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Ref. No.: 04-233-3

Friends of the Rural Communities and Environment (FORCE)
c/o Lawson Park Ltd.,
P.O. Box 15, R.R. #1
Freelton, Ontario L0R 1K0

Attention: Graham Flint, Chair, FORCE

Re: Hydrogeologic Review of GRS Work Plan, Proposed Mountsberg Quarry, East Flamborough, City of Hamilton

Dear Mr. Flint,

Please accept this letter as INTERA Engineering Ltd. (INTERA) report on hydrogeologic review of the revised work plan for evaluation of the groundwater recirculation system (GRS) at the proposed Mountsberg Quarry. The proposed Quarry is to be developed in the Amabel Formation dolostone to depths of about 36 m in Part of Lot 1, and Lots 2 and 3, Concession 11, geographic Township of East Flamborough, now the City of Hamilton.

The GRS work plan, prepared by Gartner Lee Limited (GLL), describes the proposed sequence of activities to be undertaken to further characterize the Amabel Formation dolostone aquifer and to evaluate the feasibility of the GRS to mitigate quarry-induced drawdowns in the bedrock aquifer and impacts to local surface water ecological features (seeps, ponds, wetlands).

The GRS work plan is follow-up to the draft three-volume *Hydrogeological Level 2 Report* for the proposed quarry prepared by GLL in June, 2005 and the *Preliminary Hydrogeological Assessment Report*, also prepared by GLL in August, 2004. Both of these earlier reports were prepared for Lowndes Holdings Corporation, former site owners. I previously provided hydrogeological review comments on these two earlier reports in correspondence with you dated November 11, 2005 and March 28, 2005, respectively.

This report was prepared by Kenneth G. Raven, P.Eng., P.Geo., Principal and Senior Hydrogeologist of INTERA Engineering Ltd. This report reviews the primary documentation supporting GLL application for permit to take water (PTTW, Reference No. 4455-6U9MKG) required to implement the GRS work plan. This hydrogeologic review assesses the necessity, objectives, scope and content of the proposed GRS work plan for demonstrating the ability of a full-scale GRS system to mitigate quarry-induced water level drawdowns and adverse hydrologic impacts.

This letter is organized by the following four sections:

1. Primary Documents Reviewed
2. Proposed GRS Work Plan
3. Hydrogeologic Review and Concerns
4. Conclusions

1. PRIMARY DOCUMENTS REVIEWED

The following primary documents were the focus of this review:

- *Revised Work Plan for the Evaluation of Groundwater Recirculation System, Proposed Mountsberg Quarry,* Report prepared by Gartner Lee Limited for St. Mays Cement, September 2006.

- *Temporary PTTW to Conduct a Series of Pumping Tests, Proposed CBM St. Marys Cement Flamborough Quarry, City of Hamilton, Ontario,* Gartner Lee Limited letter from Gunther Funk to Elizabeth Payer, MOE, September 28, 2006. 2006.

- *PTTW Discharge Water Quality Analysis,* Memo from Jim Perrone, Stantec Consulting Ltd., to Gunther Funk, Gartner Lee Ltd., September 5, 2006.

- *Application for PTTW Reference No. 4455-6U9MKG,* submitted by Gunther Funk, Gartner Lee Limited, September 28, 2006.

- *Evaluation of Recharge Trench System, North Boundary Containment Treatment System, Rocky Mountain Arsenal, Commerce City, Colorado,* report prepared by M. K. Corcoran, D. M. Patrick, N. G. Gaggiani and J. H. May, for U.S. Army Corps of Engineers, January, 2005.

- *Optimizing the Efficiency of Recharge Features as a Mechanism for Mitigating the Impacts of Quarry Dewatering*, *Research Report,* Report prepared by C. L. Huxley, T. S. Gill, L. S. Carroll and A. Thompson for Minerals Industry Research Organization and The Department of the Environment, Food and Rural Affairs, March, 2004.

2. PROPOSED GRS WORK PLAN

The objectives of the proposed GRS work plan as stated by GLL are to:

1. collect additional geologic and hydrogeologic data that will aid in the overall characterization of the Amabel Formation with respect to the distribution of the fractures and productive water-bearing zones within this unit and groundwater/surface water relationship;

2. evaluate the validity of the GRS as a measure to mitigate the dewatering-induced drawdown associated with the development of a quarry on the subject property; and,

3. assess the impact of simulated quarry drawdown, with and without mitigation, on a sample of ecological features (seep, ponds and wetlands) that may be affected by changes in shallow groundwater and calibrate wider modeling exercises to assess impacts on ecological features too remote from the test to be directly assessed, such as streamflow and more remote wetlands.

In short, the proposed GRS workplan is intended to provide information to support a decision on the viability/feasibility of GRS to mitigate adverse groundwater and surface water impacts from a future Mounstberg Quarry operation.

The scope of the proposed GRS work plan includes the following main activities.

1. Hydrogeologic characterization of existing test wells TW10, TW12 and TW13 including downhole geophysical logging dynamic flow profiling, groundwater sampling and conversion of TW10 to a multi-level bedrock monitoring well.

2. Establishment of a GRS pilot testing area including a 150 m long recharge trench excavated 1 m into bedrock potentially with open deep drilled wells in the trench, three new pumping wells (TW14, TW15 and TW16) installed parallel to the trench, and drilling, geophysical/flow logging and installation of five deep multi-level monitoring wells (MW1 to MW5).

3. Completion of up to a series of five 5 to 6 day duration pumping tests to assess the performance of the proposed GRS. These pumping tests are intended to create drawdowns of about 30 m in the three new pumping wells and progressively evaluate different GRS operational scenarios including Test 1 – no recirculation, Test 2 – recirculation to trench, Test 3 – recirculation to trench with open 35 m deep boreholes spaced at 5 to 10 m centres, Optional Tests 4 and 5 – recirculation with hydraulically fractured or blasted boreholes to increase bedrock permeability.

4. Monitoring of precipitation, water level, flow rate, water temperature and quality in key components (e.g. pumping wells, GRS trench outflow to Mountsberg Creek, multi-level bedrock monitoring wells, seeps, wetlands, etc) during performance of the pumping tests.

5. Completion of water use survey for all wells within 1 km of the proposed test and implementation of contingency plan for any well water supply complaint.

3. HYDROGEOLOGIC REVIEW AND CONCERNS

Based on my review of the primary documents outlined in Section 1 and in consideration of previous reports prepared for this site as listed in my earlier review letters, I offer the following comments and identify the following hydrogeologic issues and concerns for the proposed GRS work plan.

1. To be useful for reliable prediction of mitigation of likely future Quarry impacts, the field GRS pilot testing needs to be of sufficient spatial and temporal scale. By spatial scale we mean the actual physical size of the GRS. The physical size of the GRS pilot test needs to be large enough to provide a representative sampling of the hydraulic properties of the bulk rock that would be expected in the full scale application of the GRS for the proposed Quarry. The proposed 150 m long trench positioned about 35 m from the pumping wells appears to be of

sufficient size to provide a representative sampling of bulk rock hydraulic properties for assessment of hydraulic behaviour of a full-scale GRS.

2. The proposed GRS pilot testing also needs to be of sufficient temporal scale. There are two time scales to be considered. Short-term time scales of the order of days to a week or two for which initial hydraulic responses can be determined, and long-term time scales of the order of years for which changes in hydraulic properties due to well and aquifer clogging or dissolution can be quantified. The proposed GRS pilot-scale testing is likely of sufficient duration to evaluate short-term hydraulic responses of the bedrock aquifer and recharge systems. However, the proposed 5 to 6 days of pumping for each GRS Test will not allow for any real long-term assessment of the potential for well/aquifer clogging or dissolution.

3. To be representative of future Quarry-induced drawdowns and GRS conditions, the drawdowns in the three new pumping wells need to achieve the target drawdowns of about 30 m. If the new pumping wells intersect very permeable and transmissive zones, how will these target drawdowns be achieved? If the required pumping rates exceed the PTTW amounts how will the GRS pilot test be undertaken?

4. The calculation of water quality impacts to Tributary A of Mounstberg Creek and downstream in Mounstberg Creek from PTTW discharges are not realistic and underestimate the impacts that are likely to occur. The Stantec method of predicting surface water quality impacts relies on a simple mixing box model of background stream water quality and quantity and pumped discharge water quality and quantity. Because the volumes of groundwater to be pumped (112 L/s) are significantly greater than the estimated low flow in the Creek (virtually zero, according to Stantec), Stantec correctly concludes that the water quality of Tributary A downstream of the discharge would essentially reflect the pumped groundwater quality. The water quality impacts are underestimated because the more dilute shallow groundwater quality at the site is used to represent pumped water quality. The more sensible and realistic estimates of pumped water quality from the 7-day pumping tests of TW12 and TW13 should be used since these data more accurately reflect the deep groundwater quality that will be produced in the GRS pilot test. As GLL note in their *Level 2 Hydrogeologic Report* (Volume 1, page 27), groundwater from these wells showed exceedences of Provincial Water Quality Objectives (PWQOs) for iron, aluminum and zinc. Consequently, a more realistic prediction of water quality impacts will be that pumped discharge water will most likely exceed PWQOs for selected parameters.

5. The failure to address long-term GRS performance is a significant shortcoming of the proposed GRS pilot testing as changes in hydraulic performance are recognized as the most critical operational issue for long-term success of such systems. The reports by Huxley et al. and Corcoran et al. supplied by GLL, clearly distinguish between short-term and long-term GRS performance and identify the long-term deterioration of recharge rates due to particulate plugging, chemical precipitation, bio-fouling and air bubble entrainment as the most common problematic feature and concern with GRSs. How will this long-term GRS performance need be addressed for the proposed Mounstberg Quarry?

6. The GRS pilot testing even if it were to run for a duration sufficient to evaluate long-term performance, cannot reproduce the physical, chemical and microbiological conditions that will create plugging problems in the proposed Mounstberg Quarry and GRS. Re-injection of pumped groundwater in a closed-circuit pumping system is the not the same as collection of groundwater seepage on a quarry floor that oxidizes, picks up atmospheric CO_2 and suspended particulates and then is pumped from a sump as surface water to a GRS. The research report by Huxley et al. notes (page 13) that suspended solids concentrations as low as a few mg/L can create GRS plugging problems. Since most MOE sewage works approvals

for quarry dewatering set average effluent concentrations at 25 mg/L suspended solids, typical quarry effluents for re-injection can create GRS plugging problems and hence may not be suitable for long-term re-injection.

7. Additional hydrogeologic investigations to characterize the location and hydraulic properties of the permeable "production zone" within the Amabel Formation dolostone aquifer will be critical to selecting locations for multi-level groundwater monitoring and hence for evaluation of the ability of the GRS to maintain water levels within the deeper bedrock. For reliable evaluation of GRS performance, water levels need to be monitored in those deep permeable horizons that will create and propagate drawdowns away from the Quarry. GLL proposed borehole investigations are intended to identify these horizons. However, as GLL have historically not created monitoring intervals in the most permeable sections of bedrock that are expected to create the greatest drawdowns, there needs to be assurance in the GRS work plan that the most permeable bedrock horizons that correspond to the expected greatest drawdown will be selected for water level monitoring during the GRS pumping tests.

8. The potential for long-term plugging and reduction of injection flowrates in GRSs is a critically important factor that is not addressed in the proposed GRS pilot testing program. The supporting documents clearly identify this as the most important aspect of GRS operation.

   Huxley et al. (page 59, points 7.2.1 and 7.2.2) concludes:

   The main concern expressed in published literature, and reference design guides, related to the potential reduction in infiltration capacity with time as a result of clogging with fines, micro-organisms, or precipitates as a result of exposing groundwater at the surface and mixing of waters of different chemistries.

   Consideration of the groundwater chemistry has been shown to be important. In the case of the Eversley Quarry, trial recharge trenches became rapidly clogged with iron oxide deposits within the space of only a few days as a result of low pH groundwaters, with high iron concentrations being discharged at surface.

   And on page 60 (points7.2.3 and 7.2.6) they add:

   Experiments undertaken at the Rock Mountain Arsenal in the early 1990s found that sedimentation and microbial fouling tended to be restricted to the gravel filled trench and that it had not progressed far into the aquifer. It was observed that 100 days (over 3 months) after recharging of the trench with water laden with sediment and micro-organisms significant reductions in the recharge rates were observed.

   It has not been possible to investigate these long-term clogging issues in the field experiments, since these were of limited duration.

9. If the GRS experiences reduction of injection flowrates due to local clogging of trenches and open injection wells, then the GRS will be unable to maintain water levels in deeper bedrock and to prevent propagation of drawdowns away from the proposed Quarry. In this likely situation the GRS will be largely ineffective. What measures are proposed in the GRS pilot test work plan to evaluate this likely situation and would it be prevented during full-scale GRS operation?

10. In the permeable fractured bedrock setting of the proposed Mounstberg Quarry, there is also the potential for escape of injected water from the GRS that will not be captured by the Quarry.

Consider the simple case of an injection well that is open to depth of 35m and intersects the "production zone" and other permeable zones along its length. If the permeability of the production zone is locally reduced and other perhaps shallow bedrock zones have higher permeability, then injected water will preferentially recharge the shallow bedrock over the "production zone". If water levels are maintained in the "production zone" by overall operation of the GRS, then this shallow injected water may escape from the GRS. Given the extremely heterogeneous nature of the bedrock, this escape is a very real possibility. How will the proposed GRS pilot testing identify and quantify this escaping water?

11. Given the potential for escape of injected water, what water quality standards would apply to re-injection water to ensure long-term protection of groundwater quality in the regional Amabel Formation dolostone aquifer that provides domestic and municipal drinking water? Water quality standards for temperature, microbiological, physical and chemical parameters in injected water should be defined for both the GRS pilot test and any future full-scale GRS.

12. GLL in the Revised Work Plan (page 4) in reference to GRS state:

    This mitigation approach employs methods that are commonly applied to induce infiltration for purposes of recharge, maintenance of water levels and for establishing hydraulic barriers to alter groundwater flow patterns (Huxley et al., 2004).

    The inference from this statement is that the Huxley et al reference contains supporting information on the common successful application of these recharge methods/features that would be relevant to the proposed Mounstberg Quarry site. In fact the Huxley et al reference concludes that these recharge methods are not commonly applied and remain unproven. Huxley et al. (page 13) state:

    No examples of the use of recharge wells as a mitigation measure for quarry dewatering were found within published literature.

    And on page 59 (Point 7.1.4) they also note:

    Despite the collation of new case study information from mineral operators, there is still very little clear evidence on the extent to which recharge features have actually succeeded in their objective.

    The two case study examples cited in the Huxley et al report (Chamberhouse Farm and Methley Quarry) are not directly relevant to the proposed Mounstberg Quarry GRS. These two case studies evaluated short-term hydraulic responses for shallow overburden (soil) using recharge trenches. The critical performance issues for the proposed Mountsberg Quarry GRS is the long-term performance using trenches and wells in deep fractured bedrock setting. The experience gained from the two case studies are of little to no help in ascertaining the likelihood of successful performance of the proposed GRS for the Mounstberg Quarry site.

    Thus the GRS being proposed for Mounstberg Quarry, based on the Huxley et al. report, is an unproven technology without any demonstrated successful precedent.

4. CONCLUSIONS

1. Field pilot GRS testing is necessary for reliable assessment of the viability/feasibility of the full-scale GRS for the proposed Mountsberg Quarry. For the results of the field pilot GRS testing to be of use in assessing full-scale GRS operation, the spatial and temporal scale of the pilot tests must be of appropriate spatial and temporal scale. Although the proposed spatial scale appears to be appropriate, the temporal scale of the pilot GRS testing will not provide meaningful information on the long-term performance of the proposed GRS.

2. Independent research reports supplied by GLL in support of the PTTW application and GRS work plan, clearly distinguish between short-term and long-term GRS performance and identify the long-term deterioration of recharge rates due to particulate plugging, chemical precipitation, bio-fouling and air bubble entrainment as the most common problematic feature and concern with GRSs. The GLL GRS work plan does not discuss these important long-term performance issues and therefore the GRS work plan needs to identify how these concerns will be addressed and evaluated for a full scale GRS.

3. The predictions of water quality within Tributary A and Mounstberg Creek from PTTW discharge underestimate the concentration of pumped water quality parameters and therefore impact to surface water. The water quality predictions assume pumped water will be represented by shallow groundwater quality. The more accurate and representative data from actual November 2004 pumping tests of similar duration at the site shows that the GRS pilot test discharge will most likely exceed PWQOs for iron, aluminum and zinc.

4. Based on available documentation, there are no identifiable examples of successful application of GRS in deep fractured bedrock settings as exist at the proposed Mounstberg Quarry. Consequently, the GRS is considered unproven and the GRS pilot testing needs to provide a robust and rigorous demonstration and documentation of the potential for successful application of GRS at the proposed Mounstberg Quarry site. This will require, among other things, creation of drawdown conditions representative of actual Quarry conditions, thorough investigation of the bedrock hydrogeologic conditions, comprehensive monitoring of water levels and water quality sampling in an appropriate number of key deep bedrock monitoring intervals and careful monitoring of well pumping rates, flows to the recharge trench/wells and diversion flows to Mountsberg Creek. Careful documentation of the methods and results of the GRS pilot test is essential for demonstrating the potential for successful operation of such a full-scale system at the proposed Quarry site.

5. Since the proposed GRS pilot test is conceptual at this time and will likely be revised following the completion of the hydrogeologic characterization of the Amabel Formation, it would be appropriate for GLL to prepare a more detailed and focused field test plan prior to conducting the GRS pumping tests. This more focused test plan would provide specifics on exact locations for water quality and quantity monitoring which are only generically defined at this time. This field test plan should be prepared following the drilling, dynamic flow logging, geophysical logging, groundwater quality testing and multi-level monitoring completions of the old and new test wells (TW10 and TW14 to TW16) and the new monitoring wells (MW1 to MW-5).

6. Given the unproven application of GRS at this site, the strong potential for unforeseen and unanticipated results and hence the probable necessity for modification of the GRS pilot test as the it evolves, stakeholders other than the proponent should be allowed to monitor field implementation of the proposed GRS pilot test.

Respectfully submitted,

Intera Engineering Ltd.

Kenneth Raven, P.Eng., P.Geo.
Principal

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