DRAFT - Technical Memorandum

DATE: March 31, 2010

TO: Craig Wightman, BCCF

FROM: Craig Sutherland, P.Eng.

CC: Michelle Vessey, Catalyst Paper

RE: **BC CONSERVATION FOUNDATION**
DRAFT - Cowichan Lake – Weir Operation Protocol Assessment and Review
Our File 0673.013

EXECUTIVE SUMMARY

The Cowichan Lake weir is used to store water in Cowichan Lake to regulate flow in the Cowichan River during the spring and summer period. The weir is usually operated from April 1st or but not earlier than March 1st in dry years until lake levels start to rise as a result of increased inflow in the fall. The operation of the weir is guided by a set of operational protocols that have been developed based on past experience and knowledge of the system. The primary purpose of these protocols is to maintain minimum flow in the river of 25 m3/s from April 1st to April 30th, 15 m3/s from April 1st to June 14th and 7 m3/s from June 15th until the end of the control season when lake levels rise as a result of increased inflow in the fall (typically before Nov 4th). The purpose of this study was to assess these protocols using hydrological analysis and recommend changes to improve the reliability of the system.

An operational model of the Cowichan Lake Weir has been developed to assess impacts of changing the weir operation protocol on the ability to maintain lake levels at or above the weir crest during the early control season (prior to July 9th) and to maintain lake levels above zero storage before the end of the control season (when lake levels rise due to increased inflow typically before Nov 4). In addition, an assessment of how changing the weir operation impacts peak lake levels has also been completed.

The results of the assessment indicate that:

1. Due to the frequency of above average peak lake levels prior to April 1st, the gates should not be operated unless lake levels drop 20 cm below the weir crest and forecasting models indicate below average inflow for the spring period.

2. Closing gates and maintaining lake levels about 20 cm above the weir from April 1st to April 30tht, 13 cm above the weir from May 1st to June 15th and at the weir crest from

June 15th to July 9th would improve the ability to have lake levels at full storage on July 9th. When lake level is at or above these elevations, the minimum flow release can be maintained with the gates closed 100%. However, the ability to maintain lake levels above the weir is dependant on lake inflows being at or above the minimum flow release values. When net-inflow to the lake falls below the minimum flow release then lake level will fall below the target level and gates will have to be lowered to maintain minimum flow. A set of minimum lake levels is recommended at which point flows should be considered to be reduced to help maintain lake levels near full storage level.

3. The proposed early season control levels (20 cm and 13 cm above the weir crest) are well within the bounds of past recorded lake levels. Maintaining lake levels above the weir crest prior to April 1st could increase peak lake levels during rainfall events in April and May, however these peaks are well below the average peak lake level. Based on a review of past records, increased inflow as a result of snowmelt contribution to the lake is well below that during rain and rain-on-snow events in the fall/winter period.

4. Providing an allowance to capture increased summer inflow by allowing lake levels to rise above the rule curve after July 9th, does not have a significant impact to the ability to maintain lake levels above zero storage. A review of the results indicates that during years when storage is depleted there is less likely to be periods of increased summer rainfall, so lake level remains below the rule curve the whole period. However, capturing summer inflow does increase the likelihood of being able to provide fish pulses near the end of the season (from about 52% of the time to 72% of the time).

5. Higher lake levels at the end of the control season would have some impacts on peak lake levels in October and early November. Based on using the October 2003 storm (the peak of this event falls between the average lake level and the 5-year return period lake level) as an example, the model indicates that being 20 cm higher at the start of the storm results in the peak being 8 cm higher. Any impact of the end of season lake level becomes insignificant after the first fall peak lake level. Any adjustment to the operation protocol should take this into account by allowing lake levels to be as low as possible by early to mid October as well as to ensure that gates are opened as soon as possible when large inflow events occur.

The results of the assessment are based on analysis using the net-inflow to the lake calculated using lake level and river discharge data collected from 1962 to 2007. Therefore, the analysis does not account for any future changes in net-inflow as a result of climate change or land cover changes. Further assessment would be needed using hydrological modelling to assess longer term impacts. However, using historical data for analysis does provide a good indication of impacts of changing weir operation protocols in the short term (over the next few years).

BACKGROUND

In October 2008, the Cowichan River Ad-hoc Committee prepared revised "Cowichan Weir Start-up, Operation and Seasonal Protocols" which provide guidance on operating the Cowichan Lake Weir that is owned and operated by Catalyst Paper. The primary principles of the protocol are to:

1. maintain full storage behind the weir until July 9th, if possible;
2. maintain a minimum 25 m^3/s prior to May 1 if conditions allow;
3. maintain a minimum 15 m^3/s prior to June 15; and
4. maintain a minimum 7 m^3/s from June 15 to end of weir control period (when lake levels rise due to increased inflow typically before Nov 4)

In addition, the weir should be operated to provide allowance for fish pulses (increasing river flow up to 18 m^3/s for two 30 hrs periods near the end of the operation period, usually the last week of September and first week of October) when practical.

The protocol also places limits on how quickly the discharge rate can be adjusted. Except for the periods prior to and after fish pulses, the ramping rates in the protocol are:

- early spring season up to May 1st maximum ramping rate is 3 m^3/s per day; and
- after May 1st maximum ramping rate is 2 m^3/s per day.

A copy of the full protocol is enclosed in Appendix A.

The protocols were originally developed based on past experience of the weir operator without extensive hydrological analysis. In order to formalize the protocols, a more thorough analysis of impacts of weir operation on lake levels and river discharges has been requested. This memo outlines the analysis completed to assess the guidelines and provides recommended amendments.

PROJECT SCOPE

The scope is summarized as follows:

- Refine understanding how operation of the weir impacts both spring and early fall peak lake levels as well as the ability to support minimum conservation flow (7 m^3/s) until the end of the summer control season;
- Assess potential revisions to the weir protocol and their impacts on peak lake levels; and
- Provide comment on existing protocol and recommend revisions.

GLOSSARY

Table 1 provides a list of definitions for the many terms relating to the operation of the weir.

TABLE 1 – Definitions

Term	Definition
Control Lake Level	Level at which the lake is held during the early part of the control season. The control level is at Full Storage Level prior to July 9th.
Control period (earliest February 28 to as late as early November)	Period when gates are raised and the boat lock is closed such that river flows and lake levels are regulated at the weir structure. The period typically lasts from early spring, when the lake level begins to fall below the weir crest, to the end of summer season when fall rains return and the lake level starts to rise.
Cowichan Lake Weir	Tiber-crib and rubble structure constructed at the outlet of Cowichan Lake in 1957 and upgraded in 1961. The structure consists of a boat lock on the left bank (looking downstream), the timber weir and a set of four overshot gates on the right bank. The overshot gates are used to control both lake level and river discharge during the control period.
Fish Pulse	Increased flow near the end of the control period to assist with adult salmon migration. The pulses typically occur around the last week of September and the first week of October, if conditions permit. A pulse consists of ramping discharge from 7 m^3/s to 18 m^3/s over 6 hours, maintaining flow at 18 m^3/s for 30 hours and then reducing flow back to 7 m^3/s over a 6 hour period.
Full Storage Level (FSL) (162.37 m-GSC)	Elevation of the top of the weir crest. Maximum lake level where river flow can be fully controlled by the weir gates.
Minimum Flow Release Schedule	The schedule that defines the minimum preferred discharge rates to the Cowichan River through the control period: - 25 m^3/s prior to May 1 if conditions allow; - 15 m^3/s prior to June 15; and - 7 m^3/s from June 15 to the end of weir control period when inflow increases and lake levels start to rise (typically before Nov 4).
Natural Outflow Limit	The Natural Outflow Limit is the lake level versus river flow relationship defined by the river channel downstream of the weir. It is the river flow that would occur at any given lake level if the gates and the boat lock were fully open. It defines the maximum flow that can be released from the weir for a given lake level.
Ramping Rate	The rate at which the river flow can be adjusted. This defines how quickly the controlled river flow can be changed. The protocol defines the rate as: - 3 cms per day(?) up to May 1st - 2 cms per day(?) after May 1st

TABLE 1 (cont.) - Definitions

Term	Definition
Rule Curve	The Rule Curve defines the optimal lake level during the draw down season from July 9th until early November. It is the primary tool used to balance the need to conserve storage in the lake while ensuring lake levels are drawn down as low as possible at the end of the season to limit the impact to the first peak lake levels in the fall.
Trigger Level (High and Low)	A set of lake levels at which minimum flow is reduced (when lake level fall below low trigger) or flow increased (when lake level rises above high trigger) to provide some guidance to weir operation. The trigger levels would likely change throughout the control period similar to the minimum flow release schedule.
Zero Storage Level (ZSL) (161.40 m)	Lowest lake level where minimum desired flow of 7 m^3/s can be released from the lake. When lake levels fall below ZSL river flows can no longer be controlled and drop below minimum flow until inflows increase and lake level rises above ZSL.

Figure 1 provides the weir operation in a graphical format showing the "ideal" operation of the weir during a typical year.

COWICHAN LAKE WATER BALANCE MODEL

In order to assess impacts of weir operation on lake levels and river flows, the Cowichan Lake Water Balance Model was upgraded to allow for continuous simulation of lake levels and river discharges given a specified minimum flow release schedule and rule curve. The model is a spreadsheet (MS-Excel) based model which calculates daily water balance through the lake using the simple mass balance equation:

$$I - O = \Delta S / \Delta t$$

Where:
Δt is the model time step
I is the average inflow over Δt
O is the average outflow over Δt
ΔS is the change in storage in the lake over Δt

Net-inflow is defined as the volume of surface runoff from the watershed plus volume of direct rainfall on the lake minus volume of evaporation from the lake surface during time step Δt. This means that at certain times in the summer the net-inflow is negative when runoff and precipitation to the lake are less than evaporation. The average daily net-inflow data were back-calculated from daily discharge and lake level records collected since 1953 by the Water Survey of Canada. This record provides a continuous estimate of net-inflow to the lake for a 55-year period.

Average daily outflow from the lake has been modelled using a series of logical statements based on the operation protocol. An overview of the operation logic is shown in Figure 2.

RESULTS

By running the Cowichan Lake Water Balance Model using back calculated net-inflow for the period from 1962 to 2007 (the period since the weir was upgraded and gates installed), the impact of changes to how the weir is operated on peak lake levels, the ability to sustain the minimum flow release through the summer and how often a fish pulse can be released can be calculated. The results from the past 46 years of historical data can be used to provide some guidance on future likelihood of occurrence.

Historical Minimum Summer Flow

The ability to maintain summer flow throughout the summer control season is dependant on lake levels staying above the zero-storage elevation until the first of the fall rainfall events. The ability to stay above the zero-storage elevation is dependant on:

1. how much storage is available at the beginning of the draw-down season (on July 9th):
2. how much inflow occurs during the draw down season (from July 9th until November 4th); and
3. whether or not the controlled river flow is reduced below the desired minimum flow release (7 m^3/s).

A review of the past lake level and discharge records between 1962 to 2007 indicates that:

1. 7 years out of 46 years (15%), lake levels were at or above the full storage level on July 9th;
2. 10 years out of 46 years (22%), lake levels were below the zero storage level; and
3. 17 years out of 46 years (47%), river flows dropped below the desired minimum discharge of 7 m^3/s.

Figure 3 shows the historical lake levels during the summer months.

The Cowichan Lake Water Balance Model was used to run for the same 46-year period (1962 to 2007) using the current operation protocols to estimate how many years the criteria would have not been met if the weir were operated in exact accordance with the protocols. The results indicate that:

1. 14 years out of 46 years (30%), lake levels would have been at or above the full storage level on July 9th;
2. 10 years out of 46 years (22%), lake levels would have been below the zero storage level; and
3. 10 years out of 46 years (30%), river flows would have dropped below the desired minimum flow release rate of 7.0 m^3/s.

These results indicate that the operation protocol would increase the number of years that the lake levels were at or above full storage on July 9th. However, the operation protocol would have limited impacts on having the lake level staying above zero-storage during the full control period.

It is interesting to note that all ten years when lake levels would have been below ZSL are between 1985 to 2007 (last 23 years). For the first 23 years from 1962 to 1984, lake levels would have been maintained above ZSL with the operation protocol. There are many different factors that could contribute to this, including changes in land cover in the watershed, climate variability (ie: shift from El-Niño versus La-Nina) and longer term climate change trends. However, what this does indicate is that spring and summer inflow patterns to the lake are changing and that the likelihood of lake levels dropping below ZSL is increasing.

Modifications to Operation Protocols

The Cowichan Lake Water Balance Model was also used to assess how modifying the operation protocols could improve the likelihood of lake levels being at or above FSL on July 9 and maintain the lake level above ZSL by the end of the summer control season. Three options were identified and assessed:

1. Keeping lake level above the weir crest during the early part of the season (from April 1 to July 9) by keeping gates closed unless a drop in lake level results in flow falling below the minimum flow release, in which case the gates would start to be opened;
2. Reducing the early season minimum flow release (prior to July 9th) during dry years to help maintain lake levels near the weir crest; and
3. Allowing lake levels to rise above the rule curve during the draw down season (after July 9th) such that more water can be stored during the early part of the control period with a requirement to release more water near the end of the control period.

Table 2 summarize the proposed adjustments and model results.

TABLE 2 – Cowichan Lake Water Balance Model Results (based on net-inflow from 1962 to 2007)

Scenario	Lake Level above Full Storage on July 9th, 2010	Lake Level below Zero Storage prior to end of Control Season	Flow below preferred minimum release (7 m^3/s)	Fish Pulse[1]	
				Pulse on Sept 20th	Pulse on Sept 20th and Oct 10th
Historical Record	7 years out of 46 (15%)	10 years out of 46 (22%)	17 years out of 46 (47%)		
Model using current protocol	14 years out of 46 (30%)	10 years out of 46 (22%)	10 years out of 46 (47%)	24 years out of 46 (52%)	0 years out of 46 (0%)
Model using early season (prior to July 9th) target lake levels above weir crest	26 years out of 46 (56%)	9 years out of 46 (20%)	9 years out of 46 (20%)	24 years out of 46 (52%)	0 years out of 46 (0%)
Model using reduced early season minimum flow	28 years out of 46 (60 %)	6 years out of 46 (13%)	6 years out of 46 (13%)	26 years out of 46 (56%)	1 years out of 46 (2%)
Model with reduced summer flow during dry years	14 years out of 46 (30%)	6 years out of 46 (13%)	25 years out of 46 (54%)	25 years out of 46 (54%)	0 years out of 46 (0%)
Model with allowance to rise above rule curve to capture increased summer inflow	14 years out of 46 (30%)	9 years out of 46 (20%)	21 years out of 46 (54%)	24 years out of 46 (52%)	9 years out of 46 (20%)
Recommended protocol (all options combined)[2]	28 years out of 46 (60%)	1 year out of 46 (2%)	18 years out of 46 (39%)	22 years out of 46 (48%)	11 years out of 46 (24%)

Note 1: Number of years that lake level was high enough on October 1st to release 18 m^3/s. However, fish pulse may not have actually occurred.
2: For recommended protocol, early season minimum flow reduced 10 out of 46 years in April (22%), 16 3 out of 46 out of 46 years (35%) in June

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Early season control level above weir

In order to maintain lake levels above the weir crest during the early control season, the boat lock and the gates would need to be closed unless flow in the river increases above about 50 m^3/s. At this flow, the weir becomes submerged as a result of backwatering from the channel downstream. A review of past lake level and river discharge records collected by Catalyst Paper indicate that with the gates and boat lock 100% closed:

1. Lake level has to be a minimum of about 0.21 m above the weir crest (162.58 m-GSC) to maintain a discharge of 25 m^3/s; and

2. Lake level has to be a minimum of about 0.13 m above the weir crest (162.5 m-GSC) to maintain a discharge of 15 m^3/s.

The lake level versus river flow rating curve with the gates and boat lock 100% closed is shown in Figure 4.

The Cowichan Lake model was run by maintaining the early-season controlled minimum discharges (25 m^3/s prior to May 1 and 15 m^3/s prior to June 15) through the overflows from the weir while keeping the gates mostly closed. After June 30th, the lake level would be at the weir crest and the 7 cms discharge would be released by the gates. During the dry years, when net-inflow to the lake drops below the desired minimum flow release rates during the early control season (prior to July 9th), the gates would be partially opened to maintain the required release rates resulting in lake levels dropping below the weir crest.

The model results indicate that this adjustment to the operation protocol would result in:

1. 26 years out of 46 years (56%), lake levels would be at or above FSL on July 9th ; and

2. 9 years out of 46 years (20%), lake levels would fall below ZSL by the end of the control season.

This indicates that maintaining water levels above the weir crest during the early control season would increase the likelihood of lake levels being above ZSL on July 9th but would not likely change the likelihood of dropping lake levels below ZSL by the end of the control season. The reason for this is because maintaining the early season minimum flow release rates (25 m^3/s and 15 m^3/s) during dry years requires dropping lake level below the full storage level by July 9th, which results in lake levels falling below ZSL at the end of the control season. In order to reduce the likelihood of having the lake levels falling below ZSL, the early season flow release may need to be reduced during dry-years.

Reduction in early season minimum flow release during dry years

As previously discussed, when net-inflow to the lake drops below the required release rates, the gates need to be partially opened to maintain the desired minimum flow release rates during the early control season (prior to July 9th),. As a result, the lake level would be below the weir crest by July 9th. To help maintain lake levels near the weir crest, adjustments to the early season minimum flow release rates were proposed as follows:

1. For the period from April 1st to May 1st if the lake level falls below 20 cm below the weir crest elevation (162.17 m-GSC) then reduce the minimum flow release rate to 20 m^3/s;

2. For the period from May 1st to June 1st if the lake level falls below 10 cm below the weir crest (162.27 m-GSC) then reduce the minimum flow release rate to 12 m^3/s;

3. For the period from June 1st to June 15th if the lake level falls 10 cm below the weir crest (162.27 m-GSC) then reduce flow to 7 m^3/s; and

4. For the period after June 15th, the current minimum flow release of 7 m^3/s is maintained.

Flows are maintained at reduced rate until water level reaches the weir crest or rule curve.

These reduced minimum flows and trigger levels have been selected based on a review of the net-inflow record. They represent roughly the average 10th percentile flow for each of the pre-season periods (ie: flow at which 10% of recorded flows are less than this given flow). Reducing the controlled flows to the adjusted values means that lake levels should either rise or at least be maintained at the trigger level approximately 9 out of 10 years. The reduced early season minimum flow release rates during dry years have only been used as an example for this study. Further assessment of the proposed flow reductions on fisheries and recreation in the river would need to be investigated further.

The modeling results indicate that applying the reduced minimum flow criteria would result in an increase in the likelihood of being at or above FSL on July 9th and being above ZSL by the end of the control season as allowing lake levels to rise above the weir crest, such that:

1. 28 years out of 46 years (60%), lake levels would be at or above FSL on July 9th ; and

2. 6 years out of 46 years (13%), lake levels would fall below ZSL by the end of the control season.

However, maintaining lake level near full storage would require reducing river flow below the existing desired early season minimum flow release (prior to July 9th) in 14 years out of 46 years (30%).

Draw down period adjustment (after July 9th)

Maintaining lake levels as close as possible to FSL until the start of the draw-down period on July 9th would improve the likelihood of maintaining the lake levels above ZSL by the end of the control season. However, to further reduce the likelihood additional adjustments to the draw-down period protocol could be made. These include reducing minimum flow when lake levels fall below a minimum trigger level as well as allowing lake levels to rise above the rule curve to capture summer inflow.

To assess the impacts of having a reduced minimum flow during dry years, the Cowichan Lake Water Balance Model was tested with a minimum flow release of 6 m^3/s when lake levels fall 15 cm below the rule curve. In addition, reducing the minimum flow release to 6 m3/s would lower the ZSL to 161.34 m.

The model results indicate that this adjustment to the operation protocol would result in:

1. 6 years out of 46 years (13%), lake levels would fall below ZSL by the end of the control season;
2. 25 years out of 46 years (54%), a fish pulse could be released on September 20th: and
3. 0 years out of 46 years (0%), a fish pulse could be released on September 20th and Oct 10th.

Although the model indicates that the reliability of the system improves from only applying the early season measures, only reducing the river flow during the draw down period to 6 m^3/s during dry years does improve the operation to meet the water level control criteria. However, the model results indicate that 25 years out of 46 (54%) of the time river flow would have to be lowered below the preferred minimum of 7 m^3/s. By adjusting the minimum target to be greater than 15 cm below the rule curve would help reduce the number of years river flow would have to be reduced. However, this would result in increased likelihood of falling below ZSL prior to the end of the control season. More assessment would be needed to determine the best option.

In addition to a lower level trigger and reduced minimum flow during the draw down period, the impacts of allowing lake levels to rise above the rule curve has also been assessed. Using historical data, it appears that lake levels have been up to approximately 30 cm above the rule curve.

To test the impact of allowing lake levels to rise above the rule curve, the model was run using an upper trigger level about 15 cm above the current rule curve from July 9th to September 20th (assumed to be the date of the first fish pulse). When lake levels rise above this level, flows are increased to allow lake levels to drop below the limit. After September 20th, minimum flow is increased to 10 m^3/s to bring lake levels back to the rule curve prior to the end of the control season.

The model results indicate that this adjustment to the operation protocol would result in:

1. 9 years out of 46 years (2%), lake levels would fall below ZSL by the end of the control season;
2. 24 years out of 46 years (54%), a fish pulse could be released on September 20th: and
3. 9 years out of 46 years (0%), a fish pulse could be released on September 20th and Oct 10th.

The model results indicate that allowing lake levels to rise above the rule curve does not significantly improve the reliability of being above the ZSL by the end of the summer period from the current operation protocol. However, during years with increased summer precipitation it is likely that this option would improve the reliability of providing two fish pulses by the end of the control season.

Example protocols

By combining all the options together, the model has been used to test the impact of adopting a set of interim protocols based on the analysis. The results of the model indicate that:

1. 28 years out of 46 years (60%), lake levels would be at or above FSL on July
2. 1 years out of 46 years (2%), lake levels would fall below ZSL by the end of the control season;
3. 18 years out of 46 years (39%), river flows would drop below the desired minimum flow release rate of 7.0 m^3/s;
4. 22 years out of 46 years (39%), a fish pulse could be released on September 20th: and
5. 11 years out of 46 years (24%), a fish pulse could be released on September 20th and Oct 10th.

Figures 5 and 6 are used to show a comparison of the results of the existing operation protocols with the impacts of adopting the proposed protocols on lake levels and discharges.

Impacts to peak lake levels on early-season control levels

A review of past lake level records indicates that the majority of the highest peak water levels occur between December and February. Table 3 shows the number of peaks over various threshold values in each month.

Table 3 – Number of years with peak lake level above threshold in given month (for period from 1962 to 2007)

Month	Average W/L 164 m-GSC	5-year Return Period W/L 164.54 m-GSC	10-yr Return Period W/L 164.85 m-GSC	20-yr Return Period W/L 165.09 m-GSC
Jan	9	3	2	1
Feb	3	1	1	0
Mar	3	0	0	0
Apr	0	0	0	0
May	0	0	0	0
Jun	0	0	0	0
Jul	0	0	0	0
Aug	0	0	0	0
Sep	0	0	0	0
Oct	1	0	0	0
Nov	6	3	0	0
Dec	12	4	2	0

Although most of the highest peaks occur from December to February, some above average peaks do occur in March. This indicates that unless lake levels are low and inflow is not expected to be significant then the weir should not be on-control earlier than April 1st and at no time before March 1st. The model indicates that having the weir on-control and maintaining lake levels near the weir crest in March increases the likelihood of lake levels being above average peak level from about 8% to 11%. As inflow to the lake in March is usually sufficient to maintain lake levels around the full supply level and there is usually sufficient inflow after April 1st to lake level to the weir crest by July 9th, there is no need to operate the gates prior to April 1st.

However, during very dry years when net-inflow to the lake drops in March, release flows should be reduced to maintain storage. For modelling purposes, we have assumed when lake levels drop below 30 cm (162.07 m-GSC) below the weir crest in March, the release flow would be reduced to 25 m^3/s by partially closing the gates

Impacts to peak lake levels on end of control season lake levels

Higher lake levels at the end of the control season do have some impact on the first peak lake levels of the fall season usually in October or early November. However, the magnitude of the increased lake levels are small in comparison with the natural variation of the lake.

Running the model using the example protocols indicates that the number of peaks above the average peak lake level in November would increase slightly from 6 to 7 times out of 46 years and would have no impact on higher lake levels such as the 5-year return period level. Based on using the October 2003 storm (the peak of this event falls between the average lake level and the 5-year return period lake level and is the highest peak recorded in October) as an example, the model indicates that being 20 cm higher at the start of the storm results in the peak being 8 cm higher. By comparison, the model indicates that the storm event results in the lake level rising about 2.86 m to elevation 164.43 m over the 12-day period from when lake levels start to rise and the weir goes off control.

Figure 7 shows the impact of higher end of season lake levels on fall peak lake levels.

LIMITATIONS

The results of the analysis are based on net-inflows calculated from historical lake level and river discharge records from 1962 to 2007. The net-inflows do take changes in climate and changes in land cover that have occurred over that time period. However, they do not reflect what could happen in the future (over the next 46-years). A more detailed hydrological assessment of climate change impacts and land use change impacts would be required to forecast future net-inflow to the lake. This assessment is outside the scope of this study but may be completed in the future.

However, the results of this assessment do provide a reasonable estimate for the short term (over the next 4 to 5 years) and are therefore a good basis to provide recommendations to adjust the weir operation protocols for the upcoming flow control season.

RECOMMENDATIONS

Based on the results of the assessment, we recommend that an interim operational protocol be considered as follows:

1. Weir should never be operated prior to Feb 28.

2. From March 1 to March 31, weir should only be operated only if lake levels fall 20 cm below the weir crest (162.17 m-GSC) and inflow forecast are dry based on the results of the River Forecast Centre Cowichan Lake Inflow Forecast Model (more assessment of this value will be needed once inflow forecasting results are available). When lake levels are below 162.17 m GSC, flow should be reduced to a minimum of 25 m^3/s.

3. On April 1st or when gates are raised as a result lake levels being below 162.17 m-GSC in March, the boat lock should be closed over period of half a day.

3. From April 1st to April 30th, gates should be closed unless the release flow is less than 25 m^3/s. Lake levels should be allowed to rise above the weir to 20 cm above the weir crest (162.57 m-GSC). If lake levels rise above 30 cm above the weir (equivalent to a discharge of 35 m^3/s in the river), the gates should be opened to help maintain lake levels no higher than 30 cm above the weir. If by maintaining a minimum flow of 25 m^3/s, lake levels drop below 20 cm (162.17 m-GSC) below the weir crest then consideration should be given to lower minimum flow release to 20 m^3/s.

4. From May 1st to June 15th, gates should be operated to either maintain lake leve1 about 13 cm above weir crest (162.50 m-GSC) or to release a minimum discharge of 15 m^3/s in the river. If lake levels rise 20 cm above the weir crest (an equivalent of 25 m^3/s in the river) then gates should be opened to increase flow and return lake levels to 13 cm above the weir crest. If lake levels fall below 10 cm below the weir crest during this period, then consideration should be given to reduce river flow to 12 m^3/s prior to May 31st and 7 m^3/s after June 1st.

5. All adjustments to the gates should be made using a ramping rate of either 15% of the average river flow recorded the previous days or 3 m^3/s from March 1st to April 30th and 2 m^3/s from May 1st to June 15th, which ever is greater.

6. After July 9th, river flows should be maintained at 7 m^3/s unless lake level fall 15 cm below the rule curve then consideration should be given to reduce flows to 6 m^3/s. If inflow to the lake increases above 7m^3/s and lake levels rise above the rule curve, then some provision should be given to maintaining lake levels above the rule curve until September 17th to provide more opportunity for fish pulse. After the fish pulse,

minimum flow should be increased to help draw lake levels back down to the rule curve by October 15th. For modelling purposes we have assumed using 20 cm above the rule curve as a target level for summer inflow storage and increasing base flow to 10 m^3/s after September 17th.

A graphical representation of these recommendations is shown in Figure 7.

Please be aware that these protocols are for discussion purposes only and provide a framework to review how changes to the operation protocol impact the ability to maintain nimum flows during the control season and the impacts on peak lake levels at the beginning and end of the control season. Any final revisions to the protocol will have to consider the impacts on downstream water users and be approved by the Provincial Comptroller of Water Rights.

CLOSING

If you have any questions or concerns regarding this assessment, please contact the undersigned at (250) 595-4223.

KERR WOOD LEIDAL ASSOCIATES LTD.

Prepared by:	Reviewed by:
Craig Sutherland, P.Eng. Project Engineer	Wendy Yao, P.Eng. Senior Water Resources Engineer

CS/eb

Encl.

STATEMENT OF LIMITATIONS

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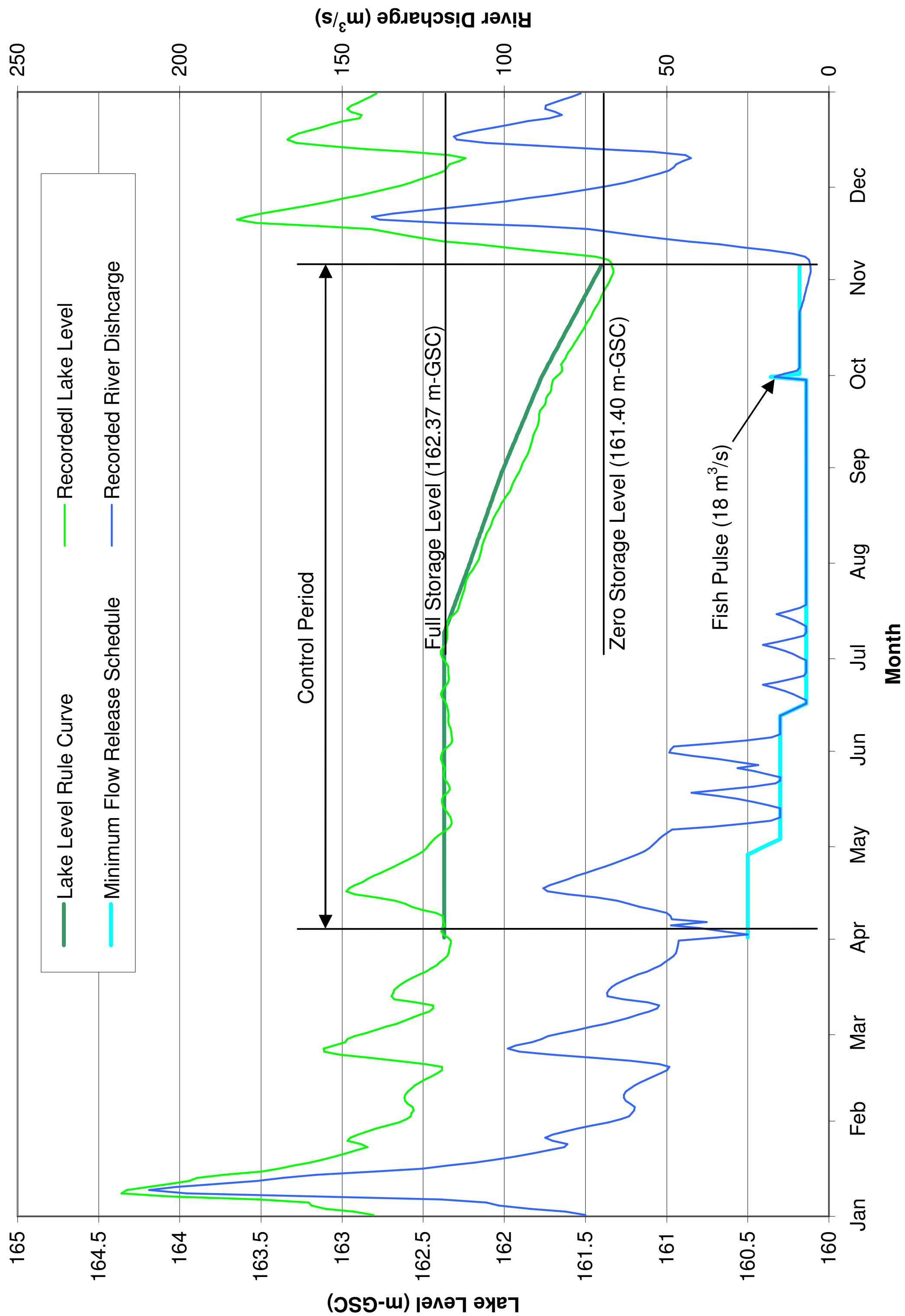

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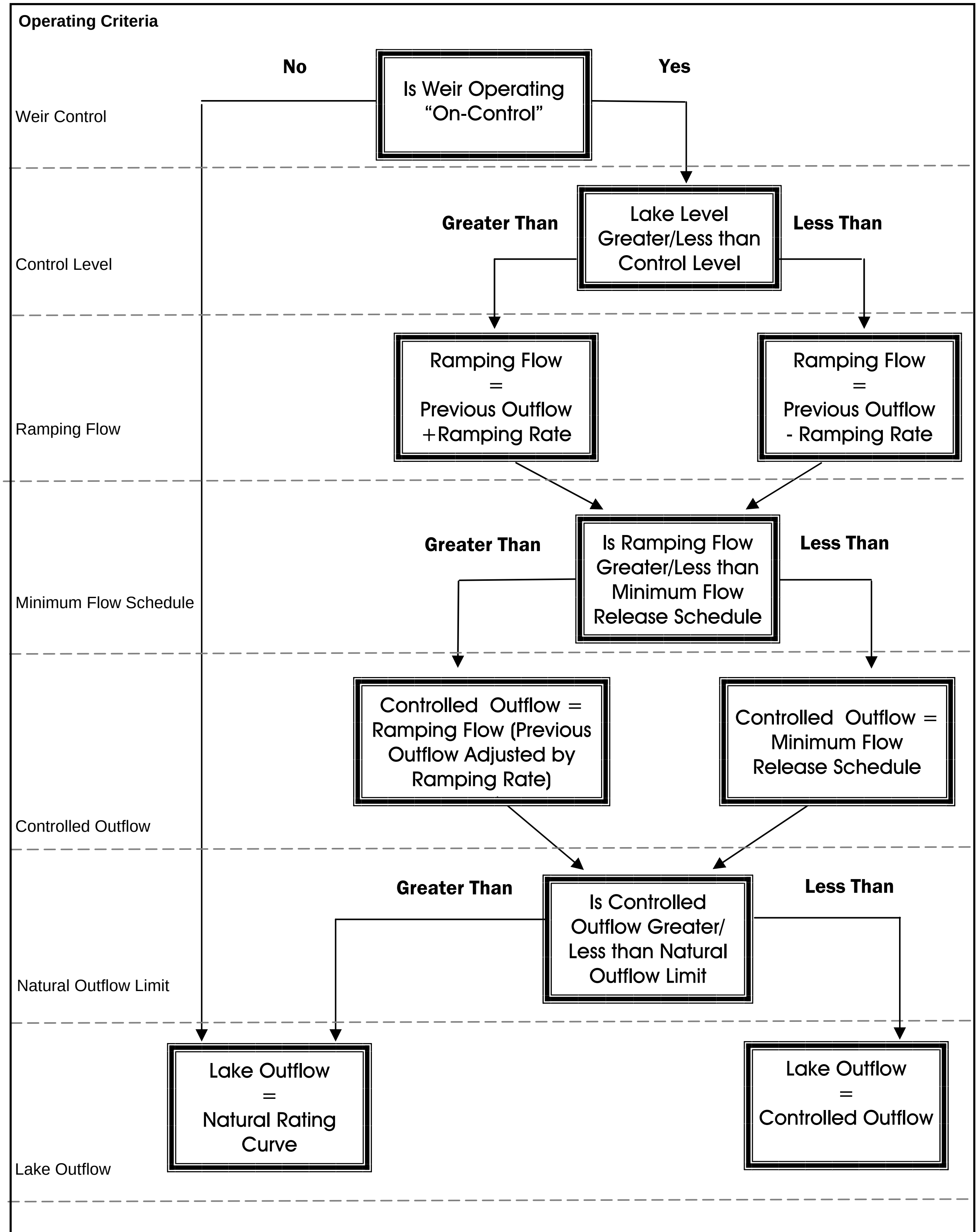
BC Conservation Foundation – Cowichan Lake Weir Operation Assessment

Project No.	Date
0673.013	Mar. 2010

Cowichan Lake Weir Operation Protocol
Minimum Flow Release Schedule and Rule Curve
Figure 1



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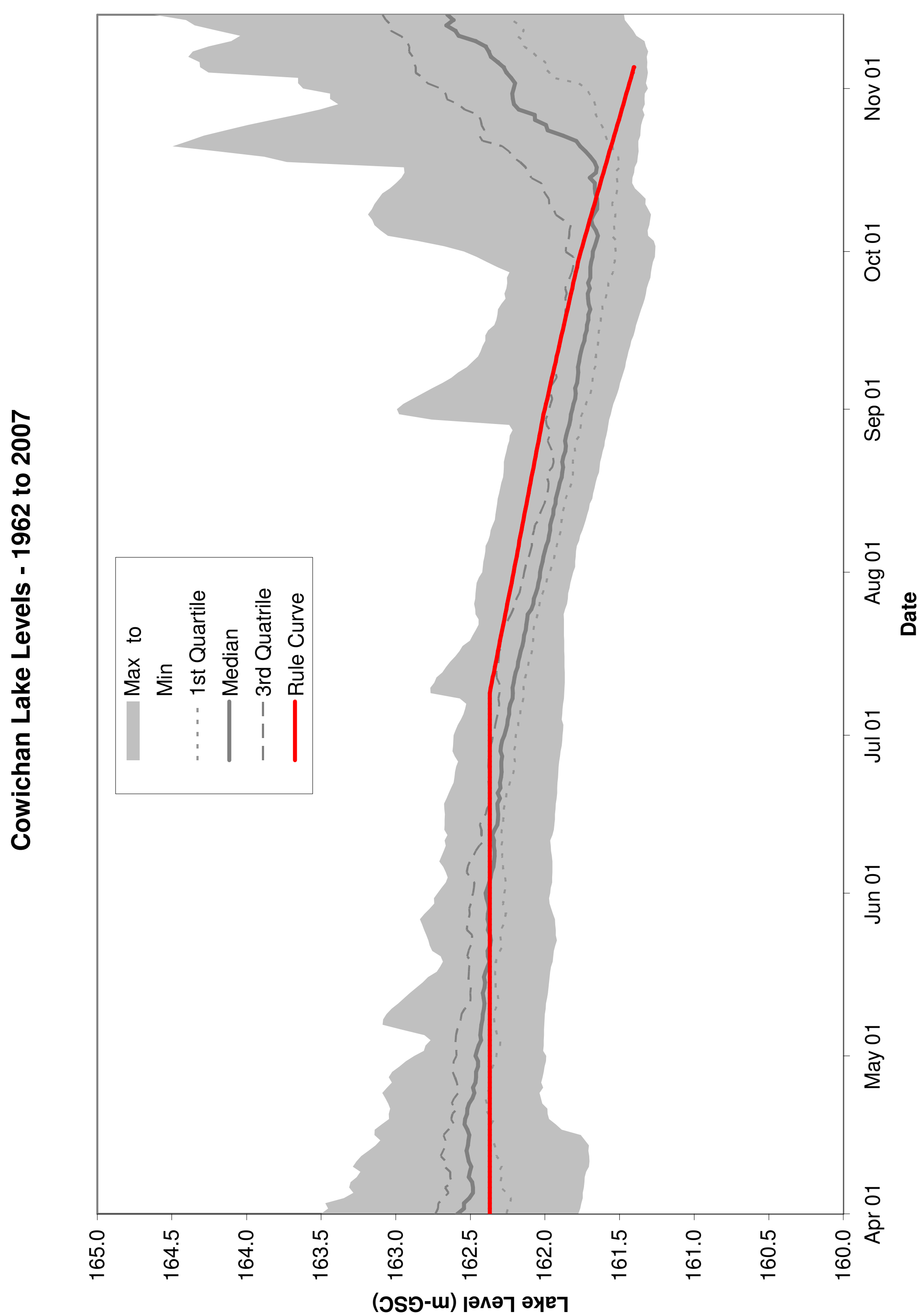
COWICHAN LAKE WATER BALANCE MODEL
OPERATION LOGIC

KWL Project No. 0673.013

FIGURE 2

BC CONSERVATION FOUNDATION
Cowichan Lake Outlet – Flood Lake Level and River Discharge Analysis



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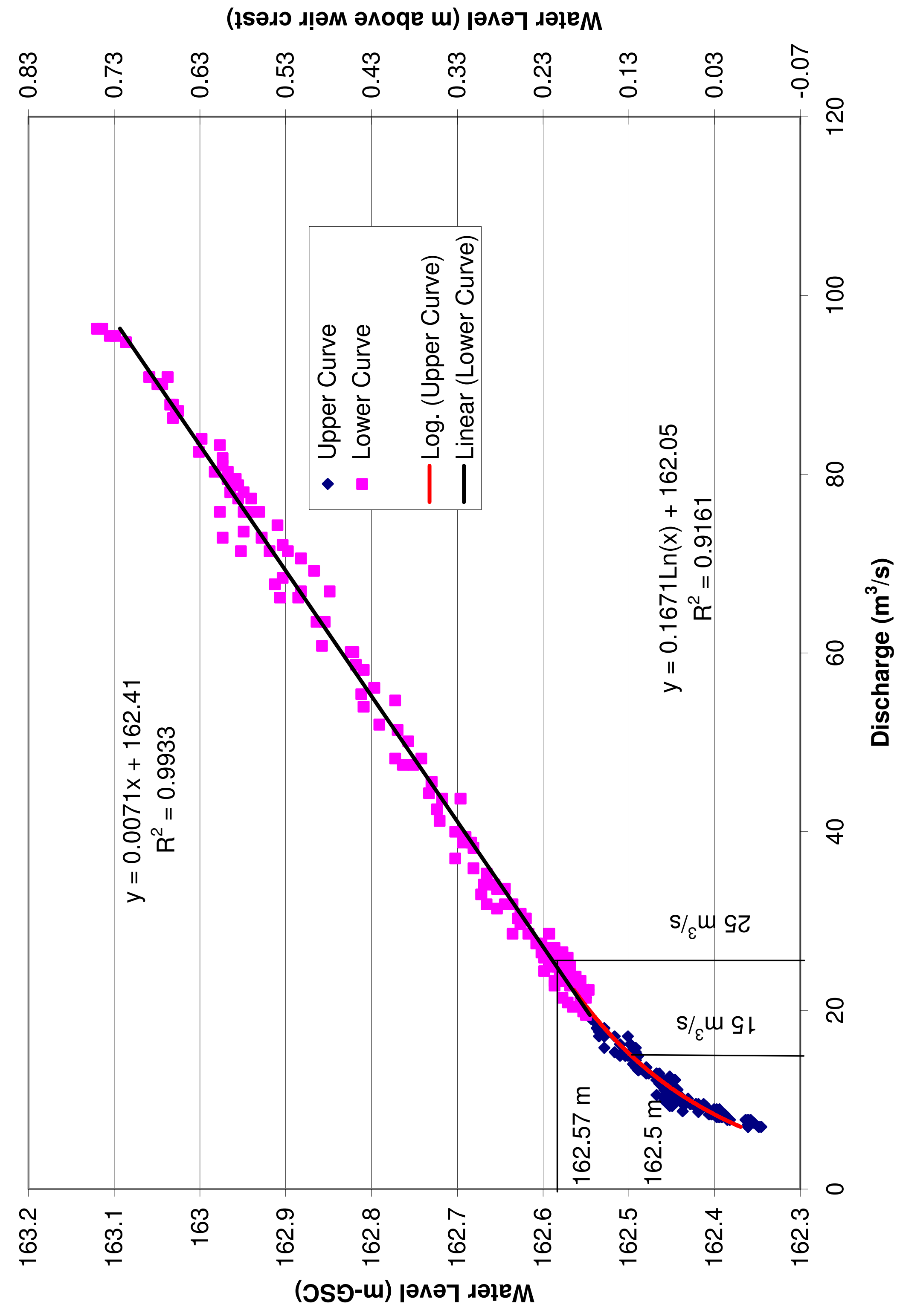
BC Conservation Foundation – Cowichan Lake Weir Operation Assessment

Project No.	Date
0673.013	Mar. 2010

Cowichan Lake Weir Operation Protocol

Historical Recorded Lake Levels (1962 to 2007)

Figure 3



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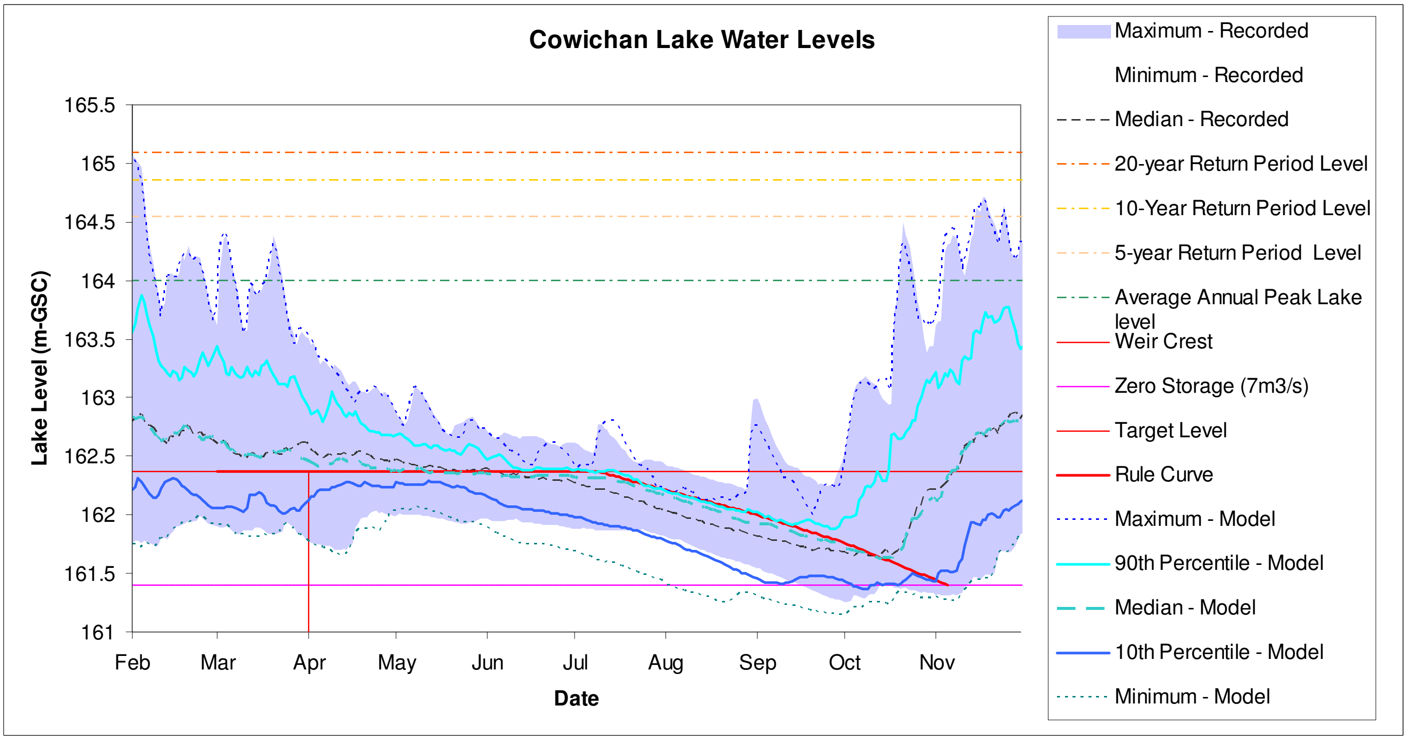
BC Conservation Foundation – Cowichan Lake Weir Operation Assessment

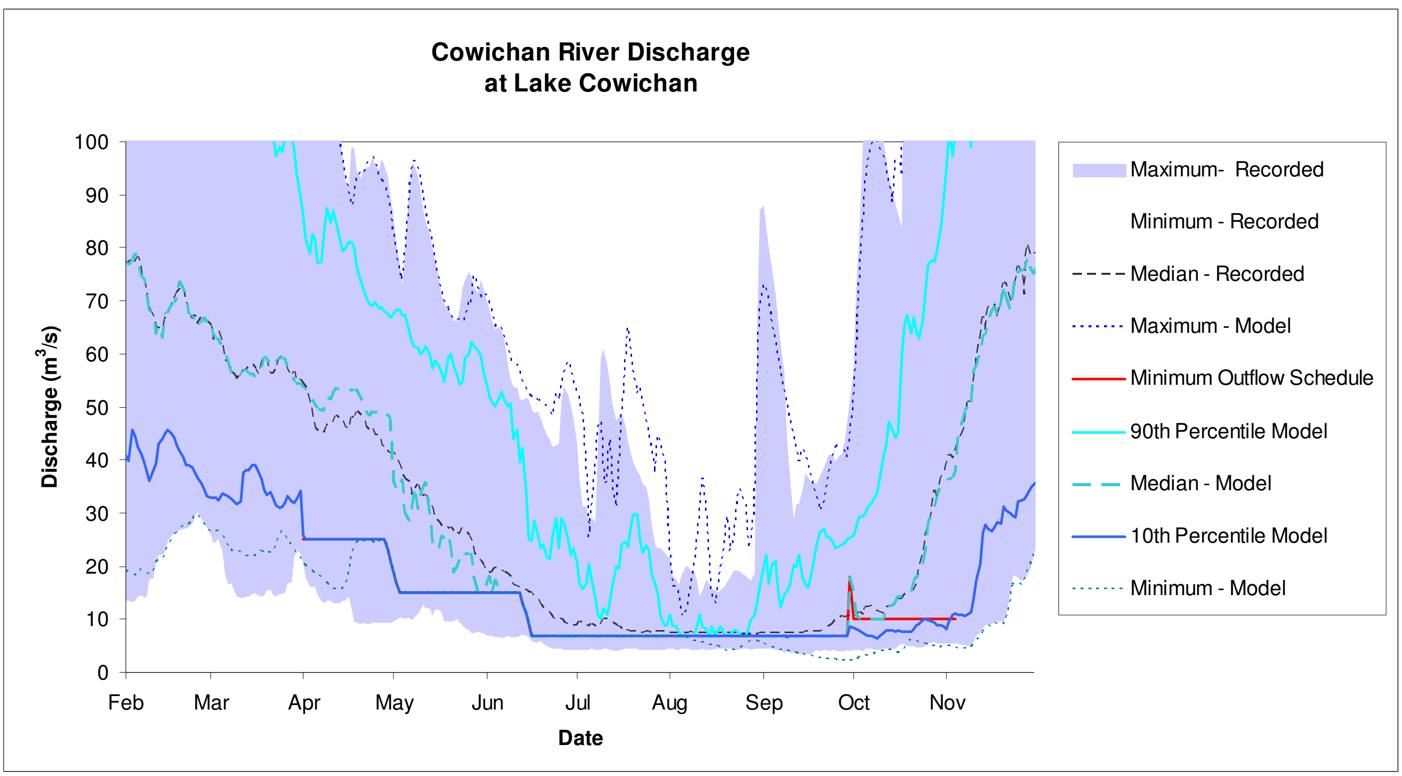
Project No.	Date
0673.013	Mar. 2010

Cowichan Lake Weir Operation Protocol

Lake Level vs. River Flow (Gates 100% Closed)

Figure 4





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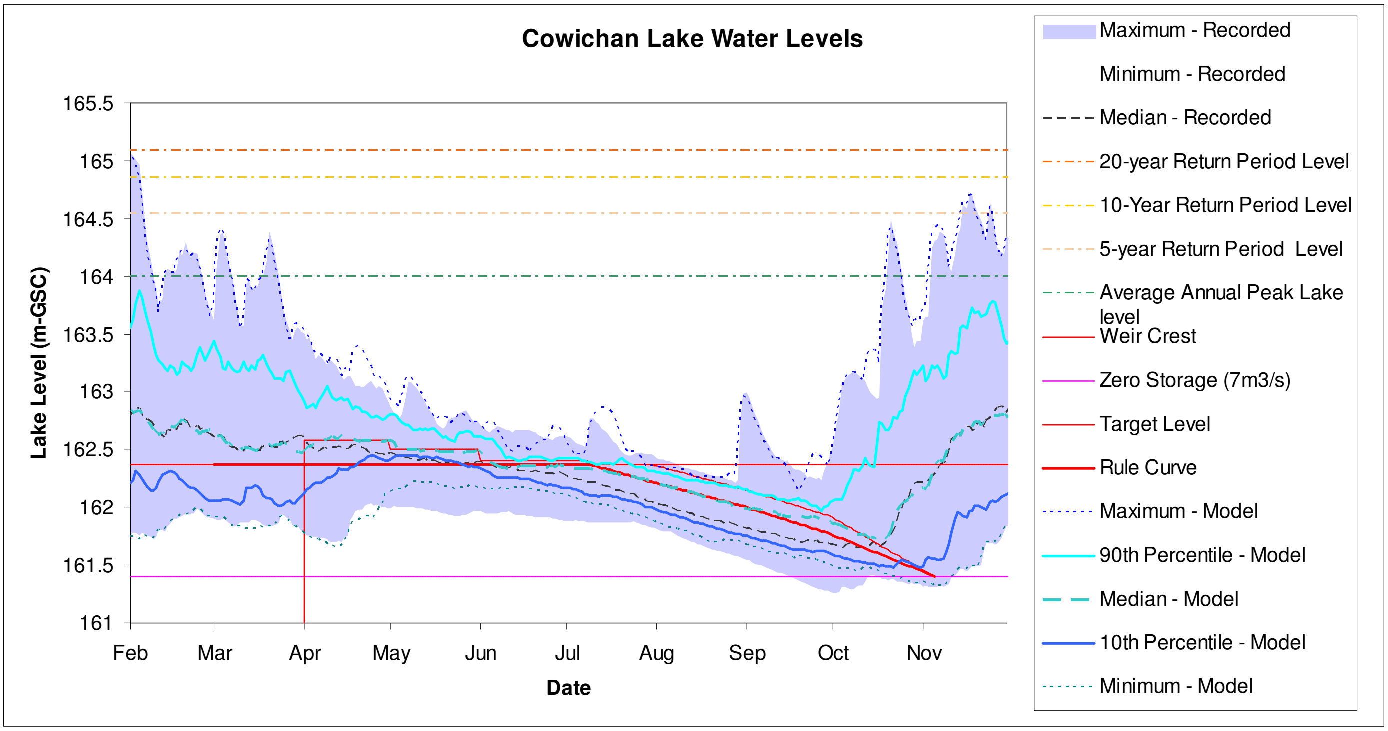
BC Conservation Foundation – Cowichan Lake Weir Operation Assessment

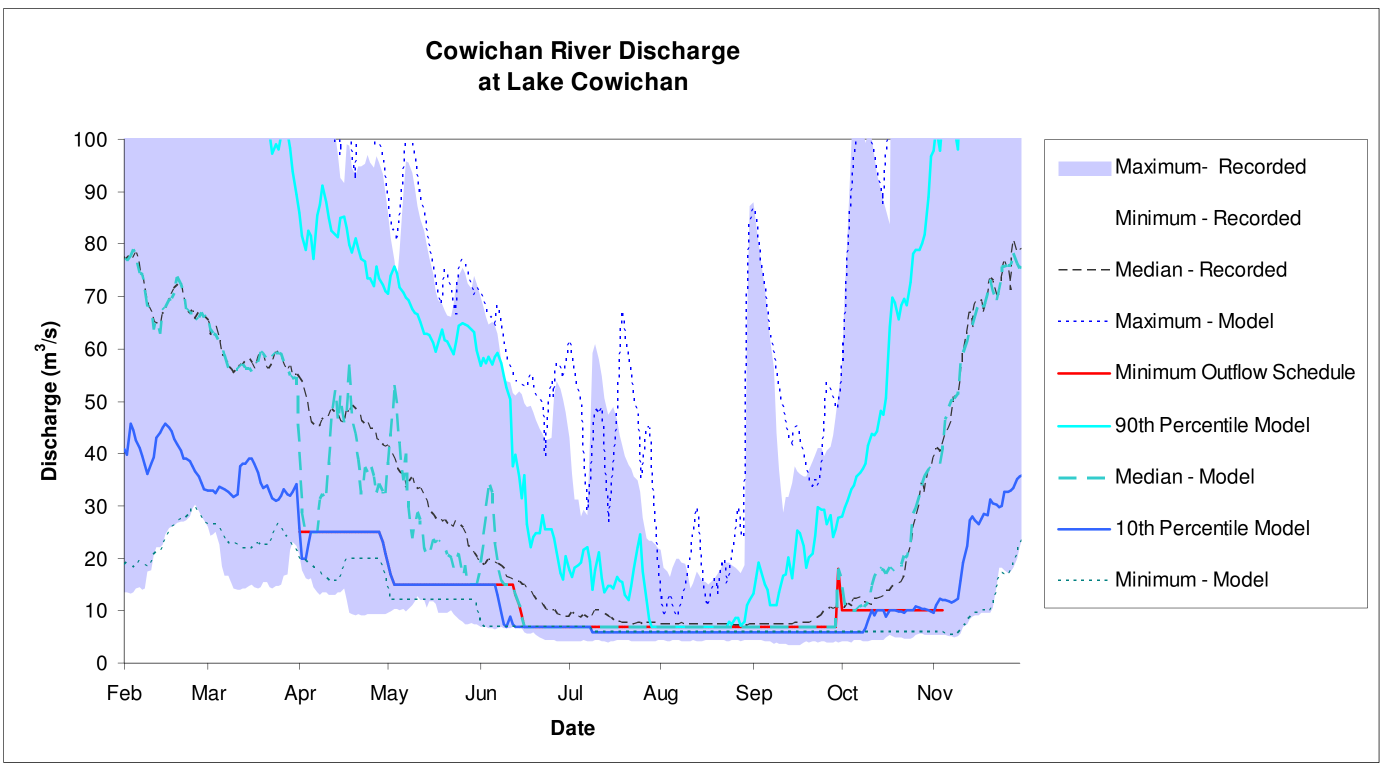
Project No.	Date
0673.013	Mar. 2010

Cowichan Lake Weir Operation Protocol

Model Results - Current Weir Operation Protocol

Figure 5





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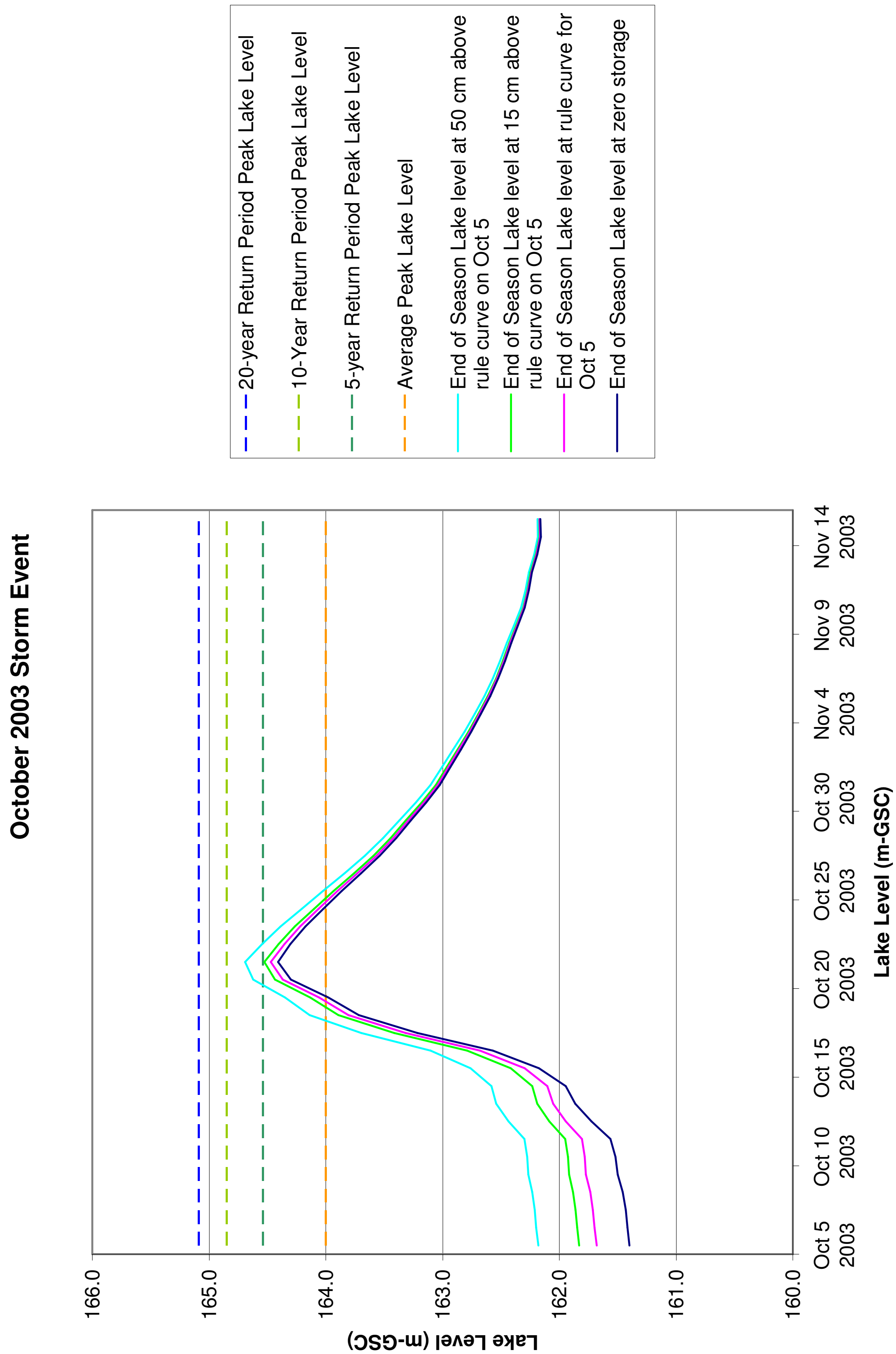
BC Conservation Foundation – Cowichan Lake Weir Operation Assessment

Project No.	Date
0673.013	Mar. 2010

Cowichan Lake Weir Operation Protocol

Model Results - Proposed Weir Operation Protocol

Figure 6



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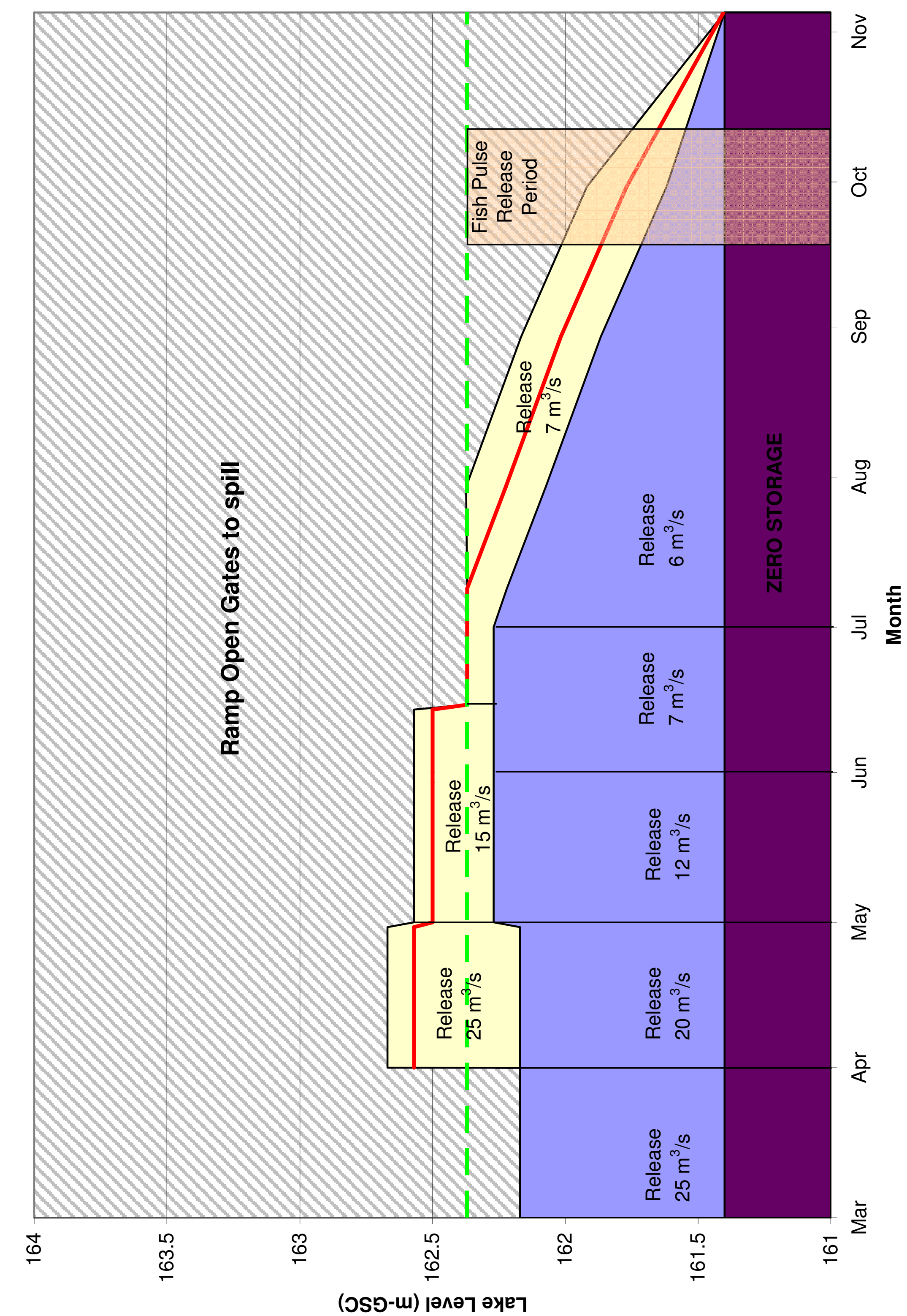
BC Conservation Foundation – Cowichan Lake Weir Operation Assessment

Project No.	Date
0673.013	Mar. 2010

Cowichan Lake Weir Operation Protocol

2003 End of Control Season Flood

Figure 7



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BC Conservation Foundation – Cowichan Lake Weir Operation Assessment

Project No.	**Date**
0673.013	Mar. 2010

Cowichan Lake Weir Operation Protocol
Recommended Weir Operation Protocol
Figure 8

APPENDIX A

2008 - Cowichan Weir Start-up, Operation and Seasonal Protocols

COWICHAN WEIR START-UP, OPERATION AND SEASONAL PROTOCOLS

Goals:

1. Maintain full storage behind the weir until July 9th if possible
2. Maintain an optimum 25 cms prior to May 1 if conditions allow
3. Maintain a minimum 15 cms in Cowichan River prior to June 15
4. Maintain a minimum 7 cms from June 15 to end of weir control period typically around Nov 1

Note: There may be provisions for possible spring and fall pulse flows for fish conservation.

A) Weir Startup Considerations:

1. Do not start-up weir earlier than Feb 28th due to the risk of a "rain on snow" flood event.

2. Schedule initial spring meeting to discuss/determine weir startup at 162.6 m GSC declining lake level which allows about 10 days before crest of weir is reached – avoid going below the crest.

3. Avoid lake level dropping below crest of weir in a year with below normal snowpack by April 15

4. Review snowpack level (currently measured at Jump Cr. – Nanaimo watershed) and assess prediction of snow water inflows to Cowichan (not currently available)
   a. Note: Estimated that about 10 to 20% of total inflow to the lake from April to June 30 is contributed by snowmelt runoff, the remainder is precipitation

5. Review likelihood of precipitation
   a. Early spring vs. late spring – likelihood of late spring rainfall vs. risk/cost of early start-up (cost to man and operate weir, risk of impact to fish resource of less than 15 cms flows)
   b. Weather forecast and long range precipitation/inflow trends

B) Weir Start-up Triggers:

Start up weir if either of the two triggers below are met.

Trigger #1: There is low snowpack, the lake level is at the crest of weir at 162.37 GSC m, and it is past Feb 28th

OR:

Trigger #2: There is average snowpack and the lake level is 17 cm below the weir crest (162.20 GSC m).

Note: Trigger #2 is based on a rule curve of 25 cms to May 1, 15 cms to June 15, then 7 cms to season end – ie. a rule curve that improves the ability to rebuild and sustain storage to July 9th and recapture of occasional summer season precipitation inflows.

C) Weir Start-up Ramp-down Protocol (Run of river to 25 cms)

* Catalyst Paper will issue one press release for the entire weir operating season, and carry out pulse(s) in-season as directed by MOE.

* River flows will be measured using the Catalyst Paper static gauge and can be cross checked with Water Survey of Canada on-line automated Cowichan Lake river gauge.

Assessment Notice: Starting in 2006, an examination of the two tier spring river minimum flow (25 cms and 15 cms) will be done with the view that in drought situations, one tier 15 cms may be used to conserve storage. Significant fish conservation and sport fishery impacts may or may not occur based on the study's findings.

Weir Start-up Protocol:

1) Close boat lock over the course of half a day. (This will drop river flow typically from run of river 48 cms to 45cms over 48 hours, however, river flow will recover to run of river flow again as velocity of flow through the 4 spill gates increases to compensate for the Boat Lock closure).

2) Make no adjustments to spill gates for 2 days after the Boat Lock is closed.

3) Natural uncontrolled river flows >30cms need to be ramped down slowly as would occur when a high pressure system prevails – reduce the river flows no more than 3 cms/day and gradually adjust flows down to maintain 25 cms until May 1.

D) First Spring Ramp-down Protocol: (25 cms to 15 cms)

On April 28 (3 days ahead of the May 1 rule curve minimum target of 15 cms to allow for a gradual decline), start reducing the river flow from 25 cms to 15 cms by gradually closing the spill gates to achieve a river flow reduction rate of no greater than 2 cms/day.

E) Second Spring Ramp-down Protocol: (15 cms to 7 cms)

This is the most sensitive fisheries period when flow ramping must be gradual due to side-channel stranding of salmonid fry, juveniles and alevins still in the river gravels.

1. An acceptable ramp down rate if conservation of storage need is urgent: June 13 to June 17, reduced by 2 cms per day.
2. An ideal ramp down rate is over a longer period from June 11 to June 19, with a reduction of flow by 1 cms per day.
3. In ideal conditions, ramp down only at dusk or at night to minimize stranding risk of newly emerged fry.

F) Spring Spilling Protocol (if required): Prior to July 9

If, after going on control, but before June 15 (the beginning of the summer river rule curve flow of 7 cms), the lake level begins to approach Full Storage Level (FSL) due to increasing inflows, open the spillgates to spill water and maintain the lake level as close to FSL as possible, without going more than 15cm above FSL.

As the lake level approaches FSL, begin increasing the river flow gradually by up to 5 cms/day, as required to meet the target FSL of 162.38 GSC m (maximum 162.53 GSC m). Continue operating the spillgates to achieve inflow = outflow and a target FSL lake level until June 15. This will be a balancing act as inflows into the lake (snowmelt and precipitation) vary depending upon the weather.

G) Summer Maintenance Flows June 15 – Fall (7 cms)

Maintain 7 cms throughout the summer period

H) Falls pulse flows: (7 cms to 18 cms) Sept 17 to Oct 11

Pulse flows released at the weir in the fall are a conservation measure used to stimulate chinook upstream migration from the estuary.

1. Trigger for a pulse flow is based on available storage and lake level. If lake level is below the rule curve, a decision may be made not to initiate a pulse flow, or it may be initiated based on an acceptable probability of rainfall.

2. Optimum pulse flow conditions
    a. Fishery is closed.
    b. Timing window set by fisheries management committee
    c. Pulse window: Sept 17 to Oct 11

   d. Optimum flow pulse is 18 cms (maximum for counting fence is 22 cms, maximum for Somenos backwatering/agricultural constraints is 24 cms
   e. Ramp-up from 7 to 18 cms over 6 hours, hold for 30 hours, ramp down from 18 cms to 7 cms over 12 hours)

3. Backwatering affect into Somenos sub-basin does not begin until flow exceeds 24 cms – therefore this is not a constraint to pulse flows.

4. Process for obtaining a pulse flow(s):
   a. The fisheries management committee will discuss and agree on pulse size and release timing.
   b. One week in advance of pulse, a request is to be co-ordinated by a DFO stock assessment staff member to Catalyst Paper, and then reviewed/approved by MOE's Water Stewardship Division based on criteria above,

5. Using the Water Survey Canada online river flow measurement at Lake Cowichan and at the Silver Bridge in Duncan shows that a pulse at the weir in Lake Cowichan takes about 12 hours to reach the estuary.

I) End of Year Weir Shutdown

1. Target the shut down of weir operation for on/about Oct 31st, providing the lake level remains below the crest of the weir. The weir's operation in the fall assists the Canada/US International salmon counting fence with a target river flow of 20cms. These flows also assist Somenos Basin agriculturists. Weir shutdown and flow ramp-up to be co-ordinated so that the counting fence is removed from the river in advance of opening the weir's gates.

2. If lake level has not reached the crest of the weir, maintain weir operation into November until fall rains begin to rebuild storage.

When going off control, the ramp-up flow rate will depend on the current flow, as it is the difference between current flow and "run of river" that will determine the ramp-up rate strategy. If the current flow is low (ie. 20 cms as the weir has been maintained in support of the fish counting fence operation and agricultural constraints in Somenos), then ramp up will be longer (over 5 days). If the current flow is high (~40 cms) ramp-up can proceed faster (approx 2 days) to run of river at which time the weir can be shut down for the season.

At an approximate flow about about 57 cms, it has been noted that the weir's spillgates do not dictate river flow but rather it is the pinch point downstream of the weir which controls the flowrate in the river.

Catalyst Paper Cowichan Lake level and Cowichan River flow data, Jump Creek snow pack and Duncan weather forecast available at:

http://www.catalystpaper.com/communities/communities_crofton_results_waterlevel.xml

On-Line Water Survey of Canada (Cowichan River at Lake Cowichan (discharge and temp.)

http://scitech.pyr.ec.gc.ca/waterweb/formnav.asp?lang=0

J) *Other information*

River kayaking is negatively impacted at flows below 7 cms. At around 6 cms it is still navigable but bumpy. At 5 cms or lower, it is very bumpy and tours may be cancelled at these kind of low flow rates.

The District of North Cowichan operated "Joint Utility Board" sewage lagoons in Duncan require a 40:1 dilution ratio, which equates to a minimum Cowichan River flow requirement of 5.1 cms (downstream of the Silver Bridge).

Broodstock collection typically occurs starting September 1 until the end of October. The fishing crews can safely handle a maximum flow of 18 cms.

K) *Authors*

Michelle Vessey, Catalyst Paper
Brian Tutty, Department of Fisheries and Oceans
Craig Wightman, Ministry of Environment
JR Elliott, Cowichan Hatchery
Tom Rutherford, Department of Fisheries and Oceans
Steve Baillie, Department of Fisheries and Oceans

Also, with input from Craig Sutherland, UMA Engineering

L) *Revision History*

Revision Date	**Change**	**Acknowledgements**
May 12, 2008	Addition of spring spilling protocol	Michelle Vessey
Oct 17, 2008	Broodstock max flow restrictions	Michelle Vessey
Oct 21, 2008	Infor re: downstream pinch point at 57 cms added	Michelle Vessey

Appendix 1

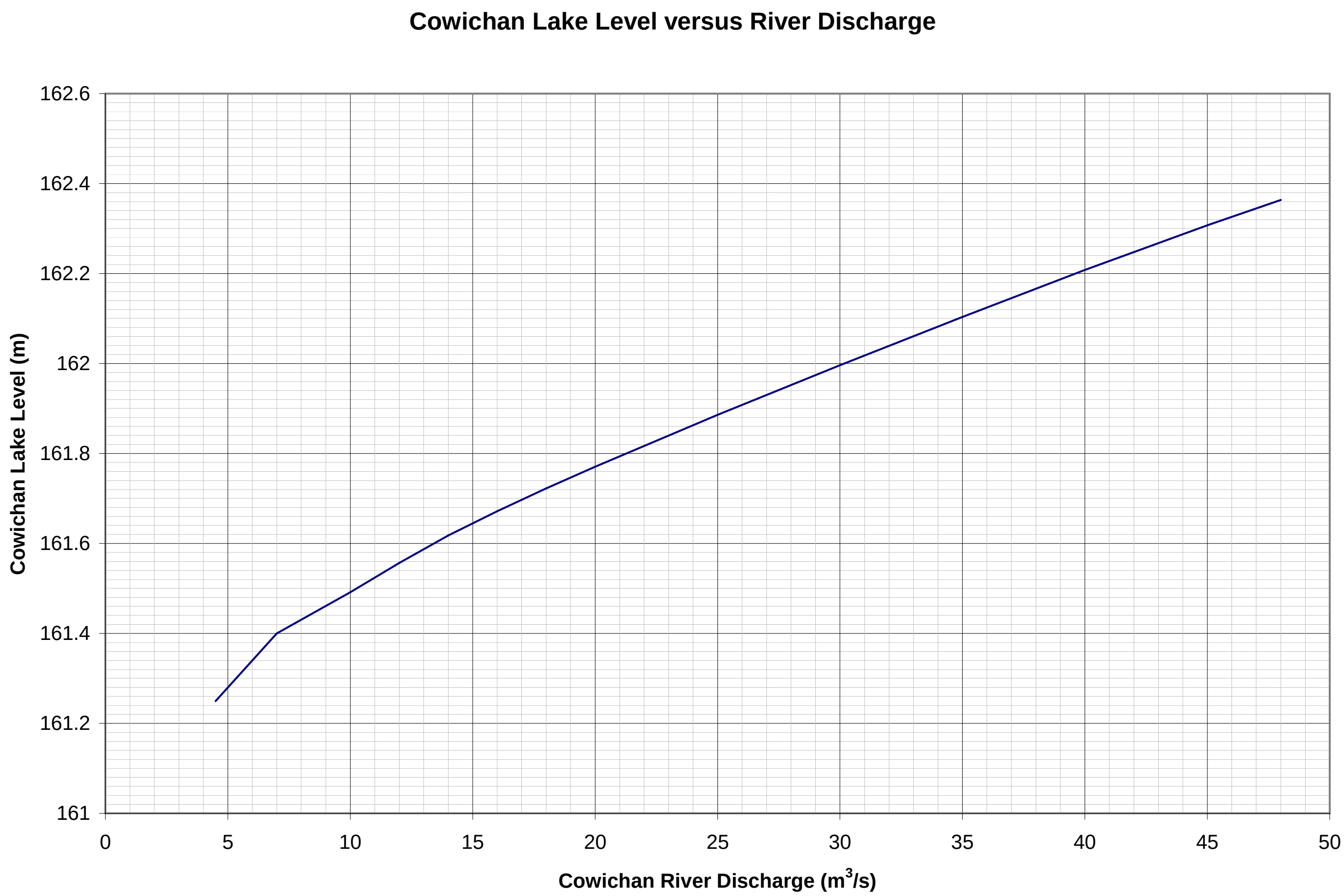
Minimum Cowichan Lake Levels required to achieve various river discharges – provided by Craig Sutherland, UMA Engineering

These are for "uncontrolled" conditions with the boat lock closed and the gates fully open. Also included are daily lake level drops for the various discharges. These assume constant flow for the 24-hr period and zero net inflow (lake inflow = lake evaporation).

Cowichan Lake Level versus Cowichan River at Lake Cowichan Discharge

Discharge (m_3/s)	Minimum Lake Level[1] (m)	24-hr Volume (million m^3)	24-hr Lake Level Drop[2] (cm)
4.5	161.25	0.39	0.6
7	161.40	0.60	1.0
10	161.49	0.86	1.4
12	161.56	1.04	1.7
14	161.62	1.21	2.0
16	161.67	1.38	2.2
18	161.72	1.56	2.5
20	161.77	1.73	2.8
25	161.89	2.16	3.5
30	162.00	2.59	4.2
35	162.10	3.02	4.9
40	162.21	3.46	5.6
45	162.31	3.89	6.3
48	162.36	4.15	6.7

Note: 1 - Minimum Lake level at which discharge can be released (equivalent to Zero Storage Elevation)
2 - Drop in lake level assuming constant discharge during the day and zero net inflow (ie: Inflow = Evaporation)


Cowichan Lake Level versus River Discharge
162.6
162.4
162.2
162
161.8
161.6
161.4
161.2
161
0
5
10
15
20
25
30
35
40
45
50
Cowichan Lake Level (m)
Cowichan River Discharge (m3/s)

Appendix 2

From: Wightman, Craig ENV:EX [mailto:Craig.Wightman@gov.bc.ca]
Sent: Wednesday, October 11, 2006 12:26 PM
To: Sutherland, Craig; XT:Harper, David Westland Resource Group EAO:IN; TuttyB@pac.dfo-mpo.gc.ca; Vessey, Michelle (Crofton); Tom Anderson
Cc: Ptolemy, Ron ENV:EX; McCulloch, Mike ENV:EX; Harlan Wright; kpellett@bccf.com
Subject: Proposed Cowichan River Rule Curve Changes

Based on direct field observations by fisheries technicians of the BC Conservation Foundation this past spring, we are prepared to make several recommendations with respect to the "rule curve" governing flows downstream of the Catalyst Paper Corp. weir. These are predicated on observations of side-channel connectivity and wetted perimeter of steelhead spawning areas at sites above/below Skutz Falls. Observations were carried out from April 8-13 at 50.5cms; May 24 at 26.5cms; June 19 at 21.5cms; and, June 21 at 15.8cms. The BCCF report is now in a second draft which we hope to finalize by early November.

<u>Existing "rule curve" conditions</u>:

(1) When lake under weir control, maintain minimum of 25cms until May 1;
(2) When lake under weir control, maintain minimum of 15cms from May 2 to June 15; and,
(3) When lake under weir control, maintain minimum of 7cms from June 16 until lake storage is replenished by fall rains and weir is deactivated for the season.

<u>Proposed rule curve amendments based on 2006 field observations:</u>

(1) Maintain minimum of 20cms and optimum of 30cms until May 1;
(2) Maintain minimum of 15cms and optimum of 30 cms from May 2 to June 15; and
(3) Maintain minimum of 7cms from June 16 until lake storage is replenished by fall rains and the weir is deactivated for the season.
(4) In severe droughts, reduce incrementally to 4.5cms when storage will not support 7cms target.
(5) In very wet summers, increase incrementally to 9cms (or more) to maintain target storage levels relative to peak lakeshore property use.
(6) Pulse flows for chinook salmon migration in late September and mid-October will be dependent on lake inflow/storage conditions annually.

<u>Rationale:</u>

Observations by BCCF and testimonials by licenced freshwater angling guides this past spring have reinforced the 30cms "optimum" for spawning by steelhead/rainbow trout and side-channel connectivity throughout the river's length. The 30cms also provides excellent angling and drift boating conditions for guides and clients, and is probably well-suited for kayaking as well.

However, in dry springs with low-negligible snowpack, it may be prudent to go "on control" earlier than May 1 to ensure there is enough storage in the lake to meet the rule curve minimums. Observations indicated a minimum flow of 20cms prior to May 1 is sufficient to keep mainstem spawning riffles largely wet, and most side-channels connected with "adequate" wetted widths.

<u>If low lake inflows are forecast</u>, going to 20cms before May 1 could pay dividends by forcing steelhead/trout to spawn in more central areas of the mainstem's cross-section, where redd desiccation is less of a threat later as flows decrease. For the record, spawning by winter steelhead can start in late January and extend until mid April. Peak spawning probably varies somewhat between years depending

on water temperature trends, but likely occurs in March. A large number of adfluvial rainbow trout also migrate from Cowichan Lake in the early spring to spawn in the upper river (mainly upstream from 70.2 Mile Trestle). Peak spawning by these fish is likely mid-March to early April. Most (if not all) steelhead and trout fry emergence is complete by June 15, based on field observations and calculations of Accumulated Temperature Units from the time of initial egg deposition (354 ATU's to 50% hatch for steelhead/rainbow trout; Clarke 1997). Hence, ramping to the 7cms summer minimum can safely occur after June 15 following the spring protocol below:

Spring Ramp-Down Protocol - 15cms to 7cms (Ramping Protocol Sub-Committee, March 9/06)

1. Acceptable ramp-down rate if conservation of storage is urgent: June 13 to June 17, drop flows by 2cms per day.
2. Ideal: June 11 to June 19, drop flows by 1cms per day.
3. Ideal: Ramp only at dusk or at night to minimize stranding risk of newly emerged fry.

A minimum of 15cms from May 2 to June 15 is considered critical for maintaining some flow (i.e., 10-15% of what was observed at a river discharge of 50.5cms) in moderate-sized side-channels, and in providing reasonable riffle coverage for successful fry emergence. 15cms is not as good as the 20cms "threshold" described above, but would be acceptable given the need to maintain lake storage for later release during forecasted dry summer and early fall conditions.

I may be prudent to have the CBWMP Steering Committee meet to discuss these recommendations or arrange a conference call for next week. It would be also useful to have the "20cms minimum before May 1" recommendation modelled in terms of its possible contribution to meeting the other conservation flow objectives outlined above.

Craig.