Taku River Tlingit Fisheries

Kuthai Lake Access Improvement Assessment - 2016

March, 2017

Executive Summary:

This Report is a summary of the field and office activities of the Kuthai Lake Access Improvement Assessment. Kuthai sockeye escapement has been low for numerous years and does not seem to be recovering. During 2016 the site was visited twice to conduct assessments of the canyon sections of the channel where the potential migration obstacles are present. Background hydrometric gauging was undertaken to provide hydrologic context to the assessment. The work completed here indicates several locations with potential migration obstacles that have been ranked and assigned mitigative prescriptions.

Acknowledgements:

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Introduction:

Silver Salmon River is a migration corridor for sockeye salmon destined for Kuthai Lake. Kuthai sockeye escapement has been low for numerous years and does not seem to be recovering (See Figure 1, below). Since 2007 returns to Kuthai Lake have been markedly lower than the long term average. The Kuthai stock is known to have early run timing, passing the lower Taku River in latter June, arriving at the confluence of the Nakina and Silver Salmon Rivers in early to mid-July. Peak enumeration into Kuthai Lake has historically been latter July to early August. The lower 700 meters of Silver Salmon River is a canyon reach with a number of boulder obstructions that pose jump height and velocity/turbulence challenges to upstream migration. Previous work and long term observations by TRT Fisheries has noted that the passage obstructions in the canyon may be the cause of these reduced returns. The TRT and the Pacific Salmon Commission are collaborating on this study to explore the cause of reduced returns to Kuthai Lake and to undertake mitigation if feasible. Project activities for 2016 included two site visits, a July trip to conduct hydrometric gauging at Silver Salmon Creek above Kuthai and at the Kuthai Lake outlet and a second trip in late October to survey the canyon reach migration obstacles. The timing of the October trip was selected to avoid the sockeye migration window (and grizzly bears) and to examine the channel at lower flows.

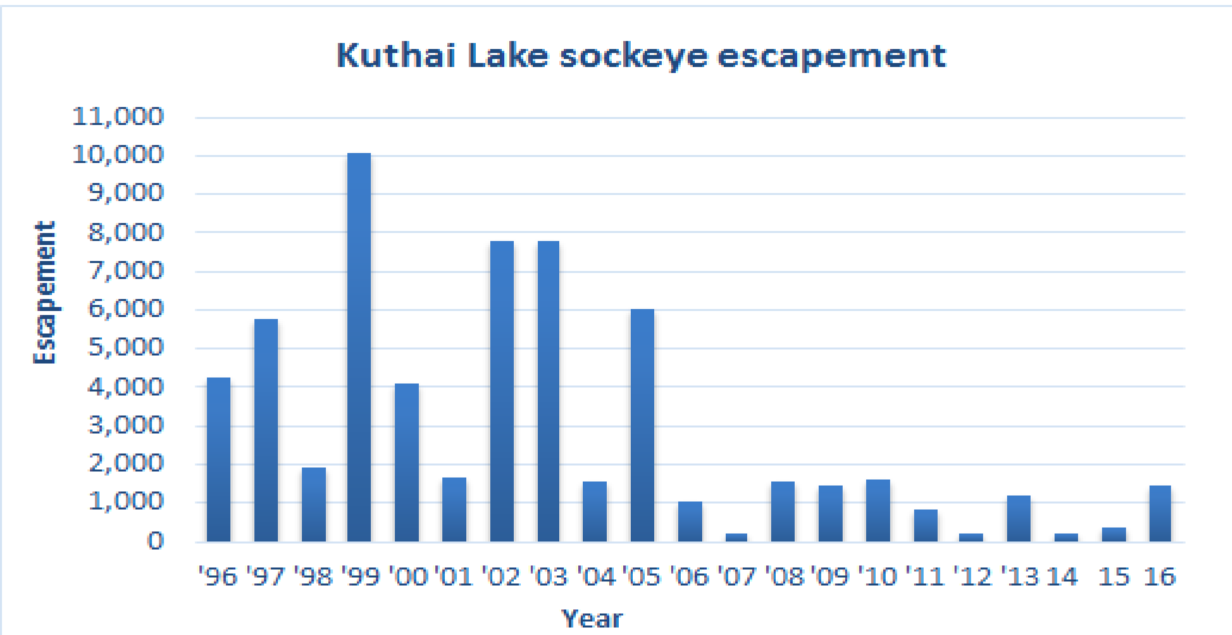

Figure 1: Kuthai Lake sockeye escapement summary.

Objectives:

The 2016 project year followed up on the work done in 2015 with a focus on the determination of mitigation options for passage through the canyon reach. The specific objectives include the following:

1. Further assessment of potential migration barriers in the lower Silver Salmon River for the Kuthai stock;
2. Collect and analyze hydrology data for the Silver Salmon River and Kuthai Lake;
3. Investigate and develop conceptual mitigation options to improve fish passage;
4. Work with the TBR Technical Committee regarding planning and implementation;
5. Present project results to the TBR agencies and the First Nation for consideration;
6. Submit a final written report which details project methods and results.

Background:

Project Area:

The Silver Salmon Watershed covers an area of approximately 430 square kilometers of mountain plateau terrain on the lee side of the Coast Mountains in British Columbia Hydrologic Zone 2. Its position on the lee side of the Coast Range translates into lower annual precipitation and unit area runoffs than watersheds further west. Silver Salmon River discharges to Nakina River on river right just downstream of the Nakina Canyon and runs northwest to Kuthai Lake. The river rises abruptly for the first 2 kilometers to a wide valley with Kuthai Lake at the top end. Silver Salmon River then turns to the north east up to a plateau and terminates at Bell Lake.

Geomorphology:

The main stem of Silver Salmon River below Kuthai Lake is an underfit river that meanders across an extensive paleo-channel alluvial deposit formed by mega-floods emanating from southward trending glaciers during the last glacial episode (see Photo 1 below). Glaciers in the basin deposited these alluvial materials during the glacial maxima and pro-glacially during deglaciation and ablation. This type of valley bottom glacial deposit tends to result in hydro-systems with large alluvial aquifers that store and release large quantities of groundwater. The effect of this groundwater influence is to augment low flows and diminish peak flows and produce ideal hydrologic conditions for spawning and rearing of salmonids.

Photo 1: The view looking northwest toward Kuthai Lake. Silver Salmon River can be seen in the foreground meandering across the wide alluvial plain of the glacial paleo-channel that underlies the valley bottom. The alluvium of the paleo-channel has high potential for groundwater aquifers that likely give the Silver Salmon River a stable flow regime and high groundwater ratio.

The glacial history of the lower watershed has also shaped the formation of Kuthai Lake and the sockeye spawning areas on its' shoreline. Kuthai Lake has the elongate, serpentine shape consistent with subglacial scour and deposition, the remnants of which form the spawning substrates utilized by sockeye (see Photo 3 below). The southern shore of the lake is formed by a mound of terminal moraine and the paleo-alluvial fan of the upper Silver Salmon River. Kuthai Creek has carved a notch through the moraine and is confined on river left as it follows the toe of the alluvial fan.

The bedrock in the basin is underlain by Paleozoic rocks of the Cache Creek Group (Aitken, 1960). These chert, limestone and argillite rocks can be expected to have relatively high porosity. Aitken (1960) maps the bedrock in the canyon reach as chert, a very durable rock type, although there are also some limestone exposures as well.

Hydrology:

The Silver Salmon watershed lies in the rain shadow of the Coast Mountains in the northwestern corner of BC Hydrologic Zone 2 (Yukon Plateau). There are no long term hydrometric stations in the watershed or in nearby hydrologically similar watersheds so estimates of hydrologic parameters can only be determined by regional analysis or hydraulic geometry. Hydrometric gauging done for this project was undertaken to provide index flows to provide hydrologic context for the assessment of obstructions in the canyon reach. Figure 2 is a chart of the average monthly flows for the Taku River USGS hydrometric station 08BB005 near Juneau Alaska.

Figure 2: Average Monthly Discharge: Taku River Near Juneau

(1988 to 2013 Stn. 08BB005)

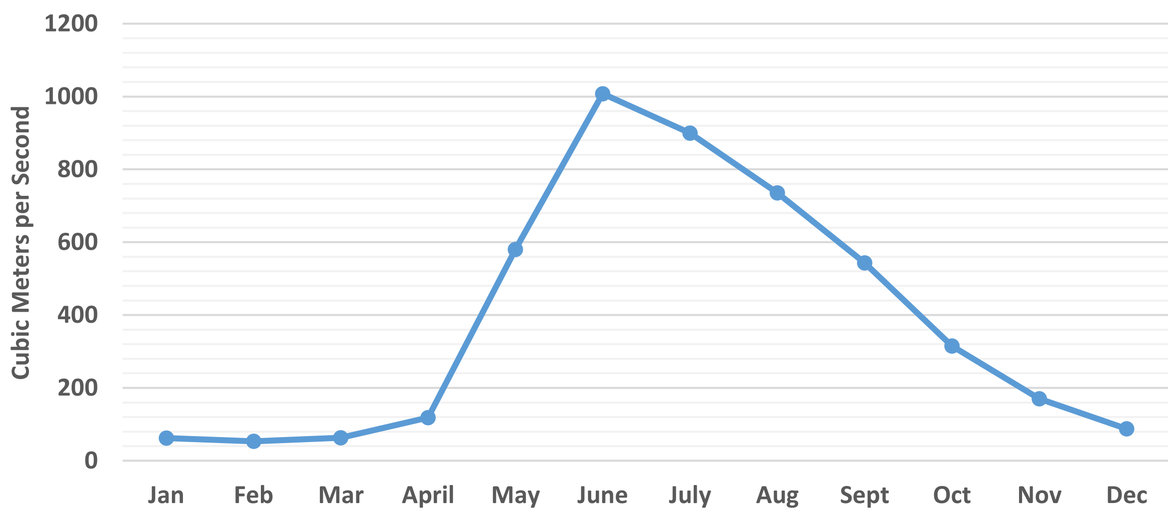

Figure 2 shows a typical spring snowmelt runoff pattern in the ascending limb of the hydrograph (March to June). Of course this station captures glacial outburst discharges during the summer which do not occur in the upper watershed but the spring and fall periods are reasonably representative of hydrograph shape for the rest of the year. As the chart indicates, the annual minimum flow is in February and the descending (fall) limb has high flows into October due in part to the influence of fall storm systems.

The watershed is in the transitional zone between the wetter Engelmann Spruce Subalpine Spruce (ESSF) / Sub Boreal Spruce (SBS) zones west of Silver Salmon River and the much drier Boreal White and Black Spruce (BWBS) / Sub-Boreal Spruce Biogeoclimatic zones to the east. Most of the watershed is forested aside from high alpine areas and areas of high water table and wetlands in the valley bottoms.

Photo 2: Bell Lake (aka Silver Salmon Lake) at the headwaters of Silver Salmon River. Photo date: October 27, 2016.

Photo 3: Glacio-fluvial deposit on the eastern shore of Kuthai Lake that supports sockeye spawning (July 2016). Note the partially dewatered spawning dunes near the shoreline.

2016 Field Program:

Field activities during the 2016 field season included 2 site visits. The first visit was conducted in July to conduct hydrometric gauging and reconnaissance at Kuthai Lake and Silver Salmon River. Hydrometric gauging is used to characterize watershed hydrology and provide index flows for the assessment of stage dependent obstructions in the canyon. A hydrometric station was established on Silver Salmon River above Kuthai Creek to collect continuous stage data and support the development of a stage discharge relationship. This location was selected since there are few stable and cross-sectionally uniform gauging sections elsewhere in the basin. Logistically, this location is a short walk from the Kuthai lake camp making repeat gauging logistically possible. Both the Silver Salmon above Kuthai and the outlet of Kuthai Lake were gauged during this visit.

The second site was conducted from October 25th to the 28th to inspect the canyon reach during lower flows and without the resident bears. The canyon reach was traversed from the bottom to the top end, obstructions were photo-documented and an underwater camera was deployed where possible to estimate staging pool depths and morphologies. The upper watershed had about 10 cm of snow at the time of the site visit but the lower end at Nakina River had only trace accumulations of snow.

Photo 4: Underwater pole photography at the "Foam Pool" during the fall 2016 assessment.

Results:

Channel Obstacle Assessment:

In late October the canyon was visited to get a closer look at the individual migration obstacles and provide assessments of the passage issues. The obstacles were photo-documented by air, on the ground and with an underwater camera. The objective was to provide a complete overview of the site and to classify the obstacles as to their fish passage difficulty. Photographs taken in the fall also provide an opportunity to look at the channel under lower flow to better appreciate the channel structure. Channel lengths, widths, jump heights and gradient measurements were estimated in the field, extrapolated from GPS data or Google Earth and are approximate. The following is a summary of the outcome of the channel obstacle assessment.

Sub-reaches:

The canyon reach can be further subdivided into three sub-reaches based on their morphology. Detailed descriptions of the rated channel obstacles are included below. Considerable professional judgement was applied in the choice of which obstacles to rate. Channel obstacles were rated based on the following criteria;

- Obstacles that appear to have jump heights that were close to their staging pool depth were rated since achievable jump heights are proportional to staging pool depths. Jump heights that are greater than staging pool depths can impede passage;
- Staging pools / channel plunge transitions that are occluded by debris or boulders were rated as these occlusions can impede passage;
- Cascade sections greater than 5 meters that may exceed burst swimming capabilities.

Sub-reach 1 (SR1):

SR1 is the first sub-reach above the Nakina River confluence. This is a step-pool boulder reach with a length of approximately 150 meters and a gradient of approximately 11%. There are three rated obstructions in this reach, two of which are jump obstacles and one, the lowermost, is a cascade with velocity/turbulence issues. This reach is confined laterally and vertically by the canyon bedrock and massive boulders. The average width of the sub-reach is approximately 10 meters.

Sub-reach 2 (SR2):

SR2 is an alluvial reach between the two bedrock controlled reaches. The west side of the channel is confined by the canyon walls but the east side widens out to over 30 meters with a small floodplain running the length of the channel down to the bottom of the upper canyon. The gradient is approximately 4% and the length is approximately 420 meters. The sub-reach was surveyed from the air and the ground and no migration obstacles were noted.

Sub-Reach 3 (SR3):

SR3 is the upper canyon reach located immediately above the alluvial sub-reach. This is a step pool/ cascade, boulder channel with an average width of approximately 8 meters. The sub-reach is approximately 110 meters in length with a gradient of 11%. There are 5 rated obstacles in this sub-reach with cascade / velocity and staging pool obstructions. This reach is laterally and vertically bedrock controlled with numerous interlocking boulder elements as keystone structural elements.

Migration Obstacle Summary:

SR-1:

The lower canyon reach starts at the Nakina confluence and is approximately 150 meters long at a gradient of 11%. Channel structure is step pool/cascade with large boulder (over 5 meters B axis width) channel architecture. The channel was assessed from the air and the ground. The following is summary of each rated obstacle in the reach starting at the downstream end of the sub-reach;

Photo 5: An aerial view of the confluence pool and upstream cascade section of rated obstacle SR-1-1. Photo date: October 28, 2016.

SR-1-1 (The "Confluence" pool): This obstacle is the first in the series of steps along the channel profile. The staging pool is confined on river left by the bedrock wall and on river right by a boulder cluster. The staging pool has several instream boulders at the cascade/pool transition point that likely reduce sockeye jump performance. There is a piece of large woody debris at the transition point that may also hinder passage. The cascade section above the pool has very high Reynolds roughness which gives it extremely turbulent flow and high rates of air entrainment that can have a negative effects on salmonid swimming performance. The overall length of the cascade (from the transition zone to the first upstream holding area) is approximately 25 meters with a vertical rise of about 3 meters. At a gradient of approximately 12% and with supercritical flow this section is a velocity and turbulence obstacle with potentially obstructing LWD.

Photo 6: Underwater photo of the Confluence pool staging area showing boulder obstructions. Photo date: July 26, 2016.

Opportunistic monitoring by TRT Fisheries indicates that the ratio of jump attempts to successes may be quite low from the staging pool to the holding water above the cascade. Tagged sockeye have also been observed to back out of the staging pool and return to hold in the main stem. The subsurface photo above shows a number of medium sized boulders immediately (approximately 0.5 meter B axis) downstream of the transition from cascade to pool. These boulder clasts may limit the staging pool dimension and have a negative effect on jump performance. The overall assessment of section SR-1-1 is that it is a complex obstacle with limited staging pool dimensions, potentially obstructing LWD and an upstream cascade section with turbulence and velocity issues. The coarse textured sediment in the cascade section reduces the flow cross sectional area since much of the flow is interstitial.

SR-1-2 (The "Foam Pool"): SR-1-2 is a bedrock controlled jump height obstacle at a pinch point spill between a large boulder and the canyon wall. The obstacle jump height is approximately 2 meters vertical over a distance of 2 meters horizontal. Most of the flow is contained to this spill point but there is some interstitial flow at river right. This site has a deep staging pool that should provide good jump performance. Photo 8 is an underwater shot of the staging pool below the plunge point. The photo shows a deep staging area without major obstructions. The overall assessment of SR-1-2 is that the staging pool is deep and relatively unobstructed which should result in good jump performance and minimal passage issues.

Photo 7: Section SR1-2, the "Foam" pool.

Photo 8: Underwater view of the staging area of section SR1-2.

SR-1-3: The "Angle" pool: SR-1-3 is an obstacle formed in the pinch point between the canyon wall and a large boulder. There is also some surface flow on river right that may be passable at higher stage. The staging pool has a massive boulder directly in line with the spill point which limits the dimensions of the staging area. The jump height is approximately 2.2 over a horizontal distance of 2.0 meters. There is a small holding pool (approx. $6m^2$) below the staging pool and a larger holding pool above (approx. $30m^2$). The top of a piece of large woody debris (LWD) can be seen wedged into a rock on river left 5 meters below the plunge. The butt of that piece of LWD appears to span the staging area and can be seen in the underwater shot below. Given the tight space in the staging pool it is likely that this piece of LWD is obstructing the staging area. The overall assessment of this obstacle is that the staging pool is limited in size by the obstructing boulder but, judging from the underwater video, the staging pool appears to have good depth which should allow for good jumping performance. The obstructing LWD could be assessed at lower stage and removed if possible.

Photo 9: The "Angle" pool (SR-1-2). A submerged piece of LWD may be obstructing this staging area.

Photo 10: Underwater photo at the Angle pool indicating a piece of LWD (center left) potentially obstructing the staging area.

SR-2: This is the alluvial sub-reach located between the two canyon sub-reaches. No potential obstructions were noted during the assessment so there are no rated obstructions. The alluvial reach does have a Large Woody Debris jam at the midpoint of the sub-reach but it has high flow by-pass options on both sides of the channel. The jam may also have a passable route under the jam. Aside from the one major jam SR-2 appears quite stable with sporadic boulders and channel armoring cobbles. A small sediment wedge immediately upstream of the jam indicates that there is some mobile alluvium transported by higher flows but as with most of the canyon reach, sediment supply is limited. There are some signs of recent channel lateral instability at the jam location (the river left bypass) possibly a result of the extreme high flows of 2007.

Photo 11: A LWD jam in the middle of the alluvial reach. The jam is stable, with several high flow channels through the trees on river left and right. There is a small sediment wedge stalled ahead of the jam that is one of the few instream mobile sediment sources.

SR-3: This is the uppermost 100 meters of the assessed reach. The reach has an approximate gradient of 12% and an active channel width of approximately 8 meters. There are 5 rated obstructions in the reach. SR-3 is confined between a bedrock wall on river left and large boulder clusters, colluvium and bedrock outcrops on river right. Above this reach the channel gradient drops and the channel form transitions to alluvial pool-riffle.

Photo 12: The top end of SR-3, in the upper Silver Salmon canyon.

SR-3-1: Moving upstream from the bottom of sub-reach 3 the first obstacle is SR-3-1, a short cascade section with a cluster of boulders obstructing the plunge pool. The jump height required is 1.5 meters over 2 meters of horizontal distance. The staging pool is obstructed with a cluster of boulders. There are three potential passage points on this section that may provide additional fish passable options at higher flows.

Photo 13: Obstacle SR-3-1. The bottom end of the upper canyon sub-reach.

Photo 14: Obstacle SR-3-1 looking upstream.

SR-3-2: This obstacle is called the "Tank" pool given the great depth of the staging pool. The staging pool is estimated at over 4 meters deep. This is a good holding pool with abundant depth cover. There is a short cascade section immediately above the tank pool. It was not possible to get into the tank pool with the underwater camera but looking at it from several angle the pool is likely over 4 meters deep.

Photo 15: The cascade section above the Tank.

The tank pool provides good quality holding water for migrating fish that is very deep and un-accessible to bears. The pool should provide for good jumping performance. More information on jump attempt and success ratios would be useful to confirm the status of the feature as a potential obstruction but at this point it appears quite passable and doesn't appear to have any obstructing LWD or boulders. A closer look during low flow conditions (April) will be necessary to confirm the assessment.

Photo 16: The Cascade above the Tank from the air.

SR-3-3: Obstacle SR-3-3 has three spill points across an upstream crest of large boulders. The pool to pool jump height is approximately 2.5 meters. The main spill point has a boulder cluster at the toe of the plunge that may reduce jump performance. The secondary spill points did not look passable at the late October stage although at higher discharges this may not be the case. Further assessment at lower stage will be useful to estimate if the staging pool can be cleared.

Photo 17: Obstacle SR-3-3

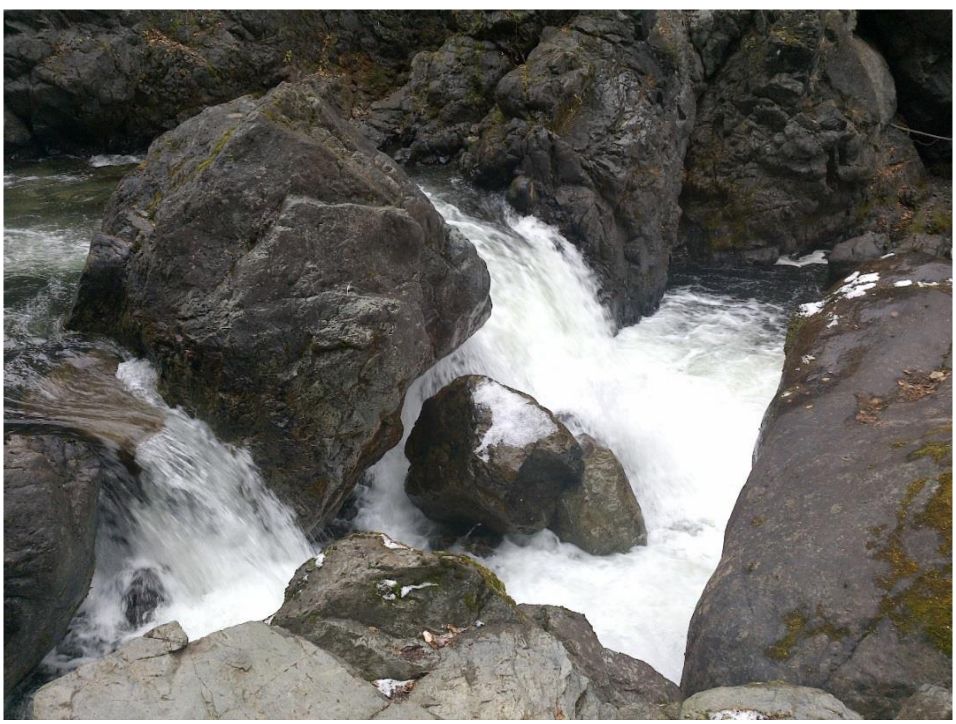

Photo 18: Close up view of SR-3-3. The staging pool is obstructed at the plunge with a clusters of boulders.

SR-3-4 (Grizzlie Rock): This obstacle is called Grizzlie Rock as it is a favored feeding location. There are three main spill points, each of which may pass fish at specific stage heights. The main spill point on river left is a steep cascade about 5m long with a pool to pool jump height of 2.5m. The cascade on river left seems to the main choice for passage. Safety considerations did not allow for access with the underwater camera so the staging pool should be checked at low flow.

Photo 19: Grizzly Rock (SR-3-4) is a favored feeding location for local bears. Photo date Oct 27, 2016.

Photo 20: View of Grizzly Rock with 2 bears actively feeding.

SR-3-5 (The Mushroom): The "Mushroom" is the uppermost obstacle assessed. This rounded boulder has 1 main spill point and a couple of other spills on either side. The main spill appears to be the most commonly attempted passage location. The spill/ pool transition is obstructed with a cluster of smaller boulders.

Photo 21: The Mushroom (SR-5-5) from downstream.

Based on long term observations by TRT Fisheries this location is a difficult passage section. The staging pool obstruction forces fish to travel a long horizontal distance as well as the vertical jump height. This location could be surveyed at lower stage to determine if the staging pool can be improved. The main flow path appears to be obstructed by a cluster of boulders at the plunge point which may make for difficult passage conditions.

Photo 22: Top view of the Mushroom (SR-3-5).

Hydrology Results:

Several sites were hydrometrically gauged to provide context to the assessments and as a check on regional hydrologic estimates. A basic stream power calculation was used to estimate the mass of the largest mobile boulder in the active channel of the canyon to assess channel stability. Flow gauging at the site has produced the following index flows:

Table 1: Flow Gauging Summary:			
Date	**Site**	**Discharge**	**Coordinates**
July 11, 2015	Silver Salmon above Nakina confluence	2.57 m^3/s	08V 614427m E: 6554503m N
July 11, 2016	Nakina above Silver Salmon	15.22 m^3/s	08V 614472m E: 6554578m N (at the Nakina Weir site)
Oct 27, 2016		10.74	
July 12, 2016	Kuthai at the weir	0.16 m^3/s	08V 60060m E: 6567113m N
July 26, 2016		0.20	
July 26, 2016	Silver Salmon above Kuthai	1.74 m^3/s	601144m E: 6567150m N
Oct 28, 2016		1.052 m^3/s	

Channel stability is an important factor when considering any form of instream works. In the case of the Silver Salmon canyon the channel vertical and horizontal alignment is mostly set by a massive boulder lag deposit left by an earlier, more generous, glacial flow regime and outburst flooding. The majority of the boulder lag in the canyon is not mobile under the current flow regime. The canyon appears to not have a large bedload budget based on the small volumes of mobile gravels stored in bars and above instream jams (photo 11). There are few gravel sources in the canyon from the sidewalls aside from a couple of active gullies in the steepest till covered sidewall in sub-reach 2. In the steeper canyon sub-reaches the active channel is highly clast dominated with a high degree of boulder to boulder contact giving it a very stable architecture. The largest mobile particle is therefore much smaller than the majority of the bed material in the active channel. As a measure of channel stability some means of estimating the size of the largest mobile particle is useful. For this an estimate of the maximum stream power is needed. A reasonable regional recurrence interval estimate is also needed to put some bounds on the current flow regime. A draft regional analysis using the USGS Regional Analysis Model gives the following flood recurrence interval estimates for the Silver Salmon River at the Nakina confluence;

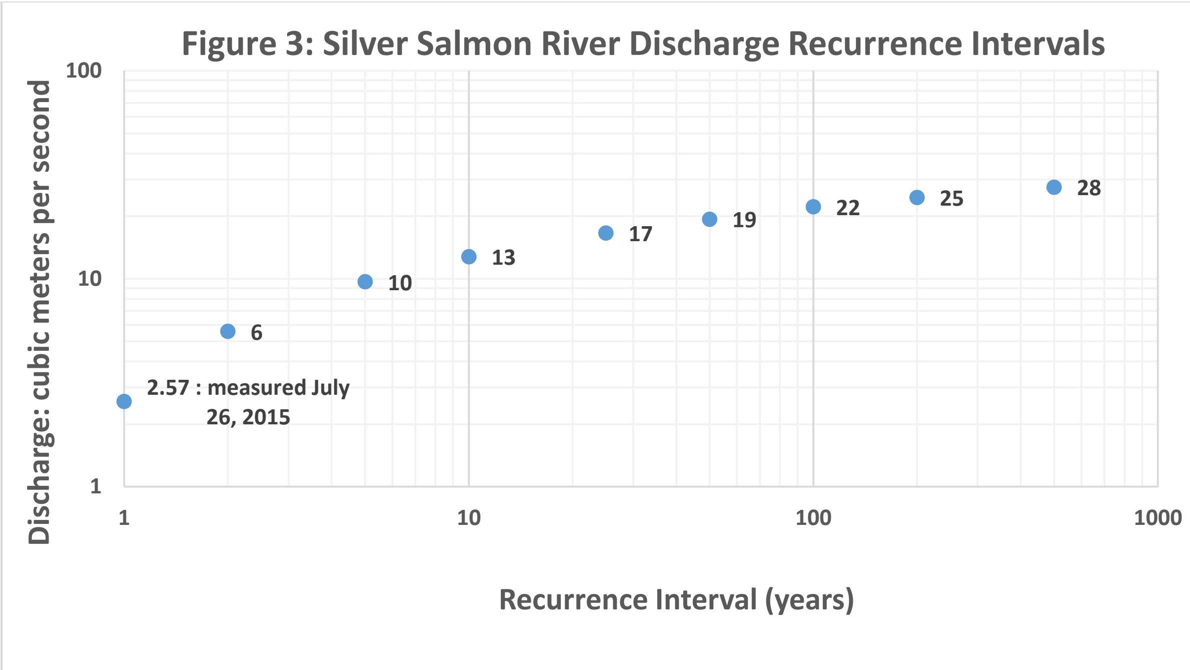

Figure 3 is a log/log plot of the recurrence interval estimates from the USGS Regionalization model (Curran et al, 2016). The lower confidence interval estimate fit the measured data (1 point) best so that data was selected as the site estimate. The July, 2015 discharge measurement was assigned a 1 year recurrence interval as late July is normally after the annual peak flow on the annual hydrograph (Figure 2).

The next step is to develop a stream power estimate for the active channel. The channel reaches (SR-1 and SR-3) are very complex hydraulic environments due to large boulder step pool morphology, very high roughness and deep staging pools that make modeling very difficult. For this reason the stream power estimate is produced using published values for similar streams. Bunte (2010) published a summary of bankfull maximum mobile particle sizes for a range of small (wade-able at low flow) streams. The maximum bankfull mobile particle published for the most similar stream is 25.9 cm diameter (Stream: E. St Louis '03). A bed lag deposit was noted at the confluence of Nakina and Silver Salmon Rivers (See photo 23 below) which is also a reasonable estimate of the largest boulders that the modern hydrology can move. These boulders have been ejected from the canyon and stalled on the floodplain flat. The largest particle measured in the field from the lag deposit was 0.7 meters in diameter (B axis). This provides a range of mobile particle sizes that brackets the high flow range (bankfull to max discharge) for the current flow regime and indicates that the majority of the boulders in the canyon are stable. The high end of the range corresponds roughly with the 1:100 year modelled recurrence interval flow (22m^3/s) from the discharge / recurrence plot. As a first order approximation of channel stability this suggest that the majority of key boulders in the canyon reach are immobile at any flow rate. Given the low sediment production of the reach this suggests that the canyon channel is very stable.

Photo 23: The lag deposit at the confluence of Nakina and Silver Salmon provides an estimate of the maximum mobile particle size for the Canyon Reach.

Assessment Summary:

Table 2 is a summary of the channel assessments for the selected rated obstructions. The passage ratings are subjectively determined and ranked between 1 and 5 with 5 being the most problematic.

Table 2: Silver Salmon Canyon Fish passage Assessment Summary:

Passage Obstacle	Obstacle type	Passage Rating	Recommendations
SR1-1 (Confluence Pool)	Turbulence, LWD obstruction, velocity, boulders	Rating **5**: Long cascade section, shallow staging pool, LWD and boulders obstructing	Assessment at annual low flow (April) and removal of LWD piece and boulders at transition point. Capture jump attempt/ success data during migration period.
SR1-2 (Foam Pool)	Jump Height	Rating **1**: deep staging	Reassessment at annual low flow.
SR1-3 (Angle Pool)	Jump height, LWD obstructing staging pool.	Rating **3**: LWD obstruction, jump height.	Assessment at annual low flow and removal of LWD at staging pool.
SR-2 (Alluvial Reach)	No obstructions.	Rating **1**: no obstructions.	Assess at low flow.
SR3-1	Jump height, boulder obstructing staging	Rating **3**: Obstructed Staging pool.	Assess boulder cluster at low flow.
SR3-2 (Tank Pool)	Cascade / velocity / turbulence obstacle	Rating **3**: Jump height and boulder obstruction.	Assess at low stage.
SR3-3	Jump height, boulder cluster at staging pool.	Rating **3**: Complex jump height cascade with boulder obstructions.	Assess at low stage.
SR3-4 (Grizzlie Pool)	Jump height, boulder cluster at staging pool.	Rating **4**: High jump and boulder cluster.	Assess at low stage, move boulders if possible.
SR3-5 (Mushroom Rock)	Jump height, boulder cluster obstructions.	Rating **4**: Jump height and boulder obstructions.	Assess at low stage, remove small boulders if possible to improve staging.

Conclusion:

The channel and passage obstruction assessments conducted in 2016 indicate 8 potential migration obstacles in the Lower Silver Salmon Canyon. The main assumption being applied in this assessment is that a morphological change in the canyon has resulted in reduced sockeye returns to Kuthai Lake. This assumption is supported by the fact that 2007 was an extreme high discharge freshet that may have resulted in changes to the canyon. Returns since 2007 remain depressed so the assumption seems reasonable. Given that the channel is bedrock bound it is also assumed that a vertical channel adjustment by the 2007 event could not have down-cut the channel and increased jump heights. Changes in the boulder channel architecture have potentially affected jump performance by obstructing staging pools or by increasing cascade roughness, turbulence and air entrainment, all of which could result in reduced fish passage. Recruitment of LWD and its subsequent lodgement in staging pools also has the potential to result in adverse passage effects. These effects could be acting independently or in concert to diminish fish passage.

The migration obstacles have been subjectively ranked by order of potential passage difficulty using a combination of field and office based assessments and professional judgement. Of the 8 ranked structures the most difficult passage conditions appear to be at the confluence pool where a combination of cascade flow, LWD obstruction and jump height challenges are present. Limited jump attempt observations support this suggestion. Further work should be undertaken to monitor jump attempts and successes once the potentially obstructing LWD in SR1-1, SR1-3, and clearing has occurred. The potential exists to backwater the confluence pool and reduce the upstream cascade length and height. Similarly, low flow assessments may indicate that restructuring some of the boulders within the mobile range may improve passage conditions.

The analysis and field observations indicate that the canyon morphology is largely controlled by bedrock and boulders that are stable in place. The assessment suggests that the canyon reach was formed by flows that were order of magnitude larger than the current flow regime which suggest a high degree of stability. The canyon reach has been hydraulically challenged by many large events. Field observations indicate that the canyon reach is bedload sediment limited which suggests that it is stabilized by a high degree of boulder to boulder contact which further enhances the stability of the reach. Preliminary calculations indicate that boulders smaller than approximately 0.7 meters in diameter are not mobile under the current flow regime so if there has been some structural boulder movement in the 2007 event the boulders affected were likely less than this dimension. Several of the potential obstructing steps have boulder clusters in that size range that are located in the transition from plunge/cascade to staging pool. More detailed assessments during low flow conditions in April can help to identify if any of these boulder clusters are affecting passage performance negatively. Several of the cascade sections in the potential obstructions may also have been restructured by boulders within the mobile particle range estimated above.

LWD recruited during the 2007 event could also be adversely affecting passage if it becomes lodged at key locations in the canyon staging pools and obstructs passage. There is a considerable volume of recruitable LWD in a channel spanning debris jam in the alluvial reach as well as potential recruitment from reaches above the canyon. The alluvial reach shows signs of relatively recent lateral channel avulsion in the area of the debris jam which seems to support the suggestion that LWD has been recruited by the 2007 event and has since worked its way into the canyon. Given the highly angular and bouldery nature of the channel the debris trapping efficiency is quite high which suggests that pieces recruited to the canyon would easily become lodged. Channel assessments conducted in fall 2016 did identify a number of individual LWD pieces that may be obstructing passage. These pieces can be removed at low flow.

Recommendations:

The following scope of work is recommended to address the passage issues described above:

- Revisit the site during the annual low flow period (April) to;
  - Remove potentially obstructing LWD;
  - Assess boulder obstructions and shift any obvious problem clasts;
  - Install rock bolts for camera mounting, to assist with boulder movement and safety lines;
  - Collect additional hydrometric information to refine the hydrologic understanding of the site.
- Revisit the site during the migration window to;
  - Install cameras to conduct migration period assessments of jump performance and assess the success of the LWD debris removal and improve the rankings of the potential obstacles.
  - Collect high flow hydrometric data.
- Summarize the years' progress in a report that includes an assessment of the fish passage observations and a draft design of a backwater structure at the confluence pool.

Supplemental information: 2015 genetic samples

Genetic samples were collected from 800 early run sockeye captured in the Canyon Island fish wheels from June 13 to July 5, 2015. Subsequent analysis was delayed as the samples were mistakenly left at the isolated field camp and could not be retrieved until early spring of 2016. Afterwards, there were 460 samples analyzed for genetic stock identification (GSI) by the Pacific Biological Station in Nanaimo, BC. Results are portrayed in Table 3 and Figure 4 below.

Table 3: 2015 sockeye genetic sample analysis (N=460).

Stock	Estimate	SD
B_Tatsamenie	0.0	(0.1)
BearSlough_RT	1.1	(1.4)
Hackett_RT	0.0	(0.2)
Kuthai	**49.8**	(2.3)
Little_Trapper	0.7	(0.4)
Nahlin	15.1	(1.7)
NakinaR	0.0	(0.1)
Shustahini_RT	0.6	(1.5)
Taku_KingSalmon	9.3	(1.4)
TakuMainstem_RT	0.0	(0.1)
Takwahoni_RT	11.2	(2.5)
Tatutula	0.1	(0.2)
Tulsequah_RT	11.7	(1.7)
Tuskwa_RT	0.1	(0.3)
Yehring_Cr_RT	0.0	(0.1)
YellowBluff_RT	0.0	(0.2)
Yonakina_RT	0.1	(0.3)

Figure 4: 2015 sockeye genetic sample analysis (N=460).

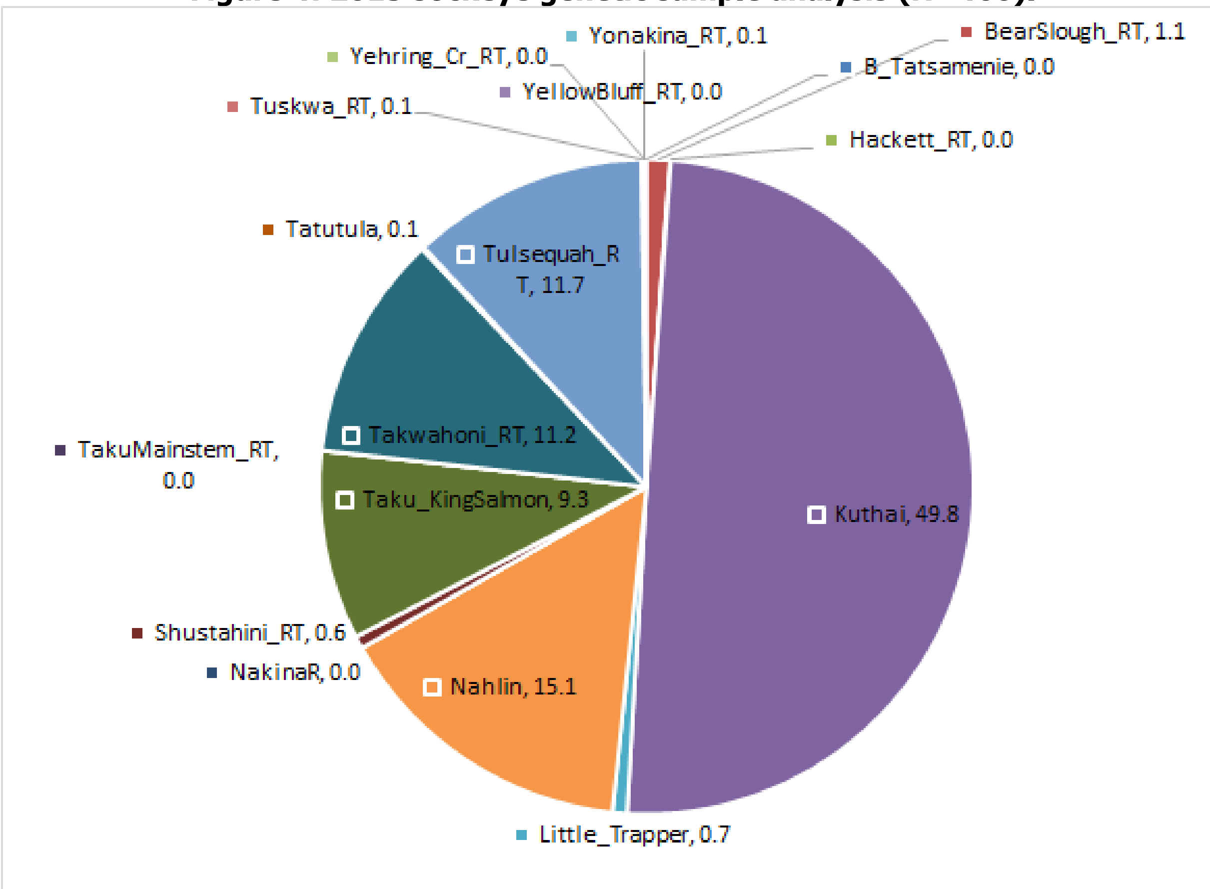

Table 4: 2015 preliminary sockeye telemetry fates vs. GSI

Stock	**Kuthai**	L. Trapper	Nahlin	King Salmon /Takwahon	Tulsequah
GSI	**49.8%**	0.7%	15.1%	20.5%	11.7%
Telemetry	**49.3%**	1.5%	7.5%	23.9%	10.4%

The Kuthai Lake stock was identified thru GSI to comprise 49.8% of the sockeye sampled during the period of June 13 to July 5, 2015. To note, this is nearly identical to the telemetry distribution resulting after 100 radio tags were applied on the lower Taku during the same time period. Table 4 below shows proportions for Kuthai (and some of the other stocks) by comparing the GSI and telemetry results. This consistency in results helps to verify that the fish held up at the mouth of the Silver Salmon and in the canyon were Kuthai origin stock. As well, it provides further information in terms of stock proportions and run timing that should help inform precautionary fishery management measures to assist in protecting the Kuthai sockeye stock.

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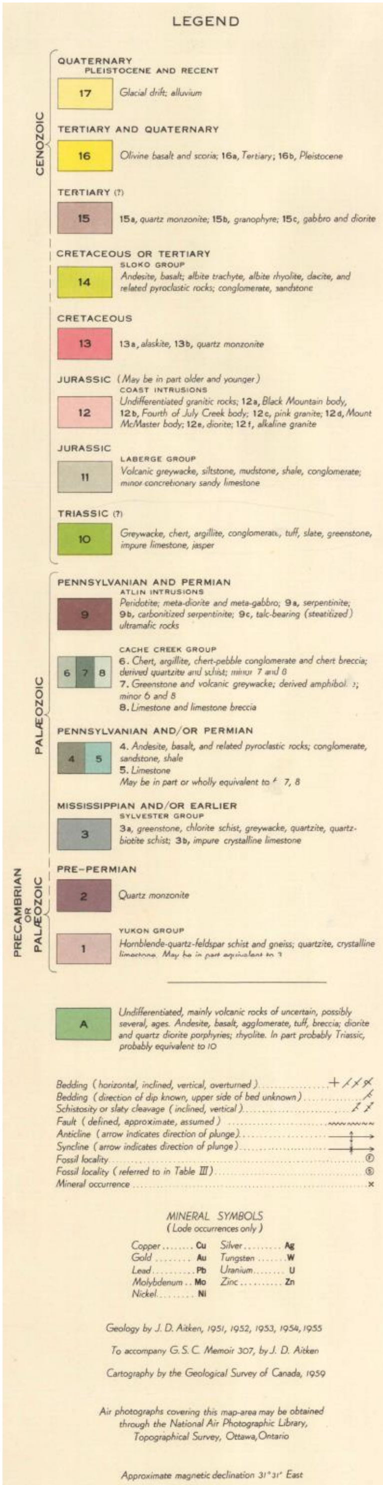

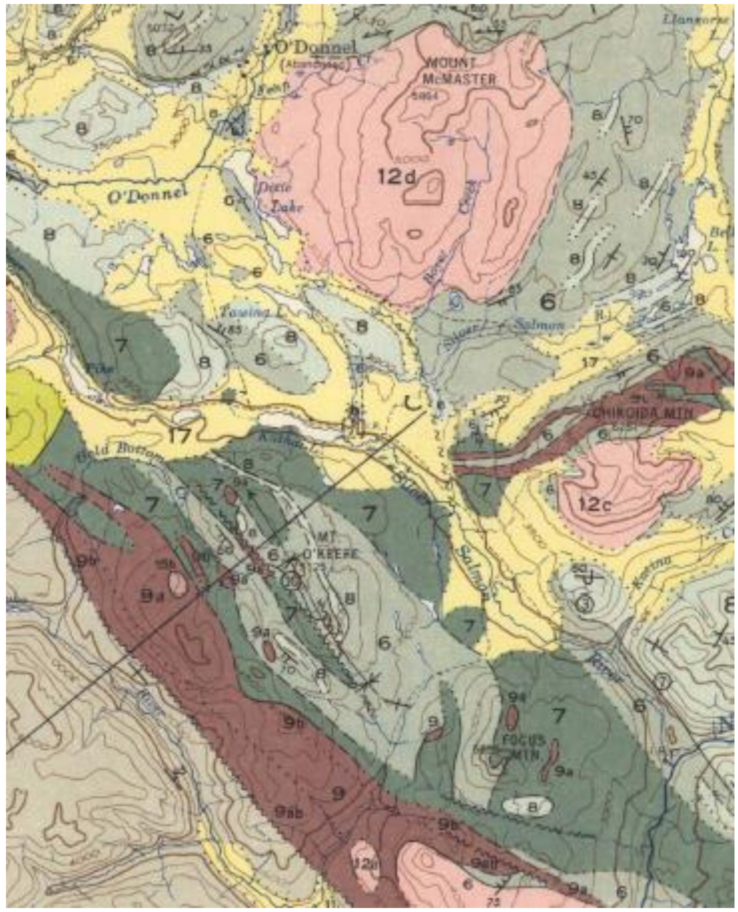

Appendix 1: Silver Salmon Watershed Geology.

Appendix 2: Site Panorama Photos.

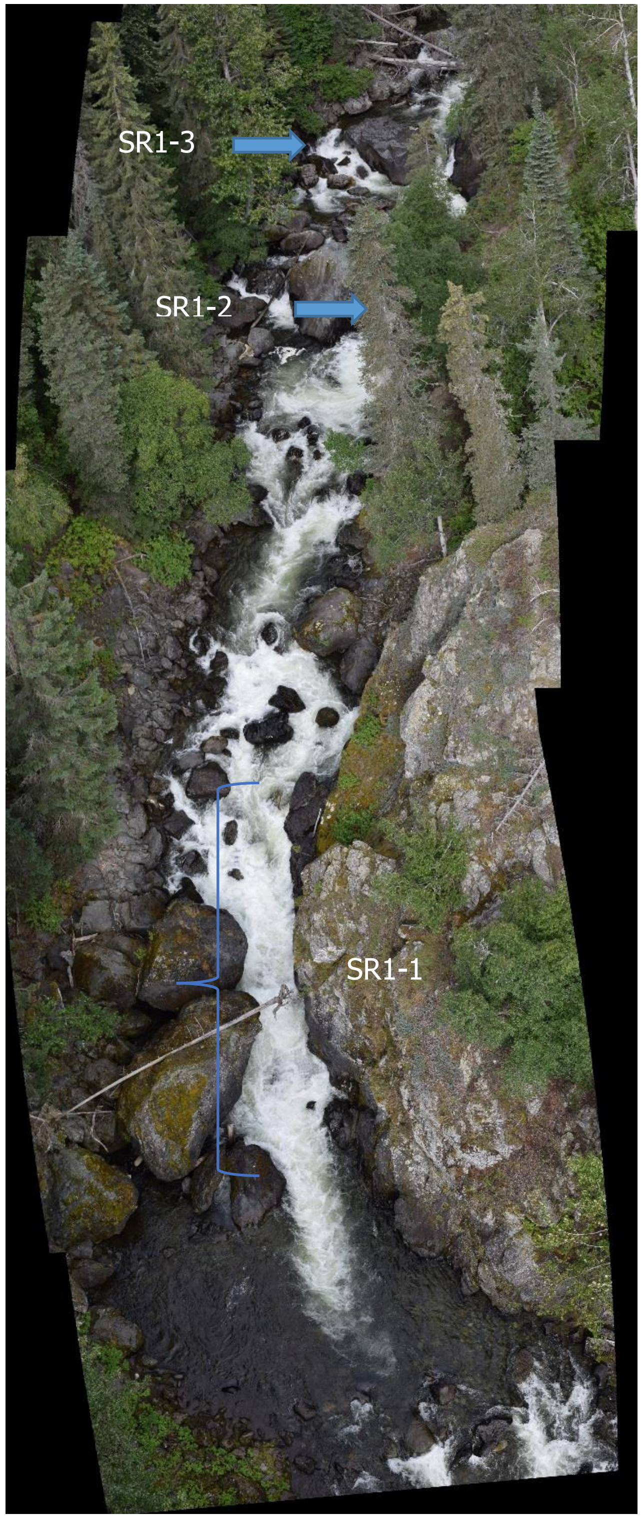

Photo A1: The three passage obstructions in the lower Silver Salmon canyon. Picture date July 2016.

Photo A2: The upper Silver Salmon canyon obstacles. Photo date July 2016.