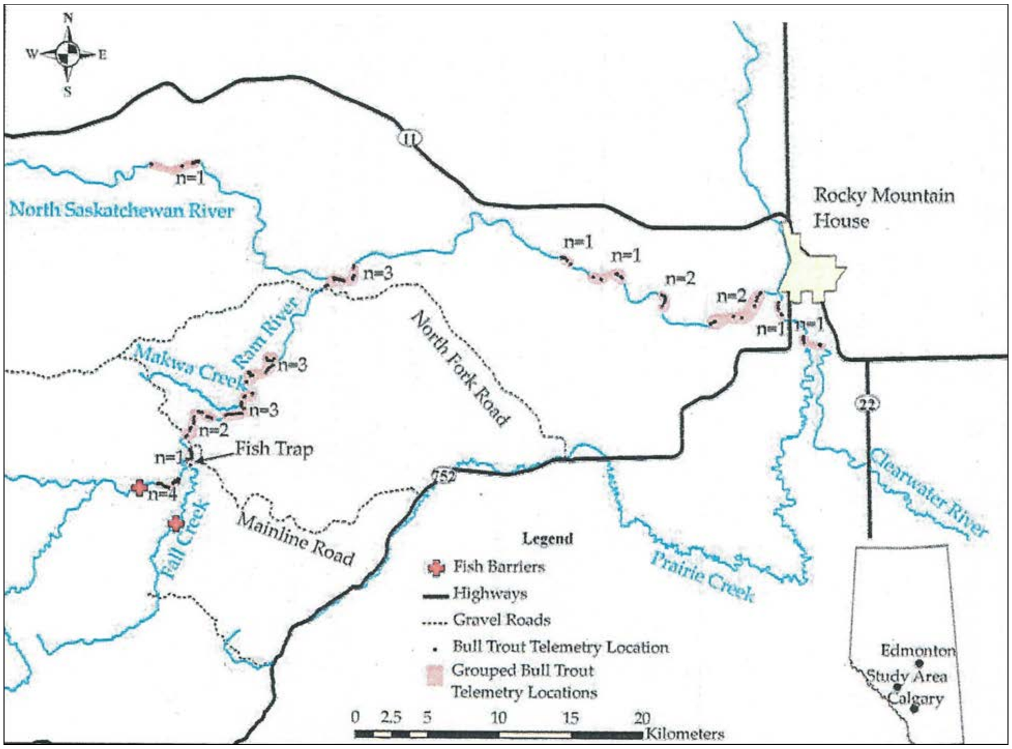

Figure 16. Location of Bull Trout overwintering habitat identified in the Clearwater, North Saskatchewan and Ram rivers, November 2008 to March 2009 (from Rodtka et al. 2010).

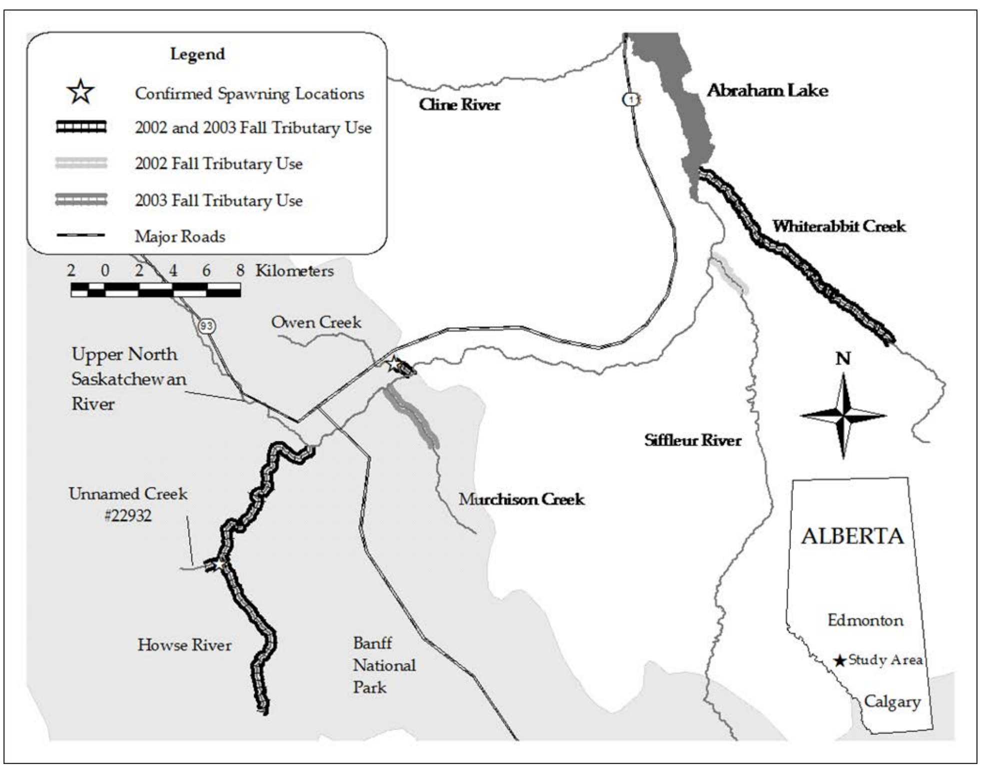

Figure 17. Location of Bull Trout redds observed in Owen Creek and Unnamed Creek (#22392) in the upper North Saskatchewan River drainage in 2002 and 2003 (from Fontana et al. 2006).

lake outlet (Herman 1997). This population is isolated by rapids or falls on the outlet (Carl et al. 1989, Donald and Alger 1993). Overwintering habitat was documented in Abraham Lake and in the upper North Saskatchewan River (up to the confluence of Owen Creek, 2.5–28 km upstream of Abraham Lake) (Figure 18). The greatest number of overwintering Bull Trout were observed at Whirlpool Point, 11 km upstream from Abraham Lake, in deep pools with groundwater input (Fontana et al. 2006).

In the Clearwater River drainage, redds have been observed in 152-A Spring, 152-Side Channel, 152-B Spring, Forty Mile Spring, Sawmill Spring and Timber Creek (Figure 19), and Elk Creek (redd locations not indicated on map) and Cutoff Creek (Figure 20; Rodtka 2005). All of the redds were created by fluvial Bull Trout; the spawning locations of stream-residents in the Clearwater drainage remain undocumented (Rodtka 2005). The Tay River supported Bull Trout as late as the 1950s (Alberta Sustainable Resource Development Fisheries Files, Rocky Mountain House) but they were incidental in the lower reaches by 1987 and absent in later surveys (Gardiner and McLeod 2000, Rodtka 2005). High water temperatures were measured in this river in 2004 (mean: 16 °C, max: 21 °C) and juveniles are unlikely to survive at temperatures greater than 15 °C (Selong et al. 2001, Rodtka 2005). Large beaver dams were also observed in 2004. These may limit upstream dispersal of Bull Trout from the Clearwater River (Rodtka 2005).

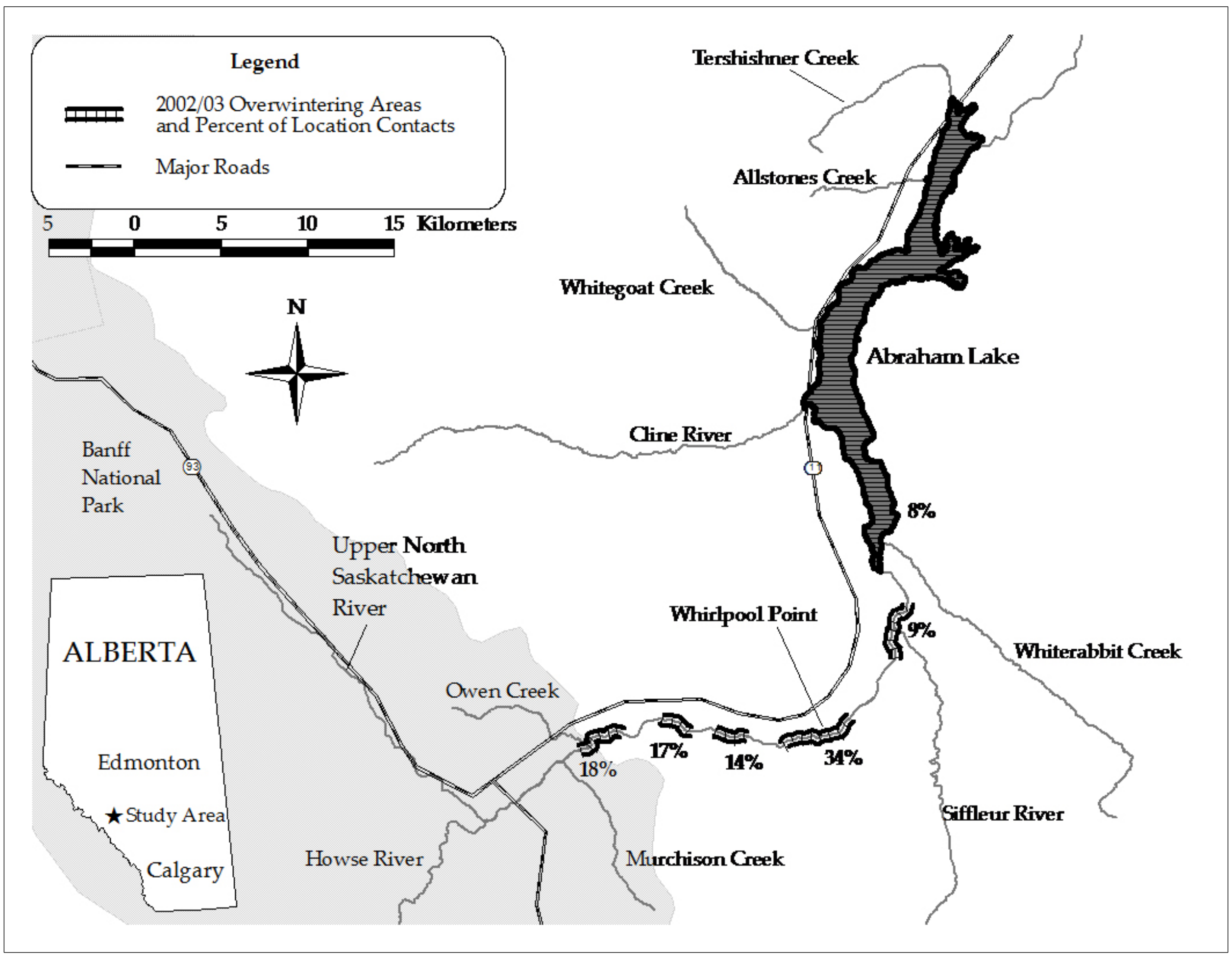

Figure 18. Location of Bull Trout overwintering habitat identified in the upper North Saskatchewan River and Abraham Lake during the 2002/2003 winter (from Fontana et al. 2006).

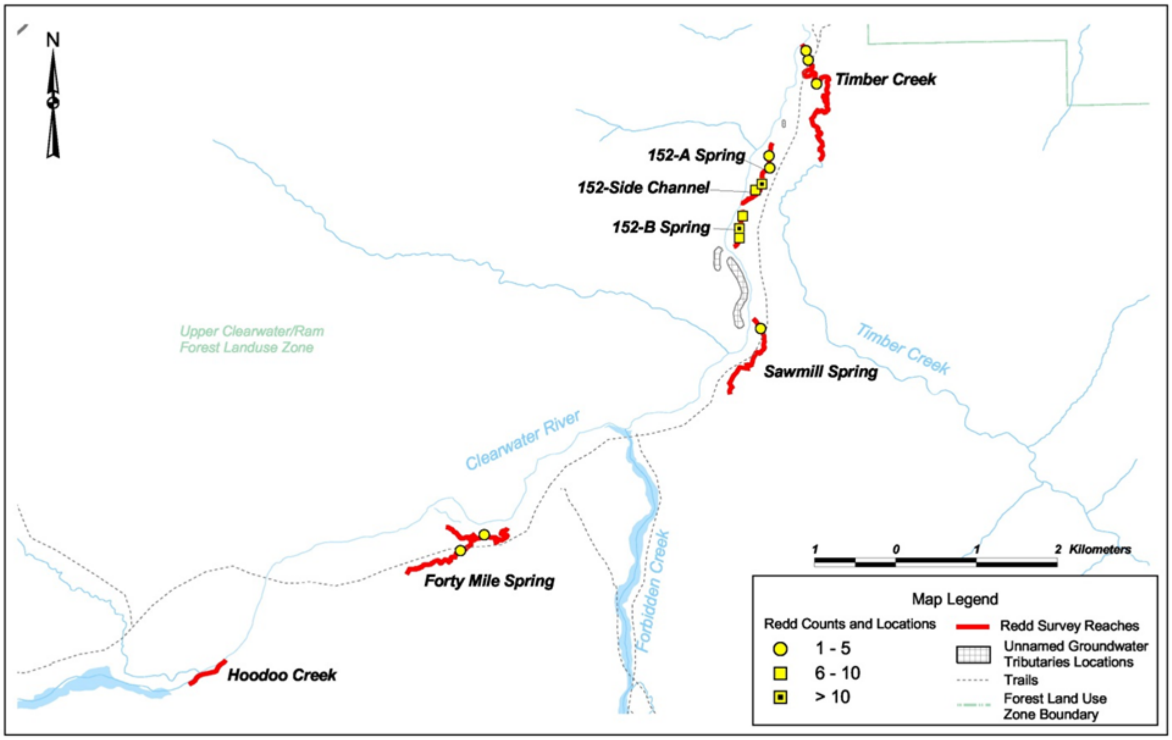

Figure 19. Location of Bull Trout redds observed in 152-A Spring, 152-Side Channel, 152-B Spring, Forty Mile Spring, Sawmill Spring and Timber Creek in the Clearwater River drainage in 2004 (from Rodtka 2005).

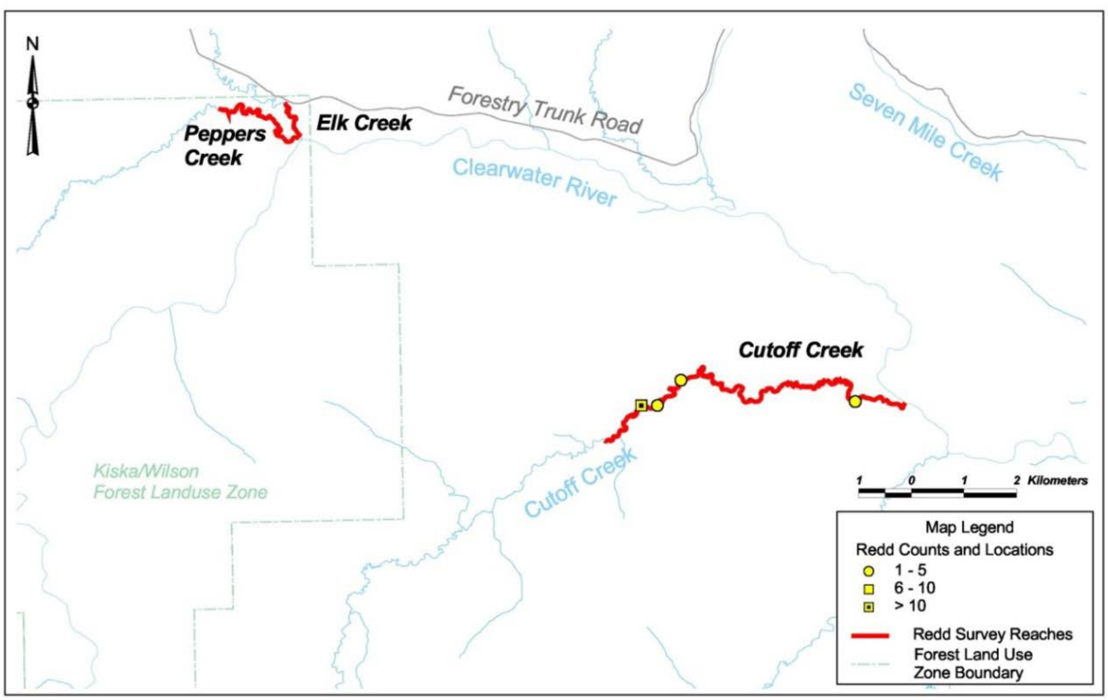

Figure 20. Location of Bull Trout redds observed in Cutoff Creek in the Clearwater River drainage in 2004 (from Rodtka 2005).

Functions, Features and Attributes

A description of the functions, features and attributes associated with Bull Trout habitat can be found in Table 6. The habitat required for each life stage has been assigned a function that corresponds to a biological requirement of Bull Trout. In addition to the habitat function, features have been assigned to each life stage. A feature is considered to be the structural component of the habitat necessary for the survival or recovery of the species. Habitat attributes have also been provided, which describe how the features support the function for each life stage. This information is provided to guide any future identification of critical habitat for this species. It should be noted that habitat attributes associated with current records may differ from optimal habitat as Bull Trout may be occupying sub-optimal habitat where optimal habitat is not available.

Residence

SARA defines a 'residence' as "a dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating" (SARA, Section 2.1). DFO (2015) uses the following four conditions to determine when the concept of 'residence' applies to an aquatic species:

1) a discrete dwelling-place that has structural form and function similar to a den or nest;
2) an individual of the species has made an investment in the creation, modification or protection of the dwelling-place;
3) the dwelling-place makes possible the successful performance of an essential life cycle process such as spawning and rearing; and
4) the dwelling-place is occupied by one or more individuals at one or more parts of its life cycle.

During the spawning season, female Bull Trout excavate a nest, or redd, by turning on their side, arching their body and forcefully beating their caudal fin (Tautz and Groot 1975). The female 'crouches' in the nest and a male positions himself beside her. Eggs and sperm are released and the fertilized eggs fall into the depression created by the female. The female then moves upstream and begins digging. The resulting displaced gravel covers the eggs (McPhail and Baxter 1996). Females generally do not deposit all of their eggs in a single spawning event. After a short rest, they move to the upstream edge of the nest and repeat the process. This sequence may be repeated several times resulting in a large redd (sequential string of nests excavated by one female) which may be over one meter in length. Nests are typically excavated to a depth of 10–20 cm (McPhail 2007). The eggs, and later alevins, remain in the substrate over winter and hatch between March and April. The length of incubation depends upon the temperature and varies between 100–200 days (Allan 1980, Berry 1994).

Redds, therefore, meet all of the conditions for consideration as a residence:

1) the dwelling-place (redd) is a nest;
2) the female Bull Trout has made an energy investment in the creation of the redd;
3) the dwelling-place has the functional capacity to support the successful performance of the essential life cycle processes of spawning, breeding, incubation and alevin development; and
4) the dwelling-place is occupied by one or more individuals at two parts of the Bull Trout's life cycle (egg and alevin).

Table 6. Summary of the essential functions, features and attributes for each life stage of Bull Trout. Numbers in brackets refer to sources cited below; bold numbers indicate information from Alberta. Modified from Stewart et al. (2007).

Life Stage	Function	Feature(s)	Attributes (Observed)	For Identification of Critical Habitat (Inferred)
Spawning / Incubation	Reproduction	• Interstices of bottom substrate in small tributary streams; redds are often constructed in areas associated with perrenial groundwater upwellings (1, **2**, **3**)	• Spawning depth range: 0.07–0.93 m (1, 27) • Incubation depth range: 0.1–0.2 m (27) • Substrate: gravel/cobble dominated substrate (1, **4**) • Substrate size: 0–200 mm(27) • Cover: overhanging vegetation, undercut banks, large woody debris, rootwads, but overhead cover is not a prerequisite for spawning (**4**, 5, 30); redds are often constructed along river margins (**4**, 6) • Run-type reaches; low gradient and flood plain sections (**35**) • Velocity: 2–99 cm/s (1, 27) • Turbidity: 0.1–1.0 NTU (7) • Oxygen: Intergravel 8–12 mg/L, mean 9 mg/L (**3**); Instream 10–11.5 mg/L, mean 10 mg/L (**3**) • Water Temperature: Spawning 5–9 °C (**8**, 9); Incubation 1.2–5.4 °C (9, 10); groundwater upwellings are important in maintaining temperature • Fluvial and adfluvial Bull Trout migrate to spawning habitat, thus unobstructed access is required	• Unimpeded access to spawning areas • Gravel/cobble dominated substrate associated with perennial groundwater upwellings • Areas with minimal disturbances and low levels of fine sediment
Young-of-the-year	Nursery Cover Feeding Overwintering	• Shallow shoreline pools and riffles of side channels; deeper pools; interstices of bottom substrate; often overwinter in areas associated with perennial groundwater upwellings	• Depth range: 0.07–0.93 m (1) • Substrate: cobble and boulder (11, 12), silt (28) • Cover: overhanging vegetation, undercut banks, large woody debris, gravel substrate, boulders (**4**, 5, 11a,b), small wood, cobble (28), velocity breaks (29) • Velocity: low velocity backwaters and side channels (10, 13, 14, **15**) • Nose velocity: 0–0.1 m/s; upper limit: 0.33 m/s (29) • Bottom velocity: 0.05–0.15 m/s; upper limit: 0.23 m/s (28) • Water Temperature: 2–20 °C (16); ultimate upper incipient lethal temperature (UUILT) 20.9 °C (60 days), 23.5 °C (7 days) (17) • Connectivity between spawning sites and rearing locations • Pool and run habitats are preferred (**18**)	• Low velocity backwaters and side channels; pool and run habitats • Adequate cover (intact riparian zone) • Seasonal and perennial groundwater upwellings • Connectivity between spawning sites and rearing locations

Life Stage	Function	Feature(s)	Attributes (Observed)	For Identification of Critical Habitat (Inferred)
Juvenile and Adult	Feeding Cover Overwintering	• Higher gradient habitats, often in shallow pools and riffles; interstices of bottom substrates; often overwinter in isolated pools maintained by perennial groundwater upwellings (**4**, 5, **18**, 19) • Pools, riffles, runs, lakes (adfluvial)	• Gradient: 1.0–15.6% (25) • Depth: deeper water during the day and shallower water (littoral zone, runs, channel margins, backwaters) at night (**18**, 19, 20, 21); pools associated with groundwater input for overwintering (**2**, **4**, 19) • Substrate: cobble, boulder (11, **18**, 19, 21), silt (juveniles) (28), rubble (31), sand (night use) (30) • Cover: overhanging vegetation, undercut banks, large woody debris, substrate, boulders (11, **18**, 19, 21), rootwads (juveniles) (28), velocity breaks (juveniles) (32),may also use deep-water habitat (34); diel shifts to habitats without cover at night are common (34) • Oxygen: acute limit = > 2 mg/L; likely the same for juveniles and adults (33) • Water Temperature: below 12 °C (22, 23); UUILT slightly lower than for young-of-the-year (17); maximum daily-maximum temperature 12 °C, maximum weekly-maximum temperature 11 °C (26); average maximum summer temperature 17 °C (34) • Fluvial Bull Trout migrate to overwintering areas and therefore require well-connected habitat (**24**) • Velocity (Juvenile) – Nose velocity: 0.05–0.25 m/s, upper limit: 0.48 m/s (29); Bottom velocity: 0.20–0.28 m/s, upper limit: 0.31 m/s (28), Mean column velocity: 0.0–0.20 m/s, upper limit: 0.8 m/s (32)	• Unimpeded access to overwintering areas • Adequate cover (intact riparian zone) • Pools and riffles • Seasonal and perennial groundwater upwellings

1. Baxter and McPhail 1999 – various systems throughout the range from 49–56°N
2. Boag and Hvenegaard 1997 – West Castle River, AB
3. Fairless et al. 1994 – Clearwater River, AB
4. Hurkett et al. 2011 – Oldman River basin, AB
5. Shepard 1985 – Flathead River, MT
6. Oliver 1985 – Wigwam River, BC
7. Craig 1997 – Yakima River basin, WA
8. Herman 1997 – Pinto Lake, AB
9. Fraley and Shepard 1989 – Flathead River, MT
10. McPhail and Murray 1979 cited in Stewart et al. 2007– Mackenzie Creek, BC
11. Mochnacz et al. 2004 – Funeral Creek, NT and Keele River, NT
12. Baxter and McPhail 1997 – Peace River drainage, BC
13. Cross and Everest 1997 – Spokane River system, ID
14. MBTSG 1998 – Montana
15. Earle and McKenzie 2001 – Copton Creek drainage, AB
16. Adams 1994 – Weiser River drainage, ID
17. Selong et al. 2001 – laboratory study
18. Mushens 2003 – Smith-Dorrien Creek, AB
19. Thurow 1997 – central Idaho
20. McPhail 2007 – British Columbia
21. Sexauer and James 1997 – Yakima and Wenatchee River drainages, WA
22. Rieman and McIntyre 1993 – literature review
23. Dunham et al. 2003a – western US
24. Warnock 2008 – south-western Alberta
25. Rich 1996 – western Montana
26. McCullough and Spalding 2002 – laboratory study
27. Baxter and McPhail 1996 – literature review
28. Baxter 1995 cited in Stewart et al. 2007 – Chowade River, British Columbia
29. Boag 1991 unpublished – Alberta
30. Sexauer 1994 – Yakima and Wenatchee River drainage, WA
31. Oliver 1979 – Wigwam River and Ram Creek, BC
32. Environmental Management Associates unpublished – Smith-Dorrien Creek, AB
33. Chambers et al. 2000b – northern Alberta
34. Al-Chokhachy et al. 2010 – interior Columbia River Basin
35. Hurkett and Blackburn 2015 – Castle River drainage, AB

THREATS AND LIMITING FACTORS

Naturally Occurring Limiting Factors

The most significant natural limiting factor for Bull Trout is its habitat specificity, particularly water temperature (typically less than 12 °C) and spawning and rearing habitat requirements (see Habitat Requirements section; Rieman and McIntyre 1993, Dunham et al. 2003a, COSEWIC 2012). These requirements strongly influence its distribution and its sensitivity makes it a good indicator of environmental disturbance (COSEWIC 2012). Additionally, interactions with other fish species (e.g., competition with Brook Trout and Brown Trout) affect Bull Trout distribution and abundance (see Interspecific Interactions section; COSEWIC 2012).

Certain life history characteristics of Bull Trout are also natural limiting factors. Density-dependent survival, its position as a top aquatic predator and its high site fidelity can contribute to relatively low densities (Hagen 2008 cited in COSEWIC 2012, Johnston et al. 2007, COSEWIC 2012). These factors, along with its restricted gene flow (Taylor et al. 2001, Taylor and Costello 2006) and naturally fragmented distribution, make Bull Trout vulnerable to local extinctions through stochastic processes (COSEWIC 2012). Natural extinctions may even be common (Rieman and McIntyre 1993, 1995).

These naturally occurring limiting factors make Bull Trout vulnerable to anthropogenic disturbances (Rieman and McIntyre 1993, 1995); however, Bull Trout have evolved strategies to persist in variable environments. Examples include phenotypic plasticity and density-dependent changes in life history traits (e.g., faster maturation and increased frequency of reproduction at lower densities). These strategies may provide some degree of compensation for human-induced changes (Johnston and Post 2009, COSEWIC 2012).

Anthropogenic Threats

Anthropogenic threats facing Bull Trout fall under three main categories: loss of habitat network through fragmentation and removal and alteration, interaction (competition and hybridization) with introduced species and mortality caused by angling and, to a lesser extent, scientific sampling (Rieman and McIntyre 1993, Brewin 2004, AESRD and ACA 2009, COSEWIC 2012). Information below is sourced from reviews by AESRD and ACA (2009), AESRD (2012) and COSEWIC (2012). Climate change and interactive and cumulative effects are also discussed. Note that only existing and imminent threats are considered. Potential future threats (e.g., new invasive species, such as Zebra Mussels, and diseases) were not considered[1].

Habitat Fragmentation

Connectivity (i.e., unobstructed passage through watersheds) is a key habitat requirement for migratory Bull Trout. It is important in linking spawning, rearing and overwintering habitats and in linking populations to facilitate gene flow and aid in the re-establishment of declining populations. Habitat fragmentation is caused by the creation of migratory barriers including elevated or undersized culverts, dams without fish passage facilities, water diversion canals or water withdrawal practices that entrain fish or decrease stream flow, and land-use practices that

[1] In September 2016, it was reported that the presence of whirling disease has been confirmed in the upper Bow River, downstream of the confluence of the Bow and Cascade rivers within Banff National Park. It was first identified in late August in Johnson Lake in Banff National Park. This was the first discovery of this disease in Canada. This discovery occurred after the RPA meetings and was unexpected; therefore it was not considered during the RPA process.

negatively impact habitat making it uninhabitable for Bull Trout. The impacts of fragmentation on Bull Trout vary, but typically result in range contractions and population declines and may delay or preclude fish assemblage recovery following a disturbance (Detenbeck et al. 1992). Fragmentation may also result in rates of extinction or extirpation exceeding rates of habitat loss by decreasing the chance of recolonization through regional connectivity (Rieman and McIntyre 1995, Rieman et al. 1997). If habitat fragementation was reduced, this would allow recolonization in the event of local extirpations. However, this may also allow other competing species access to habitats thereby resulting in increased competition. The extent of spatial configuration constraints in areas occupied by Bull Trout in DU 4 has not been quantified. However, it is likely that potential pathways of genetic interchange have been lost through the reduction in connectivity or the construction of barriers.

Culverts

When the streambed below the downstream end of a culvert erodes, it creates an elevated or hanging outfall that fish are unable to enter. This can also occur when culverts are improperly installed, undersized culverts are used or the downstream bed is inadequately armoured. Where culverts are elevated or steeply sloped, they are often impassable to fish, blocking upstream movements of spawners and removing access of juveniles to seasonal refuges from anchor ice and floods (Slaney and Zaldokas 1997, Trombulak and Frissell 2000, Porter et al. 2000). Culverts may also create velocity barriers, increase sedimentation and disrupt the natural transport of large woody debris. This is a province-wide issue in Alberta; as the road network has expanded, the scope of these problems has increased. Furthermore, where existing culverts are improperly maintained, habitat fragmentation will continue to increase (Park et al. 2008).

Dams and Weirs

Dams that do not have associated fish passage facilities create barriers to upstream fish passage, blocking access to spawning and rearing habitat and isolating populations (Goetz 1997b, Hansen and DosSantos 1997, MBTSG 1998). Dams may cause direct mortality when fish are not prevented from passing through turbines (entrainment). Furthermore, Bull Trout in fragmented reaches may become functionally extirpated if there are no spawning and rearing habitats downstream of the dam. Dams may also alter or withhold flows from areas that may otherwise have been accessible (Goetz 1997b, Hansen and DosSantos 1997, MBTSG 1998).

Large dams built between 1911 and 1991 were designed without fish passage facilities. Low head dams (weirs) generally have fish ladders although these often require regular maintenance and/or upgrading. Furthermore, the use of fish ladders by Bull Trout appears to be limited (e.g., Clark Fork River in Idaho and Montana, Cox 2016). Within DU 4, the Bow River basin is the most fragmented with 13 dams and four weirs (Bow River Basin Council 2010). The Oldman River basin has three major dams and two weirs, the Red Deer River has one major dam and the North Saskatchewan River has two major dams. Locations of dams (Table 7) and waterfalls (natural barriers) in DU 4 are shown in Figure 21. The majority of dams and weirs in Alberta do not provide fish passage.

Irrigation Canals

Irrigation canals fragment habitat by decreasing instream flows which can cause increases in water temperature above Bull Trout tolerance limits and by entraining migrating Bull Trout that move into the canals below water control structures within the canal system. In the Belly and Waterton River drainages (Oldman River basin), 15–20% of annual Bull Trout mortality was attributed to entrainment in irrigation canals or blockage of upstream movement (Clayton 2001).

Habitat Removal and Alteration

Human activities such as residential and industrial development, mining, grazing, agriculture, forestry, irrigation, dams, road construction and recreational development may all degrade Bull Trout habitat (McCart 1997, MBTSG 1998) by altering natural flow regimes, increasing sediment input and/or altering stream thermal regimes.

Alteration of Natural Flow Regimes: Disruption of Peak Flow Intensity

Peak flows result from spring runoff and storm events and are fundamental components of fluvial ecosystems affecting channel morphology, sediment transport and instream habitat characteristics. Peak flow intensity increases with increasing water yield. Water yield increases with catchment basin disturbance; the extent of increase depends upon forest harvest practices and the ecological region (Ripley et al. 2005). Increased peak flow intensity may destabilize channels, scour gravel beds (Bull Trout eggs incubate in the gravel and thus are particularly vulnerable to scour [DeVries 1997, Shellberg et al. 2010]), speed the erosion of banks and riparian areas, cause stream widening, dislodge stable woody debris and displace fish (particularly early life stages). Small streams are more easily impacted than large streams.

Table 7. Characteristics of dams present within the range of Bull Trout (DU 4). Information provided by the Government of Alberta Dam Safety Office. Consequence classification considers loss or deterioration of: Critical fisheries or wildlife habitats; Rare or endangered species; or Unique landscapes or sites of cultural significance, and restoration or compensation in kind is possible but impractical. Consequences ranged from low (minimal short-term loss or deterioration, high to very high (significant loss or deterioration) to extreme (major loss or deterioration).

DAM NAME	HUC8	HUC8 NAME	DAM HEIGHT (m)	CAPACITY (dam^3)	DAM PURPOSE	CONSEQUENCE CLASSIFICATION
Oldman River Dam Project Dyke	04010101	Upper Oldman River	0.00	490000.00	Irrigation	not available
Oldman River Dam Project Earthfill Dam	04010101	Upper Oldman River	78.89	490000.00	Irrigation	Extreme
Waldron Graz. Co-op NE5 Embankment	04010101	Upper Oldman River	6.70	49.20	Industrial Water Supply	not available
Allison Creek Hatchery Main Dam	04010102	Crowsnest River	5.48	308.37	Fish Culture	not available
Coleman Fish and Game Embankment	04010102	Crowsnest River	4.30	68.50	Recreation	not available
Ganske,H and Mielke,R Embankment	04010102	Crowsnest River	3.70	123.30	Recreation	not available
Heaton,Mark Embankment	04010102	Crowsnest River	4.30	199.80	Irrigation	not available
Skierka,Frank Embankment	04010102	Crowsnest River	3.70	184.40	Industrial Water Supply	not available
Beaver Mines Dam Embankment	04010103	Castle River	5.10	2147.50	Recreation	not available
Lang,Clifford Embankment	04010103	Castle River	9.80	64.80	Industrial Water Supply	not available

DAM NAME	HUC8	HUC8 NAME	DAM HEIGHT (m)	CAPACITY (dam^3)	DAM PURPOSE	CONSEQUENCE CLASSIFICATION
Ridder, Charles F Embankment	04010103	Castle River	12.20	157.90	Recreation	not available
Sandy Lake Project Embankment	04010103	Castle River	2.40	836.30	Recreation	not available
Beauvais Lake Dam Earth Dam	04010104	Pincher Creek	4.90	not available	Recreation	not available
Cridland Dam Embankment	04010104	Pincher Creek	14.30	178.90	Industrial Water Supply	not available
Therriault Community Embankment	04010104	Pincher Creek	13.40	462.60	Municipal Water Supply (Raw)	not available
Tompkins,Olga Embankment	04010104	Pincher Creek	4.90	482.30	Industrial Water Supply	not available
Beekman,Gerrit Et Al Embankment	04010105	Oldman River below Oldman Reservoir	4.00	359.80	Industrial Water Supply	not available
Coates,Robert Embankment	04010105	Oldman River below Oldman Reservoir	8.80	38.50	Industrial Water Supply	not available
Day,C.G. Embankment	04010105	Oldman River below Oldman Reservoir	4.60	42.40	Industrial Water Supply	not available
Desmit Etal,Ruth Embankment	04010105	Oldman River below Oldman Reservoir	4.60	36.40	Industrial Water Supply	not available
Foothill L Community Embankment	04010105	Oldman River below Oldman Reservoir	3.70	310.20	Lake Stabilization	not available
Lethbridge Northern Diversion Structure Dyke	04010105	Oldman River below Oldman Reservoir	6.10	not available	Recreation, Municipal Water Supply (Raw), Irrigiation	not available
AndersonandVanee Embankment	04010201	Willow Creek	6.44	307.80	Irrigation	not available
Bear Pond Embankment	04010201	Willow Creek	12.20	61.00	Recreation	not available
Chain Lakes N Dam Main Dam	04010201	Willow Creek	not available	16035.35	Water Storage	not available
Chain Lakes S Dam Main Dam	04010201	Willow Creek	not available	16035.35	Water Storage	not available
Granum Colony Embankment	04010201	Willow Creek	13.40	401.70	Irrigation	not available

DAM NAME	HUC8	HUC8 NAME	DAM HEIGHT (m)	CAPACITY (dam^3)	DAM PURPOSE	CONSEQUENCE CLASSIFICATION
Lewis,Roger Embankment	04010201	Willow Creek	8.80	92.50	Irrigation	not available
Mckee,Robert C Embankment	04010201	Willow Creek	8.20	38.90	Industrial Water Supply	not available
Pine Coulee Project Main Dam	04010201	Willow Creek	21.94	81399.54	Recreation, Irrigation	not available
Strangway Project Embankment	04010201	Willow Creek	6.70	133.80	Habitat	not available
Willow Diversion Main Dam	04010201	Willow Creek	13.10	1672.61	Water Storage	not available
Bradshaw, R W Embankment	04010301	Waterton River	5.80	352.80	Industrial Water Supply	not available
Eagleson Keewaters Embankment	04010301	Waterton River	4.00	77.70	Habitat	not available
Fish Lake Project Embankment	04010301	Waterton River	3.70	673.40	Recreation	not available
Gulf Oil Canada Ltd Embankment	04010301	Waterton River	14.60	641.40	Industrial Water Supply	not available
Lambert Farms Ltd Embankment	04010301	Waterton River	10.40	138.30	Irrigation	not available
Mitchell,John Embankment	04010301	Waterton River	3.70	40.50	Industrial Water Supply	not available
Nathe,Norman Embankment	04010301	Waterton River	6.70	334.70	Industrial Water Supply	not available
Prairie Bluff Lake Dam	04010301	Waterton River	4.87	166.52	Recreation	not available
Reach, Robert Embankment	04010301	Waterton River	6.10	53.70	Industrial Water Supply	not available
Waterton Gas Plant Embankment	04010301	Waterton River	12.50	161.50	Industrial Water Supply	not available
Waterton Main Dam	04010301	Waterton River	56.38	173009.16	Recreation, Irrigation, Water Storage	Extreme
West, Samuel L Embankment	04010301	Waterton River	3.50	30.80	Industrial Water Supply	not available
Ewelme Colony NW 7 Embankment	04010301	Waterton River	7.00	38.40	Habitat	not available
Belly River Main Dam	04010302	Belly River	not available	not available	Irrigation, Lake Stabilization	not available

DAM NAME	HUC8	HUC8 NAME	DAM HEIGHT (m)	CAPACITY (dam^3)	DAM PURPOSE	CONSEQUENCE CLASSIFICATION
Belly River Weir	04010302	Belly River	not available	not available	Irrigation, Lake Stabilization	not available
Bullhorn Main Dam	04010302	Belly River	11.99	4223.46	Water Storage, Irrigation	not available
East Payne Main Dam	04010302	Belly River	9.44	8685.85	Irrigation, Water Storage, Recreation	Very High
North Payne Main Dam	04010302	Belly River	4.57	8685.85	Irrigation, Water Storage, Recreation	High
Redford, Pearl Embankment	04010302	Belly River	5.50	31.50	Industrial Water Supply	not available
Leavitt Dam #1 Embankment	04010302	Belly River	not available	not available	Water Storage	not available
Little Beaver Dam Dam #1 (East Dam)	04010302	Belly River	not available	not available	Recreation	not available
Leavitt Dam #2 Embankment	04010302	Belly River	not available	not available	Water Storage	not available
Little Beaver Dam Dam #2 (West Dam)	04010302	Belly River	not available	not available	Recreation	not available
Dam #7 Main Dam	04010302	Belly River	not available	not available	Water Storage	not available
Bar K2 Ranch Embankment	04010401	St. Mary River	3.70	63.90	Industrial Water Supply	not available
Beaver Dam Lake Embankment	04010401	St. Mary River	7.90	925.10	Irrigation	not available
Crawford,Vivian Embankment	04010401	St. Mary River	3.61	47.70	Industrial Water Supply	not available
Leavitt,Dean H Embankment	04010401	St. Mary River	4.40	167.85	Irrigation	not available
Mokowan Ridge Dam Embankment	04010401	St. Mary River	16.20	7092.60	Irrigation	not available
Neimann,Edward Embankment	04010401	St. Mary River	3.40	34.70	Industrial Water Supply	not available
Police Outpost Dam Earth Dam	04010401	St. Mary River	3.04	61.67	Recreation	not available
St. Mary Main Dam	04010401	St. Mary River	58.82	395753.84	Recreation, Water Storage, Irrigation	Extreme

DAM NAME	HUC8	HUC8 NAME	DAM HEIGHT (m)	CAPACITY (dam^3)	DAM PURPOSE	CONSEQUENCE CLASSIFICATION
Goat Pond Dyke	04020301	Spray Lakes River	not available	not available	Water Storage	not available
Goat Pond Main Dam	04020301	Spray Lakes River	not available	not available	Water Storage	not available
Spray Canal Dyke	04020301	Spray Lakes River	not available	not available	Water Storage	not available
Three Sisters Canyon Dam	04020301	Spray Lakes River	not available	not available	Water Storage	not available
Three Sisters French Creek Diversion	04020301	Spray Lakes River	not available	not available	Water Storage	not available
Three Sisters Main Dam	04020301	Spray Lakes River	not available	not available	Water Storage	not available
Whiteman's Pond Whiteman's Dyke	04020301	Spray Lakes River	not available	not available	Water Storage	not available
Grotto Mountain Fish Embankment	04020401	Bow River and Ghost Reservoir	not available	57.97	Habitat	not available
Hutchinson,P and D Embankment	04020401	Bow River and Ghost Reservoir	2.40	123.30	Industrial Water Supply	not available
Kananaskis Falls Dam	04020401	Bow River and Ghost Reservoir	not available	not available	Water Storage	not available
Whiteman's Pond Whiteman's Dam	04020401	Bow River and Ghost Reservoir	not available	not available	Water Storage	not available
Barrier Dam	04020601	Kananaskis River	42.70	not available	Water Storage	Very High
Interlakes Intake Dam	04020601	Kananaskis River	not available	not available	Water Storage	not available
Interlakes Main Dam	04020601	Kananaskis River	24.40	not available	Water Storage	Extreme
Pocaterra Intake Dam	04020601	Kananaskis River	not available	not available	Water Storage	not available
Pocaterra Main Dam	04020601	Kananaskis River	29.00	not available	Water Storage	Extreme
Cascade Power Canal Power Canal Dyke	04020701	Ghost River	11.00	not available	Industrial Water Supply	not available
Control Dam Concrete Structure	04020701	Ghost River	15.20	not available	Industrial Water Supply	not available
Ghost Diversion Diversion Structure	04020701	Ghost River	3.70	not available	Industrial Water Supply	not available

DAM NAME	HUC8	HUC8 NAME	DAM HEIGHT (m)	CAPACITY (dam^3)	DAM PURPOSE	CONSEQUENCE CLASSIFICATION
Lake Minnewanka Embankment	04020701	Ghost River	35.40	not available	Industrial Water Supply	not available
Scheer.K.D. Embankment	04020701	Ghost River	4.60	30.80	Irrigation	not available
Barros,Leonard Embankment	04020801	Bow River and Bighill Creek	4.00	42.60	Industrial Water Supply	not available
Bearspaw Embankment	04020801	Bow River and Bighill Creek	29.90	not available	Water Storage	not available
Gleneagles Golf C Embankment	04020801	Bow River and Bighill Creek	12.20	20.50	Recreation	not available
Hutchinson,Jonathan Embankment	04020801	Bow River and Bighill Creek	3.00	68.10	Industrial Water Supply	not available
Prince Island Lagoon Embankment	04020801	Bow River and Bighill Creek	3.00	55.50	Unknown	not available
Reilly,Cleo E. Embankment	04020801	Bow River and Bighill Creek	4.60	43.20	Industrial Water Supply	not available
Spicer Dam Embankment	04020801	Bow River and Bighill Creek	5.20	78.90	Irrigation	not available
Stephenson,W A Embankment	04020801	Bow River and Bighill Creek	7.30	123.30	Industrial Water Supply	not available
Stoney Trail Storm Water Embankment	04020801	Bow River and Bighill Creek	8.50	47.90	Erosion Control	not available
Rocky Ridge 5c Embankment	04020801	Bow River and Bighill Creek	2.40	55.50	Unknown	not available
City of Calgary 210 Ave SE Trunk Utilities Cranston River Crossing	04020801	Bow River and Bighill Creek	not available	55.50	Unknown	not available
Dean Peterson Embankment	04020802	Jumpingpound Creek	2.70	179.80	Irrigation	not available
Livingstone Creek Ranch Ltd Embankment	04020802	Jumpingpound Creek	not available	not available	Recreation	not available
Sibbald Creek #3 Main Dam	04020802	Jumpingpound Creek	4.57	54.27	Lake Stabilization, Habitat	not available
Aspen Woods Storm Pond Embankment	04021001	Elbow River	3.00	55.50	Unknown	not available
Bragg Creek Res. Ass Embankment	04021001	Elbow River	6.10	43.80	Municipal Water Supply (Raw)	not available

DAM NAME	HUC8	HUC8 NAME	DAM HEIGHT (m)	CAPACITY (dam^3)	DAM PURPOSE	CONSEQUENCE CLASSIFICATION
Elbow River Ranch Embankment	04021001	Elbow River	6.40	58.10	Water Storage	not available
Glenmore Dam Embankment	04021001	Elbow River	30.00	17640.00	Municipal Water Supply	not available
Oland Properties Ltd Embankment	04021001	Elbow River	8.20	86.30	Recreation	not available
Robert Lyon Dam Embankment	04021001	Elbow River	6.90	54.80	Habitat	not available
Slaptail Pond Embankment	04021001	Elbow River	3.40	32.20	Recreation	not available
Strathcona Storm W Embankment	04021001	Elbow River	11.00	55.50	Unknown	not available
Wintergreen Main Dam	04021001	Elbow River	not available	not available	Industrial Water Supply	not available
Wolcott Dam Embankment	04021001	Elbow River	7.00	60.90	Erosion Control	not available
Fish Creek Storm Pond Embankment	04021101	Fish Creek	4.90	37.00	Drainage	not available
Harvie,Donald Embankment	04021101	Fish Creek	3.70	53.90	Industrial Water Supply	not available
Keith, E V Dam	04021101	Fish Creek	3.70	119.50	Recreation	not available
Priddis Greens C and G Embankment	04021101	Fish Creek	11.60	355.00	Recreation, Irrigation	not available
Priddis Greens C and G North Dyke	04021101	Fish Creek	14.90	355.00	Recreation, Irrigation	not available
Rundge,Donald L. Embankment	04021101	Fish Creek	3.70	51.10	Industrial Water Supply	not available
Botero, Arturo Embankment	04021201	Highwood River	3.70	30.80	Industrial Water Supply	not available
Burns Ranches Embankment	04021201	Highwood River	4.60	37.00	Industrial Water Supply	not available
Burns Ranches Ltd Embankment	04021201	Highwood River	3.70	209.70	Industrial Water Supply	not available
Cartwright,James S Embankment	04021201	Highwood River	3.70	203.50	Irrigation	not available
Diamond V Ranch Embankment	04021201	Highwood River	2.40	111.00	Industrial Water Supply	not available

DAM NAME	HUC8	HUC8 NAME	DAM HEIGHT (m)	CAPACITY (dam^3)	DAM PURPOSE	CONSEQUENCE CLASSIFICATION
Hays,Harry W. Embankment	04021201	Highwood River	7.00	33.60	Industrial Water Supply	not available
Hitchell,Archibald Embankment	04021201	Highwood River	6.10	30.80	Industrial Water Supply	not available
Mesabi Ranches Embankment	04021201	Highwood River	5.20	38.70	Industrial Water Supply	not available
Roenisch and Kingsford Embankment	04021201	Highwood River	2.70	74.00	Industrial Water Supply	not available
Crestveiw Ranch Ltd Embankment	04021202	Sheep River	5.20	62.30	Irrigation	not available
Cross, James B Dam	04021202	Sheep River	8.20	65.70	Irrigation	not available
Cross,James B Embankment	04021202	Sheep River	10.10	94.70	Industrial Water Supply	not available
Crystalire Develop. Embankment	04021202	Sheep River	7.90	209.70	Municipal Water Supply (Raw)	not available
Farren Ruth M Embankment	04021202	Sheep River	5.20	154.20	Industrial Water Supply	not available
Friley, William A Dam	04021202	Sheep River	11.90	62.90	Irrigation	not available
Godwin,Frederick E Embankment	04021202	Sheep River	4.60	46.00	Industrial Water Supply	not available
Harvie,Donald S. Embankment	04021202	Sheep River	5.20	52.20	Industrial Water Supply	not available
Millarville Meadows Main Dam	04021202	Sheep River	not available	not available	Storm Water Management	not available
Priddis Embankment	04021202	Sheep River	3.70	365.10	Erosion Control	not available
Quirk Creek W.S. Embankment	04021202	Sheep River	7.60	74.00	Industrial Water Supply	not available
Milford Project Embankment	08010101	Upper Red Deer River	6.70	160.40	Habitat	not available
Klein Lake Coffer Dam	08010102	Panther River	not available	not available	Unknown	not available
Klein Lake Main Dam	08010102	Panther River	7.92	not available	Unknown	not available
Burnstick Lake Stabilization Earthfill Dam	08010104	James River	not available	not available	Lake Stabilization, Recreation	not available

DAM NAME	HUC8	HUC8 NAME	DAM HEIGHT (m)	CAPACITY (dam^3)	DAM PURPOSE	CONSEQUENCE CLASSIFICATION
Burnstick Lake Stabilization Outlet Structure	08010104	James River	not available	not available	Lake Stabilization, Recreation	not available
Krenzler,W.L. Embankment	08010104	James River	7.30	58.00	Industrial Water Supply	not available
Dickson Dam East Dyke	08010201	Red Deer River and Gleniffer Lake	not available	not available	Water Storage	not available
Dickson Dam Main Earthfill Dam	08010201	Red Deer River and Gleniffer Lake	39.40	not available	Water Storage	Extreme
Dickson Dam North Dyke	08010201	Red Deer River and Gleniffer Lake	not available	not available	Water Storage	not available
Dickson Dam South Dyke	08010201	Red Deer River and Gleniffer Lake	not available	not available	Water Storage	not available
Jensen Farm Main Dam	08010201	Red Deer River and Gleniffer Lake	not available	not available	Industrial Water Supply	not available
Staben,Florence J. Embankment	08010201	Red Deer River and Gleniffer Lake	3.70	46.90	Industrial Water Supply	not available
Beaver Creek Dam Earthfill Dam	08010202	Raven River	6.70	not available	Recreation	not available
Duran Project Embankment	08010202	Raven River	3.00	61.70	Irrigation	not available
Amery and Sons Ltd Embankment	08010203	Little Red Deer River	5.20	69.10	Industrial Water Supply	not available
Gerlach Holdings Embankment	08010203	Little Red Deer River	not available	not available	Irrigation	not available
Bighorn Dam Main Dam	11010201	North Saskatchewan below Abraham	91.44	1751554.40	Industrial Water Supply	not available
Bighorn Dam North Arm	11010201	North Saskatchewan below Abraham	not available	1751554.40	Industrial Water Supply	not available
Bighorn Dam North Arm Dyke	11010201	North Saskatchewan below Abraham	not available	1751554.40	Industrial Water Supply	not available
Bighorn Dam North Containing Dam	11010201	North Saskatchewan below Abraham	30.50	1751554.40	Industrial Water Supply	not available

DAM NAME	HUC8	HUC8 NAME	DAM HEIGHT (m)	CAPACITY (dam^3)	DAM PURPOSE	CONSEQUENCE CLASSIFICATION
Bighorn Dam South Low Saddle Dyke	11010201	North Saskatchewan below Abraham	not available	1751554.40	Industrial Water Supply	not available
Cow Lake Stabilization Weir	11010201	North Saskatchewan below Abraham	2.43	not available	Lake Stabilization	not available
Fish Lake Stabilization Project (Shunda Lake) Weir-Stabilization	11010201	North Saskatchewan below Abraham	not available	not available	Lake Stabilization	not available
Gap Lake Weir	11010201	North Saskatchewan below Abraham	3.05	not available	Lake Stabilization	not available
Martin Dam Main Dam	11010201	North Saskatchewan below Abraham	not available	not available	Water Storage	not available
Nigenhuis,Gerrit Embankment	11010201	North Saskatchewan below Abraham	3.00	123.30	Recreation	not available
Nelson Saddle Dam	11010401	Brazeau River	5.50	46000.00	Industrial Water Supply	not available
Brazeau Development Main Dam	11010405	Brazeau River	65.00	46000.00	Industrial Water Supply	Low
North Arm Embankment	11010405	Brazeau River	11.60	46000.00	Industrial Water Supply	not available
Side Dam #1	11010405	Brazeau River	4.60	46000.00	Industrial Water Supply	not available
Genesee Cooling Pond Main Dam	11020101	North Saskatchewan above Wabamun	not available	not available	Waste Water Management	not available
Poudrier, Paul Main Dam	11020102	Wolf Creek	not available	not available	Industrial Water Supply	not available
Cochrane Lake Dam Embankment	04010302	Belly River	6.40	3700.50	Irrigation	not available

Figure 21. Location of natural waterfalls and man-made dams that may act as barriers to fish passage in DU 4. Dam location and capacity information was provided by the Government of Alberta Dam Safety Office.

Alteration of Natural Flow Regimes: Roads

Roads capture and concentrate surface and subsurface water flow into ditches, increasing delivery of water and sediment to stream channels. This increases the magnitude and frequency of high flows and siltation events. Road density, location (hillside vs valley bottom), watershed characteristics (topography, soils, geology) and watershed size influence the magnitude of impact. Smaller tributary watersheds are more easily impacted. In the Kakwa River basin (DU 2), Ripley et al. (2005) found that the probability of Bull Trout occurrence decreased with an increase in the percentage of sub-basin harvested (forestry) and road density. Similar results have been found in the Columbia River basin (Quigley and Arbelbide 1997, USFWS 1999), the Swan River basin, Montana (Baxter et al. 1999) and the Clearwater National Forest, Idaho (Huntington 1995).

Alteration of Natural Flow Regimes: Dams

In addition to fragmenting habitat, dams alter natural flow regimes of large rivers and the littoral zone in reservoirs through seasonal drawdown and reservoir filling. For example, in Kananaskis Lake, the surface area at drawdown is only 44% of the surface area at bankfull level. This affects the littoral zone and causes resuspension of sediments during flooding (Golder Associates Ltd 1995). By decreasing summer flows, water diversions decrease physical and thermally suitable habitat for Bull Trout. The operation of hydroelectric plants creates daily changes in river depth and velocity which displace fish and disrupt spawning. Rapid reductions in flow negatively impact aquatic insect production, may strand small fish, and may cause dessication and loss of incubating Bull Trout eggs. Flow alteration may also decrease the quality and quantity of downstream habitat and may have played a large role in the decline of Bull Trout in the Kananaskis and Highwood rivers (Bow River basin) and the North Saskatchewan River (A. Paul, pers. comm. cited in AESRD and ACA 2009). Extensive anchor ice was documented below the Bighorn Dam on the North Saskatchewan River that appeared to be impacting Bull Trout use of the reach over winter (Mike Rodtka, Alberta Conservation Association, pers. comm.). Muhlfeld et al. (2012a) found that higher flows in late August and early September caused by summer flow augmentation significantly decrease the quantity and availability of Bull Trout habitat and significantly impact the food web dynamics of the ecosystem. Subadult Bull Trout were found to be the most sensitive life stage to changes in flow (Muhlfeld et al. 2012a) and, in the upper Flathead River, Montana, the Bull Trout population growth rate was most affected by changes in subadult survival rates (Staples 2006).

Suspended and Deposited Sediments

Bull Trout are extremely sensitive to sedimentation. Sedimentation decreases ecosystem productivity, damages habitats, and has sublethal and lethal effects on fish. Suspended and deposited sediments are stressors to fish, disrupting their feeding, growth and movements, and making them more susceptible to disease (Birtwell 1999). Sediment loading increases mortality, particularly for young-of-the-year and incubating eggs (through entombment). Bull Trout fry rely on loose substrate for cover – sedimentation cements or buries the substrate, decreasing carrying capacity of the stream. Off-highway vehicle (OHV) trail crossings and traffic along and within streambeds erodes banks and disturbs streambeds, increasing the levels of suspended sediment. This often occurs at times of year with normally low levels of sediment transport when Bull Trout eggs are incubating in the gravel (Fontana 2003). In Dutch Creek (Oldman River basin), Hurkett et al. (2011) observed heavy loads of fine sediment settling on Bull Trout redds, likely a result of the high number of OHV trails that have degraded and eroded streambanks in the area. Negative impacts of OHV use have also been documented on Fall Creek, a Bull Trout spawning stream in the North Saskatchewan drainage (Mike Rodtka, Alberta Conservation Association, pers. comm.) and throughout the Castle River sub-drainage (Hurkett and Blackburn

2015). Logging and road construction increase the frequency of landslides (Hogan 1986, Slaney and Zaldokas 1997, Jones et al. 2000); the resulting sediment increase may cause widening of mainstem channels, infilling of coarser substrates and blocking of side channels (Slaney and Zaldokas 1997). Unmanaged livestock grazing/watering in riparian areas also contributes to sediment loading (Fitch and Adams 1998), moreover, trampling of simulated Westslope Cutthroat Trout (Peterson et al. 2010) and Bull Trout (Gregory and Gamett 2009) redds has been documented in the U.S.

Alteration of Stream Temperature

Bull Trout require cold water for survival and are thus susceptible to watershed disturbances that contribute to increased water temperatures. Groundwater or hyporheic influences may moderate the effects (Shepard et al. 1986, Meisner et al. 1988); however, temperature increases are directly proportional to the area of the stream exposed to sunlight and inversely proportional to stream discharge (Beschta et al. 1987, Porter et al. 2000). Disturbances such as forest harvesting, road development and grazing on riparian vegetation may increase water temperatures. Higher temperatures decrease thermally suitable habitat for Bull Trout and lead to decreased abundance and range contractions. Higher temperatures may also increase the risk of invasion of introduced species with higher temperature tolerances than Bull Trout, such as Brook Trout and Brown Trout, alter egg and juvenile development, slow growth, decrease survival, impact timing of life history events (Beschta et al. 1987), block upstream migrations and increase disease (Hallock et al. 1970, Monan et al. 1975, Bjornn and Reiser 1991, Porter et al. 2000).

Additionally, negative impacts to groundwater are a threat to Bull Trout. The impacts of land-use practices on groundwater quality and quantity require further research in Alberta.

Interaction With Introduced Species: Competition and Hybridization

Introductions of competitive species (e.g., Lake Trout, Brook Trout) have contributed to Bull Trout declines, range contraction and extirpations within Alberta. Temperature requirements, relatively slow growth, late maturity and variable spawning frequency make Bull Trout particularly susceptible to competition with introduced species. In many cases they have been out-competed resulting in reduced abundance and population viability (See Interspecific Interactions section; Berry 1994, Hunt et al. 1997, McCart 1997).

Lake Trout are the most frequently implicated species in the competitive displacement or replacement of Bull Trout in lakes (Guy et al. 2011) and Brook Trout are more frequently implicated in streams (Gunckel et al. 2002, Rieman et al. 2006).

Bull Trout numbers have declined in association with increasing numbers of Lake Trout in four lakes in Glacier National Park, Montana (Fredenberg 2002) and the expansion of Lake Trout in the Flathead system (Montana) has been implicated as the primary cause of Bull Trout decline in this area (Ellis et al. 2011, Muhlfeld et al. 2012b). The introduction of Lake Trout into Bow and Hector lakes, Alberta resulted in the displacement of Bull Trout (Donald and Alger 1993). Donald and Alger (1993) theorized that this displacement may have been due to dietary overlap, as the two species had similar growth rates, gape limitations, mouth morphology and food habits in these lakes. However, Meeuwig et al. (2011) found little evidence for complete dietary overlap in the Glacier National Park lakes, but did find evidence for some level of related competition between the two species based on carbon and nitrogen stable isotope analyses.

Brook Trout introductions in Alberta began in the first half of the 20th century and declined rapidly in the second half (Warnock and Rasmussen 2013). Brook Trout are still stocked in Alberta, but since the late 20th century stocking has been restricted to water bodies with little chance for escape into waters with native fish. The impacts of Brook Trout invasion into Bull

Trout streams range from no impact to complete replacement of Bull Trout (Rich et al. 2003, Rieman et al. 2006), one species usually dominates in mixed communities (Warnock and Rasmussen 2013).

Brook Trout can mature earlier (age 2–3; Adams 1999, Kennedy et al. 2003) than Bull Trout and if they occur in higher numbers than Bull Trout could potentially have a reproductive advantage that may lead to displacement of Bull Trout (Leary et al. 1993). Bull Trout may be displaced into smaller and more isolated populations in headwater streams. These populations are at increased risk of local extinction through other causes (e.g., habitat disturbance) (Dunham and Rieman 1999), thus displacement by Brook Trout represents a potentially serious threat to remnant Bull Trout populations (Rieman et al. 2006). However, Brook Trout were negatively associated with other non-native species (e.g., Rainbow Trout, Brown Trout) naturalized in Bull Trout spawning and nursery streams (Warnock and Rasmussen 2013), thus their presence may function as a biotic barrier to Brook Trout dominance in the fish community (Benjamin et al. 2007). In addition to the presence of other non-native species, Warnock and Rasmussen (2013) found Brook Trout invasiveness was also strongly associated with temperature and habitat structure related to fish cover, with Brook Trout having higher success at warmer water temperatures and lower success at sites with high in-stream habitat complexity concerning substrate cover. Similar results have been found in other studies (e.g., Paul and Post 2001 [temperature], Rieman et al. 2006 [temperature], Rich et al. 2003 [habitat complexity]). It is also likely that competitive displacement by Brook Trout is a greater threat to resident Bull Trout than to the migratory form (Warnock and Rasmussen 2014). Residents have an increased direct niche overlap with Brook Trout (e.g., similar diet, occur in small headwater streams) for their entire life cycle, whereas migratory Bull Trout move downstream to higher stream orders and shift to piscivory at the end of their juvenile phase (Warnock and Rasmussen 2014). Migratory Bull Trout were also more aggressive and consumed more food than Brook Trout compared with the resident form (Warnock and Rasmussen 2014).

In addition to competitive replacement or displacement, hybridization with Brook Trout is also a threat to Bull Trout. Hybridization between these species has been confirmed in Alberta, but the extent is unknown. Warnock and Rasmussen (2013) found that Bull Trout x Brook Trout hybrids were rare, with hybrids being caught at only 4 of 80 sites analysed on the east slope of the Canadian Rockies in Alberta. In Quirk Creek (Bow River basin), hybrids of the stream-resident population of Bull Trout and Brook Trout generally made up less than 4% of the catch (Earle et al. 2007). Similarly low levels of hybridization have been found in other regions where the species' co-occur (e.g., Oregon – DeHaan et al. 2010, western Montana – Leary et al. 1993, Kanda et al. 2002). Hybridization generally occurs between female Bull Trout and male Brook Trout, but in situations where Brook Trout outnumber Bull Trout, hybridization between female Brook Trout and male Bull Trout has been documented (Kanda et al. 2002, DeHaan et al. 2010). Hybrids were believed to be sterile, however F_2 backcrosses have been found in Alberta (Popowich et al. 2011) and other regions (e.g., Kanda et al. 2002). The reduced fertility of F_1 hybrids and reduced survival of the offspring are likely responsible for the absence of hybrid swarms (Kanda et al. 2002).

Brown Trout occur in most HUC8s in DU 4; however, this species has not been considered in the threats assessment. A recent study in Montana found considerable support for Bull Trout replacement, rather than displacement, by Brown Trout (Al-Chokhachy et al. 2016). This was based on the observation that, rather than occurring concurrently, Bull Trout declines preceded increases in Brown Trout. Brown Trout were generally absent at temperatures below 11 °C, although they occur at temperatures as low as 3 °C within their native range (Hari et al. 2006), thus, colonization of colder sites is physiologically possible (Al-Chokhachy et al. 2016). Al-Chokhachy et al. (2016) suggest the limited expansion of Brown Trout into colder sites may be the result of competitive advantages for Bull Trout at colder temperatures (see Taniguchi and Nakano 2000), an explanation that requires further research.

Mortality

Life history and behavioural characteristics of Bull Trout make them vulnerable to exploitation. They are slow growing, late to mature and their opportunistic and aggressive feeding behaviour increase their vulnerability to angling, especially when bait is used (Berry 1994, Brewin 1996, Van Tighem 1997, Post and Paul 2000, Post et al. 2003, Paul et al. 2003). They also form spawning aggregations in clear shallow water, making them easy targets for anglers. These characteristics make them susceptible to overharvest, even at low levels of angling effort (Post and Paul 2000, Paul et al. 2003, Post et al. 2003).

A province-wide zero harvest regulation was implemented in 1995, but prior to this Bull Trout were overexploited throughout the province in accessible areas. Angler access has increased substantially over the past 50 years with industrial development (forestry, mining, fossil fuels) (Rhude and Stelfox 1997, Walty and Smith 1997, Paul 2000, Post and Paul 2000). Even with the zero harvest regulation, poaching and misidentification are still a problem. Restrictive regulations may cause a temporary decline in fishing effort, but subsequent improvements in quality (fish size or catch-per-unit-effort) may re-attract effort, particularly in accessible regions with high concentrations of potential anglers (Post et al. 2003). Clayton (1998) estimated that 5% of Bull Trout mortality in the Belly and Waterton rivers (Oldman River basin) was a result of poaching. Campaigns to educate anglers began in the 1990s and have had some success. In 1993, 29% and 68% of Trout Unlimited and licensed non-member anglers, respectively were unable to distinguish Brook Trout from Bull Trout, whereas in 2000 only 10% and 44%, respectively were unable to distinguish between the species (Norris et al. 2001). Catch and release fisheries may also be a source of mortality from hooking-caused injuries. Studies on nonanadromous salmonids have shown hooking mortality can range from 2–40% (Dextrase and Ball 1991, Taylor and White 1992, Bendock and Alexandersdottir 1993, Post et al. 2003). The artificial gears used in many trout fisheries often result in lower mortality rates (Post et al. 2003). In the Belly and Waterton rivers, Bull Trout hooking mortality was estimated to be 5% (Clayton 1998). In systems where introduced sport fish are present, by-catch of Bull Trout by anglers targeting other trout species is also a concern (Post and Paul 2000, Paul et al. 2003). Simulations conducted by Post et al. (2003) using reasonable estimates of fishing effort and associated mortality showed that restrictive angling regulations will continue to be required for many Bull Trout populations if they are to be sustained.

Scientific sampling is a potential source of mortality but is considered a low risk threat. This activity is controlled by permitting and by following sampling protocols.

Contaminants and Toxic Substances

Contaminants may have lethal or sublethal effects on Bull Trout. Sublethal effects include decreased egg production, reduced survival, behavioural changes, reduced growth, impaired osmoregulation, and many subtle endocrine, immune and cellular changes (Shively et al. 2007). Contaminants and toxic substances may also indirectly harm Bull Trout by reducing prey availability. Lethal effects are most often caused by spills, whereas sublethal effects occur from land uses (e.g., agriculture, residential/urban, mining, grazing and forestry) (Shively et al. 2007). Examples of contaminant types from these land uses include pesticides, persistent organic pollutants, mercury and endocrine disrupting substances.

There are approximately 550 pesticide active ingredients registered in Canada under the Pest Control Products Act (Environment Canada 2001). Herbicides are the most common type of pesticide sold and applied in Alberta and the agricultural sector accounts for the majority of pesticide sales (Brimble et al. 2005). Agricultural pesticides reach surface waters primarily through surface runoff, spray drift/atmospheric deposition and soil erosion (Environment Canada 2011). Higher precipitation increases the likelihood of pesticides entering surface waters through runoff, leaching to groundwater and soil erosion. Lower precipitation levels in parts of Alberta suggest a decreased incidence of pesticides entering surface waters, however, when precipitation events occur, the pesticide concentrations in the runoff can be relatively high (Chambers et al. 2000a, Donald et al. 2005, Environment Canada 2011). Changes in agricultural practices as a result of climate change may alter pesticide use patterns and increased pesticide use may be required to deal with introduced pests (Environment Canada 2001).

Mercury and other metals and organochlorines (e.g., DDT, PCBs) enter mountain waterbodies through transportation from distant sources in polluted air masses and by falling as rain or snow or as dry, gaseous fallout. Possible sources include long range transport from Eurasia, the Pacific Northwest and California (Schindler 2000). Semi-volatile organic contaminant deposition increases with elevation (over 100-fold per thousand meters for many volatile forms) due to higher amounts of precipitation combined with lower revolatization at cooler temperatures (Blows et al. 1998). Historically deposited contaminants (e.g., DDT, endosulfan) are also of concern for lakes receiving glacial melt waters. In Banff National Park, the warm summers of the mid-1990s increased the melt of these deposits and most of the contaminant load entered Bow Lake (Blais et al. unpubl. data in Schindler 2000). However, it should be noted that contaminant concentrations in Banff National Park are low and are not a direct threat to water quality, although they are biomagnified through transfer up the aquatic food chain to fish (Campbell et al. 2000, Schindler 2000). Additionally, contaminants from landfills, including metals and volatile organics, are often detected in aquifers several kilometers from the landfill source (Environment Canada 2001).

Endocrine disrupting substances (EDS) include certain pharmaceuticals, pesticides, industrial chemicals, metals and natural compounds. EDS are found in municipal, agricultural, textile, pulp and paper, and mining effluents. They may have effects on growth, development and reproduction of biota at very low concentrations and these effects may be expressed in future generations (Environment Canada 2001).

Municipal wastewater effluents (MWWE) are made up of human waste, suspended solids, debris and various chemicals from residential, commercial and industrial sources. MWWE are the largest source of effluent discharge to Canadian waters and they will continue to increase with population growth and urbanization (Environment Canada 2001). Sludges produced by municipal wastewater treatment plants are spread on the land and the effects of this on surface and groundwater are yet to be determined (Environment Canada 2001).

Sodium and chloride are surface and groundwater pollutants that are highly soluble and mobile. The two main sources are sewage and runoff of road salt. In the Bow River, sodium and chloride concentrations have increased over time (Block et al. 1992, Environment Canada unpubl. Data, both cited in Schindler 2000). At the boundary of Banff National Park, concentrations average 2.4–4.1 times greater than those above Lake Louise, indicating that sources of elevated sodium and chloride are connected with human activities (Schindler 2000). Annual road salt use in Banff National Park ranged from 1,500–3,500 tonnes per year with most of it being applied in the Bow Valley. Given the high solubility and mobility of sodium and chloride, it is likely that much of it will eventually reach the Bow River (Schindler 2000). Other de-icing compounds have been considered, but an affordable option has not been found (Banff Warden Service 1991 cited in Schindler 2000).

Contaminant concerns at active mine sites include chronic effects of metals, bioaccumulation, sediment contamination and endocrine disruption. Abandoned or closed mine sites are also a source of contaminant input to local water systems (Environment Canada 2001). Direct effluent discharges to water from petrochemical extraction are limited, with the exception of the oil sands. Petrochemical refineries, however, are located near waterbodies that can provide cooling water. Many by-products of the refining process are toxic, hydrophobic and persistent and sediments of adjacent waterbodies are often highly contaminated (Environment Canada 2001). Oil spills/leaks (e.g., pipeline leaks, train derailments) and mine tailings pond failures are also potential threats. Hydraulic fracturing ('fracking') has the potential to impact surface and ground water quality. Fracking is an unconventional process to extract oil and gas from shale formations. A mixture of large volumes of water (approximately 4 million gallons per fractured well [Vengosh et al. 2014]), chemicals and proppants (e.g., sand) is injected into a drilled well at high pressures, causing the shale to fracture and the natural gas to flow to the surface through the fractured well (Gagnon et al. 2016). Two of the five main shale gas formations in Canada are found in Alberta (Rivard et al. 2014). Impacts may occur from the spilling of chemicals and/or fracking fluid during transport, storage or use; accidental release of flowback water from the well; leakage of methane gas into groundwater caused by deteriorating wellbore seals; and, inadequate storage, treatment or disposal of flowback and/or produced waters (Council of Canadians 2014, Gagnon et al. 2016). As of 2014, 81 chemicals used in fracking fluid have been identified (Stringfellow et al. 2014); however, many others are proprietary and undisclosed (Gagnon et al. 2016). Of these 81 chemicals identified and characterized by Stringfellow et al. (2014), mammalian toxicity data does not exist for 30 of them; the majority of the remainder are non-toxic or low toxicity. Water quality and quantity are also impacted by the large water withdrawals. These may decrease stream flow and result in increased concentrations of contaminants. Additionally, sediments in surface water runoff may increase as a result of infrastructure development around well sites (Williams et al. 2008, Entrekin et al. 2011, Gagnon et al. 2016).

Nutrient Loading

Prior to human settlement and the development of agriculture, nitrogen (N) and phosphorous (P) limited productivity in aquatic ecosystems. The amount of N and P available for plant uptake today is much higher; N has doubled since the 1940s and anthropogenic sources of P are much higher than natural sources (Environment Canada 2001). For example, P concentrations in the Bow River in Banff National Park increased by an average of 730% in the reach between Lake Louise and the east park gate compared to concentrations at its headwaters (often undetectable), indicating a relatively high level of eutrophication (Schindler 2000). Approximately 50% of the P is dissolved and likely available for algal growth (Environment Canada 1991, Block et al. 1992 cited in Schindler 2000). Total N increased by 50% in the same reach (Schindler 2000). However, this problem does not appear to be worsening rapidly and there is no significant trend in P concentrations over the past 20 years. Improved nutrient management (e.g., sewage treatment improvements) has likely offset the higher nutrient inputs from the increasing numbers of visitors and residents (Schindler 2000).

Increases in nutrients from sources such as agricultural runoff, intensive livestock operations, sewage treatment plants and other municipal sources can speed eutrophication thereby causing algal blooms which lead to decreased concentrations of dissolved oxygen as the blooms die (Khan and Ansari 2005). Low concentrations of dissolved oxygen impact fish survival and reproduction by increasing susceptibility to disease, slowing growth, decreasing swimming ability, and changing survival behaviours (e.g., predator avoidance, feeding, migration and reproduction) (Barton and Taylor 1996). Moreover, the acute toxicity of most contaminants is increased under low dissolved oxygen conditions (e.g., Sprague 1985 in Chambers et al.

2000b). Fish may also be impacted indirectly through reduced survival of prey (Chambers et al. 2000b). Eutrophication can cause increased uptake of airborne toxic contaminants (e.g., PCBs) by lakes (Smith and Schindler 2009) and increased N and P can also increase the biodegradation of petrochemicals, aromatic hydrocarbons and pesticides in aquatic ecosystems (Graham et al. 2000, Smith and Schindler 2009).

Climate Change

In the Rocky Mountains, climate warming is occurring at two to three times the rate of the global average (Hansen et al. 2005, Pederson et al. 2010, Jones et al. 2014). In parts of Alberta, the mean temperatures of the warmest month have increased by at least 1 °C, the frost-free period has increased by close to 20 days, and growing-degree-days (GDD) have increased by up to 200 GDD > 5 °C (M. Sullivan, AEP, pers. comm.). Precipitation-as-rain has been increasing in the northern mountains, parkland and northern foothills, and has been stable or declining in other areas of the province. Precipitation-as-snow is stable, or possibly declining, in most regions. With little to no increase in precipitation and warmer temperatures, the amount of water lost to evaporation is not being replaced at the same rate, compounding the effects of warmer temperatures on fishes (M. Sullivan, AEP, pers. comm.). Furthermore, predicted warming may increase evaporation by as much as 55% in some areas of the western prairie provinces (Schindler and Donahue 2006). Strahlberg (2012) scaled the Intergovernmental Panel on Climate Change models to Alberta and found that in five regions of Alberta (boreal, foothills, montane, parkland and prairies), the mean temperature of the warmest month is predicted to increase by approximately 3 °C by 2080. The frost-free period is projected to increase by approximately 6 weeks (begin approximately 3 weeks earlier in spring and end approximately 3 weeks later in autumn). For species that spawn in autumn, such as Bull Trout, this suggests a possible future reduction to the winter incubation period of nearly two months.

Climate warming is also causing glacial retreat. Snowpack and glacial meltwater maintain river and groundwater supplies (Schindler and Donahue 2006). The Bow, Saskatchewan and Athabasca glaciers now end at least 1.5 km upslope of their position in the early 20th century and they are shrinking rapidly (Schindler and Donahue 2006 and references therein). There are no predictions as to when these glaciers may disappear, however, the US Geological Survey predicts that the smaller glaciers in nearby Glacier National Park, Montana will have disappeared by 2030 (Hall and Fagre 2003). In the Canadian western prairie provinces, it is predicted that due to their decline, winter snowpacks will contribute just over half of the water they presently do (Lapp et al. 2005). The spring melt is also predicted to occur earlier in the year, compounding the effects of drought. Higher latitudes and altitudes will be most impacted by these conditions as climate continues to warm (Bradley et al. 2004).

Extreme weather events (e.g., floods, droughts) are predicted to increase as climate warms (Coumou and Rahmstorf 2012, Hansen et al. 2012), but there is uncertainty as to the extent. In June of 2013, a high amount of precipitation combined with saturated ground caused “unprecedented” flooding in Alberta – the flooding of the Bow River was the largest flood event since 1932 and produced a peak discharge (1,470 m^3/s) nearly 15 times that of the daily mean (106 m^3/s) (Schnebele et al. 2014). Large floods may cause bed scour strong enough to destroy Bull Trout redds, embryos and alevins prior to emergence (Seegrist and Gard 1972, Montgomery et al. 1996, Tonina et al. 2008) and may displace newly emerged fry as they are unable to hold their position in high velocity water (Heggenes and Traaen 1988, Crisp and Hurley 1991, Nehring and Anderson 1993, Fausch et al. 2001, Wenger et al. 2011b). Drought conditions may lead to an increase in wildfires which, in turn, may cause loss of riparian vegetation thereby reducing shade and causing an increase in water temperature (Dunham et al. 2007). Large disturbances following a severe wildfire, such as extreme flooding and debris flow, may cause local extirpations (Dunham et al. 2003b). Longer term effects, such as changes in channel form and increased water temperatures, may cause changes in riverine food webs (Minshall 2003, Rosenberger et al. 2011, Davis et al. 2013), have temperature-related physiological impacts on fish (Jager et al. 1999), and increase mortality or local extirpations if water temperatures increase beyond lethal limits (Falke et al. 2015). Falke et al. (2015) found that wildfire management was more important than managing for connectivity or nonnative Brook Trout in improving Bull Trout resilience to climate change in the Pacific Northwest.

Increasing water temperatures from climate warming may cause habitat fragmentation and loss for Bull Trout. The relationship between the lower elevation limits of Bull Trout and mean annual temperature was modelled by Rieman et al. (2007) to examine the potential impacts of climate warming in the interior Columbia River basin. Their results indicated that increasing temperatures could result in the loss of 18–92% of thermally suitable natal habitat area and 27–99% of large (> 10,000 ha) habitat patches. Jones et al. (2014) conducted modelling using a conservative climate change scenario. Their results suggested a possible 58% loss of feeding, migrating and overwintering habitat and a 36% loss of spawning and rearing habitat in the Flathead River basin with an August air temperature increase of 3.28 °C. If temperature increases by 5.5 °C, feeding, migrating and overwintering habitat is predicted to decrease by 86% and spawning and rearing habitat by 76%. However, streams with greater riparian vegetation and/or groundwater inputs are less likely to be impacted by warmer air temperatures (Arismendi et al. 2012, MacDonald et al. 2014). Wenger et al. (2011a) found that to effectively manage Bull Trout for climate change, areas with the coldest water temperatures have the best long-term potential to support the species, thus they suggest resources should be allocated to these areas. Furthermore, genetic diversity in populations can offer resilience to climate warming (Kovach et al. 2012).

Interactive and Cumulative Effects

FEMAT (1993, p. IX-8) defines cumulative effects as “those effects on the environment that result from the incremental effect of the action when added to past, present and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period of time”. Effects can cumulate in a number of ways. The Canadian Environmental Assessment Research Council and the US National Research Council identified five key types of perturbations (CEARC and US NRC 1986):

Time-crowded Perturbations – Cumulative effects can occur because perturbations are so close in time that the effects of one are not dissipated before the next one occurs.

Space-crowded Perturbations – Cumulative effects can occur when perturbations are so close in space that their effects overlap.

Synergisms – Different types of perturbations occurring in the same area may interact to produce qualitatively and quantitatively different responses by the receiving ecological communities.

Indirect Effects – Cumulative effects can be produced at some time or distance from the initial perturbation, or by a complex pathway.

Nibbling – Incremental and decremental effects are often (but not always) involved in each of the above categories.

The impacts of multiple stressors acting at the same time may also interact in various ways. They may be additive (effect is equal to the sum of the impacts when each acts alone), synergistic (effect is greater than the sum of the individual stressor impacts), or antagonistic (effect is less than additive). Several studies examining the impacts of two stressors acting at once found that antagonistic effects are generally more common (e.g., Darling and Côté 2008, Piggott et al. 2015, Jackson et al. 2016, Radinger et al. 2016), however net effects may still be detrimental (Jackson et al. 2016). Jackson et al. (2016) found this to be particularly true at the community and organismal levels (antagonistic effects 40.88 and 65.22 percent of the time, respectively) in freshwater ecosystems. Synergies may be more predominant if there are three or more stressors acting on the same system (e.g., Przeslawski et al. 2005, Mora et al. 2007, Darling and Côté 2008). The impact of cumulative effects may be even greater for species living in less than ideal habitat, nearer to their environmental tolerance limits (Radinger et al. 2016).

Climate change can interact with other stressors by affecting the timing, spatial extent and/or intensity of effects of those stressors and may also limit the ability of an ecosystem to recover following a disturbance (Staudt et al. 2013). Some stressors may also make ecosystems more vulnerable to climate change. For example, damage caused by deforestation (e.g., reduction of shade in riparian areas) can decrease the resiliency of an ecosystem to climate change and may even contribute to climate change by releasing stored carbon into the atmosphere (Hansen and Hoffman 2011, Staudt et al. 2013). Deforestation may also cause local warming and reduced rainfall, exacerbating climate change impacts (Lawrence and Chase 2010, Staudt et al. 2013). Furthermore, land use often changes in response to climate change. For example, water withdrawals for agricultural purposes may increase with reduced precipitation or drought (Oliver and Morecraft 2014, Radinger et al. 2016), further exacerbating impacts of climate change on freshwater ecosystems. Xenopoulos et al. (2005) found that the combined effects of climate change and water withdrawal were greater than the effect of climate change alone. Wenger et al. (2011a, b) studied the combined impacts of increasing temperatures, decreasing summer flows, increasing winter high flows and invasion by competing species of trout in the interior West. Both native and non-native species were negatively impacted by higher temperatures, and increased winter flows were mainly detrimental to fall spawning trout species (e.g., Bull Trout). Competition with introduced trout species negatively impacted Cutthroat Trout but not Bull Trout; however, large declines in Bull Trout were predicted based on the impacts of temperature and flow changes (summarized in Williams et al. 2015).

Interactive and cumulative effects may also affect the ability of char to withstand invasion by non-native species. It is hypothesized that native char can resist invasion and persist in undisturbed watersheds which allow the expression of the full range of life history types, including large migratory fishes. When the migratory portion of the population is lost (e.g., through habitat disturbance, overfishing, etc.), the remaining native char are more vulnerable and less able to resist invasion (Nelson et al. 2002). The mechanisms allowing native chars to resist invasion and the interactions of these with habitat disturbance require further research (Dunham et al. 2008).

Scrimgeour et al. (2003) evaluated the interactive and cumulative effects of forest harvesting, oil and gas development and road networks on the occurrence and abundance of Bull Trout in the Kakwa and Simonette river drainages of Alberta (DU 2). Interactive and cumulative effects impaired or possibly impaired 76% of test sites in the two watersheds. These sites had lower densities of Bull Trout compared to reference sites. Combined impacts of forest harvesting and road networks in the Kakwa River basin were also examined by Ripley et al. (2005). Based on their projections, local extirpations of Bull Trout from up to 43% of stream reaches are predicted to occur within 20 years with an increase in forest harvesting of up to 35% of individual watersheds.

Kovach et al. (2016) quantified the additive and interactive effects of climate, invasive species and land use on population dynamics of Bull Trout in western Montana, northern Idaho and southern British Columbia. The effects of increasing stream temperature and invasive species were additive and independent in spawning habitat; however, the authors note that these stressors may become coupled in the future because population expansion of invasive competitors, such as Brook and Brown Trout, appears to be limited by cold temperatures (Warnock and Rasmussen 2013, Al-Chokhachy et al. 2016). The impacts of land use and invasive species were additive and interactive (i.e., the impact of one depended on exposure to the other stressor). In foraging habitats, the impacts of invasive species were strongly negative, although proactive control programs appeared to be effective at moderating this impact. Patch size was found to have the strongest effect on population dynamics in spawning habitats (Kovach et al. 2016). The size of suitable patches may shrink as temperatures increase in the future (Isaak et al. 2015, Kovach et al. 2016). Given that resident Bull Trout populations are confined to spawning habitat, it is apparent that future warming may pose a particularly significant threat for this portion of the population (Kovach et al. 2016, Al-Chokhachy et al. 2016). This study highlighted the importance of considering both life history variation and existing stressors when developing climate adaptation/mitigation strategies (Kovach et al. 2016).

Threat Level Assessment

Threats were assessed following the procedure outlined in DFO (2014), *Guidance on Assessing Threats, Ecological Risk and Ecological Impacts for Species at Risk*. This document defines a threat as “any human activity or process that has caused, is causing, or may cause harm, death, or behavioural changes to a wildlife species at risk, or the destruction, degradation, and/or impairment of its habitat, to the extent that population-level effects occur” (DFO 2014, p.2). In this instance, threats were first assessed at the HUC8 level. The Likelihood of Occurrence (LO; Table 8), Level of Impact (LI; Table 9), Causal Certainty (CC; Table 10), HUC Threat Risk (HTR, product of Likelihood of Occurrence and Level of Impact; Table 11), HUC-level Threat Occurrence (HTO; Table 12), HUC-level Threat Frequency (HTF; Table 13) and HUC-level Threat Extent (THE; Table 14) were evaluated for each identified threat (Appendix 1 and 2). This assessment relied heavily on information compiled by Alberta Environment and Parks as part of their Fish Sustainability Index and cumulative effects modelling approach to threats assessment. Current information for the Oldman River Basin was not available at the time of publication; information from the 2013 version of the Fish Sustainability Index was used instead.

Table 8. Categories of Likelihood of Occurrence (LO).

Likelihood of Occurrence	Definition
Known or very likely to occur	This threat has been recorded to occur 91–100%
Likely to occur	There is 51–90% chance that this threat is or will be occurring
Unlikely	There is 11–50% chance that this threat is or will be occurring
Remote	There is 1–10% or less chance that this threat is or will be occurring
Unknown	There are no data or prior knowledge of this threat occurring now or in the future

Table 9. Categories of Level of Impact (LI) linked to a threat.

Level of Impact	Definition
Extreme	Severe population decline (e.g., 71–100%) with the potential for extirpation
High	Substantial loss of population (31–70%) or threat would jeopardize the survival or recovery of the population
Medium	Moderate loss of population (11–30%) or threat is likely to jeopardize the survival or recovery of the population
Low	Little change in population (1–10%) or threat is unlikely to jeopardize the survival or recovery of the population
Unknown	No prior knowledge, literature or data to guide the assessment of threat severity on population

Table 10. Categories of Causal Certainty (CC) linked to a threat.

Causal Certainty	Definition
Very high	Very strong evidence that threat is occurring and the magnitude of the impact to the population can be quantified
High	Substantial evidence of a causal link between threat and population decline or jeopardy to survival or recovery
Medium	There is some evidence linking the threat to population decline or jeopardy to survival or recovery
Low	There is a theoretical link with limited evidence that threat is leading to a population decline or jeopardy to survival or recovery
Very low	There is a plausible link with no evidence that the threat is leading to a population decline or jeopardy to survival or recovery

Table 11: The Threat Risk Matrix combines the Likelihood of Occurrence and Threat Impact rankings to establish the Threat Risk. The resulting Threat Risk is categorized as Low, Medium, High or Unknown.

		Threat Impact				
		Low	Medium	High	Extreme	Unknown
Likelihood of Occurrence	Known	Low	Medium	High	High	Unknown
	Likely	Low	Medium	High	High	Unknown
	Unlikely	Low	Medium	Medium	Medium	Unknown
	Remote	Low	Low	Low	Low	Unknown
	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown

Table 12. Categories of HUC-level Threat Occurrence (HTO).

HUC-level Threat Occurrence	Definition
Historical	A threat that is known to have occurred in the past and negatively impacted the population
Current	A threat that is ongoing, and is currently negatively impacting the population
Anticipatory	A threat that is anticipated to occur in the future, and will negatively impact the population

Table 13. Categories of HUC-level Threat Frequency (HTF).

HUC-level Threat Frequency	Definition
Single	The threat occurs once
Recurrent	The threat occurs periodically or repeatedly
Continuous	The threat occurs without interruption

Table 14. Categories of HUC-level Threat Extent (HTE).

HUC-level Threat Extent	Definition
Extensive	71–100% of the population is affected by the threat
Broad	31–70% of the population is affected by the threat
Narrow	11–30% of the population is affected by the threat
Restricted	1–10% of the population is affected by the threat

This was then rolled up to the watershed level and the Watershed Threat Risk (WTR; a roll-up of HUC Threat Risk [HTR]), Watershed-level Threat Occurrence (WTO), Watershed-level Threat Frequency (WTF) and Watershed-level Threat Extent (WTE; a roll-up of HUC-level Threat Extent) were evaluated (Table 15).

Table 15. Watershed-level Threat Risk (WTR), Threat Occurrence (WTO), Threat Frequency (WTF) and Threat Extent (WTE). When rolling up from the HUC-level Threat Risk, the highest level of risk for a given HUC was retained for each watershed.

THREAT	WTR	WTO	WTF	WTE	WTR	WTO	WTF	WTE
	Oldman				Bow			
Competition and Hybridization with Brook Trout	Low	Current	Continuous	Broad	Medium	Current	Continuous	Broad
Competition with Lake Trout	Medium	Current	Continuous	Broad	High	Current	Continuous	Broad
Mortality (e.g., angling, scientific sampling)	High	Historical, Current	Recurrent	Broad	High	Historical, Current	Recurrent	Broad
Habitat Fragmentation								
Culverts	High	Current	Continuous	Broad	High	Current	Continuous	Broad
Dams and Weirs	High	Historical, Current	Continuous	Extensive	High	Historical, Current	Continuous	Extensive
Irrigation Canals	Medium	Current	Continuous	Narrow	Medium	Current	Continuous	Narrow
Habitat Alteration								
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	High	Current	Recurrent	Broad	High	Current	Recurrent	Broad
Suspended and Deposited Sediments	High	Current	Recurrent	Broad	High	Current	Recurrent	Broad
Alteration of Stream Temperature (change from natural)	High	Current	Continuous	Broad	Medium	Current	Continuous	Broad
Alteration of Groundwater Quantity or Quality	High	Current, Anticipatory	Single, Recurrent	Extensive	High	Current	Single, Recurrent	Extensive
Nutrient Loading	High	Current, Anticipatory	Recurrent	Broad	High	Current, Anticipatory	Recurrent	Broad
Contaminants and Toxic Substances – assessed at Watershed and DU levels only	High	Current, Anticipatory	Single, Recurrent	Broad	High	Current, Anticipatory	Single, Recurrent	Broad
Climate Change – assessed at DU level only								
Interactive and Cumulative Effects – assessed at DU level only								

THREAT	WTR	WTO	WTF	WTE	WTR	WTO	WTF	WTE
	Red Deer				North Saskatchewan			
Competition and Hybridization with Brook Trout	High	Current	Continuous	Broad	Low	Current	Continuous	Broad
Competition with Lake Trout	Low	Current	Continuous	Broad	Low	Current	Continuous	Broad
Mortality (e.g., angling, scientific sampling)	High	Historical, Current	Recurrent	Broad	High	Historical, Current	Recurrent	Broad
Habitat Fragmentation								
Culverts	High	Current	Continuous	Broad	High	Current	Continuous	Broad
Dams and Weirs	Low	Historical, Current	Continuous	Extensive	High	Historical, Current	Continuous	Extensive
Irrigation Canals	Medium	Current	Continuous	Narrow	High	Current	Continuous	Narrow
Habitat Alteration								
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	High	Current	Recurrent	Broad	High	Current	Recurrent	Broad
Suspended and Deposited Sediments	Medium	Current	Recurrent	Broad	Medium	Current	Recurrent	Broad
Alteration of Stream Temperature (change from natural)	Medium	Current	Continuous	Broad	High	Current	Continuous	Broad
Alteration of Groundwater Quantity or Quality	High	Current	Single, Recurrent	Extensive	High	Current	Single, Recurrent	Extensive
Nutrient Loading	High	Current, Anticipatory	Recurrent	Broad	High	Current, Anticipatory	Recurrent	Broad
Contaminants and Toxic Substances – assessed at Watershed and DU levels only	Medium	Current, Anticipatory	Single, Recurrent	Broad	High	Current, Anticipatory	Single, Recurrent	Broad
Climate Change – assessed at DU level only								
Interactive and Cumulative Effects – assessed at DU level only								

This was then further rolled up to the DU level (Table 16). When rolling up HTR to WTR and then to DUTR, a precautionary approach was followed and the highest level of risk for a given HUC/Watershed was retained.

Table 16. Designatable Unit-level Threat Risk (DUTR), Threat Occurrence (DUTO), Threat Frequency (DUTF) and Threat Extent (DUTE). When rolling up from the Watershed-level Threat Risk, the highest level of risk for a given watershed was retained.

THREAT	DUTR	DUTO	DUTF	DUTE
Competition and Hybridization with Brook Trout	**High**	**Current**	**Continuous**	**Broad**
Competition with Lake Trout	**High**	**Current**	**Continuous**	**Broad**
Mortality (e.g., angling, scientific sampling)	**High**	**Historical, Current**	**Recurrent**	**Broad**
Climate Change - assessed at DU level only	**High**	**Current, Anticipatory**	**Continuous**	**Broad**
Interactive and Cumulative Effects - assessed at DU level only	**High**	**Current, Anticipatory**	**Continuous**	**Broad**
Habitat Fragmentation				
Culverts	**High**	**Current**	**Continuous**	**Broad**
Dams and Weirs	**High**	**Historical, Current**	**Continuous**	**Extensive**
Irrigation Canals	**High**	**Current**	**Continuous**	**Narrow**
Habitat Alteration				
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	**High**	**Current**	**Recurrent**	**Broad**
Suspended and Deposited Sediments	**High**	**Current**	**Recurrent**	**Broad**
Alteration of Stream Temperature (change from natural)	**High**	**Current**	**Continuous**	**Broad**
Alteration of Groundwater Quantity or Quality	**High**	**Current, Anticipatory**	**Single, Recurrent**	**Extensive**
Nutrient Loading – assessed at Watershed and DU levels only	**High**	**Current, Anticipatory**	**Recurrent**	**Broad**
Contaminants and Toxic Substances – assessed at Watershed and DU levels only	**High**	**Current, Anticipatory**	**Single, Recurrent**	**Broad**

MITIGATIONS AND ALTERNATIVES

Threats to survival can be minimized by implementing mitigation measures to reduce or eliminate potential harmful effects that could result from works or undertakings associated with projects or activities in Bull Trout habitat. Bull Trout are currently not protected under the SARA. Research has been completed summarizing the types of works, activities or projects that have been undertaken in habitat known to be occupied by Bull Trout in DU 4 (Table 17). The DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of projects that have occurred between January 2008 and March 2014. A total of 673 projects and activities were found, but this may not represent a comprehensive list of all projects and activities. Some projects may not have been reported to DFO. The works, undertakings and activities that may have directly or indirectly affected Bull Trout habitat include watercourse crossings (e.g., bridges, culverts, open cut crossings), shoreline/streambank work (e.g., stabilization, infilling, retaining walls, riparian vegetation management), mineral aggregate, oil and gas exploration, extraction and/or production, instream works (e.g., channel maintenance, restoration, modifications, realignments, dredging, aquatic vegetation removal), water management (e.g., stormwater management, water withdrawal), structures in water (e.g., boat launches, docks, effluent outfalls, water intakes) and other projects that did not fit into any of the above categories (e.g., conduit installation on bridge, bridge washing). Works/Projects/Activities dealing with control of nuisance species, contaminated site remediation and habitat improvement (e.g., habitat restoration) were also identified in PATH and are included in Table 17 for information purposes. The category ‘invasive species introductions (authorized and unauthorized)’ was added to the list although this is not tracked in PATH.

As indicated in the Threat Level Assessment, several threats affecting Bull Trout are related to habitat alteration and/or fragmentation. Habitat-related threats to Bull Trout have been linked to the Pathways of Effects developed by DFO Fisheries Protection Program (FPP) (Table 17). DFO FPP has developed guidance on mitigation measures for 19 Pathways of Effects for the protection of aquatic species at risk in the Central and Arctic Region (Coker et al. 2010). This guidance should be referred to when considering mitigation and alternative strategies for habitat-related threats.

Table 17. Summary of works, projects and activities that have occurred during the period of January 2008 to March 2014 in areas known to be occupied by Bull Trout (DU 4). Threats known to be associated with these types of works, projects, and activities have been indicated by a checkmark. The number of works, projects, and activities associated with each Bull Trout DU 4 watershed, as determined from the project assessment analysis, has been provided. Applicable Pathways of Effects from Coker et al. (2010) have been indicated for each threat associated with a work, project or activity (1 – Vegetation clearing; 2 – Grading; 3 – Excavation; 4 – Use of explosives; 5 – Use of industrial equipment, 6 – Cleaning or maintenance of bridges or other structures, 7 – Riparian planting, 8 – Streamside livestock grazing, 9 – Marine seismic surveys, 10 – Placement of material or structures in water, 11 – Dredging, 12 – Water extraction, 13 – Organic debris management, 14 – Wastewater management, 15 – Addition or removal of aquatic vegetation, 16 – Change in timing, duration and frequency of flow, 17 – Fish passage issues, 18 – Structure removal, 19 – Placement of marine finfish aquaculture site).

Work/Project/Activity	**Threats** (associated with work/project/activity)							**Watershed** (number of works/projects/activities between 2008-2014)			
	Alteration of Natrual Flow Regimes	**Suspended and Deposited Sediments**	**Alteration of Stream Temperature**	**Alteration of Groundwater Quality or Quantity**	**Invasive species**	**Contaminants and Toxic Substances**	**Nutrient Loading**	**Oldman**	**Bow**	**Red Deer**	**North SK**
Applicable pathways of effects for threat mitigation and project alternatives	16	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 18	1, 3, 7, 8, 14, 15, 16, 17	3	14, 17	1, 4, 5, 6, 7, 11, 13, 14, 15, 16, 18	1, 4, 7, 8, 10, 11, 13, 14, 15, 16				
Watercourse crossings (e.g., bridges, culverts, open cut crossings)	✓	✓				✓	✓	54	103	53	63
Shoreline, streambank work (e.g., stabilization, infilling, retaining walls, riparian vegetation management)	✓	✓	✓			✓	✓	38	67	26	10
Mineral Aggregate, Oil and Gas Exploration, Extraction, Production	✓	✓		✓		✓		1	4	2	7

Work/Project/Activity	Threats (associated with work/project/activity)							Watershed (number of works/projects/activities between 2008-2014)			
	Alteration of Natrual Flow Regimes	**Suspended and Deposited Sediments**	**Alteration of Stream Temperature**	**Alteration of Groundwater Quality or Quantity**	**Invasive species**	**Contaminants and Toxic Substances**	**Nutrient Loading**	**Oldman**	**Bow**	**Red Deer**	**North SK**
Applicable pathways of effects for threat mitigation and project alternatives	16	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 18	1, 3, 7, 8, 14, 15, 16, 17	3	14, 17	1, 4, 5, 6, 7, 11, 13, 14, 15, 16, 18	1, 4, 7, 8, 10, 11, 13, 14, 15, 16				
Instream works (e.g., channel maintenance, restoration, modifications, realignments, dredging, aquatic vegetation removal)	✓	✓				✓	✓	28	45	14	15
Water management (e.g., stormwater management, water withdrawal)	✓	✓				✓	✓	9	33	7	16
Structures in water (e.g., boat launches, docks, effluent outfalls, water intakes)	✓	✓	✓					12	15	3	4
Control of Nuisance Species								1			
Contaminated Site Remediation										1	
Habitat Improvement (e.g., habitat restoration)								2	6	5	
Other (e.g., conduit installation on bridge, bridge washing)								3	13	3	10

Work/Project/Activity	Threats (associated with work/project/activity)							Watershed (number of works/projects/activities between 2008-2014)			
	Alteration of Natrual Flow Regimes	Suspended and Deposited Sediments	Alteration of Stream Temperature	Alteration of Groundwater Quality or Quantity	Invasive species	Contaminants and Toxic Substances	Nutrient Loading	Oldman	Bow	Red Deer	North SK
Applicable pathways of effects for threat mitigation and project alternatives	16	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 18	1, 3, 7, 8, 14, 15, 16, 17	3	14, 17	1, 4, 5, 6, 7, 11, 13, 14, 15, 16, 18	1, 4, 7, 8, 10, 11, 13, 14, 15, 16				
Invasive species introductions (authorized and unauthorized)					✓						
TOTAL								148	286	114	125

Additional mitigation and alternative measures related to exotic/invasive species, scientific sampling, climate change and interactive and cumulative effects are listed below.

Exotic/Invasive Species

As discussed in the Anthropogenic Threats section, introduction and establishment of exotic/invasive species could have significant negative effects on Bull Trout.

Mitigation

- Physically remove non-native species from areas known to be inhabited by Bull Trout.
- Monitor range of Bull Trout, DU 4 for exotic/invasive species that may negatively impact Bull Trout directly, or affect Bull Trout preferred habitat.
- Develop a plan to address potential risks, impacts and proposed actions if monitoring detects the arrival or establishment of exotic/invasive species.
- Introduce a public awareness campaign and encourage the use of existing exotic species reporting systems.

Alternatives

- Unauthorized
    - None
- Authorized
    - Use only native species.
    - Follow the National Code on Introductions and Transfers of Aquatic Organisms for all aquatic organism introductions (DFO 2003).

Mortality

As discussed in the Anthropogenic Threats section, mortality caused by angling and, to a lesser extent, scientific sampling is a threat to Bull Trout in DU 4.

Mitigation

- Fishery closures.
- Catch and release only (province-wide zero-bag limit has been in effect since 1995).
- Public education to reduce misidentification and increase awareness of regulations.
- Barbless hooks to reduce hooking mortality.
- Collection/sampling licenses are issued by DFO pursuant to Part VII of the *General Fisheries Regulations*, Section 51.
- Collection/sampling licenses are issued by the Government of Alberta under the authority of the *Alberta Fisheries Act* .
- Sampling in National Parks requires a Research and Collection Permit issued by Parks Canada.
- Sampling in Alberta Provincial Parks requires a Research and Collection Permit issued by Alberta Parks.

Alternatives

- Prohibit lethal scientific sampling of Bull Trout.

Climate Change Adaptation and Mitigation

Strategies to mitigate the negative impacts of climate change are becoming increasingly important. For migratory fishes, such as Bull Trout, conserving the connectivity, size and extent of high quality habitats and helping to guide habitat restoration efforts are important strategies to mitigate the effects of climate change (Muhlfeld and Marotz 2005, D'Angelo and Muhlfeld 2013, Jones et al. 2014). Life history variation (i.e., resident and migratory populations) and existing stressors must also be explicitly considered when developing climate adaptation/mitigation strategies (Kovach et al. 2016). Mitigation/adaptation options that can be undertaken at the provincial level for climate change impacts on fisheries and water in Alberta are summarized below (M. Sullivan pers. comm.).

Regulation of fisheries – Alberta Fisheries Management Branch can increase or decrease exploitation of fish stocks through seasons, bag and size limits, and quotas. This may be used to protect vulnerable species and increase population resilience or can be used to decrease abundance and range of exotic species.

1) Restoration – Alberta Fisheries Management Branch can stock or transfer native species to new habitats that the species' are unable to access naturally (e.g., moving Westslope Cutthroat Trout to higher elevation lakes). Stocking using native strains of Alberta fishes may also be used to help restore populations that have suffered from extreme events such as floods, droughts and winter/summer kills.
2) Advice to developers – Alberta Fisheries Management Branch can influence watershed development by recommending and streamlining approvals for projects that assist in fisheries climate adaptation. The long-term benefits to fish of projects that reduce risks of extreme events or improve water quality balanced with the risks of short-term disruptions caused by construction should be considered. Resulting economic trade-offs may entice developers to consider climate adaptation projects (e.g., replacing a small culvert with another small culvert should receive strict fish protection construction requirements because both the construction phase and final product threaten fish, contrasted with replacing a small culvert with a multi-species underpass and having less stringent construction requirements because of the benefits of the final project to fish).

Gray Actions (engineered, concrete/steel solutions)

1) Dams to stabilize flashy river flow.
2) Multi-species underpasses to prevent stream fragmentation at road and railroad stream crossings.
3) Convert straight diversion and drainage channels to meanders or linked pools (reduces erosion and increases infiltration).
4) Convert linear concrete and steel retaining walls to complex meandering bank armouring using rock and rubble (adds habitat).
5) Convert weirs and low head dams to rock and rubble rapid and pool complexes (reduces fish migration barriers and entrainment and adds habitat).

Green Actions (ecological-oriented landscape solutions)

1) Large wetlands on mainstem to stabilize flashy flow.

2) Small wetlands on watershed and side tributaries to increase groundwater infiltration (cools water and stabilizes flow).
3) Increased mainstem meanders to slow erosion.
4) Increased small stream meanders and side channels to increase groundwater infiltration.
5) Upper watershed forest retention to stabilize flashy flow.
6) Reduce roads in upper watershed to stabilize flashy flow.
7) Increase deep-rooted, flood-resistant streamside riparian vegetation (cools water and reduces flood effects).

Soft Actions (legislation, agency actions, public behaviour)

1) Regulate development in upper watershed (reduces floods, increases groundwater, cools temperatures, etc.) to threshold levels (e.g., 20% land clearing, < 0.6 km/km^2 roads).
2) Regulate development on flood plain (reduce need for emergency work usually resulting in habitat loss and silt; more groundwater which will provide oxygen and temperature refuges).
3) Restrictive fishing regulations to reduce fishing mortality to compensate for increased natural mortality or decreased production. Population structure should respond with increased longevity and broader representation of mature age classes.
4) Strong and immediate (= effective) responses to first indication of exotic species (e.g., rotenone, capture, etc.)
5) Move cool water fish to vacant higher elevation habitat (will often require eradication of non-native species, e.g., Brook Trout removal in Hidden and Devon lakes in Banff National Park to create new habitat for Westslope Cutthroat Trout and Bull Trout moved from lower Bow and Red Deer rivers).
6) Develop hatchery brood sources of local, native fish for re-stocking after extreme flood or winterkill events.
7) Legislate design of floodplain gravel pits/golf course water traps/water pools to reduce stranding.
8) Create climate-oriented refuges in higher elevation areas of Alberta (e.g., Swan Hills, Christina Hills, Marten Hills) to provide refuges for cool-temperature fish. These refuges will allow development up to landscape thresholds (e.g., 20% land clearing, < 0.6 km/km^2 oil and gas roads).
9) Create non-public motorized travel refuge areas (e.g., Blackfoot Provincial Grazing Reserve, Willmore Wilderness Park, Canadian Forces Base Wainwright and Suffield) to reduce exploitation on long-lived fish (e.g., Walleye, Lake Sturgeon) and create population structures that are resilient to periodic year-class failures. These refuge areas will allow industrial development and could allow hunting and fishing.

Interactive and Cumulative Effects

In situations where multiple stressors are impacting the system it is important (and an ongoing challenge) to determine the types of stressor interactions (e.g., additive, synergistic, antagonistic) and to disentangle the pathways by which the stressors are interacting (Piggott et al. 2015). In situations with antagonistic stressors, attempts to reduce or eliminate one stressor may not result in the expected benefits unless it is the dominant stressor that is driving the interaction (Halpern et al. 2008, Brown et al. 2013, Piggott et al. 2015). In situations with synergistic stressors on the other hand, reducing or eliminating one stressor may result in larger benefits than expected (Crain et al. 2008, Piggott et al. 2015). Additive effects imply stressors that are acting independently, thus mitigation of invidual stressors should yield predictable results (Darling and Côté 2008, Piggott et al. 2015).

Alberta Environment and Parks is currently working on a cumulative effects modelling approach to aid in the determination of the primary threats in a watershed and the expected improvements in population sustainability if the impacts of these threats are decreased (J. Reilly, AEP, pers. comm.).

EXISTING PROTECTION

Within Alberta, Bull Trout are listed as Sensitive under *The Wildlife Act* and there has been a province-wide zero-bag limit in effect since 1995. Portions of the range of Bull Trout in DU 4 are within Banff National Park and are therefore on federally protected land. Additionally, critical habitat identified for Westslope Cutthroat Trout is within the range of Bull Trout in DU 4 (Tables 18–21; DFO 2014b).

Table 18. Locations of lakes identified as critical habitat for Westslope Cutthroat Trout in Banff National Park, Alberta.

Waterbody Name	Latitude	Longitude
Sawback Lake	51°20′58.9″	-115°46′10.6″
Elk Lake	51°17′18.5″	-115°39′21.16″
Little Fish Lake	51°38′38.11″	-116°10′48.36″
Big Fish Lake	51°38′32.94″	-116°11′56.99″

Table 19. Locations of flowing waters identified as critical habitat for Westslope Cutthroat Trout in Banff National Park, Alberta.

Waterbody Name	Starting Latitude	Starting Longitude	Ending Latitude	Ending Longitude
Cuthead Creek	51°25′17.0″	-115°41′19.9″	51°23′59.9″	-115°40′51.3″
Spray River	50°43′14.4″	-115°23′20.6″	50°44′24.4″	-115°23′39.6″
Upper Bow River	51°34′38.17″	-116°19′25.18″	51°39′02.43″	-116°25′09.40″
Babel Creek	51°19′41.84″	-116°09′48.62″	51°19′05.97″	-116°09′18.43″
Helen Creek	51°40′34.51″	-116°24′24.97″	51°38′59.88″	-116°22′58.39″
Outlet Creek	51°23′59.60″	-116°07′38.07″	51°24′14.44″	-116°06′41.79″

Table 20. Locations of lakes identified as critical habitat for Westslope Cutthroat Trout in Alberta (outside of National Parks).

Waterbody Name	Latitude	Longitude
Picklejar Lakes (#4 Lake)	50°31′03.633″	-114°56′59.601″
Picklejar Lakes (#2 Lake)	50°31′06.561″	-114°46′26.451″

Table 21. Locations of flowing waters identified as critical habitat for Westslope Cutthroat Trout in Alberta (outside of National Parks).

Downstream end stream name	Latitude	Longitude	Upstream end stream name(s)	Latitude	Longitude
Corral Creek	50°15′35.167″	-114°24′40.601″	Corral Creek	50°14′54.208″	-114°26′44.835″
Livingstone River	50°06′05.080″	-114°26′39.740″	Livingstone River	50°10′59.794″	-114°28′34.535″
			Isolation Creek	50°07′08.882″	-114°26′57.646″
			Mean Creek	50°09′06.371″	-114°25′50.309″
			Savanna Creek	50°08′52.644″	-114°29′12.629″
			North Twin Creek	50°11′18.567″	-114°26′31.584″
Beaver Creek	50°06′09.577″	-114°26′17.548″	Beaver Creek	50°06′37.485″	-114°25′16.033″
Speers Creek	50°02′49.860″	-114°25′34.983″	Speers Creek	50°03′32.016″	-114°27′40.696″
White Creek	49°59′40.758″	-114°20′01.472″	White Creek	50°00′57.062″	-114°17′56.124″
Hidden Creek	49°58′49.421″	-114°28′58.662″	Hidden Creek	49°59′09.688″	-114°35′35.594″
			South Hidden Creek	49°58′24.176″	-114°35′24.057″
			Unnamed tributary to Hidden Creek	49°58′46.995″	-114°34′06.132″
Oldman River	50°03′02.603″	-114°35′09.761″	Oldman River	50°07′02.698″	-114°41′26.438″
			Cache Creek	50°01′38.448″	-114°37′31.115″
			Beehive Creek	50°03′29.174″	-114°35′54.151″
			Soda Creek	50°04′39.101″	-114°36′37.002″
			Slacker Creek	50°04′52.021″	-114°36′19.702″
			Pasque Creek	50°08′00.535″	-114°37′23.192″
			Lyall Creek	50°06′18.019″	-114°37′53.645″
			Straight Creek	50°08′17.392″	-114°38′21.054″
			Unnamed tributary to Oyster Creek	50°09′26.903″	-114°41′36.476″
			Oyster Creek	50°09′42.543″	-114°39′33.733″

Downstream end stream name	Latitude	Longitude	Upstream end stream name(s)	Latitude	Longitude
Racehorse Creek	49°49′48.527″	-114°30′06.933″	South Racehorse Creek	49°45′09.149″	-114°36′53.273″
			North Racehorse Creek	49°50′52.337″	-114°38′11.042″
			Smith Creek	49°48′22.768″	-114°34′14.291″
			Spoon Creek	49°46′55.710″	-114°33′46.238″
			Unnamed tributary to South Racehorse Cr	49°46′36.487″	-114°35′05.517″
			Unnamed tributary to South Racehorse Cr	49°45′36.541″	-114°36′09.186″
			First Creek	49°49′57.771″	-114°35′27.934″
			Unnamed tributary to North Racehorse Cr	49°50′16.434″	-114°36′07.364″
			Unnamed tributary to North Racehorse Cr	49°50′29.626″	-114°36′11.018″
			Unnamed tributary to North Racehorse Cr	49°51′43.909″	-114°34′54.551″
Vicary Creek	49°45′13.544″	-114°29′18.992″	Vicary Creek	49°45′11.525″	-114°30′09.282″
Sharples Creek	49°52′52.320″	-114°04′08.479″	Sharples Creek	49°52′53.575″	-114°03′56.675″
Unnamed tributary to Todd Creek	49°46′37.939″	-114°17′40.635″	Unnamed tributary to Todd Creek	49°46′44.634″	-114°18′38.477″
South Todd Creek	49°45′04.970″	-114°17′36.964″	South Todd Creek	49°44′59.020″	-114°17′42.893″
Rock Creek	49°37′52.485″	-114°18′39.309″	Rock Creek	49°37′43.250″	-114°19′11.129″
Unnamed tributary to Blairmore Creek	49°41′01.926″	-114°27′09.614″	Unnamed tributary to Blairmore Creek	49°41′10.112″	-114°27′07.788″
Star Creek	49°37′33.832″	-114°32′17.808″	Star Creek	49°37′06.281″	-114°32′38.039″
Allison Creek	49°40′28.207″	-114°35′39.698″	Allison Creek	49°41′45.125″	-114°36′29.769″
Girardi Creek	49°38′01.010″	-114°36′23.004″	Girardi Creek	49°37′07.700″	-114°36′16.595″

Downstream end stream name	Latitude	Longitude	Upstream end stream name(s)	Latitude	Longitude
Lynx Creek	49°27′46.706″	-114°26′33.966″	Lynx Creek	49°33′09.083″	-114°30′41.366″
			Goat Creek	49°28′58.116″	-114°33′32.321″
			Unnamed tributary to Goat Creek	49°29′39.731″	-114°30′36.479″
			Unnamed tributary to Goat Creek	49°30′28.338″	-114°31′44.036″
			Snowshoe Creek	49°31′29.874″	-114°31′32.077″
			Unnamed tributary to Lynx Creek	49°32′16.900″	-114°30′46.954″
			Unnamed tributary to Lynx Creek	49°32′48.064″	-114°30′56.371″
North Lost Creek	49°26′52.795″	-114°29′49.357″	North Lost Creek	49°27′39.622″	-114°32′28.749″
			Unnamed tributary to North Lost Creek	49°26′59.268″	-114°29′47.636″
Carbondale River	49°24′24.268″	-114°29′55.227″	Carbondale River	49°24′10.413″	-114°31′55.732″
			Macdonald Creek	49°23′58.988″	-114°31′21.320″
			Unnamed tributary to Carbondale River	49°24′07.582″	-114°30′33.791″
			Unnamed tributary to Carbondale River	49°24′24.317″	-114°31′13.940″
Unnamed tributary to Gardiner Creek	49°23′06.059″	-114°27′45.055″	Unnamed tributary to Gardiner Creek	49°23′07.271″	-114°27′55.956″
Gardiner Creek	49°22′55.026″	-114°27′42.597″	Gardiner Creek	49°22′16.046″	-114°28′15.653″
O’Haggen Creek	49°26′22.272″	-114°23′24.566″	O’Haggen Creek	49°25′09.847″	-114°23′27.069″
Syncline Brook	49°20′24.381″	-114°25′16.156″	Syncline Brook	49°19′34.087″	-114°26′58.134″
South Castle River	49°13′20.414″	-114°13′41.560″	South Castle River	49°11′50.009″	-114°08′44.492″
			Font Creek	49°12′31.466″	-114°11′55.543″
West Castle River	49°16′45.402″	-114°22′46.600″	West Castle River	49°14′07.238″	-114°20′59.831″
			Unnamed tributary to West Castle River	49°14′45.571″	-114°21′09.058″

Downstream end stream name	Latitude	Longitude	Upstream end stream name(s)	Latitude	Longitude
Gold Creek	49°36′27.797″	-114°23′34.32″	Gold Creek	49°42′27.914″	-114°23′49.456″
			Morin Creek	49°39′00.586″	-114°23′41.120″
			Caudron Creek	49°41′15.680″	-114°22′17.373″
Gorge Creek	50°39′17.883″	-114°43′03.745″	Gorge Creek	50°40′33.641″	-114°46′25.228″
			Unnamed tributary to Gorge Creek	50°38′58.590″	-114°43′45.322″
Unnamed tributary to Flat Creek	50°28′15.863″	-114°26′56.282″	Unnamed tributary to Flat Creek	50°26′53.396″	-114°30′04.205″
Deep Creek	50°25′28.555″	-114°28′28.511″	Deep Creek	50°26′18.028″	-114°31′11.831″
Zephyr Creek	50°23′23.599″	-114°34′28.401″	Zephyr Creek	50°21′23.040″	-114°33′49.754″
Unnamed “Cutthroat” Creek	50°28′41.881″	-114°29′22.504″	Unnamed “Cutthroat” Creek	50°27′22.405″	-114°31′37.680″
Picklejar Creek	50°31′14.392″	-114°47′47.703″	Picklejar Creek	50°31′07.705″	-114°47′04.285″
Prairie Creek	50°52′00.711″	-114°47′08.564″	Prairie Creek	50°52′40.131″	-114°53′27.967″
Trail Creek	50°52′41.968″	-114°53′18.570″	Trail Creek	50°51′22.938″	-114°53′34.929″
Silvester Creek	50°51′58.092″	-114°43′22.128″	Silvester Creek	50°50′04.313″	-114°43′20.511″
Evan-Thomas Creek	50°53′25.816″	-115°08′09.140″	Evan-Thomas Creek	50°51′51.250″	-115°06′15.192″
Waiparous Creek	51°22′28.008″	-115°00′07.466″	Waiparous Creek	51°23′27.914″	-115°14′09.931″
			Johnson Creek	51°21′26.163″	-115°10′53.880″
			Mockingbird Creek	51°25′03.727″	-115°02′21.098″
			Lookout Creek	51°24′41.220″	-115°05′20.719″
Unnamed tributary to Jumpingpound Creek	50°58′02.567″	-114°57′25.235″	Unnamed tributary to Jumpingpound Creek	50°57′39.214″	-114°56′27.660″

SOURCES OF UNCERTAINTY

The current spatial extent of spawning, rearing, foraging and overwintering habitats have not been quantified for Bull Trout in DU 4. These habitats should be investigated and mapped. These areas should be the focus of future targeted sampling for this species.

Data on population sizes and trends are limited.To accurately determine population size, current trajectory and trends over time there is a need for continuation of quantitative sampling of Bull Trout in areas where it is known to occur.

Certain life history characteristics required to inform population modelling efforts are currently unknown for Bull Trout in DU 4. Studies to determine growth rate, fecundity, mortality and longevity of Bull Trout in DU 4 are needed.

There is a need for more causative studies to evaluate the impact of threats on Bull Trout with greater certainty as well as an estimation of the cumulative effects of interactive threats. The following are examples:

- mechanisms allowing Bull Trout to resist invasion and the interactions of these mechanisms with habitat disturbance;
- effects of anthropogenic stressors on groundwater (cause-effect linkages);
- the successful fertility rate of a spawning event between Bull Trout and Brook Trout, as there could be an increase in wasted reproduction effort if the offspring are not viable;
- impacts of fishing pressure (recreational by-catch, hooking mortality, handling stress, delayed mortality) on Bull Trout energetics and growth and reproductive success.

There is also a need to improve our understanding of the physiological capacity of populations as they relate to environmental regimes (e.g., stream temperature, flow/discharge). These types of studies examine the physiological limitations of populations and their capacity to adapt and evolve as environmental regimes are altered. They provide a mechanistic understanding of how stressors may effect individuals and populations. For Bull Trout, increasing water temperatures and changes to annual stream temperature regimes will likely be the most relevant for recovery. Flow regimes are closely tied to this and will continue to be a concern in Alberta. Parallel genomic work to determine if populations have adapted to local environmental conditions should be conducted. The effects of potential mitigation measures, for example, the impact of invasive species removal on the persistence of Bull Trout populations, should also be investigated. Threats were assessed at the HUC8 level and rolled up to the watershed and DU levels. However, the degree of Bull Trout movement between HUCs is largely unknown and was therefore not accounted for.

REFERENCES CITED

Adams, S.B. 1994. Bull Trout distribution and habitat use in the Weiser River drainage, Idaho. Thesis (M.Sc.) University of Idaho, Moscow, ID. x + 84 p.

Adams, S.B. 1999. Mechanisms limiting a vertebrate invasion: Brook Trout in mountain streams of the northwestern USA. Thesis (Ph.D.) University of Montana, Missoula, MT.

Alberta Conservation Association. 2011. Clearwater drainage Bull Trout abundance assessment (2011). Alberta Conservation Association.

AEP [Alberta Environment and Parks]. 2013. Bull Trout Fish Sustainability Index. Alberta Fish and Wildlife Policy Branch, Edmonton, AB. Retrieved 16 January 2015.

AESRD [Alberta Environment and Sustainable Resource Development]. 2009. Groundwater vulnerability: South Saskatchewan Region [Map].

AESRD [Alberta Environment and Sustainable Resource Development]. 2010a. Groundwater vulnerability: Red Deer Region [Map].

AESRD [Alberta Environment and Sustainable Resource Development]. 2010b. Groundwater vulnerability: North Saskatchewan Region [Map].

AESRD [Alberta Environment and Sustainable Resource Development]. 2012. Bull Trout Conservation Management Plan 2012-17. Alberta Sustainable Resource Development, Species at Risk Conservation Management Plan No. 8. Edmonton, AB. 90 p.

AESRD [Alberta Environment and Sustainable Resource Development]. 2014. Hierarchical unit coded (HUC) watersheds of Alberta – Metadata. AESRD. 7 p.

AESRD [Alberta Environment and Sustainable Resource Development] and ACA [Alberta Conservation Association]. 2009. Status of the Bull Trout (*Salvelinus confluentus*) in Alberta: Update 2009. Alberta Sustainable Resource Development Wildlife Status Report No. 39 (Update 2009). Edmonton, AB. 48 p.

Alberta Fish and Wildlife. 2008. Fisheries management objectives for the North Saskatchewan River. Alberta Fish and Wildlife. 52 p.

Al-Chokhachy, R., Roper, B.B., Bowerman, T., and Budy, P. 2010. A review of Bull Trout habitat associations and exploratory analyses of patterns across the interior Columbia River Basin. N. Am. J. Fish. Manag. 30: 464–480.

Al-Chokhachy, R., Schmetterling, D., Clancy, C., Saffel, P., Kovach, R., Nyce, L., Liermann, B., Fredenberg, W., and Pierce, R. 2016. Are Brown Trout replacing or displacing Bull Trout populations in a changing climate? Can. J. Fish. Aquat. Sci. 73: 1–10.

Allan, J.H. 1980. Life history notes on Dolly Varden char (*Salvelinus malma*) in the upper Clearwater River, Alberta. Alberta Energy and Natural Resources, Fish and Wildlife Division, Red Deer, AB. 57 p.

Anonymous. 2008. Bull Trout population status assessment in the upper Oldman River watershed. 2008 phase II findings. Progress report. Alberta Conservation Association, Lethbridge, AB.

*Aqua*lity Environmental Consulting Ltd. 2009. Red Deer River State of the Watershed Report. Prepared for the Red Deer Watershed Alliance, Red Deer, AB.

Arismendi, I., Johnson, S.L., Dunham, J.B., Haggerty, R., and Hockman-Wert,D. 2012. The paradox of cooling streams in a warming world: Regional climate trends do not parallel variable local trends in stream temperature in the Pacific continental United States. Geophys. Res. Lett. 39: L10401.

Bahr, M.A., and Shrimpton, J.M. 2004. Spatial and quantitative patterns of movement in large Bull Trout (*Salvelinus confluentus*) from a watershed in northwestern British Columbia, Canada, are due to habitat selection not differences in life history. Ecol. Freshw. Fish 13: 294–304.

Barton, B.A., and Taylor, B.R. 1996. Oxygen requirements of fishes in northern Alberta rivers with a general review of the adverse effects of low dissolved oxygen. Water Qual. Res. J. Can. 31: 361–409.

Baxter, J.S. 1997a. Aspects of the reproductive ecology of Bull Trout (*Salvelinus confluentus*) in the Chowade River, British Columbia. Thesis (M.Sc.) University of British Columbia, Vancouver, BC. xii + 97 p.

Baxter, J.S. 1997b. Summer daytime microhabitat use and preference of Bull Trout fry and juveniles in the Chowade River, British Columbia. University of British Columbia, Department of Zoology, Fisheries Management Report No. 107: ii + 36 p.

Baxter, J.S., and Hauer, F.R. 2000. Geomorphology, hyporheic exchange and selection of spawning habitat by Bull Trout (*Salvelinus confluentus*). Can. J. Fish. Aquat. Sci. 57: 1470–1481.

Baxter, J.S., and McPhail, J.D. 1996. Bull Trout spawning and rearing habitat requirements: summary of the literature. British Columbia Ministry of Environment, Lands and Parks, Victoria, BC. Fisheries Technical Circular No. 98: 25 p.

Baxter, J.S., and McPhail, J.D. 1997. Diel microhabitat preferences of juvenile Bull Trout in an artificial stream channel. N. Am. J. Fish. Manag. 17: 975–980.

Baxter, J.S., and McPhail, J.D. 1999. The influence of redd site selection, groundwater upwelling, and over-winter incubation temperature on survival of Bull Trout (*Salvelinus confluentus*) from egg to alevin. Can. J. Fish. Aquat. Sci. 77: 1233–1239.

Baxter, C.V., Frissell, C.A., and Hauer, F.R. 1999. Geomorphology, logging roads, and the distribution of Bull Trout spawning in a forested river basin: Implications for management and conservation. Trans. Am. Fish. Soc. 128: 854–867.

Baxter, C.V., Fausch, K.D., Murakami, M., and Chapman, P.L. 2004. Fish invasion restructures stream and forest food webs by interrupting reciprocal prey subsidies. Ecology 80: 2435–2441.

Beauchamp, D.A., and van Tassell, J.J. 2001. Modeling seasonal trophic interactions of adfluvial Bull Trout in Lake Billy Chinook, Oregon. Trans. Am. Fish. Soc.130: 204–216.

Bechara, J.G., Moreau, G., and Planas, D. 1992. Top-down effects of Brook Trout (*Salvelinus fontinalis*) in a boreal forest stream. Can. J. Fish. Aquat. Sci. 49: 2093–2103.

Bellerud, B.L., Gunckel, S., Hemmingsen, A.R., Buchanan, D.V., and Howell, P.J. 1997. Bull Trout life history, genetics, habitat needs, and limiting factors in central and northeast Oregon. Project No. 95-54 and Contract No. 94BI34342. 1996 Annual Report for U.S. Department of Energy, Bonneville Power Administration, Portland, OR. 54 p.

Bendock, T., and Alexandersdottir, M. 1993. Hooking mortality of chinook salmon released in the Kenai River, Alaska. N. Am. J. Fish. Manag. 13: 540–549.

Benjamin, J.R., Dunham, J.B., and Dare, M.R. 2007. Invasion by nonnative Brook Trout in Panther Creek, Idaho: roles of local habitat quality, biotic resistance, and connectivity to source habitats. Trans. Am. Fish. Soc. 136: 875–888.

Berry, D.K. 1994. Alberta's Bull Trout management and recovery plan. Alberta Environmental Protection, Fish and Wildlife Services, Fisheries Management Division, Edmonton, AB. 22 p.

Beschta, R.L., Bilby, R.E., Brown, G.W., Holtby, L.B., and Hofstra, T.D. 1987. Stream temperature and aquatic habitat: Fisheries and forest interactions. *In* Streamside Management: Forestry and Fishery Interactions. Edited by E.O. Salo and T.W. Cundy. University of Washington, Institute of Forest Resources Contribution No. 57, University of Washington, Seattle. p. 191–232.

Birtwell, I.K. 1999. The effects of sediment on fish and their habitat. DFO Can. Sci. Advis. Sec. Res. Doc. 99/139: 34 p.

Bjornn, T.C., and Reiser, D.W. 1991. Habitat requirements of salmonids in streams. *In* Influences of Forest and Rangeland Management on Salmonid Fishes and their Habitats. Edited by W.R. Meehan. Amer. Fish. Soc. Special Publ. 19, Bethesda, Maryland. p. 83–138.

Blackburn, J., Hurkett, B., and Johns, T. 2014. Distribution of Bull Trout in the Waterton River watershed, Alberta, 2012-2013. Data Report, D-2014-005, produced by Alberta Conservation Association, Sherwood Park, AB. ix + 61 p. Available on request from Albera Conservation Association (info@ab-conservation.com)

Boag, T.D. 1987. Food habits of Bull Char, *Salvelinus confluentus*, and Rainbow Trout, *Salmo gairdneri*, coexisting in a foothills stream in northern Alberta. Can. Field-Nat. 101: 56-62.

Boag, T.D., and Hvenegaard, P.J. 1997. Spawning movements and habitat selection of Bull Trout in a small Alberta foothills stream. *In* Friends of the Bull Trout Conference Proceedings. Edited by W.C. Mackay, M.K. Brewin, and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 317–323.

Bonneau, J.L., and Scarnecchia, D.L. 1998. Seasonal and diel changes in habitat use by juvenile Bull Trout (*Salvelinus confluentus*) and Cutthroat Trout (*Oncorhynchus clarkii*) in a mountain stream. Can. J. Zool. 76: 783–790.

Bow River Basin Council. 2005. Nurture, Renew, Protect: A Report on the State of the Bow River Basin. Bow River Basin Council, Calgary, AB.

Bow River Basin Council. 2010. Bow River Basin State of the Watershed Summary. Bow River Basin Council, Calgary, AB. 44 p.

Bradley, R.S., Keimig, F.T., and Diaz, H.F. 2004. Projected temperature changes along the American cordillera and the planned GCOS network. Geophy. Res. Lett. 31: L16210.

Brenkman, S.J., Corbett, S.C., and Volk, E.C. 2007. Use of otolith chemistry and radiotelemetry to determine age-specific migratory patterns of anadromous Bull Trout in the Hoh River, Washington. Trans. Am. Fish. Soc. 136: 1–11.

Brewin, M.K. 1994. 1993 Fishery investigations in the upper Bow River system, Banff National Park, Alberta. Prepared for Ecosystem Management, Banff National Park Warden Service, Banff, Alberta by Trutta Environments and Management, Cochrane, AB. 62 p. (Available from the DFO library)

Brewin, M.K. 1996. Identification of Bull Trout populations in the McLeod, Wildhay, Berland and Muskeg River systems, Alberta. Prepared for Trout Unlimited Canada, Calgary and Foothills Model Forest Program, Hinton, Alberta. Prepared by Trutta Environments and Management, Cochrane, AB. 54 p. + app.

Brewin, M.K. 2004. Bull Trout management and recovery in Alberta. *In* Proceedings of the Species at Risk 2004 Pathways to Recovery Conference. Edited by T.D. Hooper. Species at Risk 2004 Pathways to Recovery Conference Organizing Committee, Victoria, BC. p. 1–22.

Brewin, P.A., and Brewin, M.K. 1997. Distribution maps for Bull Trout in Alberta. *In* Friends of the Bull Trout Conference Proceedings. Edited by W.C. Mackay, M.K. Brewin and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 209–216.

Brimble, S., Bacchus, P., and Caux, P.-Y. 2005. Pesticide utilization in Canada: A compilation of current sales and use data. Environment Canada, Ottawa, ON. xvii + 144 p.

Brown, C.J.D. 1971. Fishes of Montana. Big Sky Books, Montana State University, Bozeman, MT. p. 61–62.

Brown, C.J., Saunders, M.I., Possingham, H.P., and Richardson, A.J. 2013. Managing for interactions between local and global stressors of ecosystems. PLoS ONE 8: e65765.

Buktenica, M.W. 1997. Bull Trout restoration and Brook Trout eradication at Crater Lake National Park, Oregon. *In* Friends of the Bull Trout Conference Proceedings. Edited by W.C. Mackay, M.K. Brewin, and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 127–136.

Burrows, J., Euchner, T., and Baccante, N. 2001. Bull Trout movement patterns: Halfway River and Peace River progress. *In* Bull Trout II Conference Proceedings. Edited by M.K. Brewin, A.J. Paul and M. Monita. Trout Unlimited Canada, Calgary, AB. p. 153–157.

Campbell, L.M., Schindler, D.W., Muir, D.C.G., Donald, D.B., and Kidd, K.A. 2000. Organochlorine transfer in the food web of sub-alpine Bow Lake, Banff National Park. Can. J. Fish. Aquat. Sci. 57: 1258-1û269.

Carl, L.M., Kraft, M., and Rhude, L. 1989. Growth and taxonomy of bull charr, *Salvelinus confluentus*, in Pinto Lake, Alberta. Env. Biol. Fishes 26: 239–246.

Cavender, T.M. 1978. Taxonomy and distribution of the Bull Trout, *Salvelinus confluentus* (Suckley), from the American northwest. Calif. Fish Game 64: 139–174.

CEARC [The Canadian Environmental Research Council] and US NRC [The US National Research Council]. 1986. Cumulative environmental effects: A binational perspective. Minister of Supply and Services Canada. ix + 175 p.

Chambers, P.A., Anderson, A.-M., Bernard, C., Gregorich, L.J., McConkey, B., Milburn, P.H., Painchaud, J., Patni, N.K., Simar, R.R., and van Vliet, L.J.P. 2000a. Surface water quality. *In* The Health of our Water – Toward Sustainable Agriculture in Canada. Edited by D.R. Coote and L.J. Gregorich. Agriculture and Agri-Food Canada, Ottawa, ON. p. 43–60.

Chambers, P.A., Brown, S., Culp, J.M., Lowell, R.B., and Pietroniro, A. 2000b. Dissolved oxygen decline in ice-covered rivers of northern Alberta and its effects on aquatic biota. J. Aquat. Ecosyst. Stress Recovery 8: 27–38.

Chandler, J.A., Fedora, M.A., and Walters, T.A. 2001. Pre- and post-spawn movements and spawning observations of resident Bull Trout in the Pine Creek watershed, eastern Oregon. *In* Bull Trout II Conference Proceedings. M.K. Brewin, A.J. Paul, and M. Monita. Trout Unlimited Canada, Calgary, AB. p. 167–172.

Clayton, T. 1998. 1996 and 1997 Bull Trout (*Salvelinus confluentus*) investigations in the Belly and Waterton River drainages in Alberta. Alberta Conservation Association, Lethbridge, AB. ix + 62 p., apps. Available on request from Albera Conservation Association (info@ab-conservation.com)

Clayton, T. 1999. Fish collection in the Upper Belly River, Alberta, 1999. Alberta Conservation Association, Lethbridge, AB. 9 p. Available on request from Albera Conservation Association (info@ab-conservation.com)

Clayton, T. 2001. Movements and status of Bull Trout in the Belly River, Alberta and Montana. *In* Bull Trout II Conference Proceedings. Edited by M.K. Brewin, A.J. Paul, and M. Monita. Trout Unlimited Canada, Calgary, AB. p. 137-–40.

Clipperton, G.K., Koning, C.W., Locke, A.G.H., Mahoney, J.M., and Quazi, B. 2003. Appendix A – Fisheries management objectives for rivers within the South Saskatchewan River Basin (Draft). *In* Instream flow needs determinations for the South Saskatchewan River Basin, Alberta, Canada. Alberta Environment and Alberta Sustainable Development. pp. A1-A88.

Coker, G.A., Ming, D.L., and Mandrak, N.E. 2010. Mitigation guide for the protection of fishes and fish habitat to accompany the species at risk recovery potential assessments conducted by Fisheries and Oceans Canada (DFO) in Central and Arctic Region. Version 1.0. Can. Manuscr. Rep. Fish. Aquat. Sci. 2904: vi + 40 p.

Colpitts, G.W. 1997. Historical perspectives of good vs evil: stream eugenics and the plight of Alberta's Bull Trout: 1900-1930. *In* Friends of the Bull Trout Conference Proceedings. Edited by W.C. Mackay, M.K. Brewin, and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. pp. 31-36.

Connor, E., Reiser, R., Binkley, K., Paige, D., and Lynch, K. 1997. Abundance and distribution of an unexploited Bull Trout population in the Cedar River watershed, Washington. *In* Friends of the Bull Trout Conference Proceedings. Edited by W.C. Mackay, M.K. Brewin and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 403–411.

Coombs, M., and MacPherson, L. 2013. A generic rule set for applying the Alberta Fish Sustainability Index, Second Edition. Alberta Environment and Sustainable Resource Development. 60 p.

Cope, R., Morris, M., and Bisset, J. 2002. Wigwam River juvenile Bull Trout and fish habitat monitoring program, annual report 2001. Bonneville Power Administration Report DOE/BP-00005672-1: v + 119 p.

COSEWIC [Committee on the Status of Endangered Wildlife in Canada]. 2012. COSEWIC assessment and status report on the Bull Trout *Salvelinus confluentus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON. iv + 103 p.

Coumou, D., and Rahmstorf, S. 2012. A decade of weather extremes. Nat. Clim. Change 2: 491-496.

Council of Canadians. 2014. Fracking across Canada. *In* A Fractivist's Toolkit. The Council of Canadians, Ottawa, ON. p. 6–34.

Cows and Fish Program. 2009. Excel file of Oldman watershed riparian health assessment data. February 2009.

Cox, S. 2016. BC Hydro's bizarre multi-million dollar boondoggle to save fish from Site C dam. DeSmog Canada, April 4, 2016.

Craig, S.D. 1997. Habitat conditions affecting Bull Trout, *Salvelinus confluentus*, spawning areas within the Yakima River basin, Washington. Thesis (M.Sc.) Central Washington University, Ellensburg, WA. x + 74 p.

Crain, C.M., Kroeker, K., and Halpern, B.S. 2008. Interactive and cumulative effects of multiple human stressors in marine systems. Ecol. Lett. 11: 1304–1315.

Crisp, D.T., and Hurley, M.A. 1991. Stream channel experiments on downstream movement of recently emerged trout, *Salmo trutta* L. and salmon, *S. salar* L. 1. Effect of four different water velocity treatments on dispersal rate. J. Fish Biol. 39: 347–361.

Cross, D., and Everest, L. 1997. Fish habitat attributes of reference and managed watersheds, with special reference to the location of Bull Trout (*Salvelinus confluentus*) spawning sites in the upper Spokane River ecosystem, northern Idaho. *In* Friends of the Bull Trout Conference Proceedings. Edited by W.C. Mackay, M.K. Brewin, and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 381–386.

D'Angelo, V.S., and Muhlfeld, C.C. 2013. Factors influencing the distribution of native Bull Trout and Westslope Cutthroat Trout in streams of western Glacier National Park, Montana. Northwest Sci. 87: 1–11.

Darling, E.S., and Côté, I.M. 2008. Quantifying the evidence for ecological synergies. Ecol. Lett. 11: 1278–1286.

Davis, J.M., Baxter, C.V., Rosi-Marshall, E.J., Pierce, L.L., and Crosby, B.T. 2013. Anticipating stream ecosystem responses to climate change: toward predictions that incorporate effects via land-water linkages. Ecosystems 16: 909–922.

Decker, S., and Hagen, J. 2008. Adfluvial Bull Trout spawner abundance in tributaries of the Arrow Lakes reservoir (2004-2007). Fish and Wildlife Compensation Program – Columbia Basin, Nelson, BC; BC Hydro and Power Authority, Columbia Basin Generation, Castlegar, BC. 38 p.

DeHaan, P.W., Schwabe, L.T., and Arden, W.R. 2010. Spatial patterns of hybridization between Bull Trout, *Salvelinus confluentus*, and Brook Trout, *Salvelinus fontinalis* in an Oregon stream network. Conserv. Genet. 11: 935–949.

Detenbeck, N.E., DeVore, P.W., Niemi, G.J., and Lima, A. 1992. Recovery of temperate-stream fish communities from disturbance: a review of case studies and synthesis of theory. Environ. Manag. 16: 33–53.

DeVries, P. 1997. Riverine salmonid egg burial depths: Review of published data and implications for scour studies. Can. J. Fish. Aquat. Sci. 54: 1658–1698.

Dextrase, A.J., and Ball, H.E. 1991. Hooking mortality of lake trout angled through the ice. N. Am. J. Fish. Manag. 11: 477–-479.

DFO. 2003. National code on introductions and transfers of aquatic organisms. Task Group on Introductions and Transfers. 33 p.

DFO. 2015. Directive on the Application of Species at Risk Act Section 33 (Residence) to Aquatic Species at Risk. Fisheries and Oceans Canada. 7 p.

DFO. 2014a. Guidance on assessing threats, ecological risk and ecological impacts for species at risk. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2014/013: 21 p.

DFO. 2014b. Recovery strategy for the Alberta population of Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*) in Canada [Final]. Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. iv + 28 p., appendices.

Dodson, J.J., Aubin-Horth, N., Thériault, V., and Páez, D.J. 2013. The evolutionary ecology of alternative migratory tactics in salmonid fishes. Biol. Rev. 88: 602–625.

Donald, D.B., and Alger, D.J. 1993. Geographic distribution, species displacement, and niche overlap for Lake Trout and Bull Trout in mountain lakes. Can. J. Zool. 71: 237–247.

Donald, D.B., and Stelfox, J.D. 1997. Effects of fisheries management on adfluvial Bull Trout populations in mountain lakes of southern Alberta. *In* Friends of the Bull Trout Conference Proceedings. Edited by W.C. Mackay, M.K. Brewin, and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 227–234.

Donald, D.B., Hunter, F.G., Sverko, E., Hill, B.D., and Syrgiannis, J. 2005. Mobilization of pesticides on an agricultural landscape flooded by a torrential storm. Environ. Toxicol. Chem. 20: 273–279.

Dunham, J.B., and Rieman, B.E. 1999. Metapopulation structure of Bull Trout: influences of habitat size, isolation, and human disturbance. Ecol. Appl. 9: 642–655.

Dunham, J.B., Rieman, B.E., and Chandler, G.L. 2003a. Influences of temperature and environmental variables on the distribution of Bull Trout at the southern margin of its range. N. Am. J. Fish. Manag. 23: 894–904.

Dunham, J.B., Young, M.K., Gresswell, R.E., and Rieman, B.E. 2003b. Effects of fire on fish populations: Landscape perspectives on persistence of native fishes and non-native fish invasions. Forest Ecol. Manag. 178: 183–196.

Dunham, J.B., Rosenberger, A.E., Luce, C.H., and Rieman, B.E. 2007. Influences of wildfire and channel reorganization on spatial and temporal variation in stream temperature and the distribution of fish and amphibians. Ecosystems 10: 335–346.

Dunham, J., Baxter, C., Fausch, K., Fredenberg, W., Kitano, S., Koizumi, I., Morita, K., Nakamura, T., Rieman, B., Savvaitova, K., Stanford, J., Taylor, E., and Yamamoto, S. 2008. Evolution, ecology, and conservation of Dolly Varden, White-spotted Char, and Bull Trout. Fisheries 33: 537–550.

Earle, J.E., and McKenzie, J.S. 2001. Habitat use by juvenile Bull Trout in mountain streams in the Copton Creek drainage, Alberta, and its relation to mining activity. *In* Bull Trout II Conference Proceedings. Edited by M.K. Brewin, A.J. Paul, and M. Monita. Trout Unlimited Canada, Calgary, AB. p. 121–128.

Earle, J.E., Paul, A.J., and Stelfox, J.D. 2007. Quirk Creek population estimates and one-pass electrofishing removal of Brook Trout, 2005 and 2006. Alberta Sustainable Resource Development, Fish and Wildlife Division, Cochrane, AB. 61 p.

Ellis, B.K., Stanford, J.A., Goodman, D., Stafford, C.P., Gustafson, D., Beauchamp, D.A., Chess, D.W., Craft, J.A., Deleray, M.A., and Hansen, B.S. 2011. Long-term effects of a trophic cascade in a large lake ecosystem. Proc. Natl. Acad. Sci. USA 108: 1070–1075.

Entrekin, S., Evans-White, M., Johnson, B., and Hagenbuch, E. 2011. Rapid expansion of natural gas development poses a threat to surface waters. Front. Ecol. Environ. 9: 503–511.

Environment Canada. 1991. Historical streamflow summary, Alberta. Inland Waters Directorate, Water Resources Branch, Water Survey of Canada.

Environment Canada. 2001. Threats to sources of drinking water and aquatic ecosystem health in Canada. National Water Research Institute, Burlington, ON. NWRI Report Series No. 1. 72 p.

Environment Canada. 2011. Presence and levels of priority pesticides in selected Canadian aquatic ecosystems. Environment Canada, Water Science and Technology Directorate. viii + 102 p.

Fairless, D.M., Herman, S.J., and Rhem, P.J. 1994. Characteristics of Bull Trout (*Salvelinus confluentus*) spawning sites in five tributaries of the upper Clearwater River, Alberta. Alberta Environmental Protection, Fish and Wildlife Services, Rocky Mountain House, AB. vii + 49 p. (Available from the DFO library)

Falke, J.A., Flitcroft, R.L., Dunham, J.B., McNyset, K.M., Hessburg, P.F., and Reeves, G.H. 2015. Climate change and vulnerability of Bull Trout (*Salvelinus confluentus*) in a fire-prone landscape. Can. J. Fish. Aquat. Sci. 72: 304–318.

Fausch, K.D., Taniguchi, Y., Nakano, S., Grossman, G.D., and Townsend, C.R. 2001. Flood disturbance regimes influence Rainbow Trout invasion success among five Holarctic regions. Ecol. Appl. 11: 1438–1455.

Fernet, D.A., and Bjornson, C.P. 1997. A delphi analysis of Bull Trout habitat preference criteria with comparison to information collected from Smith-Dorrien Creek, Alberta. *In* Friends of the Bull Trout Conference Proceedings. Edited by W.C. Mackay, M.K. Brewin and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 435–442.

Fernet, D.A., and O'Neil, J. 1997. Use of radio telemetry to document seasonal movements and spawning locations for Bull Trout in relation to a newly created reservoir. *In* Friends of the Bull Trout Conference Proceedings. Edited by W.C. Mackay, M.K. Brewin and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 427–434.

Fiera Biological Consulting. 2014. Oldman Watershed Headwaters Indicator Project, Final Report – Version 2014.1. Prepared for Oldman Watershed Council, Lethbridge, AB. vii + 73 p.

Fitch, L.A. 1997. Bull Trout in southwestern Alberta: Notes on historical and current distribution. *In* Friends of the Bull Trout Conference Proceedings. Edited by W.C. Mackay, M.K. Brewin, and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 147–160.

Fitch, L., and Adams, B.W. 1998. Can cows and fish co-exist? Can. J. Plant Sci. 78: 191–198.

Fitzsimmons, K. 2008. Abundance and distribution of Bull, Cutthroat and Brook Trout in the Canyon and Prairie Creek drainages (Elbow River). 2008 Data Report. Produced by the Alberta Conservation Association, Cochrane, AB. 39 p. Available on request from Albera Conservation Association (info@ab-conservation.com)

Fitzsimmons, K., and Fontana, M. 2002. Cochrane and area, Upper Bow River drainage, Co-operative Fisheries Inventory Project. Alberta Conservation Association, East Slopes Region, Cochrane, AB. 59 p. Available on request from Albera Conservation Association (info@ab-conservation.com)

Fitzsimmons, K., Judd, C., and Rodtka, M. 2010. Pinto Creek Bull Trout Study (2010). Alberta Conservation Association Program Report. 3 p. Available on request from Albera Conservation Association (info@ab-conservation.com)

Fitzsimmons, K., Halinowski, P., Hooey, K., Judd, C., and Oko, J. 2012. Life history strategies and spawning demographics of Bull Trout in the Upper Red Deer River drainage (2012). Alberta Conservation Association Program Report. 2 p. Available on request from Albera Conservation Association (info@ab-conservation.com)

Fontana, M. 2003. Upper Bow River OHV stream crossing inventory and assessment, 2002/03 annual report. Alberta Conservation Association, Rocky Mountain House, AB. Available on request from Albera Conservation Association (info@ab-conservation.com)

Fontana, M., Gardiner, K., and Rodtka, M. 2006. Upper North Saskatchewan River and Abraham Lake Bull Trout study, 2002-2003. Technical Report, T-2005-004, produced by the Alberta Conservation Association, Cochrane, AB. 32 p. + app.

FEMAT [Forest Ecosystem Management Team]. 1993. Forest Ecosystem Management Assessment Team Report. Sponsored by USDA Forest Service, US Environmental Protection Agency, US Department of the Interior Bureau of Land Management, and National Park Service. Portland, Oregon. Various pagination.

Fraley, J.J., and Shepard, B.B. 1989. Life history, ecology and population status of migratory Bull Trout (*Salvelinus confluentus*) in the Flathead Lake and River system, Montana. Northwest Sci. 63: 133-143.

Fredenberg, W. 2002. Further evidence that Lake Trout displace Bull Trout in mountain lakes. Intermt. J. Sci. 8: 143–152.

Fredenberg, W., Chan, J., and Young, J. 2005. Bull Trout core area conservation status assessment. United States Fish and Wildlife Service, Portland, OR. 94 p. + app.

Fredenberg, W., DeHaan, P., and Arden, W. 2007. Genetic analysis and photo documentation of hybridization between Bull Trout and Brook Trout in the Swan River basin, Montana. Swan Valley Bull Trout Working Group, Kalispell, MT. 34 p.

Fuller, P.L., Nico, L.G., and Williams, J.D. 1999. Nonindigenous fishes introduced into inland waters of the United States. American Fisheries Society Special Publication 27. U.S. Geological Survey, Florida Integrated Science Center, Gainesville, FL. 622 p.

Gagnon, G.A., Krkosek, W., Anderson, L., McBean, E., Mohseni, M., Bazri, M., and Mauro, I. 2016. Impacts of hydraulic fracturing on water quality: a review of literature, regulatory frameworks and an analysis of information gaps. Environ. Rev. 24: 122–131.

Gardiner, K., and McLeod, C. 2000. Rocky Mountain House and Nordegg districts Cooperative Fisheries Inventory Program (CFIP) 1999/00 annual report. Alberta Conservation Association, Rocky Mountain House, Alberta. Available on request from Albera Conservation Association (info@ab-conservation.com)

Gardiner, K., Fitzsimmons, K.M., and Berdula, J. 2001. Cooperative fisheries inventory program catalogue of sample sites conducted for Alberta Environment. Alberta Conservation Association, East Slopes Business Unit, Rocky Mountain House, Alberta. Fisheries Management Information System (FMIS) inventory project # 1189. Available on request from Albera Conservation Association (info@ab-conservation.com)

Goetz, F.A. 1989. Biology of the Bull Trout (*Salvelinus confluentus*), a literature review. U.S. Department of Agriculture, Forest Service, Willamette National Forest, Eugene, OR. 53 p.

Goetz, F.A. 1997a. Habitat use of juvenile Bull Trout in Cascade mountain streams of Oregon and Washington. *In* Friends of the Bull Trout Conference Proceedings. Edited by W.C. Mackay, M.K. Brewin and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 339–352.

Goetz, F.A. 1997b. Distribution of Bull Trout in Cascade mountain streams of Oregon and Washington. *In* Friends of the Bull Trout Conference Proceedings. Edited by W.C. Mackay, M.K. Brewin, and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 237–248.

Golder Associates Ltd. 1995. Review of the effects of reservoir operation on the productivity of lower Kananaskis Lake, draft. Prepared by Golder Associates Limited. 49 p. + apps.

Gould, W.R. 1987. Features in the early development of Bull Trout (*Salvelinus confluentus*). Northwest Sci. 61: 264–268.

Government of Canada. Accessed 2014. Federal Contaminated Sites Inventory [Database]. Contains information licensed under the Open Government Licence – Canada.

Government of Canada, Natural Resources Canada, Earth Sciences Sector and Canada Center for Mapping and Earth Observation. 2013. CanVec – Alberta shape files. Open Government Licence – Canada. Available from GeoGratis.

Graham, D.W., Miley, M.K., Denoyelles, F., Smith, V.H., Thurman, E.M., and Carter, R. 2000. Alachlor transformation patterns in aquatic field mesocosms under variable oxygen and nutrient conditions. Wat. Res. 34: 4054–4062.

Gregory, J.S., and Gamett, B.L. 2009. Cattle trampling of simulated Bull Trout redds. N. Am. J. Fish. Manag. 29: 361–366.

Gunckel, S.L. 2000. Feeding behavior and diet of native Bull Trout *Salvelinus confluentus* and introduced Brook Trout *S. fontinalis* in two eastern Oregon streams. Thesis (M.Sc.) Oregon State University, Corvallis, OR. ix + 97 p.

Gunckel, S.L., Hemmingsen, A.R., and Judith, L.L. 2002. Effect of Bull Trout and Brook Trout interactions on foraging habitat, feeding behavior, and growth. Trans. Am. Fish. Soc.131: 1119–1130.

Guy, C.S., McMahon, T.E., Smith, C.J., Cox, B.S., Fredenberg, W.A., and Garfield, D.W. 2011. Diet overlap of top-level predators in recent sympatry: Bull Trout and nonnative Lake Trout. J. Fish. Wildl. Manag. 2: 183–189.

Haas, G.R., and McPhail, J.D. 1991. Systematics and distributions of Dolly Varden (*Salvelinus malma*) and Bull Trout (*Salvelinus confluentus*) in North America. Can. J. Fish. Aquat. Sci. 48: 2191–2211.

Haas, G.R., and McPhail, J.D. 2001. The post-Wisconsinan glacial biogeography of Bull Trout (*Salvelinus confluentus*): A multivariate morphometric approach for conservation biology and management. Can. J. Fish. Aquat. Sci. 58: 2189–2203.

Hagen, J., and Baxter, J. 1992. Bull Trout populations of the North Thompson River basin, British Columbia: Initial assessment of a biological wilderness. Prepared for Ministry of Environment, Lands and Parks, Fisheries Branch, British Columbia. 37 p.

Hagen, J., and Taylor, E.B. 2001. Resource partitioning as a factor limiting gene flow in hybridizing populations of Dolly Varden char (*Salvelinus malma*) and Bull Trout (*Salvelinus confluentus*). Can. J. Fish. Aquat. Sci. 58: 2037–2047.

Hall, M.H.P., and Fagre, D.B. 2003. Modeled climate-induced glacier change in Glacier National Park, 1850-2100. Bioscience 53: 131–140.

Hallock, R.J., Elwell, R.F., and Fry, D.H., Jr. 1970. Migrations of adult King Salmon *Oncorhynchus tshawytscha* in the San Joaquin Delta as demonstrated by the use of sonic tags. California Department of Fish and Game, Fish Bulletin 151: 92 p.

Halpern, B.S., McLeod, K.L., Rosenberg, A.A., and Crowder, L.B. 2008. Managing for cumulative impacts in ecosystem-based management through ocean zoning. Ocean Coast. Manag. 51: 203–211.

Hansen, B., and DosSantos, J. 1997. Distribution of Bull Trout populations on the Flathead Indian Reservation, western Montana, USA. *In* Friends of the Bull Trout Conference Proceedings. Edited by W.C. Mackay, M.K. Brewim, and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 249–254.

Hansen, L.J., and Hoffman, J.R. 2011. Climate Savvy: Adapting Conservation and Resource Management to a Changing World. Island Press, Washington, DC.

Hansen, J., Nazarenko, L., Ruedy, R., Sato, M., Willis, J., Del Genio, A., Koch, D., Lacis, A., Lo, K., Menon, S., Novakov, T., Perlwitz, J., Russell, G., Schmidt, G.A., and Tausnev, N. 2005. Earth's energy imbalance: Confirmation and implications. Science 308: 1431–1435.

Hansen, J., Sato, M., and Ruedy, R. 2012. Perception of climate change. Proc. Natl. Acad. Sci. USA 109: 14726–14727.

Hari, R.E., Livingstone, D.M., Siber, R., Burkhardt-Holm, P., and Guttinger, H. 2006. Consequences of climatic change for water temperature and Brown Trout populations in Alpine rivers and streams. Glob. Change Biol. 12: 10–26.

Heggenes, J., and Traaen, T. 1988. Downstream migration and critical water velocities in stream channels for fry of four salmonid species. J. Fish Biol. 32: 717–727.

Hemmingsen, A.R., Bellerud, B.L., Buchanan, D.V., Gunckel, S.L., Shappart, J.K., and Howell, P.J. 2001. Bull Trout life history, genetics, habitat needs, and limiting factors in central and northeast Oregon. 1997 Annual Report. Prepared for US Department of Energy, Bonneville Power Administration, Portland, OR. Project Number 95-54, Contract Number 94B134342. 37 p.

Herman, S.J. 1997. The unique Bull Trout spawning population of Pinto Lake, Alberta. *In* Friends of the Bull Trout Conference Proceedings. Edited by W.C. Mackay, M.K. Brewin, and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 217–226.

Hogan, D.L. 1986. Channel morphology of unlogged, logged and debris torrented streams in the Queen Charlotte Islands. British Columbia Ministry of Forests Land Management Report No. 49.

Holmlund, C.M., and Hammer, M. 1999. Ecosystem services generated by fish populations. Ecol. Econ. 29: 253–268.

Homel, K., Budy, P., Pfrender, M.E., Whitesel, T.A., and Mock, K. 2008. Evaluating genetic structure among resident and migratory forms of Bull Trout (*Salvelinus confluentus*) in northeastern Oregon. Ecol. Freshw. Fish 17: 465–474.

Hunt, C.W., Hawryluk, R., and Hildebrandt, D. 1997. Bull Trout status in Fish Management Area Four, Alberta. *In* Friends of the Bull Trout Conference Proceedings. Edited by W.C. Mackay, M.K. Brewin, and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 171–186.

Huntington, C.W. 1995. Final report: Fish habitat and salmonid abundance within managed and unroaded landscapes on the Clearwater National Forest, Idaho. Prepared for Eastside Ecosystem Management Project, USDA Forest Service, Walla Walla, Washington. Clearwater BioStudies Inc., Canby, OR.

Hurkett, B. 2008. Redd surveys and winter trout abundance in the West Castle wetlands ecological reserve (2008-09). Prepared by Alberta Conservation Association, Lethbridge, AB. Prepared for AB Tourism, Parks and Recreation, Lethbridge, AB. 20 p. + app. Available on request from Albera Conservation Association (info@ab-conservation.com)

Hurkett, B., and Blackburn, J. 2015. Distribution and abundance of the migratory Bull Trout population in the Castle River drainage, 2011-2014. Technical Report, T-2015-001, produced by Alberta Conservation Association, Lethbridge, AB. 37 p. + app.

Hurkett, B., Blackburn, J., and Council, T. 2011. Abundance and distribution of migratory Bull Trout in the upper Oldman River drainage, 2007-2010. Technical Report, T-2011-002, produced by the Alberta Conservation Association, Lethbridge, AB. 34 p. + app.

Hurkett, B., Blackburn, J., Clough, A., and Goodman, C. 2012. Distribution and abundance of the migratory Bull Trout population in the Castle River Drainage (2012). Alberta Conservation Association Program Report. 5 p. Available on request from Albera Conservation Association (info@ab-conservation.com)

Hurkett, B., Blackburn, J., Buskas, M., Johns, T., and Rathier, A. 2013. Distribution and abundance of the migratory Bull Trout population in the Castle River drainage (2013). Alberta Conservation Association Program Report. 4 p. Available on request from Albera Conservation Association (info@ab-conservation.com)

Hurkett, B., Blackburn, J., Johns, T., Murphy, A., and Neigum, L. 2014. Distribution and abundance of the migratory Bull Trout population in the Castle River drainage (2014). Alberta Conservation Association Program Report. 4 p. Available on request from Albera Conservation Association (info@ab-conservation.com)

Hvenegaard, P., and Fairless, D. 1998. Biology and status of Bull Trout (*Salvelinus confluentus*) in the Kakwa River drainage, Alberta. A Fisheries Management Enhancement Project, Alberta Conservation Association. Data Summary 1995 to 1997 Progress Report. Alberta Conservation Association, Northwest Boreal Region, Peace River, AB. 30 p. Available on request from Albera Conservation Association (info@ab-conservation.com)

Irrigation Water Management Study Committee. 2002. South Saskatchewan River Basin: Irrigation in the 21st Century, Volume I: Summary Report. Alberta Irrigation Projects Association, Lethbridge, AB.

Isaak, D.J., Young, M.K., Nagel, D.E., Horan, D.L., and Groce, M.C. 2015. The cold-water climate shield: delineating refugia for preserving salmonid fishes through the 21st century. Glob. Change Biol. 21: 2540–2553.

Jackson, M.C., Loewen, C.J.G., Vinebrooke, R.D., and Chimimba, C.T. 2016. Net effects of multiple stressors in freshwater ecosystems: a meta-analysis. Glob. Change Biol. 22: 180–189.

Jager, H.I., Van Winkle, W., and Holcomb, B.D. 1999. Would hydrologic climate changes in Sierra Nevada streams influence trout persistence? Trans. Am. Fish. Soc. 128: 222–240.

Jakober, M.J. 1995. Autumn and winter movement and habitat use of resident Bull Trout and Westslope Cutthroat Trout in Montana. Thesis (M.Sc.) University of Montana, Bozeman, MT. xii + 110 p.

Jakober, M.J., McMahon, T.E., Thurow, R.F., and Clancy, C.G. 1998. Role of stream ice on fall and winter movements and habitat use by Bull Trout and Cutthroat Trout in Montana headwater streams. Trans. Am. Fish. Soc. 127: 223–235.

Jakober, M.J., McMahon, T.E., and Thurow, R.F. 2000. Diel habitat partitioning by Bull Charr and Cutthroat Trout during fall and winter in Rocky Mountain streams. Env. Biol. Fishes 59: 79–89.

James. P.W., and Sexauer, H.M. 1997. Spawning behaviour, spawning habitat and alternative mating strategies in an adfluvial population of Bull Trout. *In* Friends of the Bull Trout Conference Proceedings. Edited by W.C. Mackay, M.K. Brewin and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 325–329.

Johnston, F.D., and Post, J.R. 2009. Density-dependent life history compensation in an iteroparous salmonid. Ecol. Appl. 19: 449–467.

Johnston, F.D., Post, J.R., Mushens, C.J., Stelfox, J.D., Paul, A.J., and Lajeunesse, B. 2007. The demography of recovery of an overexploited Bull Trout, *Salvelinus confluentus*, population. Can. J. Fish. Aquat. Sci. 64: 113–126.

Jones, J.A., Swanson, F.J., Wemple, B.C., and Snyder, K.U. 2000. Effects of roads on hydrology, geomorphology, and disturbance patches in stream networks. Conserv. Biol. 14: 76–-85.

Jones, L.A., Muhlfeld, C.C., Marshall, L.A., McGlynn, B.L., and Kershner, J.L. 2014. Estimating thermal regimes of Bull Trout and assessing the potential effects of climate warming on critical habitats. River Res. Appl. 30: 204–216.

Jumpingpound Creek Watershed Partnership. 2009. Jumpingpound Creek State of the Watershed Report 2009. Compiled and edited by Palliser Environmental Services Ltd. iv + 91 p.

Jumpingpound Creek Watershed Partnership. 2014. Jumpingpound Creek Integrated Watershed Management Plan – Final. Jumpingpound Creek Watershed Partnership and Palliser Environmental Services Ltd. vi + 62 p.

Kanda, N., Leary, R.F., and Allendorf, F.W. 2002. Evidence of introgressive hybridization between Bull Trout and Brook Trout. Trans. Am. Fish. Soc. 131: 772–782.

Kennedy, B.M., Peterson, D.P., and Fausch, K.D. 2003. Different life histories of Brook Trout populations invading mid-elevation and high-elevation Cutthroat Trout streams in Colorado. West. N. Am. Naturalist 63: 215–223.

Khan, F.A., and Ansari, A.A. 2005. Eutrophication: an ecological vision. Bot. Rev. 71: 449–482.

Kovach, R.P., Gharrett, A.J., and Tallman, D.A. 2012. Genetic change for earlier migration in a pink salmon population. Proc. R. Soc. B 279: 3870–3878.

Kovach, R.P., Al-Chokhachy, R., Whited, D., Schmetterling, D.A., Dux, A.M., and Muhlfeld, C.C. 2016. Climate, invasive species and land use drive population dynamics of a cold-water specialist. J. Appl. Ecol. doi: 10.1111/1365-2664.12766

Lapp, S., Byrne, J., Townshend, I., and Kienzle, S. 2005. Climate warming impacts on snowpack accumulation in an alpine watershed. Int. J. Climatol. 25: 521–536.

Lawrence, P.J., and Chase, T.N. 2010. Investigating the climate impacts of global land cover change in the community climate system model. Int. J. Climatol. 30: 2066–2087.

Leary, R.F., Allendorf, F.W., and Forbes, S.H. 1993. Conservation genetics of Bull Trout in the Columbia and Klamath River drainages. Conserv. Biol. 7: 856–865.

Leathe, S.A., and Graham, P.J. 1981. Flathead Lake fish food habits study. Environmental Protection Agency, Region VIII, Water Division, Denver, CO. xii + 81 p.

MacDonald, R.J., Boon, S., Byrne, J.M., and Silins, U. 2014. A comparison of surface and subsurface controls on summer temperature in a headwater stream. Hydrol. Process. 28: 2338-–2347.

Mayhood, D.W. 2009. Contributions to a recovery plan for Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*) in Alberta: Threats and limiting factors. Freshwater Research Limited, Calgary, AB. FWR Technical Report 2009/05-1: ix + 68 p.

McCart, P. 1997. Bull Trout in Alberta: A review. *In* Friends of the Bull Trout Conference Proceedings. Edited by W.C. Mackay, M.K. Brewin, and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 191–208.

McCullough, D.A., and Spalding, S. 2002. Multiple lines of evidence for determining upper optimal temperature thresholds for Bull Trout. Columbia River Inter-Tribal Fish Commission (CRITFC) Technical Report 02-4: 25 p.

McLeod, C., and Clayton, T. 1993. Fish radio telemetry demonstration project, upper Athabasca River, May to August 1992. Northern River Basins Study Project Report 11: 41 p.

McLeod, C., and Clayton, T. 1997. Use of radio telemetry to monitor movements and locate critical habitats for fluvial Bull Trout in the Athabasca River, Alberta. *In* Friends of the Bull Trout Conference Proceedings Edited by W.C. Mackay, M.K. Brewin, and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 413–419.

McPhail, J.D. 1961. A systematic study of the *Salvelinus alpinus* complex in North America. J. Fish. Res. Board Can. 18: 793–816.

McPhail, J.D. 2007. Freshwater fishes of British Columbia. University of Alberta Press, Edmonton, AB. 620 p.

McPhail, J.D., and Baxter, J.S. 1996. A review of Bull Trout (*Salvelinus confluentus*) life-history and habitat use in relation to compensation and improvement opportunities. Fisheries Management Report 104, British Columbia Ministry of Environment, Lands and Parks, Victoria, BC. 35 p.

Meeuwig, M.H., Guy, C.S., and Fredenberg, W.A. 2011. Trophic relationships between a native and a non-native predator in a system of natural lakes. Ecol. Freshw. Fish 20: 315–325.

Meisner, J.D., Rosenfeld, J.S., and Regier, H.A. 1988. The role of groundwater in the impact of climate warming on stream salmonines. Fisheries 13: 2–8.

Minshall, G.W. 2003. Responses of stream benthic macroinvertebrates to fire. Forest Ecol. Manag. 178: 155–161.

Mochnacz, N.J., Reist, J.D., Cott, P., Low, G., and Wastle, R. 2004. Biological and habitat data for Bull Trout (*Salvelinus confluentus*) and associated species from stream surveys conducted in the southern and central Mackenzie River Valley, Northwest Territories, 2000 to 2001. Can. Data Rep. Fish. Aquat. Sci. 1131: iv + 38 p.

Mochnacz, N.J., Backhouse, S.M., Bajno, R., and Reist, J.D. 2009. Biological and habitat data for fish collected during stream surveys in the southern (Deh Cho) and central (Sahtu) Northwest Territories, 2007. Can. Data Rep. Fish. Aquat. Sci. 1209: vii + 29 p.

Monan, G.E., Johnson, J.H., and Esterberg, G.F. 1975. Electronic tags and related tracking techniques aid in study of migrating salmon and Steelhead Trout in the Columbia River basin. Mar. Fish. Rev. 37: 9–15.

MBTRT [Montana Bull Trout Restoration Team]. 2000. Restoration plan for Bull Trout in the Clark Ford River Basin and Kootenai River Basin, Montana. Montana Bull Trout Restoration Team, Montana Department of Fish, Wildlife and Parks, Helena, MT. xii + 114 p.

MBTSG [Montana Bull Trout Scientific Group]. 1998. The relationship between land management activities and habitat requirements of Bull Trout. Prepared for the Montana Bull Trout Restoration Team, Helena, MT.

Montgomery, D.R., Buffington, J.M., Peterson, P., Scheutt-Hames, D., and Quinn, T.P. 1996. Streambed scour, egg burial depths and the influence of salmonid spawning on bed surface mobility and embryo survival. Can. J. Fish. Aquat. Sci. 53: 1061–1070.

Mora, C., Metzger, R., Rollo, A., and Myers, R.A. 2007. Experimental simulations about the effects of overexploitation and habitat fragmentation on populations facing environmental warming. Proc. R. Soc. Lond. Ser. B Biol. Sci. 274: 1023–1028.

Muhlfeld, C.C., and Marotz, B. 2005. Seasonal movement and habitat use by subadult Bull Trout in the upper Flathead River system, Montana. N. Am. J. Fish. Manag. 25: 797–810.

Muhlfeld, C.C., Jones, L., Kotter, D., Miller, W.J., Geise, D., Tohtz, J., and Marotz, B. 2012a. Assessing the impacts of river regulation on native Bull Trout (*Salvelinus confluentus*) and Westslope Cutthroat Trout (*Oncorhynchus clarkia lewisi*) habitats in the upper Flathead River, Montana, USA. River Res. Appl. 28: 940–-959.

Muhlfeld, C.C., Giersch, J.J., and Marotz, B. 2012b. Seasonal movements of non-native Lake Trout in a connected lake and river system. Fish. Manag. Ecol. 19: 224–232.

Mushens, C.J. 2003. Migration, diel movement and habitat use of juvenile Bull Trout (*Salvelinus confluentus*). Thesis (M.Sc.) University of Calgary, Calgary, AB. 114 p.

Naiman, R.J., Décamps, H., and McClain, M.E. 2005. Riparia: Ecology, Conservation and Management of Streamside Communities. Elsevier Academic Press, Oxford. xv + 430 p.

Nakano, S., Fausch, K.D., Furukawa-Tanaka, T., Maekawa, K., and Kawanabe, H. 1992. Resource utilization by Bull Charr and Cutthroat Trout in a mountain stream in Montana, USA. Jpn. J. Ichthyol. 39: 211–217.

Nakano, S., Miyasaka, H., and Kuhara, N. 1999. Terrestrial-aquatic linkages: Riparian arthropod inputs alter trophic cascades in a stream food web. Ecology 80: 2435–2441.

Nelson, J.S., and Paetz, M.J. 1992. The fishes of Alberta, 2nd edition. The University of Alberta Press, Edmonton, AB and The University of Calgary Press, Calgary, AB. xxvi + 437 p.

Nelson, J.S., and Paetz, M.J. 1992. The Fishes of Alberta. The University of Alberta Press, Edmonton, AB and The University of Calgary Press, Calgary, AB. xxvi + 437 p.

Nelson, M.L., McMahon, T.E., and Thurow, R.F. 2002. Decline in the migratory form of Bull Charr, *Salvelinus confluentus*, and implications for conservation. Env. Biol. Fishes. 64: 321–332.

Nehring, R.B., and Anderson, R.M. 1993. Determination of population-limiting critical salmonid habitats in Colorado streams using the physical habitat simulation system. Rivers 4: 1–19.

Norris, K., Brewin, M.K., Hall, C., and Baayens, D.M. 2001. Alberta anglers' attitudes towards Bull Trout: follow-up survey. *In* Bull Trout II Conference Proceedings. Edited by M.K. Brewin, A.J. Paul, and M. Monita. Trout Unlimited Canada, Calgary, AB. p. 81–-84.

North Saskatchewan Watershed Alliance. 2005. The State of the North Saskatchewan River Watershed Report. North Saskatchewan Watershed Alliance, Edmonton, AB. 202 p.

Oldman Watershed Council. 2010. Oldman River State of the Watershed Report, 2010. Oldman Watershed Council, Lethbridge, AB. 284 p.

Oliver, G. 1979. A final report on the present fisheries of the Wigwam River with an emphasis on the migratory life history and spawning behaviour of Dolly Varden char *Salvelinus malma* (Walbaum). Fisheries investigations in tributaries of the Canadian portion of Libby Reservoir. British Columbia Fish and Wildlife Branch, Cranbrook, BC. 82 p. (Available from the DFO library)

Oliver, G. 1985. Habitat requirements of Dolly Varden char in the Wigwam River drainage. *In* Proceedings of the Flathead River Basin Bull Trout Biology and Population Dynamics Modelling Information Exchange. Edited by D.D. Macdonald. Fisheries Branch, BC Ministry of the Environment, Cranbrook, BC. p. 36.

Oliver, T.H., and Morecroft, M.D. 2014. Interactions between climate change and land use change on biodiversity: attribution problems, risks and opportunities. WIREs Clim. Change 5: 317-335.

Olmsted, W.R., den Biesen, D., and Birch, G.J. 2001. Migration timing and abundance trends in an adfluvial Bull Trout population in Kootenay Lake, British Columbia. *In* Bull Trout II Conference Proceedings. Edited by M.K. Brewin, A.J. Paul and M. Monita. Trout Unlimited Canada, Calgary, AB. pp. 159–166.

Park, D., Sullivan, M., Bayne, E., and Scrimgeour, G. 2008. Landscape-level stream fragmentation caused by hanging culverts along roads in Alberta’s boreal forest. Can. J. Forest Res. 38: 566-–575.

Parker, B.R., Schindler, D.W., Wilhelm, F.M., and Donald, D.B. 2007. Bull Trout population responses to reductions in angler effort and retention limits. N. Am. J. Fish. Manag. 27: 848–859.

Pattenden, R., McLeod, C., and Ash, G. 1991. Peace River Site C hydroelectric development. Fish movements and population status. Prepared by R.L. and L. Environmental Services Ltd, Edmonton, AB for BC Hydro, Environmental Resources Division, Vancouver, BC.

Paul, A.J. 2000. Recruitment dynamics in Bull Trout (*Salvelinus confluentus*): Linking theory and data to species management. Thesis (Ph.D.) University of Calgary, Calgary, AB. 251 p.

Paul, J., and Post, J.R. 2001. Spatial distribution of native and non-native salmonids in streams of the eastern slopes of the Canadian Rocky Mountains. Trans. Am. Fish. Soc. 130: 417-430.

Paul, A.J., Post, J.R., Sterling, G.L., and Hunt, C. 2000. Density-dependent intercohort interactions and recruitment dynamics: Models and a Bull Trout (*Salvelinus confluentus*) time series. Can. J. Fish. Aquat. Sci. 57: 1220–1231.

Paul, A.J., Post, J.R., and Stelfox, J.D. 2003. Can anglers influence the abundance of native and non-native salmonids in a stream from the Canadian Rocky Mountains? N. Am. J. Fish. Manag. 23: 109–119.

Pederson, G.T., Graumlich, L.J., Fagre, D.B., Kipfer, T., and Muhlfeld, C.C. 2010. A century of climate and ecosystem change in western Montana: What do temperature trends portend? Clim. Change 98: 133–154.

Peterson, D.P., Rieman, B.E., Young, M.K., and Brammer, J.A. 2010. Modeling predicts that red trampling by cattle may contribute to population declines of native trout. Ecol. Appl. 20: 954–966.

Phillips, R.B., Sajdak, S.L., and Dominico, M.J. 1995. Relationships among charrs based on DNA sequences. Nord. J. Freshw. Res. 71: 378–391.

Piggott, J.J., Townsend, C.R., and Matthaei, C.D. 2015. Reconceptualizing synergism and antagonism among multiple stressors. Ecol. Evol. 5: 1538–1547.

Pillipow, R., and Williamson, C. 2004. Goat River Bull Trout (*Salvelinus confluentus*) biotelemetry and spawning assessments 2002-03. BC J. Ecosyst. Manag. 4: 1–9.

Pollard, S., and Down, T. 2001. Bull Trout in British Columbia – a provincial perspective on status, management and protection. *In* Bull Trout II Conference Proceedings. Edited by M.K. Brewin, A.J. Paul, and M. Monita. Trout Unlimited Canada, Calgary, AB. p. 207–214.

Popowich, R.C. 2005. Determining Bull Trout (*Salvelinus confluentus*) habitat and prey selection using snorkel surveys and stable isotope analysis. Thesis (M.Sc.) University of Edmonton, Edmonton, AB. 62 p.

Popowich R., and Eisler, G. 2008, Fluvial Bull Trout redd surveys on the Elbow, Sheep and Highwood rivers, Alberta – Trout Unlimited Canada. Applied Aquatic Research Ltd, Calgary, AB. 16 p. + app.

Popowich, R.C., Venturelli, P.A., Stelfox, J.D., and Taylor, E.B. 2011. Validation of morphological characteristics used for field identification of Bull Trout x Brook Trout hybrids. N. Am. J. Fish. Manage. 31: 547-553.

Porter, M., Haas, G., and Parkinson, E. 2000. Sensitivity of British Columbia's freshwater fish to timber harvest: Using species traits as predictors of species at risk. BC Fisheries, Ministry of Agriculture, Food and Fisheries, Fisheries Management Report No. 114: ii + 41 p.

Post, J.R., and Paul, A.J. 2000. A quantitative assessment of the recovery of Bull Trout populations in Alberta and development of models of sustainable yield. Prepared for Alberta Conservation Association. University of Calgary, Calgary, AB. p. 143–220.

Post, J.R., Mushens, C., Paul, A., and Sullivan, M. 2003. Assessment of alternative harvest regulations for sustaining recreational fisheries: model development and application to Bull Trout. N. Am. J. Fish. Manag. 23: 22–34.

Pratt, K.L. 1992. A review of Bull Trout life history. *In* Proceedings of the Gearhart Mountain Bull Trout Workshop. Edited by P.J. Howell and D.V. Buchanan. Oregon Chapter of the American Fisheries Society, Corvallis, OR. p. 1–14.

Przeslawski, R., Davis, A.R., and Benkendorff, K. 2005. Synergistic effects associated with climate change and the development of rocky shore molluscs. Glob. Change Biol. 11: 515–522.

Quigley, T.M., and Arbelbide, S.J. (Eds). 1997. An assessment of ecosystem components in the interior Columbia basin and portions of the Klamath and Great basins. U.S. Forest Service General Technical Report PNW-405 (Volumes 1-4), Portland, OR.

Radinger, J., Hölker, F., Horky, P., Slavík, O., Dendoncker, N., and Wolter, C. 2016. Synergistic and antagonistic interactions of future land use and climate change on river fish assemblages. Glob. Change Biol. 22: 1505–1522.

Ratcliff, D.E., Thiesfeld, S.L., Weber, W.G., Stuart, A.M., Riehle, M.D., and Buchanan, D.V. 1996. Distribution, life history, abundance, harvest, habitat, and limiting factors of Bull Trout in the Metolius River and Lake Billy Chinook, Oregon, 1983–1994. Fish Division, Oregon Department of Fish and Wildlife. Information Reports 96–97: 44 p.

Reiser, D.W., Connor, E., Binkley, K., Lynch, K., and Paige, D. 1997. Evaluation of spawning habitat used by Bull Trout in the Cedar watershed, Washington. *In* Friends of the Bull Trout Conference Proceedings. Edited by W.C. Mackay, M.K. Brewin, and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 331–338.

Reist, J.D., Low, G., Johnson, J.D., and McDowell, M. 2002. Range extension of Bull Trout, *Salvelinus confluentus*, to the central Northwest Territories, with notes on identification and distribution of Dolly Varden, *Salvelinus malma*, in the western Canadian Arctic. Arctic 55: 70–76.

Rhude, L.A., and Stelfox, J. 1997. Status of Bull Trout in Alberta's Fish Management Area Three. *In* Friends of the Bull Trout Conference Proceedings. Edited by W.C. Mackay, M.K. Brewin, and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 161–170.

Rich, C.F. 1996. Influence of abiotic and biotic factors on occurrence of resident Bull Trout in fragmented habitats, western Montana. Thesis (M.Sc.) Montana State University, Bozeman, MT. viii + 53 p.

Rich, C., McMahon, T., Rieman, B., and Thompson, W. 2003. Local habitat, watershed, and biotic features associated with Bull Trout occurrence in Montana streams. Trans. Am. Fish. Soc. 132: 1053-1064.

Rieman, B.E., and McIntyre, J.D. 1993. Demographic and habitat requirements for conservation of Bull Trout. Forest Service General Technical Report INT-302, USA Department of Agriculture, Ogden, UT. 38 p.

Rieman, B.E., and McIntyre, J.D. 1995. Occurrence of Bull Trout in naturally fragmented habitat patches of varied size. Trans. Am. Fish. Soc. 124: 285–296.

Rieman, B.E., Lee, D.C., and Thurow, R.F. 1997. Distribution, status, and likely future trends of Bull Trout within the Columbia River and Klamath River basins. N. Am. J. Fish. Manag. 17: 1111–1125.

Rieman, B.E., Peterson, J.T., and Myers, D.L. 2006. Have Brook Trout displaced Bull Trout along longitudinal gradients in central Idaho streams? Can. J. Fish. Aquat. Sci. 63: 63–78.

Rieman, B.E., Isaak, D., Adams, S., Horan, D., Nagel, D., Luce, C., and Myers, D.L. 2007. Anticipated climate warming effects on Bull Trout habitats and populations across the interior Columbia River basin. Trans. Am. Fish. Soc. 136: 1552–1565.

Ripley, T., Scrimgeour, G., and Boyce, M.S. 2005. Bull Trout (*Salvelinus confluentus*) occurrence and abundance influenced by cumulative industrial developments in a Canadian boreal forest watershed. Can. J. Fish. Aquat. Sci. 62: 2431–2442.

Rivard, C., Lavoie, D., Lefebvre, R., Séjourné, S., Lamontagne, C., and Duchesne, M. 2014. An overview of Canadian shale gas production and environmental concerns. Int. J. Coal Geol. 126: 64–76.

R.L. and L. Environmental Services Ltd. 1992. Peace River Site C hydroelectric development, pre-construction fisheries studies. Data summary report. Report prepared for BC Hydro, Environmental Resource Division. 23 p. + app.

Rodtka, M. 2002. Effects of water temperature on competition between juvenile Brook and Bull Trout. University of Alberta, Edmonton, AB. Fisheries Management Information System (FMIS) inventory project # 4256.

Rodtka, M. 2005. Status of Bull Trout in the upper Clearwater River – 2004. Alberta Conservation Association, Rocky Mountain House, AB. 42 p. + app.

Rodtka, M., Judd, C., and Fitzsimmons, K. 2010. North Saskatchewan and Ram Rivers Bull Trout spawning stock assessment, Alberta 2007-2009. Technical Report, T-2010-001, produced by the Alberta Conservation Association, Rocky Mountain House, AB. 28 p. + app.

Rosenberger, A.E., Dunham, J.B., Buffington, J.M., and Wipfli, M.S. 2011. Persistent effects of wildlfire and debris flows on the invertebrate prey base of Rainbow Trout in Idaho streams. Northwest Sci. 85: 55–63.

Schindler, D.W. 2000. Aquatic problems caused by human activities in Banff National Park, Alberta, Canada. Ambio 29: 401–407.

Schindler, D.W., and Donahue, W.F. 2006. An impending water crisis in Canada's western prairie provinces. Proc. Natl. Acad. Sci. USA 103: 7210–7216.

Schnebele, E., Cervone, G., Kumar, S., and Waters, N. 2014. Real time estimation of the Calgary floods using limited remote sensing data. Water 6: 381–398.

Scrimgeour, G., Hvenegaard, P., Tchir, J., Kendall, S., and Wildeman, A. 2003. Stream fish management: cumulative effects of watershed disturbance on stream fish communities in the Kakwa and Simonette River Basins, Alberta. Report produced by the Alberta Conservation Association (Peace River) and the Alberta Research Council (Vegreville) for the Northern Watershed Project Stakeholder Committee. Northern Watershed Project Final Report No. 3. 126 p. Available on request from Albera Conservation Association (info@ab-conservation.com)

Seegrist, D.W., and Gard, R. 1972. Effects of floods on trout in Sagehen Creek, California. Trans. Am. Fish. Soc. 101: 478–-482.

Selong, J.H., McMahon, T.E., Zale, A.V., and Barrows, F.T. 2001. [Effects of temperature on growth and survival of Bull Trout, with application of an improved method for determining thermal tolerance in fishes.]() Trans. Am. Fish. Soc. 130: 1026-1037.

Sexauer, H.M. 1994. Life history aspects of Bull Trout, *Salvelinus confluentus*, in the eastern Cascades, Washington. Thesis (M.Sc.) Central Washington University, Ellensburg, WA. ix + 85 p.

Sexauer, H.M., and James, P.W. 1997. Microhabitat use by juvenile Bull Trout in four streams located in the eastern Cascades, Washington. *In* Friends of the Bull Trout Conference Proceedings. Edited by W.C. Mackay, M.K. Brewin, and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 361–370.

Shellberg, J., Bolton, S., and Montgomery, D. 2010. Hydrogeomorphic effects of bedload scour in bull char (*Salvelinus confluentus*) spawning habitat, western Washington, USA. Can. J. Fish. Aquat. Sci. 67: 626–640.

Shepard, B. 1985. Habitat variables related to Bull Trout spawning site selection and thermal preference exhibited in a thermal gradient. *In* Proceedings of the Flathead River Basin Bull Trout Biology and Population Dynamics Modelling Information Exchange. Edited by D.D. Macdonald. Fisheries Branch, BC Ministry of the Environment, Cranbrook, BC. p. 18.

Shepard, B., Leathe, S., Weaver, T., and Enk, M. 1984. Monitoring levels of fine sediment within tributaries to Flathead Lake and impacts of fine sediment on Bull Trout recruitment. *In* Proceedings of the Wild Trout Symposium III. Edited by F. Richardson and R.H. Hamre. Mammoth Hot Springs, WY. p. 146–156.

Shepard, B.G., Hartman, G.F., and Wilson, W.J. 1986. Relationships between stream and intragravel temperatures in coastal drainages, and some implications for fisheries workers. Can. J. Fish. Aquat. Sci. 43: 1818–1822.

Shively, D., Allen, C., Alsbury, T., Bergamini, B., Goehring, B., Horning, T., and Strobel, B. 2007. Clackamas River Bull Trout reintroduction feasibility assessment. USDA Forest Service, Mt. Hood National Forest; US Fish and Wildlife Service, Oregon State Office; and Oregon Department of Fish and Wildlife, North Willamette Region. Various pagination.

Slaney, P.A., and Zaldokas, D. 1997. Fish habitat rehabilitation procedures. Province of British Columbia, Ministry of Environment, Lands and Parks, Watershed Restoration Technical Circular No. 9.

Smith, V.H., and Schindler, D.W. 2009. Eutrophication science: where do we go from here? Trends Ecol. Evol. 24: 201–207.

South Saskatchewan Regional Advisory Council. 2010. Advice to the Government of Alberta for the South Saskatchewan Regional Plan. South Saskatchewan Regional Advisory Council, Alberta. ii + 66 p.

Spangler, R.E., and Scarnecchia, D.L. 2001. Summer and fall microhabitat utilization of juvenile Bull Trout and Cutthroat Trout in a wilderness stream, Idaho. Hydrobiologia 452: 145–154.

Sprague, J.P. 1985. Factors that modify toxicity. *In* Fundamentals of Aquatic Toxicology: Methods and Application. Edited by G. Rand and S.R. Petrocelli. Hemisphere Publishing Corporation, New York, NY. p. 124–163.

Staples, D.F. 2006. Viable population monitoring: Risk-based population monitoring for threatened and endangered species with application to Bull Trout, *Salvelinus confluentus*. Thesis (Ph.D.) Montana State University, Bozeman, MT. 127 p.

Staudt, A., Leidner, A.K., Howard, J., Brauman, K.A., Dukes, J.S., Hansen, L.J., Paukert, C., Sabo, J., and Solórzano, L.A. 2013. The added complications of climate change: understanding and managing biodiversity and ecosystems. Front. Ecol. Environ. 11: 494–501.

Stelfox, J.D. 1997. Seasonal movements, growth, survival and population status of the adfluvial Bull Trout population in Lower Kananaskis Lake, Alberta. *In* Friends of the Bull Trout Conference Proceedings. *Edited by* W.C. Mackay, M.K. Brewin, and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 309–316.

Stewart, R.J., McLenehan, R.E., Morgan, J.D., and Olmsted, W.R. 1982. Ecological studies of Arctic Grayling (*Thymallus arcticus*), Dolly Varden (*Salvelinus malma*), and Mountain Whitefish (*Prosopium williamsoni*) in the Liard River drainage, BC. Prepared by EVS Consultants Ltd for Westcoast Transmission Company Ltd and Foothills Pipe Lines (North BC) Ltd. 99 p. (Available from the DFO library)

Stewart, D.B., Mochnacz, N.J., Sawatzky, C.D., Carmichael, T.J., and Reist, J.D. 2007. Fish diets and food webs in the Northwest Territories: Bull Trout (*Salvelinus confluentus*). Can. Manuscr. Rep. Fish. Aquat. Sci. 2800: vi + 18 p.

Strahlberg, D. 2012. General circulation model recommendations for Alberta. Alberta Biodiversity and Climate Change Team, Alberta Biodiversity Monitoring Institute, University of Alberta, Edmonton, AB, June 2012.

Stringfellow, W.T., Domen, J.K., Camarillo, M.K., Sandelin, W.L., and Borglin, S. 2014. Physical, chemical, and biological characteristics of compounds used in hydraulic fracturing. J. Hazard. Mater. 275: 37–54.

Swanberg, T.R. 1997. Movements of and habitat use by fluvial Bull Trout in the Blackfoot River, Montana. Trans. Am. Fish. Soc. 126: 735–746.

Sweetgrass Consultants Ltd. 1997. Environmentally Significant Areas of Alberta, 3 Volumes. Prepared for Alberta Environmental Protection, Edmonton, AB. various pagination.

Taniguchi, Y., and Nakano, S. 2000. Condition-specific competition: implications for the altitudinal distribution of stream fishes. Ecology 81: 2027–2039.

Tautz, A.F., and Groot, C. 1975. Spawning behavior of Chum Salmon (*Oncorhynchus keta*) and Rainbow Trout (*Salmo gairdneri*). J. Fish. Res. Board Can. 32: 633–642.

Taylor, E.B. 2012. Microsatellite DNA analysis of populations of Bull Trout (*Salvelinus confluentus*) in the upper Red Deer River drainage, Alberta. University of British Columbia, Vancouver, BC. 25 p.

Taylor, E.B., and Costello, A.B. 2006. Microsatellite DNA analysis of coastal populations of Bull Trout (*Salvelinus confluentus*) in British Columbia: zoogeographic implications and its application to recreational fishery management. Can. J. Fish. Aquat. Sci. 63: 1157–1171.

Taylor, M.J., and White, K.R. 1992. A meta-analysis of hooking mortality of non-anadromous trout. N. Am. J. Fish. Manag. 12: 760–767.

Taylor, E.B., Redenbach, Z., Costello, A.B., Pollard, S.M., and Pacas, C.J. 2001. Nested analysis of genetic diversity in northwestern North American char, Dolly Varden (*Salvelinus malma*) and Bull Trout (*Salvelinus confluentus*). Can. J. Fish. Aquat. Sci. 58: 406–420.

Thiesfeld, S.L., Stuart, A.M., Ratliff, D.E., and Lampman, B.D. 1996. Migration patterns of adult Bull Trout in the Metolius River and Lake Billy Chinook, Oregon. Oregon Department of Fish and Wildlife, Fish Division, Information Reports No. 96-1: i + 18 p.

Thurow, R.F. 1997. Habitat utilization and diel behaviour of juvenile Bull Trout (*Salvelinus confluentus*) at the onset of winter. Ecol. Freshw. Fish 6: 1–7.

Tonina, D., Luce, C.H., Rieman, B., Buffington, J.M., Goodwin, P., Clayton, S.R., Ali, S.M., Barry, J.J., and Berenbrock, C. 2008. Hydrological response to timber harvest in northern Idaho: Implications for channel scour and persistence of salmonids. Hydrol. Process. 22: 3223–3235.

Trombulak, S.C., and Frissell, C.A. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conserv. Biol. 14: 18-30.

Underwood, K.D., Martin, S.W., Schuck, M.L., and Scholz, A.T. 1995. Investigations of Bull Trout (*Salvelinus confluentus*), Steelhead Trout (*Oncorhynchus mykiss*), and spring Chinook Salmon (*O. tshawtyscha*) interactions in southeast Washington streams, 1992 final report. Prepared by Department of Biology, Eastern Washington University and Washington Department of Wildlife for US Department of Energy, Bonneville Power Administration, Portland, OR. viii + 173 p.

USFWS [US Fish and Wildlife Service]. 1998 (Rev. 2000). Bull Trout Interim Conservation Guidance. USFWS, Washington, DC. 48 p.

USFWS [United States Fish and Wildlife Service]. 1999. Determination of threatened status for Bull Trout in the coterminous United States. Final Rule Federal Register 64: 58909–58933.

USFWS [United States Fish and Wildlife Service]. 2000. Bull Trout occurrence and habitat selection. A White Paper addressing Bull Trout distribution and habitat requirements as related to potentially occupied habitats. US Fish and Wildlife Service, Western Washington Office. 3 p.

USFWS [United States Fish and Wildlife Service]. 2008. Bull Trout (*Salvelinus confluentus*) 5-year review: summary and evaluation. US Fish and Wildlife Service, Portland, OR. 53 p.

USGS [United States Geological Survey] and USDA [United States Department of Agriculture]. 2012. Federal standards and procedures for the National Watershed Boundary Dataset (WBD). USGS Techniques and Methods Report 11-A3: ix + 56 p., app.

Van Tighem, K. 1997. My grandfather's trout. *In* Friends of the Bull Trout Conference Proceedings. Edited by W.C. Mackay, M.K. Brewin, and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 83–88.

Vengosh, A., Jackson, R.B., Warner, N., Darrah, T.H., and Kondash, A. 2014. A critical review of the risks to water resources from unconventional shale gas development and hydraulic fracturing in the United States. Environ. Sci. Technol. 48: 8334–8348.

Walty, D.T., and Smith, D.R. 1997. Incorporating local knowledge into Bull Trout management in northwestern Alberta. *In* Friends of the Bull Trout Conference Proceedings. Edited by W.C. Mackay, M.K. Brewin, and M. Monita. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB. p. 187–190.

Wang, T., Hamann, A., Spittlehouse, D.L., and Murdock, T.Q. 2012. Climate WNA – High-resolution spatial climate data for western North America. J. Appl. Meteor. Climatol. 51: 16-29.

Warnock, W.G. 2008. Molecular tools reveal hierarchical structure and patterns of migration and gene flow in Bull Trout (*Salvelinus confluentus*) populations of south-western Alberta. Thesis (M.Sc.) University of Lethbridge, Lethbridge, AB. xi + 174 p.

Warnock, W.G. 2008. Molecular tools reveal hierarchical structure and patterns of migration and gene flow in Bull Trout (*Salvelinus confluentus*) populations of south-western Alberta. Thesis (M.Sc.) University of Lethbridge, Lethbridge, AB. xi + 174 p.

Warnock, W.G. 2012. Examining Brook Trout invasion into Bull Trout streams of the Canadian Rockies. Thesis (Ph.D) University of Lethbridge, Lethbridge, AB. xiv + 184 p.

Warnock, W.G., and Rasmussen, J.B. 2013. Abiotic and biotic factors associated with Brook Trout invasiveness into Bull Trout streams of the Canadian Rockies. Can. J. Fish. Aquat. Sci. 70: 905–914.

Warnock, W.G., and Rasmussen, J.B. 2014. Comparing competitive ability and associated metabolic traits between a resident and migratory population of Bull Trout against a non-native species. Environ. Biol. Fishes 97: 415–423.

Waterline Resources Inc. 2011. Groundwater evaluation and monitoring plan Elbow River watershed sub-region TWPS 018 to 024, RGES 29W4 to 09W5 Alberta. Submitted to Alberta Environment, Calgary, AB. vii + 100 p.

Weaver, T., and Fraley, J. 1991. Fisheries habitat and fish populations. Flathead Basin Forest Practices, Water Quality and Fisheries Cooperative Program. Flathead Basin Commission, Kalispell, MT. viii + 47 p.

Weaver, T.M., and White, R.G. 1985. Coal Creek fisheries monitoring study number III. Quarterly progress report to the United States Department of Agriculture, Forest Service, Montana State Cooperative Fisheries Research Unit, Bozeman, MT. 94 p. (Available from the DFO library)

Wenger, S.J., Isaak, D.J., Dunham, J.B., Fausch, K.D., Luce, C.H., Neville, H.M., Rieman, B.E., Young, M.K., Nagel, D.E., Horan, D.L., and Chandler, G.L. 2011a. Role of climate and invasive species in structuring trout distributions in the interior Columbia River Basin, USA. Can. J. Fish. Aquat. Sci. 68: 988-1008.

Wenger, S.J., Isaak, D.J., Luce, C.H., Neville, H.M., Fausch, K.D., Dunham, J.B., Dauwalter, D.C., Young, M.K., Elsner, M.M., Rieman, B.E., Hamlet, A.F., and Williams, J.E. 2011b. Flow regime, temperature, and biotic interactions drive differential declines of trout species under climate change. Proc. Natl. Acad. Sci. USA 108: 14175–14180.

Wilhelm, F.M., Parker, B.R., Schindler, D.W., and Donald, D.B. 1999. Seasonal food habits of Bull Trout from a small alpine lake in the Canadian Rocky Mountains. Trans. Am. Fish. Soc. 128: 1176–1192.

Williams, H.F.L., Havens, D.L., Banks, K.E., and Wachal, D.J. 2008. Field-based monitoring of sediment runoff from natural gas well sites in Denton County, Texas, USA. Environ. Geol. 55: 1463–1471.

Williams, J.E., Neville, H.M., Haak, A.L., Colyer, W.T., Wenger, S.J., and Bradshaw, S. 2015. Climate change adaptation and restoration of western trout streams: opportunities and strategies. Fisheries 40: 304–317.

Yarmoloy, C., and Stelfox, B. 2011. An assessment of the cumulative effects of land uses within the Ghost River watershed, Alberta, Canada. Ghost River Watershed Alliance, Cochrane, AB. vii + 70 p.

Xenopoulos, M.A., Lodge, D.M., Alcamo, J., Märker, M., Schulze, K., and Van Vuuren, D.P. 2005. Scenarios of freshwater fish extinctions from climate change and water withdrawal. Glob. Change Biol. 11: 1557-1564.

APPENDIX 1

South Saskatchewan (Oldman Watershed) – Mountain Sub-basins

HUC8s: 04010101, 04010102, 04010103

OVERVIEW: Oldman Watershed Council (State of the Watershed Report) 2010 unless otherwise indicated

- Area: 416,264 ha
- Extensive random recreational use (hunting, fishing, camping, off-highway vehicle use) occurs throughout the area but data are not available to quantify this
- First Nations lands include Peigan Timber Limit 147B
- Approximately 22% of land is used for agriculture (grazing land, range land, cultivated)
- Nearly 2% of the land supports infrastructure, primarily linear developments (0.7% cutlines, 0.6% roads, 0.3% pipelines)
- Operating and abandoned oil and gas wells occupy < 0.1% of the area
- Approximately 25% of the area is altered by human development
- All rivers are unregulated
- Water quality is largely within guidelines and was rated GOOD (water quality guidelines not exceeded or less than 10% within the data set analysed exceeds guidelines and neutral or decreasing trend, particularly over the last decade)
- Water quantity was rated GOOD (streams have relatively high unit yields [dam^3/km^2], no significant trends in annual flow volumes, low level of water allocation and use)
- Riparian health rated as FAIR (healthy but with problems)
- Castle Special Management Area, Cataract Creek, Allison/Chinook and Willow Creek Forest Land Use Zones (FLUZ) cover approximately 21% (90,720 ha) of the land [FLUZ – established under the Forest Act to protect sensitive resources such as wildlife and their habitats, vegetation, soils or watersheds and to designate separate areas for motorized and non-motorized recreational activities]
- Recreation Areas (16), Ecological Reserves (Plateau Mountain, West Castle Wetlands) and Provincial Parks (Bob Creek Wildland, Don Getty Wildland, Beauvais Lake) cover 5% (21,600 ha) of the land area
- Crowsnest River from Bellevue to Cow Creek has been designated an Internationally Significant trout stream (Sweetgrass Consultants 1997)
- Forestry is the primary economic activity. Forest harvest operations are concentrated in the following areas: along Livingstone Creek, upper Oldman River, central Castle River and along the tributaries flowing into the upper Crowsnest River (including Allison Creek, Star Creek, McGillvary Creek, Nez Pierce Creek, Blairmore Creek and Todd Creek) (Fiera Biological Consulting 2014).
- Cattle grazing is the primary agricultural land use; some crop and hay production occurs at lower elevations (Fiera Biological Consulting 2014)
- There are Class A waters in Hidden Creek (HUC8: 04010101; designated by the Government of Alberta)
- DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of projects and activities that have occurred between January 2008 and March 2014. Sixty projects and activities were found within these HUCs, but this may not represent the total number as some may not have been reported to DFO. These fell under the following main categories: Watercourse Crossings – 34, Shoreline Work (Foreshore, Streambank and Riparian Work) – 11, Instream Works – 8, Water Management – 3, Structures in Water – 2, Mineral Aggregate, Oil and Gas Exploration, Extraction, Production – 1, and Habitat Improvement – 1

1. HUC8: 04010101 – Upper Oldman River

Competition and Hybridization with Brook Trout: REMOTE (Likelihood of Occurrence) – Brook Trout have not been reported in the lower Crowsnest River or Oldman River. Brook Trout are present above Lundbreck Falls and in the Castle River drainage, but there is no evidence that they have dispersed into the upper Oldman River (FSI[1]). Genetic analysis of approximately 210 fish collected from seven sites within the HUC indicated no hybrids (Warnock 2008). HIGH (Severity). *Threat Risk: Low*

Competition with Lake Trout: REMOTE – There are no records of Lake Trout in this HUC. HIGH. *Threat Risk: Low*

Mortality: LIKELY– The majority of this HUC is within 150 km of Calgary and is accessible by 2 wheel-drive. An extensive network of paved and gravel roads provides access to the Oldman River and tributaries. There is also a lot of random recreational use in this region (Oldman Watershed Council 2010). FSI; HIGH. *Threat Risk: High*

Habitat Fragmentation – Culverts (Road Density): LIKELY – Road density[2] = 2.082 km/km^2 (FSI based on GIS). HIGH. *Threat Risk: High*

Habitat Fragmentation – Dams and Weirs: KNOWN – Oldman Dam and Reservoir fragment habitat. The Waldron Graz. Co-op NE5 Embankment is located within this HUC (Table 7) but it is relatively small and low capacity. EXTREME. *Threat Risk: High*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – Irrigation use is low. There are no irrigation districts licensed to draw water from this HUC (Oldman Watershed Council 2010). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: LIKELY – The Oldman River mainstem in this HUC is primarily the section upstream of the Oldman Dam and Reservoir. Flow showed no trend from 1912–2001; annual recorded flows are the same as natural flows; probable decreasing trend in flow in April (Oldman Watershed Council 2010). Road density is medium at 2.082 km/km^2 (FSI based on GIS). HIGH. *Threat Risk: High*

Suspended and Deposited Sediment (Sediment Load[3] and J. Reilly, AEP, pers. comm.): LIKELY – Sediment Index = 1.12. HIGH. *Threat Risk: High*

Alteration of Stream Temperature (Summer Air Temperature)[4]: LIKELY - Current average summer air temperature (2000–2010) for HUC = 15.0 ºC. Historical average summer air temperature (1901–1930) = 12.0 ºC. FSI; EXTREME. *Threat Risk: High*

Alteration of Groundwater Quantity or Quality: UNLIKELY – There are 20 groundwater springs within this HUC (according to GIS data[5]). Urban land use is low. Forestry activity is high

[1] AEP 2013

[2] ≤ 0.7 km/km^2 = Ideal; 0.75–2.65 km/km^2 = Medium Risk; > 2.7 km/km^2 = High Risk (US Fish and Wildlife Service 1998)

[3] Sediment Load = inverse of the ALCES Online © Water Quality Sediment Index (e.g., 0.33 = 3 times the normal sediment load) (J. Reilly, AEP, pers. comm.)

[4] Analysis based on province-wide juvenile occupancy data [collected 2000–2013] and air temperatures for 1901–1930 and 2000–2010 derived using ClimateWNA (Wang et al. 2012). Mean summer air temperatures were taken on point grid 1 km/1 km. Resulting air temperatures were averaged and ascribed to each HUC for ranking. Note: this method provides a largescale average temperature for each watershed and is not meant to imply that there are not areas of more/less thermally suitable habitat in the watershed. This procedure was followed for all subsequent average summer air temperature calculations (FSI).

[5] Government of Canada et al. 2013

and road density medium. Agricultural uses are primarily native rangeland and grazing land (South Saskatchewan Regional Advisory Council 2010). Six Provincial Recreation Areas, one Heritage Rangeland and one Natural Area provide moderate protection. Approximately 90% of land is privately owned and 10% is First Nations (Peigan Timber Limit 147B – Piikanni First Nation) and provincial crown land. There are two contaminated sites listed in the Federal Contaminated Sites Inventory. There are no Class A waters (FSI). The majority of groundwater is ranked HIGH vulnerability (AESRD 2009). EXTREME. *Threat Risk: Medium*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.28 (ALCES Online ©). HIGH. *Threat Risk: Low*

2. HUC8: 04010102 – Crowsnest River

Competition and Hybridization with Brook Trout: REMOTE – Brook Trout have not been reported from the lower Crowsnest River or Oldman River, but do occur above Lundbreck Falls and in the Castle River drainage. Brook Trout occur throughout the upper Crowsnest River. Hybrids have not been reported. FSI; HIGH. *Threat Risk: Low*

Competition with Lake Trout: UNLIKELY – Lake Trout are present and appear to be expanding their range into the Oldman Reservoir and drainage and the Castle River watershed (FSI). HIGH. *Threat Risk: Medium*

Mortality: LIKELY – This entire HUC is within 150 km of Calgary and is accessible by 2 wheel-drive. There is an extensive network of paved and gravel roads in the lower portion of the HUC; the upper portion has fewer roads, but most rivers (e.g., Willow and Lyndon creeks) are paralleled by gravel roads and unimproved roads/truck trails. FSI; HIGH. *Threat Risk: High*

Habitat Fragmentation – Culverts (Road Density): UNLIKELY – Road density = 0.651 km/km^2 (FSI based on GIS). HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Dams and Weirs: KNOWN – Oldman Dam and Reservoir reduce connectivity. Castle and Crowsnest rivers are unregulated (Oldman Watershed Council 2010). Dams/weirs in this HUC include: Allison Creek Hatchery Main Dam, Coleman Fish and Game Embankment, Ganske, H and Mielke, R Embankment, Heaton, Mark Embankment, and Skierka, Frank Embankment (Table 7). EXTREME. *Threat Risk: High*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – Irrigation use is low. There are no irrigation districts licensed to draw water from this HUC (Oldman Watershed Council 2010). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: UNLIKELY – Flows in the Castle and Crowsnest rivers are typical of mountain streams and have been fairly consistent between 1912 and 2001 with segments of the Crowsnest decreasing between 0.3–0.5% per year (Oldman Watershed Council 2010). Road density is low at 0.652 km/km^2 (FSI based on GIS). HIGH. *Threat Risk: Medium*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): UNLIKELY – Sediment Index = 1.15 HIGH. *Threat Risk: Medium*

Alteration of Stream Temperature (Summer Air Temperature): LIKELY – Current average summer air temperature (2000–2010) for HUC = 13.0 ºC. Historical average summer air temperature (1901–1930) = 12.0 ºC. FSI; EXTREME. *Threat Risk: High*

Alteration of Groundwater Quantity or Quality: UNLIKELY – There are 24 groundwater springs in this HUC (according to GIS data). Urban land use and road density are low. Forestry activity is high and agricultural uses are primarily native rangeland and grazing land (South Saskatchewan Regional Advisory Council 2010). Approximately 60% of land is privately owned and the remainder is provincial crown land (FSI). Three small Provincial Recreation Areas provide minimal protection. There are two contaminated sites listed in the Federal Contaminated Sites Inventory. There are no Class A waters within this HUC (FSI). The majority of groundwater is ranked as HIGH vulnerability (AESRD 2009). EXTREME. *Threat Risk: Medium*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): UNLIKELY – Phosphorous Runoff Coefficient = 1.45 (ALCES Online ©). HIGH. *Threat Risk: Medium*

3. HUC8: 04010103 – Castle River

Competition and Hybridization with Brook Trout: REMOTE – Brook Trout have been found in several tributaries (e.g., Mill Creek). Genetic analysis of approximately 180 fish collected from six rivers within this HUC found one hybrid in Mill Creek (Warnock 2008). Projects conducted on Mill Creek between 2006 and 2010 noted an additional 10 suspected hybrids. FSI; HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – There are no records of Lake Trout in this HUC. HIGH. *Threat Risk: Low*

Mortality: UNLIKELY – The lower portion of this HUC is within 150 km of Calgary. However, Bull Trout are only present in the upper portion which is farther than 150 km from Calgary and is not within 50 km of other cities. Paved and gravel roads provide access to Drywood and Blakiston creeks. FSI; HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Culverts (Road Density): LIKELY – Road density = 0.744 km/km^2 (FSI based on GIS). HIGH. *Threat Risk: High*

Habitat Fragmentation – Dams and Weirs: REMOTE– The Castle River is unregulated (Oldman Watershed Council 2010). Four embankments are located in this HUC (Table 7) EXTREME. *Threat Risk: Low*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – Irrigation use is low. There are no irrigation districts licensed to draw water from this HUC (Oldman Watershed Council 2010). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: REMOTE – Recorded flows in the Castle River are equivalent to natural flows because the river is unregulated and water demands are low; there have not been any significant changes to annual trends in streamflow (Oldman Watershed Council 2010). Road density is the low end of medium at 0.744 km/km^2 (FSI based on GIS). HIGH. *Threat Risk: Low*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): LIKELY – Sediment Index = 1.12. HIGH. *Threat Risk: High*

Alteration of Stream Temperature (Summer Air Temperature): LIKELY – Current average summer air temperature (2000–2010) for HUC = 14.1 ºC. Historical average summer air temperature (1901–1930) = 11.8 ºC. FSI; EXTREME. *Threat Risk: High*

Alteration of Groundwater Quality or Quantity: UNLIKELY – There are 15 groundwater springs within this HUC (according to GIS data). Urban land use is low and road density is medium. Forestry activity is high and agricultural uses are primarily native rangeland and grazing land (South Saskatchewan Regional Advisory Council 2010). Most of the land is privately owned (FSI); five small Provincial Recreation Areas, one small Ecological Reserve and a portion of Beauvais Lake Provincial Park provide minimal protection. There is one contaminated site listed in the Federal Contaminated Sites Inventory. There are no Class A waters within this HUC (FSI). The majority of groundwater is ranked as HIGH vulnerability (AESRD 2009). EXTREME. *Threat Risk:* *Medium*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.32 (ALCES Online ©). HIGH. *Threat Risk:* *Low*

South Saskatchewan (Oldman Watershed) – Foothills Sub-basins

HUC8s: 04010104, 04010105, 04010201

OVERVIEW: Oldman Watershed Council (State of the Watershed Report) 2010

- Area: 424,485 ha
- Bull Trout are functionally extirpated from HUC8: 04010201 (FSI)
- Less than 1% of the area is designated for recreational use; extensive random recreational use occurs throughout the region
- Aboriginal lands include the Piikani Nation Reserve
- Approximately 37% of land is used for agriculture (crops, summerfallow, seeded grazing and irrigation)
- Approximately 2.6% of land supports infrastructure, primarily linear developments (0.9% roads, 0.5% cutlines, 0.3% pipelines)
- Operating and abandoned oil and gas wells occupy approximately 0.1% of land
- Approximately 40% of land is altered by human development
- Oldman Reservoir impacts flows in the Oldman River. Pine Coulee and Chain Lakes reservoirs are also located within this region.
- Water quality was rated FAIR (water quality guidelines exceeded no more than 50% within the dataset analysed and increasing trends for one or two indicators)
- Water quantity was rated FAIR (unit yields range from relatively high in Beaver and Pincher creeks to low in Willow Creek, no significant trends in annual flow volumes in Willow and Pincher creeks but significant annual decreasing trend in Beaver Creek, moderate to low levels of allocations and uses)
- Riparian health was rated FAIR (healthy but with problems)
- Protected areas include: Willow Creek FLUZ (access restricted to off-highway vehicles on designated trails only), portions of the Livingstone Range (ESA #48) and Porcupine Hills (ESA #183) Environmentally Significant Areas, 13 Provincial Recreation Areas, Mt. Livingston Natural Area, Chain Lakes Provincial Park, Willow Creek Provincial Park, Beauvais Lake Provincial Park and Plateau Mountain Ecological Reserve
- There are Class A waters in Mill Creek in HUC8: 04010105 (FSI)
- DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of projects and activities that have occurred between January 2008 and March 2014. Thirty-nine projects and activities were found within these HUCs (one involved remediation activities from the 2013 Alberta flood), but this may not represent the total number as some may not have been reported to DFO. These fell under the following main categories: Shoreline Works (Foreshore, Streambank and Riparian Work) – 14, Watercourse Crossings – 12, Instream Works – 4, Other – 3, Water Management – 2, Structures in Water – 2, Control of Nuisance Species – 1, and Dredging – 1.

4. HUC8: 04010104 – Pincher Creek

Competition and Hybridization with Brook Trout: REMOTE – There are no records of Brook Trout within this HUC (FSI). HIGH. *Threat Risk:* *Low*

Competition with Lake Trout: UNLIKELY – Lake Trout are present in this HUC; uncertain of density. HIGH. *Threat Risk:* *Medium*

Mortality: UNLIKELY – The majority of this HUC is farther than 150 km from Calgary but is accessible by 2 wheel-drive. HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Culverts (Road Density): LIKELY – Road density = 0.761 km/km^2 (FSI based on GIS). HIGH. *Threat Risk: High*

Habitat Fragmentation – Dams and Weirs: REMOTE – The Beauvais Lake Earth Dam, Cridland Dam Embankment, Therriault Community Embankment and Tompkins, Olga Embankment are located within this HUC (Table 7). EXTREME. *Threat Risk: Low*

Habitat Fragmentation – Irrigation Canals: LIKELY – The primary water use in this HUC is irrigation but use is comparatively low. There are no irrigation districts within this HUC (Oldman Watershed Council 2010). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: KNOWN – The rivers in this HUC are unregulated and recorded flows are approximately the same as natural flows. Flows have been declining in all months but the only months with a significant decreasing trend are April, November and December. High flows resulting from extreme precipitation events have had significant impacts (Oldman Watershed Council 2010). Road density is at the lower end of medium at 0.761 km/km^2 (FSI based on GIS). HIGH. *Threat Risk: High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): LIKELY – Sediment Index = 1.57. HIGH. *Threat Risk: High*

Alteration of Stream Temperature (Summer Air Temperature): REMOTE – Current average summer air temperature (2000–2010) for HUC = 12.6 ºC. Historical average summer air temperature (1901–1930) = 13.8 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: LIKELY – There are five groundwater springs within this HUC (according to GIS data). Urban land use is low and road density is lower end of medium. Agricultural uses are primarily native rangeland/grazing land and cultivated land (South Saskatchewan Regional Advisory Council 2010). Most of the land below Lundbreck Falls is privately owned (FSI). A portion of Beauvais Lake Provincial Park provides minimal protection. There are no Class A waters within this HUC. There are two contaminated sites listed in the Federal Contaminated Sites Inventory. Coal exploration and mining are imminent (FSI). The majority of groundwater is ranked as LOW vulnerability (AESRD 2009). Given the high potential for coal exploration and mining, the threat level is deemed high. EXTREME. *Threat Risk: High*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): LIKELY – Phosphorous Runoff Coefficient = 2.39 (ALCES Online ©). HIGH. *Threat Risk: High*

5. HUC8: 04010105 – Oldman River below Oldman Reservoir

Competition and Hybridization with Brook Trout: REMOTE – Brook Trout have not been reported in this HUC (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: UNLIKELY – Lake Trout are present in this HUC; uncertain of density. HIGH. *Threat Risk: Medium*

Mortality: UNLIKELY – The majority of this HUC is farther than 150 km from Calgary and is moderately accessible by paved and gravel roads. HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Culverts (Road Density): UNLIKELY – Road density = 0.521 km/km^2 (FSI based on GIS). HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Dams and Weirs: KNOWN - Bull Trout in the lower Oldman River are isolated from populations in the upper Oldman and Castle rivers due to the Oldman Dam

(FSI).There are five embankments and one dyke located in this HUC (Table 7). EXTREME. *Threat Risk: High*

Habitat Fragmentation – Irrigation Canals: LIKELY – The primary water use in this HUC is irrigation and use is medium (Oldman Watershed Council 2010). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: KNOWN – The Oldman Dam and the Lethbridge Northern Irrigation District diversion have impacted flows in lower Oldman River since 1991 and 1923, respectively (Oldman Watershed Council 2010). Road density is low at 0.521 km/km^2 (FSI based on GIS). HIGH. *Threat Risk: High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): LIKELY – Sediment Index = 1.69. HIGH. *Threat Risk: High*

Alteration of Stream Temperature (Summer Air Temperature): REMOTE – Current average summer air temperature (2000–2010) for HUC = 12.4 ºC. Historical average summer air temperature (1901–1930) = 14.9 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: UNLIKELY – There are 25 groundwater springs within this HUC (according to GIS data). Land use is primarily native rangeland/grazing land (South Saskatchewan Regional Advisory Council 2010). Piikani First Nations land covers a large portion of this HUC; approximately 25% is privately owned land. Oldman River and Oldman Dam Provincial Recreation Areas provide minimal protection. There are four contaminated sites listed in the Federal Contaminated Sites Inventory. Mill Creek was designated Class A in 2013 (FSI). The majority of groundwater in this HUC has been ranked as MEDIUM vulnerability (AESRD 2009). EXTREME. *Threat Risk: Medium*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): LIKELY – Phosphorous Runoff Coefficient = 2.21 (ALCES Online ©). HIGH. *Threat Risk: High*

6. HUC8: 04010201 – Willow Creek

Competition and Hybridization with Brook Trout: REMOTE – Brook Trout occur throughout Willow Creek. Bull Trout are considered to be functionally extirpated in this HUC (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – There are no records of Lake Trout in this HUC. HIGH. *Threat Risk: Low*

Mortality: LIKELY – The entire HUC is within 200 km of Calgary. There is an extensive network of paved and gravel roads in the lower portion of the HUC. There are fewer roads in the upper portion, but most rivers are paralleled by gravel and unimproved roads or truck trails. FSI; HIGH. *Threat Risk: High*

Habitat Fragmentation – Culverts (Road Density): UNLIKELY – Road density = 0.651 km/km^2 (FSI based on GIS). HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Dams and Weirs: KNOWN – Chain Lakes Dam and Pine Coulee Dam are located within this HUC. Chain Lakes Dam blocks fish movement along Willow Creek (Mayhood 2009). The Willow Diversion Main Dam and six embankments are also located in this HUC (Table 7). EXTREME. *Threat Risk: High*

Habitat Fragmentation – Irrigation Canals: LIKELY – The primary water use in this HUC is irrigation (Oldman Watershed Council 2010). Willow Creek is part of the Lethbridge Northern Irrigation District (LNID) which had 714 km of irrigation canals as of June 1999 (Irrigation Water Management Study Committee 2002) MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: KNOWN – The Chain Lakes (built in 1966) and Pine Coulee (built in 1999) reservoirs regulate flows on Willow Creek. Annual flows have been decreasing at a rate of 0.3-0.4% per year between 1912 and 2001 (Oldman Watershed Council 2010). Road density is low at 0.651 km/km^2 (FSI based on GIS). HIGH. *Threat Risk: High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): LIKELY –Sediment Index = 1.36. HIGH. *Threat Risk: High*

Alteration of Stream Temperature (Summer Air Temperature): REMOTE – Current average summer air temperature (2000–2010) for HUC = 13.0 ºC. Historical average summer air temperature (1901–1930) = 12.8 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: UNLIKELY – There are 84 groundwater springs within this HUC (according to GIS data). Land use is primarily native rangelands/grazing lands (South Saskatchewan Regional Advisory Council 2010) and road density is low. Approximately 60% of land is privately owned and the remainder is provincial crown land (FSI). Chain Lakes and Willow Creek Provincial Parks and Indian Groves Provincial Recreation Area provide minimal protection. There are eight contaminated sites listed in the Federal Contaminated Sites Inventory. There are no Class A waters (FSI). The majority of groundwater is ranked as HIGH vulnerability (AESRD 2009). EXTREME. *Threat Risk: Medium*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): UNLIKELY –Phosphorous Runoff Coefficient = 1.67 (ALCES Online ©). HIGH. *Threat Risk: Medium*

South Saskatchewan (Oldman Watershed) – Southern Tributaries Sub-basins

HUC8s: 04010301, 04010302, 04010401

OVERVIEW: Oldman Watershed Council (State of the Watershed Report) 2010

- Area: approximately 602,218 ha
- Most recreational use occurs within Waterton Lakes National Park
- Aboriginal lands include a portion of the Piikani Nation Reserve, Blood 148 and Blood Timber Limit 148A
- Approximately 66% of land is used for agriculture (crops, seeded grazing, summerfallow)
- Approximately 1.5% of land supports infrastructure, primarily linear developments (0.5% roads, 0.4% pipelines, 0.4% cutlines)
- Operating and abandoned oil and gas wells occupy < 0.1% of the area
- Approximately 69% of the area is altered by human development
- Irrigation is the primary water use and there are 8 irrigation districts that draw water from the Waterton and Belly rivers
- Water quality was rated FAIR (water quality guidelines exceeded no more than 50% within the dataset analysed and increasing trends for one or more indicators)
- Water quantity was rated POOR (streams with headwaters in the mountains have very high unit yields in their upper reaches, no significant trends in natural flow, very high water use [primarily for irrigation])
- Riparian health was assessed at 446 sites; results ranked 20% as healthy, 53% healthy but with problems and 27% as unhealthy (Cows and Fish Program 2009 cited in Oldman Watershed Council 2010). Riparian health is generally higher than in the rest of the Oldman basin.
- Protected areas include: Castle Special Management Area, seven Provincial Recreation Areas, Ross Lake Natural Area, Woolford Provincial Park, Police Outpost Provincial Park and Waterton Lakes National Park

- There are no Class A waters (FSI)
- DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of projects and activities that have occurred between January 2008 and March 2014. Forty-nine projects and activities were found within these HUCs (one involved remediation activities from the 2013 Alberta flood), but this may not represent the total number as some may not have been reported to DFO. These fell under the following main categories: Instream Works – 14, Shoreline Works (Foreshore, Streambank and Riparian Work) – 13, Structures in Water – 8, Watercourse Crossings – 8, Water Management – 4, Dredging – 1, and Habitat Improvement – 1.

7. HUC8: 04010301 – Belly River

Competition and Hybridization with Brook Trout: REMOTE – Brook Trout are distributed throughout the watershed and coexist with Bull Trout in all areas where Bull Trout occur. Suspected hybrids have been observed in Drywood Creek, Spionkop Creek, Yarrow Creek, and Blakiston Creek but none have been confirmed. FSI; HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – There are no records of Lake Trout in this HUC. HIGH. *Threat Risk: Low*

Mortality: UNLIKELY – Bull Trout only occur in the upper portion of this HUC which is farther than 150 km from Calgary and not within 50 km of other cities. Paved and gravel roads provide access to Drywood and Blakiston creeks. FSI; HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Culverts (Road Density): LIKELY – Road density = 0.744 km/km^2 (FSI based on GIS). HIGH. *Threat Risk: High*

Habitat Fragmentation – Dams and Weirs: KNOWN – Waterton Dam regulates flows in the Waterton River and has been operational since 1964. This dam is a permanent blockage to fish passage (Clipperton et al. 2003). The Prairie Bluff Lake Dam and 11 embankments are also located in this HUC (Table 7). EXTREME. *Threat Risk: High*

Habitat Fragmentation – Irrigation Canals: LIKELY – The primary water use in this HUC is irrigation. There are 42 private irrigation licenses in the Waterton River sub-basin (Oldman Watershed Council 2010). This HUC is within the United Irrigation District which has 239 km of irrigation canals and the LNID which has 714 km of irrigation canals as of June 1999 (Irrigation Water Management Study Committee 2002). Bull Trout only occur in the upper portion of this HUC (FSI), thus would not be impacted by habitat fragmentation in the LNID. MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: KNOWN – Flows in this HUC are impacted by Waterton Dam and Reservoir, diversions into irrigation districts and water uses. Recorded flows are much lower than natural flows. Annual flows have been decreasing between 0.08-0.1% per year (Oldman Watershed Council 2010). Road density is medium at 0.744 km/km^2 (FSI based on GIS). HIGH. *Threat Risk: High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): KNOWN – Sediment Index = 1.85. Irrigation water returned to the river carries large quantities of silt from unprotected earth irrigation canals, increasing suspended and deposited sediments in the river below the reservoir during and after irrigation season (Clipperton et al. 2003). HIGH. *Threat Risk: High*

Alteration of Stream Temperature (Summer Air Temperature): UNLIKELY – Current average summer air temperature (2000–2010) for HUC = 14.1 ºC. Historical average summer air temperature (1901–1930) = 13.8 ºC. FSI; EXTREME. *Threat Risk: Medium*

Alteration of Groundwater Quality or Quantity: UNLIKELY – There are 23 groundwater springs within this HUC (according to GIS data). Blakiston Creek and the headwaters of the Waterton River are located within Waterton Lakes National Park. Urban land use is low and road density is at the very low end of medium. Land use outside of the park is primarily native rangelands/grazing lands and cultivated lands (South Saskatchewan Regional Advisory Council 2010). The majority of land is privately owned, but approximately 20% is federally protected (FSI). There are six contaminated sites listed in the Federal Contaminated Sites Inventory. There are no Class A waters (FSI). The majority of groundwater in this HUC is ranked as LOW vulnerability (AESRD 2009). EXTREME. *Threat Risk:* *Medium*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): LIKELY – Phosphorous Runoff Coefficient = 2.33 (ALCES Online ©). HIGH. *Threat Risk:* *High*

8. HUC8: 04010302 – Waterton River

Competition and Hybridization with Brook Trout: REMOTE – There are many records of Brook Trout in the upper Belly River, including the Belly River mainstem, Pass Creek, Mountain View, Leavitt, and Aetna Irrigation Districts inlet canal, Little Beaverdam Lake and unnamed tributaries, however they have not been captured where immature Bull Trout occur so competition is thought to be minimal (Terry Clayton pers. comm. in FSI). Hybrids have not been reported (FSI). HIGH. *Threat Risk:* *Low*

Competition with Lake Trout: REMOTE – There are no records of Lake Trout in this HUC. HIGH. *Threat Risk:* *Low*

Mortality: UNLIKELY – The lower portion of this HUC is within 50 km of Lethbridge, but Bull Trout only occur in the upper portion which is farther than 50 km from Lethbridge. Paved and gravel roads provide access to the Belly River. The North Belly River has very limited road access. FSI; HIGH. *Threat Risk:* *Medium*

Habitat Fragmentation – Culverts (Road Density): LIKELY – Road density = 1.11 km/km^2 (road density is not evenly distributed – there are fewer roads in Waterton Lakes National Park) (FSI based on GIS). HIGH. *Threat Risk:* *High*

Habitat Fragmentation – Dams and Weirs: LIKELY – The Belly River Main Dam, Bullhorn Main Dam, East Payne Main Dam, North Payne Main Dam, Little Beaver Dams (East and West), Dam #7 Main Dam, and four embankments are located in this HUC (Table 7). There are three weirs on the Belly River. The Waterton-St.Mary Headworks weir does not have fish passage facilities and therefore blocks upstream passage. The Mountain View Irrigation District weir does not have fish passage facilities but is low enough for fish to usually cross. The United Irrigation District weir does have fish passage facilities but its efficiency is unknown (Clipperton et al. 2003). EXTREME. *Threat Risk:* *High*

Habitat Fragmentation – Irrigation Canals: LIKELY – Irrigation is the primary water use within this HUC and use is high. There are eight irrigation districts drawing water from the Belly River and 90 private irrigation licenses within the Belly River sub-basin (Oldman Watershed Council 2010). The irrigation districts near the range of Bull Trout in this HUC are Mountain View with 37 km of irrigation canals, Leavitt with 56 km of irrigation canals, Aetna with 28 km of irrigation canals and United with 239 km of irrigation canals as of June 1999 (Irrigation Water Management Study Committee 2010). MEDIUM. *Threat Risk:* *Medium*

Alteration of Natural Flow Regimes: KNOWN – High withdrawals for irrigation impact flows in the Belly River. Annual flows have shown no significant trend over the period 1912–2001; recorded flows are lower than natural flows in sections of the river (Oldman Watershed Council 2010). Road density is medium at 1.11 km/km^2 (FSI based on GIS). HIGH. *Threat Risk:* *High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): LIKELY – Sediment Index = 1.35. HIGH. *Threat Risk: High*

Alteration of Stream Temperature (Summer Air Temperature): UNLIKELY – Current average summer air temperature (2000–2010) for HUC = 14.9 ºC. Historical average summer air temperature (1901–1930) = 14.8 ºC. FSI; EXTREME. *Threat Risk: Medium*

Alteration of Groundwater Quality or Quantity: UNLIKELY – There are 16 groundwater springs within this HUC (according to GIS data). The Blood 148 First Nations Reservation and Timber Limit 148A encompass a large area of this HUC and a portion of Waterton Lakes National Park occupies a smaller area. The primary spawning habitat of Bull Trout in this HUC, the headwaters of the Belly and North Belly rivers, is protected within Waterton Lakes National Park (FSI). Urban land use is low and road density is medium. Land use is primarily cultivated lands and native rangeland/grazing land (South Saskatchewan Regional Advisory Council 2010). There are six contaminated sites listed in the Federal Contaminated Sites Inventory. There are no Class A waters (FSI). The majority of groundwater in this HUC is ranked as LOW vulnerability (AESRD 2009). EXTREME. *Threat Risk: Medium*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): UNLIKELY – Phosphorous Runoff Coefficient = 1.63 (ALCES Online ©). HIGH. *Threat Risk: Medium*

9. HUC8: 04010401 – St. Mary River

Competition and Hybridization with Brook Trout: REMOTE – Brook Trout have not been reported in this HUC (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – There are no records of Lake Trout in this HUC. HIGH. *Threat Risk: Low*

Mortality: UNLIKELY – The lower portion of this HUC is within 50 km of Lethbridge, however, Bull Trout are only present in the upper portion which is farther than 50 km from Lethbridge. Gravel roads provide access to the St. Mary River and the lower portion of Lee Creek. The headwaters of Lee Creek can only be accessed by unimproved road/truck trail. HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Culverts (Road Density): LIKELY – Road density = 0.903 km/km^2 (FSI based on GIS). FSI; HIGH. *Threat Risk: High*

Habitat Fragmentation – Dams and Weirs: KNOWN – The St. Mary Dam and Reservoir are located on the St. Mary River below Cardston. This dam blocks fish movements along the St. Mary River (Clipperton et al. 2003; Mayhood 2009). The lower section of the river below the reservoir flows through arid prairie and the water temperatures are higher than in the upper section of the river which flows through the foothills region (Clipperton et al. 2003), therefore habitat below the reservoir would likely not be suitable for Bull Trout. Although, the water temperature below the reservoir is artificially raised by reduced flows caused by the dam. A Police Outpost Earth Dam and six embankments are also located in this HUC (Table 7). EXTREME. *Threat Risk: High*

Habitat Fragmentation – Irrigation Canals: LIKELY – Water demands within the range of Bull Trout in this HUC are low (Oldman Watershed Council 2010). Irrigation districts near the range of Bull Trout include Leavitt with 56 km of irrigation canals and Aetna with 28 km of irrigation canals as of June 1999 (Irrigation Water Management Study Committee 2002). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: UNLIKELY – Recorded flow in Lee Creek is the same as natural flow because of the low water demand and lack of water storage. Recorded flow in the

St. Mary River near the Canada/United States (US) border is impacted by storage and diversions to the Milk River which occur south of the border. Water use is low immediately upstream of the border. Neither annual nor monthly flows changed significantly in Lee Creek between 1912 and 2001. On the St. Mary River, average flows are decreasing by an average of 0.03% per year near the Canada/US border and by 0.1% per year near Lethbridge between 1912 and 2001. Neither of these decreases were found to represent statistically significant trends (Oldman Watershed Council 2010). Road density is medium at 0.903 km/km^2 (FSI based on GIS). HIGH. *Threat Risk: Medium*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): KNOWN – Sediment Index = 1.89. HIGH. *Threat Risk: High*

Alteration of Stream Temperature (Summer Air Temperature): UNLIKELY – Current average summer air temperature (2000–2010) for HUC = 15.2 ºC. Historical average summer air temperature (1901–1930) = 15.2 ºC. Water temperatures in the upper St. Mary River are lower than in the lower in St. Mary River (Clipperton et al. 2003). FSI; EXTREME. *Threat Risk: Medium*

Alteration of Groundwater Quality or Quantity: UNLIKELY – There are 21 groundwater springs within this HUC (according to GIS data). Urban land use is low and road density is medium. The primary land use activities are native rangeland/grazing land and cultivated land (South Saskatchewan Regional Advisory Council 2010). The majority of land is privately owned or First Nations land (Blood 148) (FSI). Two small Provincial Parks (Police Outpost and Woolford), Outpost Wetlands Natural Area and St. Mary Reservoir Provincial Recreation Area provide minimal protection. The headwaters of Lee Creek and St. Mary River are managed by the United States (FSI). There are seven contaminated sites listed in the Federal Contaminated Sites Inventory. There are no Class A waters (FSI). The majority of groundwater in the HUC is ranked as MEDIUM vulnerability (AESRD 2009). EXTREME. *Threat Risk: Medium*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): LIKELY – Phosphorous Runoff Coefficient = 2.23 (ALCES Online ©). HIGH. *Threat Risk: High*

Bow River Basin – Reach 1; HUC8s: 04020101, 04020201, 04020301, 04020501

OVERVIEW: Bow River Basin Council (State of the Basin Report), 2005

- Area: approximately 325,800 ha
- Entirely within Banff National Park (majority of area), Spray Valley Provincial Park and Bow Valley Wildland Provincial Park
- Approximately 4.1% of the land has been cleared for linear developments, tourism, recreation, communities and hydroelectric production
- Approximately 4.7 million people visited Banff National Park in 2003 and an additional 4 million pass through the park annually via the Trans-Canada Highway and Canadian Pacific Railway which parallel the Bow River throughout much of its length within this region
- Bull Trout occur only in the headwaters and upper tributaries
- Water quality was rated GOOD (cumulative impacts are considered to be minimal and the indicator is in a desired state)
- River Flow Quantity Index was rated NATURAL (the conditions for this indicator are considered to be in a natural state)
- Riparian conditions were rated NATURAL
- Icefields/glaciers cover approximately 5,700 ha (1.75%) of this region
- DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of projects and activities that have occurred between January 2008 and

March 2014. Twenty-one projects and activities were found within these HUCs (four involved remediation activities from the 2013 Alberta flood), but this may not represent the total number as some may not have been reported to DFO. These fell under the following main categories: Instream Works – 6, Watercourse Crossings – 6, Water Management – 5, Other – 2, Shoreline Works (Foreshore, Streambank and Riparian Work) – 1, and Structures in Water – 1.

10. HUC8: 04020101 – Upper Bow River

Competition and Hybridization with Brook Trout: UNLIKELY – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). One suspected hybrid was reported in the Pipestone River by the Alberta Conservation Association in 2006. The Park biologist has noted many suspected hybrids and their numbers appear to be increasing (S. Humphries, pers. comm. in FSI). HIGH. *Threat Risk: Medium*

Competition with Lake Trout: UNLIKELY – The carrying capacity loss due to Lake Trout was estimated at 30% (FSI). Lake Trout have been stocked in Bow and Hector lakes; Bull Trout are considered functionally extirpated from these lakes (FSI). HIGH. *Threat Risk: Medium*

Mortality: REMOTE – This HUC is entirely within Banff National Park. A major highway runs parallel to the upper Bow and provides access to the river and some tributaries. Other than the highway, all access is by foot only. Based on this, angling mortality was estimated at 4%. FSI; HIGH. *Threat Risk: Low*

Habitat Fragmentation – Culverts (Road Crossing Density): REMOTE – Road crossing density = 0.023 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Low*

Habitat Fragmentation – Dams and Weirs: REMOTE – There are no dams or weirs within this HUC (Bow River Basin Council 2005; Government of Alberta 2016). EXTREME. *Threat Risk: Low*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – Water use for irrigation is low (Bow River Basin Council 2005). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: REMOTE – There are no meaningful water allocations for diversion and/or storage and flows are not generally impacted by human activities, thus recorded flows are essentially the same as natural flows. Glacial melt is a significant source of seasonal flows in the headwaters of the Bow River (Bow River Basin Council 2005). HIGH. *Threat Risk: Low*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.00. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 9.13 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 8.2 ºC. Historical average summer air temperature (1901–1930) = 7.8 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: REMOTE – There are 16 groundwater springs within this HUC (according to GIS data). This entire area is protected by Banff National Park. There are 18 contaminated sites listed in the Federal Contaminated Sites Inventory. Much of the groundwater in this HUC is ranked HIGH vulnerability (South Saskatchewan Regional Advisory Council 2010). EXTREME. *Threat Risk: Low*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.03 (ALCES Online ©). HIGH. *Threat Risk: Low*

11. HUC8: 04020201 – Brewster Creek

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). Hybrids have not been reported from this HUC, however Brook Trout are abundant and hybridization is likely. HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: REMOTE – This HUC is entirely within Banff National Park; access is primarily non-motorized. Angling mortality was estimated at 2%. FSI; HIGH. *Threat Risk: Low*

Habitat Fragmentation – Culverts (Road Crossing Density): REMOTE – Road crossing density = 0.013 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Low*

Habitat Fragmentation – Dams and Weirs: REMOTE – There are no dams or weirs within this HUC (Bow River Basin Council 2005; Government of Alberta 2016). EXTREME. *Threat Risk: Low*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – Water use for irrigation is low (Bow River Basin Council 2005). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: REMOTE – There are no meaningful water allocations for diversion and/or storage and flows are not generally impacted by human activities, thus recorded flows are essentially the same as natural flows. Glacial meltwater is a significant source of seasonal flows (Bow River Basin Council 2005). HIGH. *Threat Risk: Low*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.00. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 10.42 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 9.2 ºC. Historical average summer air temperature (1901–1930) = 8.8 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: REMOTE – There are 10 groundwater springs within this HUC (according to GIS data). This entire area is protected by Banff National Park. There are 17 contaminated sites listed in the Federal Contaminated Sites Inventory. Much of the groundwater in this HUC is ranked HIGH vulnerability (South Saskatchewan Regional Advisory Council 2010). EXTREME. *Threat Risk: Low*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.06 (ALCES Online ©). HIGH. *Threat Risk: Low*

12. HUC8: 04020301 – Spray Lakes River

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). There is a lack of evidence that competition is occurring in the watershed (FSI). Hybrids have not been reported from this HUC, however, Brook Trout are abundant and hybridization is likely (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: LIKELY – The carrying capacity loss due to Lake Trout was estimated at 60% (FSI). HIGH. *Threat Risk: High*

Mortality: REMOTE – The majority of this HUC is within Banff National Park, therefore access is likely mostly non-motorized. A gravel road in Spray Valley Provincial Park/Bow Valley Wildland Provincial Park provides access to Goat Creek and tributaries. Angling pressure is also very low due to the low quality of the fishery (M. Taylor pers. comm. in FSI). Angling mortality was estimated at 2%. FSI; HIGH. *Threat Risk: Low*

Habitat Fragmentation – Culverts (Road Crossing Density): REMOTE – Road crossing density = 0.036 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Low*

Habitat Fragmentation – Dams and Weirs: UNLIKELY – There is one major dam within this HUC – the Spray System which is located on the headwaters of the Spray River and includes the Three Sisters, Rundle and Spray hydroelectric facilities (Bow River Basin Council 2005). The Goat Pond Main Dam, Goat Pond Dyke, Spray Canal Dyke, Whiteman's Dyke are also located in this HUC (Table 7). EXTREME; *Threat Risk: Medium*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – Water use for irrigation is low (Bow River Basin Council 2005). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: KNOWN – The flows in Spray River have been heavily impacted by hydroelectric development (Bow River Basin Council 2005). Flow regime has been altered and flow volumes have been reduced in the lower Spray River (Mayhood 2009). HIGH. *Threat Risk: High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.00. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 10.35 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 9.2 ºC. Historical average summer air temperature (1901–1930) = 8.7 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: REMOTE – There are six groundwater springs within this HUC (according to GIS data). The majority of the area is protected by Banff National Park, Bow Valley Wildland Provincial Park and Spray Valley Provincial Park. There are two contaminated sites listed in the Federal Contaminated Sites Inventory. Much of the groundwater in this HUC is ranked HIGH vulnerability (South Saskatchewan Regional Advisory Council 2010). EXTREME. *Threat Risk: Low*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.05 (ALCES Online ©). HIGH. *Threat Risk: Low*

13. HUC8: 04020501 – Cascade River

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). It was assumed that competition is not occurring (FSI). Based on phenotypic assessments from electrofishing captures it is believed that hybrids are likely present, however, genetic analysis has not been conducted (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: REMOTE – The entire HUC is located within Banff National Park. Angling density is low and there is no road access except for the junction of Cascade River and Lake Minnewanka. The upper watershed can only be accessed on foot. Angling mortality was estimated at 2%. FSI; HIGH. *Threat Risk: Low*

Habitat Fragmentation – Culverts (Road Crossing Density): REMOTE – Road crossing density = 0.025 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Low*

Habitat Fragmentation – Dams and Weirs: LIKELY – Minnewanka Dam on the Cascade River at Lake Minnewanka blocks fish passage and has greatly reduced fish habitat in the lower Cascade River (Bow River Basin Council 2005; Mayhood 2009). EXTREME. *Threat Risk: High*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – No major water withdrawals are licensed (Bow River Basin Council 2005). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: KNOWN – Flows in the lower Cascade River have been drastically altered by the Cascade hydroelectric plant (Minnewanka Dam). Releases from this facility cause flows in the lowest section of the river to fluctuate from zero to 40 m^3/s up to several times per day depending on electricity demand (Bow River Basin Council 2005). HIGH. *Threat Risk: High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.00. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 9.76 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 8.9 ºC. Historical average summer air temperature (1901–1930) = 8.5 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: REMOTE – There are two groundwater springs within this HUC (according to GIS data). The entire area is protected by Banff National Park. There are 13 contaminated sites listed in the Federal Contaminated Sites Inventory. Much of the groundwater in this HUC is ranked HIGH vulnerability (South Saskatchewan Regional Advisory Council 2010). EXTREME. *Threat Risk: Low*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.02 (ALCES Online ©). HIGH. *Threat Risk: Low*

Bow River Basin – Reach 3; HUC8s: 04020401, 04020601, 04020701, 04020801, 04020802
OVERVIEW: Bow River Basin Council (State of the Basin Report), 2005

- Area: approximately 445,100 ha
- Bull Trout are functionally extirpated from HUC8: 04020801 (FSI)
- Approximately 46% (204,746 ha) of the area has park or protected status. Parks include: portion of Banff National Park, Canmore Nordic Center Provincial Park, Spray Valley Provincial Park, Bow Valley Wildland Park, Bow Valley Provincial Park, Peter Lougheed Provincial Park, Elbow-Sheep Wildland Park, Ghost River Wilderness Area, Don Getty Wildland Park, Glenbow Ranch Provincial Park and Big Hill Springs Provincial Park.
- Aboriginal lands include Stoney First Nation Reserve No. 142, 142B, 143, 144
- Approximately 8.5% (37,833 ha) of land has been cleared. Primary uses are forestry and agricultural grazing land
- Daily and seasonal flows have been significantly altered by hydroelectric development; total annual flows have only changed a small amount
- Water quality is considered high compared to downstream reaches
- Riparian habitat was rated healthy from Canmore to Kananaskis Dam and healthy but with problems from the Ghost Dam to the Bearspaw Dam (due mainly to the presence of invasive plant species and livestock grazing)
- HUC8 04020801 includes a portion of the City of Calgary. This portion is not included in the above summary. All indicators for this area (River Flow Quantity Index, Dissolved Oxygen, Water Temperature, Total Phosphorous, Nitrogen, Total Dissolved Phosphorous and *E. coli*) were rated NATURAL (conditions considered to be in a natural state) with the exception of Riparian Areas which were rated FAIR (conditions are shifting away from a desired state, but have not yet reached a cautionary threshold). These ratings apply to the entire HUC8 04020801, not just the section encompassing a portion of the City of Calgary.
- There are no Class A waters (FSI)

- DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of projects and activities that have occurred between January 2008 and March 2014. 120 projects and activities were found within these HUCs (eight involved remediation activities from the 2013 Alberta flood), but this may not represent the total number as some may not have been reported to DFO. These fell under the following main categories: Watercourse Crossings – 36, Shoreline Works (Foreshore, Streambank and Riparian Work) – 25, Instream Works – 20, Water Management – 18, Structures in Water – 7, Other – 6, Habitat Improvement – 5, Dredging – 2, and Mineral Aggregate, Oil and Gas Exploration, Extraction and Production – 1.

14. HUC8: 04020401 – Bow River and Ghost Reservoir

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). One suspected hybrid was reported from Bill Griffiths Creek in 2010 (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: KNOWN – The entire HUC is within 150 km of Calgary and paved and gravel roads provide access to the Bow River. Access may be lower on First Nations land and TransAlta property (J. Earle pers. comm. in FSI). Angling mortality was estimated at 10%. FSI; HIGH. *Threat Risk: High*

Habitat Fragmentation – Culverts (Road Crossing Density): LIKELY – Road crossing density = 0.179 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: High*

Habitat Fragmentation – Dams and Weirs: LIKELY – There are three dams located on the mainstem Bow River within this HUC – the Kananaskis Falls, Horseshoe Falls and Ghost dams. The blockage caused by Kananaskis Falls and Horseshoe Falls dams is not a threat to Bull Trout as the falls represent a natural barrier. Ghost Dam blocks movement in the Bow River mainstem (Mayhood 2009). The Whiteman's Dam and two embankments are also located in this HUC (Table 7). EXTREME. *Threat Risk: High*

Habitat Fragmentation – Irrigation Canals: LIKELY – Approximately 10% of annual water consumption from the Bow River is used for irrigation and agriculture (590,840 m^3 of 5,751,421 m^3). This is low compared to water use in downstream reaches (Bow River Basin Council 2005). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: KNOWN – Flows in this section of the Bow River have been significantly altered by hydroelectric developments. Dams affecting flows include the Pocaterra, Barrier, Kananaskis Falls, Horseshoe Falls, Interlakes and Spray dams. Peak flows in the Bow River below Seebe are lower in spring and summer and baseflows are higher in fall and winter compared to natural flows (Bow River Basin Council 2005). HIGH. *Threat Risk: High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.08. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 12.83 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 11.9 ºC. Historical average summer air temperature (1901–1930) = 11.5 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: UNLIKELY – There are 16 groundwater springs within this HUC (according to GIS data). The majority of land is privately owned or First Nations Reserve (Stoney 142, 143, 144) (FSI). Canmore Nordic Center Provincial Park, Bow

Valley Provincial Park, Wildcat Natural Area and Heart Creek and Bow Valley Provincial Recreation Areas provide minimal protection. Approximately 20% is provincial crown land (FSI). There are nine contaminated sites listed in the Federal Contaminated Sites Inventory. Much of the groundwater in this HUC is ranked HIGH vulnerability (AESRD 2009). EXTREME. *Threat Risk: Medium*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): UNLIKELY – Phosphorous Runoff Coefficient = 1.51 (ALCES Online ©). HIGH. *Threat Risk: Medium*

15. HUC8: 04020601 – Kananaskis River

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). Higher Brook Trout catch-per-unit-effort in the mid-watershed region near the golf course, but this may be due to increased effort related to local land use. The upper Kananaskis River is likely too cold for Brook Trout (FSI). One suspected hybrid was reported from Pocaterra Creek in 2006 by Alberta Fisheries Management (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: LIKELY – The entire HUC is within 150 km of Calgary. The road network is not extensive, but paved and gravel roads provide access to Kananaskis River and Muskeg Creek. Angling mortality was estimated at 8%. FSI; HIGH. *Threat Risk: High*

Habitat Fragmentation – Culverts (Road Crossing Density): REMOTE – Road crossing density = 0.079 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Low*

Habitat Fragmentation – Dams and Weirs: LIKELY – The Interlakes, Pocaterra and Barrier dams are located on the Kananaskis River (Table 7). These dams block fish movement in the Kananaskis River (Mayhood 2009). EXTREME. *Threat Risk: High*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – Information on irrigation canals could not be found – assumed low due to high recreation land-use in this HUC (Bow River Basin Council 2005). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: KNOWN – The Interlakes, Pocaterra and Barrier dams have impacted flows in the Kananaskis River (Bow River Basin Council 2005; Mayhood 2009). HIGH. *Threat Risk: High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.01. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 10.46 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 9.5 ºC. Historical average summer air temperature (1901–1930) = 9.1 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: UNLIKELY – There are six groundwater springs in this HUC (according to GIS data). The majority of the HUC has park or protected status. There are no Class A waters (FSI). Some areas have higher disturbance than others (e.g., Kananaskis Village, Waste Water Treatment Plant, golf course etc.) (J. Earle pers. comm. in FSI). There are two contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC is ranked HIGH vulnerability (AESRD 2009). EXTREME. *Threat Risk: Medium*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.09 (ALCES Online ©). HIGH. *Threat Risk: Low*

16. HUC8: 04020701 – Ghost River

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 8% (FSI). High Brook Trout catch-per-unit-effort in Waiparous watershed, particularly in Meadow Creek, Johnson Creek and Lesuer Creek; competition was assumed to not be occurring in the Waiparous mainstem (FSI). Hybrids have not been reported (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: KNOWN – The entire HUC is within 150 km of Calgary but road access is limited. Gravel roads and unimproved roads/truck trails provide limited access to Ghost River and Waiparous Creek. There is limited access to Johnson Creek. Random recreation use is high. Angling mortality was estimated at 12%. FSI; HIGH. *Threat Risk: High*

Habitat Fragmentation – Culverts (Road Crossing Density): REMOTE – Road crossing density = 0.060 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Low*

Habitat Fragmentation – Dams and Weirs: LIKELY – The Cascade Power Canal Dyke, a control dam, the Ghost Diversion and two embankments are located within this HUC (Table 7) and fragment Bull Trout habitat (FSI). EXTREME. *Threat Risk: High*

Habitat Fragmentation – Irrigation Canals: UNLIKELY **–** Irrigation use in this HUC is low with only 4 km of canals in the watershed (Yarmoloy and Stelfox 2011). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: KNOWN – The diversion of part of the North Ghost River to Lake Minnewanka and the Ghost Reservoir, which floods lower sections of the river before its confluence with the Bow River, have altered flows in the Ghost River (Bow River Basin Council 2005). Furthermore, logging activities in this HUC likely increase flood vulnerability. HIGH. *Threat Risk: High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.03. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 11.95 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 10.6 ºC. Historical average summer air temperature (1901–1930) = 10.2 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: LIKELY – There are 14 groundwater springs within this HUC (according to GIS data). Linear disturbance density and random recreational use are high (FSI). Primary land use activities include ranching, grazing, logging and oil and gas exploration and production (Bow River Basin Council 2005). Approximately 20% of land is privately owned or First Nations Reserve (Stoney 142, 143, 144) (FSI). Several small Provincial Recreation Areas, Don Getty Wildland Park and Ghost River Wilderness Area provide moderate protection. The remainder (approximately 50%) is provincial crown land (FSI). There are no Class A waters (FSI). There are three contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater is ranked HIGH vulnerability (AESRD 2009). EXTREME. *Threat Risk: High*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.14 (ALCES Online ©). HIGH. *Threat Risk: Low*

17. HUC8: 04020801 – Bow River and Bighill Creek

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). One suspected hybrid was reported in Millenium Creek in 2008. Bull Trout are considered functionally extirpated (FSI). HIGH. *Threat Risk:* *Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk:* *Low*

Mortality: REMOTE – This HUC is within 150 km of Calgary. An extensive network of paved and gravel roads provides access to rivers. Access points on the upstream section of the Bow River are limited due to privately owned land (J. Earle pers. comm. in FSI). Angling mortality was estimated to be 0 based on expert opinion. FSI; HIGH. *Threat Risk:* *Low*

Habitat Fragmentation – Culverts (Road Crossing Density): LIKELY – Road crossing density = 0.201 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk:* *High*

Habitat Fragmentation – Dams and Weirs: LIKELY – The Bearspaw Dam on the Bow River at Calgary blocks movement and floods formerly productive habitat in the Bow River (Mayhood 2009). The Calgary Weir on the Bow River at Calgary impedes fish passage. Ten embankments are located in this HUC (Table 7). EXTREME. *Threat Risk:* *High*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – Low irrigation demands. MEDIUM. *Threat Risk:* *Medium*

Alteration of Natural Flow Regimes: KNOWN – The dams located in other sections of the Bow River impact flows within this HUC. Municipal water withdrawals for the City of Calgary are significant and also impact flow regimes (Bow River Basin Council 2005). HIGH. *Threat Risk:* *High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): LIKELY – Sediment Index = 1.59. HIGH. *Threat Risk:* *High*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): UNLIKELY – Mean August air temperature = 14.63 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 13.87 ºC. Historical average summer air temperature (1901–1930) = 13.3 ºC. FSI; EXTREME. *Threat Risk:* *Medium*

Alteration of Groundwater Quality or Quantity: LIKELY – There are seven groundwater springs within this HUC (according to GIS data). The majority of land is privately owned including the City of Calgary (FSI). Two small Provincial Parks provide minimal protection. There are no Class A waters (FSI). There are two contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater within this HUC is ranked LOW vulnerability (AESRD 2009). EXTREME. *Threat Risk:* *High*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): KNOWN – Phosphorous Runoff Coefficient = 5.48 (ALCES Online ©). HIGH. *Threat Risk:* *High*

18. HUC8: 04020802 – Jumpingpound Creek

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). Generally low Brook Trout catch-per-unit-effort so it was assumed that competition is not a driving factor (FSI). One suspected hybrid has been reported from Jumpingpound Creek (FSI). HIGH. *Threat Risk:* *Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk:* *Low*

Mortality: KNOWN – This entire HUC is within 150 km of Calgary. Paved and gravel roads provide access to Jumpingpound Creek; gravel roads and unimproved roads/truck trails provide access to smaller tributaries. Angling mortality was estimated at 10%. FSI; HIGH. *Threat Risk: High*

Habitat Fragmentation – Culverts (Road Crossing Density): REMOTE – Road crossing density = 0.100 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Low*

Habitat Fragmentation – Dams and Weirs: LIKELY – The Sibald Creek #3 Main Dam, Livingstone Creek Ranch Ltd Embankment and Dean Peterson Embankment are located in this HUC (Table 7). Bull Trout migration and genetic data indicate movements are restricted (FSI). EXTREME. *Threat Risk: High*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – Information on irrigation canals could not be found, but irrigation demand is low (Jumpingpound Creek Watershed Partnership 2009). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: UNLIKELY – Existing flows are approximately equivalent to natural flows. An Integrated Watershed Management Plan has been completed and one of the goals is to maintain existing flow regimes with full use of existing water withdrawal licenses (Jumpingpound Creek Watershed Partnership 2014). Average annual flow is 58,835 dam^3 near the mouth of Jumpingpound Creek. There are currently 245 surface water licenses and registrations with allocations totalling 959 dam^3 (1.7% of average annual flow volume); actual use in 2006 was 433 dam^3 (0.7% of average annual flow volume) and 157 dam^3 was returned to the watershed (Jumpingpound Creek Watershed Partnership 2009). During low-flow periods (winter months), baseflow (portion of streamflow originating from groundwater sources) dominates streamflow in Jumpingpound Creek (Jumpingpound Creek Watershed Partnership 2009). There are 119 groundwater licenses and registrations with allocations totalling 148 dam^3 and there are approximately 470 unlicensed wells (Jumpingpound Creek Watershed Partnership 2009). HIGH. *Threat Risk: Medium*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): UNLIKELY – Sediment Index = 1.14. The Integrated Watershed Management Plan includes proposed riparian setbacks (Jumpingpound Creek Watershed Partnership 2014) which would reduce sediment input (Naiman et al. 2005). HIGH. *Threat Risk: Medium*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 13.52 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 12.3 ºC. Historical average summer air temperature (1901–1930) = 12.0 ºC. The Integrated Watershed Management Plan includes proposed riparian setbacks (Jumpingpound Creek Watershed Partnership 2014). If followed these may minimize water temperature increases by providing shade (Naiman et al. 2005). FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: LIKELY – There are 11 groundwater springs within this HUC (Jumpingpound Creek Watershed Partnership 2009). Land use activities include livestock grazing, agriculture (crop and pasture), oil and gas extraction, gravel extraction and forestry (Spray Lake Sawmills) (Jumpingpound Creek Watershed Partnership 2009). This HUC contains approximately 50% provincial crown land and 50% privately owned land/First Nations Reserve (Stoney 142, 143, 144) (FSI). Several small Provincial Recreation Areas provide minimal protection. There are no Class A waters (FSI). There are two contaminated sites listed in the Federal Contaminated Sites Inventory. In the area with the most reliable data (approximately 50% of Jumpingpound Creek watershed), the majority of groundwater is ranked at some level of risk (medium-low, medium-high, and high) (Jumpingpound Creek Watershed Partnership 2014). EXTREME. *Threat Risk: High*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): UNLIKELY – Phosphorous Runoff Coefficient = 1.70 (ALCES Online ©). HIGH. *Threat Risk: Medium*

Bow River Basin – Elbow River Sub-basin; HUC8: 04021001

OVERVIEW: Bow River Basin Council (State of the Watershed Summary 2010 and State of the Watershed 2005)

- Area: approximately 1,123,500 ha
- Elbow River supplies the City of Calgary with approximately 50% of its drinking water
- Parks and protected areas include portions of Elbow-Sheep and Don Getty Wildland Parks and 10 Provincial Recreation Areas (Little Elbow, McLean Creek, Elbow River, Elbow River Launch, Cobble Flats, Ing's Mine, Moose Mountain Trailhead, West Bragg Creek, Gooseberry and Wildhorse). Most of the PRAs are small and combined cover 1007.5 ha.
- Spray Lakes Sawmills' Forest Management Agreement includes 37,664 ha of this HUC
- River flow quantity, dissolved oxygen, water temperature, total suspended solids and total dissolved phosphorous were rated NATURAL (conditions for the indicator are considered to be in a natural state). Nitrogen, *E*. *coli*, and surface water quality were rated FAIR (conditions are shifting away from a desired state, but have not yet reached a cautionary threshold).
- There are no Class A waters (FSI)
- DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of projects and activities that have occurred between January 2008 and March 2014. Forty-five projects and activities were found within this HUC (three involved remediation activities from the 2013 Alberta flood), but this may not represent the total number as some may not have been reported to DFO. These fell under the following main categories: Watercourse Crossings – 17, Shoreline Works (Foreshore, Streambank and Riparian Work) – 16, Instream Works – 7, Structures in Water – 2, Other – 2 and Habitat Improvement – 1.

19. HUC8: 04021001 – Elbow River

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 6% (FSI). Quirk Creek has high Brook Trout catch-per-unit-effort, but recent analysis (Sullivan 2015 cited in FSI) does not support a competition hypothesis (FSI). Competition is likely not occurring in the upper Elbow River. In upper Prairie Creek, competition is likely not a driving factor but Bull Trout are not doing well in the downstream portion (6 km) and it is assumed that competition is a factor (FSI). Brook Trout is the dominant species in Bragg Creek and Ranger Creek (Bull Trout do not occur in these creeks but it is assumed they occurred here historically). It is assumed that competition with Brook Trout is not a driving factor in the Elbow River mainstem as spawning mostly in occurs in the higher reaches where Brook Trout abundance is lower (FSI). Hybrids are rare and have been reported in Quirk Creek (< 4% of catch, AESRD 2012) and Elbow River (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: KNOWN – This entire HUC is within 150 km of Calgary. The Elbow River and most of its tributaries are accessible by paved and gravel roads. The headwaters are only accessible on foot. Angling mortality was estimated at 10%. FSI; HIGH. *Threat Risk: High*

Habitat Fragmentation – Culverts (Road Crossing Density): UNLIKELY – Road crossing density = 0.156 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Dams and Weirs: UNLIKELY – The Glenmore Dam on the Elbow River impedes movements along the Elbow River (Mayhood 2009). The Wintergreen Main Dam and eight embankments are also located within this HUC (Table 7). EXTREME. *Threat Risk: Medium*

Habitat Fragmentation – Irrigation Canals: LIKELY – Water use for irrigation is very high in this HUC (approximately 444,340 dam^3), second only to municipal (City of Calgary) use (476,745 dam^3) (Waterline Resources Inc. 2011). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: KNOWN – The Glenmore Dam on the Elbow River alters flow regimes downstream (Mayhood 2009). Water demands are also high within this HUC with maximum diversions totalling 977,893 dam^3/yr (Waterline Resources Inc. 2011). A large number of referrals were received by the provincial government for bank armouring projects on the Elbow River following the 2013 flood (J. Earle pers. comm. in FSI). HIGH. *Threat Risk: High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): UNLIKELY – Sediment Index = 1.15. HIGH. *Threat Risk: Medium*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 12.32 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 11.5 ºC. Historical average summer air temperature (1901–1930) = 11.1 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: LIKELY – There are 20 groundwater springs within this HUC (according to GIS data). Maximum annual groundwater diversions total 16,384 dam^3/yr, with the commercial sector being the largest user (6124 dam^3/yr) (Waterline Resources Inc. 2011). Land use in the area includes agriculture, oil and gas extraction, forestry, recreation, residential and commercial uses. Increasing rural and urban developments are a significant concern for this HUC (Bow River Basin Council 2010). This HUC contains approximately 60% provincial crown land and 40% privately owned/First Nations Reserve (Tsuu T'ina Nation 145)/City of Calgary; there are no Class A waters (FSI). Several small Provincial Recreation Areas provide minimal protection. There are 12 contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC has been ranked as having high vulnerability to potential contaminant releases (see Waterline Resources Inc. 2011) and HIGH vulnerability overall (AESRD 2009). EXTREME. *Threat Risk: High*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): UNLIKELY – Phosphorous Runoff Coefficient = 1.51 (ALCES Online ©). HIGH. *Threat Risk: Medium*

Bow River Basin – Fish Creek Sub-basin; HUC8: 04021101

OVERVIEW: Bow River Basin Council (State of the Watershed Summary 2010 and State of the Watershed 2005)

- Area: 43,900 ha
- Bull Trout are functionally extirpated from this HUC (FSI)
- Parks and protected areas include part of Fish Creek Provincial Park and a very small portion of Brag Creek Provincial Park
- Recreational land-use is high
- Commercial land uses include agriculture (primarily cattle grazing, livestock operations and grain farming) and gasfield development

- Fish Creek receives stormwater runoff from the City of Calgary. At five of 11 outfalls, this water drains into treatment wetlands which were constructed in 2007 and have improved the quality of stormwater runoff.
- Dissolved oxygen, total phosphorous, *E. coli* and water temperature were all rated NATURAL (the conditions for this indicator are considered to be in a natural state)
- There are no Class A waters
- DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of projects and activities that have occurred between January 2008 and March 2014. Twenty-two projects and activities were found within this HUC, but this may not represent the total number as some may not have been reported to DFO. These fell under the following main categories: Watercourse Crossings – 10, Shoreline Works (Foreshore, Streambank and Riparian Work) – 5, Instream Works – 3, Water Management – 2, Dredging – 1 and Structures in Water – 1.

20. HUC8: 04021101 – Fish Creek

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). Predominantly Rainbow Trout and Cutthroat Trout-Rainbow Trout hybrids; assumed that competition with Brook Trout is not a driving factor. Bull Trout are considered functionally extirpated from this HUC. HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: REMOTE – The entire HUC is within 150 km of Calgary. Fish Creek and most of its tributaries are accessible by paved and gravel roads. Recreational use is high. Angling mortality was estimated to be 0 based on expert opinion. FSI; HIGH. *Threat Risk: Low*

Habitat Fragmentation – Culverts (Road Crossing Density): KNOWN – Road crossing density = 0.257 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: High*

Habitat Fragmentation – Dams and Weirs: REMOTE – The Keith, EV Dam, Priddis Greens C and G North Dyke, and four embankments are located in this HUC (Table 7). Bull Trout migration and genetic data indicate a low impact. EXTREME. *Threat Risk: Low*

Habitat Fragmentation – Irrigation Canals: LIKELY – Information on irrigation canals could not be found. Since agriculture is one of the primary land uses, assumed medium risk. MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: UNKNOWN – Information on natural flow regimes could not be found. Water withdrawals for irrigation and livestock watering may impact flow, but evidence of this could not be found. Road density is medium. HIGH. *Threat Risk: Unknown*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): LIKELY – Sediment Index = 1.22. HIGH. *Threat Risk: High*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): UNLIKELY – Mean August air temperature = 14.56 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 13.3 ºC. Historical average summer air temperature (1901–1930) = 13 ºC. FSI; EXTREME. *Threat Risk: Medium*

Alteration of Groundwater Quality or Quantity: LIKELY – There are 11 groundwater springs within this HUC (according to GIS data). Primary land uses include recreation, agriculture and gas-field development. This HUC includes approximately 10% provincial crown land and 90% privately owned/City of Calgary/First Nations (Tsuu T'ina Nation 145) lands. There are no Class A waters (FSI). There are four contaminated sites listed in the Federal Contaminated Sites

Inventory. The majority of groundwater has been ranked HIGH vulnerability (AESRD 2009). EXTREME. *Threat Risk: High*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): LIKELY – Phosphorous Runoff Coefficient = 2.39 (ALCES Online ©). HIGH. *Threat Risk: High*

Bow River Basin – Highwood and Sheep Rivers Sub-basins; HUC8s: 04021201 and 04021202

OVERVIEW: Bow River Basin Council (State of the Watershed Summary 2010 and State of the Watershed 2005)

- Area: approximately 398,500 ha
- Parks and protected areas include Sheep River Provincial Park, Brown-Lowery Provincial Park, portion of Elbow-Sheep Wildland Park, portion of Bluerock Wildland Park, portion of Don Getty Wildland Park, Emerson Creek Natural Area, Sheep Creek Natural Area, Threepoint Creek Natural Area, Plateau Mountain Ecological Reserve and 22 Provincial Recreation Areas
- Aboriginal lands include the Eden Valley First Nation Reservation
- Recreational land-use is high and includes hiking, fishing, rafting, kayaking, wildlife watching and biking
- In the Highwood River sub-basin, Dissolved Oxygen and River Flow Quality Index were rated NATURAL (the conditions for this indicator are considered to be in a natural state). These were the only two indicators assessed for the sub-basin. In the Sheep River sub-basin, the River Flow Quality Index was the only indicator assessed and was rated NATURAL.
- There are Class A waters in Storm Creek in HUC8: 04021201
- DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of projects and activities that have occurred between January 2008 and March 2014. Seventy-eight projects and activities were found within these HUCs (15 involved remediation activities from the 2013 Alberta flood), but this may not represent the total number as some may not have been reported to DFO. These fell under the following main categories: Watercourse Crossings – 34, Shoreline Works (Foreshore, Streambank and Riparian Work) – 20, Water Management – 8, Instream Works – 5, Structures in Water – 4, Mineral Aggregate, Oil and Gas Exploration, Extraction, Production – 3, Other – 3 and Dredging – 1.

21. HUC8: 04021201 – Highwood River

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). Brook Trout occur at a moderate density in Cataract Creek, but competition was not considered to be a driving factor due to uncertainty as to whether or not Bull Trout were present historically because of natural barriers (FSI). Brook Trout are not present at a high enough density in the rest of the watershed for competition to be occurring. Hybrids have not been reported (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: KNOWN – This entire HUC is within 150 km of Calgary. A paved road runs along the Highwood River and Emerson Creek is accessible by gravel road. Flat Creek is only accessible by unimproved road/truck trail (FSI). Recreational land-use is high (Bow River Basin Council 2005, 2010). Angling mortality was estimated at 10%. FSI; HIGH. *Threat Risk: High*

Habitat Fragmentation – Culverts (Road Crossing Density): UNLIKELY – Road crossing density = 0.104 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Dams and Weirs: UNLIKELY **–** Nine embankments are located in this HUC (Table 7) and the Highwood Diversion (at Little Bow River) is located on the boundary of this HUC. EXTREME. *Threat Risk: Medium*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – Agricultural water withdrawals are limited (Bow River Basin Council 2005). MEDIUM. *Threat Risk: Medium*

Alteration of Flow Regimes: KNOWN – There are no major impoundments and agricultural water withdrawals within the HUC are limited, however the Highwood Diversion (at Little Bow River, at boundary of HUC) transfers water from the Highwood River down the Little Bow Canal into the Little Bow River (Bow River Basin Council 2005). Water demands in the Little Bow sub-basin often coincide with low flows in the Highwood River (i.e., July and August). The Little Bow Project/Highwood Diversion plan was approved in 2008 (Bow River Basin Council 2010) and one of its aims is to change the timing of diversions from the Highwood River to coincide with the spring high flow period and store the water for later use (Bow River Basin Council 2005). HIGH. *Threat Risk: High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): LIKELY – Sediment Index = 1.22. HIGH. *Threat Risk: High*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 13.11 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 12.1 ºC. Historical average summer air temperature (1901–1930) = 11.8 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: LIKELY – There are 49 groundwater springs within this HUC (according to GIS data). Land use includes forestry (Spray Lake Sawmills), recreation, ranching, livestock operations, crop production and oil and gas extraction (Bow River Basin Council 2005). This HUC contains approximately 65% provincial crown land and 35% privately owned/First Nations (Eden Valley 216) land. A portion of Elbow-Sheep Wildland Park, Don Getty Wildland Park, OH Ranch Heritage Rangeland and several smaller Natural Areas and Provincial Recreation Areas provide moderate protection. Storm Creek is classified as Class A to protect Bull Trout spawning habitat (FSI). There are 14 contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater has been ranked HIGH vulnerability (AESRD 2009). EXTREME. *Threat Risk: High*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): UNLIKELY – Phosphorous Runoff Coefficient = 1.45 (ALCES Online ©). HIGH. *Threat Risk: Medium*

22. HUC8: 04021202 – Sheep River

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). Rainbow Trout, Cutthroat Trout-Rainbow Trout hybrids and Bull Trout are the dominant species; competition with Brook Trout assumed to not be a driving factor anywhere in the watershed (FSI). Hybrids have not been reported (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: KNOWN – This entire HUC is within 150 km of Calgary. A paved road runs along much of the Sheep River and gravel roads provide access to many other sections. Upper Sheep

River has steep banks and limited access. Angling mortality was estimated at 10%. FSI; HIGH. *Threat Risk: High*

Habitat Fragmentation – Culverts (Road Crossing Density): LIKELY – Road crossing density = 0.187 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: High*

Habitat Fragmentation – Dams and Weirs: UNLIKELY – Two irrigation dams, the Millarville Meadows Main Dam and eight embankments are located in this HUC (Table 7). Bull Trout migration and genetic data indicate a moderate impact (FSI). EXTREME. *Threat Risk: Medium*

Habitat Fragmentation – Irrigation Canals: LIKELY – Information on irrigation canals could not be found for this HUC, however, the Sheep River is the water source for a variety of acreages, farms and ranches (Bow River Basin Council 2010). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: UNLIKELY – There are no major impoundments within this HUC. The Sheep River is the municipal water source for the towns of Turner Valley, Black Diamond and Okotoks (Bow River Basin Council 2010). These towns have formed a Tri Community Watershed Initiative to help manage their water resources and Okotoks has developed a River Valley Water Management Plan (Bow River Basin Council 2005). Due to its proximity to Calgary, Okotoks is experiencing increased commuter use and population growth (Bow River Basin Council 2005). HIGH. *Threat Risk: Medium*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): UNLIKELY – Sediment Index = 1.15. HIGH. *Threat Risk: Medium*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 13.43 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 12.2 ºC. Historical average summer air temperature (1901–1930) = 11.9 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: LIKELY – There are 53 groundwater springs within this HUC (according to GIS data). Major land use activities include native rangeland/grazing land, cultivated land, oil and gas extraction and recreation (South Saskatchewan Regional Advisory Council 2010). This HUC contains approximately 50% provincial crown land and 50% privately owned land; there are no Class A waters (FSI). Sheep River Provincial Park, Brown-Lowery Provincial Park, part of Bluerock Wildland Park, part of Elbow-Sheep Wildland Park, part of OH Ranch Heritage Rangeland and part of Don Getty Wildland Park provide moderate protection. There are two contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater is ranked HIGH vulnerability (AESRD 2009). EXTREME. *Threat Risk: High*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): UNLIKELY – Phosphorous Runoff Coefficient = 1.74 (ALCES Online ©). HIGH. *Threat Risk: Medium*

Red Deer Basin

This basin includes HUC8s: 08010101, 08010102, 08010103, 08010104, 08010201, 08010202 and 08010203. The sub-basins do not align with the HUC8s in the Red Deer basin. An overview of each sub-basin and the HUC8s it encompasses is provided. All of the information was sourced from *Aqua*lity Environmental Consulting Ltd (2009).

Panther Sub-basin Overview

- Includes a portion of HUC8: 08010101 and all of HUC8: 08010102
- Area: 230,087 ha
- There are no communities located within this sub-basin

- Parks and protected areas include a portion of Banff National Park, Burnt Timber, Cartier Creek, Deer Creek, Red Deer River and Wild Horse Provincial Recreation Areas, Ya-Ha-Tinda Ranch and Ghost Forest Land Use Zone
- All linear developments (roads, cutlines/trails, pipelines, powerlines, railways) cover an area of 1,494 ha or 0.7% of the total area
- This sub-basin has the lowest density of oil/gas wells in the Red Deer basin with 107 wells of which 57 (53%) are active. Most wells are located in the eastern region of the sub-basin near Red Deer River and Burnt Timber Creek.
- Cropland and livestock densities are low
- In the State of the Watershed report, indicators were split into two categories – condition and risk. Condition indicators assessed include: Linear Developments – rated GOOD (total < 2%), Total Phosphorous – rated FAIR (0.05-0.10 mg/L), Total Nitrogen – rated FAIR (1.0-1.5 mg/L) and Land Cover – rated GOOD (wetlands, grasslands and forested areas > 50%). Risk indicators assessed include: Livestock Manure Production – rated LOW (< 5.1 tonnes manure/ha), Urban, Rural, Agricultural and Recreational Developments – rated LOW (disturbance affects < 50% of landbase) and Oil/Gas Wells – rated LOW (in the lower third of total wells relative to other sub-basins).

James Sub-basin Overview

- Includes a portion of HUC8: 08010101 and HUC8: 08010201 and all of HUC8: 08010104
- Area: 155,038 ha
- Communities include the town of Sundre, the summer village of Burnstick Lake and the hamlets of Bearberry and James River Bridge
- Parks and protected areas include James River Bridge and James-Wilson Provincial Recreation Areas
- All linear developments (roads, cutlines/trails, pipelines, powerlines, railways) cover 5,710 ha or 3.7% of the total area
- There are a total of 636 oil/gas wells of which 548 (86%) are active
- Livestock density is highest in the eastern portion of the sub-basin (0.41-0.60 head of cattle/ha); agricultural density (% area croplands) is generally low (0-20%), but increases in the east to 20.1-40%. There are two feedlots/intensive livestock operations.
- In the State of the Watershed Report, indicators were split into two categories – condition and risk. Condition indicators assessed include: Riparian Health – rated FAIR (follows existing assessments), Linear Development – rated POOR (> 3%), Total Phosphorous – rated FAIR (0.05-0.10 mg/L), Total Nitrogen – rated GOOD (< 1.0 mg/L), Bacteria (*E. coli*) – rated GOOD (0-100 CFU [Colony Forming Unit]/100 mL) and Land Cover – rated GOOD (wetlands, grasslands and forested areas > 50%). Risk indicators assessed include: Livestock Manure Production – rated LOW (< 5.1 tonnes manure/ha), Urban, Rural, Agricultural and Recreational Developments – rated LOW (disturbance impacts < 50% of landbase) and Oil/Gas Wells – rated LOW (in the lower third of total wells relative to other sub-basins).

Raven Sub-basin Overview

- Includes all of HUC8: 08010202 and a portion of HUC8: 08010201
- Area: 111,337 ha
- Bull Trout are functionally extirpated from HUC8: 08010202 (FSI)
- Communities include the village of Caroline, and the hamlets of Butte, Crammond, Kevisville, Raven and Stauffer

- Parks and protected areas include Butcher Creek Provincial Natural Area and Dickson Dam-Dickson Point, Dickson Dam-North Valley and Raven Provincial Recreation Areas
- All linear developments (roads, cutlines/trails, pipelines, powerlines, railways) cover 5,090 ha or 4.6% of the total area
- There are a total of 821 oil/gas wells in the sub-basin, of which 609 (74%) are active
- Livestock intensity is high throughout much of the watershed (0.61-0.80 head of cattle/ha) and agricultural density (% area croplands) ranges from low (0-20%) to medium (40.1-60%). There are two feedlots/intensive livestock operations.
- In the State of the Watershed Report, indicators were split into two categories – condition and risk. Condition indicators assessed include: Linear Developments – rated POOR (> 3%), Total Phosphorous – rated GOOD (< 0.05 mg/L), Total Nitrogen – rated GOOD (< 1.0 mg/L) and Land Cover – rated FAIR (wetlands, grasslands and forested areas 25-50%). Risk indicators assessed include: Livestock Manure Production – rated LOW (< 5.1 tonnes manure/ha), Urban, Rural, Agricultural and Recreational Developments – rated MEDIUM (disturbance impacts 50-89% of landbase) and Oil/Gas Wells – rated LOW (in the lower third of total wells relative to other sub-basins).

Little Red Deer Sub-basin Overview

- Includes all of HUC8s: 08010103 and 08010203 and a portion of HUC8: 08010201
- Area: 397,166 ha
- Communities include the towns of Bowden, Carstairs and Olds, the village of Cremona and many hamlets including Bergen, Bottrel, Dogpound, Eagle Hill, Elkton, Garrington, Harmattan, Madden, Mound, Shantz, Water Valley, Westerdale and Westward Ho
- Parks and protected areas include Red Lodge Provincial Park, William J. Bagnell Wilderness Park, Harold Creek Road Corridor Wildlife Sanctuary, and Dickson Dam-South Dyke, Dickson Dam-South Valley, Fallentimber Creek, Fallentimber South and Waiparous Creek Provincial Recreation Areas, and Snakes Head and Sundre North Natural Areas
- Livestock density ranges from 0-0.20 head of cattle/ha in the southwest to 0.21-0.40 in the central region and 0.41-1.00 in the northeastern area. Agricultural intensity (% area croplands) is low in the southwestern region (0-20%), increasing towards the northeastern area and is highest (60-80%) in the northern and western areas. There are 17 feedlots/intensive livestock operations in this sub-basin, mostly located in the northeast region.
- In the State of the Watershed Report, indicators were split into two categories – condition and risk. Condition indicators assessed include: Wetland Loss – rated POOR (any loss of wetlands), Riparian Health – rated FAIR (based on existing assessments), Linear Developments – rated POOR (> 3%), Total Phosphorous – rated FAIR (0.05-0.10 mg/L), Total Nitrogen – rated GOOD (< 1.0 mg/L), Bacteria (*E. coli*) – rated POOR (> 100 CFU/100 mL), Pesticides – rated GOOD (did not exceed CCME PAL [Canadian Council of Ministers of the Environment Protection of Aquatic Life] guidelines) and Land Cover – rated FAIR (wetlands, grasslands and forested areas 25-50%). Risk indicators assessed include: Livestock Manure Production – rated LOW (< 5.1 tonnes manure/ha), Urban, Rural, Agricultural and Recreational Developments – rated LOW (disturbance impacts < 50% of the landbase) and Oil/Gas Wells – rated LOW (in the lower third of total wells relative to other sub-basins).

23. HUC8: 08010101 – Upper Red Deer River

DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of projects and activities that have occurred between January 2008 and March 2014. A total of 38 projects and activities were found within this HUC, but this may not represent the total number as some may not have been reported to DFO. These fell under the following main categories: Watercourse Crossings – 14, Shoreline Works (Foreshore, Streambank and Riparian Work) – 11, Water Management – 4, Instream Works – 4, Other – 3, Mineral Aggregate, Oil and Gas Exploration, Extraction, Production – 1 and Habitat Improvement – 1.

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 17% (FSI). Brook Trout are present in Wigwam and Wildhorse creeks but not at high densities, Williams Creek at moderate-high density and the upper section of Bearberry Creek at a high density (FSI). Genetic analysis found evidence of hybridization in two Bull Trout from Red Deer River, three Bull Trout from Scalp Creek and two Bull Trout from North Burnt Timber Creek; however, only one Brook Trout allele was detected indicating low levels of hybridization (Taylor 2012). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: UNLIKELY – This entire HUC is within 150 km of Calgary. The middle and lower Red Deer River is accessible by paved or gravel road; the upper Red Deer River and Pinto Creek are only accessible by unimproved road/truck trail. The headwaters are within Banff National Park so it was assumed access is mostly nonmotorized. Angling mortality was estimated at 6%. FSI; HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Culverts (Road Crossing Density): UNLIKELY – Road crossing density = 0.121 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Dams and Weirs: REMOTE – The Milford Project Embankment (Table 7) and several smaller water infrastructures (*Aqua*lity Environmental Consulting Ltd 2009) are located in this HUC. Bull Trout migration and genetic data do not indicate an impact (FSI). EXTREME. *Threat Risk: Low*

Habitat Fragmentation – Irrigation Canals: LIKELY – Information on the incidence of irrigation canals could not be found, but given the higher densities of croplands and livestock in the eastern region, threat level was assumed to be medium. MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: UNLIKELY – Information on flow regimes was not available. There are several smaller water control structures in this HUC (*Aqua*lity Environmental Consulting Ltd 2009) and road density is low. HIGH. *Threat Risk: Medium*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.04. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 11.65 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 10.5 ºC. Historical average summer air temperature (1901–1930) = 10.0 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: LIKELY – There are 19 groundwater springs within this HUC (according to GIS data). Land use activities include agriculture and livestock, oil and gas extraction and recreation (*Aqua*lity Environmental Consulting Ltd 2009). This HUC contains approximately 55% provincial crown land, 25% federally titled land/Banff National Park and 20% privately owned land; there are no Class A waters (FSI). There are four contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC is ranked as HIGH vulnerability (AESRD 2010b). EXTREME. *Threat Risk: High*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.21 (ALCES Online ©). HIGH. *Threat Risk: Low*

24. HUC8: 08010102 – Panther River

DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of projects and activities that have occurred between January 2008 and March 2014. Three projects and activities were found within this HUC (one involved remediation activities from the 2013 Alberta flood), but this may not represent the total number as some may not have been reported to DFO. All of these fell under the main category of Shoreline Works (Foreshore, Streambank and Riparian Work).

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). It was assumed that Brook Trout are not present at a high enough density for competition to be occurring (FSI). Taylor (2012) found genetic evidence of hybridization in one Bull Trout from Panther River, but only one Brook Trout allele was detected indicating a low level of hybridization. HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: REMOTE – This entire HUC is within 150 km of Calgary, however access is limited to a few unimproved roads/truck trails. The majority of the HUC is within Banff National Park, so mostly non-motorized access was assumed. Angling mortality was estimated at 2%. FSI; HIGH. *Threat Risk: Low*

Habitat Fragmentation – Culverts (Road Crossing Density): REMOTE – Road crossing density = 0.012 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Low*

Habitat Fragmentation – Dams and Weirs: REMOTE – The Klein Lake Dam is located on the Panther River near its confluence with the Red Deer River (Table 7). Bull Trout migration and genetic data do not indicate an impact (FSI). EXTREME. *Threat Risk: Low*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – Outside of Banff National Park, agriculture and livestock density are low (*Aqua*lity Environmental Consulting Ltd 2009), therefore the threat level was assumed to be low. MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: KNOWN – The Klein Lake Dam alters flows in the Panther River (*Aqua*lity Environmental Consulting Ltd 2009). HIGH. *Threat Risk: High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.00. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 10.06 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 8.8 ºC. Historical average summer air temperature (1901–1930) = 8.4 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: REMOTE – There are six groundwater springs in this HUC (according to GIS data). Land use activities include recreation, and limited agriculture, livestock production and oil and gas extraction (*Aqua*lity Environmental Consulting Ltd 2009). The majority of this HUC (approximately 70%) is protected by Banff National Park and the remaining area is provincial crown land; there are no Class A waters (FSI). There are no contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC is ranked as HIGH vulnerability (AESRD 2010b). Given that much of the HUC is protected by Banff National Park, the threat level from anthropogenic activities is deemed to be low. EXTREME. *Threat Risk: Low*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.02 (ALCES Online ©). HIGH. *Threat Risk: Low*

25. HUC8: 08010103 – Fallentimber Creek

DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of projects and activities that have occurred between January 2008 and March 2014. No projects or activities were found within this HUC.

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 8% (FSI). Moderate-high Brook Trout catch-per-unit-effort in the very upper portion, thus it is assumed that competition is occurring in this section (FSI). Two hybrids have been reported in lower Fallentimber Creek by Alberta Fisheries Management (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: LIKELY – The entire HUC is within 150 km of Calgary, however access is limited. There are a few paved and gravel roads in the upper and lower portions of the HUC. The middle section of Fallentimber Creek is only accessible by unimproved roads/truck trails. Angling mortality was estimated at 8%. FSI; HIGH. *Threat Risk: High*

Habitat Fragmentation – Culverts (Road Crossing Density): UNLIKELY – Road crossing density = 0.104 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Dams and Weirs: REMOTE – There are no dams or weirs within this HUC (*Aqua*lity Environmental Consulting Ltd 2009). EXTREME. *Threat Risk: Low*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – Land use maps indicate low levels of agriculture and livestock production and fewer surface water licenses than in other areas of the Little Red Deer sub-basin (*Aqua*lity Environmental Consulting Ltd 2009). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: LIKELY – Flow rates in Fallentimber Creek are close to natural (*Aqua*lity Environmental Consulting Ltd 2009). However, there have been several high flow, flood watch/warning and ice jam advisories since 2005 due to early snowmelt and high precipitation events between June and September (*Aqua*lity Environmental Consulting Ltd 2009). HIGH. *Threat Risk: High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.06. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 13.12 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 12.2 ºC. Historical average summer air temperature (1901–1930) = 11.8 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: UNLIKELY – There are four groundwater springs within this HUC (according to GIS data). Agriculture, livestock production and oil and gas extraction are low (*Aqua*lity Environmental Consulting Ltd 2009). This HUC contains approximately 80% provincial crown land and 20% privately owned land (FSI) and includes a small portion of Don Getty Wildland Park; there are no Class A waters (FSI). There are no contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC is ranked as MEDIUM and HIGH vulnerability (AESRD 2009, 2010b). EXTREME. *Threat Risk: Medium*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.39 (ALCES Online ©). HIGH. *Threat Risk: Low*

26. HUC8: 08010104 – James River

DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of projects and activities that have occurred between January 2008 and March 2014. Fourteen projects and activities were found within this HUC, but this may not represent the total number as some may not have been reported to DFO. These fell under the following main categories: Watercourse Crossings – 6, Shoreline Works (Foreshore, Streambank and Riparian Work) – 3, Instream Works – 2, Contaminated Site Remediation – 1, Structures in Water – 1, and Water Management - 1.

Competition and Hybridization with Brook Trout: LIKELY – The carrying capacity loss due to Brook Trout was estimated at 56% (FSI). Brook Trout occur at a high density in the upper section of Wilson Creek, most tributaries and the upper mainstem (FSI). Hybrids have not been reported but suspected hybrids have been observed (R. Konynbelt pers. comm. in FSI). HIGH. *Threat Risk: High*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: LIKELY – This entire HUC is within 150 km of Calgary. Most of James River is accessible by gravel roads; Willson Creek and other tributaries are only accessible by unimproved roads/truck trails. Angling mortality was estimated at 8%. FSI; HIGH. *Threat Risk: High*

Habitat Fragmentation – Culverts (Road Crossing Density): UNLIKELY – Road crossing density = 0.162 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Dams and Weirs: REMOTE – The Burnstick Lake Stabilization Earthfill Dam and one embankment are located within this HUC (Table 7). Bull Trout migration and genetic data do not indicate an impact (FSI). EXTREME. *Threat Risk: Low*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – Land use maps indicate low agriculture and livestock production and fewer surface water licenses than in other areas of the James River sub-basin (*Aqua*lity Environmental Consulting Ltd 2009). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: UNLIKELY – Flows in the James River are within the natural range and there are no major water control structures within this HUC (*Aqua*lity Environmental Consulting Ltd 2009). HIGH. *Threat Risk: Medium*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.07. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 12.92 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 12.0 ºC. Historical average summer air temperature (1901–1930) = 11.5 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: REMOTE – There are five groundwater springs within this HUC (according to GIS data). Agriculture, livestock production and oil and gas extraction are low (*Aqua*lity Environmental Consulting Ltd 2009). This HUC contains approximately 90% provincial crown land and approximately 10% privately owned land; there are no Class A waters (FSI). There is one contaminated site listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC is ranked MEDIUM and HIGH vulnerability (AESRD 2010b). EXTREME. *Threat Risk: Low*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): UNLIKELY – Phosphorous Runoff Coefficient = 1.42 (ALCES Online ©). HIGH. *Threat Risk: Medium*

27. HUC8: 08010201 – Red Deer River and Gleniffer Lake

DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of projects and activities that have occurred between January 2008 and March 2014. Sixteen projects and activities were found within this HUC (two involved remediation activities from the 2013 Alberta flood), but this may not represent the total number as some may not have been reported to DFO. These fell under the following main categories: Watercourse Crossings – 9, Shoreline Works (Foreshore, Streambank and Riparian Work) – 2, Water Management – 2, Instream Works – 1, Mineral Aggregate, Oil and Gas Exploration, Extraction, Production – 1, and Structures in Water – 1.

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 12% (FSI). Brook Trout are present at a high density in Schrader Creek (FSI). Hybrids have not been reported. HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: KNOWN – This HUC is within 150 km of Calgary and an extensive network of paved and gravel roads provide access to all rivers. Angling mortality was estimated at 10%. FSI; HIGH. *Threat Risk: High*

Habitat Fragmentation – Culverts (Road Crossing Density): UNLIKELY – Road crossing density = 0.129 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Dams and Weirs: REMOTE – The Dickson Dam and one embankment are located within this HUC (Table 7). Bull Trout migration and genetic data indicate a low impact (FSI). EXTREME. *Threat Risk: Low*

Habitat Fragmentation – Irrigations Canals: UNLIKELY – According to land use maps, agricultural density is low throughout most of this HUC and livestock production is medium; irrigation water demands are low (*Aqua*lity Environmental Consulting Ltd 2009). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: KNOWN – The Dickson Dam alters flow in the Red Deer River. HIGH. *Threat Risk: High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.04. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): UNLIKELY – Mean August air temperature = 14.16 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 14.0 ºC. Historical average summer air temperature (1901–1930) = 13.4 ºC. FSI; EXTREME. *Threat Risk: Medium*

Alteration of Groundwater Quality or Quantity: UNLIKELY – There are two groundwater springs within this HUC (according to GIS data). Agricultural density is low and livestock production and oil and gas extraction are moderate (*Aqua*lity Environmental Consulting Ltd 2009). The majority of land is privately owned (FSI). There are two small natural areas and one small provincial recreation area. In the lower portion of the HUC, there are Class A waters on the Red Deer River to protect Brown Trout spawning habitat (FSI). There are no contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC is ranked MEDIUM vulnerability (AESRD 2009, 2010a). EXTREME. *Threat Risk: Medium*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): KNOWN – Phosphorous Runoff Coefficient = 3.07 (ALCES Online ©). HIGH. *Threat Risk: High*

28. HUC8: 08010202 – Raven River

DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of projects and activities that have occurred between January 2008 and March 2014. Fifteen projects and activities were found within this HUC, but this may not represent the total number as some may not have been reported to DFO. These fell under the following main categories: Watercourse Crossings – 9, Habitat Improvement – 3, Instream Works – 2, and Shoreline Works (Foreshore, Streambank and Riparian Work) – 1.

Competition and Hybridization with Brook Trout: UNLIKELY – The carrying capacity loss due to Brook Trout was estimated at 41% (FSI). Raven and North Raven rivers have very high densities of Brook Trout in the upper sections (FSI). Bull Trout are considered to be functionally extirpated from this HUC (FSI). HIGH. *Threat Risk: Medium*

Competition with Lake Trout: REMOTE - The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: KNOWN – This entire HUC is within 150 km of Calgary and has an extensive network of paved and gravel roads. The upper Raven River is accessible by truck trails/unimproved roads. Angling mortality was estimated at 10%. FSI; HIGH. *Threat Risk: High*

Habitat Fragmentations – Culverts (Road Crossing Density): UNLIKELY – Road crossing density = 0.145 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Dams and Weirs: REMOTE – The Beaver Creek Dam and one embankment are located in this HUC (Table 7). Bull Trout migration and genetic data do not indicate an impact (FSI). EXTREME. *Threat Risk: Low*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – According to land use maps, agricultural density is low throughout most of this HUC and livestock production is low-medium; irrigation water demands are low (*Aqua*lity Environmental Consulting Ltd 2009). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: LIKELY – Discharge rates in the Raven River are within the historical range (1971–2001). Between June 2005 and May 2007 there were seven high streamflow advisories caused by early snowmelt and/or high precipitation in the summer (*Aqua*lity Environmental Consulting Ltd 2009). HIGH. *Threat Risk: High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.05. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): UNLIKELY – Mean August air temperature = 14.17 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 13.6 ºC. Historical average summer air temperature (1901–1930) = 13.0 ºC. FSI; EXTREME. *Threat Risk: Medium*

Alteration of Groundwater Quality or Quantity: UNLIKELY – There are 20 groundwater springs within this HUC (according to GIS data). Agricultural density is low throughout most of this HUC, livestock production is low-medium and oil and gas extraction is medium (*Aqua*lity Environmental Consulting Ltd 2009). Approximately 30% of land is provincial crown land and 70% is privately owned (FSI). There are no large protected areas. There are Class A waters on the North Raven River and Beaver Creek to protect Brown Trout and Brook Trout spawning habitat (FSI). There is one contaminated site listed in the Federal Contaminated Sites Inventory.

The majority of groundwater in this HUC is ranked LOW vulnerability (AESRD 2010a,b). EXTREME. *Threat Risk: Medium*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): LIKELY – Phosphorous Runoff Coefficient = 2.35 (ALCES Online ©). HIGH. *Threat Risk: High*

29. HUC8: 08010203 – Little Red Deer River

DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of projects and activities that have occurred between January 2008 and March 2014. Twenty-eight projects and activities were found within this HUC, but this may not represent the total number as some may not have been reported to DFO. These fell under the following main categories: Watercourse Crossings – 15, Shoreline Works (Foreshore, Streambank and Riparian Work) – 6, Instream Works – 5, Habitat Improvement – 1, and Structures in Water – 1.

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 23% (FSI). Brown Trout are more predominant than Brook Trout; high density of Brook Trout in Dogpound Creek and tributaries (FSI). Hybrids have not been reported (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: UNLIKELY – This entire HUC is within 150 km of Calgary and an extensive network of paved and gravel roads provides access to most of the rivers. A small section of the headwaters of the Little Red Deer River is accessible only by one gravel road or truck trails/unimproved roads. Angling mortality was estimated at 6% based on expert opinion. FSI; HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Culverts (Road Crossing Density): LIKELY – Road crossing density = 0.181 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: High*

Habitat Fragmentation – Dams and Weirs: REMOTE – Harmattan Dams East and West (*Aqua*lity Environmental Consulting Ltd 2009) and two embankments (Table 7) are located in this HUC. Bull Trout migration and genetic data do not indicate an impact (FSI). EXTREME. *Threat Risk: Low*

Habitat Fragmentation – Irrigation Canals: LIKELY – According to land use maps, agricultural density is medium-high throughout much of this HUC and livestock production is medium; irrigation use accounts for 12.6% (836,770 m^3/yr) of surface and groundwater diversions in the Little Red Deer River sub-watershed of which this HUC forms a portion (third highest use, preceded by commercial – 13.5% and industrial – 42.5%) (*Aqua*lity Environmental Consulting Ltd 2009). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: LIKELY – Discharge rates within the Little Red Deer River are within the historical range. Between June 2005 and June 2008 there were seven high streamflow warnings, two flood watch/warnings and one ice jam warning issued for the Little Red Deer River due to early snow melt and/or high precipitation events (*Aqua*lity Environmental Consulting Ltd 2009). HIGH. *Threat Risk: High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): UNLIKELY – Sediment Index = 1.14. HIGH. *Threat Risk: Medium*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): UNLIKELY – Mean August air temperature = 14.31 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 13.4 ºC. Historical average summer air temperature (1901–1930) = 12.9 ºC. FSI; EXTREME. *Threat Risk: Medium*

Alteration of Groundwater Quality or Quantity: LIKELY – There are 19 groundwater springs within this HUC (according to GIS data). Agricultural density is medium-high throughout much of this HUC, livestock production is medium and oil and gas extraction is high (*Aqua*lity Environmental Consulting Ltd 2009). Approximately 80% of land is privately owned and the remaining 20% is provincial crown land; privately owned land mostly consists of farms and acreages (low level of development) (J. Earle, pers. comm. in FSI). There are no major protected areas and no Class A waters (FSI). A small portion of Stony First Nation lands are located within this HUC. There are three contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC is ranked as MEDIUM vulnerability (AESRD 2010a). EXTREME. *Threat Risk: High*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): KNOWN – Phosphorous Runoff Coefficient = 2.69 (ALCES Online ©). HIGH. *Threat Risk: High*

North Saskatchewan River Basin

Bull Trout in DU 4 occur in five sub-watersheds of the North Saskatchewan River basin – Cline, Ram, Clearwater, Brazeau and Modeste. Information for each of the sub-watershed overviews was sourced from North Saskatchewan Watershed Alliance (2005).

Cline Sub-watershed Overview

- Includes HUC8s: 11010101, 11010102 and 11010103 (a small portion of HUC8: 11010101 overlaps with the Ram sub-watershed).
- Area: 378,629 ha
- Parks and protected areas include Banff National Park, the Siffleur and White Goat Wilderness Areas, Kootenay Plains Ecological Reserve, Douglas Fir Natural Area, Thompson Creek Provincial Recreation Area and Kootenay Plains Provincial Recreation Area. Parks and protected areas cover approximately 71% of the sub-watershed.
- This is the least disturbed sub-watershed in the North Saskatchewan River basin.
- Linear developments cover only 0.1% (365 ha) of the land area. The majority (63%) are roads and the remainder (37%) are cutlines and trails.
- Recreational use is high; activities include fishing, hiking, canoeing, skiing, rock climbing and rafting.
- There are Class A waters in HUC8s: 11010102 and 11010103 (FSI)
- DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of projects and activities that have occurred between January 2008 and March 2014. Four projects and activities were found within these HUCs, but this may not represent the total number as some may not have been reported to DFO. All of these projects and activities were located within HUC8: 11010101 and fell under the following main categories: Watercourse Crossings – 3 and Water Management – 1.

30. HUC8: 11010101 – North Saskatchewan above Abraham

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). Timber Creek is probably too small to hold Bull Trout even though it is a third order stream; Brook Trout are likely not present at high enough densities for competition to be occurring (FSI). Hybrids have not been reported (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 20% (FSI). Lake Trout in the North Saskatchewan River mainstem and reservoir are competitors. Furthermore, Lake Trout may have been stocked in lakes of the Howse system. HIGH. *Threat Risk: Low*

Mortality: UNLIKELY – This HUC is farther than 150 km from Edmonton and Calgary and farther than 50 km from smaller cities. Most of the tributaries are not accessible by motorized vehicle, however, a paved road parallels much of the North Saskatchewan River. The headwaters of the North Saskatchewan River are located within Banff National Park, thus non-motorized access was assumed. Recreational use is high. Angling mortality was estimated at 6%. FSI; HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Culverts (Road Crossing Density): REMOTE – Road crossing density = 0.019 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Low*

Habitat Fragmentation – Dams and Weirs: UNLIKELY – The Bighorn Dam on the North Saskatchewan River impedes fish passage in this HUC (Alberta Fish and Wildlife 2008). No other dams or weirs are present. EXTREME. *Threat Risk: Medium*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – Given the higher elevations and low agricultural and livestock intensity in this HUC, irrigation use was assumed to be low. MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: KNOWN – The Bighorn Dam has altered flow regimes on the North Saskatchewan River within this HUC (Alberta Fish and Wildlife 2008). HIGH. *Threat Risk: High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.00. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 9.74 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 8.5 ºC. Historical average summer air temperature (1901–1930) = 8.0 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: REMOTE – There are 32 groundwater springs within this HUC (according to GIS data). Land use is primarily recreational. The majority of this HUC is protected (85%; Banff National Park, Siffleur Wilderness Area, Kootenay Plains Ecological Reserve, Thompson Creek Provincial Recreation Area and Kootenay Plains Provincial Recreation Area); the remaining 15% is provincial crown land. There are no Class A waters. A small-scale development node has been agreed to in this HUC (FSI). There are three contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC is ranked HIGH vulnerability (groundwater within Banff National Park not assessed) (AESRD 2010b). EXTREME. *Threat Risk: Low*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.02 (ALCES Online ©). HIGH. *Threat Risk: Low*

31. HUC8: 11010102 – Siffleur River

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). Bull Trout are not present above the falls where Brook Trout are present (FSI). Hybrids have not been reported (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: REMOTE – This HUC is farther than 150 km from Calgary and Edmonton and farther than 50 km from smaller cities. Access is entirely non-motorized. The Siffleur River, its tributaries and the Siffleur Wilderness Area are closed to fishing. Angling mortality was estimated at 2%. FSI; HIGH. *Threat Risk: Low*

Habitat Fragmentation – Culverts (Road Crossing Density): REMOTE – Road crossing density = 0.00 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk:* *Low*

Habitat Fragmentation – Dams and Weirs: UNLIKELY – There are no dams or weirs within this HUC but Bull Trout migration and genetic data indicate an impact from water control structures in neighbouring HUCs (FSI). EXTREME. *Threat Risk:* *Medium*

Habitat Fragmentation – Irrigation Canals: REMOTE – Given the higher elevations and the fact that nearly all of this HUC is within protected areas, irrigation use was assumed to be low. MEDIUM. *Threat Risk:* *Low*

Alteration of Natural Flow Regimes: REMOTE – There are no major water control structures within this HUC and the level of development is low. HIGH. *Threat Risk:* *Low*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.00. HIGH. *Threat Risk:* *Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 8.30 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 7.3 ºC. Historical average summer air temperature (1901–1930) = 6.9 ºC. FSI; EXTREME. *Threat Risk:* *Low*

Alteration of Groundwater Quality or Quantity: REMOTE – There are seven groundwater springs within this HUC (according to GIS data). Land use is primarily non-motorized recreational. The majority of this HUC is protected and lies within Banff National Park, Siffleur Wilderness Area and Kootenay Plains Ecological Reserve; 2.6 river km are designated Class A (FSI). There are no contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC that has been assessed is ranked VERY HIGH vulnerability (groundwater within Banff National Park not assessed) (AESRD 2010b). EXTREME. *Threat Risk:* *Low*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.01 (ALCES Online ©). HIGH. *Threat Risk:* *Low*

32. HUC8: 11010103 – Cline River

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). Brook Trout are not present in this HUC (FSI). Cutthroat Trout have been stocked in this HUC and are present at higher numbers than Bull Trout from Pinto Lake and outlet down to the falls (biomass: 80% Cutthroat Trout vs 20% Bull Trout); Pinto Lake Bull Trout may be the source population for the entire watershed (FSI). HIGH. *Threat Risk:* *Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk:* *Low*

Mortality: REMOTE – This HUC is farther than 150 km from Edmonton and Calgary and farther than 50 km from smaller cities. There are no paved or gravel roads or unimproved/truck trails other than a small section of Highway 11. Angling mortality was estimated at 4%. FSI; HIGH. *Threat Risk:* *Low*

Habitat Fragmentation – Culverts (Road Crossing Density): REMOTE – Road crossing density = 0.00 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk:* *Low*

Habitat Fragmentation – Dams and Weirs: REMOTE – There are no dams within this HUC. EXTREME. *Threat Risk:* *Low*

Habitat Fragmentation – Irrigation Canals: REMOTE – Given the higher elevations and low level of agriculture and livestock density, irrigation use was assumed to be low. MEDIUM. *Threat Risk: Low*

Alteration of Natural Flow Regimes: REMOTE – There are no major water control structures within this HUC and the level of development is low. HIGH. *Threat Risk: Low*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.00. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 9.90 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 7.8 ºC. Historical average summer air temperature (1901–1930) = 7.3 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: REMOTE – There are seven groundwater springs within this HUC (according to GIS data). Land use is primarily non-motorized recreational. A large portion (50%) of this HUC is protected by the White Goat Wilderness Area and the remaining 50% is provincial crown land. There are Class A waters on the Cline River to protect Bull Trout and Cutthroat Trout spawning and rearing habitat (FSI). There are no contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC has been ranked HIGH vulnerability (AESRD 2010b). EXTREME. *Threat Risk: Low*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.00 (ALCES Online ©). HIGH. *Threat Risk: Low*

Ram Sub-watershed Overview

- Includes HUC8s: 11010201, 11010202 and 11010203 (and a small portion of HUC8: 11010101).
- Area: 632,541 ha
- Parks and protected areas cover only approximately 5,411 ha (0.85%) of the sub-watershed and include: Crimson Lake Provincial Park, Ram Falls Provincial Park, Alexo Natural Area, Mill Island Natural Area, Cow Lake Natural Area, and Crescent Falls, Snow Creek, Goldeye Lake, Fish Lake, Beaverdam, Horburg, Jackfish Lake, Chambers Creek, Chambers Creek Group Camp, Shunda Viewpoint, Saunders, Harlech, Aylmer, Dry Haven and North Ram Provincial Recreation Areas. Ninety-nine percent of the sub-watershed is located in provincial government forest management units.
- The primary land use activities are oil and gas extraction, forestry, agriculture and tourism
- Linear developments occupy 1.6% (10,229 ha) of the land area. The majority of these are cutlines (51%), followed by roads (24.1%) and pipeline rights of way (17%)
- Livestock densities are low
- There are Class A waters in Fall Creek (HUC8: 11010202)
- DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of projects and activities that have occurred between January 2008 and March 2014. Thirty-eight projects and activities were found within these HUCs (one involved remediation activities from the 2013 Alberta flood), but this may not represent the total number as some may not have been reported to DFO. The majority of these (28) were located within HUC8: 11010201. These projects and activities fell under the following main categories: Watercourse Crossings – 23, Water Management – 7, Instream Works – 3, Shoreline Works (Foreshore, Streambank and Riparian Work) – 2,

Structures in Water – 1, Mineral Aggregate, Oil and Gas Exploration, Extraction, Production – 1 and Other – 1.

33. HUC8: 11010201 – North Saskatchewan below Abraham

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 8% (FSI). Brook Trout occur throughout this HUC, but generally not at high densities (FSI). Two suspected hybrids have been reported in Haven Creek and one in an unnamed creek near the confluence of the Ram and North Saskatchewan rivers (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: UNLIKELY – The lower section of this HUC is within 150 km of Edmonton. Paved and gravel roads provide access to rivers throughout the HUC, although some tributaries are only accessible by unimproved roads/truck trails. Angling mortality was estimated at 6%. FSI; HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Culverts (Road Crossing Density): REMOTE – Road crossing density = 0.077 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Low*

Habitat Fragmentation – Dams and Weirs: UNLIKELY – The Bighorn Dam, Martin Dam, Cow Lake Stabilization Weir, Fish Lake Stabilization Project (Shunda Lake) Weir, Gap Lake Weir and one embankment are located in this HUC (Table 7). Bull Trout migration and genetic data indicate a moderate impact (FSI). EXTREME. *Threat Risk: Medium*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – Cropland density is high in the central portion and low in the remainder of this HUC (North Saskatchewan Watershed Alliance 2005). Overall habitat fragmentation from irrigation canals is assumed to be low. MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: KNOWN – The Bighorn Dam is located upstream and affects the flow regimes in this HUC during the summer months. In winter, the impacts of hydro-peaking contribute to ice-damming, breakup, unnatural flooding of sections of the stream channel and have altered amounts of ice cover. However, the dam has increased winter minimum flow levels (Alberta Fish and Wildlife 2008). EXTREME. *Threat Risk: High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.08. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 13.19 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 12.5 ºC. Historical average summer air temperature (1901–1930) = 12.0 ºC. The large size of this HUC makes this measure less reliable as it includes a cold to cool water transition. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: LIKELY – There are 60 groundwater springs within this HUC (according to GIS data). The majority of this HUC is provincial crown land. Approximately 10% is privately owned/First Nations Reservation (Big Horn 144A). There are no Class A waters. One Provincial Park (Crimson Lake), three Natural Areas and twelve small Provincial Recreation Areas provide minimal protection. There are five contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC has been ranked MEDIUM vulnerability (AESRD 2010b). Oil and gas activity is high in the eastern and northern portions of this HUC. EXTREME. *Threat Risk: High*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.38 (ALCES Online ©). HIGH. *Threat Risk: Low*

34. HUC8: 11010202 – Ram River

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). Bull Trout are only present below the falls where there is not a high density of Brook Trout (FSI). Hybrids have not been reported (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: UNLIKELY – This HUC is farther than 150 km from Calgary and Edmonton and farther than 50 km from smaller cities. A few gravel roads and unimproved roads/truck trails provide limited access. There is high off-highway vehicle use and relatively high levels of timber harvest. Angling mortality was estimated at 6%. FSI; HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Culverts (Road Crossing Density): REMOTE – Road crossing density = 0.042 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Low*

Habitat Fragmentation – Dams and Weirs: REMOTE – There are no major dams or weirs in this HUC. EXTREME. *Threat Risk: Low*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – According to land use maps, agricultural intensity is low in this HUC (North Saskatchewan Watershed Alliance 2005) so habitat fragmentation from irrigation canals was deemed to be low. MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: REMOTE – Flows in the Ram River at Ram Glacier are within the historic average (1968–1974) and are typical of a glacial meltwater dominated headwater stream, with summer flows drastically declining in fall (North Saskatchewan Watershed Alliance 2005). There are no major water control structures in this HUC. HIGH. *Threat Risk: Low*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.02. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 11.13 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 10.3 ºC. Historical average summer air temperature (1901–1930) = 9.8 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: UNLIKELY – There are 53 groundwater springs within this HUC (according to GIS data). The majority of this HUC is provincial crown land; there are no Class A waters (FSI). Ram Falls Provincial Park and North Ram River Provincial Recreation Area provide minimal protection. Agricultural intensity is low (North Saskatchewan Watershed Alliance 2005). There are two contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC has been ranked HIGH vulnerability (AESRD 2010b). EXTREME. *Threat Risk: Medium*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.07 (ALCES Online ©). HIGH. *Threat Risk: Low*

35. HUC8: 11010203 – Baptiste River

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 28% (FSI). High density of Brook Trout present in upper

Baptiste River and tributaries, moderate density present in Chambers Creek and lower density in Brewster Creek (FSI). Hybrids have not been reported (FSI).HIGH. *Threat Risk:* *Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk:* *Low*

Mortality: UNLIKELY – Half of this HUC is within 150 km of Edmonton. The lower portion of this HUC is accessible by paved and gravel roads while the upper portion is only accessible by a limited number of truck trails/unimproved roads. Angling mortality was estimated at 6%. FSI; HIGH. *Threat Risk:* *Medium*

Habitat Fragmentation – Culverts (Road Crossing Density): REMOTE – Road crossing density = 0.035 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk:* *Low*

Habitat Fragmentation – Dams and Weirs: LIKELY – There are no major dams or weirs in this HUC but Bull Trout migration and genetic data indicate impacts from water control structures in neighbouring HUCs (FSI). EXTREME. *Threat Risk:* *High*

Habitat Fragmentation – Irrigation Canals: UNLIKLEY – According to land use maps, agricultural intensity is low in this HUC (North Saskatchewan Watershed Alliance 2005) so habitat fragmentation from irrigation canals was deemed to be low. MEDIUM. *Threat Risk:* *Medium*

Alteration of Natural Flow Regimes: UNLIKELY – There are no major water control structures in this HUC. HIGH. *Threat Risk:* *Medium*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): UNLIKELY – Sediment Index = 1.10. HIGH. *Threat Risk:* *Medium*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): UNLIKELY – Mean August air temperature = 14.05 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 13.5 ºC. Historical average summer air temperature (1901–1930) = 12.9 ºC. FSI; EXTREME. *Threat Risk:* *Medium*

Alteration of Groundwater Quality or Quantity: UNLIKELY – There are 27 groundwater springs within this HUC (according to GIS data). The majority of land in this HUC is provincial crown land and approximately 5% is First Nations land (Sun Child 202); there are no Class A waters (FSI). Three small Provincial Recreation Areas (Chambers Creek, Chambers Creek Group Camp and Jackfish Lake) provide minimal protection. Agricultural intensity is low (North Saskatchewan Watershed Alliance 2005) but off-highway vehicle use and resource extraction are high (FSI). There are five contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC has been ranked MEDIUM vulnerability (AESRD 2010b). EXTREME. *Threat Risk:* *Medium*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.35 (ALCES Online ©). HIGH. *Threat Risk:* *Low*

Clearwater Sub-watershed Overview

- Includes HUC8s: 11010301 and 11010302
- Area: 322,787 ha
- Parks and protected areas include: a small portion of Banff National Park, Chedderville Natural Area, Clearwater Ricinus Natural Area, and Elk Creek Fish Pond, Prairie Creek Group Camp, Strachan, Swan Lake, Tay River, Mitchell Lake, Phyllis Lake, Elk Creek, Peppers Lake, Peppers Lake Staging, Prairie Creek and Seven Mile Provincial Recreation Areas. The Natural Areas and Provincial Recreation Areas are all small in size and cover a combined total of approximately 851 ha (0.26% of land area).

- The primary land use activities are oil and gas extraction, forestry, agriculture and tourism
- Linear developments occupy 2% (6572 ha) of the land area. The majority of these (59.4%) are cutlines, followed by roads (28.8%), pipeline rights of way (15.3%) and transmission line rights of way (5.5%)
- Livestock densities are low throughout much of the sub-watershed with the exception of the eastern corner where they are high
- There are Class A waters in the Clearwater River (HUC8: 11010301) and Prairie Creek (HUC8: 11010302) (FSI)
- DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of projects and activities that have occurred between January 2008 and March 2014. Seventeen projects and activities were found within these HUCs, but this may not represent the total number as some may not have been reported to DFO. These fell under the following main categories: Watercourse Crossings – 7, Instream Works – 4, Water Management – 2, Shoreline Works (Foreshore, Streambank and Riparian Work) – 2, Mineral Aggregate, Oil and Gas Exploration, Extraction, Production – 1, and Other – 1.

36. HUC8: 11010301 – Clearwater River

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). Brook Trout are present in several creeks/rivers in this HUC (Elk, Cutoff, Rocky and Tay), but not at high enough densities to assume competition is a factor (FSI). Hybrids have not been reported (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: UNLIKELY – This entire HUC is within 150 km of Calgary. The lower section of the HUC is accessible by paved and gravel roads, but there are no roads in the upper section of the HUC and the headwaters are within Banff National Park so access was assumed to be mostly non-motorized in this area. The portion of the Clearwater River within Banff National Park is closed to fishing. Angling mortality was estimated at 6%. FSI; HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Culverts (Road Crossing Density): REMOTE – Road crossing density = 0.069 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Low*

Habitat Fragmentation – Dams and Weirs: REMOTE – There are no major dams or weirs in this HUC. EXTREME. *Threat Risk: Low*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – According to land use maps, agriculture and livestock densities are low throughout much of the HUC but are high in the eastern portion (North Saskatchewan Watershed Alliance 2005). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: UNLIKELY – The flow regime in the Clearwater River is typical of glacial meltwater dominated rivers, with flows peaking during the summer and declining in the fall (North Saskatchewan Watershed Alliance 2005). There are no major water control structures in this HUC. HIGH. *Threat Risk: Medium*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.03. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 11.34 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 10.5 ºC. Historical average summer air temperature (1901–1930) = 10.0 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: UNLIKELY – There are 49 groundwater springs within this HUC (according to GIS data). This HUC contains approximately 60% provincial crown land, 20% privately owned land and 20% is within Banff National Park. Additionally, several small Provincial Recreation Areas provide minimal protection (FSI). There are Class A waters in the Clearwater River to protect Bull Trout spawning habitat (FSI). Agriculture and livestock densities are low throughout much of the HUC but are high in the eastern portion (North Saskatchewan Watershed Alliance 2005). There are two contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC has been ranked MEDIUM and HIGH vulnerability (AESRD 2010b). EXTREME. *Threat Risk: Medium*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.24 (ALCES Online ©). HIGH. *Threat Risk: Low*

37. HUC8: 11010302 – Prairie Creek

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 15% (FSI). A high density of Brook Trout occur in Vetch Creek; it is unclear if Bull Trout declined from other threats before Brook Trout moved in (FSI). Suspected hybrids have been reported in Tay River and Clearwater River near Corkscrew Mountain (Nelson and Paetz 1992). One suspected hybrid was reported in Elk Creek (Alberta Conservation Association 2011). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: KNOWN – This entire HUC is within 150 km of Calgary and paved and gravel roads provide access to most areas. Angling mortality was estimated at 10%. FSI; HIGH. *Threat Risk: High*

Habitat Fragmentation – Culverts (Road Crossing Density): UNLIKELY – Road crossing density = 0.104 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Dams and Weirs: REMOTE – There are no major dams or weirs in this HUC. EXTREME. *Threat Risk: Low*

Habitat Fragmentation – Irrigation Canals: LIKELY – According to land use maps, agricultural intensity is high in most of this HUC (North Saskatchewan Watershed Alliance 2005). HIGH. *Threat Risk: High*

Alteration of Natural Flow Regimes: UNLIKELY – Information on flow regimes in this HUC was not readily available. There are no major water control structures, but road density is medium and agricultural intensity is high therefore the threat level was deemed medium. HIGH. *Threat Risk: Medium*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.09. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 13.42 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 12.7 ºC. Historical average summer air temperature (1901–1930) = 12.1 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: UNLIKELY – There are 25 groundwater springs within this HUC (according to GIS data). The majority of this HUC is provincial crown land; less than 10% is privately owned and four small Provincial Recreation Areas (Prairie Creek, Prairie Creek Group Camp, Strachan and Swan Lake) provide minimal protection (FSI). There are Class A waters in Prairie Creek to protect Brown Trout spawning habitat (FSI). Agricultural densities are high throughout much of the HUC (North Saskatchewan Watershed Alliance 2005). There are two contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC has been ranked MEDIUM vulnerability (AESRD 2010b). EXTREME. *Threat Risk: Medium*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): UNLIKELY – Phosphorous Runoff Coefficient = 1.50 (ALCES Online ©). HIGH. *Threat Risk: Medium*

Brazeau Sub-watershed Overview

- Includes HUC8s: 11010401, 11010402, 11010403, 11010404, 11010405 and 11010406
- Area: 689,198 ha
- Bull Trout are functionally extirpated from HUC8: 11010405 (FSI)
- Parks and protected areas include: part of Jasper National Park, part of White Goat Wilderness Area, Marshybank Ecological Reserve, O'Chiese and Aurora Natural Areas, Brown Creek, Elk River, Blackstone, Brazeau Reservoir, Brazeau River and Wapiabi Provincial Recreation Areas, and Brazeau Canyon and Whitehorse Wildland Parks
- This sub-watershed is sparsely populated. Common recreation activities include trail riding, hiking, camping, hunting, fishing, and canoeing/kayaking.
- Linear developments cover approximately 1.4% (9,315 ha) of the land area. The majority of these are cutlines (63%), followed by roads (17.5%), pipelines (15%) and transmission lines (4%).
- Agricultural density is generally low, but increases in the eastern portion of the sub-watershed. Livestock densities are low.
- There are no Class A waters (FSI)
- DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of projects and activities that have occurred between January 2008 and March 2014. Nineteen projects and activities were found within these HUCs, but this may not represent the total number as some may not have been reported to DFO. These fell under the following main categories: Watercourse Crossings – 12, Water Management – 3, Other – 3 and Instream Works – 1.

38. HUC8: 11010401 – Brazeau River

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). Brook Trout are not present at high density anywhere in this HUC (FSI). Hybrids have not been reported (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: REMOTE – Most of this HUC is farther than 150 km from Edmonton or Calgary and farther than 50 km from smaller cities. Access is restricted to a few gravel roads and unimproved roads/truck trails. The headwaters of the Brazeau River are within Jasper National Park where access was assumed to be mostly non-motorized. Angling mortality was estimated at 4%. FSI; HIGH. *Threat Risk: Low*

Habitat Fragmentation – Culverts (Road Crossing Density): REMOTE – Road crossing density = 0.023 km/km^2 (FSI based on GIS). HIGH. *Threat Risk: Low*

Habitat Fragmentation – Dams and Weirs: REMOTE – The Brazeau Dam is located in the this HUC. This has eliminated connectivity with the middle and lower North Saskatchewan River. However, this HUC is large and the majority of it is distant from the dam (FSI). The Nelson Saddle Dam, Side Dam #1 and North Arm Embankment are also located in this HUC (Table 7). Bull Trout migration and genetic studies indicate a low level of impact (FSI). EXTREME. *Threat Risk: Low*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – According to land use maps, agricultural density is low throughout much of this HUC but is high in the eastern portion (North Saskatchewan Watershed Alliance 2005). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: UNLIKELY – The Brazeau River in this HUC is entirely upstream of the Brazeau Reservoir (created by the Brazeau Dam). HIGH. *Threat Risk: Medium*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.03. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 11.04 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 10.1 ºC. Historical average summer air temperature (1901–1930) = 9.6 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: REMOTE – There are 28 groundwater springs within this HUC (according to GIS data). Approximately 40% of this HUC is protected by Jasper National Park and Marshybank Ecological Reserve, Brazeau River Provincial Recreation Area, Brazeau Canyon Wildland Park and White Goat Wilderness Area provide minimal protection (FSI). There are no Class A waters (FSI). Agricultural density is low in much of this HUC but is high in the eastern portion (North Saskatchewan Watershed Alliance 2005). There is one contaminated site listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC has been ranked HIGH vulnerability (AESRD 2010b). EXTREME. *Threat Risk: Low*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.11 (ALCES Online ©). HIGH. *Threat Risk: Low*

39. HUC8: 11010402 – Cardinal River

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). Brook Trout occur in low numbers in this HUC and are not widely distributed. Hybrids have not been reported (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: REMOTE – Most of this HUC is farther than 150 km from Edmonton and Calgary and farther than 50 km from smaller cities. Access is limited to a few gravel roads and unimproved roads/truck trails. Angling mortality was not estimated for this HUC. FSI; HIGH. *Threat Risk: Low*

Habitat Fragmentation – Culverts (Road Density Proxy): UNLIKELY – Road density = 0.261 km/km^2 (FSI based on GIS). HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Dams and Weirs: REMOTE – There are no major dams or weirs within this HUC. EXTREME. *Threat Risk: Low*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – Agriculture and livestock densities are low within this HUC (North Saskatchewan Watershed Alliance 2005). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: UNLIKELY – There are no major water control structures within this HUC and road density is low. HIGH. *Threat Risk: Medium*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.02. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Summer Air Temperature Proxy): REMOTE – Current average summer air temperature (2000–2010) for HUC = 10.2 ºC. Historical average summer air temperature (1901–1930) = 9.6 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: REMOTE – There are nine groundwater springs within this HUC (according to GIS data). Most of this HUC is provincial crown land; approximately 10% is First Nations land (Alexis Cardinal 234) (FSI). Whitehorse Wildland Park and a small portion of Brazeau Canyon Wildland Park provide minimal protection; there are no Class A waters (FSI). Agriculture and livestock densities are low in this HUC (North Saskatchewan Watershed Alliance 2005). There are no contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC has been ranked HIGH vulnerability (AESRD 2010b). EXTREME. *Threat Risk: Low*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.10 (ALCES Online ©). HIGH. *Threat Risk: Low*

40. HUC8: 11010403 – Blackstone River

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). Brook Trout do not occur at high density anywhere in this HUC (FSI). One suspected hybrid has been reported (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: REMOTE – Most of this HUC is farther than 150 km from Edmonton and farther than 50 km from smaller cities. Access is limited to a few gravel roads and unimproved roads/truck trails. There is no road access to the headwaters of Blackstone and Wapiabi creeks. Angling mortality was estimated at 4%. FSI; HIGH. *Threat Risk: Low*

Habitat Fragmentation – Culverts (Road Crossing Density): REMOTE – Road crossing density = 0.051 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Low*

Habitat Fragmentation – Dams and Weirs: REMOTE – There are no major dams or weirs within this HUC. EXTREME. *Threat Risk: Low*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – According to land use maps, agriculture and livestock densities are low throughout this HUC (North Saskatchewan Watershed Alliance 2005). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: UNLIKELY – There are no major water control structures in this HUC. HIGH. *Threat Risk: Medium*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.02. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 12.08 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 11.2 ºC. Historical average summer air temperature (1901–1930) = 10.6 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: UNLIKELY – There are two groundwater springs within this HUC (according to GIS data). The majority of this HUC is provincial crown land; Wapiabi (4027.6 ha), Blackstone (3.1 ha) and Brown Creek (3.8 ha) Provincial Recreation Areas provide moderate protection (FSI). There are no Class A waters (FSI). Agriculture and livestock densities are low throughout this HUC (North Saskatchewan Watershed Alliance 2005). There is one contaminated site listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC has been ranked HIGH vulnerability (AESRD 2010b). EXTREME. *Threat Risk: Medium*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.12 (ALCES Online ©). HIGH. *Threat Risk: Low*

41. HUC8: 11010404 – Elk River

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). There are no records of Brook Trout in this HUC (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: UNLIKELY – This HUC is farther than 150 km from Edmonton or Calgary and farther than 50 km from smaller cities. There are no paved roads but there is an extensive network of gravel roads and unimproved roads/truck trails. Angling mortality was estimated at 6%. FSI; HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Culverts (Road Crossing Density): REMOTE – Road crossing density = 0.062 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Low*

Habitat Fragmentation – Dams and Weirs: LIKELY– There are no dams or weirs located in this HUC but Bull Trout migration and genetic data indicate a high level of impact from water control structures in neighbouring HUCs (FSI). EXTREME. *Threat Risk: High*

Habitat Fragmentation – Irrigation Canals: LIKELY – According to land use maps, agriculture density is high in approximately 50% of this HUC (North Saskatchewan Watershed Alliance 2005). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: UNLIKELY – There are no major water control structures in this HUC. HIGH. *Threat Risk: Medium*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): UNLIKELY – Sediment Index = 1.10. HIGH. *Threat Risk: Medium*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 12.99 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 13.1 ºC. Historical average summer air temperature (1901–1930) = 12.5 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: LIKELY – There are two groundwater springs within this HUC (according to GIS data). Most of this HUC is provincial crown land; Elk River Provincial Recreation Area (28.4 ha) provides minimal protection (FSI). There are no Class A waters (FSI). Agriculture density is high in approximately 50% of this HUC (North Saskatchewan Watershed Alliance 2005) and oil and gas activities, timber harvest and off-highway vehicle use are high (FSI). There are no contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC has been ranked MEDIUM vulnerability (AESRD 2010b). EXTREME. *Threat Risk: High*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): UNLIKELY – Phosphorous Runoff Coefficient = 1.45 (ALCES Online ©). HIGH. *Threat Risk: Medium*

42. HUC8: 11010405 – Brazeau Canal

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). There are no records of Brook Trout in this HUC and Bull Trout are considered to be functionally extirpated (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: KNOWN – This HUC is within 150 km of Edmonton. There is limited access with only a few gravel roads and unimproved roads/truck trails, however, random camping and off-highway vehicle use are high. Angling mortality was estimated at 10%. FSI; HIGH. *Threat Risk: High*

Habitat Fragmentation – Culverts (Road Crossing Density): REMOTE – Road crossing density = 0.018 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Low*

Habitat Fragmentation – Dams and Weirs: LIKELY– This HUC is located downstream of the Brazeau Dam. The dam has reduced connectivity between Bull Trout in this HUC and those in the adjacent HUC8: 11010406 (Nordegg River). FSI; EXTREME. *Threat Risk: High*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – According to land use maps, agriculture and livestock densities are low in this HUC (North Saskatchewan Watershed Alliance 2005). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: KNOWN – Flow regulation from the Brazeau Dam causes severe low water and has reversed the daily and seasonal hydrographs as compared to natural flows. FSI; HIGH. *Threat Risk: High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.09. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): LIKELY – Mean August air temperature = 14.22 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 15.0 ºC. Historical average summer air temperature (1901–1930) = 13.4 ºC. FSI; EXTREME. *Threat Risk: High*

Alteration of Groundwater Quantity or Quality: REMOTE – There is one groundwater spring within this HUC. The entire area is provincial crown land; there are no Class A waters (FSI). Agriculture and livestock density are low throughout this HUC (North Saskatchewan Watershed Alliance 2005). There are no contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC has been ranked MEDIUM vulnerability (AESRD 2010b). EXTREME. *Threat Risk: Low*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.41 (ALCES Online ©). HIGH. *Threat Risk: Low*

43. HUC8: 11010406 – Nordegg River

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 10% (FSI). Brook Trout occur throughout this HUC. Ten suspected hybrids were reported in the Nordegg River in 2006 (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: UNLIKELY – Most of this HUC is farther than 150 km from Edmonton and Calgary and farther than 50 km from smaller cities. One paved road provides limited access to the Nordegg River, but there is an extensive network of gravel roads and unimproved roads/truck trails that provides access to most areas. Angling mortality was estimated at 6%. FSI; HIGH. *Threat Risk: Medium*

Habitat Fragmentation – Culverts (Road Crossing Density): REMOTE – Road crossing density = 0.082 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: Low*

Habitat Fragmentation – Dams and Weirs: UNLIKELY – There are no dams within this HUC, but the Brazeau Dam has reduced connectivity between Bull Trout in this HUC and those upstream of the dam. Bull Trout migration and genetic data indicate a moderate impact (FSI). EXTREME. *Threat Risk: Medium*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – According to land use maps, agriculture density is medium to high in approximately 50% of this HUC and low in the remainder (North Saskatchewan Watershed Alliance 2005). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: UNLIKELY – There are no major water control structures in this HUC and road density is low. HIGH. *Threat Risk: Medium*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): REMOTE – Sediment Index = 1.07. HIGH. *Threat Risk: Low*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): REMOTE – Mean August air temperature = 13.33 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 13.1 ºC. Historical average summer air temperature (1901–1930) = 12.5 ºC. FSI; EXTREME. *Threat Risk: Low*

Alteration of Groundwater Quality or Quantity: UNLIKELY – There are 20 groundwater springs within this HUC (according to GIS data). Most of the HUC is provincial crown land, approximately 10% is First Nations land (O'Chiese 203) and the O'Chiese (375.3 ha) and Aurora (906.7 ha) Natural Areas provide minimal protection (FSI). There are no Class A waters (FSI). Agriculture density is medium to high in approximately 50% of this HUC and low in the remainder (North Saskatchewan Watershed Alliance 2005). There is one contaminated site listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC has been ranked MEDIUM vulnerability (AESRD 2010b). EXTREME. *Threat Risk: Medium*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): REMOTE – Phosphorous Runoff Coefficient = 1.30 (ALCES Online ©). HIGH. *Threat Risk: Low*

Modeste Sub-watershed Overview

- Includes HUC8s: 11020101 and 11020102
- Bull Trout are functionally extirpated from both HUCs in this sub-watershed
- Area: 482,746 ha (however, approximately 40% of this area does not belong to either HUC8)
- Parks and protected areas within the two HUC8s include: Eagle Point Provincial Park, Blue Rapids Provincial Recreation Area and eight Natural Areas (Rocky Rapids, Burtonsville Island, Alsike Bat Lake, Genesee, Coyote Lake, St. Francis, Horseshoe Creek and Washout Creek. In total, these cover approximately 7,143 ha.
- The primary economic activities are oil and gas extraction, agriculture and forestry. The largest surface strip mine in Canada, the Highvale Coal Mine, is located in this sub-watershed near Wabamun Lake.
- Linear developments cover more than 3.5% (17,255 ha) of the sub-watershed area. The majority of these are pipeline rights of way (33%), followed by roads (31%), cutlines and trails (25%) and transmission line rights of way (10.3%).
- Livestock densities are moderate and agriculture density is low in approximately 50% of the subwatershed (generally the central region), medium in 30% and high in 20%

- There are Class A waters in HUC8: 11020101 (FSI)
- DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of projects and activities that have occurred between January 2008 and March 2014 within the two HUC8s. Forty-seven projects and activities were found within these HUCs (one involved remediation activities from the 2013 Alberta flood), but this may not represent the total number as some may not have been reported to DFO. These fell under the following main categories: Watercourse Crossings – 18, Instream Works – 7, Shoreline Works (Foreshore, Streambank and Riparian Work) – 6, Mineral Aggregate, Oil and Gas Exploration, Extraction, Production – 5, Other – 5, Structures in Water – 3 and Water Management – 3.

44. HUC8: 11020101 – North Saskatchewan above Wabamun

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). Few Brook Trout occur in this HUC and Bull Trout are considered to be functionally extirpated (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: KNOWN – This entire HUC is within 150 km of Edmonton. An extensive network of paved and gravel roads provides access to most streams. Angling mortality was estimated at 10%. FSI; HIGH. *Threat Risk: High*

Habitat Fragmentation – Culverts (Road Crossing Density): LIKELY – Road crossing density = 0.182 crossings/km^2 (FSI based on GIS). HIGH. *Threat Risk: High*

Habitat Fragmentation – Dams and Weirs: REMOTE – The Genesee Cooling Pond Main Dam is located in this HUC (Table 7). Bull Trout migration and genetic data do not indicate an impact (FSI). EXTREME. *Threat Risk: Low*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – Livestock density is moderate. According to land use maps, agriculture density is low throughout much of the HUC but is medium to high along the western periphery and in the northeastern region (North Saskatchewan Watershed Alliance 2005). MEDIUM. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: KNOWN – Peak summer flows have been decreased and minimum winter flows increased in the North Saskatchewan River by water releases from the Bighorn and Brazeau dams (North Saskatchewan Watershed Alliance 2005). HIGH. *Threat Risk: High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): UNLIKELY – Sediment Index = 1.13. HIGH. *Threat Risk: Medium*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): LIKELY – Mean August air temperature = 15.04 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 14.8 ºC. Historical average summer air temperature (1901–1930) = 12.5 ºC. FSI; EXTREME. *Threat Risk: High*

Alteration of Groundwater Quality or Quantity: LIKELY – There are nine groundwater springs within this HUC (according to GIS data). Approximately 80% of the land is privately owned and 20% is provincial crown land (FSI). There are Class A waters around Genesee to protect Lake Sturgeon foraging and overwintering habitat (FSI). There are several protected areas which provide moderate protection. Livestock density is moderate and agriculture density ranges from low to high (North Saskatchewan Watershed Alliance 2005). Industrial, municipal and commercial disturbance is high in approximately 30% of this HUC (North Saskatchewan

Watershed Alliance 2005). There are three contaminated sites listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC has been ranked MEDIUM vulnerability (AESRD 2010b). EXTREME. *Threat Risk: High*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): KNOWN – Phosphorous Runoff Coefficient = 2.51 (ALCES Online ©). HIGH. *Threat Risk: High*

45. HUC8: 11020102 – Wolf Creek

Competition and Hybridization with Brook Trout: REMOTE – The carrying capacity loss due to Brook Trout was estimated at 0% (FSI). Few Brook Trout are present in this HUC and Bull Trout are considered to be functionally extirpated (FSI). HIGH. *Threat Risk: Low*

Competition with Lake Trout: REMOTE – The carrying capacity loss due to Lake Trout was estimated at 0% (FSI). HIGH. *Threat Risk: Low*

Mortality: KNOWN – This HUC is within 150 km of Edmonton. An extensive network of paved and gravel roads provides access to most streams. Angling mortality was estimated at 10%. FSI; HIGH. *Threat Risk: High*

Habitat Fragmentation – Culverts (Road Crossing Density): REMOTE – Road crossing density = 0.084 crossings/km2 (FSI based on GIS). HIGH. *Threat Risk: Low*

Habitat Fragmentation – Dams and Weirs: REMOTE – One industrial water supply dam is located in this HUC (Table 7). Bull Trout migration and genetic data do not indicate an impact. EXTREME. *Threat Risk: Low*

Habitat Fragmentation – Irrigation Canals: UNLIKELY – According to land use maps, agriculture density is medium throughout approximately 50% of this HUC and low in the remainder (North Saskatchewan Watershed Alliance 2005). HIGH. *Threat Risk: Medium*

Alteration of Natural Flow Regimes: LIKELY – Information on flow regimes was not readily available. Assumed to be similar to HUC8: 11010101 (peak summer flows have been decreased and minimum winter flows increased by water releases from the Bighorn and Brazeau dams [North Saskatchewan Watershed Alliance 2005]). HIGH. *Threat Risk: High*

Suspended and Deposited Sediment (Sediment Load and J. Reilly, AEP, pers. comm.): UNLIKELY – Sediment Index = 1.16. HIGH. *Threat Risk: Medium*

Alteration of Stream Temperature (Mean August Air Temperature and J. Reilly, AEP, pers. comm.): UNLIKELY – Mean August air temperature = 14.34 ºC (ALCES Online ©). Current average summer air temperature (2000–2010) for HUC = 14.1 ºC. Historical average summer air temperature (1901–1930) = 13.4 ºC. FSI; EXTREME. *Threat Risk: Medium*

Alteration of Groundwater Quality or Quantity: UNLIKELY – There are 19 groundwater springs in this HUC (according to GIS data). Approximately 20% of the land is privately owned and 80% is provincial crown land; there are no Class A waters (FSI). The Horseshoe Creek Natural Area (325.7 ha) provides minimal protection. Agriculture density is medium throughout approximately 50% of this HUC and low in the remainder (North Saskatchewan Watershed Alliance 2005). Industrial, municipal and commercial disturbance is high in the southern end of the HUC (North Saskatchewan Watershed Alliance 2005). There is one contaminated site listed in the Federal Contaminated Sites Inventory. The majority of groundwater in this HUC has been ranked MEDIUM vulnerability (AESRD 2010b). EXTREME. *Threat Risk: Medium*

Nutrient Loading (Phosphorous Runoff Coefficient and J. Reilly, AEP, pers. comm.): LIKELY – Phosphorous Runoff Coefficient = 1.86 (ALCES Online ©). HIGH. *Threat Risk: High*

APPENDIX 2

Appendix 2. Table 1. HUC-level Threat Likelihood, Threat Severity, Causal Certainty, Threat Risk, Threat Occurrence, Threat Frequency, and Threat Extent. Contaminants and Toxic Substances – assessed at Watershed and DU levels only, Climate Change – assessed at DU level only, and Cumulative Impacts (multiplicative integrated effect) – assessed at DU level only. Medium (MED), Very High (V High), Extreme (EX), Continuous (CONT), Recurrent (REC), Historical (HIST), Extensive (EXT), Single (SIN), Current (CUR), Anticipatory (ANT).

1. Oldman Mountain Sub-basin / HUC 08: 04010101 (Upper Oldman River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Likely	High	High	High	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Likely	High	High	High	CUR	CONT	Broad
Dams and Weirs	Known	EX	V High	High	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Likely	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Likely	High	High	High	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Likely	EX	High	High	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Likely	EX	Med	MED	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

2. Oldman Mountain Sub-basin / HUC 08: 04010102 (Crowsnest River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Unlikely	High	High	MED	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Likely	High	High	High	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Unlikely	High	High	MED	CUR	CONT	Broad
Dams and Weirs	Known	EX	V High	High	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Unlikely	High	High	MED	CUR	REC	Broad
Suspended and Deposited Sediments	Unlikely	High	High	MED	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Unlikely	EX	High	High	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Unlikely	EX	Med	MED	CUR	SIN/REC	EXT
Nutrient Loading	Unlikely	High	High	MED	CUR/ANT	REC	Broad

3. Oldman Mountain Sub-basin / HUC 08: 04010103 (Castle River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Unlikely	High	High	MED	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Likely	High	High	High	CUR	CONT	Broad
Dams and Weirs	Remote	EX	V High	Low	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Remote	High	High	Low	CUR	REC	Broad
Suspended and Deposited Sediments	Likely	High	High	High	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Likely	EX	High	High	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Unlikely	EX	MED	MED	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

4. Oldman Mountain Sub-basin / 04010104 (Pincher Creek)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Unlikely	High	High	MED	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Unlikely	High	High	MED	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Likely	High	High	High	CUR	CONT	Broad
Dams and Weirs	Remote	EX	V High	Low	HIST/CUR	CONT	EXT
Irrigation Canals	Likely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Known	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Likely	High	High	High	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Likely	EX	MED	High	CUR/ANT	SIN/REC	EXT
Nutrient Loading	Likely	High	High	High	CUR/ANT	REC	Broad

5. Oldman Foothills Sub-basins / 04010105 (Oldman River below Oldman Reservoir)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Unlikely	High	High	MED	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Unlikely	High	High	MED	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Unlikely	High	High	MED	CUR	CONT	Broad
Dams and Weirs	Known	EX	V High	High	HIST/CUR	CONT	EXT
Irrigation Canals	Likely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Known	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Likely	High	High	High	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Unlikely	EX	MED	MED	CUR	SIN/REC	EXT
Nutrient Loading	Likely	High	High	High	CUR/ANT	REC	Broad

6. Oldman Foothills Sub-basins / 04010201 (Willow Creek)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Likely	High	High	High	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Unlikely	High	High	MED	CUR	CONT	Broad
Dams and Weirs	Known	EX	V High	High	HIST/CUR	CONT	EXT
Irrigation Canals	Likely	MED	MED	MED	CUR	CONT	Narrow

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Known	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Likely	High	High	High	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Unlikely	EX	MED	MED	CUR	SIN/REC	EXT
Nutrient Loading	Unlikely	High	High	MED	CUR/ANT	REC	Broad

7. Oldman Southern Tributary Sub-basins / HUC 08: 04010301 (Belly River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Unlikely	High	High	MED	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Likely	High	High	High	CUR	CONT	Broad
Dams and Weirs	Known	EX	V High	High	HIST/CUR	CONT	EXT
Irrigation Canals	Likely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Known	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Known	High	High	High	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Unlikely	EX	High	MED	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Unlikely	EX	MED	MED	CUR	SIN/REC	EXT
Nutrient Loading	Likely	High	High	High	CUR/ANT	REC	Broad

8. Oldman Southern Tributary Sub-basins / HUC 08: 04010302 (Waterton River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Unlikely	High	High	MED	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Likely	High	High	High	CUR	CONT	Broad
Dams and Weirs	Likely	EX	V High	High	HIST/CUR	CONT	EXT
Irrigation Canals	Likely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Known	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Likely	High	High	High	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Unlikely	EX	High	MED	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Unlikely	EX	MED	MED	CUR	SIN/REC	EXT
Nutrient Loading	Unlikely	High	High	MED	CUR/ANT	REC	Broad

9. Oldman Southern Tributary Sub-basins / HUC 08: 04010401 (St. Mary River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Unlikely	High	High	MED	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Likely	High	High	High	CUR	CONT	Broad
Dams and Weirs	Known	EX	V High	High	HIST/CUR	CONT	EXT
Irrigation Canals	Likely	MED	MED	MED	CUR	CONT	Narrow

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Unlikely	High	High	MED	CUR	REC	Broad
Suspended and Deposited Sediments	Known	High	High	High	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Unlikely	EX	High	MED	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Unlikely	EX	MED	MED	CUR	SIN/REC	EXT
Nutrient Loading	Likely	High	High	High	CUR/ANT	REC	Broad

10. Bow River Basin - Reach 1 / HUC 08: 04020101 (Upper Bow River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Unlikely	High	High	MED	CUR	CONT	Broad
Competition with Lake Trout	Unlikely	High	High	MED	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Remote	High	High	Low	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Remote	High	High	Low	CUR	CONT	Broad
Dams and Weirs	Remote	EX	V High	Low	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Remote	High	High	Low	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Remote	EX	MED	Low	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

11. Bow River Basin - Reach 1 / HUC 08: 04020201 (Brewster Creek)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Remote	High	High	Low	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Remote	High	High	Low	CUR	CONT	Broad
Dams and Weirs	Remote	EX	V High	Low	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Remote	High	High	Low	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Remote	EX	MED	Low	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

12. Bow River Basin - Reach 1 / HUC 08: 04020301 (Spray Lakes River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Likely	High	High	High	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Remote	High	High	Low	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Remote	High	High	Low	CUR	CONT	Broad
Dams and Weirs	Unlikely	EX	V High	MED	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Known	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Remote	EX	MED	Low	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

13. Bow River Basin - Reach 1 / HUC 08: 04020501 (Cascade River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Remote	High	High	Low	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Remote	High	High	Low	CUR	CONT	Broad
Dams and Weirs	Likely	EX	V High	High	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Known	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Remote	EX	MED	Low	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

14. Bow River Basin - Reach 3 / HUC 08: 04020401 (Bow River and Ghost Reservoir)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Known	High	High	High	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Likely	High	High	High	CUR	CONT	Broad
Dams and Weirs	Likely	EX	V High	High	HIST/CUR	CONT	EXT
Irrigation Canals	Likely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Known	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Unlikely	EX	MED	MED	CUR	SIN/REC	EXT
Nutrient Loading	Unlikely	High	High	MED	CUR/ANT	REC	Broad

15. Bow River Basin - Reach 3 / HUC 08: 04020601 (Kananaskis River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Likely	High	High	High	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Remote	High	High	Low	CUR	CONT	Broad
Dams and Weirs	Likely	EX	V High	High	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Known	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Unlikely	EX	MED	MED	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

16. Bow River Basin - Reach 3 / HUC 08: 04020701 (Ghost River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Known	High	High	High	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Remote	High	High	Low	CUR	CONT	Broad
Dams and Weirs	Likely	EX	V High	High	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Known	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Likely	EX	MED	High	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

17. Bow River Basin - Reach 3 / HUC 08: 04020801 (Bow River and Bighill Creek)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Remote	High	High	Low	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Likely	High	High	High	CUR	CONT	Broad
Dams and Weirs	Likely	EX	V High	High	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Known	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Likely	High	High	High	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Unlikely	EX	High	MED	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Likely	EX	MED	High	CUR	SIN/REC	EXT
Nutrient Loading	Known	High	High	High	CUR/ANT	REC	Broad

18. Bow River Basin - Reach 3 / HUC 08: 04020802 (Jumpingpound Creek)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Known	High	High	High	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Remote	High	High	Low	CUR	CONT	Broad
Dams and Weirs	Likely	EX	V High	High	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Unlikely	High	High	MED	CUR	REC	Broad
Suspended and Deposited Sediments	Unlikely	High	High	MED	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Likely	EX	MED	High	CUR	SIN/REC	EXT
Nutrient Loading	Unlikely	High	High	MED	CUR/ANT	REC	Broad

19. Bow River Basin - Elbow River Sub-basin / HUC 08: 04021001 (Elbow River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Known	High	High	High	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Unlikely	High	High	MED	CUR	CONT	Broad
Dams and Weirs	Unlikely	EX	V High	MED	HIST/CUR	CONT	EXT
Irrigation Canals	Likely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Known	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Unlikely	High	High	MED	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Likely	EX	MED	High	CUR	SIN/REC	EXT
Nutrient Loading	Unlikely	High	High	MED	CUR/ANT	REC	Broad

20. Bow River Basin - Fish Creek Sub-basin / HUC 08: 04021101 (Fish Creek)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Remote	High	High	Low	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Known	High	High	High	CUR	CONT	Broad
Dams and Weirs	Remote	EX	V High	Low	HIST/CUR	CONT	EXT
Irrigation Canals	Likely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Unknown	High	High	Unknown	CUR	REC	Broad
Suspended and Deposited Sediments	Likely	High	High	High	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Unlikely	EX	High	MED	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Likely	EX	MED	High	CUR	SIN/REC	EXT
Nutrient Loading	Likely	High	High	High	CUR/ANT	REC	Broad

21. Bow River Basin - Highwood and Sheep River Sub-basins / HUC 08: 04021201 (Highwood River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Known	High	High	High	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Unlikely	High	High	MED	CUR	CONT	Broad
Dams and Weirs	Unlikely	EX	V High	MED	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Known	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Likely	High	High	High	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Likely	EX	Med	High	CUR	SIN/REC	EXT
Nutrient Loading	Unlikely	High	High	MED	CUR/ANT	REC	Broad

22. Bow River Basin - Highwood and Sheep River Sub-basins / HUC 08: 04021202 (Sheep River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Known	High	High	High	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Likely	High	High	High	CUR	CONT	Broad
Dams and Weirs	Unlikely	EX	V High	MED	HIST/CUR	CONT	EXT
Irrigation Canals	Likely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Unlikely	High	High	MED	CUR	REC	Broad
Suspended and Deposited Sediments	Unlikely	High	High	MED	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Likely	EX	Med	High	CUR	SIN/REC	EXT
Nutrient Loading	Unlikely	High	High	MED	CUR/ANT	REC	Broad

23. Red Deer River Basin / HUC 08: 08010101 (Upper Red Deer River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Unlikely	High	High	MED	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Unlikely	High	High	MED	CUR	CONT	Broad
Dams and Weirs	Remote	EX	V High	Low	HIST/CUR	CONT	EXT
Irrigation Canals	Likely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Unlikely	High	High	MED	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Likely	EX	MED	High	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

24. Red Deer River Basin / HUC 08: 08010102 (Panther River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Remote	High	High	Low	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Remote	High	High	Low	CUR	CONT	Broad
Dams and Weirs	Remote	EX	V High	Low	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Known	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Remote	EX	MED	Low	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

25. Red Deer River Basin / HUC 08: 08010103 (Fallentimber Creek)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Likely	High	High	High	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Unlikely	High	High	MED	CUR	CONT	Broad
Dams and Weirs	Remote	EX	V High	Low	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Likely	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Unlikely	EX	MED	MED	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

26. Red Deer River Basin / HUC 08: 08010104 (James River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Likely	High	High	High	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Likely	High	High	High	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Unlikely	High	High	MED	CUR	CONT	Broad
Dams and Weirs	Remote	EX	V High	Low	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Unlikely	High	High	MED	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Remote	EX	MED	Low	CUR	SIN/REC	EXT
Nutrient Loading	Unlikely	High	High	MED	CUR/ANT	REC	Broad

27. Red Deer River Basin / HUC 08: 08010201 (Red Deer River and Gleniffer Lake)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Known	High	High	High	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Unlikely	High	High	MED	CUR	CONT	Broad
Dams and Weirs	Remote	EX	V High	Low	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Known	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Unlikely	EX	High	MED	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Unlikely	EX	MED	MED	CUR	SIN/REC	EXT
Nutrient Loading	Known	High	High	High	CUR/ANT	REC	Broad

28. Red Deer River Basin / HUC 08: 08010202 (Raven River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Unlikely	High	High	MED	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Known	High	High	High	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Unlikely	High	High	MED	CUR	CONT	Broad
Dams and Weirs	Remote	EX	V High	Low	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Likely	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Unlikely	EX	High	MED	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Unlikely	EX	MED	MED	CUR	SIN/REC	EXT
Nutrient Loading	Likely	High	High	High	CUR/ANT	REC	Broad

29. Red Deer River Basin / HUC 08: 08010203 (Little Red Deer River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Unlikely	High	High	MED	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Likely	High	High	High	CUR	CONT	Broad
Dams and Weirs	Remote	EX	V High	Low	HIST/CUR	CONT	EXT
Irrigation Canals	Likely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Likely	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Unlikely	High	High	MED	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Unlikely	EX	High	MED	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Likely	EX	MED	High	CUR	SIN/REC	EXT
Nutrient Loading	Known	High	High	High	CUR/ANT	REC	Broad

30. North Saskatchewan – Cline Sub-basin / 11010101 (North Saskatchewan above Abraham)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Unlikely	High	High	MED	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Remote	High	High	Low	CUR	CONT	Broad
Dams and Weirs	Unlikely	EX	V High	MED	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Known	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Remote	EX	MED	Low	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

31. North Saskatchewan – Cline Sub-basin / 11010102 (Siffleur River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Remote	High	High	Low	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Remote	High	High	Low	CUR	CONT	Broad
Dams and Weirs	Unlikely	EX	V High	MED	HIST/CUR	CONT	EXT
Irrigation Canals	Remote	MED	MED	Low	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Remote	High	High	Low	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Remote	EX	MED	Low	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

32. North Saskatchewan – Cline Sub-basin / 11010103 (Cline River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Remote	High	High	Low	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Remote	High	High	Low	CUR	CONT	Broad
Dams and Weirs	Remote	EX	V High	Low	HIST/CUR	CONT	EXT
Irrigation Canals	Remote	MED	MED	Low	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Remote	High	High	Low	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Remote	EX	MED	Low	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

33. North Saskatchewan – Ram Sub-basin / HUC 08: 11010201 (North Saskatchewan below Abraham)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Unlikely	High	High	MED	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Remote	High	High	Low	CUR	CONT	Broad
Dams and Weirs	Unlikely	EX	V High	MED	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Known	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Likely	EX	MED	High	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

34. North Saskatchewan – Ram Sub-basin / HUC 08: 11010202 (Ram River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Unlikely	High	High	MED	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Remote	High	High	Low	CUR	CONT	Broad
Dams and Weirs	Remote	EX	V High	Low	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Remote	High	High	Low	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Unlikely	EX	MED	MED	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

35. North Saskatchewan – Ram Sub-basin / HUC 08: 11010203 (Baptiste River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Unlikely	High	High	MED	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Remote	High	High	Low	CUR	CONT	Broad
Dams and Weirs	Likely	EX	V High	High	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Unlikely	High	High	MED	CUR	REC	Broad
Suspended and Deposited Sediments	Unlikely	High	High	MED	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Unlikely	EX	High	MED	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Unlikely	EX	MED	MED	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

36. North Saskatchewan – Clearwater Sub-basin / HUC 08: 11010301 (Clearwater River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Unlikely	High	High	MED	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Remote	High	High	Low	CUR	CONT	Broad
Dams and Weirs	Remote	EX	V High	Low	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Unlikely	High	High	MED	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Unlikely	EX	MED	MED	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

37. North Saskatchewan – Clearwater Sub-basin / HUC 08: 11010302 (Prairie Creek)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Known	High	High	High	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Unlikely	High	High	MED	CUR	CONT	Broad
Dams and Weirs	Remote	EX	V High	Low	HIST/CUR	CONT	EXT
Irrigation Canals	Likely	MED	MED	High	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Likely	High	High	MED	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Unlikely	EX	MED	MED	CUR	SIN/REC	EXT
Nutrient Loading	Unlikely	High	High	MED	CUR/ANT	REC	Broad

38. North Saskatchewan – Brazeau Sub-basin / HUC 08: 11010401 (Brazeau River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Remote	High	High	Low	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Remote	High	High	Low	CUR	CONT	Broad
Dams and Weirs	Remote	EX	V High	Low	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Unlikely	High	High	MED	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Remote	EX	MED	Low	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

39. North Saskatchewan – Brazeau Sub-basin / HUC 08: 11010402 (Cardinal River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Unlikely	High	High	Low	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Unlikely*	High	High	MED	CUR	CONT	Broad
Dams and Weirs	Remote	EX	V High	Low	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Unlikely	High	High	MED	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote†	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Remote	EX	MED	Low	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

*Based on Road Density rather than Road Crossing Density (Road Crossing Density not available)
† Based on Average Summer Air Temperature (2000–2010 vs 1901–1930; Mean August Air Temperature not available)

40. North Saskatchewan – Brazeau Sub-basin / HUC 08: 11010403 (Blackstone River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Remote	High	High	Low	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Remote	High	High	Low	CUR	CONT	Broad
Dams and Weirs	Remote	EX	V High	Low	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Unlikely	High	High	MED	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Unlikely	EX	MED	MED	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

41. North Saskatchewan – Brazeau Sub-basin / HUC 08: 11010404 (Elk River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Unlikely	High	High	MED	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Remote	High	High	Low	CUR	CONT	Broad
Dams and Weirs	Likely	EX	V High	High	HIST/CUR	CONT	EXT
Irrigation Canals	Likely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Unlikely	High	High	MED	CUR	REC	Broad
Suspended and Deposited Sediments	Unlikely	High	High	MED	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Likely	EX	MED	High	CUR	SIN/REC	EXT
Nutrient Loading	Unlikely	High	High	MED	CUR/ANT	REC	Broad

42. North Saskatchewan – Brazeau Sub-basin / HUC 08: 11010405 (Brazeau Canal)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Known	High	High	High	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Remote	High	High	Low	CUR	CONT	Broad
Dams and Weirs	Likely	EX	V High	High	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Known	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Likely	EX	High	High	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Remote	EX	MED	Low	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

43. North Saskatchewan – Brazeau Sub-basin / HUC 08: 11010406 (Nordegg River)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Unlikely	High	High	MED	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Remote	High	High	Low	CUR	CONT	Broad
Dams and Weirs	Unlikely	EX	V High	MED	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Unlikely	High	High	MED	CUR	REC	Broad
Suspended and Deposited Sediments	Remote	High	High	Low	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Remote	EX	High	Low	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Unlikely	EX	MED	MED	CUR	SIN/REC	EXT
Nutrient Loading	Remote	High	High	Low	CUR/ANT	REC	Broad

44. North Saskatchewan – Modeste Sub-basin / HUC 08: 11020101 (North Saskatchewan above Wabamun)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Known	High	High	High	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Likely	High	High	High	CUR	CONT	Broad
Dams and Weirs	Remote	EX	V High	Low	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Known	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Unlikely	High	High	MED	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Likely	EX	High	High	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Likely	EX	MED	High	CUR	SIN/REC	EXT
Nutrient Loading	Known	High	High	High	CUR/ANT	REC	Broad

45. North Saskatchewan – Modeste Sub-basin / HUC 08: 11020102 (Wolf Creek)

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Competition and Hybridization with Brook Trout	Remote	High	High	Low	CUR	CONT	Broad
Competition with Lake Trout	Remote	High	High	Low	CUR	CONT	Broad
Mortality (e.g., angling, scientific sampling)	Known	High	High	High	HIST/CUR	REC	Broad
Habitat Fragmentation							
Culverts (Road Density Proxy)	Remote	High	High	Low	CUR	CONT	Broad
Dams and Weirs	Remote	EX	V High	Low	HIST/CUR	CONT	EXT
Irrigation Canals	Unlikely	MED	MED	MED	CUR	CONT	Narrow

THREAT	Likelihood	Severity	Causal Certainty	Threat Risk	Threat occurrence	Threat Frequency	Threat Extent
Habitat Alteration							
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	Likely	High	High	High	CUR	REC	Broad
Suspended and Deposited Sediments	Unlikely	High	High	MED	CUR	REC	Broad
Alteration of Stream Temperature (change from natural) (Summer Air Temperature Proxy)	Unlikely	EX	High	MED	CUR	CONT	Broad
Alteration of Groundwater Quantity or Quality	Unlikely	EX	MED	MED	CUR	SIN/REC	EXT
Nutrient Loading	Likely	High	High	High	CUR/ANT	REC	Broad