Columbia River Project Water Use Plan

Lower Columbia River Fish Management Plan

Lower Columbia River Fish Stranding Assessment and Ramping Protocol

Implementation Year 12

Reference: CLBMON-42A

Lower Columbia River Assessments (CLBMON-42A) and Kootenay River Fish Stranding Assessments

Study Period: April 1, 2018 to April 1, 2019

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July 2, 2019

REPORT

Annual Summary Report

Lower Columbia River (CLBMON42[A]) and Kootenay River Fish Stranding Assessments: Annual Summary (April 2018 to April 2019)

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Cover Photo: Shallow pools formed at Norns Creek Fan (RUB) during flow reduction event RE2019-02 on 12 January 2019 (see Appendix A; Figure A1 for location).

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Executive Summary

Discharge reductions and flow ramping from Hugh L. Keenleyside Dam/Arrow Lakes Generating Station (HLK/ALH) and Brilliant Dam/Expansion (BRD/X) can result in the stranding of fish species of the lower Columbia and Kootenay rivers. The Lower Columbia River Fish Stranding Assessment and Ramping Protocol Monitoring Program (CLBMON#42) has been carried out under the 13-year Columbia River Water Use Plan (BC Hydro 2007). The primary objective of CLMBON#42 is to continue to collect fish stranding data to assess the impact of flow reductions and flow ramping rates from HLK/ALH on the native fish species of the Lower Columbia River and includes two field data collection components: 1) Lower Columbia River and Kootenay River Fish Stranding Assessments (CLMBMON#42[A], and 2) Lower Columbia River Flow Ramping Studies. The present study is Year 12 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 Columbia and Kootenay rivers between 1 April 2018 and 1 April 2019.

At total of 20 reduction events (RE) occurred between 1 April 2018 and 1 April 2019 (the present study period). All RE were due to operational flow changes at HLK/ALH. Of those 20 RE, 7 occurred during the High Risk period (1 June to 30 September) and 13 occurred during the Low Risk period (1 October to 31 May). Stranding assessments were conducted for 13 of the 20 RE. Stranding assessments were not conducted at the remaining 7 RE due to high water levels, lack of predicted stranding occurrences, and minimal flow reductions.

An estimated 4,463 stranded fishes were observed during the 13 stranding assessments. Approximately 48% of these fishes were salvaged (successfully relocated to the mainstem Columbia or Kootenay rivers). Eighteen sites were assessed at least once during the study period and the majority (83.4%) of stranded fishes were found at Genelle Mainland (LUB), Kootenay (RUB), and Norns Creek Fan (RUB) sites. Sportfishes accounted for 3.7% of the total stranded fishes and included Rainbow Trout (*Oncorhynchus mykiss*), Mountain Whitefish (*Prosopium williamsoni*), and Brook Trout (*Salvelinus fontinalis*). Of the non-sportfishes stranded, the most common were juvenile Redside Shiner (*Richardsonius balteatus*) accounting for 30.8% of the non-sportfishes stranded.

In addition to salvaging stranded fishes, 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 that help predict the effects of RE at HLK/ALH and BRD/X.

Secondary objectives of CLBMON#42 include addressing five key management questions identified under the Columbia River Project Water Use Plan (Table ES1) (BC Hydro 2007). Analyses necessary to address the first four management questions were not conducted during the present study. These management questions were addressed using data from flow ramping studies conducted on the Columbia River from 2004 to 2006 (Golder 2005, 2006, 2007), from a literature data review and analysis of the Lower Columbia River Fish Stranding Database conducted in 2010 (Golder and Poisson 2010; Irving et al. 2014), and from a Lower Columbia River Fish Stranding Database analysis on the effects of re-contouring conducted in 2018 (Golder 2018). Data collected during the present study adds to the dataset used to answer Management Question #5.

Table ES1: CLBMON#42 Status of Lower Columbia River Fish Stranding Assessment and Ramping Protocol Program Objectives, Management Questions and Hypotheses

Primary Objective	Secondary Objectives	Management Questions	Management Hypotheses	Year 12 (2018/2019) Status
To assess the impact of flow reductions and flow ramping rates from HLK/ALH on the native species of the lower Columbia River.	To determine ramping rates for flow reductions which reduce the stranding rate of fishes at different times of the year.	MQ1: Is there a ramping rate (fast vs. slow, day vs. night) for flow reductions from HLK/ALH that reduces the number of fishes stranded (interstitially and pool) per flow reduction event in the summer and winter?	Ho1: The number of stranded fishes is independent of either the ramping rate or time of day of flow reductions in the summer and winter.	The variable of ramping rate and time of day on fish stranding risk has been assessed through analyses from three years of ramping studies on the Columbia and Kootenay rivers (Golder 2007; Irvine et al. 2009) and from a statistical analyses conducted on 10 years of stranding assessment data (1999 to 2009) in the stranding database (Golder and Poisson 2010; Irvine et al. 2014). Based on these previous analyses ramping rate was not found to be a statistically significant predictor of stranding risk; however, there was a noticeable trend of increased fish stranding frequency with increased ramping rates under certain scenarios (i.e. pool stranding in summer) (Irvine et al. 2009). Given these results, the effect of ramping rate on the fish stranding component of the null hypothesis cannot be rejected at this time. An analysis on three years of ramping studies indicate that time of day (day vs night) was not a significant variable for stranding risk (Golder 2007); however when an analysis was conducted on the stranding database, time of day was found to be a significant predictor of stranding risk with the highest risk of stranding occurring in the late afternoon (Golder and Poisson 2010; Irvine et al. 2014). Given these differing results, the effect of time of day on the fish stranding component of the null hypothesis cannot be rejected at this time. Both the ramping rate and time of day component of this management question will be further clarified in year 13 with a statistical analysis conducted on data from the stranding database
	To determine whether the wetted history influences the stranding rate of fishes for flow reductions.	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/ALH?	Ho2: Wetted history does not influence the stranding rate of fishes (both interstitially and pool stranding) for flow reductions from HLK/ALH.	An analysis on flow ramping studies in the Columbia and Kootenay river systems indicated that stranding risk has been shown to increase with increased wetted history (Irvine et al. 2009). However, this relationship was not statistically significant (Golder 2007). A previous analysis on the results from the stranding database indicated a statistically significant positive correlation between wetted history and stranding risk (Golder and Poisson 2010; Irvine et al. 2014). Additionally, a significant increase in the number of stranded fishes was observed after a 10-day wetted history (Golder and Poisson 2010). Based on these previous studies, this hypothesis can be rejected. This management question will be further clarified in year 13 with a statistical analysis conducted on data from the stranding database.

Primary Objective	Secondary Objectives	Management Questions	Management Hypotheses	Year 12 (2018/2019) Status
	To determine whether a conditioning flow reduction from HLK/ALH reduces the stranding rate of fishes.	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/ALH reduce the stranding rate of fishes?	Ho3: A conditioning flow from HLK/ALH does not reduce the stranding rate of fishes in the lower Columbia River.	Previous studies have shown that the use of a conditioning flow reduction appears to reduce the incidence of pool stranding on the Columbia River (Golder 2007; Irvine et al. 2009), however this relationship was not statistically significant and the analysis was based on limited results (Golder 2007). Currently, this hypothesis cannot be rejected at this time. For a definitive answer to this management question an experimental conditioning flow study including manipulation of flows with substantial time between replicates is required. The cost of this experimental design would be high and may result in substantial fish mortalities, as indicated by similar studies on the Duncan River (Poisson and Golder 2010).
	To determine whether physical habitat manipulation will reduce the incidence of fish stranding.	MQ4: Can physical habitat works (i.e., re-contouring) reduce the incidence of fish stranding in high risk areas?	Ho4: Physical habitat manipulation does not reduce the stranding rate of fishes in the lower Columbia River.	Since 2000, six high risk stranding sites on the Columbia River have been re-contoured: Fort Shepherd Launch (RUB), Genelle Lower Cobble Island (MID), Genelle Mainland (LUB), Lions Head (RUB), Millennium Park (LUB), and Norns Creek Fan (RUB). Previous stranding database analysis have revealed that the efforts of re-contouring sites on the lower Columbia River have been successful in decreasing the incidence of stranding and the number of fishes stranded (Golder and Poisson 2010; Irvine et al. 2014; Golder 2018). Based on these previous analyses, Management Hypothesis #4 is rejected.
	Reduce the number of occurrences when a stranding crew would be deployed for a flow reduction.	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/ALH?	Ho5: The number of fish salvage events can be reduced through adaptive adjustments made as a result of ongoing data collection.	Currently this hypothesis can not be rejected. Since 2009 the number of yearly stranding assessments conducted due to flow reductions from HLK/ALH has varied from 8 to 15 (median = 13) and the response rate (percent of yearly RE from HLK/ALH that initiate a stranding assessment) has varied from 62 to 92% (median = 83%). During the present study, there were 13 stranding assessments conducted in response to 20 RE from HLK/ALH resulting in a response rate of 65%.

Key Words

Lower Columbia River

Kootenay River

Water Use Planning

Fish Stranding

Flow Reduction

Flow Ramping

Discharge Regulation

Re-contouring

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1.0 INTRODUCTION

1.1 Scope and Objectives

The Lower Columbia River Fish Stranding Assessment and Ramping Protocol Monitoring Program (CLBMON#42) has been carried out under the 13-year Columbia River Project Water Use Plan (BC Hydro 2007). The monitoring program includes two field data collection components:

- Lower Columbia River and Kootenay River Fish Stranding Assessments
- Lower Columbia River Flow Ramping Studies

The main objective of the Lower Columbia River Fish Stranding Assessment and Ramping Protocol Monitoring Program is to collect fish stranding data to assess the impact of flow reductions and flow ramping rates from Hugh L. Keenleyside Dam/Arrow Lakes Generating Station (HLK/ALH) and Brilliant Dam/Expansion (BRD/X) on native fish species of the lower Columbia and Kootenay rivers. Secondary objectives include the following: 1) determining ramping rates for flow reductions that reduced incidences of fish stranding at different times of the year; 2) determining whether wetted history influenced the stranding rate of fishes during flow reductions; 3) determining whether a conditioning flow reduction from HLK/ALH reduced the stranding rate of fishes; 4) determining whether physical habitat manipulation (e.g., re-contouring the shoreline) reduced incidences of fish stranding in the lower Columbia River; and 5) reducing (through risk management strategies) the number of occurrences when stranding crews need to be deployed during flow reductions (BC Hydro 2007).

Flow ramping studies at HLK/ALH were conducted in the summer and winter of 2004, 2005 and 2006 and the results were previously reported (Golder 2005, 2006, 2007; Irvine et al. 2009). In 2010, a literature data review and an analysis of data in the Lower Columbia River Fish Stranding Database were conducted to address Management Questions #1-3 (Golder and Poisson 2010, Irving et al. 2014). Based on these previous studies, recommendations regarding Management Questions #1-3 have been made in the present study. Stranding data from the Lower Columbia River Fish Stranding Database was analyzed to determine the probability of fish stranding before and after re-contouring and the number of fishes stranded before and after re-contouring (Golder and Poisson 2010, Golder 2018). Results from these previous analyses were used to address Management Question #4.

The present study provides the results of Year 12 (2018/2019) of the Lower Columbia River and Kootenay River Fish Stranding Assessments (CLBMON#42[A]). The present study summarizes the results of fish stranding assessments at pre-determined sites (Appendix A) on the lower Columbia and Kootenay rivers between 1 April 2018 and 1 April 2019. Results are compared to data from previous years of fish stranding assessments and contributes data designed to address Management Question #5, and the associated hypothesis outlined below.

1.2 Management Questions

The management questions identified under the Columbia River Project Water Use Plan and addressed under the Lower Columbia River Fish Stranding Assessment and Ramping Protocol Monitoring Program are summarized as follows (BC Hydro 2007):

1) Is there a ramping rate (fast vs. slow, day vs. night) for flow reductions from HLK/ALH that reduces the number of fishes 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 fishes stranded (interstitially and pool) per flow reduction event for flow reductions from HLK/ALH?

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/ALH reduce the stranding rate of fishes?

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/ALH?

1.3 Management Hypotheses

Five hypotheses that correspond to the management questions detailed above were tested using data collected during the Lower Columbia River Fish Stranding Assessment and Ramping Protocol Monitoring Program (BC Hydro 2007):

Ho1: The number of stranded fishes is independent of either the ramping rate or time of day of flow reductions in the summer and winter.

Ho2: Wetted history does not influence the stranding rate of fishes (both interstitially and pool stranding) for flow reductions from HLK/ALH.

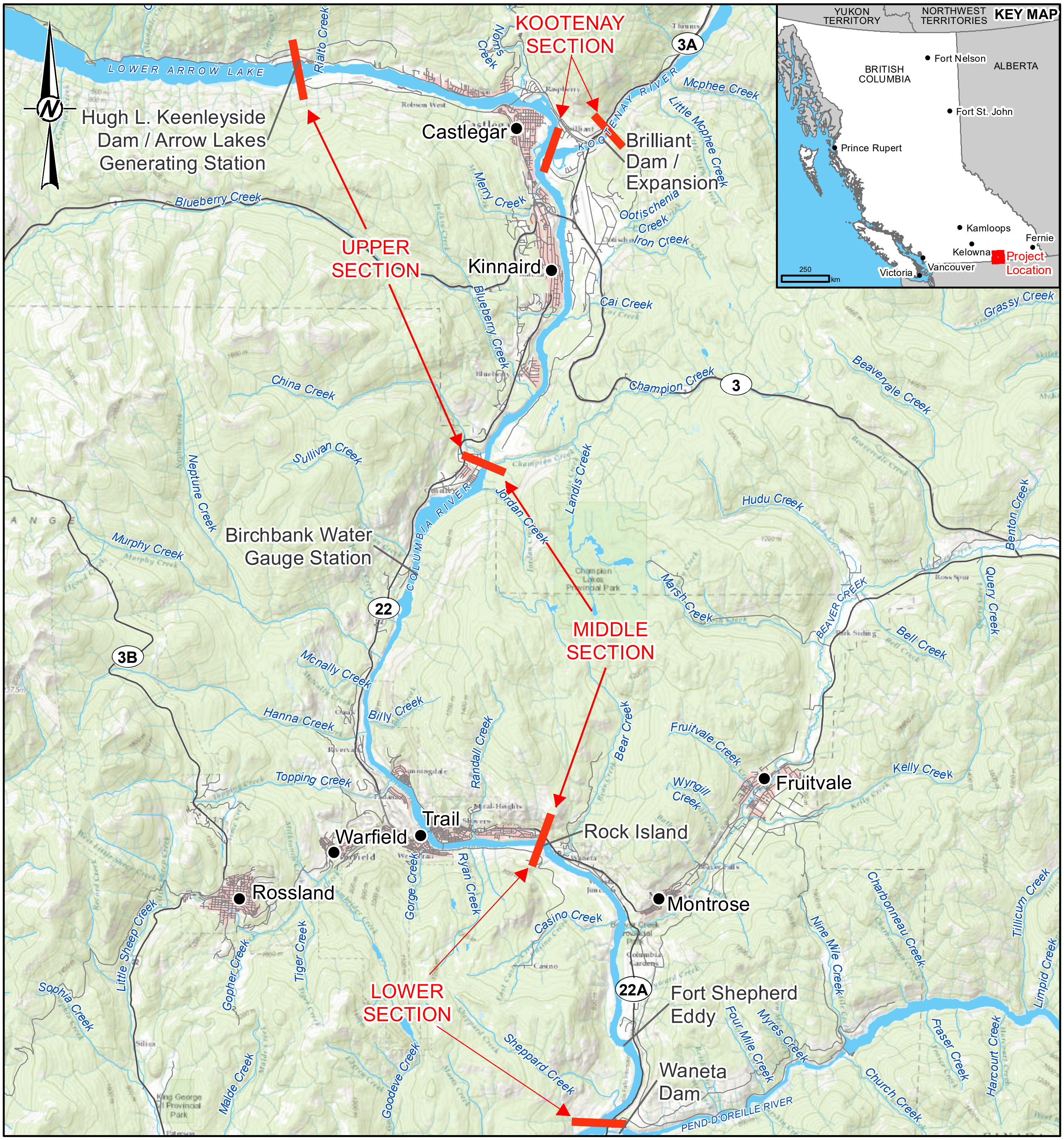
Ho3: A conditioning flow from HLK/ALH does not reduce the stranding rate of fishes in the lower Columbia River.

Ho4: Physical habitat manipulation does not reduce the stranding rate of fishes in the lower Columbia River.

Ho5: The number of fish salvage events can be reduced through adaptive adjustments made as a result of ongoing data collection.

1.4 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).



LEGEND

- ● TOWN
- HIGHWAY
- ROAD
- WATERCOURSE
- RESIDENTIAL AREA
- WATERBODY

0 5 10

1:200,000 KILOMETERS

REFERENCES
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CLIENT
BC HYDRO

PROJECT
LOWER COLUMBIA RIVER (CLBMON#42[A]) AND KOOTENAY RIVER FISH STRANDING ASSESSMENTS: ANNUAL SUMMARY (APRIL 2018 TO APRIL 2019)

TITLE
STUDY AREA OVERVIEW

CONSULTANT

GOLDER

YYYY-MM-DD	2019-04-18
DESIGNED	KL
PREPARED	CD
REVIEWED	KL
APPROVED	SR

PROJECT NO.	PHASE	REV.	FIGURE
1895371	2018	0	1

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2.0 METHODS

2.1 Fish Stranding Risk Assessment

Owners and operators (BC Hydro, Columbia Basin Trust/Columbia Power, and FortisBC) of hydroelectric facilities located on the lower Columbia and Kootenay rivers within BC have direct or indirect influences on water levels. The *Canadian Lower Columbia River: Fish Stranding 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, and outlines the roles and responsibilities pertaining to flow reductions for owners and operators of hydroelectric facilities on the lower Columbia and Kootenay rivers. The *Canadian Lower Columbia River: Fish Stranding Risk Assessment and Response Strategy* (Golder 2011) also outlines the roles and responsibilities of the Stranding Assessment Supervisor (Golder) and the protocols to be followed while conducting fish stranding assessments.

During the present study, the protocols developed in the *Canadian Lower Columbia River: Fish Stranding Risk Assessment and Response Strategy* (Golder 2011) were implemented preceding each reduction event and during all stranding surveys conducted. Fish stranding risk and response was based on current knowledge of factors known to influence fish stranding in regulated systems and the results of previous stranding assessments (Vonk 2003; BC Hydro 2005; Golder and Poisson 2010).

Once a potential flow reduction requirement is identified for HLK/ALH or BRD/X, the BC Hydro Operations Planning Engineer (OPE) for the facility consults with the BC Hydro Environmental Discharge Change Coordinator (DCC) regarding the potential flow reduction. The DCC for each RE during the present study period was either James Baxter, Dean Den Biesen, or Adam Croxall. The consultation includes information on the following:

- The timing and magnitude of the planned discharge change.
- The drivers of the discharge change.
- Flexibility of the system to modify discharge change expectations.
- Benefits of implementing the discharge change vs. consequences of not implementing the change.
- Current operations and/or planned changes at related hydroelectric facilities (HLK/ALH or BRD/X) to assist in deciding the most appropriate implementation/response strategy. It is important to ensure that there is knowledge of system operations for both the Columbia and Kootenay rivers to avoid potential incremental impacts.

Once a flow change decision is made, a fish stranding risk assessment is conducted. The assessment is based on both the current environmental conditions, as well as the results of past stranding assessments. Figure 2 summarizes the five phases in the fish stranding risk assessment process for defining fish stranding risk, as well as guiding assessment/salvage response decisions.

- **Phase 1 - Timing of Reduction:** The timing of the proposed reduction is the first factor which is taken into consideration when deciding to initiate a stranding assessment. Stranding risk is greatest in the summer months because newly emerged juvenile fishes occupy shallow near-shore habitats where they are more susceptible to stranding (Golder and Poisson 2010). The stranding High Risk period occurs from 1 June to 30 September; the Low Risk period occurs from 1 October to 31 May as defined in the *Canadian Lower Columbia River: Fish Stranding Risk Assessment and Response Strategy* (Golder 2011).
- **Phase 2 - River Stage:** Defines the current and proposed base flow level at the Water Survey of Canada Birchbank Gauging Station (Station Number 08NE049) as a result of the proposed flow reduction. Previous fish stranding assessment data is used to define risk for the proposed flow reduction change. The probability of fish stranding is typically inversely related to water levels. Low angle river bank and the presence of shallow depressions that are more common at lower water levels result in greater risk of fish stranding when compared to conditions present at higher water levels. During the High Risk period (1 June to 30 September), fish stranding risk decreases when discharge is greater than 110 kilo cubic feet per second (kcfs) (based on limited data). During the Low Risk period (1 October to 31 May), stranding risk decreases when discharge is greater than 60 kcfs (Golder and Poisson 2010).
- **Phase 3 - Info Review:** The DCC considers seasonal conditions and the significance of the planned flow reduction in relation to fish stranding. In performing this evaluation, the DCC relies on forecasted discharge, recent observations from stranding assessments, and on the historic fish stranding results identified in a query of the Lower Columbia River Fish Stranding Database.

  The Lower Columbia River Fish Stranding Database was developed to store and manage historic flow reduction and stranding assessment data (i.e., discharge, ramping rates, stranding sites, number of pools isolated, number and species of fishes/eggs stranded either interstitially or within pools, etc.) for use in predicting the potential impacts of a proposed RE. This database is updated with results of recent stranding assessments a minimum of quarterly throughout the year. Prior to a new RE, the database is queried to help define fish stranding risk for the proposed RE. Database query fields include current and expected resulting discharge at Birchbank Gauge station, current water temperature, date of proposed RE and facility responsible (HLK/ALH, BRD/X or both) for proposed RE. Based on these fields, the database queries the total number of stranding assessments conducted (year 2000 to current) and provides query results indicating total fishes stranded per assessment (including presence of listed species) and a ranking of predicted stranding risk at 22 identified stranding sites on the lower Columbia and Kootenay rivers. From high to low stranding risk, the rankings are as follows: '**Significant Stranding Event**' (greater than 5000 fishes stranded during any of the previous RE), '**Effect**' (greater than 200 fishes stranded during any of the previous RE), '**Minimal Effect**' (less than 200 fishes stranded during any of the previous RE), '**Reconnaissance**' (less than five previous stranding assessments conducted), and '**No Pools**' (No pools were recorded at the site during previous assessments conducted).

  In addition to the Lower Columbia River Fish Stranding Database query, the DCC uses the results of fish stranding assessments conducted between January 2000 to current year, which are represented in a table summarized by site, resultant Birchbank Discharge, and risk period (See Section 3.3, Table 5). This table provides total number of stranding assessments conducted and maximum number of fishes stranded at each site during a single RE. This table provides a quick reference to determine if a proposed RE has occurred historically for the time of year and which sites resulted in high stranding risk.

- **Phase 4 – Management Decision:** After timing, river stage, and results of the database query have been considered, the DCC will develop an appropriate environmental response recommendation for the proposed RE. A stranding assessment will be required at sites where the results from any previous stranding assessment indicated the following:
  - The flow reduction is likely to result in an 'Effect' (greater than 200 fishes stranded at any given site) during a flow reduction under similar conditions based on the database query (year 2000 to current) results.
  - The reduction is likely to strand potential species at risk (Umatilla Dace [*Rhinichthys Umatilla*], Columbia Sculpin [*Cottus hubbsi*], Shorthead Sculpin [*Cottus confusus*], and White Sturgeon [*Acipenser transmontanus*]) or there is uncertainty in the presence of these species.
  - The range of operations projected are outside those routinely undertaken for the time of year or few assessments have occurred at the flow range in the past two years.
  - No monitoring will be required when past survey data indicates operation will be within the range of normal operations, the anticipated stranding effects are minimal, and listed species are not likely to be stranded. Effects are considered to be minimal when results from the Lower Columbia River Fish Stranding Database query indicates either no pools are likely to form, or pools are likely to form but less than 200 fishes have been stranded at any given site during previous surveys and listed species are not likely to be stranded under similar conditions.
  - The hydroelectric utilities will undertake periodic non-mandatory assessments throughout the range of operations and risk levels over time in order to collect data that can be analysed to confirm or alter the state of knowledge about stranding risks. The number and timing of fish stranding assessments undertaken during periods when low numbers of fishes are expected to become stranded will be at the discretion of the DCC.
- **Phase 5 – Assessment Refinement:** The DCC and the Golder Stranding Assessment Supervisor (SAS) will define crew requirements based on the following:
  - Review of database query results and total number of potential sites ranked as 'Effect" and 'Significant Stranding Event'.
  - The results from the most recent previous stranding assessment, which can help to indicate which species may be occupying near-shore habitats.
  - Wetted history based on water levels recorded at the Birchbank gauging station. Habitat that has a wetted history of greater than 10 days has a greater risk of stranding fishes (Golder and Poisson 2010), which must be considered in flow reduction planning and response. During the High Risk period, YOY (young-of-year) fishes typically inhabit near-shore shallow water habitats and wetted history is less relevant to defining stranding risk.
  - Air Temperature – air temperatures greater than 25°C or less than 0°C can influence fish survival in isolated habitats by warming/cooling pool habitats and must be considered when fish salvage is anticipated.


Flow Reduction Fish Stranding Assessment Response
PHASE 1 Timing
PHASE 2 Stage
PHASE 3 Info Review
PHASE 4 Management Decision
PHASE 5 Assessment Refinement (Considerations)
HLK /ALH or BRD/BRX Flow Reduction
Day of Year
June 1 – September 30
October 1 – May 31
Minimum River Stage during reduction (BB)?
<110 kcfs
>110 kcfs
Query Stranding Database
Query Stranding Database
> 200 fish (effect) at one site or listed species expected?
No
<5 assessments at Individual sites at Risk (query), non-routine stage or ramping rate, no assessment in past 2 years at this stage?
No
Yes
Yes
Assessment Recommended
No Assessment Required
Voluntary Assessment Recommended
1. Review database query results and number of potential sites with effects.
2. Review previous reduction results for significant stranding (> 5000 fish).
3. Estimate wetted history at Birchbank, >10 days wetted history – anticipate more fish stranded.
4. Define daytime air temperature. If air temperature is greater than 25ºC or less than 0ºC, increase crews may be deployed to high risk sites.
5. Consider time of last reduction and ability to assess all potential stranding sites before dark.
If review suggests minimal risk of stranding and limited value in additional information collection an assessment is not necessary.
Undertake Assessment Baseline = 1 crew of 2 can assess approximately 7 sites per day. Consider additional crew on standby if you answered YES to questions 1 – 5 above.
Minimum River Stage during reduction (BB)?
<60 kcfs
>60 kcfs
Query Stranding Database
Query Stranding Database
>200 fish (effect) at one site or listed species expected?
No
<5 assessments at Individual sites At Risk (query), non-routine stage or ramping rate, no assessment in past 2 years at this stage?
No
Yes
Yes
Assessment Recommended
No Assessment Required
Voluntary Assessment Recommended
1. Review database query results and number of potential sites with effects.
2. Review previous reduction results for significant stranding (> 5000 fish).
3. Estimate wetted history at Birchbank, >10 days wetted history – anticipate more fish stranded.
4. Define daytime air temperature. If air temperature is greater than 25ºC or less than 0ºC, increase crews may be deployed to high risk sites.
5. Consider time of last reduction and ability to assess all potential stranding sites before dark.
If review suggests minimal risk of stranding and limited value in additional information collection an assessment is not necessary.
Undertake Assessment

2.2 Salvage Methods

Standard methodology used during the field component for each fish stranding assessment are outlined in the *Canadian Lower Columbia: River Fish Stranding Risk Assessment and Response Strategy* (Golder 2011) and are summarized below. The primary objective was to collect information on effects of flow reduction on fish stranding with fish salvage as a secondary objective. Fish stranding is defined as fishes that become stranded as a result of isolation in pools (wetted and de-watered) or stranded interstitially between substrate particles and are cut off from the mainstem river due to receding water levels.

Stranding assessment crews were on site no later than one hour after the final staged reduction from HLK/ALH or BRD/X. All fish stranding assessments were conducted via truck access. Fish stranding and salvage assessments began at the most upstream site identified for assessment by the Lower Columbia River Fish Stranding Database query and assessments continued downstream throughout the day 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 a ‘Significant Fish Stranding’ or ‘Effect’ ranking was assigned were the highest priority. The next priorities were ‘Reconnaissance’ sites, and, if time permitted, ‘Minimal Effect’ or ‘No Pools’ sites to confirm information in the database.

At each site, the crew conducted the following activities:

1) The current conditions were documented (date, time, weather, air temperature, water temperature, approximate vertical drawdown of the water level, and substrate material) on stranding field forms. The formation of new pools with future flow reductions (next 0.5 m stage decrease) was indicated for each site. Comments were also noted on the stranding field forms and any other pertinent information regarding the stranding assessment.

2) The number of new isolated pools (pools no longer connected to the mainstem of Columbia or Kootenay river) or de-watered pools that were created as a result of the flow reduction was recorded. Pools isolated during previous RE were noted in the comments but were not included in the total pools formed from the current RE.

3) Each pool was inspected for stranded fishes and crews attempted to salvage any fishes present using dipnets, backpack electrofishers (Smith-Root Model LR 24 or 12-B POW), or beach seines. The effort and number of pools sampled was recorded at each site depending on the method used for fish capture. Salvaged fishes from previously isolated pools (i.e. different RE), were recorded but were not included in the total number of fishes stranded during the current RE.

4) Captured fishes were transferred to a bucket of water where each fish was identified to species if possible. Fishes were classed into one of the following life stages; egg, YOY, juvenile, and adult. If stranded fishes were numerous (greater than 200 individuals), a subsample were captured and identified to species. The total number of live fishes, dead fishes, and salvaged fishes were recorded for each species and life stage. Salvaged fishes were returned to the main channel of the Columbia or Kootenay rivers.

5) The number of larvae and fry stranded was estimated if sample methods were ineffective at capturing these life stages.

6) Interstitial stranding areas were inspected, and any fishes observed were salvaged.

7) Representative areas of the site at the time of sampling were photographed. Photographs of representative or unusual fish species were also taken as appropriate.

8) Fish length data were collected from up to 20 individuals of each species identified during each RE. Total length was measured for sculpin species and fork length was measured for all other species.

9) Invasive species (Brook Trout) found during stranding assessments were euthanized and removed from the system based on recommendation from the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) (Pers. Comm., Matt Neufeld, FLNRORD, 22 February 2016).

3.0 RESULTS

3.1 Operations Overview 2018/2019

During the present study period, the discharge in the Columbia River at Birchbank ranged from 22 kcfs recorded on 10 April 2018 to 160 kcfs on 26 May 2018 (Figure 3). Discharge at Birchbank generally increased through April and May and through the beginning of October to mid-December, while discharge generally decreased from June to October and January to the end of March.

The mean hourly discharge from HLK/ALH ranged from 12 kcfs on 31 March 2019 to 73 kcfs on 21 August 2018. During most of the High Risk period, discharge from HLK/ALH was increasing (Figure 3).

The mean hourly discharge from BRD/X ranged from a minimum of 6 kcfs on 14 October 2018 to a maximum of 113 kcfs on 29 May 2018 (Figure 3). 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. Load factoring at BRD/X occurred during August and December (Figure 3). Flow reductions associated with load factoring were not considered individual RE.

During the present study period there were a total of 20 operational flow RE (Figure 3). Each operational flow RE occurred at HLK/ALH (Table 1). Each RE occurred on a single day. In previous years some RE have occurred over multiple days, with a stranding assessment being conducted only on a single day (Golder 2016, 2017, 2018). Based on discussions with BC Hydro (pers. Comm. James Baxter) it was decided that for the present study period and the future, each RE would be defined as occurring on a single day rather than multiple. 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.

During the present study period, the magnitude of flow RE at HLK/ALH ranged from 1 to 15 kcfs. All RE maintained an average ramping rate of 5 kcfs or less. During the High Risk period, there were 7 RE, and the remaining 13 RE occurred during the Low Risk period.

Table 1 identifies the discharge from both HLK/ALH and BRD/X for each RE during the present study period. In previous reports, when a RE occurred at HLK/ALH, the values presented for previous and resulting discharge at BRD/X were obtained from the forecasted discharge values for the day of the RE. While these forecasted values provide valuable insight into discharge plans at BRD/X, they may differ from actual measured discharge values. For comparative purposes, both the forecasted values (previous and resulting) and the measured average daily discharge values (day preceding RE and day of RE) for BRD/X were presented for each RE that occurred at HLK/ALH.

Based on the measured average daily discharge values (day preceding RE and day of RE) for BRD/X, some of the operational RE that occurred at HLK/ALH coincided with flow changes at BRD/X (Figure 3). Both RE2018-07 and RE2018-08 occurred in June at a time when flow from BRD/X were continuously dropping, and RE2018-16 and RE2018-17 occurred when flow from BRD/X was changing due to load shaping (Table 1).

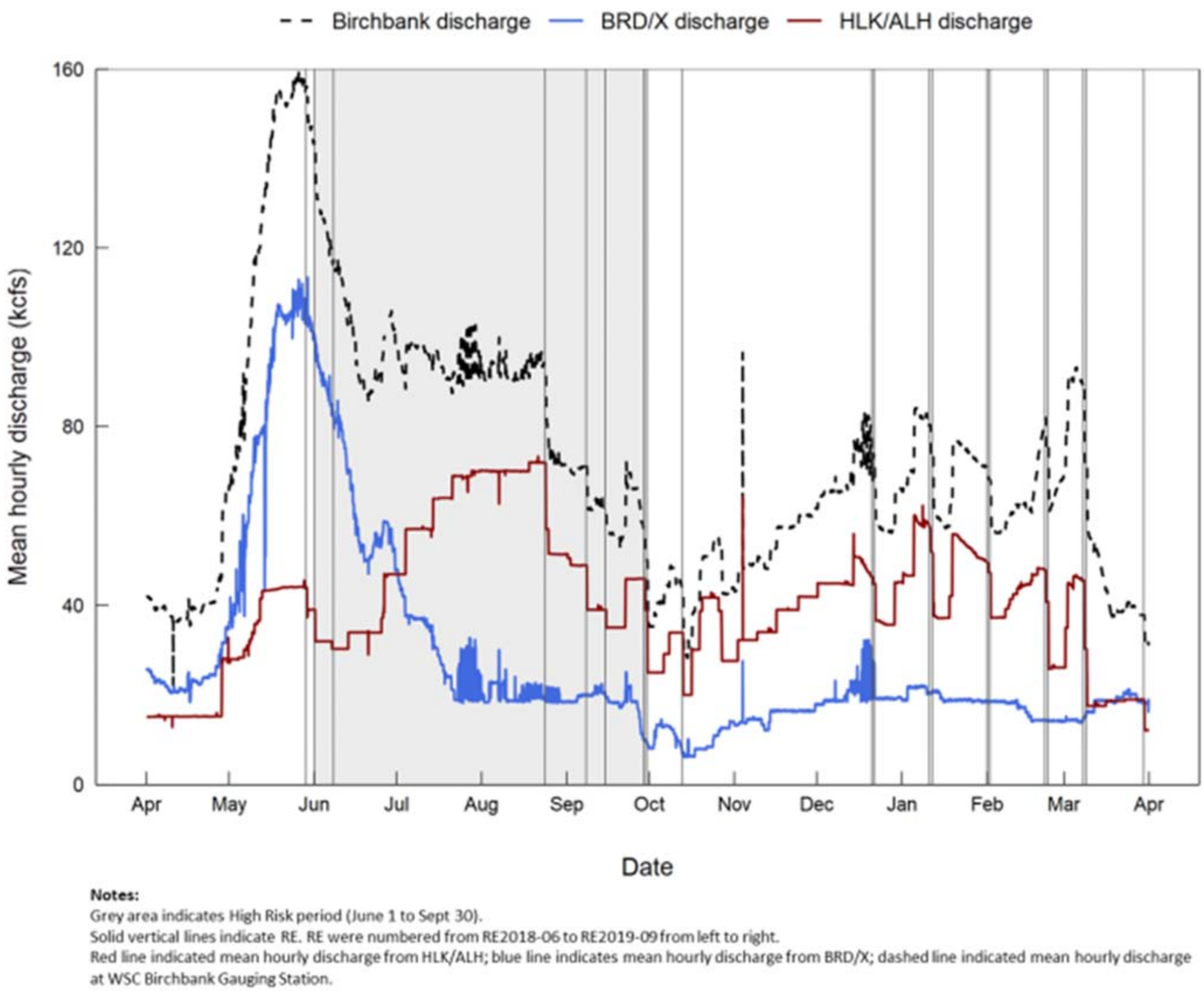

Figure 3: Mean hourly discharge from HLK/ALH, BRD/X, and at the WSC Birchbank Gauging Station 1 April 2018 to 1 April 2019

3.2 Reduction Events and Fish Stranding Assessments

Fish stranding assessments were conducted for 13 of the 20 RE that occurred during the present study period resulting in a response rate (percent of total RE that initiated a stranding assessment) of 65% (Table 1). Between 2009 and 2019 the total number of yearly RE have ranged from 17 to 23 (median = 19) and have generally increased since the 2014/2015 study period (Figure 4). Between 2009 and 2019, the total number of yearly stranding assessments has ranged from 12 to 19 (median = 15), and has generally followed the same pattern as number of yearly RE. The median response rate since 2009 has been 82%. In recent years, (2016 to 2019), there has been a decrease in the number of yearly stranding assessments (Figure 4).

As decided by the DCC, stranding assessments were not conducted for 7 of the 20 RE that occurred during the present study period (Table 1). Stranding assessments were not conducted for 3 RE (RE2018-06, RE2018-07, and RE2018-08) because water levels in the Columbia and Kootenay rivers were near bankfull at the time of these RE, there was backwatering occurring from the Kootenay River, and the database queries did not have data from previous stranding assessments.

Stranding assessments were not conducted for 3 RE (RE2018-13, RE2018-16, and RE2019-03) because the decrease in discharge at HLK/ALH were considered minimal (range = 1 to 5 kcfs per RE). Additionally, stranding assessments were conducted the day after RE2018-13, RE2018-16, and RE2019-03 in response to RE2018-14, RE2018-17, and RE2019-04, which all had a greater decrease in discharge (range = 10 to 14 kcfs per RE) (Table 1).

A stranding assessment was not conducted for RE2019-01 because no ‘Effect’ sites were identified in the database query. Golder was contacted by the DCC regarding RE2018-09 on 1 August 2018, however on 3 August 2018 this RE was cancelled, and is therefore not included in the total number of RE during the present study period.

Environmental conditions during stranding assessments were generally adequate for fish salvage purposes.

Table 1: Summary of Reduction Events (RE) from HLK/ALH and BRD/X 1 April 2018 to 1 April 2019.

				Birchbank Gauge Station				BRD/X							HLK/ALH									
Reduction Event No.	Reduction Date	Risk Period	Crew Dispatched?	Mean Daily Water Temp (°C)	Max. Q (kcfs)	Min. Q (kcfs)	Magnitude of Reduction (kcfs)	Prev Q (kcfs) [a]	Resulting Q (kcfs) [a]	Prev Q (kcfs) [b]	Resulting Q (kcfs) [b]	Magnitude of Reduction (kcfs)	No. Ramped Flow Reductions	Avg. Ramping Rate (kcfs/hr)	Prev Q (kcfs)	Resulting Q (kcfs)	Magnitude of Reduction (kcfs)	No. Ramped Flow Reductions	Avg. Ramping Rate (kcfs/hr)	Pools Formed	Interstitial Stranding	Fish Stranded	Sites Visited	Purpose of flow reduction
HLK/ALH 2018-06	29-May-18	Low	No	10.8	156.2	148.1	8.1	104.0	104.0	107.0	106.0	1.0	N/A	N/A	44.0	39.0	5.0	1	5.0	N/A	N/A	N/A	0	Operational Requirement under Treaty due to reduction in Columbia River inflow
HLK/ALH 2018-07	1-Jun-18	High	No	11.1	143.8	132.1	11.7	104.0	104.0	101.0	98.0	3.0	N/A	N/A	39.0	32.0	7.0	2	3.5	N/A	N/A	N/A	0	Operational Requirement under Treaty due to reduction in Columbia River inflow
HLK/ALH 2018-08	7-Jun-18	High	No	11.9	120.3	116.2	4.1	80.6	80.6	87.0	84.0	3.0	N/A	N/A	32.0	30.0	2.0	1	2.0	N/A	N/A	N/A	0	Operational Requirement under Treaty due to reduction in Columbia River inflow
HLK/ALH 2018-10	24-Aug-18	High	Yes	16.1	93.6	78.5	15.1	20.8	20.8	19.0	20.0	N/A [c]	N/A [d]	N/A [d]	72.0	57.0	15.0	3	5.0	Yes	No	170	7	Operational Requirement under Treaty and U.S.A. wanting to implement flow changes earlier in week due to fire hazard
HLK/ALH 2018-11	8-Sep-18	High	Yes	16.2	71.1	61.4	9.7	18.3	18.0	20.0	20.0	0.0	N/A	N/A	49.0	39.0	10.0	2	5.0	Yes	Yes	836	6	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2018-12	15-Sep-18	High	Yes	14.7	61.9	56.9	5.0	18.3	18.0	20.0	19.0	1.0	N/A	N/A	39.0	35.0	4.0	1	4.0	Yes	No	15	8	Operational Requirement under Treaty
HLK/ALH 2018-13	29-Sep-18	High	No	14.3	57.1	50.5	6.6	9.9	9.9	11.0	10.0	1.0	N/A	N/A	46.0	39.0	7.0	4	1.8	N/A	N/A	N/A	0	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2018-14	30-Sep-18	High	Yes	14	50.2	35.4	14.8	9.9	9.9	10.0	9.0	1.0	N/A	N/A	39.0	25.0	14.0	3	4.7	Yes	No	3142	10	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2018-15	13-Oct-18	Low	Yes	12.5	43.2	28.2	15.0	8.9	8.9	9.0	7.0	2.0	N/A	N/A	34.0	20.0	14.0	3	4.7	Yes	No	40	7	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2018-16	21-Dec-18	Low	No	5.5	78.4	68.0	10.4	18.4	18.4	28.0	25.0	3.0	N/A [d]	N/A [d]	46.0	45.0	1.0	1	1.0	N/A	N/A	N/A	0	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2018-17	22-Dec-18	Low	Yes	5.3	73.4	57.4	16.0	18.4	18.4	25.0	20.0	5.0	N/A [d]	N/A [d]	45.0	35.0	10.0	2	5.0	Yes	Yes	3	9	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2019-01	11-Jan-19	Low	No	4.5	80.5	74.1	6.4	20.5	20.5	20.0	20.0	0.0	N/A	N/A	58.0	53.0	5.0	2	2.5	N/A	N/A	N/A	0	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2019-02	12-Jan-19	Low	Yes	4.5	74.7	60.1	14.6	20.5	20.5	20.0	21.0	N/A [c]	N/A	N/A	53.0	38.0	15.0	3	5.0	Yes	No	15	8	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2019-03	1-Feb-19	Low	No	4.1	70.7	68.1	2.6	18.8	18.5	18.0	18.0	0.0	N/A	N/A	50.0	48.0	2.0	1	2.0	N/A	N/A	N/A	0	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2019-04	2-Feb-19	Low	Yes	4.1	68.0	56.6	11.4	18.8	18.5	18.0	18.0	0.0	N/A	N/A	48.0	38.0	10.0	2	5.0	Yes	No	8	7	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2019-05	22-Feb-19	Low	Yes	2.8	64.2	56.5	7.7	14.0	14.0	14.0	14.0	0.0	N/A	N/A	48.2	41.0	7.2	2	3.6	Yes	No	1	9	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2019-06	23-Feb-19	Low	Yes	2.8	56.6	42.3	14.3	14.0	14.0	14.0	14.0	0.0	N/A	N/A	41.0	26.5	14.5	3	4.8	Yes	Yes	139	12	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2019-07	8-Mar-19	Low	Yes	2.2	61.6	46.8	14.8	15.0	15.0	14.0	15.0	N/A [c]	N/A	N/A	46.0	31.0	15.0	3	5.0	Yes	No	12	7	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2019-08	9-Mar-19	Low	Yes	2.3	47.8	35.4	12.4	16.0	16.0	15.0	16.0	N/A [c]	N/A	N/A	31.0	17.5	13.5	3	4.5	Yes	Yes	24	14	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2019-09	30-Mar-19	Low	Yes	4.8	37.7	30.6	7.1	18.5	18.5	18.0	18.0	0.0	N/A	N/A	19.0	12.0	7.0	2	3.5	Yes	Yes	58	13	Operational Requirement under Treaty and Non-Treaty Coordination Agreement

Notes

[a] Discharge value used for database query prior to RE. Value based on predicted flow forecast on day of RE.

[b] Average of measured hourly discharge from day prior to RE, and average of measured hourly discharge on day of RE.

[c] Flows increased

[d] BRD/X load shaping on this date

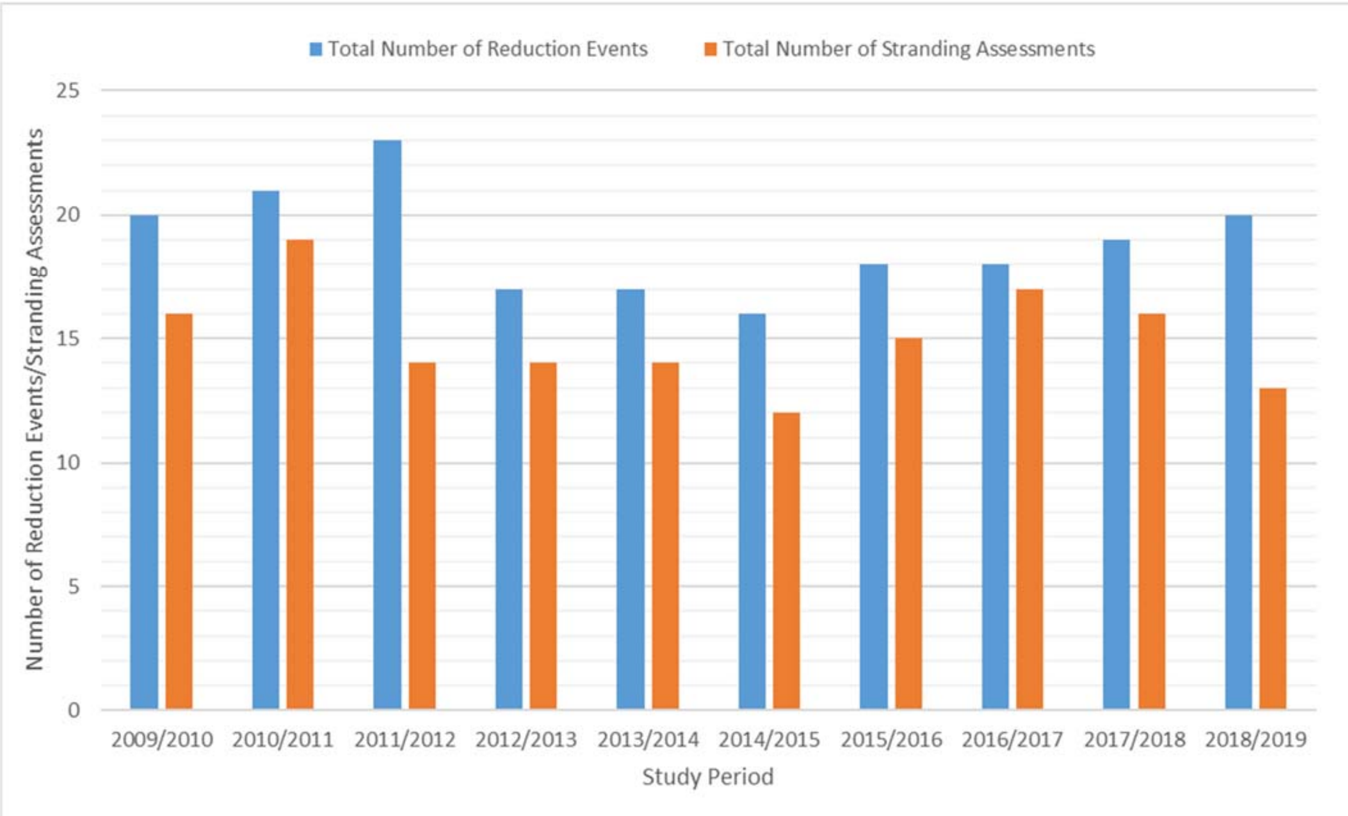

Figure 4: Total number of Reduction Events and Stranding Assessments conducted during each study period from 2009/2010 to 2018/2019

As in previous years, sites ranked as 'Effect' sites in the database queries were prioritized during stranding assessments. Out of a total of 117 individual site assessments conducted during the present study period, 82 were ranked 'Effect' sites, 32 were ranked 'Reconnaissance' sites, and 3 were ranked 'Minimal Effect' sites based on the database queries.

During the present study period, 18 stranding sites were assessed at least once (Table 2). Stranding assessments were not conducted at Genelle Upper Cobble Island, Genelle Lower Cobble Island, Beaver Creek (LUB) and Fort Shepherd (LUB) due to an inability to access these sites with a truck. Genelle Upper Cobble Island and Genelle Lower Cobble Island are islands in the middle of the Columbia River that are surrounded by water year-round. Access to Beaver Creek (LUB) and Fort Shepherd (LUB) is closed due to a permanent motorized vehicle closure of this area by the Fort Shepherd Conservancy (managed by the Trail Wildlife Association). Despite, limited assessments conducted at these sites in recent years these sites will remain in The Lower Columbia River Fish Stranding Database because previous assessments still provide valuable data to the program.

See Appendix A; Figures A1 through A8 for site locations.

3.2.1 Fishes Captured or Observed During 2018/2019 Stranding Assessments

Isolated pools and stranded fishes were observed during all stranding assessments conducted during the present study period. None of the stranding assessments conducted resulted in a 'Significant Fish Stranding Event' (greater than 5,000 fishes observed).

During the 13 RE in which fish stranding assessments were conducted, a total of 4,463 fishes were stranded (Table 2). The total number of fishes stranded during the present study period decreased compared to the 2017/2018 study period when 11,922 fishes were stranded during 16 stranding assessments (Golder 2018).

The majority (93%) of stranded fishes during the present study period were observed during the four stranding assessments conducted during the High Risk period (June 1 to September 30). During this time period, larval and YOY fishes are known to inhabit near shore habitat, and the risk of stranding is elevated (Golder and Poisson 2010). The total number of fishes observed or captured during each stranding assessment ranged from 1 to 3,142 (Table 1).

The majority (83.4%) of stranded fishes were identified from pools and de-watered substrate located at Genelle Mainland (LUB), Kootenay River (RUB), and Norns Creek Fan (RUB) (Table 2).

The greatest number of stranded fishes at Genelle Mainland (LUB) occurred during RE2018-11 (8 September 2018), and RE2018-14 (30 September 2018). During RE2018-11, a total of 798 fishes were stranded, including juvenile Cyprinids (69%), juvenile Sucker species (*Catostomidae spp.*; 30%), and Sculpin species (*Cottus spp*.; less than 1%). A particularly large pool was formed during RE2018-11 that was estimated to be 60 m x 8 m in size and 1 m deep. Given the size of the pool, sampling on 8 September 2018 was deemed inefficient. This pool was sampled again during RE2018-12 on 18 September 2018 resulting in 16 juvenile sucker species, and 94 juvenile Longnose Dace (*Rhinichthys cataractae*) being salvaged. During RE2018-14, a total of 1,720 juvenile Redside Shiner and juvenile Sucker species were found stranded in three new isolated pools at Genelle Mainland (LUB). Genelle Mainland (LUB) continues to be a high-risk stranding site, accounting for the highest number of stranded fishes in study years 2015/2016, and 2016/2017 (Golder 2016, 2017), and the second highest number of stranded fishes in study year 2017/2018 (Golder 2018). This site includes a large backwater area with shallow, slow moving water and gravel substrate along the right downstream bank of the Columbia River which provides favourable habitat for juvenile Sucker species, and YOY cyprinids including Longnose Dace, and Redside Shiners (McPhail 2007). De-watering of this habitat especially during the High Risk period often results in high stranding numbers compared to other sites.

The greatest number of stranded fishes at Kootenay River (RUB) occurred during RE2018-14. During this RE, a total of 641 fishes were found stranded in hundreds of small isolated wetted and de-watered pools that formed in fine sand and silt substrate. Due to the de-watering of some pools, there were 141 juvenile Northern Pikeminnow and 105 juvenile Sucker mortalities. The remainder of the stranded fishes were successfully salvaged and returned to the Kootenay River.

The greatest number of stranded fishes at Norns Creek Fan (RUB) occurred during RE2018-14. During this RE, 455 fishes were stranded in 14 pools and 4 de-watered pools. Stranded fishes included juvenile Longnose Dace (73%), juvenile Sucker species (15%), Sculpin species (11%) and juvenile Rainbow Trout (less than 1%).

Similar to Genelle Mainland (LUB), Kootenay River (RUB) and Norns Creek Fan (RUB) also provide shallow favourable habitat for juvenile suckers, and YOY cyprinids during the High Risk period. When water levels drop to particularly low levels (35.4 kcfs at Birchbank Gauging Station) as observed during RE2018-14 gravel and fine substrate usually covered in water becomes exposed, and an increase in stranding at these sites appears to occur.

Table 2: Total Number of Fishes Stranded at each site during Reduction Events from 1 April 2018 to 1 April 2019

Site[a]	Total Number of Assessments	Total Number of Fishes Stranded	Median Number of Fishes Stranded per Assessment	% of Total Stranded Fishes per Site
Genelle (Mainland) (LUB)	9	2523	1	56.5
Kootenay River (RUB)	12	680	2	15.2
Norns Creek Fan (RUB)	11	517	3	11.6
Gyro Boat Launch	10	159	0	3.6
Tin Cup Rapids (RUB)	8	157	5	3.5
Kootenay River (LUB)	11	123	2	2.8
Millennium Park (LUB)	8	73	5	1.6
CPR Island (MID)	7	68	1	1.5
Lions Head (upstream of Norns Fan) (RUB)	10	60	1	1.3
Blueberry Creek (LUB)	2	41	21	0.9
Beaver Creek (RUB)	3	34	3	0.8
Trail Bridge (RUB) (Downstream)	4	14	0	0.3
Zuckerberg Island (LUB)	4	12	1	0.3
Casino Road Bridge, Trail (LUB) (Downstream)	4	2	0	<0.1
Bear Creek (RUB)	5	0	0	<0.1
Casino Road Bridge, Trail (LUB) (Upstream)	3	0	0	<0.1
Fort Shepherd Launch (RUB)	5	0	0	<0.1
Kinnaird Rapids (RUB)	1	0	0	<0.1
Total	**117**	**4,463**		**100.0**

[a] Appendix A; Figures A1 through A8.

LUB = left bank as viewed facing upstream; RUB = right bank as viewed facing upstream.

3.2.1.1 Fish Species

3.2.1.1.1 Sportfishes

Sportfishes accounted for 3.7% of total fishes stranded in the present study period (Table 3). This catch represents an increase from the 2017/2018 study period, when sportfishes accounted for 1.3% of total fishes stranded. Stranded sportfishes during the present study period were limited to Rainbow Trout, Mountain Whitefish, and Brook Trout.

A total of 119 Rainbow Trout were stranded (Table 3). All Rainbow Trout were juveniles, and 93% were stranded during the High Risk period. Rainbow Trout were most commonly found at sites upstream of the Kootenay River and Columbia River confluence, including Tin Cup Rapids (RUB), CPR Island (MID), Norns Creek Fan (RUB), and Millennium Park (LUB). During RE2018-10 on 24 Aug 2018, a total of 52 Rainbow Trout were found stranded at Tin Cup Rapids (RUB). From this total, 35 Rainbow Trout were successfully captured and returned to the Columbia River, however 17 mortalities were found interstitially stranded in dewatered substrate (primarily cobble). Juvenile Rainbow Trout tend to prefer areas with coarse substrate including cobble and boulder that provides adequate cover during daylight hours (McPhail 2007).

A total of 41 Mountain Whitefish were stranded in 2018/2019 (Table 3). This total includes 38 YOY, and 3 eggs that were all stranded during RE2019-09 on 30 March 2019. The Mountain Whitefish eggs were found interstitially stranded in dewatered substrate at the upstream end of Kootenay River (RUB). All YOY Mountain Whitefish were found at Lions Head (RUB) (n = 37), and Tin Cup Rapids (RUB) (n = 1).

3.2.1.1.2 Non-sportfishes

As in previous years, non-sportfishes accounted for the majority (96.2%) of total fishes stranded during the present study period (Table 3). Of all non-sportfish species stranded, juvenile Redside Shiner were the most abundant (n = 1,376). The largest Redside Shiner stranding event occurred at Genelle Mainland (LUB) on 30 September 2018 during RE2018-14. During this stranding assessment, an estimated total of 1,360 Redside Shiner were stranded in three isolated pools with sand/silt substrate. Due to the small size of the Redside Shiner, backpack electrofishing was an ineffective capture method, therefore a seine net was used for salvage efforts. Approximately 600 Redside Shiner were successfully salvaged, however there were 160 mortalities due to the vulnerable life stage of the Redside Shiners and challenging salvage efforts using a seine net in fine substrate. Fork lengths taken from a subsample of Redside Shiner (n = 16) ranged from 24 to 63 mm, with a median value of 29 mm.

Juvenile Sucker species (n = 1,238) were the second most abundant non-sportfishes stranded during the present study period. Sucker species commonly represent the highest number of stranded fishes during yearly stranding assessments (Golder 2016 – 2018). During the present study period, the highest numbers of stranded juvenile Sucker species were found at Genelle Mainland (LUB) (n = 586), Kootenay River (LUB) (n = 330), and Gyro Boat Launch (n = 117).

A total of 390 juvenile Northern Pikeminnow (*Ptychocheilus oregonensis*) were stranded during the present study period (Table 3). Most of the stranded Northern Pikeminnow (n = 336) were found in hundreds of small (approximately 0.5m x 0.5m) dewatered pools at Kootenay River (RUB) during RE2018-14. Stranding crews managed to salvage 195 Northern Pikeminnow that were found alive; however, 141 mortalities were recorded during RE2018-14.

Sculpin species are bottom-dwellers, remaining close to the substrate throughout their life stages, and are commonly observed during stranding assessments in the Columbia River. Torrent Sculpin (*Cottus rhotheus*), Slimy Sculpin (*Cottus cognatus*), Prickly Sculpin (*Cottus asper*), Columbia Sculpin (*Cottus bairdii),* and Shorthead Sculpin (*Cottus confusus*) were stranded during the present study period (Table 3). As in previous years, Torrent Sculpin were the most commonly stranded sculpin species (Golder 2016, 2017, 2018). In 2018/2019, a total of 74 Torrent Sculpin were stranded, accounting for 77% of all sculpin that were identified to species. Total length measurements were collected for all sculpin species and both adult and juvenile life stages were observed. Of the measured sculpin (n = 93), total lengths ranged from 28 to 116 mm. Adults accounted for 62% of all measured sculpin species based on total lengths greater than 45 mm (AMEC 2014).

Table 3: Summary of Fish Species Captured or Observed during Fish Stranding Assessments Subsequent to Reductions in Discharge from HLK/ALH or from BRD/X, 1 April 2018 to 1 April 2019

Species		Total Stranded and/or Captured	Percent of Total Stranded and/or Captured (%)	Number of Mortalities	Number Salvaged	Species Classification		
						SARA [a]	COSEWIC [b]	CDC [c]
Sportfishes	Rainbow Trout (*Oncorhynchus mykiss*)	119	2.7	19	83	N/A	N/A	Yellow
	Mountain Whitefish (*Prosopium williamsoni*)	41	0.9	5	5	N/A	N/A	Yellow
	Brook Trout (*Salvelinus fontinalis*)	6	0.1	0	0	N/A	N/A	Exotic
Non-Sportfishes	Redside Shiner (*Richardsonius balteatus*)	1376	30.8	165	611	N/A	N/A	Yellow
	Sucker species (*Catostomidae spp.*)	1240	27.8	258	689	N/A [d]	N/A [d]	N/A [d]
	Longnose Dace (*Rhinichthys cataractae*)	975	21.8	306	269	N/A	N/A	Yellow
	Northern Pikeminnow (*Ptychocheilus oregonensis*)	390	8.7	143	242	N/A	N/A	Yellow
	Sculpin species (*Cottus spp.*)	123	2.8	7	96	N/A [f]	N/A [f]	N/A [f]
	Torrent Sculpin (*Cottus rhotheus*)	74	1.7	1	73	N/A	N/A	Yellow
	Umatilla Dace (*Rhinichthys umatilla*)	56	1.3	2	54	Schedule 3 Special Concern	Threatened	Red
	Unidentified [e]	34	0.8	0	1	N/A [f]	N/A [f]	N/A [f]
	Slimy Sculpin (*Cottus cognatus*)	11	0.2	0	11	N/A	N/A	Yellow
	Peamouth (*Mylocheilus caurinus*)	7	0.2	1	6	N/A	N/A	Yellow
	Prickly Sculpin (*Cottus asper*)	7	0.2	0	7	N/A	N/A	Yellow
	Columbia Sculpin (*Cottus hubbsi*)	3	0.1	0	3	Schedule 1 Special Concern	Special Concern	Blue
	Shorthead Sculpin (*Cottus confusus*)	1	<0.1	0	1	Schedule 1 Special Concern	Special Concern	Blue
Total		**4,463**		**907**	**2,153**			

[a] Species at Risk Act; Species that were designated at risk by COSEWIC (the Committee on the Status of Endangered Wildlife in Canada) 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] Conservation Data Centre; Red=any 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 (formerly Vulnerable) 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. (B.C. Conservation Data Centre. 2019).
[d] No species are listed from this region that are found under any of the classification criteria for species of concern.
[e] Not identified to species because they were observed during visual surveys but not captured.
[f] Fish identified to family level or other high-level taxa may potentially be species of concern under the classification system listed.

3.2.1.1.3 Unidentified Fishes

During the present study period, 123 sculpin were not identified to species, and 34 unidentified fishes were observed. Of the 123 sculpin not identified to species, 16% were observed during visual surveys or electrofishing efforts, but were not caught. The captured sculpin that were not identified to species were juveniles with total lengths between 17 and 40 mm. Due to the small size of juvenile sculpin and widespread interspecific hybridization is common in the Kootenay region (McPhail 2007), field identification of juvenile sculpin to the species level can be difficult.

The 34 unidentified species recorded during the present study were observed during visual surveys at CPR Island (MID), Norns Creek Fan (RUB), Lions Head (RUB), and Genelle Mainland (LUB). These fishes were not captured, therefore identification to species was not possible.

3.2.1.1.4 Listed Fish Species

Umatilla Dace, Columbia Sculpin, Shorthead Sculpin, and White Sturgeon are the four listed resident species in the study area (Table 4). Umatilla Dace, Columbia Sculpin, and Shorthead Sculpin have been documented during previous study years (Golder 2016, 2017, 2018), however White Sturgeon have never been documented during lower Columbia River and Kootenay River fish stranding assessments.

During the present study period 56 Umatilla Dace, 3 Columbia Sculpin, and one Shorthead Sculpin were stranded (Table 4). As observed in previous years, the majority (67%) of listed fishes stranded during the present study period occurred during the Low Risk period. Of all listed fishes stranded since year 2000, 94% were stranded during the Low Risk period.

The largest stranding event for listed species occurred at Kootenay (LUB) during RE2019-06. During this RE a total of 35 Umatilla Dace were stranded interstitially within dewatered cobble and boulder substrate. All Umatilla Dace found were successfully salvaged. Listed fishes have commonly been found at Kootenay (LUB), indicating this site may provide preferred habitat to species such as Umatilla Dace. Since year 2000, Kootenay (LUB) has stranded the highest total number of listed species (n = 645) compared to all other sites.

Umatilla Dace YOY may be included in the number of unidentified fishes observed during RE2018-12 (15 September 2018) and RE2018-04 (30 September 2018). Likewise, the sculpin that were not identified to species during stranding assessments may have been Columbia Sculpin or Shorthead Sculpin.

Table 4: Summary of Listed Species Captured or Observed during Stranding Assessments, 1 April 2018 to 1 April 2019

Site [a]	Risk Period [b]	Total Number of Assessments	Number of Assessments with Listed Species Present	Number of Listed Fish Stranded
Umatilla Dace (SARA: Schedule 3 Special Concern, COSEWIC: Threatened, CDC: Red)				
Gyro Boat Launch	Low	10	1	1
Kootenay River (LUB)	High	3	1	2
	Low	8	3	37
Kootenay River (RUB)	Low	12	1	1
Genelle Mainland (LUB)	High	9	1	7
Beaver Creek (RUB)	High	3	1	8
Columbia Sculpin (COSEWIC: Special Concern, CDC: Blue)				
Norns Creek Fan (RUB)	High	11	1	2
Tin Cup Rapids (RUB)	High	8	1	1
Shorthead Sculpin (COSEWIC: Special Concern, CDC: Blue)				
Norns Creek Fan (RUB)	Low	11	1	1
Total				**60**

[a] For site locations see Appendix A; Figures A1 through A8.
[b] High Risk period = 1 June to 30 September; Low Risk period = 1 October to 31 May.

3.2.1.1.5 Exotic Fish Species

The only exotic fish species observed during the present study was Brook Trout. A total of 6 juvenile Brook Trout were captured from isolated pools at Casino Road Bridge, Trail (LUB) (Downstream), Trail Bridge (RUB) (Downstream), Tin Cup Rapids (RUB), and CPR Island (MID). All Brook Trout were stranded during the Low Risk period. Stranded Brook Trout were measured for fork length and euthanized as requested by the Ministry of Forests, Lands, Natural Resource Operations & Rural Development (FLNRORD) (Pers. Comm., Matt Neufeld, FLNRORD, 22 February 2016). Since 2000, a total of 17 Brook Trout have been captured during stranding assessments. The present study period is the first time this species has been observed at stranding sites upstream of Genelle Mainland (LUB), indicating a possible upstream expansion of this species.

Exotic fish species have been identified and recorded during stranding assessments since 2000 in varying numbers. Species composition has remained constant. The majority (98%) of all exotic fish species recorded during stranding assessments were Smallmouth Bass (*Micropterus dolomieu*). The remaining 2% in order of abundance were Common Carp (*Cyprinus carpio*), Brook Trout, Yellow Perch (*Perca flavescens*), Northern Pike (*Esox lucius*), Tench (*Tinca tinca*), and Walleye (*Sander vitreus*).

3.3 Historic Fish Stranding Summary

The results of fish stranding assessments conducted between January 2000 and 1 April 2019 are summarized by site, resultant Birchbank discharge, and risk period (Table 5). This table is used by the DCC to determine if a proposed RE has occurred historically for the time of year and which sites resulted in high stranding risk. The numbers of fishes are presented as the maximum number of fishes stranded at each site during a single RE. The classification of sites where listed species have been previously identified is included as yellow highlighted cells.

During the High Risk period, ‘Effect’ sites have been identified at resultant Birchbank discharges between 30 and greater than 120 kcfs, with high stranding numbers from single historic RE occurring between 30 and 60 kcfs (Table 5). Genelle Mainland (LUB) and Tin Cup Rapids (RUB) have been identified as ‘Effect’ sites for most discharge ranges during the High Risk period and are a priority for stranding assessments during this time period. Since year 2000, few stranding assessments have been conducted during the High Risk period when Birchbank discharge reached a range of 30 to 40 kcfs. However, during the present study, Birchbank discharge reached 35.4 kcfs during RE2018-14 (Table 1). As a result of the stranding assessment conducted for RE2018-14, new ‘Effect’ sites were identified at Norns Creek Fan (RUB), Kootenay River (RUB) and Genelle (Mainland) (LUB). Additionally, listed species were stranded during RE2018-14 at Norns Creek Fan (RUB), Kootenay River (LUB), and Beaver Creek (LUB). These findings further support the evidence that the ‘High Risk’ period (when YOY and juvenile fishes are known to occupy near-shore habitat) and low discharge increase the stranding risk in the Columbia and Kootenay rivers.

During the Low Risk period, ‘Effect’ sites have been identified at resultant Birchbank discharges between less than 30 and 70 kcfs with high stranding numbers from single previous RE occurring between 30 and 40 kcfs (Table 5). During the present study, a single new ‘Effect’ site was identified at Gyro Boat launch, occurring between 50 and 60 kcfs during the Low Risk period. An Umatilla Dace was stranded in a pool at this site during RE2019-04, when discharge reached 56.6 kcfs. Historically, a greater number of listed fishes have been stranded during the Low Risk period compared to the High Risk period. Since 2000, Listed fishes have been found at 15 sites during the Low Risk period, compared to only 5 sites during the High Risk period (Table 5).

Table 5: Summary of effects and corresponding responses for fish stranding on the lower Columbia River from flow reductions at HLK/ALH and BRD/BRX sorted by time of year. (Based on data collected between 2000 and 2019).

Risk Period	Resultant Birchbank Discharge (kcfs)	Observed Effect																					
		Columbia River										Kootenay River				Columbia River							
		Lions Head		Norn's Creek Fan		CPR Island		Tin Cup Rapids		Millennium Park		Kootenay River (LUB)		Kootenay River (RUB)		Zuckerberg Island		Kinnaird Rapids		Blueberry Creek		Genelle Mainland	
		Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits
High Risk (1 June to 30 September)	≤30																	No Pools		No Pools			
	≥30 to <40	8	1	455	1	60	2	13500	2	38	1	23	1	641	4	620	2	No Pools		No Pools		1720	1
	≥40 to <50	0	1	312	5	191	5	76	4	15	2	94	3	81	8	0	1			4505	1	14302	6
	≥50 to <60	1	3	150	13	5	3	253	15	7	7	58	14	3901	19	18	8	No Pools		No Pools		37964	19
	≥60 to <70	0	4	423	29	0	5	258	28	34	10	3172	34	5737	33	55	16	0	1	1	3	3118	31
	≥70 to <80	0	7	56	17	0	1	219	15	0	12	1	10	35	14	48	11	No Pools		1299	9	1503	18
	≥80 to <90	No Pools		88	20	No Pools		34	19	24	21	No Pools		12	9	0	13	No Pools		269	9	6000	18
	≥90 to <100	No Pools		5	11	0	4	563	13	26	11	No Pools		No Pools		No Pools		No Pools		No Pools		900	12
	≥100 to <110			2	3	2	1	10307	4	7521	3	No Pools		No Pools		0	3			No Pools		0	3
	≥110 to <120			No Pools		No Pools		1500	5	60	3	No Pools		No Pools		No Pools		No Pools		0	2	No Pools	
	≥120			No Pools		No Pools		1200	3	100	1	No Pools		0	3	0	1			0	2	0	2
Low Risk (1 October to 31 May)	≤30			29	6	6	3	68	5	601	5	0	3	643	6	0	3	No Pools		No Pools		1	3
	≥30 to <40	48	10	5071	41	110	12	228	27	358	32	286	25	1168	35	95	31	No Pools		No Pools		1414	30
	≥40 to <50	14	7	623	53	337	41	117	41	526	28	517	51	1450	71	298	41	0	3	0	4	210	46
	≥50 to <60	33	5	146	29	12	16	86	24	52	22	193	30	340	37	71	31	No Pools		No Pools		400	32
	≥60 to <70	0	4	700	30	16	13	11	28	2	22	122	40	529	43	109	29	0	6	1	7	520	35
	≥70 to <80	0	2	79	15	2	4	3	17	2	18	0	14	10	18	0	19	No Pools		0	5	7	11
	≥80 to <90	No Pools		0	2	No Pools		1	3	0	4	No Pools		0	4	0	3	No Pools		0	3	1	4
	≥90 to <100	No Pools		0	1	0	1	0	1	0	1	No Pools		No Pools		No Pools		No Pools		No Pools		0	1
	≥100 to <110											No Pools		No Pools						No Pools			
	≥110 to <120			No Pools		No Pools						No Pools		No Pools		No Pools		No Pools				No Pools	
	≥120			No Pools		No Pools		0	1	0	1	No Pools		0	1	0	1					0	1

Risk Period	Resultant Birchbank Discharge (kcfs)	Observed Effect																					
		Columbia River																					
		Genelle Upper Cobble Island		Genelle Lower Cobble Island		Gyro Boat Launch		Trail Bridge		Casino Road Bridge, Trail (u/s)		Casino Road Bridge, Trail (d/s)		Bear Creek		Beaver Creek (RUB)		Beaver Creek (LUB)		Fort Shepherd Eddy		Fort Shepherd Launch	
		Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits
High Risk (1 June to 30 September)	≤30															No Pools		No Pools					
	≥30 to <40	No Pools		0	1	152	1					0	1			31	1			7500	2		
	≥40 to <50	No Pools				464	3					207	2	0	1							0	1
	≥50 to <60					0	4	0	3	0	3	11	3	0	4	358	3			0	2	0	2
	≥60 to <70	1	1	20	2	0	3	No Pools		0	7	5	8	500	10	6	8	0	1	0	2	2	4
	≥70 to <80	54	2	0	4	No Pools		No Pools		No Pools		0	5	0	8	8	10	No Pools		0	2	1	7
	≥80 to <90	0	8	3	9	500	7	No Pools		No Pools		No Pools		0	4	62	5	No Pools		0	4	134	5
	≥90 to <100	No Pools		0	3	500	6	No Pools		No Pools		No Pools		No Pools		251	7	No Pools		0	4	No Pools	
	≥100 to <110					500	2																
	≥110 to <120	No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		0	2		
	≥120	No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		0	1		
Low Risk (1 October to 31 May)	≤30					0	3	8	3	0	3	0	3	2063	4	No Pools		No Pools		0	1		
	≥30 to <40	No Pools		0	4	2024	15	19	11	0	10	1	13	12	10	38	9	0	4	80	3	9	9
	≥40 to <50	No Pools		0	6	755	37	14	12	4	12	2	10	2015	14	44	10	0	7	8	7	5	12
	≥50 to <60	0	6	0	7	48	15	0	10	0	16	21	21	1	12	0	5	20	4	2	4	29	4
	≥60 to <70	1	5	0	4	351	17	No Pools		1	20	3	23	0	16	4	6	0	2	0	2	46	6
	≥70 to <80	0	3	0	5	No Pools		No Pools		No Pools		0	8	3	15	0	6	No Pools		0	1	0	1
	≥80 to <90	0	2	0	4	0	3	No Pools		No Pools		No Pools		0	2	0	4	No Pools		0	1	0	1
	≥90 to <100	No Pools		0	1			No Pools		No Pools		No Pools		No Pools				No Pools		0	1	No Pools	
	≥100 to <110																						
	≥110 to <120	No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools					
	≥120	No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools					

Code	Description	Definition and Response
	No Pools	Site has been previously surveyed; pools have not been recorded at or near these flows. No Response.
	Minimal Effect	Site has been previously surveyed at least five time under similar flow conditions and isolated pools were observed; less than 200 fish were recorded during a single reduction event under similar conditions. No Response.
	No Data or Insufficient Data	Site has been previously surveyed less than five times under similar flow conditions; less than 200 fish were recorded during a single reduction event under similar conditions. Reconnaissance Survey.
	Effect	Site has been previously surveyed under similar flow conditions and isolated pools were observed; greater than 200 fish were recorded during a single reduction event under similar flow conditions. Stranding Survey.
	Unlikely Discharge Range	Birchbank discharge has not been recorded at these levels during the specified time period (based on discharge data collected between 2000 and 2018).
	Listed species were captured or observed.	During at least one stranding assessment under similar flow conditions listed species were captured or observed.

Does not include data pre-recontouring.

Includes all stranding assessments and stranded fish between 1 January 2000 and 1 April 2019.

4.0 DISCUSSION

4.1 Lower Columbia River Fish Standing Assessment and Ramping Protocol (CLBMON#42) Management Questions

Analyses to address Management Question #1, #2, #3, and #4 from the Lower Columbia River Fish Stranding Assessment and Ramping Protocol Monitoring Program (BC Hydro 2007) were not conducted during the present study period. These management questions were addressed using analyses conducted on three years (2004 to 2006) of summer and winter flow ramping studies on the Columbia and Kootenay River downstream of HLK/ALH (Golder 2005, 2006, 2007; Irvine et al. 2009), and on previous statistical analyses conducted on the Lower Columbia River Fish Stranding Database (Golder and Poisson 2010; Irving et al. 2014; Golder 2018). The present study contributed data to address Management Question #5.

Management questions and hypotheses to be addressed by the Lower Columbia River Fish Stranding Assessment and Ramping Protocol are as follows:

1) Is there a ramping rate (fast vs. slow, day vs. night) for flow reductions from HLK/ALH that reduces the number of fishes stranded (interstitially and in pools) per flow reduction event in the summer and winter?

   Ho1: The number of stranded fishes is independent of either the ramping rate or time of day of flow reductions in the summer and winter.

   Between 2004 and 2006, flow ramping studies were conducted in the summer and winter on the Columbia and Kootenay rivers to assess the effect of flow ramping rate on the probability of pool and interstitial stranding of juvenile fishes (Golder 2005, 2006, 2007). For these studies, experimental net pens were set up in the varial zones of the two rivers to test the effect of flow ramping rate. Ramping studies from the 2004 to 2006 winter seasons were analyzed to test the effect of ramping rate on interstitial stranding, and ramping studies from 2005 and 2006 summer seasons were analyzed to test the effect of ramping rate on pool stranding (Golder 2007; Irvine et al. 2009). Over the range of ramping rates tested (3.9 to 13.3 cm/h for interstitial stranding experiments, and 7.4 to 35.3 cm/h for pool stranding experiments), ramping rate did not have a statistically significant effect on interstitial or pool stranding (Golder 2007). However, subsequent analysis of the ramping studies data found that there was a trend of increased fish stranding frequency with increased ramping rates for pool stranding experiments (Irvine et al. 2009). Probability of stranding in pools increased from approximately 8% at a ramping rate of 10 cm/h to approximately 35% at a ramping rate of 30 cm/h (Irvine et al. 2009).

   Additional information on ramping rates and their effect on stranding risk was obtained through an analysis of fish stranding assessment results between 1999 and 2009 from the Lower Columbia River Fish Stranding Database (Golder and Poisson 2010; Irvine et al. 2014). In that analysis, four definitions of stranding levels were modelled with greater than or equal to 1, 50, 200, and 1000 stranded fishes required to constitute a stranding event. With this model, ramping rate was not a statistically significant predictor of stranding risk for any stranding level.

   In the *Canadian Lower Columbia River: Fish Stranding Risk Assessment and Response Strategy* (Golder 2011), the ramping rates were set at 1 to 5 kcfs/hr for HLK/ALH, and below 2 kcfs/hr for BRD/X to allow fishes the greatest length of time to escape stranding habitats where possible. During the present study, the ramping rates for reduction events at HLK/ALH were maintained at or below 5 kcfs/hr for all reductions (Table 1). Since some previous studies have shown an increase in stranding with increasing ramping rate (Irvine et al. 2009), and other studies have found no effect of ramping rate on stranding (Golder and Poisson 2010) the null hypothesis regarding the effect of ramping rate on fish stranding (Ho1) cannot be rejected at this time .

Time of day (day vs. night) was tested in experimental flow ramping studies in the summer and winter in 2004 and 2005 on the Columbia and Kootenay rivers (Golder 2005, 2006). During the 2004 ramping studies there was a weak trend for interstitial stranding in winter to occur more at night than during the day (Golder 2005), however results from an analysis of all years of flow ramping studies (2004 to 2006) revealed that time of day was not a statistically significant predictor for the probability of interstitial stranding in winter, or pool stranding in summer (Golder 2007; Irvine et al. 2009). It is important to note that the dataset for the analysis on all years of flow ramping studies was limited to seven night time net pens and 65 daytime net pens. Pool stranding in winter and interstitial stranding in summer were not included in this analysis.

Further analysis of the Lower Columbia River Fish Stranding Database assessed whether time of day when a flow reduction occurred at HLK had an affect on the probability of stranding fish (Golder and Poisson 2010; Irvine et al. 2014). Four definitions of stranding levels were modelled with greater than or equal to 1, 50, 200, and 1000 stranded fishes required to constitute a stranding event. The highest risk period for stranding was in the late afternoon. The relationship between time of day and fish stranding probability was significant only with the model that considered a stranding event to be equal to or greater than one fish (Golder and Poisson 2010; Irvine et al. 2014). It should also be noted that stranding assessment surveys were all conducted during the day, regardless of whether the reduction occurred during morning, afternoon or night time. Only conducting surveys during the day could have biased these results, if fish stranded during night time were less likely to be present or counted the following day (e.g. if consumed by predators).

Other studies on the effect of time of day on juvenile fish stranding have provided equivocal results. On some occasions, more fishes were stranded at night (e.g., Salveit 2001) while other studies noted greater stranding occurring during daytime (e.g., Bradford et al. 1995). Due to the limited data from night ramping experiments and the absence of night stranding assessments, the time of day component of the management hypothesis cannot be rejected.

2) Does wetted history (length of time the habitat has been wetted prior to the flow reduction) influence the number of fishes stranded (interstitially and in pools) per flow reduction event for flow reductions from HLK/ALH?

Ho2: Wetted history does not influence the stranding rate of fishes (both interstitially and pool stranding) for flow reductions from HLK/ALH.

Between 2004 and 2006, flow ramping studies were conducted in the summer and winter on the Columbia and Kootenay rivers to assess the effect of wetted history on the probability of pool and interstitial stranding for juvenile fishes (Golder 2005, 2006, 2007; Irvine et al. 2009). Longer periods of wetted history increased the probability of stranding for both interstitial and pool stranding experiments (Irvine et al. 2009), however this relationship was not statistically significant (Golder 2007).

In 2010, ten years (1999 to 2009) of stranding assessment data from the Lower Columbia River Fish Stranding Database were analyzed to determine the effects of wetted history on fish stranding (Golder and Poisson 2010; Irvine et al. 2014). In the analysis, four definitions of stranding levels were modelled with greater than or equal to 1, 50, 200, and 1000 stranded fishes required to constitute a stranding event.

Wetted history had a positive effect on the probability of a stranding event, and this relationship was statistically significant when a stranding event was defined as 1, 50, and 200 fishes (Golder and Poisson 2010; Irvine et al. 2014). The probability of stranding (≥ 1 fish) was approximately 18% at 0 days wetted history and approximately 40% at 90 days of wetted history (Golder and Poisson 2010). Additionally, there was a statistically significant increase in the probability of stranding (≥1 fish) after a wetted history of greater than 10 days (approximately 35%) versus a wetted history of less than ten days (approximately 17%) (Golder and Poisson 2010).

A wetted history of more or less than 10 days was adopted as an appropriate cut-off level for differentiating between severity of stranding risk and has been considered prior to initiating stranding assessments as per the *Canadian Lower Columbia River: Fish Stranding Risk Assessment and Response Strategy* (Golder 2011). The determination of whether to initiate a stranding assessment due to a RE should continue to be based on factors such as time of year, river stage and database query results, in addition to wetted history. Previous studies (Golder 2007; Irvine et al. 2009; Golder and Poisson 2010) suggest that wetted history does influence the stranding rate of fishes and that this management hypothesis can be rejected.

3) 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/ALH reduce the stranding rate of fishes?

Ho3: A conditioning flow from HLK/ALH does not reduce the stranding rate of fishes in the lower Columbia River.

Previous studies have shown that the use of a conditioning reduction appears to reduce the incidence of pool stranding on the Columbia River (Golder 2007; Irvine et al. 2009); however, this result was based on limited data and a recommendation was made that additional experiments be undertaken to verify the results (Golder 2007). Currently, no additional conditioning flow experiments have been conducted and conditioning flow reductions from HLK/ALH are not being considered as a management tool to reduce fish stranding. The value of implementing conditioning flows requires further discussions regarding the operational risk versus biological rationale. Two key concerns regarding adopting conditioning flow reductions as a management tool to reduce fish stranding were identified in a literature review (Golder and Poisson 2010). The first concern was the limited amount of data collected and preliminary stages of research on the suitability of conditioning flows for use on the Columbia and Kootenay rivers. The second concern was with the actual effectiveness of the method. The initiation of conditioning flows may encourage some fishes to leave high stranding risk areas, but the conditioning flow reduction may cause significant mortality within a short period of time, which would reduce the practicality of the method (Golder and Poisson 2010). In observations made on the lower Duncan River during ramping experiments conducted in the fall of 2009, less than 10% of Mountain Whitefish that were aggregated in a pool that drained survived over the 30 minutes the water was absent (Poisson and Golder 2010). Due to limited data, this hypothesis cannot be rejected at this time. If conducting additional conditioning flow experiments at HLK/ALH is not practical, abandonment of this management tool should be considered.

4) Can physical habitat works (i.e., re-contouring) reduce the incidence of fish stranding in high risk areas?

Ho4: Physical habitat manipulation does not reduce the stranding rate of fishes in the lower Columbia River.

To mitigate the occurrence and magnitude of fish stranding six previously identified high risk stranding sites have been re-contoured as identified in Table 6.

Table 6: Efforts of Re-contouring on the Lower Columbia River

Site[a]	Year of Re-contouring
Genelle Lower Cobble Island (MID)	2001
Millenium Park (LUB)	2001
Norn's Creek Fan (RUB)	2002
Genelle Mainland (LUB)	2003
Fort Shepherd Launch (RUB)[b]	Between Fall of 2012 and Spring of 2013
Lions Head (RUB)	2015

LUB = left bank as viewed facing upstream; RUB = right bank as viewed facing upstream.
[a] Appendix A; Figures A1 through A8.
[b] The Fort Shepherd Launch (RUB) site was re-contoured by Columbia Power Corporation (CPC) as a component of the CPC Owner's Commitment #39 ([Revised 10 November 2006] [CPC 2011]). This commitment included the development of a Shallow water Habitat Compensation Plan which was designed as the "Fort Shepherd Bar-Shallow-water Habitat Compensation Site" at the Fort Shepherd Launch (RUB) site.

In 2010, the effects of re-contouring were analyzed in a statistical analysis conducted on ten years (1999 to 2009) of stranding assessment data from the Lower Columbia River Fish Stranding Database (Golder and Poisson, Irvine et al. 2014). In this study a generalized linear mixed effects model analyzed the probability of a stranding event occurring in relation to before or after re-contouring at Genelle Lower Cobble Island (MID), Millenium Park (LUB), Norns Creek Fan (RUB), and Genelle Mainland (LUB). Results of the study identified a significantly higher probability of a stranding event (identified as >200 fishes) occurring before re-contouring (approximately 8%) compared to after re-contouring (approximately 3%) (Golder and Poisson 2010, Irvine et al. 2014). There was also a significantly higher probability of a stranding event occurring before re-contouring compared to after re-contouring when a stranding event was defined as equal to or greater than 1 fish, and equal to or greater than 50 fishes (Golder and Poisson 2010, Irvine et. al. 2014).

In the 2017/2018 Lower Columbia and Kootenay River Fish Stranding Annual Summary (Golder 2018), the effects of re-contouring were analyzed using all pre and post re-contouring data available from the Lower Columbia River Fish Stranding Database up to 1 April 2018. The analysis used generalized linear mixed models to estimate the probability of fish stranding events and the number of fishes stranded before and after re-contouring at Millennium Park (LUB), Norns Creek Fan (RUB), Genelle Mainland (LUB), Fort Shepherd Launch (RUB), and Lions Head (RUB). The probability of stranding (>0 fish) were significantly greater before than after re-contouring for both High and Low Risk periods. The effect of recontouring on the probability of stranding (>0 fish) differed by site, however one of the largest effects was noted at Fort Shepherd Launch (RUB) during the High Risk period, where the predicted probability of stranding decreased from approximately 60% before re-contouring to approximately 45% after re-contouring (Golder 2018). The probability of stranding greater than 200 fishes were also significantly greater before than after re-contouring for the Low Risk period. The largest effects of recontouring on the probability of stranding greater than 200 fish were noted at Genelle Mainland (LUB) (approximately 14% before to approximately 4% after), and Norns Creek Fan (approximately 6% before to 1% after) (Golder 2018). Analysis conducted on the number of fishes stranded revealed that significantly more fishes were stranded before than after re-contouring. In this analysis the greatest benefit of re-contouring was at Genelle Mainland (LUB) during the High Risk period, with predicted mean values of approximately 300 fishes stranded per reduction event before and approximately 100 to 150 fishes stranded per reduction event after re-contouring (Golder 2018). The analysis was also valuable in identifying that the odds of stranding and total fishes stranded had a negative relationship with Birchbank discharge values, suggesting higher stranding effects as Birchbank discharge decreases. Results of the generalized linear mixed model's analysis suggest that the previous efforts of re-contouring sites on the lower Columbia River have been successful in decreasing the incidence of stranding and the number of fishes stranded. Based on previous studies (Golder and Poisson 2010, Irvine et al. 2014, Golder 2018), Management Hypothesis #4 is rejected.

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?

Ho5: The number of fish salvage events can be reduced through adaptive adjustments made as a result of ongoing data collection.

Currently this hypothesis cannot be rejected. Since 2009 the number of yearly stranding assessments conducted due to flow reductions from HLK/ALH has varied from 8 to 15 (median = 13) and the response rate (percent of yearly RE from HLK/ALH that initiate a stranding assessment) has varied from 62 to 92% (median = 83%). During the present study there were 13 stranding assessments conducted in response to 20 RE from HLK/ALH resulting in a response rate of 65%. The response rate for HLK/ALH RE has decreased in recent years (92% in 2016/2017, and 83% in 2017/2018); however, this rate is affected by the definition of a RE. In previous years, some HLK/ALH RE occurred over multiple days. Based on discussions with BC Hydro during the present study period, it was decided that each RE would be defined as occurring on a single day rather than multi-day RE. This will be the designation of RE in future study years.

The response rate from year to year also varies because the decision to conduct a stranding assessment in response to a RE from HLK/ALH is based not only on results of the stranding database queries, but also on a number of other factors including timing, river stage, wetted history, daily air temperatures, results and notes from the previous stranding assessments and professional judgement (Figure 2). Since these factors differ for each RE and the total number of RE differ from year to year, the response rate is also affected.

5.0 RECOMMENDATIONS

- As written in the *Canadian Lower Columbia River: Fish Stranding Risk Assessment and Response Strategy* (Golder 2011) ‘Effect’ sites should remain the focus of stranding assessments, and if time permits it is recommended that ‘Reconnaissance’ sites be visited in order to fill in data gaps that still exist in Table 5. Additional site assessments will lead to a site designation of ‘No Pools’, ‘Minimal Effect’, ‘Effect’ or ‘Significant Fish Stranding’, thereby increasing the precision of the query. As the dataset becomes more refined, so too will the decision to initiate stranding assessments.

- Currently the database queries identify an ‘Effect’ site as any site that has had greater than 200 fishes or any listed species stranded during previous RE under similar conditions between year 2000 and the current date. In early 2020 the *Canadian Lower Columbia River: Fish Stranding Risk Assessment and Response Strategy* will be updated, and the update will re-consider when a stranding assessment is recommended. For this update it is recommended that the frequency of a site being an ‘Effect’ site be considered in the decision making process for initiating a stranding assessment.

- The sites listed below have been previously recommended as candidates for re-contouring because of high stranding risk relative to other sites (Golder and Poisson 2010). Re-contouring at these sites could be conducted using a phased approach, with higher priority sites (based on stranding risk, cost, and other factors) being enhanced first and other sites being re-contoured in subsequent years. Sites recommended for re-contouring are:

  - Kootenay (RUB) - Kootenay (RUB) and the associated Kootenay Oxbow are inundated and dewatered as a result of flow regulation from BRD/X and HLK/ALH. Re-contouring of this site would assist in the draining of Kootenay Oxbow during RE. Kootenay (RUB) is a good candidate for re-contouring because it is a common stranding site. Since 2000, this site has stranded a total of 22,247 fishes (third highest site for total stranded fishes), including 491 listed fishes during 245 RE. Listed species have been stranded for 16 of the previous 19 years. Kootenay (RUB) has also been identified as an ‘Effect’ site at common Birchbank discharge ranges (30 to 70 kcfs in High and Low Risk period) (Table 5). Additionally, re-contouring efforts would help reduce stranding at a public and logistically difficult place to salvage fishes (very large, shallow pools with large cobble substrate).

  - Genelle Mainland (LUB) - In 2003, two large pools at the downstream end of Genelle Mainland (LUB) were re-contoured. Since then, years of high flow (in particular 2012) have changed the site topography resulting in the formation of stranding pools at a variety of discharges. This site is a good candidate for re-contouring because of a large abundance of fishes that are common in this area and a history of significant stranding events. Since 2000, Genelle Mainland (LUB) has had the highest total number of stranded fishes (91,462 fishes including 81 listed species during 214 RE). Additionally, Genelle Mainland (LUB) has been designated as an ‘Effect’ site for a large range of discharges (40 to 100 kcfs during the High Risk period, and 30 to 70 kcfs during the Low Risk period) (Table 5). Suggested modifications include improving drainage between the access road and the Whispering Pines Trailer Park and infilling a large pool that forms at a Birchbank discharge near 60 kcfs.

- Gyro Boat Launch (RUB) - Since 2000, Gyro Boat Launch (RUB) has stranded a total of 9345 fishes including 269 listed species during 116 RE. This site is a good candidate for re-contouring because it would be a logistically easy place to bring equipment in to conduct re-contouring. Re-contouring efforts at Gyro Boat Launch (RUB) should include the removal of a large artificial depression (potential storm drain exit) that is prone to fish stranding.

- 1 April 2019 to 1 April 2020 will be the final year of the Lower Columbia and Kootenay River Fish Stranding Assessments under the 13 year Columbia River Water Use Plan. As part of the final report Golder recommends conducting a statistical analysis on the Lower Columbia River Fish Stranding Database that is similar to Golder and Poisson (2010). These analyses would include all data collected from stranding assessments between year 2000 and 2020. As in Golder and Poisson (2010), the analyses would be conducted with a focus to answer the CLBMON-42 management questions (BC Hydro 2007).

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.

Golder Associates Ltd.

Kevin Little, BSc Biology
Aquatics Biologist

Shawn Redden, BSc, RPBio
Associate, Senior Fisheries Biologist

KL/SR/cmc

https://golderassociates.sharepoint.com/sites/23549g/deliverables/issued to client - for wp only/1895371-001-r-rev0/1895271-001-r-rev0-lcr stranding 2018-2019 annual summary 02jul_19.docx

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APPENDIX A

Site Maps

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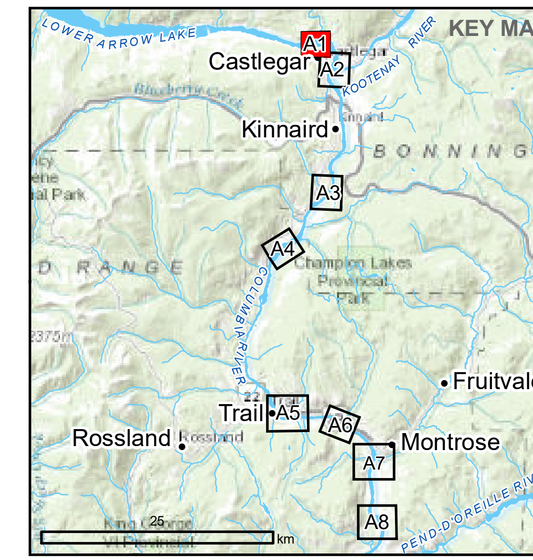
● STRANDING SITE



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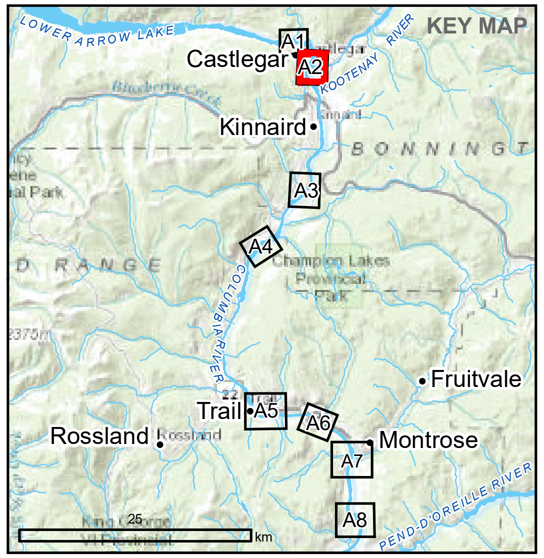

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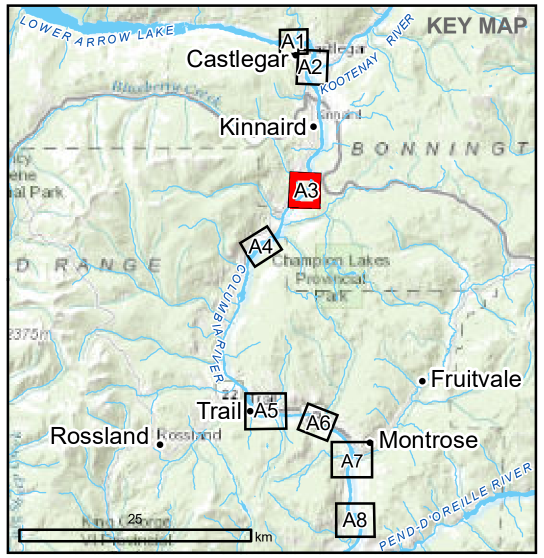

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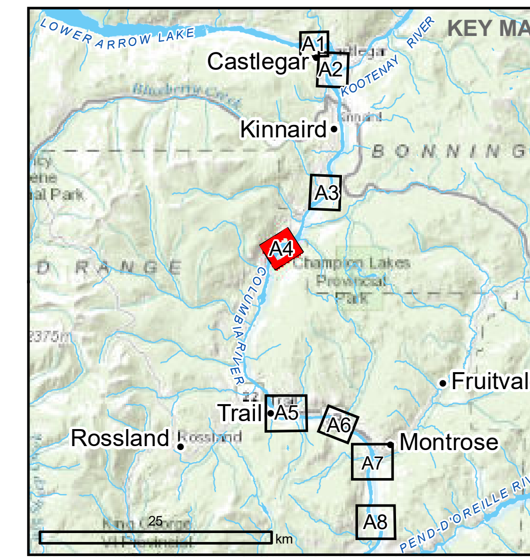

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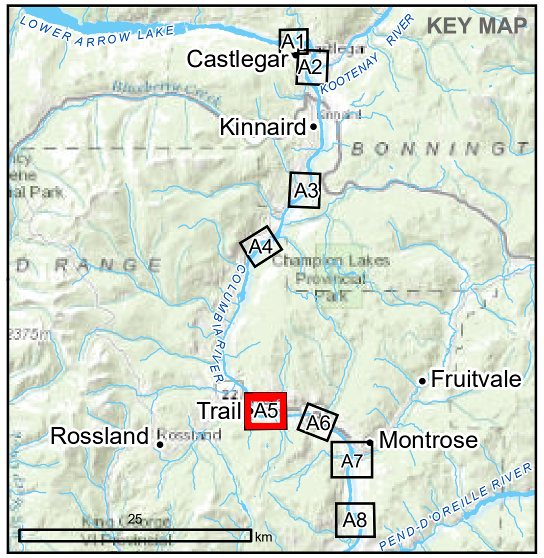

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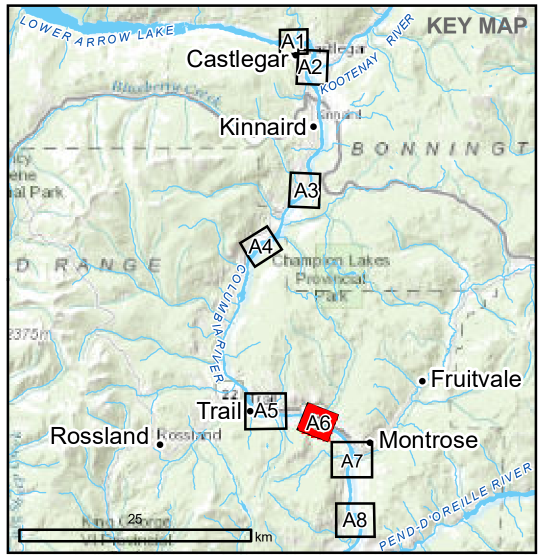

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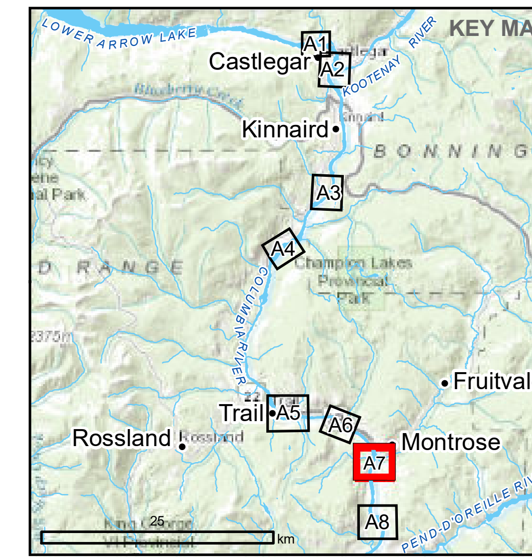

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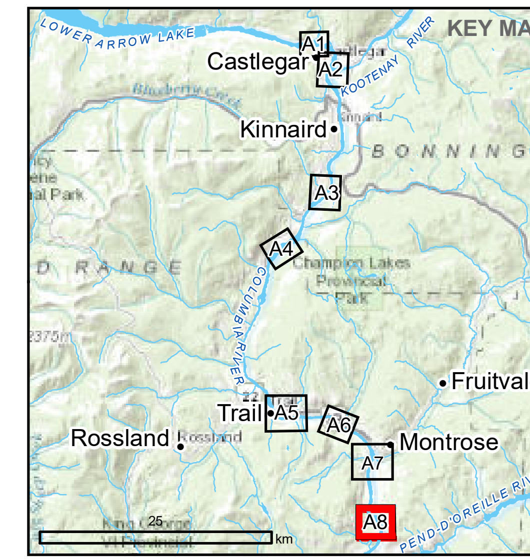

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