Determining Cowichan River Flows for Fish in 2017 and Beyond

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For Review by the Fish Flows Working Group

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Introduction and Context

The Cowichan River flows are regulated through a weir and water license held by Catalyst Paper Corp. at the outlet of Cowichan Lake. At present, operation of the weir is governed by license conditions and and an Order of Approval to vary establish minimum lake levels and flows unless otherwise authorized (MOE, 2013). The order states control of lake shall not commence prior to April 1st unless otherwise authorized. The specified lake levels are maintained until on or before Nov 5th when the gates are fully opened. Flow releases are managed according to a Rule Curve that is designed to provide a minimum maintenance flow of 7.08 m^3/s (250 ft^3/s) established to provide adequate rearing habitat conditions for salmonids and maintain a minimum flow in the river. In 2008 the Cowichan Weir Start-up, Operation and Seasonal Protocols document was created to provide guidance on goals, considerations, triggers and protocols for operating the weir (Vessey et al, 2008). In general these guidelines are followed, however, in recent years severe droughts have made achieving the guidelines more and more difficult.

The ability to sustain adequate maintenance flows is dependent on available water storage in Cowichan Lake and precipitation during the regulation period. Recent studies indicate that seasonal inflow appears to be illustrating a declining trend over the past several decades with average spring/summer inflow declining by 17% since 1953 and average summer inflows declining by 35% between 1955 and 2008 (KWL 2011, Chapman 2011). The complicated issues of climate change and longer time climate cycles such as PDO and ENSO complicate causal relationships. However, summer water releases through the Cowichan weir have been regularly less than the conditional release of 7.08 m^3/s to support Catalysts water license and to meet fisheries conservation requirements.

Since 2003, a collaborative group of technical experts has been providing advice to managers on flows in season when the weir is on control and during drought periods.

In 2005, the Cowichan Water Basin Management Plan included a series of recommendations related to water management in the Cowichan. One key to implementing the recommendations is to determine what the various sector flow needs are for the Cowichan River and to re-visit the flows needs originally established under the water license for adequate rearing habitat for salmonids. This paper documents the process undertaken and advice gathered to answer the following question:

What flows are required in the Cowichan River to provide necessary fish habitat to support all life stages in the river?

Current interest in stored water along with evolved understanding of flow wants and needs have increased the focus on water management in the Cowichan. The information and suggested fish flows generated through this process will inform current fish flow management although it is recognized that current storage capacity and lower net inflows are limiting the ability of managers to regularly meet the 7.08 m^3/s license minimum maintenance flow. However, the operation of the current weir does provide opportunities for some meger flow in the Cowichan on most dry years. The fish flow information will also be incorporated into a larger Cowichan River Flows Structured Decision Making Process (SDM) that is being overseen by the CVRD and is part of the larger discussion on water issues and watershed planning in the Cowichan Valley.

This paper provides necessary scientific analysis and identifies gaps and work required to assess biological and species impacts of various flows and management actions to salmonids and other resident fish of concern in the Cowichan River. Other impacts, including social and economic, as well as impacts on other species are to be included in the larger Cowichan River Flows SDM process.

Process

This exercise was undertaken through an expert elicitation process within the Fish and Flow Working Group of the Technical Advisory Committee of the Cowichan Watershed Board. Expert Working Group representatives were from the Ministry of Environment, Ministry of Forest, Lands and Natural Resource Operations, Cowichan Tribes, Fisheries and Oceans Canada, BC Conservation Foundation and local guides and sports fishers operating/living on the Cowichan River. Each participant was considered to have knowledge and experience on the Cowichan River with relation to flows and fish life history requirements. The expert group met a total of 6 times from August 2016 through March 2017 and followed a general Structured Decision Making (SDM) process (see Appendix A). Other technical experts were brought in from time to time to provide advice and design modelling tools.

Information and recommendations generated through this process will be provided to decision makers in government to help inform water storage license updates, infrastructure upgrades and current in-season flow management.

Definitions

This process focused on defining minimum and target flows to support fish and fish habitat in the Cowichan River. A similar process for the Koksilah River, a significant tributary to the Cowichan, would be beneficial for fisheries and other resource sector water allocation discussions, although it was not included in this exercise. In addition, the establishment of Critical Environmental Flow Thresholds (CEFT) was not within the purview of this exercise. However, it is recommended that CEFT be established for the Cowichan River (and Koksilah) as a component of the larger SDM process or as an exercise for severe drought planning.

Decision criteria were developed to justify proposed flows for each species and included an analysis of habitat requirements and life-stage criteria. The following definitions guide the flows proposed. A graphic of how these flows relate to risks to salmonid productivity can be found in Figure 1.

Target Flow – These flows apply as the ideal water discharge level that addresses the needs for all fish species at all life stages.

Minimum Flow – These flows apply as the minimum water discharge levels below which there could be significant impacts on some of the salmonid species or some of their life stages.
NOTE - It is the intention that flows are kept at Target levels. Management actions are applied to move to minimum flows when certain triggers are met.

Critical Environmental Flow Thresholds (CEFTs) - the volume of water flow below which significant or irreversible harm to the aquatic ecosystem of the stream is likely to occur (Water Sustainability Act). NOTE – this process is not setting CEFTs.

The following species were considered in this exercise.

variant abbreviations / Species
CK – Chinook Salmon
CO – Coho Salmon
CM – Chum Salmon
PK – Pink Salmon
CT – Cutthroat Trout
RB – Rainbow Trout
ST – Steelhead Trout (anadromous form of Rainbow Trout)

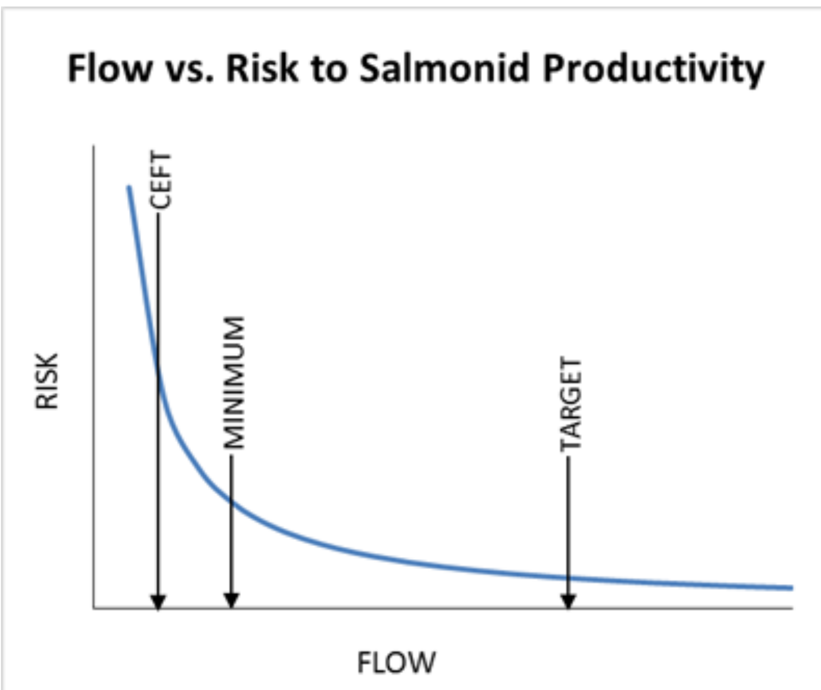

Figure 1: *As Cowichan River flows decrease risks to salmonid productivity increase. The Minimum flow is shown as the inflection point (graph generated by J.A.C. Craig, 2017).*

<u>NOTE</u>: Brown Trout are not included in this matrix as they are primarily of importance for recreational fishers and are a non-native species in the Cowichan River. Some species are also not listed as others are being used as surrogates. In addition, there may be other species that drive flow decisions or draw down of the lake to meet target or minimum flows. Assemblages of other species, such as cottids, may or may not be affected but are not considered key drivers in this flow discussion. Cutthroat trout also primarily use lake tributaries for spawning and are not rearing in the mainstem so are not considered a key driver of this flows exercise.

Defining Objectives and Evaluation Criteria and Key Considerations

Life history requirements, critical habitat and direct knowledge from the field were considered for each of the fish species listed above. Literature was referenced relating to the Cowichan River and salmonid habitat and timing of life history stages including past analysis of habitat conditions in the Cowichan River for different life history stages (See Literature Reviewed section) and past modelling work. Some key considerations included:

- Increasing trend of flows below 7 m^3/s during summer drought periods
- Spring flows are regularly curtailed below objectives to meet summer flow license targets and limited storage is currently available to address concerns of reduced spring flows and flows below 7 m^3/s
- Inadequate or downward trending inflow to the Lake to support target fish flows in the Cowichan River
- Lake shore concerns with raising water levels to achieve additional storage to support Cowichan River flows
- Past studies indicate more than 1 meter of additional storage would increase risks to shoreline properties (Westland, 2005)
- ST/RT – most of fry have emerged by May 4th (LGL, 2017)
- ST incubation to 70% @650ATU (Degree/Days) or active swimming fry by May 31st and 95% active swimming fry by June 15th (LGL, 2015) (Appendix B)
- ST Parr –best Cowichan River indicator species and life stage for evaluating the effects of different river flows – Maximum weighted usable area (WUA) for ST Parr for upper and mid Cowichan River is at flows of 6.8 m^3/s (LGL, 2015)(Appendix B)
- Side channel connectivity – below 7.5 m^3/s the proportion of active side channels that stop flowing increases at a much more rapid rate (Burns et al, 1988, S. Baillie (unpublished), 2017) (Appendix C)
- 7 m^3/s flows from lake result in 5.2 m^3/s below the Catalyst intake for the lower river and between the Allenby Road Bridge and the bifurcation of the north and south arms of the river an additional 0.5 m^3/s is 'lost' (Craig and Kulchyski, 2015). Therefore, flows at 7 m^3/s from the lake result in closer to 4.7 m^3/s in lower-river above north and south arm. In low flow times the south arm often takes proportionally more flow and the north arm can de-water. Sediment accumulations in the lower river exasperate this issue.

Evaluating Decision Criteria

Over subsequent meetings the expert group evaluated and refined the decision criteria used for establishing flows (listed in Table 2). In the beginning the proposal was for 3 distinct flows: Target; Minimum; and Drought. After reviewing the criteria it was decided that drought flows were not that different than minimum so they were combined and decision criteria were reviewed again.

Gap Analysis

Gaps in data were identified that if filled would provide more information to define flows. Where possible the group discussed the gap and attempted to fill it with either qualitative data or quantitative observations. The gaps were:

1. Side Channel and tributary connectivity analysis – Burns et al (1988) conducted an exercise to determine the influence of river discharge on side-channel fish habitat. They developed a list of

side-channels that were considered 'active' or the most important summer rearing habitats and channels that were used for spawning or over-wintering habitat. This report was mined for information and a subsequent analysis was performed to calculate the point in river discharge where side-channels loose connectivity or their flow becomes zero. The results of this exercise (provided in Appendix B) indicated that at flows lower than 7.5m^3/s an increasing amount of side channel have a flow of zero. Additional studies are needed to re-visit this issue. In 2016, LGL conducted a study to determine effects of an emergency authorization to reduce flows from 15m^3/s to 4. 5m^3/s from May 9th to May 29th. It is recommended that the data collected during this exercise be evaluated to determine currently 'active' channels and the point in river discharge where side channel disconnection accelerates.

2. Flows to navigate migration barriers and sediment management – The Cowichan River has three distinct possible migration barriers at the lower river due to gravel accumulation, at Marie Canyon (the section known as Last Drop) and at Skutz Falls. The Skutz Falls barrier has a fish ladder and if it is kept clear of debris the ladder operates well up to flows of 50 m^3/s (K. Pellett pers. comm.). At higher and lower flows fish navigate through the falls. Marie Canyon has been observed as a barrier in flows lower than 8m^3/s. It is recommended that a barrier study be implemented to determine at which flows this feature is passable. It may be possible to use PIT tags and conduct swims or visual surveys to identify times when fish pool below this feature. Particular concerns relate to lowering of spring flows too early and impacting the early run of Chinook migrating up the river.

   Sediment in the lower river combined with low flows can cause a de-watering of the north arm of the river which is the primary migration route for Chinook and coho in late summer early fall. Fall run fish have been observed to navigate up the lower river in the south arm in flows of 4.5m^3/s when the north arm is disconnected however, losses due to predation may be higher. The CVRD, Cowichan Tribes, City of Duncan and District of North Cowichan are implementing a sediment management plan for the lower river that could help in alleviating migration and habitat concerns for migrating adult salmon.

3. Seal and other predation impacts at low flows – current studies are being undertaken to understand the relative impact of predation on salmonids in the Cowichan River. It is postulated that lower flows exasperate the issue.

4. Sewage Dilution – the Town of Lake Cowichan and the Joint Utilities Board in Duncan discharge treated effluent into the Cowichan River. The JUB has a general rule of a 40:1 dilution factor which is referenced as 5.1 m^3/s in the 2008 Cowichan Weir Start-up, Operation and Seasonal Protocol document. Concerns over effluent impacts downstream of the JUB have been persistent, particularly in low flow years. Further discussion and study on appropriate dilution rates for downstream aquatic life, including fish and fish habitat and human safety are on-going. Minimum flows should be reviewed that include the Catalyst withdrawal, losses to ground-water and gravel accumulations.

5. High Water Temperatures – Severe lower river discharges have a potential to increase temperature in the river especially given the wide and shallow profile of some sections of the river. In 2015 Cowichan Tribes conducted a study to determine whether or not river discharge

related to temperature. In this study air temperature was most strongly correlated to river water temperature (LGL, 2015). In 2016 Cowichan Tribes conducted a tributary temperature and discharge study to document tributary influences on flow and temperature (CT, 2017). In times of extreme low flows some tributaries, such as Bernard Creek, provide cold water and some flows. Temperatures appear to decline in the river from the outlet of the Lake to the lower river. This is likely due to shading and ground-water influences and less likely due to low flows. This was shown in 2016 when LGL (on behalf of Catalyst) concluded that river temperature was not significantly altered from previous years in 2016 with flows being dropped to 4. 5m^3/s in May (LGL, 2017).

6. Groundwater interaction – the extent to which groundwater interacts with surface flow in the Cowichan River has not been well documented for the whole river corridor. Recent studies have focused on documenting cold water inputs in the upper and middle sections of the river and the lower river between Allenby Road bridge and the bi-furcation of the north and south arm of the river (Craig, 2015). In 2015, BCCF and Cowichan Tribes staff documented a .5 m^3/s 'loss' in flow presumably due to infiltration of surface water in the river to the ground (Craig and Kulchyski, 2015). The Ministry of Environment and the CVRD have conducted a ground-water monitoring program in the lower Cowichan River. Analysis of results is still on-going, however, initial conclusions were that there is a relationship between ground-water and river water especially in the lower reaches of the Cowichan River.

7. Flows to support out-migrating juvenile Chinook and Early migrating adult Chinook - flows in the early part of the control period are often traded off for base summer flows (flows often below 7 m^3/s) or the perceived risk that the river may 'run dry'. A full understanding of the costs and benefits of this trade off has not been completed. In addition, the early timed Chinook run timing and abundances have not been well documented and therefore the absence of knowledge limits analysis. Recent studies by BCCF (Craig, 2015) concluded that overhanging and in-stream vegetation cover for newly emerged fry is critical habitat and that edge vegetation is primarily available in normal March and April flows above 40 m^3/s. Precautionary approaches in maintaining higher than supportable early flows have potentially high socio-economic costs such as the risk of having to shut down the Catalyst pumping station, dilution issues for JUB effluent discharge and fish habitat concerns.

8. Future Climate Change Analysis – all work done on the flows for fish consider <u>current</u> climate conditions using historical inflows to the lake to determine outflows and potential storage requirements. An updated model using current downscaled climate predictions should be used to validate flows required under predicted climates in the future. Foster and Allen (2015) developed a water balance model for the CVRD that could be use and updated to include recent downscaled climate change information. However, this model did not include the current weir operation nor were inflows modeled validated. Projected costs to validate the model using a peer review process were approximately $40,000 in 2017. It is also possible that a simplified model could be developed to understand climate change dynamics for future storage needs.

Develop Alternatives

Currently the flows in the Cowichan River are controlled from April 1st through to the first major rains in the fall. Catalyst Paper, under license to the Ministry of Environment regulates the flow according to a rule curve as follows and to maintain the lake elevations below certain thresholds throughout the drier season:

1. When lake under control, maintain minimum of 25 m^3/s until May 1st;
2. When lake under control, maintain minimum of 15 m^3/s from May 2nd to June 15th; and,
3. When lake under control, maintain minimum of 7.08 m^3/s from June 16th until lake storage is replenished by fall rains and weir is deactivated for the season.

As explained above, the ability to sustain adequate maintenance flows for the Cowichan River is dependent on available water storage in the lake and precipitation over the control period. Recent studies indicate that seasonal inflows appear to be illustrating a declining trend over the past several decades.

Figure 2 depicts how many years in the last 20 that management decisions for various reasons have controlled the flows so that they have not met the 7cms licensed flows.

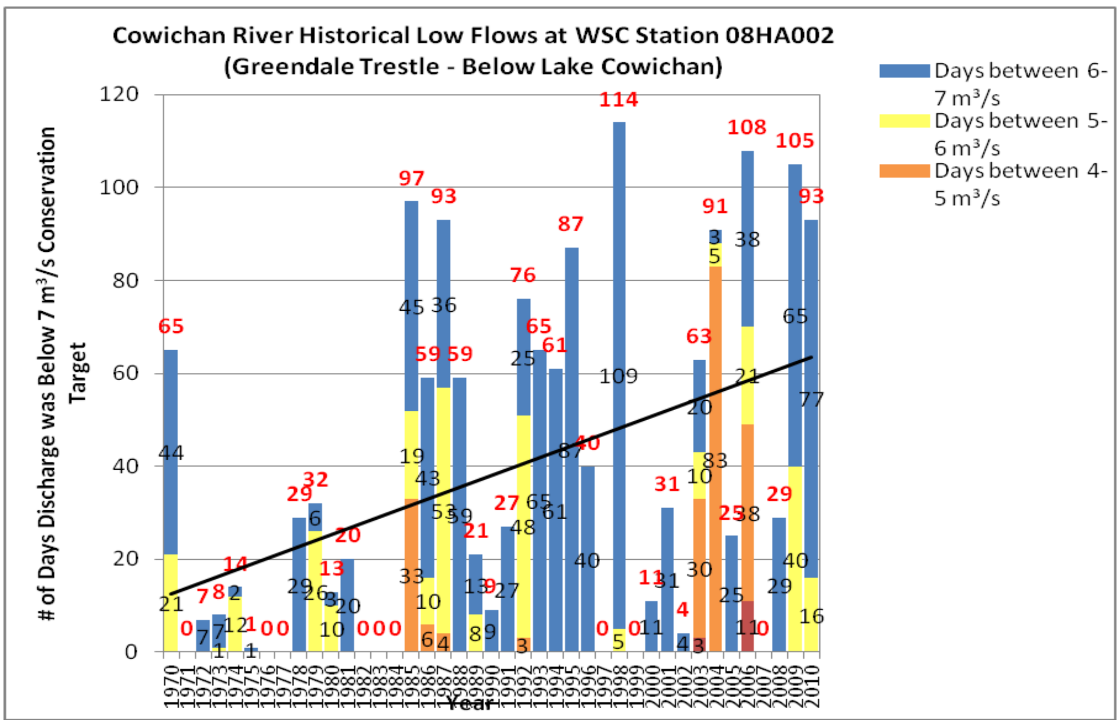

Figure 2. Historical low flows at WSC Station 08HA002 below Cowichan Lake (Chapman 2011).

Other policy or management alternatives were not identified given a current license is in place for water storage and water withdrawal and operating rules exist that direct flows for the river. However, the Expert Panel decision criteria could be used to inform weir and flow management in the Cowichan River with the aim of maximizing fisheries benefits.

Triggers were also discussed as part of this process and were focused on what conditions would precipitate a management decision in relation to flows. The following weir start up triggers were identified as part of the 2008 protocol (Vessey et al, 2008):

1. There is low snowpack, the lake level is at the crest of the weir at 162.37m and it is past Feb 28th; Or:
2. There is average snowpack and the lake level is 17cm below the weir crest (162.20m)

The Expert Flows Working Group members briefly discussed flow management triggers. Inflow generated by snow pack may be a difficult metric to use as a trigger because the timing and volume of melt is more critical. It is recognized that more work is needed on this issue.

Management decisions discussed related mostly to early control management exercises to ensure that at least minimum flows were achieved.

Estimate Consequences through Modelling

A Fish Flow Evaluation Tool was developed during this process as a means for the Expert Panel to quickly evaluate storage requirements for flow releases proposed. This provided a means to determine if flows proposed were within the realm of the possible and to adjust the flows using the decision criteria during a trade-off analysis. The Expert Panel used the general guidelines of potential weir height described in the Cowichan Basin Water Management Plan (2005) as a means to check and balance objectives. Further analysis is needed on potential storage impacts to shoreline ecosystems and socio-economic value differences with increased storage.

Proposed Flows - Evaluating Trade offs and Selecting Flows for Fish Habitat Management

Timing	Species/Issue	Decision Criteria	Target Flow	Min. Flow
March flows	**CK**: smolts migrating d/s and holding in riparian zone with cover **CO**: smolts start to migrate d/s **CM**: fry starting to emerge from redds **PK**: fry migrating d/s **RB**: spawning **ST**: 70% spawning completed by end of March	Weir: Go on control earlier than 1-Apr to allow for storage of water if triggered **ST**: < 80 m^3/s flows are desirable because higher flows would give ST access to elevated locations which may be dry before emergence has finished	Natural	25
April 1-15	**CK**: smolts migrating d/s and rearing in riparian zone with cover **CK**: Summer adults starting to move u/s **CO**: smolts migrating d/s from off channel areas and lake **CO**: fry emerging from redds **CM**: fry emerging from redds **ST**: 90% spawning completed by 15-Apr, important for benchmark for incubation values through May	**CK**: need to keep connectivity to side channels **CO**: need to keep connectivity to side channels **RB**: need to keep redds watered **ST**: need to keep redds watered	40	25

Timing	Species/Issue	Decision Criteria	Target Flow	Min. Flow
April 16-30	**CK**: smolts migrating d/s, fewer numbers in riparian, rearing in lower river **CK**: Summer adults migrating u/s **CO**: smolts migrating d/s from off channel areas and lake **CO**: fry emerging from redds **CM**: fry emerging from redds and migrating d/s **RB**: fry starting to emerge from redds **RB**: higher flows (30+ m^3/s) will cause adults to migrate u/s to lake **ST**: fry starting to emerge from redds	**CK**: need to keep connectivity to side channels **CO**: need to keep connectivity to side channels **RB**: need to keep redds watered **RB**: need <30 m^3/s flows to maintain adult presence in river **ST**: need to keep redds watered	35	25
May 1-15	**CK**: smolts migrating d/s, fewer numbers in riparian, rearing in lower river **CK**: Summer adults migrating u/s **CO**: peak of smolt migration d/s from off channel areas and lake **CO**: fry rearing in river and channels **CM**: fry migrating d/s **RB**: fry emerging from redds **ST**: fry emerging from redds, incubation 30% complete by 15-May	**CK**: need to keep connectivity to side channels **CO**: need to keep connectivity to side channels **RB**: need to keep redds watered **RB**: need <= 35 m^3/s flows to maintain adult presence in river **ST**: need to keep redds watered	35	20
May 16-31	**CK**: smolts migrating d/s, fewer numbers in riparian, rearing in lower river **CK**: Summer adults migrating u/s **CO**: smolts migrating d/s from off channel areas and lake **CO**: fry rearing in river and channels **CM**: end of fry migration **RB**: fry emerging from redds **ST**: fry emerging from redds, incubation 70% complete by 31-May	**CK**: need to keep connectivity to side channels **CO**: need to keep connectivity to side channels **RB**: need <= 35 m^3/s flows to maintain adult presence in river **RB**: need to keep redds watered **ST**: need to keep redds watered	30	20
June 1-15	**CK**: la**st** smolts migrating d/s, rearing in lower river **CK**: Summer adults migrating u/s **CO**: smolts migrating d/s **CO**: fry rearing in river and channels **RB**: end of fry emerging from redds **ST**: end of fry emerging from redds	**CK**: need to keep connectivity to side channels **CO**: need to keep connectivity to side channels **RB**: need <= 35 m^3/s flows to maintain adult presence in river **ST**: redds exposed at 15 m^3/s	30	15
June 16-30	**CK**: smolts rearing in lower river **CO**: smolts migrating d/s **CO**: fry rearing in river and channels **RB**: maintenance of base flow critical to juvenile rearing **RB**: adults migrating u/s to lake	**CK**: North Arm becomes dry below 10 m^3/s, limiting lower river chinook and coho rearing, and access for adults migrating u/s **CO**: as discharge decreases, more side channels become disconnected. Data from 1988 suggests 89% of channels are connected at 10 m^3/s, 83% at 7 m^3/s and 63% at 4.5 m^3/s	10	7

Timing	Species/Issue	Decision Criteria	Target Flow	Min. Flow
July 1-15	**CK**: Summer adult migration **CO**: fry rearing in river and channels, maintenance of base flow critical to juvenile rearing **RB**: fry rearing in river and channels, maintenance of base flow critical to juvenile rearing	**RB/ST**: fry at risk when discharge below 7 m^3/s due to decrease glide/riffle habitat	10	7
July 16-31	**CK**: Summer adult migration slowing **CO**: fry rearing in river and channels, maintenance of base flow critical to juvenile rearing **RB**: fry rearing in river and channels, maintenance of base flow critical to juvenile rearing	**RB/ST**: fry at risk when discharge below 7 m^3/s due to decrease glide/riffle habitat	10	7
Aug 1-31	**CK**: Fall adult migration starting **CO**: fry rearing in river and channels, maintenance of base flow critical to juvenile rearing **PK**: adult migration u/s **RB**: fry rearing in river and channels, maintenance of base flow critical to juvenile rearing	**CK**: although adult migration does happen at 4.5 m^3/s (2.5 m^3/s below Catalyst Intake), additional flow will facilitate u/s migration	10	7
Sept 1-30	**CK**: Fall adult migration u/s **CO**: fry rearing in river and channels **CO**: adults starting to migrate u/s **PK**: adult migration u/s and start of spawning **RB**: fry rearing in river and channels, maintenance of base flow critical to juvenile rearing	40% probability of a Fall storm event by 30 September **CK**: if water capacity is available, pulse flows should be used to draw chinook salmon u/s, would require sufficient w/l height in lake to generate a 16 m^3/s flow	10	7
Oct 1-15	**CK**: Fall adult migration u/s **CO**: fry moving to off channel areas in response to fall storm events **CO**: adults migrating u/s **CM**: start of adult migration u/s **PK**: end of spawning	**CK**: increased flow encourages adults to migrate u/s	15	7
Oct 16-31	**CK**: Fall adult migration slowing, spawning **st**arts **CK**: Cowichan Tribes' FSC fishery takes place September - October **CO**: adults migrating u/s **CM**: migration u/s and start of spawning	**CK**: increased flow encourages adults to migrate u/s	15	7

Timing	Species/Issue	Decision Criteria	Target Flow	Min. Flow
01-Nov	**CK**: Fall adult spawning **CO**: adults migrating u/s **CM**: migration u/s and spawning	**CK**: previous sampling suggests chinook prefer >25 m^3/s flow for spawning	25	7

Implement and Monitor

Partial implementation of the proposed target and minimum flows could be undertaken in years that are projected to have above average inflows to the Lake and/or springs with significant rainfall that keeps the Lake near the full supply level well into April or May. In 2017, with significant rain occurring through March and the first part of April, the ad hoc water group explored the option of testing the Target flows proposed for April, May and June.

Full implementation of the above flows will require additional storage, a new license and operating procedures. It is expected that the information in this report will be included in the larger SDM process being overseen by the CVRD this year.

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Appendix A – Structured Decision Making

Appendix B: Meso-Habitat analysis and Steelhead Spawning and Emergence

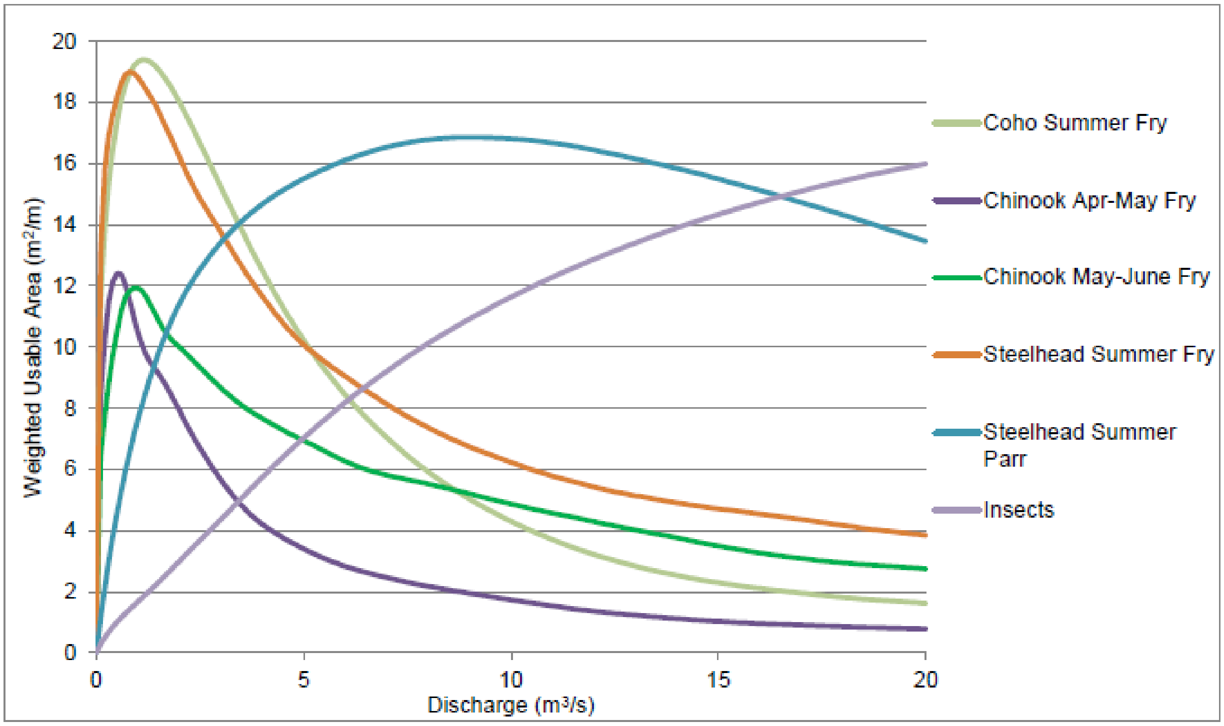


Figure 5. Weighted usable area plots for eight Middle and Upper Cowichan River glides based on rearing habitat suitability indices for Coho, Chinook, Steelhead and swift-water insects.

Figure from LGL, 2015.

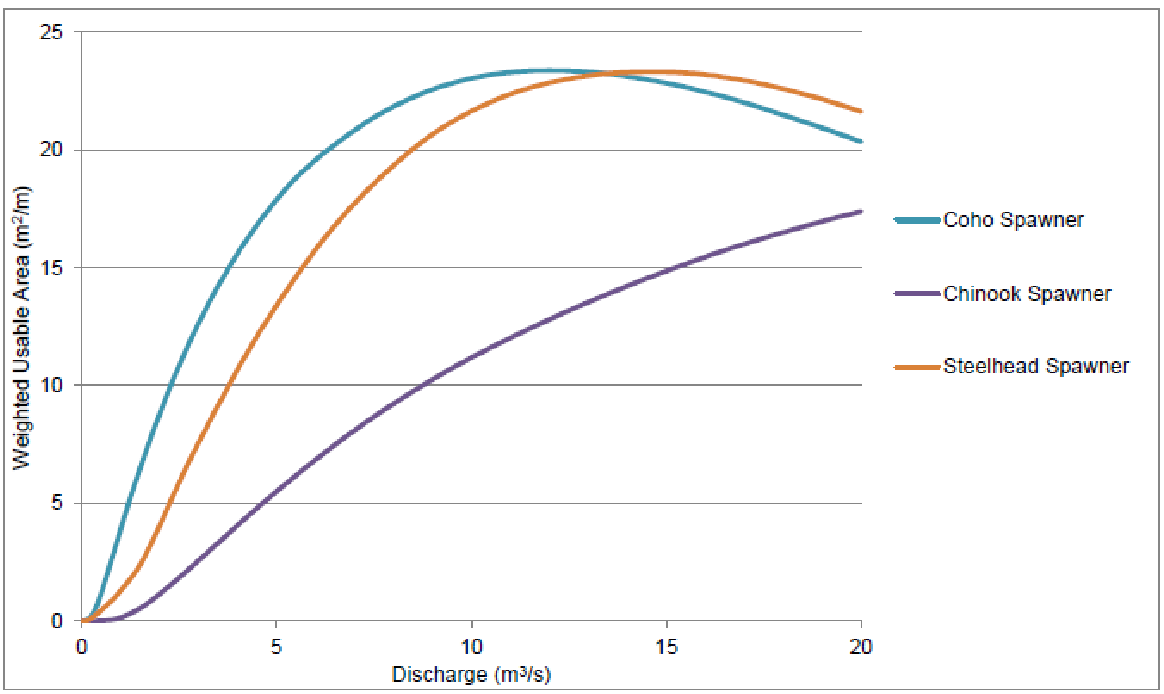
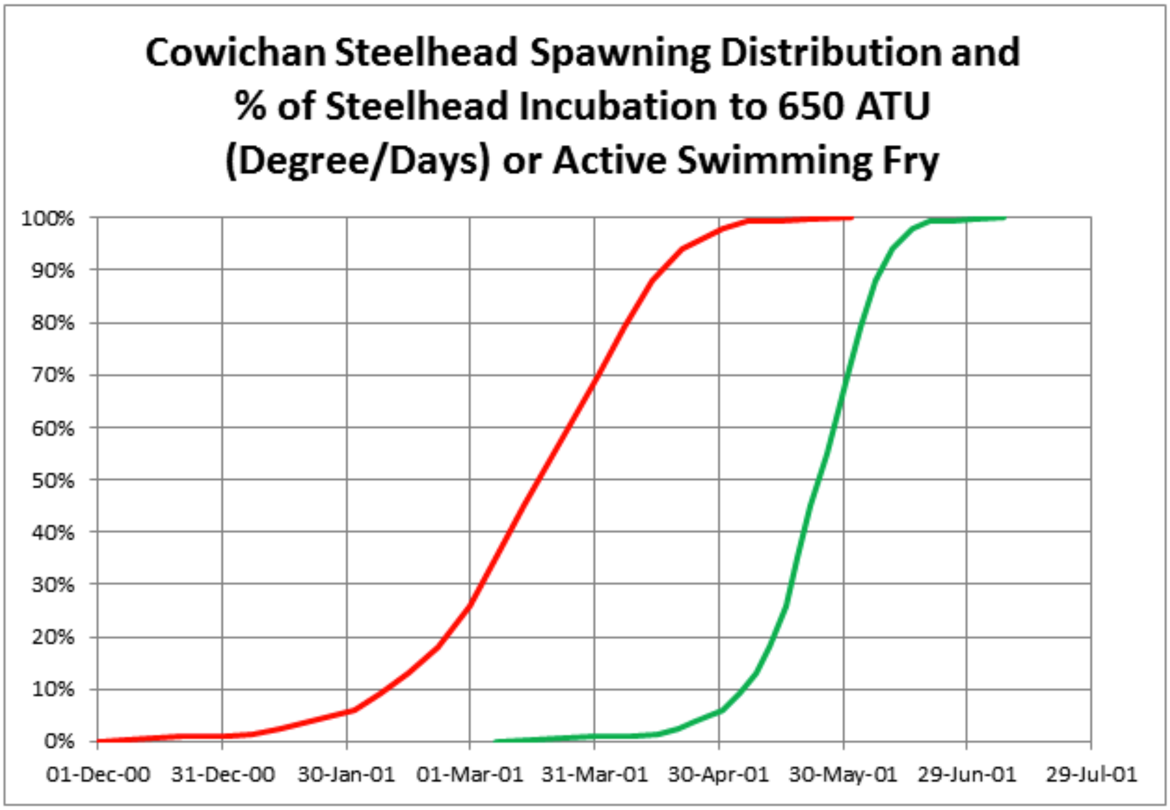


Figure 8. Weighted usable area plots for Middle and Upper Cowichan River riffles and glides based on spawning habitat suitability indices for Coho, Chinook, and Steelhead.

Figure from LGL, 2015.



Steelhead spawning (red) and emergence (green). McCulloch pers.comm. 2016

Appendix C: Connectivity of Cowichan River Side Channels

A new Analysis from Burns et al, 1988.
by Steve Baillie

Introduction

One of the processes that could inform Water Managers in the Cowichan River is the relationship between river discharge and the connectivity of side channels that are located along the mainstem of the river. To that end, I examined the document written by Ted Burns (Burns et al., 1988). The purpose of this report was to examine the sensitivity of side channel habitat at discharges below 7.08 m^3/s, the normal summer flow discharge (DeBeck, 1974). That is, does a river discharge below 7.08 m^3/s change the flow characteristics in the side channels?

The conclusion from this report was that for three types of side channels (Flood, Back and Relic) there was no significant change to the wetted area when the discharge dropped to 4.48 m^3/s. However, for Active channel where there is a high level of fish habitat, there was a significant drop in wetted area of 12-17%, from three different sample reaches (Upper, Middle and Lower Cowichan).

The report did not consider the connectivity of the Active side channels to the mainstem as part of the analysis. I examined the side channel assessment form of the report, which was a single page summary of all the side channels, containing information such as a chart of the side channel, profile, gradient, physical measurements, flow measurements by date, fish utilization and enhancement assessment.

Methods

The purpose of this exercise was to examine the relationship between connectivity of riverine side channels at different river discharge levels. I made the assumption that when the Burns data showed a channel discharge of 0 m^3/s, then that channel could be described as disconnected. Certainly it can be immediately argued that a channel may have a watered connection with the river and still have a zero discharge however I would suggest that this channel would no longer be an Active Channel, but a Back Channel.

The data from report specifically included the discharge in the side channels and also provided a mainstem discharge and a date for the observation. The mainstem flow measurement method was not described or attributed to a station so I discarded this data and used the daily average discharge as measured by the Water Survey Station #08HA002, Cowichan River at Lake Cowichan, for each observation.

I did not include the Flood, Back and Relic channels in the analysis, but started with the 38 Active Channels which are described by Burns as:

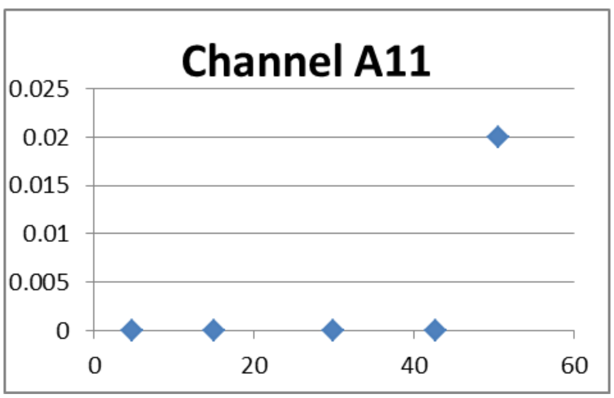
> *"Active Channels are typically perennially flowing channels that maintain some flow in the summer. The channels are usually well vegetated and contain debris cover and are often protected from the full effect of winter floods by the presence of a log jam or a natural gravel*

> *berm at the inlets. Active channels have flow all year round and their water level is usually influenced by that of the mainstem."* (p. 6).
>
> *"The Active Channels are the most important summer fish rearing habitat and many are also utilized for adult spawning and juvenile over-wintering requirements"* (p. 9).

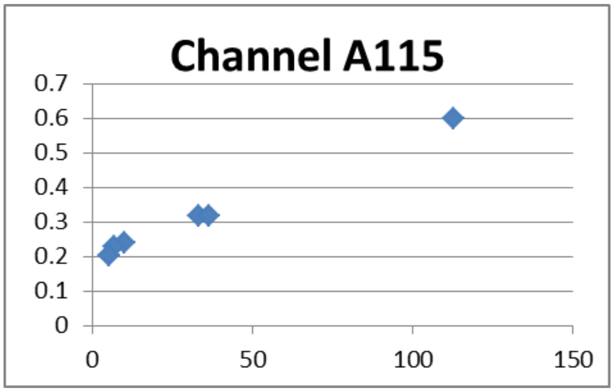
For each Active Channel, I noted the channel designation, discharge, the date of the measurement and added to that the average daily flow for the Cowichan River. I regressed the River discharge (x-axis) against the Channel discharge (y-axis) and divided the channels into four categories based on the following criteria:

DEFINITION: CD – Channel Disconnected. This value is the River discharge at which an individual channel has reached zero.

Category 1: The channel discharge decreases to zero while the river discharge is >> zero. A regression line fitted to this data would not make biological sense. A fitted line would underestimate the river discharge at which the channel reaches zero. For this type of regression, the CD would be assigned the highest river discharge value that the channel discharge is zero. As an example, Channel A11 reaches zero discharge at the river discharge level of 42.7 m^3/s. This value is used for the CD value for this channel. 5 channels fitted this description.



Category 2: The channel discharge is > zero when the regressed line reaches the y-axis (River discharge is zero). The CD for this channel is assigned the value of 0. There were 11 channels that fitted this description.

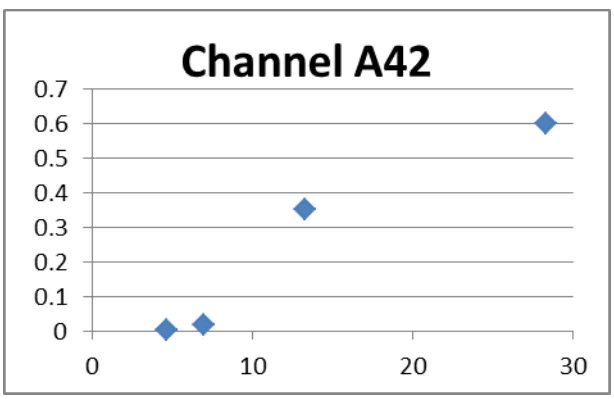


Category 3: Similar to Category 1, except that the regression does make biological sense. A fitted line does indicate the river discharge at which the channel discharge reaches zero. The CD would be assigned the value of the X-axis intercept, using the formula:

$$X\ intercept = (y - b)/m$$

which is a re-arrangement of the linear regression formula of $y = mx + b$

For example, the fitted linear regression for the data from Channel A42 would have the formula $y = 0.03x - 0.11$. Solving for X with Y = 0 results in an x-intercept of 4.06, which is designated as the CD for this channel. There were 19 channels that fitted this description.



Category 4: There is no relationship in the data. These data sets from the final three channels were not included.

Results

Table 1. Linear regression metrics and categorization of channels, with resultant Channel Disconnected value.

Channel Designation	Slope	Intercept	Category	CD value
A5	0.01	-0.05	1	20.00
A7	0.15	-1.03	3	6.84
SF A8	0.01	-0.01	3	1.01
A10 lower	0.01	-0.06	3	4.02
A11	0.00	0.00	1	43.00
AF A11	0.00	-0.01	3	7.50
A28	0.13	-0.80	3	6.04
A29	0.00	0.01	2	0.00
A31	0.01	0.20	2	0.00
A33	0.01	-0.13	1	25.00
A35	0.00	0.00	3	0.00
A42	0.03	-0.11	2	4.06
A45	0.00	0.00	2	0.69
A50	0.00	-0.03	3	6.25
A55	0.00	0.00	3	2.41
A70	0.00	0.02	2	0.00
A70 upper	0.00	0.00	2	0.00
A72	0.03	-0.38	2	0.00
A74	0.00	0.00	3	1.66
A81	0.03	-0.21	3	6.47
A83	0.00	0.01	2	0.00
A85	0.09	-0.52	3	5.94
A88	0.05	-0.20	3	4.38
A90	0.02	-0.08	3	3.43
A96	0.00	0.01	2	0.00
A97	0.09	-0.12	3	1.23
A98	0.30	0.79	2	0.00
A102	0.03	-0.30	1	30.00
A111	0.00	0.00	1	10.00
A114	0.00	0.00	2	0.00
A115	0.00	0.20	2	0.00
A118 upper	0.00	0.00	3	4.54
A119	0.07	-0.36	3	5.00
A122	0.13	-0.63	3	4.83
A131	0.13	-0.29	3	2.28

Arranging the 35 channels in ascending CD value order, and adding a cumulative % datum for each provides the following table. The cumulative % data can be described as the % of the 35 channels that are still connected at the CD value.

Table 2. Resultant Channel Disconnect values arranged in ascending order, along with a cumulative % of the total number of channels.

Channel Designation	CD value	Cumulative %
A114	0.0	3%
A115	0.0	6%
A29	0.0	9%
A31	0.0	11%
A35	0.0	14%
A70	0.0	17%
A70 upper	0.0	20%
A72	0.0	23%
A83	0.0	26%
A96	0.0	29%
A98	0.0	31%
A45	0.7	34%
SF A8	1.0	37%
A97	1.2	40%
A74	1.7	43%
A131	2.3	46%
A55	2.4	49%
A90	3.4	51%
A10 lower	4.0	54%
A42	4.1	57%
A88	4.4	60%
A118 upper	4.5	63%
A122	4.8	66%
A119	5.0	69%
A85	5.9	71%
A28	6.0	74%
A50	6.2	77%
A81	6.5	80%
A7	6.8	83%
AF A11	7.5	86%
A111	10	89%
A33	20	91%
A5	25	94%
A102	30	97%
A11	43	100%

By plotting the cumulative % against the CD value, we can look at the relationship between river discharge and the proportion of Active side channels that still have a discharge, and how this relationship changes as the river discharge decreases.

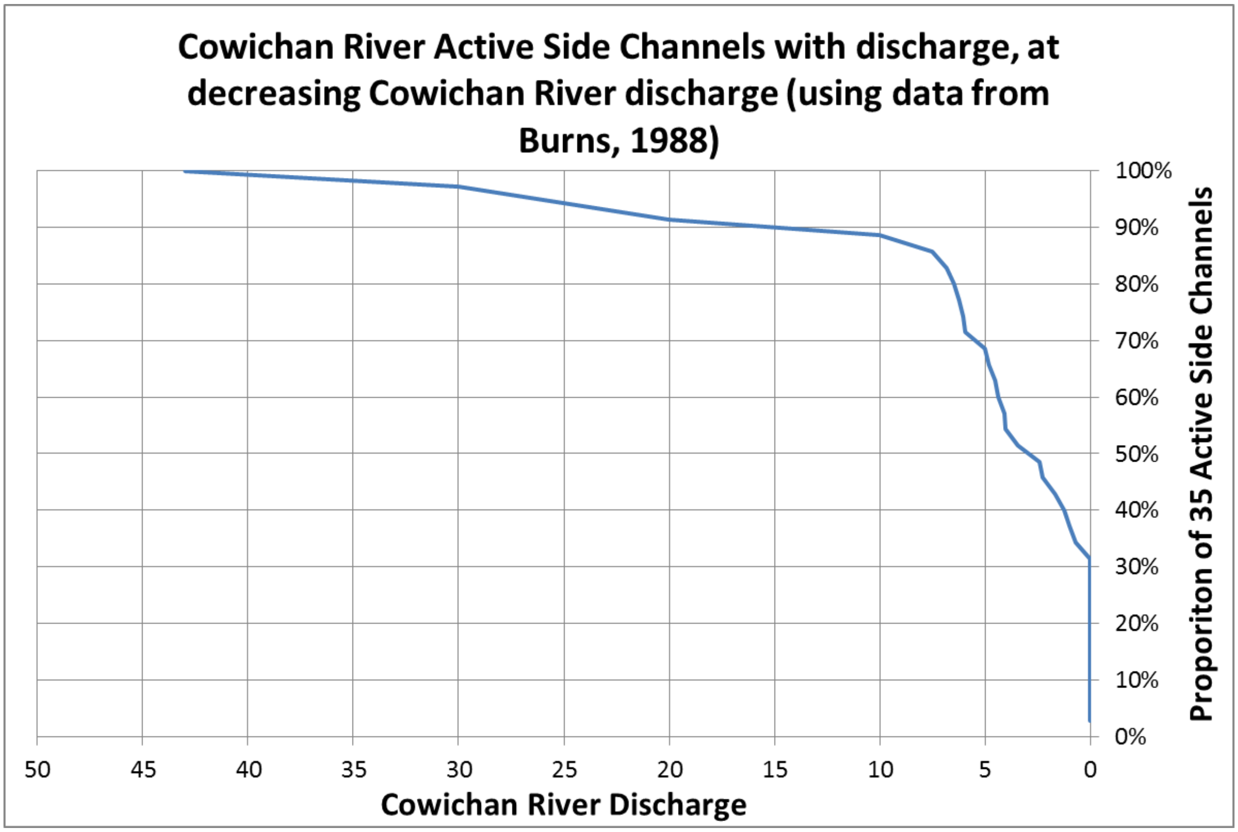


Figure 1. Relationship between river discharge and the proportion of Active Side Channels with measureable flow.

<u>Discussion and Conclusions</u>

Figure 1 provides several observations:

1. All active channels have a measureable discharge at river discharges above 45 cms
2. The proportion of channels with a measureable discharge decreases as river discharge decreases
3. There is an inflection point at approximately 7.5 cms of river discharge. At this level 85% of the channels are still flowing. Below this level the proportion of channels with measureable flow decreases quickly. At 5 cms less than 70% are flowing, at 2.5 cms only half are still flowing.

Although the number of side channels that are flowing will decrease with a descending river discharge, this proportion of channels that are affected is low until a river discharge of 7.5 m^3/s is reached. Below this level, the proportion of channels that stop flowing increases at a much more rapid rate. This leads to a conclusion that the discharge level of 7.5 m^3/s becomes important when considering side channel connectivity.

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