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MEMORANDUM

TO: **Nechako Water Engagement Initiative**

FROM: **Heidi Regehr, Ph.D., R.P.Bio. and Jayson Kurtz, B.Sc., R.P.Bio, P.Biol, Ecofish Research, Ltd.**

DATE: **December 7, 2022**

FILE: **1316-09**

RE: **Review of Flow Effects on Nechako River Wildlife**

1. INTRODUCTION

During Main Table and Technical Working Group (TWG) meetings of the Nechako Water Engagement Initiative (WEI), concerns were raised about potential effects of operational activities associated with water management in the Nechako River on wildlife. The TWG asked Ecofish Research Ltd (Ecofish) to review scientific studies and other information and summarize key factors for WEI consideration on how Rio Tinto Alcan (RTA) operations affect wildlife associated with the Nechako River. Separate investigations of wildlife issues related to water level management within the Nechako Reservoir have already been completed (Regehr and Kurtz 2022; Regehr *et al.* 2021).

Water management by RTA causes flow changes in the Nechako River which has the potential to affect wildlife using the river or adjacent habitat. Wildlife could be directly or indirectly affected if flow or water levels in the river interact with individuals, their habitats, or their key resources. Four potential issues were raised by the TWG that are related to flows/water levels in the Nechako River potentially affecting wildlife during vulnerable time periods (i.e., vulnerable or limiting life history periods) or wildlife habitat. These were key considerations in this assessment, although the potential for additional issues was also investigated. The four potential issues identified by the TWG are:

- Rising water levels in the Nechako River can cause inundation of American Beaver (*Castor canadensis*) dens;
- Rising water levels can cause inundation of bird nests that are on or near the ground;
- Dropping water levels can expose bird nests to predation; and
- Changes in flow/water levels affect hydraulic connectivity to riparian habitat, which can affect habitat availability or suitability for wildlife.

The objective of this assessment was to identify and evaluate potential effects on wildlife that may result from water management in the Nechako River and to investigate and prioritize identified issues to inform water management decisions. Results of this assessment are intended to lead to the development of performance measures that will incorporate key wildlife issues into the evaluation of trade-offs during the structured decision-making water use planning process.

The assessment was conducted through a literature review during which potential wildlife issues were identified and information needed for evaluation of potential effects was compiled. Following this, wildlife issues were evaluated, data gaps were identified, issues were prioritized, and recommendations were made regarding improvement of confidence in the assessment or performance measures that could potentially be used to incorporate wildlife issues into the evaluation of trade-offs during the water use planning process. It should be noted that when issues were identified for which the pathways of effects are being investigated as independent topics (e.g., effects of water management on fish can indirectly affect fish-eating wildlife species; however, fish are being assessed separately), such issues were identified but were not assessed in detail here, given that an evaluation specific to such issues is being conducted elsewhere.

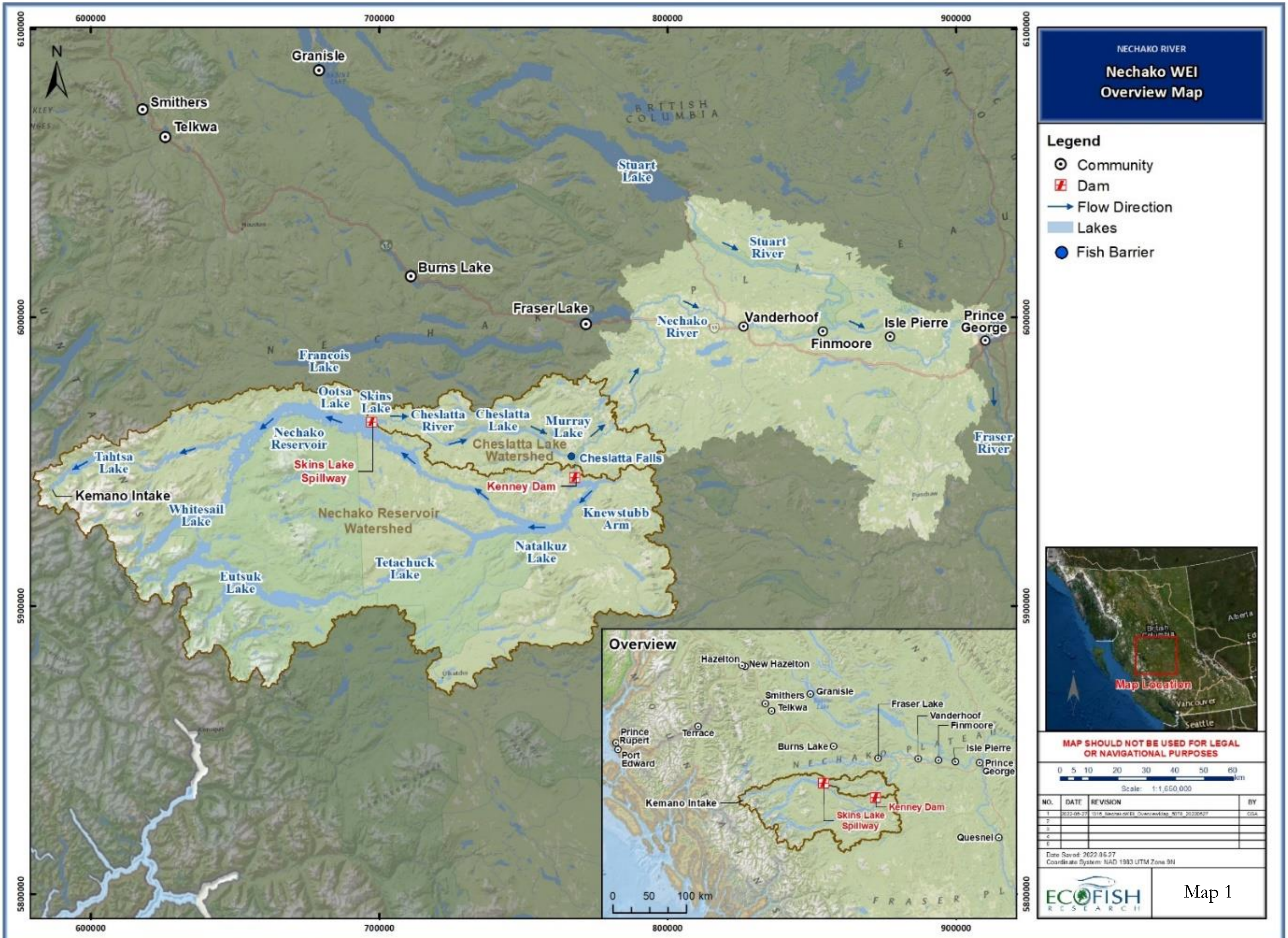
2. BACKGROUND

2.1. Nechako Watershed

The Nechako Reservoir is located approximately 200 km west of Prince George, BC and was created to provide water for Rio Tinto Alcan's (RTA) Kemano Hydroelectric Project, which was constructed in the 1950s to provide energy to operate an aluminium smelter in Kitimat, BC. The reservoir was formed by the construction of the Kenney Dam on the Nechako River (at the east end of the reservoir), which inundated a chain of six major lake and river systems (Ootsa, Whitesail, Knewstubb, Tetachuck, Natalkuz, and Tahtsa, ~420 km total length). The Nechako Reservoir is ~910 km^2 with a normal annual drawdown of ~3m (10'); low water is in late spring and high water occurs in late summer.

There are two reservoir outflows. The powerhouse intake portal on Tahtsa Lake diverts ~70% of the annual reservoir inflow 16 km west into the Kemano River watershed. The Skins Lake Spillway on Ootsa Lake diverts the remaining flow (~75 m^3/s mean annual discharge 1990-2022) ~80 km through the Cheslatta River and Skins Lake, Cheslatta Lake, and Murray Lake before discharging into the Nechako River at Cheslatta Falls (Map 1). There is no discharge facility at the Kenney Dam.

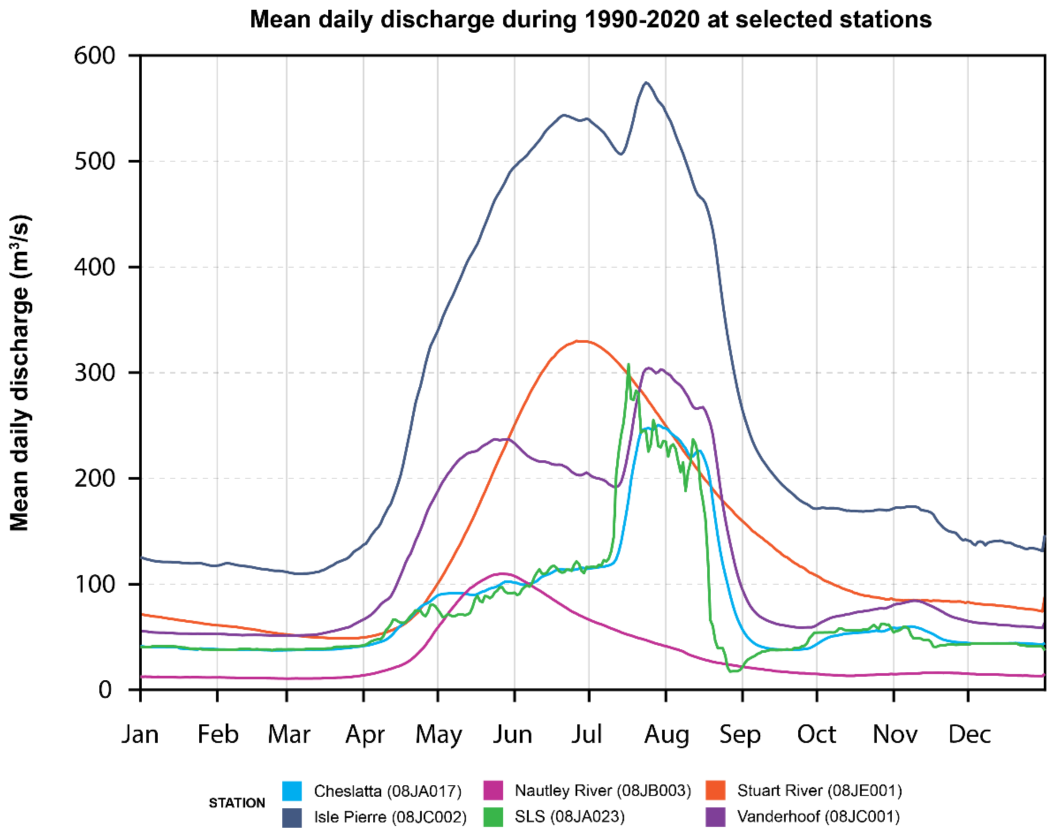
The Nechako Reservoir provides the majority of flow in the upper Nechako River (there is minimal local inflow); here, flow is reduced to ~30% of pre-dam conditions and mean flow ranges from ~40 to 240 m^3/s (Figure 1). The Nautley River (~95 km downstream of the dam) and local inflow contribute moderately and at Vanderhoof (~150 km downstream of the dam) mean flows range from ~65 to 270m^3/s. The Stuart River contributes significant inflow, and by Isle Pierre (~215 km downstream of the dam) mean flows range from ~120 to 560 m^3/s. The Nechako River flows into the Fraser River at Prince George ~275 km downstream of the dam. A detailed description of Nechako watershed hydrology is provided in a stand-alone memo (Beel *et al.* 2022).



Map 1

Path: M:\Projects-Active\1316\MXD\1316_NechakoWEI_OverviewMap_5078_20220627.mxd

Figure 1. Mean daily discharge for the Nechako River, including major tributaries, between the Nechako Reservoir (Skins Lake Spillway (SLS)) downstream to Isle Pierre.



2.2. Study Area

For the investigation and evaluation of potential wildlife issues related to flow management of the Nechako River, the study area was defined as extending along the Nechako River, from the Nechako-Cheslatta confluence to the confluence of the Nechako River with the Fraser River at Prince George. Wildlife and wildlife habitat associated with aquatic and riparian areas of the Nechako River (jointly referred to here as the Nechako River system) that could be affected by water management were the focus of this assessment. Upland areas were not considered in this assessment because they are usually outside the direct effect of Nechako River flows (see Sections 2.3.1 and 2.5).

2.3. Wildlife Habitat and Species

The Nechako River and adjacent riparian and upland areas have been reported to support a diverse wildlife community (Envirocon 1984). However, few detailed studies are available for the Nechako River system from which information on wildlife abundances and population trends, or specific breeding sites or important habitats, may be identified. Two studies provided information on numbers and distribution of wildlife species in the Nechako River and surrounding riparian and upland areas: 1) baseline studies were conducted for the proposed Kemano Completion Hydroelectric Development from 1978 to 1982 (Envirocon 1984); and 2) a study was conducted on piscivorous birds on the Nechako River in 1991 (Brown *et al.* 1995). Additional detailed information is available for American Beaver and Common Muskrat (*Ondatra zibethicus*) in the Nechako River within two known reports (Hatler 1998[1], Hatler 2002[2]) and the furbearer management guidelines[3]; however, the two Hatler reports could not be located for this assessment. Background information obtained during this review on wildlife habitat and wildlife species is summarized below, along with an overview of key wildlife management concerns related to Nechako River water management.

2.3.1. Wildlife Habitat

Riparian and aquatic habitat within the Nechako River system have been described, at high level, for baseline studies conducted for the proposed Kemano Completion Hydroelectric Development (Envirocon 1984). Although this information is dated and changes to the landscape have taken place, a review of satellite imagery (Google Earth) and provincial mapping layers (GeoBC 2022) suggests that this description generally still applies (e.g., presence of vegetated riparian strips, tree and shrub species present in riparian areas, presence of instream islands, relevant land uses in upland areas).

As described in Envirocon (1984), riparian habitat adjacent to the Nechako River is generally rich and well-developed. In many locations, there is a forested strip along the high water mark, that includes balsam poplar (*Populus balsamifera*) or trembling aspen (*Populus tremuloides*), and an understory containing willow (*Salix* sp.), red alder (*alnus rubra*), or red-osier dogwood (*Cornus sericea*). Some higher sand or gravel bars also support willows and herbaceous vegetation, and balsam poplar stands occur on portions of floodplains and islands. Riparian areas generally provide foraging habitat for mammals, such as Moose (*Alces americanus*), Mule Deer (*Odocoileus hemionus*), and mustelids (e.g., Fisher (*Pekania pennanti*), American Mink (*Neovison vison*)), foraging and denning habitat for

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[1] Hatler, D.F. 1998. Status of Nechako River beaver and muskrat populations. Alcan British Columbia, Vanderhoof, BC. Documented cited in: https://www.neef.ca/resources/wildlife-birds-insects.

[2] Hatler, D.F. 2002. Beaver colony dynamics in the upper Nechako River Watershed, British Columbia, 1989-2001. Unpubl. Rep. for Alcan Primary Metal, Kitimat, B.C. 108 p. Documented cited in https://a100.gov.bc.ca/pub/eirs/finishDownloadDocument.do;jsessionid=4DD96D83C4C05F3710E5521A244E8774?subdocumentId=831.

[3] https://paperzz.com/doc/8931923/beaver.

aquatic mammals such as American Beaver, and foraging, nesting, roosting, and migratory staging habitat for birds, such as waterbirds (particularly many species of waterfowl), raptors, and songbirds. Bat species may also use riparian areas for foraging or roosting. The Nechako River Migratory Bird Sanctuary is located along the river north and west of Vanderhoof. This sanctuary was established as an important staging area for waterfowl, especially Canada Goose (*Branta canadensis*) on route to Alaska breeding areas through the Pacific Flyway in spring (see Section 2.3.1).

Instream islands occur in the Nechako River in several locations, which, due to their isolation from the mainland shores and other riparian characteristics, provide valuable habitat for a number of wildlife species during key life stages. These islands are particularly numerous in the braided section of the Nechako River in the vicinity of Vanderhoof, including within the Nechako River Migratory Bird Sanctuary (Government of Canada 2022), but also occur in other locations. Instream islands have been identified as providing resting and gravelling habitat for migrating geese, calving habitat for ungulates, and winter foraging habitat for Moose (Envirocon 1984; Government of Canada 2022). Islands also likely provide nesting habitat for birds, especially for those that can be associated with riverine or riparian habitats (e.g., Canada Goose, some dabbling ducks, some grebes, some songbirds). The islands are shaped by yearly changes in river flows and vary in their degree of vegetation, which ranges from grass-forb to forest (Envirocon 1984; Government of Canada 2022). Some islands were historically kept bare by heavy flows and ice scouring during the spring freshet (Envirocon 1984), although these islands have become grown-over with shrubs in recent years, leaving only beach areas bare, and with little gravel remaining (bare beach areas around islands are now more typically composed of fines; authors and local residents, personal observations). Generally, islands are variously vegetated with herbaceous and shrubby plants or trees, depending on their stability and elevation. Relatively stable islands contain trees such as trembling aspen, lodgepole pine (*Pinus contorta*), and Douglas-fir (*Pseudotsuga menziesii*), and highest elevation islands are vegetated with willow, red alder, black cottonwood (*Populus trichocarpa*), and white spruce (*Picea glauca*) (Envirocon 1984). Shrubs include red alder, willow, and red-osier dogwood.

Aquatic habitat in the Nechako River is mostly found in the single main river channel, although some back and side channels also occur. Water velocity is low since the elevation drop between Cheslatta Falls and Vanderhoof is only 90 m. Many species of fish occur in the Nechako River (including three species of anadromous salmon and a number of resident species), some of which provide prey for fish-eating birds (e.g., Bald Eagle (*Haliaeetus leucocephalus*), Osprey (*Pandion haliaetus*), Common Merganser (*Mergus merganser*), gulls) and mammals (e.g., North American River Otter (*Lontra canadensis*), American Mink). Aquatic invertebrates also provide prey for some waterbirds (e.g., goldeneye (*Bucephala* sp.), Bufflehead (*Bucephala albeola*) and dabbling ducks) and mammals (e.g., American Mink, North American River Otter). In the Envirocon (1984) assessment, the aquatic habitat of the Nechako River was evaluated as "quite good" for aquatic wildlife such as American Beaver and waterfowl. Several wetlands occur adjacent to the Nechako River (e.g., large and small wetlands occur ~20 km south of Fort Fraser), although they are not considered in this assessment (see Section 2.5). However, marshy vegetation (sedges) is reported to occur in wet perimeter of islands and shallow backwaters. Brown *et al.* (1995) noted that marsh vegetation was common in the river margins below Vanderhoof, where the river is wide, deep, and slow flowing. Marsh-type vegetation may also be present in some other areas where there are side channels or backwaters. In the Nechako River Migratory Bird Sanctuary, habitat is currently roughly categorized as: 65% open river, 20% shallow backwaters, 15% islands with riparian shrubs, and 1% gravel-silt bars (Government of Canada 2022).

Diverse upland habitats surround the Nechako River, some of which provide important habitat for wildlife also using riverine or aquatic habitat. In the upstream-most portion of the study area (upstream of Cutoff Creek), upland habitats included forests and agricultural areas (farm and ranch lands). Where forests occur, these contain mostly coniferous species, but downstream of this, mixed forest, aspen stands, and brushland are common, and typical tree species include trembling aspen, lodgepole pine, and Douglas-fir (Envirocon 1984). In general, the diversity of upland habitats (including cultivated lands which provide forage for species such as Canada Geese), and the typically light snowfall in the area, results in high quality wildlife habitat (Envirocon 1984). For example, deciduous stands adjacent to the river provide forage for American Beaver and there is ample forage for Moose, including during winter. In several locations, Moose winter habitat adjacent to the river has been protected within legislated Moose Ungulate Winter Ranges (UWRs), and a relatively large Moose UWR complex extends across the Nechako River in the vicinity of (and encompassing parts of) Hallett and Tahultzu lakes (GeoBC 2022). Smaller Mule Deer UWR have also been established, especially near Fort Fraser and between Vanderhoof and Prince George (GeoBC 2022). Review of satellite imagery indicates that the uplands between Cheslatta Falls and Fort Fraser are mostly forested with patches of cultivated land, the stretch between Fort Fraser and Vanderhoof is mostly agricultural with wide riparian strips adjacent to the river, and east of Vanderhoof, uplands are mostly forested but contain patchy development. Aspen stands are common between Fort Fraser and Vanderhoof, and cultivated land occurs near Swanson Creek, Fort Fraser, and between Braeside and Vanderhoof (Envirocon 1984). Although upland habitats are not directly considered in this assessment (see Section 2.5), the characteristics of upland habitats can affect wildlife use of riparian and aquatic habitats (e.g., Moose are likely to forage in riparian areas given generally high quality habitat in upland areas; cavity nesting birds may nest in upland mixed or aspen forest and may therefore utilize aquatic and riparian habitat in the vicinity; beavers may harvest trees from upland areas).

2.3.2. Wildlife Species

Many wildlife species inhabit that Nechako River system. Information located during this review on abundance and habitat use for ungulates, aquatic mammals, and birds, which are the species groups most relevant to this assessment, are summarized in the sub-sections below.

2.3.2.1. Ungulates

Ungulates common in the study area are Moose and Mule Deer. White-tailed Deer are also known to be present (J. Kurtz, personal observation). Although caribou (*Rangifer tarandus*) inhabit the Nechako Reservoir area (the Tweedsmuir-Entiako caribou subpopulation (Cichowski 2015); discussed in Regehr *et al.* 2021), they do not occur regularly along the Nechako River. Small numbers of Elk (*Cervus elaphus*) may occur near the mouth of the Stuart River (Envirocon 1984; Shackleton 1999) and their range is expanding along the Nechako River (J. Kurtz, personal observation). As described above, Moose habitat has been evaluated as good to excellent in the vicinity of the Nechako River and the species is generally abundant. Moose browse in riparian, as well as upland, habitat and some islands in the Nechako River provide safe calving sites (Envirocon 1984). The area is near the northern limit of regular Mule Deer occurrence on the Interior Plateau of BC and important winter ranges are not associated with the river (Envirocon 1984). However, Mule Deer use riparian and island habitats in summer and some use islands for fawning and escape terrain (Envirocon 1984), and some Mule Deer UWR have been established (described above).

2.3.2.2. Aquatic Mammals

Aquatic mammals present in the area that are associated with riverine habitat include American Beaver and Common Muskrat, as well as aquatic and/or riparian associated mustelids such as North American River Otter, American Mink, and Fisher. Beavers feed on riparian, upland, and aquatic vegetation, muskrats feed mainly on aquatic vegetation (e.g., cattails, bulrushes, horsetails, or pondweeds; although they may also eat small animals such as fish, amphibians, and invertebrates), and river otter and mink typically consume a variety of aquatic wildlife that varies seasonally (e.g., fish, birds, small mammals, amphibians, reptiles, and invertebrates).

Among aquatic mammals, American Beaver is the most common species in the Nechako River system. During baseline studies conducted for the proposed Kemano Completion Hydroelectric Development in 1982 (Envirocon 1984), river surveys were conducted upstream of the Stuart River confluence. Overall, 85 occupied beaver lodges and 64 old, unoccupied lodges were identified along the banks of the Nechako River in this section. Densities were greatest in the middle reaches (south and east of Fort Fraser). Main channel density of occupied lodges per km ranged between 0.13 (downstream of Cheslatta Falls) to 0.7 (east of Fort Fraser), with an average of 0.43 lodges per km for the entire survey area. From this survey, an estimate of 450 to 650 beavers was generated for the Nechako River upstream of the Stuart River confluence. A population estimate generated for approximately the same area using intensive surveys over a 13-year period during a different study found an average of 119 active lodges which was translated to a population averaging 595 beavers[4]. Envirocon (1984) noted that beavers are also likely common along low gradient tributaries, and that there would be an interchange between individuals in the tributaries and those in the Nechako River.

North American River Otters were documented throughout the system during Envirocon (1984) surveys and research is being conducted on predation by river otters on White Sturgeon as part of the Nechako White Sturgeon Recovery Initiative (NWSRI; 2021). Envirocon (1984) considered American Mink likely to occur in riparian habitats; Common Muskrats were thought to occur primarily in marshes and ponds away from the river, but occasionally were found in quiet backwaters of the river.

2.3.2.3. Birds

Many species of birds breed in and along the Nechako River or stage there during migration. Of particular note are Canada Geese, which stage in large numbers in the Nechako River Migratory Bird Sanctuary and adjacent areas during migration. The Nechako River Migratory Bird Sanctuary (established in 1944) extends for approximately 4 km upstream of Vanderhoof. It was established due to the importance of the area for staging of northward migrating Canada Geese on the Pacific Flyway in spring. Currently, an estimated 50,000 to 75,000 geese migrate through the sanctuary and the Okanagan Valley each spring on their way to breeding areas (Government of Canada 2022). Some variations in numbers have been documented over the last fifty years, with lowest numbers documented during the 1970s. The geese generally forage in upland agricultural areas (particularly hayfields) and have been documented to use the islands/bars to rest and ingest gravel (which aids in digestion) (Envirocon 1984; Government of Canada 2022), although these islands have become grown-over with shrubs in recent years. They also rest on the water which is slow-moving in this heavily braided section of the river (Envirocon 1984). At least five races of Canada Goose are known to use the area, including the medium-sized birds that breed in the interior of BC and the smaller races that breed in Alaska. Overall, three key features important for migrating Canada Geese were identified for the sanctuary area in the baseline studies conducted for the proposed Kemano Completion Hydroelectric Development (Envirocon 1984): island bars (for resting and ingesting gravel), slow river water (for resting), and nearby cultivated farmlands (for foraging). Canada Geese also utilize the Nechako River during fall migration, although these individuals are mainly of the larger race that nests in the interior of BC because the birds that breed in Alaska use a different route to return to southern breeding areas in fall than they use to travel to breeding areas in spring (Belrose 1976). Over

[4] Government of British Columbia. Furbearer Management Guidelines: Beaver, *Castor canadensis*. Available online at: https://a100.gov.bc.ca/pub/eirs/. Accessed on April 12, 2022. Likely source of this information is Hatler 2002 (see Section 2.3).

1,500 geese were recorded by Envirocon (1984) on October 6, 1979, and 1,017 were counted on October 12, 1982; 4,366 were counted by Brown *et al.* (1995) on October 3 to 13, 1991.

Although Canada Geese are the most numerous species of waterfowl during migratory periods, other species of waterfowl also use the Nechako River as a stopover location, in both spring and fall. Greatest numbers have been reported by Envirocon (1984) and Brown *et al.* (1995) for Common Merganser (*Mergus merganser*), Mallard (*Anas platyrhynchos*), American Wigeon (*Mareca americana*), goldeneye, Blue-winged (*Spatula discors*) and Green-winged (*Anas crecca*) teal, and scaup/Ring-necked Duck (*Aythya* sp.) (Envirocon 1984; Brown *et al.* 1995). Brown *et al.* (1995) counted 2,178 Mallard, 238 Common Merganser, 50 teal, and 18 American Wigeon in October of 1991 between Cheslatta Falls and the Stuart River confluence. Envirocon (1984) documented 175 Mallard, 43 American Wigeon, 28 Green-winged Teal, 54 Common Merganser, and 8 goldeneye (among others) in October 1982. Other species of birds have also been observed during migration periods, including seabirds (gulls), shorebirds (e.g., Lesser Yellowlegs (*Tringa flavipes*)), grebes, loons, and swans (Trumpeter Swans (*Cygnus buccinator*), Tundra Swans (*Cygnus columbianus*)). A variety of songbirds also use the area on migration.

The main water-associated birds that likely breed along the Nechako River include: 1) waterfowl (which includes dabbling ducks (e.g., Mallard, American Wigeon, Northern Shoveler (*Spatula clypeata*), Blue-winged Teal, Green-winged Teal, Pintail (*Anas acuta*)), diving species (e.g., Bufflehead, goldeneye, Common Merganser, Hooded Merganser (*Lophodytes cucullatus*), Common Loon (*Gavia immer*)), and Canada Goose); 2) seabirds (Mew Gull (*Larus brachyrhynchus*), Herring Gull (*Larus argentatus*), Bonaparte's Gull (*Chroicocephalus philadelphia*)); 3) shorebirds (e.g., Spotted Sandpiper (*Actitis macularius*), Killdeer (*Charadrius vociferus*), Greater Yellowlegs (*Tringa melanoleuca*), Lesser Yellowlegs); 4) raptors (Osprey and Bald Eagle); and 5) songbirds (passerines) that are associated with water or riparian habitat (see Section 4.4.1). In general, for species for which breeding on the Nechako River has been confirmed (through the presence of broods or nests), specific nest site locations have not been reported. Exceptions are Bald Eagle and Osprey for which nests, as well as individuals, have been documented (see below).

The most common breeding waterfowl documented on the river have been Common Merganser, goldeneye, and Mallard. During baseline studies conducted for the proposed Kemano Completion Hydroelectric Development (Envirocon 1984), 18 Common Merganser, 22 goldeneye, and 16 Mallard broods were documented upstream of the Stuart River confluence in 1982. Smaller numbers of broods were counted for American Wigeon (9 broods), Green-winged and Blue-winged teal (3 broods combined), Bufflehead (3 broods), and Hooded Merganser, scaup/Ring-necked Duck, and Northern Shoveler (1 brood each). Most broods were recorded south of Fort Fraser and west of Vanderhoof. Brown *et al.* (1995) also reported large numbers of Common Mergansers (242 counted in July), Mallard (27 and 94 counted in July and August, respectively), and goldeneye (48 counted in July) in summer of 1991, and documented breeding presence of a number of other waterfowl species

(Common Loon, teal, Pintail). Some waders may breed in the Nechako River in areas where wetland type characteristics exist (see Section 2.3.1). For example, American Bittern (*Botaurus lentiginosus*), which is blue-listed in BC (CDC 2022), was documented in the Nechako River Migratory Bird Sanctuary on May 25, 2002 (E-Fauna BC 2022), although it is not known if this was a breeding record. Breeding for this species has been confirmed in the vicinity of Fort Fraser (Davidson *et al.* 2015).

Presence and nests of two fish-eating raptors have been documented on the Nechako River, with Bald Eagle being most numerous, and a number of other fish-eating birds breed and/or forage in the Nechako River system. A total of 63 adult and 40 immature Bald Eagles were counted upstream of the Stuart River confluence in July 1982 (density of 0.51 eagles per km or river) by Envirocon (1984), and a total of 23 nests were counted and characterized[5]. Osprey were less commonly observed (5 counted during the 1982 survey). Several species of gulls (see above) likely breed along the river. Black Terns are common along the river in spring through fall (66 counted in July of 1991; Brown *et al.* 1995). Black Terns were documented to occur from 115 km to 180 km below Cheslatta Falls and were most abundant downstream of Vanderhoof where the river is wide, deep, and slow, and the river margins were often covered with marsh vegetation (Brown *et al.* 1995); the species is known to breed in the general area in the summer (Campbell *et al.* 1990b; Davidson *et al.* 2015; E-Fauna BC 2022) but breeding records for the Nechako River were not found. Belted Kingfishers also were documented present in spring through fall (67 counted in July of 1991; Brown *et al.* 1995) and likely nest in the banks of the river. Other fish-eating birds that have been seen in summer and likely breed in the vicinity of the Nechako River include Common Loon (*Gavia immer*) and Red-necked Grebe (*Podiceps grisegena*) (Campbell *et al.* 1990a; Brown *et al.* 1995; E-Fauna BC 2022). Great Blue Heron (*Ardea herodias*) (which is Blue-listed in BC; CDC (2022)) occurs on the Nechako River (Brown *et al.* 1995) and may nest near Prince George (Davidson *et al.* 2015). American White Pelicans (*Pelecanus erythrorhynchos*) occasionally forage in the Nechako River during the summer, but do not breed in the river system (NWSRI 2022). A record of a Double-crested Cormorant (*Phalacrocorax auritus)* pair feeding two young on the Cheslatta River in 1997 exists (Van Damme 2004), and recent field work has confirmed nesting in Ootsa Lake of the Nechako Reservoir that was initially reported by a local resident (Regehr and Kurtz 2022). Thus, it is possible that this species nests in the vicinity of the Nechako River although no such records were found during this review. Cormorants were a group of species of concern mentioned during Main Table and Technical Working Group meetings of the Nechako WEI.

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[5] Bald Eagle nests were located in living and dead trees (black cottonwood, trembling aspen, and Douglas-fir), 3 m to >300 m from the river shoreline with tree bases having elevations above the river level between 0.75 to 10 m (Envirocon 1984).

The floodplains and riparian areas support high densities of nesting songbirds, with estimates of several hundred breeding pairs per km^2 (Envirocon 1984). Approximately 30 species of songbird have been documented in the Nechako watershed (NWSRI 2022). Bank-nesting birds, including Bank Swallows (*Riparia riparia*), Cliff Swallows (*Petrochelidon pyrrhonota*) and Belted Kingfishers (see above), are documented breeders in the river system (Envirocon 1984; Brown *et al.* 1995).

2.3.3. Overview of Key Wildlife Management Concerns

Among wildlife species known to be present in the system, greatest concern relevant to Nechako River water management (i.e., changes in flow and water level) relates to species-specific vulnerable periods, important habitat for which quantity or quality could be affected by changes in flow or water levels, and important resources (e.g., food). The nest contents of birds (eggs, and nestlings for some species) are immobile and therefore can be vulnerable to changes in environmental conditions such as changes in water level when nests occur close to water. For ungulates, winter is a time of particular stress (e.g., Kautz *et al.* 2020) and the young are highly vulnerable immediately after birth (Linnell *et al.* 1995). For aquatic mammals such as beavers and muskrats, cold winter temperature increase energy needs and ice can make food more difficult to access, can entrap individuals in lodges (which can be especially determinantal if water levels increase), and may increase predation risk if animals are forced out onto the ice (Rosell and Campbell-Palmer 2022). Further, newly born kits are particularly vulnerable to extreme conditions. Important habitats for wildlife can be affected by flow or water level changes through a variety of mechanisms, such as effects of water levels on habitat availability (amount of habitat exposed or inundated), effects on hydraulic connectivity to riparian habitat which affects riparian characteristics (e.g., vegetation), and formation and maintenance of instream islands (e.g., substrate and vegetation). Wildlife resources can be affected by flow changes on riparian and aquatic characteristics and productivity. These issues are addressed in Section 4.

2.4. Existing Flow Mitigation for Wildlife

Under the current reservoir and flow management regime, Rio Tinto currently implements mitigation to protect wildlife. Specifically, increases in spillway discharge are normally delayed in spring until there is open water around the perimeter of Cheslatta Lake to prevent the submergence of beaver dens when there is ice cover[6] (see Section 4.3.1 where this issue is addressed).

2.5. Assumptions and Limitations

As introduced in the sections above, this assessment is focused on aquatic and riparian areas within the Nechako River channel and does not extend to upland areas. Upland areas were not included because flow in the Nechako River is managed; thus, although water levels could technically increase above bankfull, this is unlikely to occur frequently enough that any resultant wildlife issues would

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[6] https://nechako.riotintoflowfacts.com/.

become a priority for management. This pertains also to wetlands located in proximity to the river channel (i.e., within upland habitat), although it is recognized that some wetlands outside of the river channel could be hydrologically connected to the river and therefore could be affected by river flows even if not affected by overland flow. However, habitats with wetland function that occur within the river channel (e.g., in backwaters) are considered in this assessment.

The issues investigated were focused on general wildlife habitat (e.g., riparian habitat) and on birds, large mammals, and other vertebrates of typical conservation concern (e.g., amphibians). Due to a general lack of information on occurrence and distribution, small mammals (e.g., rodents) and invertebrates (e.g., terrestrial mollusks) were not specifically considered; however, consideration of effects to habitat for such species groups would be encompassed within general habitat considerations for wildlife.

3. APPROACH AND METHODS

Information was obtained from multiple sources to identify and evaluate potential effects to wildlife (wildlife issues) resulting from water management in the Nechako River. This involved identifying, assessing, and prioritizing the significance of potential effects of water management on vulnerable or limiting life stages of wildlife species, important habitats, and environmental factors that affect behaviour, physiology, growth, and survival of individuals, and potentially the status of populations.

As stated in Section 2.5, upland areas were not included in the assessment and for the purposes of this assessment, the area within the river channel to the elevation of bankfull height is considered "in-channel" habitat. Given study area boundaries (Section 2.2), no lake or reservoir wildlife habitats were considered (note that reservoir habitat was considered in Regehr and Kurtz (2021) and Regehr *et al.* (2021)).

The approach taken to locating and compiling information, categorizing and evaluating potential effects of water management on wildlife, assessing data availability, prioritizing issues, and making recommendations is described below.

3.1. Literature Review – Information Sources

Information on potential wildlife issues related to flow and water level within the Nechako River specifically, and riverine environments generally, was obtained from reference documents, provincial websites, reports or assessments specific to the watershed, and input of local residents and resource professionals. Professional experience conducting wildlife studies, environmental effects assessments, and reviews of studies and monitoring programs for hydroelectric developments was also incorporated. The presence of wildlife species in the watershed that have the potential for interaction with riverine systems was evaluated from a variety of reference documents (e.g., Campbell *et al.* 1990a, 1990b, 1997, 2001; Shackleton 1999; Matsuda *et al.* 2006; Hatler *et al.* 2008) and websites (e.g., Davidson *et al.* 2015; CDC 2022; eBird 2022; E-Fauna BC 2022). Baseline studies conducted for the proposed Kemano Completion Hydroelectric Development (Envirocon 1984) and the Brown *et al.* (1995) study of piscivorous birds on the Nechako River (see Section 2.3) were key reference documents.

3.2. Evaluating Potential Effects

Wildlife issues were identified either for individual species or by species groups. Species were grouped when multiple species that may interact with Nechako River water management share life history characteristics making them vulnerable to water level management (i.e., similar life history characteristics, habitat occupied, and pathways of effects) and/or when information on specific species was generally lacking. Issues were associated with individual species when they were relatively unique in their potential for impacts and/or when particular concern had been expressed by the TWG.

For each issue identified, the magnitude of identified potential effects was evaluated and ranked as high, moderate, or low based on the potential impacts of water management on habitat, behaviour, productivity, survival, and population status. Categorization was guided by guidelines produced by the BC Environmental Assessment Office (EAO) on effects assessment (EAO 2013). Magnitude was rated as high when Nechako River flow management is anticipated to affect productivity, survival, and population status of the species/species groups in question in excess of what would be observed within the range of natural variation. Magnitude was rated as moderate if operations are anticipated to cause some changes in behaviour and habitat and may have small impacts on productivity and/or survival, but effects are not anticipated to affect population status. Magnitude was rated as low if operations are anticipated to have little or no effect on behaviour, productivity, survival, or habitat (effects are within the range of natural variation) and are not anticipated to affect population status. As the objective of this review was to identify and evaluate potential effects of Nechako River water management on wildlife at high level, detailed analyses of potential effects were not completed and other EAO criteria (i.e., context, extent, duration, reversibility, frequency) were not evaluated.

For the wildlife issues identified, the timing and magnitude of flow or water level changes are an important consideration when identifying pathways of effects and evaluating the magnitude of potential effects. However, although the current Nechako River hydrograph[6] informs evaluation of potential effects during the current operational regime, changes in flow and water level were more generally considered for the assessment because a variety of potential water management regimes are under consideration.

3.3. Data Availability/Certainty

Data availability was assessed and categorized by issue and was used to inform priority ranking because data gaps affect the potential for prioritizing risk. Data availability was considered at the spatial scale of the watershed and was ranked as high, moderate, or low depending on the amount and relevance of the data found and the confidence that this provided for the assessment. Only data relevant to the identified pathways of effects were considered when assessing data availability. For example, when assessing availability of data for birds for which potential effects of water management were associated with nesting, only available data for breeding birds was considered (e.g., not for migration). It should be noted that because the review was high level, sources of information may exist that were not found; thus, data availability classified as low should be considered preliminary based on expended effort.

3.4. Prioritization of Issues

Priority of wildlife issues in relation to consideration for Nechako River water management was ranked based on the magnitude of potential effects and data availability, the latter of which was indicative of the certainty in our assessment. As illustrated in the matrix below (Table 1), priority of the issue was ranked as low, moderate, or high based on a combination of magnitude of potential effects and data availability/certainty. This matrix indicates that the assigned priority category was the same as the anticipated magnitude of potential effects if data availability/certainty was high or moderate; however, priority was conservatively increased if data availability/certainty was low and if the magnitude of potential effects was moderate or high, given that inadequate data may be available to provide confidence in the assessment. However, if the magnitude of potential effects was considered low, data availability/certainty was considered less important (e.g., lack of certainty in a species' presence is not critical if there would be little consequence of the effect).

Table 1. Priority of wildlife issues in relation to Nechako River operational management as evaluated from the magnitude of identified potential effects and data availability/certainty.

		Magnitude of Potential Effects[1]		
		High	**Moderate**	**Low**
Data Availability / Certainty[2]	**High**	High	Moderate	Low
	Moderate	High	Moderate	Low
	Low	High	High	Low

[1] High: Nechako River operations are anticipated to affect productivity, survival, and population status in excess of what would be observed within the range of natural variation; Moderate: operations may cause changes in behaviour and habitat, and may have small impacts on productivity and/or survival, but effects are not anticipated to affect population status; Low: operations are anticipated to have little or no effect on behaviour, productivity, survival, or habitat (effects are within the range of natural variation) and are not anticipated to affect population status.

[2] High: data exist with which to adequately evaluate the issue; Moderate: some data exist with which to evaluate the issue but they may be limited in scope or are not recent; Low: few data exist with which to evaluate the issue.

3.5. Performance Measures and Recommendations

The potential to identify performance measures that could be used to inform evaluation of trade-offs during the structured decision-making water use planning process was assessed for identified issues. This involved evaluating our knowledge (data availability and data gaps) as well as a review of the literature for thresholds that have been identified for similar species groups or situations in relation to effects of hydrology or water management. All performance measures, or more general recommendations, should be considered preliminary given the high-level approach of this assessment.

4. RESULTS

Issues related to potential effects of Nechako River water management (flow/water level) on wildlife were identified for several wildlife species and species groups. The issues identified included those identified by the TWG of the WEI (Section 1), as well as additional issues not previously identified. The identified issues included direct effects on wildlife as well as effects on habitat, and most were associated with specific life history stages of wildlife, such as breeding, wintering, or migration. In total, eleven issues were identified, grouped within five high level flow-related themes: riparian condition and function, wildlife food resources, American Beaver (inundation of dens and den and food access), bird nests (inundation and stranding), and instream island habitat. The latter theme included effects to instream island habitat for ungulates during birthing and winter, and to birds during migration and nesting. It should be noted that although effects to bird nests from water level changes is addressed as a component of two themes, the pathways of effects differ. Although the potential for effects to amphibians was considered, little wetland-type habitat suitable for breeding amphibians appears to be present within the channel of the Nechako Reservoir (see Section 4.4 which discusses this in relation to bird nests) and more suitable wetland habitat in upland areas were not considered in this assessment because overland flow potentially inundating such wetlands is unlikely to occur frequently enough to become a priority for management (Section 2.5).

The sections below summarize the results of this assessment. For the identified issues, pathways of effects were described, timing of vulnerable periods was identified, data availability/certainty and the magnitude of potential effects was assessed, and priority was categorized. In some cases, data gaps limited the potential for assessing potential effects with confidence which, in turn, limited our ability to prioritize issues. Prioritization may therefore be refined if data gaps are addressed. Results for identified issues are summarized in Table 2 and are discussed in the sections below. Additional details on pathways of effects, data availability/certainty, and magnitude of potential effects are provided in Appendix A. Performance measures and recommendations, which are discussed in Section 5, are also summarized in Table 2.

Table 2. Summary of wildlife issues related to operational activities associated with water management in the Nechako River.

Issue	Pathways of Effects	Timing/ Life History Stage	Data Availability/ Certainty[1]	Magnitude of Potential Effects[1]	Priority Rating[2]	Performance Measures and Recommendations[3]
Riparian condition and function	Changes in flow can affect hydraulic connectivity to riparian vegetation, which, in turn can affect the availability or suitability of riparian habitat for wildlife (riparian habitat quantity and quality).	N/A	*This issue is being addressed separately through ongoing study and analysis.*			
Wildlife food resources	Changes in flow can affect productivity of wildlife aquatic food resources, such as fish, invertebrates, and aquatic vegetation.	N/A	*These issues are being addressed separately.*			
American Beaver: inundation of dens	Large increases in water level (e.g., sudden snowmelts) in winter or spring can flood dens, destroy lodges, and drown beavers under the ice. Kits are particularly vulnerable to floods in their first month. Muskrats are less tolerant of fluctuating water levels but are not common in the Nechako River whereas beavers are found throughout the river.	Winter - spring (December-June)	Moderate	Moderate	Moderate	• Avoid large magnitude and rapid increases in water level (i.e., minimize rate and magnitude of flow increase) when ice is present and kits are less than one month old. * Improve our understanding of the effects of flow changes in the Nechako River on beavers.
American Beaver: den and food access	Dropping water levels during winter can cause exposure of underwater den entrances and freeze-up the water column, which can limit underwater movement and prevent access to stored food supplies. Den entrances may become frozen over, which can trap beavers or force them to move. Muskrats feed on plant material under the ice during winter, and reduced water levels can lead to freezing of food resources.	Winter (November - March)	Moderate	Moderate	Moderate	• Avoid large magnitude and rapid decreases in water level (i.e., rate and magnitude of flow decrease) when ice is present. * Improve our understanding of the effects of flow changes in the Nechako River on beavers.
Birds: inundation of nests	Rising water levels during the vulnerable bird nesting period (incubation, along with nestling period for altricial or semi-precocial species) can cause mortality of eggs or nestlings through flooding.	Spring - summer (May - July)	Low	High	High	• Avoid large magnitude and rapid increases in water level (i.e., rate and magnitude of flow increase) during the bird nesting period (i.e., May – July). * Improve our understanding of where birds are breeding along the Nechako River. * Thresholds should ideally be species-specific: risks vary by species depending on life history strategy (e.g., nest location, length of vulnerable period); thus, relationships between nest survival and water level changes can be complex.

[1] See Appendix A for details on data availability/certainty and magnitude of potential effects.

[2] See Table 1 (Methods) for categorization of priority and Appendix A for details on data availability/certainty and magnitude of potential effects.

[3] Performance measures (identified with bullet point) and recommendations for addressing data gaps and improving understanding (identified with an asterisk) are discussed in Section 5.

Table 2. Continued.

Issue	Pathways of Effects	Timing/ Life History Stage	Data Availability/ Certainty[1]	Magnitude of Potential Effects[1]	Priority Rating[2]	Performance Measures and Recommendations[3]
Birds: stranding of nests (exposure to predation)	Dropping water levels during the vulnerable bird nesting period (incubation, along with nestling period for altricial or semi-precocial species) can cause mortality of eggs or nestlings through nest stranding (which can cause nest abandonment or increased predation risk).	Spring - summer (May - July)	Low	Low	Low	• Avoid large magnitude and rapid decreases in water level (i.e., rate and magnitude of flow decrease) during the bird nesting period (i.e., May – July). * Improve our understanding of where birds are breeding along the Nechako River. * Confirm that wetland-type habitat in shallow backwaters (e.g., near Vanderhoof) is not highly suitable for wetland-associated breeding birds. * Thresholds should ideally be species-specific: risks vary by species depending on life history strategy (e.g., nest location, length of vulnerable period); thus, relationships between nest survival and water level changes can be complex.
River island habitat - ungulate calving	Island habitats can provide predator protection for recently born Moose calves. River flows/water level affect the amount of island habitat available and the degree of island isolation, which is important for predator protection.	Early summer (June)	Moderate	Moderate	Moderate	• During the vulnerable period, islands should be isolated but not flooded (moderate flows likely best). * Conduct an analysis that relates the amount of island habitat available (area) and island isolation to flow to evaluate trade-offs.
River island habitat - Moose winter forage	Island riparian habitats provide valuable Moose winter foraging habitat. River flows/water level affect the amount of island habitat available; flows also affect island isolation which creates security habitat.	Winter (November - April)	Moderate	Moderate	Moderate	• During the vulnerable period, islands should not be flooded and isolation of islands likely adds value (low to moderate flows likely best). * Conduct an analysis that relates the amount of island habitat available (area) and island isolation to flow to evaluate trade-offs.
	Hydrological regime is a key force in maintaining the sub-climax seral stages in riparian and in-channel areas of the Nechako River important for Moose during winter.	N/A				• Maintain high flows during the annual cycle but outside the winter forage period to maintain sub-climax seral stages.
River island habitat - nesting birds	Island habitat likely provides secure nesting habitat for birds associated with riverine and/or riparian habitat. Hydrological regime has the potential to affect both the habitat availability and degree of island isolation, which provides protection from terrestrial predators.	Spring - summer (May - July)	Low	Moderate	High	• During the vulnerable period, islands should be isolated but not flooded (moderate flows likely best). * Conduct an analysis that relates the amount of island habitat available (area) and island isolation to flow to evaluate trade-offs.

[1] See Appendix A for details on data availability/certainty and magnitude of potential effects.

[2] See Table 1 (Methods) for categorization of priority and Appendix A for details on data availability/certainty and magnitude of potential effects.

[3] Performance measures (identified with bullet point) and recommendations for addressing data gaps and improving understanding (identified with an asterisk) are discussed in Section 5.

Table 2. Continued.

Issue	Pathways of Effects	Timing/ Life History Stage	Data Availability/ Certainty[1]	Magnitude of Potential Effects[1]	Priority Rating[2]	Performance Measures and Recommendations[3]
River island habitat - waterfowl spring	Low water levels permit access to islands, used by staging migratory waterfowl (especially Canada Geese), by predators and humans; high flows reduce island habitat availability (some islands may be flooded).	Spring (April - May)	Moderate	High	High	• During the vulnerable period, islands should be isolated but not flooded (moderate flows likely best). * Conduct an analysis that relates the amount of island habitat available (area) and island isolation to flow to evaluate trade-offs.
	Annual floods caused the scouring and deposition of sediments that maintain substrates suitable for resting and gravelling Canada Geese on migration; lack of high flows and lower mean annual discharges causes invasion of some bars/islands by woody growth, reducing suitability for geese.	N/A				• Maintain high flows during the annual cycle but outside the migratory period (e.g., spring floods after the peak in migration) to maintain bare island habitat. * Reassess the value of islands for migrating Canada Geese given recent changes.
River island habitat - waterfowl fall	Low water levels permit access to islands, used by staging migratory waterfowl (especially Canada Geese), by predators and humans; high flows reduce island habitat availability (some islands may be flooded).	Fall (September - October)	Moderate	Moderate	Moderate	• During the vulnerable period, islands should be isolated but not flooded (moderate flows likely best). * Conduct an analysis that relates the amount of island habitat available (area) and island isolation to flow to evaluate trade-offs.
	Annual floods caused the scouring and deposition of sediments that maintain substrates suitable for resting and gravelling Canada Geese on migration; lack of spring high flows and lower mean annual discharges causes invasion of some bars/islands by woody growth, reducing suitability for geese.	N/A				• Maintain high flows during the annual cycle but outside the migratory period (e.g., spring floods after the peak in migration) to maintain bare island habitat.

[1] See Appendix A for details on data availability/certainty and magnitude of potential effects.

[2] See Table 1 (Methods) for categorization of priority and Appendix A for details on data availability/certainty and magnitude of potential effects.

[3] Performance measures (identified with bullet point) and recommendations for addressing data gaps and improving understanding (identified with an asterisk) are discussed in Section 5.

4.1. Riparian Condition and Function

Changes in flow can affect hydraulic connectivity to riparian vegetation, which, in turn can affect the availability or suitability of riparian habitat for wildlife (riparian habitat quantity and quality). This was identified as one of the four potential wildlife issues raised by the TWG (Section 1).

Many wildlife species make use of riparian habitat for different reasons (e.g., foraging, nesting, denning) at different times of the year, and riparian characteristics are strongly affected by flow and water level (summarized in Cott *et al.* 2008). For example, dabbling ducks often nest in riparian areas around water bodies and fluctuating water levels can fragment nesting habitat or affect the proximity of nesting habitat to feeding areas. Similarly, impacts to riparian function can affect important foraging habitat for nesting songbirds that may select riparian areas because of the abundance of water-associated insects. Some wildlife species forage on riparian vegetation directly (e.g., Moose, Mule Deer, American Beaver), and the quantity and quality of this forage can be affected by flow. However, interactions between flow/water levels, habitat availability and suitability, and effects on wildlife species can be complex (Lloyd *et al.* 2004; Desgranges *et al.* 2006), and some changes may improve habitat conditions for some species but negatively affect habitat for others.

The relationships that affect vegetation communities in riparian areas (or lack thereof) in the Nechako River affect the wildlife species that can use this habitat for various life-history purposes, including birds, ungulates, mustelids, aquatic mammals, and bats (Section 2.3.1). Riparian vegetation occurs along most sections of the Nechako River (Section 2.3.1), but flow-related changes in hydraulic connectivity have the greatest potential to affect riparian vegetation along low gradient areas and areas with side channels. Hydraulic connectivity is generally most important during the growing season (spring through fall) and some plant species have specific relationships with soil water levels, such as that of recruitment (time of seed release) in black cottonwood (*Populus trichocarpa*) (e.g., Clayton 1996; Mahoney and Rood 1998).

For this wildlife assessment, interactions between riparian habitat and flow are identified where they are directly linked to specific wildlife issues. For example, baseline studies conducted for the proposed Kemano Completion Hydroelectric Development (Envirocon 1984) documented that much riparian Moose browse in the Nechako River system is dependent on hydraulic action and high water tables associated with the river (see Section 4.5.2). It was also noted that changes have occurred to riparian areas due to reduced flows since the Kemano development, by, for example, affecting the vegetation characteristics of instream islands important for migrating Canada Geese (see Section 4.5.4). A more detailed assessment of the interaction between riparian vegetation (i.e., function and condition) and flow in the Nechako River is beyond the scope of this wildlife assessment and this issue is being addressed separately through ongoing study and analysis.

4.2. Wildlife Food Resources

Changes in flow can affect food resources for wildlife by affecting productivity of animals and plants in riverine systems. Wildlife may consume fish (e.g., piscivorous raptors and waterbirds, mustelids), invertebrates (e.g., waterfowl, shorebirds, mustelids, songbirds), and aquatic vegetation (e.g., waterfowl, Common Muskrat, American Beaver), and changes to flow that alter aquatic productivity can therefore have adverse effects on wildlife species dependent on these resources (summarized in Cott *et al.* 2008). Several wildlife species associated with the Nechako River system forage on aquatic animals and vegetation that can be affected by water management (effects to riparian vegetation forage are addressed in Section 4.1). However, aquatic resources for wildlife that may be affected by flow management in the Nechako River are being addressed as separate issues, either directly, or within assessments conducted for fish (e.g., Nicholl *et al.* 2021; Carter and Kurtz 2022, Carter *et al.* 2022; Chudnow *et al.* 2022; Johnson *et al.* 2022a), aquatic invertebrates (Johnson *et al.* 2022b; 2022c), or primary productivity (Johnson *et al.* 2022b). Assessments and recommendations made for these other issues will therefore apply to potential effects on the food supply of wildlife. This potential pathway of effect is therefore acknowledged but was not assessed as a wildlife issue in this assessment and is not considered further in this document.

4.3. American Beaver: Inundation of Dens, and Den and Food Access

American Beaver, which are common in the Nechako River (Section 2.3.2.2), can be adversely affected when water levels in the Nechako River change, especially if changes are rapid and large in magnitude. Two main pathways of effects (issues) were identified in this review: inundation of dens due to water level increases in winter and spring, and impacts to den and food access during water level decreases during winter. Although beavers naturally tolerate fluctuating water levels, rapid changes in water levels during periods of vulnerability (such as in winter when ice is present or in spring when kits are born), can have substantial deleterious effects.

Common Muskrats may also be affected by water level fluctuations, and water level fluctuation and control are considered the most influential variable in determining muskrat abundance (Cott *et al.* 2008). For example, massive negative effects on muskrat populations have been documented in Wood Buffalo National Park owing to water regulation of the Peace River systems in Alberta, where construction of the Bennett dam caused a decrease in marsh area and edge habitat and allowed many lakes to freeze to the bottoms (Avakyan and Podol'skii 2002, cited in Cott *et al.* 2008). In general, muskrats are less tolerant of fluctuating water levels than beavers because fluctuating water levels tend to eliminate required food supply (littoral zone plants; CDC 2022).

Northern River Otter and American Mink are also aquatic mammals that occur in the Nechako River system (Envirocon 1984); however, dens tend to be further away from shorelines and although some flooding of dens may occur, potential effects of water level changes are less likely than for beavers and muskrats. Natal river otter dens in southeastern Minnesota (Gorman *et al.* 2006) and Alaska (Woolington 1984) were typically located several hundred meters from water, likely because this protects pups from flood events. Similarly, in a study of European mink (*Mustela lutreola*), females were found to mostly place dens away from flooding zones (Palomares *et al.* 2017): one of ten monitored dens was placed in an area with a high probability of flooding and the litter was lost; the other nine dens were placed where flooding events were likely to happen only every 25 years. Thus, potential impacts of Nechako River management on these two species were considered negligible; however, river otters and mink can be impacted by water management in other ways, particularly through effects pathways on aquatic prey (which is being assessed separately; see Section 4.2).

Although both American Beaver and Common Muskrat are documented to occur in the Nechako River system and can be affected by water management, muskrats have been found primarily in marshes and ponds away from the river, although occasionally in quiet river backwaters, whereas beavers have been found all along the main channel (Section 2.3.2.2). Thus, the two identified issues below are assessed mainly for beavers but have some relevance to muskrats as well.

4.3.1. Inundation of Dens

Sudden snowmelts in winter or spring that raise water levels in streams can destroy beaver lodges and drown beavers under the ice (Baker and Hill 2003; Rosell and Campbell-Palmer 2022). Since floors of beaver lodges are only about 10 cm above the water level (Buech 1985), even water level increases that are relatively low in magnitude can flood dens. Kits are particularly vulnerable to floods in their first month and elsewhere there have been observations of large numbers of dead kits during severe floods when these overlap with the birthing period (Rosell and Campbell-Palmer 2022). Although they can swim at four days of age, kits are not able to dive or stay submerged until two months of age and are therefore not able to dive properly out of the lodge's flooded entrances (Baker and Hill 2003; CWF 2022; Rosell and Campbell-Palmer 2022). Further, the fur of kits is not water repellent until about three to four weeks of age, when they begin to groom anal glad secretions over their fur (Baker and Hill 2003), and they do not become fully water-repellent until five to eight weeks old (Naughton 2012). Adults may also be drowned during floods if they become trapped under the ice (Baker and Hill 2003; Rosell and Campbell-Palmer 2022). In general, flooding is recognized as an important cause of beaver mortality (summarized in Breck *et al.* 2001). Muskrats are also vulnerable to adverse effects from den flooding (Bellrose and Low 1943; Ahlers *et al.* 2010) and density of muskrats has been strongly linked to ice-jam floods in the Peace-Athabasca Delta in northern Alberta, with density of muskrat houses dropping by approximately 79% for every year after a significant flood (Straka *et al.* 2018).

Beavers are particularly vulnerable to inundation of dens in winter and spring when ice may be present, extending until kits are one month old. Given that young beavers are likely born between mid-May and end of June (Nagorsen 2005; CDC 2022), the vulnerable period extends from December through June. The period of greatest vulnerability is likely similar for Common Muskrat, which are believed to give birth in May (Nagorsen 2005).

Although adverse effects can occur for beavers due to water level fluctuations, beavers may adapt to such conditions and when lodges are flooded, beavers may find temporary shelters elsewhere (e.g., other lodges, dens, or temporary shelters). Further, if possible, the parents will often attempt to save kits during den flooding by carrying them out in their mouths and taking them to temporary lairs above the waterline (Baker and Hill 2003; CWF 2022; Rosell and Campbell-Palmer 2022). In water bodies that are subject to floods and fluctuating water levels, beavers commonly den in burrows in the banks (Nowak 1999; CDC 2022). Such bank dens are often dug under a large tree or shrub to provide support for the roof of the den. They have a nest area above the water level, an underwater entrance, and small holes in the surface soil for air exchange (Baker and Hill 2003). The tunnels may become complex and extend for more than 10 m back and up from an entrance at or below water level (Nowak 1999).

The ability of beaver populations to adapt to water level fluctuations has been studied in some systems and consequences have varied substantially depending on location-specific conditions, given that each system has unique characteristics. Breck *et al.* (2001), who compared beaver populations on two river systems in Colorado, one flow-regulated (Green River) and one free-flowing (Yampa River), found that beavers adapted to flooding by moving to burrows located farther from the centre of the river during flooding. Some benefits were gained because this allowed them to safely access food supplies that, without flooding, would have been difficult to access due to predation risk. Beavers occurred at higher densities and were in better condition in the flow-regulated system, which was attributed to flow regulation altering fluvial geomorphic processes, influencing the availability of willow and cottonwood, as well as ice cover, in winter. Negative effects of flooding have more commonly been documented (summarized in Rosell and Campbell-Palmer 2022): in Norway, Eurasian Beavers (*Castor fiber*) that survived a 5.5. m decrease in water level drop in winter (with some human assistance) produced no kits the following spring; in Sweden, beavers were documented to have died when food cashes were washed away or stranded above the water surface during dramatic changes in water level; and in California, a flood caused by rapid snowmelt caused beaver deaths. A population of introduced Eurasian Beavers on a floodplain system of the Rhine River in the Netherlands where extreme fluctuations in water levels occur (normally between 6-7 m on an annual basis), the population was documented to initially suffer severe losses, but grow over time by adapting to the water level fluctuations (Kurstjens and Bekhuis 2003). The beavers were observed to cope with a series of floods by constructing special lodges on higher ground within a few days, and to cope with extreme dry conditions (when beaver habitat dried up completely) by constructing burrows in the banks of a sand pit where they survived the drought. Nevertheless, the study concluded that extreme flood and drought were stressful events although these also stimulated settlement of new territories which caused population growth in this introduced and expanding population.

Data availability/certainty for evaluation of the "inundation of dens" issue for the Nechako River was categorized as moderate given that some studies have been conducted documenting presence of beavers and muskrats in the Nechako system, although data were not fully available for this review and were not recent. Further, no data were found on effects of water level fluctuations on beavers in this system, and results of the literature review indicated that effects can vary by location and conditions. Nevertheless, information from the literature (from studies in other locations) coupled with data on beaver presence in the Nechako River is adequate to determine that beaver populations could be impacted by water level management if water level changes are large in magnitude and rapid, especially if this happens when ice is still present or when kits are small. Under the current operational regime for the Nechako River, water management addresses this risk to beavers: spillway discharge is normally delayed until there is open water around the perimeter of Cheslatta Lake to prevent flooding of beaver dens when there is ice cover (Section 2.4). If the water management regime were to change in this regard, adverse effects to the Nechako River beaver population could result.

Given the documented vulnerability of beavers to rapid water level increases, that the Nechako River is frozen over for approximately four months of the year, and that a variety of potential water management regimes are currently under consideration, yet that beavers have some ability to adapt to rising water levels, the magnitude of the potential effect, as well as the priority rating (Table 1), was categorized as moderate. Because fewer muskrats than beavers appear to make use of habitats in the Nechako River (with the exceptions of a few areas, habitat is considered not suitable along the river and muskrats tend to be found in nearby wetlands), greatest management concern should be focused on beavers. Additionally, management considerations are similar for the two species; thus muskrats would benefit from protective measures implemented for beavers.

4.3.2. Den and Food Access

Water is a critical habitat requirement for beavers as cover for predators during feeding and reproduction (Cott *et al.* 2008). During winter, lodges provide safety for beavers and food reserves are stored under the ice. Dropping water levels during winter can cause exposure of underwater den entrances and freeze-up of the water column, which can limit underwater movement and prevent access to stored food supplies, leading to hunger and malnutrition (Rosell and Campbell-Palmer 2022). Den entrances may also become frozen over, which can trap beavers or force them to move. Smith and Peterson (1991) found that winter drawdown in fluctuating water systems in northern Minnesota changed beaver behaviour (e.g., spending more time above the ice) and increased mortality through starvation and predation. They also found that kits were in poorer conditions in comparison to those where water levels were not drawn down. To address such adverse effects, they recommended that total annual water fluctuation should not exceed 1.5 m, and winter drawdown should not exceed

0.7 m. The timing of vulnerability is throughout winter (November to March) when ice may be present and there is reliance on food stored under the ice. Muskrats can be similarly affected by water reductions during winter. Muskrats feed on plant material under the ice during winter, and reduced water levels can lead to freezing of food resources.

For both species, changes in access to food resources and exposure of dens may force animals to move to new locations, and potentially force them to the surface of the ice. This reduces survival through factors such as malnutrition, increased predation risk, and increased parasite loading and disease (Cott *et al.* 2008). Large reductions in muskrat numbers in the Peace River systems in Alberta due to the Bennett dam were partly caused by reductions in water levels that caused many lakes to freeze to the bottom in winter (summarized in Cott *et al.* 2008), and low water levels have been documented to increase predation on muskrat by mink (Proulx *et al.* 1987). Beavers normally occupy deeper water bodies than muskrats and are more adaptable and resilient to water withdrawals from ice-covered water bodies than muskrats.

For the reasons given in Section 4.3.1, data availability/certainty for evaluation of the "dens and food access" issue was categorized as moderate. Although relatively detailed information is available on beaver occurrences in the Nechako River, these surveys were conducted twenty to thirty years ago. Further, no data were found on effects of water level fluctuations on the species in this system. However, as also discussed in Section 4.3.1, information from the literature is adequate to determine that beaver populations could be impacted by water level management if water levels are drawn down during the winter, especially when ice is present. Given that a variety of potential water management regimes are currently under consideration, the magnitude of the potential effect, as well as the priority rating (Table 1) were categorized as moderate. As also stated in Section 4.3.1, although muskrats are not common in the Nechako River system, they would also likely benefit from any protective measures implemented for beavers.

4.4. Bird Nests: Inundation and Stranding

Two key issues have been identified in relation to bird nesting success in relation to water level fluctuations: inundation of nests when water levels rise, which can lead to drowning of eggs and nestlings, and stranding of nests when water levels drop, which can lead to nest abandonment or predation of eggs or nestlings. These two issues are described below. It should be noted, however, that relationships between water levels and bird breeding success may be complex because water levels not only affect potential risks to the nest, but also habitat characteristics that may be critical for successful breeding. For example, hydrological regime impacts plant and invertebrate communities that may be critical habitat components for breeding for bird species (Lloyd *et al.* 2004; Desgranges *et al.* 2006) (see Section 4.1). As another example, exposed river sediment banks required by bank-nesting bird species (such as kingfishers and some species of swallows) are formed during scouring high flows; thus annual variability in high flows across seasons is required for the creation of breeding habitat (Royan *et al.* 2013). The issues below address only nest inundation and stranding and do not further consider potential trade-offs related to effects to foraging habitat, vegetation, or other characteristics associated with habitat suitability.

The timing of vulnerability of bird nests to inundation and stranding is during the vulnerable bird nesting period, which includes incubation and the nestling period for species that are altricial (young hatched in an undeveloped state) or semi-precocial (young hatched in fairly developed state but stay at the nest). The bird nesting period is between late April to mid-August, with highest nest intensity between mid-May through the third week in July[7].

4.4.1. Inundation of Bird Nests

Rising water levels during the vulnerable bird nesting period can cause mortality of eggs or nestlings through flooding (e.g., Desgranges *et al.* 2006; Craig and Gill 2020) for species that nest within the river channel, on or near the ground. In addition to the direct effect of nest flooding, water level fluctuations can also affect breeding bird behaviour such that fewer birds may breed if flooding risks are high. For example, the number of breeding pairs has been associated with water level fluctuations on the lower St. Lawrence River for some passerines (Song Sparrows (*Melospiza melodia*) and Veery (*Catharus fuscescens*; Desgranges *et al.* 2006).

Species potentially breeding in the Nechako River system along river shorelines or banks, or on islands, that have the potential to have their nests inundated if river flows increase during the nesting period include waterbirds (geese, ducks, mergansers), seabirds (gulls), shorebirds, and songbirds. Many of the waterfowl species documented breeding (i.e., broods observed; see Section 2.3.2.3) are ground-nesting ducks (e.g., Green-winged Teal, Mallard, Northern Pintail, Blue-winged Teal, Northern Shoveler, American Wigeon, Ring-necked Duck, Lesser Scaup) and geese (Canada Geese nest on the ground or on platforms such as muskrat and beaver lodges) that may therefore be vulnerable to nest inundation. Songbirds that nest on or near the ground and near water, and that may occur in the area, include species such as Common Yellowthroat (*Geothlypis trichas*), Northern Waterthrush (*Parkesia noveboracensis*), Wilson's Warbler (*Cardellina pusilla*), Song Sparrow, Chipping Sparrow (*Melospiza melodia*), and Dark-eyed Junco (*Junco hyemalis*). During baseline studies conducted for the proposed Kemano Completion Hydroelectric Development, it was estimated that songbirds nest in high densities (several hundred breeding pairs per km^2) in the floodplains and riparian areas of the Nechako River, as well as in bank habitat (Envirocon 1984). Seabirds (gulls) and shorebirds (e.g., Killdeer, Spotted Sandpiper, Greater Yellowlegs, Lesser Yellowlegs) also build nests on the ground that may be vulnerable to flooding.

[7] https://www.canada.ca/en/environment-climate-change/services/avoiding-harm-migratory-birds/general-nesting-periods/nesting-periods.html#ZoneA.

Bank-nesting species documented present, such as Bank Swallows, Cliff Swallows, and Belted Kingfishers (Envirocon 1984), may be vulnerable to nest inundation if river water levels were to rise to bankfull within the vulnerable nesting period. In a modeling study using national datasets of river bird surveys and river flow archives, Royan *et al.* (2013) found that occurrence of bank-nesting species were sensitive to flow timing and suggested that this species group may be particularly vulnerable to nest site inundation due to flow variability during the breeding season. Although annual variability in high flows across seasons is required for the creation of breeding habitat (i.e., exposed sediment banks created during scouring high flows), the same mechanisms required to create or maintain nesting habitat also impart risks of nest flooding. Royan *et al.* (2013) found that species with the greater tolerance of breeding season flow variability were those that tended to nest on tributaries where nests are buffered from the impact of the highest flows on the main channel. Loss of nests due to erosion caused by high water levels during the breeding season may be a more significant risk for bank nesting species in the Nechako River (note that erosion in the Nechako River is being addressed as a separate issue; Chin *et al.* 2021).

Species that breed, or likely breed, in the vicinity of the Nechako River but have little nest inundation risk due to the Nechako River hydrological regime include water-associated raptors (Osprey and Bald Eagle), cavity nesting species, and species associated with upland habitat. Nests of Osprey and Bald Eagle are unlikely to be affected by nest inundation, given typical nest heights above ground or water (Campbell *et al.* 1990b). Similarly, although cavity nesting waterfowl, particularly Common Merganser, goldeneye, and Bufflehead, likely breed in the river system, nests are typically too high off the ground to be at risk from inundation. Common Goldeneye and Hooded Merganser cavity nests are typically greater than ~3 to 4 m off the ground within riparian or adjacent upland habitat (Campbell *et al.* 1990a); thus, risk of nest flooding for these species is small. Somewhat greater risk of nest flooding may exist for Barrow's Goldeneye and Bufflehead given that they can nest closer to the ground (Barrow's Goldeneye: ground level to 18 m, with 51% between 2 m and 3 m; Bufflehead: 60 cm to 14 m, with 61% between 60 cm and 3 m; Campbell *et al.* 1990a). However, the nesting trees would need to occur within the channel (e.g., on forested islands, which occur in some locations) to be at risk from flooding. Other species that could breed within cavities if suitable sites occur in in-channel habitat include woodpeckers, such as Downy Woodpecker (*Dryobates pubescens*), Hairy Woodpecker (*Dryobates villosus*), and Pileated Woodpecker (*Dryocopus pileatus*) (NWSRI 2022). However, cavity nests for these species are typically too high for flooding to be of concern (most are above ~ 2 m; Campbell *et al.* 1990b). The cavity nest sites of Tree Swallows (*Tachycineta bicolor*) may be slightly lower to the ground (but most natural sites above 1.5 m; Campbell *et al.* 1997). Although the at-risk Long-billed Curlew (*Numenius americanus*) is known to breed in the Nechako River area (E-Fauna BC 2022) and is a ground-nester, the species is found in grassy meadows (extensive tracts of open grasslands) (Campbell *et al.* 1990b; CDC 2022) and is therefore unlikely to nest in the channel of the Nechako River but in upland areas, which is where occurrences have been documented near the Nechako River, especially in the vicinity of Vanderhoof and Prince George.

Impacts to wetland-associated species due to nest inundation are likely to be small because there appears to be little wetland-type habitat/vegetation within the river channel (see Section 2.3.1). For example, although Black Terns were recorded present in the Nechako River, this species tends to nest in marshes and breeding within the Nechako River system has not been documented. Similarly, American Bittern (which are provincially blue-listed) that were recorded in the Nechako River near Vanderhoof (see Section 2.3.2.3), typically nest in wet areas with dense growths or emergent vegetation or tall grasses, such as on large freshwater and (less often) brackish marshes, where cattails, sedges, or bulrushes are plentiful and there are patches of open water and aquatic-bed vegetation (Campbell *et al.* 1990a; CDC 2022). Wetland-associated species that may utilize wetland-type habitat within the river channel include some waterbirds (e.g., grebes) and some passerines that nest in emergent vegetation, such as Red-winged Blackbird (*Agelaius phoeniceus*).

Data availability/certainty for evaluation of the "inundation of bird nests" issue was categorized as low because, although some studies have document presence of breeding birds within the Nechako River (Envirocon 1984; Brown *et al.* 1995) and some information on breeding species generally exists (Campbell *et al.* 1990a, 1990b, 1997, 2001), few data are available to indicate where birds are nesting (including suitable nesting habitat or species-specific nesting occurrences). This information is needed to allow evaluation of the potential for water level management to affect nest success because potential risks are location-specific (e.g., nesting elevations and distances from the river shoreline). Given the lack of location-specific information, and that nesting habitat appears to exist for multiple species in in-channel areas (see Section 2.3.1), it should be assumed that multiple bird species could be impacted by nest inundation if water levels are large in magnitude and change rapidly during the period when eggs or nestlings are present. Under the current operational regime, stage changes in the Nechako River have been documented that are relatively large and rapid in some years, including in July within the nesting period (Nicholl *et al.* 2021). Further, a variety of potential water management regimes are under consideration, including those that would have greater increases in flows/water levels in spring and early summer (i.e., during the bird nesting season) than under the current regime (Section 3.2). Thus, given the vulnerability of bird nests to flooding if water levels rise during the vulnerable period when eggs or nestlings are in the nest, along with the potential high likelihood that water levels may rise during this period, the magnitude of the potential effect was evaluated as high. Priority rating was therefore also categorized as high (Table 1).

4.4.2. Stranding of Bird Nests (Exposure to Predation)

Dropping water levels during the vulnerable bird nesting period can cause mortality of eggs or nestlings due to nest stranding for birds nesting in proximity to, or over, water. Nest stranding has been documented to cause nest abandonment and/or increased predation risk (by mammalian predators such as canids, mustelids, racoons, and rodents) (e.g., Picman *et al.* 1993;

Desgranges *et al.* 2006) and nest success has been linked to maintenance of water depth and predation in many studies (e.g., Picman *et al.* 1993; Jobin and Picman 1997; Desgranges *et al.* 2006; Hoover 2006; Niemczynowicz *et al.* 2017). Species for which water depth has been associated with nest success include: Yellow-billed Loon (*Gavia adamsii*) which breeds along lake shorelines in northwestern Canada and Alaska (Earnst 2004 cited in Cott *et al.* 2008); Common Pochard (*Aythya ferina*) that nest in wetlands in the Czech Republic (Albrecht *et al.* 2010); Prothonotary Warblers (*Protonotaria citrea*) nesting in a bottomland forest wetland (Hoover 2006); European wader species nesting on floating rafts (Niemczynowicz *et al.* 2017); the Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*) nesting in the Florida Everglades (Baiser *et al.* 2008); Marsh Wrens (*Cistothorus palustris*) nesting in marshes in Manitoba (Leonard and Picman 1987); and King Rails (*Rallus elegans*) nesting in marshes in the Illinois and Upper Mississippi river valleys (Darrah and Krementz 2011). Additionally, studies have been conducted in which artificial nests were placed into marshes, and these concluded that water depth plays a key role in the breeding success of marsh nesting birds (e.g., waterfowl and passerines) because it affects accessibility by mammalian predators (Picman *et al.* 1993; Jobin and Picman 1997). However, although the connection between water depth and nest success due to predation risk has been well documented, relationships between water level fluctuations and nesting success are complex because many other important habitat characteristics can be related to water level fluctuations and the relationships may be species-specific (Desgranges *et al.* 2006). Further, as stated in Section 4.4.1, water level fluctuations may not only affect nest survival but also breeding propensity for some species (i.e., birds may not nest where water fluctuations are large).

Although water depth has been related to breeding success due to predation risk for multiple species, risks of nest stranding apply mainly to birds that nest within wetlands, typically in emergent vegetation over the water or in shrubby vegetation over water occurring within a wetted area. In such cases, nest sites depend on water surrounding them for protection from predators and thus water level drops can substantially increase predator access to nests. This issue is therefore less relevant to birds nesting in riparian areas or within the channel of the Nechako River, where predator access is less closely linked to water level changes (nest sites are not surrounded by water). Although the isolation of instream islands also likely provides predator protection through the surrounding water and this protection could be affected by water level decreases, island nests do not become stranded by dropping water levels, but instead the degree to which islands are isolated may vary with water level changes. Thus, this is assessed as a separate issue related to instream island habitat (Section 4.5.3).

Data availability/certainty for evaluation of the "stranding of bird nests" issue was categorized as low because, although some studies have documented presence of breeding birds within the Nechako River (Envirocon 1984; Brown *et al.* 1995) and some information on breeding species generally exists (Campbell *et al.* 1990a, 1990b, 1997, 2001), few data are available to indicate where birds are nesting. Also, although some portions of the Nechako River in-channel habitat may have wetland-like characteristics (Section 2.3.1) where wetland-associated birds could be breeding above water that could be vulnerable to nest stranding if water levels drop during the nesting period, data are lacking to determine how much such potential habitat exists and if birds are nesting in vegetation over water in such habitats. Nevertheless, few breeding records were found during this review for wetland-associated birds (e.g., species that breed in emergent vegetation) within the Nechako River, including for the braided river section in the Nechako River Migratory Bird Sanctuary (exceptions included American Bittern and Common Loon sightings on May 25, 2002 which were seen in the braided river area; E-Fauna BC 2022), and it is likely that some nesting records would have been found if a significant amount of wetland-associated breeding occurs, especially because other wetland-associated species that occur in the area have been documented present during the breeding period at some distance away from the river (Campbell *et al.* 1990a, 1990b; E-Fauna BC 2022).

Given the lack of breeding records for wetland-associated bird species for the braided section of the Nechako River found during this review (in contrast to records found for nearby wetlands, such as Black Tern and Red-necked Grebe; Campbell *et al.* 1990a, 1990b; E-Fauna BC 2022), it appears that the amount of wetland-type habitat potentially present in the Nechako River within which wetland-associated birds breed is likely small. Thus, the magnitude of the potential effect was evaluated as low. Priority rating was therefore also categorized as low (Table 1). However, the assumption that wetland-type habitat in shallow backwaters of braided, slow-moving parts of the river (e.g., near Vanderhoof) is not highly suitable breeding habitat for wetland-associated birds and/or that little suitable habitat is present, should be confirmed.

4.5. Island Habitat Quantity and Quality

Instream islands occur in the Nechako River in a number of locations that provide valuable wildlife habitat. In total, ~110 identifiable islands were counted upstream of the Stuart River confluence by Envirocon (1984). Most of these are of fluvial origin (a small number are formed of bedrock; Envirocon 1984), supporting vegetation ranging from grass-forb to forest; and some were historically kept bare by flows but are now increasingly becoming colonized by vegetation (Section 2.3.1).

Island habitat can be substantially affected by hydrological regime. Habitat characteristics that affect habitat suitability and value for wildlife that can be affected by flow/water levels include island habitat area (i.e., amount of habitat available), island habitat quality (e.g., vegetation presence and types), and island isolation (which provides seclusion and protection from predators and from human disturbance). Island habitat area and degree of isolation from river shorelines is generally a function of water elevation, although this relationship also interacts with topography: in general, island habitat area decreases and island isolation increases with increasing flow and water level.

Effects of hydrological regime on island habitat quality is more complex and the interaction between the timing of high or lows flows and periods of species habitat use is instrumental in evaluating trade-offs. Further, the characteristics that are associated with habitat quality differ among wildlife species. For the Nechako River, general effects to riparian habitat condition and function are being addressed as a separate issue (see Section 4.1). However, flow-related effects to islands additionally include maintenance of distinct habitat types, such as bare sandbar habitats (see Section 4.5.4) and sub-climax seral stages (see Section 4.5.2), which are typical in riparian and in-channel areas of dynamic riverine systems and are important for some wildlife species.

Five specific issues representing potential effects of flow management in the Nechako River on instream island wildlife habitat have been identified during this assessment and these are summarized below. Key wildlife uses of islands that may be affected by water level management include calving for ungulates (especially Moose), bird nesting, waterfowl staging, and winter foraging for Moose. Mule Deer also make use of use of island habitats along the Nechako River in summer, including for fawning and escape terrain, although it has been considered unlikely that use of instream islands is a widespread trait in local deer herds, or that it is of critical importance (Envirocon 1984). Whitetail Deer have since colonized the Nechako area and presumably have similar habitat use as reported for Mule Deer.

4.5.1. River Island Habitat – Ungulate Calving

Islands can provide predator protection for ungulates, particularly Moose and Caribou, during birthing and immediately afterwards when small calves are especially vulnerable to predation (Bergerud and Page 1987; Addison *et al.* 1990; Bergerud 1992; Addison *et al.* 1993; Seip and Cichowski 1996; Kie 1999; COSEWIC 2014; McGraw *et al.* 2014). Predation is a major factor affecting the dynamics of Moose populations (Gasaway *et al.* 1992; Van Ballenberghe and Ballard 1994) and security cover, found in landscape features protected by the proximity of water or in dense vegetation, is most important for Moose during spring calving (MacCracken *et al.* 1997). Some cow Moose have been shown to swim to islands for birthing when these are available (Addison *et al.* 1993) and to choose small islands for calving, even when foraging conditions there were less suitable than on mainland sites, due to the resultant increased survival of young (Kie 1999). Moose also select dense deciduous stands or tall shrubs with high canopy cover as security cover for birthing (MacCracken *et al.* 1997; Bowyer *et al.* 1999).

Some islands in the Nechako River have been considered likely to provide safe birthing sites for Moose and potentially for some Mule Deer (potentially now also for White-tailed Deer), although it was difficult to document this during field visits (Envirocon 1984). Given the abundance of Moose in the landscape around the Nechako River, instream islands may be important for escape from predators and may have other valuable features such as dense cover and available drinking water that make them attractive as ungulate birth sites. During baseline studies for the proposed Kemano Completion Hydroelectric Development (Envirocon 1984), minimum water in channels between islands and the mainland was estimated at 90 sites on July 20 to 31 in 1982 to evaluate their potential value as ungulate birthing sites. Fifty-seven islands (63%) were separated by channels estimated to be less than 1 m deep during field visits and it was estimated that most of these channels would have been dry during June of that year. However, the remaining islands were considered to have potential security habitat (i.e., for escape from predators). Moose and Mule Deer are generally born in June (Shackleton 1999);

hence this is the month when the availability of isolated island habitat should be considered during water use planning.

Hydrological regime of the Nechako River may affect availability of instream islands for ungulate birthing as well as their suitability. Water levels during the birthing period (June) determine the amount of island habitat available and the degree of island isolation, which provides predator protection. Because water level is likely to be directly related to island isolation and inversely related to habitat availability, trade-offs between availability and suitability likely to exist. However, such trade-offs have not been evaluated.

Data availability/certainty for evaluation of the "River island habitat – ungulate calving" issue was categorized as moderate because some islands had documented use by Moose and were thought to be used for birthing (Envirocon 1984); however, to our knowledge, the importance of such islands to the population have not been assessed or quantified. Further, island area (i.e., available habitat) or island isolation have not been related to flow/water levels beyond the water depth measurements conducted in the channel around islands by Envirocon (1984) in July 1982 (described above). These data gaps limit the potential for assessing the importance of island for birthing for Moose (and potentially deer) as well as their availability and security in relation to different hydrological scenarios.

The magnitude of the potential effect was evaluated as moderate because predation is recognized as a major factor affecting the dynamics of Moose populations (Van Ballenberghe and Ballard 1994), security habitat is considered of high importance for calf survival (MacCracken *et al.* 1997), Moose are known to use islands for security habitat, and islands in the Nechako River are likely to provide such habitat. However, it is likely that substantial alternative birthing habitat exists for Moose in the area (e.g., dense deciduous stands or tall shrubs with high canopy cover) and Moose use a variety of strategies for copying with predation risk during birthing (Bowyer *et al.* 1999). Further, suitable island security habitat is unlikely to be completely eliminated by any hydrological regime selected (this assumption could be tested through modelling; see below). Thus, it is expected that hydrological regime during June has the potential to cause some changes in behaviour and habitat and may have small impacts on productivity and/or survival but is not anticipated to affect population status. Islands as birthing habitat are likely less important for Mule Deer than for Moose (Envirocon 1984), although because both species birth in June, water management decisions made to benefit Moose would also likely benefit Mule Deer. Given moderate certainty and moderate magnitude of the potential effect, the priority rating was also categorized as moderate (Table 1).

Assessment (modelling) of the extent of island isolation in relation to hydrological flow scenarios evaluated for water use decisions could be used to determine optimal flows in June, such that both island isolation and available habitat are maximized during the ungulate birthing period (i.e., islands are isolated but not flooded in June). Also, the trade-offs between habitat availability (amount of island surface area) and degree of isolation could be quantified in relation to flow/water level changes.

Additionally, which islands are (or could be) used for ungulate birthing, and what characteristics other than amount of available habitat and isolation make them suitable birthing sites, could be evaluated. For example, the suitability of foraging habitat available on islands is likely to interact with hydrological regime; thus ideally, island area and isolation from shorelines would not be considered independently. Currently, our lack of understanding of the importance of islands for ungulate birthing and the potential effects on key characteristics with changes in hydrological regime are key data gaps that affect evaluation of this issue.

4.5.2. River Island Habitat – Moose Winter Forage

Winter habitat is generally of key importance for ungulates, and for Moose, winter habitat is considered a critical limiting factor for populations (McNicol and Gilbert 1980; Thompson and Vukelich 1981). Suitable winter habitat is associated with food supply, snow depth, elevation, slope, and thermal and security cover (Wall *et al.* 2011). Although food sources vary seasonally, Moose generally prefer the sub-climax semi-open successional stages of forests, which are dominated by deciduous trees and shrubs, and which may be found in river floodplains, riparian communities, wetlands, and in regenerating burns and cut blocks and avalanche chutes in early successional stages (Stevens and Lofts 1988; MacCracken *et al.* 1997). Moose make extensive use of river valleys where seasonal scouring by floods and ice create a complex pattern of young and old forest stands (Shackleton 1999), and suitable winter habitat is primarily found in low elevation riparian communities, especially riparian habitats along dynamic riverine systems, where much of the riparian vegetation is in a sub-climax seral stage (LeResche *et al.* 1974; Kelsall and Telfer 1974). Moose have been documented to preferentially select riparian habitat even when suitable feeding sites area available in upland areas (Doerr 1983; Hundertmark *et al.* 1990).

The Nechako River system contains high quality forage for Moose within riparian and upland areas, and a number of UWR have been established (see Section 2.3.1). Moose also make intensive use of Nechako River instream islands for foraging in winter (Envirocon 1984). Although Mule Deer (and potentially White-tailed Deer) may also use instream islands for foraging in winter, baseline studies conducted for the proposed Kemano Completion Hydroelectric Development concluded that islands in winter were more important for Moose than Mule Deer, whereas use of island by deer, including fawns, may be significant in early summer (early summer use of islands by deer is encompassed with the ungulate calving issue, Section 4.5.1).

Hydrological regime has the potential to affect Moose winter forage habitat by impacting the amount of suitably vegetated riparian island habitat available, which generally decreases with increasing water level (although the relationship between flow and vegetation may be more complex; see Section 4.1). It is also likely that the isolation of islands from the shorelines, which increases with increasing water levels, is also attractive as security cover for Moose during winter (though less critical than during spring calving). Further, hydrological regime is a key force in maintaining the sub-climax seral stages in riparian and in-channel areas of the Nechako River important for Moose during winter, and baseline studies conducted for the proposed Kemano Completion Hydroelectric Development concluded that riparian Moose browse in the Nechako River system is dependent on hydraulic action and high water tables associated with the river (Envirocon 1984).

Data availability/certainty for evaluation of the "River island habitat – Moose winter forage" issue was categorized as moderate because island use by Moose in the Nechako River has been documented and island riparian habitat is considered important for Moose foraging in winter (Envirocon 1984); however, to our knowledge, the importance of such islands to the population has not been assessed or quantified. Further, island area (i.e., available habitat) has not been related to flow/water levels. The magnitude of the potential effect was evaluated as moderate because winter habitat is considered a critical limiting factor for Moose populations and Moose are known to use Nechako River riparian island habitat for winter foraging. However, suitable riparian foraging habitat also exists along Nechako River shorelines, the security habitat provided by islands is likely not highly important (in contrast to the importance of security habitat during the calving period), and suitable island foraging habitat would not be completely eliminated by any hydrological regime selected. Thus, it is expected that hydrological regime has the potential to have some effect on behaviour and habitat and may have small impacts on productivity and/or survival, but is not anticipated to affect Moose population status. Given moderate certainty and moderate magnitude of the potential effect, the priority rating was also categorized as moderate (Table 1).

4.5.3. River Island Habitat – Nesting Birds

Islands within the Nechako River may provide valuable breeding sites for birds. As discussed for ungulate birthing above, islands that are isolated from river shorelines by water channels are likely to provide some protection from terrestrial predators. The effect of water depth in deterring predator access for birds breeding in wetlands is described in Section 4.4.2. Islands that are isolated from the river shorelines provide similar protection from predators (with water surrounding the island rather than the nest itself), and studies of natural nests and experimental artificial nests have documented superior bird nest survival on islands. For example, Albrecht *et al.* (2010) demonstrated that island habitat was the most important factor in explaining nest survival rate for Common Pochards due to reduced predation: island and overwater nests were more successful than terrestrial nests. Similarly, nest survival rates were greater on instream islands than on river edges for the natural nests of nine species and for artificial nests of various shapes and in various locations in Manu National Park, Peru (Ocampo and Londoño 2015). Greater nest survival on islands was also documented in a study in the Vistula River Valley (Poland), where a study using experimental nest placement reported higher survival of artificial nests on an instream island than on the river bank (Żmihorski *et al.* 2010).

Hydrological regime in the Nechako River has the potential to affect both the habitat availability and degree of island isolation during the bird nesting period, as described in Section 4.5 (note that hydrological regime also affects risks associated with nest inundation and stranding, which are considered in Section 4.4). As described in Section 4.4, the bird nesting period is late April to mid-August, with highest nesting intensity between mid-May through third week in July[7]. Among bird species known to breed in the Nechako River system, Canada Geese are known to nest on islands (Campbell *et al.* 1990a; Baldassarre 2014) and therefore likely use Nechako River islands for breeding. Other species (e.g., shorebirds, passerines, gulls) are also likely to benefit from reduced predation risk afforded by instream island habitat. For example, most seabird species breeding in marine systems nest on islands that are free from terrestrial predators (Lack 1968), and predation is known to be a key force in nest site selection (Buckley and Buckley 1980).

Data availability/certainty for evaluation of the "River island habitat – nesting birds" issue was categorized as low because, although the use of Nechako River instream islands by a variety of breeding birds is likely, specific use is not well documented and benefits have not been quantified or related to populations. The potential effects of differing hydrological regimes on island habitat are also unknown since island area (i.e., available habitat) or island isolation have not been evaluated at different flow/water levels. Magnitude of the potential effect was rated as moderate: although birds are likely to breed on islands in the Nechako River, it is unlikely that the hydrological regime could affect the amount of island breeding habitat or its value to an extent that could affect population status. Given low data availability/certainty, the priority rating was categorized as high (Table 1).

4.5.4. River Island Habitat – Waterfowl Spring Migration

Instream islands in the Nechako River are of key importance to migrating waterfowl, especially to migrating Canada Geese on route to Alaska breeding areas through the Pacific Flyway in spring (see Section 2.3.1). Geese have been reported to typically forage in upland agricultural areas and use instream islands for resting and gravelling (Envirocon 1984). The main spring migration period extends through April and May (Belrose 1976), with numbers peaking in the Nechako Lowlands in the third week of April (Campbell *et al.* 1990a). The Nechako River Migratory Bird Sanctuary, which encompasses the numerous instream islands in the braided section of the Nechako River in the vicinity of Vanderhoof, was established as a critical staging area for Canada Geese (although many other waterfowl species use the Nechako River; see Section 2.3.2.3).

Hydrological regime has the potential to affect island habitat availability and suitability for migrating waterfowl, especially Canada Geese, through impacts to island habitat area, degree of island isolation, and characteristics of island habitat (see Section 4.5). For Canada Geese on migration, islands that are isolated from river shorelines provide security habitat (freedom from disturbance) and bare island habitat provides resting and gravelling habitat. When water levels are too low, this permits access to islands by predators and by humans (including on ATVs), which can cause mortality or disturbance of migratory staging activities (Envirocon 1984). Alternatively, high flows during the spring migration period would reduce island habitat availability (some islands may be flooded).

Hydrological regime is also important in maintaining island habitat suitable for migrating waterfowl, although this applies to flows outside of peak migration periods. Prior to impoundment of the

Nechako Reservoir, annual floods caused the scouring and deposition of sediments that ensured the maintenance of substrates suitable for geese resting and gravelling the following spring. Pre-project, the peak of spring Canada Goose migration immediately preceded the annual spring flood (Envirocon 1984). The current lack of spring high flows, together with lower mean annual discharges, are not maintaining bare habitats to the same extent and this has caused some bars/islands to become invaded by woody growth, reducing suitability for geese (Envirocon 1984), and many islands now have little gravel remaining (Section 2.3.1). This effect, where water management that reduces high flows and therefore affects instream islands due to changes in gravel transport, has also been reported in the MacKenzie River, USA, in relation to reductions in salmon spawning habitat (Lloyd *et al.* 2004). Impacts of channelization and flow regulation, which impacts a variety of wildlife and fish, have been documented to diminish sandbar habitats for many large rivers (Tracy-Smith *et al.* 2012). The issue of sediment deposition in the Nechako River is being addressed directly (NHC *in prep*) and for its effects of fish habitat (Chudnow *et al.* 2022; Johnson *et al.* 2022b).

Data availability/certainty for evaluation of the "River island habitat – waterfowl spring migration" issue was categorized as moderate. The importance of the Nechako River instream islands to Canada Geese populations is documented; however, the potential effects of differing hydrological regimes on island habitat and isolation have not been quantified. As noted above (Section 4.5), a trade-off exists between island habitat availability and habitat isolation, and an analysis could be done to determine optimal flow levels during the spring migration period. Further, the relationship between flow and benefits to migrating waterfowl is complicated by the role of flows in shaping habitat suitability, for which timing windows differ from the migration period (i.e., island-shaping high flows should occur outside of the peak migration period). Magnitude of the potential effect was rated as high, given the importance of the Nechako River's instream islands for migrating Canada Goose populations and the potential effect that hydrological regime can have on island characteristics. Priority rating was therefore categorized as high (Table 1).

4.5.5. River Island Habitat – Waterfowl Fall Migration

Nechako River instream island habitat is also important for waterfowl during the fall migration (Munro 1949; Envirocon 1984; Brown *et al.* 1995), although it is used less by Canada Geese in fall than in spring (described in Section 2.3.2.3). Concentrations of geese in fall are greatest in the Vanderhoof and Fort Fraser areas (Envirocon 1984). Although the islands are less important for Canada Geese in fall, characteristics which make them suitable for resting and gravelling habitat in spring also likely provide benefits in fall. These include island habitat area (i.e., available habitat), island isolation, and island habitat suitability for resting and gravelling, as described in Section 4.5.4. Timing of the peak fall migration period is September and October, although this is only relevant to hydrological effects on island habitat availability and island isolation, not on island characteristics (which are shaped by flow magnitudes throughout the year). Data availability/certainty for evaluation of the "River island habitat – waterfowl fall migration" issue was categorized as moderate for the reasons described above for the "River island habitat – waterfowl spring migration" issue (Section 4.5.4), and magnitude of the potential effect was rated as moderate because the Nechako River's instream islands appear to be less important for migrating Canada Goose populations in fall than in spring. Priority rating was therefore evaluated as moderate (Table 1).

5. PERFORMANCE MEASURES AND RECOMMENDATIONS

Three flow-related wildlife themes were identified during this review within which a total of nine specific wildlife issues were defined[8]. In the following sub-sections, for each of the three themes, the potential for identification of performance measures that could be applied to water use planning are discussed and recommendations are made regarding improvement of assessment of the issues (Section 5.1). Additionally, the potential for alternative (i.e., not flow-related) management is considered (Section 5.2). Performance measures and recommendations for addressing data gaps and improving understanding are summarized in Table 2. Because data gaps, potential thresholds or performance measures, and recommendations are related for issues within themes, all issues are considered together for each of the three themes. Also, because a variety of water management regimes are under consideration (Section 3.2), no assumptions regarding expected seasonal flows/water levels were made. It should be noted that identified performance measures are focused on the specific issue under consideration and that potentially interacting factors are not considered. For example, performance measures that address adverse effects of high flows/water levels on bird nest inundation or stranding do not consider potential effects of flows on riparian or in-channel habitat characteristics that may also be relevant to nesting birds in other ways (e.g., vegetation characteristics, foraging habitat quality).

5.1. Potential Performance Measures

Performance measures are metrics for evaluating how changes in flow affect a particular interest or issue. The following section(s) describe favorable flow scenarios, performance measures, and/or objectives for the key issues discussed earlier in this document. This information is provided for consideration by the WEI Technical Working Group and Main Table to support the structured decision-making process. It is important to recognize that the draft performance measures etc. presented here might be revised, replaced, or ignored depending on the specific needs and interest of the WEI.

5.1.1. American Beaver: Inundation of Dens, and Den and Food Access

Adverse effects on American Beavers, through flooding of dens when water levels are rising or loss of accessibility to dens and food supplies in winter when water levels drop, were assigned a moderate priority rating based on the vulnerability of beaver populations to rapid water level changes (increases

[8] Two other related wildlife themes, riparian condition and function and wildlife food resources, are being addressed in other technical assessments.

and decreases) during sensitive time periods, as documented in the literature, although some adaptability has also been observed (Section 4.3). The key data gaps identified that limit confidence in the assessment were the lack of location-specific data on effects of current water level fluctuations and the lack of recent data on beaver populations (Section 4.3; Appendix A).

One set of thresholds for addressing adverse effects of water level fluctuations on beavers have been identified: Smith and Peterson (1991) recommended that total annual water fluctuation should not exceed 1.5 m, and winter drawdown should not exceed 0.7 m. However, these values were developed for lakes and reservoirs, not rivers. Further, effects of water level changes on American Beavers have been documented to vary according to location-specific conditions (Section 4.3), which limits the potential to confidently identify performance measures for the Nechako River.

More generally, adverse effects to beavers during water management can be minimized by reducing the speed and magnitude of flow/water level fluctuations during sensitive time periods. Specifically, to protect beavers, increases in water level, and rate of water level change, should be minimized when ice may be present and kits are very young (i.e., December-June) and decreases should be minimized when ice may be present and there is reliance on food stored under the ice (November to March). Thus, any performance measures should address rates and magnitudes of change in water levels for these periods. Although Common Muskrats are also strongly affected by water level changes, fewer muskrats than beavers appear to make use of habitats in the Nechako River (occurring primarily in wetlands in the vicinity of the river and in some backwater areas) and muskrats would also benefit from protective measures implemented for beavers.

Given evidence in the literature of adverse effects that can occur when water levels change substantially when ice is present or when kits are less than one month old, we recommend the following as a preliminary performance measure for the protection of beavers:

- Avoid large magnitude and rapid water level increases and decreases (i.e., minimize rate and magnitude of flow increase and decrease) when ice is present or kits are young (i.e., November-June).

It is reasonable to assume that a substantial American Beaver population occurs on the Nechako River (similar to that reported between the 1980s and ~2000; see Section 2.3.2.2) that could be affected by water level changes. However, to improve on the above performance measure and improve our understanding of the effects of flow changes in the Nechako River on beavers, we recommend that:

- A study is conducted in which the behaviour, success (survival, reproduction), and adaptability of beavers under varying flow conditions is determined for the Nechako River. This may include mapping the types (e.g., lodges, bank dens) and elevations of beaver dens on the Nechako River, the fates of which could then be modelled under different flow scenarios, and documenting beaver behaviour and survival when water levels change.

5.1.2. Bird Nests: Inundation and Stranding

River flow is a major driver in community dynamics. Occurrence of birds in river ecosystems has been shown to be strongly influenced by elements of river flow variability (Royan *et al.* 2013) and greater waterbird productivity has been reported for natural systems than those where timing and duration of water changes has been altered (Lloyd *et al.* 2004). As identified during this review, changing water levels during the vulnerable bird nesting period (incubation, along with nestling period for altricial or semi-precocial species) can cause mortality of eggs or nestlings through flooding for species nesting within the river channel. Stranding may also affect species nesting in wetland-type habitat if this occurs within the channel. However, effects of flow/water level on bird nests vary by species depending on life history strategy (e.g., nest location, length of vulnerable period, potential interactions such as effects on habitat or food supply). Thus, identification of performance measures that represent thresholds or benchmarks for populations is challenging (i.e., they may vary based on a wide range of considerations, including, at highest level, species, timing, and location).

Although the relationships between nest survival and water level changes can be complex, with multiple thresholds potentially identified even for single species (e.g., Desgranges *et al.* 2006; Royan *et al.* 2013), thresholds that could represent performance measures have been identified for hydrology effects in relation to measures of bird abundance or productivity for some locations and species or species groups. Thresholds have been identified for multiple metrics, including flow magnitudes, minimum and maximum water levels, maximum rates of water level change, frequency and timing of flow events, water depth, and timing, magnitude, duration, and frequency of flooding. The following studies documented in the literature have investigated or identified thresholds for nesting birds related to flow or water level:

- In a review of ecological responses to flow modifications in rivers, Lloyd *et al.* (2004) found that inter-annual variation in bird abundance was correlated with both area flooded and in-channel annual flow. Although, the relationship between the degree of flow modification and ecological or geomorphological change was not simple (i.e., flow modification and ecological response are not necessarily correlated), some thresholds could be identified. For example, for the Macquarie River in Australia, breeding by some wading birds did not occur when annual flows dropped below threshold levels.

- For the Snail Kite (*Rostrhamus sociabilis plumbeus*), results of threshold modeling suggested that both low water and high water, and high rates of change (declining or increasing water levels), had negative, threshold effects on nest survival, with nest survival potentially increasing over three-fold when thresholds were avoided during simulations (Fletcher *et al.* 2021).

- Hydrological indices found useful for predicting presence of river birds in Great Britain included variability around extremes of high and low flows, flow frequency, the timing of flow events, and flow magnitude, with hydrological associations differing among species based on their life history traits and the impacts of flow conditions on foraging and breeding habitats (Royan *et al.* 2013).

- Hoover (2006) noted that nests of wetland-dependent birds built over water were most successful when water depth remained greater than 60 cm.
- Leslie (2001) found that river management had a substantial effect on the frequency of successful breeding episodes for colonially-nesting waterbirds in south-eastern Australia relative to the natural precedent (80% reduction): fecundity was related to flow thresholds for timing, magnitude, duration, and frequency of flooding, with the interval between breeding episodes during extended drought periods identified as the most critical factor likely to affect the long-term stability or persistence of waterbird breeding.

For the Nechako River, the priority rating for inundation of bird nests was categorized as high due to the vulnerability of several types of bird nests likely present to flooding and the high likelihood of rising water levels during the nesting period (Section 4.4.1; Appendix A). However, the priority rating for nest stranding was categorized as low because this type of risk applies mainly to birds that nest within wetlands (i.e., nests are located over water), and it appears that breeding habitat for wetland-associated birds within the Nechako River channel is likely limited. Thus, rising water levels during the bird nesting period (May through July) likely presents the highest risk to nesting avian species in the Nechako River system.

The key data gap that limits confidence in the assessment was the lack of nesting site data which makes it difficult to evaluate the types of water level changes that could affect nesting success; this, in turn, makes identification of performance measures for the Nechako River system difficult. Although some data on bird populations in the Nechako River system exist, and a wide variety of species may nest within in-channel habitat throughout the length of the river, specific nesting locations are generally not known. Further, species differ in the timing of nesting and the duration of the periods during which they are vulnerable. Given this data gap along with the tendency for thresholds to be species and location-specific, no specific performance measures were identified for nesting birds in relation to Nechako River water management such as those identified in other studies (above). More generally, unless species-specific information is obtained, specific adverse effects on nesting birds through nest inundation when water levels are rising or nest stranding when water levels drop can be minimized by reducing the magnitude and rate of flow/water level fluctuations during the bird nesting period. We therefore recommend the following as a preliminary performance measure for the protection of nesting birds from inundation and stranding:

- Avoid large magnitude and rapid water level increases and decreases (i.e., minimize rate and magnitude of flow increase and decrease) during the bird nesting period (i.e., May – July).

To improve on this performance measure and the priority ranks assigned to bird nest inundation and bird nest stranding issues, we recommend that the following data gaps are addressed:

- Improve our understanding of where birds are nesting along the Nechako River; and
- Confirm that wetland-type habitat in shallow backwaters of braided, slow-moving parts of the river (e.g., near Vanderhoof) is not highly suitable breeding habitat for wetland-associated birds and/or that little such suitable habitat is present.

5.1.3. River Island Habitat

Five issues related to effects of flow/water levels on instream island habitat for wildlife (ungulates and birds) were identified. Important habitat characteristics affected by hydrological regime are habitat area (i.e., amount of habitat available) and island isolation from shorelines (by water channels) which provides seclusion and protection from predators and human disturbance. Island habitat quality is also affected by flow regime (e.g., vegetation presence and types), with optimal characteristics varying by species. Based on likely importance of island habitat to the species or species groups, and the potential for flow to affect key habitat characteristics, the issues were assigned priority classifications of moderate (ungulate calving, Moose winter forage, and waterfowl fall migration) and high (nesting bird and waterfowl spring migration).

Timing of potential effects varies for each of the five issues, as does our knowledge on the use and importance of islands to populations (Section 4.5; Appendix A). For example, the importance of the Nechako River instream islands to Canada Geese populations has been well documented (although important island characteristics have changed), whereas little specific information of the importance of islands to nesting birds was found. Further, although trade-offs likely exists between island habitat availability and habitat isolation, the importance of these two factors varies among issues/species groups. The key data gaps identified that limit confidence in the assessment were therefore the lack of quantifying benefits or relating them to populations (with the exception of waterfowl migration habitat the importance of which has been documented) and relating island areas (amount of habitat available) and degree of isolation to flow/water levels to assess and quantify benefits and trade-offs.

Given that thresholds or trade-offs for island characteristics by flow/water level could not be quantified, specific performance measures could also not be identified. In general, without more detailed information, moderate flows during which islands are isolated but not flooded during the vulnerable periods (i.e., ungulate birthing, Moose winter foraging, bird nesting, waterfowl spring and fall migration) are likely to be most beneficial. Additionally, a hydrological regime that maintains functional riparian habitat (i.e., hydraulic connectivity for the persistent of riparian vegetation; this is being addressed separately; see Section 4.1) as well as wildlife habitats typically maintained by annual floods (e.g., bare sandbar habitats for migrating geese and sub-climax seral stage riparian habitat for Moose) are important, although key habitat characteristics differ by species and the timing of floods should avoid potential adverse effects to multiple species (e.g., island-shaping high flows should not occur during peak migration periods for waterfowl or the peak nesting period for birds). Regimes with periodic high flows may generally be most beneficial for wildlife using islands; however, ideally, analyses could be done to determine optimal flow levels during the vulnerable periods to identify potential thresholds where overall benefits are maximized, and to determine the frequency of high flows required to maintain important habitat characteristics (e.g., high flows may not have to occur annually).

Given our current understanding, we recommend the following as preliminary general performance measures for the maintenance of valuable wildlife island habitat:

- During the vulnerable periods (ungulate calving, moose winter forage, nesting birds, waterfowl spring and fall migration), islands should be isolated but not flooded (moderate flows likely best); and
- Maintain high flows during the annual cycle but outside the vulnerable periods to maintain sub-climax seral stages for Moose forage and bare island habitat for migrating geese.

To improve our understanding, we also recommend that:

- An analysis is conducted that relates the amount of island habitat available (area) and island isolation to flow and allows the evaluation of trade-offs; and
- The value of islands for migrating Canada Geese is reassessed given the changes in key island characteristics (decrease in bare gravel habitat) in recent years (see Section 2.3.1).

5.2. Alternative Management Considerations

Alternative management options that could be considered in addition to, or instead of, management for flow/water level were considered for the identified wildlife issues. In some cases, it is possible that creation, enhancement, or conservation of other important habitat could compensate for potential adverse effects from flow changes. For example, protection, creation, or enhancement of high suitability Moose habitat for calving and winter forage could potentially compensate to some extent for riparian and island habitat that is reduced in quantity or quality due to hydrological regime. Similarly, enhancement of riparian habitat for nesting birds could potentially compensate for some loss in bird productivity. However, where hydrological regime has the potential to cause substantial mortality (e.g., by drowning beavers and flooding bird nests), no alterative management options are likely to be realistic for the system (although habitat could potentially be enhanced in tributaries or in other systems to help compensate for losses). Further, depending on the timing of flow changes, it is possible that habitat affected by water management may cause or exacerbate population sinks (e.g., birds may initiate breeding in what appears to be suitable habitat, but breeding attempts fail if nests are later flooded).

Where island habitat is important for wildlife, such as for migrating Canada Geese or Moose, it may be difficult to create or enhance habitat in other areas to compensate if habitat quantity or quality of island is adversely affected. However, it is also possible that flow changes may naturally cause alternative habitats to become more suitable. This was noted during baseline studies for the proposed Kemano Completion Hydroelectric Development: when water levels were very low and islands within the Nechako River Migratory Bird Sanctuary were no longer suitable (safe for geese), alternative islands become available outside of the sanctuary that were flooded at higher water levels (Envirocon 1984). The potential for alternative habitats to become available under different flow scenarios highlights the need for a holistic assessment of island habitat quantity and quality in relation to hydrological regime.

6. CLOSURE

Potential wildlife issues related to water management in the Nechako River have been identified for wildlife given that a variety of potential water management regimes are currently under consideration. For the wildlife issues identified, the magnitude of potential effects were evaluated, data availability/certainty was ranked, and priority of issues in relation to reservoir operational management were classified. The pathways of effects identified are associated with changes in flow or water levels during periods of vulnerability or due to effects that flows have on maintaining suitable habitat.

The issues identified included potential effects of high and low flows (especially if changes are rapid) to American Beaver and Common Muskrats that are vulnerable in dens or when accessing food supplies in winter, potential effects on nesting birds due to nest flooding or stranding, and effects of a number of wildlife species (birthing and wintering ungulates, nesting birds, migrating waterfowl) that utilize instream islands during vulnerable or limiting life history periods that can be flooded during high flows or become connected to shorelines during low flows, and on which habitat suitability can be affected. For some identified issues, confidence in the assessment was relatively high (e.g., the importance of island habitat for migrating Canada Goose is well documented; Moose have been documented to use of islands for foraging during winter) and in other cases, data on species occurrence and habitat were lacking (e.g., birds nesting in riparian areas and on islands). Based on data availability/certainty and magnitude of the potential effects evaluated, priorities assigned to issues ranged from low to high. Three issues were ranked high in priority: inundation of bird nests, island habitat for nesting birds, and island habitat for migrating waterfowl in spring. Among these, the former two were conservatively ranked high due to low data availability/certainty, whereas the high rank of the latter reflected the high magnitude of potential effects.

Preliminary performance measures and recommendations that could be used to inform evaluation of trade-offs during the structured decision-making water use planning process were provided for the identified issues based on our knowledge (data availability and data gaps) and review of the literature. In general, insufficient information exists to provide specific thresholds that could be considered performance measures. However, general prescriptions were made and recommendations were provided that could be implemented to improve on these general prescriptions. All performance measures, or more general recommendations, should be considered preliminary given the high-level approach of this assessment.

Yours truly,

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APPENDICES

Appendix A. Wildlife Issues Related to Operations of the Nechako River Identified During a High-Level Issues Scoping Review

Issue	Species or Species Group	Pathways of Effects	Timing/ Life History Stage	Data availability/Certainty (Low, High)	Magnitude of Potential Effects (Low, Moderate, High)	Priority Rating	Performance Measures and Recommendations[1]
Riparian condition and function	Riparian-associated wildlife species	Changes in flow can affect hydraulic connectivity to riparian vegetation, which, in turn can affect the availability or suitability of riparian habitat for wildlife (riparian habitat quantity and quality).	N/A	*This issue is being addressed separately through ongoing study and analysis.*			
Wildlife food resources	Wildlife species foraging in aquatic habitat	Changes in flow can affect productivity of wildlife aquatic food resources, such as fish, invertebrates, and aquatic vegetation.	N/A	*These issues are being addressed separately.*			
American Beaver: inundation of dens	American Beaver, Common Muskrat	Large increases in water level (e.g., sudden snowmelts) in winter or spring can flood dens, destroy lodges, and drown beavers under the ice (Baker and Hill 2003; Rosell and Campbell-Palmer 2022). Kits are particularly vulnerable to floods in their first month. Beavers commonly den in burrows in the banks in water bodies that are subject to floods and fluctuating water levels (CDC 2022). Muskrats are less tolerant of fluctuating water levels because these tend to eliminate required food supply (littoral zone plants; CDC 2022). In the Nechako River, beavers occur throughout the river and muskrats occur primarily in wetlands away from the river, but occasionally in quiet backwaters (Envirocon 1984).	Winter - spring (December - June) - when ice may be present, until kits are one month old	Moderate: • Data on beaver and muskrat populations exist, although only data from one study (Envirocon 1984) were available. Data from Hatler (1998) and Hatler (2002), which provide information on both beaver and muskrat populations, were not located for this review, although some results of these studies for beavers were found cited elsewhere. • Surveys (conducted in 1982 and early 2000s) indicate a relatively large beaver population along the Nechako River (between ~400 to ~700 individuals for an ~ 200 km stretch of river). • Available data are somewhat dated (not recent). • No data were found on effects of water levels or water level fluctuations on the two species in this system; effects can vary substantially by location and conditions.	Moderate: • Beavers are vulnerable to den flooding, especially when water levels increase rapidly while there is ice cover; rising water when lodges are frozen over can destroy lodges and drown beavers; kits are particularly vulnerable to floods in their first month. • Beavers are known to occur throughout the Nechako River. • In water bodies that are subject to floods and fluctuating water levels, beavers commonly den in burrows in the banks. • Parents can move kits by carrying them out in their mouths to temporary lairs above the waterline; however, flood events are stressful and increase risk. • Muskrats are not common in the main river channel (Envirocon 1984).	Moderate	• Avoid large magnitude and rapid increases in water level (i.e., minimize rate and magnitude of flow increase) when ice is present and kits are less than one month old. * Improve our understanding of the effects of flow changes in the Nechako River on beavers through study of den characteristics and beaver behaviour and survival under varying flow conditions.
American Beaver: den and food access	American Beaver, Common Muskrat	Dropping water levels during winter can cause exposure of underwater den entrances and increase freeze-up of the water column, which can limit underwater movement and prevent access to stored food supplies, leading to hunger and malnutrition (Smith and Peterson 1991; Rosell and Campbell-Palmer 2022). Den entrances may become frozen over, which can trap beavers or force them to move. Muskrats feed on plant material under the ice during winter, and reduced water levels can lead to freezing of food resources which can also force them to move.	Winter (November - March) - when ice may be present and there is reliance on food (stored or growing) under the ice		Moderate: • Beavers are vulnerable to malnutrition and starvation when access to stored food is prevented or when trapped by ice inside lodges, and to predation if forced onto the ice. • Muskrats feed on plant material under the ice during winter; reduced water levels can lead to freezing of food resources in which case muskrats are forced to move which reduces survival (due to malnutrition and predation risk). • Beavers are more adaptable and resilient to water drops than muskrats (thus muskrats less likely where water fluctuations are large); muskrats are not common in the main river channel (Envirocon 1984).	Moderate	• Avoid large magnitude and rapid decreases in water level (i.e., rate and magnitude of flow decrease) when ice is present. * Improve our understanding of the effects of flow changes in the Nechako River on beavers through study of den characteristics and beaver behaviour under varying flow conditions.

[1] Performance measures are identified with bullet point and recommendations for addressing data gaps and improving understanding are identified with an asterisk.

Issue	Species or Species Group	Pathways of Effects	Timing/ Life History Stage	Data availability/Certainty (Low, High)	Magnitude of Potential Effects (Low, Moderate, High)	Priority Rating	Performance Measures and Recommendations[1]
Birds: inundation of nests	Waterbirds (e.g., geese, ducks, mergansers), seabirds (gulls), shorebirds (e.g., Spotted Sandpiper), and near-ground nesting passerines (e.g., Common Yellowthroat, Northern Waterthrush, Wilson's Warbler, Song Sparrow)	Rising water levels during the vulnerable bird nesting period (incubation, along with nestling period for altricial or semi-precocial species) can cause mortality of eggs or nestlings through flooding (e.g., Desgranges *et al.* 2006; Craig and Gill 2020).	Spring - summer (May - July) - nesting period is late April to mid-August, with highest nest intensity between mid-May through the third week in July	Low: • Some data on bird populations in the Nechako River system exist (e.g., there is information on the presence of some breeding species (Envirocon 1984; Brown *et al.* 1995)); however, specific nesting locations are generally not known. • No data were found on effects of water level fluctuations.	High: • Bird eggs and nestlings can be vulnerable to nest flooding if nests are on or near the ground and near water and if water levels rise during the vulnerable period. • Large number of species and individuals potentially breed within in-channel habitat where they may be vulnerable to nest flooding during the breeding season.	High	• Avoid large magnitude and rapid increases in water level (i.e., rate and magnitude of flow increase) during the bird nesting period (i.e., May – July). * Improve our understanding of where birds are breeding along the Nechako River. * Thresholds should ideally be species-specific: risks vary by species depending on life history strategy (e.g., nest location, length of vulnerable period); thus, relationships between nest survival and water level changes can be complex and multiple performance measures may be identified even for a single species (e.g., Royan *et al.* 2013; Fletcher *et al.* 2021).
Birds: stranding of nests (exposure to predation)	Waterbirds and other species groups that can nest above water	Dropping water levels around a nest located over water during the vulnerable bird nesting period (incubation, along with nestling period for altricial or semi-precocial species) can cause mortality of eggs or nestlings through nest stranding (which can cause nest abandonment or increased predation risk). Nest success has been linked to maintenance of wetland water depth in many studies (e.g., Desgranges *et al.* 2006; Hoover 2006; Picman *et al.* 1993; Jobin and Picman 1997; Niemczynowicz *et al.* 2017).		Low: • Some data on bird populations in the Nechako River system exist (e.g., there is information on the presence of some breeding species; Envirocon 1984; Brown *et al.* 1995); however, specific nesting locations are generally not known. • No data were found on effects of water levels or water level fluctuations. • Some portions of the Nechako River in-channel habitat may have wetland-like characteristics; however, data are lacking to determine how much potential wetland-type habitat exists and if birds are nesting in vegetation over water in such habitats, in which case nest stranding could be occurring when water levels drop.	Low: • Stranding of bird nests when water levels drop which can lead to abandonment and increased predation risk is more applicable to wetland-nesting birds than birds nesting in in-channel habitat in a river. • Few breeding records for wetland-associated species were found for the Nechako River, whereas records were found for nearby wetlands. • The amount of wetland-type habitat potentially present within the Nechako River channel is likely small and wetland-associated species are more likely to nest in wetlands adjacent to the river (in upland habitat).	Low	• Avoid large magnitude and rapid decreases in water level (i.e., rate and magnitude of flow decrease) during the bird nesting period (i.e., May – July). * Improve our understanding of where birds are breeding along the Nechako River. * Confirm that wetland-type habitat in shallow backwaters of braided, slow-moving parts of the river (e.g., near Vanderhoof) is not highly suitable breeding habitat for wetland-associated birds and/or that little such suitable habitat is present. * Thresholds should ideally be species-specific: risks vary by species depending on life history strategy (e.g., nest location, length of vulnerable period); thus, relationships between nest survival and water level changes can be complex and multiple performance measures may be identified even for a single species (e.g., Royan *et al.* 2013; Fletcher *et al.* 2021).

[1] Performance measures are identified with bullet point and recommendations for addressing data gaps and improving understanding are identified with an asterisk.

Issue	Species or Species Group	Pathways of Effects	Timing/ Life History Stage	Data availability/Certainty (Low, High)	Magnitude of Potential Effects (Low, Moderate, High)	Priority Rating	Performance Measures and Recommendations[1]
River island habitat - ungulate calving	Moose and Mule Deer	Island habitats have been identified as valuable for ungulate calving because islands provide predator protection for vulnerable recently born calves/fawns. Some instream islands in the Nechako River are believed to provide birthing habitat for Moose and potentially for Mule Deer (Envirocon 1984). River flows/water level affect the amount of island habitat available and the degree of island isolation, which is important for predator protection.	Early summer (June) - birthing for Moose and Mule Deer	Moderate: • Some islands have documented use by Moose and are thought to be important for calving (Envirocon 1984). • Benefits not quantified or related to population. • Island area (i.e., available habitat) and island isolation have not been related to flow/water levels .	Moderate: • Predation is a major factor affecting the dynamics of Moose populations. • Security habitat is of high importance for Moose calf survival. • Moose are known to select island habitat for birthing and are believed to use some islands in the Nechako River. • Suitable alternative birthing habitat likely exists for Moose in the area (e.g., dense deciduous stands or tall shrubs with high canopy cover) and suitable island security habitat is unlikely to be completely eliminated by any hydrological regime selected. • Islands as birthing habitat are likely less important for Mule Deer than for Moose.	Moderate	• During the vulnerable period, islands should be isolated, but not flooded; thus, moderate flows during the period are likely best. * Conduct an analysis that relates the amount of island habitat available (area) and island isolation to flow to determine water levels that optimize the trade-off between island habitat availability and isolation (flows that isolate islands but maximize available island habitat area).
River island habitat - Moose winter forage	Moose	Island riparian habitats have been identified as valuable for Moose winter foraging, and Moose have been documented to make intensive use of Nechako River instream islands for foraging in winter (Envirocon 1984). River flows/water level affect the amount of island habitat available; flows also affect island isolation which creates security habitat, although less important for Moose in winter than during birthing.	Winter (November - April) - Moose winter period	Moderate: • Use of islands in the Nechako River by Moose during winter has been documented (Envirocon 1984). • Benefits not quantified or related to the population. • Island area (i.e., available habitat) has not been related to flow/water levels.	Moderate: • Winter habitat is considered a critical limiting factor for Moose populations. • Moose are known to use Nechako River riparian island habitat for winter foraging. • Suitable riparian foraging habitat also exists along Nechako River shorelines. • Security habitat provided by islands is likely not highly important during winter. • Suitable island security habitat would not be completely eliminated by any hydrological regime selected. • Islands are not thought to be important for Mule Deer in winter.	Moderate	• During the vulnerable period, islands should not be flooded; isolation of islands likely adds value by increasing security of habitat; thus, moderate to low flows during the period are likely best. * Conduct an analysis that relates the amount of island habitat available (area) and island isolation to flow to determine water levels that optimize the trade-off between island habitat availability and isolation (flows that maximize available island habitat area and potentially also isolate islands).
		Hydrological regime is a key force in maintaining the sub-climax seral stages in riparian and in-channel areas of the Nechako River important for Moose during winter.	N/A				• Maintain high flows during the annual cycle but outside the winter forage period to maintain sub-climax seral stages.
River island habitat - nesting birds	Waterbirds, seabirds, shorebirds, and near-ground nesting passerines	Island habitat is likely to be valuable for nesting birds associated with riverine and/or riparian habitat. Hydrological regime has the potential to affect both the habitat availability and degree of island isolation, which provides protection from terrestrial predators.	Spring - summer (May - July) - nesting period is late April to mid-August, with highest nest intensity between mid-May through third week in July	Low: • Knowledge is lacking for specific use of islands for breeding. • Benefits not quantified or related to population. • Island area (i.e., available habitat) and island isolation have not been related to flow/water levels.	Moderate: • A variety of bird species are likely to breed on islands in the Nechako River. • It is unlikely that the hydrological regime could affect the amount of island breeding habit or its value to an extent that could affect population status.	High	• During the vulnerable period, islands should be isolated, but not flooded; thus, moderate flows during the period are likely best. * Conduct an analysis that relates the amount of island habitat available (area) and island isolation to flow to determine water levels that optimize the trade-off between island habitat availability and isolation (flows that isolate islands but maximize available island habitat area).

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River island habitat - waterfowl spring migration	Canada Goose and other waterfowl	Instream islands in the Nechako River are of key importance to migrating Canada Geese through the Pacific Flyway in spring (Envirocon 1984; Government of Canada 2022). Hydrological regime during the migration period has the potential to affect island habitat suitability for migrating waterfowl, especially Canada Geese, through impacts to island habitat area and degree of island isolation. Low water levels permit access to islands by predators and humans; high flows reduce island habitat availability (some islands may be flooded).	Spring (April - May) - peak spring migration for Canada Goose	Moderate: • The importance of the Nechako River instream islands to migrating waterfowl (especially Canada Geese) populations is documented (Envirocon 1984; Government of Canada 2022). • Island area (i.e., available habitat), island isolation, and island habitat suitability for resting and gravelling have not been related to flow/water levels.	High: • The Nechako River Migratory Bird Sanctuary in the vicinity of Vanderhoof was established as a critical staging area for Canada Geese, which is indicative of the importance of this area to migratory geese. • Hydrological regime can have substantial impacts on island characteristics.	High	• During the vulnerable period, islands should be isolated, but not flooded; thus, moderate flows during the period are likely best. * Conduct an analysis that relates the amount of island habitat available (area) and island isolation to flow to determine water levels that optimize the trade-off between island habitat availability and isolation (flows that isolate islands but maximize available island habitat area).
		Hydrological regime shapes island habitat characteristics which vary in their suitability for migrating waterfowl. Annual floods caused the scouring and deposition of sediments that maintain substrates suitable for resting and gravelling geese; lack of high flows and lower mean annual discharges causes invasion of some bars/islands by woody growth, reducing suitability for geese.	N/A				• Maintain high flows during the annual cycle but outside the migratory period (e.g., spring floods after the peak in migration) to maintain bare island habitat. * Reassess the value of islands for migrating Canada Geese given the changes in key island characteristics (bare gravel habitat) in recent years
River island habitat - waterfowl fall migration	Canada Goose and other waterfowl	Nechako River instream island habitat is also important for waterfowl during the fall migration (Envirocon 1984; Brown *et al.* 1995). Hydrological regime during the migration period has the potential to affect island habitat suitability for migrating waterfowl, especially Canada Geese, through impacts to island habitat area and degree of island isolation. Low water levels permit access to islands by predators and humans; high flows reduce island habitat availability (some islands may be flooded).	Fall (September - October) - peak fall migration	Moderate: • The importance of the Nechako River instream islands to migrating waterfowl is documented (Envirocon 1984; Brown *et al.* 1995). • Island area (i.e., available habitat), island isolation, and island habitat suitability for resting and gravelling have not been related to flow/water levels.	Moderate: • The Nechako River Migratory Bird Sanctuary in the vicinity of Vanderhoof was established as a critical staging area for Canada Geese in spring; although also an important area for the fall migration for many waterfowl species, the islands appear to be less important migrating Canada Goose populations in fall than in spring. • Hydrological regime can have substantial impacts on island characteristics.	Moderate	• During the vulnerable period, islands should be isolated, but not flooded; thus, moderate flows during the period are likely best. * Conduct an analysis that relates the amount of island habitat available (area) and island isolation to flow to determine water levels that optimize the trade-off between island habitat availability and isolation (flows that isolate islands but maximize available island habitat area).
		Hydrological regime shapes island habitat characteristics which vary in their suitability for migrating waterfowl. Annual floods caused the scouring and deposition of sediments that maintain substrates suitable for resting and gravelling; lack of spring high flows and lower mean annual discharges causes invasion of some bars/islands by woody growth, reducing suitability for geese.	N/A				• Maintain high flows during the annual cycle but outside the migratory period (e.g., spring floods after the peak in migration) to maintain bare island habitat.

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