Greater Vancouver Water District

Capilano River Fish Stranding Study

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EXECUTIVE SUMMARY

The Cleveland Dam (CLD), located on the Capilano River, impounds Capilano Reservoir, which is a drinking water source for Metro Vancouver. The Capilano River supports anadromous and resident fish species, including Pacific salmon and trout. Operations of a dam for the purpose of water storage or hydropower generation can cause stranding or isolation of downstream fish populations when water levels decline rapidly, potentially causing mortality. These effects are mitigated by limiting the rate of flow change to rates that are sufficiently low to prevent isolating or stranding fish within dewatered habitats.

Ecofish was retained by the Greater Vancouver Water District (GVWD) in 2019 to conduct a fish stranding study to verify that the current operational protocols at the CLD maintain down ramping rates that are protective of fish (i.e., do not result in fish stranding and/or unintended fish mortality) within the lower Capilano River downstream of the dam. The stranding study consisted of the following components:

- Selecting stranding sensitive monitoring sites (SSMSs) throughout the lower Capilano River, installing temporary water level loggers, and conducting habitat surveys of the SSMSs.
- Developing and implementing a ramping test protocol that can be undertaken at SSMSs during scheduled ramping tests in the period that typically has highest sensitivity to ramping (i.e., the fry-present period).
- Completing data analysis and reporting to describe the effectiveness of GVWD's operational ramping protocols at the CLD and provide recommendations to further mitigate stranding risk based on the study results.

Five primary SSMSs were selected, with water level loggers installed at each site. Loggers remained in place and operational from April until November 2019. Cross-sectional survey data and habitat measurements were also collected at each primary SSMS. Two secondary SSMSs were also established; opportunistic stranding searches occurred at these sites but no hydrometric or habitat data were collected.

The stage data from the primary SSMSs were plotted against discharge data collected at an existing GVWD hydrometric station located 250m downstream of the CLD. These relationships were then used to evaluate the relationship at the SSMSs between authorized operational flow changes and Fisheries and Oceans Canada (DFO)'s standard ramping criteria. These results could be used to inform future management of the dam to manage stranding risks.

Four stranding surveys were conducted during planned ramping events at the CLD, all of which followed normal operational ramping rates. All stranding surveys occurred during the fry-present period: three surveys occurred during spring (April and May) and one survey occurred in fall (October) 2019.

During the four surveyed down ramping events, maximum measured ramping rates at the five primary SSMSs ranged from -7.3 cm/hr to -20.8 cm/hr, which are well above the maximum DFO criterion of -2.5 cm/hr (Cathcart 2005) during the fry-present period. Stranded and/or isolated fish were detected during stranding searches following three of the four events on the Capilano River during 2019. The precise role of dam operations in causing these observations is uncertain; however, operations are expected to have at least contributed to causing fish isolation and stranding.

If deemed necessary by regulatory agencies, additional mitigation measures could be employed to reduce risk of stranding mortality during future operations. Six potential measures to further mitigate stranding risk were identified and assessed: channel modification, reducing ramping rates, conducting night-time ramping, providing higher continuous flows, undertaking fish salvages, and providing pulse (i.e., conditioning) flows.

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1. INTRODUCTION

1.1. Project Description

The Cleveland Dam (CLD) is located on the Capilano River in North Vancouver, British Columbia (Map 1). The dam was constructed in 1954 to create a drinking water reservoir for the Greater Vancouver Water District (GVWD; Metro Vancouver).

GVWD is authorized to operate the CLD according to the flow ramping rates prescribed in Schedule A of the Section 93 Order issued under the *Water Sustainability Act* (Province of British Columbia 2018). The objective of this study is to verify that the current operational protocols at the CLD maintain ramping rates that are protective of fish within the downstream reaches of the Capilano River.

1.2. Environmental Background

The headwaters of the Capilano River are in the Pacific Ranges of the Coast Mountains, from which the river flows south into Burrard Inlet. The Capilano River upstream of CLD drains a watershed 190 km^2 in size and provides habitat for a number of anadromous and resident fish species (Map 1). Eleven fish species are documented to be present in the Capilano River Watershed (Ramos-Espinoza and McCubbing 2011b; MOE 2019); Table 1 lists these species and their life stage periodicity; based on this periodicity, the fry-present period for the Capilano River is considered to be January 1 – October 31.

The CLD is located six kilometres upstream of the mouth of the Capilano River. When it was constructed in 1954, the CLD blocked access to the majority of spawning and rearing habitat previously available to anadromous fish in the Capilano River (Ramos-Espinoza and McCubbing 2011a). Following dam construction, GVWD actively transported returning adult salmon upstream of the dam until the federal hatchery was constructed. In 1971 DFO began operating the Capilano River Hatchery to augment salmon stocks in the river. Today, the hatchery rears and releases Coho, Chum and Chinook Salmon, and steelhead (DFO 2019).

A large portion of the Capilano River downstream of the CLD (referred to as the "lower Capilano River") initially flows through a steep-sided canyon. This canyon section is dominated by deep pool glide habitat, suitable for adult fish, but with limited value for juvenile rearing for most species present. Downstream of the canyon section, the quality of juvenile rearing habitat improves but spawning habitat is limited throughout the lower Capilano River (McCubbing *et al.* 2012).

1.3. Fish Stranding Study Objectives

Progressive changes in stream flow within a river system, whether naturally induced or the product of operations of a water release/diversion structure, are known as flow ramping. Operating a dam for the purpose of water storage or hydropower generation can increase flow ramping rates and affect downstream fish populations.

Rapid decreases in stream flow can adversely affect fish and habitat by dewatering habitat and stranding fish. Fish may be isolated in pools that remain after discharge reductions have occurred or become stranded in the interstices on gravel or cobble banks or bars (Irvine *et al.* 2008). This can lead to mortality of fish due to suffocation, desiccation, freezing, or predation.

The risk of mortality can be mitigated by limiting the rate of flow change to rates that are sufficiently low to minimize the risk of stranding fish in dewatered habitats or causing isolation. The Section 93 Order referenced above prescribes flow ramping rates for CLD and requires that a stranding study is undertaken to verify that these flow ramping rates are protective of fish (i.e., do not result in fish stranding and/ or unintended fish mortality) within the lower Capilano River. Ecofish was retained by GVWD in 2019 to conduct the stranding study, which is presented in this report.

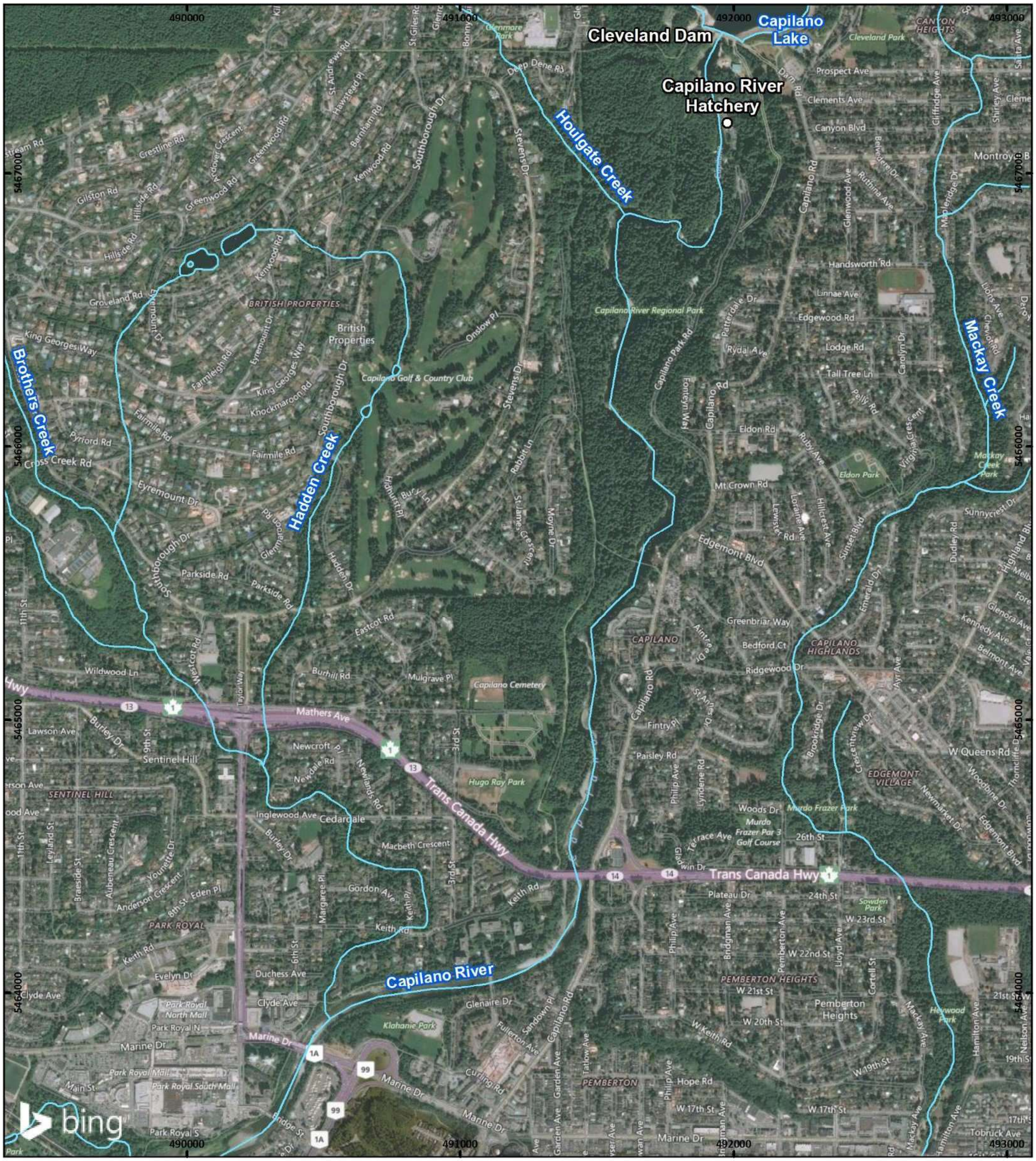
The stranding study consisted of the following components:

- Selection of stranding sensitive monitoring sites (SSMSs) distributed throughout the lower Capilano River, followed by installation of temporary water level loggers and habitat surveys of the identified SSMSs.
- Development and implementation of a ramping test protocol at SSMSs during the period with highest sensitivity to ramping (i.e., fry-present period).
- Completing data analysis and reporting to describe the effectiveness of GVWD's operational ramping protocols at the CLD, and provide recommendations to further mitigate stranding risk based on the results of the ramping monitoring and stage/discharge relationships developed at the SSMSs.

Table 1. Life Stage Periodicity for Lower Capilano River Fish Species (provided by GVWD).

Species		Presence		Life History				Other Information
Common Name	Scientific Name	Above Cleveland Dam	Below Cleveland Dam	Rearing	enile Outmigra	Escapement	Spawning	
Coho	*Oncorhynchus kisutch*	x	x	Emerge March to June. Spend one year in freshwater.	Spring freshet	Early run: May to July Mid run: July to October Late run: October to	October to January	Majority are three year old returns
Pink	*Oncorhynchus gorbuscha*		x	Emerge January to February. Outmigrate immediately.	Immediately following emergence	September to November	September to November	Two year old returns
Chum	*Oncorhynchus keta*		x	Emerge January to March. Spend one month in freshwater.	Winter	September to December	October to December	Majority are four year old returns
Chinook	*Oncorhynchus tshawytscha*		x	Emerge in January. Spend three months in freshwater.	Spring freshet	September to January	September to January	Majority are three and four year old returns
Steelhead (summer-run)	*Oncorhynchus mykiss*	x	x	Emerge May to July. Spend up to two years in freshwater.	Spring freshet	May to December	March to May	Overwinter in river before spawning
Steelhead (winter-run)	*Oncorhynchus mykiss*			Emerge May to July. Spend up to two years in freshwater.	Spring freshet	December to May	March to May	Spawn same year as return
Coastal cutthroat trout (resident)	*Oncorhynchus clarkii*	x	x				Spring	
Coastal cutthroat trout (sea-run)	*Oncorhynchus clarkii*		x			Summer and fall	Spring	
Rainbow trout	*Oncorhynchus mykiss*	x	x					
Dolly Varden	*Salvelinus malma*	x	x			Fall	Fall	
Lamprey	*Petromyzontiformes*	x	x					
Prickly sculpin	*Cottus asper*	x	x					
Coastrange sculpin	*Cottus aleuticus*	x	x					

Project Overview



Legend

Streams

0 100 200 400 600 800 m

Scale: 1:20,000

NO.	DATE	REVISION	BY
1	28/03/2019	1416_ProjectOverview_2019Mar28	CGA
2			
3			
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5			

Date Saved: 28/03/2019
Coordinate System: NAD 1983 UTM Zone 10N

ECOFISH RESEARCH

Map 1

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2. METHODS

2.1. Stranding Sensitive Monitoring Sites

SSMSs typically have one or more of the following characteristics (Lewis *et al.* 2013):

- Areas where the river cross-section has a relatively flat slope with large substrate that can strand fish, or finer substrate with depressions that could trap fish;
- Cobble and gravel bars, even with steep-sided slopes, where roughness creates refuges that juvenile fish prefer but may be reluctant to leave during a ramp-down (micro-stranding sites);
- Low gradient bank slopes;
- Wide mesohabitat units with width:mean depth ratios >50:1; and
- Side channels or pools (preferred habitat for rearing juvenile fish).

Five SSMSs within the lower Capilano River were selected by reviewing satellite imagery and other available background data (Ramos-Espinoza and McCubbing 2011b; McCubbing *et al.* 2012; NHC 2015), followed by completing a site visit to verify that selected sites appropriately represented high stranding risk habitat, based on the criteria listed above. A total of five SSMSs were selected for monitoring within the lower Capilano River, spaced roughly 300 m apart ("primary SSMSs"). The choice of five primary SSMSs was based on reviewing the total length of the lower Capilano (~5 km) and our experience in similar sized systems. An additional two sites were identified for opportunistic surveys during the course of the monitoring program ("secondary SSMSs"). Map 2 and Map 3 shows the locations of these sites.

Each primary SSMS was marked with a permanent benchmark attached to a tree or rock, and the upstream and downstream boundaries of each site defined with flagging tape attached to a tree or shrub. Each site was photographed and georeferenced by recording a GPS waypoint. Habitat data were also collected at each site, including the following:

- Fish cover types measured as per the BC Reconnaissance Level Fish and Fish Habitat Inventory methodology (RISC 2001).
- Fish habitat types identified based on four broad habitat categories: overwintering, spawning, migration, and rearing (RISC 2001).

Selected sites were distributed throughout the lower Capilano River downstream of the confined canyon section to characterize the lag and attenuation effects on water stage during operationally induced stream flow changes.

A representative cross-stream transect was established and marked at each primary SSMS. Bed-profiles and water surface elevation data (Section 2.3.3) were collected at each transect to characterize the stranding sensitive habitat.

2.2. Stage-Discharge Relationship at SSMSs

Temporary water level loggers (Solinst Levelogger Edge, 0 to 5 m range and 2.5 mm accuracy) were installed at each of the five primary SSMSs. Stage data recorded using these loggers were collected to develop a stage-discharge relationship for each site. Water level loggers were installed in April and removed in November 2019, with water level recorded at 5-minute intervals over this time period. A barometric pressure logger (Solinst Barologger) was also installed adjacent to CAP-DSSD04 to measure atmospheric pressure, which was used to correct the stage data to compensate for changes in atmospheric pressure. These data permitted stage-discharge relationships to be developed for a range of flows and ramping rates to be measured for each ramping event. Water surface elevations were recorded and surveyed relative to a benchmark during the installation and removal.

The stage-discharge relationship for each site was computed by fitting a nonlinear relationship of the form

$$Q=C(h-a)n$$

where Q is discharge (m^3/s), h is the stage (m), and C, a, and n are constants governing the relationship. Discharge data were provided by the existing hydrometric station located 250 m downstream of the CLD (the "Pool gauge", or CAP-DSLG01; Map 2 and Map 3). The derived relationships were used to calculate the change in flow (Δ m^3/s/hr) at the gauges.

2.3. Stranding Surveys

2.3.1. Overview

A detailed ramping test protocol was developed in coordination with GVWD to schedule stranding surveys in conjunction with planned ramping events at the CLD. Ramping events to survey were selected to target the following:

- Times when sensitive life stages (i.e., fry) of fish are present in the Capilano River (Table 1);
- Events following periods of relatively stable water levels when fish could be expected to have moved into shallower areas; and,
- Events with sufficiently high magnitude of flow change to potentially cause stranding.

In total, four stranding surveys were completed in 2019: three in the spring when emergent salmon fry were present and one in the fall to investigate seasonal variation. During each stranding survey, stranding searches were conducted and ramping rates were calculated at each SSMS to characterize stranding risk.

2.3.2. Stranding Searches

During the stranding surveys, two types of stranding searches were employed: broad-based and hotspot searches (Lewis *et al.* 2013). Initial broad-based searches were conducted upon arrival at each SSMS to characterize existing conditions and high-risk stranding habitat, and to identify any existing fish mortalities attributed to factors other than flow ramping (e.g., senescence, predation, dam spillway flow entrainment, or angling). Broad-based searches covered larger areas using low search intensity, with a crew of two walking along the shoreline and observing the substrate surface for microhabitats that could strand fish (i.e., low gradient, large interstitial spaces, pools likely to become isolated) and for stranded or isolated fish. The crew recorded the area searched (m^2), the area dewatered (m^2), the time spent searching (minutes), and the number and species of stranded or isolated fish and their condition (live or dead), if any.

Throughout the day, SSMSs were revisited, and intensive (hotspot) searches were conducted to identify any stranded (i.e., dewatered) or isolated (i.e., in pools with no connection to mainstem surface flow) fish. Hotspot searches were conducted by delineating an area of dewatered substrate of known dimension and intensively searching for any fish stranded in the target area. Cobbles were physically overturned where appropriate and substrate was gently excavated to search for fish. The advantage of this approach was that the most sensitive habitats were afforded the greatest search effort, and stranding was spatially quantified. The teams searched as many hotspots as judged necessary to assess the presence or extent of fish stranding. Typically, hotspots were generally greater than 2 m^2 and ranged up to 20 m^2, depending on the habitat. Once searched, excavated material was restored to the hotspot site to minimize impacts to fish habitat. The width, length, and depth searched, the time spent searching, and the number and species of fish found stranded (if any) were recorded. The number of replicate searches that were required at each site depended on the extent of dewatered area.

In the event that isolated fish (i.e., alive in wetted area but cut-off from mainstem of river) were identified during these stranding searches, they were salvaged and returned to the mainstem of the river near the stranding site but in a location that had low risk of stranding given further stage reduction. If stranded fish mortalities were found, fish specimens were collected and preserved for analysis. At each site, the number of fish found was recorded, as well as the species and the fork length (mm) of each individual. Stranding sites and fish were also photo-documented. Any live fish observed in the mainstem were also noted.

Project induced ramping events may occur during periods of natural stage change. As a result, natural water levels may fluctuate substantially between the period of time when the ramping event occurred and when the stranding search is conducted. If fish are found stranded/isolated during the ensuing stranding searches, it can be difficult to make conclusive statements regarding whether fish stranding/isolation was a result of natural stage change in the river or due to dam operation. Furthermore, the hydraulic geometry between, and even within stranding locations can vary, making it difficult to evaluate the area of the river bank that was dewatered during the ramping event. Consequently, professional judgement is often used to infer whether fish were stranded as a result of a ramping event. Where fish were observed, Ecofish noted the likely cause of the fish's condition (i.e., natural causes or operational flow changes related to the ramping event), based on the conditions at the time of observations. In providing our professional opinion, we considered several factors, including the distance of fish observations from the mainstem wetted edge, depth of water in which they were found, physical conditions of the fish at the time of discovery, signs of predation, and timing of observations with respect to the operational flow changes.

For each fish stranding/isolation event, qualitative levels of certainty were assigned to evaluate the spatial and temporal uncertainty; i.e., whether fish were stranded due to dam-induced ramping events or as a result of natural stage change. The categorization used for this purpose is as follows:

- *Certain* – instances where fish stranding/isolation was directly observed during the ramping event.
- *Likely* – instances where fish were found within the believed spatial/temporal zone of the ramping event, in a physical condition that indicates death at the time of the event and consistent with death by stranding but not other causes (i.e. desiccated/decayed), in a position relative to substrate clasts consistent with death by dewatering, but an absence of direct observation that the event caused the stranding/isolation.
- *Possible* – instances where it was unclear whether fish stranding/isolation resulted from the event (e.g., several water-level fluctuations, fish condition not entirely consistent with death by stranding); the ramping event could not be eliminated as the cause.
- *Unlikely* – instances where fish were found outside the believed spatial/temporal zone of the ramping event (e.g., fish were found outside of the suspected dewatered area, or fish displayed a level of decay that was inconsistent with the time of the event), however no supporting evidence existed to confirm that the event did not cause the stranding/isolation.
- *Not possible* – instances where conclusive evidence indicated that fish was not stranded/isolated during the ramping event (as per “Unlikely”, above, but judged to be unequivocal).

Changes in dewatered habitat were also monitored at sites as flows continued to decrease during the planned operation. If necessary, several sites where stranding risk was deemed greatest were revisited once flows had stabilized to conduct additional intensive searches and to check the status of any previously observed isolated fish.

2.3.3. Hydraulic and Habitat Response to Ramping (Ramping Rates)

Three temporary rebar pins were installed in the vicinity of the water level loggers (Section 2.2) to monitor changes in wetted area. During the stranding surveys, the wetted edge was marked with temporary rebar pins and flagging tape upon arrival. In instances when SSMSs were revisited during a single day, these pins were used as reference points to monitor changes in wetted area by measuring the change in wetted width from the three fixed pins throughout the ramping test.

Following the ramping event, ramping rates were calculated as the difference between a stage data point and the maximum stage observed in the previous hour, as follows.

The maximum stage observed over the past hour at time *ti, hmax (ti)*, was determined for each data point according to the following equation:

$$\mathrm{hmax}(\mathrm{t_i}) = \max\left(\mathrm{h}(\mathrm{t_{i-k}}), \dots, \mathrm{h}(\mathrm{t_{i-1}})\right)$$

where h is stage, k is the number of data points recorded per hour, and t is time.

The maximum stage decrease over the previous hour relative to time ti, $\Delta hmax\ (ti)$, was then defined by the equation:

$$\Delta \mathrm{hmax}(t_i) = \mathrm{h}(t_i) - \mathrm{hmax}(t_i)$$

The relationship between stage and discharge at the most sensitive SSMS was used to evaluate the relationship between authorized operational flow changes and DFO's standard stage change (ramping) criteria of -2.5 cm/hr during the fry-present period and -5.0 cm/hr during other periods (Cathcart 2005).

3. RESULTS

3.1. Stranding Sensitive Monitoring Site Characteristics

3.1.1. Primary Standing Sensitive Monitoring Sites

3.1.1.1. Overview

Water level loggers were installed at each of the five primary SSMSs on April 8, 2019. Loggers were removed on November 5, 2019 when cross-sectional survey data and habitat measurements were also collected at each SSMS. Two secondary SSMSs (CAP-DSSD06 and CAP-DSSD07) were established during stranding surveys: opportunistic stranding searches occurred at these sites but no hydrometric or habitat data were collected (Section 3.1.2). The locations of all sites are shown in Map 2 and Map 3. Habitat attributes of primary SSMSs are summarized in Table 2 and Table 3. Primary SSMSs are described further in Sections 3.1.1.2 through 3.1.1.6 below, which include bed profile plots of each site.

Table 2. Stranding Survey Site Fish Habitat Characteristics.

Site	Date	UTM (Zone 10U)		Site Length (m)	Site Gradient (%)	Cover Types Present (N/T/S/D)[1,2]								Embededness[3]
		Easting	Northing			SWD	LWD	BO	CO	CU	DP	OV	IV	
CAP-DSSD01	2019-11-05	491485	5464680	250	0.4%	T	T	D	S	N	T	T	N	M
CAP-DSSD02	2019-11-05	491417	5464306	100	1.2%	N	N	D	S	N	N	T	N	M
CAP-DSSD03	2019-11-05	491187	5464069	150	0.5%	N	N	D	S	T	S	T	N	L
CAP-DSSD04	2019-11-05	490883	5464001	90	n/c[4]	T	N	D	S	N	N	T	T	L
CAP-DSSD05	2019-11-05	490558	5463964	100	0.7%	T	N	D	S	T	T	T	N	M

[1] N - None, D - Dominant, S - Sub-dominant, T - Trace

[2] SWD - Small Woody Debris, LWD - Large Woody Debris, BO - Boulder, CO - Cobble, CU - Undercut Bank, DP - Deep Pool, OV - Overhanging Vegetation, IV - Instream Vegetation

[3] L - Low, M - Medium

[4] n/c - data not collected

Table 3. Fish Habitat Quality (Qual.) and Quantity (Quant.) Primary Stranding Sensitive Monitoring Sites.

Site	Date	Overwintering		Spawning		Rearing		Migration	
		Qual.[1]	Quant.[2]	Qual.[1]	Quant.[2]	Qual.[1]	Quant.[2]	Qual.[1]	Quant.[2]
CAP-DSSD01	2019-11-05	P	N	P	T	G	M	G	M
CAP-DSSD02	2019-11-05	P	N	P	T	G	M	G	M
CAP-DSSD03	2019-11-05	P	M	P	N	G	M	M	M
CAP-DSSD04	2019-11-05	P	N	P	N	G	M	M	M
CAP-DSSD05	2019-11-05	P	N	P	N	G	M	G	M

[1] P - Poor, M - Moderate, G - Good

[2] N- None, T - Trace, M - Moderate, H - High

3.1.1.2. CAP-DSSD01

CAP-DSSD01 is located approximately 2.5 km upstream of Burrard Inlet and 3.6 km downstream of the CLD (Map 2). The river at this site is low gradient, with extensive side bars. Substrate at this location is dominated by cobble and boulder (Figure 2). No deep pools (overwintering habitat) are present. This site primarily provides habitat for migratory life stages, although there is an area of side channel that potentially provides rearing habitat.

The boulder and cobble substrate create large interstitial spaces where fish may become trapped when water levels drop. The bars and side channel at this site also create the potential for isolated pools to form, increasing stranding risk. The stranding sensitive habitat at this site is concentrated on mid channel bar and on river right.

Figure 1. Bed profile plot of CAP-DSSD01, surveyed as distance from river left on November 5, 2019. Green line represents the water surface elevation.

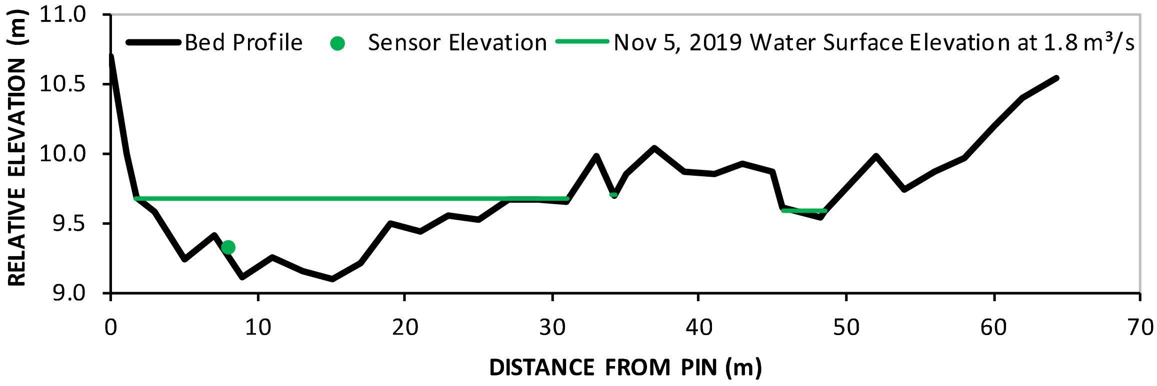
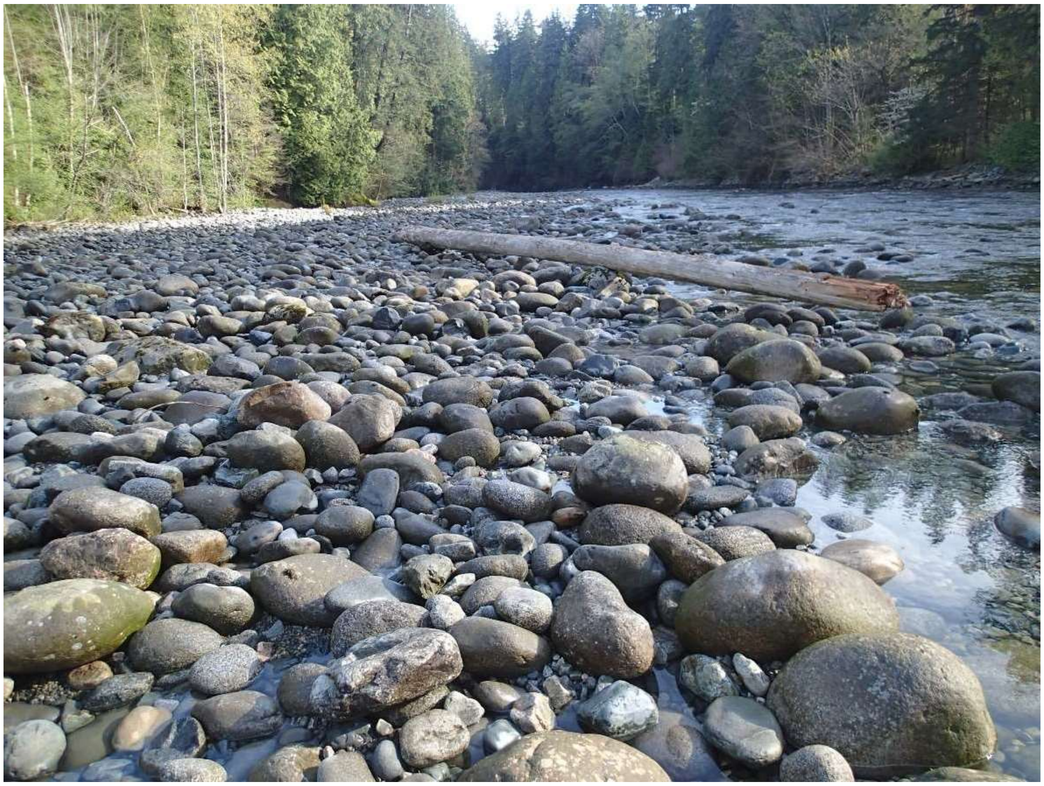


Figure 2. Looking upstream at CAP-DSSD01, April 25, 2019.



3.1.1.3. CAP-DSSD02

Habitat values at CAP-DSSD02 are similar to those at CAP-DSSD01, with boulder and cobble substrate dominant and side bars present at low flows (Figure 4). Rearing habitat is of good quality but limited; one large pool provides good overwintering habitat. The site likely primarily provides migratory habitat. As with CAP-DSSD01, there is a high stranding risk due to large interstitial spaces between boulders and the potential for isolated pools to form in the side channel. The stranding sensitive habitat is concentrated on river left at this site.

Figure 3. **Bed profile plot of CAP-DSSD02, surveyed as distance from river left on November 5, 2019.**

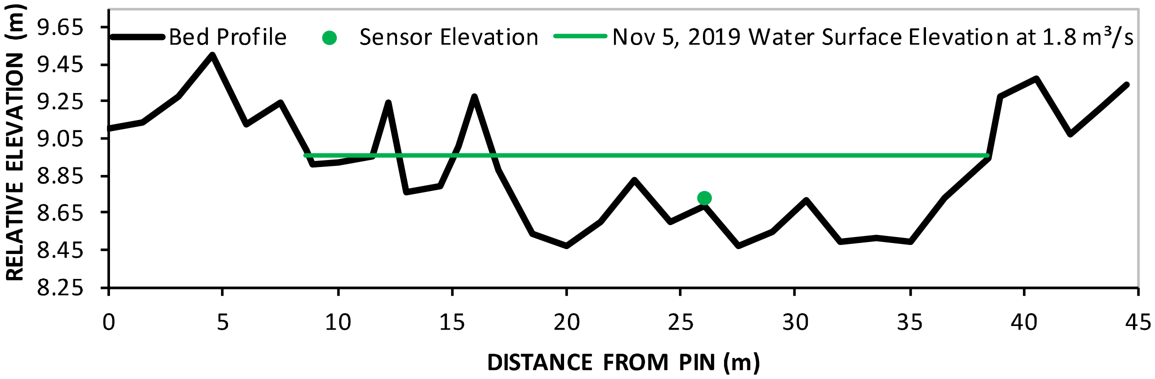


Figure 4. **Looking upstream at CAP-DSSD02, April 25, 2019.**

3.1.1.4. CAP-DSSD03

CAP-DSSD03 is also dominated by boulder and cobble habitat. Some high quality rearing habitat is present. Again, interstitial spaces and the presence of a side bar and side channel create stranding risk at this site (Figure 6). The stranding sensitive habitat is concentrated on river right and margins of the central bar at this site.

Figure 5. **Bed profile plot of CAP-DSSD03, surveyed as distance from river left on November 5, 2019.**

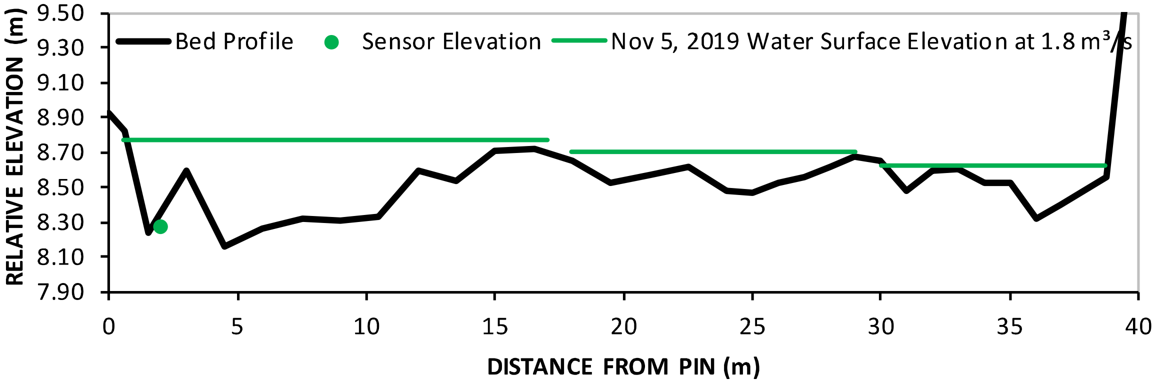


Figure 6. **Looking upstream at CAP-DSSD03, April 25, 2019.**

3.1.1.5. CAP-DSSD04

CAP-DSSD04 is also dominated by boulder and cobble substrate, with no overwintering or spawning habitat, although it but has slightly better rearing habitat than the three sites upstream. As with the other sites, the presence of interstitial spaces and the potential for isolated pools to form create a high-risk stranding site (Figure 8). The stranding sensitive habitat is concentrated closer to the river left bank at this site.

Figure 7. **Bed profile plot of CAP-DSSD04, surveyed as distance from river left on November 5, 2019.**

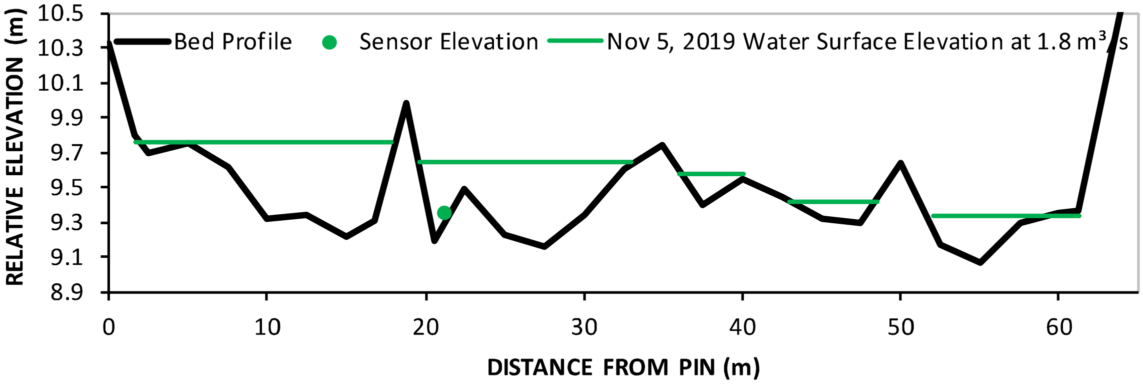


Figure 8. **Looking upstream at CAP-DSSD04, November 28, 2019.**

3.1.1.6. CAP-DSSD05

Consistent with the other SSMSs, CAP-DSSD05 is dominated by boulder and cobble substrate, creating interstitial spaces with potential for stranding. No overwintering or spawning habitat was observed at this site, and a moderate amount of good quality rearing habitat. A side channel at this site creates the potential for stranding in isolated pools. The stranding sensitive habitat is concentrated in the center of the channel and at river right at this site.

Figure 9. Bed profile plot of CAP-DSSD05, surveyed as distance from river left on November 5, 2019.

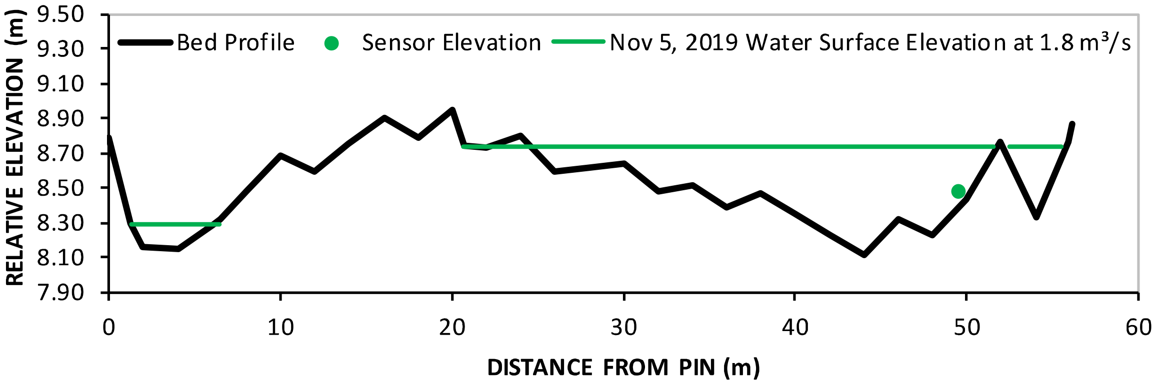


Figure 10. Looking upstream at CAP-DSSD05, November 28, 2019.

3.1.2. Secondary SSMSs

3.1.2.1. CAP-DSSD06

CAP-DSSD06 was established during the April 25 stranding survey, but was not searched during later tests. CAP-DSSD06 is tidally influenced, hence inundated at high tides regardless of flow rates in the Capilano River. As a result, this site is at a low risk for stranding at high tide, and at low tide it may be difficult to determine whether fish were stranded due to operational flow changes or due to the retreating tide. CAP-DSSD06 shares the boulder and cobble dominated substrate and other general habitat attributes of the primary SSMSs (Figure 11). The stranding sensitive habitat is concentrated on river right at this site.

Figure 11. Looking upstream at CAP-DSSD06, April 25, 2019.

3.1.2.2. CAP-DSSD07

CAP-DSSD07 is located underneath the Marine Drive bridge. In terms of stranding risk, ramping rates at this site are less of a concern than the occurrence of low flows (Figure 12) because there is a secondary channel located here that may become disconnected from the mainstem and dewatered when water levels are low. This can occur naturally but is also potentially a result of flow regulation of the Capilano River. CAP-DSSD07 was searched only during the May 7 and October 1 stranding surveys. The stranding sensitive habitat is concentrated on river left at this site.

Figure 12. Looking upstream at CAP-DSSD07, October 1, 2019.

3.2. Stage-Discharge Relationship at SSMSs

Raw water level data from the temporary stage data recorders installed at each SSMS are provided in Appendix A. Between April 8 and October 31, 2019, flow at the Pool gauge ranged from approximately 0.53 m3/s to 139.3 m^3/s (Figure 13, Table 4). The stage data from the SSMSs were plotted against discharge from the Pool gauge to develop the stage-discharge relationships shown in Figure 14. The parameters and flow ranges for the rating curves at each site are provided in Table 4.

Figure 13. Discharge as measured at the Pool gauge located 250m downstream of CLD between April 5, 2019 and October 31, 2019.

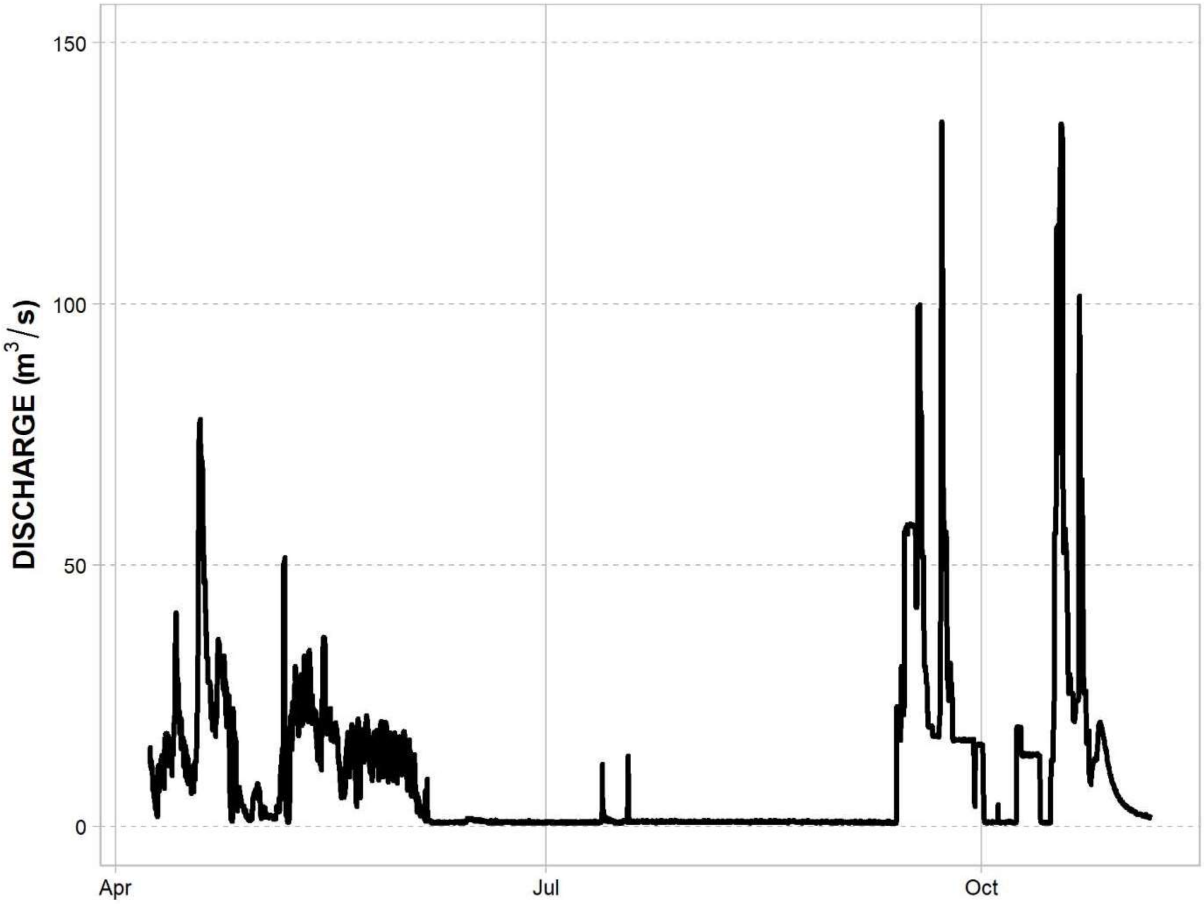


Figure 14. **Stage-discharge relationships measured at stranding sensitive monitoring sites in the Capilano River at (a) CAP-DSSD01, (b) CAP-DSSD02, (c) CAP-DSSD03, (d) CAP -DSSD04, and (e) CAP -DSSD05 in relation to Pool gauge discharge.**

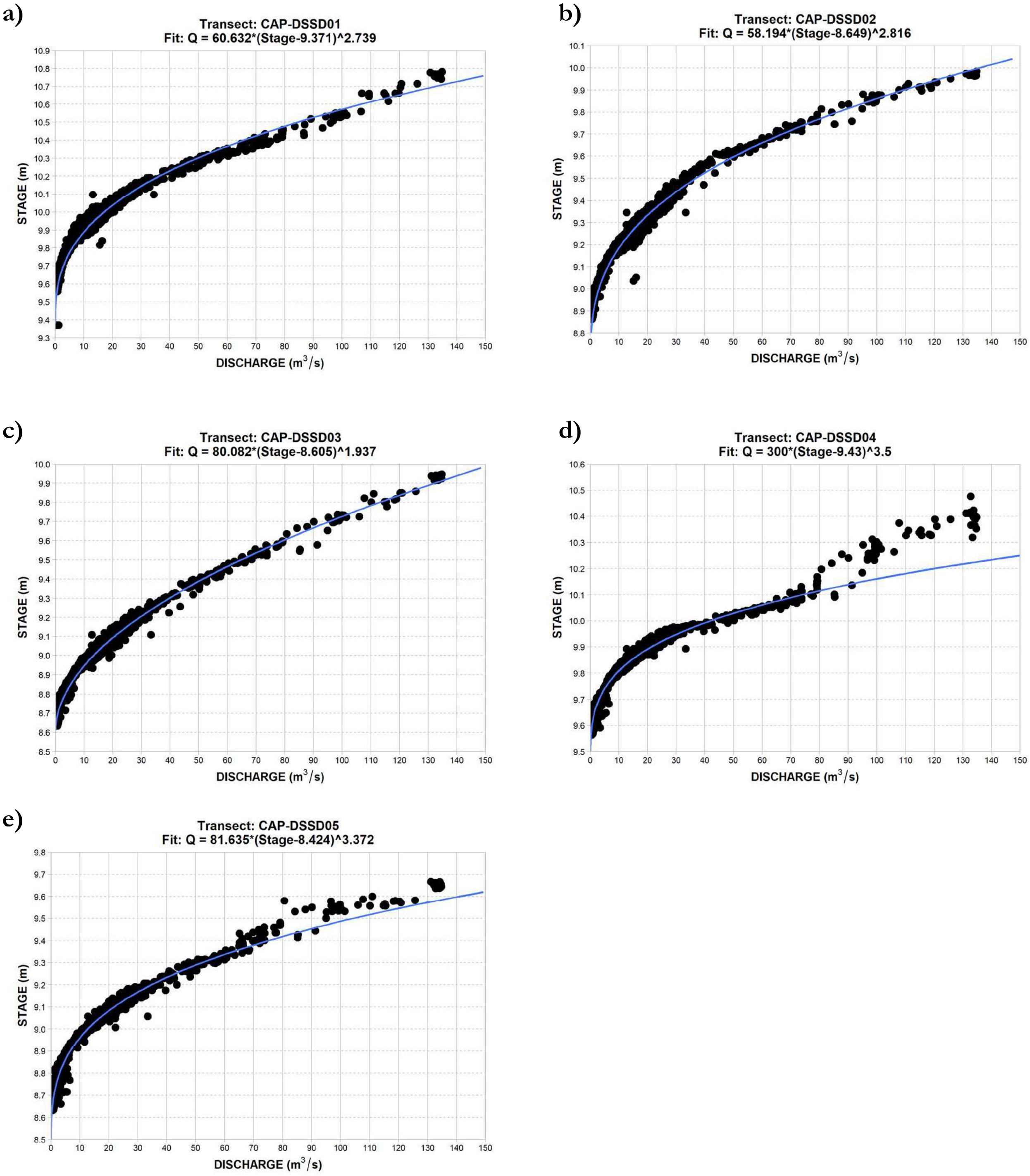


Table 4. Rating parameters for stage-discharge curves at SSMSs in the Capilano River (Figure 14). See Section 2.2 for parameter descriptions.

Site	Flow Range (m^3/s)	Parameters		
		C	n	a
CAP-DSSD01	0.583 - 135	60.6	2.74	9.37
CAP-DSSD02	0.583 - 135	58.2	2.82	8.65
CAP-DSSD03	0.583 - 135	80.1	1.94	8.61
CAP-DSSD04	0.583 - 80.0	300.0	3.50	9.43
CAP-DSSD05	0.583 - 135	81.6	3.37	8.42

3.3. Stranding Surveys

3.3.1. Overview

Four stranding surveys were conducted during planned ramping events at the CLD (Table 5). All of the ramping events described were planned by GVWD staff following normal operational procedures as described in the Section 93 Order (Province of British Columbia 2018). All stranding surveys occurred during the fry-present period: three surveys occurred during spring (April 25, May 7, May 14); and one survey occurred in fall (October 1).

Table 5. Summary of stranding search effort and fish observations during the tests.

Event #	Start (PDT)	End (PDT)	Discharge (m^3/s)		Ramping Rate (cm/hr)					Stranded or Isolated Fish				Alive in Mainstem
			Start	End	CAP-DSSD01	CAP-DSSD02	CAP-DSSD03	CAP-DSSD04	CAP-DSSD05	Stranded	Isolated		Unrelated Mortality	
											Salvage Required	Salvage not Required		
1	2019-04-25 1:06	2019-04-25 13:00	24.3	1.00	-8.4	-10.1	-9.0	-7.3	-8.2	1[1]	0	24	1	2
2	2019-05-06 19:14	2019-05-07 3:06	52.0	1.34	-16.7	-20.8	-20.6	-7.8	-13.4	1[2]	0	2	2	107
	2019-05-07 3:54	2019-05-07 4:48	9.54	3.65	-10.8	-9.5	-8.2	-9.2	-9.5	n/a	n/a	n/a	n/a	n/a
3	2019-05-14 11:44	2019-05-14 13:06	19.7	9.34	-10.2	-11.7	-10.2	-7.6	-9.3	0	0	0	0	0
4	2019-10-01 6:05	2019-10-01 15:00	15.7	0.849	-19.5	-15.9	-15.5	-12.9	-17.0	3[3]	12	0	4	14

n/a - Secondary event, overlapped with previous event; search results listed from primary event only

[1] Includes one live salvaged sculpin possibly related to the event.

[2] Includes one live salvaged sculpin likley related to the event.

[3] Includes two Coho Salmon fry mortalities, and one live salvaged juvenile trout. One live salvaged crayfish likely related to the event was also observed, not included in table.

3.3.2. Event 1: April 25, 2019

The first stranding survey occurred during a planned ramp-down at the CLD on April 25, 2019 that was initiated by raising the CLD Drum Gate. This operation caused a flow decrease from 24.3 m^3/s at 01:06 PDT to 1.00 m^3/s at 13:00 PDT as measured at the Pool gauge (Table 5 and Figure 16). This flow change resulted in a maximum ramping rates ranging from -7.3 cm/hr at CAP-DSSD04 to -10.1 cm/hr at CAP-DSSD02 (Table 5 and Figure 17). Fish stranding searches were initiated at 08:00 PDT and continued until 19:15 PDT (i.e., after the stage minimum of the ramping test was confirmed). Twelve broad-based searches were conducted in total at the five primary SSMSs and at CAP-DSSD06, covering a total area of 9,800 m^2, with a total time of five hours and ten minutes spent conducting broad-based searches. Additionally, 43 hotspot searches were conducted, covering a total area of 860 m^2, with a total of ten hours and 26 minutes spent conducting hotspot searches.

At the three sites furthest upstream, extensive interstitial spaces were observed, some of which remained wetted through sub-surface flow. Four of the six sites searched (i.e., CAP-DSSD01, CAP-DSSD02, CAP-DSS03 and CAP-DSS04) had side channel habitat that became isolated or dewatered during the event.

Two stranded sculpins were observed at CAP-DSSD06; one was alive in recently dewatered habitat (1 m from the mainstem wetted edge) and was salvaged by the search crew by returning to wetted habitat. This observation could have been influenced by intertidal stage change; accordingly, the potential for the stranding observation to have been caused by the planned event was considered "possible". The second sculpin appeared to have died prior to the first one and its deteriorated condition suggested that its death was not due to the operational down-ramping event on this date. Four isolated juveniles (three unidentified salmonids and one unidentified trout) were observed in separate small, isolated pools at the upper two SSMSs (the trout and one unidentified salmonid at CAP-DSSD01 and the other two unidentified salmonids at CAP-DSSD02). Although the area of these pools decreased substantially, they remained wetted due to subsurface flow, and would have become re-connected once flows rebounded. More than 20 Coho Salmon fry (< 60 mm length) were also observed in a shallow, isolated side channel of CAP-DSSD03 (Figure 15), which remained wetted due to sub-surface flow and input from a small tributary, the bottom of which was observed to reconnect to the mainstem as flows began rebounding in the evening. A total of two juvenile salmonids were also observed in mainstem habitat at CAP-DSSD01 and CAP-DSSD04 (one in each) at a depth of <1 m. Bird activity (blue herons, crows, ducks, and gulls) was noted at all sites.

Figure 15. Isolated area with >20 Coho Salmon fry near CAP-DSSD03, April 25, 2019.

Figure 16. **Stage and discharge at GVWD hydrometric station ("Pool") and each SSMS during the April 25, 2019 shutdown. Discharge at SSMSs is estimated using rating curves in Figure 14.**

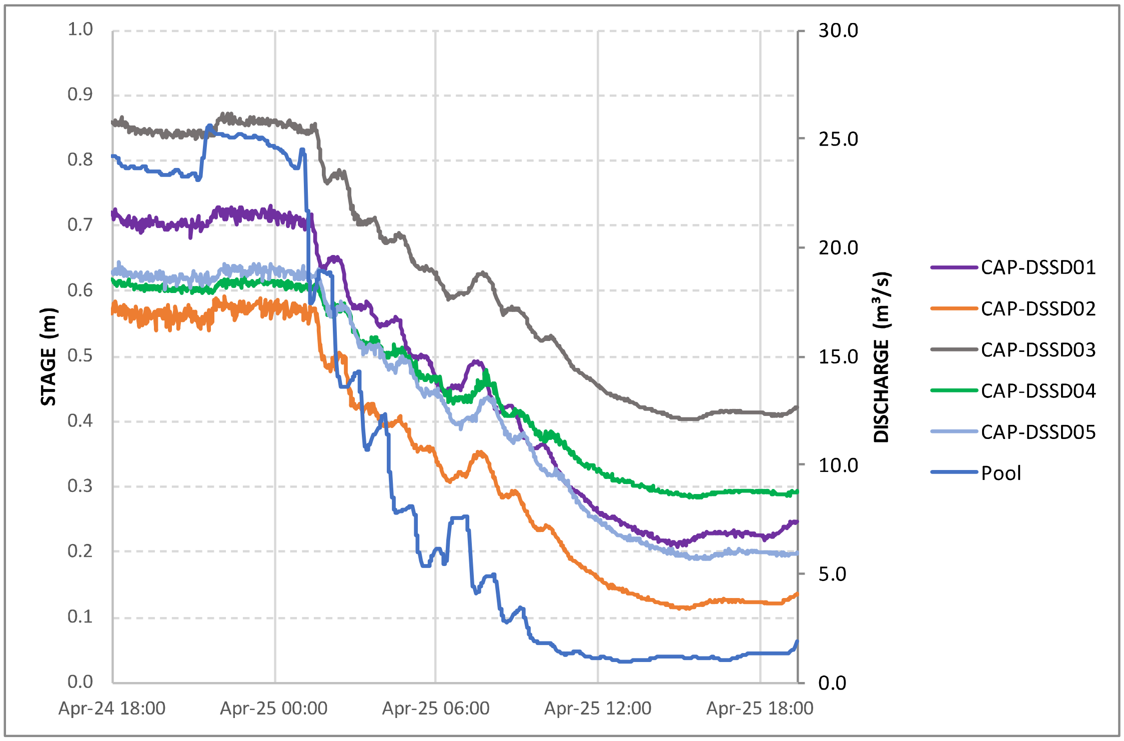
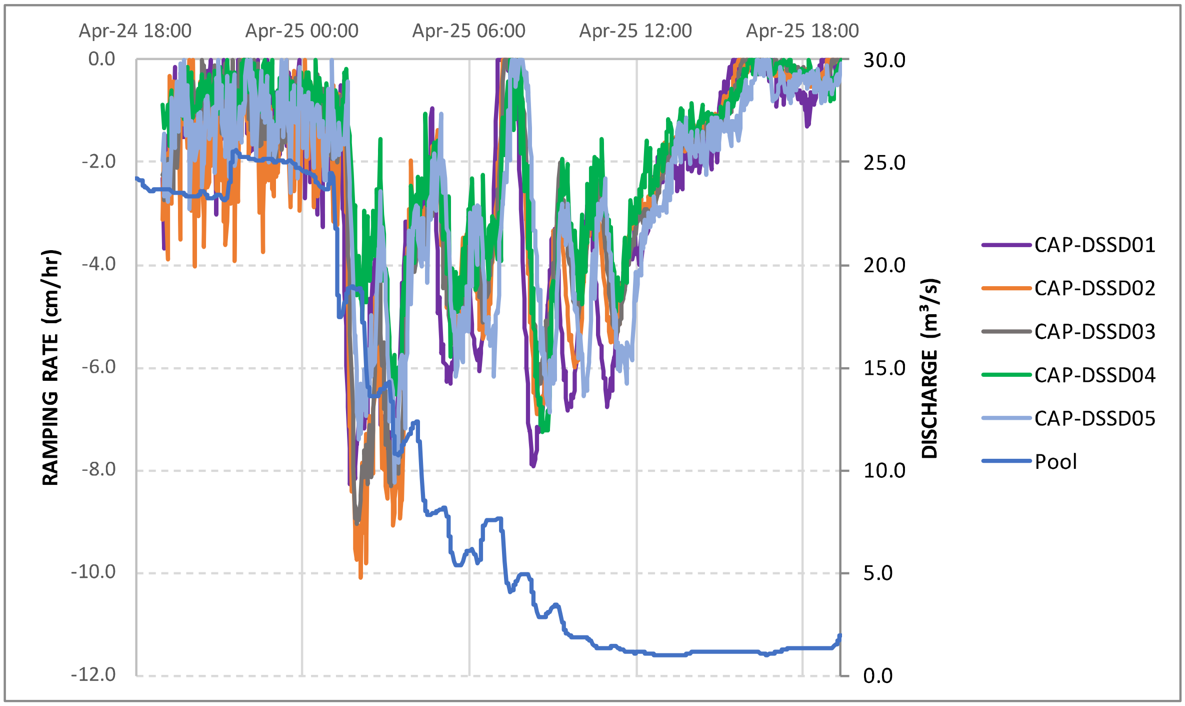


Figure 17. **Ramping rate at each SSMS and discharge at GVWD hydrometric station ("Pool") during the April 25, 2019 shutdown.**



3.3.3. Event 2: May 7, 2019

The second stranding survey occurred during a planned ramp-down at the CLD on May 7, 2019 that was initiated by raising the drum gate. The main flow decrease occurred overnight, with ramp-down beginning on May 6 at a flow of 52.0 m^3/s at 19:14 PDT and decreasing to 1.34 m^3/s at 03:06 PDT on May 7. There was a subsequent increase in flow and another ramp-down beginning May 7 from 9.54 m^3/s at 03:54 PDT and decreasing to 3.65 m^3/s at 04:48 PDT (Table 5 and Figure 18). This flow change resulted in a maximum ramping rates ranging from -7.8 cm/hr at CAP-DSSD04 to -20.8 cm/hr at CAP-DSSD02 (Table 5 and Figure 19). Fish stranding searches were initiated at 08:00 PDT on May 7 and continued until 13:25 PDT that day.

Eleven broad-based searches were conducted at the five primary SSMSs and at CAP-DSSD07, covering a total area of 4,680 m^2, with a total time of three hours and 36 minutes spent conducting broad-based searches. Additionally, 34 hotspot searches were conducted, covering a total area of 580 m^2, with a total of seven hours and nine minutes spent conducting hotspot searches.

At CAP-DSSD07, disconnection of a small side channel under the Marine Drive bridge led to the formation of isolated pools, some of which were dewatered. At this site, two dead stranded fish (unknown species) were observed; neither mortality seemed likely to have been due to the ramp-down given the advanced stage of decomposition observed. One live stranded sculpin was observed and salvaged (i.e., returned to the mainstem); stranding of this fish was deemed likely to have been due to the ramping event. However, as described in Section 3.1.2.2, the stranding of this fish appeared to be related to the disconnection and dewatering of the secondary channel (i.e., low flows caused by the CLD ramp-down), and may not be related to the rate of flow decline (i.e., the ramping rate). Two isolated fish (unknown species) were observed but not salvaged as they were located in areas with sufficient depth or groundwater flow to avoid immediate risk. No isolated or stranded fish were observed at the other sites surveyed.

Figure 18. Stage and discharge at GVWD hydrometric station ("Pool") and each SSMS during the May 7, 2019 shutdown. Discharge at SSMSs is estimated using rating curves in Figure 14.

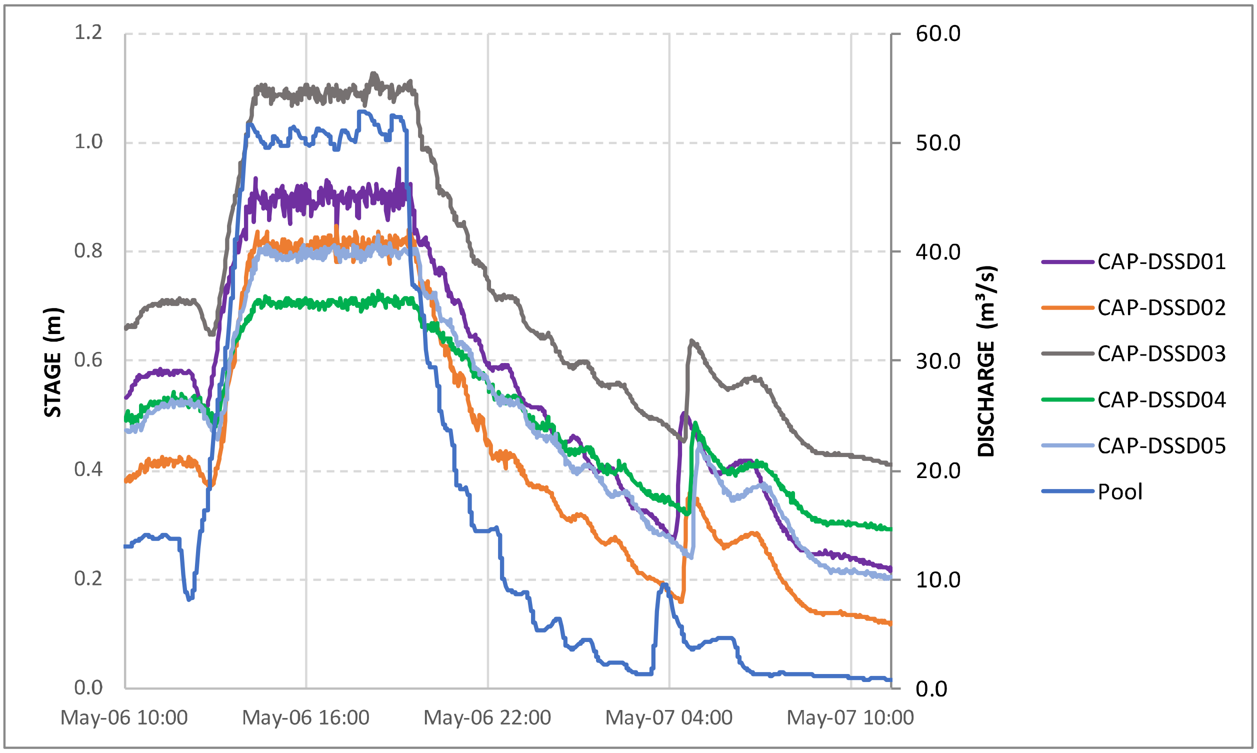
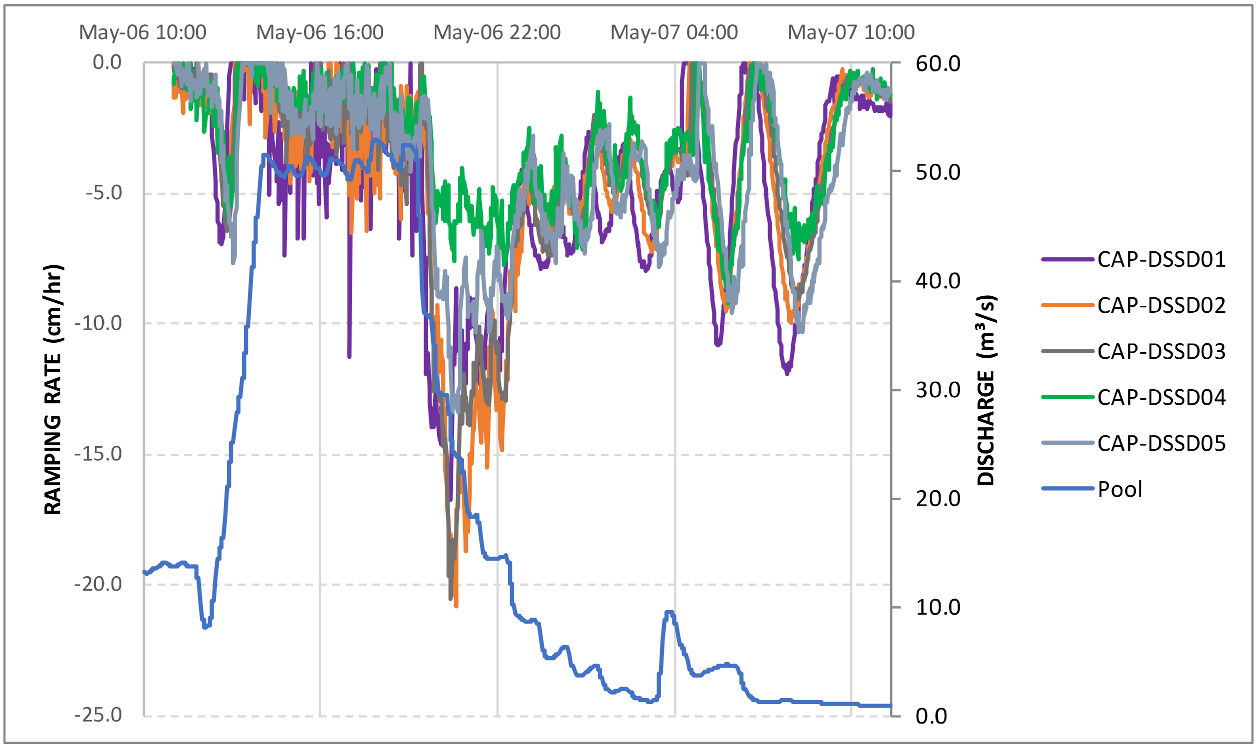


Figure 19. Ramping rate at each SSMS and discharge at GVWD hydrometric station ("Pool") during the May 7, 2019 shutdown.



3.3.4. Event 3: May 14, 2019

The third stranding survey occurred during a planned ramp-down on May 14, 2019, which was initiated by raising the drum gate. A stranding survey was deemed warranted due to the recent release of 450,000 Coho Salmon smolts by the Capilano River Hatchery on May 10, 2019. Flow was variable in the 24 hours prior to the planned ramp-down event, which began at 11:44 PDT (flow = 19.7 m^3/s) and lasted until 13:06 PDT when a minimum flow of 9.34 m^3/s was recorded (Table 5 and Figure 20) before flows began to rise naturally in response to recent rain. This flow change resulted in maximum ramping rates ranging from -7.6 cm/hr at CAP-DSSD04 to -11.7 cm/hr at CAP-DSSD02 (Table 5 and Figure 21). Fish stranding searches were initiated at 15:09 PDT on May 14 and continued until 17:23 PDT on the same day.

Upon arrival at site, Ecofish biologists observed flows in the Capilano River rapidly rebounding as a result of rainfall that day. Crews searched a subset of the sites (CAP-DSSD02, CAP-DSSD03 and CAP-DSSD04). Three broad-based searches were conducted, covering a total area of 8,600 m^2, with a total time of one hour and ten minutes spent conducting broad-based searches. Additionally, seven hotspot searches were conducted, covering a total area of 104 m^2, with a total of 46 minutes spent conducting hotspot searches. No stranded or isolated fish were observed, and no live fish were observed in the mainstem.

Figure 20. Stage and discharge at GVWD hydrometric station ("Pool") and each SSMS during the May 14, 2019 shutdown. Discharge at SSMSs is estimated using rating curves in Figure 14.

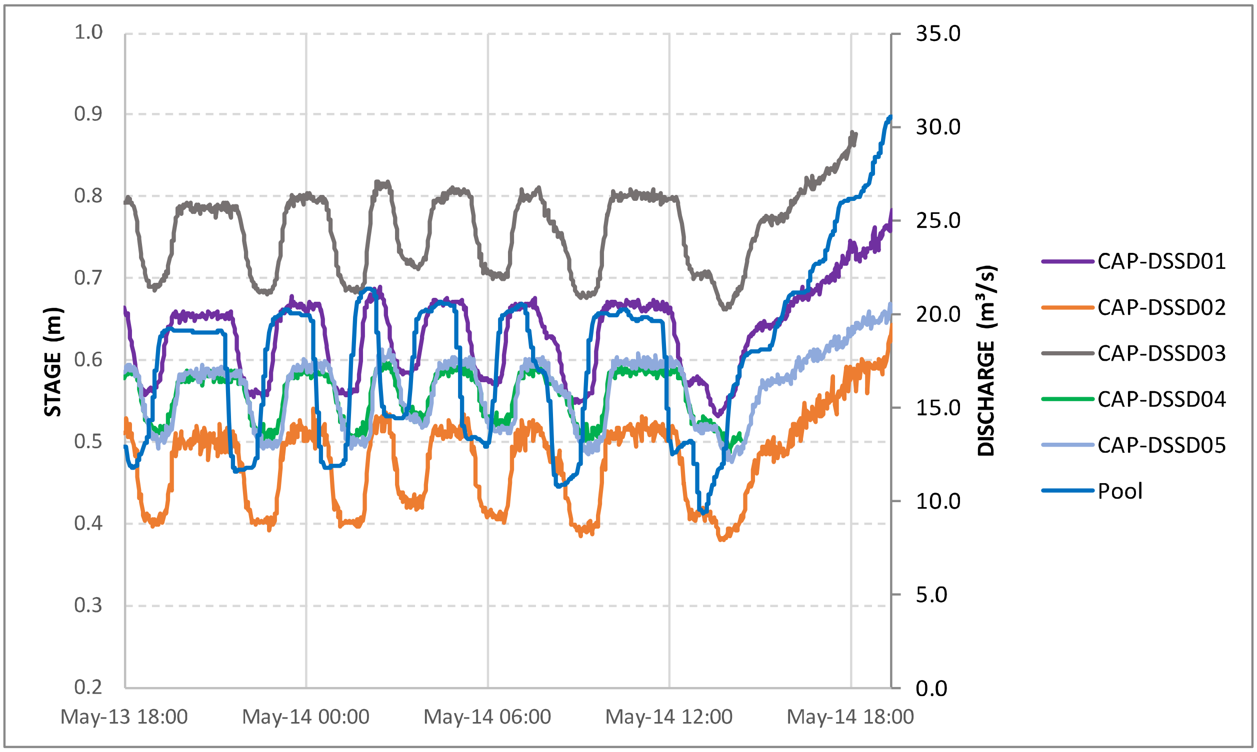
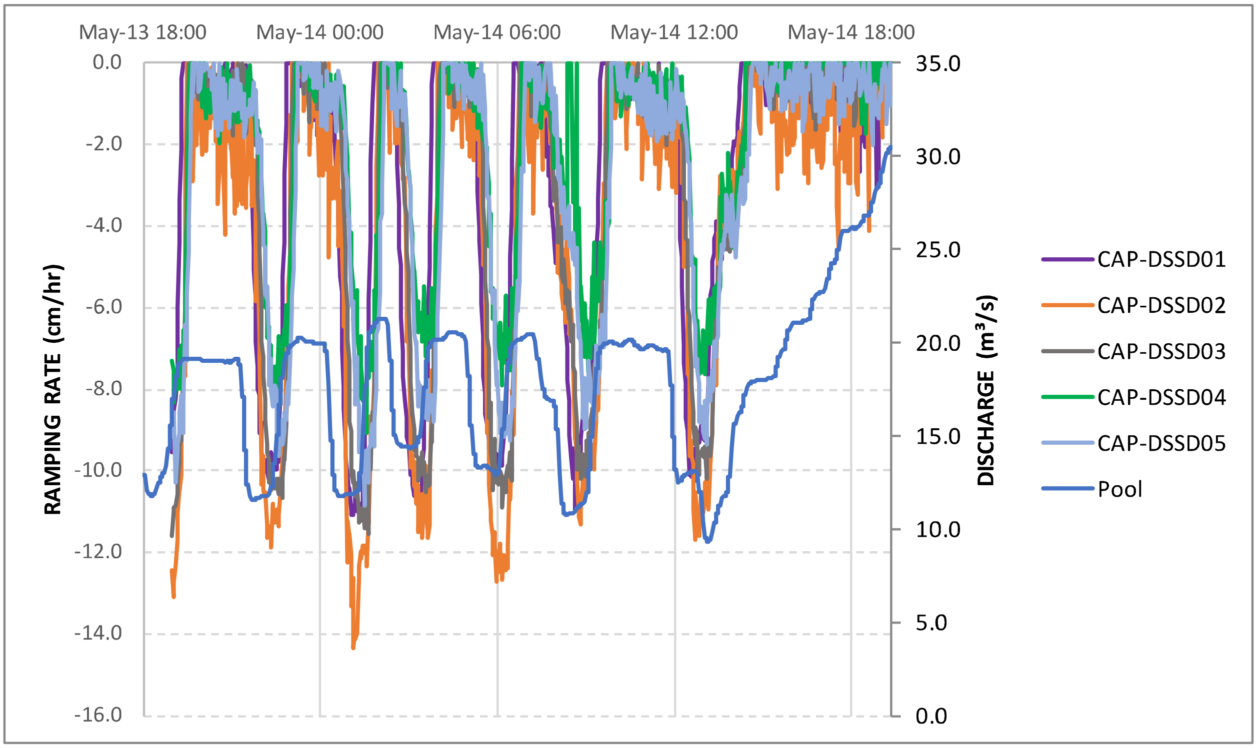


Figure 21. Ramping rate at each SSMS and discharge at GVWD hydrometric station ("Pool") during the May 14, 2019 shutdown.



3.3.5. Event 4: 1 October 2019

The fourth ramping event selected for monitoring was a planned ramp-down on October 1, 2019, which occurred due to closure of the Howell Bunger valve. The ramp-down began at a flow of 15.7 m^3/s at 06:05 PDT and decreased to 0.849 m^3/s at 15:00 PDT (Table 5 and Figure 22). This flow change resulted in maximum ramping rates ranging from -12.9 cm/hr at CAP-DSSD04 to -19.5 cm/hr at CAP-DSSD01 (Table 5 and Figure 23). Fish stranding searches were initiated at 09:12 PDT on October 1 and continued until 19:18 PDT the same day (i.e., after it was confirmed that the minimum stage had been reached during the event). In total, 24 broad-based searches were conducted at the five primary SSMSs and at CAP-DSSD07, covering a total area of 8,160 m^2, with a total time of six hours and 38 minutes spent conducting broad-based searches. Additionally, 17 hotspot searches were conducted, covering a total area of 266 m^2, with a total of three hours and 13 minutes spent conducting hotspot searches.

At CAP-DSSD02, two Coho Salmon fry mortalities were observed; given their location and fresh condition, these mortalities were deemed to have been likely due to the ramp-down. At CAP-DSSD02, a live crayfish was also found in dewatered habitat; although this stranding was likely due the ramp-down, the crayfish was successfully salvaged and returned to the mainstem. A stranded adult Coho Salmon (320 mm fork length) was observed at CAP-DSSD07; this observation was deemed to be possibly related to the ramp down. One additional adult Chinook Salmon at CAP-DSSD05 and three adult salmon at CAP-DSSD07 were found dead and/or stranded; however, based on the condition (i.e., poor condition, rate of decay of the fish, evidence of predation) and location (i.e., depth of water and distance of fish observations from the mainstem wetted edge) of the fish, these observations were unlikely to have been related to the ramp-down.

In addition, 10 juvenile salmonids and one sculpin were found isolated at CAP-DSSD01; these observations were likely due to the ramp-down, given the locations of the fish. Given that flow was expected to remain low following the planned ramp-down, six of these salmonids were successfully salvaged, however the remainder could not be relocated. Crews assessed that it was possible that fish that were not salvaged would have eventually been stranded.

A live isolated adult Coho Salmon was observed at CAP-DSSD05. Although the cause of isolation could not be determined, it was considered possible that it was related to the ramping event; the fish was salvaged and returned to the mainstem.

Figure 22. **Stage and discharge at GVWD hydrometric station ("Pool") and each SSMS during the October 1, 2019 shutdown. Discharge at SSMSs is estimated using rating curves in Figure 14.**

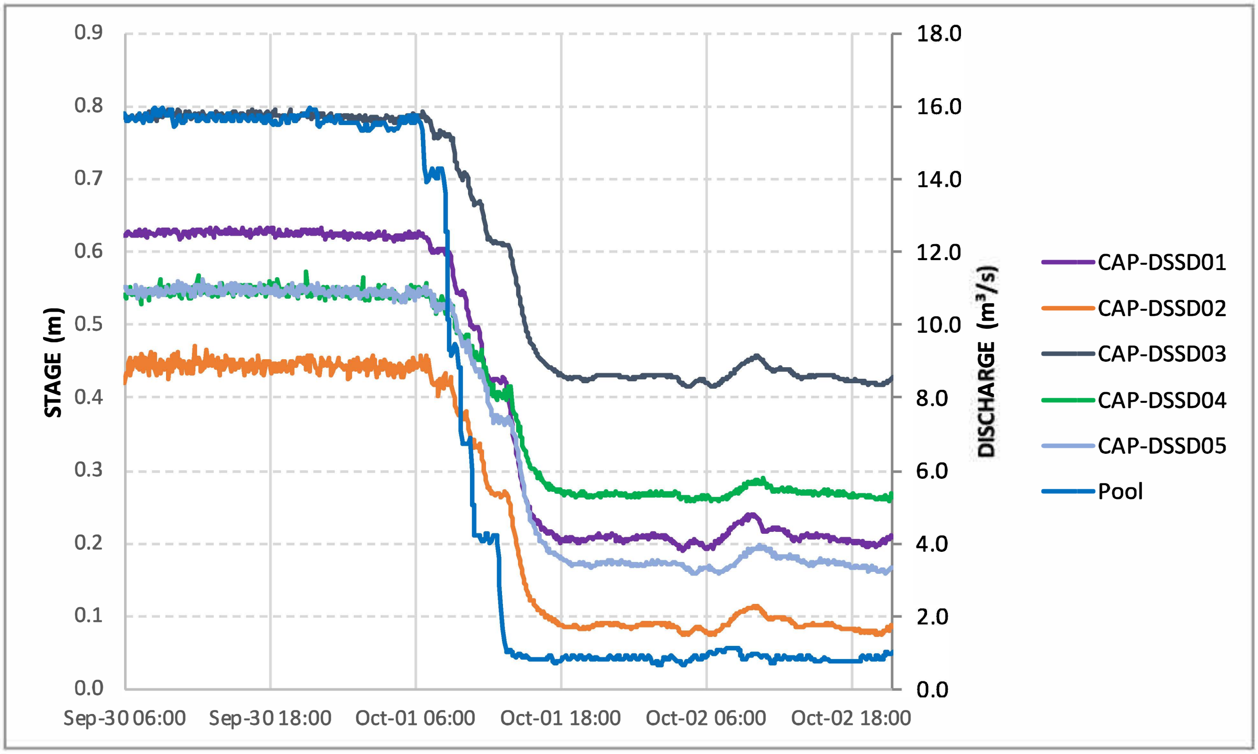
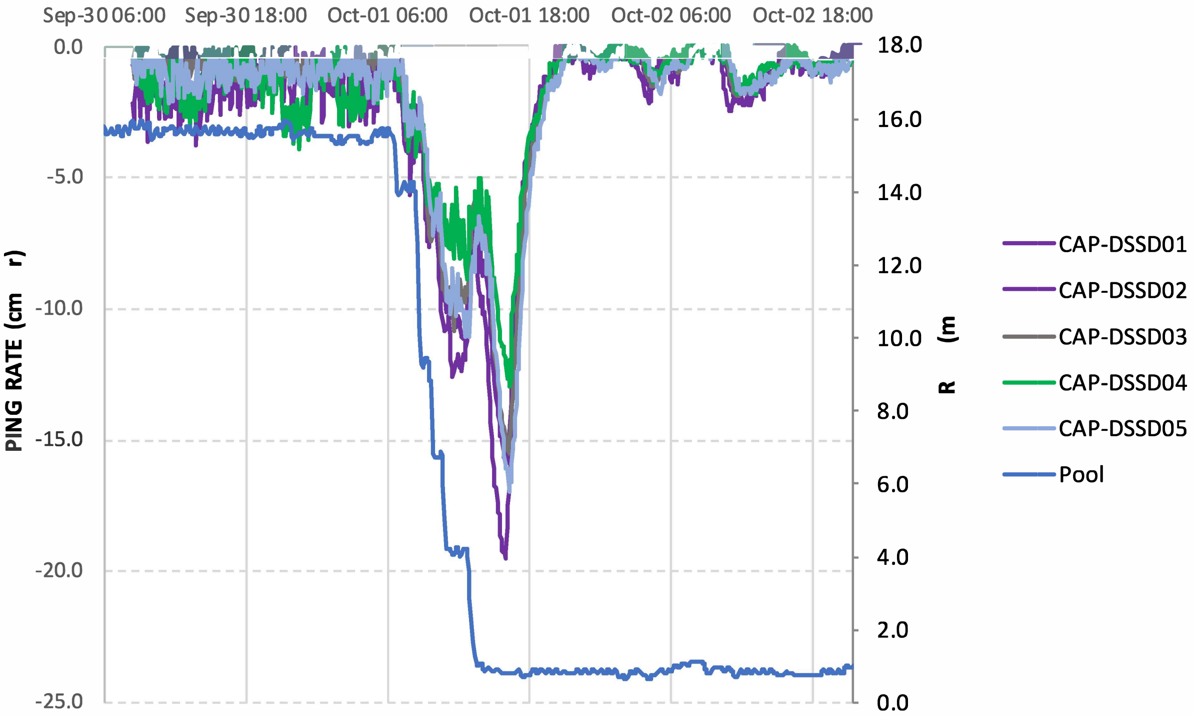


Figure 23. Ramping rate at each SSMS and discharge at GVWD hydrometric station ("Pool") during the October 1, 2019 shutdown.



4. DISCUSSION

4.1. Summary

Overall, fish stranding and isolation were detected during stranding searches during three of the four monitored events on the Capilano River during 2019. During the three events monitored in the spring, ramping resulted in low levels of stranding; specifically, ramping events were identified as the possible or likely cause of stranding of two fish (both sculpins) that were detected following separate events on April 25 and May 7. During the single event monitored in the fall (October 1), the ramping event was considered to be the likely cause of stranding of two Coho Salmon fry and isolation of an additional 10 juvenile salmonids. Further, the October 1 ramping event was assessed to have possibly contributed to the stranding of one adult Coho Salmon and isolation of one additional adult Coho Salmon, which was salvaged.

There is uncertainty regarding whether isolation of fish will result in mortality as it depends on ambient environmental conditions (e.g., temperature) and when flow subsequently increases.

Our assessment is limited to observations of four test results and does not consider the potential loss of fish productivity that may result from the current operations. Estimating total mortality would require extrapolating search results based on the area of affected habitat and number and type of operational events, while also accounting for observer efficiency. This total mortality estimate would then need to be compared to the abundance of affected species to understand the potential effects on productivity: that analysis exceeds the scope of the current study.

Additional mitigation measures could be employed to reduce stranding mortality during future operations. Six potential mitigation measures were assessed by Ecofish for biological feasibility and effectiveness, as detailed in Section 4.2 (presented in no particular order). Depending on conditions and operational constraints, these measures could be considered in isolation or combination; however, before implementing, all measures would require assessment by GVWD to consider operational and financial feasibility.

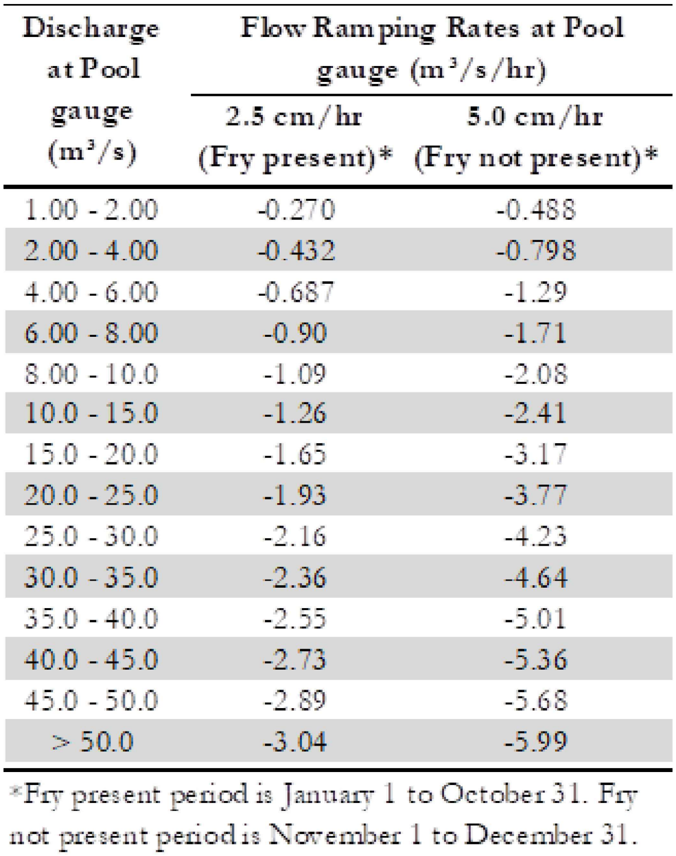
4.2. Assessment of Potential Mitigation

4.2.1. Reduced Ramping Rate

The risk of stranding fish during a ramping event depends on the wetted history, the rate of stage change (i.e., ramping rate), the magnitude of stage change, and many other biotic and abiotic factors (Nagrodski *et al.* 2012; Irvine *et al.* 2014). Reducing the ramping rate is generally expected to reduce the risk of stranding and associated mortality. Generic standard DFO ramping criteria of -2.5 cm/hr during the fry-present period and -5.0 cm/hr at other times (Cathcart 2005) are generally considered to pose a low stranding risk. As shown in Section 3, current Project operations result in faster ramping rates at SSMSs than these standard DFO ramping criteria. Ramping rates faster than the DFO criteria may adequately mitigate stranding risk and have been proven effective at other hydropower projects in BC: the specific rates required vary between rivers due to channel morphology and the stranding sensitivity of the fish species present.

To understand how ramping rates at the Pool gauge correspond to rates at the SSMSs in the lower Capilano River, we used the stage-discharge relationships (Figure 14) to calculate the standard DFO ramping criteria at the SSMSs (Table 6). These rates vary based on discharge, with higher discharge corresponding to higher permissible rates. Based on the current study, the maximum rates prescribed in Table 6 are expected to provide a high level of protection for fish as no stranded fish were detected at rates up to -20.8 cm/hr (i.e., CAP-DSSD02 on May 7, 2019), and isolation was only detected at rates at or above -8.4 cm/hr (i.e., at CAP-DSSD01 on April 25, 2019). Thus, it is possible that adequate protection could be afforded with maximum rates that are higher than those in Table 6, yet lower than the rates during the events that were monitored. However, data collected alone are insufficient to confirm the protectiveness of ramping rate criteria greater than the DFO criteria. If ramping rates higher than the DFO criteria are to be implemented as mitigation, their efficacy should be confirmed through conducting ramping tests to measure fish stranding in relation to the proposed rates; such ramping tests could be conducted actively (e.g., planned in advance) or passively (e.g., responding to unplanned events) according to the methods employed as part of this study. Such higher ramping rates may vary seasonally, reflecting differences in fish presence and habitat use, and resultant stranding risk, between seasons.

Table 6. Maximum flow ramping rates measured at the Pool gauge that will achieve the generic standard DFO ramping rate criteria at the SSMSs in the Lower Capilano River.



Discharge at Pool gauge (m^3/s)	Flow Ramping Rates at Pool gauge ($m^3/s/hr$)	
	2.5 cm/hr (Fry present)*	5.0 cm/hr (Fry not present)*
1.00 - 2.00	-0.270	-0.488
2.00 - 4.00	-0.432	-0.798
4.00 - 6.00	-0.687	-1.29
6.00 - 8.00	-0.90	-1.71
8.00 - 10.0	-1.09	-2.08
10.0 - 15.0	-1.26	-2.41
15.0 - 20.0	-1.65	-3.17
20.0 - 25.0	-1.93	-3.77
25.0 - 30.0	-2.16	-4.23
30.0 - 35.0	-2.36	-4.64
35.0 - 40.0	-2.55	-5.01
40.0 - 45.0	-2.73	-5.36
45.0 - 50.0	-2.89	-5.68
> 50.0	-3.04	-5.99

*Fry present period is January 1 to October 31. Fry not present period is November 1 to December 31.

4.2.2. Night-Time Ramping

According to the literature, the risk of fish stranding is reduced at night (Saltveit *et al.* 2001; Irvine *et al.* 2014). For instance, juvenile salmonids tend to hold in the water column at night instead of seeking cover in interstitial spaces and are therefore less likely to occupy sensitive habitats as they are dewatered. Irvine *et al.* (2014) found that night-time ramping reduced stranding risk for other fish species as well, including suckers and sculpins.

Thus, scheduling ramping events during night-time periods could reduce fish stranding risk in the lower Capilano River.

4.2.3. Providing Higher Continuous Flow

Stranding risk may vary by flow and is often highest at lower flows when flow changes cause disproportionately high amounts of dewatering and/or increases in fish density in sensitive habitats

(Ecofish, unpublished data). Based on our observations, this is likely the case in the lower Capilano River; e.g., it is notable that no stranding or isolation was observed on May 14, 2019 when minimum flows (9.34 m^3/s at CAP-DSSD02) were greater than during the other events, when fish stranding/isolation was observed. Further, on October 1, 2019, field crews observed that the majority of dewatering coincided with the final step of the Howell Bunger valve closure (e.g., from 4.2 m^3/s to 0 m^3/s; Province of British Columbia 2018).

Where feasible, scheduling ramping events during periods of higher flow (e.g., >10 m^3/s) could reduce fish stranding risk in the lower Capilano River. Similarly, applying faster ramping rates during the high flow phases of flow reduction events, and slower ramping rates during the low flow phases, may reduce the incidence of stranding. Additional fish stranding assessments consistent with the methods employed during this study would be required to confirm effectiveness of the recommended changes to the current ramp down protocol.

4.2.4. Fish Salvages

Conducting fish salvage as part of a stranding monitoring program is one of the most common methods to mitigate adverse effects caused by fish stranding during dewatering activities and hydropower plant shutdowns (Nagrodski *et al.* 2012); however, it has disadvantages for long-term use. First, fish salvages are labour intensive and expensive, particularly in response to water level fluctuations that occur regularly. Higgins and Bradford (1996) reported poor effectiveness of fish salvages to reduce the impacts of hydropeaking on a long gravel bed river similar in morphology and substrate to the Capilano River. Second, extraordinary resources would be required to monitor and salvage fish throughout the entire reach of the river, including difficult-to-access habitats, that will be dewatered during Project down-ramping. Accordingly, such fish salvages are included as a secondary consideration.

4.2.5. Pulse Flows (Conditioning Flows)

Providing conditioning flows involves rapidly decreasing and then rapidly increasing river flows within one hour before a planned major flow reduction to "teach" juvenile fish to emigrate to deeper waters during subsequent flow reductions (Nagrodski *et al.* 2012). This new procedure may be an effective mitigation strategy, particularly for stranding of fish in side-channels or pools (Irvine *et al.* 2008); however, these conditioning flows have also resulted in high levels of mortality (e.g., Mountain Whitefish within 20 minutes). Conditioning flows may be achieved by increasing or decreasing flows in the affected reach prior to the shutdown. The feasibility of pulse flows as a mitigation measure may be limited by CLD operational constraints.

4.2.6. Channel Modification

Physical habitat contouring has been shown to be effective at decreasing fish stranding in other systems (Irvine *et al.* 2014). This mitigation requires that physical works are undertaken in the stream channel to reduce stranding sensitive habitat. This is completed by:

- increasing water depth of side-channel inlets,

- increasing bank slope gradient,
- adjusting channel width,
- decreasing cover by removing larger substrate and reducing the prevalence of interstitial spaces, and
- eliminating or deepening pools (and isolated depressions).

This would require extensive effort within the lower Capilano River to reduce stranding risk. Implementation of this mitigation may be constrained by limited heavy machinery access in some areas. Any proposed channel modifications to reduce fish stranding potential must also consider potential impacts to fish habitat (i.e., changes to river morphology and hydrology) and fish productivity (loss of critical habitats). Accordingly, channel modification is the least preferred of the options presented.

5. CLOSURE

This Fish Stranding Study report has been prepared to describe the effectiveness of GVWD's operational ramping protocols at the CLD. As requested by GVWD, options have been provided to further mitigate stranding risk based on the results of the ramping monitoring and stage/discharge relationships developed at the SSMSs.

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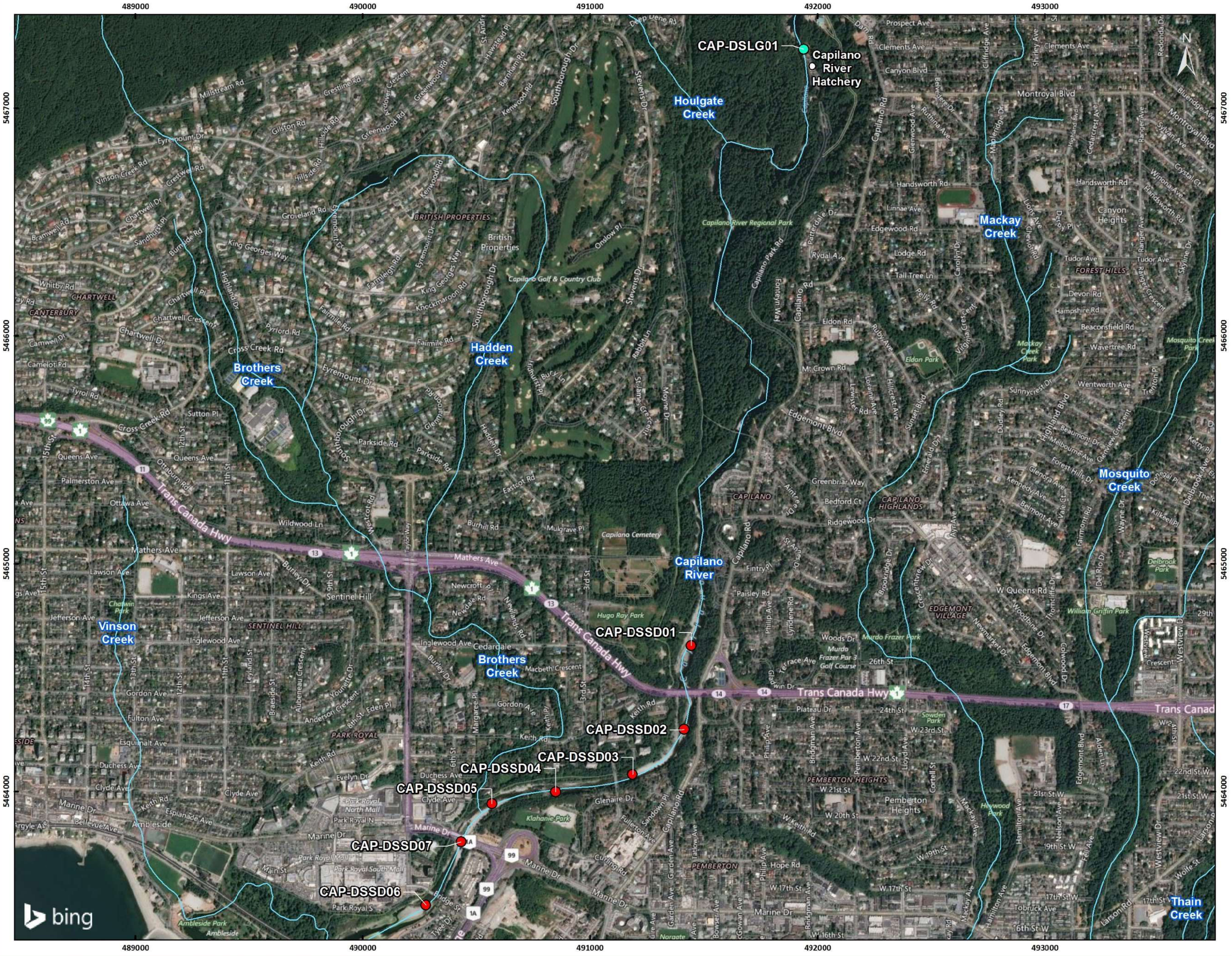
PROJECT MAPS



CAPILANO

Lower Capilano
Fish Stranding Sites

Legend

- 🔴 Stranding Sensitive Monitoring Site
- 🟢 Hydrometric Station
- Stream

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 75 150 300 450 600 750 m

Scale: 1:16,000

NO.	DATE	REVISION	BY
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2			
3			
4			
5			

Date Saved: 06/12/2019
Coordinate System: NAD 1983 UTM Zone 10N

ECOFISH RESEARCH

Map 2

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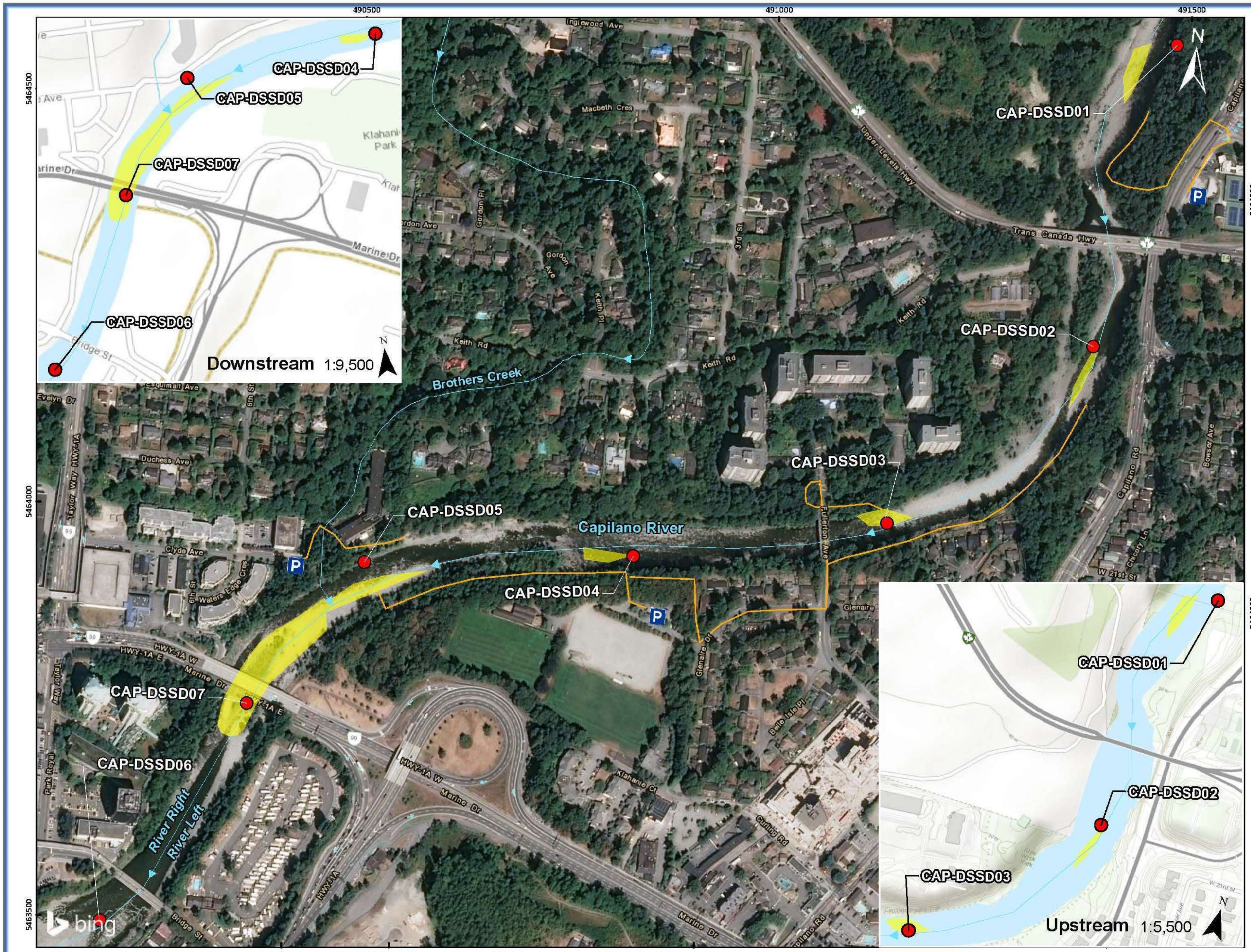

CAPILANO

Lower Capilano Fish Stranding Sites

Legend

- ● Fish Stranding Site-Gauge Location
- P Parking Location
- — Access Path
- ▨ Stranding Habitat

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 25 50 100 150 200 m

Scale: 1:4,450

NO.	DATE	REVISION	BY
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4			
5			

Date Saved: 4/21/2020
Coordinate System: NAD 1983 UTM Zone 10N

ECOFISH RESEARCH

Map 3

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APPENDICES

Appendix A. Relative Water Surface Elevation Time Series of Ramping Sites in Capilano River

LIST OF FIGURES

Figure 1. Relative Water Surface Elevation at CAP-DSSD01 from April 8, 2019 to November 5, 2019.

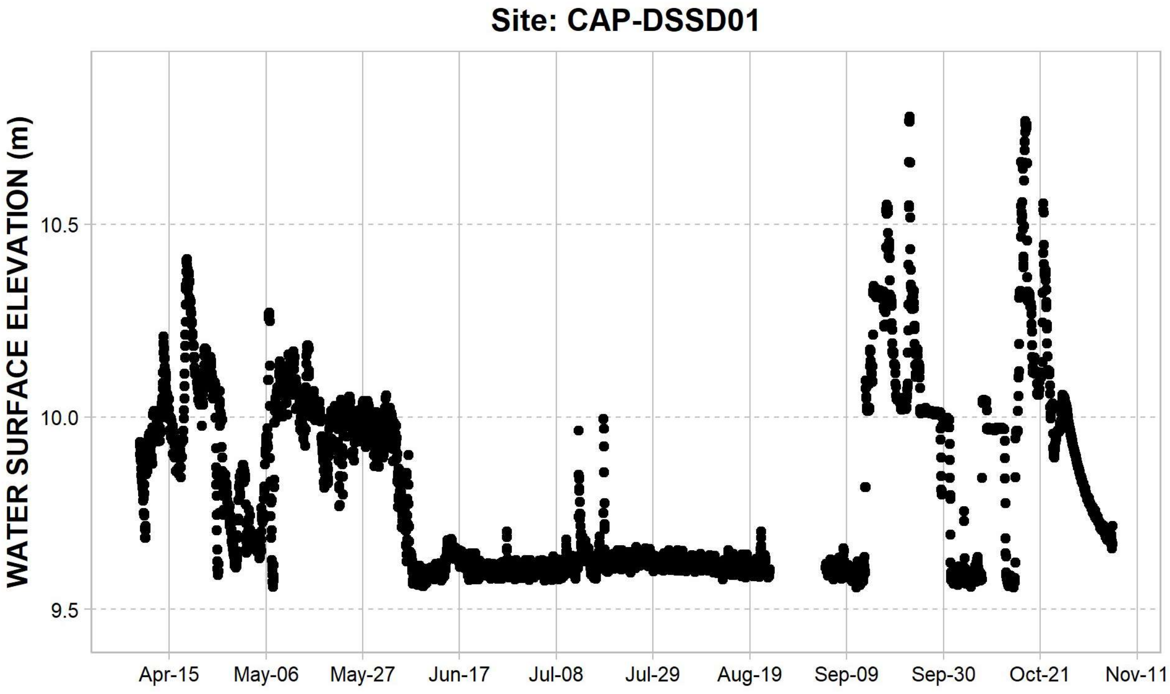

Figure 2. Relative Water Surface Elevation at CAP-DSSD02 from April 8, 2019 to November 5, 2019.

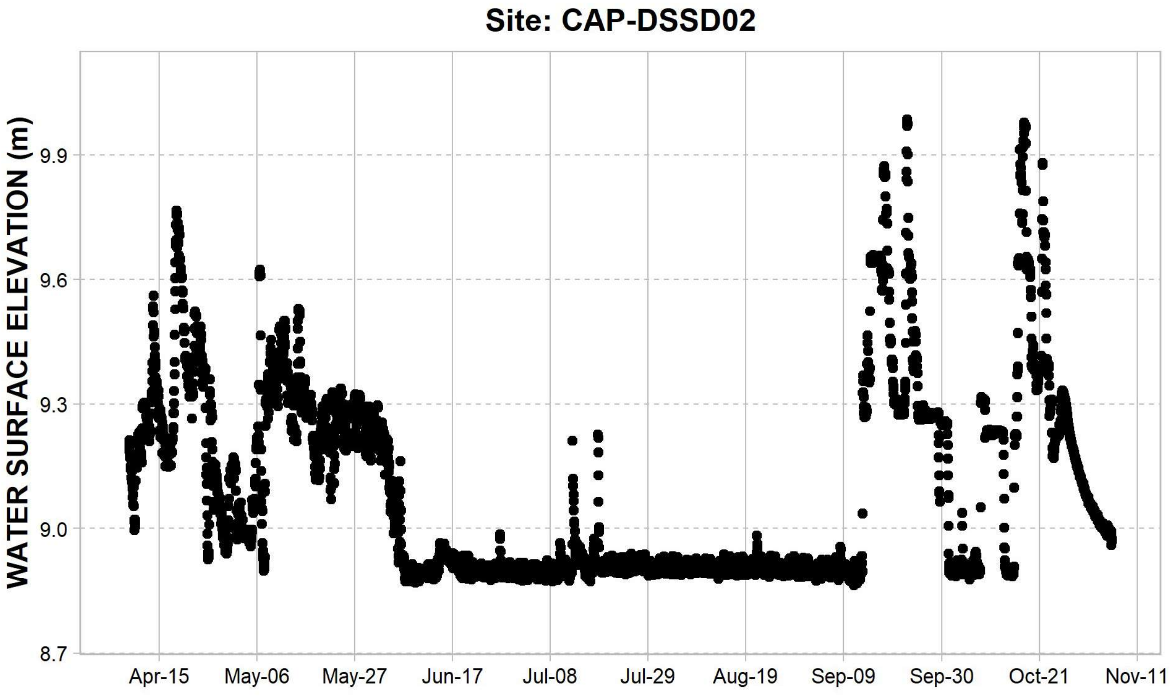

Figure 3. **Relative Water Surface Elevation at CAP-DSSD03 from April 8, 2019 to November 5, 2019.**

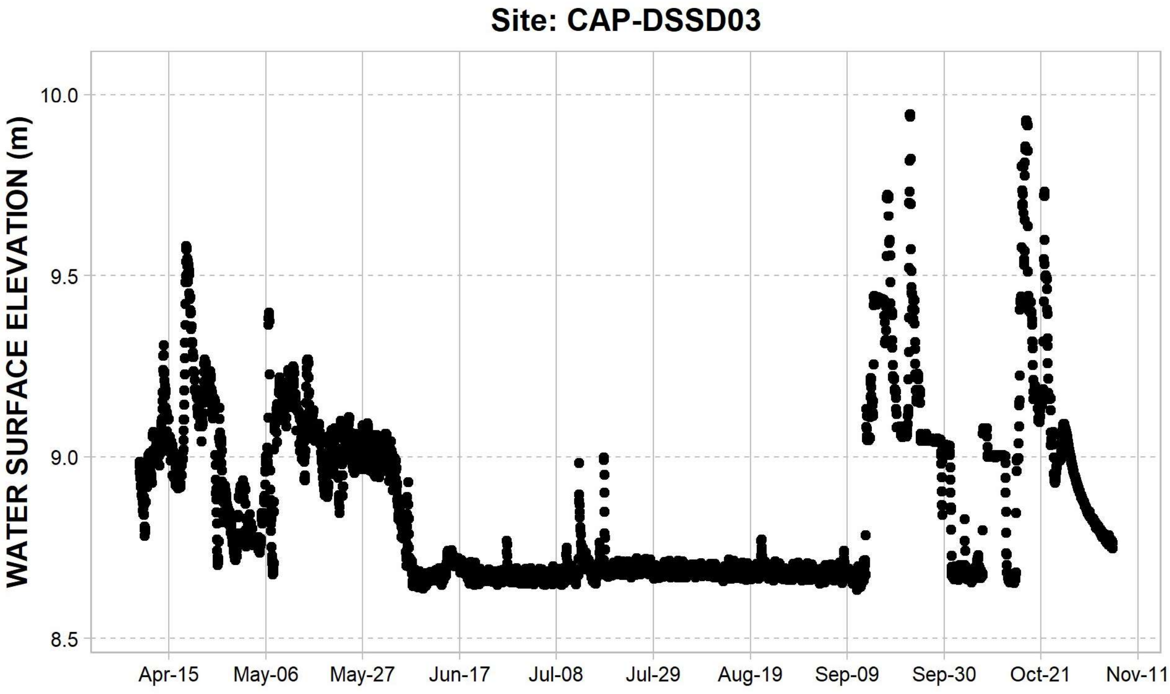

Figure 4. **Relative Water Surface Elevation at CAP-DSSD04 from April 8, 2019 to November 5, 2019.**

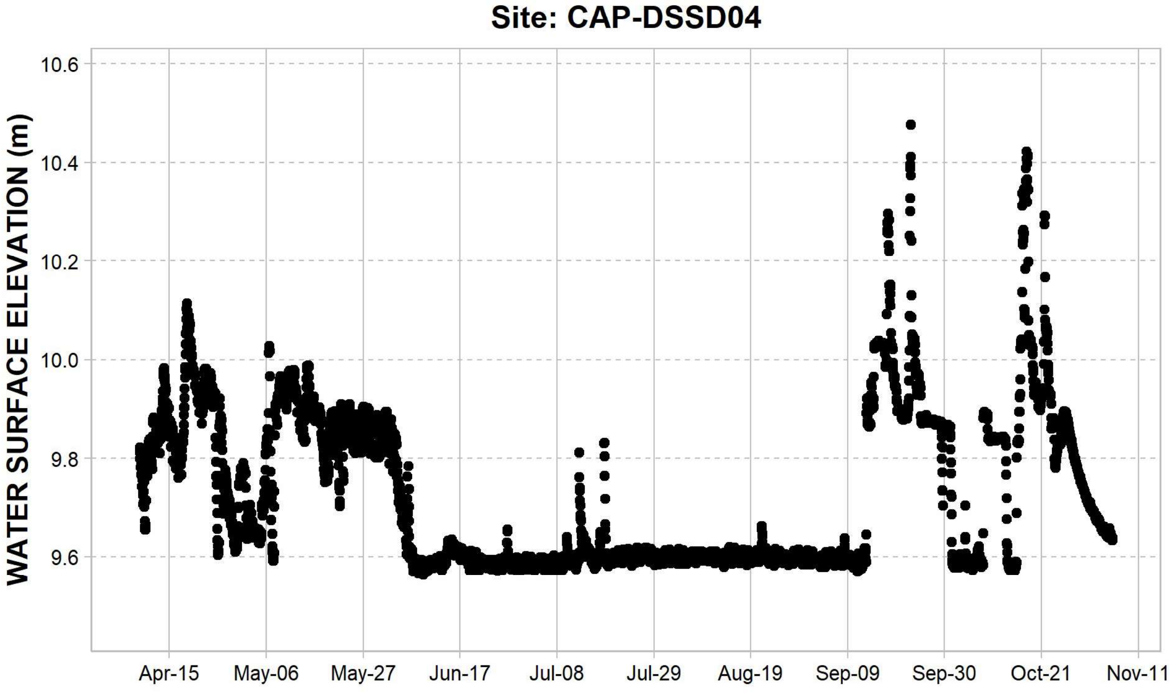

Figure 5. Relative Water Surface Elevation at CAP-DSSD05 from April 8, 2019 to November 5, 2019.