Attachment B

ME12-01 Step 2 WSSA Report and Related Information
re: EIA File 4561-3-1228

April 8, 2013 MON-00203023-A0

New Brunswick Department of Environment
P.O. Box 6000
Fredericton, NB
E3B 5H1

Attention: Pierre Doucet, Project Assessment (EIA)

Re: Village of Memramcook ME12-01 WSSA Submission, TH12-01 and TH12-02 Drilling Results, PID70001623; and TH13-01 PID PID70153572 (NBENV File 4561-3-1228)

On behalf of the Village of Memramcook, **exp** Services Inc. (**exp**) is pleased to provide the attached reports submitted under the above referenced NBENV EIA file. The reports include the following.

1) **Step 2 Water Supply Source Assessment (WSSA) Report for ME12-01:** This report provides the results of a pump test completed on the groundwater exploration well ME12-01 (originally TH10-01). Results of the pump test suggested good potential for commissioning of the well as a permanent production well for the Village subject to NBENV approval to proceed and the Village's infrastructure development plans. On this basis, the Village is requesting EIA approval of the well to serve as a Village of Memramcook production well. Note that since the well is located an appreciable distance from the Village's existing system, that actual commissioning and hook up as an active pumping well will be subject to the Village's development plans.

2) **TH12-01 and TH12-02 Letter Reports:** As follow up to the promising results found for ME12-01, the Village applied to your Department and received approval to proceed with drilling two additional test wells (TH12-01 and TH12-02) on the subject property. These two test wells were drilled during December 2012. Letter reports for these two wells are attached. Results suggested good potential for these wells concerning possible future development as production wells to supplement ME12-01 assuming subsequent regulatory steps (i.e. Step 2 Water Supply Source Assessment (WSSA) pump testing) confirms preliminary results of the test well short term air lift yields.

3) **TH13-01 Letter Report:** The purpose of this work was to complete an exploratory test well in the immediate area of the Village's existing PW1 (PID70153572) to determine if suitable well yields were present below the depth of the existing well. The well was drilled during January 2013. As noted in the attached letter report, no significant yield above that already found in the existing PW1 was suggested from the air lift yield following drilling of the test well. Plans concerning this test well (i.e. abandonment or maintain for other purposes) are to be finalized.

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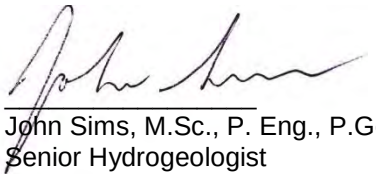
We appreciate your consideration and attention to this matter. If there are any questions, please contact the undersigned.

Yours very truly,



John Sims, M.Sc., P. Eng., P.Geo.
Senior Hydrogeologist

cc. Emery Bourque – Village of Memramcook
Roland LeBlanc (Project Manager) - **exp**

Submission Checklist for the Hydrogeological Study

Hydrogeological Study – General Requirements		Included in Report? (✓ = yes)	Page Number
Site Description	Site Description		3
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	Description of Intended Water Use		3
	Groundwater Withdrawal Details		3
	Description of Existing and Previous Water Withdrawal Approvals		3
Description of Hydrogeology	Regional and Local Geology		4
	Regional and Local Hydrogeology		4
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	Pumping Test Data and Graphs		Appendix C, D
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Notes on General Requirements:
Water supply Source Assessments and EIA Registrations are required for groundwater wells with a capacity for water withdrawals greater than 50,000 L/day (50 m^3/day).
Hydrogeological studies must be signed and professionally sealed by a qualified Engineer or Geoscientist registered with the Association of Professional Engineers and Geoscientists of New Brunswick.
Reports and data must be submitted in hard copy and electronic copy.
A constant rate pumping test and analysis is required for each pumping well included in the EIA registration.
Production well (s) must be pump tested at a rate greater than or equal to the requested withdrawals rate.
Well interference effects should be evaluated for wells within a minimum radius of 500 m.
Salt Water intrusion effects should be evaluated if the productions well is within 500 m of a salt water body.
Potential for groundwater under the direct influence of surface water (GUDI) should be evaluated for each proposed production well.
Any work that is to be completed within 30 m of a watercourse or regulated wetland first requires a Watercourse and Wetland Alteration (WAWA) Permit.

Village of Memramcook

Village of Memramcook Groundwater Exploration Program
Step 2 Water Supply Source Assessment (WSSA) Report, ME12-01
Memramcook, NB

(NBDENV File No. 4561-3-1228)

Type of Document:
Final

Project Number:
MON-00203023-A0

Prepared By:
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Date Submitted:
November 2012

Legal Notification

This report was prepared by **exp** Services Inc. for the account of the **Village of Memramcook**.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. **Exp** Services Inc. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

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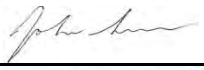
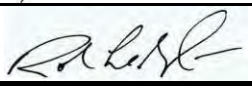
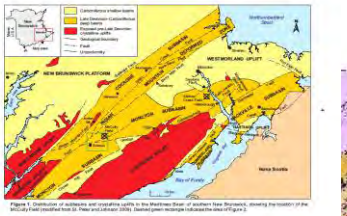
Project No.: MON-00203023-AO	Date: November 14, 2012
Type of Document: Final	Revision No.: 0
Prepared By: John Sims, M.Sc., P. Eng., P.Geo.	
Reviewed By: Roland LeBlanc, P. Eng.	

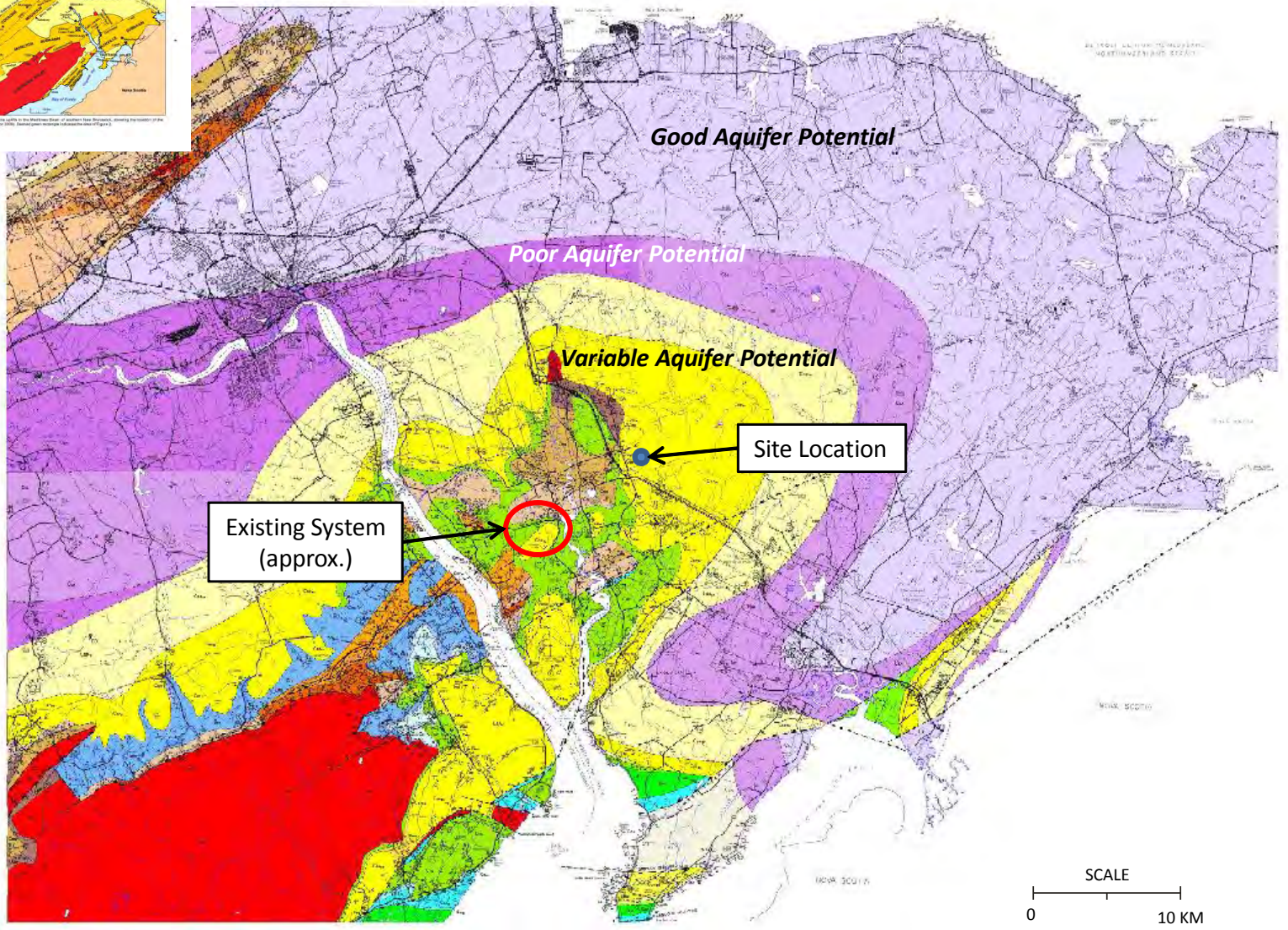
1 Introduction

Exp Services Inc (**exp**) was retained by the Village of Memramcook to oversee development and pump testing of an exploration well located on PID70001623, Memramcook Est, N.B. The well was originally drilled as TH10-01 during January 2010 as part of a groundwater exploration program approved to proceed under the New Brunswick Department of Environment EIA approval 4561-3-1228. For the purpose of this report, the well has been renamed ME12-01 (denoting Memramcook East location).

The following report presents methodology and results of well drilling and pump testing related to assessment of ME12-01 in accordance with the NBDENV Step 2 Water Supply Source Assessment (WSSA) requirements. The approximate locations of the test well and the Villages existing system in a regional general aquifer potential context are indicated on Figure 1.1.

Background information related to the work is provided in **Section 2.0** followed by an account of the project methodology in **Section 3.0**; a presentation and discussion of the project findings in **Section 4.0**; and conclusions and recommendations in **Section 5.0**. Closing statements and limitations are provided in **Section 6.0**. Project references are listed in **Section 7.0**.





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Project Title	VILLAGE OF MEMRAMCOOK WATER SUPPLY (ME12-01) STEP 2 WSSA REPORT
Dwg. Title:	**SITE LOCATION PLAN**
Drawn By: BLA	Project No. MON-00203023-A0
Dwg. Standards Ckd. By:	Dwg. No. **FIGURE 1.1**
Designed By:	Dwg. Design Ckd. By: / Rev. No.

2 Background

2.1 General

The Village of Memramcook currently meets its potable water supply requirements through a combination of a central water system servicing the core Village area of St. Joseph, and private wells in outlying areas of the Village. The centralized system consists of a series of springs and wells developed and upgraded as practical over the years, water treatment and distribution piping.

From 2004 through 2006 the Village undertook a significant upgrade of their existing water system including modification of piping to pump to a central treatment facility, addition of manganese treatment and improved controls (SCADA). Related work included application to the New Brunswick Department of Environment (NBENV) under the provincial Environmental Impact Assessment (EIA) regulation to proceed with a water source exploration program. Exploration work subsequently proceeded following NBENV approval to proceed (NBENV File No. 4561-3-1228).

The water source exploration program work included geological reconnaissance of potential test drilling areas within the Village footprint and completion of geophysical surveys to assist in identifying potential target sites. Various summary reports including results of test drilling were provided during progress of the work. A copy of the progress report summarizing the results of the exploration work through to April 2010 is provided in Attachment A.

Of the series of test wells and proposed areas assessed under the approved NBENV exploration program, only one test well, TH10-01 (now referenced as ME12-01), suggested yield suitable for the Village's municipal water source development objectives. This well was subsequently further developed to allow for pump testing and assessment in accordance to the NBENV Step 2 WSSA testing and approvals process. Results of the program are provided in subsequent sections of this report.

2.2 Site Description

Site Description - The site is located within a relatively undeveloped area of East Memramcook. The property and surrounding area are generally treed/ forested and undeveloped with the exception of a northwest/ southeast trending power transmission line and right of way located immediately west of the test well area. Other than this, land use is understood to be limited to possible seasonal camps, hunting, and seasonal berry picking although there are no known cultivated fields in the property area.

Intended Use and Groundwater Withdrawal Details - The area is currently not developed as a wellfield. It would be the intent, pending regulatory approval and subject to available funds and the Village's infrastructure development plans, that the test well and possibly additional wells be developed in the future to service the Village's municipal potable water supply requirements.

Groundwater withdrawal details would be determined based on the Village's future servicing requirements. Additional information concerning the Village's current and longer term water supply requirements has been provided previously (see related EIA registration documentation entitled *Water Supply Source Assessment Memramcook Water System – 30 Year Projection*, Crandall Engineering Ltd., dated August 19, 2009). There are no known existing or previous water withdrawal

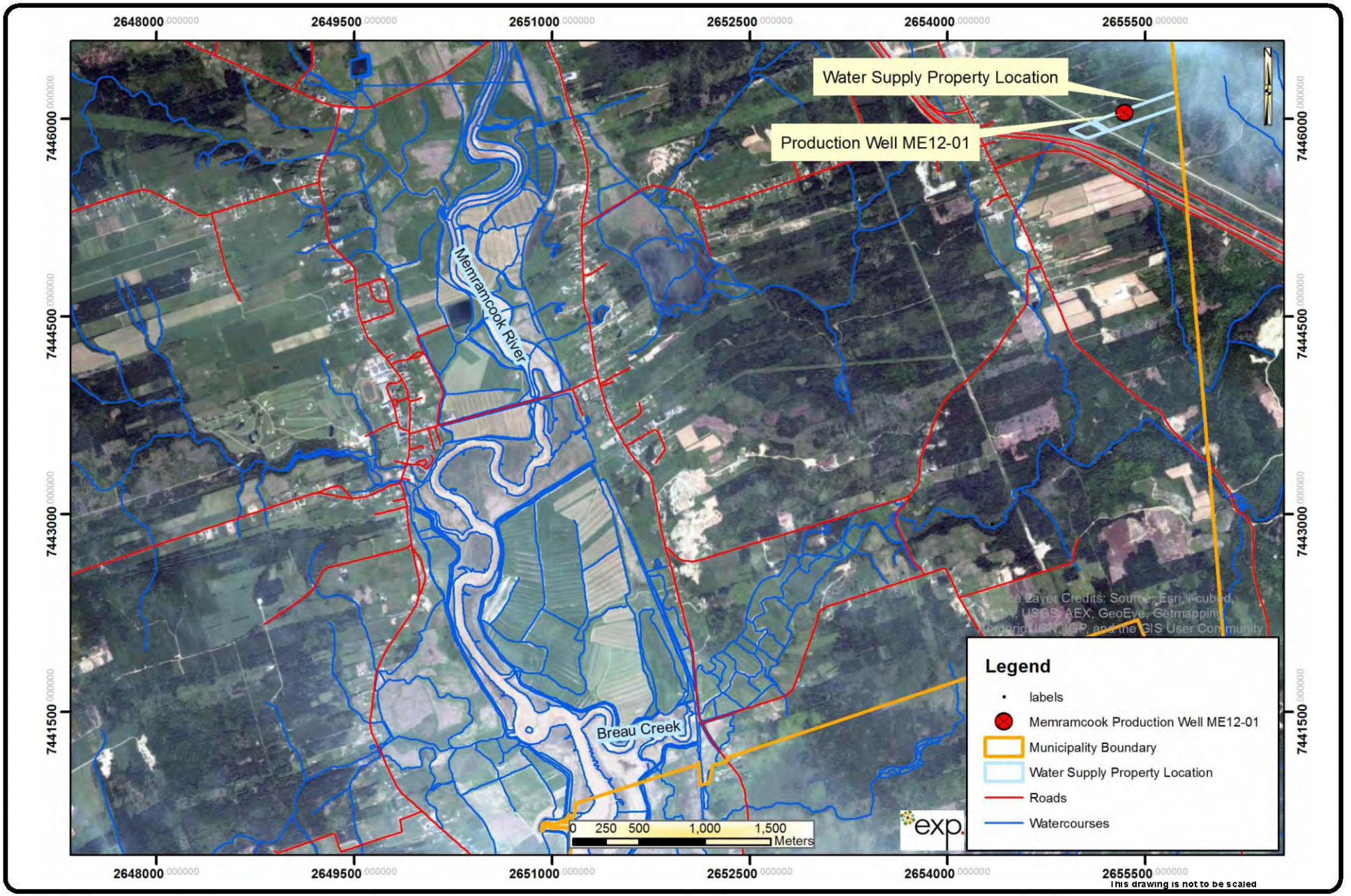
approvals related to the Village's East Memramcook groundwater exploration area; the Village's current municipal well system is located in a separate and isolated section of the Boss Point Formation and is located some distance to the west of the East Memramcook study area.

2.3 Geology, Hydrogeology and Surface Water Features

Geology and Hydrogeology - A description of the regional and local geology and hydrogeology in the East Memramcook groundwater exploration area has been previously provided in related EIA documentation (e.g. Annexe D of the EIA registration document cited above). Since that document was submitted, the "C" and "D" East Memramcook target areas identified on Drawing 1 of the EIA registration document Annexe D were refined such that the actual drilling area was moved approximately 3 km northeast of the original East Memramcook "C" and "D" target areas (supporting documentation was provided to NBENV as the exploration work progressed). This work resulted in one test well (TH10-01) being found which subsequently led to the development and testing of the ME12-01 well described herein.

In summary, the study site geology consists of a veneer of glacial till underlain by the Boss Point Formation (yellow area on Figure 1.1). The Boss Point is a sedimentary rock unit comprised of interbedded conglomerate, sandstone, siltstone and mudstone. Well yields from the Boss Point are typically from fracture/ jointing features, and can be quite variable. Shallow groundwater flow is expected to be strongly controlled by local topography with the dominant direction of flow anticipated to be toward the south. Deeper regional flow is anticipated to be to the south and southwest toward Breau Creek and the Memramcook River.

Surface Water Features – The subject property is located in the upper reach of the Breau Creek watershed (Figure 2.1). The test well site is located approximately 300 m northwest of the nearest tributary of Breau Creek.



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Project Title	VILLAGE OF MEMRAMCOOK WATER SUPPLY (ME12-01) STEP 2 WSSA REPORT
Dwg. Title:	**SURFACE WATER FEATURES**

Drawn By: BLA	Project No. MON-00203023-A0	
Dwg. Standards Ckd. By:	Dwg. No. **FIGURE 2.1**	
Designed By:	Dwg. Design Ckd. By:	Rev. No.

3 Methodology

3.1 Testhole Completions

To accommodate aquifer and ME12-01 well testing objectives, the following work was completed:

- The 37.2 m, 150 mm diameter casing installed in the original test well (TH10-01) was pulled, and the well was subsequently drilled to larger diameter (200 mm) to accommodate use as a pumping well (ME12-01) for a step drawdown (4 hr) and longer term 72 hour constant rate pump test. Temporary 200 mm (8 inch) diameter casing was set in this pumping well at 47.4 m (155.5 feet).
- An observation well location (OW12-1) was established within approximately 30 m of the existing ME12-01 test well. At this location two 150 mm diameter wells were installed: a shallow well (OW12-1S) completed to 15.2 m depth, and a deeper (OW12-1D) drilled to 85.3 m depth. The purpose of the shallow well in this "multi-level" installation was to assess the relative influence (if any) on the shallow water table during pumping of ME12-01. The deeper well was cased to the approximate depth of the 200 mm casing installed in ME12-01 pumping well.
- A 150 mm test well was drilled approximately 83 m from the ME12-01 well. The intent of this new well (assuming sufficient yield was found), was to allow for the possible future development of a second production well on the property. The test well location was chosen on the basis of suitable access conditions being already present on the subject property; and that in the event a pump test was warranted, the nested observation well location (OW12-1 noted above) could be used. On drilling , the new test well it was determined to have low yield in the deeper aquifer zone targeted, and the well was therefore subsequently used as an observation well (OW12-2D) for the purpose of the ME12-01 pump test.

All well drilling was completed using an air rotary drilling rig operated by Eastern Well Drilling of Shediac, N.B. Based on original test well results and observations during well completions, the two deeper observation wells (OW12-1D and OW12-2D) were cased to approximately 50 m depth (similar depth as the pumping well) to isolate the pumping well's main water yielding zone from the shallower water table.

3.2 Pump Testing

The pumping well program consisted of a step drawdown test followed by a 72 hour constant rate test. Pumping equipment was supplied by Eastern Well Drilling; pump make Franklin 3255R20F 66-0663, 30 horsepower, 3 phase. Flow measurement was set and monitored using a 152 mm orifice pipe with 100 mm opening. Pump was set at 65.5 m below top of casing. Drawdown and water level recovery measurements were completed over the test program period.

The step drawdown test consisted of four steps of one hour duration each with the pumping rate increased incrementally from one step to the next. The results of the step drawdown test were used to select a pumping rate for the constant rate test. Observation wells monitored over the course of the testing period included the two deeper wells (OW12-1D at approximately 30 m from the pumping

well and OW12-2D at approximately 83 m from the pumping well) and the shallow observation well OW12-1S installed approximately 38 m from the pumping well.

Selected water quality samples were collected from the pumping and observation wells at approximately 24 hr, 48 hr and 72 hr pumping times during the constant rate test. Samples were analyzed for general chemistry and trace metals; and total/fecal coliforms and E. Coli. All samples from the pumping well were submitted to the Chemical and Biotechnical Services Branch of the Research and Productivity Council (RPC) laboratory in Fredericton, NB. Samples from the observation wells were sent to the NBENV laboratory for analysis.

4 Results and Discussion

4.1 Timing of Pump Testing and Climatic Conditions

The pump test program was scheduled for the late summer, and began Aug 27, 2012. This time period is generally considered to represent low water table conditions corresponding to the summer period groundwater recession (lower water table) drier conditions. Climatic conditions were considered favourable over the course of the pump test with only minor rainfall experienced.

4.2 Testhole Results

Testhole logs for the pumping well, ME12-01 (originally TH10-01) and the observation/ test wells drilled to supplement testing objectives are provided in Appendix B. Summary information on well completions is provided in Table 4.1 A diagram showing the approximate locations of the well in relation to each other is provided as Figure 4.1.

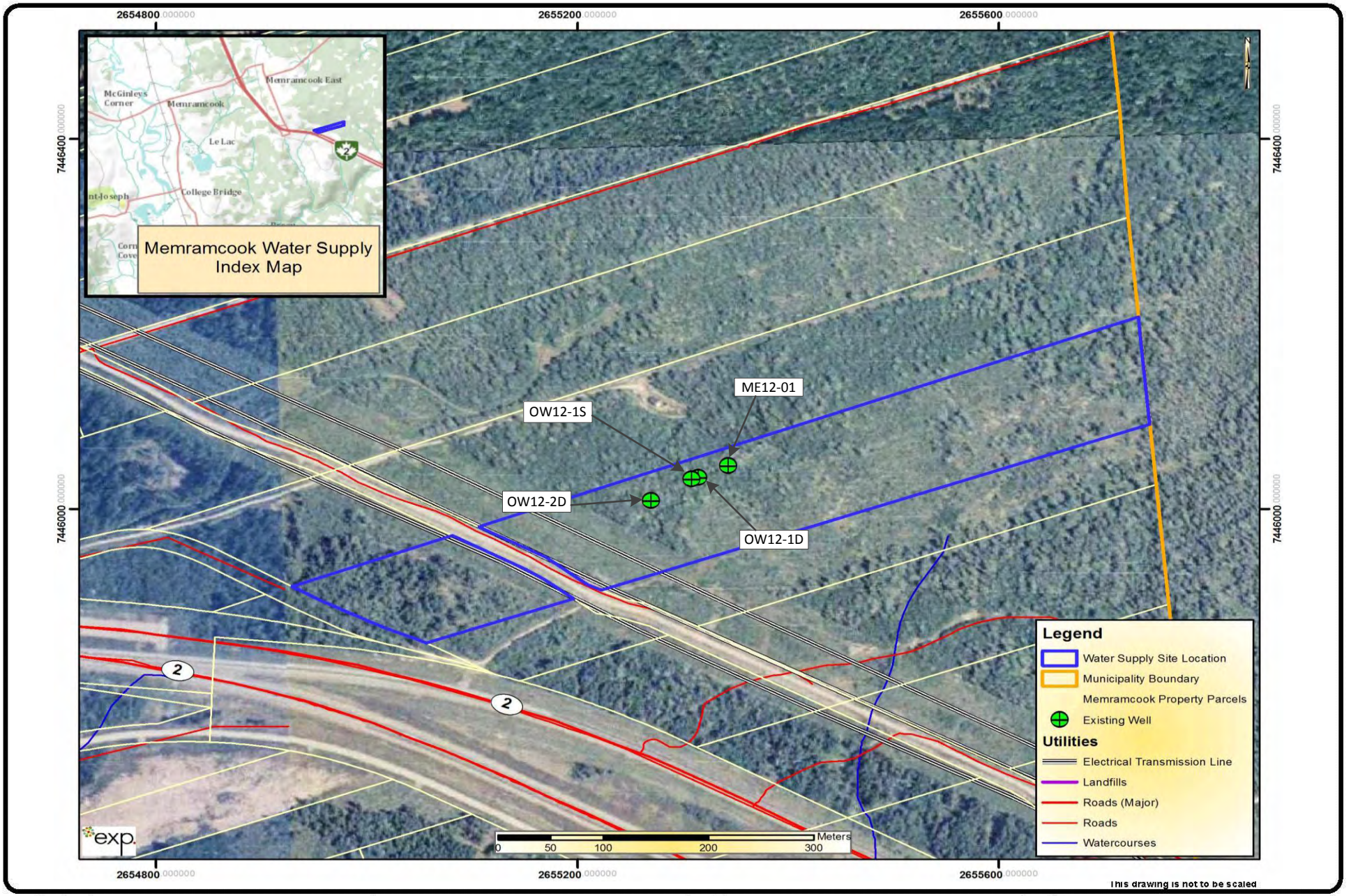
The sub-surface stratigraphy at the pumping well location consisted of shallow overburden (approximately 3 to 4 m in thickness) underlain by interbedded sandstone and siltstone bedrock interpreted as Boss Point Formation. All well openhole sections were completed in the fractured sandstone/ siltstone bedrock.

During completion of the pumping well, the well was opened to 200 mm diameter to total depth of 97.5 m (320 feet) depth, the original depth of the 150 mm test hole. Cased section was from ground surface to 46.8 m (153.5 feet) depth, with 0.6 m stickup above ground. While setting up for the subsequent pump test, it was observed that the openhole section had caved back to 73 m (240 feet). As the main yield on completing the well was interpreted to be above this depth, the caved section at the bottom of the hole was left as is and the pump test proceeded. It is expected that no significant yield would be found on final completion within the caved interval (73 m to total depth of 97.5 m).

It is noted that approximately 6,545 m^3/day (100 Igpm) was isolated in the upper sections of the deeper observation wells and pumping well; the purpose of this was to case off the shallower groundwater to assess the deeper water yielding fractures encountered on the pumping well.

Table 4.1 Pumping and Observation Well Summary

Well I.D..	Depth m (ft) (bgs)	Casing		Estimated Yield m^3/day (Igpm)	Comments
		Depth m (ft)	Diameter (mm)		
ME12-01 (TH10-01)	97.5 (320)	47.4 (155.5)	200 (8)	2618 (400)	Bottom of open hole section caved back to 73 m (240 feet). Main water yielding zones interpreted at 29.3 m, 50.9 m, 58.8 m, and 68.3 m
OW-1S	15.2 (50)	6.1 (20)	152 (6 5/8)	20 (3)	Shallow observation well.
OW-1D	85.3 (280)	46.8 (153.5)	152 (6 5/8)	1309 (200)	Estimated well yield is short term air lift. Additional testing would be required to confirm longer term safe yield.
OW-2D (TH12-01)	85.3 (280)	48.8 (160)	152 (6 5/8)	20 (3)	Casing set to similar depth as pumping well. Shallower water bearing zones cased off (refer to drillers log)



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Project Title	VILLAGE OF MEMRAMCOOK WATER SUPPLY (ME12-01) STEP 2 WSSA REPORT
Dwg. Title:	**WELL LOCATION PLAN**

Drawn By: BLA	Project No. MON-00203023-A0	
Dwg. Standards Ckd. By:	Dwg. No. **FIGURE 4.1**	
Designed By:	Dwg. Design Ckd. By:	Rev. No.

4.3 Pump Testing Program

The results of the step drawdown and constant rate testing are summarized in Appendix C and Appendix D, respectively. A discussion of the results of pump testing is provided below.

4.3.1 Step Drawdown Test

The step drawdown rate test was conducted on the pumping well as four incremental steps. Pumping rates and specific capacities corresponding to the four pumping steps are summarized in Table 4.2. Water level readings and graphs of step test results are provided in Appendix C.

Table 4.2 Step Drawdown Summary

Step No.	Pumping Rate m^3/day (lgpm)	Drawdown at End of Step		Specific Capacity m^2/day (lgpm/ft)
		Incremental m	Cumulative m (ft)	
1	982 (150)	6.32	6.3 (20.7)	155 (7.2)
2	1,296 (198)	3.87	10.2 (33.4)	127 (5.9)
3	1,623 (248)	4.59	14.8 (48.5)	110 (5.1)
4	2,179 (333)	8.48	23.3 (76.3)	94 (4.4)

The specific capacity values shown above should be considered approximations since each pumping step lasted only 60 minutes and equilibrium conditions were not reached. At the pumping rate 2,179 m^3/day (333 lgpm) which was used for the final pumping step, the pump used for the test was nearing its maximum output and, therefore, higher pumping steps were not attempted.

4.3.2 Constant Rate Test

The constant rate test was completed from 4:30 pm August 27, 2012 to 4:30 pm August 29, 2012. An initial pumping rate of 2035 m^3/day (311 lgpm) was selected for the constant pump rate test. At 21 hours pumping time the rate was reduced to 1,453 m^3/day (222) lgpm to ensure pumping level would not drop below the bottom of casing prior to the 72 hour planned pumping period ending. During completion of the test, periodic measurements of the pumping rate were recorded and minor adjustments made as required to maintain rate at the desired output.

Time drawdown plots were prepared for the pumping and observation wells with drawdown plotted as a function of time since pumping started and recovery plotted by the ratio (t/t') method described by Driscoll, 1986.

For the pumping well the slope of the time drawdown curve was observed to remain relatively constant at approximately 10 m per log cycle until the pump rate was decreased from 2,035 m^3/day (311 lgpm) to 1,453 m^3/day (222 lgpm) at 21 hours pumping time. Immediately on decreasing the rate to 1,453 m^3/day (222 lgpm), the pumping well experienced a recovery from 37.59 m (the maximum drawdown observed during the test) to 29.96 m until 28.5 hours pumping time. From this time to the end of the test, the slope of the drawdown curve reestablished itself at a new value of approximately 6 m per log cycle. Once pumping was stopped at 72 hours, the well recovered to within 87 % of the pre constant rate test static water level of 8.16 m within 18 hours (relative to the pre step test static level of 4.45 m, recovery was 75 % following cessation of pumping).

Drawdown in the main observation well (OW12-1D) was observed to be similar in magnitude and mirrored the trend of the pumping well. Drawdown in OW12-2D also followed the general trend of the pumping well although the extent of water drop in this well was less pronounced than the pumping well and OW12-1D. A more subdued drawdown effect was observed in the shallow observation well.

The specific capacity of the pumping well was estimated from the constant rate test data to be approximately 65 m^2/day (3 Igpm/ft) for the initial 2,035 m^3/day (311 Igpm) rate of 21 hours duration, and 64 m^2/day (3 Igpm/ft) for the time weighted average of the initial rate to 21 hours and the 1,453 m^3/day (222 Igpm) from 21 hours to the end of pumping at 72 hours.

The aquifer parameters were interpreted from the portion of the time drawdown data to 21 hours pumping time by the Cooper and Jacob approach. These parameters are summarized in Table 4.3. The transmissivity value was calculated to be in the range 35 to 45 m^2/day. Assuming an aquifer thickness for the pumping well of 26 m (interval from base of casing at 46.5 m to bottom of producing zone at 73 m depth), this corresponds to a hydraulic conductivity of 1.8×10^{-5} m/sec (1.8×10^{-3} cm/sec). By comparison, the range in hydraulic conductivity value suggested by the GSC (GSC Bulletin 589) for the Boss Point is 3.3×10^{-6} to 3.8×10^{-5} m/sec with average 1.1×10^{-5} m/sec. The storativity value (unitless) was calculated from the observation well data to be 1.1×10^{-3}, in comparison to a range of 1.2×10^{-4} to 1.1×10^{-2} with average 4.8×10^{-4} cited by the GSC.

Table 4.3

Interpretive Data and Calculated Aquifer Parameters from Pump Test

Well		Distance from Pumped Well	Interpreted Cooper-Jacob Parameter (from data plot)		Calculated Aquifer Parameters	
		r (m)	s (m)	t_0 (min)	Transmissivity (m^2/day)	Storativity S
Pumping Well ME12-01	Drawdown	--	11.3	--	35	--
	Recovery	--	5.9	--	45	--
Observation Well OW12-1D	Drawdown	31	11.3	1.8	35	1.1×10^{-3}
	Recovery	31	5.9	--	45	--

4.4 Results of Water Quality Analyses

Three samples were collected from the pumping well over the duration of the 72 hour test, and one sample was collected from each of the observation wells at 65 hours pumping time. Samples from the pumping well were analyzed by RPC Laboratory, and samples from the observation wells were analyzed by NBENV laboratory (due to NBENV laboratory holding times, it was necessary to collect the observation well samples prior to the end of the test).

Results of water quality analyses are summarized for the pump testing program including samples from the 150 mm observation wells and the pumping well in Appendix E. Copies of laboratory analytical certificates are provided in Appendix F.

Microbiological – the results of the microbiological analyses are summarized in Table E.1. For the three samples from the pumping well, all microbiological parameters were non detect in the 21 hour and 48 hour samples, and 2 total coliform were reported for the 72 hour sample. Presence of coliform was not expected in the pumping well samples because the casing was set well below the shallow water table. A possible explanation is that the casing was only installed as temporary and not fully grouted to surface. Assuming the well is approved and commissioned as a long term production well, it is recommended that the casing/ borehole annulus be fully grouted to surface to minimize potential for near surface influences on water quality.

Microbiological analyses for the observation wells by NBENV laboratory reported total coliform presence in the shallow observation well and the OW12-2D deep observation well. Non detect bacteriological results were reported for OW12-1D.

General Chemistry and Trace Metals – general chemistry and trace metal inorganic parameter results are summarized in Table E.2 and Table E.3, respectively. Also included in these tables are the Guidelines for the Protection of Canadian Drinking Water Quality (GPCDWQ) established by Health Canada, for comparative purposes.

For the pumping well, concentrations of all parameters were found to comply with their respective potable water criteria, where applicable, with the exception of manganese. Manganese can typically be elevated in groundwater from south eastern New Brunswick aquifers. A general increasing trend was observed over the course of the 72 hour test. In the event the well is commissioned as a production well, treatment for manganese should be included in planning for commissioning of the well.

For the observation wells, generally good water quality was observed, although turbidity, manganese and iron were typically elevated relative to drinking water quality objectives. The guideline for these parameters is mainly aesthetic to avoid staining on plumbing fixtures, although elevated turbidity is a concern regarding effectiveness of disinfection treatment for municipal water systems. In addition, lead was observed to be elevated in one observation well sample. It noted that the samples were reported to have relatively high turbidity in comparison to the pumping well samples, and it is expected that the turbidity (and elevated manganese and iron) is due to natural suspended sediment. (The observation wells were not as well developed as the pumping well, and therefore higher levels of suspended natural sediment would not be surprising). It is expected based on pumping well data that elevated parameters other than manganese would not be observed if the pumping well is commissioned as a production well as turbidity appears within acceptable limits attributable to the higher level of well development resulting from being used as a pumping well.

The calcium carbonate hardness is reported to be about 110 mg/L which is in the moderately hard range. The Langelier Index at 5 ^{o}C was in the range -0.02 to +0.06 which suggests that the well water should not be overly corrosive.

4.5 Pumping Well Flow Capacity

4.5.1 General Considerations

Estimates of long term well capacity (safe yield) from pump test information are subject to the limitation of predicting long term well response based on results of typically relatively short term (i.e. 72 hour) constant rate tests. In practice, safe yield estimates are typically based upon a combination of specific capacity calculations; careful review of pump test data; consideration of local climatic conditions; and professional judgment. *For fractured bedrock aquifers, interpretation of long term safe yield from short term pump tests is also subject to the consideration that the methods typically used for interpretation of pump tests were originally derived for sand and gravel type aquifers. Therefore, predicted yields under long term operation conditions will be subject to results of operational monitoring of water quality and pumping and observation well water levels.*

One method for estimating the long term capacity of a given well referenced by the British Columbia Ministry of the Environment (MOE) is based upon an allowable drawdown and the estimated specific capacity at a pumping time of 100 days. The rationale for this approach is that 100 days of continuous pumping represents a period when groundwater recharge is minimal (e.g. summer and fall months). Specific capacity at 100 days is typically estimated by extrapolating the time drawdown plot for the pumping well.

Well capacity according to this method is calculated by:

$$Q = SF \quad SC_{100\,days} \; (DD_{avail})$$

Where,
- Q = estimated safe well yield (m^3/day)
- SC_{100} = specific capacity at 100 days (m^2/day)
- DD_{avail} = available drawdown (m) (i.e. level to which water level can be safely lowered below static)
- SF = safety factor (typically taken to be 0.7, or 70% of available drawdown)

Calculation of the estimated safe well yield based upon this method is shown on the extrapolated time drawdown plot for ME12-01 which has been included in Appendix D. For well ME12-01, the interpreted available drawdown for the well assuming the water level is not allowed to drop below the base of casing (**assumed depth of casing once well is completed is approximately 47 m**) is approximately 40 m. Using a 100 day specific capacity of 42 m^2/day (2 Igpm/ft) and a safety factor of 0.85, the estimated safe well yield is calculated to be about 1,434 m^3/day (219 Igpm).

The use of a safety factor of 0.85 is considered warranted on the basis that the specific capacity value used in this calculation is interpreted to be lower than actual. This interpretation is based on the fact that the well was initially pumped at the much higher rate of 2035 m^3/day (311 Igpm) during the first 21 hours of the test before being decreased to the lower rate of 1,453 m^3/day (222 Igpm). In this case, projecting the drawdown curve to calculate the specific capacity at 100 days is expected to result in a conservatively low specific capacity value. Additionally, under operational conditions a low level cutoff probe would be installed in the well to prevent the pumping water level falling below the base of the production well casing (it is assumed this low level cutoff point would be set 2 m inside the production casing).

4.5.2 Summary of Recommended Safe Yield

Design Safe Yield - Based on the above discussion and consideration of the pumping data, it is recommended that the safe yield of the well if commissioned as a long term production well be specified at 1,453 m^3/day (222 Igpm). **This assumes that a low level cutoff switch will be installed to prevent the water level dropping below the depth of the production well casing to be set at a minimum of 46 m depth in the final completed well; these switches should be set to turn the pump off with the low level set 2 m inside the casing**. Given that the well was pumped at a rate of 311 Igpm for 21 hours with no apparent deleterious effect on well capability, it is recommended that under short term conditions (e.g. 8 hour period to address peak flow conditions), that the well be approved to pump at a maximum of 2,035 m^3/day (311 Igpm). Under no circumstances should the well be pumped at a rate which exceeds this upper limit unless additional pump testing is completed on application and approval by NBENV. These recommendations are in accordance with the NBDENV requirement that the well initially not be operated at a pumping rate in excess of the value used for the constant rate test.

Subsequent to the commissioning of the new well, water level data should be collected frequently from both the new well and observation wells to monitor the drawdown response in the aquifer and overall well performance. Once an adequate water level monitoring database has been established and upon the review of the data by a qualified hydrogeologist, consideration could be given to increasing the well capacity, if warranted.

Well Interference/ Water Quality and GUDI Potential – Regarding the potential relationship between the proposed production well and other possible users in the area and well interference effects, it is noted that there are no known fulltime wells in the area that service private water wells, industry or commercial users. Based on a review of aerial photos for the area, it is possible that there are seasonal camps in the study area. Should this be the case, long term pumping may result in a lowering of the water table within the area of the well which could in turn impact on wells that may service seasonal camps. If it is decided to commission the well as a long term municipal supply source, the Village can review this potential issue and discuss solutions with possible effected property owners in the area.

Concerning water quality and the potential for groundwater under the direct influence (GUDI) of surface water, it is not anticipated that GUDI will be a problem. This assumes that the permanent well is completed with casing and grout as recommended in this report.

Concerning potential for salt water impact, the well is situated on the order of 5 km from the Memramcook River and lower reach of Breau Creek which are the nearest surface water features anticipated to be subject to salt water intrusion influence (tidal influenced river). Given this distance, the higher elevation of the well property relative to sea level, and the observation that no evidence of saline water impacts were interpreted from the pump test water quality data, salt water impacts are not anticipated.

5 Conclusions and Recommendations

The following conclusions are provided on the basis of the completed work program described herein:

- Results of the pump testing program suggest that the new well would be suitable for commissioning as a long term production well to service the Village of Memramcook;

- Results of microbiological testing on the proposed production well were generally non-detectable for total coliforms, fecal coliforms and E. coli with the exception of the final sample collected at the end of the test which was reported to have low level total coliform count. The observed presence of low level coliform counts at the end of the test are interpreted at this time to be due to the fact that only a temporary casing was set. Assuming the well is commissioned with a permanently set (and grouted) production casing to minimum depth of 47 m below ground surface, potential for impacts from the surface/ near surface would be expected to be minimal (if any). Ongoing monitoring would document long term water quality conditions;

- Results of the pumping well general chemistry and trace metal inorganic water quality analyses suggest that the concentrations of all parameters with the exception of manganese in the raw water from well ME12-01 will comply with the Guidelines for the Protection of Canadian Drinking Water Quality (GPDWQ) established by Health Canada. Assuming the well is commissioned, it should be assumed manganese treatment will be required.

Based on the findings of the work, the following recommendations are provided:

- The Provincial Environmental Impact Assessment (EIA) and all other approvals required to commission the pumping well as a new municipal production well should be obtained so that the well can be commissioned when the Village determines this as feasible;

- Assuming the well is to be commissioned as a long term production well, it is recommended that the existing casing be pulled and that a permanent casing be installed and fully grouted to surface. The permanent casing should be installed to a minimum depth of 47 m but kept above the first significant water yielding zone in the open hole section encountered at 50.9 m;

- Low level shutoff switches should be installed to ensure that under no conditions does the pumping water level fall below the bottom of the casing. It is recommended that the low level point be set at 2 m inside the bottom of the casing to provide safety factor;

- The new well should be suitably disinfected prior to connection to the new distribution system;

- The initial pumping rate of the pumping well should not exceed 1,453 m^3/day (222 Igpm) on an average daily basis, although on the basis of pump test observations short term pumping (e.g. 8 hour period) at 2,035 m^3/day (311 Igpm) would be considered acceptable subject to NBENV approval. Water level and performance data should be closely monitored once the new well becomes operational. Once an adequate database has been established, the data should be reviewed by a qualified professional and the maximum pumping rate revised, if warranted;

- Observation well OW12-1D could be considered and completed as a back up well subject to obtaining appropriate approvals from NBENV. However, this well taps the same water yielding zone as the pumping well and therefore is not recommended at this time to pump at the same time as the production well.

Prior to commissioning a new production well, the New Brunswick Department of the Environment (NBDENV) requires that a municipality initiate the Wellfield Protection Program/Wellfield Protected Area Designation Order (WfPADO) process and commit to having an updated wellfield protection study completed within one year commissioning. It is suggested that a continuous 24 hr/day pumping rate of 2,035 m^3/day (311 lgpm) be used in the model to allow for possible increase in long term recommended safe yield should operational monitoring suggest this may be feasible and regulatory approval can be obtained to increase to this pumping rate.

6 Closing and Limitations

This report was prepared by **exp** for the account of the Village of Memramcook. The material in this report reflects **exp**'s best judgment in light of the information available to it at the time of preparation. Any use which a third party makes of this report, or any reliance or decisions to be made based upon it, are the responsibility of such third parties. **Exp** accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

If site conditions or applicable standards change or if additional information becomes available at a future date, modifications to the findings, conclusions and recommendations in this report may be necessary.

This report was written by John Sims, M.Sc., P. Eng., P.Geo. and reviewed by Roland LeBlanc, P. Eng.

7 References

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