Coquitlam-Buntzen Project Water Use Plan

Coquitlam River Rampdown Fish Stranding Monitoring

Implementation Year 13

Reference: COQMON-2

Study Period: May 1, 2017 – April 30, 2018

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Executive Summary

This report summarizes rampdown events occurring on Lower Coquitlam River for the water year May 1, 2017 - April 30, 2018. A total of 7 rampdown events were monitored during the annual survey period: four scheduled rampdowns; June (1, 8 and 15) 2017, September 1, November 1, 2017 and January 15, 2018 and three unscheduled rampdowns: May 3, May 13 and December 4,6, 2017. The scheduled flow adjustments on May 1 2017, and April 1, 2018 were not required due to an experimental flow release from Coquitlam Reservoir. In addition to the 2017-2018 water year, rampdown events from June 2018 are also included in this document.

The 2017-2018 water year was the ninth 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 total rampdowns per year have increased to an average of 8.0 from 2.7 per year and unscheduled rampdowns have increased to an average of 3.0 per year from 2.7.

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 four scheduled rampdowns stranded a total of 222 fish, 220 of which were salvaged alive. The three unscheduled rampdown event produced a total of 1203 stranded fish of which 1108 were salvaged alive. The total number of fish stranded for all rampdowns, was 1425 with a mortality rate of 6.8%. The majority of stranded fish (93.2%) observed during fish salvage operations were juvenile Coho Salmon.

Modifications to the June rampdown were initiated in 2013 in order to reduce the increasing number of mortalities and stranding observed during this event. This rampdown alone has been responsible for over 70% of all stranding over the past 6 years due to its timing at the height of Coho fry emergence and having the largest decrease in discharge; dropping from 2.9m^3sec to 1.1m^3sec (a 64% reduction in flow). The modified rampdown method was successful in reducing mortalities from 24.4% and 36.7% in 2011 and 2012 to 4.7% in 2013 and 2.5% in 2014. However, in 2015 mortalities rose to 10.3% and increased again in 2016 to 13.0%. The 2017 June rampdown fish salvage saw mortality reduced to a Treatment 2 low of 1.1%.

Acknowledgements

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

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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. The Coquitlam facility, with origins dating back to 1892, provides a reservoir for domestic water supply by the Greater Vancouver Water District (GVWD) for the Greater Vancouver area. The Lake Buntzen-1 Powerhouse uses the water diverted from Coquitlam Reservoir to Buntzen Lake Reservoir through the 3.9km Buntzen tunnel, prior to discharge into Burrard Inlet's Indian Arm. BC Hydro's Coquitlam-Buntzen generation project dates to 1903 when there were two Lake Buntzen powerhouses for electricity generation located on the shore of 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 GVWD 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, urbanization and the variable controlled discharges from the dam.

Controlled flow releases from the Coquitlam River Dam have potential impacts on downstream aquatic communities. Fish can be affected by the ramping rate (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 the 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 Lower Coquitlam River have been ongoing since 2001. Field methods have been developed and refined over the past six years with additional opportunistic surveys. 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 the potential for stranding of mitigating fish stranding in the Coquitlam River. With respect to this, the management questions outlined by the WUP Consultative Committee (CC) and addressed during monitoring in 2003-2005 (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 flexibility (BC Hydro 2005) (See Table 2). Following completion of the seismic upgrade on Coquitlam Dam in October 2008, a new flow release schedule (Treatment 2) was initiated. Under this new flow regime a series of scheduled rampdowns will occur at pre-determined times throughout the year. These rampdowns amount to small scale reductions (between 3.00 m^3/s and 0.60 m^3/s) in the total volume of water released from Coquitlam Dam (Table 1), but can represent a sizeable decrease in the total volume of water entering Coquitlam River. For example, rampdowns scheduled for the dates January 15 and June 1 constitute a drop in the total flow release into Coquitlam River of 51% and 62% respectively (Table 1).

The introduction of the Treatment 2 regime is tied to the Lower Coquitlam Fish Productivity Index fish monitoring (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 Coquitlam River to compare anadromous fish production under two experimental flow regimes. Fish population monitoring under the first flow regime (Treatment 1) occurred from 2000 until the completion of the Coquitlam Dam seismic upgrade in October 2008. Fish production under Treatment 2 was to be monitored for up to 9 years; 2009 was the first complete year of monitoring under Treatment 2.

The low level outlet (LLO) knife-gate installed at Coquitlam Dam in 2008 will maintain the flow reduction at the same rate as the Treatment 1 rampdown schedule (Table 2 for revised gate adjustment schedule). With the seismic upgrade to Coquitlam Dam complete, BC Hydro dam safety constraints no longer stipulate a maximum reservoir elevation of 149m, beyond which spill releases must be initiated to ensure dam integrity. The Normal Maximum Reservoir Operating Level (MROL) depends on the time of year. It was anticipated that the increased reservoir capacity would reduce the frequency of unscheduled spills from Coquitlam Dam, but this has not been the case to date.

Since 2001, stranding risk has been assessed on the Coquitlam River at several locations from the base of the dam to the confluence with Maple Creek (Macnair et.al 2004-2009). The total survey area incorporates approximately 14 river kilometers. Maps of the area in Appendix 3 identify all stranding index sites and discrete stranding locations.

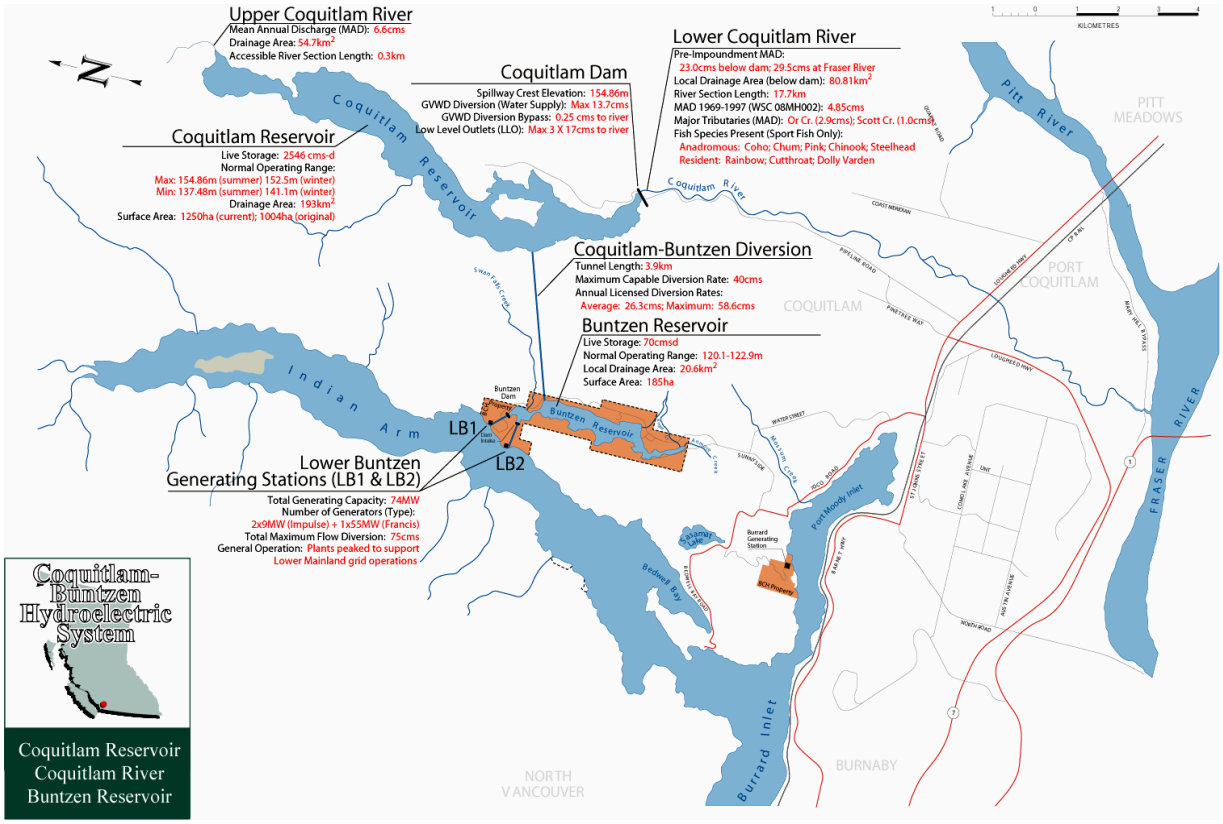

Figure 1 Coquitlam-Buntzen Reservoir, Diversion and Generating System. Map adapted from BC Hydro. Coquitlam-Buntzen Water Use Plan Monitoring Program Terms of Reference Revision 1: December 14, 2006

Due to the size of the study area, some sections of the river have received little annual investigation. 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.

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 (Chum (*Oncorhynchus keta*) and Pink Salmon (*Oncorhynchus gorbuscha*) for example) would not have the same impact on fish productivity. Redd and adult stranding, however, is much less frequent than stranding of juvenile fish.

Mortalities of adults and juveniles during rampdown events can result from fish being caught in pools or ephemeral channels which dewater during release reductions. This leaves fish isolated in pools that eventually completely drain. 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 impact redds by leaving them stranded, and rendering incubated eggs or alevin unviable.

Table 1 Coquitlam River flow release schedule 2017-2018. *Estimated flow is based on monthly flow transects performed to confirm flow target compliance. Note that April 2018 was modified for the KRSP flow release. Table adapted from BC Hydro. Coquitlam-Buntzen Water Use Plan Monitoring Program Terms of Reference Coquitlam Dam Flow Release Interim Ramping Rate Monitoring. Revision 1: December 14, 2006

		Reservoir Diversion Schedule (m^3/sec)					
		Domestic Water		Coquitlam Dam Releases			
				Treatment 1	Treatment 2		
Month	Year	Target	Min	Target	Target	Estimated*	Min
May	2017	12.0	11	1.0	2.9	3.30	1.1
June	2017	12.0	10.9	1.4	1.1	1.51	1.1
July	2017	18.0	15.8	1.4	1.2	1.35	1.1
August	2017	23.0	20.2	1.1	2.7	2.68	1.1
September	2017	23.0	20.9	0.8	2.2	2.24	1.1
October	2017	12.0	10.8	0.8	6.1	6.37	3.6
November	2017	12.0	10.8	1.1	4.0	4.22	1.5
December	2017	11.9	10.7	1.1	5.0	5.08	2.5
Jan 1-15	2018	11.9	10.7	1.0	5.9	5.91	3.6
Jan 15-Feb 28	2018	11.9	10.7	1.0	2.9	3.01	2.9
March	2018	11.9	10.7	1.0	4.3	4.39	1.1
April	2018	12.0	10.8	0.8	3.5	8.26	1.1

2.0 Methods

During spill reductions, locations susceptible to stranding risk are assessed during daylight hours by crews of between two and four people. Crew size varies depending on the 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. Therefore, fish stranding numbers presented in this report represent only what is observed in the index sites, not the entire Coquitlam River area. Areas susceptible to stranding are generally directly adjacent to the river mainstem and have a flat, un-sloped topography containing numerous potholes and depressions where isolated pools can form (Figure 8). Ephemeral side channels that fill during flow releases and drain completely following gate closures are also highly susceptible to stranding (Figure 9). 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 having ever been 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 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 if warranted.

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. For example, during the closure of the second LLO gate, survey crews know to respond to specific index sites which dewater during this stage of the rampdown. The LLO gates are classed; LLO1 starting gate = first gate to close, LLO2 second gate = second gate to close, LLO3 = third and last gate to close (Table 2). LLO gate flow reductions can be influenced by rainfall and tributary inputs to varying degrees. For example, the stranding risk at rampdown sites located downstream of Or Creek, (Coquitlam Rivers main tributary) is sometimes minimized due to high flows from this tributary which moderates or even eliminates the stage reduction below the confluence. 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 rendezvous with BC Hydro operating staff to determine rampdown start and finish time. Contact is maintained throughout the gate changes via cell phone and through direct contact at the LLO gatehouse. Remote gate operation was added to the Coquitlam Dam Low Level Outlet Gates in September 2013. The gate movements are controlled remotely from BC

Hydro's Real Time Operations Center at Fraser Valley Operations (FVO). Fish stranding assessment and salvage crews co-ordinate activities through the operations center and remain in contact during ramp down operations. The first remotely controlled rampdown was performed on November 1, 2013.

Table 2 Revised gate adjustment schedule for Coquitlam Dam Low level outlet gates during release reductions. Release varies depending on reservoir elevation, discharge data shown is assuming a reservoir elevation of 150.0m above sea level. Steps are implemented at 0.5hr intervals. Adapted from BC Hydro. Generation operating order COQ/LBD 4G-24v5. August 30, 2013

		Gate Change		
Gate	Step	From	To	Q m^3sec
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 with index sites lettered A-E, including two to three specific rampdown sub-areas in each index site (Appendix 2 & 3). Rampdown survey areas within each index site are not always contiguous, and may represent a large area of discontinuous but comparable fluvial and river edge characteristics (see Appendix 3 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 live fish are returned to areas of the river mainstem not affected by the flow reduction.

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. Isolated areas will remain continually wetted and capable of supporting fish until higher flows return whether by an increase in flow from the dam, seasonal rainfall or freshet conditions. 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 elevation changes are monitored at several staff gauge sites during the course of rampdown events (Appendix 1). Stage reductions are determined by survey crews at approximately hourly visual inspections of staff gauges located in Reach 1, Reach 4 and Reach 2b (Appendix 3). In February 2013 a staff gauge and transect site was installed in Or Creek. This will allow the survey crew to monitor the discharge in Or Creek during fish salvage operations. Or Creek is the main tributary to the Lower Coquitlam River and its flow can greatly influence fish stranding downstream of it, affecting reaches 3, 2b, 2a and 1. These gauges are monitored from the onset of flow reductions to the end of daily salvage operations. Target flow release from Coquitlam Dam is monitored during each rampdown at a transect site established in Reach 4 (Appendix 3, Figure A). River stage elevation is also monitored using hourly flow data from the Water Survey of Canada (WSC) gauge located in Port Coquitlam (08MH002).

The area of each rampdown site was calculated by estimating the extent of inundation during a full 3 LLO gate release. The full extent of each site is included in the area calculation, therefore, areas within the ramp site that do not pose a stranding risk are represented in the 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 Results

3.1 Scheduled Rampdown Summaries May 2017-April 2018

Rampdowns scheduled for May 1, 2017 and April 1, 2018 did not occur due to experimental flow releases from Coquitlam Reservoir for the KRSP program. In total, only four of the six rampdowns scheduled for 2017-18 under Treatment 2 were undertaken.

Coquitlam Rampdown June 1, 8, 15, 2017

As scheduled under the current Treatment 2 flow regime, the Low Level Outlet release from Coquitlam Dam was reduced from 2.9 m^3sec to 1.1 m^3sec for the month of June. In light of high numbers of stranded fish and mortalities during past scheduled flow reductions at this time a decision was made in 2013 to extend the flow reduction over two to three days instead of performing the entire flow reduction over a single day. It was hoped that a more gradual flow reduction would result in fewer stranded fish, and fewer mortalities due to stranding. This extended flow reduction period was first attempted in 2013 and has been successful in reducing stranding mortality when compared to single day rampdowns, however it has not led to a reduction in the number of fish being stranded.

The scheduled flow reductions in 2017 were performed over 3 days, each separated by a one week period. June 1st the flow was to be reduced from 2.9-2.2 m3/s, flow on June 8th decreased from 2.2 – 1.8 m3/s with the final flow decrease from 1.8 m3/s to 1.35 m3/s on June 15, 2017. This staggered flow reduction reduced the maximum daily stage elevation drop in Reach 4 dramatically. Flow reductions in 2011 and 2012 for this gate change dropped flow in Reach 4 approximately 16.0 cm in 2-3 hours. The maximum decrease this year was 5 cm over 3.0 hours on June 15, 2017 (Appendix 2).

Fish stranding over the course of the 3 days was by far the lowest observed since 2011 with a total of 184. Table 7 and Figure 2 show the dramatic difference in stranding and mortality observed in 2017, the previous low for this rampdown was 977 fish and the mean from 2011-2016 is 1960 stranded fish. Of the 184 fish observed there were in total: 170 Coho Salmon (*Oncorhynchus kisutch*) fry, 4 Coho smolts, and 10 Three-spined Sticklebacks (*Gasterosteus aculeatus*, Table 3). The mortality rate was 1.1%, also the lowest yet observed and far lower than the 2011-2016 average of 13.3%.

The explanation for this dramatic reduction in stranding is entirely due to river conditions present during the flow reductions. As shown in Appendix 2, heavy rain combined with freshet conditions during the rampdowns meant that river stage over the majority of Coquitlam River was rising and not falling at the time of the flow reduction. This was certainly the case on the June 8 and June 15 rampdown, though

less evident during the June 1 rampdown. The result of these high flows meant that there were no fish salvage activities required for the majority of the river, hence the large reduction in fish stranding compared to previous years.

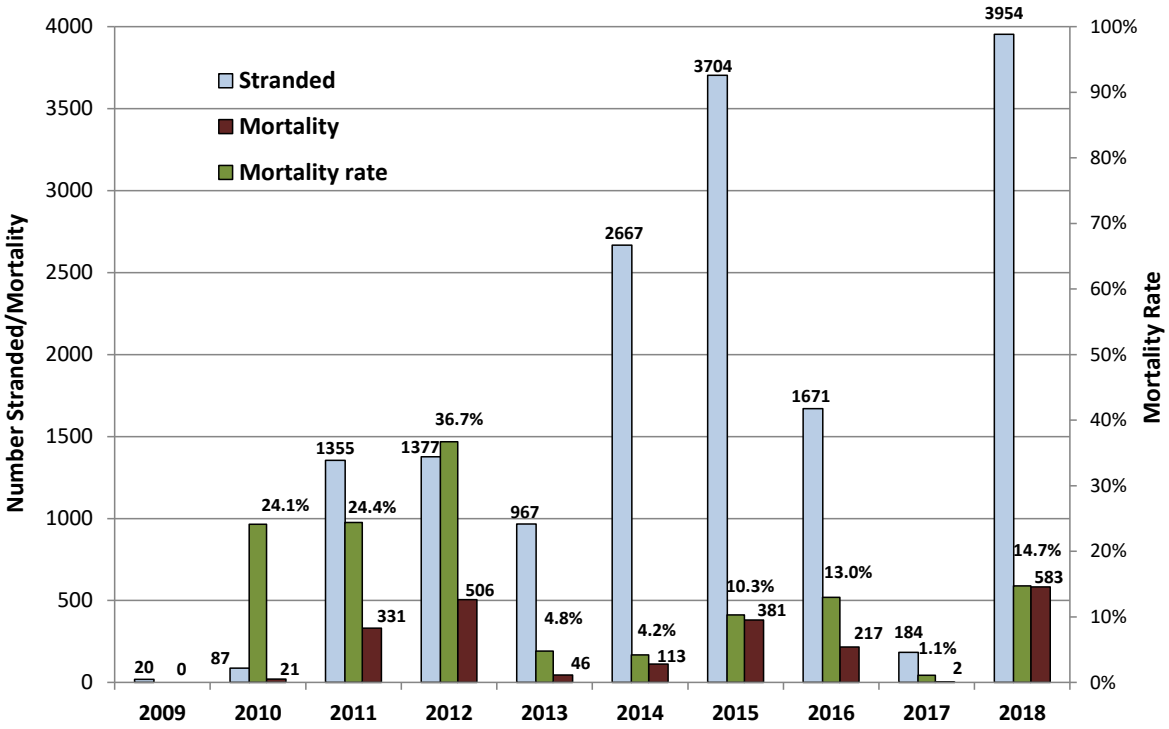

Figure 2 June rampdowns 2009-2018. 2018 rampdown is part of 2018-19 study year.

Coquitlam Rampdown September 1, 2017

On September 1, 2017 as scheduled under the current Treatment 2 flow regime, the Low Level Outlet release from Coquitlam Dam was scheduled to be reduced from 2.7 m^3s to 2.2 m^3s. The scheduled rampdown began at approximately 0900hr and was completed by 1100hr. Fish salvage activities continued until 1500hr.

Upstream of Or Creek (Reach 4), river stage dropped a total of 1.5 centimetres following completion of the flow reduction and had a maximum hourly decrease of 1.0 cm/hr. Downstream of Or creek river stage dropped 1.0 centimetre using only the Reach 2B staff gauge as the Reach 1 Water Survey of Canada online data is not yet available. Stranding was observed in three locations in Reach 4 & 2B (Table 3). A total of 30 Coho fry and 6 steelhead trout fry were observed to be stranded in small ephemeral channels. All fry were salvaged and returned to the river mainstem.

Coquitlam Rampdown November 1, 2017

On November 1, 2018 as scheduled under the current Treatment 2 flow regime, the Low Level Outlet release from Coquitlam Dam was reduced from 6.1 m^3s to 4.0 m^3s. The scheduled rampdown began at approximately 0900hr, and fish salvage activities continued until 1600hr.

Upstream of Or Creek (Reach 4), river stage dropped a total of 6.0 centimetres following completion of the flow reduction and had a maximum hourly decrease of 1.5 cm/hr. Downstream of Or Creek river stage decreased by 4.0 centimetres reduction and had a maximum hourly decrease of 2.0 cm/hr. Fish stranding was not observed in any areas surveyed.

Coquitlam Rampdown January 16, 2018

On January 16, 2018 as scheduled under the current Treatment 2 flow regime, the Low Level Outlet release from Coquitlam Dam was reduced from 5.9 m^3s to 2.9 m^3s. The scheduled rampdown began at approximately 0900hr, but due to an equipment communication problem the remote gate closure was not able to operate. A BC Hydro crew was alerted and dispatched to the Coquitlam Dam LLO gate building and the problem was rectified. The gate closure was restarted and the rampdown was able to begin at approximately 1100hr. Fish salvage activities continued until 1600hr.

In Reach 4 upstream of Or Creek, river stage dropped a total of 12.0 centimetres following completion of the flow reduction and had a maximum hourly decrease of 3.0 cm/hr. Downstream of Or creek river stage initially increased by 3.0-6.0 centimetres due to light rainfall in the watershed, before falling again due to the Coquitlam Dam gate closure Appendix 2. Fish stranding was not observed in any areas surveyed.

Table 3 Fish stranding by species, age class and Reach during scheduled rampdowns 2017-2018. Co 0 = Coho fry. Co 1+ = Coho parr/smolt. TSS = Three-spined Stickleback. Pk 0 = Pink fry. St 0 = Steelhead fry

			Reach					
Date	**Species**	**Salvaged/Mort**	**1**	**2a**	**2b**	**3**	**4**	**Total**
1-May-17	no survey	no survey						0
1-Jun-17	Co 0	s					84	84
1-Jun-17	Co 1+	s				4		4
1-Jun-17	TSS	s					11	11
1-Jun-17	Co 0	m					2	2
8-Jun-17	Co 0	s					37	37
8-Jun-17	TSS	s					1	1
15-Jun-17	Co 0	s					47	47
1-Sep-17	Co 0	s			11		19	30
1-Sep-17	St 0	s			4		2	6
1-Nov-17	no fish	no fish						
16-Jan-18	no fish	no fish						
1-Apr-18	no survey	no survey						
		Total Stranded	**0**	**0**	**15**	**4**	**203**	**222**
		Total Mortality	**0**	**0**	**0**	**0**	**2**	**2**

Table 4 Stranding results of scheduled rampdowns since the introduction of Treatment 2.

Date	**Status**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**Total**
15-Jan	Salvaged	-	0	n/s	0	5	10	0	0	31	22	0	**68**
	Mortality	-	0	n/s	0	2	10	0	0	0	0	0	**12**
1-Apr	Salvaged	-	0	n/s	0	1	129	28	48	5	68	n/s	**279**
	Mortality	-	0	n/s	0	0	15	0	14	1	0	n/s	**30**
1-May	Salvaged	-	0	0	n/s	0	100	0	95	310	n/s	n/s	**505**
	Mortality	-	0	0	n/s	0	3	0	21	56	n/s	n/s	**80**
1-Jun	Salvaged	-	20	55	1355	1377	967	2600	3327	1454	184	3371	**14710**
	Mortality	-	0	19	331	506	46	67	381	217	2	583	**2152**
1-Sep	Salvaged	-	0	0	98	0	0	7	0	n/s	30		**135**
	Mortality	-	0	0	82	0	0	0	0	n/s	6		**88**
1-Nov	Salvaged	0	0	11	0	0	n/s	0	0	n/s	0		**11**
	Mortality	0	0	2	0	0	n/s	0	0	n/s	0		**2**

3.2 Unscheduled Rampdowns Summaries May 2017-April 2018

Three unscheduled rampdown occurred on Coquitlam River during the 2017-2018 monitoring program. Two occurred in May as a result of increased flow for the KRSP and the third was a full 3 LLO gate rampdown fish salvage from December 4-6, 2017.

Coquitlam Unscheduled Rampdown May 3, 2017

On May 3, 2017 a rampdown fish salvage was undertaken on Coquitlam River following an experimental kokanee smolt attraction release flow that been ongoing since April 25, 2017. The experimental flow had temporarily increase the COQ dam release flow from 3.5 m^3/s to 8.5 m^3/s The gate closure was initiated on Friday, May 3 at 0830hr and was complete by 1530hr.

Heavy rainfall meant that the river downstream of Or Creek rose in elevation for most of the day so stranding was not an issue in the majority of the river's length. A total of 48 stranded fish were observed stranded by survey crews. Of the total, 35 were salvaged and there were 13 mortalities.

Coquitlam Unscheduled Rampdown May 13, 2017

On May 13, 2017 a rampdown fish salvage was undertaken on Coquitlam River following an experimental kokanee smolt attraction release flow that been ongoing since May 5, 2017. The experimental flow had temporarily increase the COQ dam release flow from 3.5 m^3/s to 8.5 m^3/s The gate closure was initiated on Friday, May 13 at 0830hr and was complete by 1530hr.

There was a total of 940 stranded fish observed, 893 of which were returned safely to the river for a mortality rate of 4.9%. Coho fry represented virtually all of the stranded fish with a total of 932, there were also 7 Chum fry and one lamprey salvaged (Table 5). This represents the largest single day stranding event yet observed during an unscheduled rampdown. The total of 940 stranded fish is more than double the previous high of 411 on June 30, 2010. The fact that this rampdown occurred at the peak of Coho emergence made it a very high risk

Coquitlam Rampdown December 4, 6, 2017

On December 4, 2017 a rampdown fish salvage was undertaken on Coquitlam River following a full 3 Low Level Outlet LLO gate spill that been ongoing since November 21, 2017. The first gate closure was initiated on Monday, December 4 at 0900hr when the first of two LLO gates were shut at the prescribed rate. The third and final gate was ramped down on December 6, 2017. The spill and subsequent rampdown occurred at the tail end of adult Chum spawning in Coquitlam River which meant that redd stranding was a potential outcome of the flow reduction.

In total 215 stranded fish were observed over the two day period. Fish stranding was dominated by juvenile steelhead and Coho salmon with a total of 186 of 215 or 87% represented by these two species; juvenile Coho represented 67% of the total stranded and juvenile steelhead 20% (Table 5). In addition to the stranded fish a total of 9 stranded redds were also observed in Reach 1. These redds were classified as stranded and unviable due to the fact that they will not be wetted for the remainder of the incubation period. No efforts were made to ascertain if any redds had eggs deposited within them or to salvage any eggs.

The majority of stranded fish were observed on the 2nd and final day of the rampdown with a total of 168 fish or 78%. Stranding was observed in every reach of the Coquitlam River with the majority observed in Reach 3 with 161 or 75% (Table 5). The mortality rate over the course of the two day rampdown was 17.8% or 36 of 215 fish. This rate is very near the average mortality rate for unscheduled rampdowns of 17.6% for the 2002-2017 period.

Maximum hourly river stage reduction was 15.0 cm in Reach 4 on the first day of the rampdown, total stage reduction was also highest in Reach 4 with a total two-day reduction of 74.0 centimetres (Appendix 2).

Table 5 Fish stranding by species, age class and Reach during unscheduled rampdowns 2017-2018. Lmp = Lamprey (*Lampetra sp.*)

			Reach					
Date	**Species**	**Salvaged/Mort**	**1**	**2a**	**2b**	**3**	**4**	**Total**
3-May-17	Co 0	s					35	35
3-May-17	Co 0	m				13		13
13-May-17	Co 0	s		197	570	63	56	886
13-May-17	Co 0	m		14	6	23	3	46
13-May-17	Cm 0	s			7			7
13-May-17	Lmp	s			1			1
4-Dec-17	Co 0	s					2	2
4-Dec-17	Rt 0	s		8	1			9
4-Dec-17	Rt 1+	s	1					1
4-Dec-17	Crayfish	s		1		1		2
4-Dec-17	Lmp	s	3	2	1		1	7
4-Dec-17	Co 0	m		2	1	1	1	5
4-Dec-17	Rt 0	m		1			1	2
4-Dec-17	Rt 1+	m		1				1
4-Dec-17	TSS	m			17			17
4-Dec-17	Crayfish	m		1				1
6-Dec-17	Co 0	s				137		137
6-Dec-17	Rt 0	s				17		17
6-Dec-17	Rt 1+	s				4		4
6-Dec-17	Rt 0	m		7		1		8
6-Dec-17	Co Adult	m					1	1
6-Dec-17	Crayfish	m		1				1
		Total Stranded	**4**	**235**	**604**	**260**	**100**	**1203**
		Total Mortality	**0**	**27**	**24**	**38**	**6**	**95**

4.0 Discussion

4.1 Stranding Risk

The ninth full year of rampdown monitoring under Treatment 2 in 2017-2018 had a total of 1425 stranded fish observed, which is below the Treatment 2 average of 2099 (Table 6). The total of 97 mortalities is also below the Treatment 2 average of 303 mortalities. As has been the case since Treatment 2 was initiated, the majority of stranding in 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 single contributor to fish stranding. This one rampdown has been responsible for 75.8% of all stranding observed on Coquitlam River since Treatment 2 was initiated.

River conditions can dramatically impact stranding during rampdowns as illustrated by the June 2017 rampdown fish salvage. June 2017 had the lowest amount of stranding (184) for Treatment 2 vs 2015 which has the most to date (3704). The 2015 June rampdown had the lowest discharge yet recorded during monitoring. In June 2015 Coquitlam River was at 2.5 m^3/s when the rampdown *began* and fell to 1.1 m^3/s following the flow reduction, while during the 2017 June rampdown the discharge ranged from 5.5 m^3/s to 20 m^3/s. This demonstrates how the lack of, or abundance of, water downstream of Reach 4 can influence stranding. In the example of the 2017 June rampdown, 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 seeming large drop in fish stranding.

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 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. The June flow reduction in Reach 4 is equivalent to 62% of the total flow volume in this section of Coquitlam River. Reach 4 is above the buffering influence of Or Creek, and has virtually no natural inflow. In addition, its entire length is composed of shallow pools and small channels that attract juvenile fish. Reach 4 is also narrow and confined by berms and roadways along its length, which results in the river stage elevation decreasing more rapidly and to a greater degree than areas downstream of Or Creek (See Appendix 2). Scheduled rampdowns typically see only a small decrease (or an increase depending on rainfall or freshet conditions) in river stage in the areas below Or Creek.

Adult Coho escapement in Coquitlam River is also concentrated in Reach 4. Typically between 65-75% of all Coho spawning occurs in this Reach (Shick et. al. 2014). This heavy spawning concentration, combined with the fact that May and June represent

peak emergence for Coho fry, creates a heightened risk of stranding during rampdowns at this time of year.

Figure 2 illustrates the increase in the past several monitoring years in the amount of fish stranded on 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. In the first year under Treatment 2 (2009-2010) fish stranding was limited, but the results have swung far in the other direction for the past several monitoring years (Figure 2). In addition, during the first year under Treatment 2, the flow releases from the LLO gate at Coquitlam Dam were approximately 20-40% over the target due to a miscalculation in the stage discharge curve at the LLO gate. Therefore, there was consistently more water and a higher river stage in Coquitlam River, as a result of this there was likely less of a stranding risk.

The reduction in mortality illustrated in Figure 2 and Table 6 shows the impact of the past eight scheduled flow reductions during June. The mortality rate for the June rampdown dropped from 24.4% and 36.7% in 2011 and 2012 to only 4.8% in 2013 and 4.2% in 2014. In 2015 it rose to 10.3% and then to 13.0% in 2016 before dropping to 1.1% in 2017. However, the number of fish stranded during the June rampdowns has not decreased over the same period and in fact, the years 2014-2015 and 2018 had peak amounts of stranded fish (Table 4). The act of spreading the flow reduction out over multiple days appears to have had mixed success as the mortality rate has dropped over the past five years, but the amount of fish stranded has not decreased. Yearly, the number of stranded fish continues to fluctuate based on a number of factors, but the risk of stranding fish in June has *not* been addressed through this operational approach.

In Year 9 stranding was concentrated in the mid to lower reaches of Coquitlam River with Reach 2a and 2b accounting for 60.0% of all stranding (Table 6). This result is not the norm under Treatment 2 as Reach 3 and 4 normally see 45-75% of all stranding and have averaged 56.5% over the Treatment 2 period (Figure 4). This result is again related to the lack of stranding during the June 2017 rampdown fish salvage, where stranding is typically heavily concentrated in Reach 3 & 4 (Figure 4).

The majority of unscheduled rampdowns involve large flow releases, often seeing flow reductions of all 3 LLO gates on Coquitlam River which can release up to 40-45 m^3/s of water per second, therefore the stranding impact tends to extend to the entire river length and be more evenly distributed by Reach (Figure 3).

Table 6 Yearly Reach by Reach comparison of stranded fish during all rampdown events, 2001-2018. T1 = Treatment 1 2001-2008, T2 = Treatment 2 2009-2018. Data from 2018-2019 gives stranding data to date and therefore includes only the June 2018 rampdown.

Year	Reach 1		Reach 2a		Reach 2b		Reach 3		Reach 4		Total	Total	Total	%
	Salv	Mort	Salv	Mort	Salv	Mort	Salv	Mort	Salv	Mort	Strand	Salv	Mort	Morts
2018-19	139	30	951	11	592	105	1088	343	601	94	3954	3371	583	14.7%
2017-18	4	0	208	27	584	35	228	28	306	7	1427	1330	97	6.8%
2016-17	132	23	459	25	402	100	329	118	597	26	2211	1919	292	13.2%
2015-16	278	172	521	65	147	64	2288	227	461	99	4322	3695	627	14.5%
2014-15	895	36	314	30	663	29	375	20	575	52	2989	2822	167	5.6%
2013-14	0	0	318	12	0	0	428	5	300	32	1095	1046	49	4.5%
2012-13	65	9	143	79	85	24	322	28	847	504	2106	1462	644	30.6%
2011-12	154	9	164	21	3	11	65	88	1071	338	1924	1457	467	24.3%
2010-11	103	6	389	21	39	25	78	13	134	26	834	743	91	10.9%
2009-10	21	0	40	2	0	0	5	0	45	13	126	111	15	11.9%
2008-09	31	5	33	9	49	12	12	0	13	0	164	138	26	15.9%
2007-08	67	6	32	11	199	17	20	1	65	1	419	383	36	8.6%
2006-07	39	14	3	4	47	80	36	4	0	0	227	125	102	44.9%
2005-06	95	0	0	0	1	9	0	7	85	6	203	181	22	10.8%
2004-05	75	2	10	0	13	9	0	0	48	0	157	146	11	7.0%
2001-04	36	4	0	2	0	0	6	1	0	16	65	42	23	35.4%
Total	**2134**	**316**	**3585**	**319**	**2824**	**520**	**5280**	**883**	**5148**	**1214**	**22223**	**18971**	**3252**	**14.6%**
T1	343	31	78	26	309	127	74	13	211	23	1235	1015	220	17.8%
T2	1791	285	3507	293	2515	393	5206	870	4937	1191	20988	17956	3032	14.4%
T1 mean	57	5	13	4	52	21	12	2	35	4	206	169	37	
T2 mean	179	29	351	29	252	39	521	87	494	119	2099	1796	303	

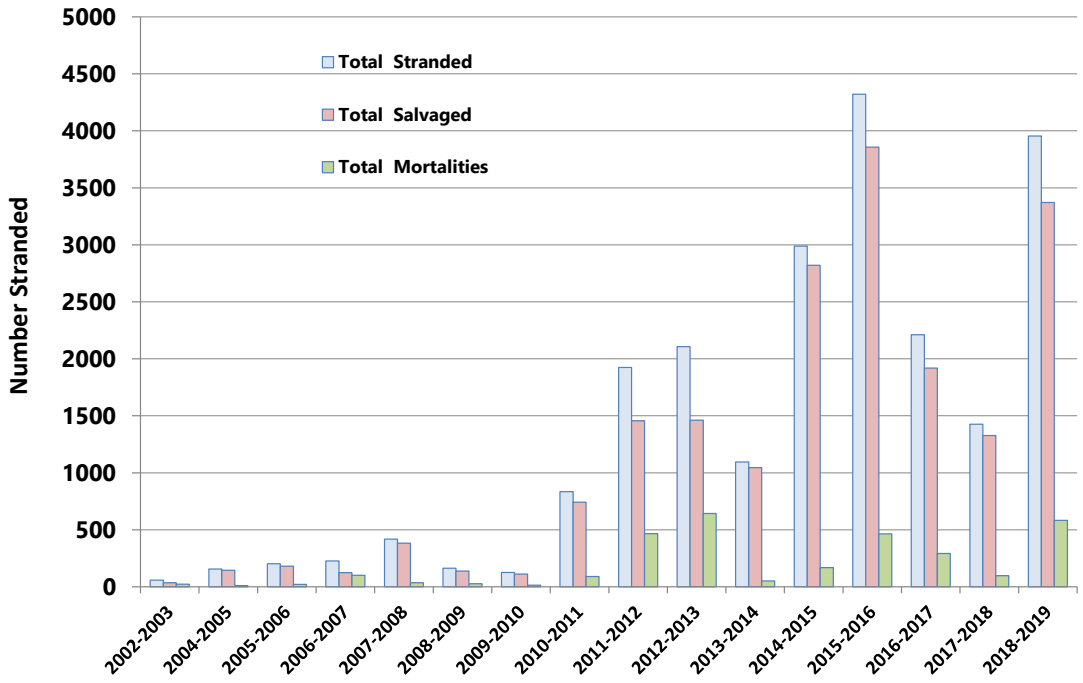

Figure 3 Number of fish salvaged and mortalities for all rampdowns 2002-2018

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As discussed, the fact that the June rampdown reduces the flow release to Coquitlam River by 62% at a sensitive time appears to be the central cause of stranding. In

addition, the fact that the flow reduction reduces the discharge to a yearly low of 1.1 m^3/s is likely problematic. Salmon fry depend on spring 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 is an increase in discharge, not a severe and rapid reduction. Therefore, the June rampdown represents the opposite of the conditions that migrating fry depend on for survival.

The total decrease in river volume in Reach 4 is also high during the January 15, and November 1 scheduled rampdowns, with a loss of 50%, and 33% of total flow volume respectively (Table 1). This compared to the March 31, April 30 and August 31 scheduled rampdowns which have flow volume decreases of 19%, 17% and 19% respectively. However, during periods of low flow in Coquitlam River (mid-late summer) even small reductions in release can have impacts.

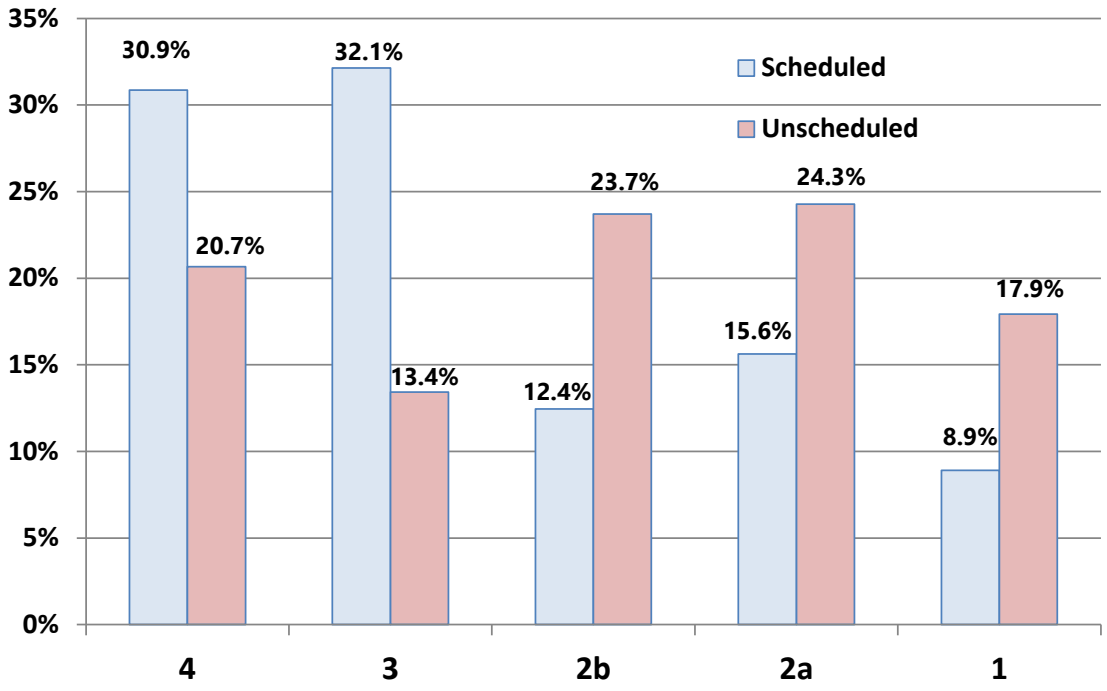

Figure 4 Stranding distribution by Reach, 2004 - June 2018, highlighting the difference in stranding distribution by Reach between scheduled and unscheduled rampdowns.

Other flow reductions where widespread stranding was observed was the May 13, 2017 rampdown (Table 4). The May 13 rampdown was significant in that it represented the highest number of fish stranded during an unscheduled rampdown that has been observed with 940, more than double the previous high of 411 on June 30, 2010. The decrease in discharge was quite high, from 8.5 m^3/s to 3.5 m^3/s, representing a drop of 59%. Coho fry were the dominant species observed, with 932 of the 940 total stranded.

May rampdowns also occur at the peak of Chum and Pink fry emergence when millions of these fry are in the river, many congregating in shallow margins along the river banks which elevates the stranding risk. However, despite the presence of large numbers of fry during these two flow reductions, stranding is nowhere near as problematic as the June 1 flow reduction. Typically Pink and Chum fry migrate almost immediately from Coquitlam River following emergence, whereas Coho fry remain in the river looking for rearing space. This fact likely plays a significant role in reducing the risk of stranding for Chum and Pink fry.

As the results of the spring and summer rampdowns demonstrate, a strong determiner of stranding risk on Coquitlam River is the time of year at which a rampdown occurs. Rampdowns that occur in the fall and winter months (September 21 – March 21) are the least likely to strand fish. Data on stranding by season and species given in Figure 5 shows that fall and winter rampdowns strand an average of 39 and 38 fish per rampdown respectively, while the average for spring and summer is 579 and 93 fish per rampdown. This seasonal difference is likely due to the reduction of juvenile fish in the system during the fall and winter (compared to spring and summer when literally millions of fry may be present) and possibly colder water conditions in winter which can minimize fish movement (Bustard 2011).

Final river stage elevation is also an important contributing factor as rampdowns occurring from October 1 -January 15 (under Treatment 2) have a higher minimum stage elevation than spring and summer rampdowns. For example, rampdowns in the spring and summer months return to an average discharge of 2.3 m^3/s respectively, while those in the fall and winter return to a discharge flow of 4.7 m^3/s. The higher minimum discharge results in an elevated river stage which can keep areas vulnerable to stranding continuously wetted.

Table 7 Stranding and mortality scheduled vs. unscheduled rampdowns 2001-2018

2001-2018	Stranded	Per Ramp	Salvaged	Mortality	Per Ramp	Rate
Unscheduled	5177	118	4264	913	21	**17.6%**
Scheduled	17054	348	14707	2347	48	**13.8%**
Total	**22231**	**239**	**18971**	**3260**	**35**	**14.7%**

Coho fry have the highest stranding risk due to their year-round residence, abundance at emergence and habit of congregating in shallow river margins, ephemeral channels and shallow pools (Dunn, 2002, Macnair 2008). 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 almost immediately migrate out of the river and are absent from the water column from June to February. Coho Salmon juveniles are the most likely fish to be stranded over the entire study period, representing 89.1% of all stranded fish between 2004-2017 (Figure 8). In Year 9

Coho fry and smolts represented 93.2% of all stranding observations. Overall, salmonids accounted for 98.6% of all stranded fish for the 2004-2017 period (Figure 8).

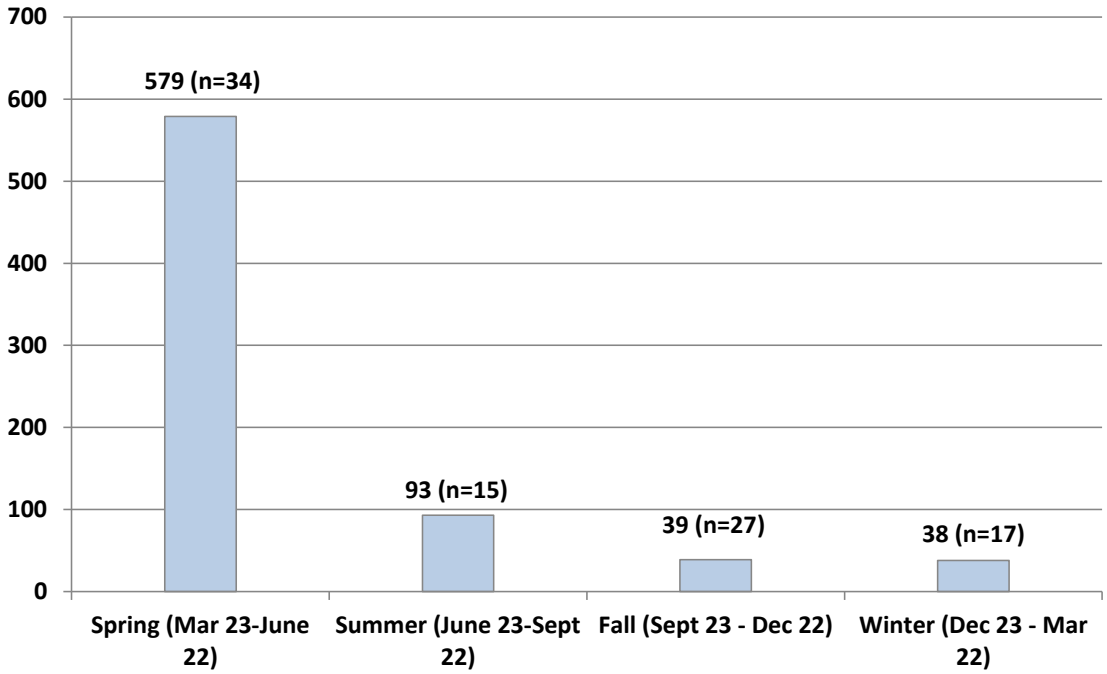

Figure 5 Average number of stranded fish observed per rampdown by season, all fish species 2001-2018. n equals number of rampdown fish salvage operations.

4.2 Redd Stranding

Redd stranding on Coquitlam River as a result of flow reductions is a risk only during fall 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 5 occasions on Coquitlam river since 2001, stranding an estimated 897 Pink and Chum redds over the 2001-2017 period (Table 8). Steelhead redd stranding is limited to one problematic area on Coquitlam River that surveyors have observed stranded in precisely the same spot in seven consecutive years (Table 10).

The relatively low number of redds stranded and the low frequency of events points to the fact that redd stranding is not a major concern. The yearly loss of 1-3 steelhead redds compares to a yearly average of 234 over the 2005-2017 period. Chum and Pink redds are not enumerated, but a look at the average escapement numbers in the 10,000-60,000 range (2016, Schick), it is certain that at minimum several thousand redds

are created each fall. The loss of a few hundred redds in infrequent intervals over 17 years of study would likely have very little to no bearing on fish productivity.

Table 8 Redd stranding on Coquitlam River 2001-2018. Steelhead spawning timing March-May, Pink and Chum, September-November

Year	Steelhead	Pink	Chum	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			
Total	**13**	**30**	**867**	**908**

4.2 Rampdowns and Flow Release Targets

Since the introduction of Treatment 2 there has been no reduction in the total number of unscheduled rampdowns (Table 9). 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 Coquitlam River averaged 2.7 unscheduled rampdowns per year, under Treatment 2 the average has risen slightly to 3.0 unscheduled rampdowns per year. With respect to the number of full 3 Low Level Outlet Gate spills, again, no reduction has been evident in the past eight years of monitoring. Under Treatment 1 Coquitlam River had 14 full LLO spills in seven years (2002-2009), under Treatment 2 there have been 14 (as of December 2017).

Flow transects performed throughout the 2017-2018 monitoring year indicated that flow releases from Coquiltam Dam have been consistently within the targeted range throughout the monitoring year (estimated flows must be within 10% for the targeted value).

Table 9 Number of rampdown per year 2001-May 2018.

Monitoring Year	Scheduled	Unscheduled	Total
2017-2018	4	3	7
2016-2017	4	1	5
2015-2016	6	4	10
2014-2015	6	3	9
2013-2014	6	1	7
2012-2013	5	4	9
2011-2012	5	3	8
2010-2011	6	5	11
2009-2010	4	5	9
2008-2009	3	1	4
2007-2008	n/a	5	5
2006-2007	n/a	4	4
2005-2006	n/a	2	2
2004-2005	n/a	3	3
2003-2004	n/a	3	3
2002-2003	n/a	1	1
2001-2002	n/a	1	1
Total	**49**	**49**	**98**
Treatment 2	**4.9**	**3.0**	**7.9**
Treatment 1		**2.7**	**2.7**

4.3 Fish Productivity Impacts

Stranding influence on fish production in Coquitlam River is likely to be minimal for all species with the exception of Coho and possibly steelhead juveniles. For Pink and Chum fry the impact is negligible. Schick et. al. 2017 reports the estimated average annual outmigrating population for Chum and Pink fry for the 2003-2017 period is 3.8 million and 1.7 million respectively. Contrast this with a total of 162 Chum mortalities and 6 Pink mortalities observed during fish salvages for the same period. Coho and steelhead parr/smolt population estimates for the same period average 13,388 and 4221 per year respectively (Schick et. al. 2017). The estimated average number of Coho and steelhead parr/smolt stranded per year due to rampdowns is 18 and 22 respectively, or less than 0.4% of the estimated population. However, in light of the impacts on Coho fry, and to a lesser extent, steelhead fry in the past four monitoring years, there may be cause for concern.

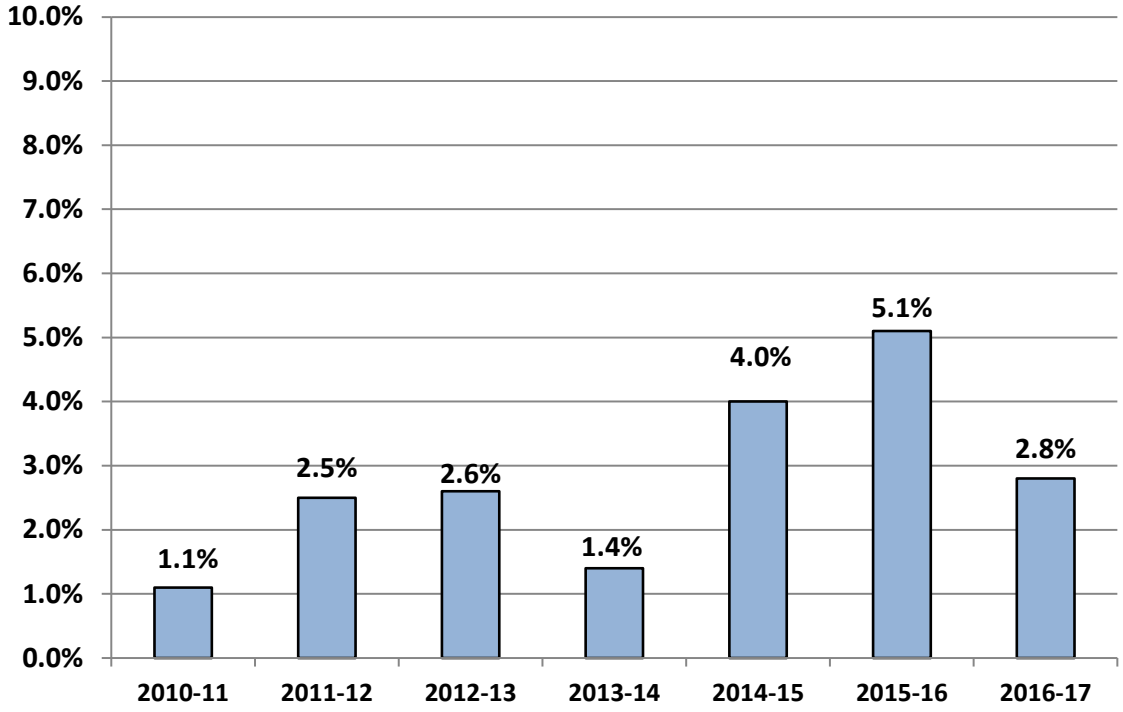

Figure 6 Estimated potential impact of rampdowns on coho fry population in Coquitlam River. Values represent the estimated proportion of the total population of Coho fry that could be impacted due to rampdowns each year *if* fish salvage activities were not conducted.

Coho fry populations are typically the hardest hit with respect to stranding, estimates of total fry productivity (based on fall standing stock estimates 2003-2016) range from 21,000 to 105,000 with a mean of approximately 56,101 (Schick 2016). Using available data, it is possible to give a rough idea of the impact of stranding on the Coho fry population in Coquitlam River. For example: using the average number of Coho fry observed stranded from 2011-2016, (2727) and comparing it to the average Treatment 2 Coho fry standing stock estimate of 70,760 (a yearly estimate of the total number of fry in the system in late summer) would represent a loss of approximately 2.8% of the Coho fry population for 2016-17 (Figure 6). This estimate lands somewhere in the middle as shown in Figure 6, with the highest estimate of loss at 5.1% in 2015-16 and the lowest 1.1% in 2010-11.

This level of loss could have the potential to have an impact on the Coho fry population. Bearing in mind that freshwater mortality can be highly variable and often substantial for juvenile Coho Salmon under natural conditions (Bradford 1995; Nickelson and Lawson 1998). For comparison, summer mortality rates - covering the period June to September - for juvenile Coho ranged from 26% - 56% in a study of three unregulated streams in the Pacific Northwest (Au 1972, Spalding 1995).

This is a rough estimate using the only available data, but does provide a useful illustration and is comparable between years. The impact on steelhead fry is not as dramatic; using the total number observed stranded (248) in the 2015-2016 monitoring

year and comparing it to the average Treatment 2 standing stock estimate (32,746), gives a potential loss of 0.8% of the population due to stranding. This is the highest estimate yet for steelhead fry loss and is still well below potential Coho fry losses.

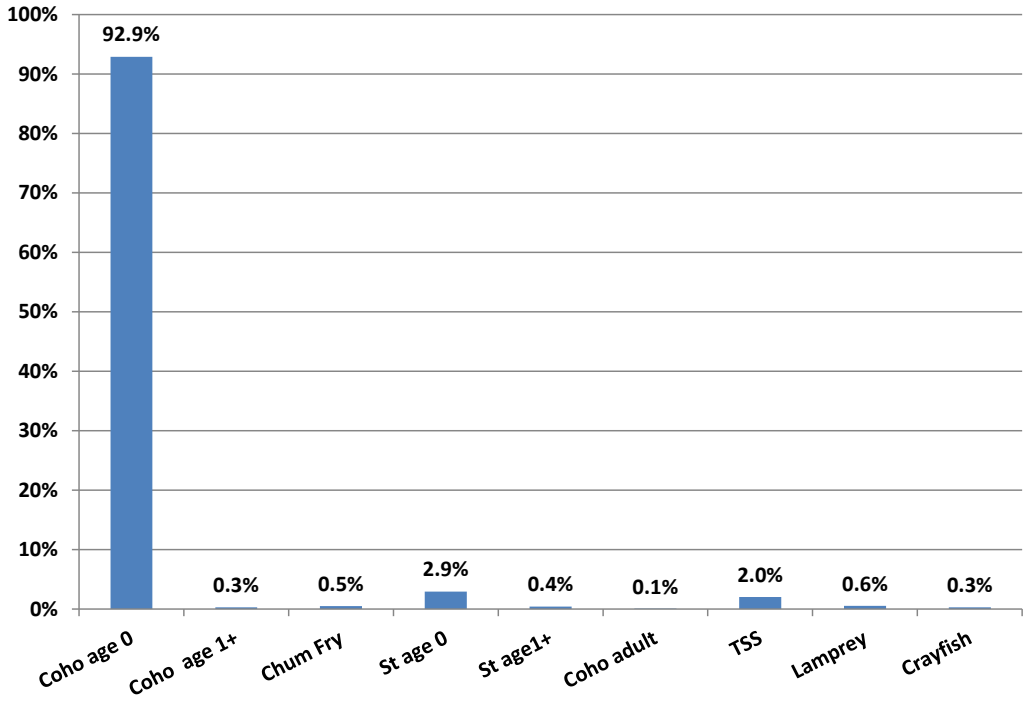

Figure 7 Stranding distribution by species and age class 2017-2018 all rampdowns

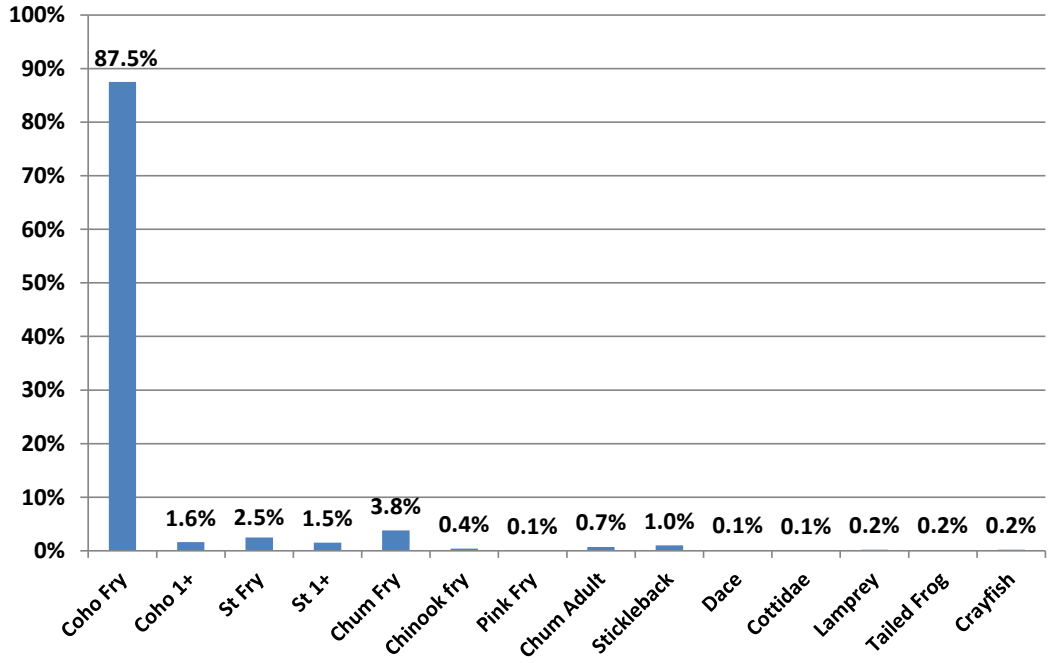

Figure 8 Stranding distribution by species and age class, 2004-July 2017, all rampdowns. In addition one kokanee, Pink adult and Northern Pike Minnow have been found.

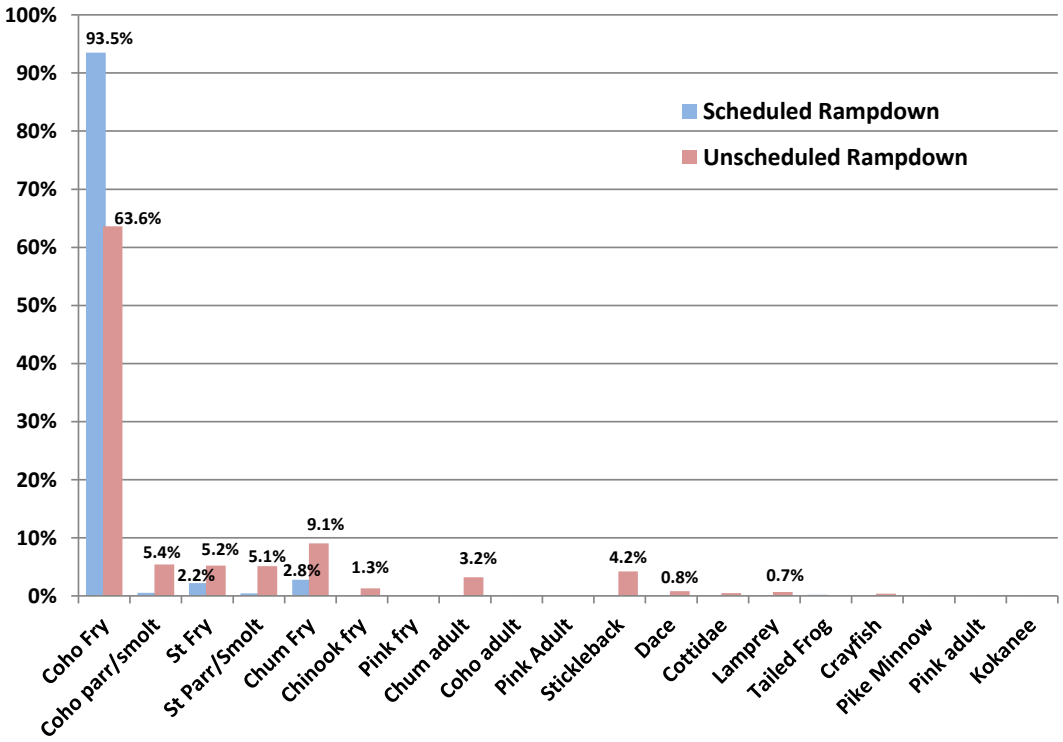

Figure 9 Comparison of scheduled vs. unscheduled rampdown impact on stranding distribution by species and age class, July 2004-June 2017.

5.0 Conclusions and Recommendations

The results of the past 10 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 6 show that under Treatment 1 survey crews observed an average of 206 stranded fish and 37 mortalities per year, while under Treatment 2 this has risen to 2099 stranded fish and 303 mortalities. The cause of this increase is likely related to two main factors:

1. An increase in the number of rampdowns per year due to monthly flow changes at Coquitlam Dam. Treatment 1 had an average 2.7 rampdowns per year (all unscheduled), while under Treatment 2 the average has risen to 8.0 per year.

2. Increase in rampdowns at critical time period for emerging juvenile fish. Scheduled rampdowns in April, May, and June occur at peak emergence for fry in Coquitlam River, which results in a consistent, yearly elevation in the risk of stranding. As discussed in Sec. 4.0 the June rampdown alone has been responsible for 76% of all stranding over the past nine years.

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. The June rampdown, may need to have its ramp rate and operational procedures reexamined and altered. The first step taken towards this was undertaken in 2013 and has had some promising results as the mortality rate has dropped. This alteration is purely an operational one (spreading out the rampdown over two or three days) and the results indicate that the June rampdown may also benefit from a more gradual flow reduction as total stranding has not been reduced despite the drop in mortality.

In addition, it is recommended that the June rampdown should undergo a reassessment of its minimum target flow. The June reduction does not fit the natural hydrograph for the watershed (according to WSC Gauge 08MH141 Coquitlam River above Coquitlam Lake). Flows are normally high and rising during the Month of May and June, but this is not reflected in Coquitlam River, particularly in Reach 4 where no buffering flows exist to offset the loss of water, and river stage instead drops significantly. A higher minimum flow target for June would very likely prevent a significant amount of stranding.

Having more water available, whether through COQ Dam release or from tributaries, can certainly reduce stranding. For example, during the rampdown on June 1, 2017 the discharge in Coquitlam River (at WSC gauge) was 9.0m^3/s at the start and fell to 8.3 m^3/s when the flow reduction was complete. During the following two flow reductions on the 8th and 15th discharge never fell below 5.0 m^3/s. This is in contrast to the 2015 Coquitlam River rampdown when the discharge was at 2.5 m^3/s when the rampdown *began* and fell to 1.1 m^3/s following the flow reduction. The impact of additional water

from Or Creek in 2017 meant that many side channels and stranding areas containing thousands of fry remained wetted and continued to provide adequate habitat. The impact this additional water had on stranding was significant, with the 2015 rampdown stranding 3708 fish versus 186 in 2017.

The May 13, 2017 rampdown that led to a record number of stranded fish for an unscheduled rampdown was directly due to the timing of the rampdown - at the height of Coho fry emergence - and the large decrease in flow (for 8 days at 8.5 m^3/s down to 2.9 m^3/s or 65% of the water in the river). The rampdown on May 3, 2017 was also of the same magnitude and duration but fortunately did not lead to widespread stranding due to the fact that the river was rising due to heavy rainfall (Table 5, Appendix 2). Future rampdowns related to Sockeye Salmon (*Oncorhynchus nerka*) smolt attraction flows will need to be carefully monitored if they occur in the spring due to the increased stranding risk associated with the timing, duration and magnitude of the event.

As Table 4 clearly demonstrates, fish stranding under scheduled rampdowns in Coquitlam River is heavily concentrated in the June rampdown, with regular, but far more limited stranding during the April 1 and May 1 rampdowns. Outside of the June flow reduction, the risk of stranding appears to be minimal during all other scheduled rampdowns downstream of Reach 4. This is largely due to the fact that the scheduled releases under Treatment 2 do not inundate large areas of habitat.

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 year. The potential for stranding definitely exists, and has been documented on all scheduled rampdown dates. In addition, with the gate operations at Coquitlam Dam now controlled remotely, it is imperative that a crew be 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 reevaluated under the new Treatment 2 conditions. The results of the eighth 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 those new areas have been categorized and included in all rampdown fish salvage surveys. The fluvial morphological structure of Coquitlam River will continue to transform as it adapts to the increased annual flow, therefore areas of stranding will shift.

Comparison of rampdown mortality to fish productivity clearly shows the negligible impact that rampdowns appear to have on fish productivity in Coquitlam River, with the exception of Coho Salmon fry. Results from the past few years show that greatly elevated Coho fry stranding during scheduled and unscheduled rampdowns at critical time periods is cause for concern. Rampdowns that occur in spring and summer could also potentially

require larger rampdown crews and a modified ramp rate to ensure that high numbers of juvenile mortalities do not occur.

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

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.

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. Minimizing impacts with careful adherence to rampdown rates, minimum flow targets and consistent monitoring of potential stranding sites will continue to be the most appropriate means to reduce the fish stranding risk while being operationally feasible.

Summary of Recommendations

- The ramp rate for the June flow reduction could be further modified to be more gradual, possibly taking place over several days for example.

- Stranding of large numbers of Coho fry during the June rampdown will continue to be an issue under the current flow regime. A reexamination of the target flow level of 1.1 should be considered as it falls outside of the natural hydrograph for Coquitlam River and clearly creates a high stranding risk.

- During scheduled rampdowns fish salvage crews should focus efforts in Reach 4, due to the elevated risk of stranding in this area.

- Monitoring for fish stranding should be continued in order to ensure that flow targets are achieved, and all potential stranding is monitored. Continued monitoring will also act to guard against any LLO gate failures or operator errors.

- Future June 1 scheduled rampdowns should continue to use the modified gate closure operation due to the successful implementation in 2013.

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

- Pay special attention to the side channel that feeds water into the hatchery during rampdowns in January and June-September when releases are less than 3.0 m^3/s as it has the potential to completely dry up.

- Future rampdowns related to Sockeye smolt attraction flows will need to be carefully monitored if they occur in the spring due to the increased stranding risk associated with the timing, duration and magnitude of these events. A reevaluation of the future need for the KRSP increase in flow is also recommended, as these events have added to overall stranding in Coquitlam River as they occur in the spring when the risk of stranding is highest.

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Appendix 1 June 2018 Rampdown Fish Stranding Summary

In response to the current Treatment 2 flow regime, the Low Level Outlet (LLO) release from Coquitlam Dam was scheduled to be reduced from 2.9 m^3sec to 1.1 m^3sec for the month of June. Adding to the magnitude of the scheduled flow reduction in 2018 was the fact that the normal operating release from COQ Dam for the months of April and May had been increased. The increase in flow was part of the Kwikwetlem River Sockeye Program (KRSP), which required a discharge of 8.0 m^3/s in order to attract sockeye smolt migration from Coquitlam Reservoir. As a result of this experimental flow increase the total reduction in river discharge for this rampdown amounted to 86% of the river volume – from 8.0 m^3/s to 1.1 m^3/s – which required an extended rampdown period of five days in order to properly manage the stranding risk

The scheduled flow reductions in 2018 were performed over 5 days with flow reductions and dates seen below:

- June 1 8.0 m^3/s - 5.0 m^3/s
- June 3 5.0 m^3/s - 2.9 m^3/s
- June 5 2.9 m^3/s - 2.2 m^3/s
- June 10 2.2 m^3/s - 1.5 m^3/s
- June 15 1.5 m^3/s - 1.1 m^3/s

Fish stranding over the course of the 5 days was the largest amount yet observed for a single rampdown with a total of 3954 fish stranded (previous high of 3704 in June 2015, Figure 1). Of the 3954 fish observed stranded there were 3907 Coho fry, which made up the overwhelming majority of fish accounting for 99.1% of all stranding. In addition, there were 10 Coho smolts, 2 steelhead smolts, 9 Threespine Sticklebacks, 10 lamprey, 2 Longnose Dace (*Rhinichthys cataractae*), 10 Signal Crayfish (*Pacifastacus leniusculus*) and 4 Northern Pike Minnow (*Ptychocheilus oregonensis*). The mortality rate was 14.7%, which is the highest observed since the switch was made to multiple day rampdown fish salvage, and slightly above the 2011-2017 mean of 13.4%, but is still lower than rampdowns done over a single day period.

The explanation for the high amount of stranding observed is likely due to river conditions during the flow reductions. The increased flow as a result of the KRSP project, along with the accompanying elevation in river stage over such a long period - two months – allowed Coho fry access to many areas of Coquitlam River that they normally could not enter. This lead directly to an increase in stranding area and the number of sites that represent a high risk for stranding.

The act of spreading the flow reduction out over multiple days still appears to have mixed success overall as the mortality rate has decreased in comparison to single day rampdown events, but total stranding observed has not declined.

Coquitlam River Fish salvage and mortalities by Reach and species June 1, 3, 5, 10, 15, 2018

			Reach					
Date	Species	Salvaged/Mort	1	2a	2b	3	4	Total
1-Jun-18	Co 0	s	20			634	70	724
	Co 0	m	30			192	46	268
	st 1+	s					2	2
	co1+	s					10	10
	tss	s					4	4
	cray	s					2	2
	dace	m					1	1
3-Jun-18	Co 0	s		625	37	14	139	815
	Co 0	m			33	5	25	63
	lmp	s					1	1
	tss	s		1			4	5
	cray	s		2				2
	dace	s		1				1
	npm	s		4				4
5-Jun-18	Co 0	s	70		489	381	302	1242
	Co 0	m			51	133	15	199
	cray	s			4			4
	lmp	s	3		3	1		7
10-Jun-18	Co 0	s	13	285	57	41	27	423
	Co 0	m		1	21	7	3	32
	cray	s			2			2
	lmp	s		2				2
15-Jun-18	Co 0	s	33	31		17	40	121
	Co 0	m		10		6	4	20
		Total Stranded	**169**	**962**	**697**	**1431**	**695**	**3954**
		Total Mortality	**30**	**11**	**105**	**343**	**94**	**583**

Coquitlam River Stage Reduction by Reach June 1, 3, 5, 10, 15, 2018. Text in red/italic indicates a rising river stage.

R4 Staff Gauge		R2B Staff Gauge		R1 WSC Staff Gauge		**June 1, 2018**
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0900	0.58	0800	0.89	0900	8.01	
1115	0.54	1000	0.89	1100	8.02	
1145	0.53	1200	0.82	1300	7.99	
1215	0.50	1400	0.77	1500	7.94	
1300	0.47	1600	0.75	1600	7.93	
1445	0.42			1800	7.90	
1600	0.41			2000	7.89	
	17.0		14.0		12.0	Max Reduction (cm)
	4.0		3.5		2.5	Max Reduction (cm)/hr

R4 Staff Gauge		R2B Staff Gauge		R1 WSC Staff Gauge		**June 3, 2018**
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0900	0.40	0800	0.77	0900	7.91	
1030	0.38	1000	0.77	1100	7.90	
1130	0.36	1200	0.74	1300	7.87	
1300	0.33	1400	0.71	1500	7.87	
1500	0.31	1600	0.70	1600	7.86	
1600	0.31	1700	0.70	1800	7.85	
	9.0		7.0		6.0	Max Reduction (cm)
	2.0		1.5		1.5	Max Reduction (cm)/hr

R4 Staff Gauge		R2B Staff Gauge		R1 WSC Staff Gauge		**June 5, 2018**
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0900	0.30	0800	0.71	0900	7.85	
1000	0.29	1000	0.70	1100	7.85	
1130	0.27	1200	0.68	1300	7.82	
1300	0.25	1400	0.67	1500	7.80	
1500	0.24	1600	0.66	1600	7.80	
1600	0.24	1700	0.66	1800	7.80	
	6.0		5.0		5.0	Max Reduction (cm)
	1.5		1.0		1.5	Max Reduction (cm)/hr

R4 Staff Gauge		R2B Staff Gauge		R1 WSC Staff Gauge		**June 10, 2018**
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0900	0.24	0800	0.69	0900	7.84	
1000	0.23	1000	0.68	1100	7.85	
1100	0.21	1200	0.67	1300	7.83	
1200	0.20	1400	0.65	1500	7.81	
1300	0.19	1600	*0.66*	1600	7.81	
1600	0.19	1700	*0.67*	1800	*7.82*	
				2000	*7.85*	
	5.0		4.0		3.0	Max Reduction (cm)
	2.0		1.0		1.0	Max Reduction (cm)/hr

R4 Staff Gauge		R2B Staff Gauge		R1 WSC Staff Gauge		**June 15, 2018**
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0900	0.19	0800	0.65	0900	7.80	
1030	0.17	1000	0.65	1100	7.80	
1130	0.15	1200	0.63	1300	7.79	
1300	0.13	1400	0.61	1500	7.77	
1500	0.12	1600	0.60	1600	7.77	
1600	0.12	1700	0.60	1800	7.77	
	6.0		5.0		3.0	Max Reduction (cm)
	2.0		1.0		1.0	Max Reduction (cm)/hr

Appendix 2 Total daily and hourly river stage reductions by staff gauge all rampdowns

May 3, 2017

R4 Staff Gauge		R2B (at Galette)		WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0830	.54	0900	.74	0600	8.14	
0930	.50	1030	.77	0800	8.19	
1100	.43	1200	.80	1000	8.22	
1200	.39	1400	.79	1200	8.22	
1330	.37	1600	.79	1400	8.20	
1530	.34			1600	8.18	
				1800	8.18	
				2000	8.20	
	4.0		3.0		2.0	Max Reduction (cm)
	2.0		1.0		1.0	Max Reduction (cm)/hr

May 13, 2017

R4 Staff Gauge		R2B (at Galette)		WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0800	.52	0900	.74	0600	8.15	
0930	.47	1030	.73	0800	8.13	
1030	.43	1200	.72	1000	8.12	
1200	.40	1400	.72	1200	8.09	
1330	.36	1600	.71	1400	8.05	
1600	.32			1600	8.00	
				1800	7.99	
				2000	8.00	
	4.0		3.0		15.0	Max Reduction (cm)
	2.0		1.0		2.5	Max Reduction (cm)/hr

1-Jun-17

R4 Staff Gauge		R2B (at Galette)		WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0700	.33	0730	.75	0700	7.96	
0830	.31	0930	.75	1000	7.97	
0930	.29	1100	.75	1200	7.96	
1000	.28	1400	.74	1400	7.95	
1200	.28	1600	.74	1600	7.94	
1500	.28	1700	.74	1800	7.94	
	5.0		1.0		2.0	Max Reduction (cm)
	2.0		0.3		0.5	Max Reduction (cm)/hr

8-Jun-17

R4 Staff Gauge		R2B (at Galette)		WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0900	.28	0900	.71	1000	7.97	
1000	.27	1100	.71	1200	7.96	
1100	.25	1200	.74	1400	8.08	
1200	.24	1400	.86	1600	8.38	
1400	.24	1600	.87	1800	8.36	
	4.0		0.0		1.0	Max Reduction (cm)
	2.0		0.0		0.5	Max Reduction (cm)/hr

15-Jun-17

R4 Staff Gauge		R2B (at Galette)		WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0900	.24	0930	.64	1000	7.80	
1000	.23	1100	.63	1200	7.80	
1100	.21	1200	.65	1400	7.81	
1230	.21	1400	.68	1600	7.82	
1400	.21	1600	.74	1800	7.93	
	3.0		1.0		0.0	Max Reduction (cm)
	2.0		0.3		0.0	Max Reduction (cm)/hr

Appendix 3 Site descriptions and photographs

Reach 1

Site A1: This area is characterized by densely treed and shrubby river margins that contain many depressions that form isolated pools. The substrate is mainly soil and vegetated cover, along with some areas of exposed gravel and cobble.
Total Area: 3800m²

Figure 10 Site A1 showing gravel bar separating river mainstem (left) with isolated pool (right), following rampdown June 1 2012.

Figure 11 Showing trench dug to allow water from river mainstem to flow into isolated pool.

Figure 12 Site A1 2015, showing gravel area on 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 dewatering. 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 flow releases.
Total Area: 19000m²

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.
Total Area: 4800m²

Reach 2A

Site B1: This area is a side channel that is normally wetted except at very low flows (below 3.00cms WSC gauge Port Coquitlam). It is a gravel and cobble substrate, that drains quickly and leaves behind many isolated pools. It rarely completely dewaters, so is only a stranding risks when flow in the river is very low.
Total Area: 270m²

Site B2: This area is a long narrow partially treed platform with a combined soil, gravel and vegetated substrate. It strands adults, juveniles and redds. This site only becomes inundated during a full three LLO release, and is one of the earliest sites to begin dewatering. ***Total Area: 3000m²***

Figure 13 Site B2, showing isolated pool formed during flow reduction, this site strands juveniles, adults and redds. Substrate is primarily mud and soil.

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: 690m²

Figure 14 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 Coquitlam River.

Site C2: The area is densely covered in shrubs. The substrate is very muddy with vegetated ground cover. Juveniles were regularly stranded in this area until the 2007/2008 rampdown period, which often requires the use of minnow traps for salvage. River Morphology changes may have reduced the risk of stranding at this site.
Total Area: 550m²

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: 60m²

Site D1: This area is long side channel that completely dewaters during the June flow reduction. It is a gravel cobble substrate combined with some deeper pools
Total Area: 300m²

Site D2: Parts of this area are densely vegetated with trees and shrubs, though It is primarily a narrow river margin with cobble and boulder substrate.
Total Area: 60m²

Reach 3

Site D3: This area is a combination of a long, narrow platform densely grown in with trees and shrubs, as well as a small side channel that is permanently wetted. It has a combined soil, 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.
Total Area: 665m²

Site D4: This area is a small series of pools, with a gravel substrate. Some of the pools are quite deep <30cm and attract Coho fry and steelhead fry and smolts.
Total Area: 40m²

Reach 4

Site E1: This area is adjacent to a rearing pond that overflows during dam releases. Juveniles spill over the pond and can become stranded. Substrate is mainly cobble and gravel intermixed with moderately treed areas.
Total Area: 900m²

Figure 15 June 7, 2016 Site E1 Channel dug to provide water for rearing ponds. This small channel had aggarded and water had stopped entering rearing ponds from the Coquitlam mainstem.

Figure 16 Showing water flowing into rearing pond following the opening of the channel.

Site E2: This area consists of narrow river margins that are densely treed and shrub covered. Many isolated pools form close to the river mainstem during gate closure. Observations over the past 3 years indicate that many of these pools remain wetted year round due to their proximity to the river channel.
Total Area: 1800m²

Site E3: This area, situated near the dam face, is densely covered in trees and shrubs. Isolated pools are minimal, but juveniles are often caught in the area of dense vegetation during dewatering.
Total Area: 340m²

Appendix 4 Coquitlam River rampdown site maps and discreet stranding locations represented by the red dots.

Figure A
Coquitlam River Stranding Reach 4 and 3.

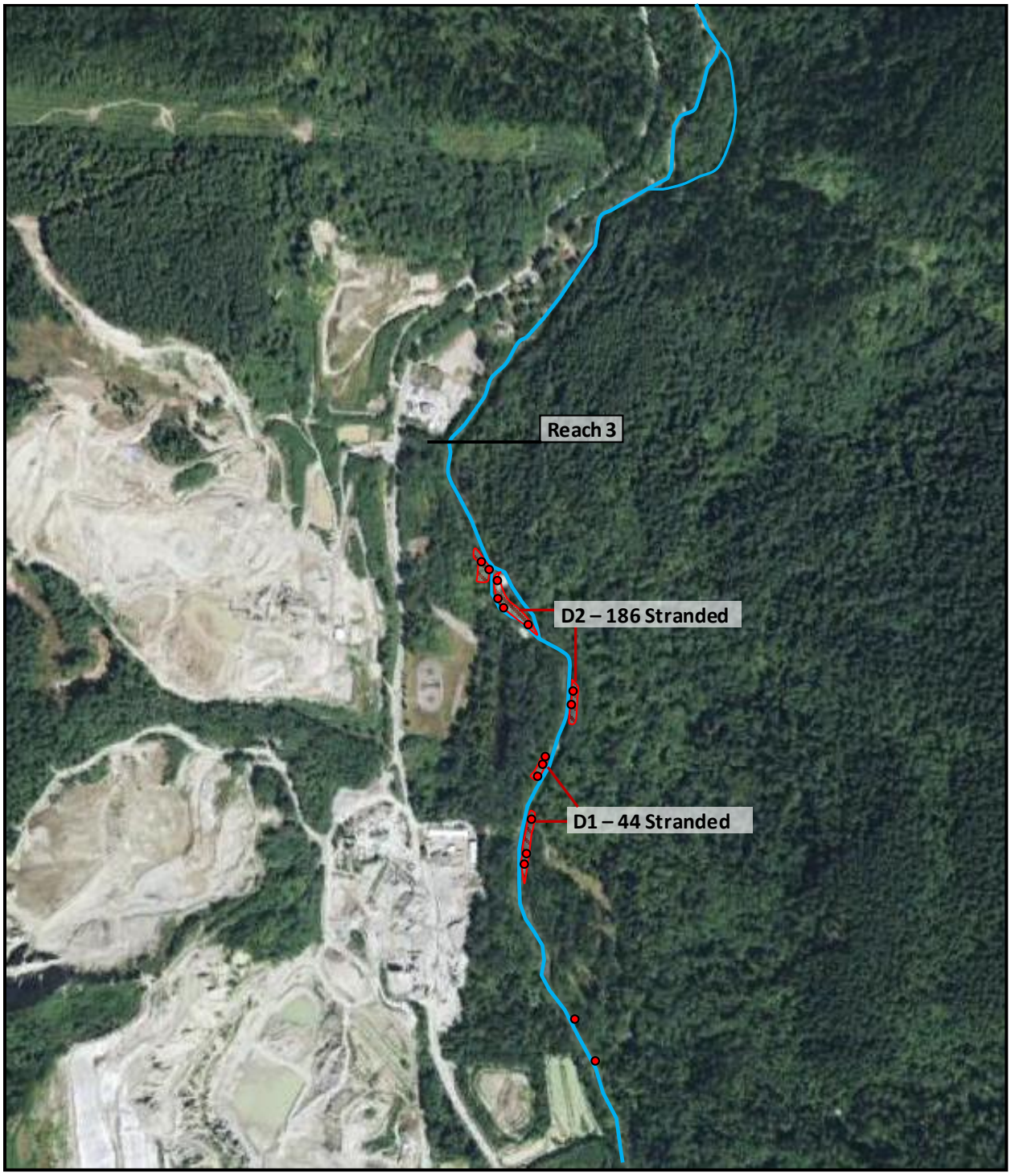

Figure B
Coquitlam River Stranding Reach 3 and 2b

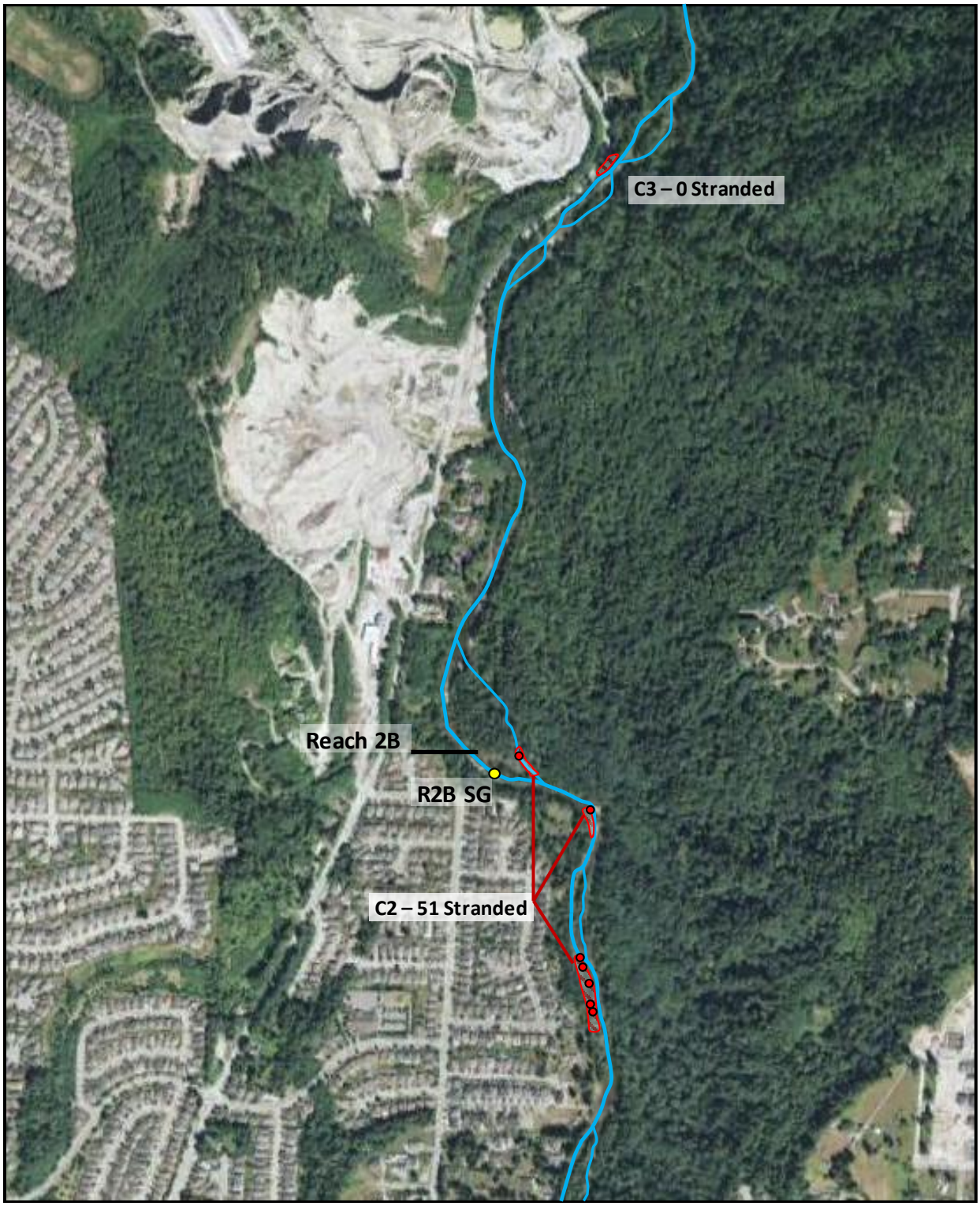

Figure C
Coquitlam River Stranding, Site C, Reach 2a & 2b.

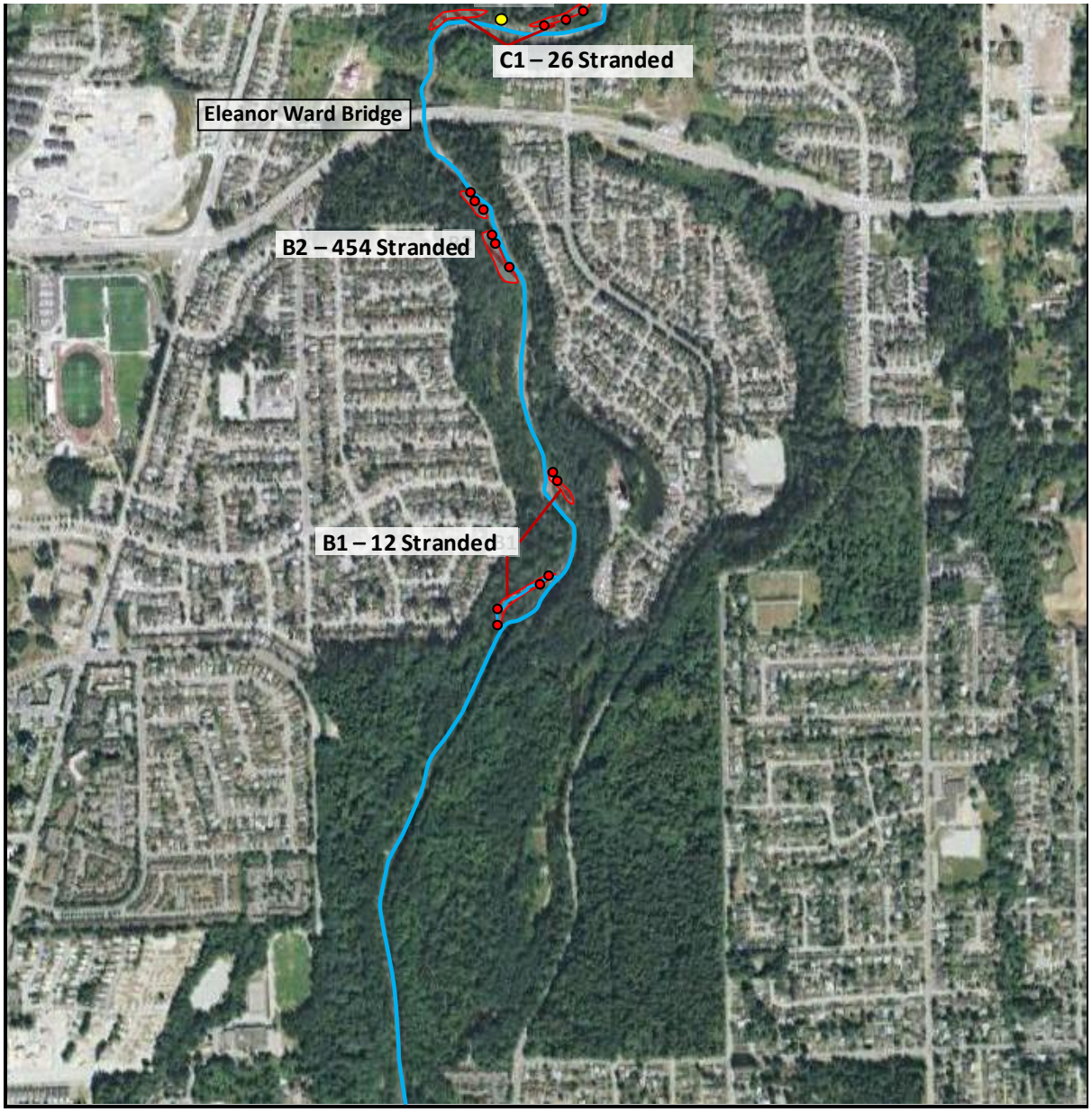

Figure D

0 250 500 750 1000

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

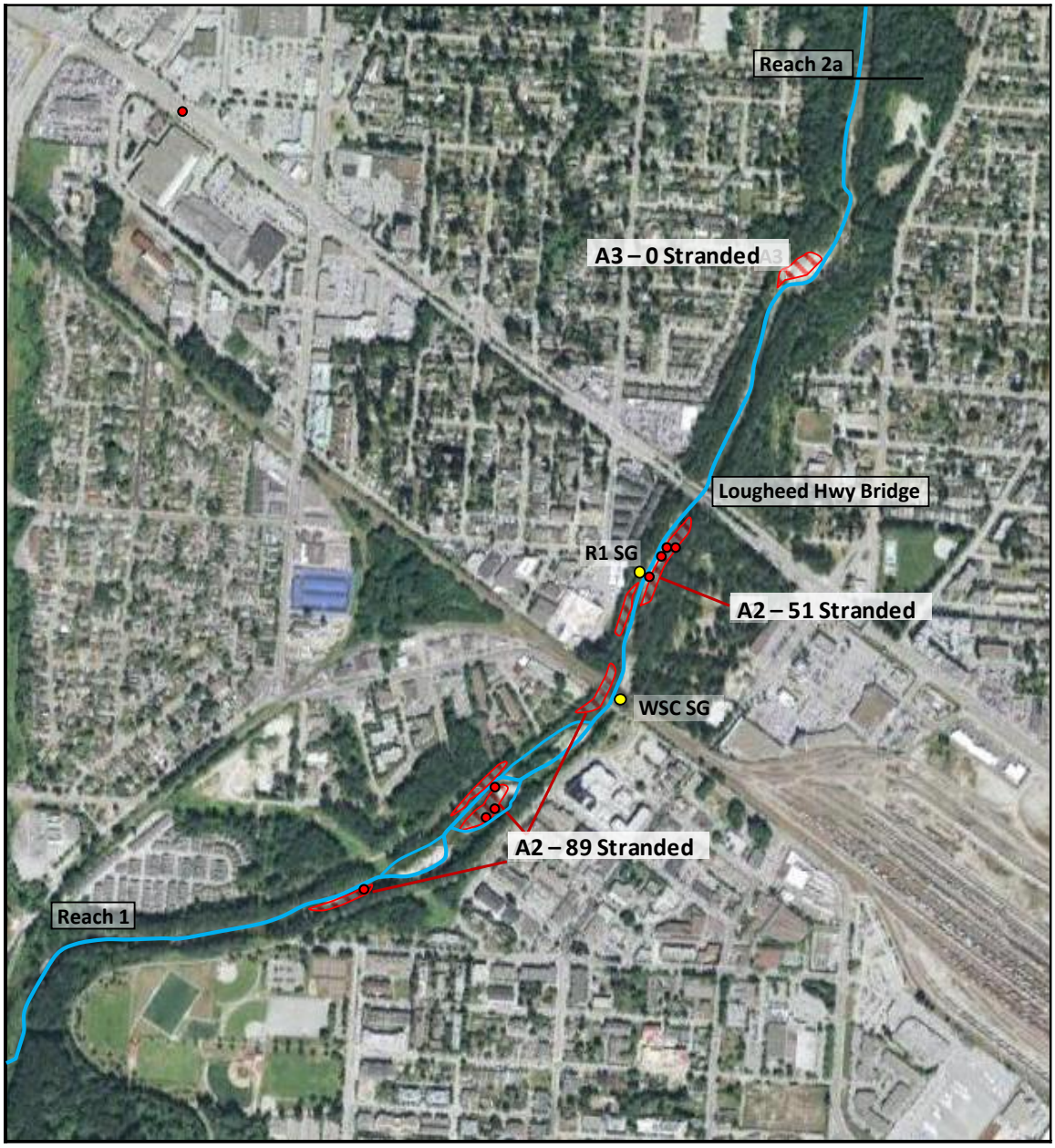

Figure E

Coquitlam River Stranding, Site A, Reach 1.