# Coquitlam-Buntzen Water Use Plan

## *Coquitlam River Rampdown Fish Stranding Monitoring*

**Implementation Year 16**

**Study Period: January 1, 2021 – December 31, 2021**

**Living Resources Environmental Services**
#503, 2095 Beach Ave. Vancouver B.C. V5Y 1S7
Ph: 604-862-2323 Email:livingresourcesbc@yahoo.ca

**April 20, 2023**

## Executive Summary

This report summarizes rampdown events occurring on the Lower Coquitlam River for the year 2021. A total of 5 rampdown events were monitored during the annual survey period: two scheduled rampdowns; in June and September 2021, and three unscheduled rampdowns in February, November and December 2021.

The year 2021 was the 13th complete year under the Treatment 2 flow regime. Under Treatment 2, rampdowns are more frequent, but of a much smaller scale in terms of total reduction in flow volume. Additionally, they are predictable due to their scheduled operational dates. The removal of the temporary dam safety 149m maximum allowable reservoir operating level in 2008, following commissioning of the new dam, increased reservoir storage but has not lead to a reduction in the frequency of large scale flow releases and subsequent full river rampdown fisheries impact surveys. Under Treatment 2, the total number of rampdowns per year has increased to an average of 6.6 up from 2.7 per year prior to 2009.

Areas previously identified as susceptible to de-watering and fish stranding were visually inspected by survey crews during each rampdown event. Stranded fish are captured and relocated to the river mainstem by dip netting, seine netting or gee-type minnow traps. The two scheduled rampdowns stranded a total of 4502 fish, 4375 of which were salvaged alive. All fish observed during these two rampdowns were stranded during the June-July rampdown, which accounted for 95.9% of all stranding in 2021. The three unscheduled rampdown event produced a total of 191 stranded fish observed and 37 mortalities. In addition to the stranded fish a total of 94 stranded redds were identified during the November and December ramp events as they occurred at the height of adult chum and coho spawning. The total number of fish stranded for all rampdowns, was 4693 with a mortality rate of 3.5%. The majority of stranded fish observed during fish salvage operations were juvenile Coho Salmon (92.4% of the total).

Efforts to reduce the amount of stranding during the scheduled flow reduction in June have been largely unsuccessful despite continued modifications to the ramping protocol. Originally planned as a one day ramp event, the high amount of fish mortality and the excessively fast ramp rate experienced in 2011 and 2012 prompted alterations to the ramping protocol.

Beginning in 2013 the rampdown was extended to multiple days in an attempt to reduce stranding and mortality and to bring the ramping rate to within Provincial standards. Initially spread out over two days in 2013, then increased to 3 days in 2015. The rampdown in 2021 was spread out over 6 days. This operational modification included 4 ramping days in June, followed by a two week pause until the remainder of the flow reduction was completed over two days in the first

week of July. The ramping rate continued to be well below Provincial standards maximum allowable rate of 2.5cm/hr. In 2021 the June ramp rate averaged 1.2cm/hr stage decrease in Reach 4 and 0.65cm/hr in Reach 1, with a maximum stage decrease of 1.7cm/hr on June 1 the first day of the rampdown.

Since modifications to the ramping protocol were introduced in 2013, ramp rates on The Coquitlam River have consistently been within provincial standards, which suggests that fish stranding during the June rampdown may not be closely related to the ramping rate. Other factors such as the target flow of 1.1 $m^3/s$ for the month of June and the time of year the flow reduction occurs likely have a greater impact on stranding. Ramping operational protocol alterations during Treatment 2 have managed to reduce the mortality rate due to stranding during the June flow reduction, but not the amount of fish stranded.

**Acknowledgements**

This project was supported by BC Hydro Water Licence Requirements. Cam Hiebert, Teri Neighbour, Alexis Hall, Andrew Walter Katy Jay (BC Hydro) kindly provided liaison with BC Hydro operations staff and information on all gate closures. Thank you to field technicians, Thibault Doix, Kate Fremlin, Lee Su-Feh, Ioana Popa, Elaine Esteban, Jaime Martz and Wylin Macnair.

BC Hydro operations staff for access to the gate house and updates.

**Table of Contents**

1.0 Introduction and Site Description ..... 6

2.0 Methods ..... 10

3.0 Fish Salvage Results ..... 13

3.1 Scheduled Rampdown Summaries 2021 ..... 15
3.2.1 Coquitlam Rampdown Summary June 1, 5, 7, 10, July 1, 5, 2021 ..... 15
3.2.2 Coquitlam Rampdown Summary September 1, 2021 ..... 16
3.2 Unscheduled Rampdowns Summaries 2021 ..... 18
3.2.1 Coquitlam Rampdown Summary February 27-28, 2021 ..... 18
3.2.2 Coquitlam Rampdown Summary November 4-6, 2021 ..... 18
3.2.3 Coquitlam Rampdown Summary December 13-14, 2021 ..... 19

4.0 Discussion ..... 21

4.1 Stranding Risk ..... 21
4.2 Ramping Rate ..... 24
4.3 Redd Stranding ..... 25
4.4 Fish Productivity Impacts ..... 26
4.4 Rampdown Frequency ..... 27

5.0 Conclusions and Recommendations ..... 28

Appendix 1 Site descriptions and photographs ..... 33

Appendix 2 June-July 2021 Coquitlam River rampdown site maps and discreet stranding locations represented by red dots. Total number of fish stranded not sorted by species. ..... 38

**List of Tables**

Table 1 Coquitlam River flow release schedule 2021. Higher flows in Jan-Feb due to COQ/BUN tunnel project spill requirement. April and May flows increased for KRSP sockeye smolt attraction flows. Higher flow in June for COQ rampdown fish salvage modification. ..... 9

Table 2 Revised gate adjustment schedule for Coquitlam Dam Low level outlet gates during release reductions. Release varies depending on reservoir elevation. Steps are implemented at 0.5hr intervals. Generation operating order COQ/LBD 4G-24v5. August 30, 2013 ..... 11

Table 3 Rampdown schedule June 2021 Treatment 2 showing daily flow reduction from CQD ..... 15

Table 4 Fish stranding by species, age class and Reach during scheduled rampdowns 2021. Co 0 = Coho fry. Co 1+ = Coho parr/smolt. TSS = Threespine Stickleback. St 0 = Steelhead fry ..... 17

Table 5 Fish stranding by species, age class and Reach during unscheduled rampdowns 2021. Co 0 = Coho fry. Co 1+ = Coho parr/smolt. TSS = Three spine Stickleback. Pk 0 = Pink fry. t 0 = Steelhead fry ..... 20

Table 6 Scheduled rampdown salvaged and mortality. Rampdowns in 2010, 2013 and 2106 were effected by rainfall during flow reduction and fish salvage activities. 2018-2109 and 2021 ramped down from KSRP flow release schedule. ..... 23

Table 7 Ramp rate and flow reductions Reach 4 SG 2021 ..... 24

Table 8 Ramp rate and flow reductions WSC gauge Reach 1 2021 ..... 25

Table 9 Stranding and mortality scheduled vs. unscheduled rampdowns 2001-2021 .... 25

Table 10 Redd stranding on Coquitlam River 2001-2021. Steelhead spawning timing March-May, Pink chum and coho, September-December ..... 26

Table 11 Number of rampdown per year 2001-2021 ..... 27

**List of Figures**

Figure 1 Coquitlam-Buntzen Reservoir, Diversion and Generating System. Map adapted from BC Hydro. Coquitlam-Buntzen Water Use Plan Monitoring Program Terms of Reference Revision 1: December 14, 2006 ..... 8

Figure 2 Coquitlam River stranding distribution by species and age class 2021. ..... 13

Figure 3 Coquitlam River stranding distribution by species and age class, January 2001-December 2021, all rampdowns. ..... 14

Figure 4 Stranding distribution by Reach, all rampdowns, 2001 – Dec 2021, and for the monitoring year 2021. ..... 14

Figure 5 Number of fish salvaged and mortalities for all rampdowns 2003-2021. 2009 was the first full year under Treatment 2. ..... 21

Figure 6 Coquitlam River Rampdown mortality rate, all rampdowns 2003-2021 ..... 23

Figure 7 Site A1 showing gravel bar separating river mainstem (left) with isolated pool (right), following rampdown June 1 2012 ..... 33

Figure 8 Site A1 showing trench dug to allow water from river mainstem to flow into isolated pool ..... 33

Figure 9 Site A1 showing gravel area on gravel bar fluvial island where fish are regularly stranded ..... 34

Figure 10 Site B2, showing isolated pool formed during flow reduction, this site strands juveniles, adults and redds. Substrate is primarily sand/silt. ..... 35

Figure 11 View of site C1 side channel that is wetted during single gate openings. This site typically has one of the highest incidences of stranding on the Coquitlam River. ..... 36

# 1.0 Introduction and Site Description

The Coquitlam River watershed, located in the Greater Vancouver area in southwestern British Columbia, is a typical southwest Pacific coastal watershed. Natural river flows are dominated by snowmelt during the spring months, with lower flows through dry summer months prior to elevated precipitation driven flows October through March. The Coquitlam Lake Reservoir portion of the watershed is utilized by two facilities. Coquitlam Dam, with origins dating back to 1892, also provides an intake for domestic water supply by Metro Vancouver for the Greater Vancouver area. The other facility, BC Hydro's Lake Buntzen generation project dates to 1903 and uses water diverted from Coquitlam Lake Reservoir via a 3.9 km tunnel to Buntzen Lake Reservoir for electricity generation, located on Indian Arm, Burrard Inlet (Figure 1) (BC Hydro 2005).

The Lower Coquitlam River watershed covers an area of approximately 80 $km^2$ and has its source at the Coquitlam Dam located within the Metro Vancouver watershed boundary. The Lower Coquitlam River flows though the municipality of Port Coquitlam before its' confluence with the Fraser River. At present the lower watershed is impacted by gravel extraction, the many impacts of urban and industrial development and the variable controlled discharges from the dam.

Controlled flow releases from the Coquiltam Dam have potential impacts on downstream aquatic communities. Fish can be affected by ramping rates (rate at which flow is released or decreased from the dam outlets) at all life-history stages. Impacts can include stranding of redds, fry, juveniles or adults depending on time of year. Rampdown monitoring serves to minimize the potential impacts by identifying areas known to be susceptible to stranding during rampdown events.

Investigations into the impact of rampdowns on fish in the Lower Coquitlam River have been ongoing since 2001. Rampdown assessments undertaken since 2001 have focused on developing survey methods that will enable BC Hydro to evaluate the performance of the interim ramping rate (Table 2), and its influence on mitigating fish stranding on the Coquitlam River. With respect to this, the management questions outlined by the WUP Consultative Committee (CC) and addressed during monitoring in 2003-2021 (BC Hydro CQD WUP TOR 2006) are:

> *a) What is the most appropriate ramping rate protocol that should be developed for the Coquitlam Dam that best reduces fish stranding risk while being operationally feasible?*
>
> *b) What are the ongoing fish stranding risks and/or impacts of the revised ramping rate protocol?*

The result of management question (a) being addressed, was the implementation of the interim ramping rate protocol in 2005. The following hypothesis will be tested over the remainder of the review period to continue to evaluate the performance of the interim ramp rate protocol:

H1: *The LB1 WUP interim ramping rate protocol does not strand fish at index sites in the lower Coquitlam River.*

The ramping rate established under Treatments 1 and 2 has the goal of minimizing the impact of stranding during rampdowns, while maintaining operational feasibility (BC Hydro 2005) (See Table 2). Following completion of the seismic upgrade on the Coquitlam Dam in October 2008, a new flow release schedule (Treatment 2) was initiated. Under this new flow regime a series of scheduled rampdowns occur at pre-determined times throughout the year. These rampdowns amount to small scale reductions (between 3.0 $m^3/s$ and 0.60 $m^3/s$) in the total volume of water released from the Coquitlam Dam (Table 1), but can represent a sizeable decrease in the total volume of water entering the Lower Coquitlam River. For example, rampdowns scheduled for the dates January 15 and June 1 constitute a drop in the total flow release into the Lower Coquitlam River of 51% and 62% respectively (Table 1).

The introduction of the new flow regime is tied to the Lower Coquitlam Fish Productivity Index study (COQMON-7) as part of the Coquitlam River Water Use Plan (LB1 WUP). It is central to a long-term adaptive management study being conducted in the Lower Coquitlam River to compare anadromous fish production under two experimental flow regimes.

Since 2001, downstream stranding risk has been assessed on the lower Coquitlam River at several locations from the dam to the confluence with Maple Creek (Macnair et.al 2004-2019). The total survey area incorporates approximately 14 river kilometers.

Areas that are not highlighted on the maps in Appendix 3 are generally free of any characteristics that would indicate susceptibility to stranding. All areas not highlighted have been surveyed at least once over the past several years and have been determined by survey crews to have minimal or no stranding risk due to the complete absence of any observed stranding and the stream morphology of the area, therefore, they are not regularly included in any rampdown assessments.

Stranding is identified by three categories:

1. Adult stranding of spawning salmon, which is confined to the active spawning period (Oct.- Jan. depending on species), or other resident adult species.
2. Redd stranding during active spawning and incubation period for Pacific salmon, autumn and winter and steelhead (*Oncorhynchus mykiss*) in the spring (March-June).
3. Juvenile stranding (fry, parr and smolt), potential risk exists year round.

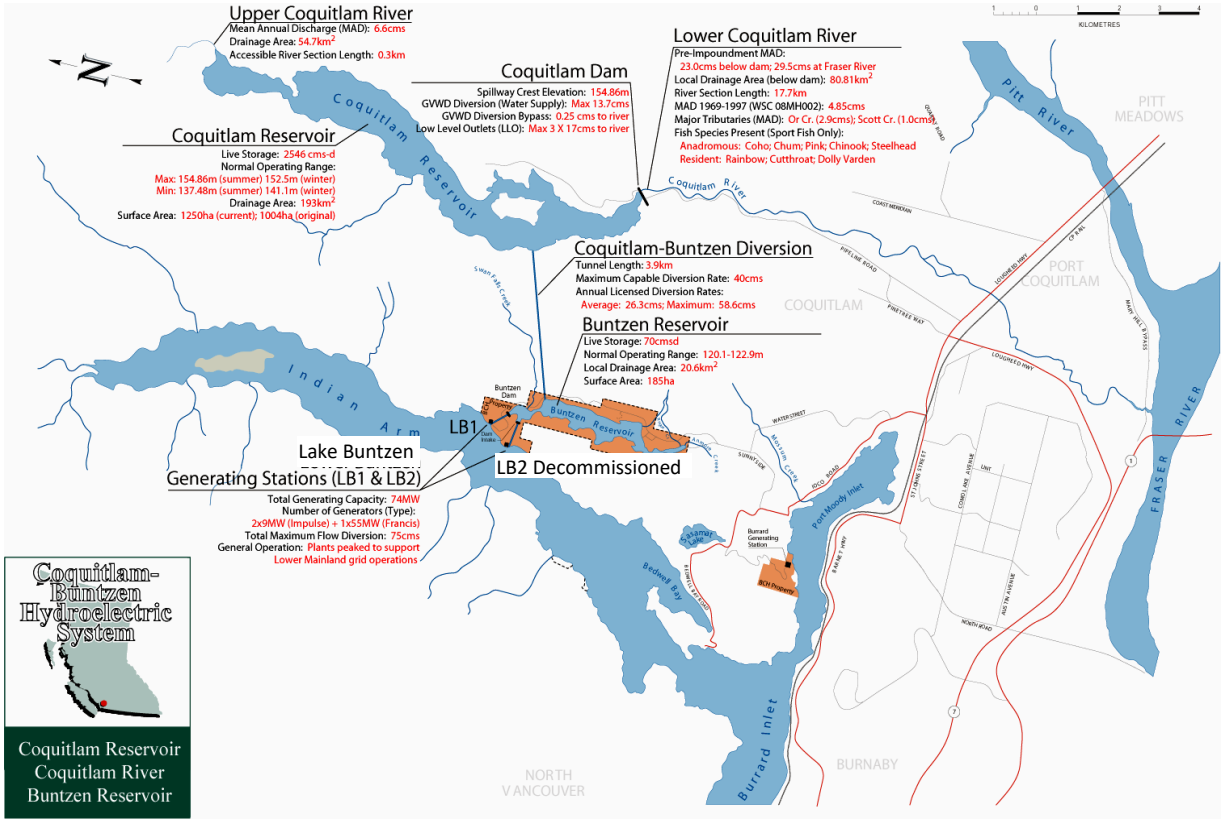


**Figure 1 Coquitlam-Buntzen Reservoir, Diversion and Generating System. Map adapted from BC Hydro. Coquitlam-Buntzen Water Use Plan Monitoring Program Terms of Reference Revision 1: December 14, 2006**

These categories are used to distinguish stranding by the life stage of salmonids using the Coquitlam River. A single adult female stranded or redd stranded may represent the possible loss of thousands of eggs and the resulting loss of fry, whereas the loss of one fry among potential millions (e.g. Chum (*Oncorhynchus keta*) and Pink Salmon (*Oncorhynchus gorbuscha*) fry) would not have the same impact on fish productivity. Redd and adult stranding, however, is much less frequent than juvenile fish stranding.

Mortalities of adults and juveniles during rampdown events can result from fish being caught in pools or ephemeral channels which dewater during flow reductions. This leaves fish isolated in areas that eventually dewater. In addition, fry are vulnerable to increased predation risk and oxygen depletion when trapped in highly visible, shallow pools (Bradford, 1997). Elevated dam releases during the fall or spring may temporarily give access to spawning areas which dewater during subsequent flow reduction. This can strand redds, and render incubated eggs or alevin unviable.

**Table 1 Coquitlam River flow release schedule 2021. Higher flows in Jan-Feb due to COQ/BUN tunnel project spill requirement. April and May flows increased for KRSP sockeye smolt attraction flows. Higher flow in June for COQ rampdown fish salvage modification. Flow increase in September (initiated on Sept 14) for KRSP adult sockeye passage. Table adapted from BC Hydro. Coquitlam-Buntzen Water Use Plan Monitoring Program Terms of Reference**

| | | Reservoir Diversion Schedule ($m^3$/sec) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Domestic Water | | Coquitlam Dam Releases | | | |
| | | | | Treatment 1 | Treatment 2 | | |
| Month | Year | Target | Min | Target | Target | Actual | Min |
| January 1-15 | 2021 | 12.0 | 10.8 | 0.8 | 5.9 | **~20** | 1.1 |
| Jan 15- March | 2021 | 12.0 | 11 | 1.0 | 2.9 | **~20** | 1.1 |
| March | 2021 | 12.0 | 10.9 | 1.4 | 4.3 | 4.3 | 1.1 |
| April | 2021 | 18.0 | 15.8 | 1.4 | 3.5 | **6.0** | 1.1 |
| May | 2021 | 23.0 | 20.2 | 1.1 | 2.9 | **6.0** | 1.1 |
| June | 2021 | 23.0 | 20.9 | 0.8 | 1.1 | **2.0** | 1.1 |
| July | 2021 | 12.0 | 10.8 | 0.8 | 1.2 | 1.2 | 3.6 |
| August | 2021 | 12.0 | 10.8 | 1.1 | 2.7 | 2.7 | 1.5 |
| September | 2021 | 11.9 | 10.7 | 1.1 | 2.2 | **2.2-4.0** | 2.5 |
| October | 2021 | 11.9 | 10.7 | 1.0 | 6.1 | 6.1 | 3.6 |
| November | 2021 | 11.9 | 10.7 | 1.0 | 4.0 | 4.0 | 2.9 |
| December | 2021 | 11.9 | 10.7 | 1.0 | 5.9 | 5.9 | 1.1 |

## 2.0 Methods

During flow reductions, locations susceptible to stranding risk are assessed during daylight hours by crews of two to six people. Crew size varies depending on the potential stranding risk associated with a particular rampdown. Due to the short duration of most rampdown events and the large amount of habitat potentially affected, only locations that are most susceptible or have been previously identified as high risk are assessed. Areas susceptible to stranding are generally adjacent to the river mainstem and have a flat, un-sloped topography containing numerous potholes and depressions where isolated pools can form (Appendix 1 Figure 10). Ephemeral side channels that fill during flow releases and drain completely following gate closures are also highly susceptible to stranding (Appendix 1 Figure 11). Areas judged to have no stranding risk are usually steeply sloped river banks that drain rapidly and do not retain any standing water, or areas that have been surveyed repeatedly with no stranding being observed.

Susceptible areas are visually surveyed several times over the course of the rampdown event to assess at what point stranding becomes evident. All isolated pools are assessed for fish and initial attempts at salvaging are conducted with dip nets or seine nets. Fish that are observed to be in danger of stranding, but are not yet stranded can be "pushed" or "chased" out of high risk areas by the survey crews. Another technique employed is the use of shovels to dig out escape channels that open access to the river mainstem, allowing fish a safe passage out of stranding areas. Areas that are difficult to net by hand or are known to strand large numbers of fish are fished overnight with baited minnow traps.

Rampdown site assessments are also linked to dam operations through the three LLO gates and their release stages (Table 2). Timing of site assessments can be correlated with the specific LLO gate flow release stage. Survey crews keep in constant contact with BC Hydro gate operators during rampdown events to ensure proper survey timing during dewatering. Prior to initiation of gate changes the rampdown survey crew checks in with BC Hydro operating staff to determine rampdown start and finish time. Remote gate operation was added to the Coquitlam Dam low level outlet gates in September 2013. The gate movements are now controlled remotely from BC Hydro's Real Time Operations Center at Fraser Valley Operations (FVO).

**Table 2 Revised gate adjustment schedule for Coquitlam Dam Low level outlet gates during release reductions. Release varies depending on reservoir elevation. Steps are implemented at 0.5hr intervals. Generation operating order COQ/LBD 4G-24v5. August 30, 2013**

| Gate | Step | Gate Change | | |
|---|---|---|---|---|
| | | From | To | Q $m^3$sec |
| LLOG1 | 1 | 100% | 55% | |
| LLOG1 | 2 | 55% | 28% | |
| LLOG1 | 3 | 28% | 11% | |
| LLOG1 | 4 | 10% | 0% | |
| LLOG2 | 5 | 100% | 77% | |
| LLOG2 | 6 | 77% | 60% | |
| LLOG2 | 7 | 60% | 40% | |
| LLOG2 | 8 | 40% | 27% | |
| LLOG2 | 9 | 27% | 15% | |
| LLOG2 | 10 | 15% | 5% | |
| LLOG2 | 11 | 5% | 0% | |
| LLOG3 (Knife Gate Valve) | 12 | 100% | 85% | 9.5 |
| LLOG3 (Knife Gate Valve) | 13 | 85% | 83% | 8.8 |
| LLOG3 (Knife Gate Valve) | 14 | 83% | 81% | 8.5 |
| LLOG3 (Knife Gate Valve) | 15 | 81% | 79% | 8.3 |
| LLOG3 (Knife Gate Valve) | 16 | 79% | 76% | 8.1 |
| LLOG3 (Knife Gate Valve) | 17 | 76% | 71% | 7.9 |
| LLOG3 (Knife Gate Valve) | 18 | 71% | 66% | 7.7 |
| LLOG3 (Knife Gate Valve) | 19 | 66% | 62% | 7.3 |
| LLOG3 (Knife Gate Valve) | 20 | 62% | 60% | 7.0 |
| LLOG3 (Knife Gate Valve) | 21 | 60% | 56% | 6.6 |
| LLOG3 (Knife Gate Valve) | 22 | 56% | 53% | 6.2 |
| LLOG3 (Knife Gate Valve) | 23 | 53% | 48% | 5.9 |
| LLOG3 (Knife Gate Valve) | 24 | 48% | 45% | 5.5 |
| LLOG3 (Knife Gate Valve) | 25 | 45% | 41% | 5.1 |
| LLOG3 (Knife Gate Valve) | 26 | 41% | 34% | 4.8 |
| LLOG3 (Knife Gate Valve) | 27 | 34% | 31% | 4.1 |
| LLOG3 (Knife Gate Valve) | 28 | 31% | 28% | 3.5 |
| LLOG3 (Knife Gate Valve) | 29 | 28% | 26% | 3.2 |
| LLOG3 (Knife Gate Valve) | 30 | 26% | 24% | 2.8 |
| LLOG3 (Knife Gate Valve) | 31 | 24% | 22% | 2.6 |
| LLOG3 (Knife Gate Valve) | 32 | 22% | 20% | 2.4 |
| LLOG3 (Knife Gate Valve) | 33 | 20% | 18% | 2.2 |
| LLOG3 (Knife Gate Valve) | 34 | 18% | 16% | 2.0 |
| LLOG3 (Knife Gate Valve) | 35 | 16% | 14% | 1.8 |
| LLOG3 (Knife Gate Valve) | 36 | 14% | 12% | 1.6 |
| LLOG3 (Knife Gate Valve) | 37 | 12% | 10% | 1.4 |
| LLOG3 (Knife Gate Valve) | 38 | 10% | 8% | 1.2 |
| LLOG3 (Knife Gate Valve) | 39 | 8% | 6% | 1.0 |
| LLOG3 (Knife Gate Valve) | 40 | 6% | 4% | 0.6 |
| LLOG3 (Knife Gate Valve) | 41 | 4% | 2% | 0.5 |
| LLOG3 (Knife Gate Valve) | 42 | 2% | 0% | 0.3 |

Dewatered areas are classified by Reach, which can include two to five specific rampdown sub-areas in each index site (Appendix 1 & 2). Rampdown survey areas within each site are not always contiguous, and may represent a large area of discontinuous but comparable fluvial and river edge characteristics (see Appendix 2 for

site maps and descriptions). All sites surveyed typically contain many small depressions and areas where fish and spawning habitat are susceptible to stranding. Isolated pools are examined and their location recorded using a GPS so that they can be located during future rampdown assessments if they are determined to pose a stranding risk. All salvaged fish, both live and dead are enumerated, identified to species and both live and dead fish are returned to areas of the river mainstem not affected by the flow reduction. Fork lengths are collected on parr and smolts but not fry, no weight information is collected on any salvaged fish.

When evaluating whether fish are stranded or not, a distinction is made between fish stranded in an area that will eventually become effectively dry (resulting in mortalities), and fish that are in temporarily isolated areas that will not dewater. Temporarily isolated areas will remain continually wetted and are large enough to be capable of supporting fish until higher flows return, whether by an increase in flow from the dam, seasonal rainfall or freshet conditions. Fish in these areas could potentially be more susceptible to predation, but follow up surveys in these areas are not performed so it cannot be determined what the survival rate is for fish found in these habitats. These isolated areas may be supported by a number of sources, such as: interstitial flows, bank seepage, tributaries or ground water which help to ensure a supply of oxygen and a degree of temperature regulation. Fish in these areas are not considered stranded and are therefore not included in stranding data.

River stage changes are monitored at two staff gauge sites during the course of each rampdown event (Appendix 2). Stage reductions are determined by survey crews at hourly visual inspections of a staff gauge located in Reach 4. Couquitlam River stage is also monitored using hourly flow data from the Water Survey of Canada (WSC) gauge located in Port Coquitlam (08MH002) and Or Creek WSC (0MH168) Or Creek is the main tributary to the Lower Coquitlam River and its flow can greatly influence fish stranding downstream, affecting Reaches 3, 2b, 2a and 1. These gauges are monitored from the onset of flow reductions to the end of daily salvage operations and provide the information that is used to determine the ramping rate.

The area of each rampdown site was calculated by estimating the extent of inundation during a full open gate release of all three gates. The full extent of each site is included in the area calculation. Therefore, areas within the rampdown site that do not pose a stranding risk are included in the stranding site area calculation. The total extent of each stranding site is represented as dewatered area in square metres (see Appendix 2 for ramp site descriptions). Survey crews perform area measurements using a hip chain and tape measure, measuring the length and width of each site to determine its areal extent. For scheduled rampdown events, the area of inundation is not quantified due to the fact that these are base flows and do not inundate areas of the river which are not normally wetted.

## 3.0 Fish Salvage Results

In 2021, the 13th full year of rampdown monitoring under Treatment 2, there was a total of 4693 stranded fish observed, the second highest number yet observed for all rampdowns in a single year (Figure 5). The June 2021 rampdown fish salvage accounted for 95.9% of all stranding observed for the year and the total of 4052 fish stranded was an all-time high for the June Scheduled rampdown. Scheduled flow reductions performed in June have been responsible for 85.9% of all stranding observed on the Coquitlam River since Treatment 2 was initiated. It was hoped that extending and spacing out the time period of flow reduction along with the gradual ramp rate would potentially result in fewer stranded fish and fewer mortalities due to stranding. However, the number of fish stranded during the June flow reduction has not decreased over the same period. Although the mortality rate has seen a reduction since the implementation of the modified ramp schedule (Figure 6).

Coho juveniles are by far the most likely fish to be stranded during flow reductions on The Coquitlam River. Coho juveniles account for 90.2% of all stranded fish between 2001-2021 (Figure 3). In 2021 Coho fry and smolts represented 93.1% of all stranding observations (Figure 2). Overall, salmonids have accounted for 98.3% of all stranded fish for the 2001-2021 period (Figure 3).

In 2021 stranding was concentrated in the lower reaches of the Lower Coquitlam River with Reach 1 and 2a accounting for 69.1% of all stranding. This result is not the norm under scheduled rampdowns as Reach 1 and 2b have averaged 38.9% of stranding over for the period 2001-2021 (Figure 4).

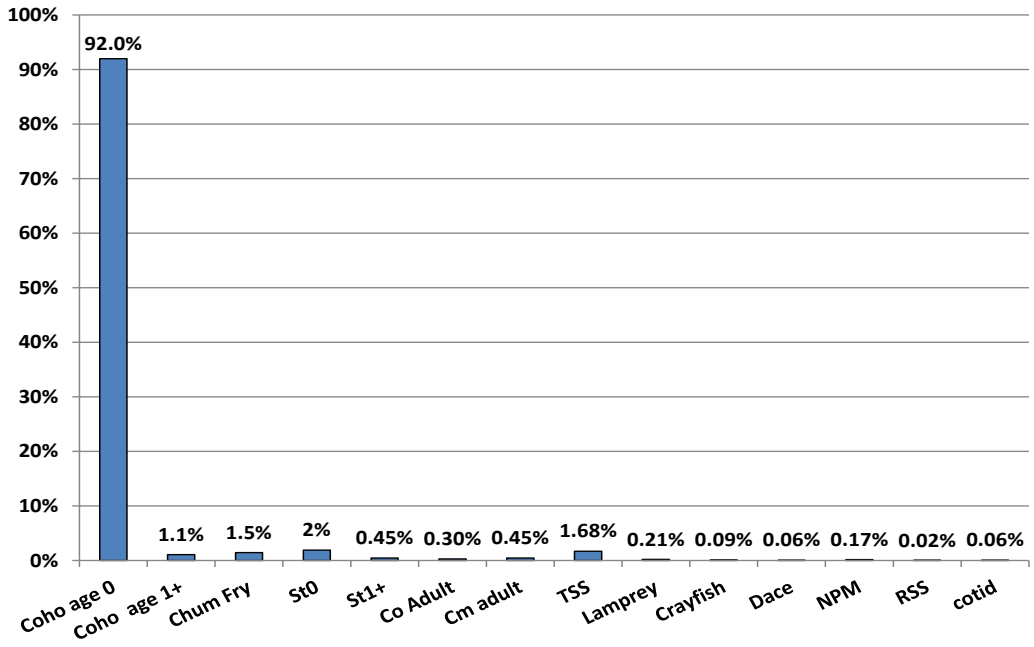


**Figure 2 Coquitlam River stranding distribution by species and age class 2021.**

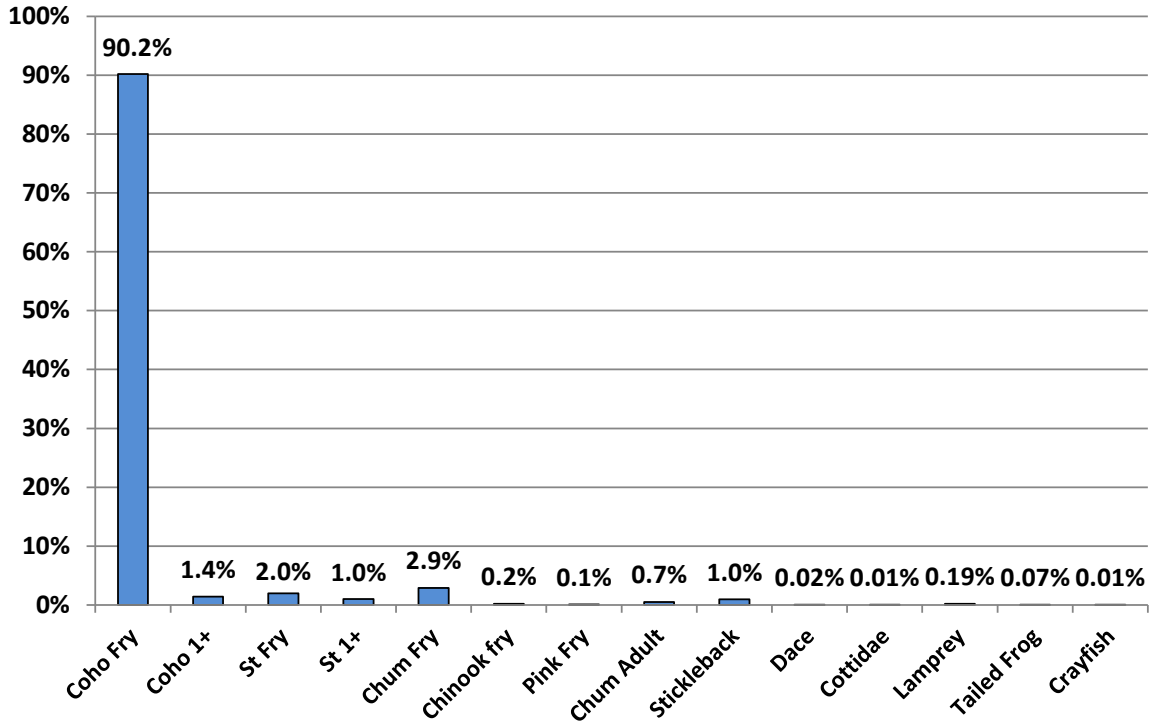


**Figure 3 Coquitlam River stranding distribution by species and age class, January 2001-December 2021, all rampdowns.**

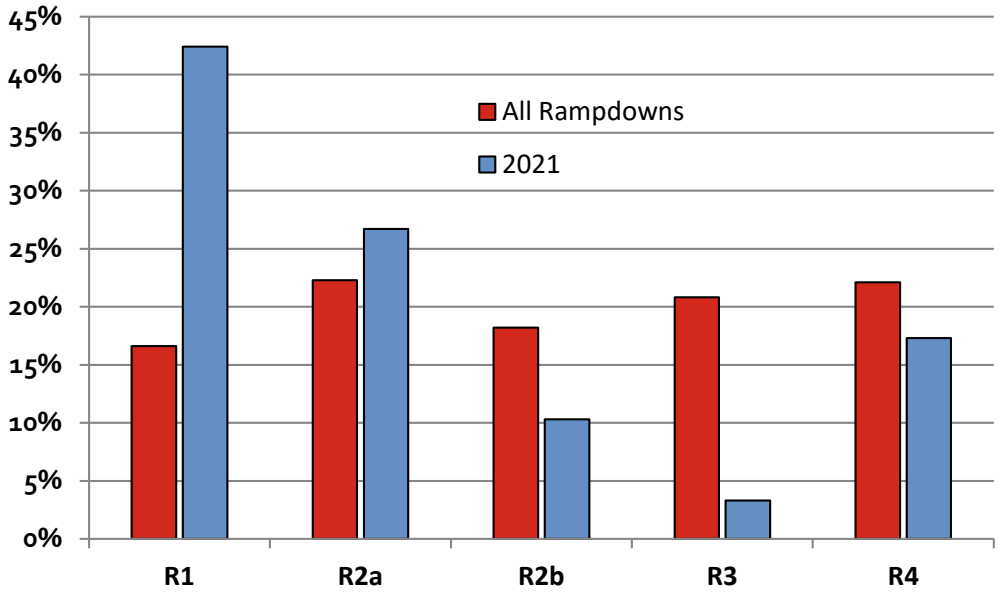


**Figure 4 Stranding distribution by Reach, all rampdowns, 2001 – Dec 2021, and for the monitoring year 2021.**

## 3.1 Scheduled Rampdown Summaries 2021

The rampdown scheduled for January 15, 2021 did not occur due to spilling from Coquitlam Dam, in addition the April 1, and May 1, 2021 did not occur due to experimental flow releases from the Coquitlam Dam for the Kwikwetlem Sockeye Restoration Program (KSRP). In total, only two of the six rampdowns scheduled for 2021 under Treatment 2 were undertaken, the fewest since Treatment 2 began in 2009.

### *3.2.1 Coquitlam Rampdown Summary June 1, 5, 7, 10, July 1, 5, 2021*

In response to the scheduled, Treatment 2, monthly flow changes on the Coquitlam River, the river discharge was reduced from 6.0-2.0 $m^{3/}s$ beginning on June 1st. In the spring of 2021 the Coquitlam River was operating under a variance condition to the order with flow targets of 6.0 $m^{3/}s$ for the months of April and May 2021 and 2.0 $m^{3/}s$ for June rather than the ordered rates of 3.5 $m^{3/}s$ (April), 2.91 $m^{3/}s$ (May) and 1.1 $m^{3/}s$ (June). The request for higher flows in April and May was submitted by the KSRP as part of their Fish Passage program in an attempt to encourage more Sockeye smolts to leave the reservoir. The request for increased flow during the month of June was submitted by DFO and supported by FLNRORD, Metro Vancouver, Kwikwetlem First Nation and the Coquitlam Monitoring Committee.

As a result of the April and May flow increase there was an extended rampdown period of six days in order to better manage the stranding risk while ramping the river down from 6.0 to 1.2$m^{3/}s$. This alternative ramp schedule is shown in Table 3.

**Table 3 Rampdown schedule June 2021 Treatment 2 showing daily flow reduction from CQD**

| Date | Start Flow Release m3/sec | End Flow Release m3/sec |
|---|---|---|
| 1-Jun-21 | 6.0 | 5.0 |
| 5-Jun-21 | 5.0 | 4.0 |
| 7-Jun-21 | 4.0 | 3.0 |
| 10-Jun-21 | 3.0 | 2.0 |
| 1-Jul-21 | 2.0 | 1.6 |
| 5-Jul-21 | 1.6 | 1.2 |

Over the course of the 6 days of fish salvage a total of 4502 fish were observed to be stranded. Of the 4502 fish observed stranded there was a total 4318 coho fry, which made up the overwhelming majority of fish, accounting for 95.6% of all stranding. In addition there were 79 three spine sticklebacks, 2 lamprey, 4 northern pike minnow, 2 dace and 3 steelhead parr (Table 4). The mortality rate was 2.9%, which is the lowest observed in any rampdown performed in June since the inception of Treatment 2 (Figure 4).

A likely contributing factor for the high amount of stranding observed is due to river conditions prior to the flow reductions. The variance for increased flows in April and May as requested by the KSRP, along with the duration of increased flow over such a long period - two months – allows Coho fry to access areas of Coquitlam River that they normally could not enter at Treatment 2 base flows. This elevated river stage leads to an increase in the Coquitlam River stranding area as well as the number of sites that represent a high risk for stranding. The three rampdowns with the largest amount of stranding have all occurred during rampdowns in 2018, 2019 and 2021, all of which ramped down from the elevated KRSP attraction flow release.

Extended flow reductions adopted since 2013 have reduced the maximum and hourly daily stage elevation reduction in Reach 4 and Reach 1 dramatically. For example, flow reductions in 2011 and 2012 for the June rampdown resulted in a Reach 4 ramp rate of 6.0 cm/hr. The maximum stage decrease this year was 1.8 cm/hr in Reach 4, 2021 and 1.0cm/hr in Reach 1 (Tables 7 & 8).

### *3.2.2 Coquitlam Rampdown Summary September 1, 2021*

On September 1, 2021 in response to the current flow regime (Treatment 2), the Low Level Outlet (LLO) release from Coquitlam Dam was scheduled to be reduced from 2.7 $m^3$s to 2.2 $m^3$s. The scheduled rampdown began at approximately 0900hr and was completed by 1100hr. Fish salvage activities continued until 1500hr. There were no observations of stranded fish by the survey crew and no salvage activity was required.

River stage reduction in Reach 4 was a total of 2.0cm with a ramping rate of 1.0cm/hr. In Reach 1 river stage reduction was 1.0cm with an average ramping rate of 0.33cm/hr (Table 7 & 8).

**Table 4 Fish stranding by species, age class and Reach during scheduled rampdowns 2021. Co 0 = Coho fry. Co 1+ = Coho parr/smolt. TSS = Threespine Stickleback. St 0 = Steelhead fry**

| | | | Reach | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Date** | **Species** | **Salv/Mort** | **1** | **2a** | **2b** | **3** | **4** | **Total** |
| 1-Jun-21 | co0 | s | | | 136 | | 377 | 513 |
| 1-Jun-21 | co0 | m | | | 8 | | | 8 |
| 5-Jun-21 | co0 | s | 398 | 20 | 21 | 15 | 241 | 695 |
| 5-Jun-21 | co0 | m | | 8 | | 3 | | 11 |
| 5-Jun-21 | TSS | s | 8 | | | | | 8 |
| 5-Jun-21 | Lamprey | s | | | 2 | | | 2 |
| 7-Jun-21 | co0 | s | 505 | 115 | 35 | 22 | 22 | 699 |
| 7-Jun-21 | co0 | m | | 30 | 42 | | | 72 |
| 7-Jun-21 | Rt 1+ | s | 2 | 1 | | | | 3 |
| 7-Jun-21 | NPM | s | 1 | | | | | 1 |
| 7-Jun-21 | Dace | s | 2 | | | | | 2 |
| 7-Jun-21 | TSS | s | 3 | | | | | 3 |
| 10-Jun-21 | co0 | s | 631 | 533 | 5 | | 81 | 1250 |
| 10-Jun-21 | co0 | m | | 9 | | | | 9 |
| 10-Jun-21 | TSS | s | 4 | | | | | 4 |
| 1-Jul-21 | co0 | s | 20 | 322 | 82 | 56 | 32 | 512 |
| 1-Jul-21 | co0 | m | 5 | | 7 | | 1 | 13 |
| 1-Jul-21 | Rb 0 | s | | | 9 | 17 | 6 | 32 |
| 1-Jul-21 | NPM | s | | 3 | | | | 3 |
| 1-Jul-21 | crayfish | s | | | | | 1 | 1 |
| 5-Jul-21 | co0 | s | 265 | 122 | 85 | 25 | 25 | 522 |
| 5-Jul-21 | co0 | m | 5 | 6 | | | 3 | 14 |
| 5-Jul-21 | Rb 0 | s | | 28 | 20 | 5 | 4 | 57 |
| 5-Jul-21 | TSS | s | 64 | | | | | 64 |
| 5-Jul-21 | crayfish | s | 1 | | | | | 1 |
| 5-Jul-21 | Cotid | s | | 1 | | | | 1 |
| 5-Jul-21 | RSS | s | | 2 | | | | 2 |
| 1-Sep-21 | n/a | | No Stranding Observed | | | | | |
| | **Total Stranded** | | **1914** | **1200** | **452** | **143** | **793** | **4502** |
| | **Total Salvaged** | | 1904 | 1147 | 395 | 140 | 789 | 4375 |
| | **Total Mortality** | | 10 | 53 | 57 | 3 | 4 | 127 |
| **Stranding Distribution by Reach** | | | 43% | 27% | 10% | 3% | 18% | |
| **Mortality Rate** | | | | | | | | **2.9%** |

## 3.2 Unscheduled Rampdowns Summaries 2021

### 3.2.1 *Coquitlam Rampdown Summary February 27-28, 2021*

On February 27, 2021 a rampdown fish salvage was undertaken on Coquitlam River following a (LLOG) spill that been ongoing since January 1, 2021. The first gate closure was initiated on Saturday, February 27 at 0900hr when the first of two LLO gates was ramped down from a release of approximately 18 $m^3$/s to 8.0 $m^3$/s. The final gate was ramped down on February 28, 2021 from 8.0 $m^3$/s to the March Treatment 2 flow target of 4.3 $m^3$/s .

In total 134 stranded fish were observed over the two day monitoring period. Fish stranding was dominated by coho smolts and chum salmon fry (Table 5) with a total of 117 of 135 or 87.3% represented by these two species; juvenile coho represented 38.8% of the total stranded and Chum fry 48.5%. In all a total of 5 separate species were salvaged over the course of the two days (Table 5). For the period 2002-2020, the average number of stranded fish observed during unscheduled rampdowns is 118.

Stranding was observed in every Reach of Coquitlam River and was concentrated in the lower reaches, with the majority observed in Reach 1 and 2a for a total of 64.9% (Table 5). The mortality rate over the course of the two day rampdown was 14.2% or 19 of 135 fish. This rate is marginally lower than the average mortality rate for unscheduled rampdowns of 18.0% for the 2002-2021 period (Table 9).

Average hourly river stage reduction was 3.6cm in Reach 4 and 2.6cm in Reach 1 on the first day of the rampdown and 1.8cm in both Reach 1 and 4 on the second day (Table 7 & 8). Total stage reduction over both days was highest in Reach 4 with a total reduction of 38.0cm compared to 33.0cm in Reach 1 (Table 7 & 8).

### 3.2.2 *Coquitlam Rampdown Summary November 4-6, 2021*

On November 4, 2021 a rampdown fish salvage was undertaken on Coquitlam River following a full 3 Low Level Outlet LLO gate spill that been ongoing since October 22, 2021. The first gate closure was initiated on November 4 at 0700hr when the first of two LLO gates was ramped down from a release of approximately 48$m^3$/s to 16.0 $m^3$/s. The final gate was ramped down on November 5 from 16.0 $m^3$/s to the November flow target of 6.1 $m^3$/s .

The spill and subsequent rampdown occurred at the peak adult chum spawning in Coquitlam River which meant that redd stranding was a potential outcome of the flow reduction as well as stranded adults and juveniles.

Stranded adult coho and chum salmon were observed, along with chum salmon redds (Table 5). A total of 30 adult salmon were observed to be stranded, of this total 9 were coho and 21 were chum. No juvenile stranding was observed. Redd stranding was also evident as the extended period of elevated river stage allowed chum salmon – which were at peak spawning timing – to spawn in areas that are inaccessible at normal fall/winter river stage levels. All stranded redds and adults with the exception of one were observed in Reach 1, the furthest downstream Reach in Coquitlam River. A total of 90 redds, all presumed to be chum, were observed stranded over the course of the rampdown (Table 5).

On both November 4 and 5 heavy rain was falling during the flow reduction which caused the river stage to initially decrease and then increase on both days (Table 8) This situation resulted in no stranding being observed on the first day of the rampdown and minimal stranding observed on the second day (Table 5)

### 3.2.3 *Coquitlam Rampdown Summary December 13-14, 2021*

On December 13, 2021 a rampdown fish salvage was undertaken on Coquitlam River following a full 3 LLO gate spill that been ongoing since November 12, 2021. The first gate closure was initiated on Monday, December 12 at 0830hr . The first gate closure was initiated on December 23 at 0800hr when the first of two LLO gates was ramped down from a release of approximately 48$m^3$/s to 16.0 $m^3$/s. The final gate was ramped down on December 14 from 16.0 $m^3$/s to the December flow target of 5.1 $m^3$/s .

Average hourly river stage reduction was 6.8cm/hr in Reach 1 on the first day of ramping and 2.6cm/hr in Reach 4. On the second day of the rampdown river stage reduction was 1.8cmhr in both Reach 1 and 4 (Table 7 & 8). Total stage reduction over both days was also highest in Reach 4 with a total reduction of 38.0cm compared to 33.0cm in Reach 1 (Table 7 & 8).

The spill and subsequent rampdown occurred at the peak of adult chum and coho spawning in Coquitlam River which meant that redd stranding was a potential outcome of the flow reduction as well as stranded adults and juveniles.

Stranded adult coho and juvenile coho and steelhead were observed, along with lamprey, crayfish and cottidae (sculpin), (Table 5). A total of 27 fish were observed to be stranded, of this total 5 were adult coho with only 2 ramp related mortalities observed. Minimal juvenile stranding was observed with only 10 fish recorded, though only 3 were salvaged alive. A total of 4 redds, all identified as being created by adult coho, were observed stranded over the course of the rampdown (Table 5).

**Table 5 Fish stranding by species, age class and Reach during unscheduled rampdowns 2021. Co 0 = Coho fry. Co 1+ = Coho parr/smolt. TSS = Three spine Stickleback. Pk 0 = Pink fry. t 0 = Steelhead fry**

| | | | Reach | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Date** | **Species** | **Salv/Mort** | **1** | **2a** | **2b** | **3** | **4** | **Total** |
| 27-Feb-21 | co1+ | s | | 1 | | | 1 | 2 |
| 27-Feb-21 | Rt 1+ | s | | | | 4 | | 4 |
| 27-Feb-21 | Cm0 | s | | 22 | | 6 | 1 | 29 |
| 27-Feb-21 | Dace | s | | 1 | | | | 1 |
| 27-Feb-21 | npm | s | | | | 1 | | 1 |
| 27-Feb-21 | co1+ | m | | | | | 1 | 1 |
| 27-Feb-21 | Rt 1+ | m | | 1 | | | | 1 |
| 27-Feb-21 | Cm0 | m | | 3 | | | | 3 |
| 28-Feb-21 | co1+ | s | 39 | | | | 9 | 48 |
| 28-Feb-21 | Rt 1+ | s | | 1 | 1 | | | 2 |
| 28-Feb-21 | Cm0 | s | 1 | 5 | 19 | | | 25 |
| 28-Feb-21 | npm | s | 2 | 1 | | | | 3 |
| 28-Feb-21 | co1+ | m | 1 | | | | | 1 |
| 28-Feb-21 | Rt 1+ | m | | 5 | | | | 5 |
| 28-Feb-21 | Cm0 | m | 2 | 2 | 3 | | 1 | 8 |
| 4-Nov-21 | *No Stranding Observed* | | | | | | | 0 |
| 5-Nov-21 | Cm adult | s | 4 | 1 | | | | 5 |
| 5-Nov-21 | Cm adult | m | 5 | | | | | 5 |
| 6-Nov-21 | Co Adult | s | 9 | | | | | 9 |
| 6-Nov-21 | Cm adult | s | 9 | | | | | 9 |
| 6-Nov-21 | Cm adult | m | 2 | | | | | 2 |
| 6-Nov-21 | **Cm Redds** | | **70** | **15** | | **5** | | **90** |
| 13-Dec-21 | Co Adult | s | | 2 | | | 1 | 3 |
| 13-Dec-21 | Co Adult | m | | 1 | | | 1 | 2 |
| 13-Dec-21 | Crayfish | m | | 1 | | | 1 | 2 |
| 13-Dec-21 | Co 0 | m | | 3 | | | | 3 |
| 13-Dec-21 | Rt 1+ | s | | 3 | | | | 3 |
| 13-Dec-21 | Rt 1+ | m | | | | | 2 | 2 |
| 13-Dec-21 | Cot | m | | | | | 1 | 1 |
| 13-Dec-21 | Lmp | s | | 1 | 7 | | | 8 |
| 14-Dec-21 | Rt 0 | m | | | 1 | | | 1 |
| 14-Dec-21 | Rt 1+ | m | | | 1 | | | 1 |
| 14-Dec-21 | Cot | m | 1 | | | | | 1 |
| 14-Dec-21 | **Co Redds** | | | | | | **4** | **4** |
| | **Total Stranded** | | **75** | **54** | **32** | **11** | **19** | **191** |
| | **Total Salvaged** | | 64 | 38 | 27 | 11 | 12 | 152 |
| | **Total Mortality** | | 11 | 16 | 5 | 0 | 7 | 39 |

# 4.0 Discussion

## *4.1 Stranding Risk*

As has been the case since Treatment 2 was initiated, the majority of stranding in the Lower Coquitlam River is the result of fish salvages occurring in the month of May and June, including scheduled and unscheduled events. Furthermore, of all rampdown fish salvage events on the Coquitlam River, it is clear that the scheduled June 1 flow reduction has been by far the main contributor to fish stranding.

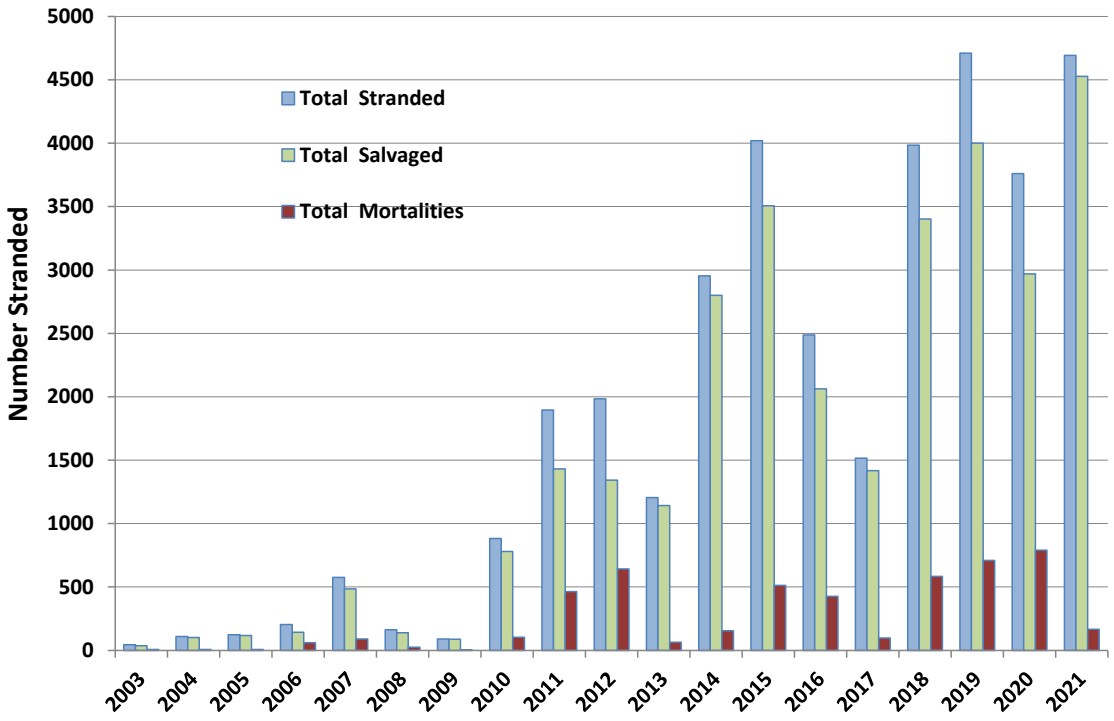


**Figure 5 Number of fish salvaged and mortalities for all rampdowns 2003-2021. 2009 was the first full year under Treatment 2.**

Figure 5 illustrates the increase in the past several monitoring years in the amount of fish stranded on the Coquitlam River under Treatment 2. This increase is influenced by a number of factors, including: the number of rampdown events, seasonal timing of rampdown events, total flow volume decrease, minimum target flow release, as well as survey crews finding more stranding areas and increased efficiency in fish salvage efforts.

The June flow adjustment of 2.9 $m^3/s$ to 1.1 $m^3/s$ represents a significant loss of flow volume and river stage in the uppermost reach of the Lower Coquitlam River. While areas downstream of Reach 4 may or may not be significantly impacted at this time of year from a scheduled flow reduction (depending on freshet and local rainfall), Reach 4

is always very vulnerable. Reach 4 is above the buffering influence of Or Creek, and has very little natural inflow. The June flow reduction in Reach 4 is equivalent to 62% of the total flow volume in this section of the Lower Coquitlam River, and in years when ramping down from the KSRP flow occurs, this increases to a reduction in discharge of approximately 82% – 86%% (KSRP flow variance was 8.0 $m^3$/s in 2018, and 6.0 $m^3$/s in 2019 and 2021). The significance of this is reflected in the fact that the three rampdowns with the largest amount of stranding observed have all occurred during rampdowns in 2018, 2019 and 2021, all of which ramped down from the elevated KSRP attraction flow release.

Final river stage elevation is also an important contributing factor as rampdowns occurring outside of June and July have a higher minimum flow (Table 1). The June flow reduction that brings the Coquitlam River to a yearly low of 1.1 $m^3$/s is looking increasingly problematic due to the minimal amount of water available for rearing and emerging coho fry. The one operational modification that has yet to be attempted in an effort to reduce stranding is increasing the Treatment 2 June minimum flow release. Keeping the minimum flow at a higher discharge such as 2.0 $m^3$/s or 2.5 $m^3$/s or not lowering it all, would greatly reduce the risk of stranding as the river stage would drop only a minimal amount, or not at all potentially.

Salmon fry depend on spring (May and June) freshet conditions to provide an increase in flow to accommodate migration within and from their natal grounds (Hartman, 1982). At this time of year, the natural flow pattern for streams and rivers in the South Coast region of British Columbia is to have an increase in discharge, not a severe and rapid reduction. Therefore it can be argued that the June rampdown represents the opposite of the conditions that migrating fry depend on for survival.

The month of June marks peak emergence for Coho fry in the Coquitlam River. This creates a heightened risk of stranding during rampdowns at this time of year as hundreds of thousands of Coho fry are emerging from the gravel. Coho fry have the highest stranding risk due to their year round residence, and habit of congregating in shallow river margins, ephemeral channels and shallow pools (Dunn, 2002, Macnair 2016). All of these factors make them heavily susceptible to stranding. This contrasts with Chum and Pink fry which are the most numerous species when emergence is underway (March-May), but immediately migrate out of the river and are absent from the river from June to February and are therefore far less likely to be stranded.

River conditions can dramatically impact stranding potential during the June rampdown. June 2017 had the lowest amount of stranding (184) and highest natural inflows for Treatment 2, while 2021 had the most stranding to date (4502) and much lower natural inflows during the flow reduction. In the example of the 2017 June rampdown, the Coquitlam River was so high due to rainfall that no stranding assessments took place below Reach 4, which translates into 80-90% of the potential stranding area going unsurveyed. Hence the large drop in fish stranding was a direct result of the increased natural flows during the rampdown.

The reduction in mortality illustrated in Figure 6 shows the impact of the past nine scheduled flow reductions on this date. The average mortality rate for the June rampdown prior to the 2013 operational change is 23.5%, with a high of 32.4% in 2012, following the operational change the mortality rate from 2013-2021 is 11.2%.

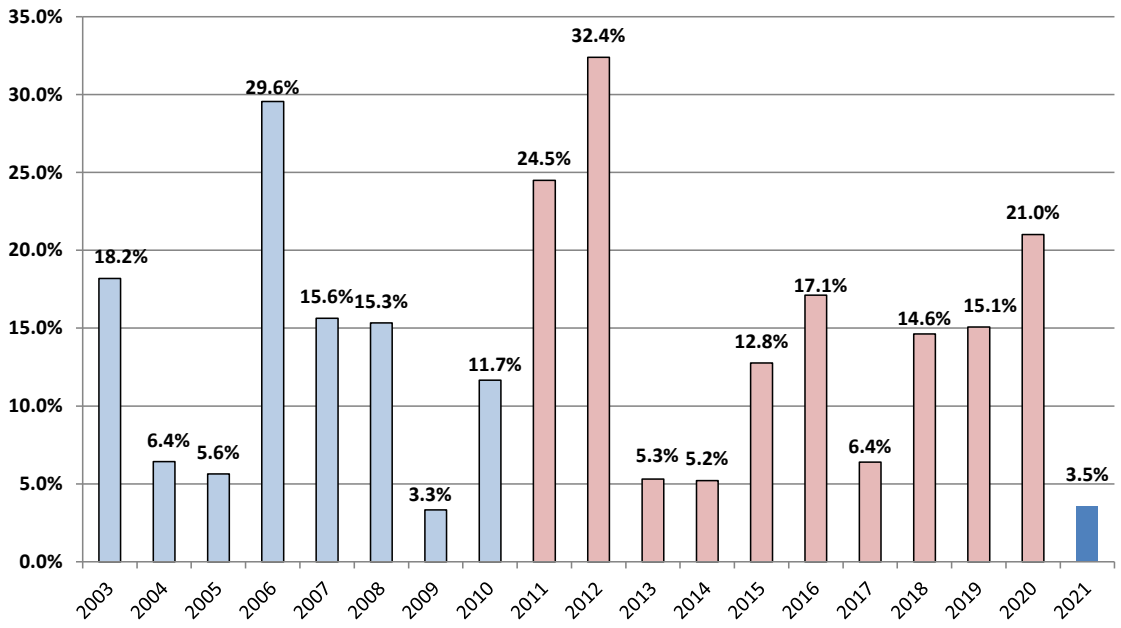


**Figure 6 Coquitlam River Rampdown mortality rate, all rampdowns 2003-2021**

**Table 6 Scheduled rampdown salvaged and mortality. Rampdowns in 2010, 2013 and 2106 were effected by rainfall during flow reduction and fish salvage activities. 2018-2109 and 2021 ramped down from KSRP flow release schedule.**

| Date | Status | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15-Jan | Salvaged | 0 | n/s | 0 | 5 | 10 | 0 | 0 | 31 | 22 | 0 | 0 | n/s | n/s | **68** |
| | Mortality | 0 | n/s | 0 | 2 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | n/s | n/s | **12** |
| 1-Apr | Salvaged | 0 | n/s | 0 | 1 | 129 | 28 | 48 | 5 | 68 | n/s | 0 | n/s | n/s | **279** |
| | Mortality | 0 | n/s | 0 | 0 | 15 | 0 | 14 | 1 | 0 | n/s | 0 | n/s | n/s | **30** |
| 1-May | Salvaged | 0 | 0 | n/s | 0 | 100 | 0 | 95 | 310 | n/s | n/s | 256 | n/s | n/s | **761** |
| | Mortality | 0 | 0 | n/s | 0 | 3 | 0 | 21 | 56 | n/s | n/s | 90 | n/s | n/s | **170** |
| 1-Jun | Salvaged | 20 | 55 | 1355 | 1377 | 967 | 2600 | 3327 | 1454 | 184 | 3371 | 3738 | 2895 | 4375 | **25718** |
| | Mortality | 0 | 19 | 331 | 506 | 46 | 67 | 381 | 217 | 2 | 583 | 620 | 757 | 127 | **3656** |
| 1-Sep | Salvaged | 0 | 0 | 98 | 0 | 0 | 7 | 0 | n/s | 30 | 31 | 0 | n/s | 0 | **166** |
| | Mortality | 0 | 0 | 82 | 0 | 0 | 0 | 0 | n/s | 6 | 0 | 0 | n/s | 0 | **88** |
| 1-Nov | Salvaged | 0 | 11 | 0 | 0 | n/s | 0 | 0 | n/s | 0 | 0 | n/s | 0 | n/s | **11** |
| | Mortality | 0 | 2 | 0 | 0 | n/s | 0 | 0 | n/s | 0 | 0 | n/s | 0 | n/s | **2** |

## *4.2 Ramping Rate*

The ramping rate that is used during flow reductions has consistently been demonstrated to be below provincial standards (2.5cm and hour when fry are present) and is operationally compatible with successful fish salvage operations. But the overall amount of stranded fish in June has *not* been addressed through this operational approach. In addition, the act of spreading the flow reduction out over multiple days and implementing multi-day gaps between flow reductions appears to have had mixed success as the mortality rate has decreased since 2013, but the amount of fish stranded has increased.

This staggered flow reduction dramatically reduced the daily and hourly stage elevation decrease in Reach 4. Flow reductions in 2011 and 2012 for the June rampdown decreased the stage elevation in Reach 4 approximately 16.0 cm in 3 hours with a maximum hourly decrease of 10.0 cm and average hourly decrease of 5.3cm/hr. The maximum decrease in 2021 was 1.8 cm over one hour in Reach 4 and 1.0 cm at the WSC gauge in Reach 1 (Table 7 & 8).

**Table 7 Ramp rate and flow reductions Reach 4 SG 2021**

| Date | R4SG Start (m) | R4SG END (m) | total stage decrease (cm) | ramp rate (cm/h) | Start Flow Release m3/sec | End Flow Release m3/sec |
|---|---|---|---|---|---|---|
| 27-Feb-21 | 0.79 | 0.50 | 29 | 3.6 | 20.0 | 8.0 |
| 28-Feb-21 | 0.50 | 0.41 | 9 | 1.8 | 8.0 | 4.3 |
| 1-Jun-21 | 0.45 | 0.40 | 5 | 1.7 | 6.1 | 5.2 |
| 5-Jun-21 | 0.39 | 0.36 | 3 | 1.0 | 5.2 | 4.2 |
| 7-Jun-21 | 0.36 | 0.29 | 7 | 1.8 | 4.2 | 2.9 |
| 10-Jun-21 | 0.29 | 0.26 | 3 | 0.6 | 2.9 | 2.0 |
| 1-Jul-21 | 0.25 | 0.22 | 3 | 1.0 | 2.0 | 1.5 |
| 5-Jul-21 | 0.22 | 0.19 | 2.5 | 1.3 | 1.5 | 1.1 |
| 1-Sep-21 | 0.27 | 0.25 | 2 | 1 | 2.7 | 2.2 |
| 4-Nov-21 | n/a | n/a | n/a | n/a | 48.0 | 16.0 |
| 5-Nov-21 | n/a | n/a | n/a | n/a | 16.0 | 6.1 |
| 6-Nov-21 | n/a | n/a | n/a | n/a | 6.1 | 6.1 |
| 13-Dec-21 | n/a | n/a | n/a | n/a | 48.0 | 16.0 |
| 14-Dec-21 | n/a | n/a | n/a | n/a | 16.0 | 5.1 |

**Table 8 Ramp rate and flow reductions WSC gauge Reach 1 2021**

| Date | WSC Stage start | WSC Stage end | total stage decrease (cm) | ramp rate (cm/h) | Start Flow Release m3/sec | End Flow Release m3/sec |
|---|---|---|---|---|---|---|
| 27-Feb-21 | 8.26 | 8.05 | 21 | 2.63 | 20.0 | 8.0 |
| 28-Feb-21 | 8.05 | 7.94 | 11 | 1.83 | 8.0 | 4.3 |
| 1-Jun-21 | 8.04 | 8.01 | 3 | 0.75 | 6.1 | 5.2 |
| 5-Jun-21 | 7.97 | 7.94 | 3 | 0.75 | 5.2 | 4.2 |
| 7-Jun-21 | 7.95 | 7.90 | 5 | 1.00 | 4.2 | 2.9 |
| 10-Jun-21 | 7.87 | 7.85 | 2 | 0.40 | 2.9 | 2.0 |
| 1-Jul-21 | 7.79 | 7.76 | 3 | 0.50 | 2.0 | 1.5 |
| 5-Jul-21 | 7.73 | 7.71 | 2 | 0.33 | 1.5 | 1.1 |
| 1-Sep-21 | 7.75 | 7.74 | 1 | 0.25 | 2.7 | 2.2 |
| 4-Nov-21 | 8.83 | 8.79 | 4 | 0.50 | 48.0 | 16.0 |
| 5-Nov-21 | 8.34 | 8.25 | 9 | 1.13 | 16.0 | 6.1 |
| 6-Nov-21 | 8.10 | 8.09 | 0 | 0.00 | 6.1 | 6.1 |
| 13-Dec-21 | 8.73 | 8.19 | 54 | 6.75 | 48.0 | 16.0 |
| 14-Dec-21 | 8.22 | 8.12 | 10 | 1.67 | 16.0 | 5.1 |

**Table 9 Stranding and mortality scheduled vs. unscheduled rampdowns 2001-2021**

| 2001-2021 | Stranded | st Per Ramp | Salvaged | Mortality | m Per Ramp | m Rate |
|---|---|---|---|---|---|---|
| **Unscheduled** | 5473 | 101 | 4488 | 985 | 18 | **18.0%** |
| **Scheduled** | 29952 | 491 | 26011 | 3941 | 65 | **13.2%** |
| **Total** | 35425 | 303 | 30499 | 4926 | 42 | **13.9%** |

## *4.3 Redd Stranding*

Redd stranding on the Lower Coquitlam River as a result of flow reductions is a risk only during fall salmon spawning and steelhead spawning in the spring. Widespread stranding of redds in the fall only occurs if there is an extended spill event that coincides with peak or near peak spawning period. This has happened on 4 occasions (2003, 2012, 2016, 2021) on the Lower Coquitlam River since 2001, stranding an estimated 1002 adult salmon redds over the 2001-2021 period (Table 10). Chum adults are by far the most at risk as they account for 957, or 95.5% of the total. Steelhead redd stranding is limited to one or two problem areas on the Coquitlam River. Surveyors observed repeated stranding in precisely the same spot in eight consecutive years from 2011-2018 (Table 8).

Other than Chum redd stranding, the relatively low number of redds stranded and the low frequency of events suggests that redd stranding is not a significant concern. The

yearly loss of 1-3 steelhead redds compares to a yearly average of 225 created redds over the 2005-2021 period, so the impact of these losses (<1%) is likely to be insignificant. Chum redds are not enumerated during surveys, but as the average adult escapement numbers is in the 10,000-60,000 range (2019, Schick), it is likely that potentially several thousand redds are created each fall. As such, the loss of a few hundred redds at infrequent intervals over 20 years of study would likely have limited to no effect on Chum salmon productivity.

**Table 10 Redd stranding on Coquitlam River 2001-2021. Steelhead spawning timing March-May, Pink chum and coho, September-December**

| Year | Steelhead | Pink | Chum | Coho | Total |
|---|---|---|---|---|---|
| 2001 | | | | | |
| 2002 | | | | | |
| 2003 | | | 300 | | 300 |
| 2004-2010 | | | | | |
| 2011 | 1 | 30 | | | 31 |
| 2012 | 1 | | 300 | | 301 |
| 2013 | 1 | | | | 1 |
| 2014 | 3 | | 17 | | 20 |
| 2015 | 1 | | | | 1 |
| 2016 | 2 | | 250 | | 252 |
| 2017 | 2 | | | | 2 |
| 2018 | 2 | | | | |
| 2019 | | | | | |
| 2020 | | | | | |
| 2021 | | | 90 | 4 | 94 |
| **Total** | **13** | **30** | **957** | **4** | **1002** |

## *4.4 Fish Productivity Impacts*

Stranding influence on fish production in the Lower Coquitlam River is likely to be minimal with the exception of Coho fry. For Pink and Chum fry the impact is negligible. Schick et. al. 2017 reported the estimated average annual outmigrating population for Chum and Pink fry for the 2003-2019 period was 2,248,900 and 958,000 respectively. Contrast this with a total of 79 Chum mortalities and zero Pink mortalities observed during rampdowns for the same period. Coho and steelhead smolt population estimates for the same period averaged 14,479 and 4,242 per year respectively (Schick et. al. 2018). The estimated average number of Coho and steelhead smolt/parr stranded per year due to rampdowns is 17 and 15 respectively, or less than 0.4% of the estimated population. No attempt to quantify the potential impacts on fish productivity has been established at this point within the framework of Coquitlam River rampdown fish salvage monitoring.

## *4.4 Rampdown Frequency*

Since the introduction of Treatment 2 there has been no reduction in the total number of unscheduled rampdowns (Table 11). It was anticipated that removal of the temporary dam safety 149m maximum allowable reservoir operating level (in place during Treatment 1 2001-2009) would reduce the number of unscheduled spill events. Under Treatment 1 the Coquitlam River averaged 2.7 unscheduled rampdowns per year, under Treatment 2 the average has dipped slightly to 2.3 unscheduled rampdowns per year.

**Table 11 Number of rampdown per year 2001-2021**

| Monitoring Year | Scheduled | Unscheduled | Total |
|---|---|---|---|
| 2021 | 2 | 3 | 5 |
| 2020 | 2 | 1 | 3 |
| 2019 | 5 | 0 | 5 |
| 2018 | 4 | 1 | 5 |
| 2017 | 5 | 3 | 8 |
| 2016 | 4 | 3 | 7 |
| 2015 | 6 | 2 | 8 |
| 2014 | 6 | 3 | 9 |
| 2013 | 6 | 0 | 6 |
| 2012 | 5 | 4 | 9 |
| 2011 | 5 | 3 | 8 |
| 2010 | 4 | 5 | 9 |
| 2009 | 6 | 3 | 9 |
| 2008 | 1 | 1 | 2 |
| 2007 | n/a | 5 | 5 |
| 2006 | n/a | 4 | 4 |
| 2005 | n/a | 2 | 2 |
| 2004 | n/a | 3 | 3 |
| 2003 | n/a | 3 | 3 |
| 2002 | n/a | 1 | 1 |
| 2001 | n/a | 1 | 1 |
| **Total** | **61** | **51** | **112** |
| **Treatment 2** | **4.4** | **2.3** | **6.6** |
| **Treatment 1** | | **2.7** | **2.7** |

## 5.0 Conclusions and Recommendations

The results of the past 13 years of rampdown monitoring clearly indicate that fish stranding and mortalities have increased due to operational changes to the flow regime under Treatment 2. An analysis of the results from Table 5 show that under Treatment 1, survey crews observed an average of 155 stranded fish and 27 mortalities per year, while under Treatment 2 this average has risen to 2630 stranded fish and 363 mortalities per year. The cause of this increase is likely related to these factors:

1. An increase in rampdowns at critical time periods for emerging juvenile fish. Scheduled rampdowns in May, and June occur at peak emergence for fry in the Lower Coquitlam River, As discussed in Sec. 4.1, the June rampdown alone has been responsible for 85.9% of all stranding over the past thirteen years

2. The total river stage reduction and final river stage elevation during the June rampdown may need to be modified if the risk of stranding on The Coquitlam River is to be reduced. All data collected to date points to this operational change as having the strongest potential to reduce the amount of stranding.

3. An increase in the number of rampdowns per year due to the introduction of 6 scheduled rampdowns per year at the Coquitlam Dam. Treatment 1 had an average 2.7 rampdowns per year (all unscheduled), while under Treatment 2 the average has risen to 6.6 per year.

With respect to the management questions and hypothesis outlined in the introduction:

*a) What is the most appropriate ramping rate protocol that should be developed for the Coquitlam Dam that best reduces fish stranding risk while being operationally feasible?*

*b) What are the ongoing fish stranding risks and/or impacts of the revised ramping rate protocol?*

The ramping rate established under Treatment 2 appears to be effective at minimizing stranding during both scheduled and unscheduled rampdowns with the exception of the June scheduled rampdown. Comparison of rampdown mortality to fish productivity clearly shows, with the exception of Coho salmon fry, the negligible impact that rampdowns appear to have on fish productivity in the Coquitlam River.

H1: *The LB1 WUP interim ramping rate protocol does not strand fish at index sites in the lower Coquitlam River.*

> Results to date indicate that fish continue to be stranded under the revised ramping rate protocol. In addition, the risk of fish stranding has increased since the introduction of Treatment 2 flow regime despite careful adherence to the ramping protocol.

The first step taken towards managing stranding was undertaken in 2013 and has shown to have had positive results as the mortality rate has dropped. Outside of the May and June flow reduction, the risk of stranding appears to be minimal during all other scheduled rampdowns. Another alteration to the June rampdown protocol was begun in 2016, with the practice having for 5 days between each flow reduction thereby spreading out the rampdown and associated salvages over three non- consecutive days. This practice was hoped to reduce stranding risk by giving fry a chance to re-orientate themselves in the river following each flow reduction. However, to date there has been no evidence that stranding has been reduced using this protocol.

The one remaining operational approach that has yet to be attempted is a change to the minimum flow in the month of June. It is clear that the reduction to 1.1 $m^3/s$ is the main issue leading to the continued large amount of stranding of coho fry during the June flow reduction it would be beneficial for this particular rampdown to undergo a reassessment of the minimum target flow. The June reduction does not follow the natural hydrograph of the upper Coquitlam River (WSC Gauge 08MH141). Flows are high and rising during the months of May and June in the upper unregulated Coquitlam River but this is not reflected in Reach 4, where flows drop significantly. A higher minimum flow target for June may prevent a significant amount of future stranding.

Though the majority of stranding each year is observed during only one scheduled rampdown, it is recommended that all rampdowns continue to be monitored by survey crews during the upcoming monitoring years. The potential for stranding definitely exists, and has been documented on all scheduled rampdown dates. In addition, with the gate operations at the Coquitlam Dam now controlled remotely, it is imperative that a crew be available on site in case of operator error or equipment failure, which has occurred on a few occasions during the past several years.

Stranding sites examined under the previous flow regime have been continually re-evaluated under the new Treatment 2 conditions. The results of the thirteenth year under Treatment 2 demonstrate that some formerly susceptible areas may now be considered low risk for stranding. Additionally, new areas have been identified during scheduled rampdowns and these new areas have been categorized and included in all rampdown fish salvage surveys. The fluvial morphology of the Lower Coquitlam River will continue to transform as it adapts to the increased annual flow, therefore areas of stranding will continue to shift.

Although fish will continue to be stranded regardless of ramp rate, survey crews are well adapted to the conditions of the ramp rate and are able to salvage the majority of fish that become stranded. Careful adherence to rampdown rates, minimum flow targets and consistent monitoring of potential stranding sites will continue to be the most appropriate means of reducing fish stranding mortalities while remaining operationally feasible.

**Summary of Recommendations**

- Stranding of large numbers of Coho fry during the June rampdown will continue to be an issue under the current flow regime. A re-examination of the minimum target flow of 1.1 $m^3/s$ should be considered as it falls outside of the natural hydrograph for the Coquitlam River and has been demonstrated to unavoidably create conditions for stranding large numbers of coho fry.

- Monitoring for fish stranding should be continued in order to ensure that flow release targets are achieved and stranded fish mortalities are minimized. Continued monitoring for fish stranding will also mitigate any LLO gate failures or operator errors.

- Continue to use the current ramping rate that was successfully implemented in 2013.

- Ensure proper communication with Fraser Valley Operations (FVO) desk during gate closures. This is critical to prevent flow changes happening when salvage crews are not present or available.

- Future rampdowns in June related to Sockeye smolt attraction flows will need to be carefully monitored, particularly if they occur in the spring due to the increased stranding risk associated with the timing, duration and magnitude of these events.

## 6.0 Literature cited


Au, D.W.K. 1972. Population dynamics of the Coho salmon and its response to logging in three coastal streams. Ph. D. dissertation, Oregon State Univ., Corvallis, Oregon. 245 p.

BC Hydro 2005, Coquitlam-Buntzen Project Water Use Plan, Revised for Acceptance by the Comptroller of Water Rights. 7 April 2005. A BC Hydro Water Use Plan.

BC Hydro 2006, Coquitlam-Buntzen Water Use Plan Monitoring Terms of Reference, January 2006, Burnaby BC

Bjornn T. C., 1971, Trout and Salmon Movements in Two Idaho Streams as Related to Temperature, Food, Stream Flow, Cover, and Population Density Transactions of the American Fisheries Society. Volume 100, Issue 3, pages 423-438

Bradford, M.J. 1995. Comparative review of Pacific salmon survival rates. Canadian Journal of Fisheries and Aquatic Sciences 52: 1327-1338.

Bradford, M. J. 1997. An experimental study of stranding of juvenile salmonids on gravel bars and in side channels during rapid flow fluctuations. *Regulated Rivers: Research and Management* 13:395–401.

Bunn, Stuart E. and A. H. Arthington, 2002, Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity, Environmental Management Vol. 30, No. 4, pp 492-507

Bustard, David R., D.W. Narver, 2011, Aspects of the Winter Ecology of Juvenile Coho Salmon (*Oncorhynchus kisutch*) and Steelhead Trout (*Salmo gairdneri*) Journal of the Fisheries Research Board of Canada, 1975, 32(5): 667-680,

Decker, Scott, G. Lewis, J. Macnair, 2009, Coquitlam River Fish monitoring Program Results 2000-2006, Prepared for BC Hydro Coastal Generation, Burnaby B.C., pp. 116

Hartman, G.F., B.C Andersen, J.C. Scrivener, Seaward Movement of Coho Salmon Fry in Carnation Creek. Canadian Journal of Fish and Aquatic Sciences, 39: 588-597.

Macnair, J., P. Troffe. 2006 Assessment of fish stranding on the Lower Coquitlam River, Prepared for BC Hydro Generation Sustainability, Burnaby B.C. pp. 20

Macnair, J., P. Troffe. 2007 Assessment of fish stranding on the Lower Coquitlam River, Prepared for BC Hydro Generation Sustainability, Burnaby B.C. pp. 29

Nickelson, T.E., and P.W. Lawson. 1998. Population viability of Coho salmon, Oncorhynchus kisutch, in Oregon coastal basins: application of a habitat-based life cycle model. Canadian Journal of Fisheries and Aquatic Sciences 55:2383- 2392.

Schick, J., J. Korman, G. Lewis, J. Macnair, 2016, Coquitlam River Fish monitoring Program Results 2012-2013, Prepared for BC Hydro Coastal Generation, Burnaby B.C., pp. 137

Spalding, S., N.P. Peter, and T.P Quinn. 1995. Summer distribution, survival, and growth of juvenile Coho salmon under varying experimental conditions of brushy instream cover. Transactions of the American Fisheries Society 124: 124-130.

**Appendix 1 Site descriptions and photographs**

**Reach 1**

**Site A1:** This area is characterized by dense tree and shrub riparian river margins that contain many depressions that form isolated pools. The substrate is mainly sand/silt and vegetated cover, along with some areas of exposed gravel and cobble.
***Total Area: 1800m$^2$***

**Figure 7 Site A1 showing gravel bar separating river mainstem (left) with isolated pool (right), following rampdown June 1 2012.**

**Figure 8 Site A1 showing trench dug to allow water from river mainstem to flow into isolated pool.**

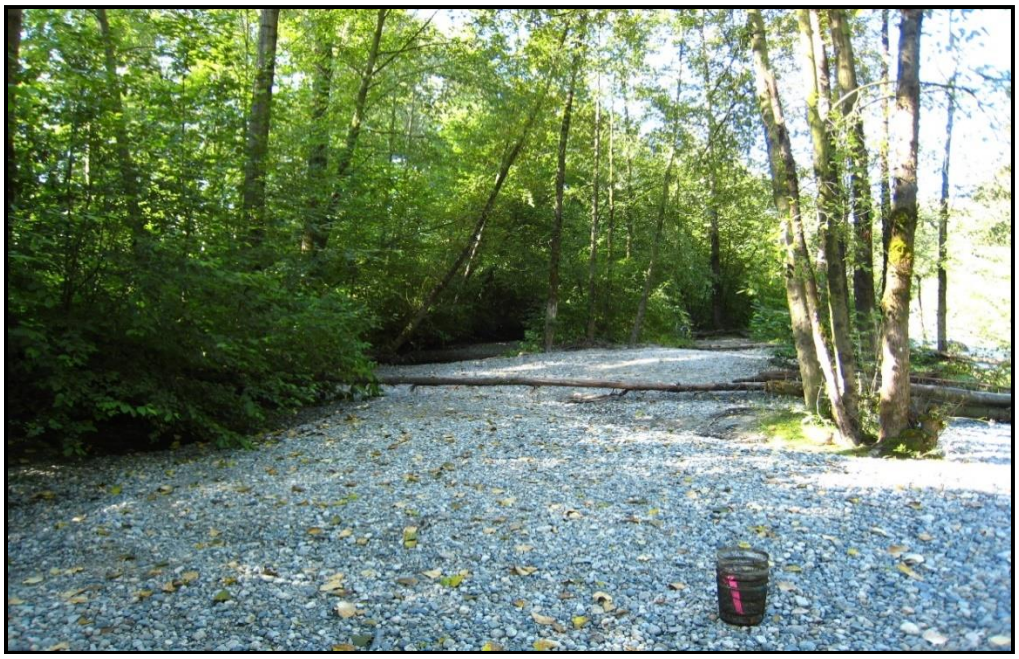

**Figure 9 Site A1 showing gravel area on gravel bar fluvial island where fish are regularly stranded**

**Site A2:** These areas are characterized by large expanses of exposed gravel and cobble suitable for spawning adjacent to the river, accompanied by moderately treed areas with numerous depressions that form isolated pools when dewatered. These areas represent a hazard for stranding of both adults, juveniles and redds due to the combination of off-channel habitat and spawning gravel that is wetted during higher flow releases.
***Total Area: 19000m$^2$***

**Site A3:** This area is primarily a large gravel and cobble fan with gently sloping topography. There are several areas where large isolated pools form during rampdowns, however this area has a very low risk of stranding.
***Total Area: 4800m$^2$***

**Reach 2A**

**Site B1:** This area is a side channel that is normally wetted except at extremely low flows (below 2.00cms WSC gauge Port Coquitlam). It has a gravel and cobble substrate, however, it rarely completely dewaters, so is only a stranding risk under extreme low flow conditions.
***Total Area: 270m$^2$***

**Site B2:** This area is a long narrow partially treed platform with a combined sand/silt, gravel and vegetated substrate. It strands adults, juveniles and redds. This site only becomes inundated during a full three LLO gate release, and is one of the earliest sites to begin dewatering.
***Total Area: 3000m$^2$***

**Figure 10 Site B2, showing isolated pool formed during flow reduction, this site strands juveniles, adults and redds. Substrate is primarily sand/silt.**

**Site C1:** This site is a long side channel composed of gravel and cobble substrate. It drains rapidly and forms many isolated pools that do not retain water well. This site experienced the highest number of stranding during the past two years.
***Total Area: 690m$^2$***

**Site C2:** The riparian area is densely covered in shrubs. The substrate is fine silt with some vegetated ground cover. River Morphology changes may also have reduced the risk of stranding at this site.
***Total Area: 550m$^2$***

**Figure 11 View of site C1 side channel that is wetted during single gate openings. This site typically has one of the highest incidences of stranding on the Coquitlam River.**

**Reach 2B**

**Site C3:** This site is a small side channel composed of gravel and cobble substrate. It drains slowly and forms many isolated pools that do not retain water well. This site experiences only minimal stranding.
***Total Area: 60m$^2$***

**Site D1:** This area encompasses two long side channels that completely dewater during the June flow reduction. they are a silt/sand gravel cobble substrate combined with some deeper pools and poses a high risk of stranding.
***Total Area: 300m$^2$***

**Site D2:** Parts of this area are densely vegetated with riparian trees and shrubs, though it is primarily a narrow river margin with cobble and boulder substrate and one side channel that nearly dewaters during the June flow reduction. Stranding risk here is high.
***Total Area: 80m$^2$***

**Reach 3**

**Site D3:** This area is a combination of a long, narrow platform with dense trees and shrubs, as well as a small side channel that is permanently wetted. It has a combined sand/silt, gravel and vegetated substrate. Isolated pools form during flow reductions, stranding juveniles which are best removed using minnow traps due to the dense concentration of roots within the pools. Stranding risk here is high.
***Total Area: 700m$^2$***

**Reach 4**

**Site E1:** This area is adjacent to a rearing pond that overflows during dam releases. Juveniles spill from the pond and can become stranded after these overflows. Channel substrate is mainly cobble and gravel intermixed with moderately treed islands.
***Total Area: 900m$^2$***

**Site E2:** This area consists of narrow river margins with dense trees and shrubs. Many small isolated pools form close to the river mainstem during gate closure. Observations over the past several years indicate that many of these pools remain wetted year round due to their proximity to the river channel. Stranding risk is high
***Total Area: 1800m$^2$***

**Site E3:** This area, situated near the dam face, is densely covered in trees and shrubs. Isolated pools are minimal, but juveniles are sometimes stranded in the area of dense vegetation during dewatering from full 3 LLO gate flow reductions. Moderate risk of stranding.
***Total Area: 340m$^2$***

**Appendix 2 June-July 2021 Coquitlam River rampdown site maps and discreet stranding locations represented by red dots. Total number of fish stranded not sorted by species.**

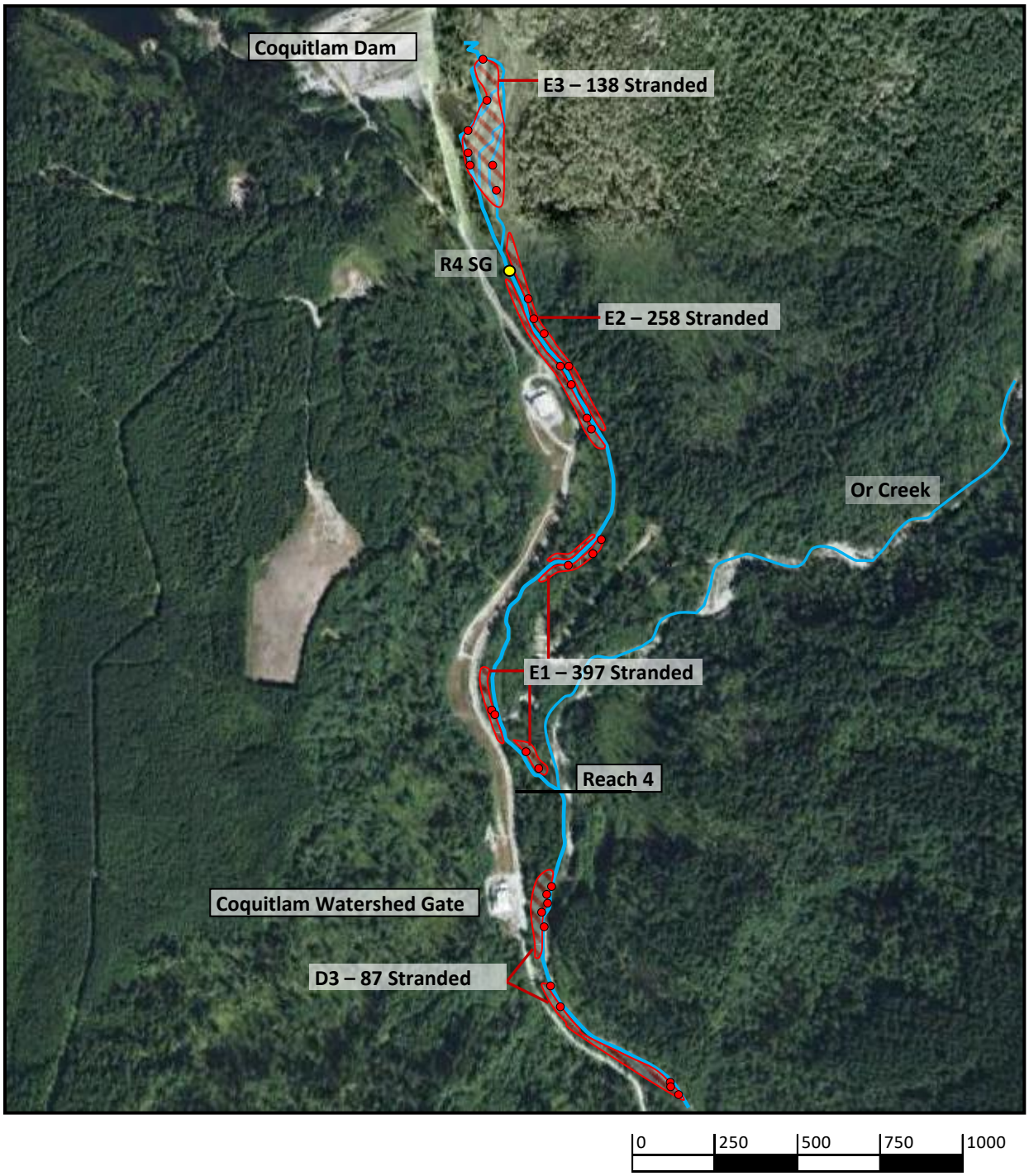


**Figure A**
**Coquitlam River Stranding Reach 4 and 3.**

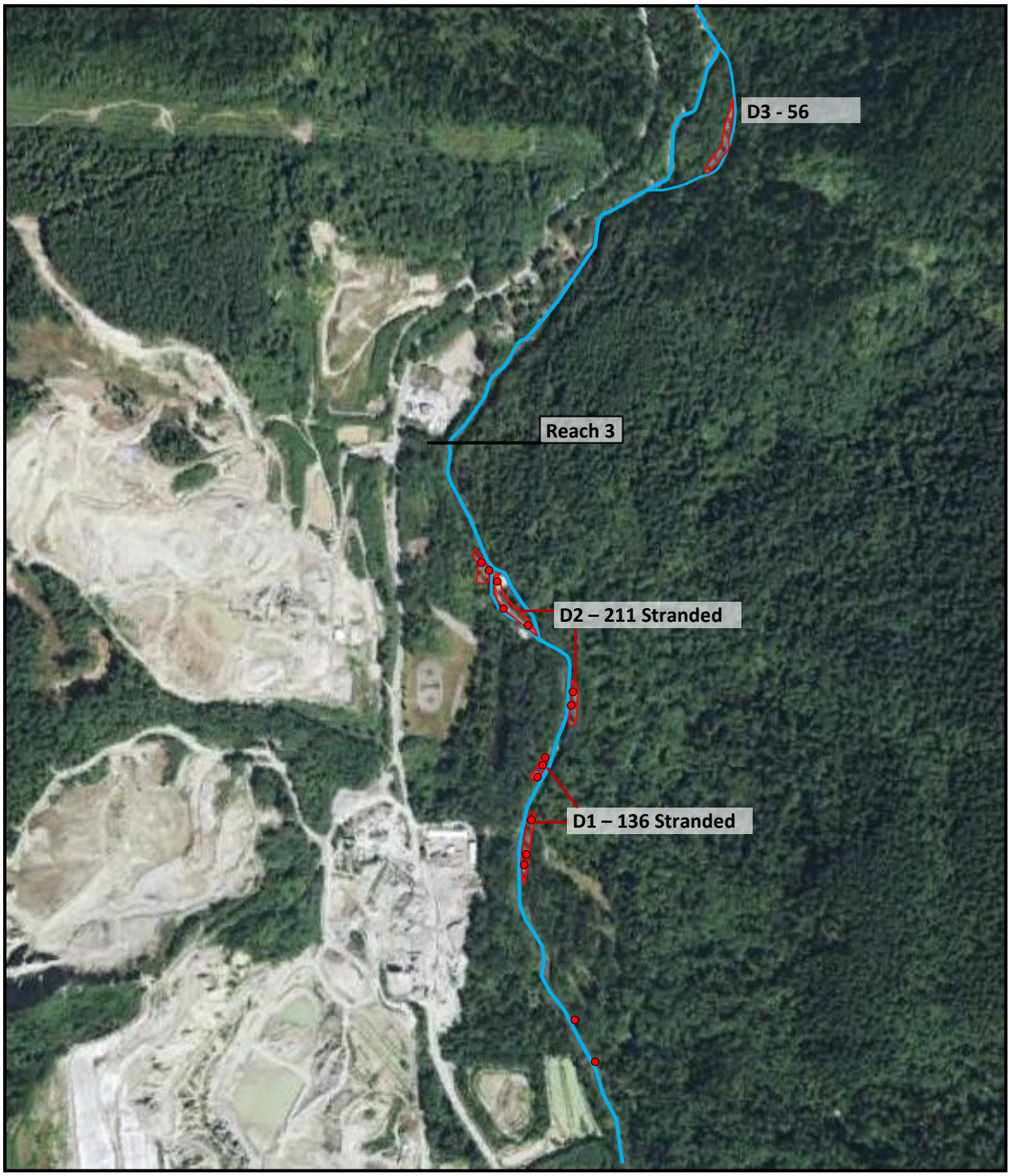


**Figure B**
**Coquitlam River Stranding Reach 3 and 2b**

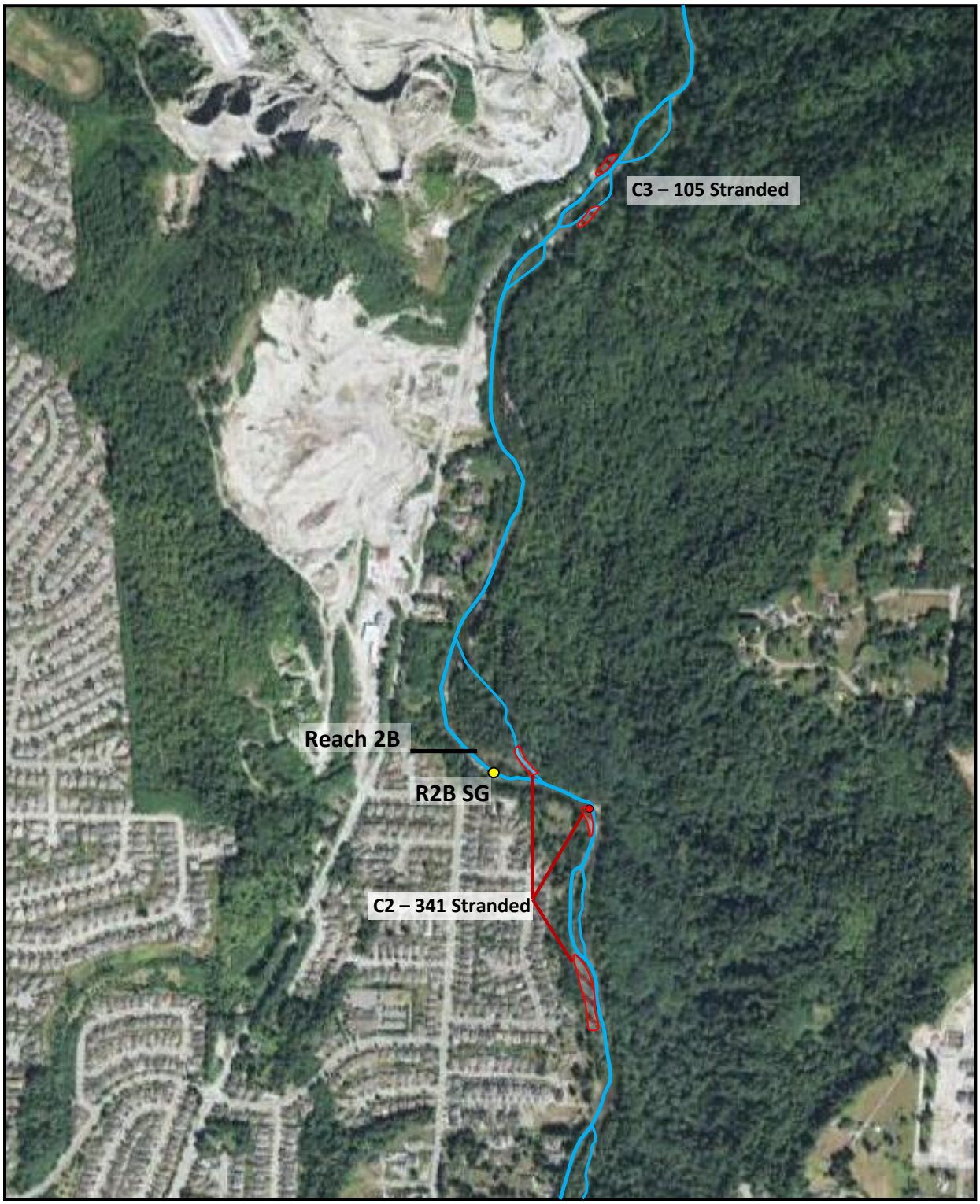


**Figure C**
**Coquitlam River Stranding, Site C, Reach 2a & 2b.**

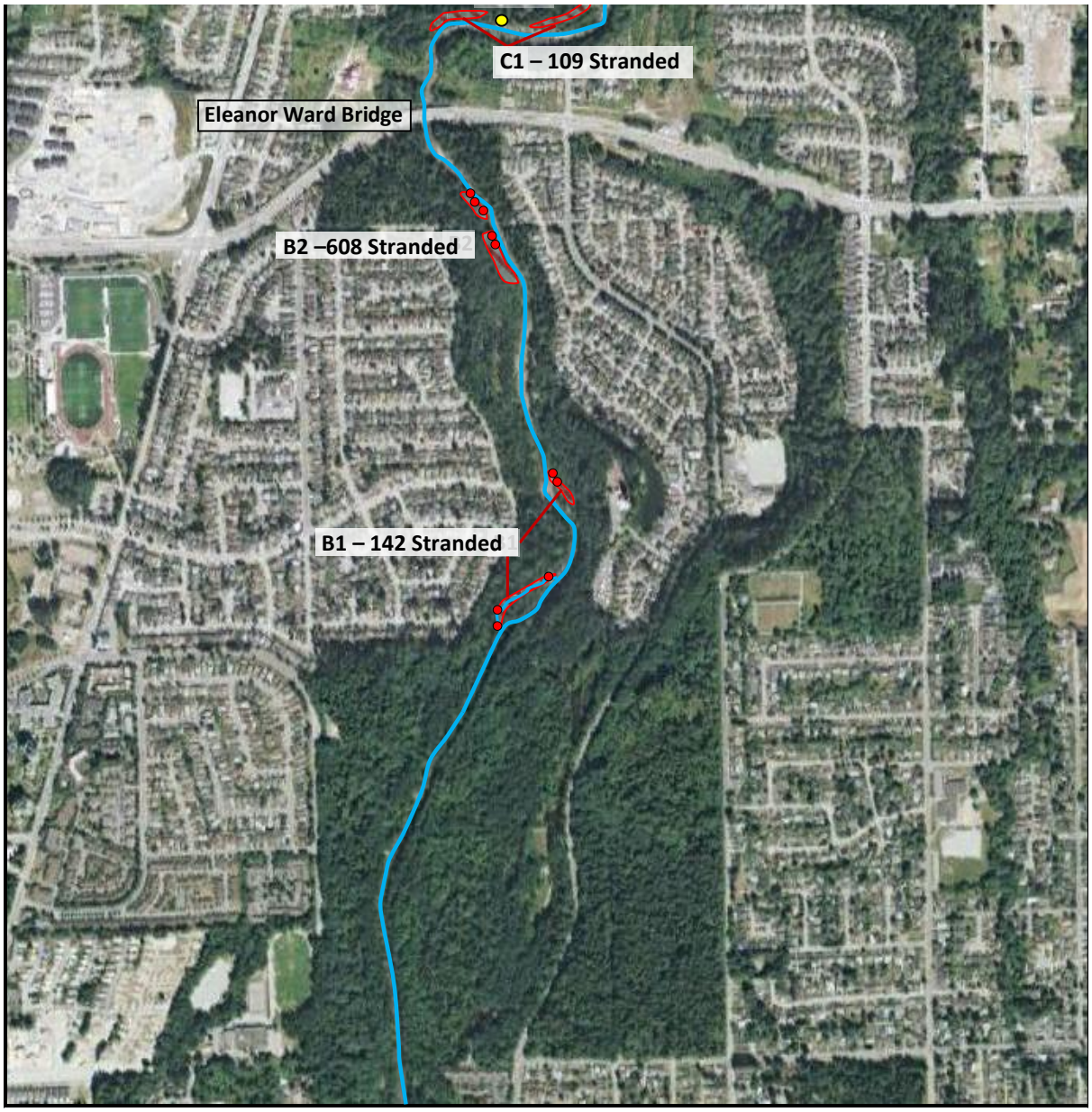


**Figure D**

0 250 500 750 1000

**Coquitlam River Stranding, Site B & C, Reach 2a.**

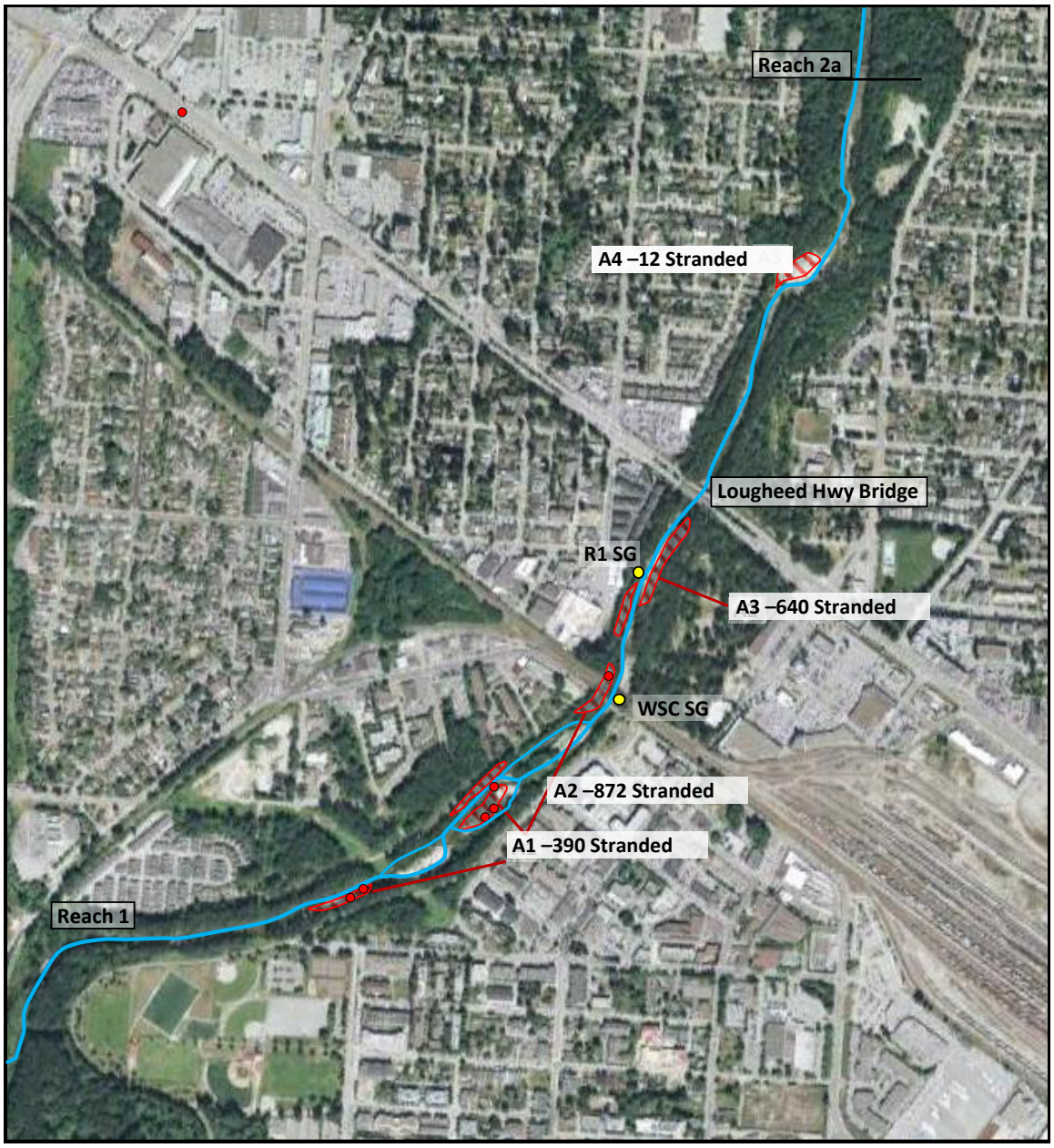


**Figure E**

**Coquitlam River Stranding, Site A, Reach 1.**