Summary of Columbia Lake Stewardship Society's 2020 Water Quantity Monitoring Program

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January 2021

Executive Summary

Despite the COVID pandemic, the Water Quality Monitoring Program operated throughout the year with only minor interruptions. Apart from a cold and wet December, near normal temperature and precipitation conditions prevailed over the Columbia Lake watershed during the fall of 2019 and the winter of 2020 leading to a slightly higher than normal snowpack by spring. Melt started about mid-April, but the usual progression of runoff was abruptly accelerated on May 31 when a significant amount of rain fell on the melting snowpack. Dutch Creek reached its highest level following the event and Columbia Lake rose by over 30 cm in a 24-hour period. There was also some local flooding. Despite the influx of water, the lake did not crest until almost one month later on June 25, about 2-3 weeks later than in previous years, and at the second highest level in the 7 years of monitoring.

Efforts that were started last year toward establishing the lake water balance continued. Precipitation, evaporation/evapotranspiration, runoff and groundwater define the rate at which water moves into or out of the watershed. An inventory was conducted to determine what is known and unknown of each including data requirements. Precipitation is inadequately measured. There are no measurements of the snowpack at high elevations. There are no stations suitable for estimating evaporation or evapotranspiration losses. Information from adjoining areas suggests those losses may be twice as great as precipitation gains by two-fold over the lake surface, and even evapotranspiration losses may equal precipitation gains at lower elevations. Wind, temperature, and humidity data are needed to better estimate the losses. Runoff cannot be calculated due to lack of representative streams. Outflow measurements from the lake suggest groundwater is entering the lake at a rate between 0.7 and 2.5 cubic metres per second in winter. No information is available in summer. In short, the inventory pointed to a need for more weather data.

Even with an adequate supply of weather data a balance cannot be achieved without accounting for water from Dutch Creek that enters and leaves the lake. More accurate flow measurements will be required at the WSC station and especially at the Dutch Creek station.

The water balance will best be established with use of a model. Modelling and the associated data management activities will require the help of specialists. Until additional resources are available, the Columbia Lake Stewardship Society (CLSS) should focus on continuing to operate the existing water level monitoring network to build up the database. CLSS should also work toward expanding the supply of weather data by either working with the Columbia Valley Airport Society to support continued operation of the CYCZ weather station, or by adding additional sensors to its own weather station.

1. Introduction

The Columbia Lake Stewardship Society started water quantity monitoring activities in the Columbia Lake Watershed in 2014. This is the seventh in a series of annual reports and it summarizes activities conducted during the 2019-20 water year.

From the outset, the purpose has been to establish a water balance by estimating the amount of water entering and leaving the lake. Long-term records reveal that the lake rises an average of about 0.9 metres each year. Work undertaken in previous years has shown that most of that water comes from Dutch Creek during the spring runoff. That water is important. It maintains the water quality at a healthy level, provides drinking water for residents, irrigates crops and supports the local tourism industry. It also provides the habitat that sustains wildlife and aquatic species. The demands for water to meet these needs are growing and are in conflict. Water quantity monitoring plays a vital role in defining a management strategy that will accommodate the demands of all users.

Measurement of the inflowing and outflowing water is complicated by the presence of the Dutch Creek delta to the north of the lake. Water is known to enter and leave the lake from the delta at several locations, not all of which can be monitored. The approach to date has been to measure the inflow upstream and the outflow downstream of the delta. The difference is assumed to have entered the lake. While this accounts for an understanding of the rise and fall of lake level, there are factors operating within the local lake drainage area that must be understood to refine the balance. Water enters the lake from local streams, precipitation and groundwater including subsurface transport from the nearby Kootenay River. These gains are offset by losses due to evaporation and evapotranspiration, consumptive use and outflow. The current emphasis is aimed at quantifying these local gains and losses.

Data collection and management is an important aspect of monitoring, and considerable effort has been expended to ensure that collected data are accurate.

2. The Watershed

For convenience of measurement, the outflow point of the Columbia Lake Watershed has been on the Columbia River at the Highway 93/95 crossing near Fairmont Hot Springs. The area of the drainage area above that point is 881 square kilometres. The bulk, 696 square kilometres, is contained in the Dutch Creek sub-basin. The boundaries of the watershed are shown in the inset of Figure 1.

The actual outlet from the lake is not at the Highway crossing but just over 3 kilometres upstream. A series of small creeks enter the Columbia River between the two points and constitute about 9 square kilometres of the entire 881 square kilometre area. Thus, the area above the outflow point is 176 square kilometres.

The flow of Dutch Creek over its delta is subject to change. In the present channel configuration, and when flow rates are low and unimpeded, water flows directly across the delta to enter the Columbia River, a few tens of metres below the actual outflow point. That has not always been the case. The main channel is continually shifting, and at certain times in the past Dutch Creek flowed into the lake before reaching the river (see Jamieson, 2011).

The overall watershed contains no active glaciers and is uncontrolled.

Figure 1 – Map showing station locations. Entire watershed boundary is shown in inset. Site abbreviations are provided in Section 4.1.

3. Antecedent and Concurrent Conditions

There are no weather stations within the watershed that have continuous long-term records. The closest station is the Cranbrook Weather Station (Cranbrook A) located at the Cranbrook - Kimberley Airport, some 60 km south of Canal Flats.

The mean monthly temperatures at that location for the 2019-20 water year (November 1, 2019 – October 31, 2020) are shown in Figure 2. The corresponding long-term normal values based on records accumulated over the 30-year period 1980-2010 are shown for comparison. A similar comparison is made for total precipitation in Figure 3.

The fall started out with temperatures above normal but they fell to below normal in December and didn't recover until almost February. They then remained near normal until July. August and September were warmer than normal. November was dry but precipitation amounts increased in December and fluctuated near normal values until May before falling off. The summer was unusually dry. Rain returned in October.

The *Snow Survey and Water Supply Bulletin* compiled by the River Forecast Centre (2020) stated that by April 1, when snow accumulation is generally greatest, the snowpack in the East Kootenays was 113 percent of normal.

Snow depths measured at the Fairmont Hot Springs Resort Ltd Ski Hill weather station (see Figure 1 for location) are shown in Figure 4. The station is within range of snowmaking equipment so it may not accurately represent the actual accumulation. However, the period of melt is believed to be accurately represented. Melt began in earnest at the beginning of April and was complete by month end. Since the station elevation is 1480 m, it can be deduced that the land surface at elevations beneath it and the 806 m elevation lake surface were nearly snow free by the end of April.

The accumulated precipitation recorded during the April-October period at the Timber Springs location is shown in Figure 5 along with the corresponding amounts for each of the previous six years for comparison. The 2020 season started out much like the previous seasons. A significant storm hit the area on May 31. The accompanying rain fell on melting snow and, as will be shown, caused a rapid rise in lake level and local flooding. After that event, moderate amounts of rain fell until mid-July and then tapered off so that the latter part of the season was quite dry.

In summary, the information from all sources points to near normal winter and spring temperatures from December onward and a slightly above normal snowpack. The summer and fall were warm and dry.

4. 2016 Activities

4.1. Stations

Four of the water level monitoring stations installed during 2014 and 2015 remained in operation. Their locations are shown in Figure 1. One was situated in the Columere Marina (Col) and measured lake level. The others were in the Headwaters Park near Canal Flats (CF), at the old Water Survey of Canada on the Columbia River near Fairmont Hot Springs (WSC) and on Dutch Creek at the Highway 93/95 Bridge (DC). A fifth station, Lansdowne Creek, installed in 2017 on Nature Conservancy of Canada property, also remained in operation. A sixth station (Outlet), installed in August 2019 on the Columbia River just below the outlet from the lake, continued to operate but only provides meaningful water level information during the October to April period. At other times the station is flooded by backwater from Dutch Creek. The Dutch Creek Station only operates during the open water season as ice jams during winter render data meaningless.

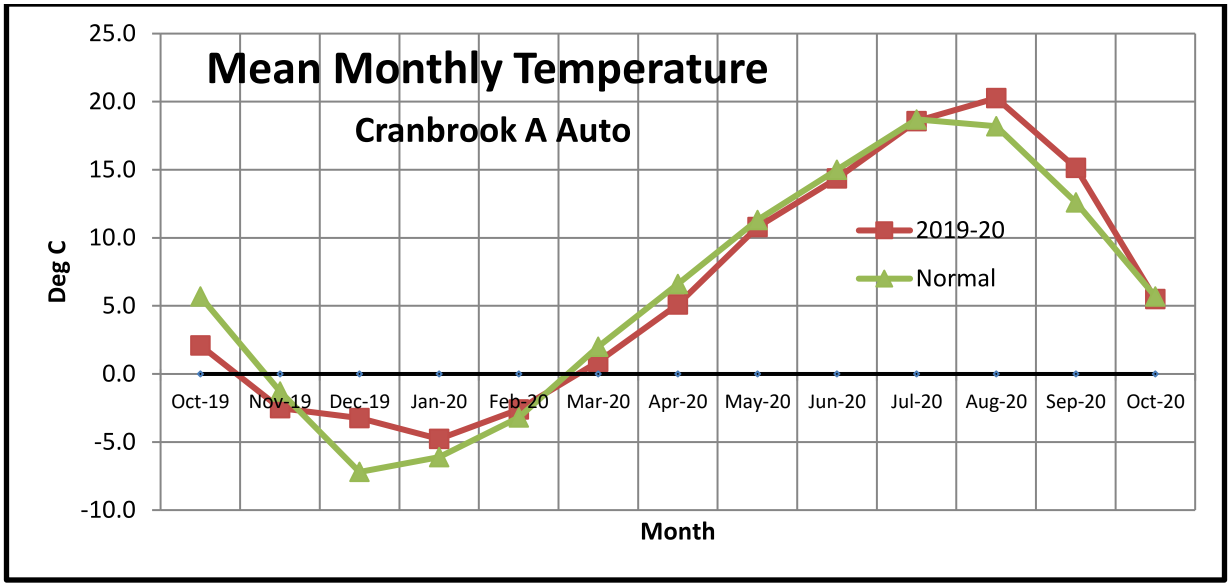

Figure 2 – Mean monthly temperatures at the Cranbrook- Kimberley Airport during the 2019-20 water year and the corresponding 1980-2010 long-term normal values.

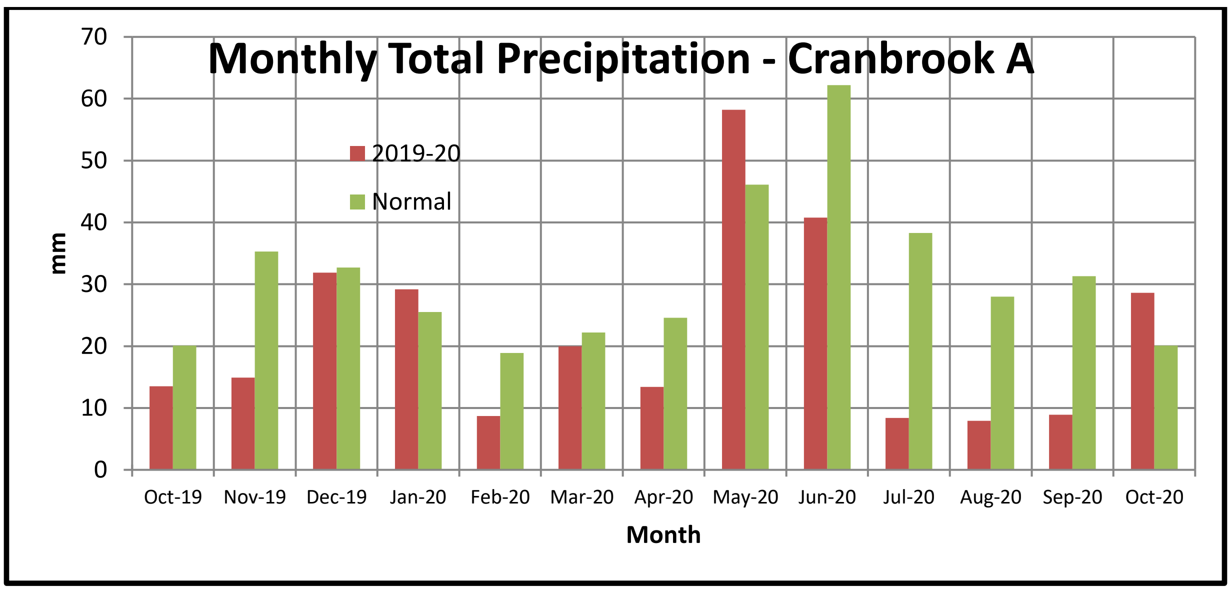

Figure 3 – As in Figure 2 except showing precipitation totals.

Two new stations were installed in April. One was on the Kootenay River near Canal Flats and the second in the south end of Columbia Lake (neither shown). Gillmor (2018), using data collected at monthly intervals, found that the hydraulic gradient between the two water bodies remained nearly uniform throughout the year. Short term variations in water level have been observed in the CF record and the purpose was see if by sampling more frequently, corresponding short term changes in the hydraulic gradient that went undetected might be exposed and account for the variations. The hydraulic gradient is the force driving water from the Kootenay River into Columbia Lake and its variation is important to understanding changes in the rate of inflow to the lake. The initiative failed when the Kootenay River station was dislodged by debris during high water.

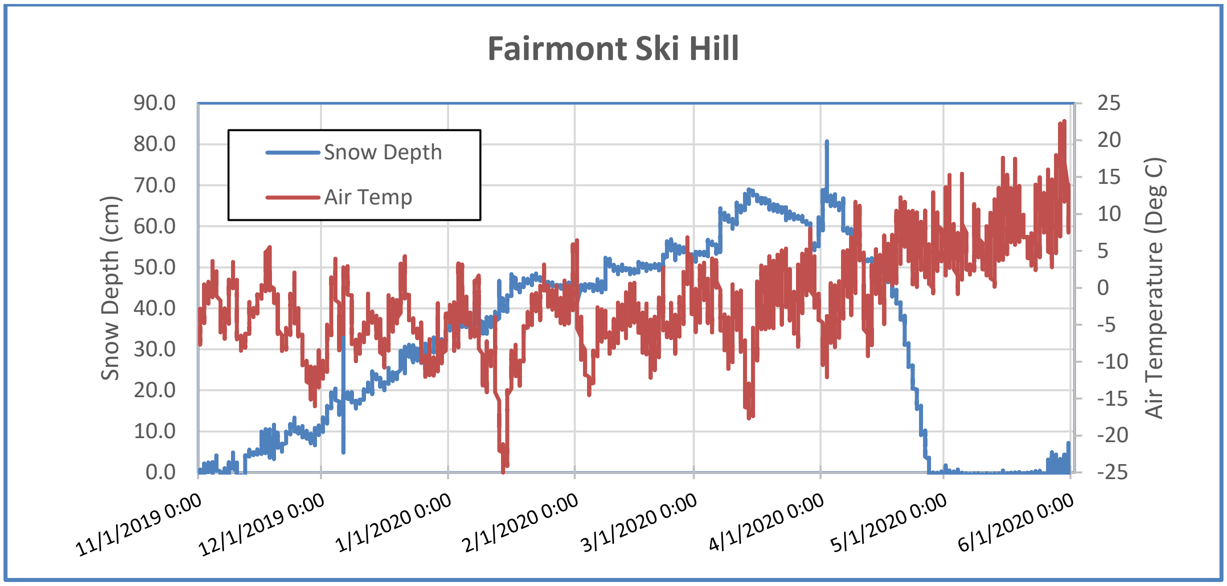

Figure 4 – Snow Depths and temperatures recorded at the Fairmont Ski Hill weather station.

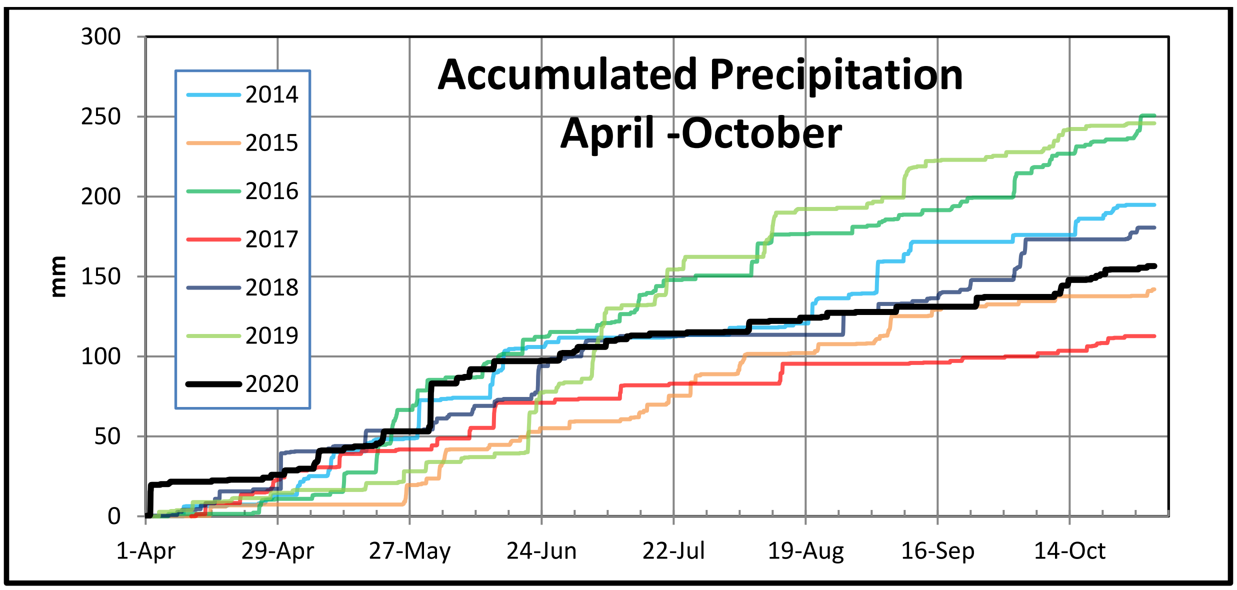

Figure 5 – Accumulated precipitation during the 2014 – 2020 summer seasons at Timber Springs. In 2020 the rain gauge was not installed until April 6 and amounts recorded at CYCZ are substituted.

The recording rain gauge located in the Timber Springs community does not operate over winter. It was opened for the season on April 6 and closed on December 7, 2020.

A weather station is operated at the Fairmont Hot Springs Airport (CYCZ) for aviation purposes. Data were abstracted from the database stored onsite and filtered to obtain hourly values of wind speed and direction, temperature, dew point, visibility, precipitation, and atmospheric pressure. The abstracted record extends from December 19, 2019 to September 22, 2020. The pressure data were used to verify the accuracy of the pressure sensors in the data loggers. Pressure data continued to be collected on an intermittent basis after September 22 by telephone.

4.2. Equipment Purchases

One new data logger was purchased during the 2019-20 water year. It was installed at the Canal Flats site to replace an ageing logger.

4.3. Data Collection and Management Issues

The accumulation of silt and algae remained a problem at the Columere Marina site despite the logger having been elevated in April 2018. Steps continued to be taken to remove the silt. A backup logger was also installed nearby to verify that the detritus was not interfering with the logger elevation.

The logger at the Lansdowne site stopped January 11 and was not restarted until May 27. There is no water level data for that period. Water temperature is measured nearby by the Nature Conservancy of Canada and values from that location were substituted for the intervening period.

Measures taken to slow the spread of the COVID virus impacted operations to some extent. The Columbia Lake Provincial Park was closed preventing access to the Outlet and Lansdowne sites during April and May but otherwise, the data collection program was not significantly hampered. They also made it necessary to halt the abstraction of data from the Fairmont Airport weather station after September 22 because the work had to be conducted in a confined environment in the presence of others.

As noted, equipment including the logger, stilling well and intake installed on the Kootenay River near Canal Flats on April 9 was lost a few weeks later when impacted and dislodged by floating debris. They have not been recovered.

As additional stage-discharge points were added to the WSC rating curve, they revealed an emerging disconnect between flow measurements made by wading and those made from the highway bridge. A review revealed that inadequate compensation had been made for downstream drift of the current meter during bridge measurements with the result that water depths were overestimated. This led to excessive discharge rates. In the future, steps will be taken to measure drift more accurately. In the meantime, the rating curve shown in Figure 12 of the 2017 Annual Summary depicts excessive flow rates in high water. The accompanying original WSC curve should be used until more measurements are available.

4.4. Sensor Accuracy

The performance of the loggers is routinely checked. The steps involved and corrective measures that were applied are outlined in Appendix A.

5. Water Temperature and Level

5.1. Winter 2019-20

The winter water temperature and water level records for all stations are shown in Figures 6 and 7 respectively. Note that the logger at the Dutch Creek station was removed November 9 when ice floes began to appear.

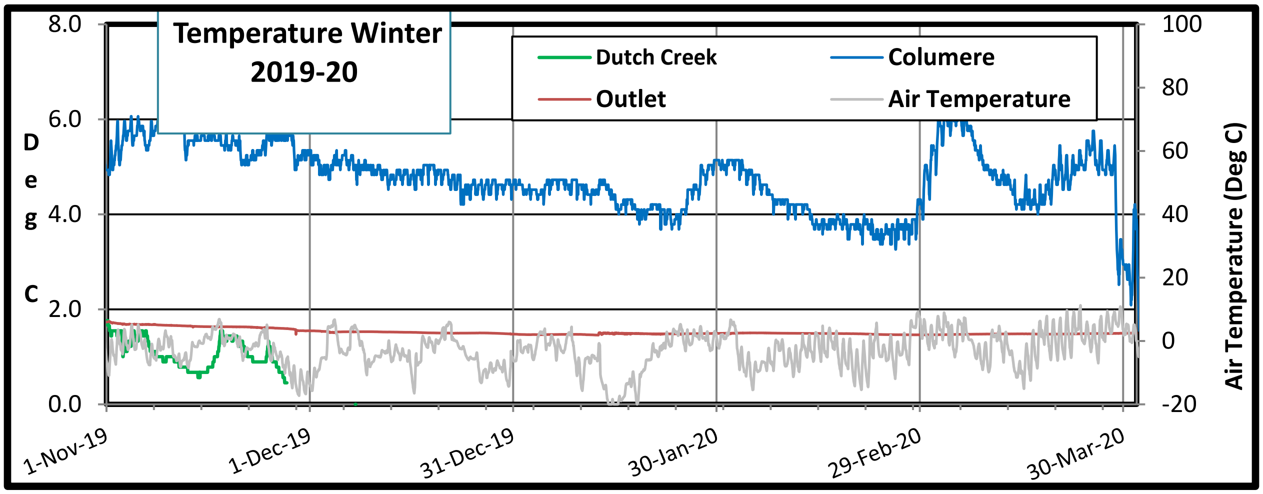

Figure 6 – Winter water temperatures. Air temperatures recorded at Timber Springs superimposed at bottom of chart. Air temperatures below -20°C were not recorded.

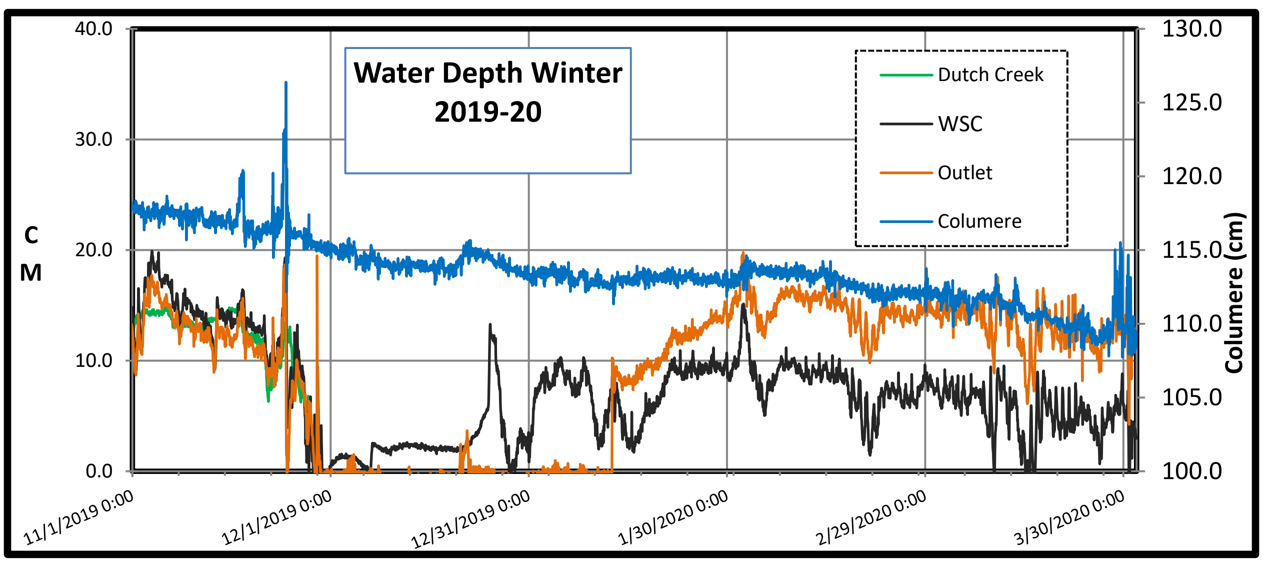

Figure 7 – Winter water depths as recorded by loggers. The intakes at the Dutch Creek and WSC sites are exposed at low water levels and are subject to freezing so that water levels below about 8 cm should be used with caution. The logger on Dutch Creek was removed in late November due to the presence of ice floes.

The air temperature recorded at Timber Springs is superimposed in Figure 6 for comparison. It was measured using a data logger (BARO). It has a cutoff temperature of -20°C and will not record below that level. It was fitted with a shield to reduce radiative effects.

5.2 Open Water Season 2020

5.2.1 Water Temperature

The water temperatures recorded during the open water season are shown in Figure 8. The Outlet temperatures delineate the period during which Dutch Creek flowed into the lake. About mid-May, the temperatures approached those of the lake indicating the passage of water out of the lake and then abruptly dropped to those of the Dutch Creek indicating the passage of water from the creek into the lake. The flow reversal dominated for some time but gradually gave way to the normal outflow condition in early July as depicted by the return of temperatures corresponding to those of the lake.

The cooler temperatures recorded at CF are attributable to the creek's groundwater source.

Air temperatures recorded at CYCZ are shown at the bottom of the chart for comparison.

5.2.2 Water Level

The recorded water levels are shown in Figure 9. The levels represent the depth of the water above the logger and bear no relationship to any known elevation standard. Backwater from the lake engulfs the Canal Flats station during mid-summer so that the rise during that period does not represent a corresponding increase in flow. The large number of spikes in the Columere and Canal Flats records are due to wind set-up.

The lake reached its highest level on June 25 at an elevation about 110 cm above its mid-April level. In contrast to previous years, this event did not coincide with the peak on Dutch Creek. That occurred on May 31 following a significant fall of rain on a melting snowpack. Although that event caused the lake to rise by over 30 cm during a 24-hour period, substantial snow remained adding additional meltwater to the lake over the following weeks.

The water levels recorded on Columbia Lake during each of the seven water years from 2013-14 to 2019-20 are shown in Figure 10. The peak recorded on June 25 was the second highest of the seven-years.

5.2.3 Rating Curves

Flow measurements were made on the Columbia river at the WSC site and also at the Outlet location. As noted above, the measurements at the WSC site revealed the need for an adjustment of the rating curve at that site. The measurements at the Outlet site will be discussed below.

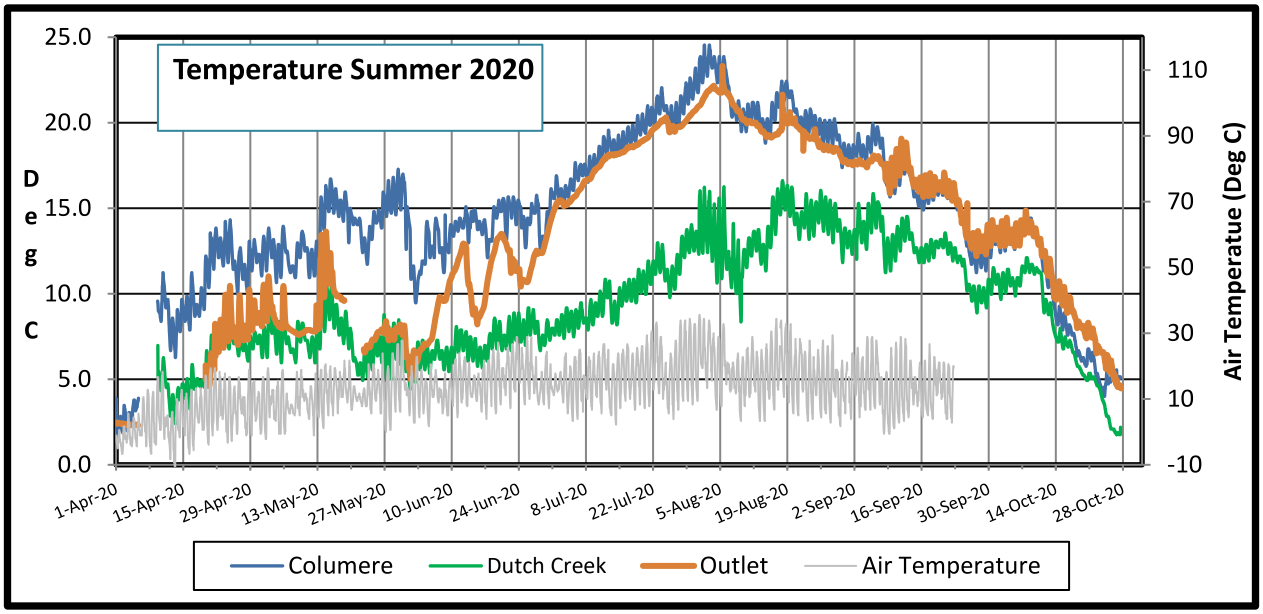

Figure 8 – Water temperatures. Air temperature at CYCZ also shown.

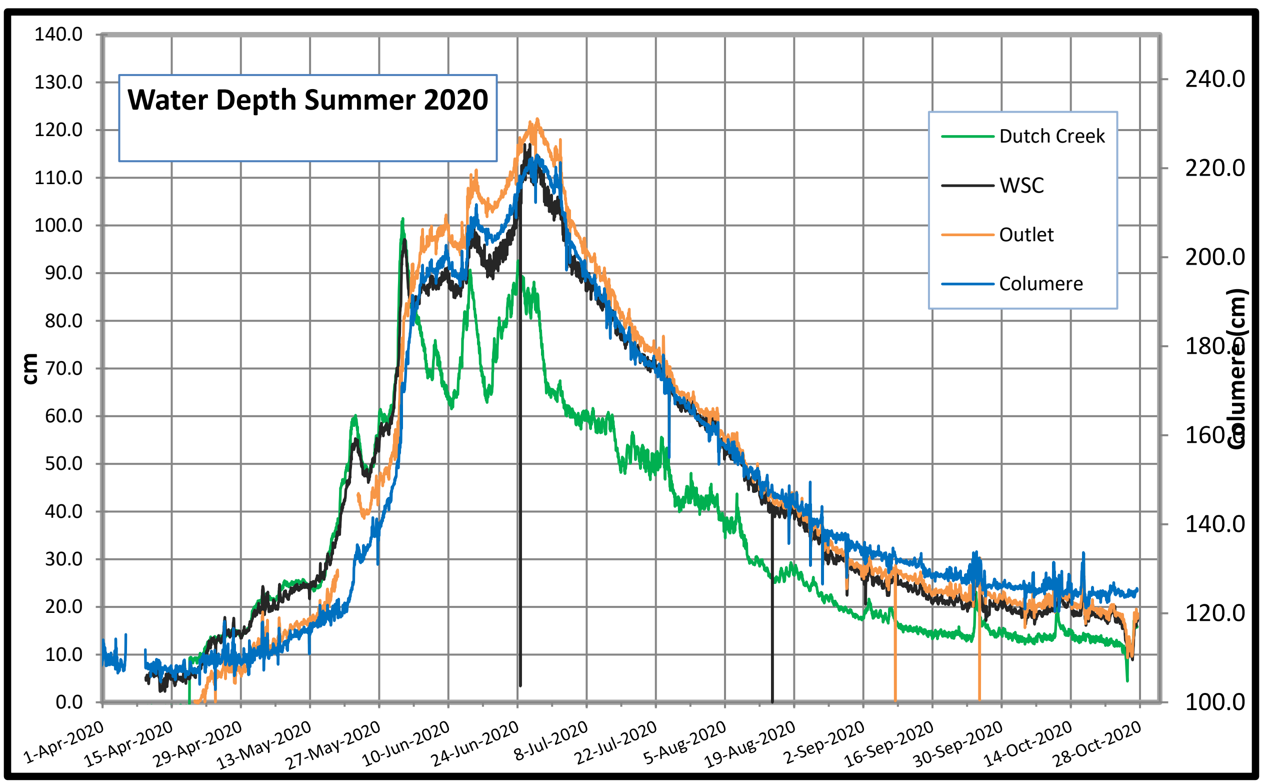

Figure 9 – Hourly water levels. Depths are as recorded by loggers and do not relate to a common reference level.

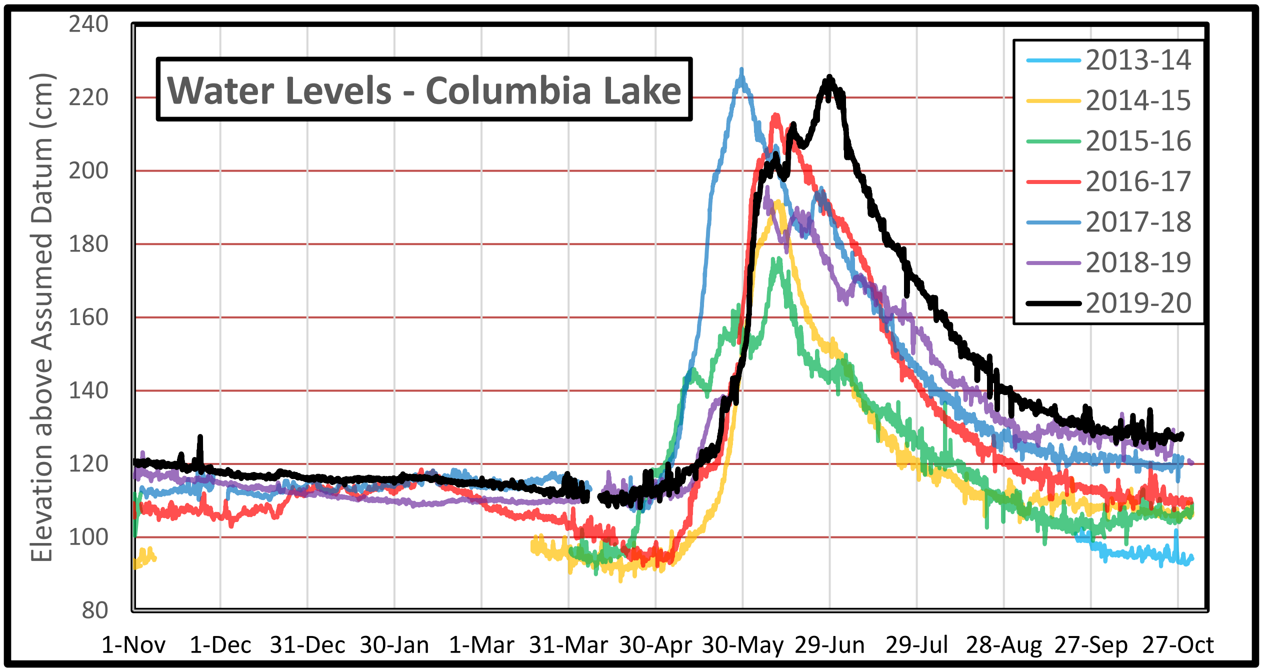

Figure 10 – Water levels recorded on Columbia Lake during the seven water years 2013-14 to 2019-20 inclusive. Levels are above an arbitrarily selected common datum. The lake is ice covered from approximately mid-November to mid-March. The logger was located beneath ice during those periods.

6. Local Water Exchanges

The Columbia Lake Stewardship Society's focus is Columbia Lake. Precipitation, evaporation and evapotranspiration, runoff and groundwater within the local basin influence the lake level as does consumptive use. This section examines their respective influences, describes what is known and unknown of each and addresses data needs.

Charts showing the results of data collected in the local basin during the present water year are shown in Figures 11 to 14.

6.1 Outflow

Outflow represents the integrated result of all meteorological and hydrological processes taking place upstream. Normally, the point at which water leaves the basin provides a convenient reference against which those influences can be evaluated and for that reason a water level monitoring station (Outlet) was installed (see 2019 Summary) with the hope that it would provide useful information, at least during the low flow season.

The hoped-for usefulness was not fully realized. Backwater occasionally extended upstream from the Dutch Creek junction impeding flow so that the relationship between stage and discharge was poor. Further, ice jams occasionally occurred in the creek causing water to be diverted through side channels into the lake from where it returned through the outlet to the Columbia River.

However, flow measurements taken at the site did provide a range of outflow rates. The outflow was measured 9 times between September 19, 2019 and Dec 20, 2020 and the results are shown in Table 1. Flows ranged from 0.7 to 2.5 cubic metres per second with a mean of 1.75 cubic metres per second.

Table 1 – Outlet Station Water levels and Flows

Date	Water Level Above a Common Reference (cm)	Flow Rate (m^3sec)
Sep 22, 2019	29.0	2.5
Oct 24, 2019	12.0	1.6
Apr 5, 2020	10.9	1.1
Apr 19, 2020	0.1	1.5
Aug 25, 2020	32.8	1.9
Sep 8, 2020	26.9	1.8
Sep 25, 2020	28.1	2.1
Oct 11, 2020	23.9	.7
Dec 20, 2020	7.5	2.5

6.2 Sources of Gains and Losses

6.2.1 Precipitation

Precipitation amounts are influenced by topography and increase with increasing elevation. Exposure is also a factor with amounts expected to differ between east and west facing slopes.

The existing monitoring network is inadequate to define either influence. The only measurements of precipitation currently being made within the basin take place at Timber Springs where a rain gauge is operated on a seasonal basis. It is at an elevation of about 860 metres above sea level and about 40 metres above lake level. Rainfall was recorded in the past on an intermittent basis in the Village of Canal Flats.

Two weather stations just outside the basin boundary are, however, representative. One, owned by the Fairmont Hot Springs Airport (CYCZ) but located on adjacent property, measures a variety of meteorological parameters including precipitation. It is geared to serving the aviation community so that the data must be filtered and reformatted for hydrometeorological applications. Data are stored on site and a database of several years exists though there are extended interruptions. Data are occasionally retrieved mainly for validating the accuracy of pressure sensors but filtering and reformatting the data are time consuming operations. Ownership of the airport has recently been transferred to the Columbia Valley Airport Society and continued operation of the weather station is under review. It may not continue to be an information source.

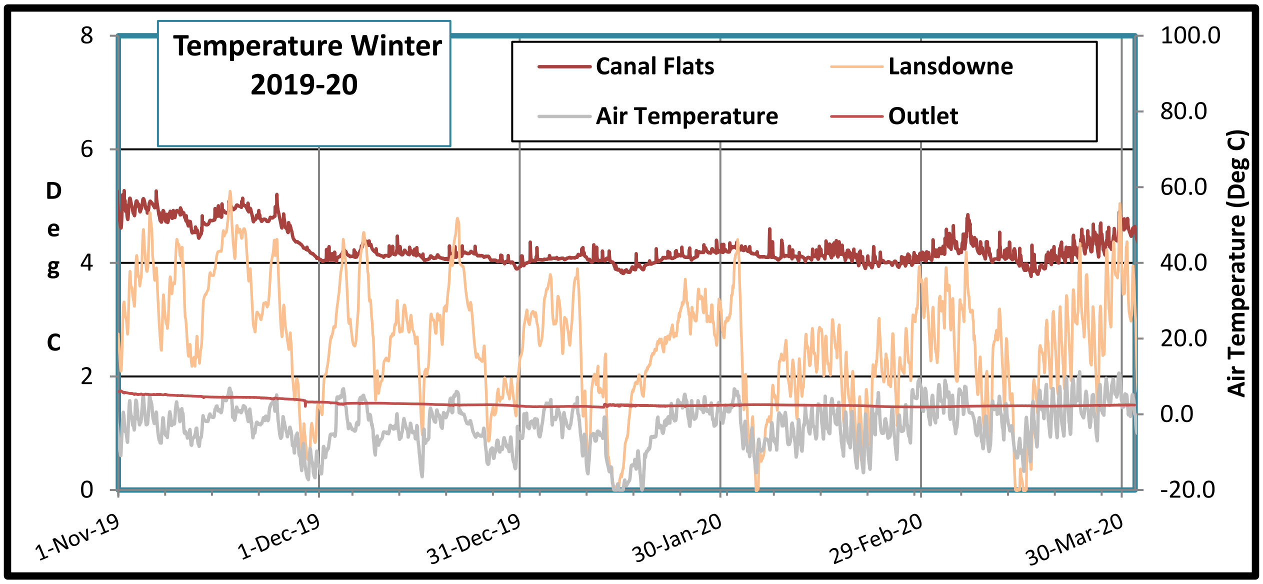

Figure 11 – Winter water temperatures. Air temperature at Timber Springs shown at bottom.

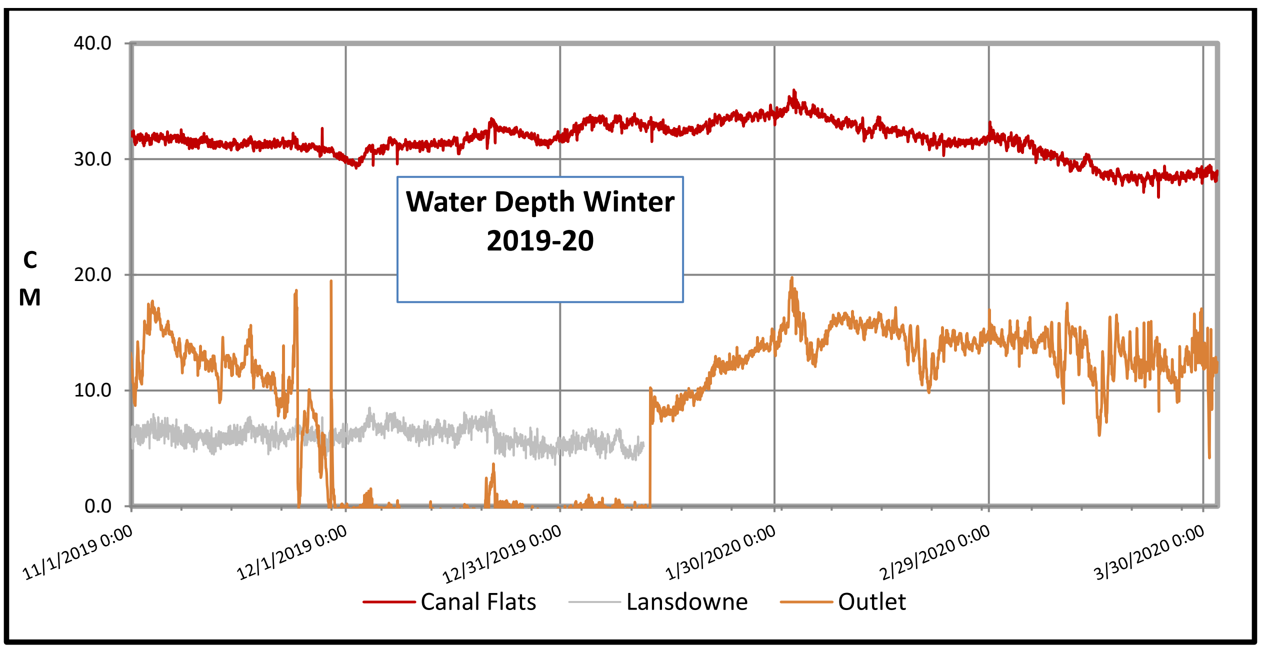

Figure 12 – Water depths during winter. Lansdowne logger stopped operating January 11. Outlet water level below intake December – January.

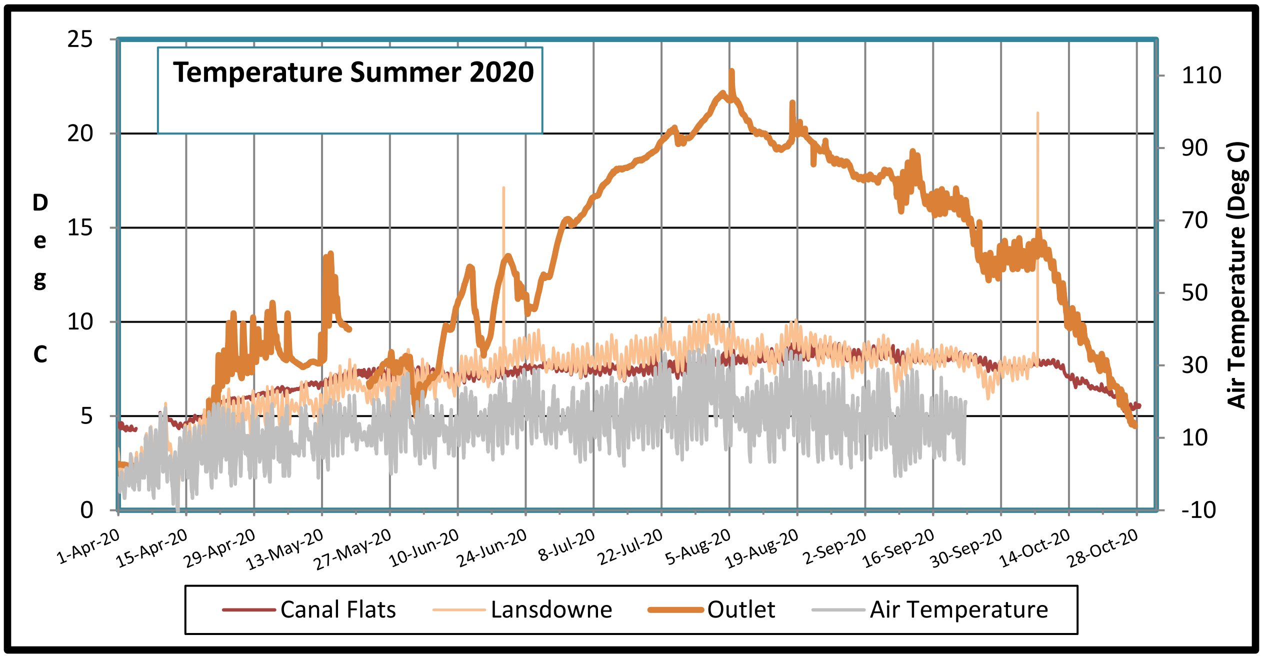

Figure 13 – Water temperatures. Air temperature at CYCZ also shown.

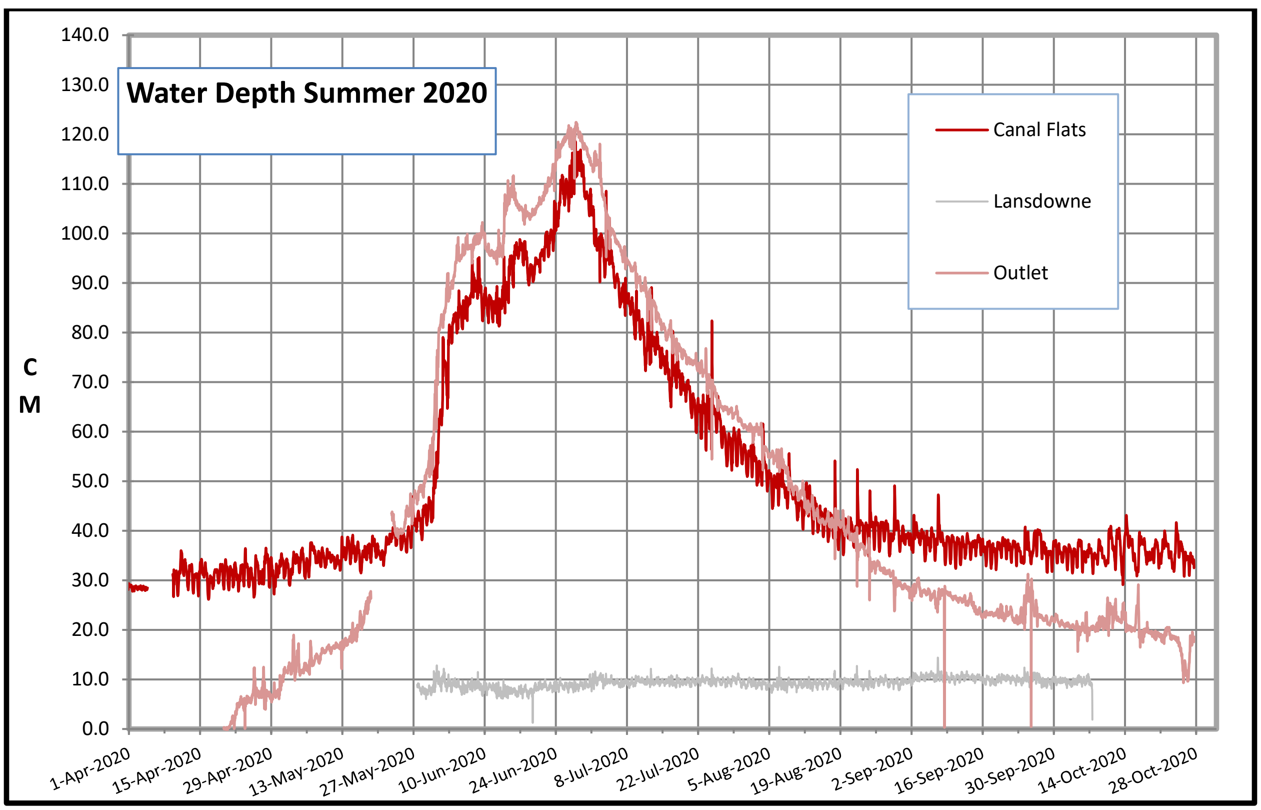

Figure 14 - Hourly water levels. Depths are as recorded by loggers and do not relate to a common reference.

The second weather station is operated on the Fairmont Ski Hill as part of the Fairmont Flood Mitigation Project. At an elevation of 1480 metres, it measures rainfall, temperature, and snow depth. The information is useful for assessing melt rates and, when used in conjunction with a valley bottom station, for estimating temperature and precipitation lapse rates.

Other weather stations exist but at greater distances. They include those operated by the BC Ministry of Highways and Infrastructure and the BC Wildfire Service. They have the appeal of being located at high elevations and integrated into telecommunications networks so that the data are available in real time.

Not all precipitation information is available from ground-based stations. Environment Canada operates a network of weather radar stations across Canada. Radar can determine precipitation intensity and type in a range of about 120 km. The East Kootenays are on the fringe of the range of the two nearest radar stations and some analysis will be required to assess their value.

6.2.2 Evaporation/Evapotranspiration

A significant amount of water is lost through evaporation. The lake makes up about fifteen percent of the area of the basin. Water is also lost through evapotranspiration but at a lesser rate.

There are no known estimates of evaporation loss in the area but estimates do exist in adjoining areas. Alberta Environment and Sustainable Resource Development (ESRD) gives annual amounts for shallow lakes ranging from 750 mm per year near Calgary to 825 mm near Lethbridge. The Okanagan Water Supply and Demand Project gives losses for the Okanagan lakes ranging from 905 to 1068 mm. The recorded average annual precipitation measured at Canal Flats was only 369 mm, so the evaporation loss from the lake surface may easily double the gain from precipitation. ESRD also records evapotranspiration losses at Calgary at 397 mm per year, again exceeding the annual precipitation rate. If this figure is representative, it would only apply to lower elevations.

The amount of evaporation can be estimated from wind speed, relative humidity and surface water temperature. Wind speed and humidity are measured at CYCZ and surface water temperature is routinely measured by the CLSS.

6.2.3 Runoff

Surface runoff represents the integrated effects of precipitation and evapotranspiration over the land surface. Where measurable, it negates or greatly reduces the need for measures of precipitation and evapotranspiration. The usual approach for calculating runoff is to divide the volume of water leaving the basin by its area, but in view of the inability to measure outflow that is not feasible. Another approach is to calculate runoff per unit area in a few representative basins and assume that rate applies to the entire watershed. Unfortunately, few representative streams exist. Most streams draining into the west side of the lake are subject to withdrawals or are controlled. One of the few streams of adequate size draining into the east side of the lake is Lansdowne Creek. Its record for the present year is shown in Figures 12 and 14. In this and previous years, it has not exhibited the seasonal variations displayed by other local streams so that it may also not be representative; therefore its use as a reference is questionable.

6.2.4 Groundwater

Water oozes from numerous locations along the shoreline of the lake and probably also from the lakebed. Assuming that precipitation, evaporation, evapotranspiration, and consumptive use are at a minimum during the winter months, groundwater constitutes most of the outflow. On that basis, Table 1 suggests that the rate of groundwater entry into the lake, including that passing through the acquifer beneath Canal Flats from the Kootenay River, is between 0.7 and 2.5 cubic metres per second during winter. It is not known if that range is applicable during summer.

A detailed examination of groundwater movement should be conducted by a hydrogeologist.

6.4 Discussion

The lake outlet is not going to be a suitable reference point even during the low flow season. The alternative is the lake level. The amount of water entering or leaving the lake can be determined from changes in lake elevation. This cannot be done without difficulty. Fluctuations in level due to wind need to be removed. Furthermore, the Dutch Creek contribution must be more accurately calculated. It overshadows the local influences and small errors in its calculation will mask them. The best available platform to measure flows is the highway 93/95 bridge. Its narrow width, high traffic volumes and extruding vertical beams make measuring flow during high water difficult.

Models exist that can be adapted to evaluate the upstream processes. The processes are simulated by physical relationships and driven by routinely measured meteorological and hydrological parameters. Once configured, the model is calibrated to match computed outflow with actual outflow by adjusting the input parameters to obtain a best “fit”. The calibrated model can then be used to evaluate “what if” impacts on lake level resulting from events such as drought, changes in land use and withdrawals and, conversely, to evaluate remediation alternatives to restore lake health.

The foregoing are not simple tasks. A substantial increase in monitoring will be required, and with it an increased need to manage data. Furthermore, technical and professional skills are required. All are beyond the capacity of a volunteer organization.

A reasonable approach is to recognize the foregoing as a framework and to undertake activities that in time will produce results. Activities that can be conducted with available resources include continued operation of the existing water level monitoring network and ensuring a continued supply of weather data either by supporting the Columbia Valley Airport Society to continue operation of the CYCZ weather station or by upgrading the existing Timber Springs station.

Agencies engaged in flood protection, resource development, stewardship, natural resources and environmental management, and highways maintenance share similar data needs, and consideration should also be given to working collaboratively with them to establish data collection programs of common interest.

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8. Acknowledgements

Amira Elwakeel, a UofC student, was of great assistance in downloading and compiling data and especially in devising a means to filter out relevant information from the CYCZ data base. The assistance of Duncan Shipley, a volunteer and recent Mt Royal University environmental program graduate, was invaluable in installing and maintaining field equipment and measuring streamflow.

Thanks to Tom Symington and Duncan Shipley for taking time to review this document and provide helpful comments.

The support of the following organizations and individuals is gratefully acknowledged:

Columbia Valley Local Conservation Fund
Regional District of East Kootenay
Lake Windermere Ambassadors
Columere Marina
Fairmont Hot Springs Resort Ltd. including the Riverside Golf Course and Fairmont Hot Springs Airport
Village of Canal Flats
Columbia Ridge Community Association
Timber Springs Community Association
Columere Park Community Association
Spirits Reach Community Association
BC Lake Stewardship Society

Appendix A

Accuracy of Measurements

The integrity of an analysis depends on accurate measurements. The following describes the steps taken to evaluate equipment performance and to minimize error.

A1 -Water Level

Water information was collected using data loggers. The loggers measured pressure and temperature and recorded them in internal memory. The loggers were programmed to record every hour on the hour. Two different brands, Diver and HOBO, have been used. Over the past two years new loggers have been purchased to replace the original loggers, some of which had began to exhibit substantial drift.

All loggers are non-vented. This means that the sensor measures the pressure exerted by the column of water above the logger plus that of the atmosphere. The atmospheric pressure must be removed to obtain the pressure exerted by the water alone. Once removed, water depth can be calculated from the water pressure. Atmospheric pressure was measured using a separate logger (HOBO logger 325) mounted at the WSC site. Most stations are located at lake level so that an elevation adjustment is not required. Exceptions are the Dutch Creek station which is 24 metres above lake level and the Lansdowne station at roughly 40 metres above lake level.

HOBO logger 325 (H325) also served as the standard for evaluating the performance of all other loggers. Its accuracy in turn was periodically evaluated against the barometer at the Fairmont Hot Springs Airport (CYCZ) also located at lake level. Samples of pressures recorded at both locations over four periods during the year were collected and the mean differences calculated. The results are shown in Table A1. The differences are small and do not warrant applying an offset factor to the H325 values. In short, the logger accurately recorded atmospheric pressure.

Table A1

Sample Period	Sample Size	CYCZ Mean Pressure (cm H2O)	H325 Mean Pressure (cm H2O)	Pressure Difference (cm H2O)
12/19 12:00 -1/15 17:00	653	936.1	936.1	0.0
3/19 00:00 – 4/5 16:00	423	935.6	935.8	-0.2
8/1 00:00 – 8/17 23:00	408	938.9	938.6	0.2
9/1 00:00 – 10/25 23:00[1]	11	937.25	936.95	.3

1. CYCZ values derived from altimeter setting, all others are station pressures.

Laboratory calibration was not undertaken due to cost. However, all loggers except 1368 were taken out of service at the beginning and the end of the open water season and collocated with H325 over periods of a few days. The resulting pressure records are shown in Figures A1 and A2. The pressure sensors were not all in agreement thereby indicating a need for an offset adjustment. The mean offsets from H325 at the beginning, middle and end of the water year are shown in Table A2. The offsets were applied at the beginning of the water year (November) and mid-year (April) following the respective comparison tests.

Lansdowne Creek is in a remote location and is only visited 3 to 4 times per year. It is inconvenient to make special visits to remove and return the logger. Hence, spot readings were made during periodic summer visits and compared with H325 considering the elevation difference. The pressure sensor drifted considerably in previous years but remained consistent over the 2019-20 year.

No attempt was made to compensate for the effects of temperature on water density. Such compensation, had it been applied, would have resulted in a change of water depth by one centimetre at Columere at most, and much less elsewhere.

Table A 2 – Measured Offsets from H325 during Calibration trials

Logger ID	Oct-2019			Apr-2020			Oct-2020	
	Mean	Offset from H325	Offset Applied Oct-Apr	Mean	Offset from H325	Offset Applied Apr-Oct	Mean	Offset from H325
U5972	954.2	5.2	-5.2	940.9	5.4	-5.4	944.6	5.1
1459	953.2	4.2	-4.2		4.5	-4.5	944.6	5.1
1368[2]			-27.4			-27.4		
1455	970.4	21.4	-21.4	956.3	20.8	-20.8		
1366	945.0	-4.0	4.0	931.2	-4.2	4.2	935.5	-3.9
BARO	951.2	2.2	-2.2	937.7	2.3	-2.3	940.6	1.2
H342	946.0	-3.0	3.0	935.2	-.3	N/A		
H109	945.5	-3.5	3.5	930.8	-4.7	4.7	935.2	-4.2
H326	949.6	.6	-.6	936.6	1.1	-1.1	938.8	.3
H325	***949.0[1]***	***0***	***0.***	***935.5***	***0.***	***0***	***939.4***	***0.***
H013[3]				936.3	.9	-.9	940.3	.8
H012				936.1	.6	-.6	940.3	.8
AV083				935.5	.1	-.1	939.5	0.0

[1] Pressure not recorded Oct 2019. Pressure assumed to have remained 0.6 cm H2O below H326 as per April 2019

[2.] 1368 only compared periodically

[3.] H013. H012 and AV083 acquired December 2019 and installed April 2020

Table A3 – Logger Deployment During 2019-2020 Water Year

U5972	Out or service – November 1 – April 9 DC – Backup - April 9 – October 27
1459	Canal Flats Nov 1- April 4 Out of service April 4-19 WSC – backup April 19- Oct 31
1368	Lansdowne
1455	Out of Service – Nov 1 - 25 CF – backup – Nov 25 – April 4 Out of service – April 4 - 21 April 21 – lost during installation on Hardie Creek
1366	Outlet
BARO (1601)	Timber Springs – Atmospheric Pressure (Back-up) – Nov 1 – May 1 Col – backup – May 1 – Oct 27
H342	DC – Nov 1 – 27 Out of service Nov 27 – April 9 KR – installed new station April 9, later lost in high water
H109	WSC – Nov 1 – April 5 Col Lk S – April 9 – October 27
H326	Columere – Lake Level
H325	WSC – Atmospheric Pressure sensor
H012	WSC – Installed April 20 - new logger acquired Dec 19
H013	DC – Installed April 20 – new logger acquired Dec 19
AV083	CF – Installed April 20 – new logger acquired Dec 19

A2- Water Temperature

Beginning and end-of-season comparisons of the temperature sensors were made in similar fashion. The records are displayed in Figures A3 and A4 respectively. Some of the loggers received a bit more sun exposure than others during the April trials causing them to record slightly warmer temperatures. Otherwise, good agreement is shown.

A3- Other

Other steps were taken to ensure the integrity of the data. Manual measurements of water level were taken at each location periodically during the season to verify the accuracy of the recorded measurements. The stilling wells and intake pipes at each of the stream sites were periodically back flushed.

The current meter was calibrated by the manufacturer prior to purchase and has not been further calibrated.

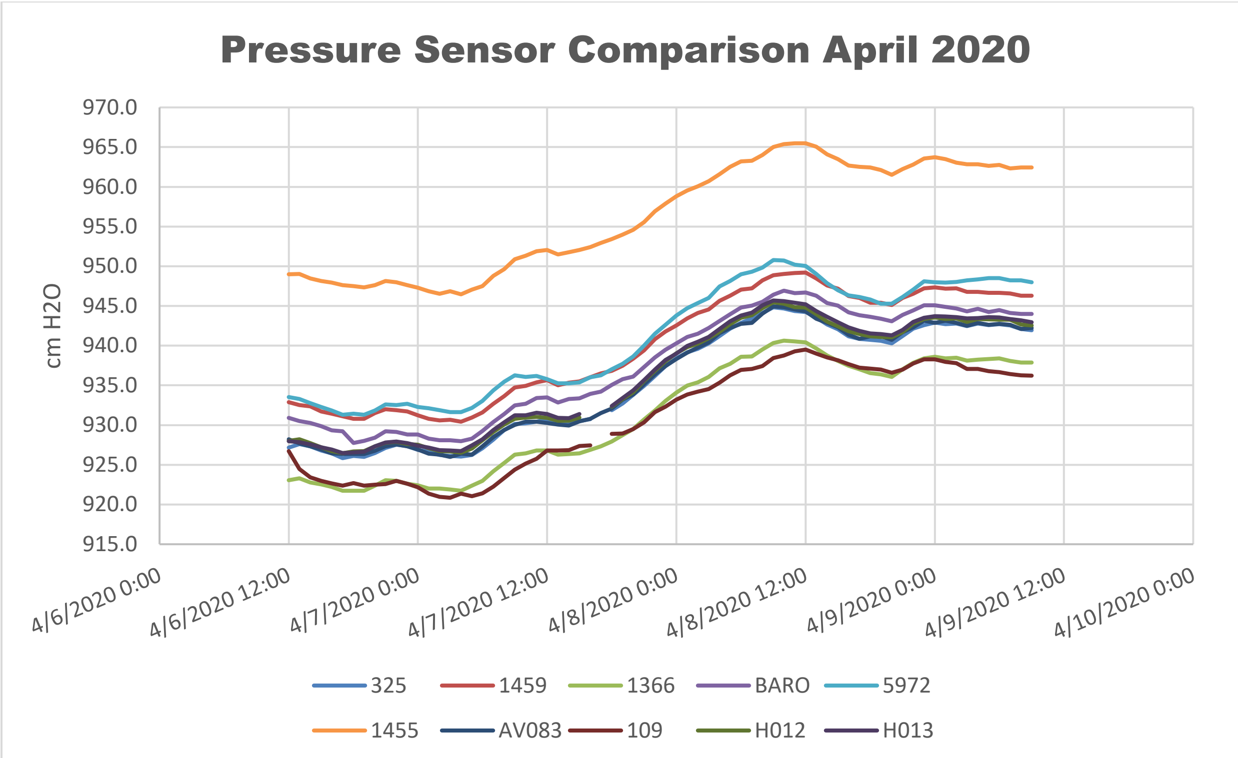

Figure A1 – Pressure readings from all loggers in relation to H325 at the start of the open water season.

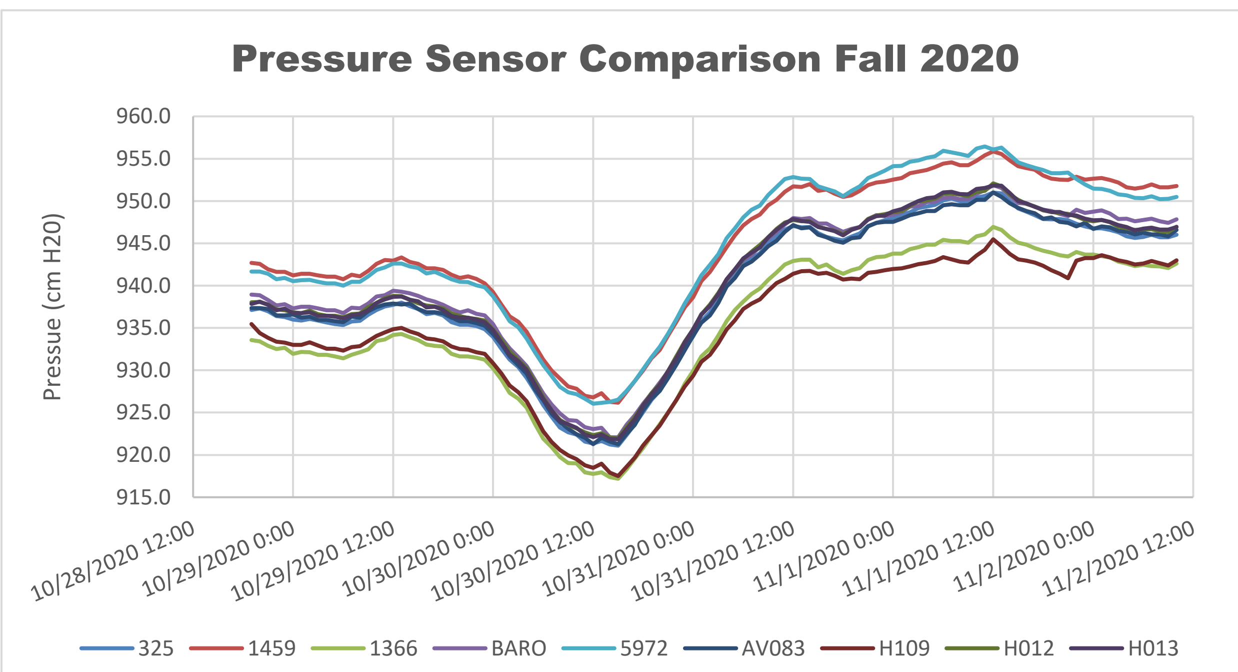

Figure A2 – Pressure readings from all loggers in relation to H325 at end of water year.

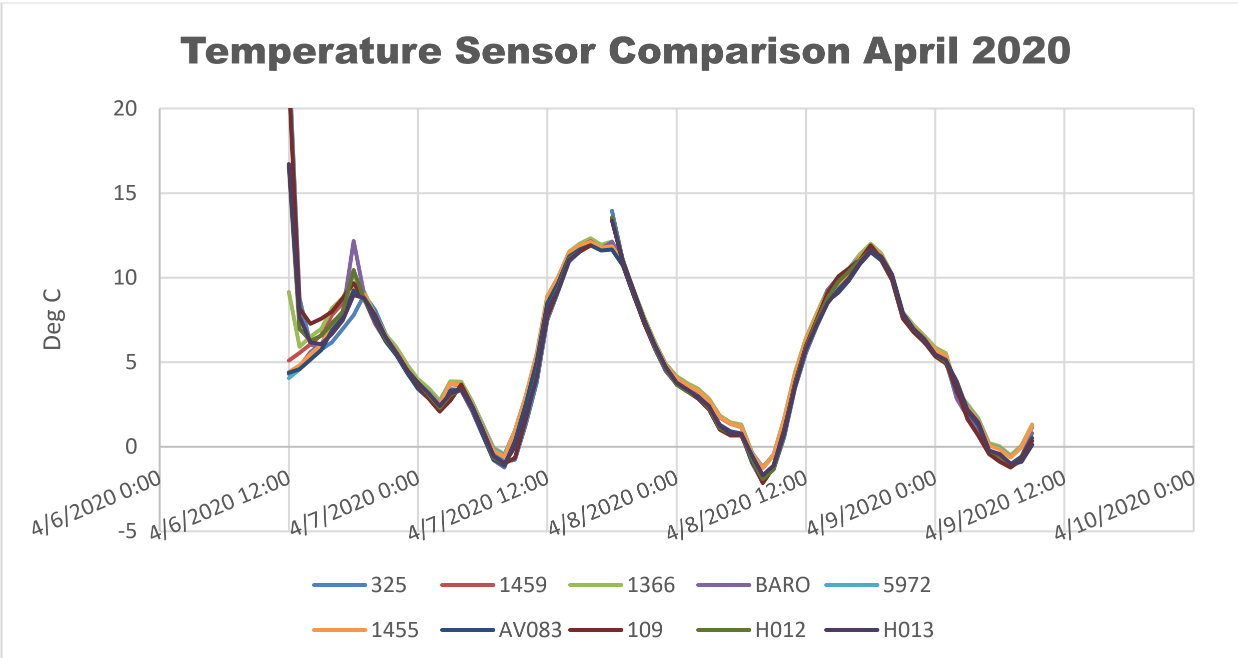

Figure A3 – Temperature readings in relation to H325 at the start of the open water season.

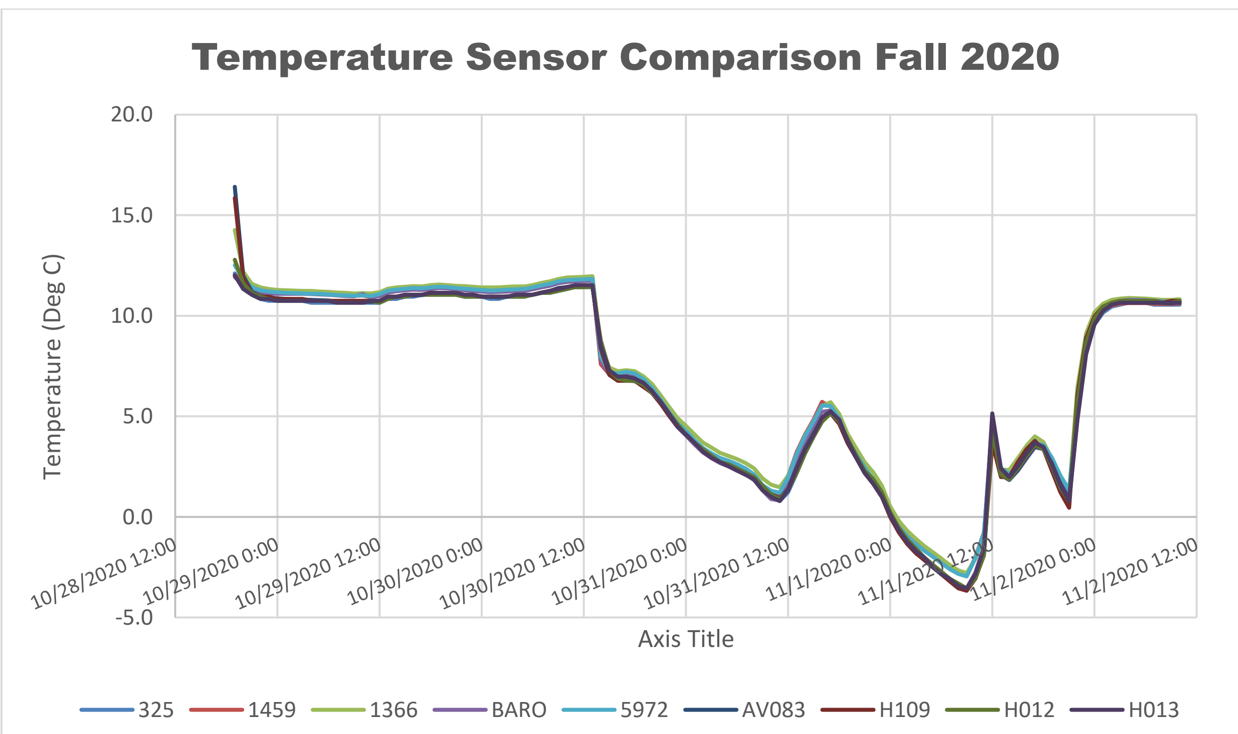

Figure A4 – Temperature readings in relation to H325 at the end of the water year.