# Report

## Cheakamus Crossing Investigation

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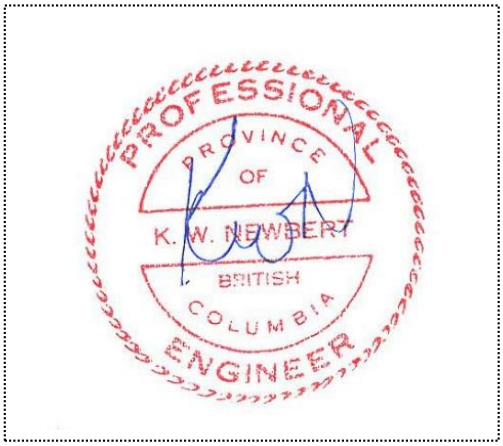

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## 1. INTRODUCTION

This project involves a detailed mechanical engineering design peer review and forensic examination of the suite systems installed in the townhouses located at Cheakamus Crossing in Whistler, BC and an investigation of the interface between the suite systems and the local District Energy System. The detailed scope of the work is listed in Section 4 – Scope of Work.

## 2. LIMITING CONDITIONS

This report has been prepared for Whistler Development Corporation and Cheakamus Crossing Strata's Group based on information gathered over multiple site visits by Integral Group Consulting (BC) LLP (Integral Group), and available information provided by representatives of Whistler Development Corporation and the representatives of the Cheakamus Crossing Strata's Group prior to and after the site visits.

Integral Group's site review is intended to be an examination of samples of work only, for the purposes and objectives stated herein. This study is not intended to represent a comprehensive detailed inspection or assessment of the systems, and should not be considered to replace any other inspections or requirements for service and maintenance. Integral Group is not responsible for identifying defects and deficiencies which are not reasonably apparent or visible in these random samples.

The recommendations presented in this report represent professional opinions of Integral Group in light of the terms of reference, scope of work, and any limiting conditions noted herein. Any use of the report, reliance on the report, or decisions based upon the report, by a third party are the responsibility of those third parties unless authorized in writing by Integral Group. The Integral Group Consulting (BC) LLP has copy-right permission for reproduction and distribution of this report.

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## 3. EXECUTIVE SUMMARY

1. Design and construction appears to have been typical for a project such as this with site instructions being issued through the construction period to clarify and further detail what was to be provided. We are a bit disappointed by the completion documentation and lack of detail on the procedures used for startup and commissioning and the lack of final Operating and Maintenance Manuals. The Homeowners Quick Reference Guide and Technical Service Guide currently being developed by the RMOW and DEC Design should go a long way to alleviate this deficiency.
2. The flow rate on the DES supply and lack of time delay on the heat pump operation until the 2-way is fully open is a concern that should be corrected as it leaves the heat pump in an operating region that is approaching the limits of efficient and reliable operation. The flow capabilities of the DES loop pumps need to be confirmed if a significant number of suites have the 6 gpm flow cartridges in lieu of the required 8 gpm as this could cause a flow increase of over 350 gpm if all the townhouses have only 6 gpm.
3. The Technical Service Guide should be used by the homeowner to outline service requirements to their service contractor and has a form included in the manual that the service contractor should fill out completely as they do each service and be inserted into the manual which should be kept in the mechanical room. This manual then provides a baseline and history of operation of the system and will be invaluable for keeping the systems running smoothly. The manual suggests 2 full services per year which we agree with. If system operation is stable after 3 services, the homeowner could consider switching to annual service.
4. We would recommend water samples from each unit except those included in my review be tested for hardness, TDS and pH and appropriate action taken where required to obtain hardness under 150 mg/L, TDS value under 250 and pH between 6.0 and 9.5. The appropriate action will typically be a flush which should be accompanied by a demineralization of the fill water if out of range of acceptability and a follow up visit to ensure pH is high enough. We would then suggest doing the same on a yearly basis to track the water quality and react as required to maintain the water within those guidelines. If the tests show stability the time between tests can be increased.
5. Any fan coils that do not have manual air vents should be equipped with them to avoid flushing to vent air. Flushing to vent air will introduce water into the system that may upset a stable water condition in the systems.
6. Because of the inconsistencies noted on the control of the backup electric heat for both the heating and domestic hot water we would suggest that each suite be checked to confirm that at a minimum the electric heat will be available if the heat pump fails. The Technical Service Guide covers this procedure quite well.
7. When shut off valves are provided on expansion tanks, these valves should be open except when replacing the tanks. The Schrader air valve on the bottom of the tank also needs to be made accessible to allow servicing the tank.
8. The RMOW appear to be doing a good job running and maintaining the DES system. The minimum supply water temperature of 10C is a good balance of energy efficiency and keeping the temperature high enough for reliable heat pump operation. We heard of some operating difficulties in the early days of DES operation but these problems appear to have addressed.
9. It is important to use service contractors who have service personnel that understand the systems, have trade tickets applicable to systems such as Refrigeration Mechanic, Pipe Fitter and Plumber and are willing to use the Technical Service Guide and do the required record keeping such as using the Service Report provided in the guide. The current service contractors (Western Technical Systems, Scoular Mechanical and Custom Air) appear to be capable of this but it will be up to the individual homeowner to ensure they provide the service required.

## 4. SCOPE OF REVIEW

4.1 The study involved the following scope of work:

1. Initial site visit to confirm existing conditions in 20 suites.
2. Review of any manuals and maintenance recommendations currently being formulated by RMOW so as not to duplicate work.
3. A critical review of the existing design mechanical drawings & specifications with the objective of identifying issues in the design, original installation, and original start up procedures or components installed.
4. From field reviews of 19 of the installations compare the installations against the mechanical drawings and specifications to assess whether the systems comply with the design mechanical drawings and specification. Identify any variances, especially deficiencies such as improperly installed hydronic heat pumps, system settings, etc.
5. Create a chemical flush and closed loop fluid specification. Confirm the suitability of the chemical flush and closed loop fluid specification with the manufacturer of the heat pump, ClimateMaster.
6. Take water samples and send them to an appropriate testing laboratory.
7. Formulate a monitoring and maintenance program for the closed loop fluid to ensure that it continues to meet specifications.
8. Investigate water temp and pressure from source side and load side closed loop. (RMOW loop data will come from their monitoring stations).
9. Review the impact of fluctuations in DES supply side fluid temperature and flow rate. Make recommendations to compensate for any fluctuations if present.
10. Investigate the significance of which water well was used at time of original installation. RMOW well W-212 in Function Junction. RMOW will provide historical water sampling data from this well.
11. Create a list of metrics with which to assess the existing installations not reviewed.
12. Provide recommendations for service technician's qualifications for servicing the systems moving forward.
13. Offer opinion of responsibility for each problem identified.

## 5. DOCUMENTS REVIEWED

5.1 Drawings

1. The following drawings were made available for this review:
    1. Whitewater (All units on Whitewater Drive) also known as Area A and Road 2.
        1. Digital (pdf) drawing set provided included 20 drawings, were dated Aug 15/07 and were Issued for BP. This set was indicated as Games mode. Set did not include a written control sequence or a control drawing.
        2. A second paper set provided was a full size set, included 21 drawings, were dated Mar 12/08 and were Reissued for Construction. This set was also indicated as Games mode. This set did include a control drawing but did not have a written control sequence indicated.
    2. The Terrace (All units at 1375 Cloudburst Drive) also known as Lot 4.
        1. Digital (pdf) drawing set provided included 11 drawings, were dated Apr 28/08 and were Issued for BP. This set was not indicated as Games mode but showed Games mode. This set included a control drawing and a written control sequence.
        2. A second paper set provided was a full size set, included 11 drawings, were dated Apr 28/08 and were Issued for BP. This set was not indicated as Games mode but showed Games mode. This set included a control drawing and a written control sequence.

3. Riverbend (All units at 1240 Mount Fee Road) also known as Lot 17 and Road 4.
    1. There was no digital set provided.
    2. The paper set provided was a full size set, included 14 drawings, were dated Dec 14/07 and were Issued for BP. This set was not indicated as Games mode but showed Games mode. This set included a control drawing but not a written control sequence. It should be noted that the drawings indicate fan coils on the second floor of these units and there is actually radiant floor heating on the second floor of all the Riverbend units.
4. The Rise (All units at 1245 Mount Fee Road and 1275 Mount Fee Road) also known as Lot 11.
    1. Digital (pdf) drawing set provided included 6 drawings, were dated Sep 2/08 and were Issued for MSI #2. This set was not indicated as Games mode but showed Games mode. This set included a control drawing, a control wiring diagram and a written control sequence.
    2. A second paper set provided was a full size set, included 9 drawings, were dated Aug 12/08 and were Issued for Construction. This set was not indicated as Games mode but showed Games mode. This set included a control drawing and a written control sequence.
5. The Heights (All units at 1380 Cloudburst Drive) also known as Lot 3.
    1. Digital (pdf) drawing set provided included 16 drawings, were dated May 15/08 and were Issued for BP. This set was not indicated as Games mode but showed Games mode. This set included a control drawing and a written control sequence.
    2. There was no paper set of drawings provided for The Heights.

5.2 Documents

1. Whitewater (All units on Whitewater Drive) also known as Area A and Road 2.
    1. Documents provided by Whistler Development Corporation (WDC) included the following:
        1. 20 Mechanical Site Instructions that include the following changes. We assume that similar instructions were issued for all the other phases of the project as the systems indicated on the drawings were all typical as they had the same schematic and where indicated had the same control sequence.
            1. Several controls clarifications.
            2. The change from 2 domestic hot water tanks to 1 tank.
            3. Changing the domestic hot water heat exchanger from double wall to single wall.
            4. Adjustments to be made to pressure settings on prv's and pressure reliefs.
            5. Provision of automatic air vents at all high points in the mechanical rooms.
            6. Called for pipe identification.
            7. Provided a completion check list for all the townhouses
            8. Called for removal of all integral check valves in pump in heat pumps.
            9. Provided specific flushing instructions for the DES supply and return lines.
            10. Added an expansion tank for the heating system.
        2. Two copies of proposed Operating and Maintenance Manuals with comments from DEC Design for changes prior to final submission. These manual submissions contained startup reports for all units in Whitewater.
        3. Inspection reports by Dec Design numbered 16 and 19 that outlined work yet to be completed for all townhouses and then specific requirements for each unit.
        4. Radiant floor piping layout shop drawings produced by Heat Link.
2. The Heights (All units at 1380 Cloudburst Drive) also known as Lot 3.
    1. Documents provided by WDC and Resort Municipality of Whistler (RMOW) included the following:
        1. Inspection reports by Dec Design numbered 1 to 16 that outlined work completed on site with some comments on the early reports and work yet to be completed for all townhouses and then specific requirements for each unit type or building for reports 12-16.

2. Copy of proposed Operating and Maintenance Manual with comments from DEC Design for changes prior to final submission. These manual submissions contained startup reports for all units in The Heights.
3. Startup reports completed by Western Technical Services dated Sept 2009.
4. Cross Connection letter from DEC Design to RMOW advising double check valve assembly was an appropriate level of cross contamination protection.

3. The Rise (All units at 1245 Mount Fee Road and 1275 Mount Fee Road) also known as Lot 11.
    1. Documents provided by Whistler Development Corporation (WDC) included the following:
        1. Copies of Schedule B-1, B-2 and separate C-B's for Buildings 1-7 (Lower Rise) and Buildings 8-15 (Upper Rise). Separate C-B's were issued as construction was split into 2 separate contracts.
        2. Various RMOW inspection reports including final sign offs some subject to engineer's approval, copy of some permit communications and various water meter inspection reports.
        3. Inspection reports by Dec Design numbered 1 to 15 for Upper Rise and 1 to 12 for Lower Rise that outlined work completed on site with some general comments on the early reports and work yet to be completed for all townhouses and then specific requirements for each unit type or building for the later reports.
        4. Startup reports for units 1 – 28 completed by WTS dated Sept, 2009.
4. The Terrace (All units at 1375 Cloudburst Drive) also known as Lot 4.
    1. Documents provided by Whistler Development Corporation (WDC) included the following:
        1. Various RMOW inspection reports including final sign offs some subject to engineer's approval.
        2. Inspection reports by Dec Design numbered 8 to 19 that outlined work completed on site with some comments on the early reports and work yet to be completed for all townhouses and then specific requirements for each unit type or building for reports 12 to 16.
5. WDC also provided Warranty invoices from Western Technical Services dated from Dec. 6/10 to Mar 21/11 which we have reviewed and attempted to analyse. It is our understanding that the final legacy occupancy occurred in the fall of 2010.
6. RMOW also provided the following information on the operation of the DES system:
    1. Information on the DES loop water quality records which are taken weekly from Jan 2015 to Oct 2015. They are testing for pH, total dissolved solids (TDS) and silica. They also provided DES loop water testing results from Pace Chemicals from Mar 2014 to October 2015.
    2. Supply and return water temperatures for the DES loop from Jul 16, 2014 to Jan Dec 1, 2015 taken every 15 minutes were also provided. They also indicated more data is available if required.
7. We had catalogue information or specific details from our site visits on all the major equipment provided in the systems including the Climatemaster heat pump, Grundfoss pumps, tanks, Spirovent air separator, Griswold automatic pressure independent balancing valve and DES 2-way control valve.
8. We have also seen a draft of the Homeowners Quick Reference Guide and Technical Service Guide being prepared by the RMOW and DEC Design and provided comments on both documents.

## 6. SITE VISITS

6.1 We visited 19 townhouses in the fall of 2015 to review the existing situation with the systems, have drawn schematic diagrams of each unit visited and report the following:

1. Generally speaking the systems are remarkably similar considering the number of installing contractors that were involved. Some variations include the following:
    1. Heating pump and domestic hot water (DHW) pump direction of flow and location. Some pumps are located in the supply to the buffer tank and DHW heat exchanger, some in the return lines and some pumps are pumping into the heat exchanger and buffer tank, some are pumping out. These differences should not present any operational problems if the pumps are performing at specified performance.

2. Spirovent air separators are all provided as indicated on the design drawings and are in an appropriate position in the system. These are very good air separators and should provide long term effective air removal from the systems. Smaller automatic air vents are also located in appropriate locations to remove air in the mechanical rooms. We did not see any fan coils with manual air vents as called for on the drawings. We heard no indication that there was air in any of the systems but the fan coils are the high points in the system and where air will accumulate if any is present in the systems and gets past the air separation in the mechanical rooms.
3. The fan coils were supplied with heating water several different ways as follow:
    1. Some townhouses had a single control valve and balancing valve.
    2. Some townhouses had a single control valve and no balancing valve.
    3. Some townhouses had control valves and balancing valves per fan coil.
    4. Some townhouses had just control valves per fan coil.
    5. The design drawings called for a single control valve and balancing valve for all the fan coils.
4. There were less pressure gauges and thermometers than I would have expected but both pressure gauge taps and the operating screen of the heat pumps provide sufficient information to service the systems.
5. Some systems have less drain points than others with many new drain valves having been installed since the systems were first put into service. These help with doing system flushes but the tank drains and drains on the domestic water heating supply and return could be used to flush and clean the systems with regular servicing.
6. The locations of the strainer, automatic balancing valve and control valve on the DES side of the system varied somewhat but the strainer was always located upstream of the other two items which is the most important thing.
7. We noted that the heat pump starts as the control valve on the DES system starts to open. This could cause problems with heat pump startup. A time delay should be introduced or if the valve has an end switch it could be utilized to allow the valve to fully open prior to the heat pump starting.
8. The switches for controlling the electric resistance heat in both the buffer tank for the heating system and the DHW tank were not consistent. Some had 2 switches, some had no switches, and some had switches including a 3 position switch on the DHW tank.
9. Specific comments on the some of the suites visited are as follows:
    1. All the Whitewater townhouses visited had the expansion tanks located very close to the floor which does not allow access to the air valve on the bottom of the tanks. These tanks should be raised to allow access to this air valve for expansion tank testing and adjusting.
    2. 1160 Whitewater has the expansion tank for the heating system isolated from the system by the shut off valve. Expansion tanks should always be open to the system they serve. The only time this valve should be shut is when replacing the tank.
    3. #16 Riverbend has had the Tekmar controller changed and we could not determine if the sequences etc. were appropriate. The owner indicated no problems with control of the systems.
    4. #20 – 1375 Cloudburst (The Terrace) has corrosion appearing inside the heat pump. Appeared to come from the unions on the 3-way valve in the heat pump. There was no evidence of water at those locations at the time of the visit. The system has been flushed and a lot of material was removed from the system.
    5. #3 – 1380 Cloudburst (The Heights) reported never having had a problem but had just completed a very low flow flush of his system.
    6. #39 – 1275 Mount Fee Road (The Upper Rise) had some problems 2 years ago but after service which included a system flush system has been OK.
    7. #8 – 1245 Mount Fee Road (The Lower Rise) system did not respond to calls for DHW heat or heating but was not “red screened”. Reset heat pump from breaker and system started and was up to temperature and seemed to be responding to calls for heat before we left.
    8. #13 Riverbend owner reported that there had never been a problem and didn’t believe the system had ever been flushed.

9. #38 – 1275 Mount Fee Road (The Upper Rise) has had the system modified in an attempt to reduce the pressure drop required to be overcome by the heating system pump and the pump size has been increased. Our impression is that the increased pump may have solved the problem without the repiping but the system will still function as intended with the repiping. Owner indicated system performance was improved

## 7. DATA ANALYSIS

7.1 Original Design and Construction

1. We reviewed the original design of the systems early in 2008 prior to initial construction for VANOC and at that time reported the systems seemed appropriate for the application considering the VANOC design criteria for domestic hot water delivery during Games Mode and how the heating system design would perform in Legacy Mode. We feel the same way today after reviewing all the drawings available. The system is both energy efficient and cost effective. The systems are not revolutionary or what we would call leading edge. The systems are still utilized in single family dwellings and townhouse developments either from a central DES style system or utilizing geo-exchange.
2. The design evolved from the design we reviewed early in 2008 but the design intent remained the same. The changes made in the design were all improvements in our view and contributed to better performance, cost effectiveness and energy efficiency.
3. The startup reports we reviewed from Whitewater, The Heights and Units 1 – 28 of the Lower Rise all indicated the units were operating within specification at the time of the report. We had to assume that the data for The Heights was metric as no units were indicated on the reports.
4. We cannot comment on the procedures used to clean, flush and fill the systems at original startup as there was nothing in any of the documents reviewed indicating what the procedure was. A brief description of the pipe cleaning and chemical treatment was included in the specification which called for a written report of how cleaning and chemical treatment was carried out. We have not seen any reports that indicate how or when this work was done.
5. Design documents called for an 8 gpm Griswold pressure independent balancing valve for the DES supply water. These valves automatically maintain the rated flow as long as the pressure differential across the valve is between 1 and 14 psi. These valves work very well. We observed 2 Griswold valves with 6 gpm indicated as the flow rate. The cartridges in these valves should be checked for all units and replaced with 8 gpm cartridges where required. The heat pumps are flow sensitive and the units were clearly specified at 8 gpm. Shop drawings for heat pump did not indicate flow rate.

7.2 Water Chemistry

1. Samples of the heating system water were taken from 15 of the units visited as well a 1 domestic cold water sample. The water samples were tested for conductivity, hardness, iron, pH and total dissolved solids (TDS) at Maxxam Analytics in Burnaby. We have summarized the results in Appendix A.
2. We would recommend the following ranges for the criteria indicated above:
    1. Conductivity: <400 µs/cm
    2. Hardness: <120 mg/L
    3. Iron: Maximum of 0.5 ppm
    4. pH: 6.0 – 9.5
    5. TDS: Maximum of <250 ppm
3. Conductivity and TDS indicate particulate content in the water and will tend to track with each other. If these values rise to near the maximum it is an indication that a complete flush or a slow drain and replace routine (open the drain from the buffer tank to slowly let water runoff and be replaced with clean water) may be required.
4. pH levels below 6.0 will cause corrosion of iron parts in the system (which are limited) and above 9.5 will cause corrosion of copper components in the system which are more common than the iron components in these systems.

5. The domestic cold water is not as hard as expected but is not so soft that it should cause problems. Water hardness is classified as soft up to 60 mg/L, medium hard up to 120 mg/L, hard up to 180 mg/L and very hard over 180 mg/L. We were initially concerned that the water was much harder and scaling would be a serious problem. This does not appear to be the case. In situations where the hardness is elevated a complete flush or a slow drain and replace routine (open the drain from the buffer tank to slowly let water runoff and be replaced with clean water) may be required. This could be done as a result of a regular water testing program.
6. In a discussion with Mr. Dave Robb of Western Technical Systems he indicated that after heavy rains the domestic water that is used to fill or top up the systems can be high in calcium which means that the hardness spikes after these weather events. Doing flushes during this time of hard water spike is not recommended.
7. Test kits are available to measure hardness and pH or homeowners can have the servicing contractor do the tests or send samples to a certified lab for high quality measurements. We used Maxaam Analytics in Burnaby. They will provide sample jars and can complete testing in 5 business days.
8. The records from the RMOW indicate they are monitoring the DES water on a regular basis. They are monitoring pH, TDS and silica and the levels maintained appear to be appropriate.
9. We have reviewed the Annual Drinking Water Reports from 2008, 2009 and 2010 relative to the water quality from Wells 212-1 and 212-2 and find the water quality available during this period to be acceptable for use in the heating water systems. The water is soft, has low conductivity, pH of about 7 and TDS below 200. These qualities are all acceptable for use in a heating water system. We have attached the summary pages from the reports in Appendix B.
10. Climatemaster recommend pH of 6 to 8.5 and the Residential Heating System Technical Service Guide recommends pH of 6 to 8.5 and TDS less than 125. We feel these are acceptable ranges and limits but the TDS limit could possibly be raised to 250 and the pH upper limit could be set to 9.5 without creating any operational difficulties.

7.3 DES Operation Review

1. We visited the DES plant to review operation and see the plant itself. The system appears to be robust with redundant heat exchangers, boilers and pumps. Controls are digital with alarms to indicate problems and 24 hour on call service available when required. The regular maintenance procedures seem sufficient to keep the plant operating at high efficiency and it was reported that there were only 2 unplanned shutdowns in 2015 and 1 planned shutdown. These were indicated to be of short duration.
2. The boilers in the plant were replaced recently with higher efficiency condensing type boilers and the boiler control and efficiency were improved by small piping changes made to make the boiler heat injection smoother.
3. We reviewed the operation logs of the system from 3 access manholes in the Cheakamus Crossing area and offer the following comments:
    1. The 3 manholes that were logged are Manhole A (2) at Mount Fee Road and Legacy Way Manhole B (18) on Mount Fee Road just north of Legacy Way and Manhole C (8) at Mount Fee Road and Cloudburst Drive.
    2. The data was from July 16, 2014 to January 15, 2015 with temperatures indicated at 15 minute intervals.
    3. Manhole A (2) had temperatures that varied from a low of 0.18C on January 9, 2015 to 25.3C on August 11, 2014. The low temperature seems to be an anomaly as the temperature 15 minutes before was 10.42C and 15 minutes after was 13.23C. The next lowest temperature was 10.1C on January 2, 2014.
    4. Manhole B (18) had temperatures that varied from a low of 0.54C on January 9, 2015 to 26.8C on August 11, 2014. The low temperature seems to be an anomaly as the temperature 30 minutes before was 10.01C and 30 minutes after was 5.31C. This log has the supply temperature stay at about 6C until January 14, 2015 then climb to about 10C.
    5. Manhole C (8) had temperatures that varied from a low of 0.64C on January 9, 2015 to 25.5C on August 11, 2014. The low temperature seems to be an anomaly as the temperature 15 minutes before was 6.85C and 15 minutes after was 11.47C. The next lowest temperature was 11.0C on December 14, 2014.
    6. Manhole A (2) is at the beginning of the distribution system through Cheakamus Crossing, manhole C (8) is about halfway through the distribution system and manhole B (18) is at the end of a supply branch over halfway through the distribution system.

7. We questioned the RMOW about the anomalies we noticed and they indicated there were some sensor problems in the manholes that were repaired. They only use these sensors for information, the system control is at the DES plant and the minimum setpoint is 10C. We received a log of the water temperatures leaving the DES plant for the same period as above and they indicate a minimum supply water temperature of 10C leaving the plant which is what we would expect. This temperature goes up in the warm months which is fine as the heat pump will be more efficient at higher entering water conditions.

7.4 Warranty Work Review

1. We received copies of warranty work orders/invoices from WDC from Dec 17/10 to March 21/10 and offer the following comments:
    1. There were a total of 48 visits to 40 different suites.
    2. There were 20 visits where control work was required. This included wiring issues, control valve actuator issues, Tekmar controller issues and defective thermostats,
    3. There were 15 visits where there was work required to heat pumps. This included failed compressors (2), failed Tx valves (4), failed capacitors (3), adjustment to refrigerant charge (1), noisy compressors (3) and excessive vibration (2). There were also 43 LWT log readings.
    4. Six pumps were replaced or had their cartridges replaced.
    5. There were 2 water leaks deal with on both the DES piping and system piping.
    6. There were 3 indications of no Spirovent present and no indication of they were installed. We saw Spriovents on all the systems we observed.
    7. There were 3 visits that required some additional balancing to resolve cold spots in the radiant slabs.
    8. There were 2 visits that corrected fan problems that related to 1 new fan and 1 new fan motor.
    9. There were 2 visits to correct air locks in the systems both of which related to fan coils.
    10. There were 2 visits where system flushes were done.
    11. There was 1 visit where there was a piping problem at a fan coil that was repaired.
    12. There were 48 LWT red screens indicated on the work orders with 8 being the cause of the visit and the remainder being read from the fault logs on the heat pumps.
2. The work indicated in the warranty work orders/invoice, for the most part, is typical of warranty work on systems of this type but some of the work appears to be work that could have and should have been done during startup and commissioning of the systems.

## 8. SERVICE CONTRACTOR'S REVIEW

8.1 We are aware of three contractors currently servicing the systems in Cheakamus Crossing and have received generally positive comments about them. It is important to use service contractors who have service personnel that understand the systems, have trade tickets applicable to systems such as Refrigeration Mechanic, Pipe Fitter and Plumber and would also add the following comments:

1. The contractor should be instructed to use the Technical Service Guide for Cheakamus Crossing produced by DEC Engineering when providing regular service and diligently use the Home Heating System Service Report sheet to report testing results when performing regular servicing. This report provides the results of the service and if the previous reports are readily available to the service technician it makes troubleshooting the systems much simpler and provides the homeowner with a record of the service provided.
2. Homeowner should ensure that the service technician is clear that all the fields in the report need to filled out to ensure a complete service check is done. These reports should be kept in the heat pump room where the service technician can get easy access to them. A copy of the Technical Service Guide should also be kept in a binder in the heat pump room with space for the Service Reports from previous visits.
3. The Technical Service Guide also provides a detailed description of the control sequences designed including recommended system settings broken down to Heat Pump settings, Storage Tank settings and Heat Pump normal operating ranges as well as a detailed troubleshooting guide to specific problems.

8.2 We are reluctant to recommend any specific contractors as they are only as good as the service technicians that actually visit the site. The current contractors we know of are Scoular Mechanical, Western Technical Systems and Custom Air. We have heard positive and negative comments (mostly positive) about these contractors from homeowners at homes we visited. We did notice Spearhead Plumbing and Heating stickers on some of the equipment during our site visits but nobody we spoke with mentioned them and their website did not indicate they have refrigeration mechanics available.

8.3 Any qualified service company that uses the Technical Service Guide mentioned above and has qualified staff doing the service work can provide proper technical service and the choice of a service contractor is a personal choice of the homeowner. Each homeowner needs to find a service contractor they have confidence in and we believe the 3 mentioned above are quite capable of doing that.

## 9. CONCLUSIONS

9.1 Documents Reviewed

1. Drawings provided were limited to Games Mode only. The mechanical systems appear to have been designed with the Legacy Mode in mind and we would not expect a lot of changes mechanically to accommodate Legacy Mode.
2. The drawings were typical of a housing development such as this with a more sophisticated heating system requiring additional detailing to achieve the end goal. All of the points I noted as being deficient and some that I hadn't were provided during construction through Mechanical Site Inspections and Inspection Reports. We have assumed that the site instructions we have seen were issued to all the other mechanical contractors on the site as the systems were the same throughout the site.
3. We were disappointed to not see final Operation and Maintenance Manuals as all we've seen is the original submission from 2 of the contractors that DEC Design had several important comments on. We are not sure if the final O & M Manuals were ever delivered to the various stratas. The Homeowners Quick Reference Guide and Technical Service Guide currently being developed by DEC Engineering and RMOW will assist homeowners with operation and maintenance of their systems but if there is a copy of a completed manual for each development a copy should be provided for the strata's use.
4. Schedules B-1, B-2 and CB as required by the BC Building Code for The Rise were submitted and we assume they were also done for each of the other phases of the initial construction project as required by the municipality.
5. Final Signoffs were done by the plumbing inspectors for RMOW and documented.
6. The warranty work we reviewed, for the most part, is typical of warranty work on systems of this type but some of the work appears to be work that could have and should have been done during startup and commissioning of the systems. The reports reviewed were only for 3 months at the beginning of the warranty period but indicate to us that while there may have been some problems we did not see a pattern that would indicate serious systemic problems.
7. We are unsure of the procedures used to clean and flush the systems prior to startup or even if the work was done. This is reinforced by some of the water samples taken, pictures of system water during flushes that have subsequently happened and indications from homeowners who had flushes recently. I am not aware of people who have had multiple flushes in a short period of time which leads us to believe the initial cleaning and flushing, if done at all, may not have been done well.
8. The combination of the possibility that the Griswold balancing valves on the DES supply to each townhome may only be 6 gpm rated rather than 8 gpm as specified and control valve CV-1 on the DES supply is only just starting to open when the heat pump starts is a serious concern for us. The heat pumps are flow sensitive and to have them start without sufficient water flow could be a contributor to the red screen problems. We feel every unit should be checked to ensure the flow cartridge in the Griswold valve is an 8 gpm unit and have a time delay put on the startup of the heat pump until the valve is fully open or utilize an end switch on the valve if there is one. This will allow the heat pump to start with proper flow conditions assured. The heat pumps should run reliably for at least 15-20 years with proper flow and water temperature conditions maintained and proper operating parameters maintained. These are all indicated in the Technical Service Guide and these guidelines should be followed.
9. We reviewed a draft of the Homeowners Quick Reference Guide and the Technical Service Guide developed by the RMOW and DEC Engineering and found these documents well written, detailed and directly applicable to the systems in each of the townhomes. The Homeowners Quick Reference Guide document should be used by the homeowners to understand the systems better and offers very simple troubleshooting suggestions that the homeowner can try before calling for service. The Technical Service Guide should be used by the homeowner to outline service requirements to their service contractor and has a form included in the manual that the service contractor should fill out completely and be inserted into the manual which should be kept in the mechanical room. This manual then provides a baseline and history of operation of the system and will be invaluable for keeping the systems running smoothly.

9.2 Site Visits

1. We did not see any fan coils with manual air vents as called for on the drawings. If fan coils are found air locked the solution should be to install a manual air vent on that fan coil, not flush the system to clear the air. This will allow any air trapped at the top of the system to be vented and not require a flush of that zone to eliminate the air.
2. Because of the inconsistencies noted on the control of the backup electric heat for both the heating and domestic hot water we would suggest that each suite be checked to confirm that at a minimum the electric heat will be available if the heat pump fails. The Technical Service Guide covers this procedure quite well.
3. All Whitewater townhomes should be checked to ensure the expansion tanks are located to allow access to the Schrader air valve on the bottom of the tank. If there is no access raise the tanks enough to provide access. These valves are used to adjust the pressure in the tank to allow optimum operation and to test the condition of the bladder in the tank.
4. We noted that 1160 Whitewater had the expansion tank isolation valve closed. If provided this valve must always be open unless changing the tank.

9.3 Water Chemistry

1. Our review of the data gathered from the domestic water sample and the data indicated in the RMOW Annual Water Reports for 2008 to 2010 has led us believe that the water quality is not the issue we first thought it might be. The domestic water would be classified as the high end of soft at 44.1 mg/L from our water sample and ranging from 33.1 to 61.1 mg/L from the Annual Water Reports for Wells 212-1 and 212-2. The TDS is below 200 and the pH is about 7.0 which are all acceptable for use in the heating system.
2. The system samples have some units that are well outside the boundaries of the acceptable limits indicated in our sample testing results report included in Appendix A and these suites should be flushed with clean, demineralized water to get the TDS and pH into the recommended range.
3. We would recommend water samples from each unit except those included in my review be tested for TDS and pH and appropriate action taken where required to obtain TDS value under 250 and pH between 6.0 and 9.5. We would then suggest doing the same on a yearly basis to track the water quality and react as required to maintain the water within those guidelines. If the tests show stability the time between tests can be increased.
4. The RMOW has a regular testing and treatment plan in place that seems to be controlling the water quality is the DES system within acceptable limits and this program should be continued.

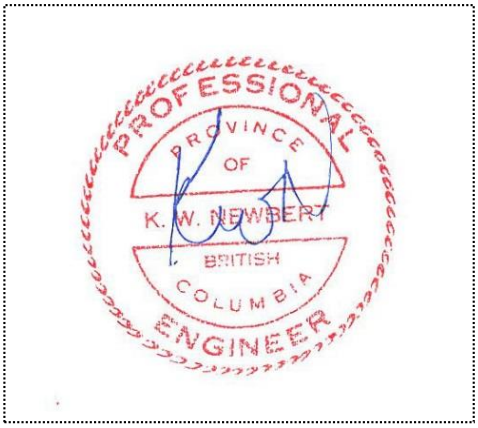
9.4 DES Operation Review

1. After reviewing the operation first hand by visiting the plant and reviewing the 6 months' worth of operating data we feel the RMOW are doing a good job running and maintaining the DES system. The minimum supply water temperature of 10C is a good balance of energy efficiency and keeping the temperature high enough for reliable heat pump operation.

INTEGRAL GROUP

Ken Newbert, PEng, LEED AP
Technical Director

KWN/KWN



# Appendix A

Integral Group

Maxxam Job Number B605356

Report Date 2016/02/01

RESULTS OF CHEMICAL ANALYSES OF WATER

| Address | Sample date | Total Hardness (mg/L) | Conductivity (µS/cm) | pH | Total Dissolved Solids (mg/L) | Iron (mg/L) | |
|---|---|---|---|---|---|---|---|
| | | <150 | <400 | 6.0 - 9.5 | <250 | 0.5 | Recommended Range |
| | | 0.50 | 1.00 | na | 10.00 | 0.01 | RDL |
| 1160 WHITWATER | 11/9/2015 | 98.2 | 273 | 9.81 | 188 (1) | 0.24 | |
| #4 - 1380 CLOUDBURST | 11/17/2015 | 156 | 2410 | 10.2 | 1740 (1) | 0.277 | |
| #39 UPPER RISE | 11/17/2015 | 5.65 | 2380 | 10.1 | 1770 (1) | 0.039 | |
| 1132 WHITEWATER | 11/27/2015 | 228 | 890 | 9.33 | 560 (1) | 0.275 | |
| #31 UPPER RISE | 11/17/2015 | 24.4 | 253 | 9.78 | 136 (1) | 0.121 | |
| 1128 WHITEWATER | 11/13/2015 | 453 | 1190 | 9.49 | 792 (1) | 1.98 | |
| #17-1380 CLOUDBURST | 11/17/2015 | 102 | 355 | 9.81 | 230 (1) | 0.144 | |
| #13 RIVERBEND | 11/24/2015 | 45.6 | 171 | 9.35 | 80 (1) | <.010 | |
| #3-1380 CLOUDBURST | 11/17/2015 | 556 | 185 | 9.57 | 96 (1) | 5.1 | |
| #1-1375 CLOUDBURST | 11/13/2015 | 231 | 1020 | 9.33 | 626 (1) | 0.788 | |
| #25-1375 CLOUDBURST | 11/13/2015 | 46.4 | 2580 | 9.95 | 1900 (1) | <.010 | |
| #8 LOWER RISE | 11/24/2015 | 85.7 | 411 | 9.55 | 280 (10) | 0.462 | |
| #16 RIVERBEND | 11/9/2015 | 96.6 | 235 | 9.43 | 134 (1) | 0.177 | |
| #45 UPPER RISE | 11/10/2015 | 29.8 | 292 | 8.02 | 141 (1) | 0.056 | |
| DOM. WATER SAMPLE | 11/9/2015 | 44.1 | 111 | 7.56 | 58 (1) | <0.10 | |

RDL = Reportable Detection Limit

(1) Sample arrived to laboratory past recommended hold time.

Results relate only to the items tested.

# Appendix B

## 2008 Annual Water Chemistry Sampling Results

Resort Municipality of Whistler

| | Sample Location: | | Village Wells | | | | Alpine Wells | | | South End Wells and Reservoir | | | Emerald Wells | | | Surface Water Intakes | | | Random Locations | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | W205-1 | W205-2 | W205-3 | W211 | W202 | W210 | W213 | W212-1 | W212-2 | R228 | W201-1 | W201-2 | W201-3 | R222 | R231 | R232 | S106 | Main Street |
| | Sample Date: | | 22-Jan-09 | 22-Jan-09 | 22-Jan-09 | 22-Jan-09 | 20-Nov-08 | 20-Nov-08 | 20-Nov-08 | 22-Jan-09 | 22-Jan-09 | 22-Jan-09 | 20-Nov-08 | 4-Feb-09 | 20-Nov-08 | 23-Jan-09 | 23-Jan-09 | 23-Jan-09 | 22-Jan-09 | 20-Nov-08 |
| **Testing Parameter** | **GCDWQ Standard[1]** | **Units** | | | | | | | | | | | | | | | | | | |
| **Misc. Inorganics** | | | | | | | | | | | | | | | | | | | | |
| Fluoride | 1.5 | mg/L | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.06 | <0.05 | <0.05 | <0.05 | <0.05 | 0.07 | <0.05 | <0.05 | <0.05 | <0.05 |
| **ANIONS** | | | | | | | | | | | | | | | | | | | | |
| Nitrite | 1 | mg/L | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| **Calculated Parameters** | | | | | | | | | | | | | | | | | | | | |
| Total Hardness[2] | | mg/L | 104 | 186 | 158 | 111 | 23.5 | 24.2 | 87 | 37 | 33.1 | 15.8 | 62.4 | 46.9 | 54.2 | 87.7 | 16.1 | 32 | 16.1 | 9.9 |
| Nitrate | 10 | mg/L | 0.18 | 0.57 | 0.48 | 0.16 | <0.05 | <0.05 | 0.12 | 0.13 | 0.1 | <0.05 | 0.44 | 0.06 | 0.22 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| **Anions** | | | | | | | | | | | | | | | | | | | | |
| Dissolved Sulphate | | mg/L | 59.1 | 113 | 78.9 | 63.7 | 6.11 | 9.47 | 60.5 | 12.4 | 8.27 | 4.33 | 20 | 14.2 | 13.7 | 34.1 | 4.46 | 4.8 | 4.3 | 2.84 |
| Dissolved Chloride | 250 | mg/L | 17.7 | 40.8 | 34.9 | 12 | 2.82 | 0.25 | 6.81 | 15.1 | 17.9 | 0.85 | 32.9 | 3.16 | 25.4 | <0.2 | 0.38 | 0.24 | 0.86 | 1.16 |
| **Miscellaneous** | | | | | | | | | | | | | | | | | | | | |
| True Colour | 15 | Col. Unit | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| **Nutrients** | | | | | | | | | | | | | | | | | | | | |
| Nitrate + Nitrite | 10 | mg/L | 0.18 | 0.57 | 0.48 | 0.16 | <0.05 | <0.05 | 0.12 | 0.13 | 0.1 | <0.05 | 0.44 | 0.06 | 0.22 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| **Physical Properties** | | | | | | | | | | | | | | | | | | | | |
| Conductivity | | uS/cm | 281 | 483 | 399 | 272 | 65 | 63 | 224 | 145 | 142 | 41 | 268 | 137 | 219 | 198 | 42 | 71 | 41 | 28 |
| pH | 6.5 - 8.5 | pH Units | 7.12 | 7.34 | 7.36 | 7.41 | 7.26 | 7.32 | 7.38 | 6.93 | 7.04 | 7.17 | 7.29 | 7.57 | 7.54 | 8 | 7.37 | 7.71 | 7.28 | 7.02 |
| **Physical Properties** | | | | | | | | | | | | | | | | | | | | |
| Total Dissolved Solids | 500 | mg/L | 162 | 310 | 248 | 166 | 26 | 38 | 137 | 81 | 90 | 29 | 140 | 65 | 112 | 138 | 34 | 43 | 19 | <10 |
| Turbidity[3] | 1 | NTU | 0.27 | <0.1 | <0.1 | <0.1 | <0.1 | 0.21 | 0.14 | 0.15 | 0.14 | 0.12 | 0.1 | 0.3 | 0.11 | 0.17 | 0.1 | 0.4 | <0.1 | 0.22 |
| **Mercury by CVAA** | | | | | | | | | | | | | | | | | | | | |
| Total Mercury | 1 | ug/L | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 |
| **Total Metals by ICP** | | | | | | | | | | | | | | | | | | | | |
| Total Aluminum | | mg/L | 0.002 | 0.002 | 0.012 | 0.002 | 0.005 | 0.022 | 0.002 | 0.003 | 0.001 | 0.026 | 0.005 | 0.015 | 0.004 | 0.004 | 0.027 | 0.037 | 0.025 | 0.047 |
| Total Barium | 1 | mg/L | 0.014 | 0.022 | 0.022 | 0.013 | 0.0077 | 0.012 | 0.023 | 0.021 | 0.015 | 0.0079 | 0.014 | 0.0058 | 0.0084 | 0.002 | 0.0081 | 0.01 | 0.0076 | 0.0047 |
| Total Boron | 5 | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Total Calcium | | mg/L | 40 | 71.3 | 59.9 | 42.8 | 8.87 | 9.04 | 33.3 | 12 | 10.1 | 5.87 | 23.3 | 17.6 | 20.3 | 33.1 | 6 | 12.3 | 5.98 | 3.7 |
| Total Chromium | 0.05 | mg/L | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 |
| Total Cobalt | | mg/L | | | | | | | | | | | | | | | | | | |
| Total Copper | 1 | mg/L | 0.0051 | 0.0027 | 0.0095 | 0.0026 | 0.0042 | 0.0008 | 0.0029 | 0.0033 | 0.0018 | 0.003 | 0.0028 | 0.0046 | 0.013 | <0.0002 | 0.0003 | 0.0004 | 0.0048 | 0.0061 |
| Total Iron | 0.3 | mg/L | 0.09 | 0.02 | 0.02 | <0.01 | <0.01 | 0.02 | <0.01 | 0.04 | 0.03 | 0.01 | <0.01 | 0.1 | <0.01 | <0.01 | 0.02 | 0.03 | 0.02 | 0.03 |
| Total Magnesium | | mg/L | 1 | 1.32 | 1.2 | 0.9 | 0.34 | 0.37 | 0.97 | 1.65 | 1.9 | 0.28 | 1.11 | 0.76 | 0.92 | 1.22 | 0.27 | 0.32 | 0.27 | 0.16 |
| Total Manganese | 0.05 | mg/L | 0.0063 | 0.001 | 0.0005 | 0.0006 | 0.0002 | 0.0005 | 0.0004 | 0.034 | 0.179 | 0.001 | 0.0002 | 0.0022 | <0.0002 | 0.0004 | 0.0003 | 0.0012 | 0.0005 | 0.0011 |
| Total Potassium | | mg/L | 1.23 | 1.27 | 1.19 | 0.88 | 0.48 | 0.47 | 1 | 1.57 | 1.92 | 0.45 | 0.98 | 0.55 | 0.58 | 1 | 0.45 | 0.42 | 0.45 | 0.27 |
| Total Sodium | 200 | mg/L | 10.5 | 16.2 | 11.7 | 3.76 | 1.71 | 0.89 | 2.93 | 10.3 | 12.5 | 1 | 22.4 | 6.71 | 16.7 | 2.4 | 1.01 | 1.08 | 0.92 | 0.72 |
| Total Zinc | 5 | mg/L | 0.01 | 0.001 | 0.003 | 0.003 | 0.006 | <0.001 | 0.008 | 0.004 | 0.001 | 0.001 | 0.004 | 0.007 | 0.005 | <0.001 | 0.001 | <0.001 | 0.001 | 0.005 |
| **Total Metals by ICPMS** | | | | | | | | | | | | | | | | | | | | |
| Total Antimony | 0.006 | mg/L | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 |
| Total Arsenic | 0.01 | mg/L | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | 0.0024 | <0.0002 | <0.0002 | <0.0002 | <0.0002 |
| Total Cadmium | 0.005 | mg/L | <0.00004 | <0.00004 | <0.00004 | <0.00004 | <0.00004 | <0.00004 | <0.00004 | <0.00004 | <0.00004 | <0.00004 | <0.00004 | <0.00004 | <0.00004 | <0.00004 | <0.00004 | <0.00004 | <0.00004 | <0.00004 |
| Total Lead | 0.01 | mg/L | 0.0003 | 0.0006 | 0.0006 | 0.0006 | <0.0002 | <0.0002 | <0.0002 | 0.0008 | 0.0003 | <0.0002 | 0.0003 | 0.0002 | 0.0003 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | 0.0003 |
| Total Selenium | 0.01 | mg/L | 0.0004 | 0.0004 | 0.0005 | 0.0005 | <0.0002 | <0.0002 | 0.0004 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | 0.0006 | <0.0002 | <0.0002 | <0.0002 | <0.0002 |
| Total Uranium | 0.02 | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |

***Comments:***

1. *Blanks under the GCDWQ Standard heading indicates that a MAC (maximum acceptable concentration) or IMAC (interim maximum acceptable concentration) has not been established for that parameter.*
2. *Although a MAC has not been established for hardness, levels up to 200mg/L is considered to be acceptable \ tolerable; levels in excess of 500mg/L are unacceptable for most domestic purposes.*
3. *RMOW surface water intakes automatically shut down when turbidity exceeds 1NTU.*

## 2009 Annual Water Chemistry Sampling Results

Resort Municipality of Whistler

| | | | Village Wells | | | | Alpine Wells | | | | South End Wells and Reservoir | | | Emerald Wells | | | Surface Water Intakes | | | Random Locations | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Sample Location:* | | W205-1 | W205-2 | W205-3 | W211 | W202 | W210 | W218 | W213 | W212-1 | W212-2 | R228 | W201-1 | W201-2 | W201-3 | R222 | R231 | R232 | S106 | Main Street |
| | *Sample Date:* | | 29-Oct-09 | 29-Oct-09 | 29-Oct-09 | 1-Dec-09 | 26-Oct-09 | 26-Oct-09 | 26-Oct-09 | 26-Oct-09 | 29-Oct-09 | 29-Oct-09 | 29-Oct-09 | 26-Oct-09 | 26-Oct-09 | 26-Oct-09 | 22-Oct-09 | 26-Oct-09 | 22-Oct-09 | 29-Oct-09 | 29-Oct-09 |
| **Testing Parameter** | **GCDWQ Standard[1]** | **Units** | | | | | | | | | | | | | | | | | | | |
| **Misc. Inorganics** | | | | | | | | | | | | | | | | | | | | | |
| Fluoride | 1.5 | mg/L | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.05 | 0.07 | 0.07 | <0.05 | <0.05 | <0.05 | 0.09 | <0.05 | <0.05 | <0.05 | <0.05 |
| **ANIONS** | | | | | | | | | | | | | | | | | | | | | |
| Nitrite | 1 | mg/L | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| **Calculated Parameters** | | | | | | | | | | | | | | | | | | | | | |
| Total Hardness[2] | | mg/L | 96.9 | 137 | 64.6 | 82.7 | 25.4 | 24.6 | 26.8 | 86.6 | 39.1 | 45 | 39.8 | 69.4 | 92.2 | 77.9 | 79.5 | 11.5 | 22.9 | 40 | 12 |
| Nitrate | 10 | mg/L | 0.22 | 0.11 | <0.05 | <0.05 | 0.06 | <0.05 | <0.05 | 0.12 | 0.12 | <0.05 | 0.12 | 0.4 | 0.23 | 0.24 | <0.05 | <0.05 | <0.05 | 0.11 | <0.05 |
| **Anions** | | | | | | | | | | | | | | | | | | | | | |
| Dissolved Sulphate | | mg/L | 51.3 | 81.8 | 30 | 48.8 | 8.01 | 9.36 | 10.8 | 54.6 | 11.2 | 8.14 | 11.1 | 23 | 22.9 | 49.1 | 38.4 | 3.2 | 3.43 | 11.2 | 3.75 |
| Dissolved Chloride | 250 | mg/L | 22.9 | 14.6 | 2.84 | 3.53 | 1.04 | <0.2 | 1.76 | 7.35 | 35.8 | 48.6 | 36 | 43.8 | 25.8 | 24.4 | <0.2 | 0.29 | 0.21 | 35.4 | 1.07 |
| **Miscellaneous** | | | | | | | | | | | | | | | | | | | | | |
| True Colour | 15 | Col. Unit | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 7 | <5 | <5 | <5 |
| **Nutrients** | | | | | | | | | | | | | | | | | | | | | |
| Nitrate + Nitrite | 10 | mg/L | 0.22 | 0.11 | <0.05 | <0.05 | 0.06 | <0.05 | <0.05 | 0.12 | 0.12 | <0.05 | 0.12 | 0.4 | 0.23 | 0.24 | <0.05 | <0.05 | <0.05 | 0.11 | <0.05 |
| **Physical Properties** | | | | | | | | | | | | | | | | | | | | | |
| Conductivity | | uS/cm | 278 | 347 | 162 | 192 | 66 | 60.3 | 73 | 218 | 200 | 251 | 200 | 299 | 250 | 287 | 210 | 31 | 56 | 200 | 32.4 |
| pH | 6.5 - 8.5 | pH Units | 7.36 | 7.65 | 7.58 | 7.16 | 7.43 | 7.44 | 7.37 | 7.6 | 7.14 | 7.25 | 7.17 | 7.64 | 7.81 | 7.76 | 7.98 | 7.22 | 7.6 | 7.14 | 7.14 |
| **Physical Properties** | | | | | | | | | | | | | | | | | | | | | |
| Total Dissolved Solids | 500 | mg/L | 169 | 211 | 94 | 119 | 60 | 47 | 59 | 134 | 117 | 131 | 105 | 143 | 132 | 159 | 132 | 15 | 54 | 83 | 22 |
| Turbidity[3] | 1 | NTU | 0.1 | 0.19 | 0.13 | <0.1 | <0.1 | 0.12 | <0.1 | <0.1 | 0.27 | 0.18 | 0.11 | 0.1 | 0.14 | 0.1 | 0.12 | 0.42 | 4.2 | 0.16 | 0.11 |
| **Mercury by CVAA** | | | | | | | | | | | | | | | | | | | | | |
| Total Mercury | 1 | ug/L | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 |
| **Total Metals by ICP** | | | | | | | | | | | | | | | | | | | | | |
| Total Aluminum | | mg/L | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.004 | 0.002 | 0.001 | 0.003 | 0.002 | 0.003 | 0.003 | 0.011 | 0.002 | 0.003 | 0.12 | 0.2 | 0.003 | 0.033 |
| Total Barium | 1 | mg/L | 0.013 | 0.014 | 0.0076 | 0.0077 | 0.0075 | 0.01 | 0.013 | 0.022 | 0.029 | 0.03 | 0.03 | 0.015 | 0.012 | 0.012 | 0.0022 | 0.0068 | 0.012 | 0.029 | 0.0063 |
| Total Boron | 5 | mg/L | <0.005 | 0.006 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | 0.005 | 0.009 | 0.005 | 0.008 | 0.006 | 0.006 | <0.005 | <0.005 | <0.005 | 0.005 | <0.005 |
| Total Calcium | | mg/L | 37.8 | 52.3 | 24.3 | 32.1 | 10.3 | 9.13 | 9.74 | 34.6 | 11.3 | 12.9 | 11.3 | 25.1 | 29.4 | 28.8 | 30.9 | 4.18 | 8.55 | 11.3 | 4.38 |
| Total Chromium | 0.05 | mg/L | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 |
| Total Cobalt | | mg/L | | | | | | | | | | | | | | | | | | | |
| Total Copper | 1 | mg/L | 0.0081 | 0.003 | 0.0081 | 0.0046 | 0.0067 | 0.0009 | 0.0008 | 0.0029 | 0.0025 | 0.0012 | 0.015 | 0.0056 | 0.0088 | 0.0097 | 0.0002 | 0.0007 | 0.001 | 0.02 | 0.0071 |
| Total Iron | 0.3 | mg/L | 0.01 | 0.02 | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.09 | 0.04 | <0.01 | <0.01 | 0.03 | <0.01 | <0.01 | 0.02 | 0.18 | 0.05 | 0.01 |
| Total Magnesium | | mg/L | 1.12 | 0.92 | 0.66 | 0.61 | 0.4 | 0.39 | 0.65 | 0.99 | 2.33 | 3.05 | 2.31 | 1.2 | 1.39 | 1.41 | 1.19 | 0.19 | 0.35 | 2.06 | 0.23 |
| Total Manganese | 0.05 | mg/L | 0.0006 | 0.0008 | 0.0008 | 0.0009 | <0.0001 | 0.0001 | 0.0002 | 0.0004 | 0.05 | 0.647 | 0.051 | 0.0002 | 0.0007 | 0.0002 | 0.0004 | 0.0012 | 0.0047 | 0.032 | 0.0004 |
| Total Potassium | | mg/L | 1.04 | 0.76 | 0.64 | 0.63 | 0.53 | 0.48 | 0.93 | 0.98 | 1.79 | 2.36 | 1.76 | 1.02 | 0.74 | 0.79 | 0.86 | 0.34 | 0.4 | 1.68 | 0.32 |
| Total Sodium | 200 | mg/L | 12.3 | 13.3 | 3.71 | 2.16 | 0.96 | 0.92 | 1.71 | 3.33 | 24.6 | 32.5 | 24.1 | 31.1 | 16.3 | 23.5 | 2.38 | 0.66 | 0.81 | 22.8 | 0.84 |
| Total Zinc | 5 | mg/L | 0.004 | 0.003 | 0.003 | 0.006 | 0.006 | <0.001 | <0.001 | 0.015 | 0.002 | <0.001 | 0.003 | 0.009 | 0.016 | 0.01 | <0.001 | 0.001 | <0.001 | 0.004 | 0.005 |
| **Total Metals by ICPMS** | | | | | | | | | | | | | | | | | | | | | |
| Total Antimony | 0.006 | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Total Arsenic | 0.01 | mg/L | 0.0002 | 0.0002 | 0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | 0.0026 | <0.0002 | <0.0002 | <0.0002 | <0.0002 |
| Total Cadmium | 0.005 | mg/L | 0.00001 | 0.00001 | 0.00001 | <0.00001 | <0.00001 | <0.00001 | <0.00001 | <0.00001 | 0.00002 | 0.00005 | 0.00002 | <0.00001 | 0.00001 | <0.00001 | <0.00001 | <0.00001 | <0.00001 | 0.00002 | <0.00001 |
| Total Lead | 0.01 | mg/L | 0.00095 | 0.00042 | 0.00032 | 0.00042 | 0.00032 | 0.00013 | 0.00013 | 0.00024 | 0.00031 | 0.00019 | 0.00089 | 0.00042 | 0.0007 | 0.00064 | <0.00005 | 0.00009 | <0.00005 | 0.00076 | 0.00036 |
| Total Selenium | 0.01 | mg/L | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | 0.0003 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0007 | <0.0002 | 0.0005 | <0.0002 | <0.0002 | <0.0002 | <0.0002 |
| Total Uranium | 0.02 | mg/L | <0.00005 | <0.00005 | <0.00005 | <0.00005 | <0.00005 | <0.00005 | <0.00005 | <0.00005 | <0.00005 | <0.00005 | <0.00005 | <0.00005 | <0.00005 | <0.00005 | <0.00005 | <0.00005 | <0.00005 | <0.00005 | <0.00005 |

***Comments:***

1. *Blanks under the GCDWQ Standard heading indicates that a MAC (maximum acceptable concentration) or IMAC (interim maximum acceptable concentration) has not been established for that parameter.*
2. *Although a MAC has not been established for hardness, levels up to 200mg/L is considered to be acceptable \ tolerable; levels in excess of 500mg\L are unacceptable for most domestic purposes.*
3. *RMOW surface water intakes automatically shut down when turbidity exceeds 1NTU.*

## 2010 Annual Water Chemistry Sampling Results

Resort Municipality of Whistler

| Testing Parameter | GCDWQ Standard[1] | Units | Sample Date: | W205-1 17-Nov-10 | W205-2 17-Nov-10 | W205-3 17-Nov-10 | W211 17-Nov-10 | W218 16-Nov-10 | W202 17-Nov-10 | W210 17-Nov-10 | W213 17-Nov-10 | W212-1 18-Nov-10 | W212-2 09-Dec-10 | W217 17-Dec-10 | R228 19-Nov-10 | W201-1 18-Nov-10 | W201-2 18-Nov-10 | W201-3 18-Nov-10 | R222 19-Nov-10 | R231 19-Nov-10 | R232 18-Nov-10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Misc. Inorganics** | | | | | | | | | | | | | | | | | | | | | |
| Fluoride | 1.5 | mg/L | | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 0.04 | 0.03 | 0.05 | 0.03 | 0.06 | 0.02 | 0.14 | 0.07 | 0.03 | 0.03 | 0.08 | 0.14 | 0.02 |
| **ANIONS** | | | | | | | | | | | | | | | | | | | | | |
| Nitrite | 1 | mg/L | | <0.005 | <0.005 | <0.005 | <0.005 | <0.05 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| **Calculated Parameters** | | | | | | | | | | | | | | | | | | | | | |
| Total Hardness[2] | | mg/L | | 119 | 198 | 77.9 | 99.1 | 30.8 | 23.6 | 28.5 | 70.8 | 44.4 | 61.1 | 32.3 | 13.2 | 63.5 | 72.9 | 71.1 | 87.8 | 12.9 | 25.9 |
| Nitrate | 10 | mg/L | | 0.11 | 0.17 | 0.07 | 0.06 | <0.02 | <0.02 | 0.03 | 0.12 | 0.1 | 0.07 | 0.1 | <0.02 | 0.12 | 0.18 | 0.28 | <0.02 | <0.02 | <0.02 |
| **Anions** | | | | | | | | | | | | | | | | | | | | | |
| Dissolved Sulphate | | mg/L | | 77 | 130 | 36 | 55 | 20 | 8.2 | 8.8 | 35 | 11 | 8.6 | 10 | 4.1 | 17 | 19 | 23 | 34 | 3.5 | 3.9 |
| Dissolved Chloride | 250 | mg/L | | 21 | 26 | 7.8 | 7.4 | 2.2 | 0.7 | 1.4 | 9.8 | 34 | 66 | 5.5 | 1.7 | 22 | 25 | 29 | <0.5 | <0.5 | 0.6 |
| **Miscellaneous** | | | | | | | | | | | | | | | | | | | | | |
| True Colour | 15 | Col. Unit | | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 5 | <5 |
| **Nutrients** | | | | | | | | | | | | | | | | | | | | | |
| Nitrate + Nitrite | 10 | mg/L | | 0.11 | 0.17 | 0.07 | 0.06 | <0.02 | <0.02 | 0.03 | 0.12 | 0.1 | 0.07 | 0.1 | <0.02 | 0.12 | 0.18 | 0.28 | <0.02 | <0.02 | <0.02 |
| **Physical Properties** | | | | | | | | | | | | | | | | | | | | | |
| Conductivity | | uS/cm | | 313 | 465 | 198 | 234 | 86 | 57 | 69 | 171 | 217 | 355 | 96 | 38 | 221 | 238 | 280 | 194 | 32 | 57 |
| pH | 6.5 - 8.5 | pH Units | | 7.22 | 7.44 | 7.22 | 7.33 | 7.09 | 7.42 | 7.39 | 7.39 | 7.09 | 7.5 | 6.81 | 7.13 | 7.43 | 7.52 | 7.33 | 7.94 | 7.12 | 7.53 |
| **Physical Properties** | | | | | | | | | | | | | | | | | | | | | |
| Total Dissolved Solids | 500 | mg/L | | 170 | 270 | 110 | 140 | 60 | 30 | 54 | 120 | 130 | 190 | 66 | 24 | 120 | 130 | 160 | 98 | 22 | 32 |
| Turbidity[3] | 1 | NTU | | <0.1 | 0.1 | <0.1 | 0.1 | 0.3 | 0.2 | <0.1 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.1 | 0.2 | <0.1 | 0.1 | 0.2 | 0.7 |
| **Mercury by CVAA** | | | | | | | | | | | | | | | | | | | | | |
| Total Mercury | 1 | ug/L | | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 |
| **Total Metals by ICP** | | | | | | | | | | | | | | | | | | | | | |
| Total Aluminum | | mg/L | | <0.003 | <0.003 | <0.003 | 0.005 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | 0.006 | 0.039 | <0.003 | <0.003 | 0.003 | <0.003 | 0.04 | <0.003 |
| Total Barium | 1 | mg/L | | 0.015 | 0.015 | 0.011 | 0.013 | 0.015 | 0.008 | 0.008 | <0.022 | <0.035 | 0.044 | 0.016 | 0.007 | 0.009 | 0.01 | 0.014 | 0.002 | 0.007 | 0.009 |
| Total Boron | 5 | mg/L | | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.005 | <0.005 | <0.005 | <0.05 | <0.005 | <0.005 | <0.05 | <0.05 | <0.05 | <0.05 | <0.005 | <0.05 | <0.05 |
| Total Calcium | | mg/L | | 45.9 | 77.1 | 30.2 | 38.3 | 11.2 | 8.83 | 10.7 | 26.9 | 14.1 | 18.8 | 11.8 | 4.87 | 23.7 | 27.3 | 26.5 | 33 | 4.76 | 9.88 |
| Total Chromium | 0.05 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Total Cobalt | | mg/L | | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 |
| Total Copper | 1 | mg/L | | 0.0236 | 0.0033 | 0.0166 | 0.0048 | 0.003 | 0.0022 | 0.0052 | 0.0032 | 0.0031 | 0.0045 | 0.004 | 0.0002 | 0.0285 | 0.0075 | 0.0095 | <0.0002 | 0.0002 | 0.0005 |
| Total Iron | 0.3 | mg/L | | 0.006 | 0.012 | <0.005 | 0.01 | 0.056 | 0.005 | <0.005 | 0.012 | 0.082 | 0.018 | 0.012 | 0.013 | <0.005 | 0.008 | <0.005 | <0.005 | 0.013 | 0.037 |
| Total Magnesium | | mg/L | | 0.00115 | 0.0013 | 0.00064 | 0.86 | 0.7 | 0.37 | 0.45 | 0.89 | 2.21 | 3.42 | 0.7 | 0.24 | 1.07 | 1.14 | 1.23 | 1.31 | 0.24 | 0.3 |
| Total Manganese | 0.05 | mg/L | | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.052 | 0.82 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.0002 | <0.001 | 0.001 |
| Total Potassium | | mg/L | | 1.22 | 1.17 | 0.81 | 0.92 | 0.86 | 0.48 | 0.55 | 1.09 | 2.04 | 3.34 | 0.79 | 0.38 | 0.71 | 0.87 | 1.19 | 1.01 | 0.36 | 0.36 |
| Total Sodium | 200 | mg/L | | 11.4 | 13.3 | 6.04 | 5.12 | 1.7 | 0.83 | 1.27 | 3.18 | 20.9 | 35 | 3.17 | 1.76 | 17.9 | 17.7 | 26.5 | 2.3 | 0.73 | 0.89 |
| Total Zinc | 5 | mg/L | | <0.005 | <0.005 | 0.006 | 0.006 | <0.005 | <0.005 | <0.005 | 0.015 | <0.005 | 0.008 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| **Total Metals by ICPMS** | | | | | | | | | | | | | | | | | | | | | |
| Total Antimony | 0.006 | mg/L | | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | 0.0005 | <0.0005 | <0.0005 |
| Total Arsenic | 0.01 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 0.0001 | <0.0001 | <0.0001 | 0.0024 | <0.0001 | <0.0001 |
| Total Cadmium | 0.005 | mg/L | | <0.00001 | 0.00002 | <0.00001 | 0.00002 | <0.00001 | <0.00001 | <0.00001 | <0.00001 | 0.00002 | 0.00001 | <0.00001 | <0.00001 | 0.00001 | 0.00002 | <0.00001 | <0.00001 | <0.00001 | <0.00001 |
| Total Lead | 0.01 | mg/L | | 0.0004 | 0.0004 | 0.0004 | 0.0005 | <0.002 | <0.0002 | 0.0002 | <0.0002 | 0.0002 | 0.0002 | <0.0002 | 0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 |
| Total Selenium | 0.01 | mg/L | | 0.0002 | 0.0003 | 0.0003 | 0.0003 | <0.0001 | <0.0001 | <0.0001 | 0.0006 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 0.0007 | <0.0001 | <0.0001 |
| Total Uranium | 0.02 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.00001 | <0.00001 | <0.00001 |

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