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Technical Memorandum - Final

Date:	December 5, 2019	**Reference No.:**	VAN-00254172-A0
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Project:	**Bluewater Park Wellfield Assessment** **Mutiny Lane, Bowen Island, BC**		
Distribution:	Glen Shkurhan, P.Eng. Interim Director of Engineering	gshkurhan@bim.ca	

1.0 INTRODUCTION

EXP Services Inc. (EXP) was retained by Bowen Island Municipality (BIM) to provide hydrogeology assessment and review services relating to the Bluewater Park water system, which is serviced by four (4) bedrock wells. The scope of EXP's services was defined in consultation with Urban Systems Ltd. (Urban) personnel and BIM engineering staff. All work was completed in agreement with the authorized scope summarized in EXP's proposal to BIM (c/o Urban) dated June 24, 2019, which was the basis for BIM's Purchase Order #5752. EXP's scope of work was also incorporated into Urban's workplan separately delivered to BIM on June 18, 2019.

The primary objectives of EXP's 3-Phase workplan were to inspect, test and monitor the four Bluewater Park (BWP) wells for the purpose of characterizing on-going wellfield supply issues and identifying options for potentially increasing the overall wellfield productivity. A Phase 1 "Background Information Review" was completed in consultation with BIM and Urban staff and was the basis for finalizing the scope for the Phase 2 "Assessment of Existing Bedrock Wells #1 to #4". The Phase 2 scope was necessarily completed in two increments during the periods of July 22 to July 26, 2019 (Wells #1 and #4) and August 22-23, 2019 (Wells #2 and #3) and included the following tasks:

- Remove the existing BWP well pumps and inspect the physical condition;
- Complete downhole camera surveys to examine the physical condition of BWP well boreholes;
- Complete short-duration pumping tests to evaluate the relative productivity of the BWP wells;
- Install new "dip tubes" to allow installation of monitoring devices to measure water levels; and
- Establish a Groundwater Monitoring Program by installing automated dataloggers in the BWP wells to obtain a continuous record of groundwater levels during typical operating conditions.

The Phase 2 results for BWP Wells #1 and #4 were summarized in EXP's Technical Memorandum #1 delivered to BIM and Urban on July 28, 2019. The Phase 2 results for BWP Well #2 and Well #3 are included in this Technical Memorandum.

EXP's original Phase 3 scope included maintenance of a Groundwater Monitoring Program for two (2) months during typical BWP wellfield operating conditions and an assessment of the productivity of a new Shallow Test Well, which was constructed in May 2019 at a location approximately mid-way between BWP Wells #2 and #4 and was completed within water-bearing sediments representing a potentially separate source of water for the BWP wellfield. However, in discussions with BIM engineering staff, the Shallow Test Well assessment was deferred until further notice.

This Technical Memorandum (Final) summarizes the results of all EXP work and provides related interpretations, comments and recommendations consistent with the content of an "Interim Summary" delivered to BIM and Urban on October 30, 2019. Use of this Technical Memorandum should include consideration of EXP's Technical Memorandum #1, the Section 5 Limitations and the attached "Interpretation & Use of Study and Report" (Attachment #1).

2.0 PHASE 2 – INITIAL ASSESSMENT OF BEDROCK WELLS

The Phase 2 program was executed by EXP field staff and a Certified Pump Installer (Precision Service and Pumps Ltd. [Precision]) with remote supervision from EXP's Senior Hydrogeologist during July and August 2019. The Phase 2 activities, observations and results are described in the following sections. Prior to commencing the Phase 2 work, the BWP wellfield pumps were turned off by BIM Operations Staff.

Upon completing the planned inspection and testing of BWP Well #1 and Well #4 during July 22 to 26, 2019, Precision was notified by BC Hydro that crane access to the remaining Wells #2 and #3 would not be allowed due to overhead powerline proximity. Accordingly, the Phase 2 inspection and testing of Wells #2 and #3 was delayed four (4) weeks until a BC Hydro representative (i.e., Rokstad) determined how to execute the work according to WorkSafeBC requirements. During Precision's work in Wells #2 and #3 on August 22-23, 2019, Rokstad provided a dedicated witness tasked solely with watching Precision's activities to alert them if inadvertent line contact was imminent.

2.1 Pump Inspections

All downhole components (i.e., pump, motor, riser pipe and wiring) were removed from the four BWP wells for examination by Precision. Details of Precision's inspections are provided in the attached Pump Inspection Reports (Attachment #2).

All wells are currently equipped with Grundfos submersible pumps and 1 horsepower motors rated for 5 USgpm (US gallons per minute) maximum capacity. All pump/motor assemblies and all wiring were visually determined to be in "very good" condition and lacked evidence of damage or misuse. The plastic drop pipe in Wells #1, #3 and #4 were likewise observed to be in "very good" condition, but the galvanized metal drop pipe in Well #2 was observed to be highly corroded. The heights of all motor shafts were confirmed to be within the manufacturer's specified range and could be manually spun, which indicated the impellers were not obstructed. Wiring resistance-to-ground checks also verified the electrical function of the motors. Accordingly, no replacements parts (other than upgrading the Well #2 drop pipe to plastic) or repairs are referenced on the Pump Inspection Report forms.

2.2 Well Borehole Camera Surveys

A submersible side-viewing, focusable camera was lowered into the wells on July 23 (Well #1), July 24 (Well #4) and August 22 (Wells #2 and #3) to examine the condition of the bedrock boreholes. The surveys confirmed that all boreholes were unobstructed and open to the original drilled depths. A small-diameter PVC tube was observed in the Well #4 borehole, from approximately 170 ft-bg (51.8 m-bg) to the bottom of the borehole, which was likely inadvertently dropped into the well during previous maintenance work. Bedrock surfaces and fractures exposed along well borehole walls were observed to be unaffected by mineral accumulations or bio-fouling (e.g., slimes, filaments) that might restrict the movement of groundwater into the boreholes.

2.3 Short-Duration Pumping Tests (Preliminary Yields)

Upon completing the submersible camera surveys, the pump assemblies were reinstalled to the original depths. Independent short-duration pumping tests were then conducted using a constant pumping rate of 4.5 USgpm[1] selected based on a maximum pump capacity of 5 USgpm. An inline flow meter and valve were temporary installed on each well riser pipe to allow monitoring and control of the applied pumping rate. Precision personnel intermittently obtained manual water level measurements during testing using a graduated electric tape. A graphical summary of the water levels acquired during testing is provided on Figure 1 (Attachment #3).

Well #1

Testing in Well #1 was completed on July 24, 2019. After 56 minutes of sustained pumping at 4.5 USgpm, the water level drawdown in Well #1 was approximately 108.6 ft (33.1 m) below the pre-test static (i.e., non-pumping) level of 243.0 ft-bg (74.0 m-bg). It was necessary to terminate the pumping test to avoid exposing the Well #1 pump and potentially damaging the motor. Based on the magnitude of the end-of-test drawdown, the applied pumping rate, and the initial static water level, the preliminary yield of Well #1 was estimated to be approximately 2.5 USgpm. For comparative purposes, the original yield of Well #1 was estimated at 10 USgpm to 12 USgpm in 1986.

Well #2

Testing in Well #2 was completed on August 23, 2019. After 44 minutes of sustained pumping at 4.5 USgpm, the water level drawdown in Well #2 was approximately 38.6 ft (11.7 m) below the pre-test static level of 240.5 ft-bg (73.3 m-bg); accordingly, it was necessary to terminate pumping to avoid exposing the pump and damaging the motor. Based on these results, the preliminary yield of Well #2 was estimated to be approximately 2.0 USgpm as compared to the original yield estimate of 15 USgpm to 20 USgpm in 1986.

Well #3

Testing in Well #3 was completed on August 23, 2019. After 120 minutes of sustained pumping at 3.8 USgpm, the drawdown in Well #3 was approximately 44.0 ft (13.4 m) below the pre-test level of 178.3 ft-bg (54.3 m-bg). Based on the measured drawdown, the applied pumping rate, and the initial static water level, the preliminary yield of Well #3 was estimated to be approximately 3.4 USgpm. For comparative purposes, the original yield of Well #3 was estimated at 8.0 USgpm in 1991.

[1] Pumping rate applied to Well #3 was subsequently determined to be 3.8 USgpm due to flow meter calibration error.

Well #4

Testing in Well #4 was completed on July 25, 2019. After 120 minutes of sustained pumping at 4.5 USgpm, the drawdown in Well #4 was approximately 35.5 ft (10.8 m) below the pre-test water level of 292.8 ft-bg (89.2 m-bg). Based on the measured drawdown, the applied pumping rate, and the initial static water level, the preliminary yield of Well #4 was estimated to be approximately 9.4 USgpm. For comparative purposes, the original yield of Well #4 was estimated at 6.5 USgpm in 1991.

3.0 PHASE 3 – GROUNDWATER MONITORING PROGRAM

EXP field staff established the Phase 3 Groundwater Monitoring Program at the BWP wellfield on July 26, 2019, by installing pressure transducers with automated dataloggers in BWP bedrock Wells #1 and 4 and in two non-operating test wells (i.e., Shallow Test Well and Bedrock Test Well) constructed in May 2019 at locations between Well #2 and #4. Monitoring devices were subsequently installed in Wells #2 and #3 on August 23, 2019, after Precision completed the Phase 2 inspection/testing of these wells and installed new PVC tubes to accommodate the devices.

All monitoring devices were programmed to record water levels at a synchronized frequency of 5-minutes. Monitoring was maintained for two (2) months until September 30, 2019, to collect water level information during typical operating conditions and also during a 10-day period of controlled sequential well operation. Data from the Shallow Test Well was further required to support an assessment of potential interactions between the deep bedrock aquifer that supplies water to the BWP wellfield and the near-surface groundwater system hosted by sediments overlying the bedrock aquifer.

The resulting 2-month record of BWP wellfield groundwater levels is summarized graphically on Figure 2 (Attachment #4). Data obtained during the period of July 26 to September 20, 2019, are representative of BIM's typical operation of the BWP wellfield, except during the two periods of Phase 2 inspection/testing. Figure 2 data during the 10-day period of September 20-30, 2019, are representative of a prescribed operational sequence comprised of alternating 24-hour intervals of zero withdrawals from the wellfield (to allow measurable aquifer recovery) followed by independent operation of each BWP well at the typical (i.e., default) pumping rate for 24 hours. Monitoring data for the September 20-30, 2019, period of controlled (i.e., sequenced) well operation are also summarized on Figure 3 (Attachment #5).

Well #1

The monitoring device installed in Well #1 was initially downloaded on August 14, 2019. Review of the preceding data confirmed the water level drawdown in Well #1 frequently exceeded the device installation depth of 331 ft-bg. Due to this unanticipated drawdown magnitude, the Well #1 transducer was replaced on August 15, 2019 with a device capable of recording the full range of water level variation. The replacement device was installed in Well #1 at the deepest practical position of approximately 365 ft-bg, near the top of the Well #1 pump.

Routine operation of Well #1 (Figure 2) at approximately 4 USgpm caused water levels to rapidly decline and reduce the entire 128 ft column of water available for drawdown within approximately 2 hours of commencing pumping, followed by a on/off cycling on an approximately 2-hour frequency. This behavior was again observed during the late-September period of independent operation (Figure 3) and verifies that Well #1 was being over-pumped.

Well #2

Routine operation of Well #2 commenced on August 24, 2019 (Figure 2). The start-up pumping rate of approximately 4.7 USgpm (confirmed by BIM Operations staff) induced an extremely rapid consumption of the water column and the water level then remained relatively stable at approximately 284 ft-bg, which is equivalent to the Well #2 pump intake position. This condition was unchanged throughout both the routine operation period and controlled operation interval (Figure 3). This behaviour was anticipated based on BIM Operations staff's reported observations that Well #2 commonly pumps on a 30-second to 60-second cycle that alternates with non-pumping intervals of the same duration.

Well #3

Routine operation of Well #3 commenced on August 24, 2019 (Figure 2). The start-up pumping rate of approximately 3.1 USgpm (confirmed by BIM Operations staff) induced a maximum drawdown magnitude of approximately 30 ft (9 m) on September 9, 2019, which infers there was a residual (i.e., available) water column height of approximately 170 ft (52 m) above the Well #3 pump depth of 351 ft-bg. This limited water level drawdown response was also observed during the late-September controlled operation period (Figure 3).

Well #4

The monitoring device installed in Well #4 was initially downloaded on August 15, 2019. Review of the data for the period of July 26 to August 15, 2019, confirmed the water level drawdown in Well #4 was typically deeper than the device installation depth of 357 ft-bg. Due to this unanticipated drawdown magnitude, the Well #4 transducer was replaced with a device capable of recording the full range of water level variation. The replacement device was installed in Well #4 at the deepest practical position of approximately 425 ft-bg, near the top of the Well #4 pump.

Controlled operation of Well #4 (Figure 3) with a start-up pumping rate of approximately 3.6 USgpm (confirmed by BIM Operations staff) induced a maximum drawdown magnitude of approximately 90 ft (27 m), which infers there was a residual (i.e., available) water column height of approximately 140 ft (42 m) above the Well #4 pump depth of 430 ft-bg. This limited water level drawdown response was also observed during the late-September controlled operation period (Figure 3).

Shallow Test Well

Monitoring of water levels in the Shallow Test Well confirms that groundwater levels within the surficial sediments overlying the bedrock aquifer were stable at approximately 12.0 ft-bg (3.6 m-bg) throughout the 2-month monitoring period. This generally indicates the shallow aquifer (i.e., water-bearing sediments) were not measurably influenced by groundwater withdrawals from the bedrock aquifer. This interpretation provides support for additional consideration of the Shallow Test Well as a potential supplementary source of groundwater for the BWP wellfield.

4.0 DISCUSSION

4.1 Declining Wellfield Productivity

The Phase 2 program confirmed that all BWP well pump assemblies are in good working condition and lacked evidence of damage or misuse that might reduce pump productivity. Inspection of the well boreholes (drilled into bedrock) further verified the wells were unaffected by mineral accumulations or bio-fouling that can impede groundwater entrance and reduce productivity. Absence of these physical or mechanical issues suggests that changes within the bedrock source aquifer are the most probable cause for the significantly reduced wellfield productivity reported in 2019. This interpretation is supported by measurement of aquifer water levels (depths) in the BWP wells on September 30, 2019, after 48 hours of zero wellfield withdrawals, which were 117.3 ft to 215.6 ft deeper than water depths measured at the time of well construction (Table 1).

Table 1. Non-Pumping Water Levels in BWP Wells

	Aquifer Water Level (below ground)		
	At Time of Construction	September 30, 2019	Difference
Well #1 (Feb. 1986)	15.0 ft	227 ft	-212.0 ft
Well #2 (Feb. 1986)	n/a	227 ft	n/a
Well #3 (Nov. 1991)	17.7 ft	135 ft	-117.3 ft
Well #4 (Nov. 1991)	33.4 ft	249 ft	-215.6 ft

The Table 1 data indicate that non-pumping water levels in the BWP wells at the end of the 2-month Groundwater Monitoring Program were 117.3 ft to 215.6 ft (35.8 m to 65.7 m) deeper than levels at the time-of-construction, which is such a significant deepening of the static water level that it cannot be attributed solely to the single-season effects of high withdrawal volumes combined with seasonally low recharge. The magnitude of the water level change also cannot be attributed solely to groundwater withdrawals that occurred during the Summer 2019 monitoring period. Instead, the changes in aquifer static water levels are interpreted to represent a depletion of the aquifer water caused by an imbalance between the seasonal and/or annual rates of groundwater withdrawal and rates of natural aquifer recharge.

The Phase 3 monitoring program also confirms that during routine wellfield operation, water levels in all BWP wells are maintained at depths below water-bearing fractures that contribute groundwater to the wells. If the BWP wellfield groundwater levels do not appreciably recover during the 2019/20 winter months, it is very likely that some relatively shallower water-bearing bedrock fractures have either been partly or entirely dewatered and their contribution to the well(s) correspondingly diminished or eliminated. Allowing well water levels to frequently exceed the depth of a “major water-bearing fracture”, as evident in the BWP monitoring data, is also not consistent with BC Provincial Government guidelines for sustainable well operation.

Although groundwater levels throughout the wellfield exhibited an overall increasing (i.e., recovery) trend both during and after the late-September controlled pumping period (Figure 3), the observed rate of increase was becoming progressively slower, which indicates aquifer water levels might only partly recover during the 2019/20 winter low-demand, higher-recharge conditions.

4.2 Bedrock Well Productivity

Short-duration pumping tests completed during the Phase 2 program were designed specifically to identify the BWP wells with the highest relative yield (i.e., productivity) by applying a common pumping rate to each well for a fixed time interval. On this basis, a comparison of the Figure 1 drawdown magnitudes generally confirms that the individual productivity (yields) of Well #3 and Well #4 exceed the productivity of both Well #1 and Well #2.

The Phase 3 sequential pumping of the BWP wells was a series of four (4) consecutive 24-hour duration, constant-rate pumping tests completed in general conformance with the current BC Provincial Government "*Guide to Conducting Pumping Tests*". Accordingly, analysis of the Phase 3 pumping test data provides a higher-confidence estimate for the BWP well yields, as compared to the values estimated from the short-duration Phase 2 tests.

Combined analysis of the Phase 2 pumping test data trends (Figure 1) and the long-duration Phase 3 pumping tests (Figure 3) indicate that the individual yields of Well #1, Well #2 and Well #4 are 46% to 90% less than the values reported at the time of well construction, as summarized in Table 2. The Well #3 yield is relatively unchanged (Table 2).

Table 2. Summary of Bluewater Park Well Yield Estimates

	Estimated Yield (USgpm)		
	Time of Construction	Summer 2019	Difference
Well #1	10-12	2.5	-75% to -80%
Well #2	20	2.0	-90%
Well #3	8	7.5	-6%
Well #4	6.5	3.0	-46%

The Well #1 pump intake can be dropped an additional 34.0 ft (10.3 m) to the bottom of the well (Figure 3) to reduce the on/off cycling frequency; however, this may not increase the well yield due to the limited increase in available drawdown relative to the known rapid drawdown rate. Likewise, the Well #2 pump can be dropped an additional 21.0 ft (6.4 m) to the bottom of the well, but this modification may neither reduce the on/off cycling frequency nor increase the Well #2 yield, due to the resulting small increase in available drawdown.

Well #3 is currently operated at a start-up rate of approximately 3.1 USgpm, whereas the theoretical sustainable yield of Well #3 is 7.5 USgpm (Table 2), which equals the combined yield from the other three BWP wells. The available drawdown in Well #3 can be optimized by lowering the pump assembly to the lowest practical position of approximately 398 ft-bg (121.3 m-bg) and the existing pump replaced with a 10 USgpm capacity assembly. On this basis, Well #3 represents the best prospect amongst the existing BWP wells for potentially increasing the productivity of the BWP wellfield.

The theoretical yield of Well #4 is approximately 3.0 USgpm (Table 2), which is the second highest rated BWP well. Also, given the favourable drawdown trends and presence of a significant residual water column water after 24 hours of uninterrupted pumping (Figure 3), Well #4 is considered to be the best candidate "back up" well for Well #3, although not a full-capacity backup.

4.3 Additional Bedrock Wells

Drilling a new bedrock well(s) and/or deepening one or more of the existing BWP bedrock wells might provide additional groundwater to the BWP wellfield. However, there is potential for this to correspondingly increase the rate of aquifer water depletion, unless the new bedrock well(s) is positioned a minimum of approximately 700-1000 ft (200-300 m) from the BWP wellfield to reduce the probability of intersecting water-bearing fractures that are currently accessed by the existing BWP wells.

4.4 Supplementary Shallow Groundwater

Phase 3 monitoring of groundwater levels in the Shallow Test Well confirms the shallow water levels were uninfluenced by the BWP wellfield withdrawals. To further assess the viability of the shallow water-bearing sediments as a supplementary source of water for the BWP bedrock wells, an initial short-duration pumping test could be completed in the Shallow Test Well to obtain a preliminary estimate of the potential yield. Results from the initial hydraulic testing would be the basis for planning additional confirmatory testing.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the observations and results of EXP's Bluewater Park Wellfield Assessment, we offer the following opinions, interpretations and recommendations:

- Significantly deepened aquifer water levels within the BWP wellfield are caused by historical and on-going operation of the BWP wells at rates exceeding the natural aquifer recharge rate, which has correspondingly reduced the productivity of all BWP wells;
- Allowing well water depths to commonly exceed the depth of major water-bearing fractures has dewatered relatively shallow fractures that contribute less water to the BWP wells;
- Monitoring data for non-pumping periods indicate that aquifer water levels may not significantly recover during low-demand recovery periods (e.g., winter), which would confirm some shallow water-bearing fractures are permanently dewatered and full water level recovery not attainable;
- Continuous groundwater monitoring is recommended in one or more BWP wells to determine actual seasonal aquifer water level recovery during the winter-spring 2019/20 period;
- It is recommended the Shallow Test Well be preferentially considered as a supplementary groundwater source for the BWP wellfield. An initial short-duration pumping test could be completed to determine a preliminary estimate of the Test Well yield and to further assess the shallow water-bearing sediments as a sustainable water source;
- It is recommended that drilling of a new bedrock well be deferred until a Shallow Test Well feasibility assessment is completed. Any new bedrock well(s) should be positioned approximately 700-1000 ft (100-200 m) from the existing BWP wells;
- It is recommended an increased capacity pump be installed in Well #3 and the pumping assembly lowered to the deepest practical position in the well borehole. Well #3 and Well #4 have the highest theoretical yields and greatest available drawdown of the BWP wells; and
- Consideration should be given to suspending use of BWP Well #1 and Well #2 following the upgrading of Well #3 and confirmation of the hydraulic performance of the modified Well #3.

5.0 LIMITATIONS

This Technical Memorandum and attachments have been prepared by EXP Services Inc. for the exclusive use and consideration of Bowen Island Municipality and Urban Systems Ltd. and have been prepared in a manner consistent with the level of care and skill ordinarily exercised by members of the engineering and science professions currently practicing under similar conditions in the jurisdiction in which the services were provided. Opinions, interpretations and assessments provided in this Technical Memorandum are based on EXP's review and analysis of data referenced in this document.

Any use of this report for purposes other than the purposes described in the preceding sections and/or by any other party must first be verified in writing by EXP Services Inc. EXP does not accept any responsibility for damages resulting from other party's reliance on or use of the information, opinions, interpretations or conclusions contained in this report. The attached "Interpretation & Use of Study and Report" is an integral part of this technical memorandum and must be included with any copies of this document.

6.0 CLOSURE

We trust the information provided by this Technical Memorandum meets your current requirements. Should you have any questions regarding any aspect of this document, please contact the undersigned.

Submitted by:

EXP Services Inc.

Matthew D. Munn, M.Sc., P.Eng.
Senior Hydrogeologist

Reviewed by:

Jay Rao, M.A.Sc., P.Eng., CSAP
Manager – Environmental Services
Western Canada

Attachments:
#1 – Interpretation & Use of Study and Report
#2 – Submersible Pump Inspection Forms
#3 – Figure 1. Pumping Tests in Wells (July and August 2019)
#4 – Figure 2. Groundwater Monitoring (July-September 2019)
#5 – Figure 3. Groundwater Monitoring (September 10-20, 2019)

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ATTACHMENT #1

INTERPRETATION & USE OF STUDY AND REPORT

1. STANDARD OF CARE

This study and Report have been prepared in accordance with generally accepted engineering consulting practices in this area. No other warranty, expressed or implied, is made. Engineering studies and reports do not include environmental consulting unless specifically stated in the engineering report.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report which is of a summary nature and is not intended to stand alone without reference to the instructions given to us by the Client, communications between us and the Client, and to any other reports, writings, proposals or documents prepared by us for the Client relative to the specific site described herein, all of which constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. WE CANNOT BE RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF THE REPORT

The Report has been prepared for the specific site, development, building, design or building assessment objectives and purpose that were described to us by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the document are only valid to the extent that there has been no material alteration to or variation from any of the said descriptions provided to us unless we are specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT OUR WRITTEN CONSENT. WE WILL CONSENT TO ANY REASONABLE REQUEST BY THE CLIENT TO APPROVE THE USE OF THIS REPORT BY OTHER PARTIES AS “APPROVED USERS”. The contents of the Report remain our copyright property and we authorise only the Client and Approved Users to make copies of the Report only in such quantities as are reasonably necessary for the use of the Report by those parties. The Client and Approved Users may not give, lend, sell or otherwise make the Report, or any portion thereof, available to any party without our written permission. Any use which a third party makes of the Report, or any portion of the Report, are the sole responsibility of such third parties. We accept no responsibility for damages suffered by any third party resulting from unauthorised use of the Report.

5. INTERPRETATION OF THE REPORT

a. Nature and Exactness of Descriptions: Classification and identification of soils, rocks, geological units, contaminant materials, building envelopment assessments, and engineering estimates have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature and even comprehensive sampling and testing programs, implemented with the appropriate equipment by experienced personnel, may fail to locate some conditions. All investigations, or building envelope descriptions, utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarising such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and all persons making use of such documents or records should be aware of, and accept, this risk. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

b. Reliance on Provided information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to us. We have relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, we cannot accept responsibility for any deficiency, misstatement or inaccuracy contained in the report as a result of misstatements, omissions, misrepresentations or fraudulent acts of persons providing information.

c. To avoid misunderstandings, **exp** Services Inc. (**exp**) should be retained to work with the other design professionals to explain relevant engineering findings and to review their plans, drawings, and specifications relative to engineering issues pertaining to consulting services provided by **exp**. Further, **exp** should be retained to provide field reviews during the construction, consistent with building codes guidelines and generally accepted practices. Where applicable, the field services recommended for the project are the minimum necessary to ascertain that the Contractor’s work is being carried out in general conformity with **exp**’s recommendations. Any reduction from the level of services normally recommended will result in **exp** providing qualified opinions regarding adequacy of the work.

6.0 ALTERNATE REPORT FORMAT

When **exp** submits both electronic file and hard copies of reports, drawings and other documents and deliverables (**exp**’s instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by **exp** shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancy, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by **exp** shall be deemed to be the overall original for the Project.

The Client agrees that both electronic file and hard copy versions of **exp**’s instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except **exp**. The Client warrants that **exp**’s instruments of professional service will be used only and exactly as submitted by **exp**.

The Client recognizes and agrees that electronic files submitted by **exp** have been prepared and submitted using specific software and hardware systems. **Exp** makes no representation about the compatibility of these files with the Client’s current or future software and hardware systems.

PRECISION
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ATTACHMENT #2
(1 of 4)

SUBMERSIBLE PUMP INSPECTION REPORT

CUSTOMER	Municipality of Bowen Island				
LOCATION	Mutiny Lane Bowen Island (Blue Water)			Well # 1	
DATE	July 29/19	W/O #	91493	INSPECTED BY	Taylor Barnett

MOTOR

MOTOR MFG.	Grundfos		MODEL	MS402			HP	1	
S/N	79453104		RMP	3450	VOLTS	230	PHASE	1	
~~1000~~ 230 VOLT		WET	DRY	OIL FILLED			WET	DRY	
RESISTANCE	RED	~~140~~	6.4760	RESISTANCE	R/Y			11	
TO GROUND	YELLOW	~~140~~	6.4760	LINE TO LINE	Y/B			11	
IN MEGOHMS	BLACK	~~140~~	6.4760	IN OHMS	B/R			11	
SPECIFICATION		MEGOHMS		SPECIFICATION			OHMS		
SHAFT HEIGHT		AXIAL PLAY			END PLAY			INCHES	

PUMP END

MFG	Grundfos	MODEL	MODEL	5510-22	S/N	B80100 33 - P11239	
SHAFT SIZE		RUNOUT					
DISCHARGE SIZE		1"	OTHER				

BUSHING TO SHAFT CLEARANCE

THRUST	SHAFT	BUSHING	DIFF.
10			
9			
8			
7		N.A.	
6			
5			
4			
3			
2			
1			
SUCTION	SPECIFICATION		

IMPELLOR TO BOWL CLEARANCE

	BOWL	IMPELLOR	DIFF.
10			
9			
8			
7		N.A.	
6			
5			
4			
3			
2			
1			
	SPECIFICATION		

COLUMN

PIPE CONDITION	Very good
CHECK VALVE CONDITION	holds and good condition
WIRE CONDITION	Good
DIP TUBE CONDITION & NUMBER	Good, new run of 1"
WELL HEAD CONDITION	N.A.
PITLESS O-RING CONDITION	Good, seats and seals

COMMENTS:

There were small gravel on top of pump, presumable from rock in hole motor was scraped, again due to rock hole

PARTS AND REPAIRS REQUIRED:

N.A.

PRECISION
SERVICE & PUMPS INC:
ESTD 1992
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www.precision-pumps.com
1334 Riverside, Abbotsford B.C. V2S 8J2

ATTACHMENT #2
(2 of 4)

SUBMERSIBLE PUMP INSPECTION REPORT

CUSTOMER	Bowen Island Municipality				Well #2
LOCATION	982 Mutiny Lane Bowen Island			(Blue water)	
DATE	Aug 22/19	W/O #	91493	INSPECTED BY	Taylor Barrett

MOTOR

MOTOR MFG.	Franklin		MODEL	2145079004			HP	.75
S/N	05D13 - 26 - 0503		RMP	3450	VOLTS	230	PHASE	1
250 ~~1000~~ VOLT		WET	DRY	OIL FILLED			WET	DRY
RESISTANCE	RED	6.5		RESISTANCE		R/Y	2.95	
TO GROUND	YELLOW	7.0		LINE TO LINE		Y/B		
IN MEGOHMS	BLACK	6.8		IN OHMS		B/R		
SPECIFICATION		MEGOHMS		SPECIFICATION			OHMS	
SHAFT HEIGHT		AXIAL PLAY			END PLAY			INCHES

PUMP END

MFG	Goulds	MODEL	MODEL	5GS07412	S/N	N.A.	
SHAFT SIZE		RUNOUT					
DISCHARGE SIZE		1 ¼	OTHER				

BUSHING TO SHAFT CLEARANCE

THRUST	SHAFT	BUSHING	DIFF.
10			
9			
8			
7			
6			
5			
4			
3			
2			
1			
SUCTION	SPECIFICATION		

IMPELLOR TO BOWL CLEARANCE

	BOWL	IMPELLOR	DIFF.
10			
9			
8			
7			
6			
5			
4			
3			
2			
1			
	SPECIFICATION		

COLUMN

PIPE CONDITION	Poor, Galvanized
CHECK VALVE CONDITION	Good, holds
WIRE CONDITION	Good
DIP TUBE CONDITION & NUMBER	Replaced, brand new 1"
WELL HEAD CONDITION	Good
PITLESS O-RING CONDITION	Good, seals

COMMENTS:
Recommend new pipe on next service

PARTS AND REPAIRS REQUIRED:

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ATTACHMENT #2
(3 of 4)

SUBMERSIBLE PUMP INSPECTION REPORT

CUSTOMER	Bowen Island				Well #3
LOCATION	982 Mutiny Lane, Bowen Island			(Blue Water)	
DATE	Aug 22/19	W/O #	91493	INSPECTED BY	Taylor Barrett

MOTOR

MOTOR MFG.	Grundfos		MODEL	~~5510-22~~ M5402			HP	1	
S/N			RMP	3450	VOLTS	230	PHASE	1	
250 ~~1000~~ VOLT		WET	DRY	OIL FILLED			WET	DRY	
RESISTANCE	RED	10.6		RESISTANCE		R/Y	2.4		
TO GROUND	YELLOW	10.6		LINE TO LINE		Y/B	13.6		
IN MEGOHMS	BLACK	10.6		IN OHMS		B/R	2.4		
SPECIFICATION		MEGOHMS		SPECIFICATION			OHMS		
SHAFT HEIGHT		AXIAL PLAY			END PLAY			INCHES	

PUMP END

MFG	Grundfos	MODEL	MODEL	5510-22	S/N		
SHAFT SIZE		RUNOUT					
DISCHARGE SIZE		1"	OTHER				

BUSHING TO SHAFT CLEARANCE				IMPELLOR TO BOWL CLEARANCE			
THRUST	SHAFT	BUSHING	DIFF.		BOWL	IMPELLOR	DIFF.
10				10			
9				9			
8				8			
7				7			
6				6			
5				5			
4				4			
3				3			
2				2			
1				1			
SUCTION	SPECIFICATION				SPECIFICATION		

COLUMN

PIPE CONDITION	Good, shur-align
CHECK VALVE CONDITION	Good, holds
WIRE CONDITION	Good
DIP TUBE CONDITION & NUMBER	Replaced, brand new 1"
WELL HEAD CONDITION	Good
PITLESS O-RING CONDITION	Good, seals

COMMENTS:

PARTS AND REPAIRS REQUIRED:

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ATTACHMENT #2
(4 of 4)

SUBMERSIBLE PUMP INSPECTION REPORT

CUSTOMER	Municipality of Bowen Island				
LOCATION	Mutiny Lane, Bowen Island (Blue Water)				Well #4
DATE	July 25/19	W/O #	91493	INSPECTED BY	Taylor Barnett

MOTOR

MOTOR MFG.	Grundfos			MODEL	79453104			HP	1
S/N	P21839			RMP	3450	VOLTS	230	PHASE	1
250 ~~1000~~ VOLT		WET	DRY	OIL FILLED				WET	DRY
RESISTANCE	RED	140	160	RESISTANCE		R/Y			
TO GROUND	YELLOW	140	160	LINE TO LINE		Y/B			
IN MEGOHMS	BLACK	140	160	IN OHMS		B/R			
SPECIFICATION		MEGOHMS		SPECIFICATION				OHMS	
SHAFT HEIGHT		AXIAL PLAY				END PLAY			INCHES

PUMP END

MFG	Grundfos	MODEL	MODEL	~~75~~ 5S10-22	S/N	A81545225100005328	
SHAFT SIZE		RUNOUT					
DISCHARGE SIZE		1"	OTHER				

BUSHING TO SHAFT CLEARANCE

THRUST	SHAFT	BUSHING	DIFF.
10			
9			
8			
7		N.A.	
6			
5			
4			
3			
2			
1			
SUCTION	SPECIFICATION		

IMPELLOR TO BOWL CLEARANCE

	BOWL	IMPELLOR	DIFF.
10			
9			
8			
7		N.A.	
6			
5			
4			
3			
2			
1			
	SPECIFICATION		

COLUMN

PIPE CONDITION	Very Good
CHECK VALVE CONDITION	Good, holds good
WIRE CONDITION	Good
DIP TUBE CONDITION & NUMBER	Good, new single run of 1"
WELL HEAD CONDITION	N.A.
PITLESS O-RING CONDITION	Good, seats and seals

COMMENTS:

There were small rocks, gravel, on top of pump, presumably from rock hole. Motor had scraps on side from rock hole.

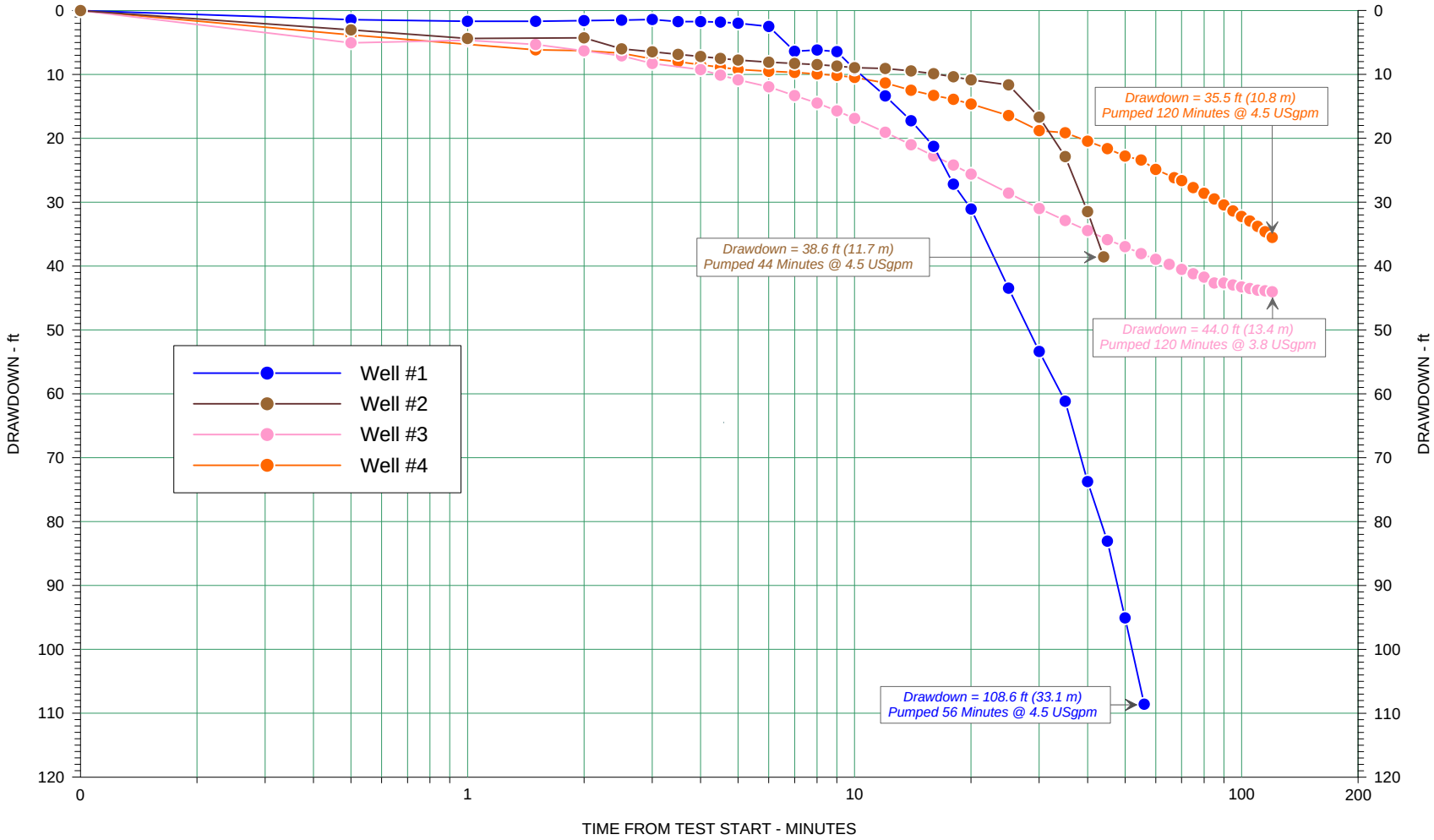
Noted * there is a run of 1" dip tube down the well from 170' to bottom of well

PARTS AND REPAIRS REQUIRED:

N.A.

ATTACHMENT #3

PUMPING TESTS IN BLUEWATER PARK WELLS
Drawdown Response Monitoring (Phase 2)
July 24-25 and August 23, 2019



NOTE - Manual water level measurements obtained by pumping test contractor

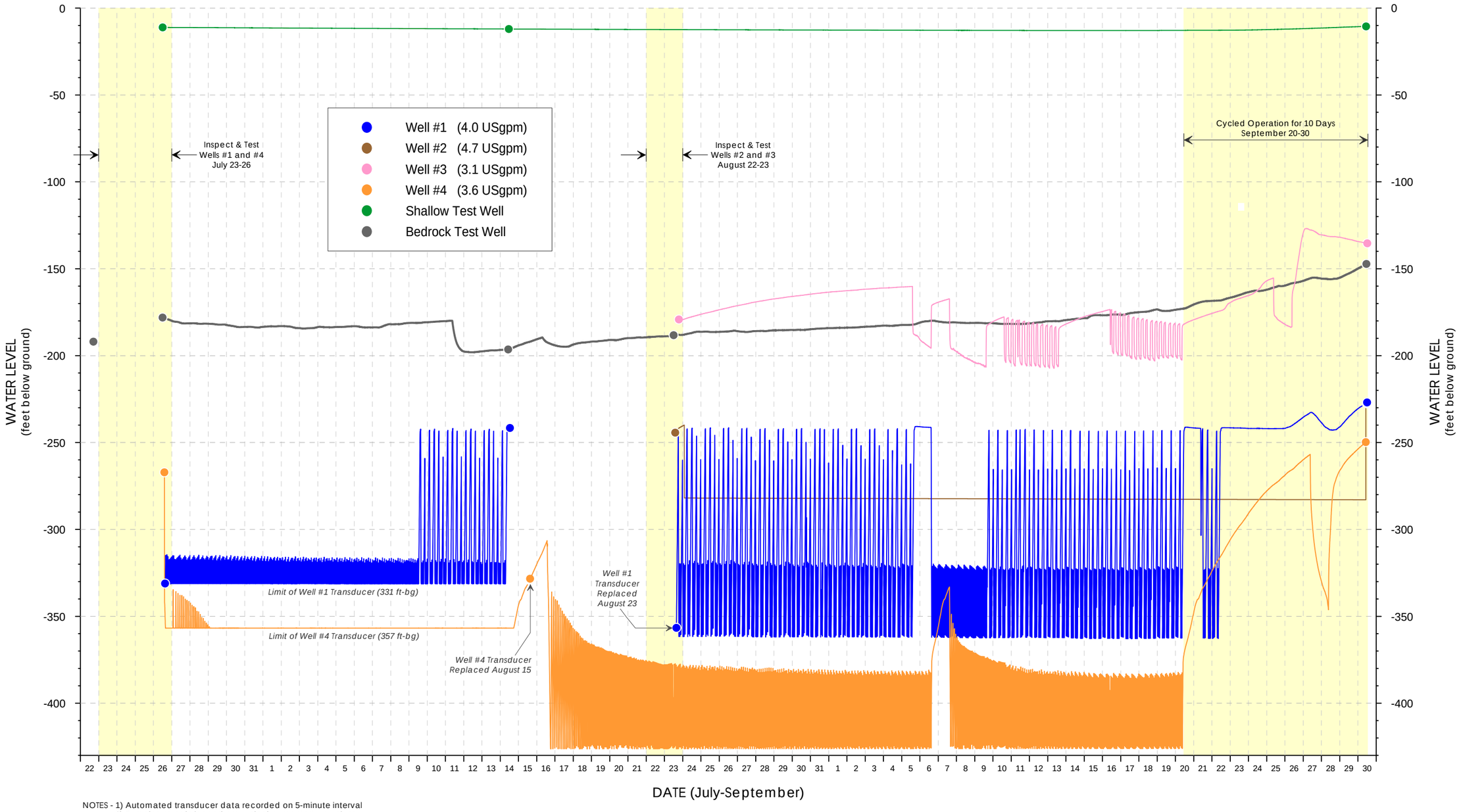
exp.	**Project No.** VAN-00254172-A0 **Drawn** MDM **Reviewed** M.D. Mumm **Date** Oct 2019	**WELLFIELD ASSESSMENT - BLUEWATER PARK WATER SYSTEM (PHASE 3)** Bowen Island Municipality Bowen Island, BC

Fig. 1

ATTACHMENT #4

GROUNDWATER MONITORING PROGRAM

(July 26 to September 30, 2019)



NOTES - 1) Automated transducer data recorded on 5-minute interval
2) Pumping rates in legend are typical pump start-up values

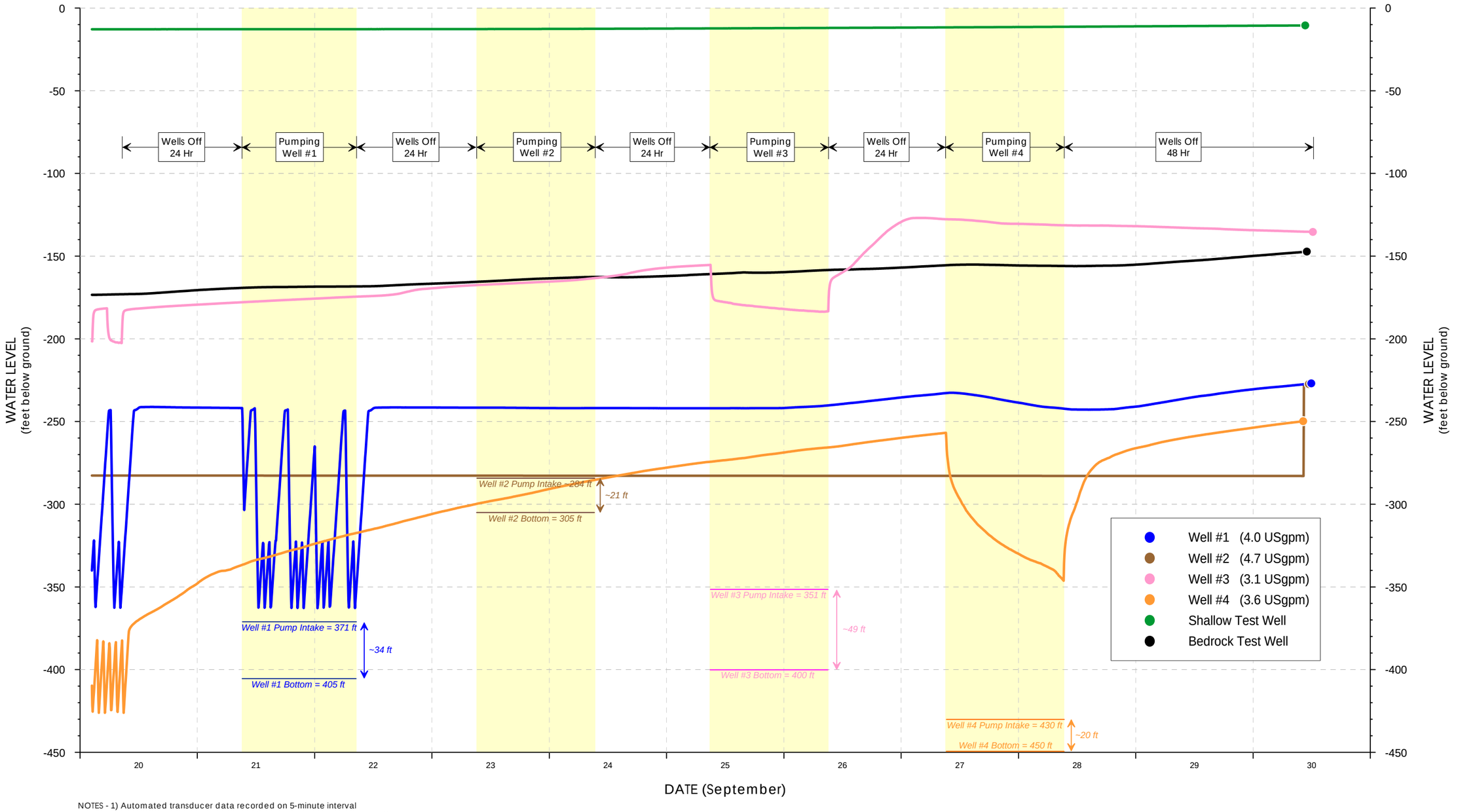
Project No. VAN-00254172-A0 **Drawn** MDM **Reviewed** M.D. Mann **Date** Oct 2019	exp.	**BLUEWATER PARK WELLFIELD ASSESSMENT (PHASE 3)** Bowen Island Municipality Bowen Island, BC	**Fig. 2**

ATTACHMENT #5

GROUNDWATER MONITORING PROGRAM

10-Day Cycled Well Operation

(*September 20 to 30, 2019*)



NOTES - 1) Automated transducer data recorded on 5-minute interval
2) Wells operated independently for 24-hour intervals separated by 24-hour non-pumping recovery period
4) Pumping rates in legend are pump start-up values

Project No.	VAN-00254172-A0
Drawn	MDM
Reviewed	M.D. Mumm
Date	Oct 2019

exp.

BLUEWATER PARK WELLFIELD ASSESSMENT (PHASE 3)
Bowen Island Municipality
Bowen Island, BC

Fig. 3