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101 Pretty River Parkway South, Suite 5  
Collingwood, Ontario  
Canada L9Y 4M8

Tel 705 444-2788  
888-285-1272

Fax 705 444-0081

Walker Aggregates Inc.  
P.O Box 340  
Collingwood, Ontario  
L9Y 3Z7

Attention: Mr. Ken Lucyshyn  
Vice President and General Manager

Dear Sirs:

Re: Duntroon Quarry Expansion Hydrogeological Evaluation  
Response To Karst Report Peer Review Comments  
File 04 930521.52

As requested, we are providing our response to the following issues raised in the peer review comments on the Karst Report, prepared by Daryl D. Cowell and Associates Inc., dated April 4, 2008:

1. Surface water flows at spring SW2, located in the southwest corner of the Duntroon Quarry expansion lands, and associated Rob Roy PSW water budget assessment.
2. Incorporating recent climate data and future climate change predictions into final lake stage modeling.
3. Incorporating specific Escarpment springs into Adaptive Management Plan Monitoring Program.

1. **SURFACE WATER FLOWS AT SW2 AND ASSOCIATED WETLAND WATER BUDGET**

On Page 4 of the review letter prepared by Daryl W. Cowell regarding his review of the Karst report and Addendum Hydrogeological report, Mr. Cowell writes:





*“Spring SW2 discharges to only one part of the Rob Roy Complex PSW (Unit 6) from the southwest corner of the proposed expansion quarry and evidence presented in the KIA and in the HAA (page 167) indicates that the mean discharge of this source is 9 L/s. However, on page 173, the cumulative reduction in flow to the entire PSW under full development was noted as only 7 L/s (page 173). Although not significant in terms of the amount of discharge available, the wetland water budget section (Section 8.2) should be re-visited.”*

Recommendation #3 of the Cowell review letter states:

*“The water budget for the Rob Roy PSW (Jagger Hims Report, Section 8.2) should be re-visited with regard to correcting estimates of existing recharge.”*

The following response has been prepared by Jagger Hims Limited to clarify the above-noted aspects of the wetland water budget.

Table E-1 from our November 2007 Hydrogeological Assessment Addendum Report (table appended) summarizes the cumulative impact assessment of the water budget for the local wetland areas adjacent to the proposed Duntroon Expansion and MAQ quarries. The table presents an estimate of the predicted change in surface water drainage catchment area for each of the individual wetland features as a result of the proposed quarry extraction operations, and also for the entire Rob Roy PSW feature.

The estimates of direct and indirect recharge are based on the results of the 30 year Normals water budget analysis that uses monthly precipitation and temperature information along with a calculation of evapotranspiration losses of moisture back to the atmosphere due to transpiration by vegetation and evaporation losses. The numerical difference between the total annual precipitation that occurs and the evapotranspiration losses is taken to represent the annual water surplus. That surplus is taken to be the amount of water that is available to the rest of the environment for recharge of the groundwater and surface water systems on an annual basis. The annual surplus is apportioned between groundwater and surface water recharge based on the physical setting of the particular area in question. For this assessment, the 30 year Normal total annual precipitation was calculated to be 966 mm. The annual evapotranspiration losses were estimated to be 571 mm. This results in an annual surplus of 395 mm that theoretically is available for recharge of the groundwater and surface water systems, the proportion of each component being dependent on the location and setting of a particular area.

Section 3.2.2 of the September 2005 Geological and Level 2 Hydrogeological Assessment Report, page 22, provides a range of infiltration (groundwater recharge) factors for the study area based on the MOE land development guideline approach. For the range of slopes, soil



types and cover materials present, the overall infiltration factor is expected to range between 0.4 and 0.8. The overall surface run-off factor, therefore, is expected to range between 0.6 and 0.2 (60% to 20%). As discussed below, the wetland areas themselves are taken to be special cases with respect to their water budget assessment.

In the case of the wetlands, the direct recharge component to individual wetland features was taken to be the full annual surplus of 395 mm, since it results from precipitation that falls directly onto the ground surface within the wetland area, with little direct run-off occurring. Since the surface topography within the wetland features generally is flat to mildly undulating, most of the direct precipitation remains within the wetland features and effectively can be considered to recharge the wetlands. The indirect recharge component for the individual wetland areas was taken to be the surface runoff that occurs within the surface drainage catchment area around each wetland feature. Based on the local physical setting, and prior to quarrying, that value was taken to be 60% of the annual surplus, or 238 mm per year, as noted above. It is recognized that this approach provides an overall picture of the water budget on an average annual basis for a particular area, and there may be specific locations that don't always fit neatly into this type of assessment due to site-specific conditions.

The predicted change in recharge to a wetland area occurs with respect to that part of the indirect recharge catchment area associated with specific wetland features that will be removed by future quarry operations. Since none of the actual wetland features themselves will be extracted, there is no change in the direct recharge catchment areas. With respect to Mr. Cowell's review comment pertaining to the water budget, in terms of the cumulative change in the indirect catchment area for the entire Rob Roy PSW, resulting from both proposed quarry operations, the effect will be to remove approximately 95.2 ha or 5.6% of the total combined indirect and direct recharge catchment areas of the wetland feature. When this change in the indirect surface catchment area is multiplied by the estimated annual water surplus recharge value of 238 mm per year, the volumetric change in surface run-off recharge to the wetland is equivalent to about 226,600 cubic metres per year, or 5% of the total indirect and direct recharge potentially available to the wetland. This is the derivation of the average value of 7L/s that is provided in the Addendum report (226,000 cubic metres per year). The Addendum report also provides an assessment of the predicted change with respect to the Rob Roy #6 wetland feature itself.

As a result of the physical setting and associated hydraulics, the spring in the southwest corner of the Duntroon quarry expansion property, and the associated watercourse at SW2 that feeds into the northwest corner of Rob Roy Wetland Unit #6, is one of those locations that does not fit "neatly" into the overall water budget assessment for the wetland. This spring currently does flow year-round. However, the magnitude of the seasonal flow varies



widely, between occasional peak values of 60 to 90 L/s for short periods during specific annual spring melts, to low-flows of 1 to 2 L/s or less, during long periods in the summer and early fall except during rainstorm events.

On a year-round basis, the overall average value of the measured flows at SW2 was indicated to be approximately 9L/s over the period of record (since 1996). The flows that have been recorded on a weekly basis at station SW2 are provided in the Duntroon Quarry Expansion Groundwater and Surface Water Monitoring Program Addendum Report, dated October 2007, copies of which were submitted to the review agencies.

The following table illustrates that between 2003 and 2007, the recorded flow at SW2 has varied seasonally and annually as follows (larger values are rounded):

	<b>Geometric Mean Range (L/s)</b>	<b>Arithmetic Average Range (L/s)</b>	<b>5 Year Average Geometric Mean (L/s)</b>	<b>Value Arithmetic Average (L/s)</b>
<b>Spring</b>	6 to13	9 to 19	11	14
<b>Summer</b>	0.5 to 3	1.2 to 3.3	1.5	2.0
<b>Fall</b>	0.5 to 4.7	1.1 to 8.9	2.1	4.6
<b>Winter</b>	8 to 14	9 to 17	10	14

Table 1A, attached, provides the seasonal averaged flow data for the period 2003 to 2008 from which the above summary was generated. Because of the wide variation in flows that are recorded at SW2, the data are shown as geometric mean values (which moderates the effect of extreme highs and lows), as well as simple arithmetic average values.

Based on these last five years of data, the annual average flow at SW2 is interpreted to have been 6 L/s, using the geometric mean values, or 9 L/s using the simple arithmetic average approach. The difference between the two methods reflects the wide variation in flows that is observed on a seasonal basis, but also on a weekly basis in some instances, depending on prevailing climatic conditions. For the purpose of this re-assessment, the value of 6 L/s is taken to reflect the year-round average flow at SW2

The source of the water that flows by SW2 is a combination of shallow groundwater discharge at the spring and surface runoff / snowmelt from within the catchment area of the spring. During periods of medium and high flows, particularly during the snowmelt period in the Spring, the water from SW2 flows through the Rob Roy Wetland Unit #6 to the south, and then west beneath Grey Road 31, and through the downstream wetland areas in the tributary of the Beaver River. This type of flow-through effect removes the surface water from the catchment area and from the wetlands relatively quickly, providing little time for evapotranspiration processes to occur and little recharge benefit to the actual wetland feature.



Based on the catchment area of 25 ha for SW2 (Karst Basin E in the Karst Report) and the total annual water surplus of 395 mm, the annual average recharge flow at SW2 would be estimated to be approximately 99,000 cubic metres per year, or slightly greater than 3 L/s, rather than the interpreted revised average flow value of 6L/s or 190,000 cubic metres per year. Thus, the rapid movement of surface water flow out of the catchment area during periods of medium to high flows skews the magnitude of the “apparent” recharge value for the wetland compared to the normal water budget approach. However, as noted above, the rapid removal of the surface flows out of the wetland in the spring and fall significantly reduces the recharge-effectiveness of this water for the wetland.

The proposed quarry extraction operations will remove most of the catchment area that supplies surface flow at SW2 (Karst Basin E). However, that water will accumulate in the extraction areas of the quarries and will be pumped out of the quarries to maintain dry working conditions. The water will be discharged into the adjacent wetlands to maintain seasonal flow and moisture conditions in those features. Monitoring of the surface water / groundwater systems and the natural environment will be undertaken to ensure that the wetlands’ features and functions are maintained. Under post-closure conditions, the lakes that develop in the quarries will provide seasonal discharge to the adjacent wetlands in the spring to maintain the features and functions of the individual wetland features and the overall Rob Roy PSW.

In summary, the information provided above describes the groundwater and surface water catchment area and the seasonal flows that are observed at the spring in the southwest corner of the expansion lands and the associated monitoring station SW2 that provides flow into Rob Roy #6 wetland unit to the south. Differences between the measured volume of surface water flowing into the wetland and the estimate based solely on catchment area and standard surface runoff factors are explained by the shallow karst features that are present in this area and their effect on surface runoff characteristics, particularly during the spring melt condition. Much of the catchment area of the spring will be removed during extraction of the proposed Duntroon expansion quarry and the MAQ quarry.

During operation of the quarries and during the post-closure period of rehabilitation when the lakes are filling, seasonal surface water flow into Rob Roy #6 and the associated downstream south tributary stream of the Beaver River will be provided by pumping water from out of the Duntroon existing quarry, the expansion quarry and the MAQ quarry. Once the final lake levels have developed, seasonal discharge will occur from the lakes in the existing quarry and the MAQ quarry during the spring snowmelt and precipitation events, that will maintain seasonal water levels and flow conditions in the wetland and downstream water course. Direct precipitation and snowmelt recharge will continue to occur within the wetland, as will runoff/recharge from within those catchment areas that are not affected by quarry activities.



The wetland impact assessment that is presented in the 2007 hydrogeologic addendum report is reasonable, and the short-term and long-term features and functions of nearby wetlands and surface water courses will be maintained.

## **2. INCORPORATING POTENTIAL FUTURE CLIMATE CHANGE INTO FINAL LAKE STAGE MODELING**

With respect to incorporating the potential effects of future climate change into final lake stage modeling, recommendation #2 of the Karst Review states the following:

*“The modeling of final lake stages (and time to fill) in each of the three quarries should be subjected to sensitivity analysis. This analysis should include the use of the most recent 10-year normals as well as projected estimates of precipitation and evaporation based on reasonable climate-warming scenarios. The lake in the proposed expansion quarry is particularly of concern due to the predicted high groundwater outflows which will likely increase over time due to on-going karstification.”*

In preparing impact assessment modeling predictions related to water resource issues, the industry-accepted approach has been to use climate data based on 30-year normals because of the inherent natural variations that occur in climatic conditions from year to year, and also longer-term cyclical variations. The 30-year normals incorporate climate data from a sufficiently long period of time that such natural variations are normalized and do not overly bias the resulting average values. As the time period over which climate normals are calculated decreases, so the variations that occur from year to year can significantly affect the apparent average values that would be applied through that time period. When those recent short-term average values are incorporated into longer-term future predictions of change, on top of which additional change is invoked such as future global warming predictions, the degree of uncertainty associated with the validity of those predictions increases significantly. Taken to the extreme, the uncertainty associated with the validity of important input parameters, such as climate, can overwhelm the reasonableness of predictions made using computer models (i.e. the garbage-in = garbage-out syndrome).

Incorporating the most-recent 10-year climate normals into a sensitivity analysis of final lake stage modeling is a reasonably straightforward process. The temperature and precipitation data are available from Environment Canada for the Shanty Bay station on Lake Simcoe, and the development of normals is a mathematical exercise.

As noted in the October 2007 Addendum Hydrogeological Report, the original water budget assessment that was presented in 2005 was based on the 30-year normals data for the period



1971 to 2000 for the climate station at Thornbury-Slama on Georgian Bay. Unfortunately, that station was closed, and so the more recent evaluations used the 30-year normals climate data for the Shanty Bay station, since the average total annual precipitation was similar for both stations (966 mm for Thornbury Slama and 962 mm for Shanty Bay), and average monthly temperatures were reasonably similar. The calculated average annual water surplus was 395 mm for Thornbury Slama and 384 mm for Shanty Bay (2.8% lower).

Annual water budget summary tables are provided for the 30-year normals climate data for the Thornbury Slama and for Shanty Bay stations, together with the water budget based on the most recent 10 year climate normals for Shanty Bay.

The climate data for Shanty Bay indicate that average monthly temperatures have increased by approximately 0,5 to 1 Centigrade degree for the most-recent 10-year normals, compared to the 30-year normals calculated for the period 1971 and 2000. In contrast, however, the precipitation data indicate that the average total annual precipitation has not changed significantly between the two sets of data, being 962 mm per year for the 30-year normals, and 985 mm per year for the 10-year normals. This represents an increase in annual precipitation of approximately 2.4%, as opposed to a decrease in precipitation that might be expected based on some climate change predictions. The calculated annual water surplus for the 10-year data is 387 mm, compared to the value of 384 mm for the 30-year normals.

Based on the above, since the most-recent 10-year normals for Shanty Bay yield a reasonably similar annual water surplus compared to the 30-year normals data, the final lake stages for the post-closure quarries and time-to-fill period are going to be reasonably similar as well.

The difficulty arises when future climatic conditions are incorporated into the modeling of potential impacts resulting from quarry operations, because of the huge uncertainty associated with trying to predict climate change on global, continental, regional and finally local scales. For example, the recent Shanty Bay climate data show a small increase in the average monthly temperatures over the last 10 years, but no real change in average annual precipitation. We do not know whether these same trends will continue into the future, or whether weather patterns will change more dramatically, such that we will see increasing temperatures and more, or less, precipitation, or different seasonal patterns of both. We do not know how such changes will affect the natural environment with or without any future development, such as the proposed quarries. When such large uncertainties are brought into the groundwater modeling process, which by its very nature has its own uncertainty factors, as discussed below, the resulting predictions become highly speculative and of little real practical value.



Groundwater models are an essential tool for performing complex analyses and making informed predictions of groundwater flow. Models allow effective use of available data and can account for complexities in the system. The implications of the assumptions used in the analysis and formulation of the conceptual model can be evaluated as can recommendations concerning management of the resource arising out of the application of the model.

Groundwater modeling efforts are aimed at predicting the likely consequences of a proposed action. However, they are also used in an interpretive sense to gain insight into the controlling parameters in a site-specific setting or as a framework for assembling and organizing field data and formulating ideas about system dynamics. In every modeling effort, these activities are carried out either as the expressed purpose of the modeling or as a consequence of the modeling.

The Duntroon numerical model is a three-dimensional representation of the groundwater system incorporating regional and local topography in terms of elevations of the ground surface and surface water features, hydrogeological stratigraphy and hydraulic properties from field tests, seasonal water level measurements and spring and stream flows and infiltration estimates from local climate records and soils information. The models used to assess the Duntroon expansion site, have undergone an evolution in terms of incorporating additional data subsequent to the construction of the original steady-state model. Those data were extracted from on-going field observations and information related to the proposed MAQ Highland Quarry application on the property immediately adjacent to, and west of, the proposed Walker expansion. In addition to the Duntroon steady-state model, considerable effort has been directed at the development of a transient model, to simulate the seasonal fluctuations of the groundwater piezometric surface, and the seasonal spring flows. The presence of the existing quarry, as a real case history and observations of location and rate of groundwater discharge, geologic mapping of stratigraphy and fracture orientation, and effect on the adjacent groundwater levels and wetlands, are all valuable features against which to calibrate the model in terms of matching measured rates of discharge and water level response. As well, a separate groundwater model has been developed by MAQ for their quarry application and includes the Duntroon expansion, and that model provides reasonably similar results to the Walker expansion modeling.

Every groundwater model has a degree of uncertainty associated with the simplified conceptual model on which the numerical model is based and a resulting uncertainty with respect to its ability to predict absolute values of change. The degree of uncertainty can be reduced through sensitivity analysis of the basic input parameters, and models are best used as an index to assess relative change in a system, rather than absolute change, when baseline conditions of a calibrated model are modified to reflect new development. Based on all of the evaluation that has been completed, we are confident that the current model provides both



reasonable and reliable predictions with respect to likely relative changes to groundwater and spring flows during extraction operations at the proposed quarries, and the ultimate long-term recovery of the groundwater / surface water systems once extraction is complete and the final lakes are full of water.

### **Uncertainty in Groundwater Modeling**

A groundwater model is by necessity a simplified mathematical representation of subsurface conditions that are interpreted and interpolated based on site-specific but widely spaced data, and which are combined with surface and climatic factors. The resulting model is, therefore, characterized by a certain degree of uncertainty, but with calibration that uncertainty can be kept within a range of expected values. This is an accepted scientific/industry norm.

There are several sources of uncertainty that can contribute to a range of possible outcomes for all groundwater models, including the following:

- Uncertainty in the absolute value of point measurements such as estimates of hydraulic conductivity at specific locations based on pumping tests, slug tests and tracer tests;
- Uncertainty in the representiveness of such point measurements when applied over large areas (both vertical and horizontal) within the model;
- Scaling effect uncertainty;
- Uncertainty in the relative distribution of model parameters;
- Uncertainty due to limitations and / or deficiencies in the conceptual model that is adopted;
- Limitations of a model chosen to represent an aquifer system;
- Uncertainty resulting from errors intrinsic to acquisition of field data;
- Uncertainty due to natural spatial and temporal variability;

As with the manual interpretation of field information, modelling literature asserts repeatedly that there will always be uncertainty associated with analytical or numerical modelling and that, as such, modeling is only one of several tools that should be included as a component of the overall assessment of a particular situation. Other tools that were used for the Duntroon assessment include manual interpretation of field data with respect to response to climatic conditions, previous experience and direct measurement of impacts using case histories in similar settings. There is, however, a natural tendency to take the results of a model as being fully accurate in an absolute sense, as presented. The reader must be reminded that the model is a simplified numerical representation of complex natural variable conditions that is limited by data availability over large geographic areas, the absolute accuracy of that data, and the nature of the system being represented. There is a significant degree of interpretation and



hence uncertainty in assessing geological systems because parameters are estimated at discrete points within the system. The uncertainty of the geometry of the system under analysis includes uncertainties in the estimates of aquifer parameters, boundary conditions, surface water elevations and recharge as well as the calibration data set.

Unacceptably high levels of uncertainty in groundwater modelling can result from a poor fit between model simulated values and field observations, from a high level of parameter correlation, from insensitivity on the part of certain parameters, and from a combination of all the above.

The process of calibration of a groundwater model is completed by defining a set of parameters and boundary conditions that produce simulated groundwater levels and input/output fluxes that reflect the field-measured conditions within reasonable and acceptable limits. This has been done for the Duntroon model.

The original Duntroon steady-state model (2005 report) was calibrated using the accepted trial and study methods whereby hydraulic conductivity parameters (including anisotropy in horizontal hydraulic conductivity) and recharge were varied until a reasonable match was obtained between average observed and simulated groundwater levels. When a transient model subsequently was constructed to simulate seasonal groundwater conditions, further modification and re-calibration of the steady state model was necessary in order to achieve a reasonable match with observed seasonal variations in groundwater conditions in certain areas

Uncertainty was evaluated by quantifying the sensitivity of parameters and confidence limits, and performing a statistical assessment of uncertainty in the model. The statistical evaluation shows that the updated model can be considered representative of groundwater conditions in the area. That is, it demonstrates that the numerical model reliably represents the conceptual model. On this basis, it is our opinion that predictions of future conditions provided by this model can be used with a high degree of confidence to evaluate the expected impact on the local environment due to the proposed quarry operations, based on long-term climatic pattern normals,

However, with respect to incorporating into the modeling assessment long-term change in future climatic conditions as a result of man's activities, the high degree of uncertainty associated with predictions / quantification of such change reduces the reasonableness of the model results to a point where they are so highly speculative as to be of little practical value.

The original 2005 model fit to the conceptual model of the groundwater system was considered to be a reasonable calibration. The current updated model (2007) is considered to



be more robust in terms of representing the annual average and seasonal groundwater conditions. Inclusion of additional hydraulic conductivity fields provides a better fit with respect to seasonal (transient) conditions and also produced a better overall fit in statistical terms. Notwithstanding the better overall calibration fit, a degree of uncertainty with respect to the model's ability to predict future absolute values is to be expected, and this aspect is incorporated into the design and operation of the quarries through the Adaptive Management Plan.

### **Uncertainty in Predicting Climate Change**

Human-induced greenhouse gas emissions and accumulation in the atmosphere is now generally accepted as contributing to global warming and climate change, and will continue to occur unless global carbon emissions are decreased. In addition to the relatively recent warming trend that is occurring, the geologic record clearly demonstrates that there have also been large swings in climatic conditions in both the relatively recent and the geological past, which have far exceeded the current changes and the predicted future changes due to anthropogenic greenhouse gas emissions.

Climate change due to natural variations in astronomical and terrestrial conditions will continue for the life of the planet. Even without the complicating factor of greenhouse gas emissions, all the natural cyclical events and their effects on climate are not yet understood. Anthropogenic effects on greenhouse gas concentrations did not occur prior to the industrial revolution in any measurable degree and these effects are impossible to accurately or reliably quantify against a backdrop of variable climate due to natural factors. It is not our intention to downplay the effects of climate change due to human activities but to point out that attempting to predict the effects of greenhouse gas accumulation in the atmosphere is a challenging process which is full of uncertainty because it is judged against a moving background of natural variations.

Predictions of climate change due to greenhouse gas emissions and accumulation in the atmosphere are produced using computer models, which are significantly more complex than groundwater models. However, researchers have concluded that even the advent of better computer models of climate and more observational data will not do much to reduce the uncertainty in predictions of absolute change because of the "deep, irreducible uncertainties", as noted below.

Variations in earth orbital elements around the sun and the tilt of the earth relative to the sun are thought to be responsible for long-term climate changes in cycles, such as approximately 26,000 years for the precession of the equinoxes, 41,000 years for the tilt cycle and changes in the eccentricity of Earth's orbit of 100,000 and 400,000 years. These Milankovitch cycles



cause periodic variations in solar radiation caused by the sum of many repeated changes in the Earth's motion. There have been at least four ice ages in the Pleistocene Epoch in the last 1.8 million years, all of which occurred extremely rapidly in terms of geologic time. Evidence from oxygen isotopes indicates 44 cycles of glacial and interglacial stages starting 2.4 million years ago in the Pliocene. Some of these cyclic variations were much larger than others, resulting in extensive glaciations across much of the earth's surface.

Other cycles which have been discovered recently include the 1470 year cycle (Bond event) and Dansgaard-Oeschger events (comparable to the Bond event during glacial periods), and the 8.2 kiloyear event (rapid cooling 8,200 years before-present, and lasting two to four centuries). Abrupt climate changes, such as the Younger Dryas, appeared to plunge the northern hemisphere back into glacial conditions over a period of a decade or so, some 12,900 to 11,500 years ago.

Shorter-term variations may be caused by variation in the sunspot cycle (witness the coldest period of the Little Ice Age which corresponded to a period with almost no sunspots – the Maunder Minimum – 1645-1715). A warm period in the 11<sup>th</sup> century allowed for grape growing in the southern UK and probably allowed for Viking exploration into North America. Other unknown factors may also contribute to climate change, such as El Nino and La Nina or the factors that cause these phenomena. Volcanic activity can have significant effects on climate, as can asteroid, comet or large meteor collisions with the earth.

It is apparent that relatively little is known about the reasons for palaeoclimate fluctuations and that these fluctuations were complex and (at present) unpredictable.

The ability to predict absolute change resulting from the emission of ever-increasing volumes of greenhouse gases into the atmosphere superimposed on the natural variations of climate is rife with uncertainty and is of little or no predictive value. Effects could range from maintaining global temperatures because of a cooling sun, to rapid global temperature changes and increasingly unpredictable weather patterns. In other words, the uncertainty associated with predicting definitive climate change values due to “natural” phenomena combined with greenhouse gas emissions is very high.

A useful way to gauge how sensitive the climate is to rising carbon levels is to focus on the temperature increase that might occur if the level of carbon dioxide in the atmosphere was to double from pre-Industrial Revolution levels. Current estimates of future temperature increases range between 2.0 to 4.5 C. degrees, but could be as high as 8 C. degrees. It is an estimate that has not become much more precise over the last 20 years. There is general acceptance that the world's climate is exhibiting a warming trend and that human activity is very likely the main cause, but we are no closer to predicting exactly how much average



temperatures are likely to rise in the foreseeable future, and how global and local weather patterns may change. If greenhouse gas emissions do not reduce, we are likely to see a continued rise in temperature around the world, and changes in weather patterns as a result. The polar ice-caps are retreating, and there may be an overall increase in sea levels. Some areas will become more arid, but some areas may experience higher rainfall, and/or changes in the seasonal climatic patterns. However, it is the quantification of those changes with any real degree of confidence, and the ensuing response of the natural environment to such change that limits our ability to build these factors into groundwater modeling with confidence.

## **Summary**

Short-term and longer-term sustained changes in global climatic conditions will undoubtedly result in changes to local weather patterns in the Duntroon area. The nature and quantification of such changes is uncertain and impossible to predict with any reliability. We may experience an increase in long-term average temperatures; there may be a wider range of seasonal temperatures combined with more extreme climatic events. As well, there may be either less or more annual precipitation and/or seasonal precipitation relative to current conditions. Changes to temperature and precipitation will result in commensurate changes to annual and seasonal evapotranspiration and water surplus components of the water budget. Such changes would affect the annual and seasonal surface water and groundwater recharge patterns, which, in turn, will affect other environmental resources, with potentially very significant implications (positive and negative).

The difficulty comes in the absolute quantification of such changes and their effects on the local, regional and global environment. The whole exercise is rife with uncertainty and changes are unpredictable and of little or no scientific value. Groundwater modeling can be used to simulate “what if” scenarios with respect to relative water budget changes and predictions of groundwater/surface water levels and flows. However, it is not possible to quantify with any degree of certainty, the actual effects on environmental resources that can and will adapt to climate change.

The relative degree of uncertainty that is inherent in the Duntroon groundwater model and the associated predictions is within industry-accepted limits, and is far less than the uncertainty inherent in climate change predictions either on a regional or global scale. The groundwater model as presented provides reasonable predictions of future impacts as a result of quarry development. The science of predicting future climate change on global and/or local scales with any real certainty is not yet at this same level, and hence we have not incorporated such potential change into the groundwater model. In our opinion, such long-term changes in future climatic conditions are best accommodated by means of an Adaptive Management Plan



for the quarry operation that is designed to detect and mitigate / manage change due to that specific operation alone, within a regional “natural” setting that may itself be changing due to changing climatic conditions that are not related to the quarry at all.

### **3. INCORPORATION OF SPECIFIC SPRING LOCATIONS INTO ADAPTIVE MANAGEMENT PLAN MONITORING PROGRAM**

Recommendation # 1 of the Karst review states the following:

*“Uncertainty in the actual impact to spring base flow, especially at those springs located closest to the proposed quarry expansion (including springs known to be fed by the SW9 watercourse—see Buck and Worthington’s Table 8—as well as selected other springs including SW22A, 77, 78, 80 series, 84 series, 85, 86, 137, 138, 140, 142 and 143) should result in these springs being included within the proposed comprehensive adaptive management plan for monitoring and mitigation of impacts to water resources. Spring monitoring need not involve detailed flow measurements but should be based on observable changes (dry following rainfall or snowmelt events, declining flow trends over time, etc.). If impacts are identified, then contingency planning should trigger the use of injection wells as appropriate.”*

The Adaptive Management Plan (AMP) monitoring program with respect to water resources at and below the Escarpment is based on detailed (continuous) monitoring of surface water flows and temperature, in well-defined stream channels in tributaries of Batteaux Creek and Pretty River at locations that are easily and permanently accessible, and which are downstream of the on-line impoundment ponds that are present below the brow of the Escarpment east and northeast of the expansion lands. These locations, which are positioned on publicly-owned lands such as municipal road rights-of-way, or on lands owned by Walker Aggregates Inc., will have Early Warning (Yellow) and Action Threshold Trigger (Red) values assigned to both seasonal flow and temperature.

The selected locations are reasonably conducive to the installation of dataloggers and establishment of stage-discharge relationships, so that a continuous record of seasonal flow conditions can be maintained. Should changes to seasonal flow and water temperature patterns occur in the future, Walker Aggregates has committed to determining the cause of such change. It is recognized that, in some instances, there may be other factors that may affect flow and/or temperature conditions at some monitoring stations and which have no connection to quarry operations, and the monitoring as proposed will assist in identifying cause and effect. Walker Aggregates Inc. will accept the responsibility to identify the cause(s) for any and all exceedances of action threshold trigger levels should they occur for



any reason. Walker Aggregates Inc. will resolve these issues in an appropriate manner, if it is determined that quarry operations are the cause of the problem.

In addition to the AMP monitoring program, monitoring of groundwater and surface water conditions on a routine basis will continue at selected representative locations, including some spring locations below the brow of the Escarpment. Such monitoring will assist in confirming that quarry operations do not interfere with groundwater and / or surface water resources above or below the brow of the Escarpment, including springs that are located upstream of the on-line impoundment ponds. This monitoring will provide additional seasonal water level, flow and water temperature data that can be used in the event that exceedances are observed at one or more of the AMP monitoring stations, thereby providing added protection to the water regimes in the vicinity of the proposed expansion.

We trust that this information is satisfactory at this time. We are available to meet with Mr. Cowell at his convenience to discuss these issues further, should this be necessary. Please contact our office if you have any questions.

Yours truly,  
JAGGER HIMS LIMITED

A handwritten signature in black ink that reads "AGHims".

Andrew G. Hims, M.Sc., P.Eng  
Consulting Engineer

AGH:Inc

Enclosures:

Table E-1 Wetland Area Water Budget, from 2007 Level 2 Hydrogeological Assessment Addendum.

Table 1A: Seasonal Averaged Flow Data

Table 1: Thornbury Slama 30-Year Climate Normals Water Budget 1971 to 2000

Table 2: Shanty Bay 28-Year Climate Normals Water Budget 1973 to 2000

Table 3: Shanty Bay 10-Year Climate Normals Water Budget 1998 to 2007

**TABLE E-1**  
**WETLAND AREA WATER BUDGET**  
DUNTROON QUARRY EXPANSION CUMMULATIVE IMPACT ASSESSMENT  
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<b>DUNTROON EXPANSION LANDS</b>														
Wetland Area Designation	Area of Wetland (ha)	Indirect Contributing Drainage Area (ha)	Total Direct and Indirect Recharge Area (ha)	Indirect Drainage Area To Be Removed (ha)	Area Removed As % of Indirect Area	Area Removed As % Of Total Area	Indirect Contributing Drainage Area Remaining (ha)	Pre-Quarry Direct Recharge (m <sup>3</sup> /year)	Pre-Quarry Indirect Recharge (m <sup>3</sup> /year)	Pre-Quarry Total Recharge (m <sup>3</sup> /year)	Post-Quarry Indirect Recharge (m <sup>3</sup> /year)	Post-Quarry Total Recharge (m <sup>3</sup> /year)	Change in Total Recharge Available (m <sup>3</sup> /year)	Change In Recharge As % Of Pre Quarry Condition
<b>Rob Roy PSW</b>														
2	6.7	38.9	45.6	19.0	48.8	41.7	19.9	26,465	92,582	119,047	47,362	73,827	45,220	38
3 & 4	13.7	77.7	91.4	2.7	3.5	3.0	75.0	54,115	184,926	239,041	178,500	232,615	6,426	3
6	53.5	122.3	175.8	12.1	9.9	6.9	110.2	211,325	291,074	502,399	262,276	473,601	28,798	6
Total PSW	381.0	1334.0	1715.0	33.8	2.5	2.0	1300.2	1,504,950	3,174,920	4,679,870	3,094,476	4,599,426	80,444	2
<b>Duntroon Esc. ANSI</b>														
A	0.6	10.0	10.6	2.0	20.0	18.9	8.0	2,370	23,800	26,170	19,040	21,410	4,760	18
B	3.9	30.5	34.4	10.6	34.8	30.8	19.9	15,405	72,590	87,995	47,362	62,767	25,228	29
A AND B	4.5	40.5	45.0	12.6	31.1	28.0	27.9	17,775	96,390	114,165	66,402	84,177	29,988	26
<b>MAQ HIGHLAND QUARRY</b>														
<b>Rob Roy PSW</b>														
3 & 4	13.7	77.7	91.4	23.8	30.6	26.0	53.9	54,115	184,926	239,041	128,282	182,397	56,644	24
5	2.7	20.9	23.6	16.6	79.4	70.3	4.3	10,665	49,742	60,407	10,234	20,899	39,508	65
7	73.8	185.5	259.3	21	11.3	8.1	164.5	291,510	441,490	733,000	391,510	683,020	49,980	7
Total PSW	381	1334	1715	61.4	4.6	3.6	1,273	1,504,950	3,174,920	4,679,870	3,028,788	4,533,738	146,132	3
<b>CUMULATIVE EFFECTS</b>														
<b>Rob Roy PSW</b>														
2	6.7	38.9	45.6	19	48.8	41.7	19.9	26,465	92,582	119,047	47,362	73,827	45,220	38
3 & 4	13.7	77.7	91.4	26.5	34.1	29.0	51.2	54,115	184,926	239,041	121,856	175,971	63,070	26
5	2.7	20.9	23.6	16.6	79.4	70.3	4.3	10,665	49,742	60,407	10,234	20,899	39,508	65
6	53.5	122.3	175.8	12.1	9.9	6.9	110.2	211,325	291,074	502,399	262,276	473,601	28,798	6
7	73.8	185.5	259.3	21	11.3	8.1	164.5	291,510	441,490	733,000	391,510	683,020	49,980	7
Total PSW	381	1334	1715	95.2	7.1	5.6	1,239	1,504,950	3,174,920	4,679,870	2,948,344	4,453,294	226,576	5
<b>Duntroon Esc. ANSI</b>														
A	0.6	10.0	10.6	2.0	20.0	18.9	8	2,370	23,800	26,170	19,040	21,410	4,760	18
B	3.9	30.5	34.4	10.6	34.8	30.8	19.9	15,405	72,590	87,995	47,362	62,767	25,228	29
A AND B	4.5	40.5	45	12.6	31.1	28.0	27.9	17,775	96,390	114,165	66,402	84,177	29,988	26

**TABLE 1A**  
**SW2**  
**SURFACE WATER FLOW SUMMARY**  
DUNTROON QUARRY EXPANSION  
04 930521.52

	SPRING		SUMMER		FALL		WINTER		ANNUAL	
	Geometric Mean	Arithmetic Mean	Geometric Mean	Arithmetic Mean	Geometric Mean	Arithmetic Mean	Geometric Mean	Arithmetic Mean	Average of Geometric Means of Seasonal Means	Average of Arithmetic Means of Seasonal Means
2003	11.0	12.9	2.2	2.5	3.7	6.8	7.7	17.2	6.2	9.9
2004	13.3	16.9	3.0	3.3	0.9	4.9	11.1	15.3	7.1	10.1
2005	12.5	19.0	1.1	1.5	0.9	1.1	8.0	8.7	5.6	7.6
2006	9.5	13.0	0.5	1.2	4.7	8.9	13.8	16.3	7.1	9.9
2007	6.3	9.1	0.8	1.4	0.5	1.2	9.4	13.5	4.3	6.3
Average Seasonal Mean Value	10.5	14.2	1.5	2.0	2.1	4.6	10.0	14.2	6.1	8.8
Average of Seasonal Mean Value									6.0	8.7

Note:

- Seasonal average flow values ranged between:
  - Spring: 6.3 to 13.3 L/s geometric mean values, Average 5 years 10.5 L/s  
9.1 to 19.0 L/s arithmetic average, 5 year average 14.2 L/s
  - Summer: 0.5 to 3.0 L/s geometric mean values, Average 5 years 1.5 L/s  
1.2 to 3.3 L/s arithmetic average, 5 year average 2.0 L/s
  - Fall: 0.5 to 4.7 L/s geometric mean values, Average 5 years 2.1 L/s  
1.1 to 8.9 L/s arithmetic average, 5 year average 4.6 L/s
  - Winter: 7.7 to 13.8 L/s geometric mean values, Average 5 years 10.0 L/s  
8.7 to 17.2 L/s arithmetic average, 5 year average 14.2 L/s
- 5 Year Annual Average flow **6 to 9 L/s** depending on geometric mean or arithmetic average seasonal values used.

**TABLE 1: 30-YEAR NORMAL 1971-2000 WATER BUDGET THORNBURY SLAMA CLIMATOLOGICAL STATION**

Month	Mean Temperature deg C	Precipitation mm	Calculated Snowmelt mm	Potential Evapotranspiration mm	Actual Evapotranspiration mm	WHC mm	Calculated Water Surplus mm	Calculated Deficit mm
January	-6.6	94	29	1	1	146	46	0
February	-6.1	64	42	2	2	150	53	0
March	-1.6	64	86	8	8	150	117	0
April	5.2	62	37	30	30	149	67	0
May	11.5	71	0	72	72	133	14	0
June	16.6	76	0	106	105	101	2	0
July	19.7	81	0	128	121	58	3	7
August	19.0	86	0	114	103	41	0	11
September	15.1	94	0	78	72	58	5	6
October	9.0	81	0	42	40	93	6	2
November	2.9	97	12	14	14	137	33	0
December	-3.1	97	25	3	3	146	42	0
Total		966		598.0	571.0		388	26
Surplus							395.0 mm	

Notes: Data reported and calculated by Environment Canada  
 WHC –water holding capacity

**TABLE 2: SHANTY BAY WATER BUDGET: 1973–2000**

Month	Mean Temp Deg C	Precip mm	Rain mm	Snow Melt mm	PE mm	AE mm	WHC mm	Calculated Water Surplus mm	Calculated Deficit mm
January	-8.0	92	19	21	1	1	148	36	0
February	-7.2	58	16	34	1	1	149	48	0
March	-1.9	65	36	94	8	8	150	121	0
April	5.5	65	61	37	31	31	149	66	0
May	12.2	74	74	0	76	76	134	13	0
June	17.1	87	87	0	109	109	109	4	0
July	19.9	74	74	0	129	125	57	1	4
August	19.1	92	92	0	114	102	47	0	12
September	14.6	96	96	0	75	71	64	8	4
October	8.5	76	76	0	39	39	93	8	0
November	2.3	97	78	13	13	13	131	40	0
December	-4.3	86	28	22	2	2	145	34	0
Total		962	737	221	598	578		380	20
Water Surplus								384	

Notes: PE- Potential evapotranspiration  
 AE Actual evapotranspiration  
 WHC Water Holding Capacity of soil

**TABLE 3: SHANTY BAY WATER BUDGET: 1998-2007 – 10-YEAR NORMAL**

Month	Mean Temp Deg C	Precip mm	Rain mm	Calculated Snow Melt mm	PE mm	AE mm	WHC mm	Surplus mm	Deficit mm
January	-7.0	92	24	24	2	2	150	42	0
February	-6.0	85	26	27	1	1	150	52	0
March	-1.3	63	35	98	9	9	150	124	0
April	6.1	65	58	42	33	33	149	67	0
May	12.7	80	80	0	79	79	129	21	0
June	18.0	92	92	0	114	114	100	7	0
July	20.4	75	75	0	129	127	47	0	2
August	19.8	74	75	0	117	99	23	0	18
September	16.2	78	78	0	84	74	27	0	10
October	9.3	78	78	0	42	42	63	0	0
November	3.3	100	86	11	15	15	127	19	0
December	-3.2	103	41	21	3	3	149	38	0
Totals		985	749	223	628	598		370	30
Water Surplus								387	

Notes: PE- Potential evapotranspiration  
 AE Actual evapotranspiration  
 WHC Water Holding Capacity of soil