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Attention: Mr. Frank Cairo

Peer Review of Groundwater Vulnerability Study
Richmond Village Well System, Richmond, Ontario

Dear Mr. Cairo:

This letter summarizes our peer review of the report, titled *Groundwater Vulnerability Study, Richmond Village Well System, Richmond, Ontario*, prepared by Golder Associates Ltd., dated March 2012. The peer review objectives are to:

- Compare the methodology and results of the study with the expectations of the final Technical Rules: Assessment Report, *Clean Water Act, 2006* dated November 2009.
- Assess the approach used to determine the groundwater vulnerability.
- Assess from a scientific viewpoint the results of the groundwater vulnerability study.

BACKGROUND

A new well field has been established for new development on the west side of Richmond, Ontario on property owned by Richmond Village (South) Limited and Richmond Village (North) Limited (together referred to as RV). The new well field will also service development completed by Mattamy Homes Limited (Mattamy). Currently, existing homes in the village are serviced by individual private wells and septic systems. Starting in 2004, studies were completed including a Class Environmental Assessment and subsequent Final Design of a new municipal water supply system, based on communal wells. In 2009, Golder was retained by the Mississippi-Rideau Source Protection Region (MRSPR) to complete a Groundwater Vulnerability Study for the communal water supply system.

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There are three proposed municipal wells designated PW08-1, PW09-1 and PW09-2. PW08-1 is 137.2 m deep, and has a steel casing extending to a depth of 45.7 m. PW09-1 is 70.0 m deep with a steel casing also extending to a depth of 45.7 m. PW09-2 was installed less than 5 m from PW09-1 with a similar completion depth. The average water demand for the well system was calculated to be 1,630 m³/day for the combined RV/Mattamy development, which includes 2,000 single homes (835 L/day/unit) and 350 town homes (720 L/day/unit).

The primary aquifer for the production wells is the Nepean Formation, a regional extensive bedrock formation consisting of alternating beds of sandstone and quartz. Overlying the Nepean Formation in the Richmond area are the March and Oxford Formations. These bedrock units are also aquifers but are less productive than the Nepean Formation aquifer. Generally, two distinct aquifers are present within the area: an upper aquifer, typically defined as the upper 35 m of the Oxford Formation and a lower aquifer consisting of the lower portion of the March Formation and the upper portion of the Nepean Formation. The majority of private residential wells are completed within the upper aquifer and communal wells are installed in the more productive lower aquifer.

In addition to the new production wells for the RV/Mattamy development lands, there are several other large production wells in the Richmond area. These include the Kings Park communal well system, located about 1.5 km north of the RV wells, and the Hyde Park communal well system located approximately 1 km north of the RV wells. The Munster communal wells are located further away from the RV wells, about 8 km west-southwest from Richmond. Also included in the study area is a golf course well located about 14 km west-northwest of Richmond.

GROUNDWATER FLOW MODEL

The groundwater flow model is based on a conceptual flow model consisting of the overburden and bedrock formations of the Richmond area. The conceptual flow model is based on previous assessments in the area, notably a 2003 groundwater vulnerability study completed for the Kings Park and Munster well systems (Golder, 2003) and a 2010 study that addressed the Hyde Park well system.

A numerical model called MODFLOW was used to complete the groundwater flow modeling. MODFLOW is a widely accepted program and is recognized by the MOE as being a preferred method for delineating wellhead protection zones.

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Boundary Conditions

Boundary conditions define input/output zones for the model and MODFLOW allows a number of different types of boundary conditions. Report Figure 13 shows the boundary conditions used in the model. The eastern boundary consists of a 'constant head boundary' representing the Rideau River. Similarly, the western boundary is a constant head boundary representing Mississippi Lake and the Mississippi River. The values for the constant head cells varied to represent the actual stage of both the Rideau River and the Mississippi River.

The northern and southern boundaries were also defined as constant head boundaries and assigned constant head values based on groundwater elevations in the bedrock aquifer map.

In addition to the perimeter boundary conditions, other features were represented in the model. These include the use of a 'river boundary condition' to represent the Jock River which flows through the central area of the model and four large marches/wetland areas which were modeled as constant head boundaries.

Model Calibration - Hydraulic Conductivity and Recharge

Six hydraulic conductivity zones (report Figure 6 and report Figure 15) were specified in the model: overburden, Oxford / March Formation, Upper Nepean, Lower Nepean, Upper Precambrian and Lower Precambrian.

Recharge was defined in the model based on overburden type and thickness. Three recharge zones were designated (report Figure 14) representing clayey overburden located mainly east of Richmond (5 mm/year), till and rock outcrop areas west of Richmond (15 mm/year) and a stratified ice contact deposit located northeast of Richmond (200 mm/year).

The flow rate assigned to the production wells was 1,630 m^3/day, equally proportioned between PW08-1 and PW09-1 (since PW09-2 is located less than 5 m from PW09-1 it was not distinctly included in the model). A flow rate of 265 m^3/day, representing full build out, was used for the Hyde Park well system and a 210 m^3/day was used for the Kings Park well system.

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The primary calibration procedure used for the model development was to complete a steady-state calibration using 982 calibration wells from the MOE Water Well Information System (WWIS). The calibration plot shown on report Figure 17 indicates a good fit for calibration wells with a normalized root mean square of 5.5% which is considered to be a 'good' result given the variability in the Water Well Record data. It is unclear in the report if the ratio of hydraulic conductivities of the units were kept constant in the calibration process. Likewise, information on how the recharge rates were varied in the calibration process is also not provided.

There is good documentation in the report comparing the results of the calibrated hydraulic conductivity values with measured hydraulic conductivity values determined using other means such as pumping test analyses. Overall, the model construction, boundary conditions and calibration procedure was adequately described in the report.

To define capture zones based on the MODFLOW groundwater flow model, an adjunct computer program called MODPATH was used. A critical parameter used by MODPATH is the effective porosity. Effective porosity assumptions used in the model were: 0.25 for overburden, 0.001 for 0.017 for the upper Nepean and 0.001 for the lower Nepean, and the Oxford /March formations and upper Precambrian layers and 0.0001 for the lower Precambrian layer. Overall, we agree with the approach taken in assessing effective porosity.

Once the groundwater flow model was calibrated, a sensitivity assessment was completed by varying hydraulic conductivity and recharge values. A total of 21 steady-state sensitivity simulations were completed. The defined capture areas are an overlay of all of the sensitivity runs. The sensitivity assessment approach was very comprehensive.

COMMENTS ON THE MODEL

The following are remarks made on the results of the model.

- A full build-out pumping rate was used for the RV wells. In reality it will be many years until that flow rate is achieved and as such, is considered to be an appropriate conservative assumption. There is some ambiguity in the documentation on the exact pumping values used for all communal wells and a table summarizing the flow rates used in the simulations would have been beneficial.

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- As stated previously, the defined capture zones are the combination of a number of sensitivity simulations of assumed conditions. This approach is considered the best way to assess uncertainty with the model and is considered to be an appropriately conservative approach to establishing the capture zones. It would be interesting to have an illustration of the capture zones based only on the calibrated model. A comparison could then be made between the calibrated capture zones and the ultimate combined capture zones.

- More information is required on how the calibration process was completed (i.e., how the hydraulic conductivity and recharge values were varied in the calibration process).

- Data gaps and limitations are documented in the report. We concur with the data gaps assessment and limitations that are inherent in groundwater modelling.

The concerns expressed in the first three comments above all indicate that the capture zones depicted in report are 'conservatively' large. While such conservativeness is appropriate given the uncertainty associated with groundwater modeling and the lack of good hydrogeological data in areas distant from the wellfield, it is reinforced that the model (and thus capture zone delineation) can be improved with additional study and reduction of data gaps.

AQUIFER VULNERABILITY AND VULNERABILITY SCORING

Aquifer vulnerability mapping was undertaken using the Intrinsic Susceptibility Index (ISI) approach. The results from this analysis were combined with the modeled vulnerability zones (WHPA-A, B, C, D) to generate vulnerably scores. The method used is consistent with the requirements of the MOE *Clean Water Act* Technical Rules – Assessment Report. Overall, the results of the assessment appear reasonable; however, Dillon does make the following recommendations:

- Section 4.2/5.2. It is not clear if ISI values were calculated at each MOE water well location within the vulnerability zones (WHPAs), or whether the assessment was performed using interpolated geological/model layer thicknesses. It is recommended that the report further describe how the ISI equation was applied in this study. In addition, it is recommended that the text refer to the actual calculated ranges of ISI values, rather than just identifying that the aquifer had a score >80. A map showing the contoured ISI values would be useful.

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- Section 4.2/5.2. It is recommended that the report provide further discussion on the significance of the deep casings in these wells as it relates to calculation of the aquifer vulnerability. We note that areas around other municipal bedrock wells (where more shallow casings are used) in other portions of eastern Ontario have been assigned higher aquifer vulnerabilities. It would be useful to reference specific field observations in the local area that support the conclusion that the Nepean Formation is inherently confined and therefore deserving of a low vulnerability ISI value. For example, specific information (if available) on flowing well conditions, large vertical gradients or lack of response in shallow aquifers/surface water features from pumping of the Nepean aquifer would be useful.

- Section 5.3 – It would be useful to compare the vulnerability score results to those of the Kings Park system. Since the geology is similar, we would expect that the vulnerability scoring to be similar.

UNCERTAINTY ANALYSIS

The study concludes that the uncertainty is considered low within Zone A and B, and high within Zone C and D. Dillon is in general agreement with this conclusion; however, it is recommended that the authors expand on this section to provide a rational for this decision. Section 4.4 outlines the key variables that are considered in the uncertainty analysis, however, the report does not comment on how these variables were applied/evaluated in this situation. Further explanation would be beneficial.

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CLOSURE

We appreciate the opportunity to assist you with this project. If you have any questions or require clarification regarding our review, please call the undersigned.

Yours sincerely,

DILLON CONSULTING LIMITED

Rob Kell, P.Eng., P.Geo.
for Darin Burr, P.Geo.
Project Manager

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Our File: 12-6360