Summary of Columbia Lake Stewardship Society's 2015 Monitoring Program

Prepared by W. Thompson
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Executive Summary

The Columbia Lake Stewardship Society successfully completed its second year of water quality and water quantity monitoring in the Columbia Lake watershed.

Water quality monitoring on Columbia Lake began in April shortly after breakup. By the time the season ended in mid-October fifteen sampling missions had been completed. The sampling was again carried out at four points but two of the sites, S3 and S4 were moved 1.7 km and 2.4 km southward respectively, from the 2014 locations to coincide with historical locations. Ten parameters: dissolved oxygen (two levels), water temperature (surface and bottom), conductivity (top and bottom), pH, turbidity, and water clarity were measured. On six of these missions samples were taken to be analyzed for phosphorous and nitrates. In the absence of local objectives, the objectives for Lake Windermere were used as a reference. All parameters were in or very close to compliance with exception of levels of total phosphorous. In addition to the sampling missions, water temperature was continuously monitored in two inflowing streams, in the outflowing Columbia River and in Columbia Lake itself.

Water quantity monitoring resumed in late March at the two stations installed in 2014. A third station was installed in the Columbia Lake Headwaters Park near Canal Flats in early May and a fourth on Dutch Creek in late July. Manual readings were also taken from staff gauges at the Dutch Creek and the old Water Survey of Canada sites. Towards the end of the season the old Water Survey of Canada site was remediated and readied to be put back into operation in 2016. Fifty six years of records exist from that location and provide an excellent set of baseline data with which future data can be compared to assess changes in the watershed. It will ultimately replace the station currently operating downstream on the Riverside Golf Course.

The season followed a winter with a low snowpack. The winter and spring months were warmer than normal. The spring runoff peaked during the June 11-12 period, about one week earlier than normal. Current records are not directly compatible with historical records so that it is not possible to compare runoff volume with any certainty. Precipitation amounts during the months April through August were below normal.

Installation of the water level monitoring stations is the first step in the CLSS's ultimate goal of simulating water movement through the Watershed. A few lessons were learned along the way, the most significant of which was that great attention must be given instrument accuracy. The next step will be the measurement of flow to establish stage-discharge relationships. The Society is in the process of procuring a current meter for that purpose.

Introduction

The Columbia Lake Stewardship Society (CLSS) was formed in 2013. Its mission was defined as follows:

- "Act as a citizen-based, water stewardship group for Columbia Lake.
- Implement activities which monitor and help maintain the ecological health of Columbia Lake.
- Communicate and network with others, as required, to achieve the above."

In pursuit of this mission the Society established seasonal water quality and water quantity monitoring programs in 2014. The results of the 2014 program were previously reported (see Thompson, 2014).

The programs resumed in the spring of 2015. This document summarizes the activities conducted during 2015 and presents the results of those activities.

The Watershed

The drainage area of the Columbia Lake Watershed above the Highway 93/95 crossing near Fairmont Hot Springs is 881 square kilometres. The bulk, 696 square kilometres, is contained in the Dutch Creek sub-basin. Not all of the water from Dutch Creek enters the Lake, some by-passes to the north and flows directly into the Columbia River. The proportion flowing into the Lake has varied over the years due to shifting drainage channels in the Creek delta. The boundaries of the Watershed are shown in the inset of Figure 3.

The Watershed is non-glaciated and uncontrolled.

Antecedent and Concurrent Conditions

The quality and quantity of water in a watershed is influenced by several factors. Some are determined by physical characteristics of the basin but others are atmospheric in origin and include precipitation rates and amounts, melt rates, intensity of solar radiation, wind and evapotranspiration. Complex interrelationships exist but much of the variability in runoff is explained by only two elements; temperature and precipitation.

There are no weather stations within the Watershed having long term records. The closest such station is the Cranbrook Weather Station located at the Cranbrook - Kimberley Airport some 60 km south of Canal Flats.

The mean daily temperatures at that location for each month in 2014 and 2015 are shown in Figure 1. The corresponding long term normal values based on records accumulated over the 30 year period 1980-2010 are shown for comparison. For the most part, the summers of 2014 and 2015 were warmer than normal.

A similar comparison is made for total precipitation in Figure 2. The spring and summer months of 2015 were abnormally dry though they had been preceded by a period from August 2014 to March 2015 wherein precipitation amounts ranged from above normal to near normal.

According to the River Forecast Centre (2015) the water content of the 2015 snowpack in the East Kootenays was below normal. In fact measurements made on May 1, 2015 indicated that the snowpack index was only 46 percent of normal. This was the lowest in the thirty year period of records, 1985-2015.

These records indicate appropriate conditions for groundwater recharge existed prior to freeze-up but by late spring any gain would have been offset by an abnormally low snowpack and a melt rate that had accelerated runoff. The subsequent warm, dry conditions would have further depleted soil moisture reserves.

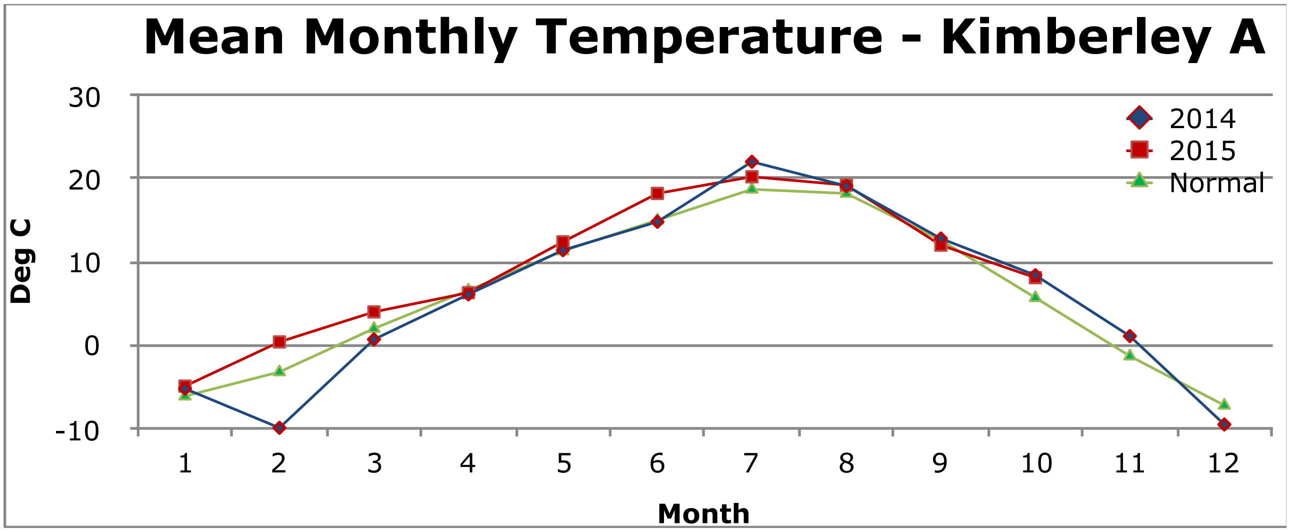

Figure 1 – Comparison of mean monthly temperatures at the Cranbrook- Kimberley Airport during 2014 and 2015 with the 1980-2010 long term normal values.

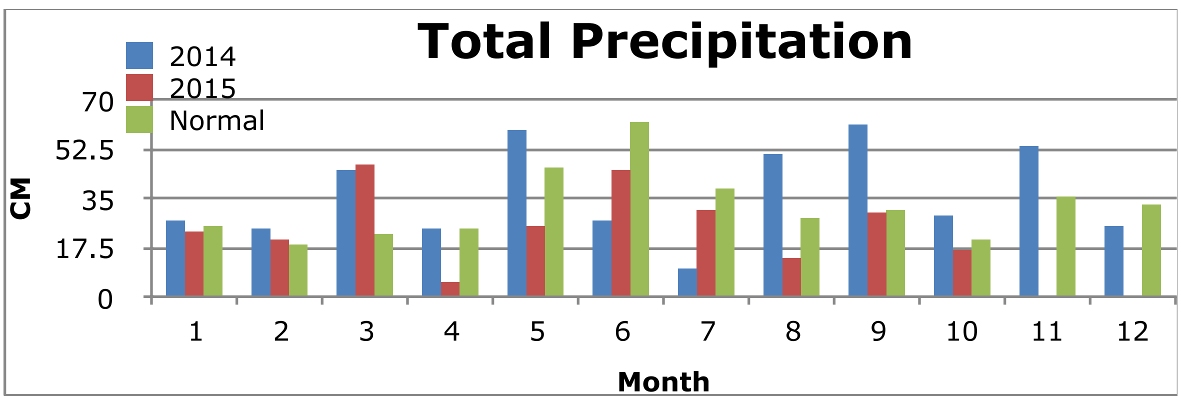

Figure 2 - Comparison of monthly total precipitation amounts at Cranbrook - Kimberley Airport during 2014 and 2015 with the 1980-2010 long term normal values.

Water Quality

Standards for Comparison

The 2014 Water Quality Program was largely shaped by a recommendation contained in the Columbia Lake Management Strategy (see Urban Systems, 1997) stating that water quality and water level monitoring programs be established. The 2014 Water Quality Program was oriented to the collection of data with a view to determining whether or not changes had taken place since the preparation of the Strategy. The Program showed that no substantial deterioration in the quality of water had occurred.

As the CLSS moves forward it is necessary to periodically revisit the purpose of the Program to ensure that it is in pursuit of its mission. If it is to “Implement activities which monitor and help maintain the ecological health of Columbia Lake” it is necessary to ensure that the appropriate data are being collected and that the network is designed to provide those data in a manner that enables sound management decisions to be made in the future.

One of the problems in doing so is the identification of issues. Water quality has a different meaning to different consumers. To illustrate, a fisherman or a farmer has a different view of water quality than those that drink water. Public acceptance and socio-economic factors therefore become very much part of the process for establishing standards. The result is that no single standard exists and those that exist vary from jurisdiction to jurisdiction.

The Province of BC provides guidance on two levels. One is set of guidelines; the second is a set of objectives. The Water quality guidelines "are used to determine what levels of substances or physical attributes found in fresh and marine surface water are safe for the environment. Water quality guidelines are developed for different water uses including aquatic life, wildlife, drinking water, recreation and agriculture." On the other hand, water quality objectives "are developed on a site specific basis. The objective report includes a waterbody's water uses, impacts to water quality, water quality assessments, rationale for recommended water quality objectives values, and a recommended monitoring program."

A set of Objectives does not exist for Columbia Lake but Objectives do exist for Lake Windermere. They were initially prepared by the Ministry of Environment in 1985 and updated in 2010 (see Neufield et al 2010) following a period of renewed monitoring between 2006 and 2009. The Revised Objectives are shown in Table 1. The Objectives are not legally binding.

In the absence of a local set of objectives, those for Lake Windermere will be cited here for comparison purposes.

Table 1 – Revised Water Quality Objectives for Lake Windermere

Variable	*Revised Objectives (2010)*
Turbidity	< 1 NTU (average) clear-flow period < 5 NTU (maximum) clear-flow period 5 NTU (95th percentile) turbid flow period
Phosphorus	0.010 mg/L (maximum)
Temperature	20 °C June (average) 25 °C July (average) 23 °C August (average)
pH	No recommended objective
DO	> 5 mg/L (instantaneous minimum) > 8 mg/L (30 day mean)

Conductance	No recommended objective

Changes in and Additions to Monitoring Sites

During 2015 three significant changes or upgrades to the 2014 Program took place.

1. Relocation of two monitoring sites on Columbia Lake to better correspond with sites used in the preparation of the Columbia Lake Management Strategy. Site S4 was moved 2.4 km and Site S3 1.7km, both southward. The new S4 is in relatively shallow water offshore from Canal Flats.
2. Incorporation of water temperature data collected at water level stations into the Water Quality program. Detail on the operating dates, locations and programming of these stations is contained in the Water Quantity section below.
3. Recording of local air temperature. Atmospheric pressure was required for the Water Quantity Program. A side benefit was that that the equipment used for that purpose contained a temperature sensor. The equipment was installed in the Timber Springs community at an elevation of about 40 metres above Lake Level and about 200 metres inland from the Lake. Precautions were taken to isolate the sensor from radiative effects and those precautions are described in Appendix 2.

The locations of the Water Quality and Water Quantity monitoring sites are shown in Figure 3.

Data Collection

Field activities commenced following ice breakup in April. The first samples were taken on April 9. Field sampling continued until October 13 with various shoreline communities providing observers and boats. Fifteen sampling missions were conducted over the six month period. Sampling was conducted at four designated locations: N1, S1, S3 and S4. At each location onsite measurements were made of: dissolved oxygen (two levels), water temperature (Lake surface and bottom), conductivity (top and bottom), pH, turbidity, and water clarity (using a Secchi plate). On six of these missions water samples were taken and submitted to a laboratory to be analyzed for total phosphorous and nitrate. Basic weather and wave conditions as well as Lake depth were recorded to provide background information.

Figure 3 – Locations of Water Quality sites (N1, S1, S3 and S4) and Water Quantity monitoring sites used in 2015. Watershed boundary is shown in inset.

The measurements recorded at Sites N1, S1, S3 and S4 during the 2015 season are shown in Appendix 1.

Examination of Individual Water Quality Parameters

Water Temperature

Water temperature in combination with other parameters most noticeably, dissolved oxygen and pH, defines the habitat that allows fish, other animals and plants to survive.

The water temperatures recorded at the four water level stations are shown in Figure 4. Temperatures recorded in the Lake were consistently warmer than those recorded in the inflowing and outflowing waters. Much cooler temperatures were recorded from about June 1 to August 31 in the unnamed creek flowing into Columbia Lake in the Headwaters Park near Canal Flats. The source of that stream is groundwater and the temperatures are reflective of that origin. The temperatures at all sites displayed diurnal variation with significant day to night differences apparent in the Dutch Creek and Columere records.

The extent to which the temperatures recorded in the Columere Marina represent those in the Lake is of some interest because the Marina is surrounded by a breakwater that restricts water circulation. The issue is addressed in Figure 5 by comparing the surface water temperatures recorded at each of the four Lake sampling sites with those recorded in the Marina. Although there were some noticeable differences, there was fairly good agreement overall suggesting that the Marina temperatures are a reasonable reflection of temperatures within the overall Lake. The sensor at the Columere Marina is mounted about 70 cm above the Lake bed and 75 to 175 cm below the surface depending on month.

The Lake water temperature did not exceed 25 Deg C at any time. The average water temperature for the month of June was less than 20 Deg C and that for August did not exceed 23 Deg C. Thus the water temperature objectives for Lake Windermere shown in Table 1 were met.

Dissolved Oxygen

During the 2015 season dissolved oxygen was measured at two levels instead of one level as was the case during the 2014 season. The upper level was 0.5 metres below the surface and the lower level was 0.5 metres above the Lake bed.

The observed measures of dissolved oxygen at the upper level are shown in Figure 6.

Normally the level of dissolved oxygen is higher in cool water and lower in warm water so that the decline shown during mid-season is to be expected.

The difference between the level of DO at the upper level and lower level are shown in Figure 14. For the most part the levels of DO at the upper level were between 0 and 0.5 mg/l less than those at the lower level.

The instantaneous measurements were well above the instantaneous 5.0 mg/l minimum Objective specified for Lake Windermere in Table 1. However, the longer term averages were not so compliant. Based on the three sets of readings taken during July the average values at N1and S1 slightly exceeded the 30 day 8.0 mg/L minimum average threshold.

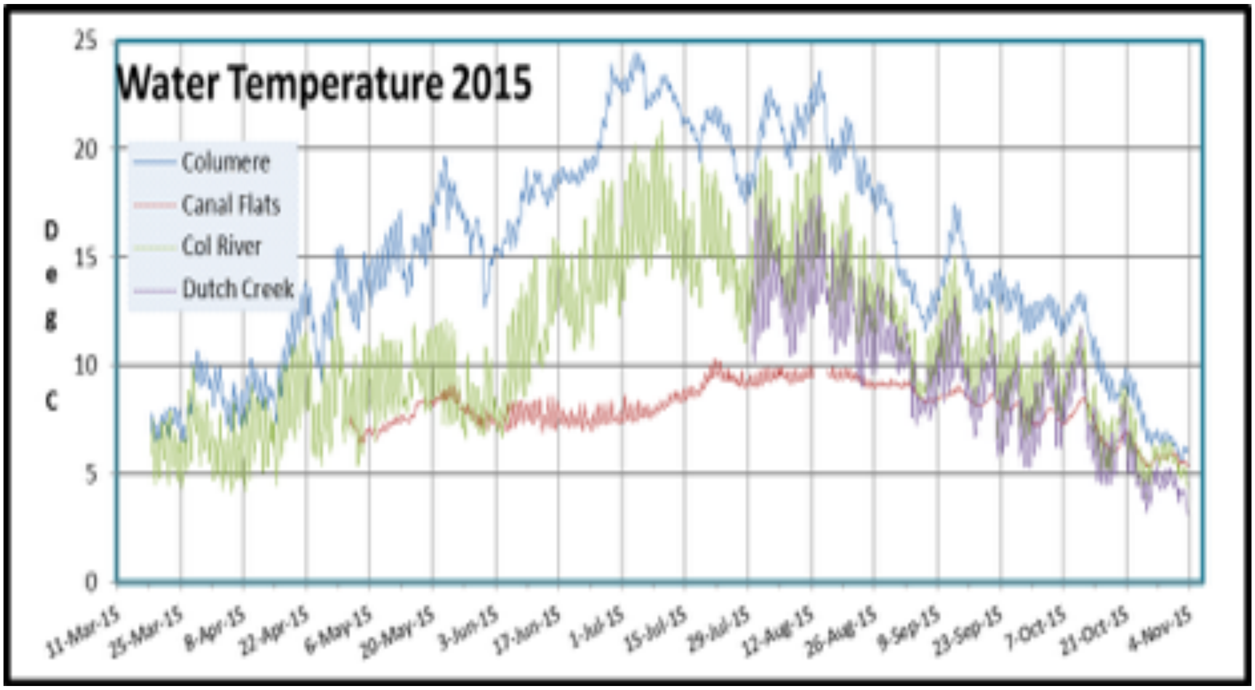

Figure 4 – Water temperatures recorded at the inflow, outflow and Lake monitoring points.

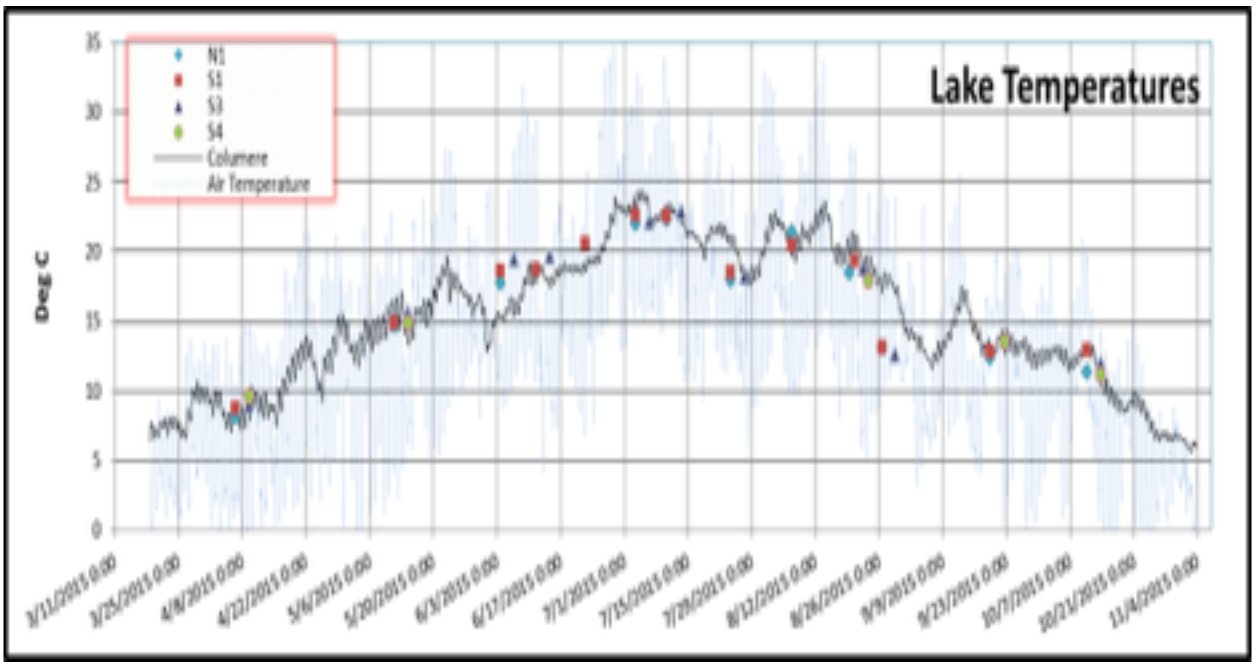

Figure 5 – Comparison of surface water temperatures at Lake sampling sites with water temperature recorded at the Columere Marina. Air temperature recorded at Timber Springs appears in the background.

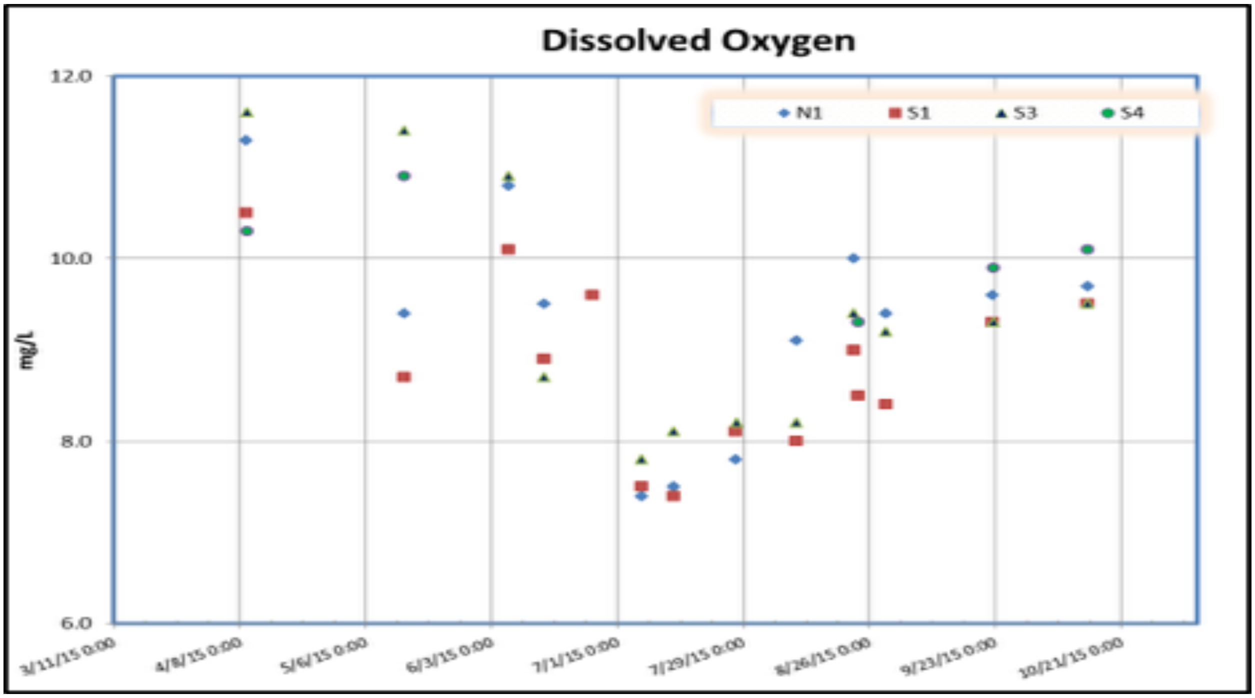

Figure 6 – Levels of dissolved oxygen made at the 0.5 depth level. Levels were lowest during the warm water period in accordance with expectation.

pH

The observed measures of pH are shown in Figure 7. Water is neutral at level 7 and alkaline at higher values. Columbia Lake was alkaline throughout the season. This is characteristic of local lakes fed by water flowing over carbonaceous materials.

A seasonal trend was observed at all four locations. Values were lowest during the early spring and reached a peak by late August or early September before tapering off.

These results are comparable to the levels measured in Lake Windermere during the 2006 to 2009 sampling program that led to the revision of the Water Quality Objectives. Such levels there were deemed to indicate that the alkalinity was natural in origin. The same conclusion is drawn here.

Conductivity

Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Conductivity is also affected by temperature: the warmer the water, the higher the conductivity.

Conductivity in streams and rivers is affected primarily by the geology of the area through which the water flows. Streams that run through areas with granite bedrock tend to have lower conductivity. Streams that run through areas with clay soils tend to have higher conductivity.

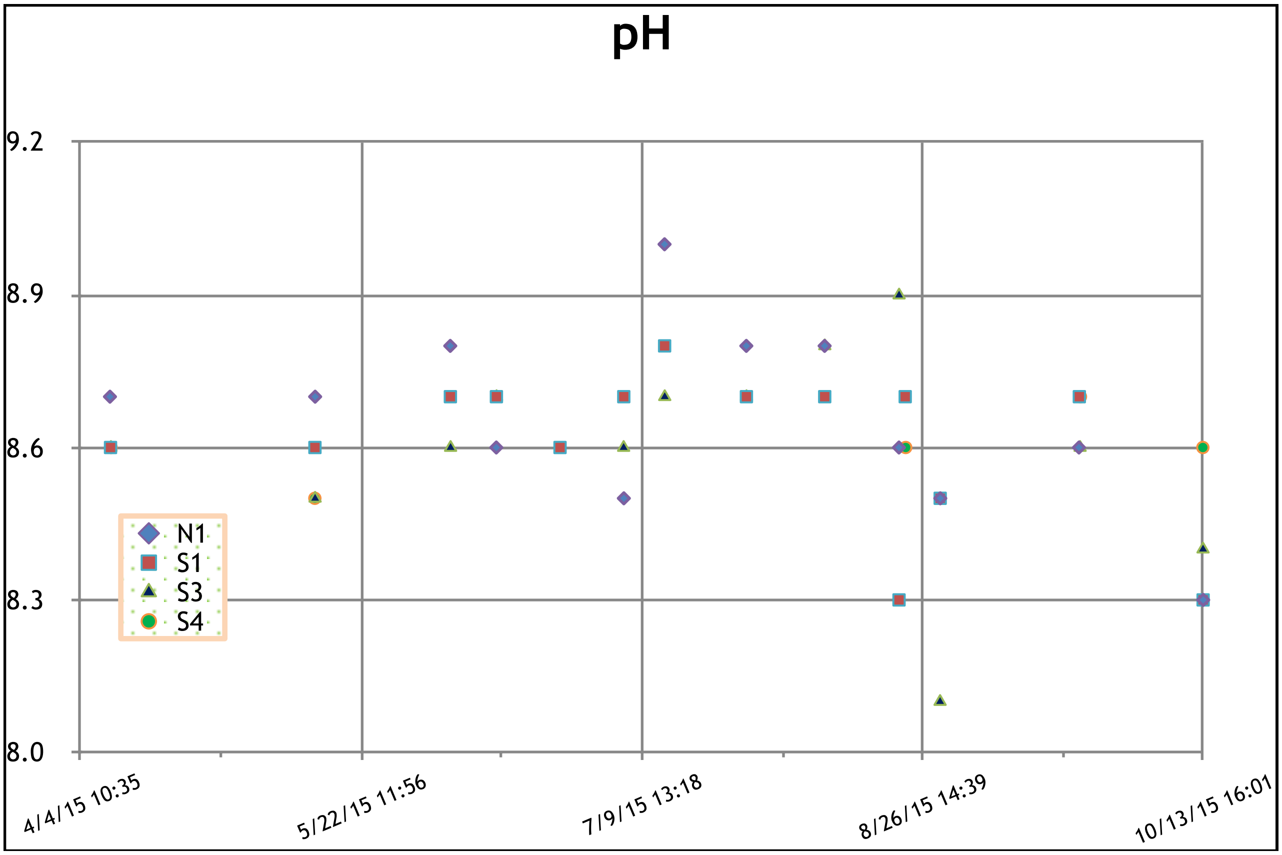

Figure 7 - pH.

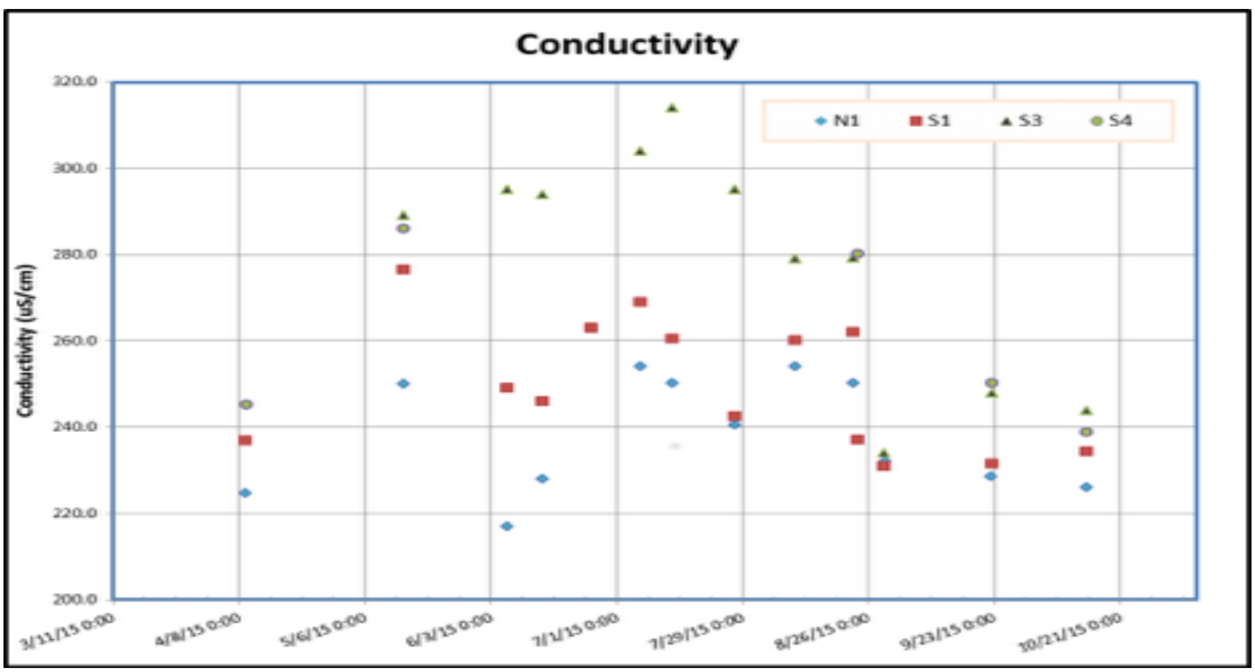

Figure 8 - Conductivity.

Conductivity levels offer a clue to the nature of discharges entering the water system. A failing sewage system raises the conductivity because of the presence of chloride, phosphate, and nitrate; an oil spill lowers the conductivity.

The observed measures of surface conductivity are shown in Figure 8. Values of conductivity progressively increased from late spring until early July and then began to decrease. The mid-season peak is presumed to be due to warmer water temperatures and the influx of ions in runoff waters.

The authors of the revised Lake Windermere Report set no objectives for conductivity. They felt that levels within the 240 to 300 µS/cm range were typical of natural levels. The values measured on Columbia Lake generally fell within that range and it is concluded that they do not deviate from normal. However, it is noted that on the whole conductivity levels were higher at Site S3 than elsewhere. The reason is not known.

Turbidity

Turbidity is a measure of water clarity. Suspended material decreases the passage of light through the water. Suspended materials include soil particles (clay, silt, and sand), algae, and other substances. Turbidity generally affects the color of the water.

Higher turbidity increases water temperatures because suspended particles absorb solar radiation more efficiently than pure water. The amount of light penetrating the water is also reduced which in turn reduces photosynthesis and the production of DO.

Sources of turbidity include shoreline erosion, construction, sediment transport by inflowing streams, mud stirred up from the Lake bottom by wave action and motor boat activity, and excessive algal growth.

Table 1 presents turbidity objectives for two periods, a clear flow period and a turbid flow period. The turbid flow period coincides with the spring runoff and runs from about May 1 when the freshet begins and continues until about mid-August when the freshet is well into recession. The clear flow period lies outside this range

The observed measures of turbidity are shown in Figure 9. For the most part the values were mainly in the 0.5 to 1.5 NTU range with a slight elevation in late July-early August. These values were well within the Lake Windermere Objectives for the turbid flow period (5 NTU) and slightly higher than the Objectives for the clear flow period (1 NTU).

Columbia Lake is shallow. It is also subject to frequent winds that blow along the length of the Lake creating wave action that stirs up sediment. This combination tends to create turbidity levels that are higher than in deeper water lakes including Lake Windermere.

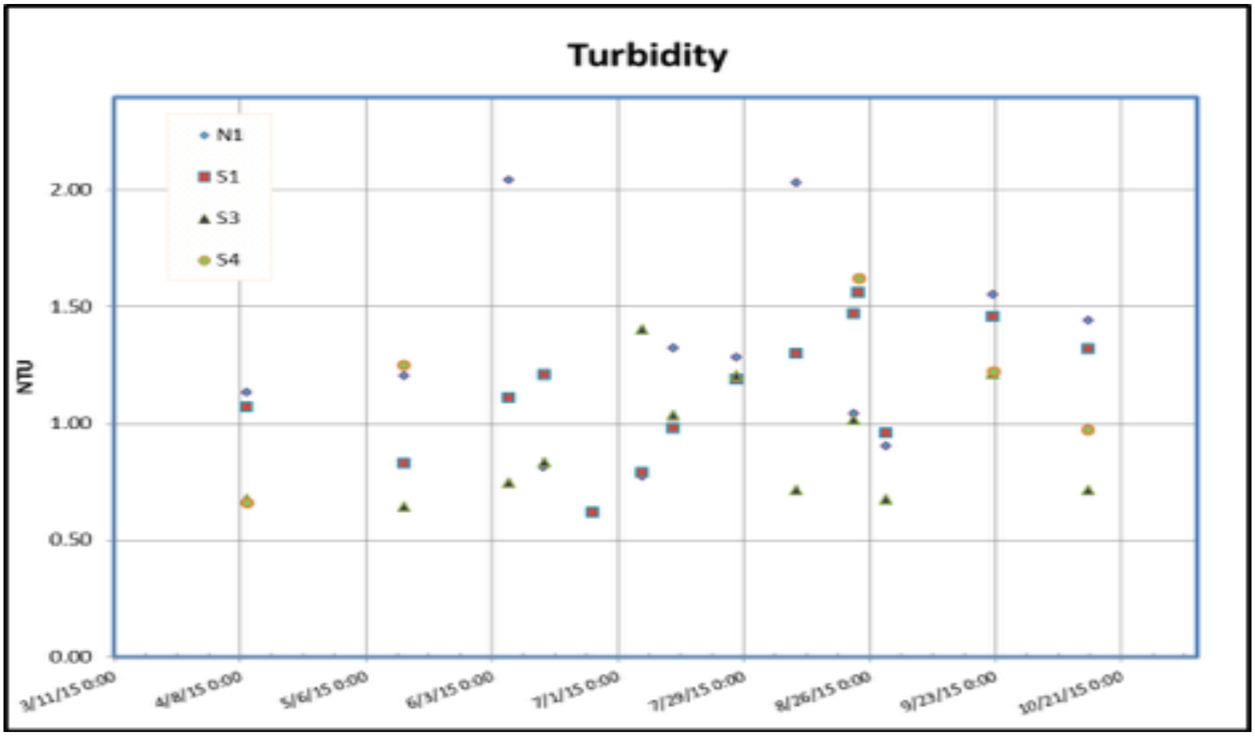

Figure 9 - Turbidity.

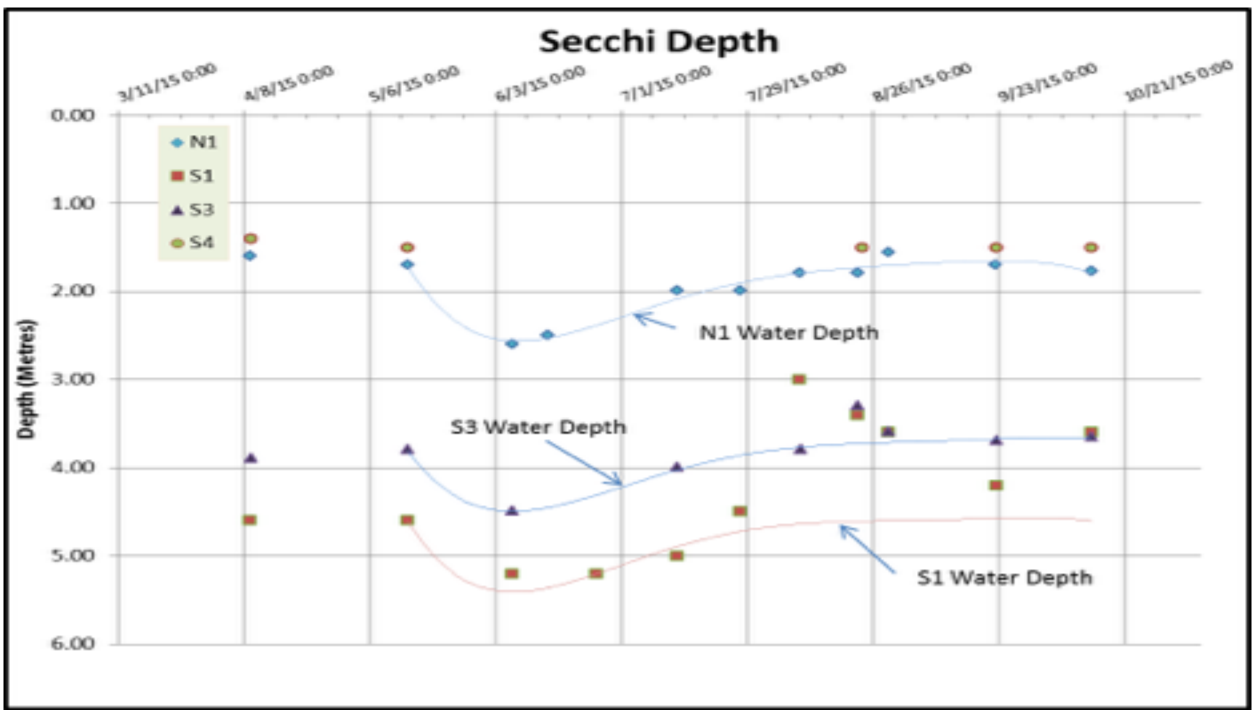

Figure 10 - Secchi Plate depths. Solid lines depict water depths during the May 14 to Oct 13 period and are derived from measured values.

Secchi Depth
Water clarity can also be measured by observing the depth at which a Secchi Disc (a black and white plate) disappears from view when submerged. The greater the depth, the greater the clarity. A survey conducted by BC Lake Stewardship Society (2014) revealed that the median “Secchi” depth for BC Lakes is in excess of 4 metres so that the procedure is not particularly applicable to Columbia Lake where the maximum depth is only 5.3 metres at high water. Nevertheless it can be seen in Figure 10 that the “Secchi” depths started to become less than the water depths at S1 during late July and persisted until the end of the season with greatest differences in August. The differences were not so noticeable at S3.

Phosphorous
Phosphorus is one of two essential nutrients necessary to sustain the food web, specifically algae. In the absence of phosphorous algae cannot exist. An increase in phosphorus has the potential to set off a series of events that starts with rapid plant growth and algae blooms. These in turn lead to low levels of dissolved oxygen and ultimately to fish kill.

Sources of phosphorus include soil and rocks, runoff from fertilized lawns and cropland, failing septic systems, runoff from animal manure storage areas, disturbed land areas, and drained wetlands.

Phosphorous was sampled on five occasions; April 12, June 14, July 27, September 22 and October 13. The results are shown in Figure 11.

Six readings exceeded the 0.010 mg/L Objective for Lake Windermere. Five of these were observed during the September 22 and October 13 sampling missions. They were in excess of values observed in 2014 and also available historical values. However, they are not higher than values measured on Lake Windermere. Harma (2014) reported values in excess of 0.040 mg/L on that Lake, a value more than four times the Objective.

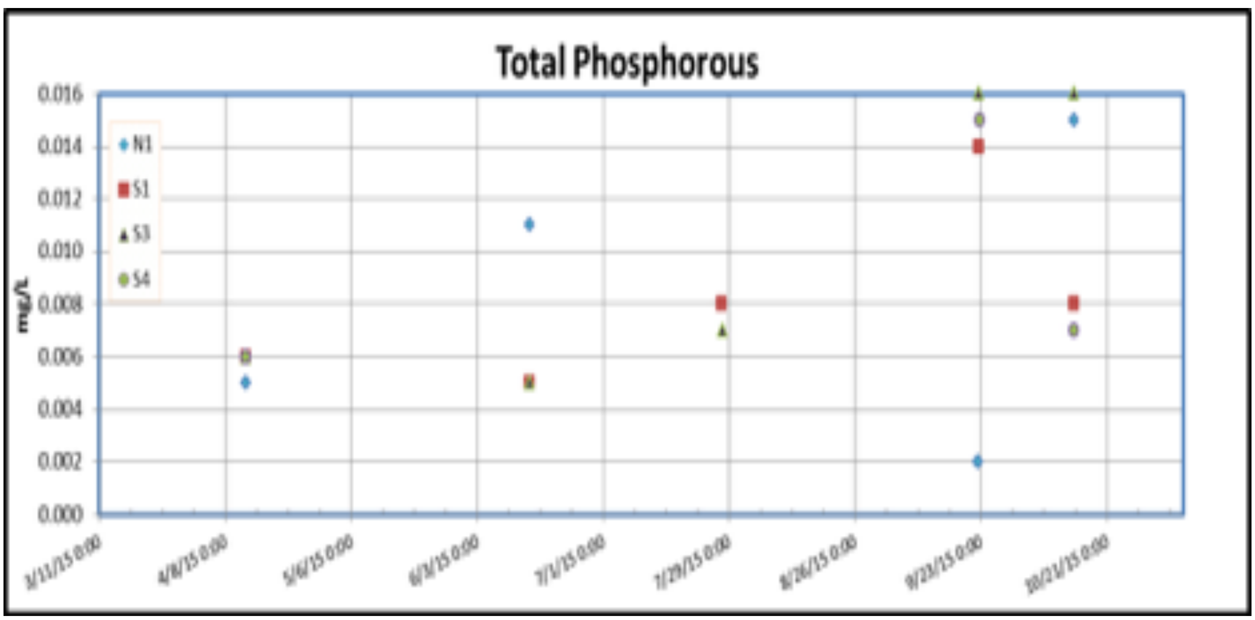

Figure 11 - Observed measurements of Total Phosphorous

Nitrogen

The second essential nutrient is nitrogen. Nitrogen is needed for plant growth. As is the case with phosphorous, elevated nitrogen levels cause more algae to grow which in turn block out sunlight and reduce the amount of oxygen available for fish. Nitrogen can be oxidized by microorganisms to produce nitrates and nitrites. Elevated levels of nitrates and nitrites in drinking water can produce undesirable health effects.

The most common sources of nitrogen and nitrogen compounds are agricultural activities, wastewater treatment, and discharges from industrial processes and motor vehicles.

Samples were taken on the same dates and following the same routine as those for phosphorous.

The samples were tested for Nitrate. All results were less than or equal to 0.010 mg/L, the Method Reporting Limit. The maximum acceptable concentration for nitrates according to the Canadian Drinking Water Guideline is 10 mg/L. All samples fell well below that threshold.

Stratification

Cooler water entering lakes tends to settle to the bottom underlying the less dense, warmer water. In such cases the Lake is said to be stratified. Urban Systems speculated that Columbia Lake was not stratified on the basis that its clarity allowed for heat absorption deep within the water. Wind and wave activity further contributed to overturning.

Figures 12 to 14 display the difference in values of selected parameters between the surface and the Lake bed at the two deep water locations, S1 and S3. Figure 12 shows that the temperatures near the bottom of the Lake were less than 0.5 Deg C of those at the surface during July, August and early September. A tendency to higher values existed outside that period. Negative differences are unsustainable. Ignoring outliers Figure 13 indicates that surface levels of Conductivity tended to be greater than those at depth early in the season but the difference disappeared by about August 1. Again ignoring outliers Figure 14 shows that the levels of Dissolved Oxygen at depth were mainly within the range of 0 to 0.5 mg/L above those near the surface and the difference was consistent over the course of the season.

The data tend to confirm Urban Systems assessment, at least during mid-season. Some stratification may exist early in the season.

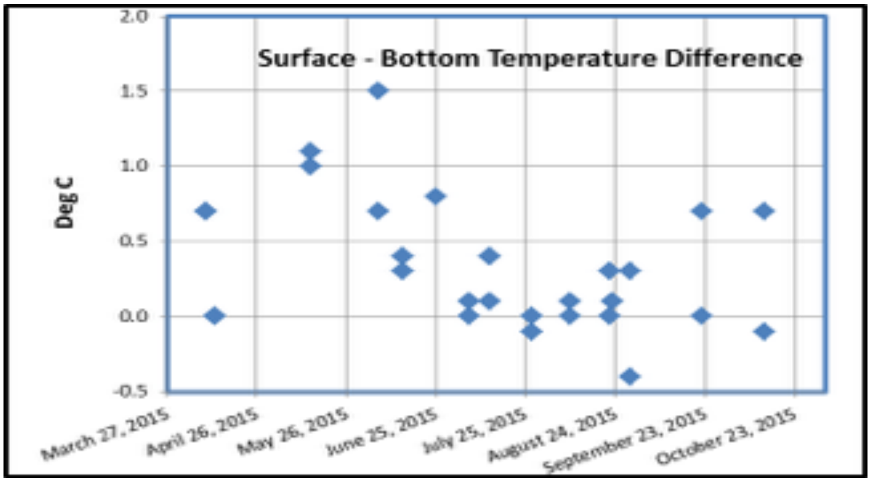

Figure 12 – Difference in water temperature between surface and Lake bed at Sites S1 and S3.

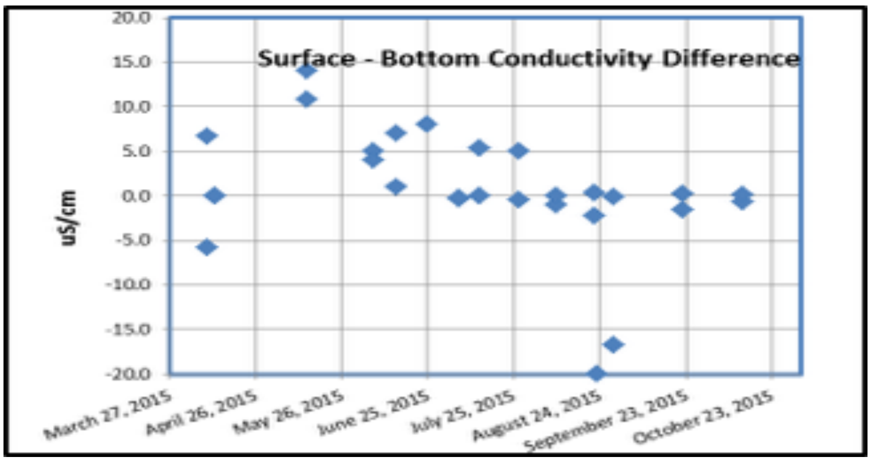

Figure 13 – Difference in Conductivity values between Lake surface and Lake bed at Sites S1 and S3.

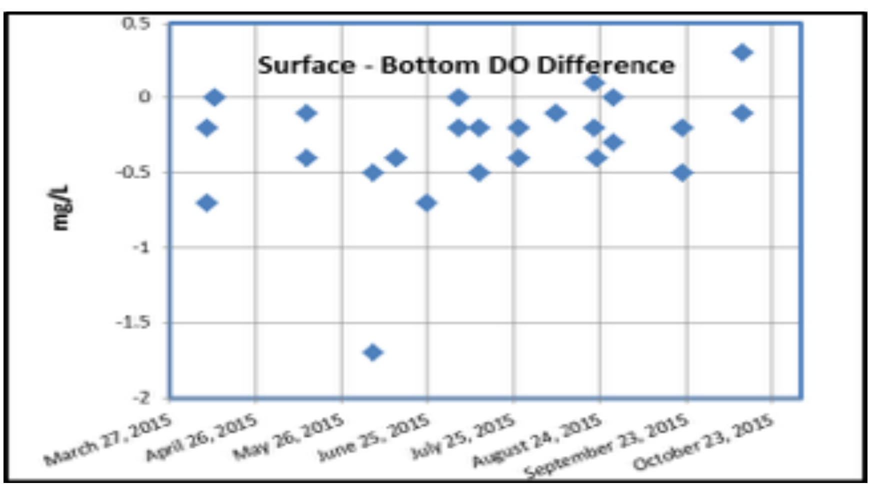

Figure 14 – Difference in Dissolved Oxygen values between a level 0.5 metres below the Lake surface and a level 0.5 above the Lake bed at Sites S1 and S3.

Water Quantity

At the end of 2014 two automatic water level monitoring stations were in operation. One was located in the Riverside Golf Course to monitor water level on the Columbia River; the second was in the Columere Marina to monitor Lake Level. Both were re-started for the 2015 season on March 18.

Two new stations were later added. The first was installed on May 1 in the Columbia River Headwaters Park near Canal Flats to measure water level in the unnamed stream flowing into Columbia Lake at that location. The second was installed on July 29 on the Highway 93/95 Bridge over Dutch Creek to monitor water level in that Creek.

In addition to the automatically recorded measurements manual measurements were made periodically at the Dutch Creek site and at a location on the Columbia River just south of the Bridge on Highway 93/9 where the Water Survey of Canada (WSC) operated a stream flow station for over 50 years. Occasional measurements were also made at the Columere and Canal Flats sites to verify the accuracy of the automatic equipment.

All stations remained in operation until November 3 when the equipment at Riverside, Dutch Creek and Columere Marina was removed as a safeguard against overwinter frost damage. Water in the unnamed creek near Canal Flats does not freeze so that station remained in operation owing to the lesser risk of frost damage.

Equipment

Monitoring was conducted using Diver D1501 capsules (see http://www.novametrixgm.com/groundwater-monitoring/groundwater-dataloggers/mini-diver for technical detail). The capsule is a self-contained unit consisting of a pressure sensor, a temperature sensor, a clock, and a programmable data logger. The capsules are small, only about 9 cm in length and 2 cm in diameter. The preferred method of operation is to suspend the capsule in a stilling well dug into a river bank in the case of river monitoring or attached to a pier in the case of lake monitoring.

Water level is derived from the measurements provided by the pressure sensor. It senses total pressure, that is, the pressure created by the overriding water and the atmosphere. The atmospheric pressure must be subtracted from the total pressure to yield the water pressure. Once the water pressure is known, the depth of water is easily calculated from its density.

Measurement of atmospheric pressure requires the use of a barometer. The manufacturer of the Diver units also provides a unit for that purpose called a BARO. If all the water level measuring units are at the same elevation and in close proximity as is the case for most of the stations in the Columbia Lake network, only one BARO is required since changes in the atmospheric pressure are quite small. For convenience the BARO was located in the Timber Springs Community at an elevation of about 850 metres above sea level (asl) and about 40 metres above Lake level. Its readings were converted to Lake level before compensating total pressure measurements. Details for calculating the conversion factor are provided in Appendix 2.

The Dutch Creek Station is about 20 metres above Lake level. Special consideration was made for compensating the data from that station.

All units were programmed to measure pressure and temperature hourly on the hour.

Data Collection and Management Issues

The water levels recorded at all four water level stations are shown in Figure 15. Also shown are manual readings made from staff gauges at the Dutch Creek and WSC locations. The reference level at all sites was arbitrarily chosen. Thus the water levels shown simply reflect the relative changes in water level at each station over the course of the season. They bear no relationship to any known elevation standard.

Two issues were encountered during the season that necessitated corrections to the data. One occurred at the Riverside station. Sediment accumulated in the stilling well and gradually encased the capsule during the period of high flow. This was not discovered until July 19 when the River had receded sufficiently to allow retrieval of the capsule. The sediment could not be removed at that time and the capsule was returned to a position on top of the encased sediment. The sediment was estimated to have been 20 cm in thickness. It remained in that position until August 9 when the water lowered sufficiently to remove and clean the stilling well. The capsule was then returned to its original level. The record for the July 19 to August 9 period was corrected for the 20 cm offset and the corrected values are presented in Figure 15. While the overall downward trend during that period appears reasonable, spikes exist that are not readily explained. The record from that period should be used with caution.

The second issue occurred at the Columere Marina Station. At the end of the season it was found that the pressure sensor was recording pressures 7.6 cm higher than at the beginning of the season even though the measured water levels were the nearly the same. It was assumed that the pressure sensor had drifting during this period and the rate of drift was linear. A correction factor was applied to the recorded measurements to bring them back in line with the manual measurements. The corrected values are presented in Figure 15.

In addition to the foregoing it was discovered that the pressure sensors were not properly calibrated. Lack of calibration had been recognized as a potential problem at the outset and steps were implemented that would enable correction of erroneous measurements but in the end were found not to be entirely adequate. No changes were therefore made to the records of any of the other stations and the data are presented in Figure 15 as observed. Further detail on the steps taken to detect sensor inaccuracy is given in Appendix 2.

Some Observations

The peak water level was reached during the period June 11-12 at all of the three hourly recording stations operating at the time. According to Water Survey of Canada the historical median date on which the peak was reached on the Columbia River near Fairmont Hot Springs is June 19. Thus the peak runoff occurred about one week earlier than normal.

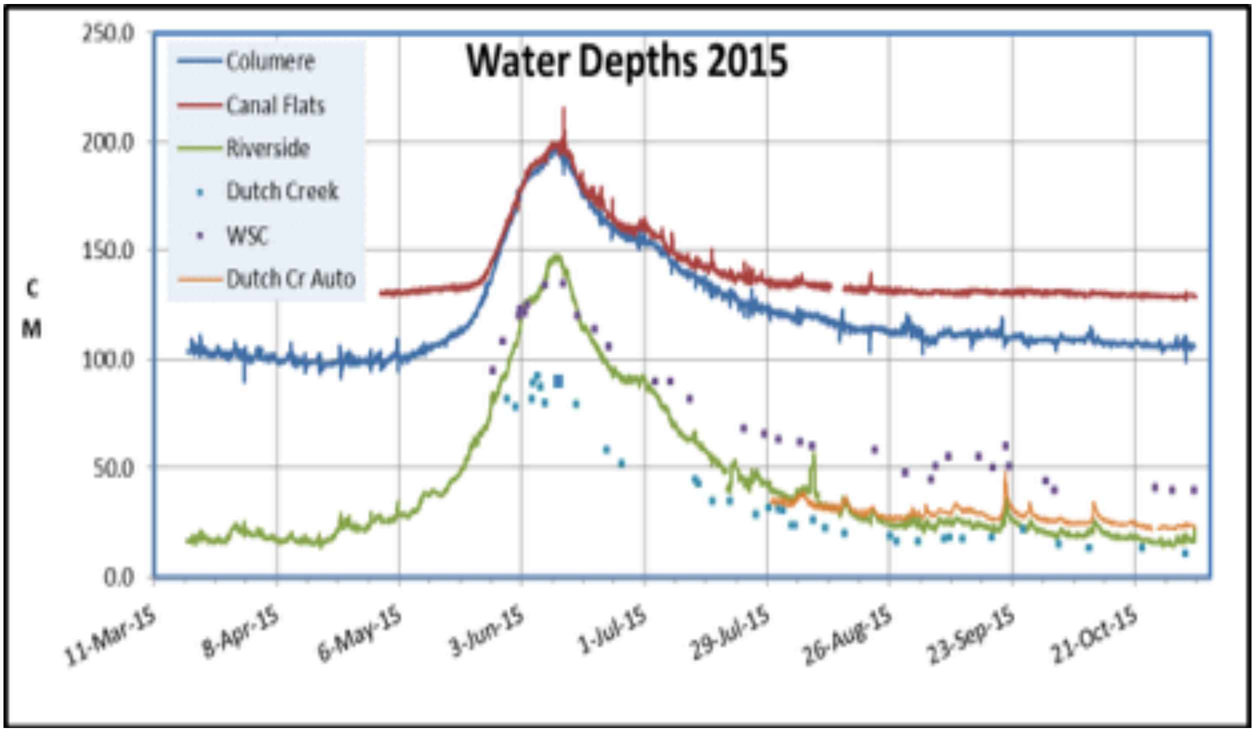

Figure 15 – Hourly water levels recorded at the Columere Marina, Riverside, Dutch Creek and Canal Flats stations. Dots represent manual measurements made at the Dutch Creek and WSC locations. Note that the reference level at the Riverside station was changed during the July 19 to August 9 period due to mud clogging the stilling well.

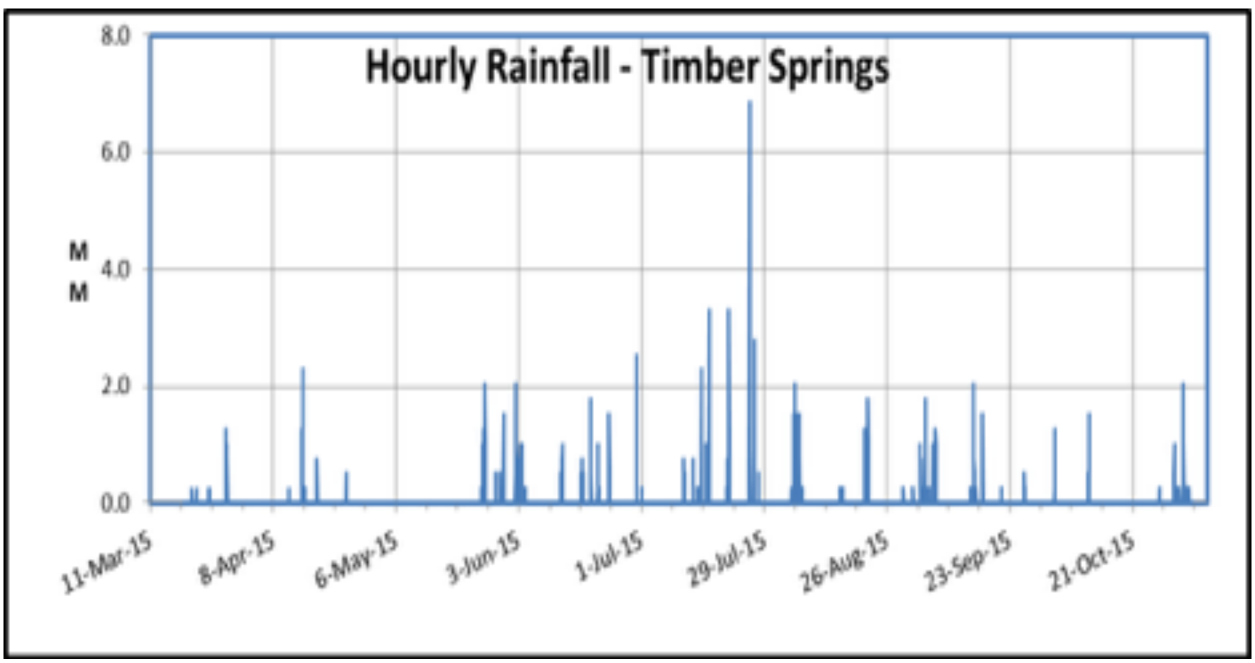

Figure 16 – Hourly rainfall amounts recorded in the Timber Springs community.

It is not so easy to relate water levels to historical values. The Columere Marina station indicates that the Lake was nearly one metre higher at peak than at the beginning of the season. According to charts presented by Urban Systems using Water Survey of Canada measurements collected over the period 1967 to 1984, this is approximately the average annual amount of rise. However, closer inspection reveals that the historical measurements were manual measurements made only once per month. Thus the highest and lowest values would not have been recorded and therefore the full range of fluctuation would not have been recorded.

Comparisons on rivers should be made on the basis of flow not water level. Water level can be used to estimate flow but only at locations where stage-discharge relationships exist. Such relationships were compiled in the past at the WSC site but do not necessarily apply now because the channel profile may have changed. Even if the profile has not changed the reference level used to measure water level in 2015 has not yet been linked to the historical reference level used by WSC so that the measurements probably do not coincide. In short, it is not possible to relate the 2015 runoff to historical values, at least not with any confidence.

The Canal Flats station is slightly above Lake Level. Figure 15 shows the Canal Flats and Columere lake level records to have been in unison from late May to mid-July. Rising water in the Lake likely created a backwater condition that reached the level of the Canal Flats station in late May. From then until mid-July both stations would have been recording Lake level.

Several spikes appear in the Columere record and also in the Canal Flats record during that period. These were most were likely due to wind. Long, narrow, shallow lakes are known to be subject to wind set-up, a condition under which wind stress causes water levels to increase at the downwind shore, and to decrease at the upwind shore. An illustration of the effect can be seen at 1400 MDT on June 12. The mean Lake level at Canal Flats was about 25 cm higher than at the Columere Marina. Wind speeds in excess of 30 knots (56 km/hr) from the North were recorded at the Fairmont Hot Springs Airport earlier in the day.

*My father ran Fairmont Hot Springs as well as the farm…. Our family lived in the old log house that is still standing (*near Mountainside Club House*) …. As I recall the water level readings were started in 1940. The meter or water level readings were on a post on the East side of the river south of the*

Future Activities and Recommendations

The most significant water quality matter requiring attention is the need for a set of Objectives for Columbia Lake. This should be taken up with the Ministry of Environment.

As for water quantity, several improvements are planned and a few changes are recommended.

To date the emphasis has been on measuring water level. The ultimate goal is to measure volume and for that velocity measurements are required to establish stage-discharge relationships. Steps are underway to purchase a current meter and velocity measurements will start to be taken in 2016.

The Riverside location is viewed as temporary. Water Survey of Canada operated a flow monitoring station on the Columbia River just upstream of the Bridge on Highway 93/95 near Fairmont Hot Springs (see Figure 3) from 1937 to 1998, a period of 56 years. This provided an excellent set of baseline data against which future measurements can be used to assess changes taking place in the watershed. The site was restored at the end of the season and will be put back into operation at the beginning of next season. The Riverside site will eventually be removed from service.

In addition the Water Survey of Canada data bank contains water level or flow records from Dutch Creek, Hardie Creek and Columbia Lake. These records need to be reviewed to determine precise locations and operating procedures to evaluate their quality and the applicability.

A more rigorous plan must be put in place to enable correction of erroneous and missing data. This will include the preparation of a test bed in which all sensors are compared at the beginning and end of the season and the installation of staff gauges at each site to verify measurements.

Better weather information is required, especially wind, temperature and humidity detail. The Fairmont Hot Springs Airport weather station monitors the appropriate elements but does not record them in a digital format suitable for non-aviation users. Software is being installed that will overcome this deficiency. Once completed, copies of the data should be incorporated with water records to facilitate simulation activities that in time will be used in the preparation of impact assessments, meeting planning and design needs and to managing water resources in general.

At least one recording rain gauge is required in the Dutch Creek basin to provide more accurate information on precipitation in the headwaters of the Watershed.

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- Village of Canal Flats
- Columbia Ridge Community Association
- Timber Springs Community Association
- Columere Park Community Association
- Spirits Reach Community Association
- BC Lake Stewardship Society
- Volunteer Observers
- Various boat owners that provided monitoring platforms

APPENDIX 1

Observed Data 2015

Location	Date	Time (MDT)	Time Excel Format	Wave Conditions	Air Temp (Deg C)	Wind Direction	Wind Speed (km/hr)	Sky Cover (Percent)	Water Temp Surface (Deg/C)	Water Temp Bottom (Deg/C)	Lake Depth (m)	Secchi Depth (m)	Conductvity Sfc(uS/cm)	Conductivity Bottom (uS/cm)	ph	Dissolved Oxygen Upper Level (mg/L)	Dissolved Oxygen Lower Level (mg/L)	Turbidity (NTU)	Phosphorous (mg/L)	Nitrogen (mg/L)
Columbia N1	April 9, 2015	10:40	4/9/15 10:40	calm	9		0	0	8.1	8.1	1.60	1.60	224.8	227.0	8.7	11.3	11.3	1.13		
Columbia S1	April 9, 2015	13:00	4/9/15 13:00	calm	9		0	0	8.7	8.0	4.60	4.60	236.8	230.1	8.6	10.5	10.7	1.07		
Columbia S3	April 9, 2015	14:15	4/9/15 14:35	calm	10		0	0	8.9	8.2	3.9	3.9	247.8	253.6	8.6	11.6	12.3	0.67		
Columbia S4	April 9, 2015	15:15	4/9/15 15:15	calm	11		0	0	9.6	8.7	1.4	1.4	245.2	259.5	8.6	10.3	10.5	0.66		
Columbia N1	April 12, 2015	13:00	4/12/15 13:00																0.005	<0.01
Columbia S1	April 12, 2015	13:15	4/12/15 13:15																0.006	<0.01
Columbia S3	April 12, 2015	13:30	4/12/15 13:30																0.006	<0.01
Columbia S4	April 12, 2015	14:00	4/12/15 14:00																0.006	<0.01
Columbia N1	May 14, 2015	14:00	5/14/15 14:00	ripples	18		5	95	14.6	13.6	1.7	1.7	250	236	8.7	9.4	9.8	1.2		
Columbia S1	May 14, 2015	13:07	5/14/15 13:07	calm	17		0	75	14.8	13.8	4.60	4.60	276.5	265.7	8.6	8.7	9.1	0.83		
Columbia S3	May 14, 2015	13:46	5/14/15 13:46	calm	18		0	60	15.6	14.5	3.80	3.80	289.0	275.0	8.5	11.4	11.5	0.64		
Columbia S4	May 14, 2015	12:46	5/14/15 12:46	calm	16		0	30	14.8	14.5	1.50	1.50	286.0	285.0	8.5	10.9	11.2	1.25		
Columbia N1	June 6, 2015	17:20	6/6/15 17:20	ripples	28		10	10	17.7	16	2.60	2.6	217.0	200.0	8.8	10.8	13	2.04		
Columbia S1	June 6, 2015	17:50	6/6/15 17:50	chop	27		11	10	18.6	17.1	5.40	5.20	249.0	244.0	8.7	10.1	11.8	1.11		
Columbia S3	June 6, 2015	18:40	6/6/15 18:40	ripples	24		14	10	19.4	18.7	4.50	4.50	295.0	291.0	8.6	10.9	11.4	0.74		
Columbia N1	June 14, 2015	14:35	6/14/15 14:35	chop	24		12	60	18.7	18.7	2.50	2.50	228.0	228.0	8.6	9.5	9.7	0.81	0.011	<0.01
Columbia S1	June 14, 2015	15:00	6/14/15 15:00	chop	24		15	50	18.7	18.3			246.0	245	8.7	8.9	9.3	1.21	0.005	<0.01
Columbia S3	June 14, 2015	15:36	6/14/15 15:36	white caps	25		20	40	19.6	19.3			294	287	8.7	8.7	9.1	0.83	0.005	<0.01
Columbia S1	June 25, 2015	12:30	6/25/15 12:30	ripples	27		5	10	20.5	19.7	5.2	5.2	263	255	8.6	9.6	10.3	0.62		
Columbia N1	July 6, 2015	10:45	7/6/15 10:45	white caps	18	SE	22	90	22.0	22.2			254.0	255.0	8.5	7.4	7.4	0.77		
Columbia S1	July 6, 2015	10:27	7/6/15 10:27	white caps	18	SE	18	90	22.6	22.5			269.0	269.4	8.7	7.5	7.7	0.79		
Columbia S3	July 6, 2015	9:55	7/6/15 9:55	white caps	18	SE	16	80	22.1	22.1			304.0	304.2	8.6	7.8	7.8	1.40		
Columbia N1	July 13, 2015	10:05	7/13/15 10:05	calm	20	SW	6	70	22.3	22.2	2.00	2	250.2	250.7	9.0	7.5	7.8	1.32		
Columbia S1	July 13, 2015	10:20	7/13/15 10:20	calm	21	S/SW	4	70	22.5	22.4	5.00	5.00	260.4	260.4	8.8	7.4	7.6	0.98		
Columbia S3	July 13, 2015	10:50	7/13/15 10:50	calm	22		0	80	22.8	22.4	4.00	4.00	314.0	308.7	8.7	8.1	8.6	1.03		
Columbia N1	July 27, 2015	10:10	7/27/15 10:10	ripples	12	NW	4	100	18.0	17.9	2.00	2.00	240.5	242.2	8.8	7.8	7.85	1.28	0.008	<0.01
Columbia S1	July 27, 2015	10:32	7/27/15 10:32	chop	15	NW	8	90	18.5	18.5	4.5	4.5	242.5	243	8.7	8.1	8.3	1.19	0.008	<0.01
Columbia S3	July 27, 2015	10:50	7/27/15 10:50	white caps	13	NW	11	90	18.2	18.3			295	290	8.7	8.2	8.6	1.2	0.007	<0.01
Columbia N1	August 9, 2015	20:00	8/9/15 20:00	choppy	24	S		50	21.4	21.2	1.8	1.8	254	255	8.8	9.1	9.3	2.03		
Columbia S1	August 9, 2015	20:20	8/9/15 20:20	small chop	23	SE		50	20.4	20.4	4.75	3.00	260.0	261.0	8.7	8	8.1	1.30		
Columbia S3	August 9, 2015	20:40	8/9/15 20:40	choppy	21	SE		50	20.5	20.4	3.80	3.80	279.0	279.0	8.8	8.2	8.3	0.71		
Columbia N1	August 22, 2015	13:30	8/22/15 13:30	choppy	20	S	10	25	18.5	18.7	1.80	1.80	250.3	249.0	8.6	10	9.7	1.04		
Columbia S1	August 22, 2015	13:45	8/22/15 13:45	choppy	20	s	10	15	19.3	19.0	4.90	3.40	262.1	261.8	8.3	9	9.2	1.47		
Columbia S3	August 22, 2015	14:00	8/22/15 14:00	choppy	20	S	10	25	18.8	18.8	3.8	3.3	279.3	281.6	8.9	9.4	9.3	1.01		
Columbia S1	August 23, 2015	15:11	8/23/15 15:11	Choppy	20	S	15	15	19.3	19.2	4.5		237	257	8.7	8.5	8.9	1.56		
Columbia S4	August 23, 2015	17:11	8/23/15 17:11	ripples	27	S	13	10	17.9	17.8	1.5	1.5	280.1	279.8	8.6	9.3	9.4	1.62		
Columbia N1	August 29, 2015	15:20	8/29/15 15:20	calm	12	SE	14	97	13.1	13.0	1.56	1.56	232.1	230.9	8.5	9.4	9.3	0.90		
Columbia S1	August 29, 2015	14:57	8/29/15 14:57	ripples	12	SE	14	95	13.1	12.8	4.40	3.60	230.9	231.0	8.5	8.4	8.7	0.96		
Columbia S3	August 29, 2015	14:30	8/29/15 14:30	calm	12	SE	14	90	12.6	13	3.6	3.6	234	250.8	8.1	9.2	9.2	0.67		
Columbia N1	September 22, 2015	9:20	9/22/15 9:20	ripples	4	NE	3	0	12.4	12.4	1.70	1.70	228.5	228.9	8.6	9.6	9.7	1.55	0.002	<0.01
Columbia S1	September 22, 2015	10:50	9/22/15 10:50	chop	10	N	10	0	12.8	12.8	4.60	4.20	231.5	231.3	8.7	9.3	9.5	1.46	0.014	<0.01
Columbia S3	September 22, 2015	1:55	9/22/15 13:55	calm	14			0	13.5	12.8	3.70	3.70	248.0	249.6	8.6	9.3	9.8	1.21	0.016	<0.01
Columbia S4	September 22, 2015	3:30	9/22/15 15:30	chop	18	S	10	5	13.5	13.5	1.50	1.50	250.2	250.6	8.7	9.9	10	1.22	0.015	<0.01
Columbia N1	October 13, 2015	4:01	10/13/15 16:01	chop	16	S		0	11.3	11.3	1.78	1.78	226.0	226.0	8.3	9.7	9	1.44	0.015	<0.01
Columbia S1	October 13, 2015	3:32	10/13/15 15:32	calm	16	S		5	12.9	12.2	4.60	3.60	234.3	235.0	8.3	9.5	9.2	1.32	0.008	<0.01
Columbia S3	October 13, 2015	3:15	10/13/15 15:15	chop	16	S		5	11.9	12.0	3.66	3.66	243.8	243.7	8.4	9.5	9.6	0.71	0.016	<0.01
Columbia S4	October 13, 2015	2:30	10/13/15 14:30	chop	16	S		0	11.1	11.2	1.50	1.50	238.8	238.8	8.6	10.1	9.3	0.97	0.007	<0.01

Site Locations

	2015		2014	
N1 `	N50.28769°	W115.87126°	N50.287694	W115.871258
S1	N50.25329°	W115.86256°	N50.25147	W115.862639
S3	N50.20107°	W115.84820°	N50.218389	W115.85275
S4	N50.17533°	W115.83442°	N50.197639	W115.843806

APPENDIX 2

Instrument Accuracy and Calibration

Accuracy of measurement is essential when it comes to calculating gains to and losses of water from a watershed. A simple error of only one cm in the measurement of the depth of Columbia Lake is equivalent to 260,000 cubic metres of water and about 18 hours of outflow during low flow periods.

Calibration is thus a necessary a part of any monitoring program. This means setting or correcting sensors to match or conform to known standards. The following outlines the steps taken to establish accuracy of pressure and temperature readings. Known errors are also outlined.

Pressure

Normally a precision instrument serves as standard for calibration. The CLSS does not have such instruments. In lieu it was planned to establish the accuracy of the BARO and use it as a standard for evaluation of the remaining Diver capsules at the beginning and end of the season.

This did not happen exactly as hoped because two of the capsules (Canal Flats and Dutch Creek) were not available at the beginning of the season and the BARO and Canal Flats station remained in operation at the end of the season. The end result was that not all pressure sensors were evaluated simultaneously and not all were simultaneously compared with the BARO though intercomparisons did take place during the season.

Calibration of the BARO

The Fairmont Hot Springs Airport operates a weather station for aviation purposes. That station is equipped with two barometers. At five second intervals a reading from each barometer is taken, the readings averaged, the average converted to an altimeter setting and the setting broadcast to approaching aircraft. Forty six of these messages were intercepted during the May 4 -28, 2015 period. The altimeter setting was abstracted and converted to atmospheric pressure. The resulting values were correlated with concurrent pressure measurements made by the BARO capsule located in the Timber Springs Community approximately 4 km distant and 40 metres higher in elevation. The results (see Figure 1) showed that the BARO would be an acceptable standard and further that it could be used to compensate the readings from the submerged capsules for atmospheric pressure by applying the algorithm $y=0.09942x + 9.1534$ where y is the atmospheric pressure at Lake level and x is the BARO reading.

The elevation of the Fairmont Hot Springs Airport is 810 metres asl, the mean water level at the WSC station is about 806.5 metres and the mean Lake Level is about 808.5 metres. The elevation of the Riverside station is about 800 metres. The elevation of the Dutch Creek station has not yet been determined but is believed to be about 20 metres above Lake level.

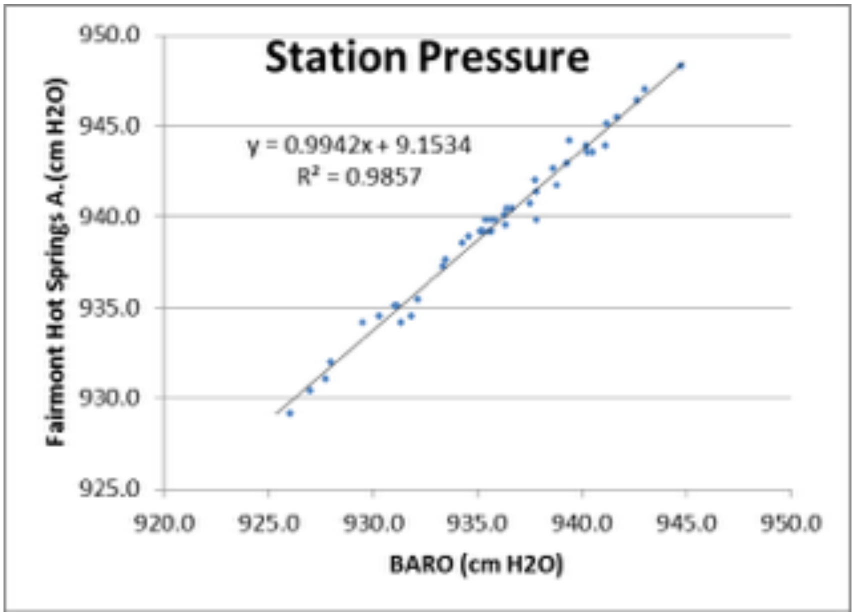

Figure 1 – Comparison of atmospheric pressure measurements made by the BARO located in the Timber Springs community with those at the Fairmont Hot Springs Airport.

Other Diver Sensors

At the beginning of the season Capsules 1366 (later installed at Riverside) and 1368 (Columere Marina) were placed next to the BARO (1601). The hourly pressure readings from all three capsules are shown in Figure 2. The pressure readings from 1366 were in almost exact agreement with those of the BARO but those from 1368 were consistently 5.3 cm of H2O higher (see Figure 2).

At the end of the season the comparison was repeated with four capsules but not including the BARO because it remained in operation. The results are shown in Figure 3. During that comparison the difference between Capsules 1366 and 1368 had increased to 20.2 cm H2O. The pressure sensor in Capsule 1366 is presumed to have remained stable since recorded values were in good agreement with manually measured readings at the same location. The sensor in 1368 is deduced to have drifted during the season.

Capsule 1455 (Dutch Creek) also displayed a significant departure from capsule 1366 at the end of the season. Other comparisons indicate that the difference remained constant throughout the season.

Capsule 5972 was a new Capsule and was delivered just prior to the comparison.

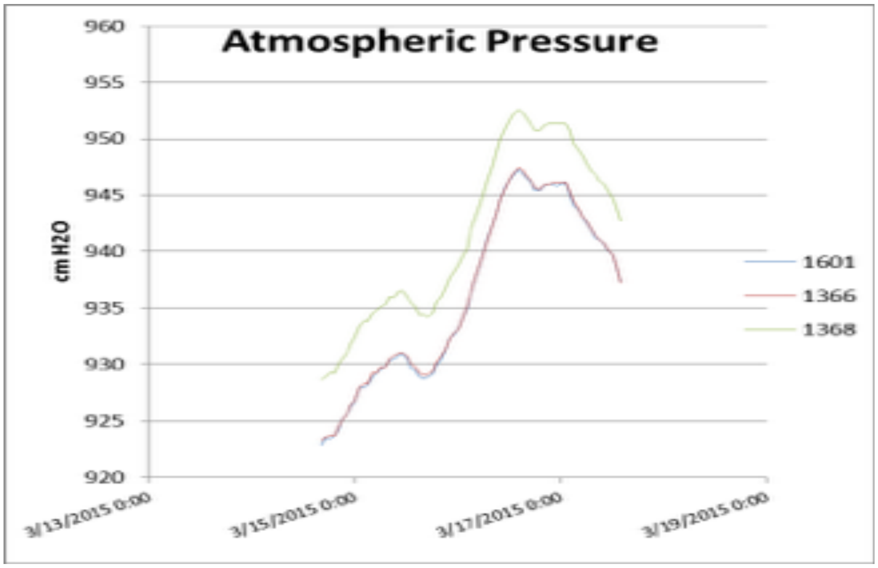

Figure 2 – Comparison of atmospheric pressure measurements at the beginning of the season made by Capsules 1366 (Riverside), 1368 (Columere Marina) and BARO (1601). All were mounted together at a location in the Timber Springs Community.

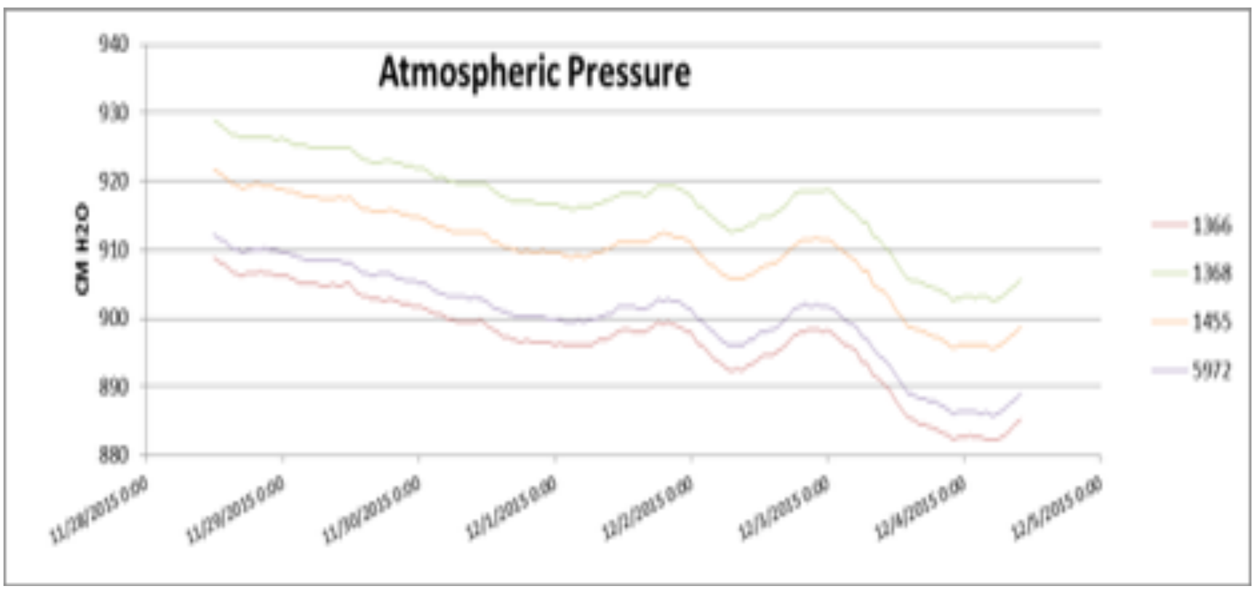

Figure 3 – Comparison of atmospheric pressure measurements made at the end of the season by Capsules 1366 (Riverside), 1368 (Columere Marina), 1455 (Dutch Creek) and 5972(a new capsule).

Temperature

The main sources of error in temperature measurements are heat transfer to the sensor mainly by radiation but also by conduction. The sensors themselves are generally quite reliable. The BARO was the main source of hourly temperature information and two protective measures were taken to lessen heat transfer. First, the capsule was mounted in a white PVC tube on the shaded north side of an unheated building about 1.5 above ground level to reduce the effects of direct and indirect solar radiation. Second, the assembly was suspended by wire from a hanger with about 25 cm separating it from the building wall to lessen heat transfer from the building.

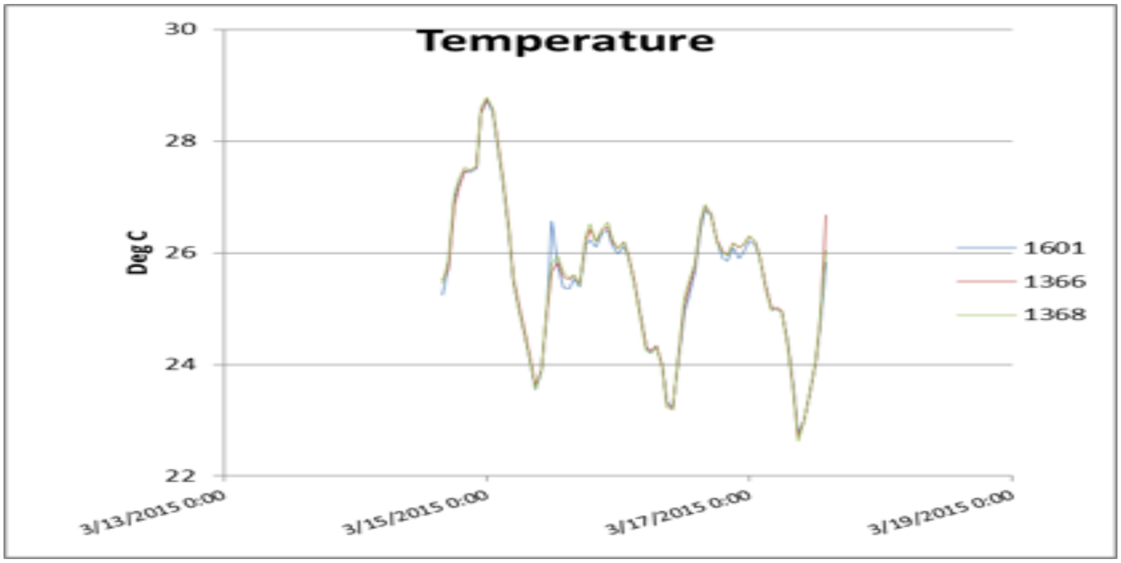

Figure 4 – Comparison of temperature measurements at the beginning of the season made by Capsules 1366 (Riverside), 1368 (Columere Marina) and BARO (1601). All were mounted together at a location in the Timber Springs Community.

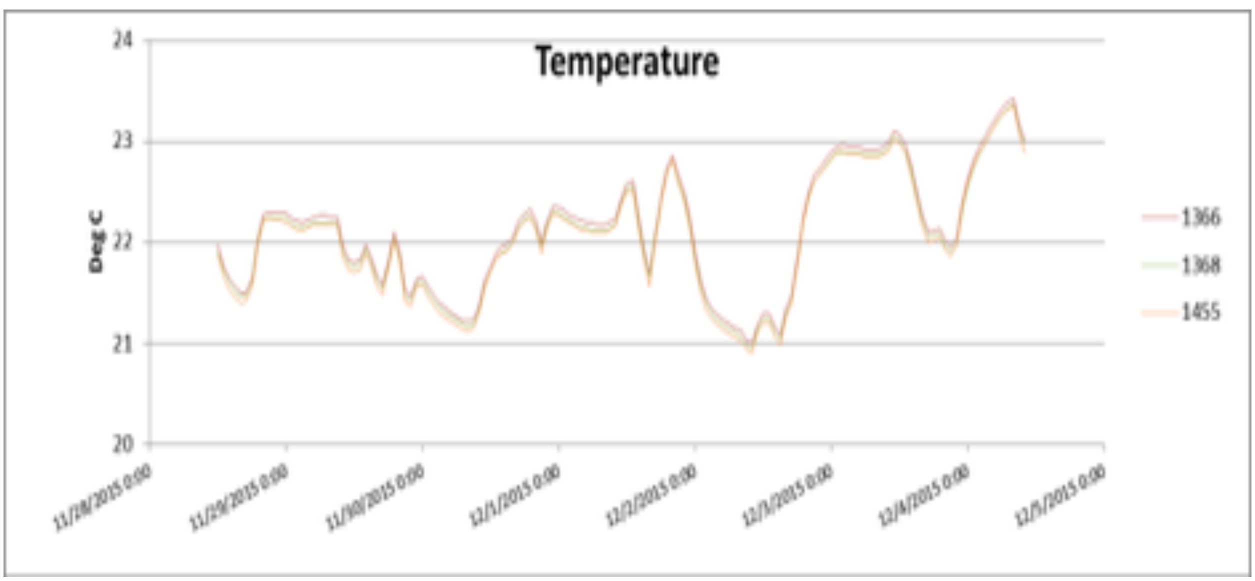

Figure 5 – Comparison of temperature measurements made at the end of the season by Capsules 1366 (Riverside), 1368 (Columere Marina), 1455 (Dutch Creek) and 5972(a new capsule).

Since the primary purpose of the remaining capsules was to record water pressure, placement to minimize heat transfer was a secondary consideration. The records from all sites exhibited diurnal variation. The extent to which this variation was influenced by the absorption of solar radiation is unknown. The accuracy of the sensors themselves does not appear to be an issue. Comparisons of the temperatures recorded by the sensors at the beginning and end of the season are shown in Figures 4 and 5, respectively. The values were consistently within a fraction of a degree from one another and displayed no evidence of change over the course of the season.