Columbia River Project Water Use Plan

Lower Columbia River Fish Management Plan

Lower Columbia River Fish Stranding Assessment and Ramping Protocol

Implementation Year 14

Reference: CLBMON-42A

Annual Monitoring Report

Study Period: April 2020 to April 2021

Golder Associates Ltd

201 Columbia Avenue

Castlegar, BC

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REPORT

Annual Summary Report

Lower Columbia River (CLBMON-42[A]) and Kootenay River Fish Stranding Assessments: Annual Summary (April 2020 to April 2021)

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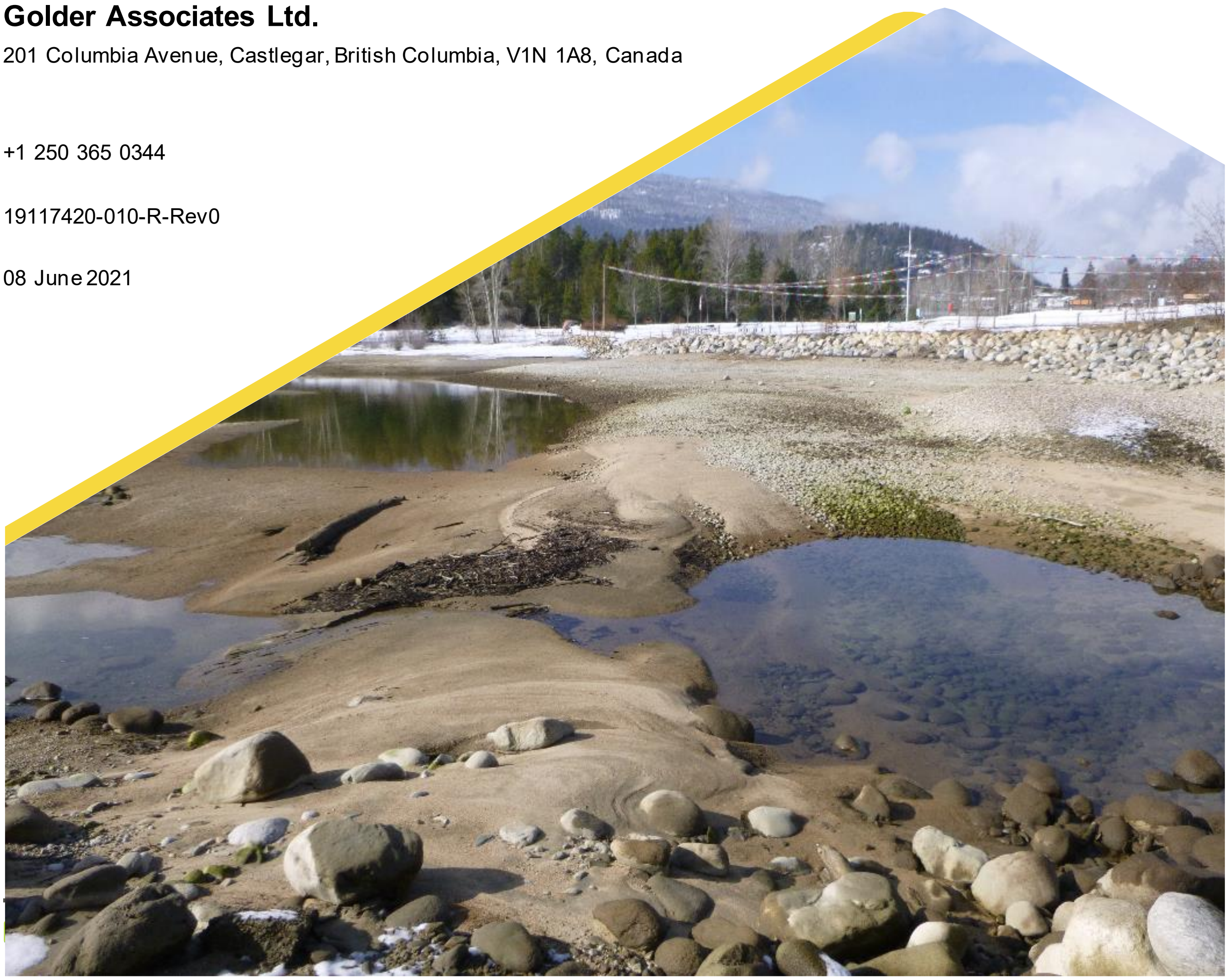

Cover Photo: Pools formed at Millennium Park (LUB) during flow reduction event RE2021-07 on 26 February 2021 (see Appendix A; Figure A2 for location).

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Executive Summary

Discharge reductions and from Hugh L. Keenleyside Dam/Arrow Lakes Generating Station (HLK/ALH) and Brilliant Dam/Expansion (BRD/X) can result in fish stranding on the lower Columbia and Kootenay rivers downstream of these facilities. To address this concern, the Lower Columbia River Fish Stranding Assessment and Ramping Protocol (CLBMON-42) was implemented in 2007 as part of BC Hydro's Water Use Plan for the Columbia River (BC Hydro 2007). The primary objective of CLBMON-42 was to collect fish stranding data to assess the impact of flow reductions and flow ramping rates from HLK on the native fish species of the lower Columbia River. In 2020, upon completion of the 13-year Water Use Plan for the Columbia River, an analysis was conducted on a 20-year dataset of fish stranding assessments to address the five management questions of CLBMON-42 (Table ES1).

The present study is an extension (Year 14) on the Lower Columbia River and Kootenay River Fish Stranding Assessments (CLBMON-42[A]), which summarizes the results of stranding assessments collected following flow reductions at HLK/ALH and BRD/X at sites on the lower Columbia and Kootenay rivers between 1 April 2020 and 1 April 2021.

At total of 28 reduction events (RE) occurred between 1 April 2020 and 1 April 2021 (the present study period). A total of 26 reduction events occurred at HLK/ALH, one reduction even occurred at BRD/X, and one reduction event occurred at HLK/ALH and BRD/X on the same day. Of those 28 reduction events, 11 occurred during the High Risk period (1 June to 30 September) and 17 occurred during the Low Risk period (1 October to 31 May). Stranding assessments were conducted for 17 of the 28 reduction events. Of those stranding assessments, 8 occurred during the High Risk period and 9 occurred during the Low Risk period.

An estimated 11,486 stranded fish were encountered during the 17 stranding assessments, with 96% of stranded fish identified as Young-of-Year (YOY) or juvenile life stage. The majority (83%) of stranded fish were salvaged and successfully relocated to the mainstem Columbia or Kootenay rivers. A total of 25 sites were assessed at least once during the study period including 7 sites that were either new or re-introduced to the program. The majority (87%) of stranded fish were found at Genelle Mainland (LUB) and Kootenay (RUB).

Sportfish accounted for 1% of the total stranded fish and were limited to YOY and juvenile Rainbow Trout (*Oncorhynchus mykiss*). Stranded invasive species, not native to the lower Columbia or Kootenay rivers included 29 Common Carp (*Cyprinus carpio*), one Brook Trout (*Salvelinus fontinalis*), and one Yellow Perch (*Perca flavescens*). The remainder of stranded fish were non-sportfish; the most abundant being Sucker species (*Catostomidae spp.*), Redside Shiner (*Richardsonius balteatus*), and Northern Pikeminnow (*Ptychochelius oregonensis*), which combined accounted for 79% of all stranded fish. Stranded species at risk accounted for less than 1% of total fish stranded and included Umatilla Dace (*Rhinichthys umatilla),* Columbia Sculpin (*Cottus hubbsi*) and Shorthead Sculpin (*Cottus confusus*).

In addition to salvaging stranded fish, the stranding assessments conducted during the present study period provided valuable data for the Lower Columbia River Fish Stranding Database, particularly at discharges where previous stranding data were limited, thereby improving the resolution of database queries which aim to predict the future potential stranding risk of flow reductions from HLK/ALH and BRD/X.

Table ES1: Summary of status on the management questions of CLBMON-42 (Golder 2020a).

Objective	Management Questions [1]	Summary of Key Results
To assess the impact of flow reductions and flow ramping rates from HLK on the native species of the lower Columbia River.	MQ1: Is there a ramping rate (fast vs. slow, day vs. night) for flow reductions from HLK that reduces the number of fishes stranded (interstitially and pool) per flow reduction event in the summer and winter?	A statistical analysis conducted on the 20-year dataset of fish stranding assessments indicated little or no evidence of an effect of ramping rate within the range of operational ramping rates currently used at HLK/ALH on fish stranding in the lower Columbia River (Golder 2020a). Flow ramping studies conducted prior to CLBMON-42 also found no effect of ramping rate (Golder 2005, 2006, 2007). Previous analyses indicated that time of day was not a strong predictor of fish stranding risk; however, there were few night ramping experiments conducted, and no night-time stranding assessments were conducted (Golder 2005; Golder and Poisson 2010; Irvine et al. 2009; Irvine et al. 2014). Currently, there is insufficient data to determine whether time of day is a significant predictor of the probability of fish stranding. Additional night-time ramping experiments, or night-time reduction events and stranding assessments would be required to balance the dataset and determine if there is any difference in the probability of fish stranding between day and night.
	MQ2: Does wetted history (length of time the habitat has been wetted prior to the flow reduction) influence the number of fishes stranded (interstitially and pool) per flow reduction event for flow reductions from HLK?	In a statistical analysis conducted on the 20-year dataset of fish stranding assessments in the lower Columbia and Kootenay Rivers, wetted history had a statistically significant positive effect on both the probability and number of fish stranding (Golder 2020a). Modelling indicated that the predicted number of fish stranded per site increased from 21 fish at 1 day of wetted history to 52 fish at 50 days of wetted history. These findings were consistent with previous analyses conducted on lower Columbia and Kootenay River fish stranding assessment data (Golder and Poisson 2010; Irvine et al. 2014). This supports the idea that substrate that has been inundated for a longer period is more likely to strand fish if dewatered, compared to substrate that is inundated for a shorter period. Given these findings, wetted history is a key variable to assess prior to initiating a fish stranding assessment or fish salvage response to an operational flow reduction.
	MQ3: Can a conditioning flow (temporary, one step, flow reduction of approximately 2 hours to the final target dam discharge that occurs prior to the final flow change) from HLK reduce the stranding rate of fishes?	Experimental flow ramping studies conducted in the summers and winters of 2004, 2005 and 2006 (prior to CLBMON-42) indicated that the use of a conditioning flow reduction appears to reduce the incidence of pool stranding on the Columbia River; however, this relationship was not statistically significant. The analysis was based on limited results and further conditioning flow experiments were recommended (Golder 2007; Irvine et al. 2009). A literature review in 2010 did not identify conclusive evidence regarding the effectiveness of a conditioning flow as a mitigation strategy for reducing fish stranding (Golder and Poisson 2010). During the 14-year period of CLBMON-42, conditioning flows have not been conducted and there is still considerable uncertainty regarding the efficacy of a conditioning flow at reducing the probability of stranding. Given the limited experiments conducted, a definitive answer regarding whether a conditioning flow can reduce the stranding rate cannot be determined.
	MQ4: Can physical habitat works (i.e., recontouring) reduce the incidence of fish stranding in high risk areas?	Six fish stranding sites on the lower Columbia River were recontoured between 2001 and 2015. To assess the effectiveness of recontouring, a statistical analysis was conducted on the 20 years of lower Columbia River fish stranding data to model the probability of stranding and number of fish stranded before vs. after recontouring (Golder 2020a). Results indicate a significant reduction in both probability and number of fish stranding after recontouring compared to before recontouring. These results agree with previous analyses (Golder and Poisson 2010, Irvine et al. 2014) on recontouring and suggest that recontouring sites that pose a high stranding risk to fish is an effective mitigation strategy to reduce overall stranding.
	MQ5: Does the continued collection of stranding data, and upgrading of the lower Columbia River stranding protocol, limit the number of occurrences when stranding crews need to be deployed due to flow reductions from HLK?	During the 14-year period of CLBMON-42, the number of annual stranding assessments conducted in response to reduction events from HLK/ALH has not decreased. Over the study, the annual number of stranding assessments conducted due to flow events at HLK/ALH [2] has ranged from 8 to 15 (median = 12; average = 12) with no increasing nor decreasing trend. The stranding protocol was developed in 2011 (Golder 2011). It is currently undergoing an update based on the findings of the CLBMON-42 program (Golder in prep.).

[1] The CLBMON-42 monitoring program is specific to operations at HLK; however, this facility operates in association with Arrow Lakes Generating Station (ALH) and will be referred to as the combined operation of HLK/ALH. The management questions of the program are presented as written in the CLBMON-42 Terms of Reference (BC Hydro 2007a).
[2] Flow reductions from BRD/X and/or both facilities (when a discharge reduction occurred at HLK/ALH and BRD/X) not included.

Key Words

CLMBON-42

Discharge

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Flow Reduction

Kootenay River

Lower Columbia River

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1.0 INTRODUCTION

1.1 Background

Fish stranding has been broadly recognized as a factor contributing to fish mortality. Fish can become stranded when water levels recede within the varial zone (the zone subject to seasonal inundation) of riverine habitats. When this occurs, fish can become stranded in habitats that are disconnected from the main channel (pool stranding) or become stranded between substrate particles in dewatered habitat (interstitial stranding).

Hydroelectric facilities have direct influences on water levels and thus, can affect fish stranding downstream of their operations. The Columbia River water levels below Hugh L. Keenleyside Dam and Arrow Lakes Generating Station (HLK/ALH) and the lower Kootenay River below Brilliant Dam and Brilliant Expansion Powerplant (BRD/X) are influenced by the operations of these facilities.

Fish stranding was raised as an environmental issue associated with Hugh L. Keenleyside Dam (HLK) operations by the regulatory agencies in the mid-1990's, at which time environmental monitoring began. Since that time, fish stranding assessments and flow ramping studies have been conducted, dam operations have been reviewed, flow smoothing (reductions in magnitude and frequency of reductions) has occurred, and habitat recontouring of high risk fish stranding sites has been conducted. In addition, since the mid-1990's fish stranding assessment methods have been improved, standardized and adapted to include Kootenay River operations (BRD/X).

To continue studies related to fish stranding and dam operations, the Lower Columbia River Fish Stranding Assessment and Ramping Protocol (CLBMON-42) was implemented in 2007 as part of BC Hydro's Water Use Plan for the Columbia River (BC Hydro 2007). The primary objective of CLBMON-42 was to continue the collection of fish stranding data to assess the impact of flow reductions and flow ramping rates from HLK[3] on the native fish species of the lower Columbia River.

The approach to the monitoring program included three components:

- The continued collection of fish stranding data due to flow reduction events that occurred due to HLK/ALH (CLBMON-42[A]), and the subsequent establishment of a lower Columbia River stranding protocol;
- Conduct flow ramping studies designed to determine the effect of different flow reduction strategies on the stranding rates of fish; and
- Conduct physical habitat works in the form of gravel bar recontouring at locations where high rates of fish stranding occurs.

[3] The CLBMON-42 monitoring program is specific to operations at HLK; however, this facility operates in association with Arrow Lakes Generating Station (ALH) and will be referred to as the combined operation of HLK/ALH. The management questions of the program are presented as written in the CLBMON-42 Terms of Reference (BC Hydro 2007).

The monitoring program identified five management questions (BC Hydro 2007) which are as follows:

1) Is there a ramping rate (fast vs. slow, day vs. night) for flow reductions from HLK that reduces the number of fish stranded (interstitially and pool) per flow reduction event in the summer and winter?
2) Does wetted history (the length of time the habitat has been wetted prior to the flow reduction) influence the number of fish stranded (interstitially and pool) per flow reduction event for flow reductions from HLK?
3) Can a conditioning flow (a temporary, one step, flow reduction of approximately 2 hours to the final target dam discharge that occurs prior to the final flow change) from HLK reduce the stranding rate of fish?
4) Can physical habitat works (i.e., re-contouring) reduce the incidence of fish stranding in high risk areas?
5) Does the continued collection of stranding data, and upgrading of the lower Columbia River stranding protocol, limit the number of occurrences when stranding crews need to be deployed due to flow reductions from HLK?

In 2020, an analysis was conducted on a 20-year dataset of fish stranding assessments conducted on the Lower Columbia and Kootenay rivers due to flow reductions from HLK/ALH and BRD/X operations to address the above management questions (Golder 2020a). This dataset included 13 years (2007/2008 to 2019/2020; study period of 1 April to 1 April annually) of fish stranding assessments conducted under CLBMON-42 and 7 years (2000 to 2007) of fish stranding assessments that were conducted in response to flow reduction events from HLK/ALH and BRD after stranding assessment methods were standardized in 1999. The status of the CLBMON-42 management questions, including a summary of the Golder (2020a) analysis and additional studies related to CLBMON-42 (Golder 2005, 2006, 2007, Golder and Poisson 2010, Irvine et al. 2009, Irvine et al. 2014), are included in Table ES1.

1.2 Scope and Objectives

The present study is an extension (Year 14) of the Lower Columbia River and Kootenay River Fish Stranding Assessments (CLBMON-42[A]), which summarizes the results of stranding assessments collected following flow reductions at HLK/ALH and BRD/X at pre-determined sites (Appendix A) on the lower Columbia and Kootenay rivers between 1 April 2020 and 1 April 2021. The primary objective of the fish stranding assessments is to collect fish stranding data associated with hydro-electric dam flow reductions occurring on the lower Columbia and Kootenay Rivers to address fish stranding impact (Golder 2011). Field crews assess sites where stranding is expected, data is collected on the number of fish stranded, and where practical, fish are salvaged by returning them to the mainstem of the Kootenay or Columbia River (BC Hydro 2007).

1.3 Study Area

The study area encompassed the approximately 56 km long section of the lower Columbia River from HLK/ALH to the Canada/USA border, and included the lower Kootenay River (approximately 2.8 km) from downstream of BRD/X to the Columbia River confluence (Figure 1). The Columbia River study area is further delineated into the upper section (HLK/ALH to Genelle), middle section (Genelle to Rock Island downstream of Trail), and lower section (Rock Island downstream of Trail to the confluence of the Pend d'Oreille River). Fish stranding assessments were conducted at 25 stranding sites within this study area. See Appendix A; Figures A1 through A11 for specific fish stranding site locations.

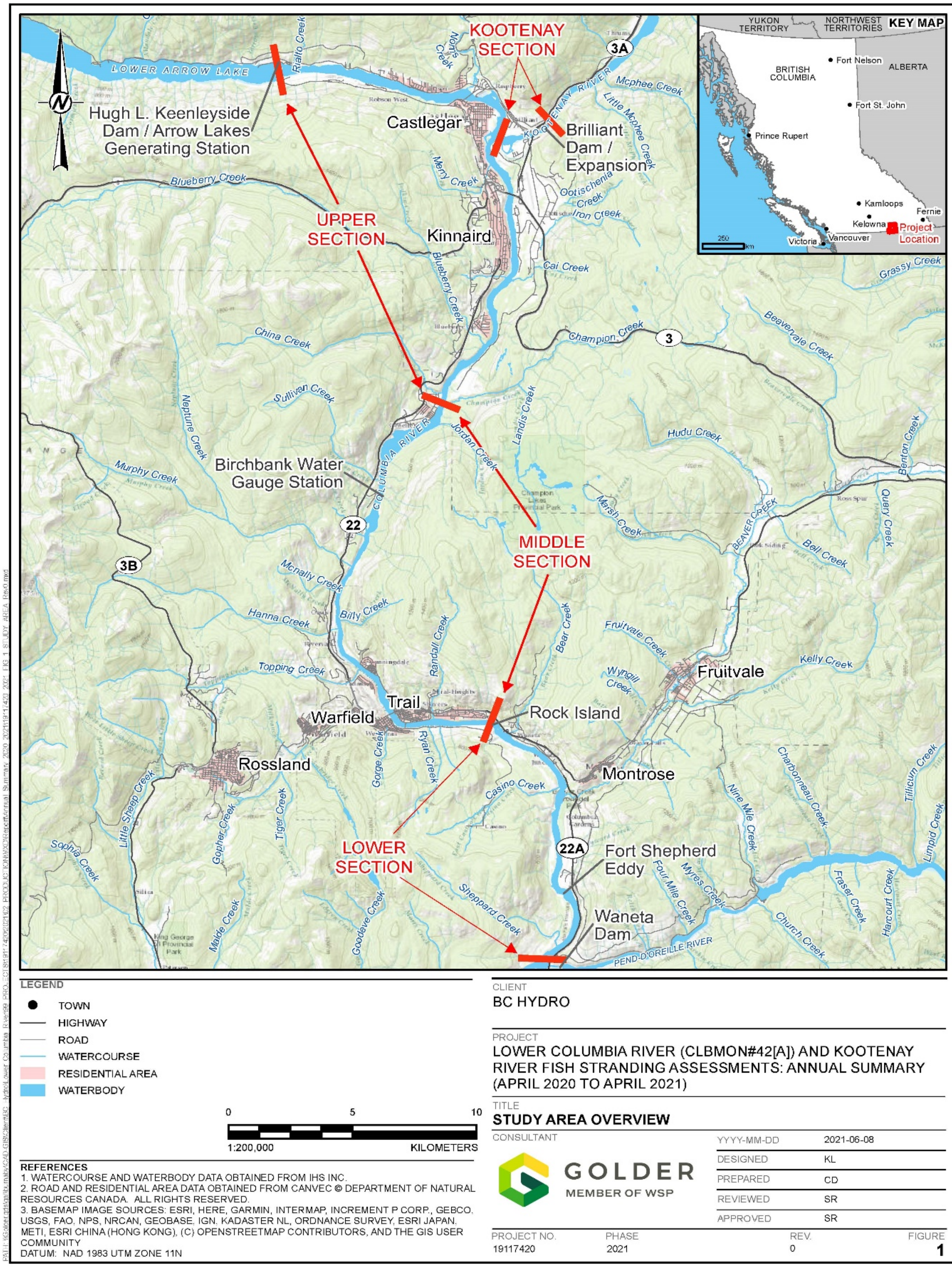

Figure 1: Study area overview map

2.0 METHODS

As part of the CLBMON-42 program, *The Canadian Lower Columbia River: Risk Assessment and Response Strategy* (Golder 2011) was developed with the primary objective to mitigate the effects of flow reductions from HLK/ALH and BRD/X on native fish species through flow reduction planning. This document outlines the roles and responsibilities pertaining to flow reductions for owners and operators of hydroelectric facilities on the lower Columbia and Kootenay rivers. In addition, this document outlines the standardized protocols for conducting fish stranding risk assessments, and field-based fish stranding assessments. During the present study period, the protocols described in *The Canadian Lower Columbia River: Risk Assessment and Response Strategy* (Golder 2011) were followed and are summarized below.

2.1 Fish Stranding Risk Assessment

Once a flow change decision was made, a fish stranding risk assessment was conducted by the BC Hydro Discharge Change Coordinator with input from the Golder Stranding Assessment Supervisor to determine the appropriate environmental response (i.e., whether to conduct a field-based fish stranding assessment or not). The risk assessment was based on both the current environmental conditions, as well as results of past stranding assessments stored in the Lower Columbia River Fish Stranding Database (the Database). For a proposed flow reduction, risk period (High Risk period [1 June to 30 September] and Low Risk period [1 October to 31 May]; Golder and Poisson 2010, Golder 2011), magnitude of flow reduction, resulting river discharge (fish stranding risk is generally inversely related to river discharge), water temperature and wetted history were all considered. Additionally, a query was conducted on the Database using input values for the proposed flow reduction which included the following:

- The current discharge at Birchbank (in kcfs [thousands of cubic feet per second]);
- The predicted resulting discharge at Birchbank after the proposed flow reduction (in kcfs);
- The current water temperature at Birchbank (in Celsius);
- The date of the proposed reduction; and
- The facility responsible for the proposed reduction (HLK/ALH, BRD/X, or reduction at both facilities).

Based on the above input values, the database query output provided a fish stranding concern category for individual fish stranding sites on the lower Columbia and Kootenay rivers downstream of HLK/ALH and BRD/X based on previous fish stranding assessment data (year 2000 to present). The concern categories and their definitions are as follows:

- No Pools – Isolated pools (pools no longer connected to the mainstem of Columbia or Kootenay river) have not been identified based on previous assessments;
- Reconnaissance – Fewer than five stranding assessments have been conducted since year 2000;
- Minimal Effect – Less than 200 fish and no species at risk stranded during each previous reduction; and
- Effect – Greater than 200 fish and/or greater than one species at risk stranded during a previous reduction.

Based on the above variables and the results of the database query, a decision was made by the BC Hydro Discharge Change Coordinator whether or not to conduct a field-based fish stranding assessment during the proposed flow reduction. The fish stranding risk assessment process for defining fish stranding risk, as well as guiding assessment/salvage response decisions is summarized in Figure 2, and an example of a typical Database query is provided in Appendix B.

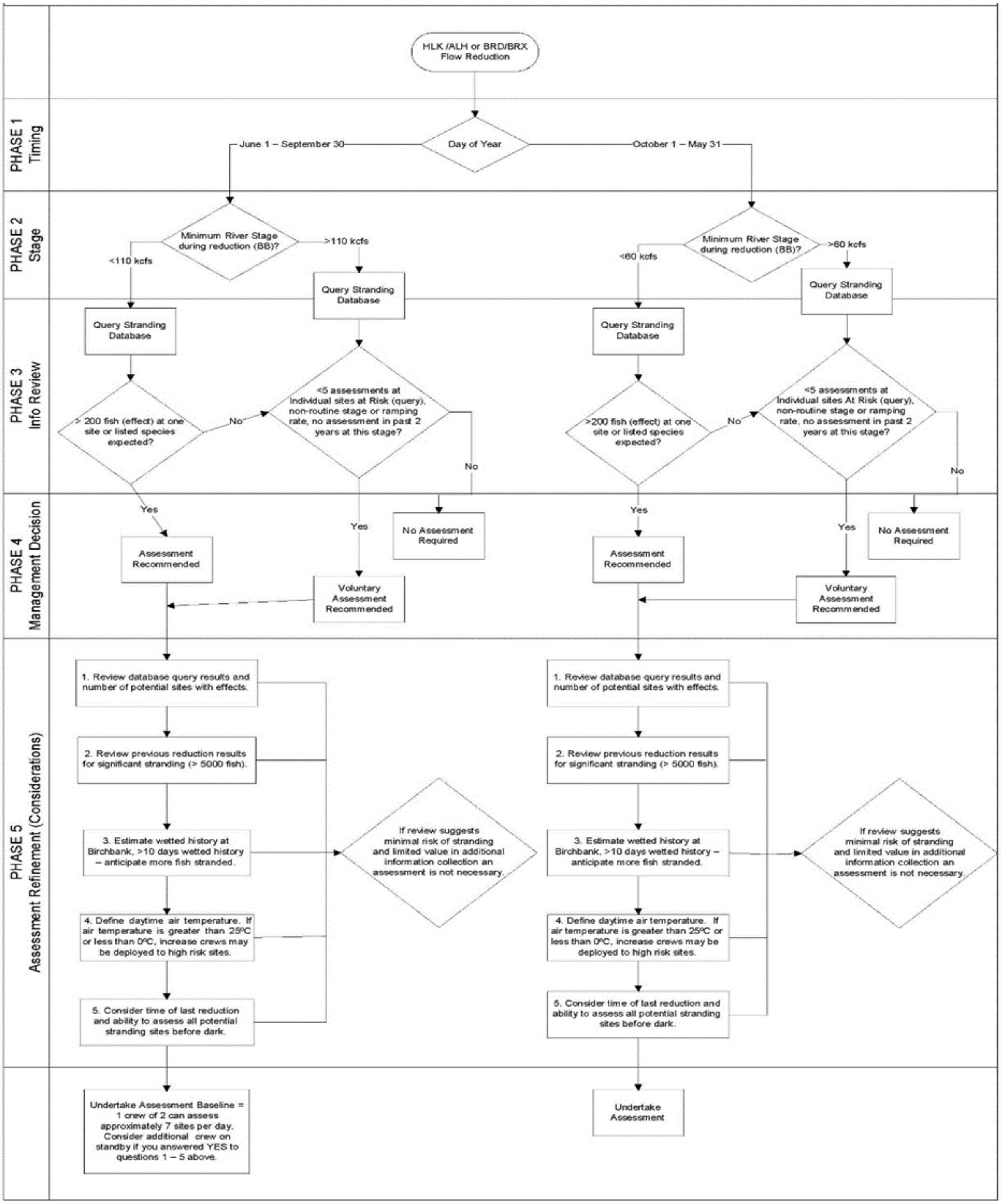

Figure 2: Flow reduction fish stranding assessment response procedure (Golder 2011).

2.2 Fish Stranding Assessment and Salvage Methods

Fish stranding assessments are typically conducted by a single two-person crew. However, for some reduction events with a high number of 'Effect' sites identified in the Database query, crew sizes are increased during stranding assessments. All fish stranding assessments were conducted at sites accessible by truck.

Stranding assessment crews arrived at the first stranding site no later than one hour after the final staged reduction from HLK/ALH or BRD/X. Fish stranding and salvage assessments began at the most upstream 'Effect' site identified by the Database query. Throughout the day, site assessments were conducted from upstream to downstream following the stage recession. This standardized order of site assessment ensured that no site would be assessed prior to the effects of the flow reduction reaching each site. Sites were also assessed in order from high to low priority based on the site ranking from the database query. Sites where an 'Effect' ranking was assigned were the highest priority, followed by 'Reconnaissance' sites. If time permitted, 'Minimal Effect' and/or 'No Pools' sites were assessed to confirm the site ranking identified by the Database query.

At each site, the field crew conducted the following activities:

1) Habitat variables were recorded at each site to identify potential fish habitat, characterize the stranding mechanisms present (i.e., pool stranding or interstitial stranding), and characterize general site conditions (Table 1).

6) A broad scale search of the dewatered area was conducted. The total number of new isolated pools (pools no longer connected to the mainstem of the Columbia or Kootenay river) and dewatered pools that were present due to the current flow reduction were recorded. Pools isolated during previous reduction events were noted in the comments but were not included in the tally for total pools formed due to the current reduction event.

7) Each new isolated pool was inspected for stranded fish and crews attempted to salvage any fish present using Smith-Root™ model 12-B POW or LR24 backpack electrofishers (Smith-Root, Vancouver, WA, USA), dipnets (if pools were too shallow to use backpack electrofishers), or beach seines. Backpack electrofishing was conducted with one crew member operating the electrofisher and one crew member netting fish. All captured fish were transferred to 20 L buckets filled with water. The effort and number of pools sampled was recorded at each site depending on the method used for fish capture. Captured fish from previously isolated pools (i.e., previous reduction events), were recorded but were not included in the tally for total number of fish stranded during the current reduction event.

8) Interstitial stranding areas (i.e., habitat amongst dewatered substrate) were also searched to look for stranded fish. The total interstitial area searched (in m^2) was recorded.

9) Captured fish were identified to species when possible and classified into one of the following life stages; egg, YOY, juvenile, and adult. The total number of live stranded fish (including those observed during sampling, but not captured), dead fish, and salvaged fish were recorded for each species and life stage. The stranding mechanism (i.e., pool stranding or interstitial stranding) for each was recorded. If stranded fish were numerous (i.e., greater than 200 individuals), a subsample were identified to species to expedite the fish salvage process. If stranded larval fish were encountered and sample methods were ineffective at capturing this life stage, the total number stranded was estimated.

10) Fish length measurements were collected from up to 20 individuals of each species captured during each stranding assessment. Total length was measured for sculpin species and fork length was measured for all other species.

11) All salvaged fish were returned to the main channel of the Columbia or Kootenay rivers.

12) Representative photographs were taken at each site to document current conditions. Photographs of representative fish species were also taken where possible.

13) Invasive species captured during stranding assessments were euthanized and removed from the system as per permit requirements.

Table 1: Habitat variables recorded at each stranding site as part of the Lower Columbia River and Kootenay River Fish Stranding Assessments, 2020/2021.

Variable	Description
Site Names	Name of stranding site
Date	The date the site was sampled
Time	Arrival time on site
Air Temp	Air temperature at the time of sampling (to the nearest 1°C)
Water Temp	Water temperature at the time of sampling (to the nearest 0.1°C)
Conductivity	Water conductivity at the time of sampling (to the nearest 10 µS/cm)
Estimated Vertical Drop	The estimated change in water level due to the current flow reduction
Slope	Estimated slope percent of dewatered area at site (less than or greater than 4%)
Cloud Cover	A categorical ranking of cloud cover (Clear = 0-10% cloud cover; Partly Cloudy = 10-50% cloud cover; Mostly Cloudy = 50-90% cloud cover; Overcast = 90-100% cloud cover); Fog
Instream Cover Type	Interstices, Woody Debris, Aquatic Vegetation, or Terrestrial Vegetation (% of 100)
Substrate	Boulder, Cobble, Gravel, Sand (% of 100)
New Pools Present	Total number of new pools isolated due to the current reduction
New Pools Sampled	Total number of new pools assessed for presence of stranded fish
De-watered Pools	Total number of de-watered pools due to the current reduction
Interstitial Area Sampled	Estimated area of interstitial (i.e., dewatered substrate) sampled for stranded fish (m^2)
Electrofisher Model	The model of electrofisher used during sampling
Volts	The voltage (V) used during sampling
Frequency	The frequency (Hz) used during sampling
Pulse Width	The pulse width (ms) used during sampling
Crew	The field crew that conducted the sampling
Sample Comments	Any additional comments regarding the stranding site or sampling conditions
Future Flow Reduction Problems	Identify whether new stranding pools will form if water level were to drop another 0.5 m
Photographs	Representative photographs documenting site conditions or fish species captured were recorded.

3.0 RESULTS

3.1 Operations Overview 2020/2021

During the present study period (1 April 2020 to 1 April 2021), the discharge in the Columbia River at the Birchbank Gauging Station ranged from 26.7 kcfs on 20 October to 151.6 kcfs on 28 June (Figure 3). Discharge at Birchbank generally increased from April to July, and from mid-October to end of January. Discharge at Birchbank generally decreased from July to mid-October and from February through March. The annual trend in discharge at Birchbank in 2020/2021 was typical of previous years (Golder 2018, 2019, 2020b).

The mean hourly discharge from HLK/ALH ranged from 14.1 kcfs on 13 March to 78.2 kcfs on 26 July. During the High Risk stranding period, discharge from HLK/ALH increased rapidly for approximately two weeks starting in mid-June. This rapid increase was followed by an overall decrease in discharge from HLK/ALH for the remainder of the High Risk period. The majority (70%) of reduction events from HLK/ALH during the High Risk period occurred in August and September (Figure 3).

The mean hourly discharge from BRD/X ranged from 9.7 kcfs on 2 October 2020 to 107.6 kcfs on 31 May (Figure 3). Discharge from BRD/X generally followed the same seasonal trend as discharge at Birchbank Gauging Station. This is partly due to the limited capacity of BRD/X to store water upstream compared to HLK/ALH operations. During the High Risk stranding period, discharge from BRD/X exhibited a steady decline from June to August and remained relatively constant through September at approximately 18 kcfs. Kootenay River system operation can be more dynamic in certain situations due to the need to meet system load requirements. Load factoring at BRD/X, which results in shaping average daily inflows into peak discharge during the high load hours (typically 0600 to 2200 hrs) and minimum discharge during low load hours (typically 2200 to 0600 hrs), can occur when Kootenay River inflows are between 18 and 43 kcfs. Flow reductions associated with load factoring were not considered individual reduction events.

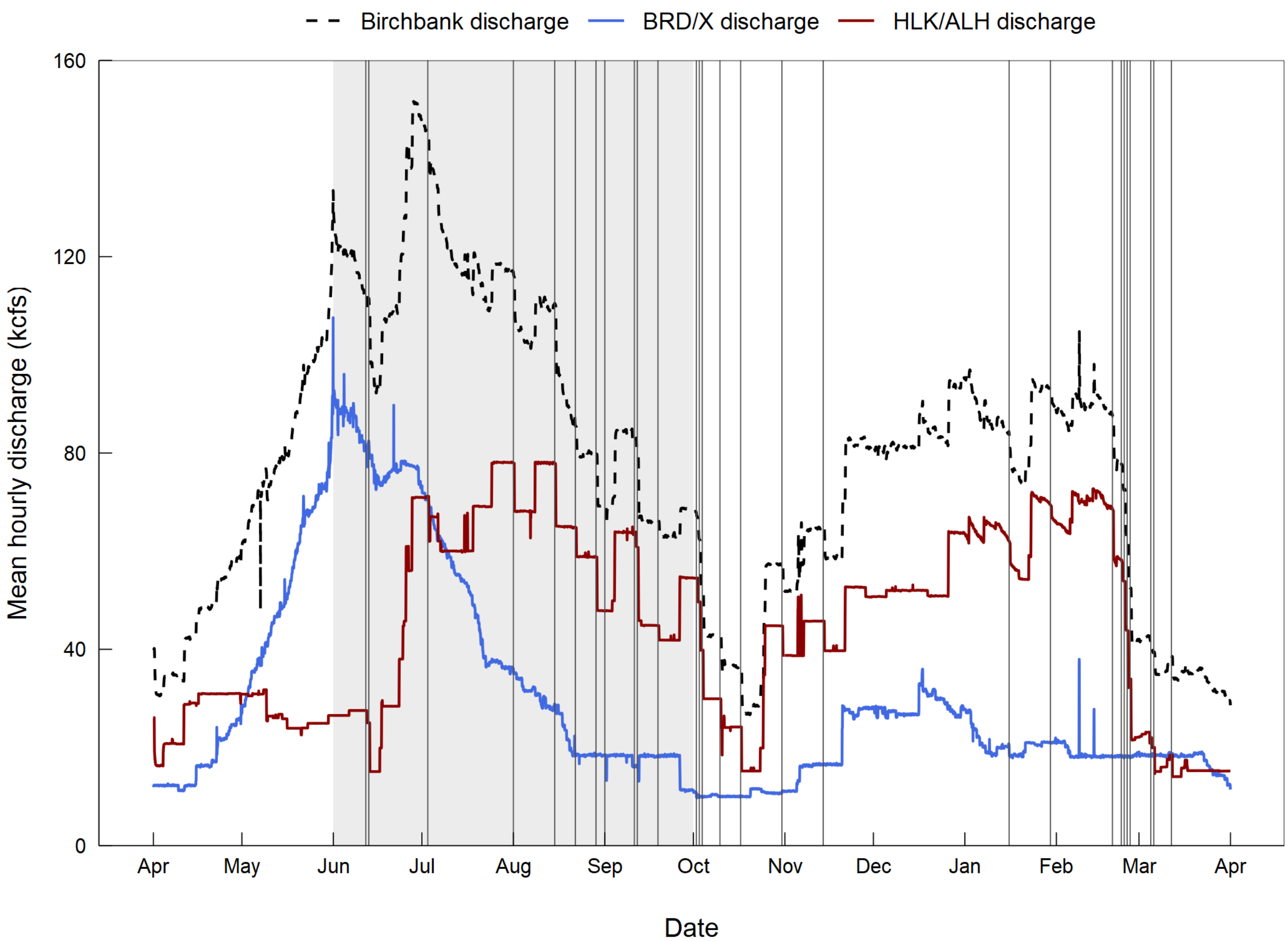

Figure 3: Mean hourly discharge from HLK/ALH, BRD/X, and the WSC Birchbank Gauging Station 1 April 2020 to 1 April 2021. Shaded area represents High Risk stranding period (1 June to 30 September). Vertical lines represent reduction events.

3.2 Reduction Events and Fish Stranding Assessments

During the present study period there were a total of 28 operational flow reduction events (Figure 3); 26 occurred at HLK/ALH, one occurred at BRD/X, and one occurred at both HLK/ALH and BRD/X on the same day (Table 2). A total of 11 reductions events occurred during the High Risk period, while the remaining 17 occurred during the Low Risk period. The reduction events from HLK/ALH and BRD/X corresponded to reductions in discharge in the Columbia River at Birchbank Gauging Station that ranged from 2.7 kcfs to 14.9 kcfs (Table 2). Each reduction event occurred on a single day. In previous years, reduction events have occasionally been defined as multi-day events, with a stranding assessment conducted on a single day (Golder 2016, 2017, and 2018). Based on discussions with BC Hydro (pers. comm. BC Hydro), during the 2018/2019 study period it was decided that each reduction event would be defined as occurring on a single day rather than over multiple days. The rationale for this decision was to simplify the Database to keep fish salvaged during each stranding assessment linked to a specific reduction event occurring on the same day.

The magnitude of flow reduction for each reduction event at HLK/ALH ranged from 2 to 14.9 kcfs (Table 2). All reduction events from HLK/ALH had an average ramping rate of 5 kcfs per hour or less. The majority (26 out of 27) of reduction events at HLK/ALH were required to fulfill Columbia River Treaty Coordination Agreements. RE2021-10 (12 March 2021) was required to allow divers to conduct maintenance at HLK/ALH.

The single reduction event at BRD/X (RE2021-19) had a magnitude of 5 kcfs. This was a short-term reduction that occurred between approximately 10:00 and 14:00 on 1 September 2020. By 16:00 on the same day, discharge flow at BRD/X had returned to pre-reduction levels.

During RE2020-21 on 12 September 2021, flow reductions occurred both HLK/ALH and BRD/X. The reduction from HLK/ALH had a magnitude of 14.9 kcfs and the reduction from BRD/X had a magnitude of 3 kcfs; however, the reduction from BRD/X was short-term and by the end of the day discharge flows at BRD/X had returned to greater than pre-reduction levels.

Fish stranding assessments were conducted for 17 of the 28 reduction events (Table 2) resulting in a response rate (percent of total reduction events that initiated a stranding assessment) of 61%. Between study year 2007/2008 and the current study year (2020/2021), the total number of annual stranding assessments ranged from 12 to 21 (median = 16) and has generally followed the same pattern as the number of annual reduction events (Figure 4). The average and median response rate over the same period is 78% and 82%, respectively.

With the exception of RE2021-06 (25 February 2021), environmental conditions during the present study period were adequate for fish salvage purposes. During RE2021-06, the field crew experienced heavy snow fall in the morning which tapered off after mid-day. The accumulation of snow and slush in the morning within isolated pools and dewatered interstitial habitat reduced visibility while conducting assessments and therefore reduced sampling effectiveness.

Table 2: Summary of reduction events from HLK/ALH and BRD/X, 1 April 2020 to 1 April 2021.

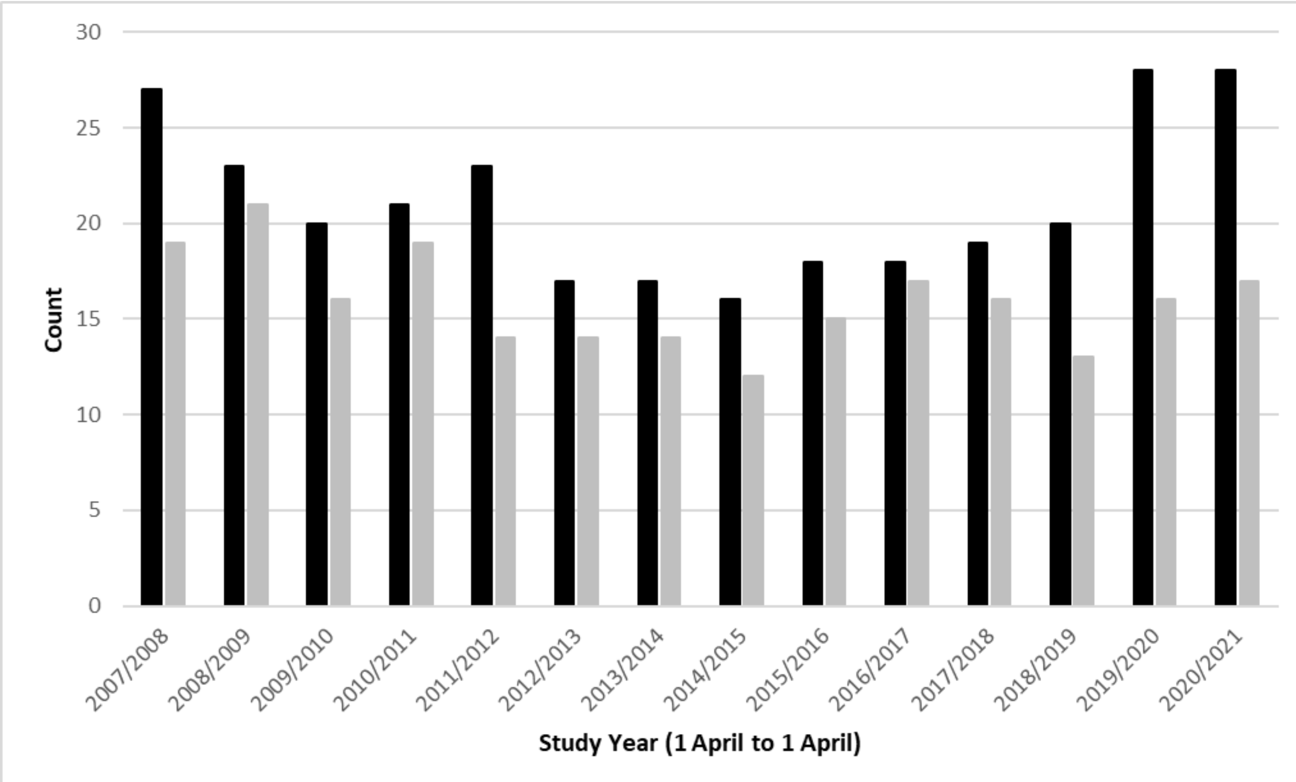

Figure 4: Count of annual reduction events (black bars) and stranding assessments (grey bars) conducted during each study period of the Lower Columbia River and Kootenay River Fish Stranding Assessments, 2007/2008 to 2020/2021.

As in previous years, sites ranked as 'Effect' sites in the database queries were prioritized during stranding assessments. Out of a total of 129 individual site assessments conducted, 72 were ranked 'Effect' sites, 56 were ranked 'Reconnaissance' sites, and one was ranked as a 'Minimal Effect' site based on the Database queries (Table 3). To provide an evaluation of the Database query (Section 2.1), Table 3 identifies each Database query site designation and categorizes each into the 'Effect', 'Minimal Effect' or 'No Pools' ranking based on the results from site assessments conducted during the present study period. The majority (76%) of 'Effect' designated sites and the majority (64%) of 'Reconnaissance' designated sites stranded less than 200 fish and no species of concern (i.e., Minimal Effect). The single 'Minimal Effect' designated site was assessed during RE2020-27 on 17 October 2020 at Norns Creek Fan (RUB). This site was assessed because it had been identified as having a potential future stranding risk during the previous site assessment on 10 October 2020, and to confirm its Database query designation. During this assessment, 36 new pools had formed and a total of 46 fish were stranded and subsequently salvaged. The results of this assessment were consistent with the designation provided in the Database query.

Table 3: Comparison of site designation from Database query and site designation based on results of fish stranding assessments, 1 April 2020 to 1 April 2021.

Site Designation from Database Query (Section 2.1)	Site Designation Based on Result of Stranding Assessments		
	Effect [a]	Minimal Effect [b]	No Pools [c]
72 Effect	12 (17%)	55 (76%)	5 (7%)
56 Reconnaissance	1 (2%)	36 (64%)	19 (34%)
1 Minimal Effect	0 (0%)	1 (100%)	0 (0%)

[a] ≥ 200 fish or > 1 species of concern stranded.
[b] < 200 fish stranded and no species of concern stranded.
[c] No fish stranded and no isolated pools identified.

During the present study period, 25 stranding sites were assessed at least once (Table 4). At the request of BC Hydro, a desktop review of Google Earth™ imagery and the Database was conducted to identify new or infrequently assessed fish stranding sites. Seven sites were identified as candidates for future assessment efforts. These sites were: Waterloo U/S (RUB), Waterloo Eddy (RUB), Blueberry Creek D/S (LUB), Sandbar Eddy (LUB), Birchbank Snye (LUB), Gyro Park (RUB), and Korpack (LUB) (Appendix A). Each of these sites was assessed at least once during the present study period (Table 4).

As in previous years (Golder 2018, 2020b), stranding assessments were most frequently conducted at Genelle Mainland (LUB). This site is a common location of fish stranding and is anked as an 'Effect' site in Database queries at a variety of discharge levels. In general, sites in the Upper Section and Kootenay Section of the study area (Figure 1) were more frequently assessed than sites in the Middle and Lower Sections. This was due to sites within the Upper and Kootenay Sections frequently being ranked as 'Effect' sites in the Database query. Furthermore, crews could not begin to assess sites in the Lower Section of the Columbia River until the reduction reached those sites, limiting the number of sites that could be assessed in the Lower Section during a typical 10-hour field day. The stage reduction generally reaches Norn's Creek Fan (RUB) within 1-2 hours, Genelle Mainland (LUB) within 6 hours, and Fort Shepherd Launch (RUB) within 10 hours (Golder 2011).

3.3 Fish Encountered During 2020/2021 Stranding Assessments

Isolated pools and stranded fish were identified during all stranding assessments conducted in response to flow reduction events. During the 17 fish stranding assessments conducted, an estimated total of 11,465 fish were stranded (Table 4). The total number of fish observed or captured during each stranding assessment ranged from 6 to 4,190. Pool stranding accounted for 97% of all fish stranded, while the remaining 3% were stranded interstitially within dewatered substrate.

On a temporal scale, the number of fish stranded was close to equal between the High Risk period (1 June to September 30; 53%) and the Low Risk period (1 October to May 31; 47%). Typically, a greater number of fish are stranded during the High Risk period compared to the Low Risk Period (Golder 2017, 2018, 2019, 2020b). During this time period, larval and YOY fish are known to inhabit near shore habitat, and the risk of stranding is elevated (Golder and Poisson 2010, Golder 2020a). The higher than typical stranding numbers observed during the Low Risk period were largely attributed to RE2021-06 on 25 February 2021, when HLK/ALH decreased discharge by approximately 10 kcfs, and a total of 2,945 fish were stranded. The effects of this reduction may have been confounded by the fact that this reduction occurred on the second day of three reductions in a row (RE2021-05, RE2021-06, RE2021-07). Over this three-day period, discharge at the Birchbank Gauging Station decreased from approximately 73 to 41 kcfs (Table 2). The relatively large reduction over a short period may have hindered the ability of fish to escape from stranding habitat. Previous analysis conducted on the lower Columbia River fish stranding assessment data also found an increased stranding risk with an increase in reduction magnitude (Golder 2020a, Golder and Poisson 2010, Irvine et al. 2014).

The majority (87%) of stranded fish were found in pools and dewatered substrate located at Genelle Mainland (LUB) and Kootenay River (RUB) (Table 4). Both sites have often been associated with high fish stranding numbers during annual assessments (Golder 2016, 2017, 2018, and 2019). Of the seven new fish stranding sites assessed, Waterloo U/S (RUB) was the only site where fish were stranded. A detailed assessment of the new stranding sites is presented in Section 3.4.

The number of fish stranded by site and date during the present study period is presented in Appendix C.

Table 4: Count of site assessments and fish stranded by site during reduction events, 1 April 2020 to 1 April 2021.

Site[a]	Total Number of Assessments	Total Number of Fish Stranded	Median Number of Fish Stranded per Assessment	% of Total Stranded Fish
Genelle Mainland (LUB)	14	5,918	13	51.6
Kootenay River (RUB)	12	4,090	58	35.7
Norns Creek Fan (RUB)	12	315	11	2.7
Tin Cup Rapids (RUB)	12	138	3	1.2
Lions Head (RUB)	11	85	2	0.7
Kootenay River (LUB)	10	114	2	1.0
Millennium Park (LUB)	8	59	4	0.5
CPR Island (MID)	8	42	0	0.4
Gyro Boat Launch (RUB)	6	338	0	2.9
Bear Creek (RUB)	5	62	2	0.5
Blueberry Creek (LUB)	5	50	0	0.4
Zuckerberg Island (LUB)	4	93	12	0.8
Beaver Creek (RUB)	3	107	42	0.9
Waterloo U/S (RUB)	3	29	5	0.3
Fort Shepherd Launch (RUB)	3	9	0	0.1
Casino Road Bridge, Trail (LUB) (Downstream)	3	0	0	0.0
Kinnaird Rapids (RUB)	2	10	5	0.1
Waterloo Eddy (RUB)	2	0	0	0.0
Casino Road Bridge, Trail (LUB) (Upstream)	1	6	6	0.1
Birchbank Snye (LUB)	1	0	0	0.0

Site[a]	Total Number of Assessments	Total Number of Fish Stranded	Median Number of Fish Stranded per Assessment	% of Total Stranded Fish
Blueberry Creek D/S (LUB)	1	0	0	0.0
Gyro Park (RUB)	1	0	0	0.0
Korpack (Trail) (LUB)	1	0	0	0.0
Sandbar Eddy (LUB)	1	0	0	0.0
Total	**129**	**11,465**		**100.0**

[a] Appendix A; Figures A1 through A11.
LUB = left bank as viewed facing upstream
RUB = right bank as viewed facing upstream
MID = island in mid-channel

3.3.1 Fish Species

3.3.1.1 Sportfish

Sportfish accounted for approximately 1% of total fish stranded and were limited to a total of 127 Rainbow Trout (*Oncorhynchus mykiss*) (Table 5). All stranded Rainbow Trout were either Young-of-Year (YOY) or juvenile age class. The highest numbers of stranded Rainbow Trout were encountered at Tin Cup Rapids (RUB) (*n* = 55) and CPR Island (MID) (*n* = 27). These sites are located immediately downstream of Norn's Creek, which is a known Rainbow Trout spawning area (Thorley et al. 2017). Tin Cup Rapids (RUB) and CPR Island (MID) are characterized by coarse substrate composed of mostly cobble and boulder. The cobble/boulder substrate provides shelter and adequate rearing habitat for young Rainbow Trout (McPhail 2007). As a result, when the water level drops at these sites, Rainbow Trout can become stranded in small pools that form in and around cobbles and boulders. Furthermore, the summer appears to be a higher risk period for stranding for Rainbow Trout (Golder 2020b). During the present study period, 56% of Rainbow Trout were stranded between 1 June and 30 September. The peak spawning period for Rainbow Trout typically occurs within the first two weeks of May (Thorley et. al. 2017), with emergence occurring approximately 4 to 6 weeks later depending on water temperature (McPhail 2007). Therefore, high numbers of YOY Rainbow Trout are to be expected within near-shore habitat vulnerable to dewatering during the summer months.

In previous years (i.e., 2019/2020), sportfish have comprised a higher percentage of total stranded fish; however, when this has been the case it has typically been due to a high number of YOY Mountain Whitefish (*Prosopium williamsoni*) being stranded (Golder 2020b). During the present study period, Mountain Whitefish were not encountered.

3.3.1.2 Non-sportfish

As in previous years, non-sportfish accounted for the majority (99%) of total fish stranded (Table 5). Of all non-sportfish species stranded, YOY and juvenile Sucker species were the most abundant. Sucker species (*Catostomus spp.*) commonly represent the highest number of stranded fish during yearly stranding assessments (Golder 2016, 2017, 2018, 2020b). During the present study period, 63% of Sucker species were stranded during the High Risk period. The highest numbers were found at Genelle Mainland (LUB) (n = 4,027) and Kootenay River (RUB) (n = 1,653). An estimated 3,600 YOY Suckers were stranded in a single large pool that formed at the upstream end of a channel along the left upstream bank at Genelle Mainland (LUB) during RE2020-18 on 29 August 2020. Of this total, approximately 3,400 were successfully captured using a beach seine and salvaged (i.e., returned to the mainstem of the Columbia River). During the 2018/2019 and 2019/2020 study periods, Genelle Mainland (LUB) also had the highest number of stranded Sucker species (n = 586 and n = 3,889, respectively) in comparison to other sites. This site is characterized by low angle sloping banks with gravel and sand substrate, and a shallow back channel that runs along the left upstream bank. The shallow sheltered water within the back channel at Genelle Mainland (LUB) provides suitable rearing habitat for YOY and juvenile Sucker species during the summer months. As a result, this area poses a high stranding risk for Sucker species when reduction events occur during the High Risk period.

Redside Shiner (*Richardsonius balteatus*) were the second most abundant non-sportfish stranded (Table 5). Approximately, 67% of Redside Shiner were stranded in an isolated pool that formed near the entrance of a beaver lodge in the oxbow at Kootenay River (RUB) during RE2021-06 (25 February 2021). Stranding crews were able to salvage these fish by excavating a trench in the sand substrate and flushing them out of the isolated pool using buckets of water. This pool also stranded approximately 1,000 juvenile Northern Pikeminnow (*Ptychochelius oregonensis*), and 800 juvenile Sucker species, all of which were successfully salvaged. A high number of stranded Redside Shiner (n = 385) were also identified at Genelle Mainland (LUB) during the present study period. All remaining sites where Redside Shiners were encountered, stranded less than a total of 25 individuals all assessments combined (range = 2 to 22) during the present study period.

A total of 1,388 YOY and juvenile Northern Pikeminnow were stranded during the present study period (Table 5). Of the total, 99% Northern Pikeminnow were stranded during the Low Risk period and the greatest number (n = 1,000) were found at Kootenay River (RUB) during RE2021-06. An additional 235 Northern Pikeminnow were identified at the same site during RE2021-07 on the following day (26 February 2021). All remaining sites where Northern Pikeminnow were encountered, stranded less than a total of 10 individuals all assessments combined (range = 1 to 9) during the present study period. These findings suggest that Kootenay River (RUB) poses a high stranding risk for this species.

Sculpin species are commonly observed during stranding assessments on the lower Columbia and Kootenay rivers. Torrent Sculpin (*Cottus rhotheus*), Prickly Sculpin (*Cottus asper*), Slimy Sculpin (*Cottus cognatus*), Columbia Sculpin (*Cottus hubbsi*), and Shorthead Sculpin (*Cottus confusus*) were stranded during the present study period (Table 5). As in previous years (Golder 2016, 2017, 2018, 2019, 2020b), Torrent Sculpin represented the highest number of all stranded sculpin species. In 2020/2021, a total of 262 juvenile and adult Torrent Sculpin were stranded, accounting for 75% of all sculpin that were identified to species. Stranded Torrent Sculpin were found predominantly at Genelle Mainland (LUB) (n = 107) and Norns Creek Fan (RUB) (n = 83). All remaining sites where Torrent Sculpin were encountered, stranded less than a total of 20 individuals all assessments combined (range = 1 to 17) during the present study period.

3.3.1.3 Unidentified Fish

A total of 1,392 unidentified fish and 46 Sculpin were observed during stranding assessments but were not identified to species. The majority of fish not identified to species (n = 840) were visually observed during salvage efforts but were not captured either due to time constraints or because they avoided capture (i.e., buried into coarse substrate) during electrofishing efforts. A total of 552 fish listed as unidentified were salvaged, of which 550 were not captured but were flushed out of isolated pools by creating channels to the mainstem of the

Columbia River at Genelle Mainland (LUB: during RE2020-19) and at Lions Head (RUB: during RE2020-15). An additional two fish listed as unidentified were salvaged; however, these fish were in the larval life stage and could not be identified to species. Given the timing of capture (25-26 February 2021), it is possible that these larval fish were Mountain Whitefish.

Of the total number of captured Sculpin not identified to species, 98% were juvenile life stage with total lengths between 17 and 40 mm. Due to the small size of juvenile Sculpin and widespread interspecific hybridization common in the Kootenay region (McPhail 2007), field identification of juvenile Sculpin to the species level can be challenging.

3.3.1.4 Exotic Fish Species

Exotic species (i.e., not native to the lower Columbia and Kootenay rivers) stranded during the present study period were limited to Common Carp (*Cyprinus carpio*), Brook Trout (*Salvelinus fontinalis*), and Yellow Perch (*Perca flavescens*) (Table 5). The greatest number (n = 19) of Common Carp were found in an isolated pool at Beaver Creek (RUB) during RE2020-16 on 15 August. The remaining Common Carp (n = 8) were found at Gyro Boat Launch (RUB) and Kootenay River (RUB) during RE2020-25 on 4 October. Since 2000, a total of 135 Common Carp have been identified during fish stranding assessments, with most identified at Kootenay River (RUB) (n = 65) and Genelle Mainland (LUB) (n = 35).

A single juvenile Brook Trout was identified in an isolated pool at Norns Creek Fan during RE2021-06 on 25 February 2021. Since 2000, a total of 19 Brook Trout have been identified at 9 sites throughout the lower Columbia River during fish stranding assessments. Brook Trout have not been identified in the lower Kootenay River below BRD/X.

A single adult Yellow Perch was identified in an isolated pool at Zuckerberg Island (LUB) during RE2021-07 on 26 February 2021. This adult was a pre-spawn female that was filled with eggs. Since 2000, only 4 Yellow Perch have been identified during fish stranding assessments. The last recorded occurrence of this species during a fish stranding assessment was in 2015.

All stranded exotic species were euthanized as requested by the Ministry of Forests, Lands, Natural Resource Operations & Rural Development (FLNRORD) (Pers. Comm., Matt Neufeld, FLNRORD, 22 February 2016).

Table 5: Summary of fish species captured or observed during fish stranding assessments, 1 April 2020 to 1 April 2021.

	Species	Total Stranded	Percent of Total Stranded	Total Mortalities	Total Salvaged	Species Classification		
						SARA a	COSEWIC b	CDC c
Sportfish	Rainbow Trout	127	1.1	18	96	N/A	N/A	Yellow
Non-Sportfish	Sucker species	6,185	53.9	272	5,509	N/A [d]	N/A [d]	N/A [d]
	Redside Shiner	1,500	13.1	27	1,400	N/A	N/A	Yellow
	Unidentified [e]	1,392	12.1	10	552	N/A [f]	N/A [f]	N/A [f]
	Northern Pikeminnow	1,388	12.1	31	1,345	N/A	N/A	Yellow
	Longnose Dace	375	3.3	95	214	N/A	N/A	Yellow
	Torrent Sculpin	262	2.3	4	202	N/A	N/A	Yellow
	Sculpin species	46	0.4	0	40	N/A [f]	N/A [f]	N/A [f]
	Prickly Sculpin	41	0.4	0	41	N/A	N/A	Yellow
	Slimy Sculpin	40	0.3	0	40	N/A	N/A	Yellow
	Peamouth	39	0.3	25	14	N/A	N/A	Yellow
	Umatilla Dace	33	0.3	0	31	Schedule 3 Special Concern	Threatened	Red
	Columbia Sculpin	4	< 0.1	0	4	Schedule 1 Special Concern	Special Concern	Blue
	Shorthead Sculpin	2	< 0.1	0	2	Schedule 1 Special Concern	Special Concern	Blue
	Longnose Sucker	1	< 0.1	0	1	N/A	N/A	Yellow
Exotic Fish	Common Carp	28	0.2	0	0	N/A	N/A	Exotic
	Brook Trout	1	< 0.1	0	0	N/A	N/A	Exotic
	Yellow Perch	1	< 0.1	0	0	N/A	N/A	Unknown
Total		**11,465**		**482**	**9,491**			

[a] Species at Risk Act (SARA); Species that were designated at risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) before the creation of the *Species at Risk Act* must be reassessed according to the new criteria of the Act before they can be added to Schedule 1. These species are listed on Schedules 2 and 3 and are not yet officially protected under SARA (COSEWIC 2010).
[b] Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2010).
[c] BC Conservation Data Centre (CDC); Red = indigenous species or subspecies that have, or are candidates for, Extirpated, Endangered, or Threatened status in British Columbia; Blue = any indigenous species or subspecies considered to be of Special Concern in British Columbia. Yellow = species that are apparently secure and not at risk of extinction. Exotic = species that have been moved beyond their natural range as a result of human activity. (BC Conservation Data Centre. 2021).
[d] No Sucker species are listed as species of concern in the Columbia and Kootenay rivers.
[e] Individuals not identified to species observed during visual surveys but not captured.
[f] Fish identified to family level may potentially be species of concern under the classification system listed.

3.3.1.5 Species of Concern

Umatilla Dace (*Rhinichthys umatilla*), Columbia Sculpin (*Cottus hubbsi*), Shorthead Sculpin (*Cottus confusus*), and White Sturgeon (*Acipenser transmontanus*) are the resident species of concern (i.e., designated at risk by the Committee on the Status of Endangered Wildlife in Canada [COSEWIC][4] and/or the BC Conservation Data Center [CDC][5]) in the study area. Umatilla Dace, Columbia Sculpin, and Shorthead Sculpin have been documented during previous study years (Golder 2016, 2017, 2018, 2019, 2020b). White Sturgeon have never been identified during lower Columbia River and Kootenay River fish stranding assessments.

During the present study period, 33 Umatilla Dace, 4 Columbia Sculpin, and 2 Shorthead Sculpin were stranded (Table 6). The greatest number of stranded Umatilla Dace (*n* = 15) occurred in isolated pools with cobble and sand substrate at Gyro Boat Launch (RUB) during RE2020-24 (3 October 20) and RE2021-06 (25 February 2021). Since 2000, a total of 2,424 Umatilla Dace have been identified during fish stranding assessments with 94% stranded during the Low Risk period. In particular, the highest numbers of stranded Umatilla Dace have occurred in February (*n* = 703) and March (*n* = 961) (Figure 5). These findings indicate that the summer months do not pose a higher stranding risk for Umatilla Dace, as is the case for other species (i.e., Sucker species, and Redside Shiner). Based on studies in the Slocan River, Umatilla Dace likely spawn from early July to mid-September (AMEC 2014). Only sparse information is available regarding Umatilla Dave preferred spawning habitat, but adults may congregate in deeper water to spawn, then upon emergence, the YOY and juveniles use shallow habitat for rearing throughout the fall, winter, and spring. In a study conducted by R.L. & L. Environmental Services Ltd. (1995), YOY Umatilla Dace were recorded in the mainstem Columbia River in shallow nearshore areas throughout the year and juveniles (1+) were abundant in nearshore areas in the summer, but then moved to deeper water during the fall. Since 2000, the highest number of stranded Umatilla Dace have been found at Kootenay River (LUB; *n* = 655), Kootenay River (RUB; *n* = 504), Gyro Boat Launch (RUB; *n* = 316), and Bear Creek (RUB; *n* = 402) (Figure 6).

The total number of Columbia and Shorthead Sculpin found during annual stranding assessments is often low. Since 2000, there have been a total of 275 Columbia Sculpin (including those previously identified as Mottled Sculpin[6]) and 32 Shorthead Sculpin found stranded during fish stranding assessments on the lower Columbia and Kootenay rivers.

With the exception of two Umatilla Dace that were observed during fish salvage efforts but not captured, all identified species of concern were successfully salvaged and returned to the mainstem of the Columbia or Kootenay rivers.

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[4] https://www.cosewic.ca/index.php/en-ca/

[5] https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/conservation-data-centre/explore-cdc-data

[6] Recent genetic sequence comparison between Mottled Sculpin (*Cottus bairdii*) in the Great Lakes drainage and those identified as Mottled Sculpin in the Columbia River system indicate a distinct divergence between the two areas. Consequently, the species previously identified as Mottled Sculpin in the Columbia River are now identified as Columbia Sculpin (*Cottus hubbsi*) (McPhail 2007).

Table 6: Summary of Species of Concern identified during stranding assessments, 1 April 2020 to 1 April 2021.

Site [a]	Total Number of Assessments	Number of Site Assessments with Species of Concern	Risk Period when Stranding Occurred [b]	Number of Fish Stranded
Umatilla Dace (SARA: Schedule 3 Special Concern, COSEWIC: Threatened, CDC: Red)				
Gyro Boat Launch (RUB)	5	2	Low	15
Kootenay River (LUB)	10	2	Low	6
Kootenay River (RUB)	12	1	Low	10
Waterloo U/S (RUB)	3	1	Low	2
Columbia Sculpin (SARA: Schedule 1 Special Concern, COSEWIC: Special Concern, CDC: Blue)				
Kootenay River (RUB)	12	1	Low	2
Tin Cup Rapids (RUB)	12	1	Low	2
Shorthead Sculpin (SARA: Schedule 1 Special Concern, COSEWIC: Special Concern, CDC: Blue)				
Norns Creek Fan (RUB)	12	1	Low	1
Waterloo U/S (RUB)	3	1	Low	1
Total				**39**

[a] Appendix A; Figures A1 through A11.
[b] High Risk period = 1 June to 30 September; Low Risk period = 1 October to 31 May.

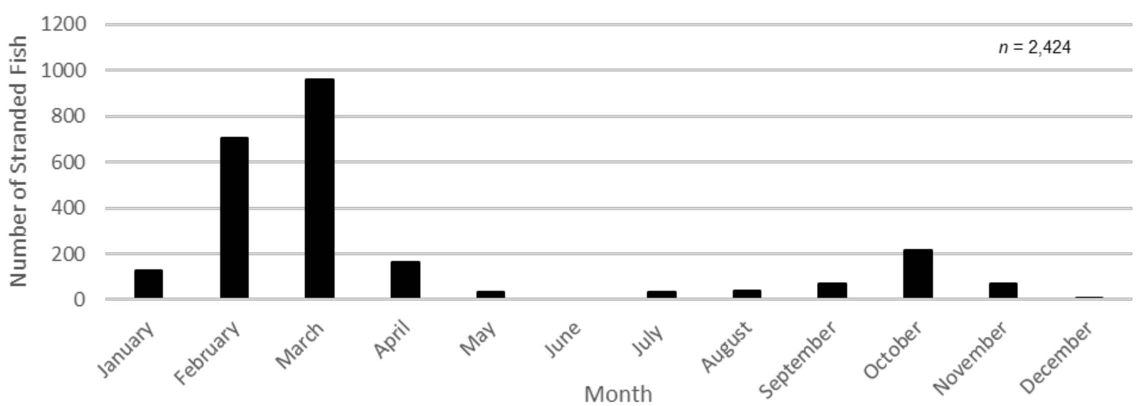

Figure 5: Number of Umatilla Dace stranded by Month from 1 January 2000 to 1 April 2021.

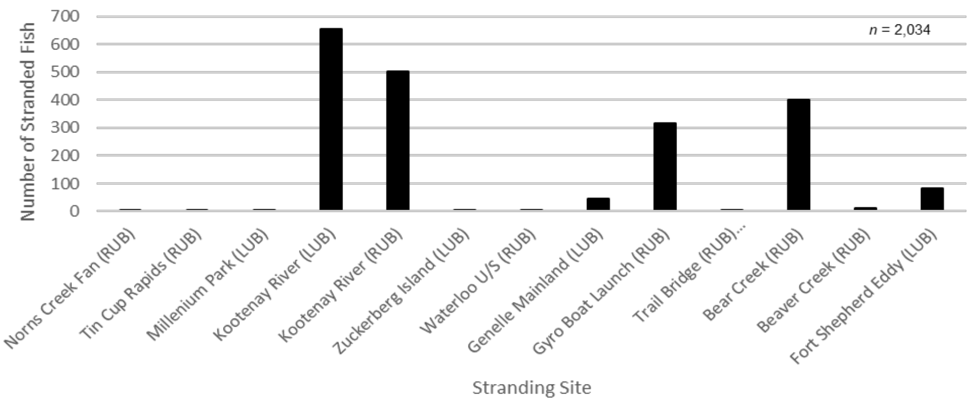

Figure 6: Number of Umatilla Dace stranded by site from 1 January 2000 to 1 April 2021. Sites ordered from upstream to downstream. Figure does not include Umatilla Dace stranded at Lions Head (RUB), Genelle Mainland (LUB), and Fort Shepherd Launch (LUB) before these sites were recontoured.

3.3.1.6 Fish Length Analysis

A total of 653 fish captured during fish stranding assessments were measured for either fork length or total length. The average length (mm) of all measured individuals is shown in Table 7.

Table 7: Descriptive statistics of fork length and total length by species, 1 April 2020 to 1 April 2021.

Species	Average Length ± SD (mm)	Range (mm)	n
Brook Trout	87 +/- 0	N/A	1
Common Carp	52 +/- 6	43 – 60	8
Columbia Sculpin	87 +/- 5	83 – 93	4
Longnose Dace	32 +/- 12	16 – 97	74
Longnose Sucker	67 +/- 0	N/A	1
Northern Pikeminnow	30 +/- 5	20 – 39	47
Peamouth	28 +/- 8	14 – 46	22
Prickly Sculpin	48 +/- 14	31 – 87	36
Rainbow Trout	62 +/- 21	17 – 125	83
Redside Shiner	27 +/- 8	14 – 50	57
Shorthead Sculpin	66 +/- 13	56 – 75	2
Slimy Sculpin	61 +/- 19	28 – 93	36
Sucker spp.	44 +/- 11	17 – 73	155
Torrent Sculpin	53 +/- 22	26 – 126	97
Umatilla Dace	30 +/- 7.4	19 – 58	29
Yellow Perch	212 +/- 0	N/A	1
Total			**653**

Total length (mm) represented for all sculpin species; fork length (mm) represented for all remaining species.

3.4 Assessment of New and Re-introduced Fish Stranding Sites

Currently, physical site data and fish stranding data from Waterloo U/S (RUB), Waterloo Eddy (RUB), Blueberry Creek D/S (LUB), Sandbar Eddy (LUB), Birchbank Snye (LUB), Gyro Park (RUB), and Korpack (LUB) is limited for both the High and Low Risk periods. A preliminary summary of the assessments conducted at these sites in 2020/2021 and predicted stranding risk for future reductions is provided in Table 8.

Table 8: Summary of new and re-introduced fish stranding sites, 1 April 2020 to 1 April 2021.

Site [a]	New or Re-introduced	Total Number of Assessments	Summary of Fish Stranding Assessments	Priority for Future Stranding Assessments
Waterloo U/S (RUB)	New	3	**RE2021-05:** (63 kcfs MinQ[b]; 0 pools formed; 0 fish stranded) **RE2021-07:** (41 kcfs MinQ; 12 pools formed; 24 fish stranded) **RE2021-10:** (34 kcfs MinQ; 2 pools formed; 5 fish stranded including Umatilla Dace) Site not likely to strand fish at Birchbank discharge >60 kcfs due to steep banks above this discharge. During RE2021-07 12 pools of varying size formed within cobble/boulder substrate. Two of these pools were >1m deep. During RE2021-10, one small pool (approx. 1m x 2m) and one large pool (approx. 40m x 10m) formed in cobble/boulder substrate.	High priority at discharge <60 kcfs Low priority at discharge >60 kcfs
Waterloo Eddy (RUB)	Re-introduced (last assessed in 2008).	2	**RE2021-05:** (63 kcfs MinQ; 0 pools formed; 0 fish stranded) **RE2021-07:** (41 kcfs MinQ; 15 pools formed; 0 fish stranded) Site not likely to strand fish at Birchbank discharge >60 kcfs due to steep banks above this discharge. During RE2021-07, 14 small stranding pools formed (less than 1m x 1m), as well as one large pool (approx. 4 m deep) capable of supporting long-term fish survival. Pools likely form at discharge <40 kcfs.	Moderate priority at discharge <60 kcfs Low priority at discharge >60 kcfs
Blueberry Creek D/S (LUB)	New	1	**RE2021-05:** (63 kcfs MinQ; 0 pools formed; 0 fish stranded) Site not likely to strand fish at Birchbank discharge >60 kcfs due to steep banks above this discharge. A single large pool (approx. 15m x 6m) will likely isolate between 30 and 40 kcfs; however, fish habitat appears poor (sand/silt substrate with no cover).	Moderate priority for future fish stranding assessments <40 kcfs Low priority for future fish stranding assessments >40 kcfs
Sandbar Eddy (LUB)	New	1	**RE2021-05:** (63 kcfs MinQ; 2 pools formed; 0 fish stranded) During RE2021-05 one pool (approx. 25m x 10m) with gravel substrate and one pool (approx. 20m x 2m) with sand/silt substrate had formed. Additional pools are expected to form at discharge <60 kcfs.	High priority at all discharge ranges due to limited previous stranding assessments

Site [a]	New or Re-introduced	Total Number of Assessments	Summary of Fish Stranding Assessments	Priority for Future Stranding Assessments
Birchbank Snye (LUB)	Re-introduced (last assessed in 2004)	1	**RE2021-05:** (63 kcfs MinQ; 2 pools formed; 0 fish stranded) Two large pools (approx. 200 x 70 m) connected by shallow water had become isolated from the Columbia River during a previous assessment. Due to the size of the pools fish salvage would not have been effective; however, these pools likely provide sufficient habitat for long-term fish survival after they become isolated. Golder (2009) identified that these pools isolate at approximately 88 kcfs; and found them to be inhabited by predominately cyprinids (Northern Pikeminnow, Redside Shiner, Peamouth Chub, and dace spp.) and Sucker species.	High priority at discharge <50 kcfs to evaluate if pools contain fish and if they have the potential to completely dewater Low priority at discharge >50 kcfs
Gyro Park (RUB)	New	1	**RE2021-05:** (63 kcfs minQ; 7 pools formed; 0 fish stranded) During RE2021-05, 7 pools (approximately 1m x 1m) were found within bedrock substrate at upstream end of site and within cobble substrate at the downstream end of site. There is potential for pools to form above and below Birchbank discharge of 60 kcfs.	High priority at all discharge ranges due to limited previous stranding assessments
Korpack (LUB)	Re-introduced (last assessed in 2017)	1	**RE20201-05:** (63 kcfs minQ; 0 pools formed; 0 fish stranded) Site was also assessed by BC Hydro personnel on 1 March 2021 when Birchbank discharge was 42 kcfs (pers. comm. BC Hydro). Five large pools within cobble/boulder substrate were identified. These pools likely formed during the previous reduction event (RE2021-07) on 26 February 2021. Not likely to pose a high stranding risk at Birchbank discharge > 60 kcfs due to steep banks above this discharge. Future stranding assessments are recommended at discharges less than 60 kcfs.	Moderate priority at discharge <60 kcfs Low priority at discharge >60 kcfs

[a]Appendix A: Figures A1 through A11.
[b]Min Q = minimum discharge recorded at Birchbank Gauge Station during reduction event.

3.5 Historic Fish Stranding Summary

The results of fish stranding assessments conducted between January 2000 and 1 April 2021 are summarized below by site, risk period and resultant Birchbank discharge (classified into 10 kcfs ranges) (Table 9). This table can be used by BC Hydro during the risk assessment process (Section 2.1) to determine if a proposed reduction event has occurred historically at a given time of year, and which sites are most likely to have high stranding risk based on historical fish stranding data. The maximum and average number of fish stranded per reduction event are presented. Sites where species of concern (i.e., Columbia Sculpin, Shorthead Sculpin, and Umatilla Dace) have been previously stranded are also identified.

During the High Risk period, Tin Cup Rapids (RUB) and Genelle Mainland (LUB) have high stranding risk, with both maximum and average number of fish per reduction event being greater than 200 fish at a variety of discharge ranges (Table 9). These sites should remain a focus for fish stranding assessments during the High Risk period. Norn's Creek Fan (RUB) and Kootenay River (RUB) pose a higher risk of stranding within discharge ranges of 30 to 70 kcfs, in comparison to higher discharges.

During the Low Risk period, at sites in the Kootenay River and in the Columbia River upstream of the Kootenay River confluence pose an elevated risk of stranding (Table 9). The majority of sites downstream of the Kootenay River confluence appear to have generally lower fish stranding risk. Genelle Mainland (LUB), and Gyro Boat Launch (RUB) have had relatively high numbers of stranded fish and the presence of species of concern at variety of discharge ranges. Overall, there has been a greater occurrence of species of concern during the Low Risk period than the High Risk period. Stranding risk during the Low Risk period appears to decrease sharply when discharge is greater than 70 kcfs.

Table 9: Summary of fish stranded by site, risk period and discharge on the lower Columbia and Kootenay rivers due to reduction events at HLK/ALH and BRD/X, 1 January 2000 to 1 April 2021.

4.0 SUMMARY

The present study provides the results of fish stranding assessments conducted on the Lower Columbia and Kootenay rivers in response to flow reductions at HLK/ALH and BRD/X between 1 April 2020 and 1 April 2021. The main findings of these assessments are as follows:

- Discharge in the Columbia River at the Birchbank Gauging Station was typical of previous years and ranged from 26.7 to 151.6 kcfs.
- There were 28 operational flow reduction events; 26 from HLK/ALH, one from BRD/X, and one that occurred at HLK/ALH and BRD/X on the same day. Stranding assessments were conducted for 17 of the 28 reduction events, resulting in a response rate of 61%.
- During the 17 fish stranding assessments conducted, an estimated total of 11,486 fish were stranded. The majority (83%) of stranded fish were successfully salvaged and returned to the Columbia or Kootenay River. Similar to previous years, the majority of stranded fish (53%) were observed during the High Risk period. Genelle Mainland (LUB) and Kootenay River (RUB) accounted for 87% of all stranded fish identified.
- Sportfish accounted for approximately 1% of all stranded fish and all were YOY and juvenile Rainbow Trout. Non-sportfish accounted for the remaining 99% of stranded fish with Sucker spp., Redside Shiner, and Northern Pikeminnow representing the highest abundance.
- Stranded exotic species included 28 Common Carp, 1 Brook Trout, and 1 Yellow Perch. All exotic species encountered were euthanized and removed from the lower Columbia or Kootenay River at the request of FLNRORD.
- Stranded species of concern included 33 Umatilla Dace, 4 Columbia Sculpin, and 1 Shorthead Sculpin. All were identified during the Low Risk period. Despite their listed status, Umatilla Dace are regularly encountered during stranding assessments in the lower Columbia and Kootenay rivers.

5.0 RECOMMENDATIONS

The following recommendations are provided for consideration for future fish stranding assessments in the lower Columbia and Kootenay rivers:

- Genelle Mainland (LUB) should be a focus of fish stranding assessments in 2021/2022. Historically this site has had a high risk of fish stranding at a various range of discharges (Table 9). Because of this, BC Hydro conducted physical habitat recontouring at Genelle Mainland (LUB) in March 2021. Recontouring efforts included infilling of depressions where isolated pools were likely to form and adjusting gradient to reduce the likelihood of stranding. Fish stranding assessments should be conducted at Genelle (Mainland) at various discharge volumes. Results of these assessments will provide an evaluation of the effectiveness of the recontouring on fish stranding risk at this site.
- Results of the fish stranding assessments conducted during the present study period on new and re-introduced fish stranding sites (Waterloo U/S [RUB], Waterloo Eddy [RUB], Blueberry Creek D/S [LUB], Sandbar Eddy [LUB], Birchbank Snye [LUB], Gyro Park [RUB], and Korpack [LUB]) are considered preliminary. It is recommended that fish stranding assessments continue to be conducted at these sites at various discharge volumes. For specific discharge volumes where stranding risk data gaps exist refer to Table 8.
- To maximize the potential for fish salvage, 'Effect' sites (as identified in the Database query) should remain the focus of fish stranding assessments. These sites represent the highest number of stranded fish based on historical stranding data for a given time of year and Columbia River discharge value. If time permits, it is recommended that 'Reconnaissance' sites be visited to fill in data gaps that remain in Table 9.
- Based on historical stranding assessment data since 2000, Casino Road Bridge, Trail (LUB) (Upstream) and Casino Road Bridge, Trail (LUB) (Downstream) have relatively low stranding risk when compared to other sites (Table 9). For Casino Road Bridge, Trail (LUB) (Upstream) stranding assessments have been conducted for a total of 86 reduction events, and the maximum number of stranded fish was 6. For Casino Road Bridge, Trail (LUB) (Downstream) stranding assessments have been conducted for a total of 103 reduction events, and the maximum number of stranded fish was 207. Furthermore, species of concern have not been found at these sites in the past. As a result of the relatively low stranding numbers per assessment effort, it is recommended that these sites should be low priority for future stranding assessments.

6.0 CLOSURE

We trust that this report meets your current requirements. If you have any further questions, please do not hesitate to contact the undersigned.

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KL/SR/cmc

https://golderassociates.sharepoint.com/sites/104258/project files/6 deliverables/draft report annual summary 2020_2021/19117420-010-r-rev0-lcr stranding_2020_2021_annual_summary 08jun_21.docx

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APPENDIX A

Site Maps

APPENDIX B

Database Query Example

APPENDIX C

Fish Stranding Frequency by Site

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