Columbia River Project Water Use Plan

Lower Columbia River Fish Management Plan

Lower Columbia River Fish Stranding Assessment and Ramping Protocol

Implementation Year 10

Reference: CLBMON-42A

Lower Columbia River (CLBMON#42[A]) and Kootenay River Fish Stranding Assessments: Annual Summary (April 2016 to April 2017)

Study Period: April 1, 2016 to April 1, 2017

Golder Associates Ltd. 201 Columbia Ave. Castlegar, BC V1N 1A8

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ANNUAL SUMMARY REPORT

Lower Columbia River (CLBMON#42[A]) and Kootenay River Fish Stranding Assessments: Annual Summary (April 2016 to April 2017)

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REPORT

Cover Photo: Small shallow pools formed at Genelle Mainland (LUB) during flow reduction event 2016-09 on 20 August 2016 (see Appendix A; Figure A4 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 stranding of fish species of the lower Columbia and Kootenay rivers. This study assessed fish stranding at pre-determined sites (Appendix A) between HLK/ALH and the Canada/USA border. The primary objective of the revised fish stranding protocol, “Canadian Lower Columbia River: Fish Stranding Risk Assessment and Response Strategy” (Golder 2011), was to mitigate the effects of flow reductions from HLK/ALH on native fish species through flow reduction planning. This report summarizes the information collected following flow reductions at HLK/ALH and BRD/X on the Columbia and Kootenay rivers between 1 April 2016 and 1 April 2017.

The number of stranding assessments initiated due to reduction events (RE) at HLK/ALH and BRD/X has fluctuated from 12 to 18 over the past eight years of data collection. During the present study (1 April 2016 to 1 April 2017), stranding assessments were conducted for 17 of the 18 RE. Eleven stranding assessments were conducted in response to RE at HLK/ALH, three stranding assessments were conducted in response to RE at BRD/X, and three stranding assessments were conducted in response to RE from both hydroelectric facilities. The high number of stranding assessments in 2016/2017 was due to low discharge from HLK/ALH in the fall and insufficient inflows into Kootenay Lake in late summer affecting BRD/X minimum flows. In addition, the study focused on ‘Reconnaissance’ sites (48% of surveyed sites) to fill data gaps at recently re-contoured sites and other sites with limited stranding data during different discharge volumes.

An estimated 3,315 isolated or stranded fishes were observed during the 17 stranding assessments and 66.8% were salvaged (successfully relocated to the main stem Columbia or Kootenay rivers). Nineteen sites were assessed at least once during the study period and the majority (56.5%) of fishes were found at Genelle Mainland (LUB) site. Sportfishes accounted for 24.5% of the total stranded fishes and included Mountain Whitefish (*Prosopium williamsoni*), Rainbow Trout (*Oncorhynchus mykiss*), and Smallmouth Bass (*Micropterus dolomieu)*. Of the non-sportfishes observed, the most common were young-of-the-year and juvenile Sucker species (*Catostomidae* spp.) accounting for 38.9% of the non-sportfishes stranded.

The stranding assessments from 2016/2017 provided valuable data for the Lower Columbia River Fish Stranding Database, particularly at discharges where there was limited fish salvage data, further improving the ability of database queries to predict the effects of reduction events at HLK/ALH and BRD/X.

Secondary objectives of the study include addressing five key management questions identified under the Columbia Water Use Plan (BC Hydro 2007). Analysis to address the first three management questions was not conducted during the present study. These management questions were addressed using data presented in 2007, 2009/2010 and 2010/2011 annual summaries and recommendations have been made. Data collected during the present study, along with historical fish stranding assessments focus on answering management questions #4 and #5 (Table ES1).

Table ES1: CLBMON#42A Status of Hugh L. Keenleyside Dam and Arrow Lakes Generating Station (HLK/ALH) Program Objectives, Management Questions and Hypotheses

Primary Objective	Secondary Objectives	Management Questions	Management Hypotheses	Year 10 (2016/2017) 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 fish 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 fish stranded (interstitially and pool) per flow reduction event in the summer and winter?	Ho1: The number of stranded fish is independent of either the ramping rate or time of day of flow reductions in the summer and winter.	Ramping rates within the range of variability experienced in the previous years of study were not a statistically significant predictor of fish stranding in the Columbia and Kootenay river systems (Golder 2007, Golder/Poisson 2010, Golder 2016). Given these results the ramping rate component of this hypothesis is not rejected. Previous studies indicate that time of day (day vs night) was not a significant variable for stranding risk (Golder and Poisson 2010). However, this finding is based on limited data. Time of day ramping studies were not conducted during the present study. The time of day component of this hypothesis can not be rejected and must be deferred until additional time of day ramping experiments are conducted. Additional ramping experiments are outside of the scope of the present study, therefore this component of the hypothesis will not be addressed.
	To determine whether the wetted history influences the stranding rate of fish for flow reductions.	MQ2: Does wetted history (length of time the habitat has been wetted prior to the flow reduction) influence the number of fish stranded (interstitially and pool) per flow reduction event for flow reductions from HLK/ALH?	Ho2: Wetted history does not influence the stranding rate of fish (both interstitially and pool stranding) for flow reductions from HLK/ALH.	A significant increase in the number of stranded fish was observed after a 10-day wetted history, although the effect size (proportion of the population affected and the response to wetted histories of variable lengths greater than 10 days) has not been accurately quantified (Golder and Poisson 2010). Previous studies suggest that this hypothesis can be rejected, however Golder recommends that the hypothesis be deferred and the feasibility of using River2D models from Golder (2013) in Year 11 should be considered. These models allow for quantification of fluctuations in river stage at select stranding sites and can be used to calculate wetted history.
	To determine whether a conditioning flow reduction from HLK/ALH reduces the stranding rate of fish.	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 fish?	Ho3: A conditioning flow from HLK/ALH does not reduce the stranding rate of fish in the lower Columbia River.	This hypothesis cannot be rejected at this time and must be deferred due to limited data (Golder 2007, Golder/Poisson 2010). Conditioning flow studies were not conducted during the present study. For a definitive answer to this management question an experimental conditioning flow study including manipulation of flows with significant time between replicates would be required. Experimental studies would be both costly and may lead to significant mortality as indicated by previous studies (Poisson and Golder 2010). Abandonment of this mitigation method should be considered if there is no desire for conducting conditioning flow experiments.

Primary Objective	Secondary Objectives	Management Questions	Management Hypotheses	Year 10 (2016/2017) Status
	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 fish in the lower Columbia River.	Previous analysis (Golder and Poisson 2010, Irvine et al. 2014) and the results of recent re-contouring efforts suggest that this hypothesis can be rejected; however Golder recommends the hypothesis should be deferred to Year 11 of the current study to allow for a statistical analysis of stranding assessments on all re-contoured sites. The effect size (the proportion of the population or the relative number of fish not stranded as a result of the physical habitat works) has not been estimated for previously re-contoured sites due to limited data. Additional stranding assessments at varied discharge volumes at recently re-contoured sites (Lions Head and Ft. Shepherd Launch [RUB]) is recommended.
	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.	Based on 10 years of data collection this hypothesis is rejected. Continued collection of stranding data and updating the Lower Columbia River Fish Stranding Database has not decreased the number of stranding events where crews were deployed. During the previous 8 years, 84% of HLK/ALH reduction events initiated stranding assessments. During the present study (1 April 2016 to 1 April 2017), 100% of HLK/ALH reduction events initiated a stranding assessment.

Key Words

Lower Columbia River

Kootenay River

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Flow Reduction

Discharge Regulation

Re-contouring

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1.0 INTRODUCTION

1.1 Scope and Objectives

The main objective of the monitoring program was to collect fish stranding data to assess the impact of flow reductions from Hugh L. Keenleyside Dam/Arrow Lakes Generating Station (HLK/ALH) on native fish species of the lower Columbia and Kootenay rivers. The program assessed fish stranding at pre-determined sites (Appendix A) between HLK/ALH and the Canada/USA border. Secondary objectives included: 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). Analysis to address the first three management questions was not conducted during the present study. These management questions have been addressed based on previous studies (Golder 2007, Golder and Poisson 2010) and recommendations regarding these management questions have been made. The present study contributes data to address management questions #4 and #5.

This report describes the results of fish stranding assessments conducted in the lower Kootenay and Columbia rivers from 1 April 2016 to 1 April 2017. Results are compared with data from previous years of monitoring and are discussed in relation to the objectives, management questions #4 and #5, and associated hypotheses outlined below.

1.2 Management Questions

The key management questions identified under the Columbia Water Use Plan and addressed under the overall monitoring program are (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 fish stranded (interstitially and pool) per flow reduction event in the summer and winter?

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

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

5) Does the continued collection of stranding data, and upgrading of the lower Columbia River stranding protocol, limit the number of occurrences when stranding crews need to be deployed due to flow reductions from HLK/ALH?

1.3 Management Hypotheses

For fish stranding in the lower Columbia River, the following hypotheses (BC Hydro 2007) will be tested:

Ho_1: The number of stranded fish is independent of either the ramping rate or time of day of flow reductions in the summer and winter

Ho_2: Wetted history does not influence the stranding rate of fish (both interstitially and pool stranding) for flow reductions from HLK/ALH

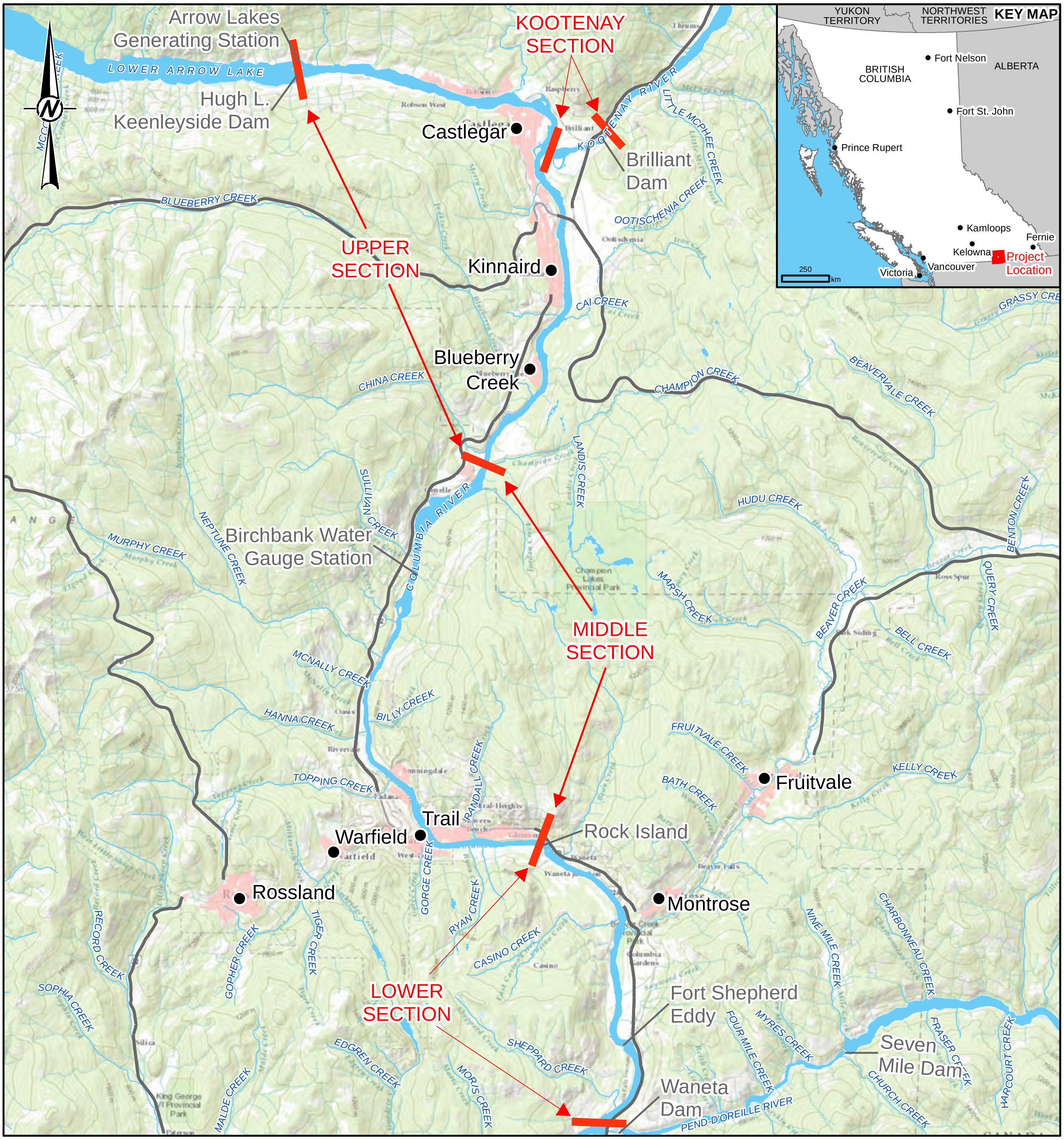
Ho_3: A conditioning flow from HLK/ALH does not reduce the stranding rate of fish in the lower Columbia River

Ho_4: Physical habitat manipulation does not reduce the stranding rate of fish in the lower Columbia River

Ho_5: 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 encompasses the approximately 56 km long section of the lower Columbia River from HLK/ALH to the Canada/USA border and the lower Kootenay River (approximately 2.8 km) from below Brilliant Dam/Expansion (BRD/X) to the Columbia River confluence (Figure 1).



LEGEND

- TOWN
- HIGHWAY
- WATERCOURSE
- RESIDENTIAL AREA
- WATERBODY

DRAFT

0 5 10

1:200,000 KILOMETERS

REFERENCES
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PROJECT
LOWER COLUMBIA RIVER AND
KOOTENAY RIVER FISH STRANDING

TITLE
STUDY AREA OVERVIEW

CONSULTANT

Golder Associates

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2.0 METHODS

2.1 Fish Stranding Risk Assessment

The fish stranding protocol *Canadian Lower Columbia River Fish Stranding Risk Assessment and Response Strategy* (Golder 2011) was implemented preceding each reduction event and during all stranding surveys conducted during the present study. Fish stranding protocols were previously developed by BC Hydro, Columbia Power Corporation (CPC) and FortisBC, in collaboration with the Columbia Operations Fish Advisory Committee (COFAC). The protocols were developed to manage fish impacts associated with flow reductions from the Columbia (HLK/ALH) and the Kootenay (BRD/X) systems. 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). Figure 2 summarizes the five phase process for defining fish stranding risk, as well as guiding assessment/salvage response decisions.

Fish stranding risk assessments and salvage responses were determined using the following factors:

- **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. The high stranding risk period occurs from 1 June to 30 September; the Low Risk period occurs from 1 October to 31 May (Golder and Poisson 2010). 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).
- **River Stage**- The probability of fish stranding is typically inversely related to water levels. There are certain river stage elevations that have a high risk for stranding because of the formation of pools and the presence of low slope habitat that is uncovered at given water elevations. The low angle river bank and presence of shallow depressions at lower water levels result in greater risk of fish stranding than during higher water levels. During the High Risk period (1 June to 30 September), fish stranding risk is less 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).
- **Info Review**- The Lower Columbia River Fish Stranding Database was developed to store and manage historic flow reduction and stranding assessment data (discharge levels, ramping rates, 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 flow reduction. This database is updated throughout the year to take into account results from recent stranding events. Prior to a new reduction event from HLK/ALH or BRD/X this database is queried to help define fish stranding risk at 22 known stranding sites (Appendix A) based on historical data collected during similar times of the year under similar flow conditions. Data entered into the query include current discharge from HLK/ALH and BRD/X, proposed resultant discharge from HLK/ALH and BRD/X on the day of reduction, the Columbia River water temperature from Birchbank Water Station (water temperature from Norns Creek Water Station is used if temperature from Birchbank Water Station is unavailable), and the date of the proposed reduction. Based on these data, the database provides a ranking of predicted stranding risk at individual sites. From high to low stranding risk priority the rankings are as follows: '**Significant Stranding Event'** (greater than 5000 fishes stranded during a previous assessment), **'Effect'** (greater than 200 fishes stranded during a previous assessment), '**Minimal Effect'** (less than 200 fishes stranded during a previous assessment), '**Reconnaissance'** (less than five previous stranding assessments) and '**No Pools'** (No pools have been discovered at previous assessments).


Flow Reduction Fish Stranding Assessment Response
HLK /ALH or BRD/BRX Flow Reduction
PHASE 1 Timing
Day of Year
June 1 – September 30
October 1 – May 31
PHASE 2 Stage
Minimum River Stage during reduction (BB)?
<110 kcfs
>110 kcfs
Minimum River Stage during reduction (BB)?
<60 kcfs
>60 kcfs
Query Stranding Database
Query Stranding Database
Query Stranding Database
Query Stranding Database
PHASE 3 Info Review
> 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
>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
PHASE 4 Management Decision
Yes
Assessment Recommended
Yes
Voluntary Assessment Recommended
No Assessment Required
Yes
Assessment Recommended
Yes
Voluntary Assessment Recommended
No Assessment Required
PHASE 5 Assessment Refinement (Considerations)
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.
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.
Undertake Assessment

After timing, river stage, and results of the stranding database query have been considered, a management decision is made to determine whether a stranding assessment is recommended or not. If a stranding assessment is recommended further variables are considered including:

- Number of potential sites from the database query designated as 'Effect' sites
- Review of previous reduction results for 'Significant Fish Stranding'
- Wetted history at Birchbank Water Station
- Daytime air temperature
- Time of last reduction

2.2 Salvage Methods

Standard methodologies used during the field component for each fish stranding assessment were 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.

Stranding assessment crews were on site no later than one hour after the initiation of a flow reduction from HLK/ALH or BRD/X. Fish stranding and salvage assessments began at the most upstream site identified for assessment by the Lower Columbia River Fish Stranding Database query and site surveys continued downstream following the stage recession. Sites were also visited 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 assessed first. 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) Documented the current conditions (date, time, weather, air and water temperature, approximate vertical drawdown of the water level, etc.) on Stranding Field Forms.
2) Observed and recorded the number of new isolated pools that were created as a result of the flow reduction. Pools isolated during previous reductions were not enumerated.
3) Inspected each pool for fishes and attempted to salvage any fishes present using dipnets, backpack electrofishers (Smith-Root Model LR 24 or 12-B POW), or beach seines. Effort was recorded at each site depending on method used for fish capture.
4) Transferred the captured fishes into a bucket of water where each fish was identified to species and life stage and released into the main channel of the river. Where possible, fishes were classed into one of the following life stages; egg, young-of-the-year, juvenile, and adult. If stranded fishes were numerous (>200), a subsample of 20 individuals were captured and identified to species.
5) A visual estimate of the number of larvae and fry was made if sample methods were ineffective at capturing these life stages.
6) Inspected interstitial stranding areas and salvaged any fishes observed.

7) Photographed representative areas of the site at the time of sampling and photographed representative or unusual fish species where appropriate.

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

9) Invasive species (Northern Pike, Smallmouth Bass, Brook Trout, Yellow Perch, Common Carp and Tench) found stranded were euthanized with clove oil and removed from the system based on recommendation from the Ministry of Forests, Lands and Natural Resources (FLNRO)(Pers. Comm., Matt Neufeld, FLNRO, 22 February 2016).

3.0 RESULTS

3.1 Operations Overview 2016/2017

During the present study, the discharge in the Columbia River at the Birchbank gauging station (08NE049) ranged from 28.6 kcfs recorded on 25 October 2016 to 117.2 kcfs on 2 January 2017 (Figure 3). Discharge at Birchbank generally increased from April to June and November to January, while discharge generally decreased from June to October and January to March. The mean hourly discharge from HLK/ALH ranged from 5.0 kcfs on 4 November 2016 to 84.0 kcfs on 28 July 2016 and the Kootenay River mean hourly discharge ranged from a minimum of 11.0 kcfs on 7 October 2016 to a maximum of 72.8 kcfs on 31 May 2016 (Figure 3).

During the study period, there were a total of 18 operational flow reduction events (RE) (Figure 3). Twelve flow RE occurred at HLK/ALH, three RE occurred at BRD/X, and three RE were a result of flow reductions at both HLK/ALH and BRD/X (Table 1). Eight RE occurred during the High Risk period (1 June to 30 September) and the remaining 10 RE occurred during the Low Risk period (1 October to 31 May). The magnitude of flow reductions from the facilities ranged from 2.0 to 24.0 kcfs. The largest reduction event occurred at HLK/ALH on 10 and 11 February 2017 (RE2017-02) when flows dropped from 54.0 to 30.0 kcfs (12.0 kcfs per day) over the two day period. This decrease in flow from HLK/ALH resulted in a drop in discharge at Birchbank from 74.5 to 49.4 kcfs over the same two day period. This reduction from the HLK/ALH facility occurred as a result of negotiations with BC Hydro’s U.S. counterparts in order to smooth out flows in February and March to allow for improved storage capabilities to abide by Columbia River Treaty requirements (Pers. Comm. Dean Den Biesen, BC Hydro, 9 February 2017). Three reduction events (RE2016-10, RE2016-11 and RE2016-12) occurred at BRD/X which resulted in the facility running below its target minimum flow of 18 kcfs. These reductions occurred to prevent excessive drafting of Kootenay Lake due to low inflows in late summer (Table 1). Four RE (RE2016-13, RE2016-15, RE2017-01 and RE2017-02) from this study period involved a drop in operational flows over a two day period. All remaining reduction events occurred on a single day.

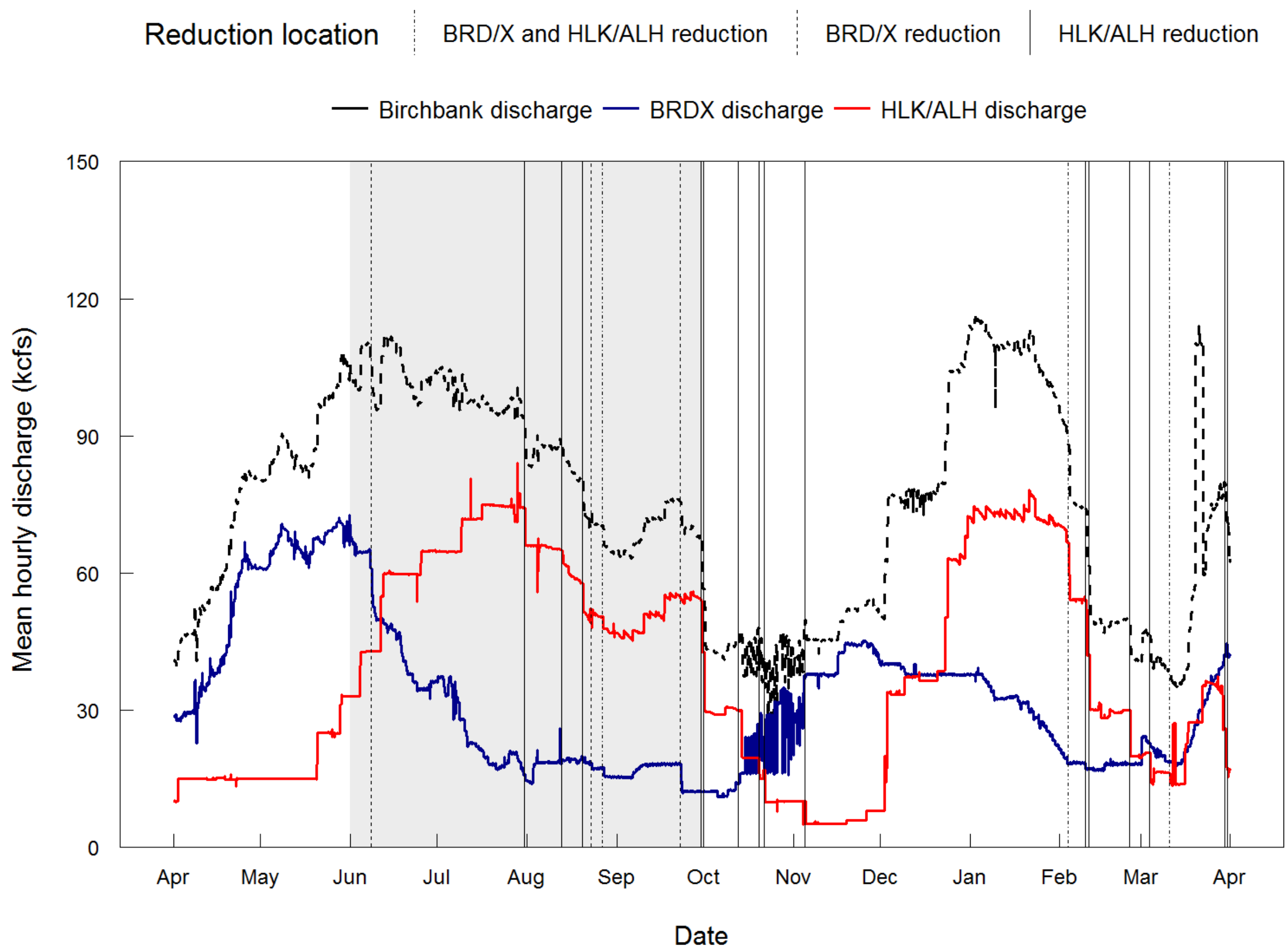

Figure 3: Mean hourly discharge from HLK/ALH (red line), BRD/X (blue line), and at the Water Survey of Canada Gauging Station at Birchbank (dotted black line), 1 April 2016 to 1 April 2017. The solid vertical lines indicate RE at HLK/ALH, dashed vertical lines indicate RE at BRD/X and dash-dot vertical lines indicate RE at BRD/X and HLK/ALH. RE were numbered from RE2016-06 to RE2017-07 (left to right on the figure). RE2016-13, RE2016-15, RE2017-01 and RE2017-02 include a discharge reduction over a two day period. The shaded area represents the period of high risk.

3.2 Reduction Events and Fish Stranding Assessments

Fish stranding assessments were conducted for 17 of the 18 RE (94%) that occurred between 1 April 2016 and 1 April 2017 (Table 1). The median number of stranding assessments for the previous eight reporting periods (2009/2010 to 2016/2017) is 14.5 (Figure 4). The median number of reduction events for the previous eight reporting periods is 18. Since 2014/2015 the number of stranding assessments conducted has steadily increased. Between the previous study period (2015/2016) and the present study period the total number of reduction events has remained the same at 18, yet the total number of stranding assessments has increased (Figure 4).

The number of RE from HLK/ALH have ranged between 11 and 18 during the eight previous reporting periods (2009/2010 to 2016/2017), with a median of 13 RE. Reductions from BRD/X have ranged from 0 to 6 over the same period, with a median of 3 RE. In terms of response rate, during the previous eight reporting periods, RE have initiated a stranding assessment an average of 83% of the time. In the present study period, stranding assessments were conducted for 94% of the RE, representing the second highest response rate from the previous eight years. The highest response rate was in 2013/2014 when 100% of RE initiated a stranding assessment (Figure 4).

No stranding assessment was conducted for RE2017-04. This management decision was made due to the fact that the resulting discharge from RE2017-04 would be greater than the resulting discharge from the previous reduction (RE2017-03) and the fact that only three fishes were salvaged during the previous reduction (Pers. Comm. James Baxter, BC Hydro, 2 March 2017).

Environmental conditions during stranding assessments were generally adequate for fish salvage purposes. However, during the stranding assessment for RE2017-02 on 10 February 2017, heavy snow was falling and ice covered many of the isolated pools. Field crews sampled as best they could given the conditions, although snow and ice in pools and interstitial areas made observing fishes difficult. Results from this RE are presented in this report, but this RE will be flagged and removed from queries in the Lower Columbia River Fish Stranding Database due to the reduced effectiveness of the stranding assessment.

Table 1: Summary of Reduction Events (RE) from HLK/ALH and BRD/X 1 April 2016 to 1 April 2017.

				Birchbank				Brilliant Dam/BRX					HLK/ALGS									
Reduction Event No.	Reduction Date	Concern Category	Crew Dispatched?	Mean Daily Water Temp (°C)	Max. Q (kcfs)	Min. Q (kcfs)	Magnitude of Reduction (kcfs)	Prev Q (kcfs)	Resulting Q (kcfs)	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
BRD/BRX 2016-06	08 June 2016	High	Yes	14.1	107.4	98.9	8.5	50.0	40.0	10.0	4	2.5	70.0	70.0	0.0	N/A	N/A	Yes	Yes	0	6	Reduction of inflows; Treaty requirements
HLK/ALH 2016-07	31 July 2016	High	Yes	16.3	93.2	83.7	9.5	17.5	17.5	0.0	N/A	N/A	75.0	66.0	9.0	2	4.5	Yes	Yes	274	8	Columbia River Treay requirements
HLK/ALH 2016-08	13 August 2016	High	Yes	16	87.6	84.4	3.2	21.0	21.0	0.0	N/A	N/A	66.0	60.0	6.0	2	3	Yes	No	107	7	Columbia River Treaty requirements
HLK/ALH 2016-09	20 August 2016	High	Yes	17.0	80.9	72.7	8.2	19.0	19.0	0.0	N/A	N/A	58.0	51.0	7.0	2	3.5	Yes	Yes	120	9	Columbia River Treaty requirements
BRD/BRX 2016-10	23 August 2016	High	Yes	17.0	73.1	70.3	2.8	19.2	17.2	2.0	1	2.0	51.0	51.0	0.0	N/A	N/A	Yes	Yes	757	8	Columbia River Treaty requirements and insufficient inflows on Kootenay Lake to maintain BRD/X minimum flows.
Both 2016-11**	27 August 2016	High	Yes	17.0	70.3	65.7	4.6	17.0	15.5	1.5	1	1.5	50.0	47.0	3.0	1	3.0	Yes	Yes	477	9	Columbia River Treaty requirements and insufficient inflows on Kootenay Lake to maintain BRD/X minimum flows.
BRD/BRX 2016-12	23 September 2016	High	Yes	15.0	74.9	67.8	7.1	18.1	12.0	6.1	4	1.5	55.0	55.0	0.0	N/A	N/A	Yes	Yes	441	10	Columbia River Treaty requirements and insufficient inflows on Kootenay Lake to maintain BRD/X minimum flows.
HLK/ALH 2016-13	30 September 2016	High	Yes	14.5	68.2	56.5	11.7	12.0	12.0	0.0	N/A	N/A	55.0	43.0	12.0	3	4.0	Yes	No	59	7	Reduction of inflows; Treaty requirements
	01 October 2016	Low	Yes	14.5	56.9	43.4	13.5	12.0	12.0	0.0	N/A	N/A	43.0	32.0	11.0	3	3.6	Yes	No	7	9	
HLK/ALH 2016-14	13 October 2016	Low	Yes	12.0	47.3	44.9	2.4	16.0	16.0	0.0	N/A	N/A	30.0	20.0	10.0	2	5.0	Yes	Yes	132	6	Reduction of inflows; Treaty requirements
HLK/ALH 2016-15	20 October 2016	Low	Yes	10.0	48.4	38.1	10.3	21.0	21.0	0.0	N/A	N/A	20.0	15.0	5.0	2	2.5	Yes	Yes	2	6	Reduction of inflows; Treaty requirements
	22 October 2016	Low	Yes	10.0	42.4	35.3	7.1	21.0	21.0	0.0	N/A	N/A	15.0	10.0	5.0	2	2.5	Yes	Yes	52	7	
HLK/ALH 2016-16	05 November 2016	Low	Yes	10.0	50.5	45.9	4.6	36.0	36.0	0.0	N/A	N/A	10.0	5.0	5.0	1	5.0	Yes	Yes	0	9	Columbia River Treaty requirements
Both 2017-01	03 February 2017	Low	No	3.0	92.5	88.0	4.5	19.0	19.0	0.0	N/A	N/A	70.0	67.0	3.0	2	1.5	N/A	N/A	N/A	0	Treaty and non-Treaty requirements
	04 February 2017	Low	Yes	3.0	88.3	75.2	13.1	20.0	19.1	0.9	1	0.9	67.0	54.0	13.0	3	4.3	Yes	Yes	0	10	
HLK/ALH 2017-02	10 February 2017	Low	Yes	2.0	74.5	61.8	12.7	17.0	17.0	0.0	N/A	N/A	54.0	42.0	12.0	3	4.0	Yes	Yes	54	6	Flow decrease negotiated with U.S. counterparts in order to smooth out flows in February and March for improved storage operations under the terms of the Columbia River Treaty.
	11 February 2017	Low	Yes	2.0	61.8	49.4	12.4	17.0	17.0	0.0	N/A	N/A	42.0	30.0	12.0	3	4.0	Yes	Yes	74	13	
HLK/ALH 2017-03	25 February 2017	Low	Yes	1.5	50.1	41.0	9.1	18.2	18.2	0.0	N/A	N/A	30.0	20.0	10.0	3	3.3	Yes	Yes	3	14	Non-Treaty storage agreement requested by BPA.
HLK/ALH 2017-04	04 March 2017	Low	No	2.0	46.6	39.6	7.0	18.2	18.2	0.0	N/A*	N/A*	20.0	16.0	4.0	2	2.0	N/A	N/A	N/A	0	Reduction of inflows; Treaty requirements
Both 2017-05	11 March 2017	Low	Yes	2.3	38.5	36.0	2.5	19.3	18.5	0.8	1*	0.8*	16.0	14.0	2.0	1	2.0	Yes	Yes	23	6	Non-Treaty storage agreement requested by BPA.
HLK/ALH 2017-06	30 March 2017	Low	Yes	2.0	79.8	70.6	9.2	41.2	41.2	0.0	N/A*	N/A*	36.0	26.0	10.0	3	3.3	Yes	Yes	1	8	Columbia River Treaty requirements and Rainbow Trout spawning protection flow target of April 1, 2017.
HLK/ALH 2017-07	31 March 2017	Low	Yes	2.0	70.9	62.5	8.4	41.2	41.2	0.0	N/A*	N/A*	26.0	17.0	9.0	3	3.0	Yes	Yes	732	6	Columbia River Treaty requirements and Rainbow Trout spawning protection flow target of April 1, 2017.

*Brilliant Dam was load factoring at this time.
**Both indicate that flow reduction occurred at HLK/ALH and BRD/X.
N/A = not applicable

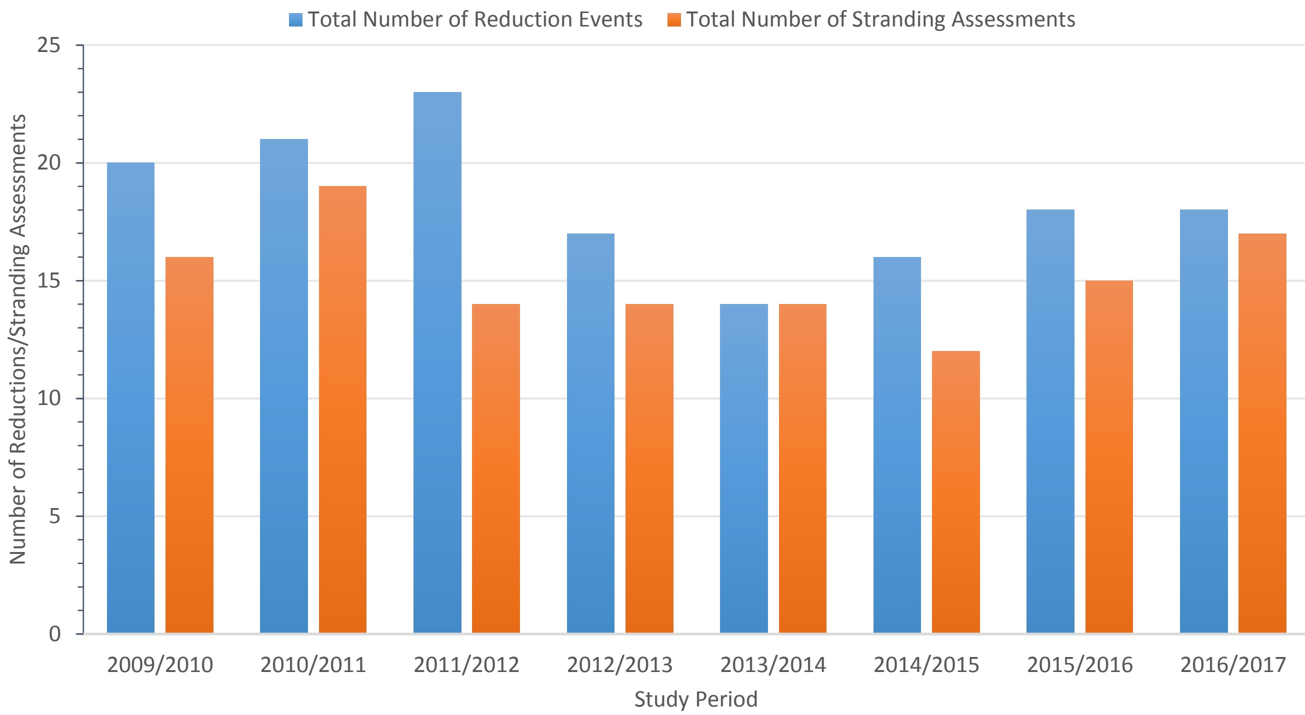

Figure 4: Total number of Reduction Events and Stranding Assessments conducted during each study period from 2009/2010 to 2016/2017.

In total, 19 different sites were assessed at least once during the 2016/2017 study period (Table 2). As with previous study years, assessment efforts were concentrated on sites identified as having a high risk of stranding fishes defined by a database query and outlined in the *Columbia River Project Water Use Plan Monitoring Program Terms of Reference - Lower Columbia River Fish Management Plan (CLBMON-42 Lower Columbia River Fish Stranding Assessment and Ramping Protocol, 31 August 2007).*

Fort Shepherd Launch (RUB) and Lions Head (RUB) were also areas of focus during the present study since they were recently re-contoured (Fort Shepherd Launch in 2014 and Lions Head in April 2015). These sites require a number of reconnaissance stranding assessments to be conducted at multiple discharge levels to assess the effectiveness of the re-contouring efforts. As a result of focused efforts at Fort Shepherd Launch (RUB) and Lions Head (RUB) in 2016/2017, some remote sites along the left downstream bank of the Columbia River, including Beaver Creek (LUB) and Fort Shepherd (LUB), were not assessed in 2016/2017. Additionally, road access to these two sites is closed annually by Fort Shepherd Conservancy from 1 December to 1 April, further limiting the possibility of conducting stranding surveys at these locations. Based on the database queries conducted during the present study there was only one occurrence of an ‘Effect’ designation at Beaver Creek (LUB) or Fort Shepherd (LUB) sites. All other designations were either ‘Reconnaissance’ or ‘No Pools’.

The most commonly assessed sites were Lions Head (RUB), Genelle Mainland (LUB) and Fort Shepherd Launch (RUB), with 17 stranding assessments conducted at each (Table 2). Genelle Mainland (LUB) was commonly assessed because it is known to be an ‘Effect’ site at a variety of discharge volumes and is therefore a higher priority for stranding assessments. Genelle Lower Cobble Island (MID) and Genelle Upper Cobble Island (MID) were assessed from Highway BC-22, therefore only the presence or absence of pools were noted. To conduct a thorough stranding assessment of Genelle Lower Cobble Island (MID) and Genelle Upper Cobble Island (MID), a boat would be required since these sites are surrounded by the Columbia River year round. See Appendix A; Figure A1 through A8 for site locations.

3.2.1 Fish Captured or Observed During 2016/2017 Stranding Assessments

Isolated pools were observed during all stranding assessments in 2016/2017 and stranded fishes were recorded at all but three events (RE2016-06, RE2016-16 and RE2017-01) (Table 1). A stranding assessment was initiated for RE2016-06 due to a 10 kcfs drop in flows from BRD/X. Birchbank discharge measurements at the time were high (approx. 110 kcfs). During this assessment crews visited 6 sites and noted a drop in water level of 0.15 to 0.2 m. Only 9 pools were found and stranded fishes were not observed. During RE2016-16 HLK/ALH dropped flows from 10 kcfs to 5 kcfs, bringing the resulting discharge to the lowest volume for the entire study period (Figure 3). A stranding assessment was initiated for this RE because discharge volumes from HLK/ALH rarely reach these levels, therefore it was beneficial to investigate ‘Reconnaissance’ sites for stranding potential at these low discharge volumes. A total of 9 sites were assessed but stranded fishes were not observed. Lion’s Head (RUB) was the only site with pools present. Assessment crews noted that it was difficult to see any noticeable reduction downstream of the Kootenay River since the drop in discharge at HLK/ALH coincided with a discharge increase from BRD/X. Reduction event RE2017-01 took place over two days (3 and 4 February 2017). The database queries conducted for each day indicated no ‘Effect’ sites, therefore the stranding assessment response on 4 February was focused on ‘Reconnaissance’ sites. A total of 11 pools were found at four sites (Tin Cup Rapids, Blueberry Creek, Genelle Lower Cobble Island, and Fort Shepherd Launch RUB). Stranded fishes were not observed.

None of the stranding assessments conducted during the sample period were classified as a ‘Significant Fish Stranding’ event (>5,000 fishes observed). Four RE did not yield any fishes, and 3,315 stranded fishes were recorded from the other 14 RE (Table 1). The RE with the highest numbers of stranded fishes were RE2016-10, RE2017-07, RE2016-11 and RE2016-12 with stranding numbers of 757, 732, 477 and 441 fishes, respectively (Table 1). Three of these RE (RE2016-10, RE2016-11, and RE2016-12) occurred during the high risk period.

The majority (81.4%) of the isolated fishes were recorded in pools located at the Genelle Mainland LUB (56.5%) and Norns Creek Fan (RUB) (24.9%) sites (Table 2). See Appendix A; Figure A1 through A8 for site locations.

Table 2: Percentage of the Total Number of Fishes Stranded at each site during the Reduction Events from 1 April 2016 to 1 April 2017.

Site[a]	Total Number of Visits	Total Number of Fishes Stranded	Median Number of Fishes Stranded per Visit	% of Total Stranded Fishes at each Site
Genelle (Mainland) (LUB)	17	1874	8	56.5
Norns Creek Fan (RUB)	15	824	2	24.9
Blueberry Creek (LUB)	5	375	0	11.3
CPR Island (MID)	4	67	0	2.0
Fort Shepherd Launch (RUB)	17	65	0	2.0
Zuckerberg Island (LUB)	7	44	0	1.3
Kootenay River (RUB)	15	32	0	1.0
Tin Cup Rapids (RUB)	12	14	0	0.4
Kootenay River (LUB)	14	9	0	0.3
Lions Head (upstream of Norns Fan) (RUB)	17	4	0	0.1
Millennium Park (Tin Cup LUB)	8	3	0	0.1
Trail Bridge (RUB) (Downstream)	2	3	1.5	0.1
Bear Creek (RUB)	10	1	0	0.0
Beaver Creek (RUB)	3	0	0	0.0
Casino Road Bridge, Trail (LUB) (Downstream)	5	0	0	0.0
Casino Road Bridge, Trail (LUB) (Upstream)	1	0	0	0.0
Genelle Lower Cobble Island (MID)	3	0	0	0.0
Genelle Upper Cobble Island (MID)	1	0	0	0.0
Gyro Boat Launch	8	0	0	0.0
Total	**163**	**3315**		**100.0**

[a]Appendix A; Figures A1 through A8
[b]LUB=left upstream bank; RUB=right upstream bank

3.2.1.1 Fish Species

3.2.1.1.1 Sportfishes

Sportfishes accounted for 24.5% of total fishes stranded in 2016/2017 (Table 3). This catch represents an increase from last year, where sportfishes only accounted for 4.6% of total fishes stranded. The median percent of sportfishes stranded since 2009 is 12.7%. The higher percentage of stranded sportfishes during the present study is attributed to 730 Mountain Whitefish fry that were found in pools on 31 March 2017 during RE2017-07. On that day, 95.8% of the Mountain Whitefish fry were found at Norns Creek Fan (RUB). Norns Creek is a known Mountain Whitefish spawning area. Once hatched, the Mountain Whitefish fry drift downstream to the mouth of the creek which provides good rearing habitat (Golder 2014). In addition to fry, two Mountain Whitefish eggs were found during stranding surveys in 2016/2017. One egg was found at Norn's Creek Fan (RUB) on 27 February 2017 (RE2017-02), and the other egg was found at Millenium Park (Tin Cup LUB) on 22 February 2017 (RE2017-03).

A total of 76 juvenile and young-of-the year Rainbow Trout were found stranded during the present study accounting for 9.4% of all stranded sportfishes. Since 2009 the median percentage of Rainbow Trout was 15.8% of all sportfishes stranded. The greatest number of stranded Rainbow Trout were observed at CPR Island (MID) (n=54), Fort Shepherd Launch (RUB) (n=10) and Tin Cup Rapids (RUB) (n=9). Of the 76 stranded Rainbow Trout 79% were salvaged. Fork length measurements (based on 39 fishes, 8 different stranding assessments) ranged from 23 to 123 mm.

3.2.1.1.2 Non-sportfishes

Non-sportfishes accounted for 75.5% of total fishes stranded during the present study. The most commonly stranded non-sportfishes were juvenile and young-of-the-year sucker species (n=973), which accounted for 38.9% of non-sportfishes recorded (Table 3). Of the total sucker species stranded in 2016/2017, 80.7% were found at Genelle Mainland (LUB). Forth lengths (n=159) ranged from 11 to 105 mm with a median value of 34 mm.

Unidentified cyprinids (n=701) were the second most abundant non-sportfishes species (See Section 3.2.1.1.3 Unidentified Fishes), followed by Longnose Dace (n=410). Longnose Dace were most commonly found stranded at Blueberry Creek (LUB) (n=208) and Genelle Mainland (LUB) (n=119). Fork lengths taken from a sub-sample (n=112) of Longnose Dace ranged from 11 to 62 mm with a median value of 25 mm.

All five Sculpin species known to inhabit the Columbia River (Columbia, Prickly, Shorthead, Slimy, and Torrent) were observed during 2016/2017 stranding assessments. The most abundant species was Torrent Sculpin (n=94), which accounted for 65% of all sculpin observed. Both adult and juvenile sculpin were recorded during the stranding assessments. Total length measurements were collected for all sculpin species. Of the measured sculpin (n=94) from the present study, 67% were considered adults, based on total lengths >45 mm *(*AMEC 2014).

Table 3: Summary of Fish Species Captured or Observed during Fish Stranding Assessments Subsequent to Reductions in Discharge from Hugh L. Keenleyside Dam/Arrow Lakes Generating Station or from Brilliant Dam/Brilliant Expansion, 1 April 2016 to 1 April 2017.

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	Mountain Whitefish (*Prosopium williamsoni*)	731	22.1	0	108	N/A	N/A	Yellow
	Rainbow Trout (*Oncorhynchus mykiss*)	76	2.3	9	60	N/A	N/A	Yellow
	Smallmouth Bass (*Micropterus dolomieu*)	4	0.1	0	1	N/A	N/A	Exotic
Non-Sportfishes	Sucker species (*Catostomidae spp.*)	973	29.4	86	821	N/A[d]	N/A[d]	N/A[d]
	Unidentified[f] Cyprinid species (*Cyprinidae spp.*)	701	21.1	0	701	N/A[e]	N/A[e]	N/A[e]
	Longnose Dace (*Rhinichthys cataractae*)	410	12.4	50	261	N/A	N/A	Yellow
	Redside Shiner (*Richardsonius balteatus*)	168	5.1	53	64	N/A	N/A	Yellow
	Torrent Sculpin (*Cottus rhotheus*)	94	2.8	5	89	N/A	N/A	Yellow
	Northern Pikeminnow (*Ptychocheilus oregonensis*)	49	1.5	2	41	N/A	N/A	Yellow
	Unidentified[f]	31	0.9	4	13	N/A[e]	N/A[e]	N/A[e]
	Columbia Sculpin (*Cottus hubbsi*)	25	0.8	0	25	Schedule 1 Special Concern	Special Concern	Blue
	Peamouth (*Mylocheilus caurinus*)	17	0.5	1	8	N/A	N/A	Yellow
	Slimy Sculpin (*Cottus cognatus*)	13	0.4	1	12	N/A	N/A	Yellow
	Umatilla Dace (*Rhinichthys umatilla*)	10	0.3	5	5	Schedule 3 Special Concern	Threatened	Red
	Sculpin species (*Cottus spp.*)	8	0.2	0	0	N/A[e]	N/A[e]	N/A[e]
	Shorthead Sculpin (*Cottus confuses*)	4	0.1	0	4	Schedule 1 Special Concern	Special Concern	Blue
	Prickly Sculpin (*Cottus asper*)	1	<0.1	0	1	N/A	N/A	Yellow
Total		**3,315**		**216**	**2,214**			

[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=ecological communities and indigenous species and subspecies that are extirpated, endangered or threatened in British Columbia; Blue=ecological communities and indigenous species and subspecies of special concern in British Columbia; Yellow=ecological communities and indigenous species and subspecies that are not at risk in British Columbia (B.C. Conservation Data Centre. 2017).
[d]No species are listed from this region that are found under any of the classification criteria for species of concern.
[e]Fish identified to family level or other high level taxa may potentially be species of concern under the classification systems listed.
[f]Not identified to species because they were young-of-the-year life stage or observed but not captured.

3.2.1.1.3 Unidentified Fishes

During this study period 31 unidentified fishes, 8 unidentified sculpin (*Cottus spp.*) and 701 unidentified cyprinids (*Cyprinidae spp*.) were observed. Of the 31 unidentified fishes observed, 83.9% were found in a large pool at Blueberry Creek (LUB) on 31 July 2016 (RE2016-07). Juvenile sucker, Longnose Dace, Northern Pikeminnow, Peamouth, Rainbow Trout, and Redside Shiner were also observed within the same pool during electrofishing efforts.

The unidentified sculpin were observed at Fort Shepherd Launch (RUB), Norns Creek Fan (RUB) and Genelle Mainland (LUB) during RE2016-11, RE2016-13, and RE2017-02. All unidentified sculpin were observed during electrofishing efforts at these sites, but none were captured or salvaged.

Of the 701 unidentified cyprinids noted in the present study, 700 were observed in a large pool at Genelle Mainland (LUB) on 23 August 2016 (RE2016-10). This pool was disconnected from the main stem of the Columbia River, but stranding assessment crews dug out a shallow channel to connect the large pool to the Columbia River. Fishes were then guided out by walking slowly through the large pool towards the newly formed escape channel. All 700 cyprinids were salvaged by escaping through the new channel.

3.2.1.1.4 Listed Fish Species

Currently, four resident fish species in the study area are considered at risk: Columbia Sculpin, Shorthead Sculpin, Umatilla Dace, and White Sturgeon (*Acipenser transmontanus*). Columbia Sculpin, Shorthead Sculpin, and Umatilla Dace were all documented during the 2016/2017 stranding assessment period (Table 4). White Sturgeon have never been observed during the Lower Columbia River Fish Stranding project.

Table 4: Summary of Listed Species Captured or Observed during Stranding Assessments, 1 April 2016 to 1 April 2017.

Site[a]	Risk Period[b]	Total Number of Visits	Number of Visits with Listed Species Present	Number of Listed Fish Stranded
Columbia Sculpin				
Genelle Mainland (LUB)	Low	17	2	21
Tin Cup Rapids (RUB)	Low	12	1	2
Kootenay River (RUB)	Low	15	1	2
Shorthead Sculpin				
Fort Shepherd Launch (RUB)	Low	17	1	2
Genelle Mainland (LUB)	Low	17	2	2
Umatilla Dace				
Genelle Mainland (LUB)	High	17	2	10
Total				**39**

[a]Appendix A; Figures A1 through A7
[b]High Risk Period = 1 June to 30 September and Low Risk period = 1 October to 31 May

Historically, the majority (95%) of listed species recorded in the Standing Database (from 2001 to present) were captured during the Low Risk period; however, it is possible that listed fishes were also stranded during the High Risk period, but were not identified to species because of their life stage (i.e., immature) or because they were simply incidentally observed during electrofishing efforts.

Umatilla Dace probably spawn in the late spring or early summer similar to closely related species (McPhail 2007); therefore, larval stage Umatilla Dace may be included in the numbers of unidentified cyprinids noted at Genelle Mainland (LUB) during RE2016-10 (23 August 2016) or the unidentified fishes observed at Blueberry Creek (LUB) during RE2016-07 (31 July 2016). Likewise the eight unidentified sculpin that were noted during electrofishing efforts may have been Columbia or Shorthead Sculpin.

Genelle Mainland (LUB) accounted for 85% of all observed listed species in 2016/2017. Historically, listed species have commonly been observed at this site (Table 5).

3.2.1.1.5 Exotic Fish Species

The only exotic fish species observed during the present study was Smallmouth Bass. One Smallmouth Bass was found stranded at Kootenay River (RUB) and three Smallmouth Bass were found stranded at Fort Shepherd Launch (RUB). The three Smallmouth Bass captured at Fort Shepherd Launch were euthanized using clove oil as requested by FLNRO (Pers. Comm., Matt Neufeld, FLNRO, 22 February 2016). One specimen was kept as a voucher. The Smallmouth Bass caught at Kootenay River (RUB) on 30 September 2016 was released alive because the fish stranding crew was not aware of the request by FLNRO to remove exotic fishes from the system.

Based on the historical catch of Smallmouth Bass (2006 to present) Fort Shepherd Launch (RUB) has accounted for 99% of all stranded Smallmouth Bass. This site is approximately 2.5 km upstream from the Columbia River confluence with the Pend d'Oreille River, which is known to have an established population of Smallmouth Bass and other invasive species (Golder 2005b).

Exotic fish species have been identified and recorded during stranding assessments since 2002 in varying numbers. Species composition has remained constant. The majority (98%) of all of the exotic fish species recorded during stranding assessments were Smallmouth Bass. The remaining 2% in order of abundance were Common Carp (*Cyprinus carpio*), Yellow Perch (*Perca flavescens*), Brook Trout (*Salvelinus fontinalis*), Tench (*Tinca tinca*) and Walleye (*Sander vitreus*).

3.2.2 Historic Fish Stranding Summary

The results of fish stranding assessments conducted between January 2000 and 1 April 2017, are summarized by site, resultant Birchbank discharge, and risk period (Table 5). This table can be used as a tool for personnel managing flow reductions to readily identify sites, flows, and seasons of high stranding risk. The numbers of fishes are presented as the maximum number of fishes observed stranded at each site during a single assessment. The classification of sites where listed species have been previously identified is included (yellow highlighted cells). In 2016/2017 Fort Shepherd Launch (RUB) was newly designated as an 'Effect' site at a resultant discharge of 60-70 kcfs during the low risk period. This designation change was a result of two Shorthead Sculpin observed at this site during RE2017-02 on 10 February 2017. The other instances where listed species were observed during the present study occurred at sites that were already designated 'Effect' sites for the associated resultant discharge.

The total number stranded, salvaged and frequency of stranding occurrences for listed species within the lower Columbia River since 2000 are as follows: 2,243 Umatilla Dace stranded (1,987 salvaged) at 14 sites during 56 reduction events, 61 Columbia Sculpin stranded (52 salvaged) at 7 sites during 10 reduction events, and 17 Shorthead Sculpin stranded (17 salvaged) at 5 sites during 4 reduction events. Based on historical data since 2000, a greater number of sites had listed species identified during the Low Risk period (n=37) than in the High Risk period (n=8). This is may be a result of the High Risk period being only four months of the year and therefore a greater number of yearly stranding events occur during the Low Risk period. For the majority of sites upstream of Trail Bridge, higher total fish numbers were recorded during the High Risk period irrespective of resultant discharge levels (Table 5).

In comparison to the Low Risk period, the High Risk period had a larger range of resultant Birchbank discharge (30 to 120 kcfs) where effects were recorded (Table 5). During the Low Risk period, resultant Birchbank discharges between 30 and 40 kcfs had the greatest number of stranded fishes of all sites. Conducting surveys at sites with no previous data or insufficient data (surveyed less than five times) will continue to help identify sites that pose a high risk of fish stranding during flow reductions.

During the present study, based on the database queries, 45% of total site visits were 'Effect' sites and 48% were 'Reconnaissance' sites. In order to confirm the accuracy of the database, 9 'Minimal Effect' sites and 3 'No Pools' sites were visited. The 'No Pools' sites were Fort Shepherd Launch (RUB), and new pools were found at all three, therefore changing the site designation from 'No Pools' to 'Reconnaissance'. As a result of focused efforts at Lions Head (RUB) and Fort Shepherd Launch (RUB) in 2016/2017, an additional four site designations have changed from 'Reconnaissance' to 'Minimal Effect' at these sites. All 'Minimal Effect' sites visited in 2016/2017 confirmed their designation with less than 200 fishes stranded.

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 2017).

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		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	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								No Pools										No Pools		No Pools					
	30-40							13500	1					0	1	620	1	No Pools		No Pools				No Pools		No Pools								0	1							200	1		
	40-50	6	3	311	4	457	4	76	3	0	1	72	3	81	5							14302	3	No Pools		No Pools		464	2					207	2	No Pools									
	50-60	425	12	215	12			253	10	34	4	2894	8	2700	13	18	6	No Pools		No Pools		2865	14			No Pools		No Pools		0	1	0	1	11	4	0	3	1	1	27	1	0	1	No Pools	
	60-70	16	10	423	22	0	1	258	13	0	6	492	23	2686	24	55	9	No Pools		1	1	37964	24			20	3	500	2	No Pools		No Pools		0	2	500	9	1	6	0	1	0	0	2	5
	70-80	42	9	56	12	No Pools		219	8	0	5	1	8	35	10	48	8	No Pools		50	4	6000	13	54	1	0	1	500	3	No Pools		No Pools		0	2	0	2	8	6	No Pools		0	2	1	4
	80-90	2	6	88	10	No Pools		34	7	4	8	No Pools		12	4	No Pools		No Pools		269	6	90	7	No Pools		3	5	0	4	No Pools		No Pools		No Pools		No Pools		0	2	No Pools		380	2	0	2
	90-100	0	4	5	9	No Pools		458	11	26	5	No Pools		No Pools		No Pools				No Pools		3060	10	No Pools		0	1	500	9	No Pools		No Pools		No Pools		No Pools		251	4	No Pools		No Pools		0	3
	100-110	No Pools		2	2	2	2	10307	4	7521	3	No Pools		No Pools		0	3	No Pools		0	1	20	3					500	2																
	110-120	0	2	No Pools		No Pools		1500	4	60	1	No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		0	1		
	>120	0	1	No Pools		No Pools		0	1	100	1	No Pools		No Pools		No Pools				0	1	No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools							
Low Risk (1 October to 31 May)	≤30	13	3	38	3	93	2	54	3	601	3	0	2	642	2	1	3	No Pools		No Pools		33	2					8	3	8	6	0	4	1	2	2013	2	No Pools		0	2	8	2	5	1
	30-40	717	21	5002	30	82	6	224	13	522	19	210	5	971	26	95	13	No Pools		No Pools		280	20	No Pools		No Pools		1455	11	19	5	0	3	1	4	12	5	38	2	0	2	80	3	9	6
	40-50	1445	36	623	40	147	29	117	34	92	20	450	31	1450	54	298	30	0	2	0	3	1414	35	No Pools		0	2	755	27	5	8	4	7	4	6	2015	2	44	9	0	3	7	5	5	9
	50-60	176	21	320	24	4	7	59	16	52	19	157	23	332	33	71	17	7	3	No Pools		400	30	0	2	0	2	351	6	0	2	0	10	21	12	0	8	2	3	20	2	2	3	0	2
	60-70	8	13	700	24	16	6	11	15	0	15	103	26	529	31	109	21	0	1	2	4	520	26	1	4	0	3	4	8	No Pools		1	9	3	9	0	5	4	3	0	2	0	2	46	4
	70-80	0	5	79	10	No Pools		0	4	0	8	0	5	10	6	0	10	No Pools		0	4	7	7	No Pools		0	2	No Pools		No Pools		No Pools		0	2	3	5	0	2	No Pools				0	1
	80-90					No Pools		0	1	0	2	No Pools				No Pools		No Pools		0	1	1	3	No Pools		0	1			No Pools		No Pools		No Pools		0	1			No Pools					
	90-100	No Pools				No Pools						No Pools		No Pools		No Pools								No Pools		No Pools		No Pools		No Pools		No Pools		No Pools		No Pools				No Pools		No Pools			
	100-110	No Pools										No Pools		No Pools														No Pools																	
	110-120			No Pools		No Pools				No Pools		No Pools		No Pools		No Pools				No Pools		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						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; isolated pools were observed; less than 200 fish were recorded during each reduction event under similar conditions (minimum of 5 visits under similar conditions). No Response.
	No Data or Insufficient Data	Site has been previously surveyed less than five times at or near these flows; less than 200 fish were recorded during each reduction event under similar conditions. Reconnaissance Survey.
	Effect	Site has been previously surveyed; isolated pools were observed; more than 200 fish were recorded during a single reduction event under similar 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 2015).
	Listed species were captured or observed.	During at least one of the visits at these sites listed species were captured or observed, during these resultant discharge levels.

Does not include data pre-recontouring.

Includes all stranding assessments and fish until 1 April 2017.

4.0 DISCUSSION

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

Analyses necessary to address management questions #1, #2, and #3 from BC Hydro Water Use Plan terms of reference were not collected during the current study period. These management questions were addressed using data presented in 2007, 2009/2010 and 2010/2011 annual summaries. The present study has contributed data to address management questions #4 and #5. Management questions to be addressed by the program include:

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

   Between 2004 and 2006 six phases of flow ramping studies (Golder 2007) were conducted to address the potential effects of HLK operations on downstream interstitial and pool based fish stranding. Ramping rate and time of day were primary variables for Phase I to Phase IV and secondary variables for Phases V and VI. Results of these studies showed that in both summer and winter studies ramping rate was not a statistically significant effect on the probability of interstitial or pool stranding. Further analysis regarding ramping rates and their effect on stranding risk was obtained through a review of fish stranding assessments between January 1999 and July 2009 from the Lower Columbia River Fish Stranding Database and presented in Golder and Poisson (2010). Results of this study reveal that there has been a consistent trend for increased stranding with increased ramping rates since the onset of experimentation in the Columbia and Kootenay river systems, however ramping rate as a variable has not been statistically significant. Based on these findings the recommendation was made to maintain ramping rates within the ranges tested (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 (1 April 2016 to 1 April 2017) the ramping rates for reduction events at HLK/ALH were maintained below 5 kcfs/hr (Table 1). Ramping rates for reduction events at BRD/X remained below 2 kcfs/hr except for RE2016-06 where rates were 2.5 kcfs/hr. Despite this higher than normal reduction rate, no stranded fishes were recorded (Table 1). The effect of ramping rate on total number of fish stranded for reduction events between 2000 and 2016 was presented by Golder (2016). There was no indication that a larger ramping interval stranded more fishes than a smaller ramping interval. Based on all previous analysis the ramping rate component of this hypothesis is not rejected.

   Results of the Phase I to Phase VI studies showed that time of day did not show a statistically significant effect on the probability of interstitial or pool stranding (Golder 2007). However it is important to note that the dataset from all phases was limited to seven night time net pens and 65 daytime net pens. Further analysis of the Lower Columbia River Fish Stranding Database by Golder and Poisson (2010) found that time of day of reduction on the stranding risk for juvenile fishes in the Columbia and Kootenay rivers, was not a highly significant variable, but did influence stranding risk. The highest risk period was in the afternoon. However, stranding assessment surveys did not occur during night time hours and therefore the dataset was completely biased towards daytime. 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 can not be rejected and must be deferred until additional time of day ramping experiments are conducted. Additional ramping experiments are outside the scope of the present study, therefore this component of the hypothesis will not be addressed.

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

An analysis on the Lower Columbia River Fish Stranding Database based on data between January 1999 and July 2009 revealed that the risk of stranding increased with increased wetted history (Poisson 2010). Additionally, there was a statistically significant increase in the number of fishes stranded during assessments conducted after a wetted history of greater than 10 days versus a wetted history of less than ten days (Poisson 2010, Golder and Poisson 2010); however, there were insufficient data to define the size of the effect (proportion of the population affected and the response to wetted histories of variable lengths greater than 10 days). A wetted history of less than or greater than 10 days represents an appropriate cutoff level for differentiating between severity of stranding risk, however the determination of whether or not to initiate a stranding assessment due to a RE should continue to be based on factors such as timing, river stage and database query results in addition to wetted history. Previous studies suggest that this management hypothesis can be rejected, however Golder recommends considering the feasibility of using River2D models from Golder (2013) in Year 11 of the current study to further investigate the effects of wetted history on the number of fish stranded per flow reduction. The River2D models incorporate 70 ADCP transects near CPR Island and the confluence area of the Columbia and Kootenay rivers which allow for quantification of fluctuations in river stage (water elevation). The River2D models can be used with hourly discharge data from HLK/AH and BRD/X to calculate wetted history prior to RE for the following stranding sites: Lions Head, Norn's Creek Fan, CPR Island, Kootenay LUB, Kootenay RUB, and Zuckerberg Island.

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 fish?*

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); however, this result was based on limited data and a recommendation was made that additional experiments be undertaken to verify the results. 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 is still under consideration and further discussions regarding the operational risk versus biological rationale are needed. 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). Due to limited data, this hypothesis cannot be rejected at this time and must be deferred. If there is no desire for conducting additional conditioning flow experiments at HLK/ALH due to the risks of mortality inherent to any intentional conditional flow reductions, abandonment of this strategy should be considered.

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

Over the past 16 years, five previously identified high risk stranding sites have been re-contoured in an attempt to mitigate the occurrence and magnitude of fish stranding. The Genelle Lower Cobble Island site and Millennium Park site were re-contoured in 2001, Norn's Creek Fan site was re-contoured in 2002, Genelle Mainland site was re-contoured in 2003 and most recently Lions Head (upstream of Norn's Fan) was re-contoured in April 2015. At Genelle Lower Cobble Island, Millennium Park, Norn's Creek Fan, and Genelle Mainland re-contouring reduced the incidence of fish stranding (Golder and Poisson 2010); however, the effect size (the proportion of the population or the relative number of fishes not stranded as a result of the physical habitat works) was not estimated due to limited data. Irvine et al. (2014) indicated significant benefits of re-contouring on reducing the rate of stranding using a data set from this system. This suggests that physical habitat alteration has benefits, particularly at sites that have high stranding potential and have physical conditions suitable for re-contouring. As of April 2017 there have been 30 stranding assessments conducted at Lions Head after it was re-contoured. Stranding assessments since re-contouring efforts have showed a reduced stranding rate (34 stranded fishes for 30 assessments [median = 0, average = 1.3] after re-contouring compared to 1618 stranded fishes for 87 assessments [median = 0, average = 18.6] before re-contouring).

The Fort Shepherd Launch (RUB) site was re-contoured between fall of 2012 and spring of 2013 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. The previous Fort Shepherd Launch (RUB) site was renamed as 'Fort Shepherd Launch (RUB) Before Re-contouring'. A total of 40 stranding assessments have been conducted at this site since re-contouring occurred. Similar to Lions Head site, the initial results of re-contouring efforts are promising (80 stranded fishes for 40 assessments [median = 0, average = 2.2] after re-contouring compared to 20,493 stranded fishes for 151 assessments [median = 0, average = 137.5] before re-contouring). CPC is investigating post-project benefits of these physical alterations at this site (Pers. Comm., Teal Moffat, CPC, July 2015).

Additional stranding assessments at both Lions Head and Fort Shepherd Launch (RUB) should be conducted in order to fill in data gaps at different discharge volumes. Golder recommends at least five site visits be conducted at each 10 kcfs/hr discharge interval (see Table 5) before removal of these sites from the current study should be considered. While previous analysis (Golder and Poisson 2010, Irvine et al. 2014) suggests that management hypothesis #4 can be rejected, Golder recommends that in Year 11 of the current study, a generalized linear Poisson counts model be applied to all re-contoured sites to provide a statistical analysis regarding the effectiveness of re-contouring.

5) *Does the continued collection of stranding data, and upgrading of the lower Columbia River stranding protocol, limit the number of occurrences when stranding crews need to be deployed due to flow reductions from HLK?*

In the previous ten years, the continued collection of stranding data has not proven to limit the number of stranding assessments required due to reduction events from HLK/ALH and the hypothesis can be rejected. Since 2009, the number of stranding assessments conducted due to flow reductions from HLK/ALH has fluctuated from 8 to 15, with 84% of HLK/ALH reduction events initiating a stranding assessment. In recent years there has been an increase in the percent of HLK/ALH reduction events that initiate stranding assessments (73% in 2014/2015, 83% in 2015/2016 and 92% in 2016/2017).

A potential explanation for the higher percentage of stranding assessments in 2016/2017 were low discharge volumes from HLK/ALH in late October and November 2016 (RE2016-16 dropped HLK/ALH flow to 5 kcfs). Due to a limited number of stranding assessments previously conducted during low discharge volumes (Table 5), a number of assessments were initiated to assess 'Reconnaissance' sites and fill in data gaps. Additionally, the identification of listed species (i.e., Umatilla Dace, Columbia Sculpin, Shorthead Sculpin) at sites where they had previously not been found has in some cases changed the site designation from 'Reconnaissance' or 'Minimal Effect' to 'Effect' thereby increasing the assessment priority for future reduction events. In 2016/2017 two new sites at a given discharge interval became 'Effect' sites due to the identification of listed species (Table 5).

Although the use of the Columbia River Stranding Protocol and the continued collection of stranding data has not shown to limit the number of stranding assessments required, the data has lead to the designation of sites from "Reconnaissance' to 'No Pools', 'Minimal Effect', 'Effect' or 'Significant Fish Stranding' and has therefore refined the accuracy of database queries. As database queries become more accurate with additional data, the decision to initiate a stranding assessment and the stranding assessments themselves become more effective. Since the majority of the data clusters around resultant Birchbank discharge between 70 and 30 kcfs (Table 5), the elimination of data gaps in less common discharge levels will further focus stranding assessment efforts.

5.0 RECOMMENDATIONS

- In an effort to definitively address management question #2 Golder recommends considering the feasibility of using River2D models from Golder (2013) in Year 11 of the current study to further investigate the effects of wetted history on the number of fishes stranded per flow reduction. The River2D models incorporates 70 ADCP transects near CPR Island and the confluence area of the Columbia and Kootenay rivers which allow for quantification of fluctuations in river stage (water elevation). The River2D models can be used with hourly discharge data from HLK/AH and BRD/X to calculate wetted history prior to RE for the following stranding sites: Lions Head, Norn's Creek Fan, CPR Island, Kootenay LUB, Kootenay RUB, and Zuckerberg Island.

- Very limited experimentation has been conducted to address whether 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 will reduce the stranding rate of fish (management question #3). Currently the hypothesis can not be rejected. If there is no desire for conducting additional conditioning flow experiments at HLK/ALH due to the risks of mortality inherent to any intentional conditional flow reductions, abandonment of this strategy should be considered.

- In an effort to definitively address management question #5 Golder recommends that in Year 11 of the current study a generalized linear Poisson model be applied to all re-contoured sites based on data from the Lower Columbia River Fish Stranding Database. This analysis would compare fish stranding results from sites before and after re-contouring and will provide an assessment on the statistical significance of re-contouring efforts. Based on the results of this analysis re-contouring may be recommended at a number of areas, including sites that have previously been re-contoured because of recent changes in morphology. 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 taking into account the results of the statistical analysis, 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. 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 discharge volumes. 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. Suggested modifications include improving drainage between the access road and the Whispering Pines Trailer Park and removing a depositional berm that has formed since the original re-contouring.

- **Gyro Boat Launch (RUB)**

  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.

- Target sites designated as 'Reconnaissance' sites by database queries in order to fill in data gaps. Additional 'Reconnaissance' site data will lead to a site designation of 'No Pools', 'Minimal Effect', 'Effect' or 'Significant Fish Stranding', thereby increasing the accuracy of the database. As the database becomes more refined so too will the decision to initiate stranding assessments. An additional emphasis should be made to visit Lions Head (upstream of Norns Fan RUB) and Fort Shepherd Launch (RUB), due to recent re-contouring, and stranding sites downstream of Trail, BC, as the majority of data gaps at all flow levels occur for these sites.

- It is probable that not all stranded fishes are detected during assessments, leading to underestimates of the stranding risk in terms of the number of fishes. However, as the thresholds for an 'Effect' (>200 fishes) or 'Significant Fish Stranding' (>5000 fishes) are often based on visual estimates by observers that are highly experienced in fish stranding assessments, and these guidelines are used consistently over time, these methods are unlikely to seriously bias the stranding risk categories predicted by using the Lower Columbia River Fish Stranding Database; however, if managers wish to validate assumptions of this method or refine estimates of the number of stranded fishes, then additional studies or modifications to the assessment and survey protocols would be necessary.

- Assess the validity of keeping sites in the Lower Columbia River Fish Stranding Database that are rarely assessed, as access to these sites over a range of flow reductions is challenging. These would include upper and lower Cobble Island sites in Genelle since these sites can only be accessed by boat and Beaver Creek (LUB) and Fort Shepherd (LUB) since access to these sites is blocked by the Fort Shepherd Conservancy between 1 December and 1 April.

6.0 CLOSURE

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

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APPENDIX A

Site Maps

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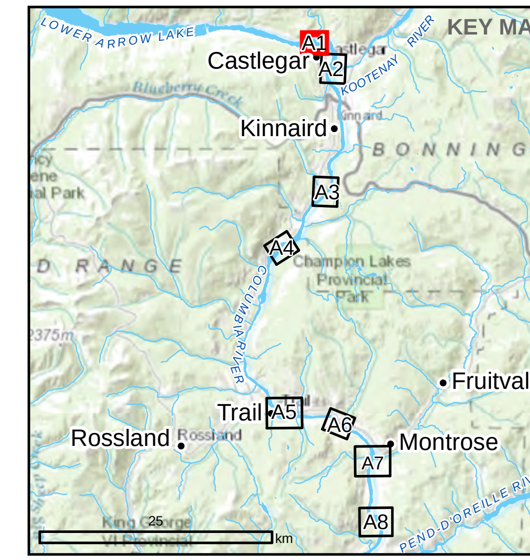

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PROJECT
LOWER COLUMBIA RIVER AND KOOTENAY RIVER FISH STRANDING

TITLE
STRANDING SITES: UPPER SECTION - COLUMBIA RIVER

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-04-21
PREPARED	CD
DESIGN	KL
REVIEW	
APPROVED	

PROJECT No.	CONTROL	Rev.	FIGURE
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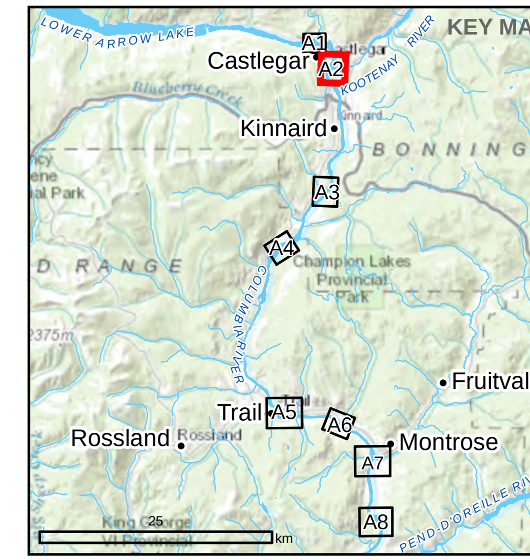

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PROJECT
LOWER COLUMBIA RIVER AND KOOTENAY RIVER FISH STRANDING

TITLE
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CONSULTANT
Golder Associates

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PREPARED	CD
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REVIEW	
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PROJECT No.	CONTROL	Rev.	FIGURE
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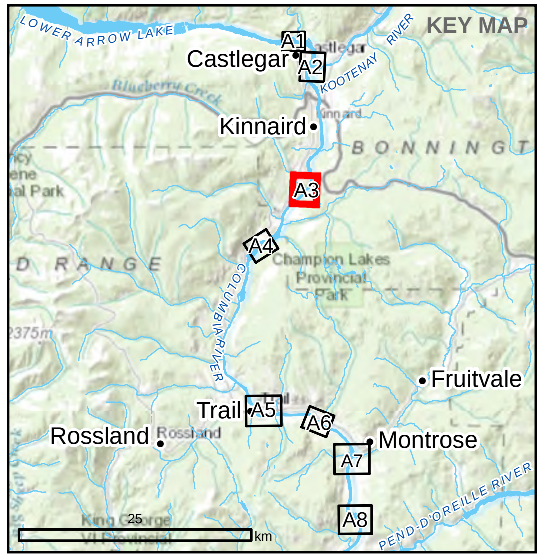

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LOWER COLUMBIA RIVER AND KOOTENAY RIVER FISH STRANDING

TITLE
STRANDING SITES: UPPER SECTION - COLUMBIA RIVER

CONSULTANT
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YYYY-MM-DD	2017-04-21
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DESIGN	KL
REVIEW	
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PROJECT No.	CONTROL	Rev.	FIGURE
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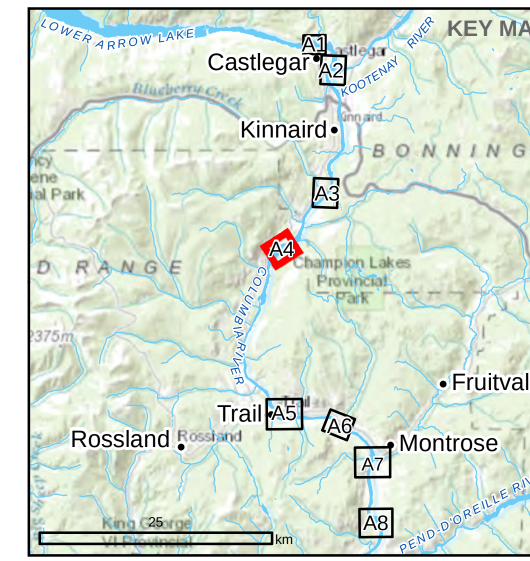

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LOWER COLUMBIA RIVER AND KOOTENAY RIVER FISH STRANDING

TITLE
STRANDING SITES: MIDDLE SECTION - COLUMBIA RIVER

CONSULTANT		
Golder Associates	YYYY-MM-DD	2017-04-21
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PROJECT No.	CONTROL	Rev.	FIGURE
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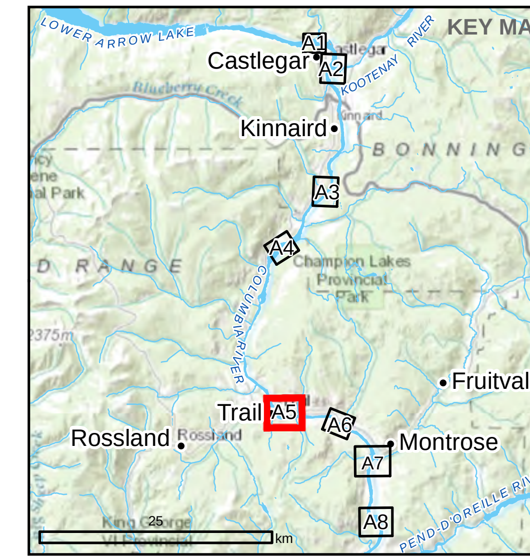

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PROJECT
LOWER COLUMBIA RIVER AND KOOTENAY RIVER FISH STANDING

TITLE
STRANDING SITES: LOWER SECTION - COLUMBIA RIVER

CONSULTANT

Golder Associates

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DESIGN	KL
REVIEW	
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PROJECT No.	CONTROL	Rev.	FIGURE
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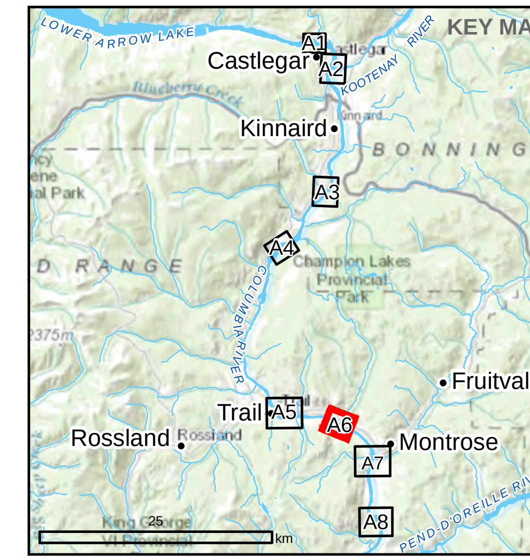

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PROJECT
LOWER COLUMBIA RIVER AND
KOOTENAY RIVER FISH STRANDING

TITLE
STRANDING SITES: LOWER SECTION - COLUMBIA RIVER

CONSULTANT

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PROJECT No.	CONTROL	Rev.	FIGURE
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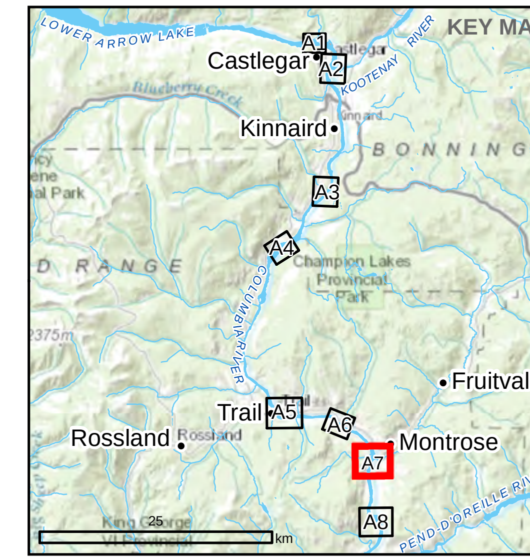

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PROJECT
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KOOTENAY RIVER FISH STRANDING

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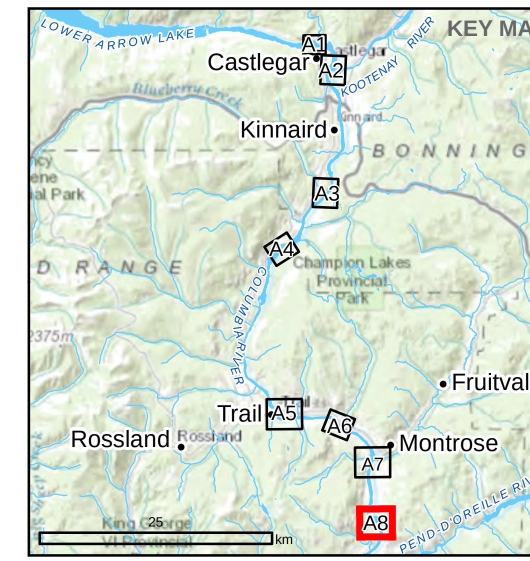

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