Golder Associates

TECHNICAL MEMORANDUM

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TO Mr. Frank Cairo
Richmond Village

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PREDICTIVE SIMULATION OF LONG TERM PUMPING FOR MATTAMY RICHMOND

To estimate the potential drawdown associated with the long term pumping related to water supply for the Mattamy/Richmond Village Lands development a simplified three-dimensional numerical (MODFLOW) groundwater model was constructed and predictive simulations completed given the proposed water taking rates. The objective of the model was to estimate the potential impact of long term pumping on nearby residential wells screened within the oxford formation (upper aquifer).This section summarizes the model conceptualization and predictive results as well as its assumptions and limitations.

The modelling analysis is based on the results of the pumping test completed on PW09-1, the summary of existing hydrogeological conditions completed for the site (Golder, 2008), and the wellhead protection study completed for the Munster Hamlet and King's Park communal wells (Golder, 2003).

Grid Discretization and Model Layering

The model covers a rectangular area 2000 m wide, 2000 m long and 130 m deep. The model is horizontally discretized into a 100 m by 100 m grid over the outer portions of the model domain. The grid transitions to 1 m by 1 m blocks surrounding the pumping and observation wells. The model domain was vertically discretized into 17 horizontal layers defined as follows:

- Layer 1 represents the overburden materials from ground surface to a depth of 5 m. Overburden materials encountered on the site consist of gray clay, and till;
- Layers 2 through 6 represent the limestone bedrock of the Oxford formation;
- Layers 7 through 15 represent the sandstone bedrock of the Nepean formation. The formation was divided into two hydrostratigraphic units based on the analysis completed in wellhead protection study (Golder, 2003), the depth of water bearing zones encountered during the drilling of PW09-1 and PW08-1, and the results of the 72-hour pumping test. The upper Nepean formation extends from 45 m depth of 90 m depth. Layers 13 through 15 represent the lower Nepean formation from a depth of 90 m to a depth of 100 m;
- Layer 15 represents the upper Precambrian bedrock from a depth of 100 m to a depth of 150 m; and,
- Layer 15 represents the lower Precambrian bedrock from a depth of 150 m to a depth of 200 m.

Groundwater Flow Boundaries

Groundwater flow direction and regional gradients were defined based on the results of the WHPS completed for the region (Golder, 2003). The inferred direction of groundwater flow across the site is from east to west. No flow boundaries are defined along the sides of the model domain, parallel to the direction of groundwater flow. A constant head boundary of 103.5 masl was applied to the easternmost side of the model. A constant head boundary of 101.5 masl was applied to the westernmost side of the model to represent a 0.0015 m/m regional gradient. A recharge rate of 5 mm/year was applied to the uppermost model layer based on the predominance of clay as an overburden material on the site.

The pumping wells were simulated using the MODFLOW Wells package. Pumping well properties are summarized below:

Pumping Well	Easting (m)	Northing (m)	Top of Screen (m Depth)	Bottom of Screen (m Depth)
PW09-1	433898	5003808	46	70
PW08-1	433874	5003838	46	90

Model Parameterization

Hydraulic parameters (hydraulic conductivity and specific storage) of the various units used to populate the model are summarized below:

Unit	Hydraulic Conductivity (m/s)	Source
Clay overburden	5×10^{-7}	WHPS (Golder, 2003)
Upper Oxford	1×10^{-8}	Calibration to PW09-1 Pumping test
Lower Oxford	6×10^{-5}	Calibration to PW09-1 Pumping test
Upper Nepean	2×10^{-4}	Analysis of and calibration to PW09-1 pumping test
Lower Nepean	1×10^{-5}	WHPS (Golder, 2003)
Upper Pre-Cambrian	1×10^{-7}	WHPS (Golder, 2003)
Lower Pre-Cambrian	1×10^{-8}	WHPS (Golder, 2003)

Unit	Specific Storage (1/m)	Source
Clay overburden	0.001	Neville (2008)
Upper Oxford	1×10^{-6}	Domenico and Mifflin (1965)
Lower Oxford	1×10^{-7}	Calibration to PW09-1 Pumping test
Upper Nepean	1×10^{-4}	Analysis of and calibration to PW09-1 pumping test
Lower Nepean	1×10^{-6}	Domenico and Mifflin (1965)
Upper Pre-Cambrian	1×10^{-6}	Domenico and Mifflin (1965)
Lower Pre-Cambrian	1×10^{-6}	Domenico and Mifflin (1965)

Model Results: Calibration to Pumping Tests

The numerical model was calibrated to drawdown observations made during the 72-hour pumping test conducted on September 27, 2011.

To provide a more conservative estimate of the connection between the Nepean aquifer and the Oxford aquifer (i.e. to provide a larger estimate of drawdown in the Oxford formation), the initial conditions for the calibrated simulation over predicts the hydraulic head in the Oxford formation by approximately 0.5 to 2.0 m. The impact of the predicted drawdown on simulated wells will be discussed in reference to the observed static condition, and not that of the modelled static condition.

The ability of the numerical model to simulate the pumping test results was evaluated by comparing the maximum drawdown observed at the end of pumping to the maximum drawdown predicted by the numerical model. Monitoring well OW-2 was not included in the comparison as it does not appear to be hydraulically connected to the pumped aquifer. The results of the comparison are summarized below.

Observation Location	Depth (m)	Observed Max. Drawdown (m)	Predicted Max. Drawdown (m)	Residual (m)
MW10-3A	5	0.7	1.0	-0.3
MW08-1C	10	1.9	2.0	-0.1
OW-1	22	1.8	1.8	0.0
OW-3	29	1.7	1.4	0.3
MW08-1B	51	3.4	2.4	1.0
PW09-2	58	4.8	10.6	-5.8
PW08-1	69	3.8	3.6	0.2
MW08-1A	71	3.6	2.3	1.3

The average magnitude of the residual for wells in the oxford formation was approximately 0.2 m, and it is concluded that the calibrated model can provide a reasonable estimate of the response of the Oxford aquifer to pumping of the supply wells in the Nepean aquifer. The average magnitude of the residual for wells in the Nepean formation was approximately 2.1 m. Drawdown at PW09-2 was significantly over predicted, while drawdown at MW08-1A and B, and PW08-1 were slightly under predicted. This difference is likely due to localized variations of hydraulic conductivity in the fractured rock aquifer. In general the model provides an adequate representation of the expected response to pumping on site.

Model Results: Predictive Simulation of Long Term Pumping

To estimate the potential drawdown associated with the long-term pumping related to water supply for the Western Development Lands, a simplified three-dimensional numerical groundwater model was constructed based on the results of the aquifer testing program. The code used was MODFLOW (McDonald & Harbaugh). Predictive simulations were completed using the assumed water taking rates required to supply the Western Development Lands. The assumptions are as follows:

- The RV lands will contain 1,000 units, including 650 singles and 350 town homes;
- The Mattamy lands will contain 1,000 singles; and,
- Average water demand is 835 L/day/unit for singles and 720 L/day/unit for town homes.

The number of planned units was provided by representatives of Mattamy and RV. The unit demand rates were taken from the Master Servicing Study (Stantec, 2011).

Using these assumptions, the average water demand for the Western Development Lands is 1,132 L/min.

The results of the numerical simulations suggest that pumping of PW09-1 (completed within the lower sandstone aquifer) at a rate equal to the assumed average daily pumping rate for the Mattamy/RV development (1,132 L/min), will result in a drawdown of approximately 1.0 metre at OW-1, and approximately 0.8 metres at OW-3 after 20 years of pumping. These two observation wells are completed in a similar manner and to a similar depth as typical private wells in Richmond. However, because they are flowing wells, they are considered representative of wells obtaining water from the upper limestone aquifer within an area of enhanced connection to the lower sandstone aquifer. OW-1 is located approximately 130 metres from the pumped well, and is closer than any existing private well. OW-3 is located approximately 220 metres from the pumped well, which is similar to the approximate radial distance of the nearest private well. A drawdown of less than one metre is considered insignificant and would not be noticed by local groundwater users.

If a maximum day demand of 2,320 L/day/unit for single family homes and 720 L/day/unit for town homes (Stantec, 2011) is assumed, a total demand of 2,833 L/min is predicted. This is slightly more than the pumping rate used during the 72 hour pumping test, and could be accommodated by one or both of the production wells without causing significant drawdown in the aquifer. Maximum day is typically not experienced for more than a few days at a time; however, a numerical simulation was run using the maximum day rate for a period of 20 years. After this time, the drawdown at OW3 is predicted to be approximately two metres, which is considered minimal.

Based on these simulations, the lower bedrock aquifer can easily support the proposed development without causing significant drawdown in local wells.

Yours truly,

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