DUNTROON QUARRY EXPANSION
GEOLOGICAL REPORT AND LEVEL 2
HYDROGEOLOGICAL ASSESSMENT
Lot 25 and Part Lot 26 Concession 12 and Part Lot 25 Concession 11
CLEARVIEW TOWNSHIP, COUNTY OF SIMCOE

(Volume 1 of 3)

Report Prepared For
Georgian Aggregates and Construction Inc.

September 2005
File 930521.50
Distribution:
30 c MacNaughton Hermsen Britton Clarkson
2 c File
September 29, 2005

Georgian Aggregates and Construction Inc.
P.O. Box 340
Collingwood, Ontario
L9Y 3Z7

Attention: Mr. Ken Lucyshyn
Vice President and General Manager

Dear Sirs:

Re: Duntroon Quarry Expansion
Geological Report and Level 2 Hydrogeological Assessment
Project 930521.50

We are pleased to provide our geological report and Level 2 hydrogeological assessment for the proposed expansion of the Duntroon Quarry. The report has been prepared as technical support for the application to license the expansion lands under the Aggregate Resources Act for extraction as a Category 2 quarry.

This report provides an assessment of the geology, groundwater and surface water resources in the vicinity of the existing quarry and the expansion lands north of Simcoe Road 91. The historical and existing groundwater and surface conditions in and around the active quarry operation are used to help predict potential future effects of quarrying below the water table at the proposed expansion lands. Computer modelling is used as a predictive tool to assist with the assessment of potential impacts and the design of mitigative measures to minimize impacts on the surrounding environment.

Continued monitoring of the groundwater and surface water resources around the quarry and the expansion lands, together with an evaluation of effects, is an integral part of future quarry operations. Options for mitigation measures are provided with respect to water management aspects to ensure that potential future impacts to off-property groundwater and surface water resources around the quarry are controlled and managed appropriately.
Additional field investigations and assessment of karst development within the dolostone bedrock and associated surface water resources are on-going and will be reported in an addendum document.

We trust that this report is satisfactory at this time. Please contact our office if you have any questions.

Yours truly,
JAGGER HIMS LIMITED

Andrew G. Hims, P.Eng
Consulting Engineer

AGH:jmm
EXECUTIVE SUMMARY

Georgian Aggregates and Construction Inc. (Georgian Aggregates), a wholly-owned subsidiary company of Walker Industries Holdings Limited, owns and operates the Duntroon Quarry. The quarry is located in Part Lot 24, Concession XII, Clearview Township, County of Simcoe on the south side of Simcoe Road 91, just east of Grey Road 31 which is the boundary line between the two counties.

As part of a long-term plan to continue to supply existing and future markets, Georgian Aggregates is proposing to expand the quarry operation onto the lands directly north of Simcoe Road 91. The expansion lands are located in Lot 25, Concession 12, Part of Lot 26, Concession 12, and Part of Lot 25, Concession 11. The expansion lands comprise approximately 127.0 ha (313.7 acres), of which 68.9 ha (170.2 acres) is proposed for extraction. The land between the proposed limit of extraction and the boundary of the area to be licensed will remain as buffer land between the adjacent neighbours and the extraction operation. The size of the buffer area is 58.1 ha (143.5 acres).

A detailed geological and hydrogeological assessment of the expansion lands and surrounding area has been undertaken. Technical information used in this assessment of the proposed expansion was obtained from site specific field investigations at the expansion lands. In addition, information from previous studies and groundwater monitoring, completed at the existing quarry to the south and Georgian’s Osprey Quarry property to the west, has been incorporated into this report. Details of the site investigations and the assessment of that information are provided in the main text of the report. The potential effect of the proposed expansion was evaluated and mitigation measures are provided to ensure that water resources and the natural environment are protected.
A groundwater computer model of the expansion lands and surrounding area has been developed to assist in the assessment of potential effects on local water resources associated with the proposed expansion, and the mitigation of those effects. The resulting extraction plan and mitigation measures are designed to minimize short-term and long-term effects on adjacent groundwater and surface water resources and associated wetland features. A comprehensive groundwater and surface water monitoring program is included as an integral part of the proposed expansion to ensure that water resources are protected.

The dominant terrain feature in the immediate vicinity of the expansion property is the steeply sloping land of the Niagara Escarpment, the brow of which is located in excess of 400 metres to the east of the proposed extraction area. The Escarpment is a provincially significant landform feature that extends from Niagara Falls to Tobermory. The Amabel Formation dolostone forms the erosion-resistant cap-rock of the Escarpment through this area. The Amabel dolostone is recognized as a provincially significant aggregate resource that is used to manufacture a variety of products including asphalt and concrete products, building stone and lime, and crushed granular materials. It is the Amabel dolostone that is being extracted in the existing quarry, and is proposed for extraction in the expansion quarry.

There are approximately 43 million tonnes of aggregate resource within the footprint of the proposed limit of extraction. A maximum annual extraction rate of three million tonnes per year is proposed. The extraction operation has been designed in three phases, down to elevation 500 metres above sea level (m asl), commencing in the south-central part of the property, and then moving in a clockwise direction. The last phase (Phase 3) to be extracted will be along the northern and then eastern sections of the property, followed by extraction of the rock beneath Phase 1 from 500 m asl down to elevation 490 m asl. The overall objective is to maximize recovery of the high quality aggregate resource, while maintaining the environmental integrity and functions of the adjacent groundwater and surface water resources and the associated wetland features. A predictive and adaptive
groundwater and surface water monitoring program that is tied to early warning and action thresholds is an integral component of the quarry operation.

The height of the rock extraction face generally will vary from a minimum of 4 m along the north-central boundary to a maximum of almost 39 m in the south-central area, and up to three lifts may be used to extract the rock. Extraction will occur above and below the groundwater table. Water that accumulates on the quarry floor from direct precipitation, surface runoff and from groundwater inflow will be removed by pumping to maintain dry working conditions across the quarry floor.

Water will be required for quarry operations, including washing of aggregate in a closed-loop system, dust control and irrigation of landscaped/rehabilitated areas of the quarry. Excess water will be discharged off-site at strategic locations around the quarry to assist in maintaining seasonal surface water flow conditions, where appropriate, in adjacent wetland areas. As well, excess water may be stored in the existing quarry, once extraction operations have ceased. As extraction in the expansion quarry progresses, it may be necessary to implement additional mitigation measures involving groundwater recharge wells located around the perimeter of the expansion lands. Excess water from the quarry will be used to supply the recharge wells.

The expansion quarry will be subject to progressive rehabilitation as part of normal operations. Once extraction has been completed and the equipment removed, the quarry will undergo final rehabilitation to a lake, similar to the existing quarry. The expansion quarry will start to fill with water as soon as the dewatering system is turned off; however, the filling process will take several decades to complete. The sources of the water to fill the lake include direct precipitation and surface runoff, and groundwater discharge into the extraction area.
Water will continue to be required for the mitigation systems including surface discharge and groundwater recharge. The groundwater model indicates that there will be an average water surplus of approximately 4 L/s available to fill the lake while the recharge wells are operating. As a contingency, water can be transferred from the lake that will be present in the existing quarry on an as-needed basis if necessary.

The average lake level in the expansion quarry is predicted to be 510.7 m asl, based on the groundwater model, and 510.3 m asl in the existing quarry area. The lake levels will be subject to normal seasonal variation resulting from prevailing climatic conditions. The modeled post-rehabilitation conditions around the expansion quarry property indicate that long-term changes to the groundwater, surface water and wetland systems are expected to be relatively minor, with no negative impacts. Groundwater discharge at the springs at the Escarpment is predicted to be similar to, or slightly greater than, existing conditions. The adjacent wetland areas will continue to receive direct precipitation, snowmelt and surface runoff from surrounding lands, and potentially seasonal discharge from the lakes in the two quarries. Water table levels in the wetlands are expected to be similar to historical seasonal patterns.

Groundwater discharge at the spring in the southwest corner of the expansion lands will cease as a result of extraction, and it is not expected to be re-established upon final rehabilitation of the quarry to the lake. There will be some seasonal surface flow in the downstream watercourse that feeds into the wetland south of Simcoe Road 91; however, groundwater discharge to the watercourse is not expected to occur.

A residual drawdown of between 1 m and 4 m in the groundwater levels in the rock around the expansion quarry is predicted. As well there will be a minor shift in the groundwater divide west of the quarry. The net result of the shift is that the groundwater recharge
across approximately 50 ha of land that currently contributes to the Beaver River system, will be transferred into the Batteaux Creek system. The volume of recharge affected is not considered to represent a negative impact, given the size of the Beaver River drainage basin. A similar volume of seasonal surface runoff from the expansion property that currently is within the Beaver River system will be captured by the lake and transferred into the Batteaux Creek system.

Details of the predictive-adaptive groundwater and surface water monitoring program and the water interference complaint response procedure are provided in the text. Additional groundwater monitors will be established within and beyond the proposed extraction area to monitor the progressive increase in the magnitude and extent of the drawdown zone of influence. Measured values will be compared to predicted values based on the model, and the information will be incorporated into the predictive impact assessment. A preliminary set of early warning and action threshold values, together with a defined action response protocol, will be developed in consultation with agency staff prior to extraction in Phase I. These values will be based on the baseline groundwater and surface water conditions that have been established through the monitoring completed to-date. The action response protocol will define a specific course of action such as the implementation of mitigation measures that will be undertaken to ensure that water resources are protected. The groundwater and surface water monitoring program will be integrated with the program for the natural environment.

Based on the field investigations, analysis and groundwater modelling that have been completed, and the experience gained at the existing quarry, it is our opinion that the aggregate resource present beneath the expansion lands can be extracted in an environmentally acceptable manner, based on the proposed design of the quarry and the associated mitigation measures as described.
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1.0 INTRODUCTION

1.1 BACKGROUND

Georgian Aggregates and Construction Inc. (Georgian Aggregates), a wholly-owned subsidiary company of Walker Industries Holdings Limited, owns and operates the Duntroon Quarry. The quarry is located in Part Lot 24, Concession XII, Clearview Township, County of Simcoe on the south side of Simcoe Road 91, just east of Grey Road 31 which is the boundary line between the two counties. Figure 1-1 provides location details and also identifies other property owned by Georgian Aggregates in the immediate vicinity of the active quarry. The figures are located in Volume 2 of this report.

The Duntroon Quarry commenced operations in 1964 under the name McKean Quarry. The quarry was purchased by Georgian Aggregates from Seeley and Arnill Aggregates Limited in the mid-1990s. The licensed area is 57.5 ha (142.1 acres), and the extraction area is 47.1 ha (116.4 acres). The quarry is licensed to extract down to a final floor elevation of 500 m above sea level (m asl). Currently, extraction occurs in a single lift which varies between about 15 to 20 m in height depending on the elevation of the bedrock surface. Since extraction occurs below the water table, dewatering is required in order to maintain dry working conditions across the quarry floor. Figure 1-2 is a sketch of the existing conditions at the quarry in June 2005. Based on the current extraction rate of approximately 1.3 million tonnes per year, there are approximately 5 years of resource remaining within the licensed extraction area.

As part of a long-term plan to continue to supply existing and future markets, Georgian Aggregates is proposing to expand the quarry operation onto the lands directly north of Simcoe Road 91. The expansion lands are located in Lot 25 and Part Lot 26 Concession 12, and Part Lot 25 Concession 11, as shown on Figure 1-1. Figure 1-3 is an airphoto of the area flown in April 2002 which shows the existing quarry and the proposed expansion lands, as well as the surrounding property ownerships. Figure 1-4, taken from the proposed
site plans, shows the existing features on the subject property and surrounding lands. The expansion lands comprise 127.0 ha (313.7 acres), of which 68.9 ha (170.2 acres) is proposed for extraction. The land between the proposed limit of extraction and the boundary of the area to be licensed will remain as buffer land between the adjacent neighbours and the extraction operation. The size of the buffer area is 58.1 ha (143.5 acres).

The proposal is to extract the dolostone rock down to a general elevation of 500 m asl, and then down to 490 m asl in the central/southern part of the site, in up to three lifts. The height of the rock extraction face generally will vary from a minimum of 4 m along the north-central boundary to a maximum of almost 39 m in the south-central area, and up to three lifts may be used to extract the rock. Pumping of water that accumulates in the excavation from direct precipitation/surface water runoff and from groundwater inflow will be required in order to maintain dry working conditions across the quarry floor. There are approximately 43 million tonnes of recoverable aggregate resource within the proposed limit of extraction. The extraction operation is to be completed in three phases, down to elevation 500 m asl, commencing in the south-central part of the property, and then moving in a clockwise direction. The last phase (Phase 3) to be extracted will be along the northern and then eastern sections of the property, followed by extraction of the rock beneath Phase 1 down to elevation 490 m asl.

The application is for a maximum extraction rate of three million tonnes per year. Initially, extraction in Phase 1 of the expansion lands down to an elevation of 500 m asl will occur concurrently with mining in the existing quarry until that latter resource is fully extracted. The two operations are to be connected by means of a proposed tunnel beneath Simcoe Road 91, subject to municipal approvals. The base of the tunnel will be at elevation 500 m asl. Blasted rock from Phase 1 in the expansion lands will be transported through the tunnel to the existing quarry for processing. As soon as sufficient space exists in Phase 1, the processing plant will be moved from the current location to the floor of the new quarry. The aggregate remaining in the existing quarry will then be extracted and transported.
through the tunnel to Phase 1 of the new quarry for processing. Once extraction is complete in the existing quarry, the tunnel will be filled in and sealed, and the existing quarry rehabilitated. The proposed rehabilitation for both locations is to include lakes, wildlife habitat and recreation lands.

1.2 PURPOSE AND SCOPE

An application is being made under the Aggregate Resources Act for a Class A licence for a Category 2 Quarry, that will allow extraction of the bedrock resource from above and below the water table within the area shown on Figures 1-3 and 1-4. The Provincial Standards of the Aggregate Resources Act set out specific requirements for technical reports that must accompany an application for a licence. Section 2.2.1 for Category 2 applications states the following with respect to a Level 1 hydrogeological assessment:

“2.2.1 Level 1 Hydrogeological

Preliminary hydrogeologic evaluation to determine the final extraction elevation relative to the established groundwater table(s) in both unconsolidated surficial materials (if present) and the consolidated bedrock strata, and the potential for adverse effects to groundwater and surface water resources and their uses (e.g. waterwells, groundwater aquifers, surface water courses and bodies, discharge areas, etc.).

NB: A Permit To Take Water may be required if any part of the operation utilizes ponds by flow restriction, or diverts ground and/or surface water on, or from the site.”

Section 2.2.2 for Category 2 applications states that where the results of the Level 1 assessment identify a potential for adverse effects on groundwater and/or surface water resources and their uses from the quarry operation, an impact assessment is required to determine the significance of the effects and feasibility of mitigation. The assessment should address the potential effects of quarry operation on features located within the zone.
of influence for extraction below the established groundwater table, where applicable. A technical report is to be prepared that addresses the following items:

(a) water wells;
(b) springs;
(c) groundwater aquifers;
(d) surface water courses and bodies;
(e) discharge to surface water;
(f) proposed water diversion, storage and drainage facilities on site;
(g) methodology;
(h) description of the physical setting including the local geology, hydrogeology and surface water system;
(i) water budget;
(j) impact assessment;
(k) mitigation measures including trigger mechanisms;
(l) contingency plan;
(m) monitoring plan; and
(n) technical support data in the form of tables, graphs and figures appended to the report.

The existing quarry has been extracting rock from below the water table for more than 10 years. There are groundwater and surface water resources present around the quarry, including water wells, springs, surface water courses and wetland features. Monitoring on and around the quarry property demonstrates that the dewatering operation has a drawdown influence on local groundwater around the extraction area, and that this influence extends beyond the limits of the licensed property. Adjacent water well supplies, surface water resources and wetlands have not been adversely affected by the existing quarry operation.
Since the physical setting of the expansion lands is similar to that of the existing quarry, the proposed extraction below the water table has the potential to affect groundwater and surface water resources located beyond the property boundaries. This document provides the technical report for a combined Level 1 and Level 2 hydrogeological assessment of the proposed undertaking.

The overall objectives of the Level 2 hydrogeological study are summarized below.

(a) To define the existing physical conditions on and around the expansion lands and the existing quarry, including the physiography, geology, groundwater setting, surface drainage and climate.

(b) To describe the existing quarry extraction and dewatering operations, and their effects on local groundwater and surface water resources, as input to the impact assessment for the proposed expansion.

(c) To describe the proposed extraction and dewatering operations on the expansion lands; to evaluate potential effects on groundwater and surface water resources; to provide options for on-site water management and mitigative measures that will minimize potential off-site effects and maintain acceptable local water resources; to describe an appropriate groundwater and surface water monitoring program and associated trigger mechanisms for implementation of mitigation measures, and provide a contingency plan.

(d) To document the field investigation information that has been collected to-date and provide technical support for the application to license the expansion lands, as required under the Aggregate Resources Act and by other approval agencies.

In addition, the report contains the results of the aggregate resource assessment. This assessment is based on geological data obtained in conjunction with the hydrogeological program.
1.3 REPORT ORGANIZATION

Geological, groundwater and surface water investigations have been on-going at the existing quarry property and surrounding lands since the early 1980’s. Jagger Hims Limited has been involved with water monitoring and geological/hydrogeological testing and assessment at the quarry since 1993. A detailed assessment of the expansion lands and surrounding area commenced with the drilling of boreholes in December 2002 and April 2003, and a groundwater/surface water monitoring program that was initiated in May 2003.

With the exception of the earlier studies completed by other consultants, and groundwater/surface water monitoring reports required by the Ministry of the Environment as a condition of the Permit To Take Water, much of the historical field investigation and assessment work undertaken by Jagger Hims Limited was for internal operational purposes. That information forms part of the database for the current investigation. In view of the magnitude of the technical data, this report consists of three volumes, as follows.

Volume 1: Contains the main body of the text.

Volume 2: Contains the figures that accompany the text.

Volume 3: Contains the technical appendices as follows.

- Appendix A Geologic Information
- Appendix B Groundwater Information
- Appendix C Surface Water Information
- Appendix D Climate Data
- Appendix E Residential Water Supplies and Ministry of Environment Water Well Records
- Appendix F Groundwater Model
- Appendix G Curricula Vitae
The report combines the geological report and the water resources assessment report into a single document to facilitate technical review and non-duplication of information. The report provides the results of field investigations and analysis/interpretation of information that has been obtained to the end of May 2005. Water monitoring is ongoing. Further field investigations with respect to the karstic nature of the dolostone bedrock and associated aquifer characteristics are being undertaken by specialists in that area. The results of that work will be documented in an addendum report in the fall of 2005.

2.0 STUDY METHODOLOGY

2.1 BACKGROUND

Technical information used in the assessment of the expansion lands was obtained from current investigations on the proposed expansion lands, and from previous investigations and water monitoring at Duntroon Quarry and Osprey Quarry property as completed by Jagger Hims Limited and other consultants.

The following sections describe the work carried out for the investigations at each individual property.

2.2 OSPREY QUARRY PROPERTY

In the 1980’s, Seeley and Arnill (former owner of the existing quarry), commissioned hydrogeologic investigations of a property to the west of Grey Road 31, identified as Osprey Quarry Property on Figure 2-1. That work was undertaken for the application to license the property for extraction of the dolostone aggregate. The property is licensed to extract aggregate from above the water table and it is now owned by Georgian Aggregates, but there has not been any extraction activity to-date.
The following is a general summary of work that was undertaken at the Osprey property.

(i) 1982: Hydrology Consultants Limited prepared a report entitled “Hydrogeologic Investigation of Proposed Seeley and Arnill Quarry Township of Osprey”. Four boreholes were drilled to a depth of 6 m to 10 m below ground surface, groundwater table monitors were installed, and an assessment of the effects of extraction of the bedrock from above the groundwater table was completed.

(ii) 1991: Trow Dames & Moore prepared a report entitled “Report On Pumping Test, Proposed Seeley And Arnill Quarry, Township Of Osprey”. The results of a 24-hour pumping test were used to assess the potential effects on the local water resources resulting from quarrying below the water table to an elevation of 503 m asl. Some information from that report was provided by Dames & Moore (now URS), but the actual document could not be located.

(iii) 1991: Trow, Dames & Moore prepared a report entitled “Mitigative Techniques To Prevent Deleterious Impacts On Beaver Creek And The Associated Wetlands During Dewatering At the Proposed Osprey Quarry”. That report provides options for measures to mitigate potential impacts to the nearby surface water resource and wetland area arising from the proposed dewatering operations at the property.

Available information from the above-noted reports was incorporated into the present study, where appropriate.
2.3 EXISTING DUNTROON QUARRY - 1990 TO 1993

During the period of 1990 to 1993 Henderson Paddon Limited and Trow, Dames & Moore conducted the following geological and hydrogeological studies at the existing Duntroon Quarry.

(i) 1990 (April): Henderson Paddon Limited supervised the drilling of three cored boreholes generally located in the northeast, southeast and northwest corners of the property. Two boreholes penetrated the full thickness of the dolostone bedrock and were terminated in the underlying shale, and one was terminated in dolostone. Preliminary borehole logs were prepared.

(ii) 1991 (March): Trow, Dames & Moore prepared a report entitled “Hydrogeology Of Proposed Expansion Of The McKean Quarry, Lot 24, Concession 12, Township Of Nottawasaga”. That report provides an assessment of possible effects that quarrying to an elevation of 517 m asl would have on groundwater levels in the surrounding area. The expansion referred to was for the so-called “20 Acres” parcel of land that now forms the eastern limit of the quarry. A series of monitoring wells and a test well were installed on the quarry property in 1989 and 1990 as part of the study. An assessment of the potential impact from the proposed expansion on local water wells was provided.

(iii) 1991 (July): Trow, Dames & Moore prepared a draft report entitled “Report On Pumping Test McKean Quarry, Lot 24, Concession 12 Township of Nottawasaga”. That report provides the results of a 24-hour pumping test carried out on the quarry property, and an assessment of potential impacts arising from deepening the quarry to a proposed elevation of 503 m asl.

Information from the above-noted reports has been incorporated into the present study, where appropriate.
2.4 EXISTING DUNTRROON QUARRY – 1993 TO PRESENT

Jagger Hims Limited has been involved with various aspects of quarry operations at the Duntroon Quarry since 1993. This work has included (a) geological/rock quality investigations and assessments, (b) Permit To Take Water and Amendment applications, (c) water management aspects, (d) routine groundwater and surface water monitoring, (e) hydrogeological testing, (f) assessment of the implications associated with the deepening of the quarry floor in the eastern 20-Acre parcel from elevation 514 m asl to an elevation of 500 m asl, and (g) input to various site plan updates. The final floor elevation based on the original licence was 503 m asl. It was subsequently determined that due to an historical survey error, the quarry floor was extracted to elevation 500 m asl. In 2001, the site plans were amended and approved to reflect the final floor elevation of 500 m asl.

A general chronology of field investigation programs and/or assessments at the existing quarry is provided below.

(i) 1993 to 1995: Evaluation of existing conditions, rock quality and available hydrogeological data with respect to on-going extraction below the groundwater table.

(ii) 1996 to 1997: Preparation of an application for a Permit To Take Water (PTTW) for dewatering and wash plant operations. The Permit was issued by the Ministry of the Environment in January 1997. A groundwater and surface water monitoring program, which included on-site and off-site locations, was initiated in 1996.

(iii) 1996 to Present: Routine groundwater and surface water monitoring has been undertaken on-site and around the quarry property since 1996. Monitoring is required as a condition of the Permit To Take Water. Annual monitoring reports were prepared and submitted to either the Ministry of Natural Resources and/or Ministry of the Environment for the years 1996 through to 2001. The reporting
schedule is now every three years, with the first three-year report for the period 2002, 2003 and 2004 to be submitted in 2005. The annual report documents the results of the monitoring program, as well as providing an assessment of any water supply interference complaints from residents in the vicinity of the quarry that are received by Georgian Aggregates.

(iv) 1997 to 1999: Rock quality investigations were undertaken within the licensed property during this period. Cored boreholes were drilled at locations 98-1 through 98-7 in July 1998, and at locations 98-8 through 98-13 in December 1998. Borehole locations are shown on Figure 2-1. Some of the boreholes penetrated the entire thickness of the dolostone rock of the Amabel and the Fossil Hill Formations and were terminated in the underlying shale of the Cabot Head Formation, while other boreholes were terminated in the Amabel Formation. Selected rock core samples were submitted to a laboratory for rock quality testing. Selected boreholes were maintained as open-hole groundwater monitors.

In-situ hydraulic conductivity testing, consisting of packer testing using either falling head tests or constant head tests, was completed in boreholes 98-8 and 98-9 to provide a vertical profile of the hydraulic conductivity of the rock adjacent to the boreholes. As well, three test pumping wells, designated PW99-1, PW99-2 and PW99-3, and observation wells OW99-1 and OW99-2 were installed and tested in 1999 to further characterize the hydraulic characteristics of the rock, as part of ongoing operations. Shallow drivepoint groundwater monitors DP99-1 (DP1) through DP99-4 (DP4) were installed in wetland features to the west and south of the licensed property as part of that program.

(v) 1999 to Present: Ongoing monitoring and evaluation of groundwater and surface water influx to the quarry, dewatering aspects, off-site discharge, process water recirculation and general water management issues as they arise.
(vi) 2000 and 2001: Provided input to the update of the site plans to reflect the existing operations and the final floor elevation of 500 m asl. Revised site plans were approved by the Ministry of Natural Resources in 2001.

(vii) 2000 to 2003: Provided groundwater and surface water assessment of the application for a site plan amendment to deepen the quarry floor in the eastern “20-acre” parcel of the licensed property from 514 m asl down to 500 m asl. The amendment, which included an undertaking to not extract the bedrock beneath the small wetland feature in the southwest corner of the licensed property, was approved by the Ministry of Natural Resources in 2003.

(viii) 2000/2001 and 2004: Prepared applications to the Ministry of the Environment to amend the Permit To Take Water. The 2000/2001 amendment increased the approved volume of water that could be pumped to the wash plant to accommodate higher-capacity processing equipment. The dewatering component was also increased to reflect the additional size of the quarry and water influx to the quarry floor. The August 2004 application was to reflect current conditions and proposed modifications to the water management operations at the quarry. The 2004 application is under review by the Ministry of the Environment.

2.5 EXPANSION LANDS

Field investigations, monitoring and office assessment of the expansion lands and surrounding area started in late 2002, and have included the following tasks.

(i) Six cored boreholes, designated BH02-1 through BH02-6 were drilled on the former Millar property in December 2002, in the eastern half of the proposed expansion area. Locations are shown on Figure 2-1. In April 2003, three cored boreholes designated BH03-7, BH03-8 and BH03-9 were drilled on the former MacDonald property, within the western section of the proposed expansion area. With the
exception of BH03-7, which is a shallow borehole, the boreholes were extended through the entire sequence of the Amabel and Fossil Hill dolostone, and were terminated in the underlying Cabot Head shale. The boreholes were completed as open-hole bedrock groundwater monitors except at location BH03-7. At BH03-7 which is located at the northern limit of the former MacDonald property, two shallow boreholes were drilled and groundwater monitors installed to assess groundwater conditions in the upper part of the Amabel Formation and in the overburden. At each borehole location the soil and rock core samples were logged in the field by the supervising geologist. The rock core was transported to Newmarket for detailed assessment and peer review by the senior geologist, and selected rock core samples were submitted to a laboratory for rock quality testing.

(ii) Published geological maps and reports were reviewed to provide background information with respect to the general geological setting. Surface exposures of the bedrock that are present on the expansion lands and along the Niagara Escarpment on the adjacent properties, as well as the exposed rock faces in the existing quarry operation were inspected to verify the geology. The presence of dissolution features related to karst development in the dolostone was documented. The strike and dip of fracture planes present at accessible exposures of the Amabel and Manitoulin Formations were mapped in detail. The data were analyzed to identify orientation of fracture sets within the exposed dolostone rock.

(iii) The topography and surface drainage characteristics of the study area were determined from the Ontario Base Mapping. Four sub-catchment basins were identified. Surface water courses around the expansion lands were inspected in the field. Site walk-overs were completed with several of the adjacent landowners. Those neighbours provided personal knowledge of the surrounding lands, and gave permission for access to their properties for monitoring and geological/hydrogeological mapping. A surface water monitoring program was established starting in May 2003. Monitoring, which is ongoing, includes manual
measurements of streamflow at selected stations on a monthly frequency, field analysis of routine chemistry parameters, and chemical analysis of water samples from selected locations. This program is carried out in conjunction with the routine groundwater and surface water monitoring program that is undertaken for the existing quarry operation.

(iv) Hydrogeological testing on the expansion lands included in-situ hydraulic conductivity testing in 2003 at the BH02 and BH03 series of boreholes, except BH03-7 which is too shallow. Initially, the standing water in each borehole was purged to assist with the development of the borehole as a monitor. The testing, which utilized either falling head or constant head packer tests, provides a vertical profile of the hydraulic conductivity of the bedrock in the immediate vicinity of each borehole. The results of previous pumping tests at the existing quarry operation, together with low-rate short-term pumping tests that were undertaken at selected borehole locations on-site and at the nearby Kenwell farm well located west of the Duntroon Quarry, were used to provide additional information for the determination of the hydraulic characteristics of the dolostone. Well capacity testing was completed in October 2004 in the two northern water supply wells at Camarthen Lake Farms (wells CLF1 and CLF2 in Figure 2-1), in response to a request from the landowner. Additional pumping tests are to be carried out in newly constructed water wells located in the southwest corner of the expansion lands as part of the ongoing assessment of the general hydraulic and karstic characteristics of the Amabel dolostone bedrock.

(v) A groundwater monitoring program was initiated at the borehole locations starting in May 2003. Water levels have been measured on a monthly basis at the on-site monitors and at selected residential water wells located around the expansion lands. Automatic water level dataloggers were installed at three borehole locations (BH02-1, BH02-4 and BH03-09) in May 2005 as part of the karst assessment.
(vi) A door-to-door survey of residents around the expansion lands was undertaken in 2003. Residents were asked to provide information related to their water supply systems and waste water disposal systems. Some residents who previously had been surveyed were not included in the 2003 survey.

(vii) An open-house for neighbours was held on February 13, 2003 to present information on the proposed undertaking. As well, meetings were convened with staff from several of the regulatory agencies on June 4 and October 29, 2003. A field visit with agency staff was held on June 20, 2003. A technical meeting was held on November 21, 2003 with staff from the Ministry of the Environment Southwest Region and the Nottawasaga Valley Conservation Authority, to discuss groundwater, surface water and biological aspects of the application. General details of the field investigation and monitoring programs were provided to agency staff at that time.

(viii) The computerized water well records for Clearview Township in Simcoe County and for the Municipality of Grey Highlands (formerly Osprey Township) in Grey County were obtained from the Ministry of the Environment. The well records were used to provide general information with respect to the regional geology, as well as residential and agricultural water supplies in the vicinity of the expansion lands. Published Ministry maps and other publicly available reports were used to obtain background information on the hydrogeological setting specifically as related to the lateral extent of the Amabel aquifer within the study area.

(ix) Commencing in the spring of 2004 and continuing in 2005, a program to assess the karstic nature of the dolostone rock was initiated using recognized karst specialists. This program is ongoing, and field testing began in the fall of 2004. Results will be documented in a separate addendum report in 2005.
The geological, groundwater and surface water information that was collected from the expansion lands and from the surrounding properties was compiled and analyzed to document the physical setting of the area. The existing conditions at the quarry combined with historical monitoring data provide a case-history of extraction and dewatering operations at the quarry. This information, together with predictive modelling were used as a basis for assessing the potential effects on local groundwater and surface water resources that may occur as a result of the proposed quarry operations on the expansion lands. Options to mitigate potential impacts and contingency plans were developed, and long-term rehabilitation of both quarries was evaluated. Given the nature of groundwater movement in fractured rock, the magnitude and location of potential future effects on local water resources will be variable, and the options for mitigation and associated contingency plans must by necessity be feasible, practical and adaptable to address a variety of potential impacts.

A three dimensional computer model of the regional and local geological and hydrogeological setting was developed to assist with the assessment of potential impacts on water resources due to the proposed quarry operations. The model was developed in conjunction with the manual interpretation of the field data, and it is also used for input to the evaluation of options for mitigation, as well as the plan for long-term rehabilitation of the existing and proposed quarry operations.

A groundwater and surface water monitoring program to monitor the progressive effects of extraction and dewatering operations both at the existing quarry property and at the expansion lands is provided. The proposed extraction on the expansion lands will occur in specifically-defined phases, and the monitoring program will be modified periodically to reflect the extent and location of quarrying activities. A monitoring program with respect to biological aspects is provided by Stantec (under separate cover).
(xiii) The results of the geological and hydrogeological assessment as they address the objectives contained in Section 1.2 are contained in this report.

3.0 SITE CHARACTERIZATION

3.1 REGIONAL TERRAIN CONDITIONS

The general physical setting of the area is illustrated on Figure 3-1. Figure 3-1(a) provides a satellite image of the area. The area is located within and/or adjacent to the Niagara Escarpment physiographic region, as described by Chapman and Putnam, (1984). Below and to the east of the Escarpment is the Simcoe Lowlands physiographic region that slopes gently towards Nottawasaga Bay to the north. To the west of the Escarpment is the Horseshoe Moraines physiographic region that in the area around the expansion lands consists of relatively shallow stony glacial till and/or silt soil overlying the bedrock. Further to the west, there are also areas of sand deposits that are glacial ice-contact and/or fluvial in origin. The Beaver Valley physiographic region is located further to the west, and stretches approximately 35 km northwards from Flesherton to Thornbury, where the Beaver River flows into Nottawasaga Bay.

The dominant terrain feature in the vicinity of the expansion lands is the steeply sloping land of the Niagara Escarpment that is present to the east and north. The brow of the Niagara Escarpment is located in excess of 400 m to the east of the extraction area at its closest point. The brow has an elevation generally in the range of about 500 to 535 m asl, is more than 320 m above the lake level at Nottawasaga Bay. The dolostone rock of the Amabel Formation, which forms the erosion-resistant cap-rock at the brow of the Escarpment, often is visible as near-vertical cliffs that can be in the order of 30 to 40 m high. Near the face of the Escarpment, large blocks of dolostone rock slowly break away from the face and in places leave deep crevasses such as are present at the Singhampton Cave area, to the north of the expansion lands, and also at the Scenic Caves at Blue
Mountain further north. Karst features such as sinking streams and small sinkholes are present along the top of the Escarpment and affect local surface drainage patterns in the area.

To the east of the expansion lands, the Escarpment is oriented approximately north-south down to the Mad River at Devil’s Glen. To the north, the Escarpment is oriented east-west where it forms the south wall of the Pretty River valley. To the west of the Escarpment, the land surface comprises a series of low rounded hills that are 20 to 30 m in height and which are separated by flat-lying valley lands and associated surface drainage courses.

The hills are formed by knobs of bedrock that typically are covered by a relatively thin veneer of soil. Chapman and Putnam indicate that the highest point of land within this area occurs on one of the hills that overlooks Edward Lake, between the existing quarry and Singhampton, and has an elevation of approximately 545.6 m asl (1790 feet asl).

The re-entrant valley in the Niagara Escarpment through which the Beaver River flows is another significant physical terrain feature that influences regional surface drainage and groundwater movement to the west of the subject lands. A deeply incised section of the Beaver River is located approximately 22 km to the west of the expansion lands. The valley is about 10 km across at its widest point, and the flat valley floor is about 200 m below the rim in the central section between Heathcote and Kimberly.

The terrain across the expansion lands is typical of the area and consists of a series of knobby hills that are bedrock-controlled, from which the land surface slopes away in a generally radial pattern into local surface drainage features in the lower-lying areas. The individual hills attain an elevation of slightly above 530 m asl, and the lower lying areas have an elevation of approximately 510 to 515 m asl. Surface grades typically are in the range of 10% to 20% or steeper on the sideslopes of the hills. In the low-lying areas in the northwest and northeast corners of the expansion lands, surface topography is flat, with grades less than about 0.4%.
3.2 REGIONAL CLIMATE AND WATER BUDGET

3.2.1 Climate

Climate data that are used in hydrogeologic studies generally are obtained from the closest active climate station with at least 30 years of monitoring data. Environment Canada routinely calculates 30 Year Normals (or averages) for active climate stations that have at least 30 years of data every 10 years (for example 1951 to 1980; 1961 to 1990 and 1971 to 2000). These 30 Year Normals are used as a historical baseline against which recent climate data can be compared to determine if a particular year or month is wetter or drier than normal. For this study, the recent climate data is compared to the 30 Year Normals for the period 1971 to 2000.

In this instance, the closest climate station to the study area with at least 30 years worth of data is the Thornbury Slama Station of Environment Canada. This station is located below the Escarpment at Thornbury, approximately 25 km northwest of the expansion lands. Historically, data from the Thornbury Slama Station was used to assess annual water budget components as part of the monitoring programs. It is recognized that the station is located below the Escarpment and that there is about 300 m of vertical relief between the two locations, such that some differences between local weather patterns will occur.

There is another climate station located at Ruskview, about 20 km southeast of the expansion lands, and which is much closer in elevation to that of the expansion lands. Unfortunately, that station only reports data from November 1985 to 2000 and does not have 30 years of records. Based on a comparison of the monthly precipitation data from both stations as shown in Appendix D, the annual average precipitation between 1986 and 2000 was 1013 mm for the Thornbury Stama Station and 1000 mm for the Ruskview station, which are within 1.3% of each other. The annual precipitation for the Thornbury Slama Station based on the 30 Year Normals is 966 mm, which is slightly lower than the 15-year averages. On this basis, the 30 Year Normal climate data for the Thornbury Slama
Station are considered to be reasonably representative of general climatic conditions both below and on top of the Escarpment, and are used for this assessment.

The 30 Year Normal climate data and the calculated water budget, together with recent climate data and water budgets for 2003 and 2004 from the Thornbury Slama Station are provided in Appendix D in Tables D-1, D-2 and D-3 respectively. Figures D-1 and D-2 in Appendix D provide a graphical plot of the monthly precipitation and water surplus for 2003 and 2004 respectively. The 30 Year Normal data are also provided on the figures for comparison.

2003 was a slightly wetter year (by 35 mm) compared to the 30 Year Normals, with the months of January, October, November and December receiving at least 10% more precipitation than normal. The precipitation during the other eight months was either similar to, or less than, normal.

Overall, 2004 was slightly wetter than normal (by 55 mm); however, the individual monthly totals varied from being substantially wetter to substantially drier than normal. For example, the precipitation in January, March, May and December was considerably higher than normal, and contributed additional water to surface run-off and groundwater recharge. Precipitation in May was approximately 222 mm, compared to the 30 year normal value of 71 mm.

In contrast, the months of February, April and June through September received considerably less rainfall than normal. The total amount of rainfall through the late spring and summer months was 152 mm, compared to a normal value of 336 mm, with September’s total being only 15.4 mm compared to the normal value of 94 mm.

In summary, whereas the 30 year normals provide a general measure of the long-term average conditions, individual months and sometimes seasons in a particular year can exhibit considerable variation compared to those average trends. However, for assessment
purposes, the long-term data are useful in characterizing typical climatic conditions that reasonably can be expected to occur within a given geographic area over an extended period of time, recognizing that actual short-term patterns will be variable.

3.2.2 Water Budget

The temperature and precipitation climate data are used to calculate a general water budget for the area that provides a measure of potential evapotranspiration losses of the precipitation, which represents water lost to evaporation and/or uptake by vegetation. The difference between the monthly precipitation and the monthly evapotranspiration yields the estimated water surplus or deficit for that month, and similarly for the annual totals. The estimate of potential and actual evapotranspiration is based on the method originally developed by Thornthwaite, and incorporates a water holding capacity for the soil, which is taken into account in the calculation of the actual water surplus. The annual water surplus is a measure of the amount of water that is available for surface runoff and groundwater recharge. Environment Canada provides a service to estimate potential and actual evapotranspiration values based on daily climatic data, which are summed monthly. Climatic data are summarized below.

<table>
<thead>
<tr>
<th></th>
<th>30 Year Normals</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1971-2000)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Precipitation (mm)</td>
<td>966</td>
<td>1004</td>
<td>1021</td>
</tr>
<tr>
<td>Potential Evapotranspiration (mm)</td>
<td>598</td>
<td>589</td>
<td>638</td>
</tr>
<tr>
<td>Actual Evapotranspiration (mm)</td>
<td>571</td>
<td>568</td>
<td>516</td>
</tr>
<tr>
<td>Potential Water Surplus (mm)</td>
<td>368</td>
<td>415</td>
<td>383</td>
</tr>
<tr>
<td>Actual Water Surplus (mm)</td>
<td>395</td>
<td>436</td>
<td>505</td>
</tr>
</tbody>
</table>
The water surplus represents the amount of water that is available on an annual basis for infiltration into the ground surface to recharge the groundwater flow system and for surface runoff to the creeks. The partitioning of the annual water surplus into the groundwater recharge and surface water runoff components is usually estimated based on the surface topography or slope of the land that is present in a particular area, the soil or rock type present and the type of vegetation that is present. The Ministry of the Environment has provided estimates of infiltration factors for various types of slope, soil and vegetation in their land development guidelines. For the general conditions present across the expansion lands and the surrounding area, the infiltration factor is estimated to be as follows.

<table>
<thead>
<tr>
<th>Infiltration Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope: Hilly land to rolling land 0.1 to 0.2</td>
</tr>
<tr>
<td>Soil type: Medium combinations of clay and loam to exposed fractured bedrock. 0.2 to 0.4</td>
</tr>
<tr>
<td>Cover: Cultivated lands to woodland 0.1 to 0.2</td>
</tr>
<tr>
<td>Overall Infiltration Factor Range 0.4 to 0.8</td>
</tr>
</tbody>
</table>

Based on this likely range of infiltration values, the annual water surplus can be separated into groundwater recharge and surface runoff components as follows.

<table>
<thead>
<tr>
<th>Annual Surplus</th>
<th>Groundwater recharge</th>
<th>Surface Water Runoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 Year Normals (395 mm)</td>
<td>158 to 316 mm per year 0.05 to 0.10 L/s/ha</td>
<td>237 to 79 mm per year 0.075 to 0.025 L/s/ha</td>
</tr>
<tr>
<td>2003 Data (436 mm)</td>
<td>174 to 349 mm per year 0.055 to 0.11 L/s/ha</td>
<td>262 to 87 mm per year 0.083 to 0.028 L/s/ha</td>
</tr>
<tr>
<td>2004 Data (505 mm)</td>
<td>202 to 404 mm 0.064 to 0.128 L/s/ha</td>
<td>303 to 101 mm 0.096 to 0.032 L/s/ha</td>
</tr>
</tbody>
</table>
In areas where the slope and/or nature of the land changes significantly (such as on the Escarpment or in low-lying wetland areas as extreme examples), the partitioning of recharge and runoff will vary from that indicated above. In addition, the presence of karst features at the ground surface, such as sinking stream channels and suffusion dolines, particularly near the brow of the Escarpment, will also affect the proportions of recharge and runoff that occur. In the vicinity of the Escarpment, the entire water surplus (or more) may recharge the local groundwater system above the Escarpment to become groundwater discharge springs at the Escarpment face that drain into local surface water courses on the Escarpment slope below.

3.3 GEOLOGY

3.3.1 Regional

The study area has been glaciated on a number of occasions. However, the area on top of the Escarpment and around the existing quarry and the expansion lands contains relatively little surficial soil material for the most part, and bedrock outcrops are present along the road cuts and as natural exposures. This pattern is common along the top of the Niagara Escarpment throughout much of southern Ontario. Quaternary mapping for the area (Burwasser, 1974) notes either “bedrock” or “thinly covered” bedrock in the vicinity of the Escarpment and the proposed quarry. Glacial materials comprised of outwash sands and tills are noted on the lower flanks of the Escarpment.

Figure 3-2 illustrates the bedrock geology of the area around the expansion property. The Paleozoic rocks of southern Ontario are part of a sequence of sedimentary rocks deposited near the edge of a large marine embayment during the Middle Silurian Period approximately 400 million years ago. The marine basin, called the Michigan Basin, with a centre in what is now Michigan. Duntroon is near the northeastern edge of the Basin. Regionally, the bedrock strata dip gently toward the south-southwest into the centre of the Basin at approximately 5 to 10 metres per kilometre (0.3 to 0.6 degrees). The bedrock
consists of a thick sequence of relatively undisturbed sedimentary limestones, dolostones and shales, that at the edge of the basin, in Ontario subcrop as a sequence of parallel northwest – southeast trending bands that become progressively younger in a northeast to southwest direction. The bands of rock types, combined with the gentle southwesterly slope and their different resistances to erosion, have led to the formation of several north-facing escarpments where a resistant cap rock such as dolostone overlies a less resistant unit such as shale. The most prominent of these escarpments is the Niagara Escarpment which can be traced from northern Michigan, through southern Ontario, and into western New York.

Figure 3-3 is a cross sectional sketch of the geologic units present in the vicinity of the Duntroon Quarry drawn from west to east along Simcoe Road 91. The Amabel Formation, which is a dolostone, is the surface rock unit (cap rock) which is often exposed along the Escarpment brow, and occurs near ground surface for several kilometres to the south and west. The Fossil Hill Formation is a dolostone unit with thinner bedding which underlies the Amabel Formation. The Amabel Formation is quarried at the existing operation, and has been used to manufacture a variety of aggregate products. It is the Amabel Formation that is proposed to be quarried at the expansion lands.

The Amabel Formation is recognized as a provincially significant aggregate resource, and has been used to manufacture a variety of products, including crushed granular, asphalt and concrete products, building stone and lime.

The full sequence of rocks present in the Niagara Escarpment near Duntroon is summarized in the table below. The Amabel Formation rock is exposed at the Duntroon Quarry and in several road-cuts nearby. The Fossil Hill Formation and the underlying Cabot Head Formation (shale) are not exposed near Duntroon, but both formations were encountered in boreholes that were drilled on the expansion lands and in the existing quarry. The Manitoulin Formation is exposed in a number of small, abandoned quarries in a secondary scarp (Manitoulin Scarp) located east of the quarry near Concession Road 10. The
Whirlpool Formation sandstone is exposed in the floor of a small abandoned quarry on the south side of Simcoe Road 91, west of Concession Road 10 (the Swinton Property). The red shale of the Queenston Formation is not generally exposed, but gives the overlying soils a characteristic “brick red” colour to the east of Concession Road 10.

<table>
<thead>
<tr>
<th>FORMATION</th>
<th>ROCK DESCRIPTION</th>
<th>APPROXIMATE THICKNESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amabel</td>
<td>Grey medium to coarse grained fossiliferous dolostone (reefal and flank facies)</td>
<td>15 to 40 + m</td>
</tr>
<tr>
<td>Fossil Hill</td>
<td>Grey thin bedded fossiliferous dolostone</td>
<td>5 to 10 m</td>
</tr>
<tr>
<td>Cabot Head</td>
<td>Red to greenish grey shale with limestone interbeds</td>
<td>10 m</td>
</tr>
<tr>
<td>Manitoulin</td>
<td>Grey medium grained argillaceous dolostone</td>
<td>15 m</td>
</tr>
<tr>
<td>Whirlpool</td>
<td>Grey fine grained quartz sandstone</td>
<td>2 m</td>
</tr>
<tr>
<td>Queenston</td>
<td>Red shale with siltstone and carbonate layers</td>
<td>84 m</td>
</tr>
<tr>
<td>Georgian Bay</td>
<td>Grey shale with limestone interbeds</td>
<td>120 m</td>
</tr>
</tbody>
</table>

Figure 3-3 also illustrates the presence of groundwater springs that occur on the slope of the Escarpment at the base of the Amabel/Fossil Hill dolostone and at the base of the Manitoulin dolostone. To the west of the Escarpment face, the underlying Cabot Head shale bedrock tends to restrict the vertical movement of groundwater in the dolostone units, and springs develop at the Escarpment face.

3.3.1.1 Niagara Escarpment Brow

The Niagara Escarpment Plan requires that the extraction area for any new quarry licence be situated a minimum of 200 m behind the brow of the Niagara Escarpment.
The “Escarpment Brow” is defined in the Niagara Escarpment Plan (2005, page 121) as

“the uppermost point of the Escarpment slope or face. It may be the top of a rock cliff...”.

The geological definition of “brow” states

“The projecting upper part or margin of a steep slope just below the crest; the edge of the top of a hill or mountain, or the place at which a gentle slope becomes abrupt.”

(Glossary of Geology, American Geological Institute, 1997, p. 84).

The brow of the Niagara Escarpment in the vicinity of the Duntroon Quarry and Expansion Lands is a well developed classical bedrock feature which fits both the Niagara Escarpment Plan and the geological definition. The brow is located in excess of 400 m east of the proposed extraction area at its closest point, and is marked on Figure 3-2. It is noted that there are several rounded elongated hills on and around the expansion land property. These are bedrock features relating to the presence of reef structures in the upper portion of the Amabel Formation, and they have no relationship with the Niagara Escarpment other than the fact they occur in the Amabel Formation dolostone.

### 3.3.2 Karst Features

When carbonate rocks such as the dolostone of the Amabel Formation are elevated above sea level, they are susceptible to dissolution by precipitation and surface water, particularly when the water is mildly acidic. This process is known as karstification, the net result of which forms karst topography at ground surface and channels/conduits in the rock below ground. The degree and severity of karst development within a particular area is subject to many controlling factors, such as rock type and geologic structure, climate, regional and local topography, and surface drainage conditions.
Infiltrating surface water can enlarge fractures in the rock at or near ground surface that results in sinking streams/sinkhole features, and that water also moves along bedding planes and fracture planes and other structural discontinuities within the rock mass to create preferential flow paths of groundwater movement through the rock. The factors that affect the development of karst features can be highly variable, both regionally and at the local scale, which results in variable groundwater flow conditions.

As summarized in the Grey and Bruce Counties Groundwater Study report (2003), areas that contain karst features are relatively common on the Bruce Peninsula, and there are karst features present within the study area. Features include occasional sinkholes and sinking streams, groundwater springs at the Escarpment face and occasionally at other locations, and preferential groundwater movement along solution-enhanced bedding planes and/or fracture planes.

Investigations on the expansion property identified an exposure of dolostone in the western section with enhanced surface fractures in the rock and indications of internal drainage. This feature illustrates that karst development has occurred on the property. Surface depressions that also show internal drainage occur to the east of the property on the former Bridson property (now owned by Georgian), and to the north on the Urbaniak property.

Geological traverses in the vicinity of the Escarpment brow to the east of the expansion lands identified a number of depressions which meet the definition of a ‘sinkhole’. They are several metres across, several metres deep, have internal drainage, and tend to occur in an east-west orientation. Many of these features may be observed between the Bruce Trail and the brow of the Niagara Escarpment, to the east. Most of the features do not contain bedrock exposures, and several exhibit a classical conical shape.
One example of a karst feature in the area is a sinkhole and a sinking stream located south of the existing quarry on the Redpath property, near the unopened road allowance for 21/22 Sideroad. A stream which drains the large wetland south of the existing quarry drains southward and flows into a 20+ m diameter sinkhole with a depth of approximately 6 m. That stream flows out of the wetland in a well defined channel, enters the sinkhole, and disappears into a pile of boulders at the edge of the hole. There is no outlet for surface drainage from the sinkhole, and the bottom of the sinkhole typically shows no standing water. Silt is exposed in the bank of the stream, but bedrock is not visible. There are several additional smaller and less well-defined depressions in this general area which may also be small sinkholes.

The karst features noted above occur on the area underlain by the Amabel Formation. Also, it is recognized that many of the features are situated on the flanks of several large reefal bedrock structures which are characterized by their distinctive elevated topography.

The existence of the karst features noted above indicates that karst is developed in the area, and that some karst development occurred on and adjacent to the proposed extraction area. A detailed assessment of karst development on and around the expansion lands was initiated as a result of the initial observations. The extent and significance of karst features is the subject of an on-going investigation by specialists in this subject. Detailed field testing and assessment was initiated in the fall of 2004 and is continuing in 2005. An addendum report is to be prepared to document the findings of that work and to evaluate the results relative to the proposed mining plan.
3.4 SITE AND ENVIRONS

3.4.1 Site Investigations

A description of the soil cover and the underlying bedrock through the Amabel and Fossil Hill Formations and into the top of the Cabot Head Formation is provided in the borehole logs in Appendix A. Borehole locations are illustrated on Figure 2-1. Borehole logs are provided for the following locations.

Expansion Lands

a) Nine HQ-size cored boreholes on the expansion lands designated BH02-1 to BH02-6 and BH03-7 to BH03-9 inclusive that were drilled in 2002 and 2003 respectively.

b) MOE drillers’ records for three 150 mm diameter test wells / observation wells that were constructed in the vicinity of BH03-9 in the southwest corner of the expansion lands in August 2004.

c) Four shallow hand auger hole logs designated Bridson Drivepoint, and HA1 to HA3 that are located in the wetland areas on the former Bridson property to the east of the proposed extraction area and in the wetland north of the extraction limit. A sample of the overburden soil from HA3 was subjected to a particle size analysis, the results of which are also provided with the log.

Existing Quarry Property

(a) Thirteen exploratory HQ-size cored boreholes within the existing quarry property designated 98-1 to 98-13 that were drilled in 1998.

(b) Three 150 mm diameter test wells within the existing quarry property designated PW99-1 to PW99-3, and two 150 mm diameter observation wells designated OW99-1 and OW99-2, that were drilled in 1999. PW99-1 was drilled by a
licensed water well driller, and the remainder of the holes were drilled using an air-track drill rig.

(c) Four shallow hand auger drivepoint monitor holes designated DP99-1 to DP99-4 that were installed in 1999 in the wetland features to the west and south of the existing quarry. These locations are also designated DP1 to DP4 on some figures.

(d) Brief descriptive logs provided in the July 1991 draft report by Trow Dames and Moore on the pumping test at the existing quarry. Drilling locations are designated as PW1 (pumping well), OW1, OW2 (believed to be MW2), MW3, MW4 and MW5.

**Osprey Quarry Property**

a) Brief descriptive logs provided in the 1982 report by Hydrology Consultants on an investigation of water table conditions at the Osprey Quarry property. Records are provided for boreholes designated as 101 to 104. Logs for other holes that were drilled at the Osprey property were not available.

**Cross Sections**

Figure 3-4 illustrates the orientation of several cross sections that were constructed through the area to illustrate the geologic setting of the expansion lands and the existing quarry. Figure 3-5, Cross Section A-A’, which extends through Edward Lake in the south, through the existing quarry and the expansion lands, and through the Niagara Escarpment to the north, summarizes the geology beneath the two properties in the context of the general sequence of bedrock that forms the lower slope of the Escarpment. Figure 3-6, Cross Section B-B’ extends from Edward Lake northeastwards through the existing quarry to illustrate the geology and groundwater conditions between the quarry and the lake.
3.4.2 Overburden

The expansion lands are located above the Niagara Escarpment on the thinly covered bedrock surface. Bedrock outcrops occur at several locations along the roads and at several locations on the property. There is, however, a fairly consistent layer of silt to fine sand that obscures the bedrock. Figure 3-7 illustrates the thickness of the overburden at the borehole locations on the expansion lands and at the existing quarry. On the expansion lands, this veneer is commonly 1 m to 3 m thick, but locally is 9 m thick at borehole BH02-5. At borehole BH03-8, the overburden is 6.2 m thick and consists of silt till. There are, however, no significant glacial overburden landforms on the expansion lands.

A similar silt/fine sand covering is observed on adjacent lands. The overburden in the existing quarry property was up to 7.6 m thick at borehole 98-8 in the southwest corner and 8.6 m thick at borehole 98-13 at the eastern limit of the quarry where it consists of a silty clay till with occasional boulders. At 98-8, the till becomes sandy below 3.1 m.

Figure 3-8 illustrates the elevation of the top of the bedrock surface at the borehole locations. On the expansion lands, the highest elevation of the top of the bedrock in the boreholes is 528.7 m asl at borehole BH02-4 located on the top of the hill on the former Millar farm, and the lowest elevations are 503.9 m asl and 503.7 m asl at boreholes BH02-5 and BH03-7 respectively. These boreholes are located along the northern limit of extraction adjacent to the wetland feature. To the north of the wetland, the ground surface rises to form another hill. It is inferred that the bedrock surface also rises, such that the wetland developed in a local trough in the bedrock surface. Within the wetland, the soils at HA2 and HA3 consisted of a 0.35 m to 0.5 m thick surficial layer of organic-rich silt to silt, underlain by silty fine to medium sand with some gravel and coarse sand and trace clay to a depth of 0.9 m to 1.2 m. Within the wetland feature on the former Bridson property, on the eastern side of the expansion lands, the soils at the drivepoint location and at HA1 consisted of organic silt at surface underlain by silt with trace to some sand and trace clay down to a depth of between 0.76 m and 1.2 m below ground surface.
A similar situation is present at the southwestern section of the existing quarry where the bedrock surface steps down to the west beneath the wetland, from an elevation of 518.7 m asl at borehole MW2 to approximately 509 m asl to 510 m asl at 98-8 and PW99-1. In the wetland to the west of the quarry, the soil profile at DP1 and DP2, and west of Grey Road 31 at DP4, consist of silty fibrous organic soil overlying silt with some clay or silt with some sand. The holes were terminated due to refusal (on assumed bedrock) at a depth of between 1.0 and 1.5 m (elevation 509.9 to 510.8 m asl).

To the south of the existing quarry in the closed basin wetland feature, the soil at DP3 consisted of 2.14 m of silty fibrous organics and organic silt underlain by grey silty sand in which the hole was terminated (elevation 511.4 m asl). Similar to the other wetland features, it is interpreted that the wetland has developed in a depression in the buried rock surface between the rock-knob hills on either side.

3.4.3 Bedrock

3.4.3.1 Lithology

Beneath the overburden cover is the dolostone rock of the Amabel Formation, which is the rock being mined at the existing quarry. Figure 3-9 presents the thickness of the Amabel Formation as determined at the borehole locations. Beneath the expansion lands, the Amabel attains a maximum thickness of 42.7 m at BH02-4, which is located on the top of one of the hills. Elsewhere, the Amabel Formation is between approximately 26 m to 40 m thick. An exception occurs in the area around BH02-5 and BH03-7, at the north end of the site near the wetland feature, where the surface of the buried rock was eroded down to elevation 504 m approximately, and the thickness of the Amabel is reduced to 14.7 m.

At the existing quarry, the Amabel Formation varies in thickness between 41.2 m at 98-9 in the northwest corner, to 21.5 m at 98-8 in the southwest corner.
The Amabel Formation contains a series of “reefal” structures and “flank” facies rocks at this location. The reefal rocks were originally deposited as coral reefs or bioherms in a shallow warm sea environment similar to that in the present-day Caribbean Sea. The reefs are composed of an irregular assemblage of corals, bryozoans, crinoids and other fossils. Over time, these deposits became rock (i.e. dolomitized) and lost much of their original form, but there is evidence of the original organisms preserved in the rock.

The reefal rock materials are exposed in the existing faces in the quarry (Photo 2) and are recognized in the boreholes. The rock is irregularly bedded, fairly hard, somewhat brittle and contains occasional sizable fossil remnants. While the colour is variable, particularly where weathering has occurred, the freshly exposed rock is often a medium grey with a bluish cast.

The reefs were continually subjected to wave action, which broke up and eroded the components of the reef. Reef growth and wave erosion are opposing natural forces and consequently substantial amounts of broken skeletal remains of the reef-forming organisms were washed off the reef and into the adjacent deeper-water areas of the sea. Those materials were often broken to sand or fine gravel sized pieces, and settled in the deeper areas of the sea as successive and regular layers of fossil fragments. They are referred to as the “flank” facies of the reef. These materials were also dolomitized over time.
The flank materials exposed in the current quarry faces tend to be more regularly bedded, moderately hard and contain numerous small fragments of fossils. The colour is often light grey, becoming almost white when it is weathered, and it readily takes on a stained reddish colour where soil materials were washed down into fractures.

The two facies of the rock, the reefal facies and the flank facies, are well developed and fairly distinct in several exposed areas of the quarry. The reefs in the Amabel Formation rocks are commonly referred to as “patch” reefs. They are often metres thick and extend laterally several tens of metres. The flank facies rocks are the dominant rock type, and the reefal facies rocks tend to occur as patches or layers within the flank facies rocks.
The thickness of the Amabel Formation dolostone on the expansion lands ranges from 14.7 m at BH02-5 to 42.7 m at BH02-4, with an average thickness of approximately 30 m. Approximately one third of the rock is reefal facies and the remainder is flank facies. The base of the Amabel Formation occurs between elevation 485.5 m asl at BH03-9 and 489.9 m asl at BH02-2.

The rock cores obtained from the boreholes on the expansion lands confirm the general geology as established for the existing quarry.

The reefal portion of the rock mass exhibits little evidence of actual reef organisms in their original growth positions. It is apparent that much of the actual reef structure was obscured by either wave erosion or by diagenetic rock-forming processes. The rock does not exhibit a noticeably porous nature. The north wall of the quarry has exposed several occurrences of stromatoporoids (spherical algal growths), and at least one small pinnacle reef structure. The stromatoporoids are up to approximately two metres in size, and the pinnacle reef was approximately one to three metres wide and five metres in height. These features are localized zones in the rock which may be more porous; however, they are of limited size and represent a fraction of one percent of the rock mass. The blasting in the quarrying process occasionally pulverizes these features, as the rock is not as strong as the adjacent rock mass, and they can be visible as indentations in the quarry face. The presence of these features in the quarry face suggests that similar fossil features may be encountered in the expansion property, although none of the features were identified in the borehole rock cores.

A third unit of dolostone, known as the Fossil Hill Formation, occurs below the reefal/flank facies material described above. At the expansion lands, this unit is a finer grained dolostone with distinct thin (1 to 3 mm) shale partings. Chert was detected in this unit in boreholes on the expansion lands, but not in boreholes on the existing quarry property.
This unit has variously been described as a unit within the Amabel Formation or, more recently, as a separate unit called the Fossil Hill Formation. The unit is poorly exposed in the Bruce Peninsula to Collingwood area and is therefore not well documented.

Figure 3-10 presents the elevation of the top of the Fossil Hill Formation as interpreted from the boreholes. The contact between the two formations can be somewhat gradational and is based partly on a subtle colour change from light grey to bluish-grey, and partly on the presence of shale partings. Based on this interpretation, there is an overall dip to the west/southwest as expected, and there is a small undulation oriented approximately northeast to southwest in the top of the Fossil Hill beneath the expansion lands. Figure 3-11 shows the interpreted thickness of the Fossil Hill Formation based on the borehole data. The unit is approximately 4.0 m to 6.9 m thick at the expansion lands, and 4.9 m to 7.2 m at the existing quarry. It is not intended to mine the Fossil Hill Formation in the expansion quarry operation.

The Cabot Head Formation is present beneath the Fossil Hill Formation. The Cabot Head is a distinctive greenish grey shale with occasional limestone interbeds. This unit was encountered in the bottom of the deeper boreholes; it is of no interest as an aggregate resource. Figure 3-12 presents the elevation of the top of the Cabot Head Formation based on the borehole data, and the interpreted configuration of the contact with the overlying Fossil Hill Formation. The data indicate that the contact has an overall dip to the west/southwest as expected, and there are two undulation features in the top of the Cabot Head, particularly beneath the existing quarry property, with a less defined feature beneath the expansion lands.

3.4.3.2 Aggregate Quality

The Amabel Formation commonly is exposed along the brow of the Niagara Escarpment and as the uppermost bedrock unit for several kilometres to the southwest of the brow. The Amabel consists of fine to coarse grained dolostone of bioclastic origins, and medium to
coarse grained biohermal mounds or small reefs are common in many areas. Minor amounts of chert have been noted near the base of the formation (Bolton 1957, Liberty and Bolton 1971, and Hewitt 1960). The formation is 15 m to 40 m thick in this area.

The Amabel Formation is recognized as a provincially significant aggregate resource, and has been used to manufacture a variety of products, including crushed granular, asphalt and concrete products, building stone and lime. The presence of chert may locally limit the use of the rock, and the quality of the resource may vary due to the existence of reefs in the rock which display different physical quality. Regionally, test data are acceptable but, variable and suggest potential local concerns with respect to absorption, and possibly micro-Deval results. Experience from the Amabel Formation rocks in the Grey County – Collingwood area has also identified occasional elevated absorption values, but product performance has generally been acceptable from these materials.

The Duntroon Quarry has been producing aggregates for several decades, and the stone from the quarry has a well-documented history of meeting aggregate performance requirements. Test data from several of the boreholes on the expansion lands confirm the same geology and aggregate resource quality as the existing quarry. The test variability noted at a regional level has been observed at the quarry from time to time and elevated values for absorption have been encountered in the flank facies rocks. Elevated absorption values have not been associated with other physical quality concerns, and aggregate performance has been maintained through many years of production. Production blending commonly reduces test values to acceptable levels. Many local aggregate sources experience variable and occasionally elevated absorption values and local redimix and asphalt producers tend to use slightly higher cement and asphalt contents to address the greater absorption

The Duntroon Quarry produces a range of granular, asphalt and concrete sand and stone products, and the expansion lands are expected to produce similar commercial products.
3.4.3.3 Fracture Analysis

Fracture mapping was completed at 14 outcrops of the Amabel Formation totaling 137 fracture measurements, and at 7 outcrops of the Manitoulin Formation totaling 98 fracture measurements (see Appendix A for details). The Amabel Formation outcrops included faces at the existing quarry, as well as road cuts and natural outcrops in the area. The Manitoulin Formation outcrops included a former quarry at the Swinton residence on Simcoe Road 91, as well as natural outcrops and former small quarry workings in the area. There are no known outcrops (exposures) of the Fossil Hill Formation or the Cabot Head Shale Formation in the area.

The majority of the fractures that were mapped had dip angles that were vertical to sub-vertical (generally 85 to 90 degrees). Analysis of the results was completed for all of the fracture measurements combined from both rock formations, as well as individually for the fractures in the Amabel Formation and in the Manitoulin Formation. Since the fractures are vertical to sub-vertical, the rose diagram analyses results are used to identify sets of preferred orientations of fractures.

Figure A-8 from Appendix A is provided at the rear of this report and summarizes the results for the two rock formations. The fractures in the Amabel Formation outcrops show three sets of fracture planes, two of which are more dominant than the third set. The two dominant sets each exhibit major and minor preferred orientations, with the two major orientations being as follows.

Set 1: Trending 090° to 110° containing a total of 15.2% of fractures
     Mid-point bearing 100°

Set 2: Trending 135° to 150° containing a total of 12.2% of fractures
     Mid-point bearing 142.5°
The fracture patterns in the Manitoulin Formation outcrops include three reasonably equal preferred sets of fracture orientations, and any distinction between major and minor axes within each set is less evident compared to the Amabel Formation. The orientations of the three sets in the Manitoulin outcrops are reasonably similar to those in the Amabel Formations outcrops, but frequency of occurrence of each set is more consistent when compared to the Amabel.

The presence of the quasi-orthogonal fracture sets imparts a characteristic blocky appearance to exposures of the bedrock, particularly in the upper section of the Amabel Formation where it consists of flank facies bedded rock, and also in the Manitoulin Formation which is regularly and more thinly bedded. The blocky nature of the Amabel Formation flank facies rock can be seen throughout the existing quarry, particularly in the upper sections of the quarry walls that generally exhibit more fracturing than the lower sections. The blocks that are formed by the intersection of fracture planes and bedding planes include both small sections of rock formed by smaller fracture planes, as well as much larger volumes of rock that are formed by intersecting fractures that extend the full height of the quarry wall. The larger fracture planes tend to pass through bedding planes, indicating that the fractures were formed at some point following formation of the rock.

The existing quarry walls are oriented approximately north-south or east-west, and provide an opportunity to view the various fracture sets and associated blocky structure present in the Amabel Formation. For example, in the northwest corner of the quarry, the north wall is oriented approximately east-west and part of the wall is formed by a single full-face fracture plane. Further along the wall to the east, the sub-vertical trace of another full-face fracture plane oriented approximately north-south is exposed in the face. Full-face fracture planes with orientations similar to those identified by the fracture analysis are present at locations around the quarry, and they may be present as individual fractures or as a group of several fractures spaced 1 m to 2 m apart.
The surfaces of the fracture planes that are exposed in the quarry walls vary from being relatively flat and smooth, to more undulating and rougher, and the fractures may be open or closed. Open fracture planes tend to have an oxidized brown colouration, while closed fracture planes usually have a similar colour to that of the surrounding rock mass. Open fractures may be partially infilled with sediment. The sediment observed in the fractures is similar to the soil in the overburden, which may have entered the fracture with percolating groundwater at some point in the past. Some of the sediment may be the result of the overburden stripping process and/or due to the stockpiling of wash pond fines on the exposed bedrock surface above the extraction face.

3.5 HYDRAULIC CONDUCTIVITY

The hydraulic conductivity characteristics of the Amabel/Fossil Hill dolostone bedrock aquifer were investigated at the expansion lands and historically in the existing quarry through field testing that included detailed packer testing of the saturated rock column in individual boreholes, pumping tests and visual examination of the rock cores.

3.5.1 Packer Testing

Packer testing provides a measure of the bulk hydraulic conductivity of the rock mass in the near-vicinity of the borehole, typically within a radius of a few metres. Packer testing was completed below the groundwater table at each of the deep cored boreholes on the expansion lands in 2003, and in 1999 at BH98-8 in the southwest corner and at BH98-9 in the northwest corner of the existing quarry property. The packer testing involved hydraulic conductivity testing of discrete horizons within the borehole column by means of inflatable packers to isolate the individual test zones in the rock column. One of two types of tests was undertaken depending on the hydraulic response at a particular horizon: either a falling head (or “slug”) test, or a constant head test. Testing was completed at regular intervals throughout each borehole to provide a vertical profile of the horizontal hydraulic conductivity of the rock near the borehole. Since the rock mass includes reefal facies rock,
flank facies rock, fractured and/or bedded rock, and more-massive bedded rock, the hydraulic conductivity results obtained from the packer testing are variable through the rock column.

Results of the packer testing are provided on the borehole logs in Appendix A and are summarized in Tables B-8 to B-14 for the expansion land boreholes, and in Table B-15 for the two boreholes that were tested at the existing quarry property. Table B-16 provides a summary of the packer testing results, separated into the Amabel Formation reefal facies, Amabel Formation flank facies and Fossil Hill Formation. Figure 3-13 provides a cross section (C-C’) drawn from west to east through the expansion lands to illustrate the geology and the local variation in hydraulic conductivity both vertically and laterally between boreholes. Figure 3-14 provides a similar cross section (D-D’) drawn from north to south through the expansion lands and the existing quarry.

The results indicate the following bulk hydraulic conductivity ranges, geometric mean values, and spatial patterns as noted on the cross-sections.

<table>
<thead>
<tr>
<th>Rock Type</th>
<th>Range of Bulk Hydraulic Conductivity Values (m/s)</th>
<th>Geometric Mean (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amabel Reefal</td>
<td>$1 \times 10^{-7}$ to $4 \times 10^{-5}$</td>
<td>$1 \times 10^{-6}$</td>
</tr>
<tr>
<td>Amabel Flank</td>
<td>$5 \times 10^{-8}$ to $2 \times 10^{-5}$</td>
<td>$7 \times 10^{-7}$</td>
</tr>
<tr>
<td>Fossil Hill</td>
<td>$6 \times 10^{-10}$ to $4 \times 10^{-6}$</td>
<td>$2 \times 10^{-8}$</td>
</tr>
<tr>
<td>Cabot Head Shale</td>
<td>One value $5 \times 10^{-8}$</td>
<td></td>
</tr>
</tbody>
</table>

➢ The bulk hydraulic conductivity values observed at the two locations in the existing quarry are similar to those observed at the expansion lands.
➢ Where reefal zones are present in the Amabel Formation, they usually overlie the flank facies rock, and since the reefal zones are located at the topographic high areas much of the reefal rock is situated above the water table.
At some borehole locations such as BH02-1 and BH02-4 on Figure 3-15, the flank facies rock includes zones that have bulk hydraulic conductivity values that vary by an order of magnitude or more, while at other locations any zoning is less evident.

At some borehole locations such as BH02-4, the lower section of the Amabel Formation flank facies unit exhibits a progressive decrease in the overall bulk hydraulic conductivity of the rock, while at other locations this trend is not apparent.

The Fossil Hill Formation unit typically has lower bulk hydraulic conductivity values compared to the overlying Amabel Formation units.

Overall, the reefal facies of the Amabel Formation tends to exhibit bulk hydraulic conductivity values that are slightly higher than those of the flank facies. The geometric mean value for the reefal facies is higher by about a factor of two compared to the flank facies, and the maximum and minimum values for the reefal facies are higher than those of the flank facies rock by a factor of approximately two. When viewed on a borehole by borehole basis, individual zones within each unit may exhibit a variation in bulk hydraulic conductivity values of two orders of magnitude or greater, and the flank facies rock in a particular borehole may have a geometric mean value that is similar to, or higher than, that of the reefal zone of rock in the same borehole.

The Fossil Hill Formation rock exhibits a much wider range of bulk hydraulic conductivity values compared to the Amabel Formation, and the geometric mean value is lower than those of the reefal and flank facies rock by factors of 58 and 28 respectively. Within the individual boreholes, the values observed in the Fossil Hill Formation typically are in the order of $10^{-8}$ m/s to $10^{-9}$ m/s, with some higher values that raise the overall geometric mean. The highest value observed in the Fossil Hill Formation was approximately $4 \times 10^{-6}$ m/s at the base of the unit in BH02-5 in the northern part of the expansion lands. Based on the bulk hydraulic conductivity values observed in the boreholes, the Fossil Hill Formation is considered to represent a zone of relatively low hydraulic activity with respect to
groundwater movement compared to the overlying Amabel Formation, although there may be exceptions locally.

There was only one bulk hydraulic conductivity value calculated for the shale of the Cabot Head Formation. The value is $5 \times 10^{-8}$ m/s in the upper section of the shale in BH02-1.

### 3.5.2 Pumping Tests

Pumping tests provide a measure of the response of groundwater in the aquifer over a relatively wide area due to the stress resulting from the removal of water from a pumping well. Pumping tests were carried out at various locations at the existing quarry in 1991 and 1999 as part of on-going operations. Short-term testing was undertaken in 2003 at the Kenwell farm residence supply well and at BH02-4 on the expansion lands, and also at the two northern wells CLF1 and CLF2 at Carmarthen Lake Farm in the fall of 2004. As well, a 24 hour pumping test was undertaken at the Osprey Quarry property in 1991 by Trow Dames and Moore Limited. Table B-17 provides a summary of the results from the 1999 testing in the existing quarry, and Table B-18 summarizes the results of pumping tests that have been undertaken in the general area.

The 1991 24-hour pumping test by Trow Dames & Moore at the existing quarry, which was carried out at a rate of 22.7 L/min (5 gpm) in the south central part of the quarry west of the then extraction face, provided an aquifer transmissivity value of approximately 5 m²/day and a hydraulic conductivity of approximately $2 \times 10^{-6}$ m/s.

The August 1999 pumping tests completed by Jagger Hims Limited were carried out at three locations in the existing quarry. The three wells were step-tested prior to the actual pumping test to determine the appropriate pumping rate for the tests. The test at PW99-1 at the southwest corner of the property was carried out for 72 hours at a rate of 227 L/min (50 gpm). The test at PW99-2 at the northwest corner of the property was carried out at a rate of 30 L/min (6.6 gpm) for 6 hours, commencing 25 hours after the start of the test at
PW99-1. The test at PW99-3 in the floor of the quarry in the southeast corner of the extraction area was carried out at a rate of 70 L/min (15.3 gpm) for 20 hours, commencing 47 hours after the start of the test at PW99-1. Water levels were monitored at various locations during the testing, and a variety of analytical methods for confined and unconfined aquifers was utilized to analyze the data. The resulting values of hydraulic conductivity ranged from a high of approximately $3 \times 10^{-3}$ m/s at BH98-8 in the southwest corner of the quarry property, to a low of approximately $7 \times 10^{-7}$ m/s at PW99-2 in the northwest corner. The geometric mean value for the rock mass was approximately $2 \times 10^{-5}$ m/s.

The short-term test at the Kenwell farm/residence supply well was carried out in 2003 at the request of the property owner to assess the general capacity of the system to supply sufficient water for the livestock through the winter. The test was carried at a rate of 24 L/min (5.3 gpm), which was the capacity of the in-place pump/plumbing system, for 2 hours. The hydraulic conductivity of the dolostone was estimated to be about $6 \times 10^{-5}$ m/s based on the test results.

The 1991 pumping test at the Osprey Quarry property by Trow Dames and Moore was completed at a rate of 1.1 L/s (15 gpm) for 24 hours. The early-time data from the pumping well yielded a hydraulic conductivity of approximately 1 to $2 \times 10^{-4}$ m/s, while the mid to late-time data yielded a value of $1 \times 10^{-6}$ to $7 \times 10^{-7}$ m/s. The drawdown data for one of the observation wells yielded a hydraulic conductivity of between 2 to $4 \times 10^{-4}$ m/s for the near-surface rock aquifer.

The short-term pumping test in the fall of 2004 at Carmarthen Lake Farm wells CLF1 and CLF2 were completed at rates from approximately 0.4 L/s to 1 L/s (5.3 to 13.2 gpm). The early-time data yielded hydraulic conductivity values of between $1.2 \times 10^{-6}$ m/s to $3 \times 10^{-6}$ m/s, while the late-time values were lower at $1.7 \times 10^{-7}$ m/s to $3 \times 10^{-7}$ m/s. Using the drawdown data from the other well, the hydraulic conductivity of the rock mass averaged about $5 \times 10^{-6}$ m/s. Overall, the geometric mean of the various values was $1 \times 10^{-6}$ m/s.
A short-term pumping test was carried out in 2003 in BH02-4 in the centre of the expansion lands at a rate of 37 L/min (8.2 gpm) for three hours to assess the aquifer characteristics at that location. A similar test was attempted at BH03-9 at the southwest corner of the property, but the pump had insufficient capacity to create a measurable drawdown beyond the pumping well. It is noted that the size and capacity of pump is restricted by the borehole diameter. As well, there is a groundwater spring present just to the west of BH03-9 which moderates the groundwater level at that location.

The results of the pumping tests are summarized below. The values are rounded to the nearest whole number.

<table>
<thead>
<tr>
<th>Pumping Test Location And Date</th>
<th>Estimated Hydraulic Conductivity of Aquifer (m/s)</th>
<th>Estimated Storativity of Aquifer</th>
</tr>
</thead>
<tbody>
<tr>
<td>PW1: 1991</td>
<td>$2 \times 10^{-6}$</td>
<td>$1 \times 10^{-3}$ to $3 \times 10^{-5}$</td>
</tr>
<tr>
<td>PW99-1: 1999</td>
<td>Geometric Mean $2 \times 10^{-5}$</td>
<td>$2 \times 10^{-1}$ to $8 \times 10^{-4}$</td>
</tr>
<tr>
<td>PW99-2: 1999</td>
<td>Geometric Mean $1 \times 10^{-5}$</td>
<td>$6 \times 10^{-5}$ to $2 \times 10^{-4}$</td>
</tr>
<tr>
<td>PW99-3: 1999</td>
<td>Geometric Mean $4 \times 10^{-5}$</td>
<td>$7 \times 10^{-1}$ to $5 \times 10^{-2}$</td>
</tr>
<tr>
<td>Geometric Means: 1999</td>
<td>Geometric Mean $2 \times 10^{-5}$</td>
<td></td>
</tr>
<tr>
<td>Kenwell: 2003</td>
<td>$6 \times 10^{-5}$</td>
<td>(late time data)</td>
</tr>
<tr>
<td>BH02-4: 2003</td>
<td>Geometric Mean $5 \times 10^{-6}$ late time data $1 \times 10^{-6}$</td>
<td>$2 \times 10^{-1}$ to $6 \times 10^{-4}$</td>
</tr>
<tr>
<td>Osprey Quarry Property: 1991</td>
<td>Early time data: 1 to $2 \times 10^{-4}$ m/s</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mid to late-time data: $1 \times 10^{-6}$ to $7 \times 10^{-7}$ m/s</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Observation well data: $2$ to $4 \times 10^{-4}$ m/s</td>
<td></td>
</tr>
<tr>
<td>Carmarthen Lake Farm CLF1 and CLF 2 Wells: 2004</td>
<td>Early time data: $2$ to $3 \times 10^{-6}$ m/s</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Late time data: $2$ to $3 \times 10^{-7}$ m/s</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drawdown at Observation Wells: $5 \times 10^{-6}$ m/s</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overall Geometric mean of all values: $1 \times 10^{-6}$ m/s</td>
<td></td>
</tr>
</tbody>
</table>

In summary, the results of the pumping tests and packer testing demonstrate that the dolostone rock exhibits variable hydraulic characteristics both laterally and vertically, as expected for a fractured and bedded dolostone aquifer. The values of hydraulic
conductivity obtained from packer testing typically are lower than those determined through pumping tests by a factor of about 5 to 10. The reefal facies rock in the Amabel Formation tends to have higher hydraulic conductivity values compared to the flank facies, and both have significantly higher values than the underlying Fossil Hill Formation. Based on the pumping test results, the hydraulic conductivity of the dolostone aquifer generally ranges between about $5 \times 10^{-5}$ m/s to $5 \times 10^{-6}$ m/s, with some zones that exhibit higher values (in excess of $2 \times 10^{-4}$ m/s) and some that are lower (less than $5 \times 10^{-7}$ m/s).

The results of the investigations completed to date indicate that the hydrogeologic setting of the expansion lands is similar to that of the existing quarry, such that the hydraulic characteristics of the Amabel Formation dolostone as determined at the quarry are applicable to the expansion lands also.

### 3.6 GROUNDWATER REGIME

#### 3.6.1 Regional Setting

The Amabel Formation dolostone is the main water supply aquifer for residential, agricultural and commercial activities above and to the west of the Escarpment. This aquifer, known as the Amabel Aquifer, is part of the Guelph and Lockport-Amabel Aquifer System, as described by the Ministry of the Environment (MOE) in its series on Major Aquifers In Ontario, 1978 mapping publication. That series describes aquifers considered to be of major lateral extent and which have the potential to yield water supplies above normal residential needs that would include municipal, industrial, commercial and irrigation uses. The Guelph and Lockport-Amabel dolostone rock formations extend from Niagara Falls to Tobermory. In vicinity of the expansion lands, the northern and eastern limits of the aquifer coincide with the geological extent of the Amabel Formation which outcrops at the face of the Niagara Escarpment.
Groundwater movement occurs along open sections of bedding planes and fracture planes, and causes preferential chemical dissolution of the dolostone along some discontinuities (i.e. karstification). The Ministry notes that, in general, the dolostone appears to be most transmissive in the upper 6 m of the rock, which is reflective of the greater number of fractures in that zone, and the accompanying karstification that can occur.

Underlying the Amabel Formation dolostone is the more thinly bedded Fossil Hill Formation dolostone, which typically is approximately 5 m to 10 m thick. For the purpose of this assessment, the Fossil Hill Formation is considered to be a low-activity basal section of the Amabel aquifer system.

Figure 3-15 provides an extract from the Ministry of the Environment Maps 78-4 and 78-5 (by M.E. Turner, 1978) to illustrate the extent of the Amabel aquifer and the general groundwater configuration in the vicinity of the expansion property. The mapping as originally published by MOE was based on available water well record information including the depth to the static water level in the wells at the time of construction and the depth at which water was found, as recorded by the well driller. The depth to the static water level was converted to an approximate elevation to develop the water level elevation contours shown on the map. Units on the map are in the Imperial system. The information provided on Figure 3-15 is as originally published by the MOE with the exception of the addition of the properties owned by Georgian Aggregates.

From well data on this map, the depth at which water was found ranged between approximately 8 m and 40 m. The static water levels in the wells ranged between 2 m and 21 m below grade.

The configuration of the groundwater contours on Figure 3-15 reflects the topography of the ground surface and the limits of the aquifer as defined by the Niagara Escarpment to the east and north, and the Beaver Valley re-entrant to the west. In effect, the aquifer is present in the form of a peninsular tableland of dolostone bedrock that is bounded by the
steep slopes of the Escarpment and the eastern valley wall of Beaver River. Based on the contours, there is a local groundwater high extending northeastwards into the area of the expansion lands, and another high further to the north resulting in a regional groundwater divide through the area. To the west, groundwater flow is interpreted to be westwards, towards the Beaver River valley. Adjacent to the Escarpment, groundwater flow is eastwards towards the Escarpment.

The Amabel aquifer is underlain by shale of the Cabot Head Formation. The shale is considered to be an aquitard which acts to restrict the vertical movement of groundwater. As a result, groundwater movement in the Amabel aquifer is generally sub-horizontal towards the Escarpment and the Beaver River valley in response to the prevailing hydraulic gradient. At the Escarpment face, groundwater discharges from the lower sections of the aquifer at or near the contact with the underlying shale. The discharge may occur both as diffuse seepage areas and as individual spring locations, similar to those present to the east of the expansion lands and the existing quarry. The groundwater springs form the headwaters of the many small tributary streams that feed into the larger rivers such as Batteaux Creek, Pretty River and Mad River, as illustrated on Figure 3-15.

Beneath the Cabot Head shale is the argillaceous dolostone of the Manitoulin Formation and the sandstone of the Whirlpool Formation. Both the Manitoulin and the Whirlpool Formations are considered confined aquifers though water yields typically are low. The shale aquitard that overlies these two formations restricts the amount of vertical groundwater recharge into the confined aquifers. Since the overall dip of the rock strata is towards the southwest, it is inferred that away from the influence of the Escarpment and the Beaver River valley, groundwater flow will be in a similar direction. In the vicinity of the Escarpment, groundwater movement in the Manitoulin and Whirlpool formations will be towards, and will discharge at, the face of the Escarpment. Field investigations at the Escarpment identified groundwater springs discharging from the face to the east and northeast of the expansion lands. In the area east of the expansion lands, some of the groundwater that discharges from the Amabel aquifer along the Escarpment face re-
infiltrates into the Manitoulin Formation where the Cabot Head shale was eroded. That groundwater travels through the Manitoulin dolostone the short distance to the Manitoulin scarp section of the Escarpment where it discharges.

Beneath the Whirlpool sandstone are the thick shale sequences of the Queenston Formation and the Georgian Bay Formation. Both of these shale formations are considered aquitards that restrict the vertical and horizontal movement of groundwater.

In summary, based on the above, for the purpose of this assessment the active groundwater system in the vicinity of the expansion lands consists of the Amabel aquifer. With the exception of the local discharge from the Manitoulin Formation at the Escarpment face, the groundwater systems in the bedrock beneath the Cabot Head shale are not considered further.

### 3.6.2 Groundwater Levels

Details of the groundwater monitoring that was undertaken are provided in Appendix B. Table B-1 provides details of the groundwater monitors that were constructed on the expansion lands, at the existing quarry and at the Osprey Quarry property. The table also provides general information with respect to the water supply wells that are monitored at the Camarthen Lake Farms property and the neighbouring residential wells that are part of the monitoring program. The groundwater elevation data are provided in the following tables, and hydrographs are also provided in Figure B-1 to B-58 as noted.

- Table B-2 Existing Quarry monitors starting in May 1995. Figures B-1 to B-21.
- Table B-3 Osprey Quarry monitors starting in April 1999. Figures B-22 to B-30.
- Table B-4 Proposed Expansion Lands monitors starting in March 2003. Figures B-31 to B-40.
Groundwater levels respond to prevailing climatic conditions, and exhibit a relatively consistent seasonal variation. Water levels generally are highest in the spring as result of the annual snow melt and spring rains. There is a progressive decline through the summer and early fall due to increased evapotranspiration losses. Water levels generally increase somewhat in the late fall and early winter as temperatures decrease and evapotranspiration lessens, followed by relatively constant conditions through the winter when most precipitation is bound up in the snow pack. Mid-winter thaws can also result in increased groundwater levels.

The magnitude of the seasonal variation generally is greatest at the topographically high groundwater recharge areas, with less seasonal variation occurring in the lower lying lands and adjacent to surface water courses and/or lakes that serve as groundwater discharge areas.

It is noted that since the recent monitoring program began, the lowest groundwater levels were observed during the fall of 2004. However, as a result of the snowmelt in the spring of 2005, groundwater levels rebounded to exhibit some of the highest levels for several years. Depending on location, groundwater levels in the rock typically increased by 2 m to 4 m, with groundwater levels at several locations increasing by 5 m to 8 m. However, by the end of May, groundwater levels at most locations had decreased to more typical seasonal values, which indicate that the effects of that high recharge event were short-lived.

The water level data and seasonal variation are discussed in the following subsections as general groupings based on the location of the monitors.
3.6.2.1 Existing Quarry

The earliest documented groundwater levels at the quarry are for November 1990 and February 1991 in the 1991 reports by Trow Dames and Moore. At that time, extraction in the quarry generally had not extended below the groundwater table. Based on data corrected for the survey error that had occurred, the groundwater levels around the perimeter of the quarry property varied between approximately 514 m asl to 515 m asl along the southern limit at MW2 and MW3, to approximately 515 m asl to 517 m asl in the northeast corner at MW4 and MW5. Since that time, mining occurred below the groundwater table to the elevation of 500 m asl, starting in the southern part of the quarry. Routine groundwater monitoring within the existing quarry property occurred since 1995. It is noted that extraction occurred down to the final floor elevation of 500 m asl in the southern part of the quarry prior to the onset of routine monitoring.

Based on the hydrographs for several of the monitors within the quarry, long-term groundwater levels around the perimeter exhibit a progressive decline since monitoring began due to extraction activities, in association with seasonal variation. Typical examples are illustrated by the hydrographs for MW6, PW99-2 and OW99-1 in Figures B-5, B-14 and B-15 respectively.

Other monitors show seasonal variation that is in the order of 1 m to 3 m, but with no apparent long-term decline since monitoring began. The hydrograph for MW5 in Figure B-4 is one example of this trend. Another example is the office/scalehouse water supply well that is located in the northeast corner of the quarry property. That well was drilled in July 1968, prior to any dewatering, at which time the static water level was 12.8 m below grade, or approximately elevation 519.7 m asl. The water elevation in the well in March and July 2004 was approximately 521.3 m asl and 520.2 m asl respectively, which is higher than when the well was drilled. The well is located underneath the office building (limited access) and is not monitored on a regular basis.
Groundwater levels in monitors that are located in the vicinity of the wash plant and the aggregate stockpiles, such as BH98-11 (Figure B-10) and Well E shop well (Figure B-6), have remained relatively high, given their location close to the extraction face. This is due to recharge by incident precipitation onto the stockpiles and/or process water that is spilled onto the ground and/or drains out of the washed aggregate in the stockpiles.

Water table conditions in the wetlands to the west of the quarry property are illustrated by the hydrographs for DP1, DP2 and DP4 in Figures B-18, B-19 and B-21 respectively. Water levels recorded in these shallow monitors indicate that the water table in the wetland adjacent to the quarry generally remains within the soil horizon that overlies the bedrock, although water levels seasonally decline to the base of the monitors that is inferred to be close to or on the bedrock surface. The seasonal variation in the soil horizon is in the order of 1 m, that is approximately elevation 511 to 512 m asl. The water table in the wetland adjacent to the quarry does appear to have been lowered at least seasonally as a result of quarry dewatering operations. The groundwater elevation in DP4 as shown in Figure B-21 in the wetland west of Grey Road 31 is generally within the range of 511.2 m asl to 511.6 m asl. The elevation of the water table recorded at DP4 is occasionally slightly higher than that at DP1 to the east, which may reflect an influence of quarry discharge water at the culvert at Grey Road 31, and/or dewatering operations at the quarry.

Water table conditions in the wetland to the south of the quarry are illustrated by monitor DP3. See Figure B-20 for details. Water levels range between approximately 512.5 m asl to 513.5 m asl on a seasonal basis, with the water table near the ground surface in the spring. Quarry operations do not appear to have affected the seasonal water table levels in this wetland area through the period of monitoring.
3.6.2.2 Osprey Quarry Property

The groundwater levels at the Osprey Quarry property exhibit normal seasonal variation. Water levels are a subtle reflection of the bedrock hill, and are lower around the flanks of the hill and higher towards the higher ground. Similarly, the seasonal variation of approximately 3 m to 4 m is greatest at Monitor 104-A (Figure B-25) compared to the monitors at a lower topographic elevation around the flanks of the hill, such as OW6-3, where there is a seasonal variation of less than 1 m (Figure B-30).

3.6.2.3 Expansion Lands

Groundwater levels beneath the expansion lands were monitored on a monthly frequency starting in May 2003. Water levels are measured in the open-hole monitors in the rock and are a subtle reflection of the bedrock / topographic surface, similar to those at the Osprey property. The highest groundwater elevations are recorded at the monitor pair BH02-3 and BH02-4, located on top of one of the hills on the expansion lands. The maximum recorded seasonal variation is from a low of elevation 517.5 m asl in December 2004 to a spring high of 526.3 m asl in April 2005, which is about 12.5 m to 3.7 m respectively below the ground surface. See Figures B-33 and B-34 for details. Monitor BH02-3 extends just into the seasonally high water table while BH02-4 extends through the full depth of the Amabel aquifer. When water is present in BH02-3, the elevation is consistently higher than the water level in BH02-4 by approximately 0.1 m to 0.3 m. Based on this configuration, there is a slight downward vertical hydraulic gradient in the rock at this location.

The elevation of the water table in the rock decreases in a radial pattern away from the topographic high. At the southern limit of the expansion lands, the groundwater elevation ranges seasonally from approximately 515.9 m asl to 522 m asl at BH02-6 (Figure B-36) in the central portion to about 515.7 m to 515.9 m asl at BH03-9 in the southwest corner (Figure B-39), and 511.6 m asl to 517.7 m asl at BH02-1 in the southeast corner (Figure B-31). The water level in BH03-9 exhibits only a small seasonal variation of approximately
0.1 m due to the presence of a groundwater spring located a short distance to the west and which flows year-round moderating the local groundwater level fluctuations.

Along the north limit of the expansion lands, the groundwater elevation in the rock varies seasonally from approximately 513.3 m asl to 515.9 m asl at BH03-8 (Figure B-38) in the northwest corner, to about 508.5 m asl to 510.8 m asl at BH03-7 (Figure B-37) and up to 511.5 m asl at BH02-5 (Figure B-35) in the centre where the lowest groundwater elevations are observed in those monitors. Similar groundwater elevations are expected in the northeast corner of the expansion lands, where the elevation of the ground surface decreases to the northeast. The two monitors at BH03-7 provide water level information in the overburden and shallow bedrock in the eastern end of the PSW wetland feature. The water table in the overburden soil (BH03-7-II) exhibits a seasonal variation of about 1.5 to 2 m (508.8 m to 510.7 m asl), with the spring high condition at or above grade. The water elevation in the shallow bedrock (BH03-7-I) is similar to that in the overburden, with apparent small vertical gradients that vary between downward to upward.

The water table in the wetland feature on the former Bridson property at the east end of the expansion lands is monitored at the drivepoint monitor designated Bridson DP. See Figure B-40 for details. At that location, the water table in the soil exhibits a seasonal variation of up to 0.6 m (509.9 m asl to 510.5 m asl)

3.6.2.4 Camarthen Lake Farms Wells

Camarthen Lake Farms has several water supply wells that are used for livestock watering and for the various residences that are present on the extensive property. Copies of the original water well records for the wells were provided by the Farm, although the correlation between the records and some of the actual well locations is tenuous. Water level monitoring was carried out at the five wells designated CLF1 to CLF5 on Figure 2-1, starting in June 1996. Monitoring currently occurs on a monthly frequency.
CLF1 and CLF2 are the closest wells to the existing quarry, and are approximately 700 m from the southern limit of the extraction face. The two wells are about 100 m apart and exhibit generally similar groundwater elevations for the most part, as shown in Figures B-41 and B-42 respectively. Elevations generally range between about 509 m asl to 511 m asl, although the spring high water level rose to about 512.4 m asl in CLF2 in April 2004 and 511.9 m asl in April 2005. The hydrographs for the two wells indicate that there was a slow but progressive decline in the groundwater levels in this area starting in about 1999. Summer seasonal groundwater levels declined from approximately 511.9 m asl in August 1997, to about 508.2 m asl in November 2004 at the end of an extended dry period. As noted above, water levels temporarily rebounded to 511.4 m asl at CLF1 and 511.9 m asl at CLF2 in April 2005.

Wells CLF3, CLF4 and CLF5 are located further to the south, and are closer to Edward Lake than CLF1 and CLF2. Based on the hydrographs for these wells as shown in Figures B-43 to B-45, the water levels and seasonal variations remained consistent over the monitoring period and reflect their proximity to Edward Lake.

3.6.3 Groundwater Configuration

The borehole monitors and the water wells are constructed as open-holes that extend into and sometimes through the dolostone rock strata of the Amabel Formation and the Fossil Hill Formation. The overburden soil, where present, is cased off with metal casing that is seated into the buried surface of the rock. The water levels that are obtained in the monitors and water wells provide a general measure of the water table and groundwater conditions through the rock column, rather than the piezometric pressure at a specific elevation within the rock mass that would be provided by a monitor that is screened across a specific horizon in the borehole. Since the open holes extend above and below the groundwater table, the water level in the holes represents general water table conditions in the rock.
Groundwater level elevations were contoured for specific occasions in 2003, 2004 and spring 2005 to illustrate the groundwater configuration and general flow directions in the Amabel aquifer in this area. Figure 3-16 presents the interpreted groundwater configuration for June 26, 2003, which is taken to represent the spring high condition for that year. Figure 3-17 presents the interpreted configuration for September 25, 2003, which is taken to represent the summer low groundwater condition for 2003. Groundwater levels for November 2004 and April 2005 are provided in Figures 3-18 and 3-19 respectively to illustrate the lowest summer/fall and highest spring recharge conditions observed to date. All four figures illustrate a consistent groundwater configuration and flow pattern, the only differences being that the water level elevations reflect the prevailing seasonal climatic conditions. The November 2004 low water levels reflect the drier-than-normal conditions that occurred during the late summer and early fall. The April 2005 high water levels reflect the increased recharge that occurred during the snowmelt and spring freshet in 2005. By the end of May 2005, most water levels had decreased to more typical seasonal values.

The quarry sump in the southwest corner extends below the quarry floor to about elevation 496 m asl so that quarry water levels can be maintained at or below elevation 500 m asl. The drawdown influence of the quarry extends out into the surrounding rock as illustrated by the groundwater contours and the general flow arrows that converge on the quarry. The figures also illustrate the influence of the recharge that occurs in the area of the wash plant on top of the unexcavated rock surface in the north section of the quarry where the groundwater levels are maintained higher than elsewhere around the quarry.

To the south of the existing quarry, groundwater movement is radially away from the higher ground and towards Edward Lake, which is interpreted to be a local groundwater discharge area as well as a collection area for local surface water run-off. Based on the surface topography, the elevation of the water in the lake is approximately 507 m asl +/- . It is our understanding that the lake is approximately 4 m deep. There is an overflow outlet
culvert at the southwest corner of the lake that is monitored as part of the surface water program.

The groundwater configuration beneath the expansion lands and the land to the west exhibits an elliptical radial pattern centred on the areas of higher ground formed by the local bedrock hills. A groundwater divide is present, with groundwater movement beneath the eastern section of the expansion lands being towards the Escarpment. Beneath the western part of the expansion lands, groundwater movement is to the north and west forming part of the more-regional flow system to the west. In addition, there is a southerly component of flow towards the existing quarry.

Figure 3-20 provides a year-over-year comparison between the groundwater levels observed in June 2003, June 2004, and April 2005. The water levels generally are similar between 2003 and 2004, with some values being slightly higher in 2004 and some lower. The April 2005 water levels are the highest for the three periods, and it is noted that groundwater levels decreased to more typical seasonal values by mid-May 2005.

3.7 GROUNDWATER QUALITY

Groundwater samples were collected during hydraulic testing in 2003 at BH02-4 and BH03-9 on the expansion lands, and from the water supply on the former Bridson property in October 2003, and submitted for general chemical analysis of water quality in the Amabel aquifer beneath the expansion lands. Water samples were also obtained in February 2005 for chemical analysis from the Urbaniak residence (water softener installed) in response to a specific request from the residents. Water samples were collected from Camarthen Lake Farm wells CLF1 and CLF2 during hydraulic testing November 2004. Water samples were also obtained during hydraulic testing in August 1999 at PW99-1 and PW99-3 in the existing quarry and submitted for general chemical analysis.
Results of chemical analysis are provided in Table B-7, Appendix B together with the applicable Ontario Drinking Water Standards Objectives and Guidelines for comparison.

Based on these data, the groundwater quality generally meets the current standards for drinking water for the parameters tested. The groundwater is naturally hard, bicarbonate water with elevated concentrations of calcium, magnesium and bicarbonate. It is noted that water quality results at the former Bridson water supply are affected by a water softener which lowers the hardness and increases the sodium and chloride concentrations.

Other parameter concentrations of interest are the chloride and nitrate values. Chloride is elevated at BH03-9 and at the former Bridson well, relative to the groundwater at BH02-4. Borehole BH03-9 and the former Bridson well are located relatively close to the County roads, and are likely affected by road salting in the winter. BH02-4 is located on the top of the bedrock hill in the centre of the expansion lands, and is further removed and upgradient from the influence of the County road. The chloride concentrations from the two test wells in the existing quarry had lower values in 1999, although they were still considered elevated relative to groundwater not affected by road salt. Based on recent sampling of the surface water in the quarry sump, chloride concentrations at 95 mg/L are elevated, which is interpreted to reflect road salt activities along the County roads. Although the nitrate concentrations in the groundwater are within the Ontario Drinking Water Quality Standard of 10 mg/L, values in the range of 2 to 4 mg/L are considered elevated relative to natural background. Potential non-point sources of nitrate include agricultural fertilizer and livestock manure, as well as local sewage disposal systems.

The test well PW99-1 is developed in the middle to lower portions of the Amabel aquifer and is interpreted to draw most of the water from the middle of the aquifer. PW99-3 was developed in the base of the quarry floor and extends through the lower section of the Amabel aquifer. Groundwater quality from the two wells was similar, although the water from PW99-3 had lower concentrations for most of the parameters tested.
Water quality from the two Camarthen Lake Farm wells is similar to other local wells in the Amabel aquifer. Of note, however, are the elevated nitrate concentrations (16 to 20 mg/l) and potassium concentrations (5 to 10 mg/l), which may be associated with the livestock operation.

3.8 WATER USE

A summary of the water well records that are available from the Ministry of the Environment digital database for the area around the expansion lands is provided in Table E-2 in Appendix E. Well locations based on the UTM coordinates provided in the database are illustrated on Figure 3-21. With the exception of those residences immediately around the expansion lands and the existing quarry, the precise location and details of wells identified in the Ministry database were not verified. Also, for completeness, the Ministry water well information that was provided in the 1982 report by Hydrology Consultants for the Osprey Quarry property and the 1991 reports by Trow Dames and Moore for the existing quarry is also included in Appendix E as background.

Water supplies in the area can be grouped into those located above the Escarpment, and those located below the brow of the Escarpment. Above the Escarpment, potable water supplies typically are obtained by means of drilled wells that are developed in the Amabel aquifer. Since the Amabel aquifer is fractured dolostone rock that is susceptible to varying degrees of karstification, the depth of the wells, the static water elevation and the yield of the wells are variable across the area. Generally, water supplies are developed in the rock within a depth range of approximately 15 m to 25 m below ground surface with well yields usually in the range of about 0.4 L/s to 1.5 L/s (5 to 20 Imperial gallons per minute), which is satisfactory for residential needs, and also for agricultural livestock requirements when more than one well is developed. In areas where the overburden soils are thicker and contain sand or gravel materials, water supplies can be developed in those materials without the need for drilling into the bedrock.
Below the brow of the Escarpment, drilled water supplies can be more difficult to develop because of the nature of the underlying geologic materials. The soils that are of glacial origin consist of a variable sequence, thickness and texture of materials that may or may not yield sufficient quantities of water. Sometimes, larger diameter wells that are dug or bored are developed to provide individual water supplies. Below the glacial soils are the thick shale bedrock sequences of the Queenston and the Georgian Bay Formations. Even though these formations do contain interbeds of limestone, the potential for developing a reasonable and potable water supply in the shale sequences is low. Water quality can also be marginal due to the influence of the shale bedrock that can impart a brackish nature to the water. Immediately adjacent to the upper section of the Escarpment, some landowners utilize groundwater springs that discharge at the Escarpment face from the Amabel and/or Manitoulin Formation bedrock for their water supplies.

Eleven residential wells located around the expansion lands and two on the property were monitored for water levels on a monthly frequency, starting in the summer of 2003. In addition, three residential water supplies that utilize surface water from groundwater springs located east and northeast of the expansion lands were monitored as part of the surface water program.

Monitored water wells located above the Escarpment are drilled wells that are developed in the Amabel aquifer. The Kenwell farm and Scott wells are also developed in the Amabel aquifer, but they are not part of the routine program. The Kenwell farm well is situated in a below-grade pit in the implement shed that is difficult to access, and the Scott well is located further to the west.

The former Millar water supply on the expansion lands is an exception, and consists of two shallow dug wells that are developed in the vicinity of a groundwater spring at the toe of the slope, north of the barn. Mr. Millar indicated that there is an old 20 m deep drilled well near the barn, but it is not used. Water wells that are present along Grey Road 31 at the former old schoolhouse property, (structure now removed and well is buried), the former
MacDonald farm, and the former Silligman property, are on property now owned by Georgian Aggregates. Those wells are not monitored since the properties are owned by the applicant, and there are groundwater monitors in reasonable proximity.

The Kekanovich drilled well, which is just west of the expansion lands, is developed in the Amabel dolostone at a depth of 27.4 m below ground surface. The seasonal variation of the groundwater level in the Kekanovich well ranged between a low of 516.4 m asl in the fall of 2004 and a high of 521.8 m asl in spring 2005, about 2.2 m to 7.6 m below ground surface (Figure B-52). The well provides sufficient water for the residence year-round. It is noted that the older summer residence to the north on the Kekanovich property has a 9 m deep drilled well located in the basement. The water supply is reported as adequate. The well was not accessible for monitoring.

The well at the Urbaniak residence located north of the expansion lands on 26/27 Sideroad is recorded as 17.1 m deep. The well record indicates that the well was tested at 36 L/min (8 gpm). The well record also indicates that bedrock was not encountered until a depth of 14.6 m below grade, and that the overburden consists of red clay. Given the inferred presence of bedrock at or close to ground surface at this property, the geologic log in the well record is considered questionable. One water shortage is reported to have occurred in the summer of 2002 due to low water levels, but the problem resolved itself when the water level in the well recovered. There was a problem with sediment in the pressure tank in January/February 2005; the tank was flushed of sediment and the problem was resolved. The seasonal variation in the water level ranged between a low of 510.4 m asl in November 2004, to 513.8 m asl in April 2004 and April 2005, or about 8.3 m to 4.9 m below grade. See Figure B-57 for details.

The Young residence has an older drilled well that is about 18.5 m deep which reportedly has run out of water on occasion. A newer replacement well was drilled in 1998 to a depth of 55 m. The water well record number for the newer well is 5733789. The new well reportedly lost water below a depth of 45.7 m, during drilling, and was backfilled to that
depth. It is also understood that the water supply in the older well has recovered. Both wells are plumbed into the house and the combined capacity of the system is reported to be about 11 L/min (2.5 gpm). Based on the well record, the Cabot Head shale was encountered from a depth of 25.3 m to 42.7 m below grade (elevation 487 m asl to 470 m asl), followed by the Manitoulin dolostone to a depth of 53.3 m (elevation 459 m asl), and then “grey shale”, which may be the Whirlpool sandstone since the underlying Queenston Shale is characteristically red in colour. The water level in the new well seasonally varied between elevation 507.4 m asl to 510.3 m asl, which is about 2.4 m below ground surface to 0.5 m above grade. See Figure B-58 for details.

There is a new residence (Cowan) recently constructed on the north side of the 26/27 Sideroad, near the brow of the Escarpment. The water supply for that residence was constructed at the site of the former abandoned shallow well developed near a groundwater spring location, designated SW20, that is part of the surface water monitoring program.

Further to the east, on the slope of the Escarpment south of the Sideroad, the former Sestito seasonal residence (now owned by H. and E. Franks) utilizes surface water from groundwater springs that discharge from the Manitoulin rock scarp and the associated stream channel as a water supply. That system is part of the surface water monitoring program (stations SW24, SW24A and SW24B).

To the east of the expansion lands and the existing quarry along Simcoe Road 91, but above the brow of the Escarpment, there are four residential wells designated as Millar, Bridson (now owned by Georgian Aggregates), Dempsey/Brown, and Fabrizio. The former Millar wells are on the expansion lands and are shallow dug/groundwater spring wells. The seasonal variation of the water level in the wells ranges from 511.5 m asl to 512.9 m asl, which is within 1 metre of ground surface. See Figure B-53 for details. The other three residential wells are drilled wells.
Water level elevations in the three drilled wells decrease from the former Bridson well eastwards to the Fabrizio well near the Escarpment. As shown on Figure B-47, the elevation at the former Bridson well ranged seasonally between 508.8 m asl to 513.1 m asl, which is about 0.6 m to 4.9 m below grade. Water levels in the Dempsey well ranged seasonally between 501.6 m asl to 507.4 m asl which is about 7.5 m to 1.7 m below grade. See Figure B-48 for details. At the Fabrizio well, the water elevation as shown on Figure B-49 ranged seasonally between 484.9 m asl to 486.7 m asl, which is about 19.6 m to 17.8 m below grade. The Ministry of the Environment records indicate that there is a well located north of Simcoe Road 91, near the brow of the Escarpment on the property now owned by Escarpment Biosphere Conservancy Inc. The reference number is 13359, but the well was not located.

The W. Franks and H/E Franks farm properties which are located north of Simcoe Road 91 and which front onto Concession Road 10, utilize surface water supplies that originate as groundwater springs near the base of the Amabel/Fossil Hill Formations at the Escarpment face. At the W. Franks property, the groundwater discharge and local surface runoff is collected in three concrete tiles connected in series in a gravel-filled depression in the ground. The water is piped by gravity down slope and is valved-off to a cistern in the basement of the house and to the barn. There is a pressure tank and water treatment system in the house. The barn supply is gravity fed.

At the H/E Franks property the surface water collects in a small gravel-filled pond located down slope from the spring source. Water drawn from the collection pond is piped by gravity down slope to a covered cistern located in the northwest corner of the field west of the house. There is an overflow outlet from the cistern into a drainage ditch that discharges into the pond on the property. Water is piped by gravity down slope from the cistern to a holding tank in the basement where there is a pressure tank and water treatment system.
Both water sources are monitored as part of the surface water monitoring program. Since these are open surface water systems, they are susceptible to contamination from surface sources such as coliform bacteria and suspended sediment. It is noted that the Ministry records list a drilled well, number 5733354 for Amelia Franks located to the north of the current H/E Franks property, north of 26/27 Sideroad. The well, which was drilled in 1998, was developed in red shale and was tested at a rate of 23 L/min (5 gpm). Since the current resident of that property did not respond to the well survey, the status of the well is unknown.

There are several dug or drilled residential water supply wells located on the slope of the Escarpment that are monitored as part of the program. The Swinton well which is located adjacent to the former quarry at Simcoe Road 91 and Concession Road 10, is drilled through the Manitoulin/Whirlpool Formations (14 m thick) and is developed in the underlying Queenston shale. The water level in the well ranged seasonally between 458.7 m asl to 461.1 m asl, which is a few metres below the base of the Manitoulin/Whirlpool Formations. See Figure B-56 for details. The other wells located along Concession Road 10 are either dug wells that are developed in the overburden soils, or drilled wells developed in the underlying shale bedrock. The groundwater elevations in those wells, which reflect their location part way down the slope of the Escarpment, are in the range of 426 m asl to 447 m asl, depending on location.

4.0 SURFACE WATER SETTING

4.1 SURFACE WATER DRAINAGE BASINS

Figure 2-1 illustrates the approximate boundaries of the four surface water subcatchment basins that are present in the vicinity of the expansion lands. Part of the interpreted surface drainage divide between two of the subcatchment basins is located on the expansion lands.
and also extends around the eastern limit of the existing quarry. The four subcatchment basins are as follows.

(i) **Batteaux Creek Subcatchment**

Batteaux Creek (also called Batteaux River) and its un-named tributary headwaters originate on the Escarpment and flow eastwards and then north to Nottawasaga Bay just east of Collingwood. The subcatchment includes approximately the eastern half of the expansion lands and, prior to the start of quarry operations, would also have included the eastern section of the existing quarry that now is within the Beaver River subcatchment as a result of the quarry discharge to the west.

As shown on Figure 2-1, there are numerous tributary water courses that originate on the Escarpment, many of which start as groundwater springs that occur near the base of the Amabel and/or Manitoulin dolostone. Several of these springs are included in the surface water monitoring program that is on-going for the expansion application. In these upper reaches of the drainage basin, the tributary streams are relatively fast flowing first order or second order streams and are bottomed in relatively steeply sloping channels that eroded down through the soil cover on the Escarpment. Bedrock is exposed in the base of the channels at various locations. The average slope of the land surface through this upper section of the drainage basin is approximately 150 m in 4 km, or 3.75% grade, but locally can be steeper.

The individual watercourse channels progressively merge on their way down the Escarpment to form the main channel of Batteaux Creek (fourth order channel) just west of County Road 124. The flow in the main channel was monitored at the culvert crossing at County Road 124, about 900 m south of Duntroon. This station is designated as SW19.
(ii) **Beaver River Subcatchment**

The western part of the expansion lands and the existing quarry are situated within the drainage basin of Beaver River, which discharges into Georgian Bay at Thornbury. There is a Water Survey of Canada gauging station on Beaver River at Clarksburg (ID# 02FB009). The catchment basin is reported to be 572 km², and the average baseflow is stated to be 2.96 m³/s, which equates to an equivalent recharge of 163 mm per year (Grey and Bruce Counties Groundwater Study, 2003), assuming negligible deep groundwater movement.

The surface drainage within the subcatchment area flows from east to west, and forms the headwaters of one of the eastern tributaries of Beaver River. Excess water from dewatering operations at the existing quarry is discharged into this tributary. Surface drainage occurs within the lower-lying areas between the soil-covered bedrock knob hills that rise above the bedrock plain west of the Escarpment. Topographic relief in between the hills is relatively flat, with an overall slope from east to west of approximately 20 m over 4.5 km, or 0.44%, but locally can be much flatter. As a consequence, surface drainage in the tributary streams is often slow and meandering, and wetland areas are common, such as the Rob Roy Swamp Wetland complex that is a designated provincially significant wetland area.

The meandering nature of the surface drainage and the associated wetland features are evident along the Grey Highlands 10th Line Road (formerly Osprey Twp), west of the Osprey Quarry property, where the average grade is about 0.33% and the watercourse crosses the road three times within a distance of about 1 km. The flow in the main channel leaving this reach of the drainage basin is monitored at station SW6A, as shown on Figure 2-1.
(iii)  **Pretty River Subcatchment**

To the north of the expansion lands is the Pretty River subcatchment drainage basin. The Pretty River discharges into Georgian Bay at Collingwood. The surface drainage conditions in the upper section of the basin are similar to those in the Batteaux Creek basin in that there are numerous first order and second order tributary streams that originate as groundwater springs at the face of the Escarpment from the Amabel and/or Manitoulin formations. Several of the springs and associated tributary creeks located to the immediate northeast of the expansion lands along the 26/27 Sideroad are included in the surface water monitoring program.

The creeks in the upper section of the valley are relatively fast flowing due to the steep grade of the channel bottom, down the slope of the Escarpment, which can be in the order of 10%. Bedrock is exposed in the channels at various locations. The individual tributary channels progressively merge further down the Escarpment as the grade decreases.

(iv)  **Mad River Subcatchment**

The fourth subcatchment drainage basin includes the Mad River which is located to the south of the existing quarry and includes Edward Lake. The Mad River joins the Nottawasaga River to the east of the study area which discharges into Georgian Bay at Wasaga Beach. The tributaries of Mad River that originate on the lands to the west, above the Escarpment, are generally slow moving water courses due to the relatively flat grade. To the east of Singhampton, the river cuts through the bedrock of the Escarpment at Devils Glen and forms a 75 to 100 m or more steep-sided valley in which much of the upper section of the Escarpment bedrock is exposed. Since the Mad River is located more than 3 km south of the existing quarry, it is considered to be beyond the influence of quarry operations. With the exception of monitoring the groundwater levels at the supply wells for Camarthen Lake Farms and the outflow from Edward Lake, no other monitoring is carried out in this subcatchment.
As shown on Figure 2-1, to the south of the existing quarry and east of Edward Lake, there is a small closed drainage basin from which there is no apparent surface drainage outlet. There is a wetland feature present in the centre of the basin, and a watercourse drains southwards out of the wetland. That stream flows into the bottom of a circular sinkhole feature that is approximately 22 m in diameter and 6 m deep. The stream infiltrates into the ground in the sinkhole and forms a sinking stream, which likely discharges as a groundwater spring or springs at the Escarpment face to the east. Whereas there is no bedrock exposed in the base or sides of the sinkhole feature, it is likely present at a shallow depth.

There is also a small closed drainage basin feature in the farm field in the south central part of the expansion lands, as indicated by the topography on the Existing Features map of Figure 1-4. There is no obvious sinkhole feature present at that location, and the field is actively cropped. There is a topographic low point present at the fence/bushline to the west, with bedrock boulders at grade, and surface drainage may infiltrate at that location. The former landowner indicated that this area usually remains wetter for longer in the spring due to the lack of drainage. In addition, during particularly wet springs, the landowner has indicated that surface drainage may occur to the west through a channel in the woodlot.

4.2 SURFACE WATER FEATURES

There is an area of wetland directly west of the existing quarry. This feature is part of the Rob Roy Swamp Wetland Complex which is a provincially significant wetland (PSW). Excess water from the existing quarry is discharged into this wetland. Water flows through the wetland westwards beneath Grey Road 31 through twin culverts into a continuation of the wetland and a watercourse. From the wetland the watercourse traverses around the northern limit of the Osprey Quarry property as shown on Figure 2-1.
There is a groundwater spring feature located in the extreme southwest corner of the expansion lands, just to the west of BH03-9. Water flows year-round at this bedrock spring, except possibly under extreme dry climatic conditions. The ground elevation at the spring is approximately 517 m asl. The water flows southwards along the east side of Grey Road 31 and through a culvert beneath Simcoe Road 91 where it enters the wetland that is west of the existing quarry. The flow at the culvert was monitored either monthly or weekly as part of the program for the existing quarry, and is designated as station SW2 on Figure 2-1. Water from the spring eventually flows to the tributary of the Beaver River, which supports fish habitat further downstream.

There is a surface drainage valley feature developed upstream from the spring that extends across the open field and back into the bush to the northeast. Within that valley feature, there is a small closed depression in which surface drainage accumulates and infiltrates into the ground. In addition, bedrock is exposed at ground surface a short distance to the east where groundwater discharges to ground surface during the spring melt period. That water infiltrates back into the ground in a depression a short distance to the west. It is interpreted that this area forms at least part of the surface recharge area for the spring in the southwest corner of the expansion lands.

A second groundwater spring and associated small pond are located in the northeast corner of the former Millar farm property designated SW7, just on the edge of the Escarpment Natural Area. Two shallow dug wells are present at the spring, one of which is used to supply the farm. The spring area also flows into a small pond that collects local surface runoff and was used in the past to water livestock. The pond discharges to the east into a small wetland feature, although water in the channel does not flow year-round.

There is another small dugout pond feature located to the east of the proposed extraction area, on the former Bridson property. See Figure 1-4. This pond is fed by a small intermittent spring and by local surface runoff. When pond water levels are high, the pond
discharges through an overflow culvert designated as station SW8 into the wetland feature to the east. A surface drainage channel through the wetland flows during the spring season and the late fall. Bedrock is exposed at ground surface towards the eastern limit of the wetland, and the flow in the channel progressively infiltrates, or sinks, into the ground in this area, such that surface flow rarely extends beyond the eastern boundary of the former Bridson property within the expansion lands, except during spring melt conditions when flow may occur across the Dempsey property. This area, designated as station SW9, is proposed for use as a natural infiltration recharge area during quarry operations.

In the northwest corner of the expansion lands, beyond the proposed limit of extraction, there is another wetland feature present in the low-lying area that formed between the bedrock-controlled hills to the north, east and south. Similar to the individual wetland areas to the west, this feature was designated as part of the Rob Roy Swamp Provincially Significant Wetland (PSW) complex. The surface grade in the feature is flat, and surface drainage temporarily accumulates in this area for a short time during the spring melt and following high rainfall events. Surface water flows are monitored at the outflow culvert beneath Grey Road 31, designated as station SW3, and with the exception of occasional periods during the spring snowmelt and the late fall, there is no flow out of the wetland though the culvert.

The wetland feature continues to the west of Grey Road 31 as part of a larger section of the PSW that provides surface drainage for one of the tributary streams of Beaver River that flows southwestwards down to Osprey 10th Line. There the tributary joins with the other tributary that originates in the wetland between the existing quarry and the Osprey quarry property. A dugout pond is present in the wetland just west of Grey Road 31 in Lot 22 Concession A, just beyond the 120 m radius from the northwest corner of the expansion lands.

There is another small wetland area that also is part of the Rob Roy Swamp PSW located approximately 400 m west of the expansion lands, on the Kekanovich property. It is likely
that surface outflow from that wetland will be seasonal, occurring in the late fall and spring snowmelt period.

Numerous groundwater springs are present along the upper steep slope of the Escarpment that discharge from the Amabel Formation and/or from the Manitoulin Formation. These springs form the headwaters of small tributary streams that feed into Batteaux Creek to the east of the expansion lands, and into the Pretty River system to the north. To the west of the expansion lands, the regional slope of the land is much flatter towards the Beaver River system. Surface drainage in that area consists of slow-moving meandering watercourses that are bounded on either side by low-lying wetland areas.

The largest body of open water present in the study area is Edward Lake which is located on Camarthen Lake Farms property adjacent to Grey Road 31, south of the existing quarry. The lake, which reportedly is about 4 m deep, is approximately 800 m long (north-south) by 250 to 400 m wide, and is developed in a low-lying area that is bordered to the west, northeast and east by bedrock-controlled hills. The hill to the northeast forms the local topographic high point in this area. It is interpreted that the lake receives both surface runoff and groundwater discharge from the higher lands around the lake. The lake has an overflow outlet in the southwest corner which is monitored as part of the ongoing program, designated as stations SW25 and SW25A.

4.3 SURFACE WATER CHARACTERISTICS

Surface water monitoring has been on-going at the existing quarry since 1996 as part of the Permit To Take Water program, and since May 2003 at stations around the expansion lands. The surface water monitoring station locations are presented on Figure 2-1, Topography And Surface Drainage, and also on Figure 4-1 Surface Water Flows. Results of the monitoring programs are provided in Appendix C as follows:
Table C-1 Surface Water Monitoring Location Information. This table is separated into the drainage basins of Batteaux Creek, Beaver River, Pretty River, and Mad River. The table provides the UTM northing and easting (NAD 27) for each station, together with the estimated ground elevation based on the surface topographic mapping, a short description of the station, culvert dimensions where appropriate, and the type of flow measurement that is obtained at each station. The type of flow measurement methodology that is used at each station depends on the physical conditions present during each monitoring event.

Table C-2 lists the surface water flows at the three stations that are monitored as part of routine quarry operations: SW1, SW2, and SWB-1, as well as three stations that were monitored as part of pumping/dewatering operations at the quarry: SWO-2 and QFSW2. Station SW1 is located at the twin culverts outlet of the wetland west of the quarry at Grey Road 31. Station SW2 is located at the culvert beneath Simcoe Road 91 in the northwest corner of the wetland west of the quarry. Station SWB-1 is located at the culvert outlet beneath the perimeter berm adjacent to the small wetland feature in the southwest corner of the licensed quarry property. SWO-2 is located downstream of SW1 on the Osprey Quarry Property. QFSW1 was located on the existing quarry floor in the southwest corner of the quarry and was monitored for a short period to establish groundwater seepage volumes into the quarry. QFSW2 is located on the existing quarry floor in the surface water collection channel prior to discharge into the main sump pond and is used to monitor the volume of surface water entering the sump pond. Surface water hydrographs for these stations are provided in Figures C-1 to C-6.

Table C-3 presents the monthly flow monitoring results for stations SW3 to SW26A that are located around the expansion lands. Surface water hydrographs for these stations are presented in Figures C-7 to C-48.
Table C-4 presents the results of the field chemistry monitoring that was completed at various surface water stations.

Table C-5 presents the results of the laboratory chemical analyses that were completed at various surface water stations.

The surface water monitoring results are discussed for each of the four subcatchment drainage basins for flow and water quality, starting with the Beaver River subcatchment basin. Figure 4-1 presents a summary of flow monitoring results for each station to illustrate the high flows recorded in spring 2004, the low flow results for either 2003 or 2004, and the spring high flow recorded in 2005.

4.3.1 Beaver River Tributary Subcatchment

The monitoring stations located within the Beaver River tributary subcatchment basin include those stations at or near the existing quarry, SW1, SW2, SWB-1, since the excess water from the quarry is discharged into the wetland that feeds into the tributary stream to the west. The other stations are located on the tributary channel downstream from the quarry and are designated as SW4, SW5, SW6 and SW6A, and Osprey Quarry property (SW0-2). Stations SW3 and SW3A are located on small tributary channels at the northwest corner of the expansion lands and at 26/27 Sideroad respectively.

Flows at stations SW1, SW2 and SWB-1 are monitored on a weekly basis as part of water management operations and the Permit To Take Water program at the quarry, details of which are discussed in Section 5.0 of the report. The water management operation information summarized below includes surface water that contributes to flow that leaves the wetland through the twin culverts at Grey Road 31 (station SW1).
The upstream flow at station SW2 enters the northwest corner of the wetland through a culvert beneath Simcoe Road 91. Surface water at this location includes the natural flow from the bedrock groundwater spring located near BH03-9 on the expansion lands, as well as surface runoff from the field and bush area to the east and from a short section of roadside ditch. The hydrograph (Figure C-2) illustrates that surface flows exhibit seasonal variations that range from highs in the spring of about 50 to 60 L/s, summertime flows that typically range between less than 1 L/s to 5 L/s (0 L/s in October 2004), fall values that may increase to 10 to 15 L/s, and winter flows of about 5 to 10 L/s depending on prevailing air temperatures. The annual average recorded flow is approximately 8 to 9 L/s, and typical baseflows provided by the groundwater spring in the summertime are in the order of 2 to 4 L/s. The flow from SW2 enters the wetland as channel flow, but becomes more diffuse flow further into the wetland. Prior to development of the quarry, and in particular the west perimeter berm, flow from SW2 entered the western limit of the quarry property before turning west out to Grey Road 31, based on the early site plan mapping.

The flow that is monitored at station SWB-1 provides a measure of one component of the quarry discharge from the area of the main sump. Depending on water level conditions at the sump, excess water was discharged from the old concrete tile sump adjacent to the crusher into the small wetland area to the west by means of a 150 mm (6”) pump and discharge line. Historically, this was the main discharge line for the quarry, prior to the establishment of the larger 250 mm (10”) pump that is present in the main sump.

The use of the 150 mm pump system was temporarily suspended in the summer and fall of 2004 because much, if not all, of the water that was being discharged into the main wetland west of the berm infiltrated into the ground and was recycled back into the quarry, such that it did not actually leave the wetland at Grey Road 31. When the 150 mm pump was operated (switched on and off manually), at full-bore, it discharged into the small wetland at a rate of about 70 to 80 L/s. Flow measurements at the culvert outflow at the berm (SWB-1) would reflect a similar rate. Because that pump was operated manually, there were times that the discharge pipe did not flow full-bore due to low water levels, and the
flow rate recorded at SWB-1 would be less than 70 L/s. When the pump was not operating, there was no discharge through the culvert at SWB-1 into the main wetland west of the quarry. The hydrograph for this station (Figure C-3) illustrates this variation in the flow.

The flow that is measured leaving the wetland at station SW1, minus the flow that enters the wetland at SW2 and any incident precipitation or runoff into the wetland, is taken to represent the net discharge of excess water from the existing quarry operation. That excess water consists of leakage out of the on-site ponds as well as groundwater that enters the quarry extraction area together with precipitation/runoff and snowmelt that accumulates on the floor of the quarry and is collected at the sump.

The pump in the main sump normally is operated by means of a float switch that can be raised or lowered to maintain the desired water level at the sump, based on prevailing climatic conditions and process water requirements. Excess water can be discharged into the wetland by means of a 300 mm diameter plastic and/or aluminum pipeline. Historically, the pipe discharged water adjacent to Grey Road 31, just north of the twin culverts outlet. When the 250 mm pump was operated, water discharged into the west end of the wetland at a rate of approximately 128 L/s. There were periods during the spring snowmelt period, or during particularly wet periods, when additional pumps were required to lower the water level in the quarry. The discharge rate into the wetland was proportionately higher during such periods.

During the spring of 2005, water discharged into the wetland adjacent to the perimeter berm at the hydro line at a rate of about 200 L/S when the pump was operating. Following construction of the containment berm and new storage pond excess water from the sump is discharged into the pond for temporary storage.

The elevation of the invert of the twin outlet culverts at Grey Road 31 is set above the surrounding grade in the wetland, such that standing water accumulates in the wetland before flow can occur through the culverts. Historically, when the pump stopped
discharging, flow through the culverts would continue until the water level in the wetland dropped below the invert of the culverts. It is estimated that approximately half of the water that was discharged into the wetland from the quarry infiltrated into the ground and recycled back into the quarry extraction area. The new storage pond is intended to provide a hydraulic barrier against the western limit of the quarry to reduce the amount of water that recycles back into the quarry from the wetland.

Figure C-1 presents the hydrograph of flows recorded at the outlet culverts at station SW1. Flows ranged between 0 L/s, when the pump was not operating, to spring high values in the order of 100 to 130 L/s. During 2003/2004, and spring 2005, the recorded flows varied seasonally as follows.

<table>
<thead>
<tr>
<th>SEASON</th>
<th>MEASURED FLOW DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter 2002/2003</td>
<td>Approximately 20 L/s to 30 L/s</td>
</tr>
<tr>
<td>Spring 2003</td>
<td>High of 135 L/s, low of 0 L/s, typically 50 L/s to 80 L/s</td>
</tr>
<tr>
<td>Summer 2003</td>
<td>Variable from 0 L/s to about 40 L/s</td>
</tr>
<tr>
<td>Fall 2003</td>
<td>Typically 30 L/s to 60 L/s</td>
</tr>
<tr>
<td>Winter 2003/2004</td>
<td>Variable 40 L/s to greater than 100 L/s</td>
</tr>
<tr>
<td>Spring 2004</td>
<td>Variable 0 L/s to 136 L/s</td>
</tr>
<tr>
<td>Summer 2004</td>
<td>Typically 40 to 75 L/s, occasionally dry</td>
</tr>
<tr>
<td>Fall 2004</td>
<td>Mostly 0 L/s; one value of 90 L/s</td>
</tr>
<tr>
<td>Winter 2004/2005</td>
<td>Variable 45 to 80 L/s, occasional low values</td>
</tr>
<tr>
<td>Spring 2005</td>
<td>Variable 40 to 90 L/s, high value 122 L/s</td>
</tr>
</tbody>
</table>

In summary, during discharge from the quarry, the contribution to flow from SW2 is obscured. However, during periods of no quarry discharge, the baseflow from SW2 infiltrates into the ground prior to reaching SW1, and the water moves through the rock and into the quarry.
The water that leaves the wetland at SW1 provides flow in the upper reaches of the tributary stream of the Beaver River that flows north and then west past the Osprey Quarry property. That section of the stream includes beaver dams that affect flow, although the major controlling factor is the discharge pattern from the quarry. Flow monitoring in the creek carried out at the Osprey Quarry property in 2004 (station SW0-2, Table C-2 and Figure C-4) shows that there are times when the quarry is discharging water and the twin culverts at SW1 are flowing (July 16, 2004, for example, at 58 L/s), the flow in the creek adjacent to the Osprey Quarry property is similar (61 L/s). When the discharge from the quarry stops (July 9 for example), the flow at SWO-2 decreases (3.5 L/s on July 9). On one occasion in July 2004, the discharge from the quarry did not occur for several days, and flow in the creek adjacent to the Osprey Quarry property stopped until the quarry discharge started again, after which flow in the creek resumed.

There are other occasions when the quarry is discharging and flow is occurring at SW1, the recorded flow in the creek adjacent to the Osprey Quarry is less than the flow leaving the wetland at SW1. The difference in flow is attributed to the time-lag between the start of quarry discharge/flow at SW1, the effect of beaver dams and the resultant time it takes for increased flow in the creek to reach station SWO-2. The creek continues to flow west past the Osprey Quarry property and through additional wetland areas where it merges with other surface water courses that originate to the north.

Flow out of the Provincially Significant Wetland (PSW) feature in the northwest corner of the expansion lands is monitored at station SW3, which is at the culvert at Grey Road 31. Flow was observed on only six occasions since monitoring started in May 2003 (a total of 23 measurements). Recorded flows occurred between December 2003 and May 2004, and in the spring of 2005, and varied between 0.2 L/s and about 3 L/s, with two high values of about 14 L/s and 31 L/s recorded in April 2004 and April 2005 respectively.
Flow is monitored at another culvert beneath Grey Road 31, at 26/27 Sideroad (station SW3A). Flows ranging between 1 L/s and 7.5 L/s were recorded at this location during the spring and fall seasons, with no detectable flow through the summer.

Station SW4 is located at the culvert beneath Osprey 10th Line just west of Grey Road 31, and is intended to monitor the flow in the surface water channel that originates at the livestock barns at the northern part of Camarthen Lake Farms. Whereas the channel contains standing surface water, flow through the culvert into the wetland north of the road was not observed, with one exception, due to the elevated position of the culvert invert on the south side of the road. There may be flow through the culvert into the wetland to the north during extreme climatic conditions, but the majority of the flow in the tributary channel in the wetland is provided by the discharge from the quarry property and by incident precipitation and surface runoff.

Station SW5 is at a concrete box culvert located downstream where the tributary channel crosses Osprey 10th Line. Station SW6 is located at another concrete box culvert crossing of Osprey 10th Line further to the west, and includes flow from a second tributary channel that originates in wetland areas to the north (including stations SW3 and 3A). Streamflow in the vicinity of Osprey 10th Line is slow and meandering due to the flat grade through the wetland and the presence of beaver dams. As a result, flow measurements are difficult to obtain when velocities are low. The flow measurements at SW5 indicate spring high values of 246 L/s and 742 L/s (2004 and 2005 respectively), and summer low flows of 4 to 12 L/s (2003). At SW6, measured flows varied between spring highs of 371 L/s and 1376 L/s (2004 and 2005 respectively), and summer low values recorded as 0 L/s, although it is likely that there was minor flow in the channel, but the velocity was very low. Generally the flow at SW6 is higher than that recorded at SW5, with differences ranging between approximately 40% to in excess of 100%.
Station SW6A provides a measure of the total flow in the stream channel at the twin culvert crossing at Osprey Sideroad 30, and includes the flow in the two tributaries from the north of Osprey 10th Line, and one from the south. Recorded streamflows varied from spring highs of 607 L/s and 1671 L/s in 2004 and 2005 respectively, to lows of 9 L/s to 40 L/s in summer and fall. Flows at this location are higher than those at station SW6 by a factor of between 17% to almost 300%. It is noted that the September 23, 2003 low-flow value of 9 L/s also coincided with a period of non-discharge from the quarry, when the recorded flow at station SW1 was less than 1 L/s. However, there were other occasions when the flow at SW1 was low to zero yet there was measurable flow occurring at SW6A. Given the physical separation between the two stations (more than 4 km), and the slow meandering nature of the stream flow, there is a large time-lag factor between the stop / start of discharge from the quarry and flow at SW1, and corresponding changes in the flow regime at SW6A.

The land area of the drainage basin subcatchment upstream from station SW6A is approximately 16.2 km². Based on an estimated average baseflow of about 50 to 75 L/s at station SW6A, an equivalent groundwater recharge rate of about 100 mm to 150 mm per year is calculated.

The tributary continues to flow to the west where it joins with other tributary streams and enters Eugenia Lake which discharges into Beaver River to the west. The MOE reports low-flow characteristics for the regulated flow in the Beaver River at Clarksburg (station 02FB009, drainage basin area 221 square miles, or about 572 square kilometres) for the period between 1961 and 1971. The published 7-day Q2 flow (which is the 7-day low flow that occurs on the average once in two years, or has a 50% chance of occurring in any given year) is 87 cubic feet per second (approximately 2.5 cubic metres per second, or 2500 L/s). The Grey and Bruce Counties Groundwater Study Report (2003) provides an average baseflow value of 2960 L/s for the same station (an increase factor of 1.2). Pro-rating those flow values to reflect the area of the subcatchment upstream from SW6A (16.2/572 or 2.8%), yields an equivalent baseflow of between 70 L/s and 85 L/s. This is
equivalent to a groundwater recharge value of between 135 mm and 160 mm per year and, which is reasonably similar to the values estimated for station SW6A.

The MOE also reports low flow data for another regulated gauging station on Beaver River upstream from Clarksburg, just downstream of the confluence with the tributary outflow from Eugenia Lake (station 02FB003, drainage basin area 101 square miles, or 262 square kilometres) for the period 1930 to 1950. The published 7-day Q2 low flow is 53 cubic feet per second (1.5 cubic metres per second, or 1500 L/s). Increasing that reported flow value by a factor of 1.2 to reflect a baseflow value (from above), and pro-rating that value to reflect the area of the basin upstream from station SW6A, yields an equivalent baseflow value of approximately 93 L/s at station SW6A. This suggests an average groundwater recharge value of approximately 180 mm per year in the upper part of the basin, which is higher than the previous estimates, but within the range of values discussed in the section on climate (approximately 160 mm to 315 mm per year based on the 30-year normals). It is noted that since the flow is regulated, the reported low flow characteristics may show higher flow values relative to the natural flow conditions observed at station SW6A.

**Water Quality**

Surface water field chemistry data for monitoring stations are provided in Table C-4. Table C-5 provides laboratory chemistry results for stations SW1, the quarry sump and SW2, as well as for station SW6A on the Beaver River tributary at Osprey Sideroad 30. Table C-5 also provides the Provincial Water Quality Objectives (PWQO) for specific parameters, as published by the MOE. It is noted that the laboratory detection limits for cadmium, cobalt and silver were above the relevant PWQO standards for those parameters.

The field chemistry data show that the recorded temperature of the surface water flowing through the wetland and the culverts at station SW1 varies seasonally according to the ambient air temperature, reaching a high of just over 20°C on July 22, 2004. The water temperature in the tributary at the Osprey Quarry property was 29°C on the same day. The
pH of the water at SW1 typically is in the range of 7 to 8, and conductivity varies between a low of about 280 µS/cm in the spring to a high of 764 µS/cm in September 2004. Dissolved oxygen varies between a low of 7.5 mg/L in June 2005 to a high of 18 mg/L in May 2004.

The laboratory chemistry results indicate that the water in the sump on the quarry floor and the water that is discharged from the quarry at SW1 is similar in quality (as would be expected), and is characterized as being hard bicarbonate water that is typical of water from a carbonate aquifer environment. Of interest are the chloride concentrations of about 100 mg/L, the sodium values of about 25 mg/L, the nitrate concentrations of about 2 to 3.4 mg/L, and the aluminum concentration at SW1 of 0.11 mg/L, all of which are considered to be elevated above normal values for a carbonate aquifer. The sodium and the chloride are likely related to road salting activities on the County roads in the winter, and the nitrate concentrations may be related to local agricultural practices. The aluminum concentration at SW1 is likely related to the presence of suspended clay-sized sediment in the water. With the exception of the aluminum concentration, water quality at SW1 was within the PWQO for the parameters tested.

Surface water quality at SW2 is also considered to represent groundwater quality from the shallow carbonate aquifer since flow is sustained by groundwater discharge at the spring in the southwest corner of the expansion lands. Field temperatures range between about 4°C to 15°C; pH ranges between 7.0 to 8.5; conductivity varies between about 320 µS/cm to 570 µS/cm, and dissolved oxygen varies between approximately 7 mg/L and 14 mg/L. Water quality at this location is typical of bedrock groundwater, being hard bicarbonate water, and is similar to groundwater quality detected at BH03-09. The chloride concentration, at about 32 mg/L is slightly elevated above the normal, expected for surface water and may be related to road salting along Grey Road 31. The nitrate concentration is also slightly elevated at 1.7 mg/L. Water quality at SW2 was within the PWQO for the parameters tested.
Table C-5 provides two sets of results (October 2003 and July 2004) for water quality in the Beaver River tributary at station SW6A. The water quality is reasonably consistent between the two sampling events and is similar to the other sampling locations. Of note is the fact that the concentrations of chloride (10 to 12 mg/L), sodium (3 to 4 mg/L) and nitrate (0.3 to 0.4 mg/L) are considerably lower than concentrations observed at the upstream locations, and is interpreted to be due to dilution by the surface waters from the other areas in the subcatchment area that are not as affected by road salting / agricultural activities. Water quality was within the PWQO for the parameters tested.

Field parameters vary as follows: temperature less than 1°C to approximately 20°C; pH between 6.1 to 7.8; conductivity between about 200 µS/cm to 870 µS/cm, and dissolved oxygen between 6.4 mg/L and 12.4 mg/L.

### 4.3.2 Batteaux Creek Basin

The surface water monitoring stations that are located in the Batteaux Creek drainage subcatchment are grouped as follows.

- SW22 and SW22A are groundwater springs located east of the existing quarry, below the brow of the Escarpment, near to the base of the Amabel/Fossil Hill bedrock scarp section. The ground elevation at these two locations is estimated (by GPS and surface topography mapping) to be between 485 m and 492 m asl. Station SW22B initially was included as a spring location, but flow was not observed at that location except for a short time in the spring. Hydrographs of the streamflow measurements are provided in Figures C-39 to C-41.

The recorded flows at the two spring locations varied from highs of approximately 9.5 L/s and 4.9 L/s (SW22 and SW22A respectively) in April 2005, to summer lows of 0.2 L/s to 0.4 L/s at SW22, and 0.1 L/s to 0.3 L/s at SW22A. The averages of
the recorded flow values for the two stations between June 2003 and April 2005 are 2.3 L/s at SW22, and 1.4 L/s at SW22A.

It is noted that these two groundwater springs are situated approximately 300 m (SW22) and 600 m (SW22A) to the east of the existing quarry face, the ground elevation at the springs is about 10 to 15 m below that of the quarry floor, and the springs continue to flow year-round. The flow from the two springs and the associated watercourses converge approximately 600 m east of SW22. The flow is impounded in an on-line pond at Duntroon Highlands Golf Course to the southeast and the pond is used as source water for the irrigation system at the golf course throughout the golf season.

The field chemistry data for the two springs is reasonably similar, with temperatures that ranged between approximately 2 to 6° C in March 2004, to 7 to 10° C in the early summer 2004, and a high of 13.5 ° C in September 2004 at SW22A which are generally indicative of groundwater. The pH of the water varied between about 6.8 to 7.9 at SW22, and 7.1 to 8.7 at SW22A. The specific conductivity of the water varied from about 300 to 380 uS/cm at SW22, and 390 to 690 uS/cm at SW22A, with the seasonal variation attributed to the relative amounts of groundwater and surface runoff that were present at the time of sampling and other seasonal influences. The dissolved oxygen content varied between approximately 10 mg/L to 16 mg/L.

A sample of water from station SW22 was submitted for laboratory chemical analysis in July 2004 (see Table C-5). Water quality is characterized as hard bicarbonate water that exhibits slightly elevated concentrations of chloride (24.7 mg/L), sodium (10.9 mg/L) and nitrate (0.6 mg/L). The concentrations of aluminum (0.38 mg/L) and iron (0.5 mg/L) are elevated and exceed the PWQO for those parameters. The other parameters are within their respective PWQO.
Station SW26 is located in the stream channel near the unopened road allowance just upstream from the sinkhole feature at the southern end of the wetland, south of the existing quarry. This station is included in the Batteaux Creek basin since the sinking stream likely discharges as one or more groundwater springs at the Escarpment to the east. The hydrograph for this station for the period November 2003 to April 2005 is provided as Figure C-47.

Streamflow into the sinkhole stream channel, as provided by the results for SW26, is highly variable as a result of surface runoff and prevailing climatic conditions. The recorded high value is approximately 184 L/s (April 2004), while the low value is 0 L/s recorded in the summer and fall 2005, and the spring/fall flows generally vary between about 10 to 20 L/s. It is noted that the flow that was observed entering the sinkhole infiltrated into the ground, such that there was no surface overflow from the deep sinkhole.

Laboratory water analysis was not undertaken at this location. The field chemistry data show the temperature at SW26 to range between a low of 0.2°C in February and March 2004 to a high of about 15°C in July, which is indicative of surface water temperatures rather than groundwater. The pH ranged from about 7.0 to 8.2, and conductivity ranged between approximately 100 uS/cm in April 2004 (high flow period) to 521 uS/cm in July 2004 (close to low flow). Dissolved oxygen concentrations ranged between a high of almost 13.5 mg/L in April 2004 to a low of 8.6 mg/L in July 2004.

Stations SW7 and SW8 are located on the eastern section of the expansion lands at the former Millar farm pond outlet and the former Bridson property pond outlet respectively. Surface water at these two locations drains into the wetland area on the former Bridson property and sinks into the bedrock which is exposed at ground surface near SW9. Hydrographs for these stations are provided in Figures C-13, C-14 and C-15 respectively.
The estimated flow out of the former Millar pond (SW7), which is fed by groundwater discharge at the spring/dug wells at that location, ranged between a low of 0 L/s (either dry or no flow) to spring highs of 0.5 L/s to 1 L/s. Flows out of the pond on the former Bridson property (SW8) ranged between 0 L/s on several occasions to spring highs of 0.5 to 1.0 L/s. Flow in the channel just upstream from the sinkhole feature area in the wetland (SW9) was observed from November 2003 until June 2004, at rates of between 0.6 to 7 L/s, but there was no flow observed from May to October 2003, and similarly no flow during the summer and fall of 2004, although there may have been standing water present. The spring 2005 high flow was recorded as 41.7 L/s. When surface flow is observed, it infiltrates into the ground in the area of exposed bedrock within the east end of the property. During high flow conditions, flow may extend across the Dempsey property also and infiltration occurs. Based on the results of the groundwater tracer work completed by others, the water that infiltrates into the ground on the former Bridson property re-emerges as groundwater springs below the brow of the Escarpment to the east.

The field chemistry results at the three stations show temperatures that are indicative of surface water, ranging between lows of less than 1° C to highs of 15 to greater than 20° C. The pH of the surface water was generally in the range of 7.5 to 8.5, and the conductivity varies between approximately 260 to 617 uS/cm. Dissolved oxygen varied between about 10 to 16.4 mg/L at the Bridson pond outlet, but was lower at SW9 where it ranged between about 7 to 11.5 mg/L.

- Station SW10 is located at a groundwater spring east of the expansion lands below the brow of the Escarpment on the W. Franks property, just below the base of the Amabel/Fossil Hill Formation scarp, and is utilized as the water supply for the residence and barn. The station is located in the small channel above the water supply catchment tile system, and the hydrograph for this station is presented in Figure C-16.
The recorded flows ranged between less than 0.1 L/s in the summers of 2003 and 2004, to highs of about 2 to 3 L/s in the spring and late fall. Field temperatures ranged between a low of about 1°C to a high of 16.5°C, which reflects the influence of the air temperature, since the monitoring station is lower down the scarp from the actual spring location. The pH was generally in the range of about 7.0 to 8.0, although two higher values were recorded. The conductivity ranged between a low of 261 uS/cm in April 2004 to a high of 523 uS/cm in October 2003, and dissolved oxygen ranged between 7.7 mg/L to 14.2 mg/L.

Water samples were collected for laboratory analysis in October 2003 and July 2004, and results are reasonably consistent. The water is characterized as hard bicarbonate water that is similar to natural groundwater quality in the area. The aluminum and iron concentrations exceed the criteria set for surface water and drinking water. Colour and turbidity exceed the criteria for drinking water. Other parameter concentrations are within their respective criteria for surface water and drinking water. Chloride concentrations at 18 to 24 mg/l are slightly elevated, and together with the sodium values likely indicate influence from road salting activities. The nitrate concentrations of 0.5 and 1.2 mg/L are slightly elevated. It is noted that there is a water treatment system in the residence which is required to ensure that bacteriologic quality is maintained in the event that the water is to be consumed by people.

Stations SW11A through 11D are groundwater spring areas located on the W. Franks property at various points along the toe of a section of the Escarpment below the Manitoulin scarp. It is noted that not all of the spring areas at this location are monitored. The flows from several of the springs coalesce to form a single channel that discharges into the man-made pond on the property. Flow in the channel is measured at stations SW11 (above the pond) and SW11E (at the pond). Hydrographs for stations SW11, and SW11A though SW11E are provided in Figures C-17 to C-22 respectively. Stations SW12A and SW12 provide a measure of the
flow in another surface drainage channel that originates in a small valley at the toe of the Escarpment on the property south of the residence and which also discharges into the pond (see hydrographs Figures C-24 and C-23). Station SW13 is at the controlled overflow outlet pipe and channel for the pond (see hydrograph Figure C-25), and SW14 is located further downstream on the outlet stream channel just east of the culvert beneath Concession 10 (see hydrograph Figure C-26).

The flows at the individual springs generally range between less than 1 L/s to 1 to 2 L/s for much of the year, with spring highs that reached 6 to 12 L/s in 2004 and 2005 at specific locations. Some locations were observed as being dry during monitoring events conducted in the summer of 2003 and in the summer/fall of 2004. The recorded cumulative discharge into the pond from the springs in this area (SW11E) varied between less than 1 L/s in the summer, to high values in excess of 20 L/s in the late fall of 2003 and the spring of 2004. The flow recorded in April 2005 was 61 L/s. The correlation between the sum of individual flows recorded at the springs and the cumulative flow recorded in the main channel either at SW11 or just above the discharge into the pond at SW11E. The discharge to the pond typically exhibits higher flows compared to the sum of the monitored individual flows, which is due to the fact that not all of the input spring sources are monitored. The flow recorded through the summer period at the discharge into the pond (SW11E) is considered reasonably representative of the overall low-flow groundwater discharge from the Escarpment bedrock at this location, and varies from less than 1 L/s to about 2 L/s.

Field temperature of the water at the spring sources reflects groundwater temperatures for the most part with minor influence from the ambient air and ranged between about 4 to 5°C in the winter/spring to summer highs of about 8 to 10°C. The summertime temperature in the main channel reached about 13°C. The pH of the water varied from about 8 to 9, and the conductivity ranged between approximately 200 to 400 uS/cm, and was reasonably consistent between the various
locations. The recorded dissolved oxygen concentrations ranged between about 9 to 17.5 mg/L, with the highest values observed in the spring when flows are highest.

A water sample was obtained from station SW11D in July 2004 for laboratory chemical analysis, and results indicate that water quality is typical of the bedrock groundwater in the area. The water is hard bicarbonate water, that shows elevated aluminum and iron concentrations (above PWQO). These springs are interpreted to originate from the Manitoulin Formation scarp section of the Escarpment, but the water quality is similar to that observed in the overlying Amabel formation. This supports the interpretation that groundwater that discharges at the Escarpment from the Amabel Formation re-infiltrates (or sinks) into the ground where the Cabot Head shale is thin or missing, enters the Manitoulin Formation and emerges lower down the Escarpment at the base of the Manitoulin Formation.

The flow recorded at SW12 provides a measure of groundwater and surface water discharge into the pond from the south. Again, the flow was variable seasonally, and ranged between summertime lows of less than 1 L/s, to spring and late fall values of 3 to 5 L/s. The recorded spring highs ranged between 11 L/s and 16 L/s. There was no flow recorded for most of the monitoring events at station SW12A, which is located upstream from SW12, near the head of the small valley. Flows recorded in the spring and fall varied between 5 and 10 L/s.

The pond into which the springs and surface water runoff discharge is a man-made feature that has an earthen dam along the east side. There is an outlet control structure at the east end of the dam, with water that discharges to a channel below the dam through a culvert system. Pond discharge is controlled manually by the property owner in order to maintain the water level in the pond. Station SW13 provides a measure of the discharge from the pond immediately below the dam, and station SW14 monitors flow in the channel further downstream just east of Concession 10. The discharge from the pond is difficult to measure at the culvert
pipe directly below the dam, particularly when flows are high (25 to 80 L/s). At station SW14, the flow in the channel is considered more reliable, and recorded flows varied from summer lows of less than 1 L/s to 3 L/s, to spring highs of almost 50 L/s to 70 L/s.

Water temperatures at the stations below the dam reflects the influence of ambient air temperatures, with winter lows of less than 1°C, to spring and summer highs of 15 to 20°C. The pH varied between 7.1 and 8.5, and conductivity ranged from about 250 to 435 uS/cm. Dissolved oxygen varied between about 7.8 to 16.4 mg/L, with the higher values occurring in the spring high-flow condition.

- Station SW21C (hydrograph Figure C-37) is the stream channel located northeast of the expansion lands below the brow of the Escarpment on the H/E Franks property, below the base of the Amabel Formation scarp. The stream, which originates as a groundwater spring higher up at the Escarpment face, is utilized as the water supply for that property. SW21C is physically located in the Pretty River subcatchment, but since the majority of the water from that location is piped to the water supply cistern that is within the Batteaux Creek basin, it is included here.

Occasionally, surface water from SW21C overflows the inlet of the collection pipe and flows northward overland to the former Sestito property (now H/E Franks). This overflow is measured at SW24, which is detailed in Section 4.3.3. Station SW21B (Figure C-36) is the overflow outlet from the cistern and discharges into a channel that leads down into the pond on this property at station SW21A (Figure C-35). The pond outlet is monitored at station SW21 (Figure C-34), and flow in the channel is monitored further downstream at the culvert beneath Concession 10 at station SW15 (Figure C-27). Station SW21D is a culvert that is located beneath the trail to the west of the water supply cistern and allows surface water that ponds at the toe of the scarp (in the Batteaux Creek subcatchment) occasionally to drain...
northwards to the east of the former Sestito property (now H/E Franks), and eventually to SW16, which is within the Pretty River subcatchment.

The recorded flows at SW21C ranged between summer lows of less than 1 L/s to spring highs of 4 to 5 L/s in 2004, and 16.6 L/s in April 2005. Water temperatures ranged between about 4 to 10°C, which is indicative of its groundwater origin. The overflow discharge from the cistern (SW21B) can be affected by water usage at the residence and/or by blockage of the inlet pipe at the collection pond, and recorded flows varied between a low of 0.1 L/s in April 2004 to highs of 4 to 5 L/s in June/July 2004 and April 2005. The correlation with the flow at SW21C is variable between good to poor, which may reflect the seasonality of the flows at the collection pond and/or water usage at the residence. The recorded flow into the pond (SW21A) varied between lows of 0.0 L/s to spring highs of about 2 L/s in 2004 and 5.8 L/s in 2005. The flow at this location is a combination of discharge from the cistern and surface runoff that is captured by the drainage ditch. Some of the flow infiltrates into the base of the ditch between the cistern and the pond under dry conditions.

The discharge from the pond is monitored at the overflow culvert (SW21), and recorded flows are reasonably consistent through the year, ranging between about 1 L/s to 2 L/s. Seasonal low flow was less than 1 L/s, and the spring high flow was 3.9 L/s in April 2005. Further downstream at Concession 10 (SW15), the recorded flow in the stream channel shows reasonable correlation with the flow out of the pond through most of the year (being 1 to 2 L/s), although the November and December 2003 values are considerably higher (approximately 8 and 13 L/s, respectively), and may reflect the capture of surface runoff in the area by the ditch. The April 2005 flow was 5.3 L/s which is reasonably similar to the outflow from the pond (3.9 L/s).
As noted above, the water temperature in the stream at SW21C near the Escarpment reflects the groundwater origin, ranging between about 4 to 10.5° C. The pH was consistent between 8.0 to 8.2, and the conductivity ranged between 240 and 409 uS/cm. Dissolved oxygen varied between 8.5 and 13.1 mg/L. The chemical quality of the water was determined in July 2003 (at the request of the land-owner), and results show the water to be typical of local groundwater from the Amabel Formation. The water is hard bicarbonate water and is low in dissolved metals such as copper, zinc, iron, sodium and potassium. The chloride concentration is low (1.3 mg/L), indicating no impact from local road salting activities. Nitrate/nitrite is present at a relatively low concentration of 1.4 mg/L. Bacteriological analysis showed the presence of E. coli and total coliform, and the resident was advised of the results since the water is used in the residence. It is noted that there is a UV and filtration water treatment system in the residence.

The field temperature data obtained at the other stations on the property show the progressive effect of ambient air temperature on surface water temperature as the water flows down into the pond and in the stream channel below the pond. Water temperature at the pond outlet (SW21) ranged between a low of 0.3° C in February 2003, to a recorded high of 23° C in July 2004. Further downstream at Concession 10 (SW15), the recorded water temperature between May and July 2004 ranged between 18 and 20.5° C; pH was approximately 7.5 to 8 and conductivity was about 300 to 400 uS/cm. Dissolved oxygen varied between 7.5 and 12 mg/L.

- Streamflow in the main channel of Batteaux Creek was monitored at station SW19 which is located at the large diameter culvert beneath County Road 124 south of Duntroon. The flow at this location provides a measure of the cumulative streamflow leaving the drainage basin upstream from County Road 124, and includes the flow from the groundwater springs that originate at the Escarpment face as well as surface runoff in the basin. The approximate area of the drainage basin above SW19 is 13 square kilometres, including the closed drainage basin wetland...
south of the existing quarry. The hydrograph for this station is provided in Figure C-32.

The recorded flows ranged between summer lows of about 10 to 40 L/s, to spring / fall values of 100 to 200 L/s, and spring high values of 508 L/s in April 2004 and (visually estimated) 700 L/S in April 2005. A baseflow of about 30 L/s is estimated, which suggests an equivalent shallow groundwater recharge rate of about 73 mm per year.

The recorded water temperatures have ranged from less than 1° C in the winter to a summer high of 21.5° C. The pH varied between about 7.4 and 8.9, and the conductivity ranged between approximately 130 and 530 uS/cm. The dissolved oxygen varied between 10.8 and 13.4 mg/L.

Chemical water quality was determined in October 2003 and is similar to other surface water quality in the area. Water quality was within the PWQO for the parameters tested. The water is characterized as hard bicarbonate water that is low in dissolved metals such as copper, iron, lead and zinc. The chloride concentration was 21.4 mg/L, indicating a low but detectable impact from road salting, and the nitrate concentration of 0.3 mg/L was low. The aluminum concentration was low (less than 0.05 mg/L), unlike some of the groundwater spring / surface water samples that contribute flow in the basin.

4.3.3 Pretty River Subcatchment

Surface water monitoring was carried out in the section of the Pretty River subcatchment that is located immediately to the northeast of the expansion lands, centered on the 26/27 Sideroad. Streamflow monitoring locations include groundwater spring areas that originate near the brow of the Escarpment in the Amabel Formation (SW20), groundwater springs that originate lower down the Escarpment at the Manitoulin Formation scarp (SW24A) or
stream channels below the scarp just above their discharge into the pond on the former Sestito (now H/E Franks) property (SW24B and SW24). The stream channels are also monitored at the 26/27 Sideroad (SW17, SW17A, SW16 and SW23), and the cumulative flow in the main channel is monitored at Concession 10 at station SW18. The results for the various locations are discussed below.

- Station SW20 initially was located at the outflow from an old stone crib well that was fed by a groundwater spring in the lower section of the Amabel Formation. The hydrograph for station SW20 is provided in Figure C-33. In the fall of 2004 a residence was constructed at this location and the old stone well was replaced with a large diameter tile well from which there is no outflow. Monitoring station SW20 was re-located a short distance downstream, near the footbridge, and flows are now monitored in the tributary channel. Recorded flows ranged between summer and fall lows of 0 to 0.7 L/s, winter flows of about 2 L/s, spring values of 3 to 5 L/s, with spring highs of about 19 L/s in April 2004 and April 2005.

Water temperature reflects the groundwater origin at this location, generally ranging between about 6.5 and 9.0° C. The pH varied between 7.1 to 7.7, and conductivity ranged between approximately 250 and 485 uS/cm, with the lower values occurring under the high-flow conditions. The dissolved oxygen varied between 7.5 and 14.4 mg/L.

Water samples were collected from two other spring sources from the Amabel Formation just to the north (SW27A and SW27B) in July 2004 as part of the preliminary karst evaluation. Water quality is consistent between the two sampling locations and is typical of local groundwater from the Amabel aquifer, being characterized as hard bicarbonate water. Dissolved metals are generally low, although the aluminum concentrations at both locations and the zinc concentration at SW27B exceeded their respective PWQO. The chloride concentrations were at background values of about 1 mg/L, and do not indicate road salting effects. It is
noted that the section of the 26/27 Sideroad down the Escarpment is not maintained open through the winter. The nitrate concentrations were consistent at 0.9 mg/L, and iron was 0.22 mg/L at station SW27A which is just below the PWQO of 0.3 mg/L, and 2.22 mg/L at station SW27B.

> Some of the water discharging at the groundwater spring at the Manitoulin Formation scarp on the former Sestito (now H/E Franks) property (SW24A, Figure C-44) is collected in a barrel and piped down the slope for use as a non-potable water supply for the seasonal residence. Water from a second stream channel at the toe of the slope below the bedrock scarp (SW24B, Figure C-45) is also used for irrigation of the gardens at this residence, and together with SW24 (Figure C-43) provides a measure of the surface water discharge into the on-site man-made pond.

The recorded flows at SW24A ranged between summer time values of 0.2 to about 1 L/s, a winter value of 0.9 L/s and spring values of between 2 and 3 L/s, up to the highest recorded flow of 7.9 L/s in April 2005. The flows recorded in the second channel at SW24B were generally less than those at SW24A, and varied between lows of 0.1 to 0.2 L/s up to the high of 4.5 L/s in April 2005. The channel at SW24 extends southwards towards the H/E Franks property, with flow rates that relate to the SW21C flow conditions as discussed earlier, varying between dry conditions through the summer period to high values of about 4 to 7 L/s in the late fall and spring seasons. The April 2005 flow was 17.8 L/s.

Water temperatures reflect the general location of the stations with respect to the water source, with SW24A showing groundwater temperatures of about 5.6 °C to 8.2° C, and SW24B showing air temperature effects with recorded values ranging between 2 and 12.4° C. Values at SW24 varied between 5.7 and 12.9° C. The pH of the water at SW24A was generally about 7.4 to 8.0, the water at SW24B and SW24 was generally between 7.3 to 8.2. Recorded conductivity values ranged between 274 and 440 uS/cm at SW24A, 255 to 471 uS/cm at SW24B, and 243 to 370 uS/cm.
at SW24. Dissolved oxygen values were generally slightly higher at SW24A relative to SW24B and SW24, and ranged between about 11 to 17.8 mg/L.

A water sample was collected for chemical analysis from the groundwater spring source at the base of the Manitoulin Formation at SW24A. The water quality is similar to other spring locations and is characterized as hard bicarbonate water. The concentration of aluminum exceeded the PWQO, and iron was close to the PWQO. The chloride concentration was 23.9 mg/L and sodium was 12.9 mg/L, suggesting possible road salt effects, although given the location of the station away from the winter-maintained roads, there may be some influence from the overlying shale bedrock of the Cabot Head Formation. The nitrate concentration was 0.6 mg/L which is similar to other waters in the area.

- The overflow outlet from the pond on the former Sestito property (now H/E Franks) is a culvert located at the north end of the pond. Flow was monitored lower down in the stream channel at the 26/27 Sideroad at station SW17 (Figure C-29). Station SW17A (Figure C-30) provides a measure of the stream flow in the channel on the north side of 26/27 Sideroad that transmits the flow from the groundwater springs that originate from the Amabel Formation higher up the Escarpment to the west.

The recorded outflow from the former Sestito pond (now H/E Franks) varied between summer lows of 0.1 to 1 L/s, winter values of about 2 L/s, spring and fall values of about 2 to 7 L/s, and spring high values of about 13 to 17 L/s in April 2004 and 2005. The flows recorded at SW17A are considerably higher, and ranged between summertime values of 2 to 10 L/s, a winter value of 9 L/s, spring and fall values of 10 to 20 L/s, and spring high values of approximately 72 L/s and 69 L/s in April 2004 and 2005.

Water temperatures in the channel below the pond outlet channel show the effects of the ambient air temperature, ranging from 1°C in the winter to almost 20°C in July.
2004. The water temperature at SW17A also reflects ambient air temperature but to a lesser degree, varying between about 1.5°C in the winter to about 12.6°C in July 2004, which is interpreted to be due to the moderating effects of the groundwater spring component from the west. The pH of the water at both stations was generally between 7.6 and 8.6, and conductivity ranged between about 270 and 430 µS/cm. Dissolved oxygen has varied between approximately 7.4 to 16.3 mg/L.

Streamflows in two other tributary streams lower down the Escarpment to the east are monitored at the 26/27 Sideroad at station SW16 (Figure C-28) and a smaller channel at SW23 (Figure C-42). Recorded summer low flow values at SW16 are 0 to less than 1 L/s. Spring and fall values are about 1 to 3 L/s and the spring high value was approximately 40 L/s in April 2004 and 27 L/s in April 2005. Flows at SW23 ranged between summer lows of 0.1 L/s or less to spring and fall values of 1 to 2 L/s and a winter value of 0.8 L/s. The highest values were about 2 L/s, recorded in November 2003 and April 2005.

Water temperatures at both stations reflect ambient air effects on the surface waters, ranging between near-freezing in March 2004 at SW23 to 19.4°C at SW16 in June 2003. The pH of the water was generally between 7.5 and 8.2, and the conductivity at SW16 ranged between 230 and 480 µS/cm, and 275 to 520 µS/cm at SW23. Recorded dissolved oxygen concentrations at SW16 were variable, ranging between 3.5 to 11.9 mg/L. At station SW23, the dissolved oxygen concentrations ranged between 7.9 and 14.6 mg/L.

Station SW18 provides a measure of the cumulative flow in the main tributary channel at Concession 10, and includes the flow from the stations discussed above. The hydrograph is presented in Figure C-31. Recorded streamflows show a wide seasonal variation that reflects the larger surface water catchment area and the groundwater discharge flow components. The summertime flows range between about 2 to 9 L/s, while the spring and fall values vary between approximately 10 to
50 L/s and the winter value was 48 L/s. The April 2004 high-flow value was approximately 124 L/s, and the April 2005 value was 207 L/s.

Surface water temperature reflected ambient air temperature effects, varying from about 1° C in the winter to 16° C in the summer. The pH was generally between 7.2 and 8.6, and conductivity varied from 272 uS/cm in the high-flow period in April 2004 and April 2005, to 320 to 485 uS/cm at other times. Dissolved oxygen varied from 10 to 14.7 mg/L during the monitoring period.

A water sample was collected from this station in October 2003 for general chemical analysis, and results characterize the water as hard bicarbonate water that is low in dissolved metals. The parameters concentrations were within their respective PWQO, with the possible exception of the ammonia concentration. Of note is the low aluminum concentration (<0.05 mg/L), the chloride value of 8.8 mg/L, the low iron concentration of 0.2 mg/L and the low nitrate value of <0.2 mg/L. The streamflow at the time of the October sampling was about 26 L/s (compared to less than 2 L/s in September), and reflects a large surface water component relative to the groundwater component.

### 4.3.4 Mad River Subcatchment

The outflow from Edward Lake is monitored at station SW25 and is the one station within the Mad River Subcatchment that was monitored, starting in October 2003. The hydrograph for this station is provided in Figure C-46. The outflow occurs through a culvert that passes beneath Grey Road 31 at the southwest corner of the lake. The recorded flow in October 2003 was 13 L/s and increased in the late fall to about 31L/s. The winter flow was about 21 L/s, and the spring 2004 flows generally varied between 23 to 36 L/s with a high value in April 2004 of almost 50 L/s. The value in July 2004 was approximately 22 L/s but flow reduced to less than 1 L/s in the later summer and fall. Flows in the spring 2005 reached 80 L/s in April.
Water temperatures at the outlet reflected the effect of ambient air temperatures on the lake water, ranging between about 1°C to a recorded high of 22.4°C in July 2004. The pH of the water varied between 6.4 to 8.7, and the conductivity ranged between a low of 182 uS/cm to a high of 564 uS/cm in July 2004. The dissolved oxygen concentration varied between a low of 6.2 mg/L in March 2004 to 15.1 mg/L during the high-flow event in April 2004.

5.0 EXISTING QUARRY OPERATIONS

5.1 HISTORICAL DEVELOPMENT

The Duntroon Quarry commenced operations in 1964, initially under the name of the McKean Quarry. The first set of site plans were prepared by Zubek and Emo, dated 1970, and showed a proposed excavation down to elevation 1650 feet above sea level (asl) or 502.9 m asl. The original ground elevation in the area proposed for extraction varied from approximately 1700 feet asl in the western section to a high of 1784 feet asl in the southeastern corner (518.2 m to 543.8 m asl). The site plans acknowledged that extraction to the proposed base of the quarry would extend below the water table, and that the final end use of the central part of the quarry would be a lake 38 acres (15.4 ha) in size. The cross sections indicate that the final lake level elevation would be approximately 1678 feet asl (511.5 m asl).

Since that time, the quarry was purchased by Seely & Arnill Aggregates Inc. and subsequently by Georgian Aggregates and Construction Inc. Several sets of site plans were prepared for the quarry over the intervening years by various consultants, and the licensed area of the quarry was increased to include the eastern section of what is now the existing quarry, known locally as the 20-Acre parcel.
The most recent site plan revision was prepared by MacNaughton Hermsen Britton Clarkson Planning Limited, and is dated February 2002. The revisions were prepared as part of the application to permit extraction in the eastern 20-Acre parcel down to the final floor elevation of 500 m asl. The site plans state that the licensed boundary of the quarry is 57.5 ha (142.1 acres), and the area to be excavated is 47.09 ha (116.36 acres). The Progressive Rehabilitation Plan includes five specific features to provide for recreational and natural resource activities and connection to the Bruce Trail system. The final lake is shown to have an average depth of 12 m and a controlled outlet to the wetland west of the quarry.

5.2 CURRENT OPERATIONS

Figure 1-2 provides a sketch of the general conditions at the quarry as of August 2005. Approximately one million tonnes of aggregate has been extracted and processed each year, of which about one third, or 350,000 tonnes per year, is washed in order to manufacture specific products. The various aggregate products are stockpiled on the upper central part of the quarry, along with the wash plant and processing equipment. The limit of extraction has been reached along the south, west, northwest and eastern boundaries, and rehabilitation of portions of the internal final slopes of the quarry and the area around the southwest corner of the property has been completed.

Extraction occurred in the central and eastern sections of the quarry through the 2005 season. Extraction occurs in a single lift that is 15 to 20 m in height, depending on location, using time-delayed controlled blasting to limit the overbreak and throw of the material. The explosive used is either a wet or dry ANFO mix (ammonium nitrate / fuel oil), depending on water conditions in the rock at the time of blasting.

The primary crusher is located on the quarry floor in the southwest corner of the site. The blasted rock from the active extraction areas is hauled by truck to the primary crusher. The crushed aggregate is moved by means of a conveyor system across the southern part of the
quarry floor and then across and up to the main processing area for secondary crushing, processing and washing where required.

The dewatering sump is located adjacent to the primary crusher and is approximately 60 m in diameter (depending on water level) and is a maximum of about 4 m deep. Water from the sump is used for washing about one third of the aggregate production, for dust control in the quarry, for washing the approach road to the quarry and for irrigation of selected vegetated areas in and around the quarry when required.

The water management system at the quarry has evolved over many years, and has changed periodically as a result of where rock was being extracted, and the conditions that were encountered. The current system has been evolving since extraction started to move into the northwest corner of the licensed area in 2000. The main sump was developed in the quarry floor adjacent to the crusher in the central southwest corner of the extraction area in late 2000/2001. The quarry floor is graded to direct surface water runoff towards and into the sump. A new, large water storage pond and retention berm were constructed across the quarry floor in the western section of the quarry in the winter–spring of 2005, as part of the water management system.

5.2.1 Sedimentation Pond System

A sedimentation pond system to remove fines from the process wash water was first developed on the upper level of the quarry directly north of the asphalt plant. The source of the wash water was the dewatering sump on the quarry floor. Excess water from the wash pond was channeled to the west and was pumped off-site into the adjacent wetland. As extraction progressed to the north and west, the amount of the discharge water that was recycled through the rock surface back onto the quarry floor progressively increased.

Once extraction reached the western limit, a new sedimentation pond system was constructed against the southwest rock face and a small section of the western face, as
shown on Figure 1-2, using on-site soil strippings and rock-fill to create the outer containment berm. Clean process water is pumped from the sump by means of a 10” pump (designated WP1 on Figure 1-2) and booster pump system that provides water to the wash plant and classifier at approximately 242 L/s (3200 Igpm).

Prior to the development of the new water storage pond in 2005, the sediment-laden process water was pumped from the wash plant to the west end of the sedimentation pond where it was discharged into the first settling cell. There are three settling cells within the structure that are separated by rock-fill and sand/gravel internal filter berms. As the process water moved through each cell, the suspended fines progressively settle out. There is a vertical concrete tile collection culvert at the east end of the third basin that directs water back to the sump.

Historically, the washing operation essentially has been a closed-loop system that recycles process water through the sedimentation pond back to the sump. Water losses do occur within the system as a result of spillage onto the ground at the wash plant, minor leakages in the lines, and water that is retained within the processed aggregate in the stockpiles, and/or is shipped off site with the aggregate. Of the water that is spilled onto the ground or which seeps out of the stockpiles, some infiltrates back into the rock and discharges through the rock faces as small seepage areas to the quarry floor, some is directed via surface drainage channels into the former small wash pond area located north of the asphalt plant from where it discharges back to the quarry floor, and some will evaporate from the ground surface. A relatively small percentage of the process water will be retained in the aggregate which is stored within the stockpiles and/or is shipped off-site. That retained water is estimated to be less than 5% by weight of the aggregate that is washed, and is less than 15,000 tonnes of water, or 15,000 m³, per year (less than 0.5 L/s or 6 Igpm taken over the course of the year).
The sedimentation pond structure was not designed to be watertight, and leakage (seepage) occurs through the containment berm and the quarry floor. That water makes its way back to the quarry floor and ultimately into the sump via surface drainage channels that have been developed across the quarry floor.

**5.2.2 Dewatering and Water Management System**

Water accumulates on the quarry floor as a result of (a) the accumulation of surface water on the quarry floor resulting from precipitation events and the annual spring snowmelt, (b) groundwater influx through the rock, and (c) the recycling of discharge water from the wetland back into the quarry. As the extraction area has increased in size, so has the accumulation of surface water and groundwater on the quarry floor.

Water entering the quarry is directed across the quarry floor along a series of shallow channels and into the sump where it is used for washing aggregate and dust control. Excess water is discharged off-site to the wetland area to the west of the quarry, which is also owned by Georgian Aggregates. From the wetland, water flows westwards beneath Grey Road 31 (formerly known as Townline Road) via twin culverts that are 0.6 m in diameter, into a continuation of the wetland feature that is under different private ownership. The culverts are designated as monitoring station SW1 on Figure 1-2.

The discharge water from the quarry that flows westwards through the culverts at SW1 moves through the adjacent wetland. That unnamed water course is a tributary of the Beaver River and flows westwards around the north side of the undeveloped Osprey Quarry property, which is also owned by Georgian Aggregates. The southern portion of the Osprey property and the adjacent wetland is part of the Kenwell farm. Further to the west, the tributary joins with another south-flowing tributary water course that then flows west, meandering back and forth beneath the Osprey Township 10th Line Road through large diameter culverts/box culverts.
Historically and into the spring of 2005, a significant amount of the water that was discharged to the wetland infiltrated into the ground and recycled back into the quarry through the rock at the west face and the southwest face. That water entered the quarry through specific bedding plane seepage zones along those two faces and became part of the surface water flow across the quarry floor to the sump.

The outflow of excess water from the quarry to the west through the wetland is monitored manually at the twin culverts (station SW1 on Figures 2 and 3) at Grey Road 31. The flow through the culverts is monitored weekly using a Valeport velocity flowmeter and measurement of the cross-sectional area of the discharge. Accuracy is expected to be within +/- 10 to 15% using this method. The natural inflow to the northwest corner of the wetland is monitored on a weekly basis (station SW2). Because there is recycling back to the quarry of water that is discharged into the wetland, the rate of discharge of excess water from the quarry that actually leaves the property is determined by subtracting the flow at SW2 from that at SW1. It is recognized that inclusion of direct precipitation and surface run-off from the wetland and additional catchment areas overestimates the actual discharge of excess water from the quarry. The Ministry has accepted this approach. In addition to monitoring the outflow at SW1, the discharge from the ancillary (tile) sump into the small beaver pond wetland west of the quarry is monitored manually on a weekly basis at the culvert beneath the perimeter berm (designated SWB-1 on Figure 1-2).

5.2.3 Permit To Take Water (PTTW)

The PTTW for the quarry was first issued in January 1997 (No. 96-P-5019) to permit the pumping of water from sumps established in the quarry floor for the purpose of aggregate processing and dewatering to maintain dry working conditions. That permit was amended in 1999 (same permit number) to reflect the change of ownership of the quarry from Seeley & Arnill Aggregates Inc. to the current owner, Georgian Aggregates and Construction Inc.
The permit was amended to the current PTTW (No. 01-P-1036) in April 2001 to reflect the higher volume of water that was required by the higher capacity aggregate wash plant that is now present at the site. In addition, the dewatering discharge component was increased to reflect the additional size of the quarry excavation and the re-circulation of discharge water back into the quarry from the adjacent wetland area to the west (also owned by the applicant). The current PTTW, which expires on May 15 2011, provides for the following:

(1) Quarry dewatering sump: maximum amount to be taken 2,300 L/minute (38.3 L/s or about 500 Igpm), 24 hours per day, 365 days per year.

(2) Settling pond process water: maximum amount to be taken 22,700 L/minute (378 L/s or about 5000 Igpm), maximum of 16 hours per day, average of 10 hours per day, maximum of 220 days per year.

The technical support documentation that accompanied the application in 2001 for the current permit also stated that during the spring snow melt period and times of prolonged rainfall, surface water accumulation on the quarry floor can necessitate temporary periods of increased pumpage in order to maintain relatively dry working conditions.

The Special Conditions of the current PTTW specify the monitoring program that is required. Essentially, the program requires the following:

(i) Ground water monitoring at the existing locations on the quarry property and at the supply wells on the Camarthen Lake Farms property to the south, and streamflows at stations SW1 and SW2, all of which is to be done four times per year.

(ii) Provide a weekly record and total record of water discharged from the quarry.

(iii) Provide an analysis and report of the monitoring data to the Ministry every three years. Any anomalies in the monitoring data shall be reported to the Ministry forthwith. The first 3-year report required under this current PTTW is to include
the period to the end of 2004, and is due in 2005. Maintain a record of all water takings (dates, times, and volumes pumped, for each source).

(iv) Maintain all records up to date and available for Ministry inspection.

Groundwater and surface water monitoring is undertaken on a monthly basis, and streamflows are measured at SW1, SW2 and SWB-1, and since the spring of 2004 internally at the sump, on a weekly basis. Monitoring results do not indicate any adverse interference effects on local water resources.

5.2.4 Modification of the Water Management System

The volume of water that is managed by the quarry pumping systems has increased progressively as the extraction area has expanded. In 2004, Georgian Aggregates was proactive in advising MOE of the need to modify the water management system, and Georgian is now implementing a program to provide additional on-site temporary storage of water as well as controlled discharge off-site to the wetland and surface water receiver to the west.

In August 2004, following a pre-application consultation meeting with Ministry staff, an application to amend the PTTW was submitted to the Ministry. That amendment application, which reflects more-representative seasonal pumping conditions and changes to the water management system, is under review and discussion with Ministry staff.

One of the main modifications to the system is the construction of a water retention berm and water storage pond across the quarry floor in the western part of the site. The berm, which was constructed through the winter and spring of 2005, extends across the quarry floor from the north face of the quarry southwards to the existing freshwater pond / sedimentation pond system. The crest of the berm is located approximately 110 m east of the western limit of extraction, and it has an elevation of approximately 515 m asl. The core of the berm was constructed using compacted fines reclaimed from the washing operation to provide a central zone of lower hydraulic conductivity material. The outer
slopes consist of compacted overburden materials that were reclaimed from the existing perimeter berms in the southwest corner of the quarry property and which is undergoing final rehabilitation.

Construction of the containment berm was completed in June 2005. During construction, the influx of recycled quarry discharge water through the west wall of the quarry from the wetland was allowed to accumulate in the new storage pond between the berm and the west wall. In addition, the sediment-laden process water from the wash plant was diverted from the sedimentation pond system into the new storage pond in order to assist with the filling. Following completion of the berm, the water level in the pond was raised by diverting the excess water from the sump into the pond. A gravity-fed overflow outlet from the pond to the wetland is present so that excess water from the quarry continues to discharge off-site, depending on the level of the pond. The elevation of the overflow outlet at pond side is approximately 512.8 m asl, and 512.3 m asl at the wetland.

The purpose of the storage pond is threefold:

(i) To provide a hydraulic barrier against the west face of the quarry that will reduce / prevent the influx of water into the quarry from the wetland to the west. Under existing conditions, the influx of water from the wetland is a combination of (a) recycled quarry discharge water that infiltrates into organic soil and the rock beneath the wetland, and (b) groundwater in the rock aquifer that originates within the zone of influence of the quarry to the west and southwest.

(ii) To provide on-site temporary storage of excess water during the spring melt and heavy rains in order to achieve controlled seasonal discharge off-site of sediment-free water to the wetland and receiving water course.

(iii) To provide a supply of water that is available as needed for use in the washing operations during the summer / fall when dry conditions prevail.
By maintaining a high water level in the pond through most of the year, the recycling of water from the wetland back into the quarry will be reduced, and discharge of excess water from the pond will occur under more natural gravity-feed conditions via the overflow outlet. It may occasionally be necessary under heavy precipitation conditions to supplement the natural overflow from the pond by pumping. In addition, water will be pumped from the pond to the wetland at times during the late fall, winter and early spring in order to reduce the water level in the pond in preparation for the heavy influx of surface water that can occur during snowmelt and spring rains.

5.2.5 Water Influx To Quarry

Historically, prior to the development of the new water storage pond, water accumulating on the quarry floor has done so from four main sources:

(i) Direct precipitation and surface runoff. Based on the existing surface topography around the perimeter of the quarry, it is estimated that approximately 80%, or 46 ha, of the licensed quarry property contributes surface runoff into the quarry, with the remainder running off into the wetland or eastwards in the Batteaux Creek system. The amount of surface water runoff that accumulates on the quarry floor varies seasonally, being highest in the spring and late fall, with lesser amounts through the winter and summer seasons.

(ii) Of the excess water that is pumped from the quarry floor and discharged into the wetland, some leaves the wetland at Grey Road 31 and some recycles back into the quarry through the west face and the southwest face. It is interpreted that most, if not all, of the water that is discharged into the small beaver pond wetland area in the southwest corner of the quarry and which enters the main wetland at station SWB-1, recycles back into the quarry. Of the water that was discharged from the main sump into the western section of the wetland, up to approximately 60% recycled back into the quarry.
(iii) Process water is pumped from the main sump at a rate of 242 L/s (3,200 Igpm). Some of that water spills onto the ground and re-infiltrates into the rock in the area of the wash plant and some water is retained in the aggregate in the stockpiles. Prior to the development of the new water storage pond, the dirty process water from the wash plant was recycled through the sedimentation pond system. Some of that process water seeped out from the cells and the freshwater pond through the containment berms and through the quarry floor beneath the ponds back onto the quarry floor.

(iv) Because extraction is occurring below the surrounding water table, some groundwater is drawn into the quarry excavation area from the surrounding lands. Historical and recent visual inspection of the quarry walls shows that the majority of water entering the quarry through the exposed rock faces has done so along the west / southwest face. There is very little groundwater seepage through the exposed rock observed along the north, east and south walls of the quarry. Historically, as extraction was occurring to the west significant influx occurred at the west / southwest face along a bedding plane that was exposed approximately mid-way up the west and southwest faces (elevation about 506 to 508 m asl). Visual observation of that discharge through the bedding plane is now obscured by the accumulation of fines present in the central and western cells of the sedimentation pond, and by the slope rehabilitation along the west wall of the quarry and the water in the new storage pond. The development of the new water storage reservoir along the west wall of the quarry is intended to reduce and potentially eliminate the influx of water into the quarry at this location. In addition to groundwater seepage at the west / southwest face, there will also be a component of groundwater movement towards the sump through the rock beneath the quarry floor.
The volume and timing of dewatering and associated off-site discharge pumping that historically occurred at the main sump and the old ancillary sump reflects the seasonal variation in the precipitation / runoff components and the other sources of water, and the cyclic operation of the wash plant.

During the quarry operating season, which generally runs between April and December, the sump discharge pump is operated on a float switch that can be raised or lowered depending on the water level in the sump. Under these conditions, the pump discharged into the wetland at full capacity when it was running. During the winter season (usually mid-December to early-April), the pump is operated continuously so that freezing problems do not occur. Under these conditions, the pump does not always operate at full capacity depending on the water level in the sump. When the water level is low, the pump may cavitate and the discharge is reduced. Visual observations in the wetland indicate that the pump discharge varies from a low of about 40% up to full capacity during winter operations.

The 6” pump in the old ancillary sump can be operated either manually or on a float switch. When operated manually, a similar cavitation condition can occur depending on the water level in the old sump. Hence, the pump does not always discharge at full capacity, particularly during the winter season.

The following general trends are provided with respect to the volume of water that was pumped from the main sump and discharged into the wetland through to the end of 2004.
Seasonal Monthly Averages:

<table>
<thead>
<tr>
<th>Seasonal Period</th>
<th>Average Volume</th>
<th>Average Discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter season (January to March)</td>
<td>232,511 m³</td>
<td>approximately 90 L/s</td>
</tr>
<tr>
<td>Spring season (April to June)</td>
<td>273,507 m³</td>
<td>approximately 105 L/s</td>
</tr>
<tr>
<td>Summer season (July to September)</td>
<td>147,963 m³</td>
<td>approximately 56 L/s</td>
</tr>
<tr>
<td>Fall season (October to December)</td>
<td>248,017 m³</td>
<td>approximately 94 L/s</td>
</tr>
<tr>
<td>Monthly high volume</td>
<td>335,711 m³</td>
<td>approximately 125 L/s  (Dec 2003)</td>
</tr>
<tr>
<td>Monthly low volume</td>
<td>99,000 m³</td>
<td>approximately 38 L/s  (Sept 2004)</td>
</tr>
</tbody>
</table>

These data illustrate the seasonal nature of the influx of water onto the quarry floor and the resulting discharge into the wetland to the west. The precipitation and surface runoff component that accumulates in the quarry is variable and seasonal, being dependent on the prevailing climatic conditions.

The recycling of discharge water that has occurred from the wetland back into the quarry has been variable. Under recent conditions, it is interpreted that most, if not all, of the water that is discharged from the old ancillary sump into the small beaver pond wetland in the southwest corner of the quarry recycles back into the quarry through the west and southwest walls. Visual observation in the summer of 2004 and 2005 of the discharge at station SWB-1 into the main wetland, at a time when the pump in the main sump was not discharging, indicated that none of the flow reached the culverts at Grey Road 31. A similar situation occurs at the natural surface water course that enters the northwest corner of the wetland, in that during the drier periods of the year, the channel flow through the wetland becomes diffuse and does not reach the culverts.
5.2.5.1 Groundwater Influx to Quarry

Because of the generally spatially diffuse nature of groundwater movement relative to that of surface water, it is impractical to measure directly the total influx of groundwater into the quarry. The influx of groundwater can be estimated through a variety of methods, including:

- Analytical equations of groundwater flow based on the hydraulic characteristics of the dolostone rock.
- Water balance approaches based on seasonal climate data and discharge volumes.
- Groundwater modeling.

Based on these three approaches, the average groundwater influx to the existing quarry is estimated to range between approximately 8 L/s from groundwater modeling, and 10 to 20 L/s for the analytical equations and water balance approaches. Seasonally, the groundwater influx will vary, depending on prevailing climatic conditions, being higher in the spring and late fall, and lower in the summer and winter frozen ground conditions.

5.2.6 Groundwater Drawdown Influence

Rock has been extracted from below the groundwater table at the existing quarry starting in the late 1980’s to early 1990’s and continues at the present time. Extraction occurs in a single lift down to the approved final floor elevation of 500 m asl. Based on the earliest recorded groundwater levels at the quarry property, the pre-extraction water table is estimated to have been in the range of approximately 512 m asl in the lower-lying western section and eastern sections of the quarry property, to about 520m asl in the topographically higher central parts of the site. The water table elevation fluctuates seasonally in response to prevailing climatic conditions.
Thus, within the extraction area, there has been a progressive drawdown influence of 12 to 20 m on the local water table. As the size of the extraction area increased, so has the zone of influence of the quarry on the local groundwater system. The magnitude of the drawdown influence is greatest within the extraction area at the quarry, and decreases relatively quickly with distance away from the extraction faces. The magnitude and lateral extent of the drawdown zone of influence will also be variable around the quarry, being affected by the bedding and fracture pattern and the resulting hydraulic conductivity of the rock mass adjacent to the quarry faces.

In order to quantify the magnitude and lateral extent of the zone of influence of the quarry on the local groundwater system, the historical and recent groundwater level data obtained from on-site monitors and local agricultural and residential water wells have been evaluated. The data are used to provide distance-drawdown information for locations on and around the quarry property.

Figure 5-1 provides a summary of the distance-drawdown relationships obtained at individual monitor and water well locations. The figure illustrates a lower boundary influence envelope and an upper boundary influence envelope which identify the interpreted minimum and maximum extent, respectively, of the distance-drawdown relationship. It is noted that within the envelope, there are three distance-drawdown relationship curves presented for monitor OW99-1 for various dates. The individual dates provide a measure of the progressive increase over time in the drawdown influence at OW99-1, as the quarry extraction face approached that monitor. The three curves are provided to reflect different estimates of the pre-extraction groundwater level at that location. Monitor OW99-1 was developed after rock had been extracted from below the water table in the south-central part of the quarry, and there may have been some influence on the water table at the monitor before water level monitoring began.

As would be expected in a fractured rock aquifer, the distance-drawdown relationship is variable within and around the quarry property, reflecting variable hydraulic...
interconnectivity conditions between the extraction faces and the surrounding rock mass. At the lower boundary condition, the drawdown influence of the quarry extends approximately 125 m out from the quarry.

At the upper boundary condition, which is based on the two northern supply wells at Camarthen Lake Farms, designated CLF1 and CLF2, there is an apparent seasonal drawdown of up to 3m at those two wells. Those wells are located approximately 700 to 750m southwest of the quarry face. The 3m drawdown influence is based on the static water levels shown on the water well records (June 1970 and March 1973 respectively) believed to be for CLF1 and CLF2, and the water levels recorded in the two wells in April 2004. Monitoring at the two wells began in 1996, several years after extraction in the south part of the quarry had reached the 500 m asl final floor elevation. The monitoring data (Figures B-41 and B-42) indicate reasonably stable water level conditions between 1996 through to mid-1999, which was one of several drier-than-normal years. Those water levels were 1.5 to 2m lower than the original levels shown on the well records. Since 1999, there has been an overall slow progressive decline in the water levels in the wells, although there was some seasonal recovery in the water levels in the spring of 2004 and again in April 2005.

The supply wells CLF1 and CLF2 were subjected to capacity testing in the fall of 2004, and results indicate that satisfactory supplies continue to be available. CLF1 was tested at a rate of 30 L/minute (6.6 gpm) and CLF2 was tested at a rate of 45 to 60 L/minute (10 to 13 gpm). Those rates are reasonably similar to the pumping rates listed on the original water well records.

Figure 5-1 shows that the distance-drawdown relationships for the other monitors and wells fall within the upper and lower boundary limits. Two locations (Kekanovich and monitor 03-8) do not indicate any drawdown influence at distances of approximately 500 m and 700 m away from the quarry extraction face. Similarly, the water level observed in the Georgian Aggregates office well in March 2004 did not indicate any drawdown influence at
that location (approximately 275 m from the extraction face). Water levels observed in the Binczyk hand pump shallow well (owned by Georgian) to the east of the office well, suggest a potential influence of approximately 2.5 m relative to the water level recorded on the original water well record for the actual deeper drilled supply well at that location (now buried). However, since the two wells at that location are of different depths, their original static water levels may not correlate directly.

Groundwater levels to the north of the quarry on the expansion lands do not indicate significant drawdown influence. Visual observation of the quarry wall at the limit of extraction confirms that there is minimal groundwater discharge through the rock around the majority of the quarry. The exception is the west and southwest walls of the quarry, although the influx at those locations is also associated with recycling of discharge water through the wetland.

Water level measurements at the Urbaniak well, located approximately 1400 m north of the quarry, and at the Kenwell Farm well (approximately 1100 m to the west) do not indicate any drawdown interference.

5.2.6.1 Water Supply Interference Reports

Water supply interference reports have, on occasion, been submitted to the quarry owner by local residents. Those complaints were investigated by the quarry as follows.

- Kekanovich Residential Well (early to mid-1990’s): The water supply at the wellhead of the drilled bedrock well was interrupted on one occasion due to a break in the connection below-grade at the wellhead. Whereas the cause of the problem was not determined, the connection at the wellhead was repaired by the then-quarry owner as a “good neighbour” gesture.
Kenwell Farm Pond (May 2001): The water level in the small stockwatering pond at the Kenwell farm west of the quarry was reported by the owner to have declined in the spring of 2001 and remained low, with insufficient water to supply the stock. The conditions at the pond were investigated by Jagger Hims Limited and the quarry provided water to the pond to assist the property owner. The cause for the low water level in the pond was not attributed to the quarry operation. The nearby drilled water supply well at the farm has not been affected by low water levels. The capacity of the well was tested on behalf of Georgian Aggregates by Jagger Hims Limited in October 2003 as a goodwill gesture to ensure that there was sufficient water available for the stock and the residence during the winter period. The well was tested at a rate of 24 L/minute (5.3 gpm) for 2 hours. The water level in the pond subsequently recovered and remains satisfactory to date through 2005.

Scott Residential Well (July 2001): A water supply shortage problem was reported to Georgian Aggregates by the Scott residence in July 2001. The residence is located west of the Kenwell Farm, approximately 1700 m from the quarry. The owner reported that since approximately November 2000, the well could not provide sufficient water to supply normal household needs without having to wait for the system to recharge. The conditions at the well were investigated by Jagger Hims Limited on behalf of Georgian Aggregates. The well, which was constructed in 1990, was 18.9 m deep, had a static water level of 6.1 m below grade and was rated at 73 L/minute (16 gpm). There did not appear to be any change in the static water level in the well relative to when the well was first constructed. The static water level in the well on July 12, 2001 was 6.4 m below grade, and the elevation was estimated to be approximately 501.6 m asl, which was about 1.6 m higher than the elevation of the quarry floor. It was suggested that the system be inspected by a plumber to determine if there was a mechanical problem that would cause the water shortage. No further action was undertaken by the quarry operator.
Singhampton Residential Wells (October 2002): Four residents located in Singhampton, on the south side of the Mad River valley (Devil’s Glen), reported problems with their drilled well water supplies. The wells are located approximately 3500 m south of the quarry. All of the problem supplies were investigated by Jagger Hims Limited on behalf of Georgian Aggregates. With one exception, the problems with the water supplies were found to be due to electrical/mechanical malfunctions with the submersible pumps and/or the filter systems, and were not associated with quarry operations. One well continued to experience supply problems, but they were not associated with quarry operations.

5.2.6.2 Groundwater Springs

There are two groundwater springs located on the Sampson property east of the quarry at the base of the Amabel Formation at the Escarpment that have been monitored as part of the surface water program. The springs are designated SW 22 and SW 22A on Figure 2-1, and they are the headwater areas of a tributary stream of Batteaux Creek. The tributary stream flows across Duntroon Highlands golf course to the southeast and is used as the irrigation water supply (from an on-stream pond) by the golf course.

Based on the flow estimates recorded between June 2003 and December 2004, the recorded flows at the two springs have varied between 0.2 and 9.5 L/s. During the summer / fall months, the combined flow from the two springs has varied between approximately 0.5 to 2.5 L/s, depending on rainfall, and the average of the monthly values has been approximately 1.2 L/s.

The on-line pond that is fed by the tributary stream has been used by the golf course for irrigation purposes for many years, throughout the below-water table extraction operations at the quarry. There has not been any indication by the golf course operator that the flows in the tributary stream have changed noticeably over the years as a result of the quarry operations.
operations. Similarly, the property owner of the spring locations (Mr. Sampson) has indicated that he has not observed any noticeable change in the general flow conditions in the two water courses over the years.

There are several other groundwater springs located at the Escarpment face, northeast of the quarry. There is no indication from local residents that quarry operations have affected the groundwater discharge conditions at those springs.

The surface water flow entering the northwest corner of the wetland immediately west of the quarry, designated station SW2, is sustained in large part by a groundwater spring located on the expansion lands. The flow at SW2 has been monitored since September 1996 as part of the routine monitoring program associated with the Permit To Take Water. The flow pattern at SW2 does not appear to have been affected by quarry operations as extraction has progressed northwards. The groundwater spring that feeds into SW2 continues to flow year-round, and the groundwater level in the adjacent monitor BH03-9 has remained relatively consistent (and similar to the surface water level at the spring) since monitoring began in 2003. The groundwater level and spring discharge do not appear to be affected by quarry operations. The nearest quarry face is located approximately 350 m to the south.

5.2.6.3 Adjacent Wetland Areas

There are wetland areas located immediately west of the quarry that are part of the Rob Roy Swamp Wetland Complex which is a designated provincially significant wetland (PSW). The quarry discharges excess water into the wetland. As discussed previously, historically a significant component of that discharge water infiltrated into the ground in the wetland and recycled back into the quarry extraction area. The remainder of the discharge water exited through the twin culverts at Grey Road 31 (station SW1).
The ground surface elevation in the wetland is approximately 512 to 513 m a.s.l., which is 12 to 13 m above the floor of the quarry. The water table in the surficial soils varies seasonally from being at or above ground surface in the spring and late fall, to in excess of 1 m below ground in the summer. Stantec has indicated that the wetland continues to function as a wetland under the present quarry operating conditions.

There is another relatively large wetland area located directly south of the quarry on Camarthen Lake Farm property that is situated within the closed drainage basin that outlets at the sinkhole at the southern limit of the wetland (station SW 26). The surface flow out of the wetland into the sinkhole has been monitored starting in October 2003, and recorded flows have varied seasonally from dry in the late summer to a high value of 184 L/s in the spring of 2004. The water table in the surficial soil in the wetland has been monitored at DP3 starting in July 1999, and it varies from being at or above ground surface in the spring to about 1 m below grade in the late summer. The seasonal fluctuation of groundwater levels at DP3 is similar to when monitoring began in 1999. Stantec has indicated that the wetland continues to function as a wetland.

5.3 SUMMARY OF CURRENT OPERATIONS

The existing quarry has been extracted down to the final floor elevation of approximately 500 m a.s.l. over much of the extraction area. Only the north-central area remains to be extracted. The southern portion of the quarry was extracted down to the final floor elevation first (in the early 1990’s), and extraction has moved northward since that time.

The extraction of the rock and the associated perimeter dewatering system influences surface runoff and groundwater conditions on site, as well as local groundwater patterns around the quarry property. Groundwater levels in the rock have been drawndown the maximum amount around the perimeter of the extraction area, being approximately 12 to 20 m depending on location. The magnitude of the drawdown decreases with increasing distance away from the quarry, and is variable around the quarry.
To the southwest, there appears to have been a seasonal drawdown impact of about 3 m at a distance of 700 m from the extraction face. The two northern supply wells at Camarthen Lake Farm continue to provide sufficient capacity to meet the stock watering needs at that location.

At the northern end of the quarry, the extent of the drawdown zone is significantly more limited and does not appear to have extended very far into the expansion lands. Local residential water wells have not been negatively affected by quarry operations.

To the west and south, quarry operations do not appear to have negatively affected the functions of the wetland areas that abut the quarry property. To the east of the quarry, there is no indication that quarry operations have negatively affected local water supply wells, or the groundwater springs that are present at the face of the Escarpment.

### 6.0 PROPOSED EXPANSION OPERATIONS

### 6.1 EXPANSION PROPERTY AND PROPOSED EXTRACTION OPERATIONS

Figure 1-4 illustrates the existing features and the boundary of the property which is to be licenced (approximately 127 ha or 314 acres), and the area in which extraction activities are proposed (approximately 69 ha or 170 acres). The difference between the two land areas includes the additional properties to the north and east of the extraction area owned by Georgian Aggregates to serve as buffer lands, and the regulatory set-backs as required under the Aggregate Resources Act.

Figure 6-1 illustrates the proposed Operational Plan within the extraction area, a brief description of which is provided below. Figures 6-2 to 6-5 provide a series of cross-sections through the expansion lands to illustrate the geology and groundwater conditions.
in and around the proposed quarry. Figure 6-6 illustrates the final rehabilitation concept for the expansion lands.

The proposal is to extract the dolostone rock down to a general elevation of 500 m asl around the west, north and east perimeters, and down to 490 m asl in the south-central part of the site. The height of the rock extraction face generally will vary from a minimum of 4 m along the central section of the northern boundary, to a maximum of almost 39 m in the south-central area, and up to three lifts may be used to extract the rock. Pumping of water that accumulates in the excavation as a result of direct precipitation and surface water run off, as well as from groundwater inflow, will be required in order to maintain dry working conditions across the quarry floor. There are approximately 43 million tonnes of recoverable aggregate resource within the proposed limit of extraction, assuming vertical perimeter extraction faces. Based on an extraction rate of between one and three million tonnes per year, the life expectancy of the quarry will be between 14 and 43 years.

The extraction operation is to be completed in three phases, down to elevation 500 m, commencing in the south central part of the property, and then moving in a clockwise direction. The last phase (Phase 3) to be extracted will be along the northern and then eastern sections of the quarry down to elevation 500 m asl, followed by final extraction of the rock beneath Phase 1 down to a final elevation 490 m asl, as shown on the cross-sections.

The license application is for a maximum extraction rate of three million tonnes per year.

Initially, extraction in Phase 1 of the expansion lands down to an elevation of 500 m asl will occur concurrently with mining in the existing quarry until that latter resource is extracted. The two operations are to be connected by means of a proposed tunnel beneath Simcoe Road 91. The base of the tunnel will be at elevation 500 m asl which is the elevation of the quarry floor in the existing quarry. Blasted rock from Phase 1 in the expansion lands will be transported to the existing quarry for processing. Once sufficient
space exists in Phase 1, the processing plant will be moved from the current locations to the floor of the new quarry. Any aggregate remaining in the existing quarry will then be extracted and transported to Phase 1 of the new quarry for processing. Following completion of all extraction activities in the existing quarry, bulkheads will be constructed and the tunnel closed and sealed, and the existing quarry rehabilitated. The proposed rehabilitation for both locations is to include lakes, wildlife habitat and recreation lands.

The overall objective of the design of the quarry is to maximize recovery of the high quality aggregate resource while maintaining the environmental integrity and functions of the surrounding lands, and minimize environmental impact on local groundwater, surface water and wetland resources. A predictive and pro-active monitoring program that is tied to specific early warning and action thresholds with respect to the water resources and other environmental features around the property is an integral part of the design and operation of the quarry expansion. Quantification of the early warning and action thresholds will be finalized in conjunction with the technical review agencies. Mitigation measures are available to ensure that environmental impacts around the quarry are minimized as extraction proceeds.

As with the existing quarry, water will accumulate in the floor of the expansion area as a result of direct precipitation, surface run-off and snow melt, and groundwater influx to the extraction area. A component of that water will be required for aggregate processing operations and for seasonal dust control, road cleaning and irrigation of landscaped areas, as occurs at the existing quarry. However, there will be excess water in the quarry, particularly in the spring and fall. A water management system similar in concept to that at the existing quarry will be developed to provide sufficient water for operations, and excess water will be discharged off-site at strategic locations to maintain seasonal flow patterns in the surface watercourses around the quarry. In addition, areas within the existing quarry will be available for the storage of excess water from the expansion, and / or for the supply of water to the expansion operations, depending on seasonal requirements at each location.
**Phase 1**

Phase 1, which encompasses an area of approximately 26 ha (64 acres), is located in the south central part of the property and abuts Simcoe Road 91. The proposed floor elevation in Phase 1 is 500 m asl, similar to the existing quarry, and there will be a tunnel access between the operations beneath Simcoe Road 91. The top of the rock surface is at elevation 527 m +/- asl, in this area, such that the extracted rock face will be approximately 27 m high (89 feet). The tonnage of rock available for extraction is estimated to be approximately 17 million tonnes. At an extraction rate of between one and three million tonnes per year, Phase 1 will take between six and seventeen years to extract.

Initially, rock will be transported from Phase 1 back to the existing quarry for primary crushing, screening and for processing / washing operations. Once sufficient space is opened up on the quarry floor at the 500 m level, the processing plant will be moved into Phase 1 such that processing, washing and product stockpiling operations can be undertaken in Phase 1 throughout the life of the quarry. A dewatering sump and settling / wash pond will be established in the southwest corner of Phase 1 as shown on Figure 6-1. In addition, the maintenance shop, office, and scales / scalehouse will be located in Phase 1 as illustrated.

Ultimately, near the end of Phase 3, the quarry floor in Phase 1 will be deepened to the proposed final elevation of 490 m asl to extract most of the remaining Amabel Formation resource in that area.

Mitigation measures to maintain groundwater and surface water resources during extraction operations will be undertaken as required, and are discussed in subsequent sections.
Extraction in the existing quarry will continue during Phase 1 until such time as the resource is mined down to the approved final quarry floor elevation of 500 m asl to the maximum extent allowed under the site plans. Following full extraction and rehabilitation of the slopes and perimeter areas, and removal of all mechanical / electrical plant material, the existing quarry will be allowed to progressively fill with water as part of the final rehabilitation plan. The water that accumulates in the base of the existing quarry will be available for use in the expansion area for a variety of purposes, as needed.

Extraction in Phase 1 will result in progressive drawdown of the groundwater in the surrounding rock, as is discussed in subsequent sections. The practical experience gained from the existing quarry operation together with the results of the groundwater model simulations provide a good starting point for the predictive monitoring program and assessment of progressive impacts. As extraction begins in Phase 1 and extends below the water table, predicted drawdowns will be compared to actual measured values so that an extraction depth-distance-drawdown relationship can be established for subsequent phases of extraction. This information will be incorporated into the groundwater model so that the model can be refined to assist in planning for future mitigation, should that be required. Implementation of mitigation measures will be undertaken on a progressive basis as necessary, but they will be in place, tested and ready for operation before they are actually required.

**Phase 2**

Phase 2 is located across the west side of the expansion lands, and encompasses an area of approximately 12 ha (30 acres). Extraction of the rock resource will extend down to a final floor elevation of 500 m asl. The elevation of the top of the rock surface varies between
517 m asl in the south to approximately 514 m asl at the north end, and the extracted rock face will have a total height of approximately 14 to 17 m (46 to 56 feet). Phase 2 contains approximately 5 million tonnes of available resource which will take between two to five years to extract.

A small dewatering sump may be developed in the southwest corner of Phase 2 equipped with a discharge pump to remove excess water into the adjacent surface drainage channel that feeds down into the wetland to the south at station SW2. Surface flows at SW2 will be maintained similar to historical seasonal ranges, except possibly during the spring melt when excess water may be stored on site or on the quarry floor for later use during the year.

Extraction of the rock resource out to the western limit of Phase 2 is predicted to result in drawdown of the groundwater in the rock beneath the Kekanovich property to the west. That drawdown will affect the drilled well water supplies, and potentially the small wetland feature further to the west. Mitigation of those impacts can be achieved through the use of groundwater recharge wells that can be developed in the set-back area along the western limit of the quarry property.

**Phase 3**

Phase 3 is located around the north and east sides of the expansion lands and encompasses an area of approximately 31 ha. Extraction of the rock resource is proposed to extend down to a final floor elevation of 500 m asl. The elevation of the top of the rock surface is variable within Phase 3, ranging from a high point of about 528 m in the topographically high central area near BH02-3, to a low of approximately 504 m asl along the north boundary in the area of BH02-5 and BH03-7 at the wetland feature. Elsewhere in Phase 3, the elevation of the rock surface is expected to be above 514 m asl. Phase 3 contains
approximately 14 million tonnes of available resource which will take between approximately 5 years and 14 years to extract.

Part of the northern limit of extraction of Phase 3 abuts the provincially significant wetland feature, and this area will be a focus of the predictive monitoring program to protect the integrity and function of the wetland. Mitigation measures are available to protect the wetland throughout the life of the quarry and into post-closure. Those measures include controlled surface discharge of excess quarry water into the east end of the wetland to maintain surface water conditions in the wetland similar to pre-quarry baseline conditions. Should monitoring predict that additional mitigative measures are required, groundwater recharge wells can be developed to help maintain seasonal water table conditions in the wetland.

Similarly, drawdown is predicted to occur to the north and to the east of Phase 3 that may require mitigation in order to maintain residential water supplies, wetland features and groundwater springs that are present in those areas. Mitigation options include the surface discharge of excess quarry water onto the ground surface in a controlled manner in the vicinity of the wetland system in the northeast quadrant of the expansion lands of the former Millar farm and Bridson property. That water will infiltrate into the exposed rock surface on the former Bridson property, as currently occurs, and will help maintain seasonal flows at the groundwater springs to the east and northeast. If additional mitigation is required, groundwater recharge wells will be established on the former Bridson property to the east and on the former Young property to the north so that seasonal groundwater and surface water conditions can be maintained around the quarry.

The final part of Phase 3 involves extraction of the rock resource beneath the Phase 1 area from the 500 m level down to a final quarry floor elevation of 490 m asl. This will require the progressive removal / re-location of the operational plant and stockpiles in the Phase 1 area in order to extract the underlying rock. There are approximately 7 million tonnes of aggregate resource available which will take between about 2.5 years and 7 years to
extract. The results of the predictive monitoring program and the groundwater model will be used to ensure that effective mitigation measures are in place at the appropriate time to maintain seasonal groundwater and surface water conditions around the quarry.

**Final Rehabilitation**

The proposed final rehabilitation for both the existing quarry and the expansion quarry is that of passive lakes and associated aquatic shoreline habitat features. Figure 6-6 illustrates the proposed final rehabilitation concept for the expansion lands. As noted previously, the existing quarry will be allowed to fill with water during the progressive extraction of the expansion lands. Once extraction is completed in the expansion lands, the equipment removed, and the last of the perimeter sideslopes graded into their final form, the quarry will be allowed to fill with water.

Once the dewatering system is turned off, the combination of the annual surplus of water (incident precipitation minus evaporation / evapotranspiration) and groundwater discharge into the quarry will progressively fill the quarry to an equilibrium lake level. The level will continue to increase to the point where the annual addition of the water surplus is balanced by the outflow of water through the rock as groundwater flow, and as surface water outflow at the topographically low points around the perimeter of the quarry extraction area. The filling of the expansion quarry extraction area will include the continuing operation of those mitigation measures that are required to maintain sensitive groundwater and surface water features on the lands around the quarry property. Therefore, the predicted time-for-filling of the lakes may be longer than would be required if the dewatering system and recharge system were simply turned off. The timeframe for filling the lake in the expansion lands to an equilibrium level is in the order of several decades.

Based on the observed seasonal groundwater levels around the perimeter of the expansion lands, the annual average final lake level is predicted to be in the range of 510 to 511 m
asl, with associated seasonal variation. The average final lake elevations based on the groundwater model simulations are 510.7 m asl in the expansion lands and 510.3 m asl in the existing quarry. For impact assessment purposes, the final lake levels are based on the computer model and represent long-term annual average levels. Adjacent wetlands will continue to receive direct precipitation and surface runoff from non-extracted lands, as well as surface discharge from the lake during periods of high lake levels. Groundwater movement out of the lake will be to the east, towards the Escarpment.

6.2 IMPACT ASSESSMENT

The following impact assessment is based on the practical experience gained to date at the existing quarry, together with the results of the groundwater model simulations which are provided in Appendix F. Following calibration to existing conditions, the model was used to simulate the progressive extraction in each phase, and results were compared to the existing conditions (2003 / 2004) to quantify the change that is predicted to occur as a result of future extraction. Initially, the model was run for each phase with no mitigation measures in place, in order to assess the maximum predicted change and associated impact from the proposed expansion. The model was then re-run with the following progressive contingency mitigation measures in place.

(a) Groundwater recharge wells were progressively incorporated in the set-back along the western perimeter, and in the Georgian-owned buffer lands adjacent to the northern and eastern limits of extraction. The purpose of the recharge wells is to provide groundwater recharge into the rock mass around the perimeter of the quarry, and thereby maintain seasonal groundwater levels and surface water flow conditions beyond the extraction area.

Whereas the model simulations are based on the use of recharge wells, the first approach will be to use controlled surface discharge into the adjacent wetland areas to promote
infiltration and help maintain surface flows and local groundwater levels. Monitoring will be undertaken to ensure the effectiveness of the recharge system.

Mitigation of interference at existing water supply wells may also include the development of a deeper well or a replacement well at a specific location, should local conditions be favourable in that regard. See the well interference complaint procedure in Section 7.7.

The groundwater recharge wells are used in the model simulations to quantify the amount of recharge that may be required in order to control the drawdown around the perimeter of the quarry and thereby minimize off-site impacts. The actual number and location of the recharge wells, and the recharge pumping rate, will be determined at the time of installation and will depend on the local conditions.

As noted above, it is proposed that the first-option mitigation is to discharge excess water from the quarry in a controlled manner into the surface water system at key locations around the quarry. Those locations are illustrated on the site plans and include the following:

(i) The surface water course in the southwest corner of the expansion lands that provides surface flow into the Rob Roy Swamp wetland area to the south at station SW2.

(ii) The Rob Roy Swamp wetland area adjacent to the northwest corner of the extraction area.

(iii) The Duntroon Escarpment ANSI wetland area and associated surface water system adjacent to the northeast corner of the extraction area in order to promote infiltration recharge of the rock that is present in the sinkhole area on the former Bridson property and which helps maintain flows at the groundwater springs to the east and northeast.
The need for implementation of one or more of these mitigation measures will be determined based on the magnitude and lateral extent of the dewatering influence zone of the quarry that develops as extraction proceeds through the various phases. As is discussed later, the progressive development of the dewatering interference zone will be monitored and quantified carefully by means of the comprehensive groundwater, surface water and ecology monitoring program that will be established prior to any extraction at the expansion lands.

Monitoring data will be compared to the early warning and action threshold levels that will be established as part of the monitoring and mitigation program, so that mitigation measures can be implemented in a timely manner to ensure that quarry operations do not result in negative impacts at sensitive off-site features.

### 6.2.1 Existing Conditions

The groundwater model was calibrated to existing conditions, using the water levels measured on and around the property. The model simulates the steady-state condition based on average annual recharge values rather than one specific moment in time, and results reflect annual average groundwater levels across the site. The overall calibration of the model is considered reasonable in that the simulated groundwater levels and the resulting flow configuration exhibit a generally similar pattern to that of measured water levels and the interpreted flow pattern. As with any computer model, there are areas that show water levels that are similar to the observed conditions, and there are areas that show water levels that are either higher or lower than measured values at specific locations. Such differences are expected and are a result of local variations in surface topography and local recharge, and rock hydraulic conductivity. Provided that the overall configuration of the groundwater system simulated by the model is similar to the observed conditions, the model can be used as a predictive tool to help quantify the relative change as quarry extraction progresses, and to assist in the evaluation of appropriate mitigation measures.
Figure 6-7 illustrates the simulated existing regional configuration across the model area, while Figure 6-8 focuses on the area around the existing quarry and the proposed expansion lands. The figures illustrate the presence of local groundwater highs to the north of the existing quarry beneath the expansion lands and to the south and to the southwest centred on the Camarthen Lake Farm property. Similar to the interpretation of the observed groundwater levels and regional conditions, there is a groundwater divide passing through the highs that separates flow into an easterly component that goes towards the Escarpment, and a westerly component that goes towards the Beaver River.

The existing quarry is located within the zone of easterly groundwater flow towards the Escarpment. As described previously, excess water which accumulates in the quarry as direct precipitation, surface run-off and groundwater influx is directed off-site into the wetland to the west. Some of that water re-circulates through the wetland and the underlying bedrock back into the quarry, and the remainder moves to the west as surface water in the tributary of the Beaver River.

Figure 6-9 shows the simulated groundwater conditions prior to any extraction in the existing quarry and shows a local groundwater divide oriented north-south through the quarry property. To the east of the divide, flow is towards the Escarpment, and to the west of the divide, flow is westerly. Figure 6-10 illustrates the simulated drawdown effect around the existing quarry, relative to the pre-extraction condition shown in Figure 6-9. On this figure and on subsequent drawdown figures, the lateral extent of the drawdown influence zone is represented by the position of the 1 m drawdown contour since this is within the range of the seasonal fluctuation of groundwater levels in the rock and in the overburden.

At the quarry, the maximum drawdown effect is simulated to be just over 18 m, and it decreases with distance away from the quarry in an oval pattern, with the long axis oriented east-west. The resulting pattern reflects both the shape of the existing quarry extraction
area, surface topography, and anisotropy in the horizontal hydraulic conductivity of the rock inferred from the fracture pattern

Figure 6-10 indicates that the simulated drawdown due to the existing quarry is approximately 1.3 m at the Kekanovich house well which is located about 500 m to the northwest of the quarry. Since current water levels in the well do not indicate any impact from quarry operations, the model overestimates the impact at that location. Similarly, the model appears to overestimate the drawdown influence to the north of the quarry beneath the expansion lands since groundwater levels remain high in that area and there is no evidence of significant seepage into the quarry through the rock face along the northern limit of extraction. Conversely, the model underestimates the apparent drawdown influence at the two northern supply wells at Camarthen Lake Farm, which are approximately 700 m to the southwest of the quarry. The model indicates a drawdown influence of approximately one metre whereas current water levels in the northern wells indicate a seasonal influence in the order of 3 m.

Figure 6-10 indicates that there has been drawdown beneath the Rob Roy Swamp wetland area west of the quarry, being a maximum of about 12 m at the quarry face and decreasing to 1 m west of Grey Road 31. The wetland continues to receive recharge due to direct precipitation and surface run-off, as well as discharge of excess water from the quarry. Stantec (2005) has indicated that the wetland continues to function as a wetland. On this basis, quarry operations do not appear to have resulted in significant impact on the function of the wetland.

The magnitude of the predicted impact for each phase of extraction is based upon the relative change in conditions compared to the existing situation, which is predicted to occur as each phase progresses. Those changes are then evaluated with respect to the likely impact that will ensue with respect to off-site groundwater supplies, surface water flow patterns and ecological conditions in adjacent wetlands, using the existing quarry as a practical example of aggregate extraction under similar conditions.
In summary, conditions at the existing quarry include the following.

(1) The aggregate resource has been extracted from above and below the water table down to a final floor elevation of +/- 500 m asl, over an area of approximately 25 ha of the licenced extraction area.

(2) Below-water table extraction down to the final floor elevation commenced in the southern part of the quarry in the early 1990’s. The water table has been drawn down by approximately 12 to 20 m around the perimeter of the quarry.

(3) The quarry influences the groundwater configuration over an area of approximately 157 ha around the limit of extraction. The quantity of groundwater entering the quarry is estimated to be in the order of 8 L/s based on the computer model. Manual methods of analysis indicate an average groundwater influx of approximately 10 to 20 L/s. Excess water (groundwater and direct precipitation / run-off) is discharged off-site into the wetland that abuts the quarry extraction area on the west side.

(4) A groundwater drawdown interference zone extends out beyond the property boundary of the quarry. The maximum observed extent of the interference zone appears to be to the southwest and includes the two northern supply wells at Camarthen Lake Farm. Those wells are located approximately 700 m from the quarry, and the drawdown interference is estimated to be up to 3 m seasonally. The wells continue to provide sufficient water for the cattle operation.

(5) The observed drawdown influence zone does not appear to extend as far to the west or north as that simulated by the model. The drawdown zone does extend beneath the adjacent wetland west of the quarry.
(6) The western wetland continues to function as a wetland, with no apparent negative impact as a result of quarry operations. Similarly, the large wetland feature located to the south of the quarry continues to function as a wetland, with no apparent negative impact.

(7) There are two groundwater springs located 300 m and 700 m east of the quarry at the Escarpment (base of the Amabel / Fossil Hill), designated as stations SW22 and SW22A, and those springs continue to flow. Surface water from those two springs is used further downstream by a local golf course for irrigation purposes. There is no indication that quarry operations have negatively impacted seasonal flows in the surface water course, and the golf course continues to use the flow to irrigate.

(8) The simulated average groundwater (baseflow) discharge at the springs located along the face of the Escarpment, based on the groundwater model, is as follows:

(i) Area immediately north of the 26 / 27 Sideroad is 0.9 L/s or 75 cubic metres per day;

(ii) Area from the 26 / 27 Sideroad south to the southern limit of the H / E Franks property is 2.2 L/s or 190 cubic metres per day, and

(iii) Area from the W. Franks property to south of Simcoe Road 91 including the two springs at SW 22 and 22A is 2.8 L/s or 245 cubic metres per day. It is noted that the average of the recorded streamflow values at SW22 was 2.3 L/s and 1.4 L/s at SW22A for the period June 2003 to April 2005.
6.2.2 Phase 1 Extraction

Figure 6-11 illustrates the simulated groundwater configuration at the end of extraction in Phase 1 down to a floor elevation of 500 m asl,, with no mitigation measures in place, together with full extraction of the existing quarry down to the final floor elevation of 500 m asl which remains dewatered. Figure 6-12 shows the resulting drawdown influence zone around the quarries, relative to the current existing conditions. The combined extraction areas influence the groundwater configuration over an area of approximately 160 ha. The groundwater influx to the Phase 1 extraction area is estimated to be approximately 5 L/s, and 8 L/s into the completed existing quarry.

To the south and southwest of the existing quarry, the groundwater configuration remains similar to the existing conditions, and there is no additional drawdown influence in that area from either quarry. Thus, no changes are predicted with respect to water supply wells, surface water resources or wetland functions located to the west and south of the existing quarry.

Figure 6-11 shows that the groundwater configuration is predicted to change to the immediate west, north and east of Phase 1 and to the east of the existing quarry. Figure 6-12 shows the extent of the additional drawdown influence zone around the two extraction areas. The maximum drawdown is just in excess of 19 m and occurs within the extraction area for Phase 1. The drawdown influence zone is elliptical in shape, extending further to the west and east than it does to the north.

To the west of Phase 1, the drawdown off-site at the Kekanovich house well is predicted to be about 1.5 m which will not result in water shortage problems at that well. A drawdown of between 2 and 3 m is predicted to occur in the vicinity of the groundwater spring in the southwest corner of the expansion lands. This would reduce the surface water flow into the wetland to the south of Simcoe Road 91, at least seasonally. Excess water from the quarry
floor will be discharged into the surface water course to maintain historical seasonal flow patterns into the wetland.

To the east, the combined extraction of Phase 1 and the existing quarry extends the drawdown zone out towards the Escarpment. The drawdown at the residential supply wells east of Phase 1 is predicted to be 3m on the former Bridson property, approximately 1.5 m at the Dempsey house well, and less than 1 m at the Fabrizio house well which is located closer to the Escarpment face. These wells are not expected to experience supply problems at this level of interference.

The drawdown in the rock beneath the wetland features located within the expansion lands but to the northeast and east of the proposed limit of extraction (designated as the Duntroon Escarpment ANSI) is predicted to be between 1 and 2 m. These wetland areas will continue to receive direct precipitation, snowmelt and surface run-off from the adjacent lands, and seasonal groundwater levels in the soil will be similar to historical patterns. The groundwater drawdown in the rock will not result in negative impacts to the functions of the wetland features (Stantec, 2005). Excess water from the quarry will be discharged to ground surface in a controlled manner in the vicinity of the features to maintain seasonal flow patterns, as appropriate.

With respect to the groundwater discharge at the springs at the Escarpment, the combined extraction in Phase 1 and the existing quarry results in additional drawdown to the east of the existing quarry. This is predicted to reduce the average discharge at the three spring areas by approximately 12 % relative to existing conditions.

To the north, the drawdown zone extends out to the proposed limit of extraction. The drawdown in the rock beneath the Rob Roy Swamp wetland feature in the northwest corner is expected to be less than 1 m. This wetland area will continue to receive direct precipitation, snowmelt and surface run-off from the adjacent lands, and seasonal groundwater levels in the soil will be similar to historical patterns. Excess water from the
quarry will be discharged to ground surface in a controlled manner in the vicinity of the feature to maintain seasonal flow patterns, as appropriate. Extraction in Phase 1 will not result in negative impact to the function of this wetland area (Stantec, 2005).

The drawdown that is predicted to occur at off-site locations is not expected to result in negative impacts to the local groundwater, surface water or wetland systems. However, should monitoring show that water levels and/or flows are decreasing below the established early warning levels as a result of quarry operations (as opposed to natural climatic conditions), mitigation measures will be implemented to maintain seasonal groundwater and surface water conditions around the quarry. Mitigation measures include the discharge of excess quarry water into the wetland features to augment seasonal surface water flows and to promote infiltration recharge of the bedrock. In addition, recharge wells can be used to inject water into the rock mass to maintain groundwater levels and groundwater discharge conditions at the spring areas.

In order to simulate the effect of mitigation measures to maintain groundwater levels at pre-quarrying conditions along the west and northwest boundaries of the expansion lands, groundwater recharge wells are positioned in those areas. The number and location of the recharge wells, and the rate at which water is injected into the rock, will be designed to suit the particular conditions that occur.

Figure 6-13 illustrates the effect of injecting a total of 7.5 L/s (approximately 100 igpm) into the rock. Of that amount, approximately 5.8 L/s re-circulates back into the quarry, and the remainder moves away from the extraction area with the groundwater flow system. Figure 6-14 illustrates the extent of the resultant drawdown zone and shows that it is much reduced to the west of the extraction area such that there is no drawdown off-site along the west and northwest sides of the property. Seasonal groundwater levels in the vicinity of the two residential wells on the Kekanovich property would be maintained, and there would not be any drawdown beneath the Rob Roy Swamp wetland feature in the northwest corner of the expansion lands.
6.2.3 Phase 2 Extraction

Figure 6-15 shows the predicted groundwater configuration at the end of extraction in Phase 2 with no mitigation in place, and Figure 6-16 illustrates the cumulative drawdown relative to existing conditions. The quarry floor in Phase 2 is extracted down to elevation 500 m asl, similar to the floor in Phase 1. Extraction in the existing quarry is assumed to have been completed by the end of Phase 1, the tunnel sealed, and the quarry is progressively filling with water. The simulation has the water level in the existing quarry at elevation 503 m asl.

The extraction areas of the combined quarries influence the groundwater configuration over an area of approximately 257 ha. The groundwater influx to the Phase 1/2 extraction area is estimated to be 7.5 L/s, and 7.4 L/s into the existing quarry.

With no mitigation in place, the cumulative drawdown zone extends further off-site around the expansion lands. The presence of water across the quarry floor in the existing quarry will prevent any extension of the drawdown zone to the south beyond the existing quarry. Groundwater levels to the south will recover a little due to the presence of the lake in the quarry. Additional drawdown is predicted to occur in the rock beneath the Rob Roy Swamp wetland areas to the south and southwest of Phase 2. West of Phase 2, the drawdown zone in the rock extends beneath the small wetland area on the Kekanovich property, with 2 to 4 m predicted, and approximately 10 m of drawdown is predicted in the rock at the residential well.

To the north of the expansion property, a drawdown of between 2 m and 6 m is predicted in the rock beneath the Rob Roy Swamp wetland area adjacent to the northwest corner, and approximately 1 m of drawdown in the rock is predicted at 26/27 Sideroad.

To the east of the existing quarry and the expansion lands, the drawdown zone extends further to the east, towards the Escarpment. The predicted drawdown in the rock at the
Dempsey well is between 5 and 6 m. The average groundwater discharge at the springs is predicted to reduce by approximately 5 to 15%, depending on location.

The extent and magnitude of the predicted drawdown zone, without mitigation, is significantly greater at the end of Phase 2 compared to the end of Phase 1, and local water supply wells, wetland conditions and surface water flows may be affected. The wetland features will continue to receive direct precipitation, surface run-off and discharge of excess water from the quarry, and seasonal water table conditions in the soil are expected to be similar to pre-quarrying conditions. Mitigation measures may be required to maintain seasonal groundwater conditions in the rock around the quarry. Figure 6-17 illustrates the groundwater configuration with recharge wells in place around the west, north and east perimeters of the quarry. The cumulative injection rate for the recharge wells is 12.5 L/s (165 igpm). Of that amount, approximately 8.4 L/s re-circulates back into the quarry, and the remainder moves away from the extraction area in the groundwater flow system. The resulting groundwater configuration is reasonably similar to existing conditions.

Figure 6-18 illustrates the cumulative drawdown zone at the end of Phase 2 with the recharge wells operating. The effect of the recharge wells is to greatly reduce the magnitude and extent of the drawdown zone off-site to a level where no negative impact occurs to local water supply wells, wetlands and groundwater discharge springs.

### 6.2.4 Phase 3 Extraction

Figure 6-19 shows the predicted groundwater configuration for extraction in Phase 3 with no mitigation in place, and Figure 6-20 illustrates the resulting cumulative drawdown relative to existing conditions. The quarry floor in Phase 3 is extracted down to elevation 500 m asl similar to Phase 2 and Phase 1. The lake level in the existing quarry is simulated to be at elevation 507 m asl at the end of Phase 3 such that there is a 7 m deep lake present across the quarry floor.
The combined quarries influence the groundwater configuration over an area of approximately 304 ha. The groundwater influx to the expansion extraction area is estimated to be 12.6 L/s, and 7.1 L/s into the existing quarry.

Without mitigation in place, the magnitude and lateral extent of the predicted drawdown zone increases to the north and east relative to that of Phase 2. The presence of the lake in the existing quarry prevents drawdown from occurring to the south, and groundwater levels recover slightly to the south. As with Phase 2, without mitigation, the drawdown resulting from the extraction of Phase 3 is predicted to result in interference concerns at local water wells, wetlands and groundwater springs / surface water flows. Figure 6-21 illustrates the groundwater configuration with recharge wells in place around the west, north and east sides, the cumulative injection rate for which is 18.5 L/s (244 igpm). Of that amount, approximately 13.2 L/s re-circulates back into the quarry, and the remainder moves away from the extraction area in the groundwater flow system. The resulting groundwater configuration is reasonably similar to the existing conditions.

Figure 6-22 illustrates the cumulative drawdown zone at the end of Phase 3 with the recharge wells operating at a combined rate of 18.5 L/s. The magnitude and extent of the drawdown zone is significantly reduced off-site around the quarry such that most of the drawdown is confined to property owned by Georgian Aggregates. Whereas a small amount of residual drawdown is predicted to occur beneath private property to the west (Kekanovich), and to the east towards the Escarpment, any interference with local water supply wells and groundwater springs should be minimal. Some residual drawdown is predicted for the rock beneath the Rob Roy Swamp wetland feature adjacent to the northwest corner of the extraction area, and beneath the Duntroon Escarpment ANSI. However, those wetlands will continue to receive direct precipitation, surface run-off and discharge of excess water from the quarry, such that seasonal water table conditions in the wetland soils are expected to be similar to pre-quarrying conditions. Should additional recharge wells be required to maintain seasonal conditions in the wetland areas, the design of the system can be modified as needed.
Therefore, based on the above, no negative impact is predicted for extraction of the first part of Phase 3.

6.2.5 End of Quarry Extraction--Phase 1 Down to 490 m asl

The final extraction at the quarry will remove the rock beneath the Phase 1 area down to a final floor elevation of 490 m asl, which will deepen the excavation by 10 m at that location. The quarry floor will be approximately 2 to 4 m above the contact between the Amabel Formation and the underlying Fossil Hill Formation.

Figure 6-23 shows the predicted groundwater configuration at the end of quarry extraction, with no mitigation in place, and Figure 6-24 illustrates the resulting cumulative drawdown relative to existing conditions. The lake level in the existing quarry is assumed to be at elevation 507 m asl. Without mitigation, deepening the quarry increases the magnitude and lateral extent of the drawdown zone to the west, north and east of the expansion lands. The presence of the lake in the existing quarry prevents any extension of the drawdown zone to the south. Since the lake level is assumed to remain at elevation 507 m asl during this last part of the extraction, groundwater levels to the south do not recover any further while the expansion quarry is operating.

The combined quarries influence the groundwater configuration over an area of approximately 321 ha. The groundwater influx to the expansion quarry is estimated to be 13.7 L/s, and 6.3 L/s into the existing quarry.

Figure 6-25 illustrates the groundwater configuration with recharge wells in place around the west, north and east sides of the quarry. The cumulative injection rate for the recharge wells is 18.5 L/s (244 igpm) which is similar to the rate used for the extraction of Phase 3. Of that amount, approximately 13.9 L/s re-circulate back into the quarry, and 4.6 L/s moves away from the quarry with the groundwater flow system. The resulting configuration is similar to existing conditions.
Figure 6-26 illustrates the cumulative drawdown zone at the end of extraction with the recharge wells operating, and is similar to that predicted for the end of Phase 3. The magnitude and extent of the drawdown zone is significantly reduced off-site around the quarry, such that most of the drawdown is confined to property owned by Georgian Aggregates. A small amount of residual drawdown is predicted to occur beneath private property to the west (Kekanovich), and to the east towards the Escarpment; however, any interference with local water supply wells and groundwater springs should be minimal. Some residual drawdown is predicted for the rock beneath the Rob Roy Swamp wetland feature adjacent to the northwest corner of the extraction area, and beneath the Duntoon Escarpment ANSI. However, those wetlands will continue to receive direct precipitation, surface run-off and discharge of excess water from the quarry, such that seasonal water table conditions in the wetland soils are expected to be similar to pre-quarrying conditions. Should additional recharge wells be required to maintain seasonal conditions in the wetland areas, the design of the system can be modified as needed.

Therefore, based on the above, no negative impact is predicted for the completion of extraction in Phase 3.

6.2.6 Progressive Rehabilitation

The quarry will be subject to progressive rehabilitation of the sideslopes and other areas of the property as part of normal operations, once extraction in a particular Phase or area of a Phase has been completed. In order to maintain dry working conditions on the quarry floor until all extraction has been undertaken, it will be necessary to operate the dewatering and water management systems throughout the life of the quarry. Once extraction has been completed the quarry can undergo final rehabilitation, the main feature of which is proposed to be a lake, similar to the plan for the existing quarry.

The quarry will start to fill with water as soon as the dewatering system is turned off; however, the filling process will take many years to complete. The quarry will fill as a
result of the progressive accumulation of water from two distinct sources. One source is the water surplus that occurs due to the positive difference, or surplus, between the annual precipitation that falls onto the ground and the evapotranspiration of part of that moisture back to the atmosphere. The annual surplus based on the 30 year normal climate data is estimated to be approximately 370 mm to 400 mm, depending on the actual availability of moisture for evapotranspiration processes. Annually, the water surplus may vary between less than 100 mm to in excess of 500 mm, depending on prevailing climatic conditions. Over the long term and depending on actual surface run-off conditions around the perimeter of the property, the water level in the quarry would be expected to rise by about 0.37 m to 0.4 m per year due to the water surplus, in the absence of other factors. Taken over the full 69 ha extraction area of the quarry, that equates to 255,000 to 276,000 cubic metres of water per year, or 8.1 to 8.8 L/s (107 to 116 igpm).

The second source of water to fill the quarry is groundwater discharge through the rock into the quarry. Absent any mitigation measures, the groundwater influx to the quarry at the end of extraction is estimated to be 13.7 L/s. As noted above, when recharge wells are used to mitigate off-site impacts around the quarry, one component of the water that is injected into the rock will re-circulate back into the quarry, and the remainder will move away from the quarry in the groundwater flow system. At the end of extraction, with recharge wells operating at 18.5 L/s, 13.9 L/s re-circulates back into the quarry, and 4.6 L/s leaves the quarry property as groundwater flow.

In order for the quarry to progressively fill with water, there has to be a surplus of water remaining in the quarry on an annual basis, relative to the amount of water that is pumped from the quarry to operate the mitigation systems. Based on the model, there will be an average surplus of approximately 4 L/s available to fill the quarry while the mitigation system is operating. As the quarry begins to fill, the amount of water that is required for the mitigation system will progressively decrease. In addition, it may be possible to further reduce the volume of water that is injected into the perimeter recharge wells so that more water can be available to fill the quarry, while still managing the off-site impacts. Also,
water can be transferred from the lake that will be present in the existing quarry to help fill the lake in the expansion area.

6.2.6.1 Final Rehabilitation

The end result of the rehabilitation will be the development of a lake in both the existing quarry and the expansion area. The water level in the two lakes will be similar to the average groundwater level around the perimeter of the quarries prior to extraction, and there will be seasonal fluctuations. Based on the observed water levels to date, the lake levels are predicted to be between 510 m asl and 511 m asl, and the groundwater model indicates that the long-term average water level will be 510.7 at the expansion lands and 510.3 m asl at the existing quarry.

6.2.6.2 Post Rehabilitation

Figure 6-27 illustrates the predicted long-term average groundwater configuration in the rock around the quarry properties following final rehabilitation. Figure 6-28 illustrates the predicted residual drawdown relative to existing conditions. These figures illustrate that predicted long-term changes to the groundwater, surface water and wetland systems around the quarry extraction areas are expected to be modest. Groundwater discharge at the springs at the Escarpment is predicted to be similar to, or slightly greater than, the existing conditions, as summarized below:

<table>
<thead>
<tr>
<th>Groundwater Discharge at Springs (cubic metres per day)</th>
<th>North of 26/27 Sideroad</th>
<th>H / E Franks Property</th>
<th>W. Franks Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Conditions</td>
<td>75</td>
<td>190</td>
<td>245</td>
</tr>
<tr>
<td>Post Rehabilitation</td>
<td>75</td>
<td>205</td>
<td>262</td>
</tr>
</tbody>
</table>

Therefore, there should not be any long-term change to the groundwater discharge pattern at the Escarpment once the lakes have attained their equilibrium levels in the extraction
areas. The adjacent wetland areas will continue to receive direct precipitation and surface runoff from surrounding lands, and potentially seasonal discharge from the lakes when levels are high. Water table levels in the wetland soils are expected to be similar to historical seasonal patterns. Surface flows in the adjacent wetlands should be reasonably similar to pre-quarrying activities and will reflect the prevailing seasonal climatic conditions.

Figure 6-27 illustrates that groundwater levels to the south of the existing quarry will recover slightly relative to the existing conditions, as a result of the presence of the lake in the extraction area. For example, groundwater levels in the vicinity of the two northern supply wells at Camrthen Lake Farm (CLF1 and CLF2) are predicted to recover by approximately 0.5 to 1.0 m relative to existing conditions.

Overall, a residual drawdown is predicted around the expansion quarry extraction area, as shown on Figure 6-28, as a result of final lake levels that will be lower than the pre-extraction groundwater levels across the quarry properties. Also, there is a modest shift to the west in the location of the interpreted groundwater divide that currently extends across the expansion lands. This is not unexpected given that quarrying will remove the local rock high, and the associated groundwater high, across the expansion lands. There is a small shift of the divide in the opposite direction, to the east, in the area to the south west of the existing quarry due to the recovery of groundwater levels there relative to existing conditions. The net result of the shift in the position of the groundwater divide is that the groundwater recharge across approximately 50 ha of land, that currently contributes water to the Beaver River system, will be re-directed into the Bateaux Creek system. Based on the modeled recharge value of 160 mm per year for this area, the volume of groundwater affected is 80,000 cubic metres per year, or about 2.5 L/s. This is not considered to represent a significant negative impact, given the size of the two drainage basins.

The magnitude of the residual drawdown in the rock adjacent to the lake in the expansion lands varies from less than 1 m to approximately 4 m. Figure 6-28 indicates that there is a
predicted residual drawdown of about 1 m beneath the wetland area on the Kekanovich property and beneath the wetland adjacent to the northwest corner of the expansion lands. Since both wetland areas will continue to receive direct precipitation and surface run-off from surrounding lands, seasonal water table levels in the soil and surface flow conditions are expected to be reasonably similar to historical patterns, with no long term negative impact on the function of the wetland.

At the Kekanovich water supply wells, the residual drawdown is predicted to be between 3 m and 4 m relative to the modeled current conditions. That magnitude of drawdown is not anticipated to affect the ability of the wells to continue to supply water to the residences. Should that not be the case, one or more replacement wells can be developed further to the west on the property where groundwater levels will not be affected. Elsewhere around the quarry, any changes in long-term groundwater levels are not expected to affect the operation of local water supply wells, such as at the Dempsey well where 1 m of residual drawdown is predicted.

There will be a permanent decrease in the surface water flow conditions at the groundwater spring and associated surface water course in the southwest corner of the expansion property that flows into the wetland to the south. That spring will cease to flow as a result of quarrying in Phase 2. Groundwater discharge is not expected to be re-established upon final rehabilitation to the lake because the water level in the lake will be below the elevation of the current spring. There will be seasonal flow of surface water in the channel as a result of local snowmelt and run-off during storm events. Stantec (2005) has assessed this and concluded the loss of groundwater contribution from this spring will not result in negative impacts to the wetland. Since water from the spring eventually flows to the tributary of the Beaver River, which supports fish habitat, Stantec has recommended that fish habitat enhancement be undertaken further downstream.
6.3 QUARRY DEWATERING AND WATER MANAGEMENT PLAN

In order to maintain reasonably dry working conditions across the quarry floor, it will be necessary to manage all water that accumulates in the quarry extraction area as a result of direct precipitation, surface run-off and groundwater influx through the walls and floor of the quarry. The volume of water that has to be managed will vary seasonally and will increase progressively as the extraction area expands both laterally and below the water table. Water will be required for washing / processing approximately one third of the aggregate that is produced, as well as for dust control, road cleaning and irrigation of some of the landscaped areas around the perimeter of the property. Surplus water may be discharged off-site as part of normal operations or, alternatively, water may be stored in ponds on-site on a temporary seasonal basis for later controlled discharge off-site or for use in mitigation of drawdown impacts around the perimeter of the quarry.

A Permit To Take Water for dewatering, washing and mitigation operations will be required from the Ministry of the Environment, as will a Certificate of Approval for sewage works for the off-site discharge of surplus water and / or water that is used for mitigation purposes. The required permits are subject to separate application and approval processes that are regulated under the Ontario Water Resources Act by the Ministry of the Environment. Applications for those permits will be submitted at the appropriate time.

6.3.1 Aggregate Washing Operations

Aggregate washing operations will utilize a closed-loop process similar to that used in the existing quarry. Clean wash water will be obtained from the main sump or other storage pond that will be developed on the quarry floor within the Phase 1 extraction area. The existing washing equipment uses a water supply of up to 242 L/s (3200 igpm) when the boost pump is operated for the classifier. Sediment-laden process water will be directed through a settling pond system for removal of the fines, and clean water will be returned to the sump or other source pond for re-use. As with the existing quarry operations, the use
and management of process wash water will be variable through the life of the quarry, depending on the aggregate products being produced and the phase of extraction. Inevitably, some process water will be spilled onto the ground in the area of the wash plant, but that water will be directed back to the sump as surface flow, or it will infiltrate back into the exposed rock surface, such that it is not removed from the system.

A small component of the wash water will be retained in the processed aggregate in the stockpiles until it is shipped off-site. Depending on the length of time that the aggregate remains in the stockpiles, some of the retained water will drain out and some will be retained in the aggregate. The water that is retained in the washed aggregate is estimated to be less than 5% by weight of the aggregate that is processed. Based on a maximum production rate of 3 million tonnes per year, of which one third is washed, the process water retained in that aggregate would be equivalent to approximately 50,000 cubic metres per year. In the absence of other factors, that water would be removed off-site when the aggregate is shipped. However, the experience at the existing quarry is that the stockpiled aggregate retains more of the precipitation that falls on it, which recharges the local system and maintains higher than normal groundwater levels in the rock beneath the stockpiles. This additional recharge would tend to offset the volume of process water retained in the aggregate. Any process water that actually is removed off-site in the washed aggregate is considered to represent a minor component of the overall water budget for the site.

6.3.2 Dust Control

The volume of water that is used for dust control, road cleaning and irrigation of landscaped areas will vary with the season and prevailing climatic conditions. In 2004 at the existing quarry, between the period of mid-July to the end of October (a particularly dry summer), a total of 213 tanker loads of water were used, which is equivalent to approximately 2,900 cubic metres. Extending this usage over the full operating season, the annual consumption is expected to be in the order of 5,000 to 6,000 cubic metres per year, which is considered to be a minor component of the overall water budget.
6.3.3 Quarry Dewatering

The quarry floor will be maintained in a reasonably dry condition through collection of direct precipitation, surface run-off and groundwater discharge that occurs. Water that accumulates on the quarry floor will be channeled into the main sump for re-use in the washing operations and dust control etc. In order to prevent the sump from flooding, excess water will be removed by pumping and placed into temporary storage ponds either on-site or in the existing quarry. The water in the ponds will be available for controlled discharge off-site to wetlands and surface water courses to help maintain seasonal conditions in those features, and also for use in the recharge well mitigation system, as needed.

At this time, it is proposed that the main sump be located within the Phase 1 extraction area, and that it remain there throughout the life of the quarry. The sump is to be sized at the outset to provide sufficient storage of water for use in the washing operations throughout the life of the quarry and will be approximately 50 m by 50 m in plan, with a depth of at least 5 m. This will provide a storage capacity for 12,500 cubic metres of water which will allow for approximately 14 hours of washing operations at a maximum pumping rate of 242 L/s in the event that there is no return water back to the sump for a short period of time.

6.3.4 Operational Water Budget

The following operational water budget is provided to demonstrate that there will be sufficient water entering the quarry extraction area to supply all of the internal needs of the quarry, as well as the external needs for maintenance of off-site groundwater and surface water conditions.

As noted above, the internal requirements of the quarry will include water for aggregate washing, and water for dust control, road cleaning and landscape irrigation. Initially, the
aggregate that is extracted in the early stages of Phase 1 will be processed and stockpiled in
the existing quarry, and any water requirements for operations in the expansion property
will be provided by the existing quarry. When sufficient area has been extracted in Phase
1, the processing, washing and product stockpiling operations will be transferred to Phase
1. The aggregate washing operations will use a closed-loop system that takes clean water
from the sump at a pumping rate of up to 242 L/s. The used process water will be
discharged to a sedimentation pond system for removal of fines, and clean water will be
returned to the sump for re-use. The annual water losses from the washing operations are
anticipated to be minor when considered in combination with the additional recharge that
will occur in the product stockpile areas. The water requirement for dust control etc. will
vary seasonally, and is expected to be in the order of 5,000 to 6,000 cubic metres per year,
based on the current usage at the existing quarry. For a period of time, both quarries will
operate concurrently, and the water requirement for dust control may be higher.

Experience at the existing quarry shows that the volume of water entering the extraction
area exceeds the operational needs of the quarry, such that there is excess water that has to
be managed and discharged off-site in order to maintain dry working conditions across the
quarry floor. A similar condition will occur in the expansion property, and that excess
water will be available for off-site discharge during Phase 1, and for future mitigation
measures, as appropriate, to minimize off-site impacts during extraction in Phases 2 and 3,
and during the final rehabilitation period. The following sections provide a summary of the
predicted influx of water to each phase of extraction and how that water will be managed
with respect to off-site discharge and other mitigation measures.

6.3.5 Phase 1 Extraction

The Phase 1 extraction area is approximately 26 ha in size. Extraction down to the interim
quarry floor level of 500 m asl will include removal of rock from above and below the
water table. Water will enter the extraction area as a result of direct precipitation, local
surface run-off and groundwater influx once extraction proceeds below the water table.
The amount of water that enters Phase 1 will increase in proportion to the size of the extraction area.

Based on the model predictions and the experience from the existing quarry, water that enters Phase 1 is not anticipated to be required for mitigation purposes, and therefore it will be available for discharge off-site in a controlled manner to the local surface water systems. Phase 1 encompasses the small closed surface drainage area at the south end of the property that does not have a surface outlet to the adjacent surface water courses, as well as a small area in the western part of Phase 1 that is within the drainage basin of the tributary of the Beaver River. With respect to the interpreted groundwater regime, Phase 1 includes flow components that are within the Beaver River basin and the Batteaux Creek basin. Therefore, excess water will be discharged into both the adjacent drainage basins, on an approximately equal basis.

With respect to the Batteaux Creek system, excess water will be discharged into the existing pond in the northeast corner of the former Millar property. From there it will flow through the natural surface drainage / wetland system (Duntroon escarpment ANSI) present across the former Bridson property to the east. Similar to the existing situation, the surface flow will continue to infiltrate into the exposed and shallow bedrock on the property, and will recharge the local groundwater system. Together with the surface water monitoring data at the springs below the Escarpment, this will provide on-going information with respect to the effectiveness of this approach for possible future mitigation around the east / northeast side of Phase 3.

Excess water will be returned to the Beaver River system by discharging it into the existing surface drainage course through the woodlot in the southwest corner of the expansion property. Similar to existing conditions, that water will infiltrate into the near-surface bedrock in the sinkhole area, and will re-appear at ground surface at the groundwater spring adjacent to borehole BH03-9. That spring provides much of the flow in the surface
water course that flows into the wetland south of Simcoe Road 91 at monitoring station SW2.

At the full extent of extraction in Phase 1, the influx of water is estimated to be as follows:

- Average annual water surplus of approximately 400 mm over 26 ha will generate 104,000 cubic metres of water per year (3.3 L/s, or 44 igpm).
- Average influx of groundwater to Phase 1 (no mitigation) is predicted to be 164,000 cubic metres per year (5.2 L/s or 69 igpm).
- Total volume of water available for operational needs and for discharge / mitigation off-site is predicted to be 268,000 cubic metres per year (8.5 L/s or 112 igpm).
- Excess water to be discharged to the two locations on an approximately equal basis.

Similar to the existing operation, the volume of excess water in the quarry will vary through the year on a seasonal basis, typically being highest in the spring and lowest in the late summer to early fall. The actual volume of excess water that is available for discharge off-site will be determined at the time and will depend on several factors, including operational needs, surface water needs off-site together with any requirements to store water either on-site for later use or in the existing quarry to assist in the final rehabilitation to a lake.

Whereas it is not anticipated to be the case, should the monitoring program show that water is required to mitigate drawdown interference effects at locations off-site, the modeling indicates that an average injection rate of 7.5 L/s will be sufficient to confine the drawdown zone to within property owned by Georgian Aggregates. Of that amount, approximately 75%, or 5.8 L/s, re-circulates back into the quarry and 1.7 L/s moves away from the quarry in the groundwater flow system. The water budget indicates that there will be sufficient water available to maintain the level of mitigation injection noted above, and there will be a surplus that is estimated to be 1.6 L/s (approximately 50,000 cubic metres per year).
6.3.6 Phase 2 Extraction

Phase 2 comprises an area of approximately 12 ha such that by the end of extraction, the quarry floor will be 38 ha in size. The influx of water to the quarry floor is estimated as follows:

- Average annual water surplus of approximately 400 mm over 38 ha will generate 152,000 cubic metres of water per year (4.8 L/s, or 63 igpm).
- Average influx of groundwater to Phase 1 and Phase 2 (mitigation operating) is predicted to be 265,000 cubic metres per year (8.4 L/s or 111 igpm).
- Volume of water available for operational needs and for discharge / mitigation off-site is predicted to be 417,000 cubic metres per year (13.2 L/s or 174 igpm).
- Volume of water required for mitigation system will be 394,000 cubic metres per year (12.5 L/s or 165 igpm).

Phase 2 is located entirely within the drainage basin of the Beaver River tributary. As such, the additional water entering the quarry, relative to that in Phase 1, will be a result of activities in the Beaver River basin and most of the additional excess water will be returned to that basin. Under the full mitigation scenario, recharge wells will be operated around the west, north and east sides of the expansion property. The total recharge injection rate is estimated to be 12.5 L/s on average, recognizing that there may be a small drawdown effect extending off-site. Of the 12.5 L/s, approximately 67%, or 8.4 L/s, re-circulates back into the quarry (mostly in Phase 2), and the remaining 4.1 L/s moves away from the quarry in the groundwater flow system. The water budget indicates that there will be sufficient water available to operate the recharge system as described, and there will be a small surplus that is estimated to be 0.7 L/s (approximately 22,000 cubic metres per year). Any seasonal deficit can be remedied by using water from the lake in the existing quarry.

As with Phase 1, the actual volume of excess water available in the quarry will vary on a seasonal basis based on prevailing climatic conditions. The existing quarry will be filling
with water during Phase 2, and excess water can be stored either in ponds on the expansion property or in the lake in the existing quarry. In addition, the water that is stored in the lake in the existing quarry will be available to supplement the water supply for the recharge system on a temporary basis, should the need arise during a particularly dry period.

6.3.7 Phase 3 Extraction

(i) Phase 3 Down to 500 m asl

Phase 3 comprises an area of approximately 31 ha such that by the end of extraction in the Phase 3 area, the quarry floor will be 69 ha in size. The influx of water to the quarry floor is estimated as follows:

- Average annual water surplus of approximately 400 mm over 69 ha will generate 276,000 cubic metres of water per year (8.7 L/s, or 116 igpm).
- Average influx of groundwater to Phases 1, 2 and 3 (mitigation operating) is predicted to be 416,000 cubic metres per year (13.2 L/s of 174 igpm).
- Volume of water available for operational needs and for discharge / mitigation off-site is predicted to be 692,000 cubic metres per year (21.9 L/s or 290 igpm).
- Volume of water required for mitigation system will be 583,000 cubic metres per year (18.5 L/s or 244 igpm).

The western section of Phase 3 is located within the surface drainage basin of the Beaver River tributary, and the eastern section is within the Batteaux Creek basin. As such, the additional water entering the quarry, relative to that in Phases 1 and 2 will be a result of activities in both basins, and most of the additional excess water will be returned to those basins. Under the full mitigation scenario, recharge wells will be operated around the west, north and east sides of the expansion property. The total recharge injection rate is estimated to be 18.5 L/s on average, again recognizing that there may be a small drawdown effect extending off-site around the quarry. Of the 18.5 L/s, approximately 71%, or 13.2
L/s, re-circulates back into the quarry around Phase 2 and Phase 3, and the remaining 5.3 L/s moves away from the quarry in the groundwater flow system.

The water budget indicates that there will be sufficient water available to operate the recharge system and to supply the operational needs of the quarry. There will be a surplus of water that is estimated to be 3.4 L/s (107,000 cubic metres per year). Excess water will be stored in ponds on site or in the lake in the existing quarry.

As with Phases 1 and 2, the actual volume of excess water available in the expansion quarry will vary on a seasonal basis based on prevailing climatic conditions. The existing quarry will continue to fill with water during Phase 3, and excess water can be stored either in ponds on the expansion property or in the lake in the existing quarry. In addition, the water that is stored in the lake in the existing quarry will be available to supplement the water supply for the recharge system on a temporary basis, should the need arise during a particularly dry period.

(ii) Final Extraction Of Phase 1 To 490 m asl

The final extraction of Phase 1 down to a quarry floor elevation of 490 m asl will not increase the lateral extent of the quarry, and the floor will cover an area of 69 ha. The influx of water to the quarry floor will be similar to that for Phase 3 and is estimated as follows:

- Average annual water surplus of approximately 400 mm over 69 ha will generate 276,000 cubic metres of water per year (8.7 L/s, or 116 igpm).
- Average influx of groundwater to Phases 1, 2 and 3 (mitigation operating) is predicted to be 438,000 cubic metres per year (13.9 L/s or 183 igpm).
- Volume of water available for operational needs and for discharge / mitigation off-site is predicted to be 714,000 cubic metres per year (22.6 L/s or 298 igpm).
- Volume of water required for mitigation system will be 583,000 cubic metres per year (18.5 L/s, or 244 igpm).

Similar to the full mitigation scenario for Phase 3, recharge wells will be operated around the west, north and east sides of the expansion property. The total recharge injection rate is estimated to be 18.5 L/s on average (583,000 cubic metres per year), again recognizing that there may be a small drawdown effect extending off-site around the quarry. Of the 18.5 L/s, approximately 75%, or 13.9 L/s, re-circulates back into the quarry around Phase 2 and Phase 3, and the remaining 4.6 L/s moves away from the quarry in the groundwater flow system.

The water budget indicates that there will be sufficient water available to operate the recharge system and to supply the operational needs of the quarry. There will be a surplus of water that is estimated to be 4.1 L/s (129,000 cubic metres per year). Excess water will be stored in ponds on-site or in the lake in the existing quarry.

As with the previous phases, the actual volume of excess water available in the expansion quarry will vary on a seasonal basis based on prevailing climatic conditions. The existing quarry will continue to fill with water, and excess water can be stored either in ponds on the expansion property or in the lake in the existing quarry. In addition, the water that is stored in the lake in the existing quarry will be available to supplement the water supply for the recharge system on a temporary basis, should the need arise during a particularly dry period.

6.3.8 Rehabilitation Phase

At the end of extraction, with full mitigation operating, the water budget will be similar to that for Phase 3, as noted above:
• Average annual water surplus of approximately 400 mm over 69 ha will generate 276,000 cubic metres of water per year (8.7 L/s, or 116 igpm).
• Average influx of groundwater to Phases 1, 2 and 3 (mitigation operating) is predicted to be 438,000 cubic metres per year (13.9 L/s or 183 igpm).
• Volume of water available for operational needs and for discharge / mitigation off-site is predicted to be 714,000 cubic metres per year (22.6 L/s or 298 igpm).
• Volume of water required for mitigation system will be 583,000 cubic metres per year (18.5 L/s or 244 igpm).

This indicates that there will be an annual water surplus of approximately 129,000 cubic metres (4.1 L/s or 54 igpm) that will be available to start filling the extraction area once all plant and equipment have been removed. As the lake fills, the volume of water that will be required to operate the mitigation system will decrease progressively due to the rising lake level, and there will be increasingly more water available to fill the lake on an annual basis.

6.3.9 Final Rehabilitation / Post-Closure Phase

The long-term average equilibrium water level in the two lakes is predicted to be in the range of 510 to 511 m asl; the groundwater model predicts values of 510.7m asl for the expansion quarry and 510.3 m asl for the existing quarry. There will be seasonal fluctuation of the lake levels due to prevailing climatic conditions, as well as annual fluctuations due to temperature and precipitation trends. The lake level will recharge in the spring due to the annual melt and spring rains, followed by a progressive decrease through the summer and early fall period as a result of increased evapotranspiration losses. The lake level likely will recover somewhat during the later fall and early winter as a result of decreased losses, and the annual cycle will repeat the following spring.

There will be an annual surplus of water since precipitation exceeds evapotranspiration losses on an annual basis. That surplus is expected to be in the order of 400 mm annually. The water level in the lakes will achieve an equilibrium level between the influx of water
and the outflow either as surface water, depending on local topography around the lakes, or as groundwater flow through the rock.

Figure 6-27 illustrates the predicted average groundwater configuration around the two lakes once they have achieved their equilibrium levels. Based on the predicted lake levels, the lakes will exert an influence on the local groundwater system, drawing water in from the south, west and north. Water will move out of the lakes as groundwater through the rock along the east side, towards the Escarpment. Relative to the existing conditions, the groundwater divide that separates flow into easterly and westerly components will be shifted to the west. This will result in a re-direction of groundwater recharge from approximately 50 ha of land from the Beaver River basin into that of Batteaux Creek. Based on the modeled groundwater recharge of 160 mm per year, this equates to 80,000 cubic metres of groundwater per year, or approximately 2.5 L/s (33 igpm). Based on the estimated baseflow component of between 80 and 111 L/s in the tributary of the Beaver River at monitoring station SW6A (see Section 4.3.1), the predicted change of 2.5 L/s to the groundwater recharge contribution in the basin represents approximately 2 to 3% of the baseflow.

In addition, the surface runoff component from the western section of the expansion lands, that currently is located in the Beaver River drainage basin, will be captured by the lake in the quarry and re-directed into the Batteaux Creek basin. The land area affected is approximately 35 ha, the surface run-off component of which equates to about 84,000 cubic metres of water per year (2.7 L/s or 35 igpm).

Therefore, relative to the groundwater / surface water flow system that exists today, the development of the lake in the expansion quarry will result in re-direction of approximately 164,000 cubic metres of water per year (5.2 L/s or 69 igpm), from the drainage basin of the Beaver River into the drainage basin of Batteaux Creek. This change is not expected to result in long-term negative impact on hydraulic conditions in the Beaver River. The
additional water in the Batteaux Creek system will result in increases to the average flow conditions in the Creek.

Depending on the actual lake level in the existing quarry, there may be limited seasonal outflow to the wetland to the west of the quarry and into the Beaver River system. Similarly, limited seasonal outflow may occur from the lake on the expansion property to the wetland feature in the northwest corner, and also to the Duntroon Escarpment ANSI to the east. These wetland features will continue to receive direct precipitation and surface run-off from surrounding lands, such that seasonal water table levels in the soil and surface flows should be similar to historic conditions, with no long-term negative impact.

6.3.10 Summary

Experience gained to-date at the existing quarry shows that dewatering operations have not resulted in significant impacts to local water resources around the property. A similar situation is anticipated for the expansion quarry, particularly for Phase 1. Subsequent phases of extraction may require mitigation of off-site drawdown interference to maintain impacts within acceptable limits. The groundwater, surface water and biological monitoring programs will provide early-warning information necessary to identify if and when mitigation is required in order to protect off-site resources.

The groundwater model provides an assessment of the level of mitigation that may be required, and future performance monitoring will allow refinement of those predictions to ensure that off-site resources remain protected. The various levels of mitigation discussed in previous sections include surface discharge to promote infiltration recharge, as well as injection wells located around the perimeter of the property if needed. These mitigation measures are practical and straightforward to implement, and will provide a flexible system that can be adapted to suit specific conditions as they arise.
The water budget information provided above illustrates that there will be sufficient water available in the quarry to supply the operational needs as well as future mitigation requirements. Once extraction is complete, there will be surplus water available to progressively fill the quarry to create the lake that is part of the final rehabilitation plan. The lakes will continue to fill until an equilibrium level is achieved whereby the annual influx of water is balanced by the annual outflow, as groundwater, through the rock towards the Escarpment. A relatively minor amount of groundwater and surface water will be re-directed from the drainage basin of the Beaver River into that of Batteaux Creek in response to changes that will result from quarry operations and final rehabilitation to lakes. This change should not result in long-term negative impact on hydraulic conditions in either drainage basin.

7.0 GROUNDWATER AND SURFACE WATER MONITORING PROGRAM

7.1 GENERAL

Groundwater and surface water monitoring has been on-going at and around the existing quarry since the mid-1990’s. Monitoring on and around the expansion property was initiated in 2003 and continues at the present time. Baseline conditions for seasonal groundwater levels, surface water flows and general water quality aspects both on-site and within the potential influence zone of the expansion quarry have been established using the information collected over the previous two years. The monitoring data from around the existing quarry provide the basis for an assessment of the progressive changes that have occurred on-site and around the property. The information from both properties has been evaluated to provide an understanding of the groundwater and surface water systems that are present prior to any quarrying at the expansion property.

A numerical groundwater model has been developed to assist in understanding how the local groundwater and associated surface water systems may be affected by the proposed
quarry operations. The groundwater model is used first to simulate the existing conditions in the area, and then is used to predict changes that result from the extraction of the rock resource in the various phases of the quarry. The predicted magnitude of the changes resulting from quarry operations in Phases 2 and 3 may affect the groundwater, surface water and wetland systems beyond acceptable limits, such that mitigation of those impacts would be required. The numerical model is used to develop suitable mitigation measures, in the form of recharge wells that inject water back into the rock, to ensure that the environment around the quarry property is protected. Finally, the model is used to predict the final lake levels following rehabilitation of the existing quarry and the expansion quarry, and the groundwater levels around the lakes, to assess what residual effects may remain once quarry operations are completed.

The existing quarry operations have modified local groundwater and surface water systems around the quarry; however, those changes do not appear significant and have not resulted in off-site problems. A similar situation is predicted to occur for Phase 1 of the expansion. A predictive-adaptive groundwater and surface water monitoring program is proposed that will quantify progressive changes in seasonal groundwater conditions on-site that result from annual quarry operations in Phase 1, and that information will be compared to the predictions based on the current model. The model will be refined based on information collected during quarry operations, and predictions of impacts for Phases 2 and 3 will be modified accordingly to confirm whether or not the mitigation measures proposed remain appropriate.

A second component of the monitoring program is to establish a series of seasonal early warning values and action threshold criteria for groundwater levels at monitors located around the periphery of the expansion property and in off-site wetland features. Similar criteria will be established for surface water flows at monitoring stations located off-site around the property. The groundwater and surface water programs will also be integrated with the natural environment monitoring program. The early warning and action threshold
values will be based on pre-quarrying seasonal baseline conditions that are being developed for existing monitoring locations, and that will be developed for new monitoring locations.

The early warning values will be used to identify when quarry activities begin to affect groundwater and/or surface water conditions near the perimeter of the property. This will trigger a pre-determined course of action to evaluate the significance of the impact, and will also provide lead-time to implement mitigation measures, where appropriate. The action threshold values will be established to identify when quarry impacts have reached a pre-determined critical level that require quarry activities to cease at that location, until such time as mitigation measures are implemented that will return groundwater levels and/or surface flows to acceptable conditions.

The early warning and action threshold values will be determined in consultation with the regulatory agencies, prior to any extraction in Phase 1. The additional monitoring data that are collected through the interim period will provide further understanding of the natural seasonal variation that occurs to assist in quantifying the criteria.

Details of the proposed monitoring program are provided below with respect to groundwater levels on-site and around the two quarry properties, for residential water wells and for surface water courses around the quarries.

7.2 GROUNDWATER MONITORING PROGRAM

7.2.1 Existing Quarry

The groundwater monitoring program that is undertaken on and around the existing quarry will continue in compliance with the requirements of the current Permit To Take Water. Any additional components that may be included on an amended permit, should one be issued by the Ministry of the Environment, will be incorporated into the program. The current Permit requires monitoring on a quarterly basis for groundwater levels at the on-
site monitors and the supply wells on the Camarthen Lake Farm property, and for streamflow at stations SW1 and SW2, as illustrated on Figure 2-1. In addition, the amount of water discharged from the quarry shall be totaled on a weekly basis, and the dates and times of water takings, pumping rates and total volumes pumped each day shall be recorded. Compilation, analysis and reporting of the monitoring data are to be undertaken, with submission to the Ministry every three years. The first three-year report is due in 2005.

It is noted that groundwater levels and surface water flows currently are monitored more frequently (monthly and weekly respectively) as part of routine operations. In addition, surface water samples are collected several times per year from station SW1 and submitted for chemical analysis of pH, temperature, total oil and grease, ammonia, un-ionized ammonia (calculated) and total suspended solids as part of internal due diligence by Georgian Aggregates. This program will be continued through the active life of the quarry and into the rehabilitation period to ensure that future quarry operations and post-closure conditions do not cause interference problems off-site.

7.2.2 Expansion Property

Figure 7-1 identifies the existing and proposed groundwater monitoring locations on and around the expansion property. The initial focus of the program is centred on quantification of the progressive magnitude and lateral extent of the drawdown zone that develops as quarrying moves through Phase 1. That information will be used to refine the predictions for drawdown and associated impacts in Phase 2 and Phase 3.

Additional monitor locations are proposed as shown on Figure 7-1. The resulting network of monitors will provide good spatial coverage of groundwater conditions beneath the entire expansion property, and will allow the progressive effects of extraction in Phase 1 to be quantified in a radial pattern centred on the initial sinking-cut at the tunnel entrance. As extraction approaches the outer limits of Phase 1 and internal monitors are removed, it may
be beneficial to install additional monitors at key locations in Phase 2 to provide additional coverage in certain areas. A similar situation may arise in preparation for extraction in Phase 3 down to the 500 m asl floor elevation, followed by final extraction beneath Phase 1 down to elevation 490 m asl.

The new monitors will, for the most part, be extended down to the bottom of the Amabel Formation as an open-hole monitor, unless conditions warrant establishing a shallow monitor and a deep monitor in the Amabel at some locations. Figure 7-1 also shows the location of monitors that are to be located in or adjacent to the wetland features to the west, north and east of the expansion property. The monitors in the wetlands will be shallow water table monitors developed in the overburden soils, and they will be installed manually so as to not cause any damage to the vegetation in the wetland.

Continuous water level data will be recorded in the seven monitors located within the Phase 1 area by means of pressure transducers and dataloggers (signified by “D” on Figure 7-1). Manual water level measurements will be obtained for QA/QC purposes on a quarterly basis, and the dataloggers will be downloaded at that time for review and evaluation. Groundwater levels will be measured manually on a monthly frequency at the monitors located around the periphery of the property and at off-property locations. Once baseline conditions have been established at the new peripheral monitor locations, (one to two years), the frequency of monitoring will be reviewed and may be reduced to quarterly, if appropriate. As extraction in Phase 1 extends outwards and drawdown effects are observed at the internal monitors, dataloggers will be installed in additional monitors located in Phase 2 and Phase 3 in preparation for extraction in those areas. The dataloggers in the Phase 1 monitors will be removed from their locations as the extraction face approaches and they no longer provide useful information with respect to drawdown effects in Phase 1, and they will be re-used at other locations.

Since extraction below the water table in Phase 1 will induce groundwater to enter the quarry (as opposed to leaving it), water quality on-site will be monitored through sampling
at the dewatering sump on a quarterly frequency. Samples will be analyzed for the following parameters:

- General chemistry including pH, temperature, dissolved oxygen, specific conductance, alkalinity, hardness, colour, suspended solids.
- Major and minor ion constituents and nutrients
- Total petroleum hydrocarbons
- Bacteriological content (e.coli, total coliform and heterotrophic plate count). These parameters will be tested since excess water from the sump will be discharged off-site during Phase 1 operations and may infiltrate / recharge the rock east of the quarry. The local groundwater is used for residential water supplies water.

Water quality will be compared to the Ontario Drinking Water Standards (for groundwater) and to the Provincial Water Quality Objectives (for surface water). The list of analytical parameters and the frequency of monitoring will be reviewed once baseline conditions have been established for the sump water. In addition, the sump water quality will be compared to the groundwater quality to be obtained from the two closest private residential wells (Kekanovich residence to the west and Dempsey / Brown to the east provided that permission is granted). This will provide water quality information for future use during operation of mitigation recharge wells.

7.3 RESIDENTIAL WATER SUPPLY WELLS

Monitoring of water levels in the residential supply wells is being undertaken on a monthly frequency at locations around the expansion property as part of the assessment of existing conditions and predicted impacts from the proposed quarry operations. Extraction in the expansion quarry will not affect the residential wells that are located below the Escarpment since those wells obtain their water from groundwater that is present either in the local overburden soil or in the underlying bedrock, neither of which are within the zone of influence of the quarry. It is not proposed to continue monitoring the wells located below the Escarpment as part of quarry operations.
Monitoring will continue at the residential wells located around the expansion property above the brow of the Escarpment, since they are within the predicted drawdown influence zone of the quarry. Currently, those wells include the following residences:

- Kekanovich residence drilled well (Grey Road 31)
- Urbaniak residence drilled well (26/27 Sideroad)
- Young residence drilled wells (26/27 Sideroad)
- Cowan residence shallow spring / dug well (26/27 Sideroad)
- Former Bridson residence drilled well (owned by Georgian Aggregates; Simcoe Road 91)
- Former Binczyk residence (owned by Georgian Aggregates, Simcoe County Road 91)
- Dempsey / Brown residence drilled well (Simcoe Road 91)
- Fabrizio residence drilled well (Simcoe Road 91)
- In addition to the wells listed above, the groundwater springs / surface water supplies that are used by the W. Franks residence and the H/E Franks residence, located below the brow of the Escarpment, are monitored on a monthly basis as part of the surface water program.

Water level monitoring will continue on a monthly frequency at the Kekanovich, former Bridson, former Binczyk and Dempsey/Brown wells since they are located closest to the Phase 1 extraction area. It is also proposed that water samples be obtained from the Kekanovich well and the Dempsey/Brown well, and from the groundwater spring supplies at the W. Franks property and the H/E Franks property once per year (late summer / early fall) for chemical analysis.

The frequency of monitoring at the residential wells can be reviewed and modified as necessary as extraction progresses through Phase 1 into Phase 2 and later into Phase 3.
7.4 SURFACE WATER MONITORING

The surface water monitoring program that has been undertaken starting in 2003 has provided a good understanding of the surface water resources and the seasonal variation around the expansion property. To date, monitoring has been undertaken at several locations within the drainage basins of the Beaver River, Batteaux Creek, Pretty River and the Mad River. That monitoring has included estimates of surface water flows and measurement of the field chemistry parameters pH, temperature, conductivity and dissolved oxygen, as well as laboratory analysis for general chemistry and major ions for water samples collected from specific locations. That information has provided baseline conditions for the surface water courses in the four drainage basins.

A scaled-down version of the current monitoring program is proposed to be carried out through extraction in Phase 1, since potential off-site drawdown effects on surface water resources are not anticipated until extraction in Phases 2 and 3. The final decision on the scope of the surface water monitoring program will be based on discussions with the regulatory agencies to ensure that all aspects of potential concern are addressed. It is proposed that the monitoring program include quarterly estimates of flow and measurement of field chemistry parameters at selected key locations below the brow of the Escarpment to the northeast, east and southeast of the expansion property. Water samples will be collected for laboratory chemical analysis once per year at specific locations as a minimum. In addition, continuous water level recorders (pressure transducers and dataloggers) will be installed at selected locations to provide more-detailed information at key locations. The scope of the program will be reviewed on an annual basis so that modifications can be made as appropriate through consultation with the review agencies.
At this time, the following program is proposed as a basis for discussion with the review agencies:

- Continuous water level recorders in the three tributary stream channel culvert crossings at the 10th Concession Road at stations SW14, SW15 and SW18. The dataloggers will be downloaded on a quarterly basis. Stage-discharge relationships will be established for these stations provided that data are meaningful.

- Quarterly estimate of streamflow and measurement of the field chemistry parameters: pH, temperature, conductivity and dissolved oxygen at the following stations:
  - SW10 Groundwater spring for water supply on W. Franks property
  - SW11E Combined groundwater springs input to lake on W. Franks property.
  - SW17 Combined groundwater springs channel flow north side of 26/27 Sideroad.
  - SW21C Groundwater spring for water supply on H/E Franks property.
  - SW22 and 22A Groundwater springs located east of the existing quarry on the Sampson property.

- Annual sampling for water quality parameters at SW10, SW11E, SW21C and SW24A, as follows:
  - General chemistry including pH, temperature, dissolved oxygen, specific conductance, alkalinity, hardness, colour, suspended solids.
  - Major and minor ion constituents and nutrients.
  - Total petroleum hydrocarbons.
  - Bacteriological content at SW10 and SW21C only (e.coli, total coliform and heterotrophic plate count).
7.5 QUARRY PUMPING AND OFF-SITE DISCHARGE

The Permit To Take Water and the Certificate of Approval for Discharge off-site of excess water from the expansion quarry operations will include conditions that will require monitoring of the amount of water that is pumped on-site for dewatering and other purposes, and monitoring of the amount and quality of the water that is discharged off-site from the quarry property. Typically, these operational monitoring programs include daily records of the number and types of pumps that are in use, the hours of operation and volumes pumped, as well as details of the volume and quality of water that is discharged off-site. Final details of the required monitoring program will be developed in conjunction with the Ministry of the Environment as part of the approvals process for the Permit To Take Water and the Certificate of Approval for Discharge. This monitoring information will be incorporated into overall monitoring program for the quarry.

7.6 REPORTING

The results of the groundwater and surface water monitoring program and the operational pumping monitoring program will be analyzed and documented as part of a coordinated report that will integrate the results with those from the terrestrial and aquatic biology (where appropriate) monitoring program. The coordinated report will be compiled and submitted to the regulatory agencies for review on an annual basis. The scope of the various monitoring programs can be reviewed based on the previous years’ results and historical data, with recommendations for change and supporting rationale to be included in the annual report. Any changes to the program would not be implemented without the prior agreement of the appropriate regulatory agencies.
7.7 WATER INTERFERENCE COMPLAINT RESPONSE PROCEDURE

Georgian Aggregates and their parent company Walker Industries Holdings Limited have a proven track-record for addressing interference complaints of any sort from neighbours in the vicinity of the existing Duntroon quarry, as well as at their other aggregate properties throughout the province. This process will continue for the expansion quarry to ensure that quarry operations do not unduly interfere with local residents. The groundwater and surface water monitoring programs are intended to provide early warning of off-site interference, before it occurs, so that suitable mitigation measures can be implemented to prevent unacceptable impact. However, in the event that an unforeseen water interference problem does arise, the following procedure is suggested to address and resolve the issue.

1) The complaint / concern should be submitted to the quarry manager who will collect the following information:

   a) date and time of complaint;
   b) name, address and phone number of the resident, and
   c) details of the interference problem that has occurred and the level of urgency.

2) The quarry manager will determine the appropriate course of action to investigate and resolve the problem / concern in a timely manner and the resident will be informed. In the case of a water interference complaint, the information will be forwarded to Georgian’s groundwater / surface water consultant (Jagger Hims Limited) within 24 hours for investigation. Should the problem be one of immediate concern related to insufficient water supply for residential or other needs, and which appears to be a result of quarry operations, the quarry manager will attempt to provide a suitable alternate supply as quickly as possible.
3) Georgian Aggregates will advise the local office of the Ministry of the Environment that a complaint has been received and that an investigation is underway.

4) Jagger Hims Limited will contact the resident to obtain additional details of the water interference problem, and a site meeting will be arranged with the resident as soon as possible so that an investigation can be completed.

5) If the interference problem is determined to be the result of quarry operations, a suitable program to mitigate and resolve the problem will be discussed with the resident and the quarry manager. The program will be implemented upon agreement with the resident. If the problem is not a result of quarry operations, the supporting information will be provided to the resident. Should the resident continue to be of the opinion that the problem is a result of quarry operations, they will be provided with the contact information at the Ministry of the Environment so that the problem can be pursued with Ministry staff.

6) A report to document the resolution of the interference problem will be submitted to the Ministry of the Environment, with copies provided to the resident and to Georgian Aggregates.
8.0 CONCLUSIONS AND RECOMMENDATIONS

A detailed geological and hydrogeological assessment of the proposed expansion of the Dunroon Quarry has been undertaken. Based on the information presented in this report, the following summary conclusions are provided.

1. The Amabel Formation dolostone forms the cap-rock of the Niagara Escarpment which is located immediately to the east of the existing quarry. The Escarpment is a provincially significant landform feature that extends from Niagara Falls to Tobermory. The Amabel dolostone is recognized as a provincially significant aggregate resource that is used to manufacture a variety of products, including asphalt and concrete products, building stone and lime, and crushed granular materials.

2. The existing Dunroon Quarry encompasses a licenced area of 57.5 ha, of which 47.09 ha is permitted for extraction. The Amabel dolostone rock has been extracted at this location since the mid-1960’s. The quarry floor is at the approved final elevation 500 m above seal level (m asl) across approximately three quarters of the quarry. Rock has been extracted from below the local groundwater table for many years at this location.

3. The quarry floor is maintained in a dry condition by means of a perimeter dewatering system and internal channels that direct surface run-off water and groundwater into the main sump in the southwest quadrant of the property. Water from the sump is used in a closed-loop system for processing (washing) approximately one third of the aggregate that is produced annually (1 to 1.5 million tonnes), and for other on-site uses. A system of on-site sedimentation ponds and water storage ponds has been developed to manage the process water and the water that accumulates on the quarry floor.
4. Excess water is discharged off-site to the adjacent wetland area and associated surface water receiver that is a tributary of the Beaver River. The wetland is part of the larger Rob Roy Swamp wetland complex, a provincially significant wetland. Groundwater and surface water monitoring has been an integral part of the routine operations at the quarry since the mid 1990’s.

5. Quarry operations affect groundwater and surface water resources on-site and locally around the property, but off-site impacts are not significant. Local water supply wells continue to provide sufficient water for residential and agricultural purposes, adjacent wetland areas continue to function as wetlands, and surface water courses do not appear to be negatively impacted by on-going operations.

6. The expansion lands encompass a total area of 127.02 ha located immediately north of Simcoe Road 91 of which 68.92 ha are proposed for extraction, and the remainder will be used as buffer lands around the extraction area. The quarry floor around the west, north and east sides will be extracted down to a final elevation of 500 m asl, similar to the existing quarry. Initially, the southern section of the quarry will be extracted down to an interim floor elevation of 500 m asl, and the last stage of extraction will deepen this area to a final floor elevation of 490 m asl.

7. There are approximately 43 million tonnes of high quality dolostone aggregate resource within the footprint of the proposed quarry extraction area. Annual extraction rates are expected to range between one and three million tonnes per year. Initially, extraction will occur in both the existing quarry and Phase 1 of the expansion, and they will be linked by a tunnel beneath Simcoe Road 91, subject to municipal approval. When sufficient space is available in Phase 1, the processing plant, maintenance shop, stockpiles and scalehouse will be moved from the existing quarry into Phase 1.
8. Surface and sub-surface investigations confirm that the physical setting of the expansion lands is similar to that of the existing quarry, such that the aggregate resource can be extracted safely with no negative impact on sensitive groundwater, surface water and wetland resources around the quarry. Mitigation measures to ensure continued protection of sensitive water resources and wetlands during the later stages of the extraction are described in the text. The final rehabilitation plans for both the existing quarry and the expansion property include lakes in the extraction areas that will reach lake levels that are in equilibrium with local groundwater levels and surface water features. Predicted groundwater flow is from the lakes towards the Escarpment to the east which will maintain flows at the groundwater springs along the Escarpment.

9. The dominant terrain feature in the vicinity of the expansion property is the steeply sloping land of the Niagara Escarpment, the brow of which is located in excess of 400 m east of the proposed extraction area. Another significant landform is the deeply incised Beaver Valley located several kilometers west of the study area. The dolostone rock of the Amabel Formation forms the erosion-resistant cap-rock of the Niagara Escarpment and is present beneath the overburden soil between the Escarpment and the Beaver Valley. To the west of the Escarpment, the dolostone rock serves as the major groundwater aquifer in which most local residential and agricultural water supply wells are developed. The dolostone rock is also used to make high quality aggregate that is shipped to both local and regional markets.

10. To the west of the Escarpment the land surface forms a series of low, rounded hills that are elevated approximately 20 to 30 m above the adjacent lower-lying lands in which surface drainage courses and wetland areas may be developed. The hills are formed by knobs of rock that are covered by a relatively thin veneer of soil. The expansion property is typical of this terrain.
11. The full sequence of rocks present at the Niagara Escarpment near Duntroon is as follows:

**Rock Unit** | **Approximate Thickness**
--- | ---
Amabel Formation dolostone | 15 to 40 + m
Fossil Hill Formation dolostone | 5 to 10 m
Cabot Head Formation shale / limestone interbeds | 10 m
Manitoulin Formation dolostone | 15 m
Whirlpool Formation sandstone | 2 m
Queenston Formation shale / siltstone | 84 m
Georgian Bay Formation shale / limestone interbeds | 120 m

12. The Amabel dolostone is extracted at the existing quarry and is to be extracted at the expansion property. The Amabel Formation includes zones that originally developed as coral reefs, designated as reefal facies rock, and zones that developed on the flanks of the reefal structures, designated as flank facies rock. Both rock types are used to produce quality aggregate materials.

13. Groundwater springs occur at the face of the Escarpment near the base of the Amabel / Fossil Hill formations and near the base of the Manitoulin formation. Dolostone rock is moderately susceptible to dissolution along bedding and fracture planes by infiltrating precipitation, a process known as karstification, and there are karst features present in the vicinity of the expansion lands. The nature and extent of karst features within the study area are being evaluated by specialists in the subject. Information obtained to-date indicates that some karst development is present in the upper horizons of the Amabel dolostone in the form of sinking streams, emergent groundwater springs and enhanced permeability of the rock, particularly adjacent to the Escarpment, and in the Manitoulin dolostone at the Escarpment. The degree of fracturing decreases with depth below surface in the Amabel rock, and extensive karst development is not observed in the deeper horizons of the rock that are exposed in the walls of the existing quarry nor in the rock cores obtained from boreholes drilled on the expansion property. Based on the
experience at the existing quarry, any karst features that are encountered by quarry operations at the expansion property can be mitigated.

14. Detailed subsurface drilling and assessment of the groundwater and surface water systems both on-site and off-site has been undertaken to characterize the physical setting of the expansion property and the surrounding lands. Details are provided in the text. A numerical groundwater model of the area has been developed which, in conjunction with the practical experience gained at the existing quarry, is used to assess the magnitude, extent and mitigation of potential impacts associated with the development of the quarry on the expansion property.

15. The configuration of the water table beneath the expansion property is a subtle reflection of the ground surface topography with local highs centred on the elevated portions of the site. Regionally, there is a groundwater divide that passes through the expansion lands that separates flow into an easterly component towards the Escarpment, and a westerly component towards the Beaver Valley. Similarly, there is a regional surface drainage divide present across the property that partitions surface run-off into the Batteaux Creek basin to the east, the Beaver River basin to the west, the Pretty River basin to the north and the Mad River basin to the south. Details of the seasonal groundwater levels and surface water flows in the various drainage basins are provided in the text.

16. Locally at the Escarpment face, groundwater discharges as seeps or small springs near the base of the Amabel dolostone and also lower down near the base of the Manitoulin dolostone. These springs form the headwater areas for several tributary streams of Batteaux Creek and also for the Pretty River system. The surface discharges are also used as a water supply by specific residents located below the Escarpment face.
17. Above the Escarpment, most residents obtain water supplies by means of drilled wells that are developed in the Amabel dolostone rock. Camarthen Lake Farm obtains water for its cattle operation from several drilled wells that are developed in the Amabel rock. Below the face of the Escarpment, residents obtain water supplies from shallow wells or drilled wells that are developed in the overburden soil or from drilled wells developed in the underlying rock formations. Occasionally, residents use surface water from the groundwater springs as their water supply.

18. Extraction of the aggregate resource will occur in three phases, beginning in the south-central section of the expansion quarry. The dewatering operations will be similar in concept to that used at the existing quarry. Water will enter the extraction area as a result of direct precipitation and surface run-off, and groundwater discharge around the perimeter of the quarry and to the sump. Water will be required for quarry operations including aggregate processing (washing) using a closed-loop system, and for dust control and watering of landscaped areas. Excess water will be stored in ponds on-site and / or in the existing quarry area and will be available for controlled discharge off-site and for use in mitigation measures designed to minimize off-site impacts.

19. Experience gained at the existing quarry and the results of the groundwater model indicate that Phase 1 can be extracted without negative impacts affecting off-site groundwater, surface water and wetland resources. Without mitigation, subsequent phases of extraction are predicted to result in more extensive groundwater drawdown that may affect local water resources and / or wetland features adjacent to the quarry. Mitigation measures are provided that will protect off-site water resource features and associated wetlands.
20. A predictive-adaptive groundwater and surface water monitoring program is outlined in the text. The program includes the establishment of early warning and action threshold levels for groundwater and surface water that will be based on pre-quarrying conditions and linked to specific courses of action / mitigation measures designed to protect the local water resource features. The early warning and action threshold criteria will be developed prior to any extraction in Phase 1 in consultation with the review agencies. The groundwater and surface water monitoring program will be integrated with the program for the natural environment. The results of monitoring during Phase 1 will be compared to predictions based on the groundwater model. The model will be refined as appropriate so that potential future impacts, mitigation measures and monitoring program can be re-evaluated and adapted as needed to ensure continued protection of off-site resources. The water budget outlined in the text illustrates that there will be sufficient water available through the life of the quarry to supply the operational needs and mitigation requirements as described. In addition, there will be a large volume of water available in the lake that will develop in the existing quarry once extraction is completed. That water will also be available for use on a periodic basis in the expansion area, if needed.

21. The final rehabilitation plans for both quarries include lakes in the extraction areas that progressively will fill with water once the dewatering systems are shut down. It is expected that the lakes will require several decades to fill with water. Ultimately, the lakes will achieve levels that are in equilibrium with the annual influx of water and the outflow of water, as groundwater through the rock along the eastern sides of the quarries. That outflow of groundwater will move eastwards to discharge as springs below the brow of the Escarpment similar to conditions today. A relatively small volume of groundwater and surface run-off will permanently be re-directed from the Beaver River drainage basin into that of Batteaux Creek, the impact of which should be negligible for both drainage basins. Adjacent wetland areas will continue to receive direct precipitation and surface run-off from
surrounding lands. Seasonal water table levels in the wetland soils and surface flows are expected to remain similar to historical conditions.

22. In summary, the proposed design and operation of the Duntroon Quarry expansion as described herein is considered acceptable from a water resources perspective. Suitable mitigation measures are available that will ensure protection of local groundwater, surface water and associated wetland resources through all phases of operation and the final rehabilitation to lakes. A detailed groundwater and surface water monitoring program is provided that will incorporate early warning and action threshold levels which will be used to determine if and when mitigation measures are required as extraction proceeds.

The following recommendations are provided:

1. The results of the karst investigations should be incorporated into the overall hydrogeologic assessment of the expansion lands and the potential impacts associated with the quarry operations as proposed. The design and operation of the quarry can be modified as necessary to address specific aspects related to the presence of karst features either on-site within the extraction area or off-site around the perimeter of the property.

2. Develop a long-term predictive/adaptive monitoring program for monitoring and mitigation of the water resources. The program shall be developed in consultation with the appropriate agencies prior to implementation and commencement of quarry extraction activities in the proposed expansion, and shall be integrated with the program for the natural environment. A preliminary set of early warning and action threshold values, together with a defined action protocol, should be developed in consultation with technical review staff, based on the baseline groundwater and surface water conditions as they have been established through the monitoring completed to-date. The additional groundwater monitors that are proposed should
be installed with sufficient lead-time to establish seasonal baseline conditions prior to any extraction in Phase 1. A minimum period of one year is recommended in this regard.

3. This report should be submitted for review by the regulatory agencies as part of the technical documentation in support of the application to expand the Duntroon Quarry as proposed. This information will also be used at the appropriate time in support of the applications for a Permit To Take Water and for a Certificate of Approval for sewage works (for off-site discharge of excess water) for the quarry operation under the Ontario Water Resources Act.

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