1990 Warm Water Supply Well (PW2)

Field Program Results
Yukon Territory

Prepared for
Village of Mayo

Prepared by
hydrogeological consultants ltd. **(HCL)**
1.800.661.7972

January 2011

Our File No.: 10-186.00

PERMIT TO PRACTICE
HYDROGEOLOGICAL CONSULTANTS LTD.
Signature _____
Date 2011-01-20
PERMIT NUMBER P 385
The Association of Professional Engineers,
Geologists and Geophysicists of Alberta

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1. Introduction

The Village of Mayo has two warm water supply wells that are used by the Village. Since the Village noticed changes in the quality and quantity of groundwater from the 1975 Mayo Warm Water Supply Well (PW1), they also became concerned that the 1990 Mayo Warm Water Supply Well (PW2) may also fail, leaving the Village without a supply of warm water. Hydrogeological Consultants Ltd. (HCL) were hired to propose a work plan to resolve the current problems and help prevent future issues, with the warm water supply wells, using the services of Aqua Tech Supplies & Services Ltd. (Aqua Tech) based in Whitehorse, Yukon Territory and the data they provide.

Google Earth Image

A letter report outlining a proposed field program to be completed with PW1 and PW2 was prepared by HCL in May 2010 and was submitted to the Village. Following the May 2010 letter report, Aqua Tech conducted a downhole video camera inspection of both warm water supply wells in July 2010 and forwarded the results to HCL. Upon reviewing the videos, HCL proposed a field work plan specific to PW2 in August 2010 and a field work plan for PW1 in January 2011. Aqua Tech conducted work with PW2 in September and October 2010 and forwarded the results to HCL for review. The present report will summarize the results of the data provided by Aqua Tech and comment on the current status of PW2.

2. Background

2.1. PW2

PW2 is a flowing water well, completed on June 4, 1990 by Hi-Rate Drilling 1985 Ltd. PW2 is completed with 356-millimetre outside diameter (OD) steel surface casing to a depth of 245.9 metres below ground level (BGL) and a 40-slot steel water well screen in the depth interval between 246.7 and 251.5 metres BGL in a sand and gravel aquifer. The non-pumping water level (NPWL) of PW2 was measured to be 1.76 metres above the datum upon completion.

As noted in the May 2010 letter to the Village of Mayo, the specific capacity (a measure of efficiency) was 118 litres per minute per metre of drawdown (lpm/m of dd) when the water supply well was put into service in 1990. One chemical analysis is available for PW2, analyzed June 26, 1990. The chemical analysis results of groundwater from PW2 indicate that the groundwater from PW2 is a bicarbonate-sulfate-type groundwater with no dominant cation, a total dissolved solids (TDS) content of 379 milligrams per litre (mg/L) and a chloride concentration of 5 mg/L. Completion and chemical analysis data for PW2 are in Appendix A.

2.2. Recommended Field Program

A letter report was prepared by HCL in August 2010 outlining a recommended field program for the servicing of PW2. The report recommended that the following five tasks be completed.

1. Step-Drawdown Pre-Test and Groundwater Sampling

Prior to servicing PW2, a step-drawdown test consisting of five ten-minute steps, each with differing pumping rates was to be conducted. A meaningful NPWL was to be obtained along with accurate water-level and discharge measurements.

After one minute of pumping during each step, groundwater samples were to be collected and submitted to an accredited laboratory for routine potability and total suspended solids analyses. Biological Activity Reaction Test (BART) samples and groundwater samples to be submitted for microbiological analysis were also to be collected near the beginning and the end of the step-drawdown test.

2. Pre-Servicing Downhole Video Inspection

Prior to servicing PW2 and following the step-drawdown pre-test and groundwater sampling, the pump was to be removed from PW2 to allow for a complete downhole video inspection of the water supply well. Two to three locations on the screen of PW2 were to be selected in order to document the condition of the water well screen prior to servicing and to allow for an assessment of the effectiveness of the rehabilitation of the water supply well following servicing.

3. Water Well Servicing

Aqua Tech was to complete an airburst process to remove any mineral and/or biological deposits present on the water well screen installed in PW2.

4. Post-Servicing Downhole Video Inspection

A second downhole video inspection of PW2 was to be completed following the airburst rehabilitation attempt. It was recommended that the video inspection be completed both when there was discharge from the water supply well and non-discharge. The water well screen locations observed during the first downhole video inspection were to be used to assess the success of the airburst procedure.

5. Step Drawdown Post-Test and Groundwater Sampling

After servicing PW2, the water supply well pump was then to be reinstalled to perform a step-drawdown post-test. It was recommended that the post-test procedure be conducted the same as the pre-test and that the same suite and frequency of groundwater sampling as during the pre-test be collected and submitted for analysis.

3. Field Program Results

3.1. Grain Size Analysis

A sample of the sediment from PW2 was supplied to HCL by Aqua Tech and submitted to J.R. Paine & Associates Ltd. for a grain size analysis. The grain size analysis was conducted on June 22, 2010; the results indicate that approximately 20% of the grains sampled from PW2 are larger than one-millimetre. The grain size analysis results are in Appendix A.

3.2. Pre-Servicing

3.2.1. Aquifer Testing

Aquifer Test III (AT III) with PW2 was a step-drawdown aquifer test conducted by Aqua Tech on September 23, 2010. AT III consisted of measuring water levels every minute during a total of 50 minutes of groundwater diversion at five different pumping rates which varied from 96.3 lpm to 379 lpm. The NPWL of PW2 prior to the start of AT III was unable to be obtained because the water supply well was flowing. AT III results are in Appendix A.

3.2.2. Groundwater Sampling

Groundwater samples prior to servicing PW2 are not available.

3.2.3. Video Inspection

A video inspection of PW2 was conducted prior to the servicing of the water supply well. From the video, the following was observed:

- The total depth of the water supply well was 251 metres below top of casing (BTOC).
- Significant amounts of sand were present in the bottom ten centimetres of the water supply well.
- The top of the water supply well screen was at 245.5 metres.
- Some encrustation on the water supply well screen, although the encrustation did not appear to be significant.

3.3. Water Well Servicing

Aqua Tech began the air shock treatment of PW2 on September 29, 2010. Problems with the air shock apparatus delayed the completion of the process; ultimately, the air shock procedure was performed on three additional occasions (on September 30, October 1 and October 5, 2010) following the initial treatment.

3.4. Post-Servicing

3.4.1. Video Inspection

A video inspection of PW2 was conducted after the servicing of the water supply well. From the video, the following was observed:

- The total depth of the water supply well was 251 metres BTOC.
- Sand was no longer present in significant amounts in the bottom ten centimetres of the water supply well. Sand was present on the well bottom, but only several small upwellings of sand were observed.

- Sand entering the water supply well between the screen and liner.
- There was no noticeable change in the condition of the water supply well screen.

3.4.2. Aquifer Testing

AT IV with PW2 was a step-drawdown aquifer test conducted by Aqua Tech on October 15, 2010. AT IV consisted of measuring water levels every minute during a total of 50 minutes of groundwater diversion at five different pumping rates which varied from 96.0 lpm to 474 lpm. The NPWL of PW2 prior to the start of AT IV was unable to be obtained because the water supply well was flowing.

AT V with PW2 was conducted after the water level had recovered from AT IV. AT V was conducted on October 15, 2010 by Aqua Tech and consisted of measuring the water level while pumping PW2 at an average of 663 lpm for 36 minutes. Prior to AT V, the water supply well was flowing.

During the pumping interval of AT V, the water level was lowered to a depth of 32.82 metres BTOC. Aqua Tech personnel reported the water level began to flow again after 3:37 minutes of recovery. The early pumping data indicate an aquifer transmissivity of 4.8 m²/day and the late pumping data indicate an effective transmissivity of 48.3 m²/day. AT IV and AT V data are in Appendix A.

3.4.3. Groundwater Sampling

Groundwater samples were collected on October 15, 2010 after one minute of pumping during Steps 1 through 4 of AT IV. The groundwater samples were submitted to Exova Canada Inc. (Exova) for routine potability and suspended solids analyses.

Complete routine potability analyses were not able to be performed with the groundwater samples because of insufficient sample volumes. Also as a result of the insufficient sample volumes, the detection limit for the suspended solids analyses was adjusted from one milligram per litre (mg/L) to 3 mg/L for groundwater samples from Steps 1 and 4, and adjusted to 2 mg/L for groundwater samples from Steps 2 and 3.

The adjacent table shows that the concentrations of total, fixed and volatile suspended solids are all less than the analysis detection limit. Other notable results include turbidity which increased to 1.2 Nephelometric Turbidity Units (NTU) during Step 4 from 0.3 NTU during Step 1. The turbidity of 1.2 NTU exceeds the maximum acceptable concentration as stated in the Summary of Guidelines for Canadian Drinking Water Quality[1] (SGCDWQ). In addition, the concentration of chloride increased to 470 mg/L during Step 4 from 84.6 mg/L during Step 1 and the conductivity increased from 851 miroSiemens per centimetre (µS/cm) to 1,290 µS/cm. The concentrations of the remaining constituents did not change significantly between Steps 1 and 4.

		Step 1	Step 2	Step 3	Step 4
	1990-06-04	2010-10-15			
Constituent	mg/L	mg/L	mg/L	mg/L	mg/L
Total Suspended Solids	---	< 3	< 2	< 2	< 3
Fixed Suspended Solids	---	< 3	< 2	< 2	< 3
Volatile Suspended Solids	---	< 3	< 2	< 2	< 3
Chloride	5	84.6	---	---	470
Turbidity (NTU)	---	0.3	---	---	1.2
Conductivity (µS/cm)	604	851	---	---	1,290
Fluoride	0.28	0.13	---	---	0.13

Chemical Analyses Results

[1] Federal–Provincial–Territorial Committee on Drinking Water. May 2008. Summary of Guidelines for Canadian Drinking Water Quality. Health Canada. http://www.hc-sc.gc.ca/hecs-sesc/water/keep_up-to-date_poster.htm.

4. Interpretation

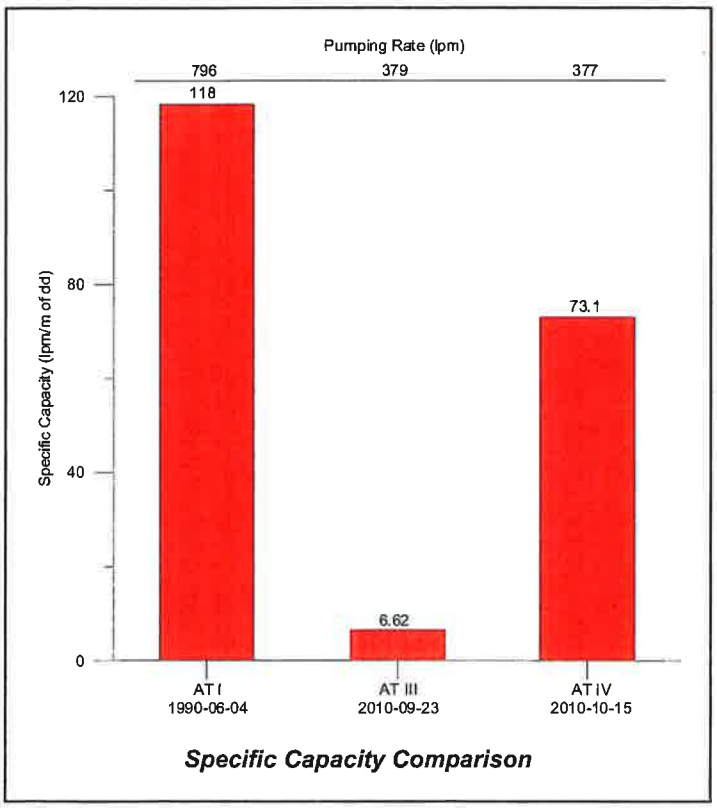
4.1. Grain Size Analysis

The grain size analysis results indicate that approximately 20% of the grains collected from PW2 are larger than one-millimetre; the screen slot size in PW2 is one-millimetre. It is not expected that sediment larger than the size of the screen slots will enter the water well. As a result, the grain size analysis results are considered questionable.

4.2. Aquifer Testing

When comparing AT III and AT IV results, the water level at the end of Step 4 is more than 50 metres higher during AT IV than during AT III when pumping groundwater from PW2 at a similar rate.

Even though the specific capacity has improved dramatically from before servicing (AT III) to after servicing (AT IV), the specific capacity of PW2 is still less than when the water supply well was first put into service in 1990. The adjacent graph shows the specific capacity of PW2 when it was put into service (AT I), before servicing (AT III), and after servicing (AT IV). From the graph, it can be seen that the efficiency of PW2 has improved significantly since Aqua Tech serviced the water supply well; however, the specific capacity has not improved to the original level of well efficiency as calculated from AT I[2].



Specific Capacity Comparison

4.3. Groundwater Sampling

Since a full routine potability analysis was unable to be completed due to insufficient sample volumes, a full comparison of the June 1990 to the October 2010 chemical analyses could not be completed. From the parameters able to be compared between the sampling events, the concentration of chloride and the value of conductivity have increased, while the concentration of fluoride has decreased. The reason(s) for these differences is not known at this time. From the data available, there has been no significant change in the concentrations of bicarbonate or alkalinity between June 1990 and October 2010.

2 All calculations involving NPWLs assumed that the NPWLs for AT III and AT IV were 1.76 metres above top of casing based on the NPWLs reported for AT I and AT II.

4.4. Video Inspection

There appears to be less groundwater entering PW2 through the bottom of the water supply well after the servicing was conducted. Prior to servicing, the flow of groundwater into the water supply well through the well bottom was enough to cause the bottom ten centimetres of PW2 to have considerable amounts of sand present. After servicing, the sand was no longer swirling around the bottom of the water supply well, but a few upwellings of sand on the well bottom indicate that a lesser volume of groundwater continues to enter PW2 from the well bottom. Screen shots of selected observations made during the pre- and post-servicing video inspections are included in Appendix B.

It is possible that there is less water entering the well bottom because the servicing has made it easier for groundwater to enter PW2 through the water well screen. The fact that the groundwater is more easily entering PW2 is shown by the increased specific capacity.

There was no noticeable change in the condition of the water supply well screen from before and after the servicing of PW2. After the servicing though, sand was observed entering the water well from the top of the water well screen, between the screen and the liner; this was not observed prior to servicing.

5. Conclusions

Data from the aquifer tests conducted prior to and after the servicing of PW2 were used to determine water well and aquifer characteristics, and to assist in quantitatively evaluating the effectiveness of the water well rehabilitation.

Based on the available data, the air shock procedure conducted by Aqua Tech was effective in improving the efficiency of PW2. The aquifer test results from AT III and AT IV show that there was a significant difference in the maximum drawdown of the water level in PW2 from before servicing to after.

The video inspections show a considerable decrease in the amount of groundwater entering PW2 through the well bottom, indicating that servicing has likely improved the condition of the water supply well screen enough to allow groundwater to pass through the screen with greater ease than prior to servicing. This redirection of groundwater entry has likely attributed to the increased efficiency of PW2. Conversely, the observation of sediment entering the water well from between the screen and the liner after the servicing of PW2 indicates the servicing may have damaged the water well.

The quality of groundwater from PW2 has changed between 1990 and 2010. Notable changes include an increased concentration of chloride and increased electrical conductivity; the concentration of fluoride has decreased. The reason(s) for these differences is not known at this time. The October 2010 chemical analysis results showed that the concentrations of total, fixed and volatile suspended solids were all less than the analysis detection limit.

6. Recommendations

It is recommended that the Village of Mayo monitor the quality of groundwater from PW2 by collecting groundwater samples from the water supply well and submitting them to an accredited laboratory for routine and total suspended solids analyses on a biannual basis. No less than one litre of groundwater should be collected during each sampling event.

It is recommended that an in-line turbidity meter be installed to monitor and record the turbidity of the groundwater discharge from PW2. The turbidity meter will provide data that, if reviewed regularly, can be used as part of the PW2 maintenance program; allowing for the proactive scheduling of water well servicing before a significant failure of the water well can occur.

It is recommended that the sand observed to be entering the water supply well between the liner and the screen in the post-servicing video inspection be monitored using the previously recommended turbidity meter. Before any additional servicing of PW2, it is recommended that another video inspection of the water supply well be completed and, if the video inspection shows that sediment is still entering the water well from between the screen and the liner, PW2 may need to be recompleted in a similar manner as to that proposed for PW1[3].

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Junior Hydrogeologist

PROFESSIONAL GEOLOGIST ALBERTA
JASON T. SANDERS

January 20, 2010

Jason Sanders, P.Geol.
Project Hydrogeologist

[3] Hydrogeological Consultants Ltd. January 2011. Proposal. Recompletion of the 1975 Mayo Warm Water Supply Well (PW1). Yukon Territory. (unpublished contract report – January 2011) [10-186.01]

7. Bibliography

Hydrogeological Consultants Ltd. May 2010. Issues with Two Warm Water Supply Wells. 2010 Investigation. Village of Mayo. Yukon Territory. (unpublished contract report – May 2010) [10-186]

Hydrogeological Consultants Ltd. August 2010. Field Program for the 1990 Mayo Warm Water Supply Well (PW2). 2010 Investigation. Yukon Territory. (unpublished contract report – August 2010) [10-186]

MLM Ground-Water Engineering Ltd. August 27, 1990. Construction and Testing of Warm Water Well PW 2. Mayo, Yukon. Prepared for Stanley Associates Engineering Ltd.

8. Glossary

BGL	Below Ground Level
BTOC	Below Top of Casing
m^2/day	metres squared per day
mg/L	milligrams per litre
NPWL	non-pumping water level
SGCDWQ	Summary of Guidelines for Canadian Drinking Water Quality
Transmissivity	the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient: a measure of the ease with which groundwater can move through the aquifer Apparent Transmissivity: the value determined from a summary of aquifer test data, usually involving only two water-level readings Effective Transmissivity: the value determined from late pumping and/or late recovery water-level data from an aquifer test Aquifer Transmissivity: the value determined by multiplying the hydraulic conductivity of an aquifer by the thickness of the aquifer

9. Conversions

Multiply	by	To Obtain
Length/Area		
feet	0.304 785	metres
metres	3.281 000	feet
hectares	2.471 054	acres
centimetre	0.032 808	feet
centimetre	0.393 701	inches
acres	0.404 686	hectares
inches	25.400 000	millimetres
miles (statute)	1.609 344	kilometres
kilometres	0.621 370	miles (statute)
square feet (ft^2)	0.092 903	square metres (m^2)
square metres (m^2)	10.763 910	square feet (ft^2)
square metres (m^2)	0.000 001	square kilometres (km^2)
Concentration		
grains/gallon (UK)	14.270 050	parts per million (ppm)
parts per million (ppm)	0.998 859	milligrams per litre (mg/L)
milligrams per litre (mg/L)	1.001 142	parts per million (ppm)
Volume (capacity)		
acre feet	1233.481 838	cubic metres
cubic feet	0.028 317	cubic metres
cubic metres	35.314 667	cubic feet
cubic metres	219.969 248	imperial gallons (UK)
cubic metres	264.172 050	gallons (US liquid)
cubic metres	1000.000 000	litres
imperial gallons (UK)	0.004 546	cubic metres
imperial gallons (UK)	4.546 000	litres
Rate		
litres per minute	0.219 974	imperial gallons per minute (ipgm)
litres per minute	1.440 000	cubic metres/day (m^3/day)
imperial gallons per minute (igpm)	6.546 300	cubic metres/day (m^3/day)
cubic metres/day (m^3/day)	0.152 759	imperial gallons per minute (ipgm)
Pressure		
pound per square inch (psi)	6.894 757	kilopascal (kpa)
kilopascal (kpa)	0.145 038	pound per square inch (psi)
Miscellaneous		
Celsius	F° = 9/5 (C° + 32)	Fahrenheit
Fahrenheit	C° = (F°- 32) * 5/9	Celsius
degrees	0.017 453	radians

Appendix A – Water Supply Well Details

TABLE OF CONTENTS

1990 Mayo Warm Water Supply Well (PW2)

SE 13-123-03 W5M
(M40261.571663)

Well Spatial Location:

Easting: ***-1,022,357***
Northing ***7,218,828***
::*(spatial accuracy GPS — Other — 10TM NAD83)*

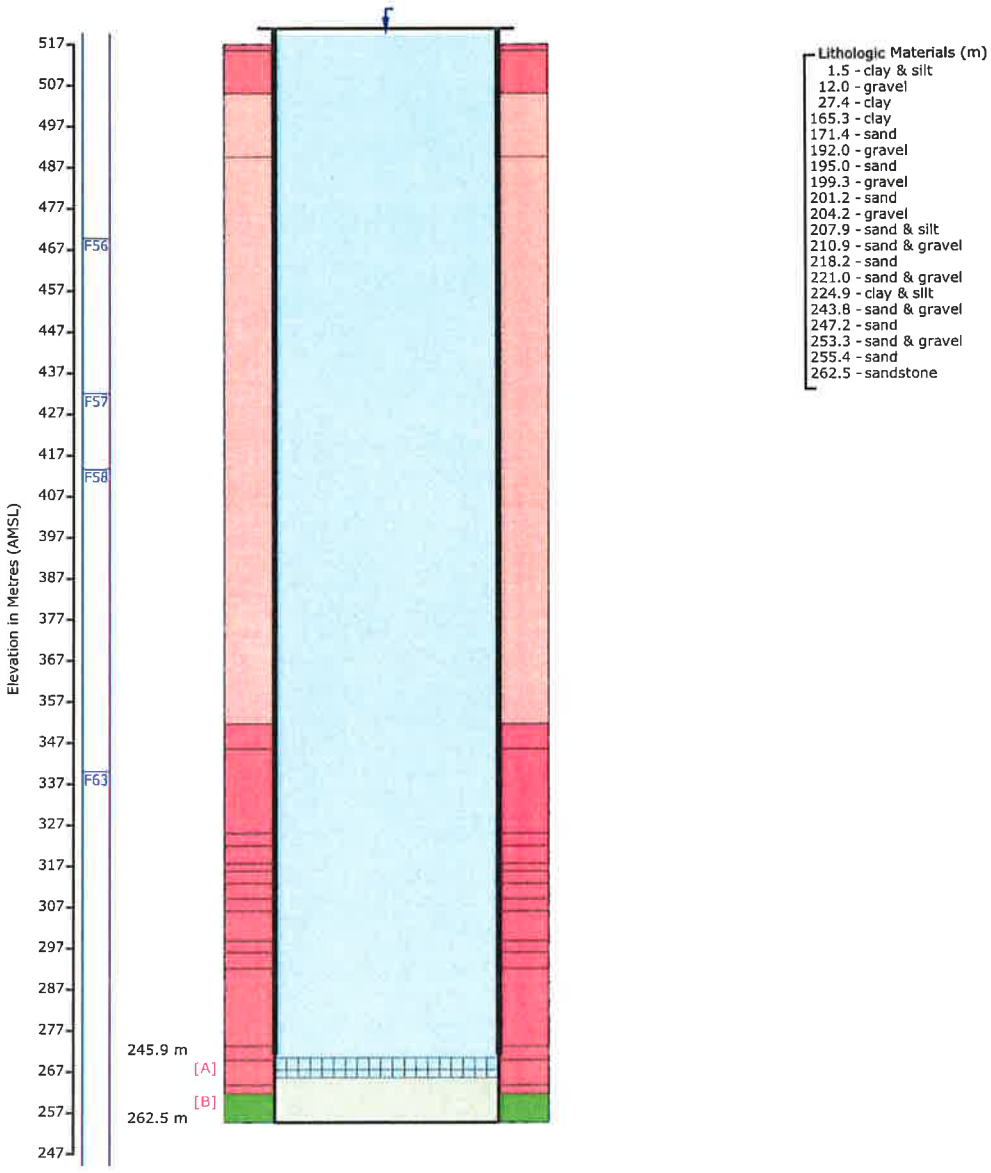
Ground Elevation AMSL (m): ***517***
::*(elevation accuracy MT DEM)*

Date Completed: ***June 04, 1990***

Depth Drilled (m): ***262.5***

Completion Interval (m): ***246.7 — 251.5 ****
::*(* TGWC determined value)*

1990 Mayo Warm Water Supply Well (PW2)
Well Diagram



Lithology Legend

Surficial: Unsorted; Fine Grained; Coarse Grained

Bedrock: Fine Grained; Coarse Grained

Other

Geologic Unit Legend (Top) - Regional Analysis

F56 - Viking Formation
F57 - Joli Fou Formation
F58 - Upper Mannville Formation
F63 - Winterburn Group

Summary

TGWC ID: M40261.571663
Well Name: 1990 Mayo Warm Water Supply Well (PW2)
Legal Location: SE 13-123-03 W5M
Casing (OD): 356.0 mm; Steel (14.0")
Casing Stick-Up: 0.77 m (not drawn to scale)
Interval [A]: 246.7 to 251.5 m; Screened
Interval [B]: 251.8 to 262.5 m; Plugged (Cuttings)

NOTE: Geologic Unit is a guide based on a regional groundwater assessment completed by hydrogeological consultants ltd. (HCL). --- http://www.hcl.ca
Drawn: November 26, 2010 13:46 --- http://www.tgwc.ca

Owner: *Village of Mayo*
P.O. Box 160, Mayo, YT Y0B 1M0
Contractor: *Hi-Rate Drilling 1985 Ltd.*
Well Name: *1990 Mayo Warm Water Supply Well (PW2)*

Field Survey: *March 24, 2010 - Confirmed - Expected Location*

METRIC REPORT

Easting (m): *-1022357* ** 79/80
Northing (m): *7218828* **
Elevation (m): *517* ***
Google Earth

SE 13-123-03 W5M

M40261.571663

190400-5

Work Type: *New Well*
Drilling Method: *Drilled*
Proposed Use: *Municipal*
Completion Type: *[unknown]*

Date Started: *May 20, 1990*
Date Completed: *June 04, 1990*
Well Status: *Producing*

Elog Taken: *No*
Gamma Taken: *No*
Stick Up (m): *0.8*
Flowing *Yes*

General Details

Depth Completed (m): *251.5*
Depth Drilled (m): *262.5*
Completion Aquifer: - *Top: 165.3 m* *
Sand & Gravel Thickness (m): *96.7 (total) — 86.2 (below 15 m)* *
Plugged / Backfilled (m): *251.8 — 262.5 (Cuttings)*

Top of Bedrock: *Surficial Water Well* *
Completion Interval (m): *246.7 — 251.5* *

Completion Details

Surface Casing: *Steel — 356.0 mm (O.D.) x 9.53 mm (thick) x 245.85 m (bottom)*

Screen Material: *Steel — (Jetted)*

Intervals

(Liner: 244.9 m - 251.8 m)

Completion Interval: *Screen: 246.7 to 251.5 m - 40*

Lithology Details

Elevation (AMSL)	Depth (BGL)	Lithology Descriptions (rate lpm)
515.5	1.5	Sandy Brown Clay & Silt
505.0	12.0	Gravel
489.6	27.4	Silty Dark Grey Clay
351.7	165.3	Silty Dark Grey Clay
345.6	171.4	Coarse Grained Sand
325.0	192.0	Gravel
322.0	195.0	Coarse Grained Sand
317.7	199.3	Gravel
315.8	201.2	Silty Sand
312.8	204.2	Gravel
309.1	207.9	Clayey Sand & Silt
306.1	210.9	Sand & Gravel
298.8	218.2	Sand
296.0	221.0	Sand & Gravel
292.1	224.9	Sandy Clay & Silt
273.2	243.8	Sand & Gravel
269.8	247.2	Clayey Sand
263.7	253.3	Angular Sand & Gravel
261.6	255.4	Silty Sand
254.6	262.5	Fractured Sandstone

Chemistry Summary Details (mg/L, except as noted)

(most recent first)

Sampling Details: *October 15, 2010*
Analysis Details: *October 28, 2010 - Exova (770178-1)*

Constituent	Result	Constituent	Result	Constituent	Result
Conductivity (µS/cm):	*851*	Nitrate as N:	*< 0.01*	Colour (TCU):	
TDS (Calculated):		Nitrite as N:	*0.021*	Turbidity (NTU):	*0.3*
Hardness (as CaCO3):		pH (pH Unit):	*7.63*	Fluoride:	*0.13*
T-Alkalinity (as CaCO3):	*245*	Ion Balance (%):		Carbonate:	*< 6*
P-Alkalinity (as CaCO3):	*< 5*	Total Coliforms**:		Bicarbonate:	*299*
Nitrate + Nitrite as N:	*0.02*	Fecal Coliforms**:		Hydroxide:	*< 5*
Total Suspended Solids:	*< 3*	Escherichia coli**:		Total Iron:	
Sulfate Reducing Bacteria*:				Total Mn:	
Iron Related Bacteria*:				Temperature (°C):	*21.9*

Constituent	Extractable	Dissolved	Constituent	Extractable	Dissolved
Calcium:			Mercury:		
Chloride:		*84.6*	Molybdenum:		
Iron:			Magnesium:		
Manganese:			Sodium:		
Aluminum:			Potassium:		
Arsenic:			Vanadium:		
Barium:			Strontium:		
Beryllium:			Nickel:		
Cadmium:			Zinc:		
Chromium:			Copper:		
Cobalt:			Lead:		
Sulfate:					

Extractable = unfiltered
Dissolved = filtered

(1 / 5)

Comments: *Sample collected by Aqua Tech Supplies & Services Ltd.*

note: constituents have been compared to the maximum acceptable concentration, as stated in the Summary of Guidelines for Canadian Drinking Water Quality (Federal–Provincial–Territorial Committee on Drinking Water, May 2008)

General Comments / Observations

Stanley Associates Engineering Ltd. reported the warm water wells are located within a Public Works compound in the northwestern part of the Village of Mayo (September 13, 1990).

Oil Present: *No*
Gas Present: *No*

Water Used For Drilling

Aquifer Tests

No.	Date	Testing Method	Duration (minutes) Pumping	Duration (minutes) Recovery	Avg. Rate (lpm)	NPWL (metre)	Drawdown (metre)	Level-End (metre)	Pump (metre)	Q20 (m³/day)* Apparent	Q20 (m³/day)* Effective	Transmissivity (m²/day)* Apparent	Transmissivity (m²/day)* Aquifer	Transmissivity (m²/day)* Effective	
5	2010-10-15 13:30	Pump	36.0		662.5	—	32.82	32.82	—	1911.7		30.5	4.8	48.3	R C
4	2010-10-15 11:30	Pump	50.0		step test	—	7.90	7.90	—	3665.8		58.5			R C
3	2010-09-23 17:00	Pump	50.0	17.0	step test	—	67.20	67.20	—	333.6		5.3			R C
2	1990-06-04 18:00	Pump	2760.0		1272.9	—	17.37	17.37	—			161.3	303.0	121.0	R C

Alias IDs

** TGWC calculated or determined value.*
*** 79 - GPS — Other — 10TM NAD83*
**** 80 - MT DEM — (Ground; AMSL)*

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F: +1 (780) 438-0396
E: Edmonton@exova.com
W: www.exova.com

Exova

Analytical Report

Bill To:	Hydrogeological Consultants	Project:		Lot ID:	**770178**
Report To:	Hydrogeological Consultants	ID:	10-186	Control Number:	Z184522
	17740 - 118 Avenue	Name:	Village of Mavo - 2010	Date Received:	Oct 22, 2010
	Edmonton, AB, Canada	Location:	Yukon Territory	Date Reported:	Oct 28, 2010
	T5S 2W3	LSD:	SE 13-123-3 W5M	Report Number:	1373702
Attn:	Tara Parker	P.O.:	14143		
Sampled By:		Acct code:			
Company:	Aqua Tech Supplies & Services				

Reference Number	770178-1
Sample Date	October 15, 2010
Sample Time	NA
Sample Location	
Sample Description	M40261.571663 (Mayo-STEP 1)
Sample Matrix	Water

Analyte		Units	Result	Nominal Detection Limit	Guideline Limit	Guideline Comments
Physical and Aggregate Properties						
Turbidity		NTU	0.3	0.1	0.1	Above OG
Solids	Total Suspended	mg/L	<3	1		
Solids	Fixed Suspended	mg/L	<3	1		
Solids	Volatile Suspended	mg/L	<3	1		
Routine Water						
pH			7.63		6.5 - 8.5	Within AO
Temperature of observed pH		°C	21.9			
Electrical Conductivity		µS/cm at 25 C	851	1		
Chloride	Dissolved	mg/L	84.6	0.4	250	Below AO
Fluoride		mg/L	0.13	0.05	1.5	Below MAC
Nitrate - N		mg/L	<0.01	0.01	10	Below MAC
Nitrite - N		mg/L	0.021	0.005	1	Below MAC
Nitrate and Nitrite - N		mg/L	0.02	0.01	10	Below MAC
Hydroxide		mg/L	<5	5		
Carbonate		mg/L	<6	6		
Bicarbonate		mg/L	299	5		
P-Alkalinity	as CaCO3	mg/L	<5	5		
T-Alkalinity	as CaCO3	mg/L	245	5		

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Exova

Analytical Report

Bill To:	Hydrogeological Consultants	Project:		Lot ID:	**770178**
Report To:	Hydrogeological Consultants	ID:	10-186	Control Number:	Z184522
	17740 - 118 Avenue	Name:	Village of Mavo - 2010	Date Received:	Oct 22, 2010
	Edmonton, AB, Canada	Location:	Yukon Territory	Date Reported:	Oct 28, 2010
	T5S 2W3	LSD:	SE 13-123-3 W5M	Report Number:	1373702
Attn:	Tara Parker	P.O.:	14143		
Sampled By:		Acct code:			
Company:	Aqua Tech Supplies & Services				

Reference Number	770178-2
Sample Date	October 15, 2010
Sample Time	NA
Sample Location	
Sample Description	M40261.571663 (Mayo-STEP 2)
Sample Matrix	Water

Analyte		Units	Result	Nominal Detection Limit	Guideline Limit	Guideline Comments
Physical and Aggregate Properties						
Solids	Total Suspended	mg/L	<2	1		
Solids	Fixed Suspended	mg/L	<2	1		
Solids	Volatile Suspended	mg/L	<2	1		

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Exova

Analytical Report

Bill To:	Hydrogeological Consultants	Project:		Lot ID:	**770178**
Report To:	Hydrogeological Consultants	ID:	10-186	Control Number:	Z184522
	17740 - 118 Avenue	Name:	Village of Mavo - 2010	Date Received:	Oct 22, 2010
	Edmonton, AB, Canada	Location:	Yukon Territory	Date Reported:	Oct 28, 2010
	T5S 2W3	LSD:	SE 13-123-3 W5M	Report Number:	1373702
Attn:	Tara Parker	P.O.:	14143		
Sampled By:		Acct code:			
Company:	Aqua Tech Supplies & Services				

Reference Number	770178-3
Sample Date	October 15, 2010
Sample Time	NA
Sample Location	
Sample Description	M40261.571663 (Mayo-STEP 3)
Sample Matrix	Water

Analyte		Units	Result	Nominal Detection Limit	Guideline Limit	Guideline Comments
Physical and Aggregate Properties						
Solids	Total Suspended	mg/L	<2	1		
Solids	Fixed Suspended	mg/L	<2	1		
Solids	Volatile Suspended	mg/L	<2	1		

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Analytical Report

Bill To:	Hydrogeological Consultants	Project:		Lot ID:	**770178**
Report To:	Hydrogeological Consultants	ID:	10-186	Control Number:	Z184522
	17740 - 118 Avenue	Name:	Village of Mavo - 2010	Date Received:	Oct 22, 2010
	Edmonton, AB, Canada	Location:	Yukon Territory	Date Reported:	Oct 28, 2010
	T5S 2W3	LSD:	SE 13-123-3 W5M	Report Number:	1373702
Attn:	Tara Parker	P.O.:	14143		
Sampled By:		Acct code:			
Company:	Aqua Tech Supplies & Services				

Reference Number	770178-4
Sample Date	October 15, 2010
Sample Time	NA
Sample Location	
Sample Description	M40261.571663 (Mayo-STEP 4)
Sample Matrix	Water

Analyte		Units	Result	Nominal Detection Limit	Guideline Limit	Guideline Comments
Physical and Aggregate Properties						
Turbidity		NTU	1.2	0.1	0.1	Above OG
Solids	Total Suspended	mg/L	<3	1		
Solids	Fixed Suspended	mg/L	<3	1		
Solids	Volatile Suspended	mg/L	<3	1		
Routine Water						
pH			7.74		6.5 - 8.5	Within AO
Temperature of observed pH		°C	22.1			
Electrical Conductivity		µS/cm at 25 C	1290	1		
Chloride	Dissolved	mg/L	470	0.4	250	Above AO
Fluoride		mg/L	0.13	0.05	1.5	Below MAC
Nitrate - N		mg/L	<0.01	0.01	10	Below MAC
Nitrite - N		mg/L	0.021	0.005	1	Below MAC
Nitrate and Nitrite - N		mg/L	0.02	0.01	10	Below MAC
Hydroxide		mg/L	<5	5		
Carbonate		mg/L	<6	6		
Bicarbonate		mg/L	301	5		
P-Alkalinity	as CaCO3	mg/L	<5	5		
T-Alkalinity	as CaCO3	mg/L	247	5		

Approved by:
Jacqueline Tiedemann
Client Services Team Leader

* ***The Groundwater Centre*** *calculated or determined value.*

Report was generated on: ***November 26, 2010 ; Page 5 of 5***

Detailed Chemical Result(s) — 1990 Mayo Warm Water Supply Well (PW2)

Owner: ***Village of Mayo***
P.O. Box 160, Mayo, YT Y0B 1M0
Legal Location: ***SE 13-123-03 W5M***

Depth Drilled (m): ***262.5***
Depth Completed (m): ***251.5***
Top of Bedrock: ***Surficial Water Well ****

Completion Interval (m): ***246.7 — 251.5 ****
Completion Aquifer: ***(Top: 165.3 m) ****

:: 5 of 5

General

Sample Details: ***June 04, 1990*** *from* ***[unknown]***
Analysis Details: ***July 26, 1990 - Alpha Laboratory Services Ltd. (2675)***

Nutrients

Nitrate + Nitrite as N: ***< 0.10***

Routine

pH (Units): ***8.05***
Conductivity (µS/cm): ***604***
T-Alkalinity (as CaCO3): ***252***
Hardness (as CaCO3): ***206***
TDS (Calculated): ***379***
Fluoride: ***0.28***
Carbonate: ***< 1***
Bicarbonate: ***307***

Field

Extractable Metals - Unfiltered

Manganese: ***0.06***
Calcium: ***48***
Potassium: ***2.0***
Sodium: ***65***
Lead: ***0.001***
Zinc: ***< 0.01***
Selenium: ***< 0.001***
Boron: ***< 0.1***
Mercury ***0.0006***
Cadmium: ***< 0.001***
Silver: ***< 0.001***
Barium: ***0.3***
Chromium: ***0.004***
Magnesium: ***21***
Iron: ***0.60***
Arsenic: ***< 0.001***
Sulphate: ***86***

Micro-Biological

Dissolved Metals - Filtered

Chloride: ***5***

Miscellaneous

H2S: ***0.02***

CCME

Organics

Gas

Pesticides

Comments

Sample collected by Hi-Rate Drilling 1985 Ltd. Water sample analyzed by Alpha Laboratory Services Ltd.

1990 Mayo Warm Water Supply Well (PW2)
Summary of Guidelines for Canadian Drinking Water Quality – Maximum Concentrations

Constituent	AO	MAC
pH (pH units)	6.5 - 8.5	---
Conductivity (µS/cm)	---	---
Total Dissolved Solids	500	---
Sodium	200	---
Potassium	---	---
Calcium	---	---
Magnesium	---	---
Total Hardness	---	---
Manganese	0.05	---
Carbonate	---	---
Bicarbonate	---	---
Total Alkalinity	---	---
Sulfate	500	---
Chloride	250	---
Fluoride	---	1.5
Iron	0.3	---
Nitrate (as N)	---	10
Nitrate	---	45
Nitrite (as N)	---	1
Nitrite	---	3.2
Nitrate + Nitrite (as N)	---	10
Total Coliforms (CFU/100 mL)	---	0*
Fecal Coliforms (CFU/100 mL)	---	0
Escherichia coli (CFU/100 mL)	---	0
Ionic Balance (%)	---	---

Note: Constituents marked with --- do not have a recommended maximum concentration associated with them.
Concentrations are in milligrams per litre unless otherwise stated.
CFU/100 mL - Colony Forming Units per 100 millilitres
AO - Aesthetic Objective
MAC - Maximum Acceptable Concentration
SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality, Federal–Provincial–Territorial Committee on Drinking Water, May 2008

*No sample should contain total coliform bacteria. The presence of total coliform bacteria, in the absence of Escherichia coli, may indicate the water well is prone to surface water infiltration and therefore faecal contamination. Total coliform detection may also indicate the presence of biofilm in the water well or plumbing system.

1990 Mayo Warm Water Supply Well (PW2)
Grain-Size Analysis

From:J R Paine & Associates LTD To:7804849413 06/28/2010 09:09 #404 P.004/004

J.R. Paine & Associates Ltd.

CONSULTING AND TESTING ENGINEERS
EDMONTON - GRANDE PRAIRIE - PEACE RIVER

SCREEN ANALYSIS

Sample: PW - 2 Depth:
Location: Mayo Well

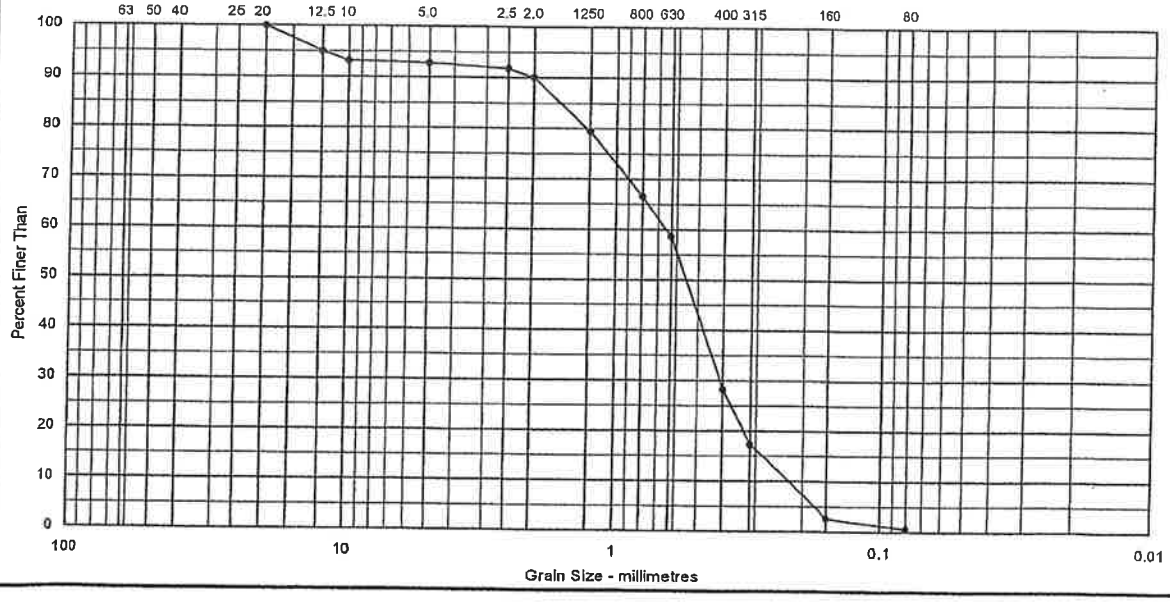
Client: Hydrogeological Consultants Ltd.
Project: General Aggregate Testing - Mayo Well Samples
Made By: LK File: Edmonton General
Ck'd By: Date: June 22, 2010

Sieve No.	Size of Opening millimetres	Specifications Minimum	Specifications Maximum	Percent Finer Than	Percent Finer Than Basis Original Sample
50,000	50.0				
40,000	40.0				
25,000	25.0				
20,000	20.0				100.0
12,500	12.5				95.0
10,000	10.0				93.2
5,000	5.0				92.8
2,500	2.5				91.8
2,000	2.0				90.1
1,250	1.25				79.5
800	0.800				66.5
630	0.630				58.5
400	0.400				28.3
315	0.315				17.3
160	0.160				2.6
80	0.080				0.6

Description of Sample:
Sand, Trace Gravel

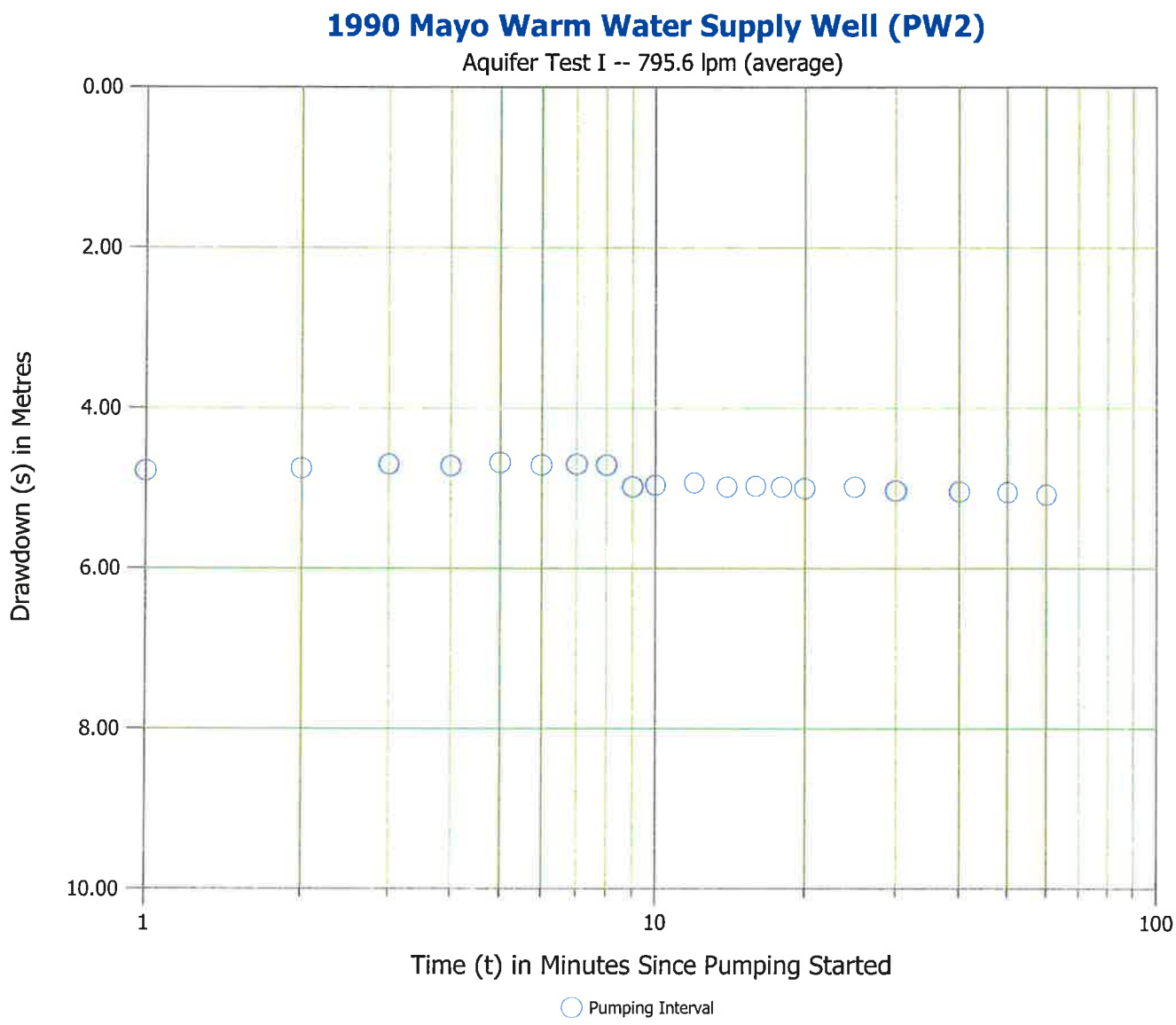
Time of Sieving: 15 minutes

Method of Preparation: Dry ☐ Washed ☑
Moisture Content: % 2 Face Crush Count = %
Remarks: Sampled by Client.
Note: Tar/Oily Substance Noted on the Majority of the +5.0mm Material in the Sample.



Received Time Jun. 28. 2010 9:10AM No. 2850

1990 Mayo Warm Water Supply Well (PW2)
Aquifer Test I



Aquifer Test I

1990 Mayo Warm Water Supply Well (PW2)

SE 13-123-03 W5M

Average Discharge (lpm):	**795.6**	Pre-Test Water Level - NPWL (m):	**-1.76**
Date Test Started:	**June 04, 1990**	Depth to Pump Intake (m):	**N/A**
Time Test Started (hours):	**16:30**	Test Interval - Top (m):	**246.6**
Pumping Interval (minutes):	**60**	Test Interval - Bottom (m):	**251.5**
Recovery Interval (minutes):	**N/A**	Top of Main Aquifer (m):*	**165.3**

***N/A** - Information Not Available*

Reference: M40261,571663 (AT 1)

** **TGWC** calculated or determined value.*

Pumping Interval

Measurement Point: [see comments]

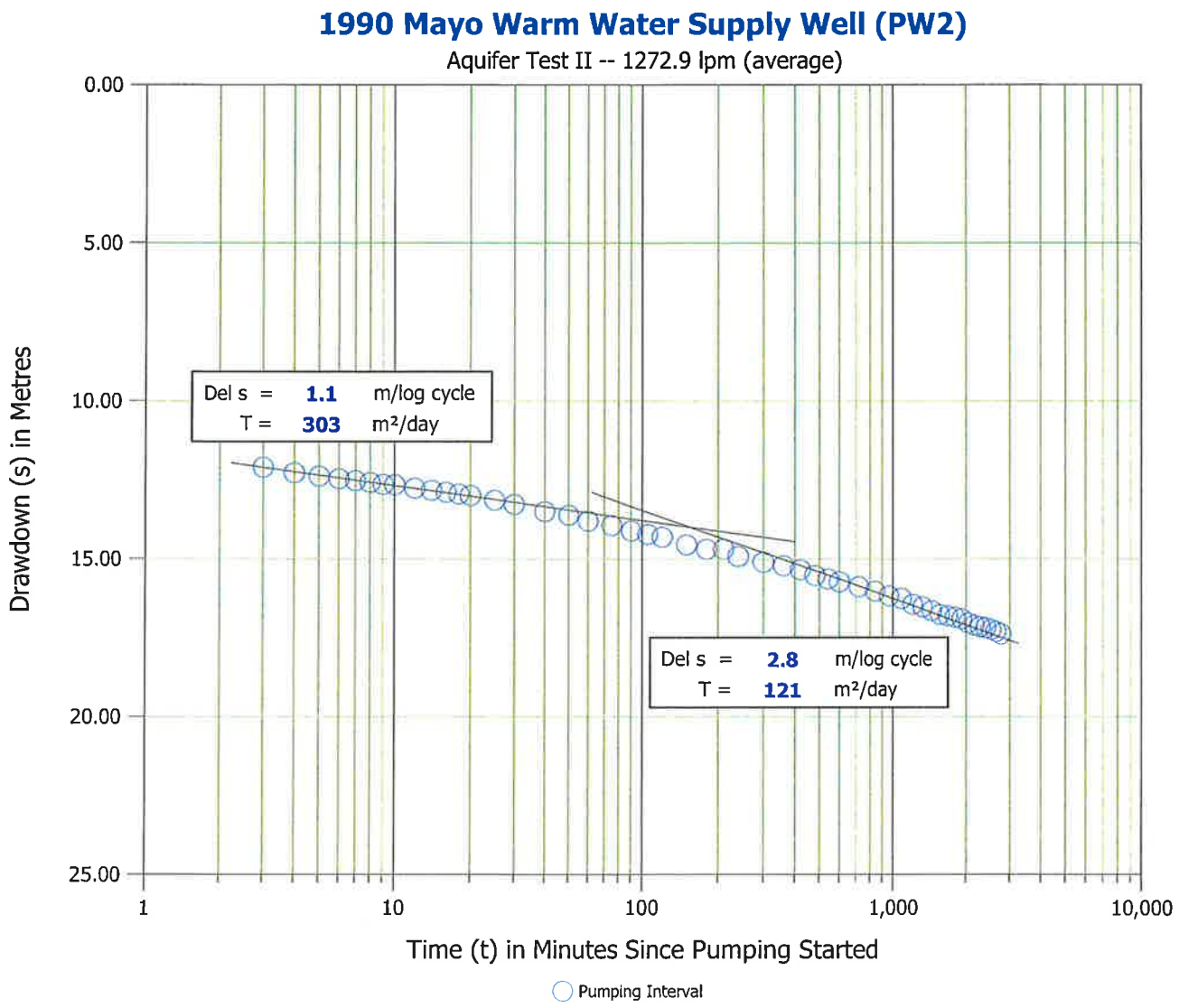
Time (t) Since Pumping Started (minutes)	Drawdown (s) (metre)	Discharge (Lpm)
1	6.54	795.6
2	6.51	795.6
3	6.46	795.6
4	6.48	795.6
5	6.44	795.6
6	6.47	795.6
7	6.46	795.6
8	6.47	795.6
9	6.74	795.6
10	6.72	795.6
12	6.69	795.6
14	6.74	795.6
16	6.73	795.6
18	6.74	795.6
20	6.76	795.6
25	6.74	795.6
30	6.79	795.6
40	6.80	795.6
50	6.81	795.6
60	6.84	795.6

Recovery Interval

Test Comments:

Confined step-drawdown test was conducted by Hi-Rate Drilling 1985 Ltd. The reproted datum was at the top of the four inch tee. Flowing water well recovered to flowing conditions after 30 seconds of recovery. Hi-Rate Drilling 1985 Ltd. reported a flow rate of 796 lpm for the entire pumping interval despite a reported rate adjustment after 8 minutes of pumping.

1990 Mayo Warm Water Supply Well (PW2)
Aquifer Test II



Aquifer Test II

1990 Mayo Warm Water Supply Well (PW2)

SE 13-123-03 W5M

Average Discharge (lpm):	**1272.9**	Pre-Test Water Level - NPWL (m):	**-1.76**
Date Test Started:	**June 04, 1990**	Depth to Pump Intake (m):	**N/A**
Time Test Started (hours):	**18:00**	Test Interval - Top (m):	**246.6**
Pumping Interval (minutes):	**2,760**	Test Interval - Bottom (m):	**251.5**
Recovery Interval (minutes):	**N/A**	Top of Main Aquifer (m):*	**165.3**

N/A - Information Not Available

Reference: M40261.571663 (AT 2)

** TGWC calculated or determined value.*

Pumping Interval

Measurement Point: [see comments]

Time (t) Since Pumping Started (minutes)	Drawdown (s) (metre)	Discharge (Lpm)
3	13.86	1272.9
4	14.03	1272.9
5	14.14	1272.9
6	14.22	1272.9
7	14.28	1272.9
8	14.34	1272.9
9	14.40	1272.9
10	14.41	1272.9
12	14.52	1272.9
14	14.59	1272.9
16	14.65	1272.9
18	14.70	1272.9
20	14.75	1272.9
25	14.90	1272.9
30	15.03	1272.9
40	15.26	1272.9
50	15.37	1272.9
60	15.56	1272.9
75	15.70	1272.9
90	15.87	1272.9
105	15.98	1272.9
120	16.07	1272.9
150	16.31	1272.9
180	16.45	1272.9
210	16.45	1272.9
240	16.68	1272.9
300	16.86	1272.9
360	16.97	1272.9
420	17.10	1272.9
480	17.28	1272.9
540	17.39	1272.9
600	17.48	1272.9
720	17.64	1272.9
840	17.78	1272.9
960	17.93	1272.9
1,080	18.01	1272.9
1,200	18.20	1272.9
1,320	18.28	1272.9
1,440	18.40	1272.9
1,560	18.52	1272.9
1,680	18.56	1272.9
1,800	18.61	1272.9
1,920	18.66	1272.9
2,040	18.79	1272.9
2,160	18.86	1272.9
2,280	18.91	1272.9
2,400	18.94	1272.9
2,520	19.00	1272.9
2,640	19.06	1272.9

Recovery Interval

Aquifer Test II

1990 Mayo Warm Water Supply Well (PW2)

SE 13-123-03 W5M

Average Discharge (lpm):	**1272.9**	Pre-Test Water Level - NPWL (m):	**-1.76**
Date Test Started:	**June 04, 1990**	Depth to Pump Intake (m):	**N/A**
Time Test Started (hours):	**18:00**	Test Interval - Top (m):	**246.6**
Pumping Interval (minutes):	**2,760**	Test Interval - Bottom (m):	**251.5**
Recovery Interval (minutes):	**N/A**	Top of Main Aquifer (m):*	**165.3**

N/A - Information Not Available

Reference: M40261.571663 (AT 2)

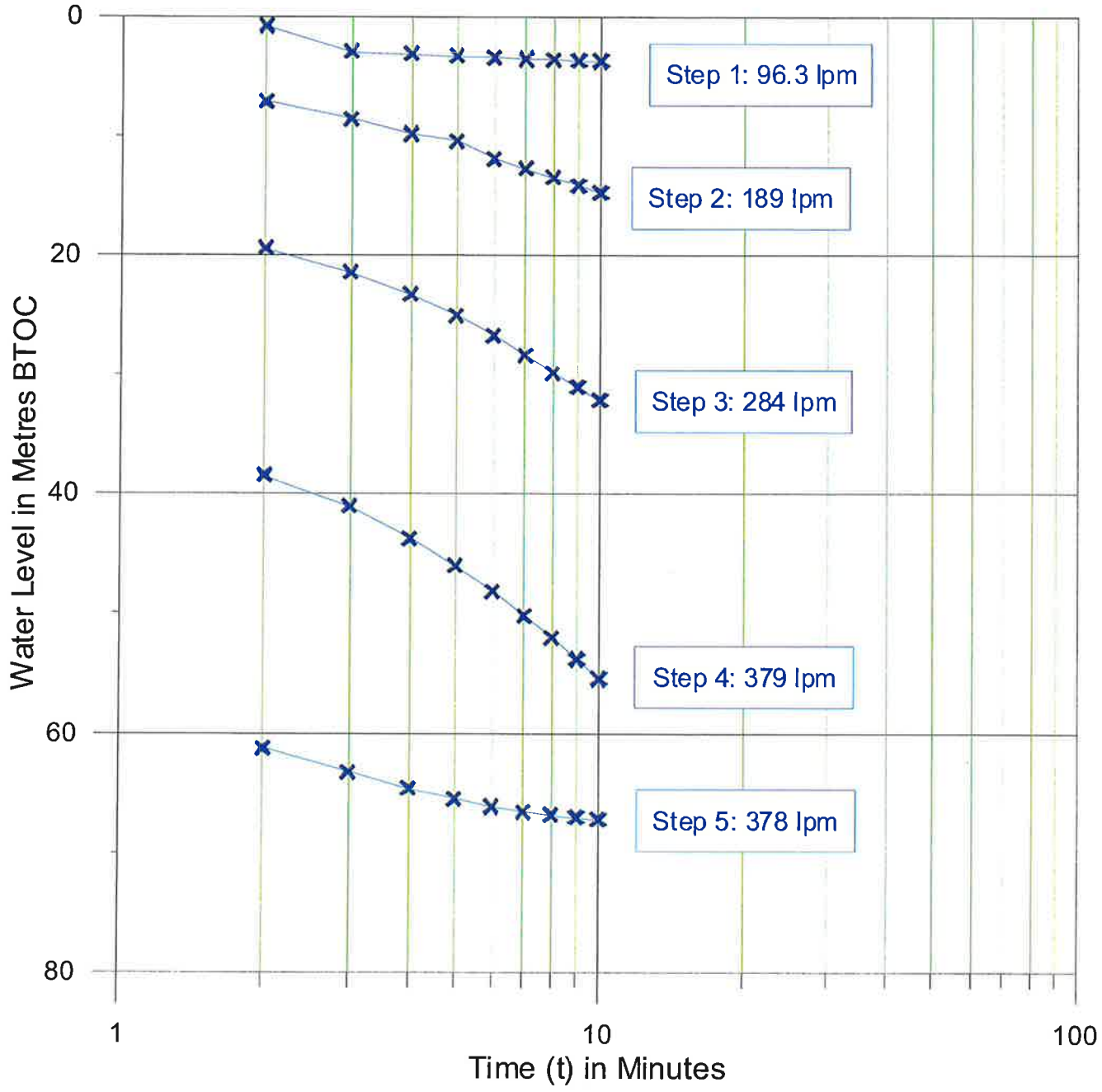
** TGWC calculated or determined value.*

2,760	19.13	1272.9

Test Comments:

Confined constant-rate test conducted by Hi-Rate Drilling 1985 Ltd. Water well tester had difficulty inserting tape probe through rubber packer in well head assembly. Reported datum was the top of the four inch tee. The generator stopped working after 2,760 minutes of pumping. Flowing water well recovered to flowing conditions within 10 minutes.

1990 Mayo Warm Water Supply Well (PW2)
Aquifer Test III



Aquifer Test III

1990 Mayo Warm Water Supply Well (PW2)

SE 13-123-03 W5M

Step Drawdown

Manual Measurements

Test Details		Well Details	
Discharge (lpm)	Variable	Pre-test Water Level (m)	Flowing
Date Test Started	September 23, 2010	Depth to Pump Intake (m)	#N/A
Time Test Started (Hrs)	17:00	Top of Aquifer (m)	165.3
Pumping Interval (min)	50	Completion Interval Top (m)	246.7
Recovery Interval (min)	17	Completion Interval Bottom (m)	251.5

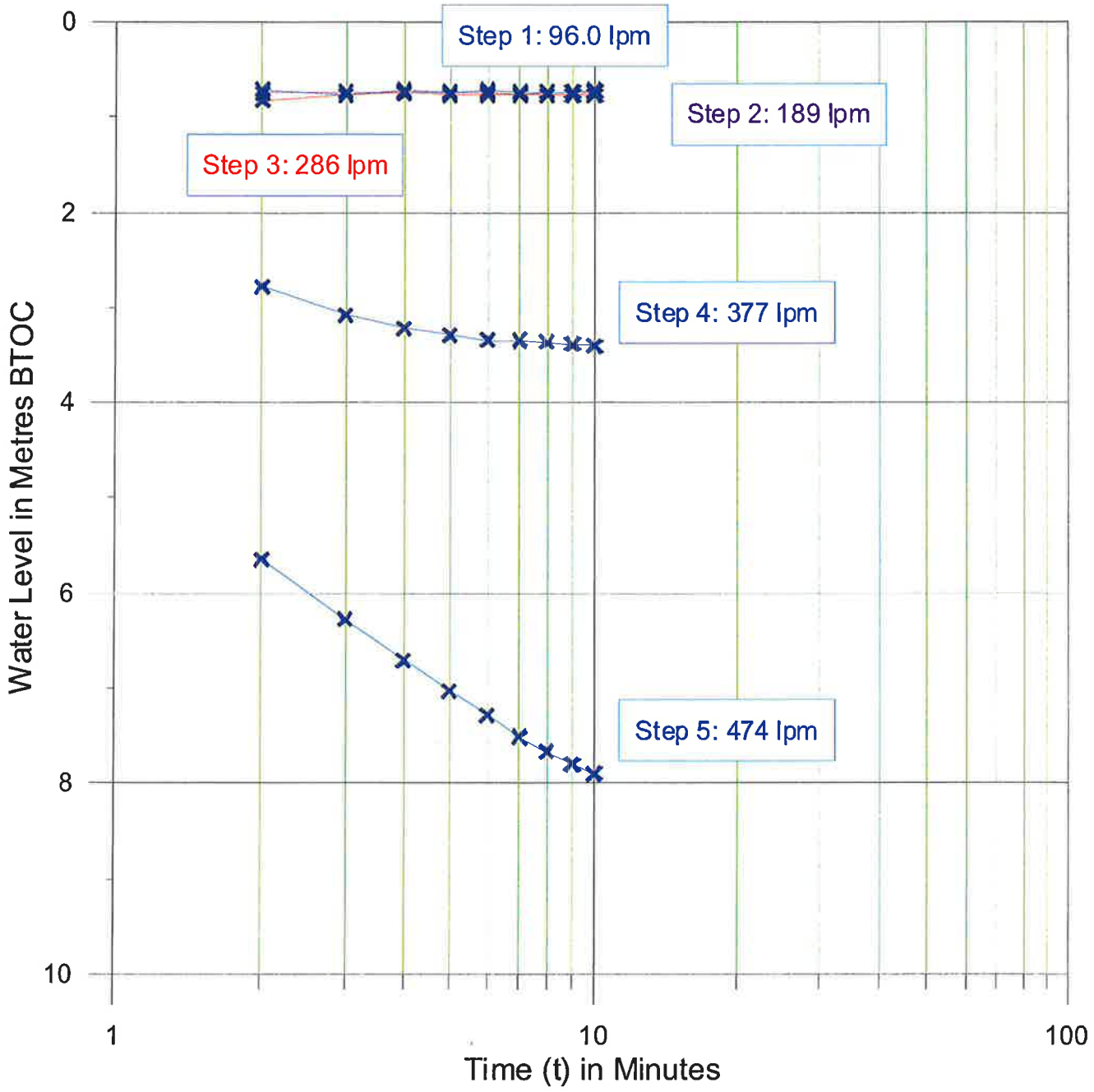
Reference Point: Top of Casing
Reference: M40261.571663 (AT III)
#N/A - Information Not Available

Pumping Interval

	Time (t) Since Pumping Started (minutes)	Depth to Water (metres)		Time (t) Since Pumping Started (minutes)	Depth to Water (metres)
Step 1: 96.3 lpm	1	0.37	Step 4: 379 lpm	1	35.31
	2	0.77		2	38.37
	3	2.95		3	41.00
	4	3.16		4	43.72
	5	3.33		5	46.00
	6	3.45		6	48.10
	7	3.56		7	50.18
	8	3.62		8	52.00
	9	3.68		9	53.79
	10	3.73		10	55.45
Step 2: 189 lpm	1	5.41	Step 5: 378 lpm	1	58.47
	2	7.14		2	61.26
	3	8.60		3	63.28
	4	9.84		4	64.61
	5	10.44		5	65.50
	6	11.94		6	66.15
	7	12.74		7	66.57
	8	13.49		8	66.83
	9	14.13		9	67.00
	10	14.73		10	67.20
Step 3: 284 lpm	1	16.89			
	2	19.37			
	3	21.40			
	4	23.27			
	5	25.00			
	6	26.71			
	7	28.35			
	8	29.81			
	9	31.00			
	10	32.10			

Comments:
Step-draw dow n test conducted by Aqua Tech Supplies & Services Ltd.

1990 Mayo Warm Water Supply Well (PW2)
Aquifer Test IV



Aquifer Test IV

1990 Mayo Warm Water Supply Well (PW2)

SE 13-123-03 W5M

Step Drawdown

Manual Measurements

Test Details		Well Details	
Discharge (lpm)	Variable	Pre-test Water Level (m)	Flowing
Date Test Started	October 15, 2010	Depth to Pump Intake (m)	#N/A
Time Test Started (Hrs)	11:30	Top of Aquifer (m)	165.3
Pumping Interval (min)	50	Completion Interval Top (m)	246.7
Recovery Interval (min)	None	Completion Interval Bottom (m)	251.5

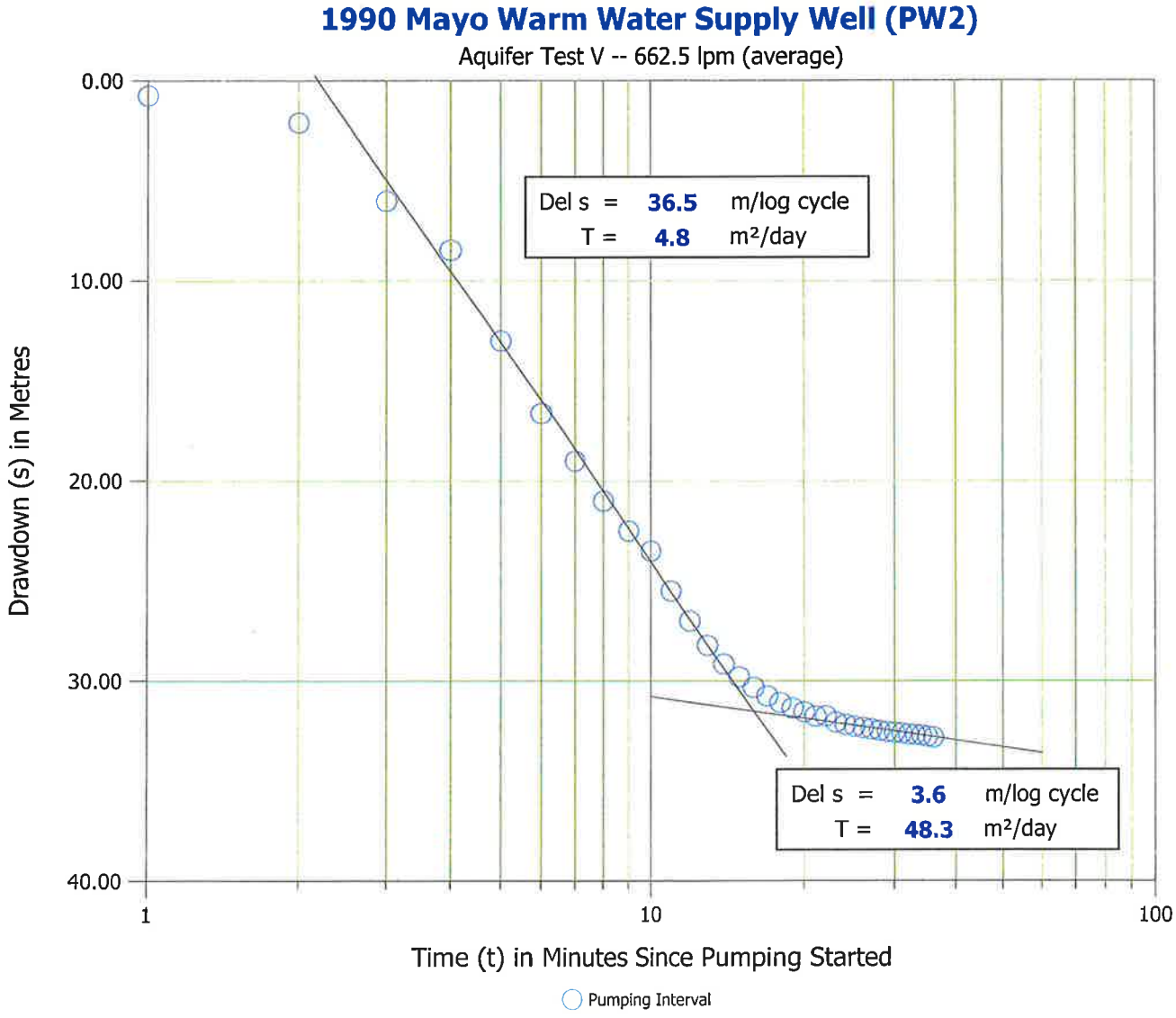
Reference Point: Top of Casing
Reference: M40261.571663 (AT IV)
#N/A - Information Not Available

Pumping Interval

	Time (t) Since Pumping Started (minutes)	Depth to Water (metres)		Time (t) Since Pumping Started (minutes)	Depth to Water (metres)
Step 1: 96.0 lpm	1	0.78	Step 4: 377 lpm	1	2.02
	2	0.71		2	2.78
	3	0.77		3	3.08
	4	0.72		4	3.22
	5	0.74		5	3.29
	6	0.72		6	3.34
	7	0.74		7	3.35
	8	0.74		8	3.37
	9	0.74		9	3.39
	10	0.72		10	3.40
Step 2: 189 lpm	1	0.73	Step 5: 474 lpm	1	4.76
	2	0.75		2	5.64
	3	0.74		3	6.28
	4	0.74		4	6.71
	5	0.75		5	7.03
	6	0.75		6	7.28
	7	0.76		7	7.51
	8	0.74		8	7.66
	9	0.74		9	7.79
	10	0.74		10	7.90
Step 3: 286 lpm	1	0.97			
	2	0.83			
	3	0.77			
	4	0.75			
	5	0.77			
	6	0.77			
	7	0.77			
	8	0.77			
	9	0.77			
	10	0.77			

Comments:
Step-draw dow n test conducted by Aqua Tech Supplies & Services Ltd.

1990 Mayo Warm Water Supply Well (PW2)
Aquifer Test V



Aquifer Test V

1990 Mayo Warm Water Supply Well (PW2)

SE 13-123-03 W5M

Average Discharge (lpm):	**662.5**	Pre-Test Water Level - NPWL (m):	**N/A**
Date Test Started:	**October 15, 2010**	Depth to Pump Intake (m):	**N/A**
Time Test Started (hours):	**13:30**	Test Interval - Top (m):	**246.7**
Pumping Interval (minutes):	**36**	Test Interval - Bottom (m):	**251.5**
Recovery Interval (minutes):	**N/A**	Top of Main Aquifer (m):*	**165.3**

***N/A** - Information Not Available*

Reference: M40261.571663 (AT 5)

** **TGWC** calculated or determined value.*

Pumping Interval

Measurement Point: Top of Casing

Time (t) Since Pumping Started (minutes)	Depth to Water (metre)	Discharge (Lpm)
1	0.74	192.8
2	2.09	357.3
3	6.00	567.6
4	8.46	556.8
5	13.00	746.4
6	16.62	721.6
7	19.00	683.8
8	21.00	692.5
9	22.50	682.8
10	23.50	674.2
11	25.50	739.9
12	27.00	728.1
13	28.22	719.5
14	29.15	709.8
15	29.80	705.5
16	30.32	696.8
17	30.75	695.8
18	31.08	690.4
19	31.36	691.5
20	31.55	686.1
21	31.76	690.4
22	31.75	686.1
23	32.06	686.1
24	32.18	682.8
25	32.27	682.8
26	32.34	686.1
27	32.41	682.8
28	32.48	685.2
29	32.54	679.6
30	32.58	680.7
31	32.61	680.7
32	32.67	677.2
33	32.69	678.5
34	32.72	678.5
35	32.78	677.5
36	32.82	674.4

Recovery Interval

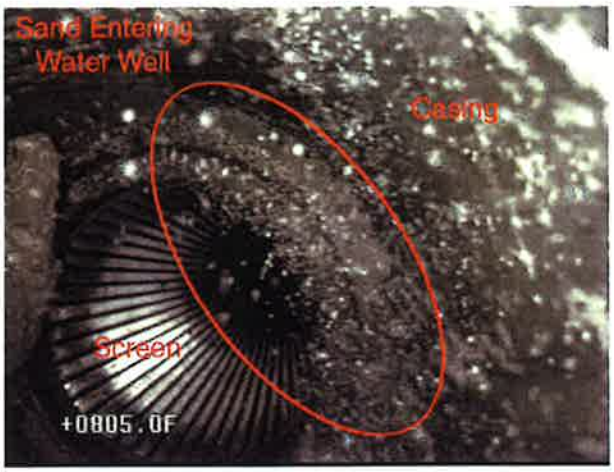
Test Comments:

Aquifer test conducted by Aqua Tech Supplies & Services Ltd. The NPWL was not obtained from the water well tester because the water well was flowing at the start of the pumping interval. Water well returned to flowing conditions following 3:37 minutes of recovery.

Appendix B – Video Inspection

Top of Water Well Screen

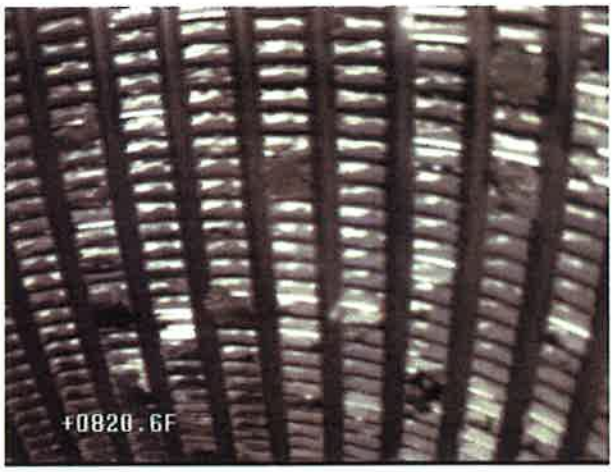
Pre-Servicing



Post-Servicing

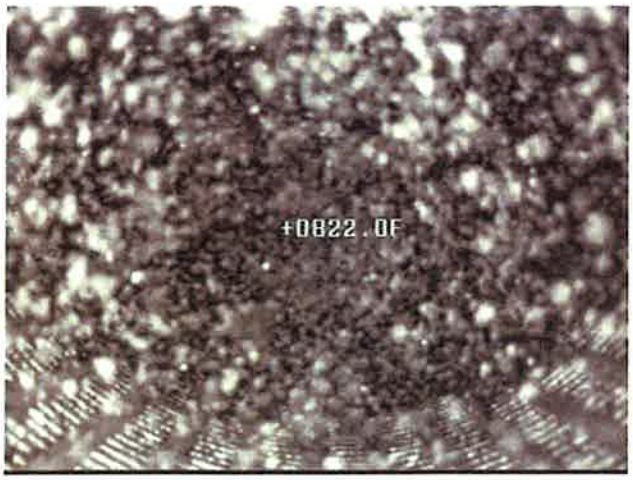
Water Well Screen

Pre-Servicing



Post-Servicing

Bottom of Water Well



Pre-Servicing

Post-Servicing