Proposed Dolostone Quarry, Hamilton

Volume 1: Hydrogeological Level 2 Report

Prepared for
Lowndes Holdings Corp.

Submitted by
Gartner Lee Limited

June, 2005

Draft for Discussion

Gartner Lee

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1. Introduction

1.1 Background

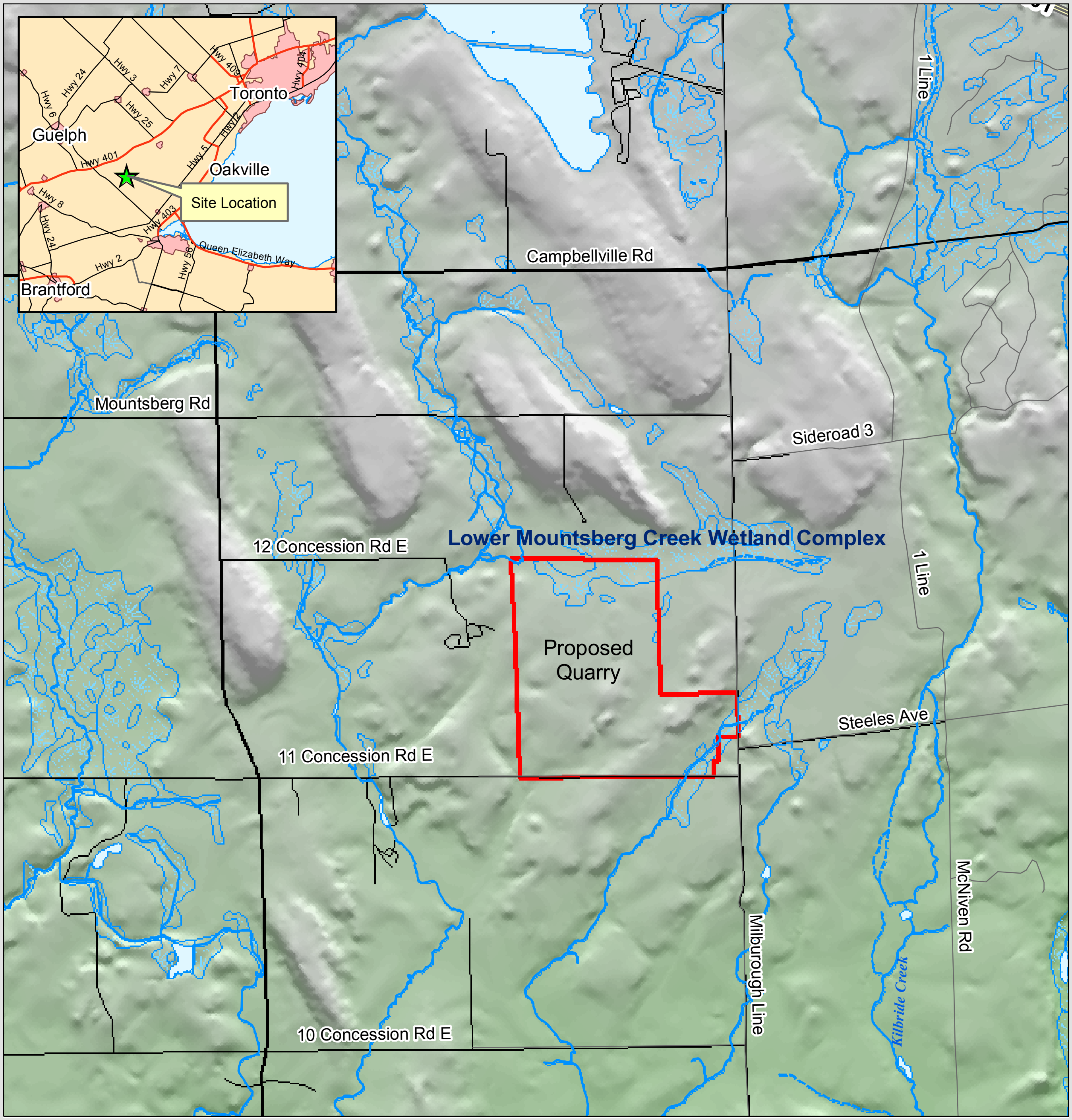
Lowndes Holdings Corp. business objective is to establish a quarry in the Amabel Formation dolostone to supply aggregate. The proposed quarry site is located on Part of Lot 1, and Lots 2 and 3, Concession 11, geographic Township of Flamborough, now The City of Hamilton (Figure 1). The site is located between Regional Road 508 (Centre Road) and Milburough Line, and is about 3.5 km north of the community of Carlisle. At the time of the September 2004 planning amendment application, the property covered an area of about 154 ha (380 acres). Since then, Lowndes Holdings Corp. purchased the 4 ha (10 acres) Abbot property on Milburough Line.

The Amabel Formation dolostone is a high quality aggregate resource, which at the site is between 27 m and 40 m thick. Quarrying the dolostone will result in an open excavation that will extend below the water table. To develop the site, Lowndes Holdings Corp. will be required to obtain a below-water quarry licence under the Aggregate Resources Act and to seek amendments to the former Township of Flamborough Official Plan and Zoning By-Law.

Gartner Lee was retained by Lowndes Holdings Corp. in September 2003, to provide hydrogeologic services related to the undertaking. This report, Volume 1 - Hydrogeological Level 2 Report is one of the studies required to support a quarry licence application and Planning Act amendment application.

1.2 Objectives

To develop a quarry in the Province of Ontario the proponent is required to undertake various studies directed at the assessment of the potential effects of the quarry on the natural environment, and on adjacent property owners and the community at large. The assessment of the potential effect of the proposed quarry undertaking on the water resources in the vicinity of the property is one of the studies. The legislation and policies pertaining to quarry development in the context of water resources are identified in Sections 1.2.1 through 1.2.4. The scope of work outlined in Section 1.3 has been developed to obtain the information required to support the applications under The Aggregate Resources Act (Act) and amendments to local Official Plans and By-laws, and considers the Provincial Policy Statement under Section 3 of the Planning Act (March 1, 2005) and the Greenbelt Plan (February 28, 2005).



Legend

Proposal License Limit

Provincially Significant Wetland

Roads

Expressway

Highway

Secondary Highway

Major Road

Local Road

River/Stream

Intermittent Stream

Stream

Draft for Discussion

Proposed Dolostone Quarry | Figure 1

Location Plan

Project 23827, Hydrogeological Level 2 Report
July 2005

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1.2.1 Aggregate Resources Act Requirements

Section 2.2 of the *Aggregate Resources of Ontario Provincial Standards* (Version 1.0; Ministry of Natural Resources; 1997) details the following requirements for the hydrogeologic assessment of a Category 2 Class "A" Quarry Below Water:

> *Hydrogeological Level 1: Preliminary hydrogeologic evaluation to determine the final extraction elevation relative to the established groundwater table, and the potential for adverse effects to groundwater and surface water resources and their uses.*
>
> *Hydrogeological Level 2: Where the results of the Level 1 have identified a potential for adverse effects of the operation on groundwater and surface water and their uses, an impact assessment is required to determine the significance of the effect and feasibility of mitigation. The assessment should address the potential effects of the operation on the following features if located within the zone of influence for extraction below the established groundwater table, where applicable.*
>
> *The technical report must be prepared by a person with appropriate training and/or experience in hydrogeology to include 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 local geology, hydrogeology, and surface water systems;*
> *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, usually appended to the report.*

1.2.2 Official Plan and Zoning Requirements

The proposed undertaking is subject to the policies of both the Hamilton-Wentworth and the former Flamborough Official Plans.

The lands are designated "Rural Area" and "Rural" in the respective Plans. The Flamborough Zoning By-Law No. 90-145-Z zones the land parcel as both "A" Agricultural Zone and "CM" Conservation Management Zone.

The Hamilton-Wentworth Official Plan 1980 includes policies for rural areas and mineral aggregate resources. A number of Maps are included in the Plan, which guide physical development within the Region. Portions of the property fall within Map 4 Environmental Significant Areas or ESAs (specifically ESA No. 1, the Mountsberg Wetlands and Wildlife Centre and ESA No. 2 Carlisle North Forests). The property (part of Lots 2 and 3) is also designated "Mineral Aggregate Area" in Map 5. Therefore, no amendment of this plan is required.

Lands designated Mineral Aggregate Areas in Map 5 are to be protected for future extraction. The general intent of the Plan with respect to groundwater resources is to maintain groundwater quantity and quality.

Natural environmental features are addressed in Part C-1 Resource Protection of the Hamilton-Wentworth Official Plan and mineral aggregates, groundwater and agriculture are addressed in Part C-2. Development restrictions apply within and adjacent to ESAs unless the proponent can demonstrate via an environmental impact study that the land use change will not impact or functionally alter the ESA.

The former Town of Flamborough Official Plan (Office Consolidation – December 2000) identifies much of the site as Mineral Aggregate Resource Lands, on Schedule J and provides detailed guidance with respect to the establishment of new pits and quarries or the expansion of existing operations. Two Sections (Section B.7.4 and B.7.5) require the proponent to provide sufficient detail in the form of studies to facilitate the council's evaluation of the impact of the undertaking on groundwater and surface water resources.

Lowndes Holdings Corp. is therefore required to submit applications for a local Official Plan Amendment and Amendments to the Zoning By-Law, as the subject lands are not designated or zoned in the former Town of Flamborough planning documents, for the development of a quarry. Gartner Lee prepared a Preliminary Hydrogeological Assessment in August 2004, which accompanied the Lowndes Holdings Corp. September 2004 planning amendment application.

1.2.3 Provincial Policy Statement

The Provincial Policy Statement (PPS) regarding 'water' provided below, was issued under Section 3 of the Planning Act that came into effect on March 1, 2005. This replaces the PPS issued May 22, 1996, amended February 1, 1997 for applications filed after the effective date. The new PPS was considered in developing the scope of work outlined in Section 1.3.

2.2 Water

2.2.1 Planning authorities shall protect, improve or restore the quality and quantity of water by:

- *a) using the watershed as the ecologically meaningful scale for planning;*
- *b) minimizing potential negative impacts, including cross-jurisdictional and cross-watershed impacts;*
- *c) identifying surface water features, groundwater features, hydrologic functions and natural heritage features and areas which are necessary for the ecological and hydrological integrity of the watershed;*
- *d) implement necessary restrictions on development and site alteration to:*
  - *i. protect all municipal drinking water supplies and designated vulnerable areas; and*
  - *i. protect, improve or restore vulnerable surface and groundwater, sensitive surface water features and sensitive groundwater features, and their hydrological functions;*
- *e) maintaining linkage and related functions among surface water features, groundwater features, hydrologic functions and natural heritage features and areas;*
- *f) promoting efficient and sustainable use of water resources, including practices for water conservation and sustaining water quality;*
- *g) ensuring stormwater management practices, minimize stormwater volumes and contaminant loads, and maintain or increase the extent of vegetative and pervious surfaces.*

2.2.2 Development and site alteration shall be restricted in or near sensitive surface water features and sensitive groundwater features such that these features and their related hydrologic functions will be protected, improved or restored.

Mitigative measures and/or alternative development approaches may be required in order to protect, improve or restore sensitive surface water features, sensitive groundwater features, and their hydrologic functions.

1.2.4 Greenbelt Act, 2005

The Greenbelt Plan established under the Greenbelt Act, 2005, was implemented on December 16, 2004 for mineral aggregate applications after December 16, 2003 (O. Reg. 61/05). Those policies identified in the Greenbelt Plan for non-renewable resources, which are specific to hydrologic features and water resources, are presented below. These policies were factored into the work undertaken in preparing this Level 2 report.

4.3.2 Non-Renewable Resource Policies

3) Notwithstanding the Natural System policies of Section 3.2 of this Plan, within the Natural Heritage System, mineral aggregate operations and wayside pits and quarries are subject to the following:

i) No new mineral aggregate operations and no wayside pits and quarries, or any ancillary or necessary use thereof will be permitted in the following key natural heritage features and key hydrologic features:
i. Significant wetlands;…..

ii) An application for a new mineral aggregate operation or new wayside pits and quarries may only be permitted in other key natural heritage features and key hydrologic features not identified in 4.3.2.3(a) and any vegetation protection zone associated with such other feature where the application demonstrates:
i. How the Water Resource System will be protected or enhanced; and
iii. That the specific provisions in 4.3.2.5 [c], [d] and 4.3.2.6 [c] have been addressed, and that they will be met by the operation;

iii) Any application for a new mineral aggregate operation, or the expansion of an existing mineral aggregate operation, shall be required to demonstrate:
i. How the connectivity between key natural heritage features and key hydrologic features will be maintained before, during and after the extraction of mineral aggregates;
ii. How the operator could immediately replace any habitat that would be lost from the site with an equivalent habitat on another part of the site of on adjacent lands; and
iii. How the Water Resource System will be protected or enhanced; and

4) *The Ministry of Natural resources will pursue the following under the Aggregate Resources Act, for all mineral aggregate operations, including wayside pits and quarries, within the Protected Countryside:*

   d) *An application for a mineral aggregate operation or wayside pits and quarries may be permitted only where the applicant demonstrates that the quantity and quality of groundwater and surface water will be maintained as per Provincial Standards under the Aggregate Resources Act.*

5) *When operators are undertaking rehabilitation of mineral aggregate operation sites in the Protected Countryside, the following provisions apply:*

   c) *If there are key natural heritage features or key hydrologic features on the site, or if such features existed on the site at the time of the application:*

      i. *The health, diversity and size of these key natural heritage features and key hydrologic features will be maintained or restored and, to the extent possible, improved to promote a net gain of ecological health; and*

      iii. *Any permitted extraction of mineral aggregates that occurs in a feature will be completed, and the area will be rehabilitated, as early as possible in the life of the operation.*

   d) *Aquatic areas remaining after extraction are to be rehabilitated to aquatic enhancement which shall be representative of the natural ecosystem in that particular setting or ecodistrict, and the combined terrestrial and aquatic rehabilitation shall meet the intent of 4.3.2.5 [c].*

6) *Final rehabilitation in the Natural Heritage System will meet these additional provisions:*

   c) *Rehabilitation will be implemented so that the connectivity of the key natural heritage features and key hydrologic features on the site and on adjacent lands will be maintained or restored, and to the extent possible improved.*

10) *Municipalities should insure that all land use activities related to the post excavation rehabilitation of mineral aggregate operations are consistent with any relevant approved source protection plan and relevant watershed or sub-watershed plan.*

1.3 Scope of the Level 2 Hydrogeological Assessment

A preliminary Hydrogeological Assessment of the subject property was completed in August 2004, to identified the potential for impacts on groundwater and surface water resources and their uses, from the development of the property as a quarry. Based on this preliminary assessment, it was recommended that a Level 2 Hydrogeological Assessment be undertaken.

The scope of work for the Level 2 Hydrogeological Assessment is outlined in this section. The work was completed under the direction of Steve Hollingshead (P.Eng.) by a study team under the management of Gunther Funk, Hydrogeologist, P.Geo., which included professionals in geology, hydrogeology and hydrology. Key team members were Dennis German, Hydrogeologist, P.Geo. (groundwater modeling), Sandra Beranger, Hydrogeologist, and Kevin Warner Hydrogeologist (data collection and analysis). Keith Lang Water Well Drilling Inc. provided drilling support and conducted the initial pumping test. The second pumping test was conduced by Jim Wilson Ontario Water Well Services Inc. Resumes of the Gartner Lee team members are presented in Appendix A, Volume 3 - Appendices.

This Level 2 Hydrogeological Assessment incorporates information obtained from published studies and maps, in addition to new information obtained from field investigations conducted on the subject property by Gartner Lee and other consultants retained by the Lowndes Holdings Corp.

Existing regional information on the geology and hydrogeology, and the groundwater and surface water resources in the vicinity of the site was initially compiled and reviewed to develop a general overview of the site and surroundings. This information was supplemented by data provided in Water Well Records obtained from the Ministry of the Environment (MOE). The water well records information is summarized in Appendix B of this report.

Site-specific information on the geology was obtained from the geological investigation completed by John Emery Geotechnical Engineers Limited (JEGEL) and documented in the JEGEL report dated July 16, 2004. A Gartner Lee geologist inspected the bedrock core collected by JEGEL to identify fractures and identify zones of potentially higher transmissivity.

Information on the natural environment, surface water and wetlands was obtained from Stantec Consulting Ltd. 2005 Report titled "Level 2 Natural Environmental Report and Environmental Impact Study, Proposed Dolostone Quarry, Flamborough" and discussions with the principal investigators.

Building on this data and the preliminary Level 1 Hydrogeological interpretation of the site, Gartner Lee developed a work plan to collect field derived geologic and hydrogeologic information. The hydrogeological work program, which is described herein, involved the following tasks:

a) drilling and logging of 13 boreholes in the bedrock at 7 locations on the property (referred to as GLL BH1-D, GLL BH 1-S, etc., see Table 1, Appendix C) to characterize the geology;

b) completion of downhole packer testing in the deeper boreholes to establish the distribution of hydraulic conductivity with depth;

c) installation of 51 mm ID PVC riser pipe and screen in the above boreholes and in boreholes BHB, BHC, BHD, BHE and BHF installed by JEGEL for use as monitoring wells (Note these boreholes are referred to as JEGEL BHB, JEGEL BHC, etc., see Table 1, Appendix C);

d) installation of four (4) large diameter (200 mm and 254 mm) wells to be used as test wells (TW10, TW11, TW12 and TW13) for aquifer evaluation;

e) installation of 16 piezometers, 9 located within a wetland area in the northern portion of the site, 5 piezometers installed adjacent to the watercourse that crosses the southeast corner of the property to monitor shallow groundwater levels and 2 piezometers internal to the site to assess seeps;

f) installation of stream gauges along each of the watercourses to measure stream level and to estimate flow;

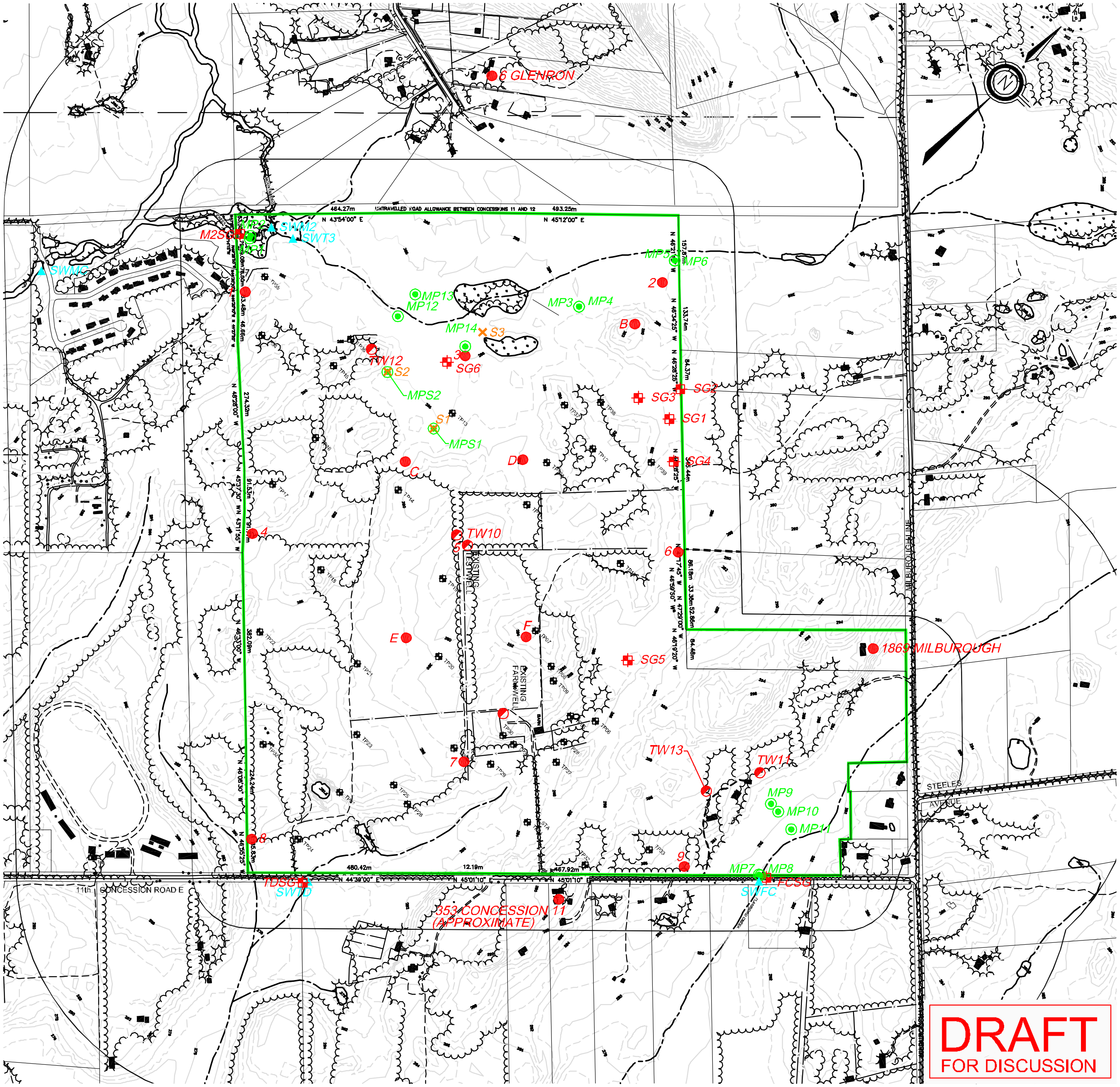
g) completion of two pumping tests, one initially using a well located in the centre of the property to establish the bulk hydraulic properties of the bedrock and aquifer response (i.e., extent of the associated drawdown), and a second test using two wells one located in the northwest and the second in the southeast corners of the property to evaluate potential effects of groundwater stresses on adjacent wetlands;

h) monitoring of the natural seasonal response in groundwater levels and surface flows to climatic events; and,

i) collection of groundwater and surface water samples for chemical analysis.

- **<u>Boreholes</u>**

The boreholes were advanced using conventional rotary drilling techniques (Keith Lang Water Well Drilling Inc.). A tricone bit (8-inch) was used to penetrate the overburden into the top of bedrock. Casing was then seated into the top of rock and the bedrock was cored with an HQ core barrel producing a 97 mm corehole to the target depth of each well. The JEGEL boreholes were reportedly drilled using a 152 mm core barrel. JEGEL and Gartner Lee staff logged the core from each deep bedrock borehole. The shallow boreholes were advanced to the target depths without being logged. Borehole completion information is provided in Appendix C, and the borehole locations in Figure 2.



LEGEND

- PROPERTY BOUNDARY
- 310 — EXISTING 1m CONTOURS
- 307.0 EXISTING SPOT ELEVATIONS
- EXISTING TREE COVER
- EXISTING CONIFER
- EXISTING DECIDUOUS
- EXISTING FENCE LINE
- EXISTING SURFACE DRAINAGE
- TP9 TEST PITS, 2003
- EXISTING WELL
- TW12 PRODUCTION WELL
- 1 MONITOR WELL LOCATION AND DESIGNATION
- MP8 PIEZOMETER LOCATION
- SWFC SURFACE WATER STATION
- S1 SEEP LOCATION
- SG6 STAFF GAUGE LOCATION

NOTE:
BASE DRAWING FROM LONG ENVIRONMENTAL CONSULTANTS INC. DRAWING 2 "EXISTING FEATURES" DATED MARCH 30, 2004.

SCALES

100m 0 250m 500m

Scale 1:12,500

PROPOSED DOLOSTONE QUARRY

PLAN SHOWING MONITORING LOCATIONS

Designed By: SB	Drawn By: JEP
Checked By: —	Approved By: —
Date Issued: JUNE 2005	Project No.: 23–827
Gartner Lee	FIGURE 2

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- **Packer Tests**

  Pump in packer tests were completed by Keith Lang Drilling under the supervision of Gartner Lee staff at 10 locations [boreholes GLL BH1-D, GLL BH4-D, GLL BH6-D, GLL BH7-D, GLL BH8-D, GLL BH9-D, JEGEL BHB-D, JEGEL BHC, JEGEL BHD and JEGEL BHF]. The testing was completed to establish the vertical distribution of hydraulic conductivity. Hydraulic conductivity was determined by measuring the rate of percolation into the rock across each 3 m section of the borehole as it was being drilled.

  A more detailed description of this testing is provided in Appendix E, with the packer test results provided in Tables 1 to 10, and Figures 2 to 11, Appendix E-1. The test results are summarized in Section 2.4 of the report.

- **Monitoring Wells**

  Monitoring wells were installed in 18 of the available boreholes following the April 2004 pumping test (see text describing this test). Well installation involved lowering a 3 m length of 51 mm ID PVC screen attached to a riser pipe to the base of the borehole and backfilling the annular space around the screen with washed sand to a height of about 0.3 m above the screen.

  A cement/bentonite grout was placed above the sand pack interval by injection to fill the balance of the annular space to surface. If necessary, risers were threaded or welded onto the existing overburden casing to extend the casing to about 0.6 m above ground surface. A locking cap was added to each casing. The shallow monitoring wells were equipped with protective casing at surface.

  Well construction details are provided in Table 1, Appendix C. Well locations are shown in Figure 2.

- **Piezometers**

  A total of 16 piezometers were installed as part of the work program. The initial six piezometers (P1 through P6) were installed in November 2003 to provide background information on shallow groundwater levels in the Lower Mountsberg Creek Wetland Complex. Two additional piezometers (P7 and P8) were installed in April 2004 along Flamboro Creek. Six piezometers were installed in November 2004, to evaluate the shallow groundwater responses in the wetland during a second pumping test. These including MP9, MP10 and MP11 installed along Flamboro Creek and MP12, MP13 and MP14 installed in the Lower Mountsberg Creek Wetland Complex.

  Additional piezometers (2) were installed in May 2005 at locations on the property to assess seeps (potential springs) that were observed.

The piezometers were supplied by Solinst (Model 615) and consist of a stainless steel piezometer tip attached to steel extensions. The piezometers were manually driven into the ground to the target depth or refusal on bedrock. Water enters the piezometer through screened perforations in the tip.

Construction details are provided in Table 1, Appendix C. The locations of the piezometers are shown in Figure 2.

- **Staff Gauges**

Staff gauges were established in March 2003 along the principal surface watercourses. These include: SWM2 on the east leg of Mountsberg Creek at the property line: SWFC on the main channel of Flamboro Creek at the property line; and, SWTD on Tributary D of Flamboro Creek downstream of the pond. Stream flow measurements are obtained at the above stations as well as SWT3 on Tributary A of Mountsberg Creek upstream of its confluence with Mountsberg Creek and SWMC on the main channel of Mountsberg Creek. The station locations are shown in Figure 2. The channel dimensions were established at each station and the water stage levels were correlated with measured flows to provide a rating curve for each station.

- **Pumping Tests**

Two pumping tests were completed. The initial test was performed between April 20 and April 23, 2004 and involved pumping test well TW10. The open well bore straddles the full thickness of the Amabel Formation. Testing was authorized under Permit to Take Water 03-P-2402(T).

The initial test was designed to stress the rock formation to provide the data needed to calculate the hydraulic parameters such as transmissivity, horizontal hydraulic conductivity, and storage for the Amabel Formation across its full thickness.

Prior to the test, a four-stage step test was completed to select a pumping rate. The actual test was conducted at a rate of 1,309 m^3/day (200 igpm) for a period of 72 hours. The water was discharged through piping to the roadside ditch along Concession 11, a distance of about 750 m from the pumping well. The water level response to pumping was recorded using pressure transducers/data loggers installed in 25 monitoring wells and piezometers. An atmospheric pressure transducer was used to correct for barometric pressure changes. Manual groundwater level measurements were complete to check the data loggers. The data loggers were downloaded on April 26th, 2004 and the data corrected for atmospheric pressure.

The second test was completed between November 27, 2004 and December 6, 2004, with the objective of establishing the degree of connectivity between the groundwater regime and the surface water regime. This testing was authorized under Permit to Take Water 0714-65YNCS.

The second pumping test as initially designed, was to continue for at least 168 hours with synchronous pumping at two locations (TW12 and TW13) at a rate of up to 500 IGPM at each location (Figure 2). The open well bores for both wells straddle the full thickness of the Amabel Formation. The objective of this second test was to stress the groundwater system to the point where a response could be observed in the piezometers and shallow wells located in the vicinity of the wetlands. As noted above, additional piezometers were installed in the Lower Mountsberg Creek Wetland Complex. These piezometers were instrumented with pressure transducers to collect high-resolution water level data. This level of data collection was necessary to identify subtle responses in the shallow groundwater associated with the wetlands to the pumping test at TW12 and TW13. Various other shallow and deep wells were also instrumented with data loggers, as were selected piezometers in the wetland areas.

Several private residential wells are located in the vicinity of the proposed quarry site. PTTW Condition 4.1 required that prior to the commencement of the pumping test that a water well survey be completed to identify all wells within the anticipated potential cone of influence, or within a 1,000 m radius of each test well. Available water well records were initially reviewed to identify residences with wells. This was followed by a door-to-door survey, where efforts were taken to contact private well owners to inform them of the proposed testing. An information sheet describing the test and a contact telephone numbers was left with the owner/occupant if encountered or in the residents' mailbox if no one was home.

During the survey, two residents agreed to have their wells monitored during the pumping test. The locations of the wells are shown in Figure 2.

Downhole problems were encountered during installation of the pump in TW13 as part of the testing. The driller re-entered the well on November 23, 2004, re-drilled the well with a 200 mm OD bit and re-developed the well. Pump installation problems were again encountered and it was decided that the well would be reamed to a larger diameter.

On November 26, the driller pulled the 200 mm overburden casing, set 254 mm casing to 7.3 m and reamed the well bore to 250 mm. Slotted steel liner with a shale packer was set at a depth of 14 m to stabilize the upper rock.

Pumping at well TW13 was initiated on November 27, 2004 at 3:30 p.m. at a rate of 864 m^3/day (132 igpm) and held at this rate until the test was terminated on December 4 at 3:30 p.m.

Testing of TW12 was also initiated on November 27, 2004 (at 6:00 p.m.) at a rate of 980 m^3/day (150 igpm). At 8:21 p.m. the rate was increased to 1,962 m^3/day (300 igpm) and at 8:27 p.m. reduced to 1,635 m^3/day (250 igpm) when it became evident that the higher rate could not be sustained. On November 29 at 8:30 p.m. it was decided to terminate pumping because of the poor production performance. The driller was mobilized to the site on November 29, 2004. The 200 mm casing was pulled, a 254 mm casing was set at 3.6 m and the well bore was reamed to 250 mm.

The testing of TW12 was resumed on November 30 at 9:00 p.m. at a rate of 1,962 m^3/day (300 igpm). The rate was subsequently increased on December 1, 2004 at 8:30 a.m. initially to 2,616 m^3/day (400 igpm) and at 9:30 a.m. to 3,270 m^3/day (500 igpm). This pumping rate was sustained until the test was terminated on December 6 at 1:00 p.m.

Flow from well TW12 was discharged to a tributary of Mountsberg Creek and flow from TW13 was discharged to Flamboro Creek.

Monitoring and collection of the pressure transducer data took place during the pumping test and was continued until December 11, 2004 to record the recovery in the groundwater system after termination of the pumping after which the transducers were removed and the data recovered.

The description of the testing methodology is provided in Appendix E. The hydrographs generated from the test data are presented in Appendix E. The results are discussed in Section 3.1 of this report.

- **Seasonal Water Level Data**

Surface water and groundwater levels have been measured on site since April 2004 to establish baseline information on seasonal responses. The water level data are provided in Appendices F and G.

- **Water Chemistry**

Baseline sampling of selected shallow and deep monitoring wells was conducted on November 19, 2004. Samples were also collected from two private residential wells located at 124 Glen Ron and 1869 Milburough on December 6, 2004.

To evaluate any changes in the chemistry during the second pumping test, samples were collected from the two test wells TW12 and TW13 on November 27, 2004 at the start of pumping and again on December 2, 2004 about midway through the test.

Surface water samples were collected during the second pumping test from Mountsberg Creek and Flamboro Creek on November 27, December 4 and from Mountsberg Creek only on December 6, 2004.

The samples were submitted to PSC Analytical Services for analysis of major and minor ions and metals. The chemistry data are present in Appendix H and described in Section 2.6. The surface water samples in the laboratory report are referred to as North Creek (Tributary A of Mountsberg Creek), Mountsberg (Mountsberg Creek at Staff Gauge SWMC) and TW13 stream (Flamboro Creek at station SWFC). Repeat samples were also collected [16-II, which is a replicate sample from GLL4-S, TW13 (repeat) and North Creek (repeat)] for quality control purposes.

Stantec Consulting Ltd. has been conducting additional surface water quality monitoring in the vicinity of the property ("Level 2 Natural Environmental Report and Environmental Impact Study, Proposed Dolostone Quarry, Flamborough", 2005). The Gartner Lee and Stantec reports are complementary and are being prepared together to enable integration of water quality/quantity analysis, the assessment of off-site effects, and mitigation and monitoring efforts. .

- **Analysis and Reporting**

  Field data was subsequently summarized, analyzed where applicable and interpreted. A groundwater flow model was subsequently developed that incorporates information on the hydrology, geology and hydrogeology of the property, and the subwatershed in which the property is located. A water balance was completed as part of this assessment. This model has been calibrated through comparison of computer simulated and field measured groundwater level, and responses to pumping tests. The model is detailed in the Volume 2 report, the results of which are summarized in Section 3.2.

1.4 Report Organization

The Level 2 Hydrogeological Assessment is contained in three volumes. Volume 1 is the summary document, with Section 1 providing an introduction to the Level 2 Hydrogeological Assessment study and provides a brief background to the undertaking. The physical setting of the site (i.e., surface features and topography, surface water resources and use, geology, hydrogeology and groundwater use) is described in Section 2. The assessment of potential impacts from quarry excavation and operations are presented in Section 3 and recommended measure to mitigate identified impacts are identified in Section 4. The 'Summary and Conclusions' is provided as Section 5. Section 6 'References' included at the end of this report, lists studies, maps etc. that were consulted.

Volume 2 is the hydrogeologic model study that builds on and incorporates the information collected during the investigation. The field data, testing methodologies and results are provided in Volume 3 Appendices.

2. Physical Setting

2.1 Location, Land Uses and Topography

The property is bounded by residential development to the north[1], residential development and agricultural land (horse farm) to the west, forest to the east and Concession Road 11 to the south. Components of the Lower Mountsberg Creek Wetland Complex are located in the northern portion of the site and a component of this Wetland is present in the southeast, associated with Flamboro Creek. The Lower Mountsberg Creek Wetland Complex has been designated a Provincially Significant Wetland (PSW) by the MNR. The central portion of the property consists of cultivated land separated by treed hedgerows. The southwest portion of the property is in mixed coniferous and deciduous forest.

The central area of the subject property is fairly hummocky, with several low rolling hills. The ground elevation on the southern part of the property, closest to Concession 11, is about 281.5 mASL[2] and rises to about 294.2 mASL in the center portion of the property, sloping downward to the north to an elevation of about 285 mASL in the wetland. A dugout pond is found near the southern property line, with a pond elevation of 280.7 mASL.

2.2 Drainage

The property is within the Upper Bronte Creek Watershed, draining either to Mountsberg Creek (north, west and southwest) or Flamboro Creek (southeast/east). The headwaters of a tributary (referred to as tributary A) of the Mountsberg Creek originate within the wetlands/swamp located on the northern portion of the property. The wetlands are mapped as part of the Lower Mountsberg Creek Wetland Complex. The organic soils of the wetland are thin, generally between 1 m to 2 m thick, and directly overlie bedrock. The wetland appears to be fed by a combination of overland and shallow groundwater flow from adjacent uplands. From piezometer measurements, the water level in the wetland is the surface expression of the water table in the bedrock. Tributary A connects with the main branch of Mountsberg Creek about 250 m west of the site.

A small pond, present near the south end of the property, is located on a tributary (Tributary D) of Mountsberg Creek. Flow in this tributary is intermittent.

1. *For simplicity, "north" in this report generally refers to the top of the drawings and directions correspond to the road alignment, following local convention, rather than the actual compass directions (which are also shown in the drawings for reference).*
2. *mASL refers to the elevation expressed in metres above mean sea level.*

Tributary D connects with Tributary C, immediately south of the property and with the main channel of Mountsberg Creek about 1 km south of the property.

The other major watercourse that crosses the property is Flamboro Creek, which drains towards the south. Both Flamboro Creek and Mountsberg Creek connect to Bronte Creek over 2 km to the south. Low areas adjacent to Flamboro Creek on the property are a component of the Lower Mountsberg Creek Wetland Complex.

As noted in Section 1.3, staff gauges were established in March 2003 along the principal surface watercourses. These include: SWM2 on the east leg of Mountsberg Creek at the property line: SWFC on the main channel of Flamboro Creek at the property line; and, SWTD on Tributary D of Flamboro Creek downstream of the pond. Stream flow measurements are obtained at the above stations as well as SWT3 on Tributary A of Mountsberg Creek upstream of its confluence with Mountsberg Creek and SWMC on the main channel of Mountsberg Creek. The station locations are shown in Figure 2.

The surface water data collected as part of this study are compiled in Table 1 and Table 2 provided in Appendix G. The daily and annual average flow hydrographs for the watershed are presented in Graphs 3 to 6, Appendix G. The hydrological flow stations (HYDAT) for this subwatershed exhibit flow fluctuations that range in the 300 to 16,000 Litres per second (Lps) range. The average recorded flows for the various stations on Mountsberg Creek for the monitoring period (March 2004 through April 2005) follow:

a) SWMC- 595 L/s
b) SWM2- 357 L/s
c) SWT3- 20 L/s
d) SWFC- 21 L/s
e) SWTD- 16 L/s

2.3 Water Budget

The mean annual precipitation at the meteorological station located in the City of Hamilton based on 55 years of meteorological data from 1935 to 1990, is estimated as 849 mm per year. Employing the water balance methodology in Thornthwaite and Mather (1957), the mean annual evapotranspiration is estimated to be 511 mm (assumes a soil moisture storage of 100 mm). The mean annual water surplus (i.e., the amount of water available for runoff and infiltration) is calculated to be 338 mm. The annual surplus is likely to range from 257 mm to 439 mm during 13 out of 20 years. Key elements of the water balance are presented in the groundwater modeling report (Volume 2). Explicit details of the water balance from the quarry and the subwatershed are discussed in detail in Section 3.3.

2.4 Geology

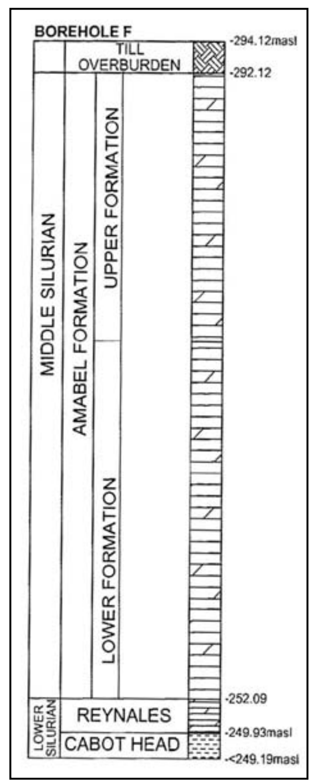
The site is located in the Flamborough Plain physiographic region, described as a limestone plain, locally overlain by glacial deposits, scattered drumlins and low-lying swampy areas (Chapman & Putnam, 1984).

The following description of the geology is based on published maps and a detailed assessment of the site geology conducted by JEGEL (2004). This assessment involved the excavation of 39 test pits and advancement of 12 boreholes to establish the overburden thickness, and provide samples and rock core for the detailed characterization of the overburden and underlying bedrock.

- **Surficial Geology**

The overburden from regional mapping by Karrow (1986, 1987) consists of silt till with boulders and cobbles over most of the property. Organic deposits are present in the northern portion of the property, bedrock outcrops along the western boundary, and outwash gravel deposits are observed in the southern portion of the property. The till is mapped as Wentworth Till, which is described as a sandy-silt till, which is locally stony and associated with outwash deposits. The overburden varies in thickness from 0.0 m to 7.9 m, and averages about 2.4 m.

- **Bedrock Geology**



The geology is illustrated schematically in the stratigraphic column to the left. This column and the description of the bedrock provided below were reproduced from JEGEL (2004). The primary bedrock formation (Amabel Formation) is of Middle Silurian in age and can be divided into two units. The upper unit, average 14 m thick, is described as a light brown-gray, fine crystalline, fossiliferous dolostone having some brittle sections. The lower unit, average 18.6 m thick, is a light to dark, blue-gray, fine crystalline, fossiliferous dolostone. Visible porosity is significantly lower than the overlying member.

Although several bedding plane and vertical fractures are noted in the log, the core recovery across the Amabel Formation was generally good with an average recovery of 95.36% reported in JEGEL (2004). No obvious or visible karst topography or features were detected in the rock assemblage.

From boreholes advanced on the property the Amabel Formation varies from 27 m to 40 m thick, averaging 32.6 m.

The contact with the underlying Reynales Formation is sharp. The Lower Silurian Reynales Formation averages 2 m thick and is described as a grey to white, thinly bedded, fine to very finely crystalline dolostone with calcareous shale. Fossils are rare and visible porosity (vugs) is low.

The Reynales Formation marks a transition between the carbonates of the Amabel Formation and the underlying Cabot Head shale.

The boreholes advanced on site for this investigation were drilled to the top of the Cabot Head shale.

2.5 Hydrogeology

The overburden can be expected to have varying hydraulic properties. The till has a comparatively low hydraulic conductivity and acts to retard infiltration and where saturated, it acts as a confining unit. The outwash deposits are permeable and the infiltration rate through this material is expected to be high.

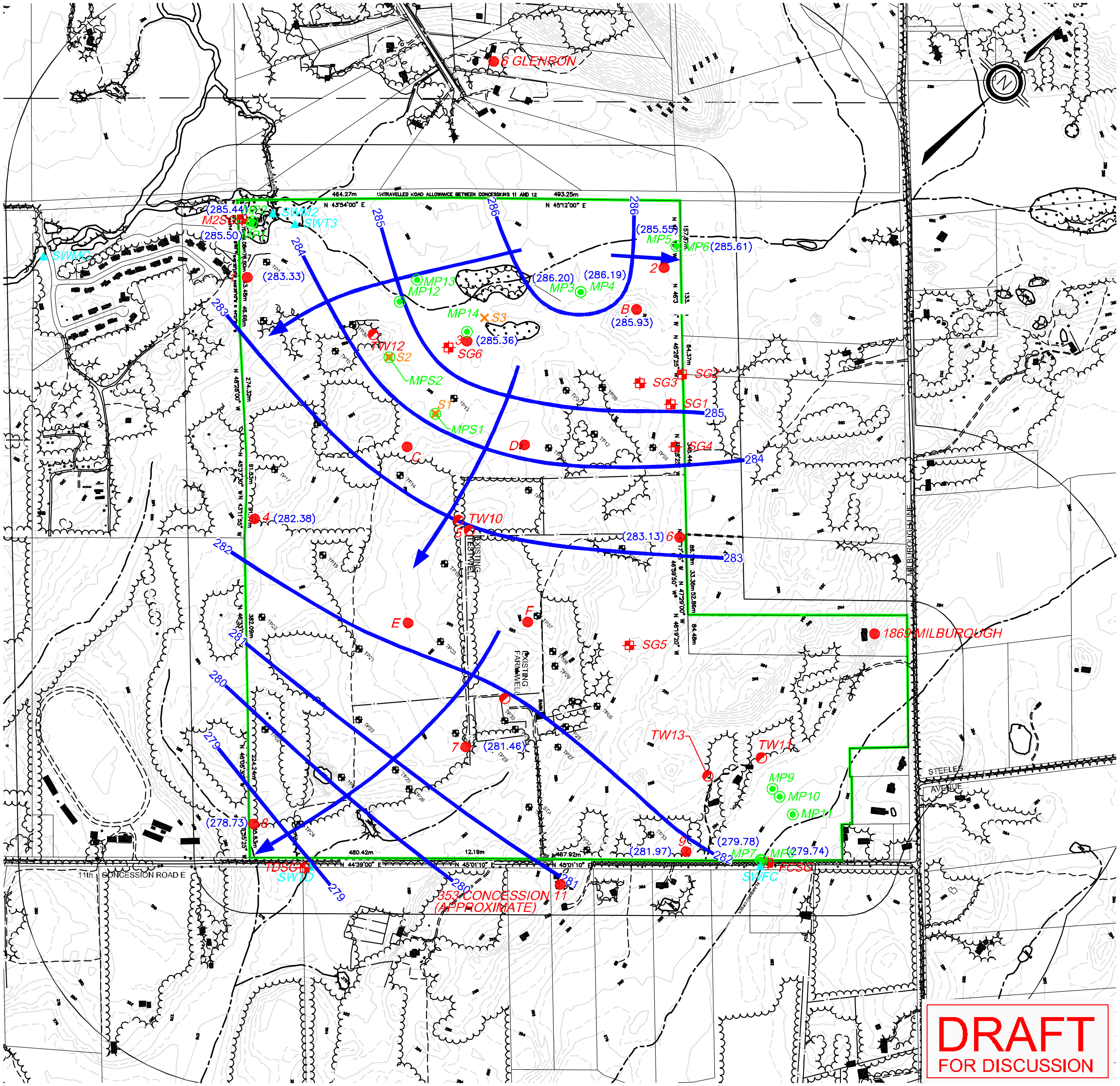
The Amabel Formation dolostone is a regionally significant aquifer. The aquifer potential is related to fractures and solution cavities along bedding planes within the rock. It is generally possible to install wells in the bedrock that will satisfy individual residential water demand, and locally more demanding municipal requirements.

2.5.1 Groundwater Flow

Groundwater level data have been collected by either manual measurement or with data loggers installed in selected wells. The period of record extends from April 2004 through April 30, 2005. The hydrographs generated using these data are presented in Appendix F. As is expected, the water level declined through the dry summer months and increased starting in mid October, with cooler weather conditions and increasing precipitation.

The water table in the northern and southeastern portion of the site within the wetland associated with the Mountsberg and Flamboro creeks is near surface.

Groundwater levels measured on July 26, 2004 in shallow and deep monitoring wells installed on the property are shown in Figure 3 and Figure 4 respectively, along with the interpreted groundwater flow directions. The direction of groundwater movement is similar in the shallow and deep portions of the bedrock.



DRAFT
FOR DISCUSSION

LEGEND

- PROPERTY BOUNDARY
- 310 — EXISTING 1m CONTOURS
- .307.0 EXISTING SPOT ELEVATIONS
- EXISTING TREE COVER
- EXISTING CONIFER
- EXISTING DECIDUOUS
- EXISTING FENCE LINE
- EXISTING SURFACE DRAINAGE
- TP9 TEST PITS, 2003
- EXISTING WELL
- TW12 PRODUCTION WELL
- 1 MONITOR WELL LOCATION AND DESIGNATION
- MP8 PIEZOMETER LOCATION
- SWFC SURFACE WATER STATION
- S1 SEEP LOCATION
- SG6 STAFF GAUGE LOCATION
- (285.30) WATER LEVEL ELEVATIONS (JULY 2004)
- 284 DEEP GROUND WATER CONTOURS
- DIRECTION OF FLOW

NOTE:
BASE DRAWING FROM LONG ENVIRONMENTAL CONSULTANTS INC. DRAWING 2 "EXISTING FEATURES" DATED MARCH 30, 2004.

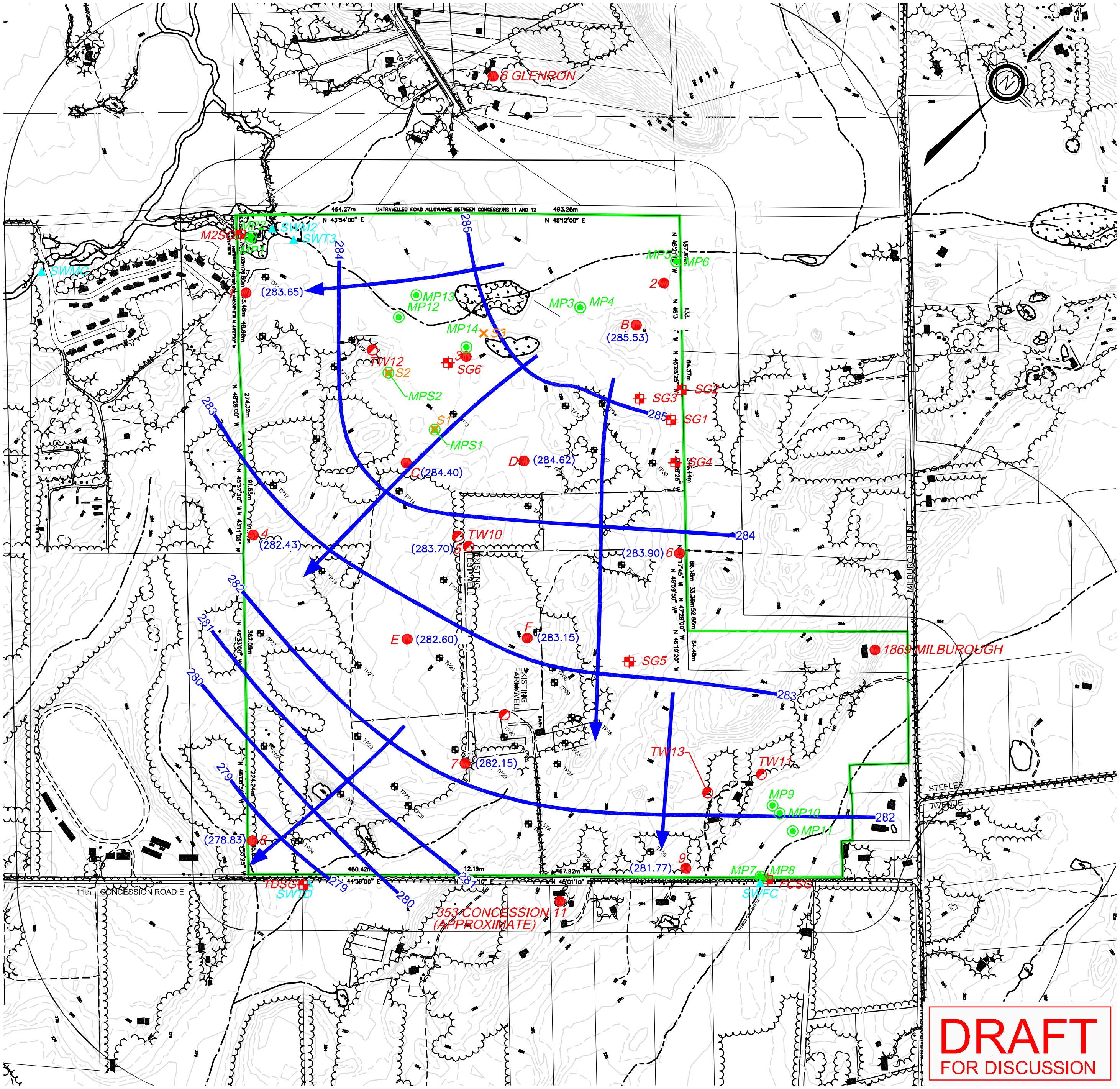
SCALES
100m 0 250m 500m
Scale 1:12,500

PROPOSED DOLOSTONE QUARRY

GROUNDWATER ELEVATIONS & INTERPRETED CONTOURS IN SHALLOW WELLS

Designed By: KDW	Drawn By: JEP
Checked By: SCH	Approved By: –
Date Issued: JUNE 2005	Project No.: 23–827
Gartner Lee	FIGURE 3

Jul 07, 2005 – 12:52pm N:\Projects\2003\23827\2005\Final\ACAD\23827–F01.dwg



LEGEND

- PROPERTY BOUNDARY
- 310 – EXISTING 1m CONTOURS
- .307.0 EXISTING SPOT ELEVATIONS
- EXISTING TREE COVER
- EXISTING CONIFER
- EXISTING DECIDUOUS
- EXISTING FENCE LINE
- EXISTING SURFACE DRAINAGE
- TP9 TEST PITS, 2003
- EXISTING WELL
- TW12 PRODUCTION WELL
- 1 MONITOR WELL LOCATION AND DESIGNATION
- MP8 PIEZOMETER LOCATION
- SWFC SURFACE WATER STATION
- S1 SEEP LOCATION
- SG6 STAFF GAUGE LOCATION
- (285.30) WATER LEVEL ELEVATIONS (JULY 2004) (APPROXIMATE, BASED ON OPEN BOREHOLES)
- 284 DEEP GROUND WATER CONTOURS
- DIRECTION OF FLOW

NOTE:
BASE DRAWING FROM LONG ENVIRONMENTAL CONSULTANTS INC. DRAWING 2 "EXISTING FEATURES" DATED MARCH 30, 2004.

SCALES

100m 0 250m 500m

Scale 1:12,500

PROPOSED DOLOSTONE QUARRY

GROUNDWATER ELEVATIONS & INTERPRETED CONTOURS IN DEEP WELLS

Designed By: SB	Drawn By: JEP
Checked By: –	Approved By: –
Date Issued: JUNE 2005	Project No.: 23–827
Gartner Lee	FIGURE 4

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Hydraulic gradients as determined from the water levels observed in shallow and deep monitoring well pairs, vary across the property. Upward gradients were consistently observed at well pairs GLL BH6 (D & S), GLL BH7 (D & S) and GLL BH8 (D & S).

In contrast, the gradient is consistently downward at well pairs GLL BH9 (D & S) and JEGEL BHB (D & S). The gradient at well pairs GLL BH1 (D & S) and GLL BH4 (D & S) changed during the monitoring interval with a downward gradient observed between April and June 2004, and an upward gradient over the balance of the year.

2.5.2 Aquifer Properties

As indicated, aquifer properties were determined through packer testing and pumping tests.

The parker tests were conducted during borehole advancement to determine the distribution of the hydraulic conductivity with depth across the Amabel Formation. The horizontal hydraulic conductivity varies from a high of 5.27×10^{-3} m/s (JEGEL BHD, depth of 30.1 m) to a low of 9.14×10^{-9} m/s (GLL BH4-D depth of 37.3 m). Zones, which are more conductive, are identified in the individual boreholes and presumably relate to the degree of fracturing encountered across the packer test interval (see graphs provided in Appendix E). Conductive zones (>10E-5 m/s) are identified in many of the boreholes between the elevations of 279 mASL and 274 mASL, 271 mASL and 268 mASL, and 260 mASL and 251 mASL.

The initial pumping test performed between April 20 and April 23, 2004, which involved test well TW10 was designed to stress the rock formation to provide the data needed to calculate the hydraulic parameters such as transmissivity, horizontal hydraulic conductivity, and storage for the Amabel Formation across its full thickness. This testing was authorized under Permit to Take Water 03-P-2402(T).

The results for the pumping test are provided in Appendix E, along with drawdown/time and drawdown distance graphs and curve matching analysis for each of the data sets and each analytical method. The results of the second test are provided in a stand-alone letter report, which was submitted to the MOE in early March 2005 (Gartner Lee, 2005).

The bulk transmissivities and hydraulic conductivities calculated from data collected during the April 2004 pumping test are presented in Table 1. The average bulk transmissivity and hydraulic conductivity determined for the April 2004 pumping test data are 5.9×10^{-3} m^2/s and 1.4×10^{-4} m/s, respectively.

PVC casing and screen were installed in the deep open boreholes following the April 2004 pumping test. The observed water level response in the 'deep wells' during the November/December 2004 pumping test is therefore reflective of the horizontal hydraulic conductivity of the rock over the lower 3 m (10 ft) of each borehole where the screen was set. The upper portion of the bedrock in each of these boreholes above the screen was effectively sealed with grout.

Table 1. Aquifer Properties from the April 2004 72-Hour Pumping Test

Borehole	Maximum Drawdown (m)	Distance from Pumping Well (m)	Transmissivity (m^2/s)	Hydraulic Conductivity (m/s)
BH4	0.32	465	4.31×10^{-3}	1.01×10^{-4}
BH5	12.18	2.5	6.87×10^{-3} 1.78×10^{-4}*	1.61×10^{-4} 4.16×10^{-6}*
BH6	0.14	460	9.71×10^{-3}	2.27×10^{-4}
BH7	0.22	465	4.54×10^{-3}	1.06×10^{-4}
BHC	1.40	225	3.27×10^{-3}	7.66×10^{-5}
BHF	1.28	235	1.76×10^{-2} 1.00×10^{-3}*	4.13×10^{-4} 2.35×10^{-5}*
Averages			**5.9×10^{-3}**	**1.4×10^{-4}**

*Note: * Using the Hantush-Jacob (Walton) method; the remaining analyses employed the Cooper-Jacob method.*

The second pumping test conducted in late November 2004, synchronous pumping at two locations (TW12 and TW13, shown in Figure 2) for 168 hours. As noted, the second test was intended to stress the groundwater system to the point where a response could be observed in the mini-piezometers and shallow wells located in the vicinity of the wetlands adjacent to Mountsberg Creek and Flamboro Creek. Although, the testing was not designed to collect additional information on the hydraulic properties of the bedrock, transmissivities of 3.25×10^{-3} m^2/s and 4.14×10^{-3} m^2/s were calculated using the drawdown and recovery data respectively, for TW12. A similar analysis of the data was not completed for TW13 due to the lack of the data. Well JEGEL BHC was used in this analysis to confirm the transmissivity estimates and to also estimate a storativity value for the formation. These results are presented in Figures 59 through 64, Appendix E-3.

In several instances it is not possible to discern any water level response in the observation wells attributable to the second pumping test. This would suggest that the hydraulic continuity between the observation well and the pumping well is poor and the corresponding transmissivity and hydraulic conductivity are low. [Note: This conclusion is tempered by the fact that several precipitation events occurred during the test and the water level increases related to precipitation events could have obscured the pumping response.] Responses to precipitation events were identified in the piezometer installations, while responses to the same precipitation events in the deeper boreholes were not obvious.

2.5.3 Groundwater Use

- **Private Residential Well Supplies**

Residents use the Amabel Formation aquifer as a source of water supply for domestic and farm use. To determine the extent of use, a search of Ministry of the Environment (MOE) water well records was undertaken in June 2004 to identify wells located within about 1 km of the quarry. Copies of the individual records were obtained and the well locations were plotted on an Ontario Base Map using the UTM co-ordinates provided in the MOE well records. Information on the MOE well records is compiled in Appendix B and described below.

A total of forty-four (44) water wells plot within 1 km of the site boundaries (Figure 5). These wells, with a single exception, are completed in the bedrock.

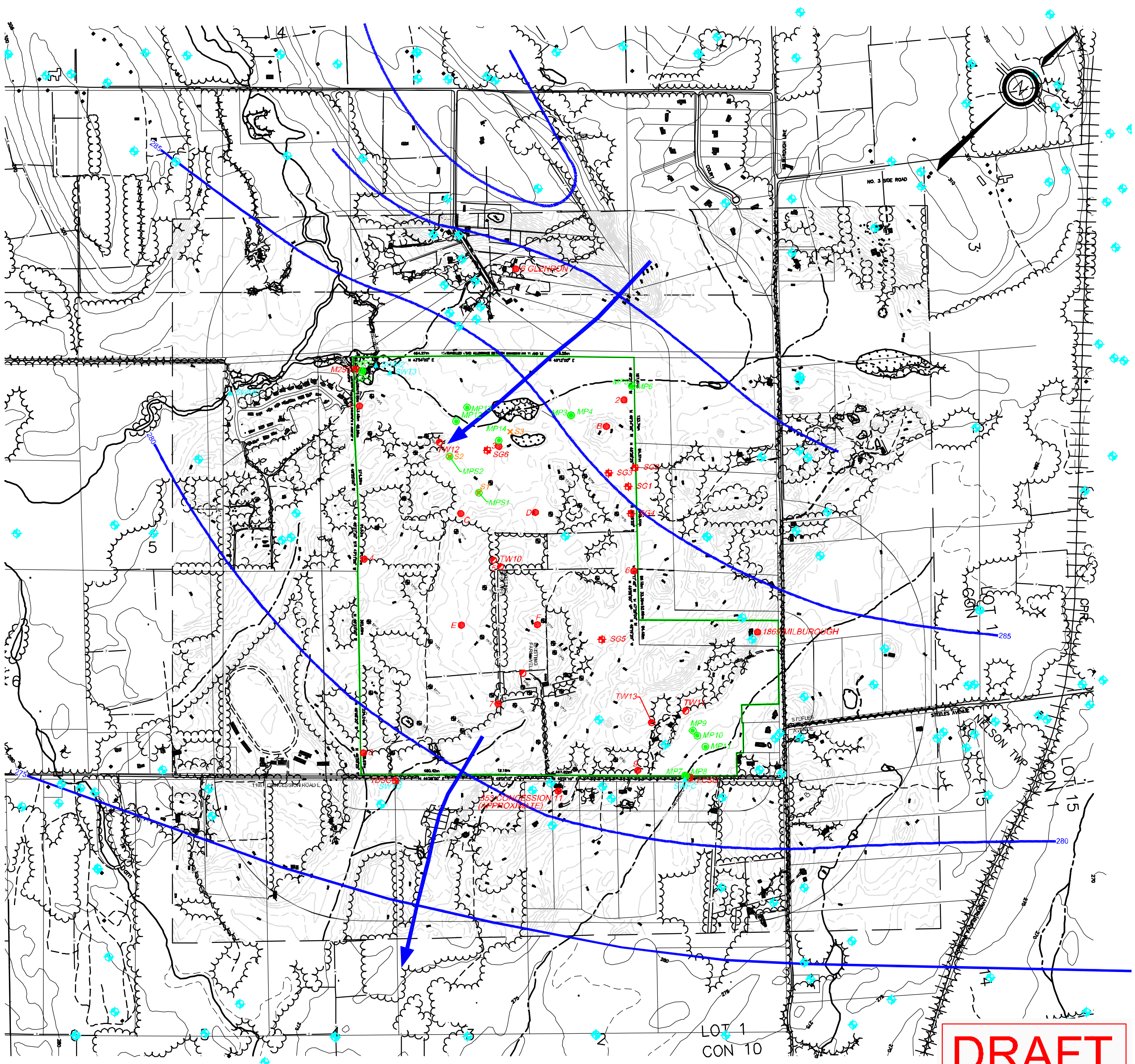
Groundwater quality is reported to be ‘fresh’ and the water use is identified as being for domestic purposes. The specific capacities reported in the records vary from 0.20 to 40. Recommended pumping rates are typically 20 igpm or higher, indicating that the wells can sustain most domestic requirements.

The average elevation of the bedrock surface reported in the records is 282.5 m ASL, but range from 281 to 283.5 m ASL in the south and north, respectively. Based on the plotted elevations, the bedrock surface dips generally towards the south, with the average bedrock surface elevation being 2.5 m higher north of the site compared to the south. Wells depths average 16.7 m, ranging from 7.6 to 35.1 m. Wells are on average, deeper north of the property than south, 19.0 compared to 13.4.

The average static water level of the MOE well records is 285.5 mASL. Based on the plotted water levels, groundwater movement is in a southerly direction, with wells north of the site (26 wells) having higher water levels on average than those found south of the site (18 wells); 289 mASL compared with 281 mASL. Figure 5 shows a general interpretation of ground water level (potentiometric) contours based on the well records, illustrating a north-south groundwater flow direction. The on-site flow directions mapped in Figure 3 and 4 from the detailed site investigations are generally similar to those from the water well records surrounding the site (Figure 5).

A water well inventory was undertaken within about 1.5 km of the quarry boundaries to obtain anecdotal information on the wells related to historical issues or problems, etc., and to identify key wells, which may be used in the future for monitoring purposes. The door-to-door survey was undertaken in November 2004 prior to the pumping test conducted on wells TW12 and TW13. Of the 24 residences visited, the occupants of 10 residences provided additional information on their wells. For the most part, the occupants provided information on water use and indicated that they were satisfied with the yield and quality of the water produced from their wells. The occupants of two residences agreed to allow their wells to be monitored during the proposed November 2004 pumping test.

Information, obtained from the water well survey is summarized in Table 1, Appendix B.



DRAFT
FOR DISCUSSION

LEGEND

PROPERTY BOUNDARY
310 — EXISTING 1m CONTOURS
.307.0 EXISTING SPOT ELEVATIONS
EXISTING TREE COVER
EXISTING CONIFER
EXISTING DECIDUOUS
EXISTING FENCE LINE
EXISTING SURFACE DRAINAGE
TP9 TEST PITS, 2003
EXISTING WELL
MOE WELL RECORD
TW12 PRODUCTION WELL
1 MONITOR WELL LOCATION AND DESIGNATION
MP8 PIEZOMETER LOCATION
SWFC SURFACE WATER STATION
S1 SEEP LOCATION
SG6 STAFF GAUGE LOCATION
284 PRELIMINARY POTENTIOMETRIC CONTOUR BASED ON MOW WATER WELL RECORD
DIRECTION OF GROUNDWATER FLOW

NOTE:
BASE DRAWING FROM LONG ENVIRONMENTAL CONSULTANTS INC. DRAWING 2 "EXISTING FEATURES" DATED MARCH 30, 2004.

SCALES: 250m 0 250m 500m 750m
Scale 1:20,000

PROPOSED DOLOSTONE QUARRY

POTENTIOMETRIC CONTOURS FROM WATER LEVELS IN THE WATER WELLS RECORDS

Designed By: SB	Drawn By: JEP
Checked By: –	Approved By: –
Date Issued: JUNE 2005	Project No.: 23-827
Gartner Lee	FIGURE 5

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- **Municipal Well Supplies**

The community of Carlisle, located about 3.5 km to the south is the nearest municipality that draws water from Amabel Formation. The Carlisle water works consists of four bedrock wells (FDC01 FDC02, FDC03 and FDC04) and an elevated storage tank with a capacity of 1,400 m^3. The production wells, which vary in depth from 25.6 m to 40 m, have a combined permitted capacity of 2,293 L/minute. Based on a survey completed by Stantec (2004), 539 of the 805 lots in the community of Carlisle (67%) are serviced by the municipal well supply with the remainder supplied by private wells.

The four municipal wells, based on their location and depth, are installed in the Amabel Formation. According to Stantec (2004) two wells FDC03 and FDC04, have in the past, provided the main supply with one well in operation and the second on standby. The system was to be upgraded during the summer of 2004 with the addition of a UV system. Water demand during this period was being met by wells FDC01 and FDC02. These wells are normally used as a supplemental source of supply.

Details on the individual production wells and a monitoring well installed in 2003 as part of the City of Hamilton Groundwater Characterization Study follow:

Well	Construction Details		Capacity (L/S)	Permit Number
	Depth (m)	Diameter (mm)		
FDC01	39.6	150	9.83 from either or both wells	75-P-2072
FDC02	35.9	250		
FDC03	36.6	200	10.0	95-P-2010
FDC04	25.6	200	8.5	01-P-2107
CM-04-03	11.5	250	Monitoring well	

The communal system was reportedly not able to meet peak demand requirements in the summer of 2002, which were estimated to be between 35 L/s and 40 L/s. As a result, the City undertook to commission an assessment of future supply options resulting in the preparation of the Carlisle Water Supply Master Plan and Class Environmental Assessment Project File Report (Stantec, 2004). Short-term and long-term solutions were identified. The recommended short term-solution combines a water conservation program to reduce per capita water use with the addition of additional supplies (either additional supplies from the existing well field or additional supplies from a new well field to be established). The long-term solution may involve extending a water main to convey water from the Woodward Avenue Treatment Plant to Carlisle from Waterdown.

As part of its broader Water and Wastewater Master Plan efforts the City of Hamilton retained SNC Lavalin Engineers & Consultants in association with Charlesworth & Associates to undertake a citywide '*Groundwater Resources Characterization and Well Head Protection Study*'. The Carlisle well field was included in this study. The Hamilton study report and groundwater model are not currently available.

Figure 6 shows the capture zone for the Carlisle municipal well field as defined through groundwater flow modeling. The proposed quarry property is within the 25-year capture zone for these wells. This implies that a portion of recharge falling on the quarry property will be drawn towards the wells within a 25-year reference period. An expanded, discussion of the potential effects associated with development of the quarry on the Carlisle municipal water supply is presented in Section 3.3.3.

2.6 Water Quality

Groundwater samples were collected on November 19, 2004 from selected shallow and deep monitoring wells to establish ambient (baseline) water quality. Additional groundwater and surface water samples were collected on November 27, December 2, December 4 and December 6 during the December 2004 pumping test completed at wells TW12 and TW13. Both sets of samples were analyzed for general chemical parameters and metals.

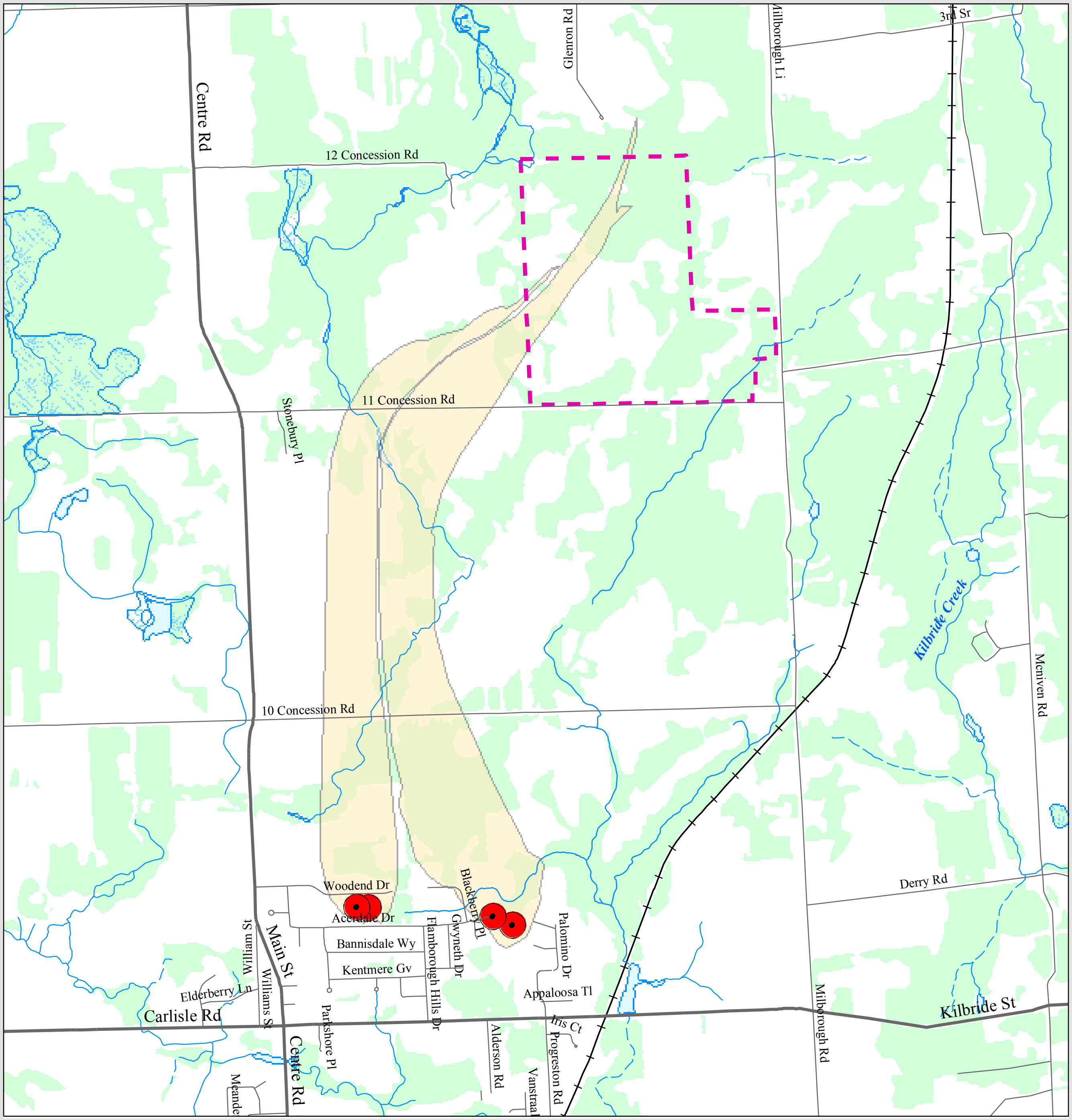
The analysis results are compiled in Table 2 and Table 3. The Ontario Drinking Water Standards (ODWS) and Provincial Water Quality Objectives (PWQO) are included for reference. The laboratory reports are presented in full in Appendix H. A discussion of the analysis results follows:

- **Groundwater**

  The baseline chemistry is presented in Table 2. The groundwater is hard, enriched in calcium and bicarbonate alkalinity, and deplete in sodium and chloride, in comparison with the surface water. The Dissolved Organic Carbon (DOC) is about an order of magnitude lower in the groundwater samples. The remaining parameters are similar to or slightly higher in concentration than the surface water samples. Of note, the samples from the two deep wells (GLL BH7-D and GLL BH9-D) are on average, more mineralized than the samples from the shallow wells.

  Most parameters meet the ODWS and PWQO with the exception of arsenic (0.029 mg/L) in both the initial and replicate samples from deep well GLL BH9-D and iron (0.35 mg/L) in the sample from shallow well GLL BH2-S. Nitrate was elevated in two shallow wells, with a concentration of 15.4 mg/L observed in the sample from GLL BH8-D and 10.5 mg/l (10.3 mg/L repeat) in samples from GLL BH4-S. Iron is a naturally occurring parameter. The elevated nitrate concentration may be attributed to the agricultural use of the property in the vicinity of these shallow wells.

  Groundwater samples were also collected during the November/December 2004 pumping test from the two test wells TW12 and TW13 (Table 3). Generally, the discharge from TW12 was more mineralized than that from TW13. Most parameters meet the ODWS and PWQO with the exception of iron (between 0.30 mg/L to 0.39 mg/L) in the samples from TW12, aluminum (0.132 mg/L & 0.143 mg/L) in the November 27, 2004 samples from TW13 and zinc (between 0.05 mg/L & 0.49 mg/L) in the samples from TW13. The ODWS and PWQO for iron are both set at 0.3 mg/L. The ODWS and PWQO for aluminum are 0.1 mg/L and 0.075 mg/L, respectively. The PWQO for zinc is 0.02 mg/L.



Legend

Property Boundary

Carlisle Wellhead Protection Zones

Draft for Discussion

Basemapping from OMNR

Proposed Dolostone Quarry	Figure 6

Capture Zones for Carlisle Municipal Wells as Modeled by the City of Hamilton

Project 23827, Hydrogeological Level 2 Report
July 2005

Gartner Lee Limited

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1:35,000

Map Document: (N:\Projects\2003\23827\2004\Final\GISSpatial\23827_lowndes_quarry_WHPCZ.mxd)
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Gartner Lee

Table 2: Baseline Groundwater Quality
Proposed Lowndes Holdings Corp. Quarry
Flamborough, Ontario

DRAFT FOR DISCUSSION

	Units	Ontario Drinking Water Standards		Provincial Water Quality Objectives		Deep Well GLL9-I	Deep Well GLL9-I repeat	Deep Well GLL7-I	Average Deep Groundwater Quality	GLL9-II	GLL7-II	GLL1-II	GLL2-II	GLL6-II	GLL8-II	GLL4-II	GLL16-II (repeat of GLL4-II)	Average Shallow Groundwater Quality
						Nov-19	Nov-19	Nov-19	Nov-19	Nov-19	Nov-19	Nov-19	Nov-19	Nov-19	Nov-19	Nov-19	Nov-19	Nov-19
General Parameters																		
Conductivity (umhos/cm)-SM 2510B	**us/cm**					668	668	792.0	709.3	548	518	630	635	560	556	532	534	564.1
DOC	**(mg/L)**					1.5	0.9	0.4	0.9	1.9	1.6	1.3	2.7	0.6	0.4	0.6	0.6	1.2
TDS	**(mg/L)**					490	488	597	525.0	342	300	399	405	347	295	295	292	334.4
Hardness (as CaCO3)-SM2340B	**(mg/L)**					404.1	399.2	395.7	399.7	285.8	288.1	347.9	340	315.6	301.8	311.7	303.3	311.8
pH (at 20 degrees C)- SM 4500B	**Unitless**	6.5 - 8.5	OG			8.08	7.99	8.16	8.08	8.09	8.19	8.25	8.25	7.88	8.00	7.90	7.90	8.06
Anions																		
Bromide	**(mg/L)**					<0.5	<0.5	<0.5	0.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Chloride	**(mg/L)**	250	AO			7	7.1	28.6	14.2	10.6	4.6	30.3	42.9	21.3	11.1	5.7	5.7	16.5
Fluoride	**(mg/L)**	1.5	MAC			0.1	0.1	0.3	0.2	0.2	0.1	0.1	<0.1	0.1	<0.1	<0.1	<0.1	0.1
Nitrate as N	**(mg/L)**	10	MAC			<0.2	<0.2	<0.2	0.0	0.3	3.7	<0.2	<0.2	<0.2	**15.4**	**10.5**	**10.3**	4.95
Nitrite as N	**(mg/L)**	1	MAC			<0.2	<0.2	<0.2	0.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ammonium (NH3-N)	**(mg/L)**					<0.03	<0.03	0.33	0.1	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Phosphate-P (ortho)	**(mg/L)**					<1	<1	<1	0.0	<1	<1	<1	<1	<1	<1	<1	<1	<1
Alkalinity (CaCO3)- SM 2320B	**(mg/L)**	30 - 500	OG			248	251	252	250.3	304	287	331	306	300	249	283	283	292.9
Bicarbonate Alkalinity (HCO3)	**(mg/L)**					300	304	305	303.0	368	348	401	371	363	301	343	343	354.8
Sulphate	**(mg/L)**	500	AO			183	181	230	198.0	35.3	18.6	40.2	45.6	32	22.8	13.1	13.1	27.6
Metals / Major Ions																		
Aluminum	**(mg/L)**	0.1	OG	0.075	Interim	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.022	<0.005	<0.005	<0.005	<0.005	0.0049
Antimony	**(mg/L)**			0.02	Interim	0.0005	0.0005	<0.0005	0.0004	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Arsenic	**(mg/L)**	0.025	IMAC	0.005	Interim	**0.029**	**0.029**	<0.002	0.020	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Barium	**(mg/L)**	1	MAC			0.047	0.047	0.019	0.038	0.028	0.140	0.037	0.060	0.020	0.047	0.007	0.007	0.043
Beryllium	**(mg/L)**			1.1		<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Bismuth	**(mg/L)**					<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	**(mg/L)**	5	IMAC	0.2	Interim	0.026	0.026	**0.206**	0.086	0.016	0.019	0.007	0.009	0.008	0.017	<0.0005	0.007	0.0104
Cadmium	**(mg/L)**	0.005	MAC	0.0005	Interim	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Calcium	**(mg/L)**					116	115	120	117	70	67.4	86.8	85	76	85.5	72.8	71.5	76.9
Chromium	**(mg/L)**	0.05	MAC			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cobalt	**(mg/L)**			0.0009		**0.0012**	**0.0012**	<0.0001	0.0001	0.0002	0.0007	<0.0001	0.0001	<0.0001	0.0002	<0.0001	<0.0001	0.0002
Copper	**(mg/L)**	1	AO	0.005	Interim	<0.0005	<0.0005	<0.0005	<0.0005	0.0005	0.0013	0.0012	<0.0005	<0.0005	<0.0005	<0.0005	0.0006	0.0006
Iron	**(mg/L)**	0.3	AO	0.3		0.16	0.17	0.20	0.18	<0.03	0.05	0.03	**0.35**	<0.03	<0.03	<0.03	<0.03	0.06
Lead	**(mg/L)**	0.01	MAC	0.005	Interim	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Magnesium	**(mg/L)**					27.3	27.0	23.3	25.9	27.0	29.0	31.8	31.0	30.5	21.4	31.5	30.3	29.1
Manganese	**(mg/L)**	0.05	AO			0.016	0.016	0.021	0.018	0.029	0.047	0.011	**0.095**	<0.005	<0.005	<0.005	<0.005	0.0240
Molybdenum	**(mg/L)**			0.04	Interim	0.002	0.002	<0.001	0.0015	0.006	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.0013
Nickel	**(mg/L)**			0.025		0.002	0.002	<0.001	0.0015	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Phosphorus	**(mg/L)**			0.03	Interim	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Potassium	**(mg/L)**					1.3	1.2	4.9	2.5	0.8	4.8	0.5	1.0	0.5	3.4	0.2	0.2	1.4
Selenium	**(mg/L)**			0.1		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Silicon	**(mg/L)**					2.66	2.63	3.05	2.78	3.03	2.09	3.50	3.08	2.62	3.29	1.77	1.70	2.64
Silver	**(mg/L)**			0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Sodium	**(mg/L)**	200	AO			5.5	5.4	38.5	16.5	15.8	3.0	10.9	15.4	6.9	1.7	1.3	1.2	7.0
Strontium	**(mg/L)**					1.83	1.8	4.65	2.76	0.203	0.05	0.131	0.143	0.087	0.124	0.046	0.045	0.104
Tin	**(mg/L)**					<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Titanium	**(mg/L)**					<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Vanadium	**(mg/L)**			0.006	Interim	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Zinc	**(mg/L)**	5	AO	0.02	Interim	0.008	0.006	<0.005	0.0055	0.008	0.008	0.019	<0.005	0.008	0.011	0.008	0.007	0.009

Notes
Bold - concentration exceeds Provincial Water Quality Objective.
Highlighted - concentration exceeds Ontario Drinking Water Standard.

Summary of Abbreviations
Ontario Drinking Water Standards
MAC - Maximum Acceptable Concentration
IMAC - Interim Maximum Acceptable Concentration
AO - Aesthetic Objective
OG - Operational Guideline

Gartner Lee

Table 3: Groundwater Quality Observed during Pumping Test
Proposed Lowndes Holdings Corp. Quarry
Flamborough, Ontario

DRAFT FOR DISCUSSION

	Units	Ontario Drinking Water Standards		Provincial Water Quality Objectives		TW12	TW12	TW12 (repeat)	TW12	TW13	TW13 (repeat)	TW13	TW13	Dance	6 Glenron	124 Glen Ron	124 Glen Ron (Repeat)	1869 Millbrough	1869 Millbrough (Repeat)	1869 Millborough
						Nov-27	Dec-02	Dec-02	Dec-06	Nov-27	Nov-27	Dec-02	Dec-04	Nov-23	Nov-27	Dec-06	Dec-06	Nov-27	Nov-27	Dec-06
General Parameters																				
Conductivity (umhos/cm)	us/cm					704.7	704.4	687.1	698.2	644.6	653.0	634.8	646.1	600.0	600.0	623.2	617.9	860	600	942.9
DOC	(mg/L)					0.6	<0.2	<0.2	0.3	0.9	0.6	<0.2	<0.2	<0.50	0.9	0.4	0.4	0.67	0.88	0.8
TDS	(mg/L)					363	362	355	356	328	333	321	326	400.0	390.0	312.0	309	560	390	465
Hardness (as CaCO3)	(mg/L)					307.4	305.7	292.1	306.8	299.4	299.7	299	308.3	290.0	300.0	301.7	299.3	350		365.5
pH (at 20 degrees C)- SM4500B	Unitless	6.5 - 8.5	OG			8.08	7.98	7.96	7.99	8.09	8.16	7.96	8.07	7.92	7.99	8.07	8.08	8.13	7.99	8.03
Anions																				
Bromide	(mg/L)					<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.10	<0.10	<0.5	<0.5	<0.10	<0.10	<0.5
Chloride	(mg/L)	250	AO			13.1	16.7	16.4	18.4	13.5	14.3	13.2	12.7	27.0	7.2	10.3	9.9	57	7.2	69.3
Fluoride	(mg/L)	1.5	MAC			0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.1	0.1	<0.1	0.14	0.11	0.1
Nitrate as N	(mg/L)	10	MAC			<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	5.40	1.30	1.70	1.7	1.7	1.3	1.5
Nitrite as N	(mg/L)	1	MAC			<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.10	<0.010	<0.2	<0.2	<0.010	<0.01	<0.2
Ammonium (NH3-N)	(mg/L)					0.04	0.04	0.06	0.03	<0.03	<0.03	<0.03	<0.03	<0.02	<0.02	<0.03	<0.03	<0.02	<0.02	<0.03
Phosphate-P (ortho)	(mg/L)					<1	<1	<1	<1	<1	<1	<1	<1	<0.50	<0.50	<1	<1	<0.5	<0.50	<1
Bicarbonate Alkalinity (HCO3)	(mg/L)					293	295	291	293	328	332	327	330	240.0	300.0	295.0	293	340	300	343
Alkalinity (CaCO3)- SM 2320B	(mg/L)	30 - 500	OG			242	244	241	242	271	274	270	273			357.0	355			416
Sulphate	(mg/L)	500	AO			89.6	83.7	83.8	76.7	43.8	46.3	39.2	39.6	40.0	16.0	14.3	14.1	23	16	26
Metals / Major Ions																				
Aluminum	(mg/L)	0.1	OG	0.075	Interim	0.014	0.007	0.005	<0.005	**0.132**	**0.143**	**<0.005**	**<0.005**	<0.01	<0.01	<0.005	<0.005	0.015	<0.010	<0.005
Antimony	(mg/L)			0.02	Interim	<0.0005	<0.0005	<0.0005	<0.0005	0.0006	0.0005	0.0007	0.0006	<0.002	<0.002	<0.0005	<0.0005	<0.002	<0.002	<0.0005
Arsenic	(mg/L)	0.025	IMAC	0.005	Interim	0.003	0.003	0.003	0.003	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Barium	(mg/L)	1	MAC			0.058	0.060	0.057	0.063	0.042	0.042	0.042	0.042	0.140	0.024	0.022	0.022	0.023	0.023	0.024
Beryllium	(mg/L)			1.1		<0.001	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Bismuth	(mg/L)					<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.002	<0.002	<0.001	<0.001	<0.002	<0.002	<0.001
Boron	(mg/L)	5	IMAC	0.2	Interim	0.031	0.022	0.021	0.022	0.023	0.021	0.016	0.017	<0.005	0.0060	0.0140	0.014	0.009	<0.005	0.008
Cadmium	(mg/L)	0.005	MAC	0.0005	Interim	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00007	0.00009	<0.0001	<0.0001	0.00008	<0.00007	<0.0001
Calcium	(mg/L)					81.2	78.8	75.2	78.7	74.9	74.4	72.9	74.7	65.0	78.0	79.8	78.9	89		92.6
Chromium	(mg/L)	0.05	MAC			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.002	<0.002	<0.005	<0.005	<0.002	<0.002	<0.005
Cobalt	(mg/L)			0.0009		0.0001	0.0001	0.0001	0.0001	0.0004	0.0004	0.0004	0.0005	<0.0005	<0.0005	<0.0001	<0.0001	<0.0005	<0.0005	<0.0001
Copper	(mg/L)	1	AO	0.005	Interim	0.0008	<0.0005	<0.0005	<0.0005	0.004	0.0039	0.0024	0.0024	0.0020	0.0180	0.0298	0.0289	0.012	0.002	0.0406
Iron	(mg/L)	0.3	AO	0.3		**0.39**	**0.31**	**0.30**	**0.30**	0.11	0.10	<0.03	<0.03	0.12	<0.010	<0.03	<0.03	0.01		<0.03
Lead	(mg/L)	0.01	MAC	0.005	Interim	<0.0005	<0.0005	<0.0005	<0.0005	0.0019	0.0018	0.0012	0.0012	0.0017	0.0014	0.0007	0.0007	0.0006	0.0006	0.0006
Magnesium	(mg/L)					25.3	26.4	25.3	26.8	27.3	27.6	28.4	29.5	30.0	25.0	24.8	24.8	31		32.6
Manganese	(mg/L)	0.05	AO			0.013	0.012	0.011	0.012	0.008	0.008	<0.005	<0.005	<0.002	<0.002	<0.005	<0.005	<0.002	<0.002	<0.005
Molybdenum	(mg/L)			0.04	Interim	0.001	0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.002	<0.002	<0.001	<0.001	<0.002	<0.002	<0.001
Nickel	(mg/L)			0.025		<0.001	<0.001	<0.001	<0.001	0.003	0.003	<0.001	<0.001	<0.002	0.003	<0.001	<0.001	<0.002	<0.002	<0.001
Phosphorus	(mg/L)			0.03	Interim	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.06	**0.08**	<0.05	<0.05	**0.09**		<0.05
Potassium	(mg/L)					1.1	1.1	1.0	1.1	0.8	0.8	0.8	0.8	<1.0	2.7	1.9	2	1.3		0.6
Selenium	(mg/L)			0.1		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Silicon	(mg/L)					4.11	4.66	4.47	4.86	2.69	2.72	2.69	2.81	6.00	3.10	3.03	3.12	3		2.98
Silver	(mg/L)			0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Sodium	(mg/L)	200	AO			7.8	8.5	8.2	9.3	5.0	5.0	4.8	4.9	10.0	3.3	3.6	3.6	30		38.4
Strontium	(mg/L)					0.96	1.05	1.00	1.02	0.253	0.256	0.266	0.267	0.120	0.083	0.076	0.076	0.09	0.088	0.089
Tin	(mg/L)					<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.002	0.002	<0.001	<0.001	<0.002	<0.002	<0.001
Titanium	(mg/L)					<0.005	<0.005	<0.005	<0.005	0.005	0.010	<0.005	<0.005	<0.001	0.001	<0.005	<0.005	0.001	<0.001	<0.005
Vanadium	(mg/L)			0.006	Interim	<0.0005	<0.0005	<0.0005	<0.0005	0.0007	0.0006	<0.0005	<0005	<0.002	<0.002	0.0008	0.0008	<0.002	<0.002	0.0007
Zinc	(mg/L)	5	AO	0.02	Interim	0.01	0.007	0.007	0.006	**0.05**	**0.049**	**0.044**	**0.049**	**0.110**	**0.110**	0.057	**0.057**	**0.026**	**0.027**	**0.026**

Notes
Bold - concentration exceeds Provincial Water Quality Objective.
Highlighted - concentration exceeds Ontario Drinking Water Standard.

Summary of Abbreviations
Ontario Drinking Water Standards
MAC - Maximum Acceptable Concentration
IMAC - Interim Maximum Acceptable Concentration
AO - Aesthetic Objective
OG - Operational Guideline

- **Surface Water**

  The chemistry of the surface water samples collected from Tributary A (North Creek) of Mountsberg Creek and from the main channel of Mountsberg Creek (at SWMC) is similar with the downstream sample (SWMC) exhibiting slightly higher concentrations of several ions in comparison with the upstream sample. The samples collected from Flamboro Creek are also enriched in calcium, magnesium, bicarbonate, sulphate, and manganese and depleted in sodium, chloride and DOC in comparison with the samples from Mountsberg Creek. Additional information on the surface water quality is presented in the Stantec (2005).

3. Detailed Hydrogeologic Assessment

The detailed hydrogeologic assessment contained herein, focuses on two components of this study, namely the observed water level responses during the two pumping tests and the computer modeling that provides a prediction of the future effects of the quarry on groundwater use and local surface water resources. The drawdown response observed during the pumping tests is of particular value as it establishes the hydraulic properties of the bedrock used in the model (Section 3.1), as well as data that could be employed during model calibration where the transient groundwater response is simulated (Volume 2).

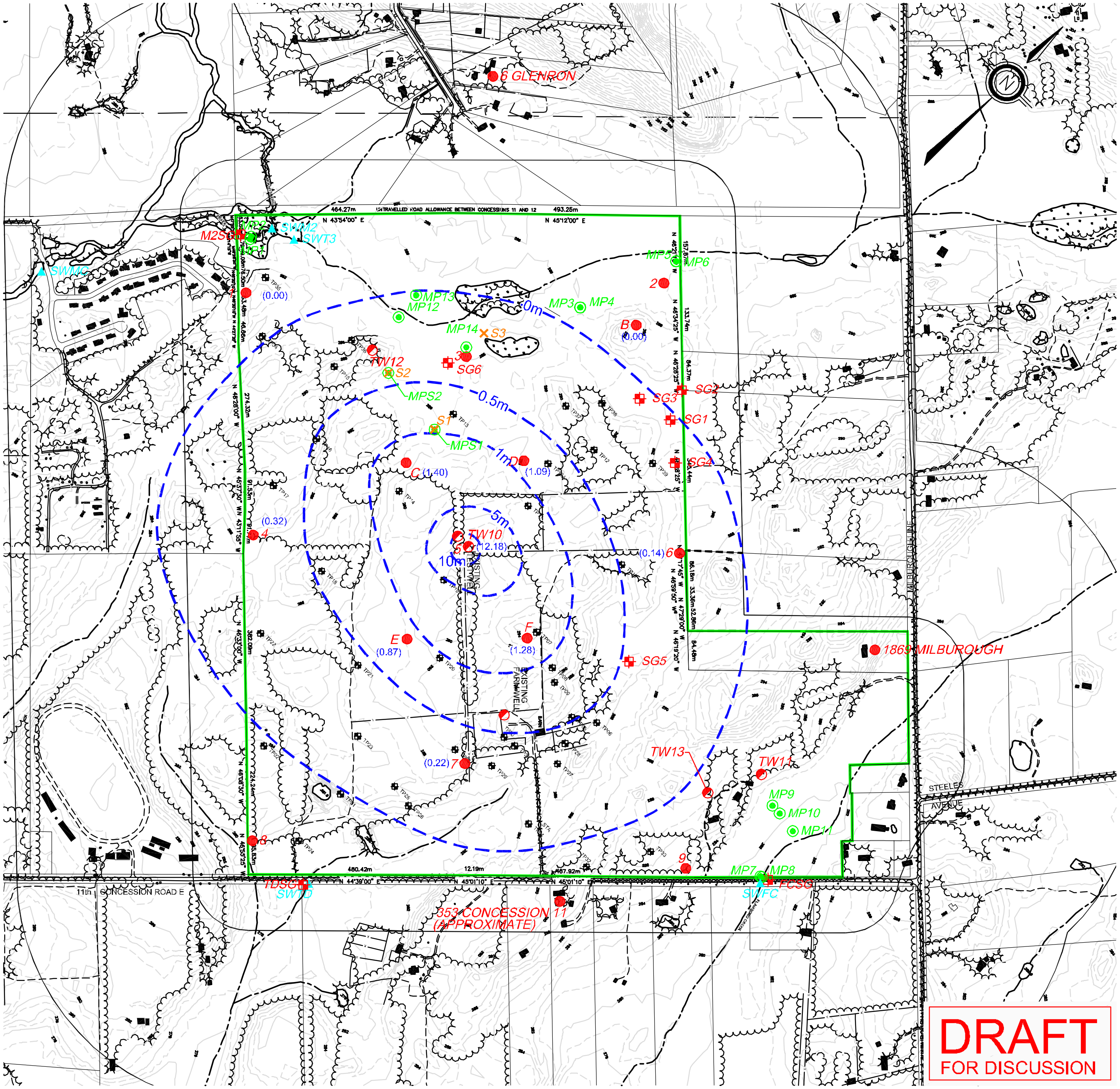
3.1 Observed Responses to Pumping

3.1.1 April 2004 Pumping Test at TW10

A 72-hour pumping test was conducted at a pumping well TW10, located in the approximate center of the proposed quarry. The well was pumped at a rate of 1,309 m^3/day (200 igpm). Hydrographs for each monitoring point are presented in Appendix E.

The water level response to pumping was monitored using the ‘wells’ installed to collect bedrock core. The open well bore in these ‘wells’ straddles the entire section of the Amabel Formation. The maximum drawdown induced during the April 2004 pumping test as measured at each of the deep monitoring wells is plotted in Figure 7. As depicted the zone of influence created during the test is limited to the central portion of the property with the drawdown ranging from 12.2 m at GLL BH5-D (located about 2.5 m distance from the pumping well TW10) to 1.4 m at JECEL BHC (225 m from TW10), 1.28 m at JEGEL BHF (235 m from TW10) and 0.32 m at JEGEL BH4-D (465 m from TW10). There was no measurable drawdown in monitoring wells GLL BH1-D, JEGEL BHB-D, GLL BH8-D and GLL BH9-D at the property boundaries (> 500 m from TW10).

The piezometers installed within the Lower Mountsberg Creek Wetland Complex did not respond to the pumping test.



LEGEND

	PROPERTY BOUNDARY
310	EXISTING 1m CONTOURS
307.0	EXISTING SPOT ELEVATIONS
	EXISTING TREE COVER
	EXISTING CONIFER
	EXISTING DECIDUOUS
	EXISTING FENCE LINE
	EXISTING SURFACE DRAINAGE
TP9	TEST PITS, 2003
	EXISTING WELL
TW12	PRODUCTION WELL
1	MONITOR WELL LOCATION AND DESIGNATION
MP8	PIEZOMETER LOCATION
SWFC	SURFACE WATER STATION
S1	SEEP LOCATION
SG6	STAFF GAUGE LOCATION
(1.40)	MAXIMUM DRAWDOWN (m)
1m	INTERPRETED DRAWDOWN CONTOURS

NOTE:
BASE DRAWING FROM LONG ENVIRONMENTAL CONSULTANTS INC. DRAWING 2 "EXISTING FEATURES" DATED MARCH 30, 2004.

SCALES
100m 0 250m 500m
Scale 1:12,500

PROPOSED DOLOSTONE QUARRY

72 HOUR PUMP TEST
DEEP AQUIFER DRAWDOWN

Designed By: CRM	Drawn By: JEP
Checked By: KDW	Approved By: –
Date Issued: JUNE 2005	Project No.: 23–827
Gartner Lee	FIGURE 7

DRAFT
FOR DISCUSSION

Jul 07, 2005 – 12:51pm N:\Projects\2003\23827\2005\Final\ACAD\23827–F01.dwg

3.1.2 November 2004 Pumping Test Conducted at TW12 and TW13

The November 2004 pumping test involved simultaneous pumping from wells TW12 and TW13 for a period of about 7-days at the maximum rate achievable for the wells. The objective of this testing was to stress the groundwater system to the point where a response could be observed in the piezometers and shallow wells located in the vicinity of the wetlands. The two test wells TW12 and TW13 were installed at the east and west corners of the subject property within about 100 m of Mountsberg Creek and Flamboro Creek, respectively.

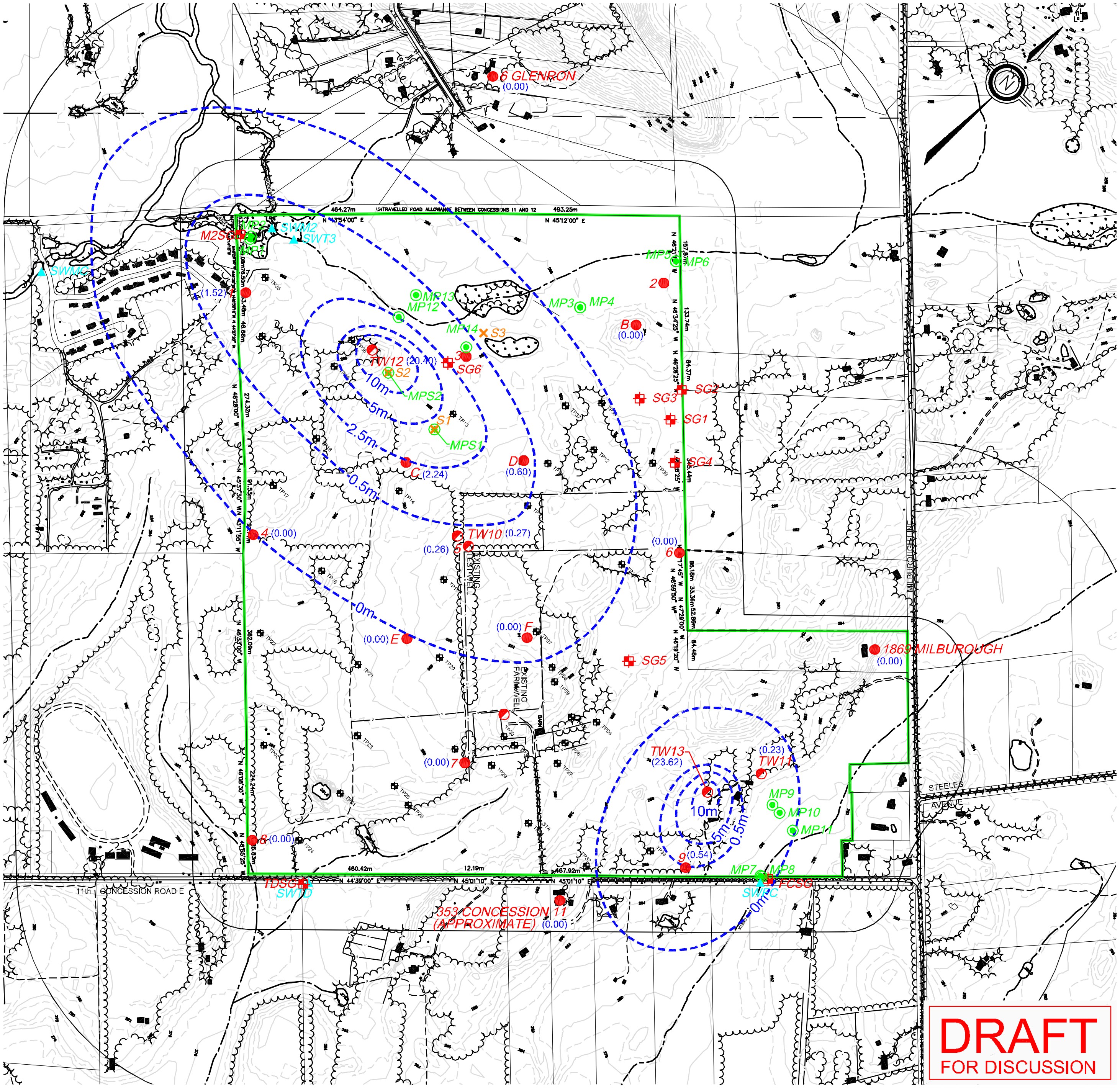
It is important to note that the 'wells' employed during the April 2004 were reconfigured. Specifically, PVC casing and screen where installed in the deep boreholes, effectively isolating the deep bedrock zones from the shallow zones. The pumping wells employed open well bore construction and therefore straddled both the shallow and deep zones.

- **<u>Observed Response in the Bedrock Aquifer</u>**

  As noted in Section 1.3, wells TW 12 and TW13 were pumped at rates of 3,270 m^3/day (500 igpm) and 864 m^3/day (132 igpm), respectively, resulting in drawdown of 20 m at TW12 and 24 m at TW13. The maximum drawdown responses observed in the monitoring wells located in the general vicinity of the two pumping wells are summarized in Table 4 and depicted in plane view in Figure 8 (deep wells) and Figure 9 (shallow wells).

Table 4. Maximum Observed Drawdown in Monitoring Wells

Borehole		Maximum Drawdown (m)	Distance and Direction from Pumping Well TW12
Deep Bedrock	TW12	20.4 m	0 m
	TW10	0.27 m	440 m southeast
	GLL BH1-D	1.52 m	300 m southwest
	GLL BH2-D	No discernable response	600 m north
	GLL BH4-D	No discernable response	475 m southeast
	GLL BH5	0.26 m	470 m southeast
	GLL BH8-D	No discernable response	1,090 m southeast
	JEGEL BHB-D	No discernable response	575 m northeast
	JEGEL BHC	2.24 m	250 m southeast
	JEGEL BHF	No discernable response	700 m south
Shallow Bedrock	GLL BH1-S	No discernable response	300 m west
	GLL BH3-S	0.60 m	200 m to northeast
	GLL BH4-S	No discernable response	475 m southeast
	GLL BH 8-S	No discernable response	1,090 m southeast
	JEGEL BHB-S	0.16 m	575 m northeast



LEGEND

(green line)	PROPERTY BOUNDARY
310	EXISTING 1m CONTOURS
307.0	EXISTING SPOT ELEVATIONS
	EXISTING TREE COVER
	EXISTING CONIFER
	EXISTING DECIDUOUS
	EXISTING FENCE LINE
	EXISTING SURFACE DRAINAGE
TP9	TEST PITS, 2003
	EXISTING WELL
TW12	PRODUCTION WELL
1	MONITOR WELL LOCATION AND DESIGNATION
MP8	PIEZOMETER LOCATION
SWFC	SURFACE WATER STATION
S1	SEEP LOCATION
SG6	STAFF GAUGE LOCATION
(1.40)	MAXIMUM DRAWDOWN (m)
1m	INTERPRETED DRAWDOWN CONTOURS

NOTE:
BASE DRAWING FROM LONG ENVIRONMENTAL CONSULTANTS INC. DRAWING 2 "EXISTING FEATURES" DATED MARCH 30, 2004.

SCALES
100m 0 250m 500m
Scale 1:12,500

PROPOSED DOLOSTONE QUARRY

168 HOUR PUMP TEST
DEEP AQUIFER DRAWDOWN

Designed By:	SB	Drawn By:	JEP
Checked By:	–	Approved By:	–
Date Issued:	JUNE 2005	Project No.:	23–827

Gartner Lee

FIGURE 8

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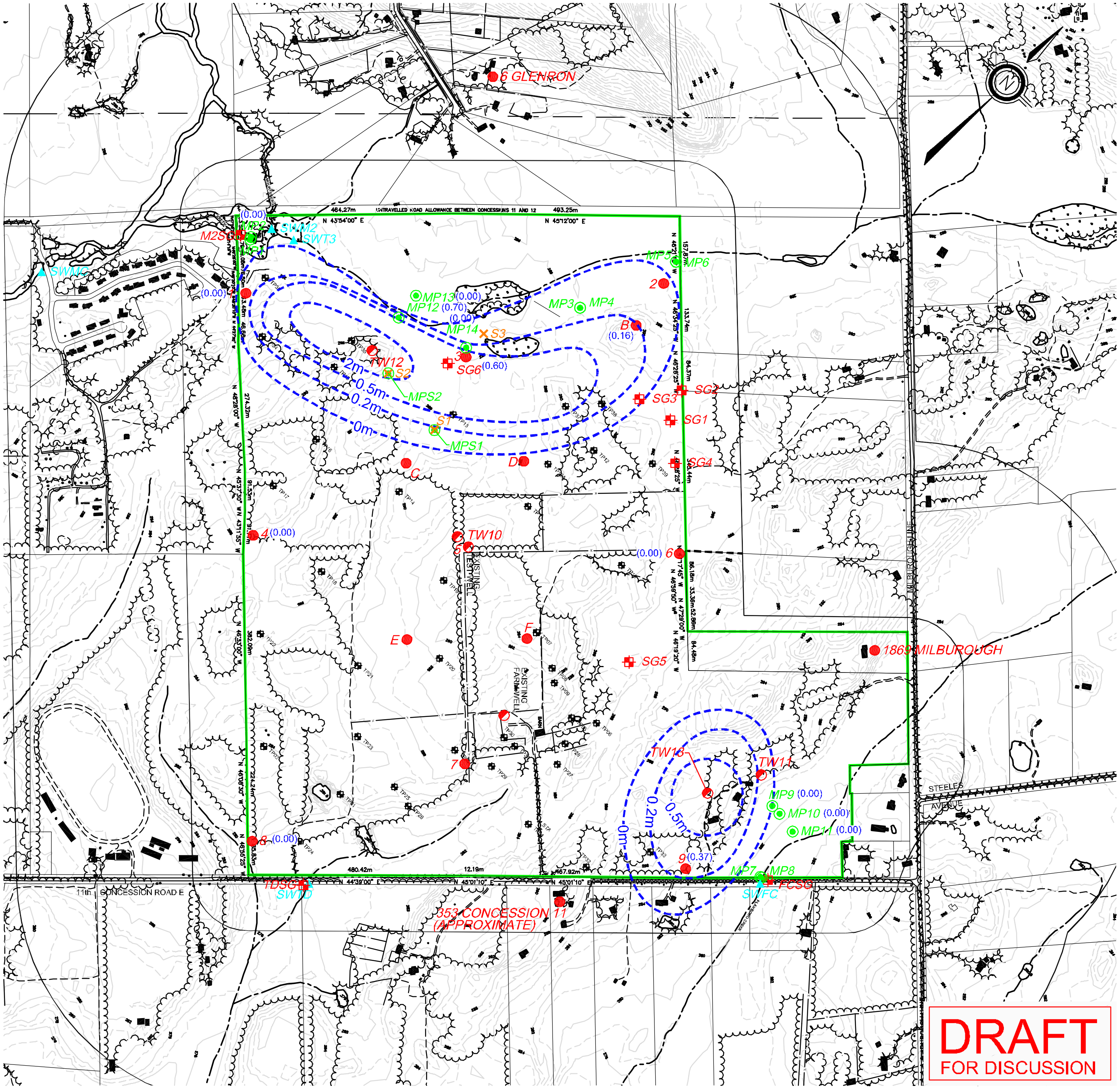


LEGEND

(green line)	PROPERTY BOUNDARY
310	EXISTING 1m CONTOURS
.307.0	EXISTING SPOT ELEVATIONS
	EXISTING TREE COVER
	EXISTING CONIFER
	EXISTING DECIDUOUS
	EXISTING FENCE LINE
	EXISTING SURFACE DRAINAGE
TP9	TEST PITS, 2003
W	EXISTING WELL
TW12	PRODUCTION WELL
1	MONITOR WELL LOCATION AND DESIGNATION
MP8	PIEZOMETER LOCATION
SWFC	SURFACE WATER STATION
S1	SEEP LOCATION
SG6	STAFF GAUGE LOCATION
(1.40)	MAXIMUM DRAWDOWN (m)
- -1m- -	INTERPRETED DRAWDOWN CONTOURS

NOTE:
BASE DRAWING FROM LONG ENVIRONMENTAL CONSULTANTS INC. DRAWING 2 "EXISTING FEATURES" DATED MARCH 30, 2004.

SCALES: 100m 0 250m 500m

Scale 1:12,500

PROPOSED DOLOSTONE QUARRY

168 HOUR PUMP TEST SHALLOW AQUIFER DRAWDOWN

Designed By: SB	Drawn By: JEP
Checked By: –	Approved By: –
Date Issued: JUNE 2005	Project No.: 23-827
Gartner Lee	FIGURE 9

Borehole		Maximum Drawdown (m)	Distance and Direction from Pumping Well TW13
Deep Bedrock	**TW13**	23.62 m	0 m
	TW11	0.23 m	120 m northeast
	GLL BH6-D	No discernable response	520 m northwest
	GLL BH7-D	No discernable response	520 m west
	GLL BH8-D	No discernable response	990 m southeast
	GLL BH9-D	0.54 m	170 m southeast
	JEGEL BHE	No discernable response	720 m west
Shallow Bedrock	**GLL BH6-S**	No discernable response	520 m northeast
	GLL BH7-S	No discernable response	520 m west
	GLL BH8-S	No discernable response	990 m southeast
	GLL BH9-S	0.37 m	170 m southeast

As illustrated in Figure 8, the zone of influence in the deep bedrock around each of the two wells is distinctive and does not converge.

The 2.5 m drawdown contour encompasses well JEGEL BHC located about 250 m southeast of the TW12, and the 0.5 m contour extends out to TW10 (about 440 m from TW12). There was no measurable drawdown in monitoring wells JEGEL BHE, GLL BH7-D, GLL BH6-D, JEGEL BHB-D, GLL BH4-D, JEGEL BHF and GLL BH8-D.

An important observation is that the deeper groundwater system is slow to respond to rain events, in contrast to the shallow piezometers. The response in the shallow bedrock is rapid, whereas the response in the deep bedrock is not readily evident in the hydrographs.

Well TW13 was pumped at a lower rate (about one third of that at TW12) and the zone of influence is significantly smaller. A drawdown response attributable to pumping of TW13 was observed at two wells, specifically GLL 9-D (0.5 m) and TW11 (0.23). Wells GLL 9-D and TW11 are within 200 m of pumping well TW13. BH9-D did not respond directly to rain events as observed in the shallow monitors. The water level recovered rapidly following termination of the pumping at TW13.

The drawdown cone in the shallow bedrock around TW12 is also elliptical, extending in a northeasterly direction roughly parallel to Mountsberg Creek (Figure 9). A drawdown response of 0.9 m was observed at well JEGEL BHB-S, located about 575 m to the northeast, and no discernable response was observed at GLL BH1-S located about 300 m to the west.

A drawdown response attributable to pumping of TW13 was observed at GLL 9-S (0.37 m) about 200 m to the south of the pumping well.

- **Observed Response in the Piezometers**

A summary of the test responses for the piezometers is provided in Table 5, which follows.

Table 5. Maximum Observed Drawdown in Piezometers

Borehole	Maximum Drawdown (m)	Distance and Direction from Pumping Well TW12
MP-12	0.7 m	90 m northwest
MP-13	No discernable response	150 m northwest
MP-14	No discernable response	160 m northwest
MP-2	No discernable response	200 m northwest

Borehole	Maximum Drawdown (m)	Distance and Direction from Pumping Well TW13
MP-9	No discernable response	150 m southeast
MP-10	No discernable response	160 m northwest
MP-11	No discernable response	200 m northwest

A clear response was observed in only one of the seven piezometers used as monitors for the pumping test. MP-12 appeared to respond to the pumping phase of the test. However, due to a number of rain events before and during the pumping test it was unclear whether the water level response was due to pumping in the deeper groundwater system or cessation to a storm surge in the wetland.

Upon termination of the pumping at TW12 it was obvious that the water level response at MP-12 was related to the pumping activity at the TW12 location. The rapid recovery in water levels at MP-12 is evident in the hydrograph for this piezometer presented in Appendix E.

MP-9, MP-10, and MP-11 all exhibit a characteristic response to rain events as is observed in each of the hydrographs prepared for these piezometers. The rain events that occurred during the pumping test are posted on each of the hydrographs to better illustrate the effect of the rain events on the water levels associated with the wetland features and the shallow groundwater system.

MP-2, located in the north west corner of the property was just down gradient from the discharge point for TW12. The locations available for the discharge were limited and off-site discharge was not an option. The receiving stream flows at a low of 200 to 300 Lps and can exhibit a high of up to 800 Lps and more. As a result it was not possible to identify water level drawdown in response to the pumping test at this location. However, some valuable information was obtained at this location. As the pumping test proceeded water levels were monitored closely at this location and it became apparent that the discharge water was surging the wetland system in the vicinity of MP-2. The transducers recorded a water level increase in the piezometer at this location in response to the pumping well. This response demonstrates the feasibility of sustaining water levels in the wetland feature in proximity to the pumping activity.

3.2 Groundwater Flow Model

A groundwater flow model was developed to simulate the potential effect of the quarry on water resources. Given the size and scope of the proposed quarry development, and the new Provincial policy directives (Section 1.2.3 and Section 1.2.4), the model was constructed on a subwatershed scale. A water balance approach was applied that considers various inputs and outputs with respect to the groundwater and natural heritage system within the Mountsberg Creek subwatershed. The key objectives of the modeling effort were to:

a) estimate the potential effects of the proposed dolostone quarry on existing wetlands, streams and recharge areas;

b) predict the potential influence of the quarry dewatering on residential supply wells in the vicinity of the quarry and on the Carlisle Municipal wells;

c) provide a tool for assisting in the design and evaluation of quarry development plans and possible mitigation measures; and,

d) evaluate rehabilitation plans for the completed quarry.

Groundwater models are by nature an approximation of the natural physical system. There strength lies in the fact that the model can be used to evaluate a combination of hydrogeologic parameters under a variety of stress scenarios imposed upon the natural groundwater and surface water systems within the watershed context. This type of assessment would be impossible to complete by simple hand calculation and estimates.

The continued monitoring and auditing of the modeling predictions is essential to ensuring adaptive management of groundwater impacts due to quarry activity and maintenance of natural heritage function in relation to the development.

3.2.1 Proposed Quarry Development

Geologic mapping indicates that there is between 27 m and 40 m of Amabel dolostone. The resulting quarry will have a target depth of between 247 mASL and 249 mASL. Given that the average groundwater table elevation below the proposed quarry is approximately 285.5 mASL, the dewatering operations at full quarry development will lower the water table in the immediate area of the quarry face by about 31 m.

The full details of the quarry development have not yet been finalized. However, to facilitate peer review and agency dialogue, it is intended that quarry development proceed as generally reflected in the 2004 Site Plan (Long, 2004). The initial stage of development (Stage 1 Quarry) will be centrally located on the property and it is intended that the processing plant and material stockpiles will be established within its footprint on the first lift. During subsequent stages the quarry will be deepened to recover additional high quality stone.

Since the 2004 Site Plan was developed, the extent of the development area has been refined to accommodate natural heritage features and the results of the preliminary hydrogeologic modeling. Additional refinement of the development area will occur as a result of the Stantec EIS and agency consultation. To enable initial modeling and predictive analysis, conceptual limits for quarry Stage 1 and full excavation have been conservatively established. These limits are shown in Figure 10. For the modeling proposed, Stage 1 will be excavated to an approximate elevation of 272 mASL and the Full Quarry to an approximate elevation of 249 mASL.

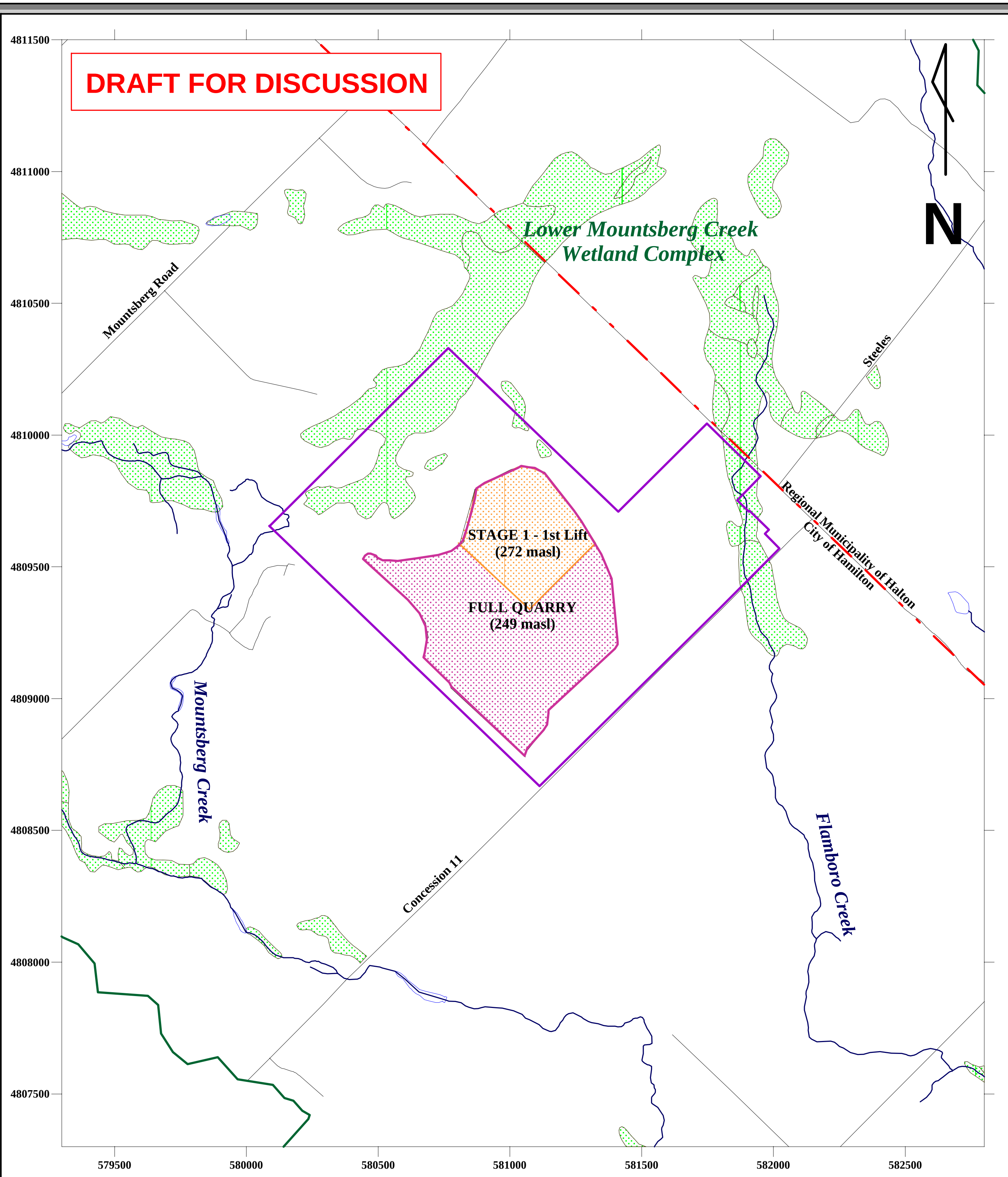
3.2.2 Model Construction

A numerical model, based on the USGS MODFLOW code (McDonald and Harbaugh, 1988) was developed to simulate three-dimensional groundwater flow in the study area. The numerical model domain depicted in Figure 11 encompasses the Mountsberg Creek subwatershed, extending from north of Highway 401, to just south of Carlisle. Where possible, the perimeter boundary of the model coincided with natural physical boundaries such as rivers, lakes and subwatershed divides.

Internal boundaries in the model were designed to represent natural drainage features such as streams creeks and rivers. These features were represented with flux river boundaries, whereby water can be removed from the model but can also be added to the model domain. Wetland features were represented by evapotranspiration boundaries to provide groundwater uptake by these features. No-flow boundaries were applied to surface water divides that were assumed to approximate groundwater divides. The model boundary conditions are included in Figure 11.

The numerical model is based on a conceptual model of the subwatershed that was developed using information on the geology (stratigraphy), hydraulic boundaries, recharge distribution, confined and unconfined aquifers, and local stresses such as pumping wells assembled from field investigations and regional data sources.

Once the numerical model was suitably compiled, it was calibrated to steady-state conditions by adjusting aquifer and aquitard properties until a reasonable match with observed groundwater levels and flow direction was achieved.



Legend

- Surface Drainage Features
- Water Bodies
- Wetlands
- Active Model Domain
- Property Boundary
- Roads
- Footprint - Stage 1 - 1st Lift
- Footprint - Full Quarry

SOURCE: Base mapping produced by Gartner Lee Limited under license with the Ministry of Natural Resources, Queen's Printer 1997 - Reproduced 2004.

PROPOSED DOLOSTONE QUARRY	**Figure 10**
FOOTPRINT OF PROPOSED DOLOSTONE QUARRY STAGE 1 AND FULL DEVELOPMENT	
Project # 23827, Hydrogeological Modeling Investigation	
Gartner Lee Limited	Scale 1:20,000

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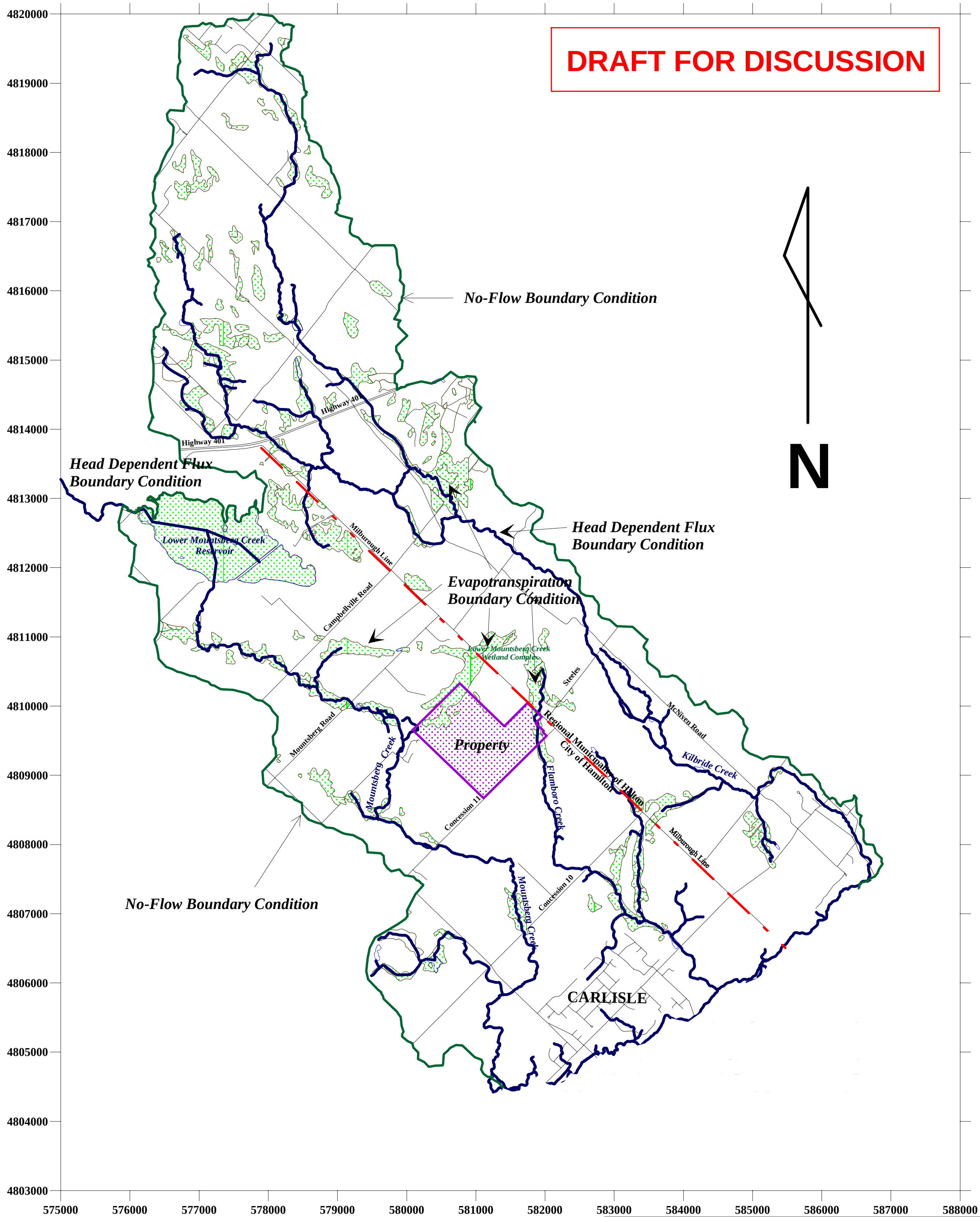


Legend

- Surface Drainage Features
- Water Bodies
- Wetlands
- Active Model Domain
- Property Boundary
- Roads
- Boundary Conditions

SOURCE: Base mapping produced by Gartner Lee Limited under license with the Ministry of Natural Resources, Queen's Printer 1997 - Reproduced 2004.

PROPOSED DOLOSTONE QUARRY	Figure 11
ACTIVE MODEL DOMAIN WITH BOUNDARY CONDITIONS	
Project # 23827, Hydrogeological Modeling Investigation	
Gartner Lee Limited	
	Scale 1:80,000

:07/07/05:\ N:\Projects\2003\23827\2005\WIP\Data Interpretation\Level 2 Report\Figures\Figure 11.srf

Post-calibration sensitivity analyses were conducted by varying parameters within a reasonable range to demonstrate that the calibrated model parameters truly lie at a minimum point on the sensitivity curve. Furthermore, the model was calibrated to stream baseflow values obtained from HYDAT stations within the model study area. The model parameters were adjusted until reasonable agreement was achieved between simulated and observed water levels through out the modeled area. A volumetric match to groundwater discharge to streams and rivers for the entire study area was used as further model verification to consider the potential impacts to ecological features such as cold-water fisheries.

Additional calibration of the model was conducted using the transient groundwater responses observed during the 168-hour pumping test completed in November/December 2004. The pumping rates and duration were input for the respective pumping wells, TW12 and TW13 utilized for this pumping test. The resulting groundwater drawdown for both the deep groundwater system and more importantly the shallow groundwater system in proximity to the wetland features was matched to an acceptable degree.

A more complete description of the groundwater flow model development process and the information considered in constructing the model is presented in Volume 2.

3.3 Water Balance

3.3.1 Subwatershed Water Balance (Baseline)

The primary driving factors (water input and output) for any subwatershed water balance are: i) the recharge distribution throughout the given study area; ii) the surface water drainage network, including streams, rivers, creeks, and wetlands; and iii) existing water takings in both domestic water supply and Permits to Take Water for industry, commercial and municipal applications. The groundwater flow model accommodates these inputs.

The distribution of water to various receptors was included in the groundwater model and is discussed in Volume 2.

The subwatershed water balance was first evaluated under pre-quarry conditions using the calibrated model. This water balance provides a baseline from which the influence of the quarry on the subwatershed water balance is evaluated.

The water balance, which is a summary of the water inputs and water outputs for the subwatershed prior to quarry development, is provided in Table 6.

Table 6. Subwatershed Water Balance Pre-Quarry Development

Active Model Domain Water Balance Components

A	Water Input	Active Model Area (m^3/Year)	Lps
I	Groundwater Recharge	14,549,995	461.38
II	River Leakage	22,526,705	714.32
Total		**37,076,700**	1,175.69
B	**Water Outputs**	**Active Model Area (m^3/Year)**	**Lps**
I	Rivers	32,658,010	1,035.58
II	Water Wells (Domestic & PTTW)	890,600	28.24
III	Drains (creeks)	180,310	5.72
IV	Evapotranspiration (Wetlands)	3,347,780	106.16
Total		**37,076,700**	1,175.69

The total volume of water available for natural and anthropogenic receptors for this study area is 37,076,700 m^3/yr (1,175 Lps). This includes the volume of water infiltrating to the aquifer from precipitation, as well as surface water infiltration and recharge. The primary output for the subwatershed is the volume of water released to the network of streams, creeks and rivers, represented by drain and river drainage boundaries. This volume accounts for 88.5% of the total water available in the system. The next largest output (9.0%) is in the water uptake from wetlands (evapotranspiration). The third largest output (2.5%) is water uptake from domestic water use and PTTWs through out the sub-watershed.

3.3.2 Subwatershed Water Balance (With Quarry Development)

The following is a listing of given assumptions and parameters that were used to develop the quarry water balance:

a) the surface area of the Stage 1 Quarry, as currently established, will cover 15 ha;

b) the developed area of the Full Quarry, as currently established, will cover 73 ha;

c) the annual production rate of stone proposed from the quarry is 3,000,000 tonnes;

d) it is estimated that about 50% of the product will be washed and will consist of coarse aggregate (1,2 million tones or 80%) and fine aggregate (0.3 million tones or 20%). The coarse aggregate will have an estimated water content of about 2% at the time it is shipped and the fine aggregate about 10%. The water loss for the coarse aggregate is estimated as 24,000 tonnes and 30,000 tonnes for the fine aggregate for a total of 54,000 m^3/yr);

e) other water losses include water used for dust suppression [assumed two trucks (10,000 L tanks) per day for four months of the year (50 m^3/yr)] and the water used in ancillary operations [assumed to include a water supply for a shop and office including 25 staff at 150 L/day per staff member for a 250-day working year (938 m^3/yr)];

f) the bulk of the precipitation that falls on the quarry will rapidly infiltrate the quarry floor due to blast induced fractures in the bedrock;

g) evaporation of precipitation within the quarry is assumed to be 20% of normal evaporation rates for the area (511 mm/yr x 0.2 =102 mm/yr within quarry);

h) pond evaporation rates for the quarry sump ponds is based on rates observed at Acton Quarry, 710 mm/year;

i) quarry sump pond area is expected to not exceed 3% of the quarry footprint at any given point during quarry development; and,

j) the productive zone identified in the Amabel Formation is present across the property and elsewhere within the local area.

The water balance is discussed from two perspectives: 1) the proposed quarry; and, 2) the subwatershed. The water balance of the quarry was initially completed based on assumptions on quarry operations and was then used as an input to analyze the water balance of the subwatershed and the overall disturbance to the subwatershed water balance from the quarry operation. Furthermore, for operational maintenance, it is important that a site-scale water balance be completed for the quarry apart from the watershed.

The quarry water balances for the Stage 1 Quarry and Full Quarry scenarios, under the above assumptions and given parameters, derived for annual mean climate conditions are presented in Table 7.

Table 7. Un-mitigated Quarry Water Balance

Water Balance Components		Stage 1 (m^3/year)	Full Quarry (m^3/year)
A	**Water Input**		
I	Precipitation (849 mm average annual)	127,350	465,252
II	Groundwater inflow (from the model)	725,624	3,611,310
Total		**852,974**	**4,076,562**
B	**Water Loss**		
I	Evaporation (Quarry Floor - 20% of 510 mm/yr evaporation = 102 mm/yr)	15,300	55,896
II	Evaporation (Pond Evaporation 710 mm/yr), from quarry sump ponds	459	1,677
III	Stone Shipments	54,000	54,000
IV	Dust Suppression	50	50
V	Ancillary Operations	938	938
Total		**70,747**	**112,561**
C	**Water removed from quarry (i.e., water available for discharge to Mountsberg Creek)**		
	C = A – B	**782,227**	**3,964,001**
	Lps conversion	24.80	125.70

- **Subwatershed Water Balance (Stage 1 Quarry)**

As indicated in Table 7, the amount of water loss from the Stage 1 quarry is estimated as 70,747 m^3/yr (6.3 Lps). [Note, various components of a quarry operation such as the water adsorption in stone product shipped off site however cannot be incorporated directly into the groundwater model and must be considered outside the model and subsequently added in the overall to the water balance analysis for the quarry for evaluation in the subwatershed context.]

The water inputs/outputs for the Stage 1 Quarry condition calculated using the groundwater model are listed in Table 8. The primary output for the sub-watershed is still the network of streams, creeks and rivers, represented by drain and river drainage boundaries. Under the Stage 1 Quarry conditions this amount represents 86.6% of the total water available in the system. The next largest output (8.7%) is in the form of the water uptake from wetlands (evapotranspiration). The third largest (2.4%) form of water uptake is from domestic water use and PTTW through out the subwatershed. The quarry water uptake represents 0.19% of the subwatershed water balance and the water discharge to the subwatershed from the quarry represents 2.11% of the subwatershed water balance.

Table 8. Un-mitigated Stage 1 Quarry Subwatershed Water Balance

Stage 1 Quarry Conditions – Subwatershed Water Balance Components

A	Water Input	Active Model Area (m^3/Year)	Lps
I	Groundwater Recharge	14,638,325	464.18
II	River Leakage	22,669,055	718.83
Total		**37,307,380**	**1,183.01**
B	**Water Outputs**	**Active Model Area (m^3/Year)**	**Lps**
I	Rivers	32,196,285	1,020.94
II	Water Wells (Domestic & PTTW)	890,600	28.24
III	Drains (creeks)	136,123	4.32
IV	Evapotranspiration (Wetlands)	3,263,100	103.47
V	Quarry Operations	725,624(1)	23.00
Total		**37,211,732(2)**	**1,179.97**

Notes: (1) The majority of this water is returned to the subwatershed through direct discharge to surface drainage features. The volume returned is estimated as 654,877 m^3/yr (20.80 Lps), which means the subwatershed experiences a net loss from the quarry of about 70,747 m^3/yr (2.24 Lps).

(2) The difference between the total input and output is due to mass balance error in the model simulations and represents about 0.26%, which is acceptable under ASTM standards for model applications.

- **Subwatershed Water Balance (Full Quarry)**

The volume of water loss from the Full Quarry is estimated as 112,561 m^3/yr (Table 7). The balance of the water collected in the quarry (3,964,001 m^3/year or 125.70 Lps) would be discharged directly to local surface drainage features. The water inputs/outputs for the Full Quarry condition as calculated using the groundwater model, are presented in Table 9.

Again, the primary output for the subwatershed is to the network of streams, creeks and rivers, represented by drain and river drainage boundaries. Under the Full Quarry condition this amount represents 79.9% of the total water available in the system. The next largest outputs are from water uptake from wetlands as evapotranspiration (8.0%) and water uptake is from domestic water use and PTTW (2.3%). The quarry water uptake represents 0.29% of the sub-watershed water balance and the quarry discharge to the subwatershed represents 9.51% of the subwatershed water balance.

Table 9. Full Quarry Subwatershed Water Balance

Full Quarry Conditions – Subwatershed Water Balance Components

A	Water Input	Active Model Area (m^3/Year)	Lps
I	Groundwater Recharge	14,638,325	479.17
II	River Leakage	24,136,355	765.36
Total		**38,774,680**	**1,229.53**
B	**Water Outputs**	**Active Model Area (m^3/Year)**	**Lps**
I	Rivers	30,863,305	978.67
II	Water Wells (Domestic & PTTW)	890,600	28.24
III	Drains (creeks)	103295	3.27
IV	Evapotranspiration (Wetlands)	3,088,265	97.93
V	Quarry Operations	3,611,310(1)	114.51
Total		**38,556,775(2)**	**1,222.62**

Notes: (1) The majority of this water is returned to the subwatershed through direct discharge to surface drainage features. The amount returned is 3,498,749 m3/yr (110.94 Lps), which means the subwatershed experiences a net loss from the quarry of about 112,561 m3/yr (3.57 Lps).

(2) The difference between the total input and output is due to mass balance error in the model simulations and represents about 0.56%, which is acceptable under ASTM standards for model applications.

3.3.3 Quarry Effects - Predictive Simulations

The groundwater model was also employed to address specific questions regarding the influence of the proposed dewatering as the quarry advances through the sequential staging developed for the quarry operations. The focus of the first round of predictive simulations (which are provided in this report) is to promote dialogue with the City of Hamilton peer reviewer and the applicable agencies.

This preliminary assessment involved the simulation the effects of quarry development on groundwater levels in the vicinity of the quarry development to:

a) assess the influence of the quarry on the water balance of the wetlands;
b) assess the influence of the quarry on residential water supplies (i.e., wells); and,
c) assess the influence of the quarry on the Carlisle Municipal Water Supply.

- **Effects of Quarry Development on Groundwater Levels**

Two scenarios of quarry development were evaluated, namely Stage 1 Quarry development with an excavation depth to 272 mASL, and the Full Quarry development with an excavation depth elevation of 249 mASL. The simulated drawdown associated with the two scenarios is shown in Figure 12 through Figure 15, respectively.

As depicted in the above figures, quarry development and the associated dewatering impacts will reduce groundwater levels adjacent to, and beneath, the wetlands in proximity to the property. This reduction in the water level will, in turn, result in a decrease in the volume of groundwater (flux) that discharges and sustains the wetland features, and will affect the baseflow in Mountsberg Creek and Flamboro Creek.

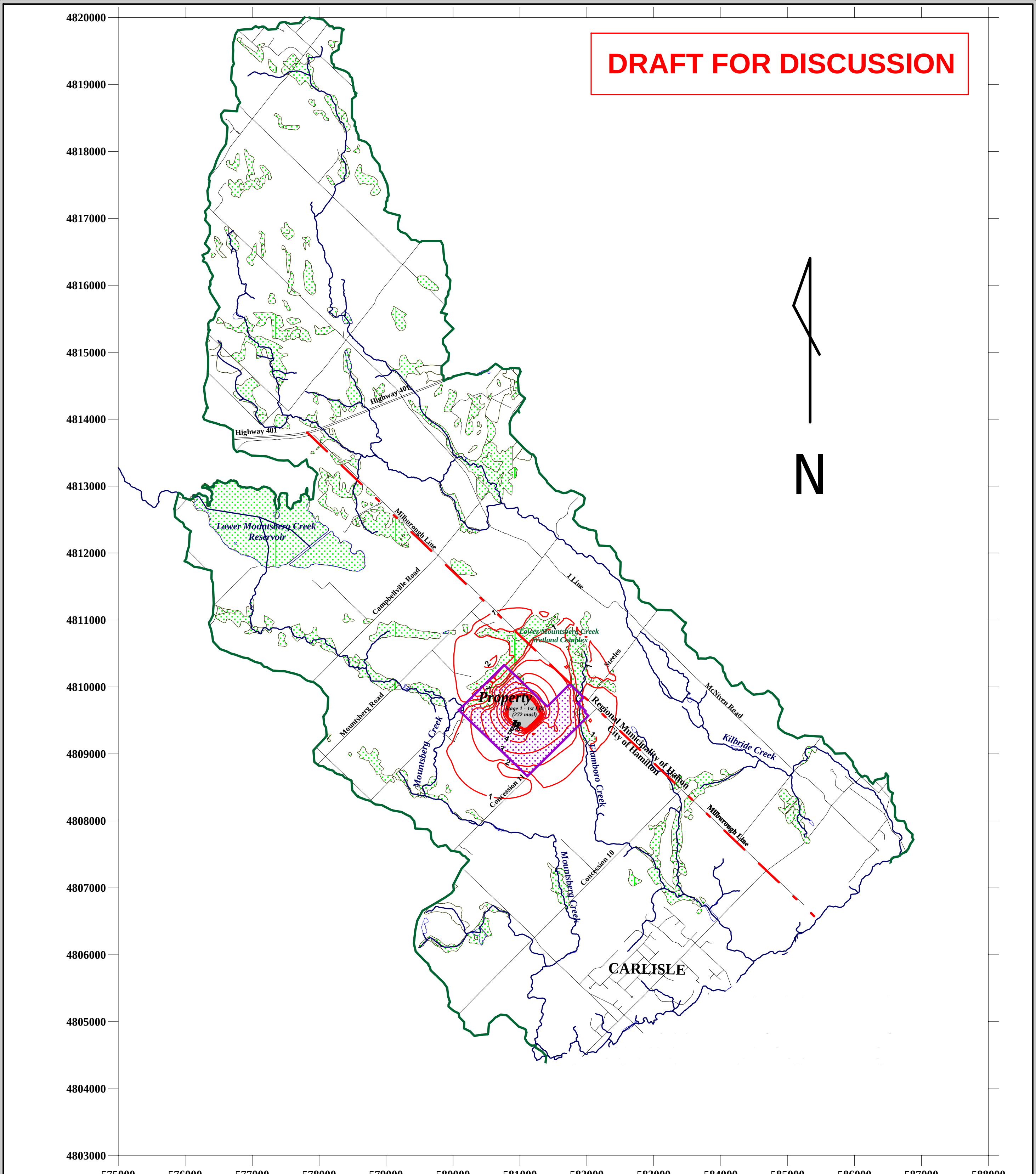
The simulated volume of groundwater pumped from the quarry during the Stage 1 Quarry dewatering operations is predicted to be about 27.0 Lps (488 igpm). Figure 12 and Figure 13 illustrates the simulated zone of influence and the drawdown in the groundwater level from the Stage 1 dewatering operations, at a regional and site scale, respectively. The zone of influence per the 1 m contour extends through both wetlands with a radius of about 1,000 m in the longest axis (southwest to northeast).

The simulated volume of groundwater pumped from the Full Quarry during the dewatering operations is predicted to be about 129.26 Lps (1,706 igpm). The simulated zone of influence and predicted drawdown in the groundwater level for full quarry development to a base elevation of 249 mASL is shown in Figure 14 (regional scale) and Figure 15 (site scale). As illustrated, the 1 m drawdown contour extends well beyond the Mountsberg Creek and Flamboro Creek wetlands with a radius of over 2,500 m in the longest axis (southwest to northeast).

The simulated groundwater drawdown to the north is buffered to some degree because of the positive hydraulic boundary namely Mountsberg Creek, and the fact that this area is upgradient of the quarry. Groundwater moves through this area prior entering the quarry property where it discharges into the quarry under gravity drainage. The continuous flow in Mountsberg Creek will act to recharge the bedrock reducing the drawdown induced from quarry dewatering.

- **Effects of Quarry Development on the Wetlands and Surface Water Balance:**

'Zone budget' is a module that is used in conjunction with MODFLOW to calculate the water balance or volumes of inputs and outputs for given areas delineated within a model. For example, a particular zone can be applied to the quarry area, a second zone applied to the wetlands near Mountsberg Creek and a third applied to the wetlands near Flamboro Creek.



Legend

- Surface Drainage Features
- Water Bodies
- Wetlands
- Active Model Domain
- Property Boundary
- Roads
- Simulated Drawdown (m)
- Extraction Limits

SOURCE: Base mapping produced by Gartner Lee Limited under license with the Ministry of Natural Resources, Queen's Printer 1997 - Reproduced 2004.

NOTE:
Stage 1 - 1st Lift - Without mitigation
Quarry dewatering: 1988 m^3/d

PROPOSED DOLOSTONE QUARRY	Figure 12
SIMULATED DRAWDOWN - NO MITIGATION STAGE 1 - 1st LIFT (272 masl) - REGIONAL SCALE	
Project # 23827, Hydrogeological Modeling Investigation	
Gartner Lee Limited	Scale 1:80,000

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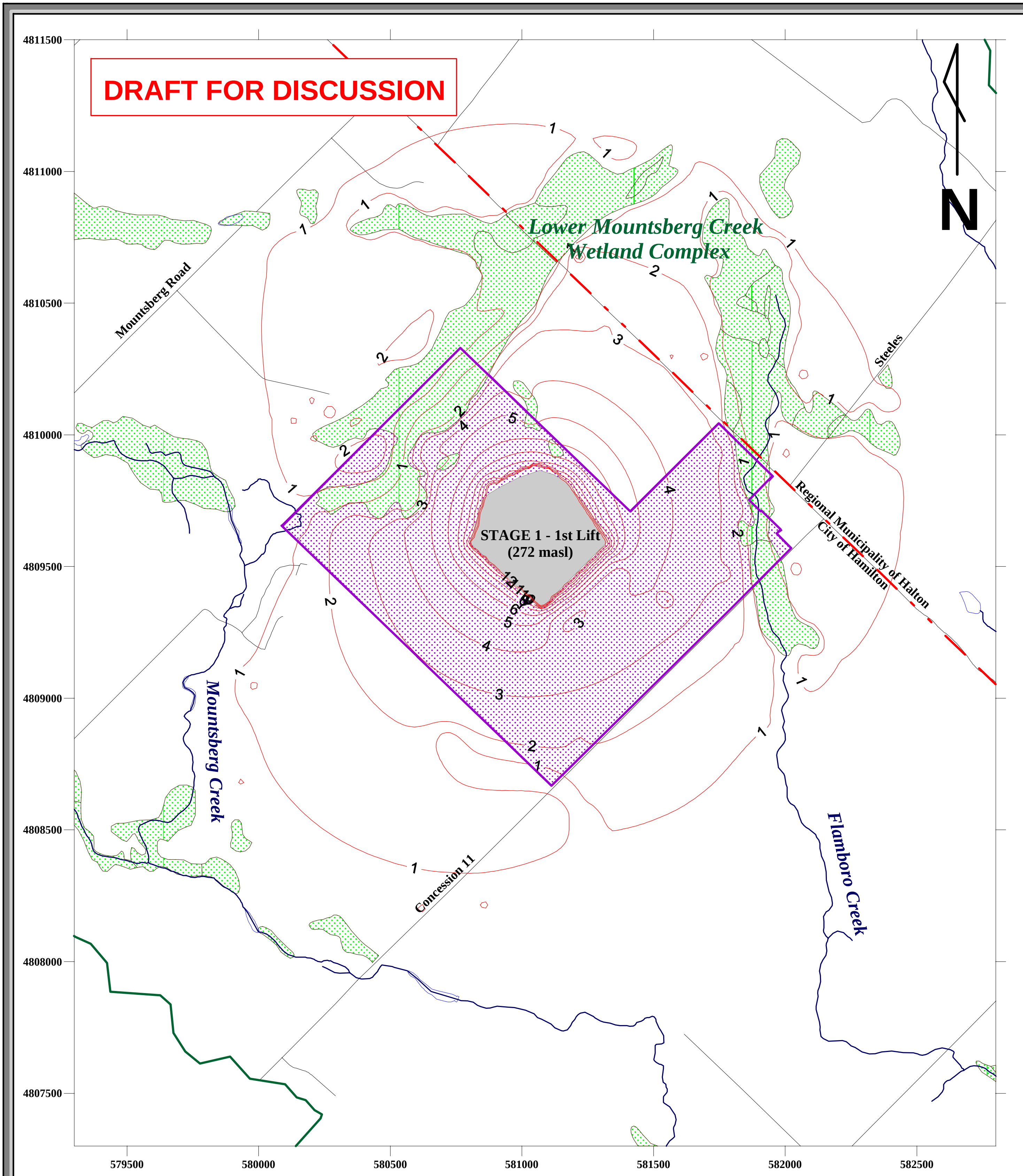

Legend

- Surface Drainage Features
- Water Bodies
- Wetlands
- Active Model Domain
- Property Boundary
- Roads
- Simulated Drawdown (m)
- Extraction Limit

SOURCE: Base mapping produced by Gartner Lee Limited under license with the Ministry of Natural Resources, Queen's Printer 1997 - Reproduced 2004.

NOTE:
Stage 1 - 1st Lift - Without Mitigation
Volume of Quarry Dewatering: 1988 m^3/d

PROPOSED DOLOSTONE QUARRY	Figure 13
SIMULATED DRAWDOWN - NO MITIGATION STAGE 1 - 1st LIFT (272 masl) - SITE SCALE	
Project # 23827, Hydrogeological Modeling Investigation	
Gartner Lee Limited	Scale 1:20,000

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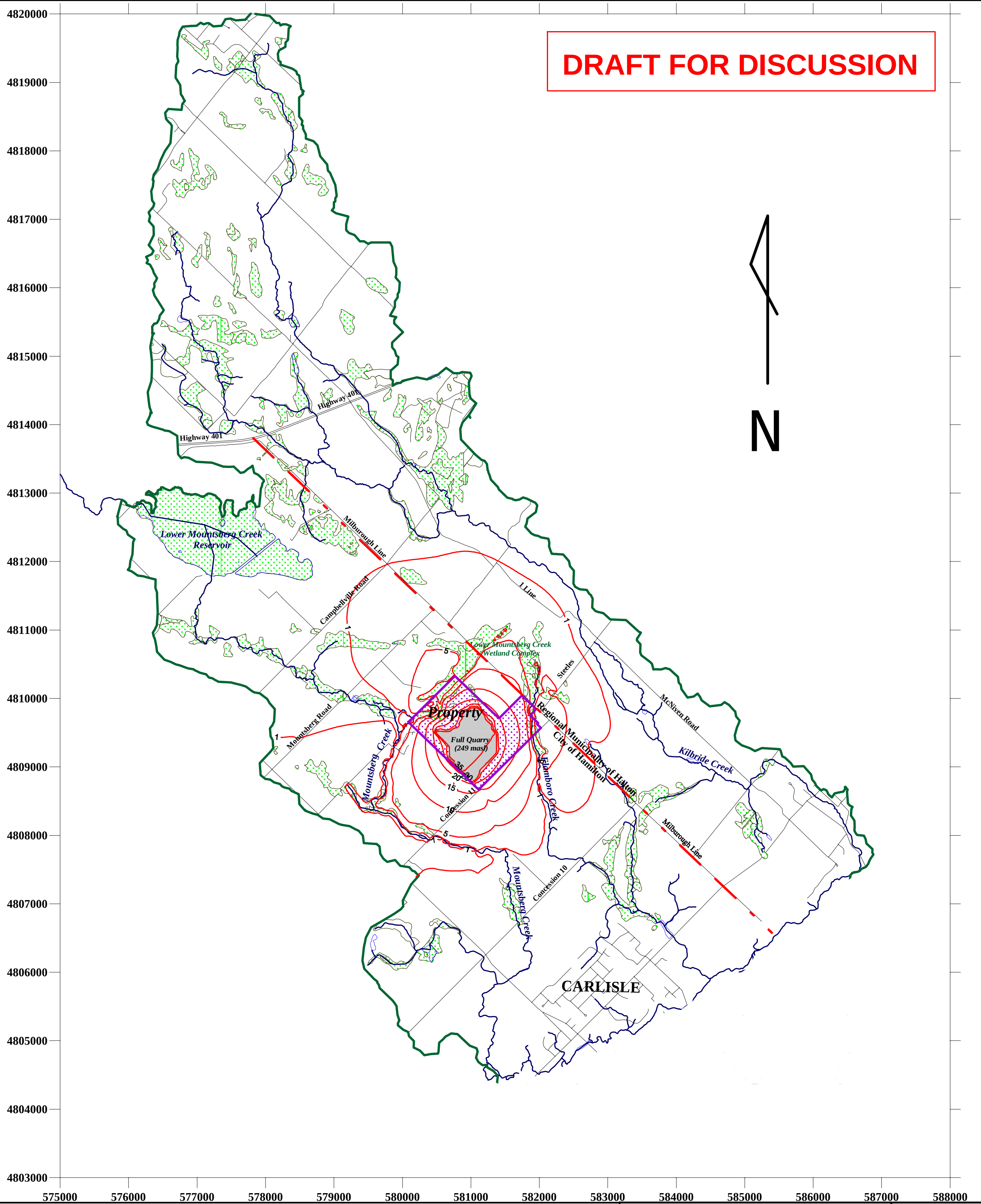

Legend

- Surface Drainage Features
- Water Bodies
- Wetlands
- Active Model Domain
- Property Boundary
- Roads
- Simulated Drawdown (m)
- Extraction Limit

SOURCE: Base mapping produced by Gartner Lee Limited under license with the Ministry of Natural Resources, Queen's Printer 1997 - Reproduced 2004.

NOTE:
Full Quarry - Without mitigation
Quarry dewatering: 9894 m^3/d

PROPOSED DOLOSTONE QUARRY

Figure 14

SIMULATED DRAWDOWN - NO MITIGATION
FULL QUARRY (249 masl) - REGIONAL SCALE

Project # 23827, Hydrogeological Modeling Investigation

Gartner Lee Limited

Scale
1:80,000

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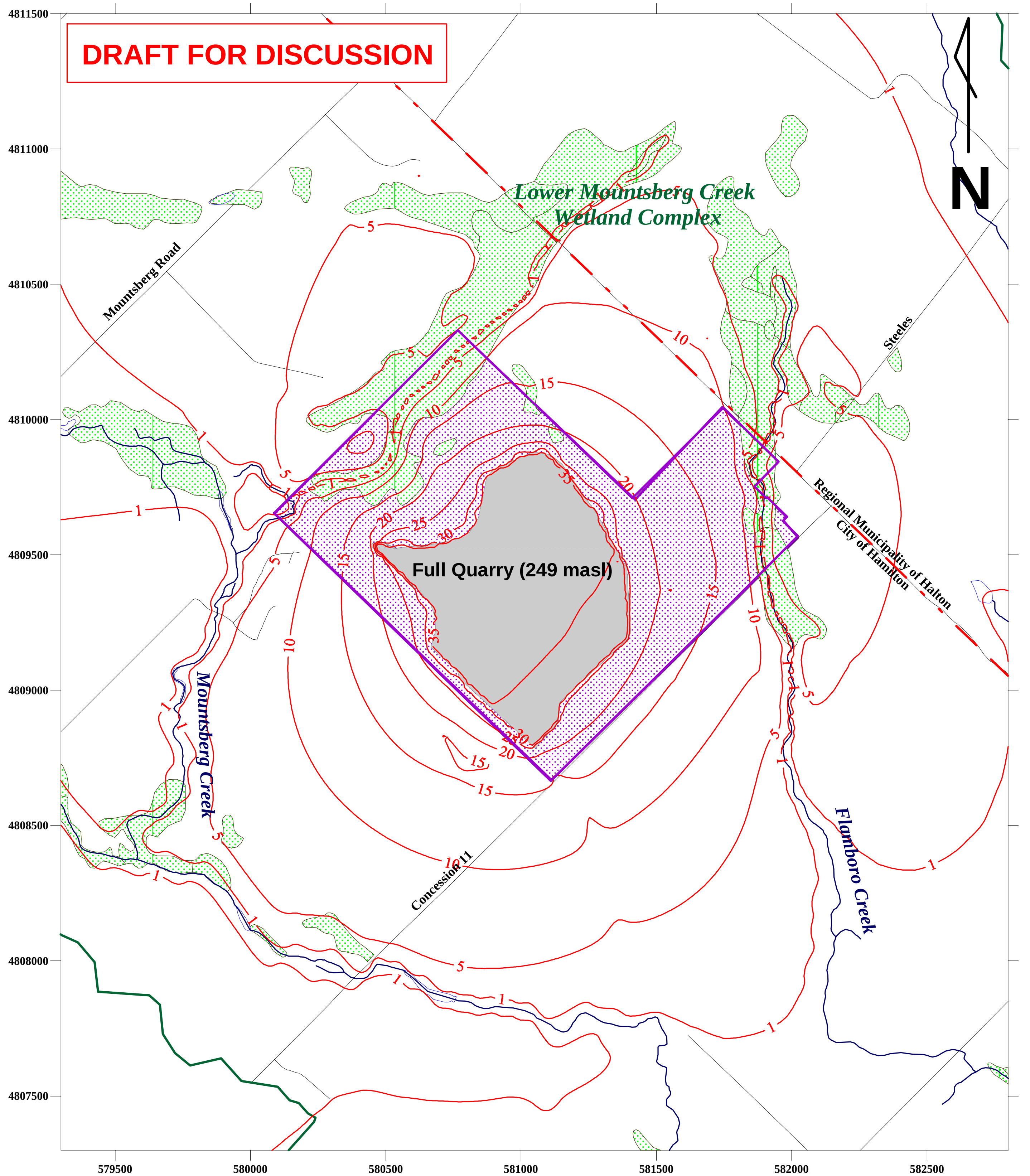

Legend

- Surface Drainage Features
- Water Bodies
- Wetlands
- Active Model Domain
- Property Boundary
- Roads
- Simulated Drawdown (m)
- Extraction Limit

SOURCE: Base mapping produced by Gartner Lee Limited under license with the Ministry of Natural Resources, Queen's Printer 1997 - Reproduced 2004.

NOTE:
Full Quarry - No Mitigation
Quarry Dewatering = 9894 m^3/d

PROPOSED DOLOSTONE QUARRY | **Figure 15**

SIMULATED DRAWDOWN - NO MITIGATION
FULL QUARRY (249 masl) - SITE SCALE

Project # 23827, Hydrogeological Modeling Investigation

Gartner Lee Limited

Scale
1:20,000

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A zone budget analysis was used to determine the pre- and post- water flux to the wetland features in proximity to the quarry. The results of this analysis are presented in Table 10.

Table 10. Predictive Groundwater Model Results for Quarry Configurations

Scenario	% Change in Groundwater Flux to Wetland		River Loss to Recharge *(% change)*	Predicted Flows (Lps) Into Quarry[(1)]
	Wetlands Near Mountsberg Creek	*Wetlands Near Flamboro Creek*	*Mountsberg Creek Subwatershed*	
Calibrated Base Case Model	0	0	0	n/a
Stage 1, 1st Lift (272 mASL)	28%	29%	18%	27.00
Full Quarry, final depth (249 mASL)	86.8%	79%	342%	129.26

Notes: (1) This value includes both the groundwater discharge and the direct precipitation on the quarry.

The groundwater model predicts that as a result of the Stage 1 Quarry dewatering, the wetlands adjacent to Mountsberg Creek will experience up to a 28% decrease in the groundwater flux from dewatering. The wetlands adjacent to Flamboro Creek will experience up to a 29% decrease in the groundwater flux. The river loss to recharge in the Mountsberg Creek subwatershed is simulated as 18%.

The decreases in groundwater flux for the wetlands along Mountsberg Creek and Flamboro Creek respectively for the Full Quarry are estimated as 86.8% and 79%. The river loss to recharge in Mountsberg Creek subwatershed is simulated as 342%.

- **Effects of Quarry Development on Creek Flows and Water Quality**

The water extracted from the quarry during development would most likely be discharged to Mountsberg Creek. To estimate the potential effect on the creek both with respect to creek flow and water quality, it is first necessary to estimate the volume that could potentially be extracted from the quarry. This volume would include the groundwater flows into the quarry (identified in Table 7 and discussed in Section 3.3.2) the water surplus from precipitation. As summarized in Section 2.3, the mean annual precipitation is estimated as 849 mm per year. Because there will be no soils or plants within the quarry, the open pit on development, it is reasonable to expect that the much of the available precipitation (849 mm) will infiltrate and need to be managed (i.e., extracted at the quarry sump along with the groundwater drainage).

The volume that is potentially discharged to Mountsberg Creek would need to be adjusted downward by the amount of water lost or consumed through the quarry operations, which is estimated as 54,000 tonnes/year (54,000 m^3/year).

The quarry development will largely fall within the Mountsberg Creek subwatershed and this creek would represent the likely discharge point for any quarry dewatering that occurs.

As noted in Table 7, the average rate of water discharged to Mountsberg Creek for the Stage 1 Quarry and for the Full Quarry is estimated as 24.8 Lps and 125.7 Lps, respectively. The average flow in Mountsberg Creek (Station SWMC) for the period of record is 595 Lps (Section 2.2). The quarry contribution for the Stage 1 Quarry and for the Full Quarry to the average creek flow would represent about 4.1% and 21.1%, respectively.

The potential impact on the water quality of Mountsberg Creek would be proportionate to the quantity and quality of the discharge from the quarry. Water samples were collected from the pumping wells and Mountsberg Creek during the November 2004 pumping test (Table 3). The analysis results for those parameters approaching or exceeding the Provincial Water Quality Objectives (PWQO) in either the groundwater or surface water samples are summarized in Table 11.

Table 11. Summary of Water Chemistry During November 2004 Pumping Tests

Parameter	PWQO	TW12	TW13 (repeat)	Average of Two Wells	Mountsberg Creek at SWMC
Aluminum	0.075	0.014	0.132 (0.143)	0.076	0.015
Iron	0.3	0.39	0.11 (0.11)	0.25	0.05
Zinc	0.02	0.01	0.05 (0.049)	0.035	0.011

Note: All values expressed in mg/L.

The following equation was applied to assess the magnitude of the impact of the quarry discharge on Mountsberg Creek:

$$\textbf{Average Concentration after Mixing} = \frac{\text{(Quarry discharge x parameter concentration) + (Creek flow x parameter concentration)}}{\text{(Quarry Discharge + Creek Flow)}}$$

The average parameter concentrations within Mountsberg Creek under average flow conditions after mixing are summarized below:

	Stage 1 Quarry	Full Quarry
Mountsberg Creek Flow	595 Lps	595 Lps
Quarry Discharge	24.8 Lps	125.7 Lps

Parameter (PWQO)	Predicted Concentration	Predicted Concentration
Aluminum (0.075 mg/L)	0.017	0.026
Iron (0.3 mg/l)	0.058	0.085
Zinc (0.02 mg/L)	0.0119	0.015

As noted above, the concentrations of the three parameters (aluminum, iron and zinc) in the quarry discharge will be reduced, on mixing with the flow in Mountsberg Creek.

- **Effects of Quarry Development on Residential Wells**

Dewatering associated with the development of the quarry and the resulting reduction in the groundwater level has the potential to affect the supply of groundwater to residential wells. The actual effect of this drawdown on a residential well supply however will vary depending on the location of the well, the depth of the well and the pump setting or elevation at which the intake of the pump is set.

The locations of the various water wells in the study area from the MOE Water Well Record files are shown in Figure 1, Appendix B (Volume 3). Information on the static water level at the time the well was installed, the depth at which water was found, and the total well depth are provided in Table 2, Appendix B (Volume 3).

Also provided in Table 2, Appendix B (Volume 3), is an estimated of the available drawdown as calculated two ways: 1) the difference between the static level and the level at which water was found; and, 2) the difference between the static level and the depth at which the pump intake is set. [Note: For purposes of this assessment, the pump intake level is assumed to be 1 m above the bottom of the well.]

The projected drawdown at each well location listed in Table 2 is based on the computer simulations for the Stage 1 Quarry and the Full Quarry development scenarios that were assessed.

For purposes of this assessment, the potential exists for a reduction in the water supply where the difference between the available drawdown and the projected drawdown induced by the quarry is less than 3 m. However, as noted, the actual effect on a residential well supply will vary.

Using the above criterion for assessing a potential impact, the Stage 1 Quarry dewatering could result in a decline in the available water supply for six (6) wells. Although, the model-simulated drawdown is generally 2 m or less below the closest residential properties, these six wells are relatively shallow and have limited available drawdown.

Based on the simulated zone of influence and predicted drawdown in the groundwater level for full quarry development to a base elevation of 249 mASL, the impact to domestic water supplies in the vicinity of the quarry is potentially significant, with a predicted drawdown in groundwater level of 10 m or more below the residential properties to the northeast, west and south. The Full Quarry dewatering could potentially result in a decline in the available water supply at several more wells (36 wells). The water level at about one third of these wells will be drawn below the available drawdown for these wells.

- **Influence of Quarry on Carlisle Municipal Production Wells:**

The Village of Carlisle municipal production wells are located approximately 3.5 km from the proposed dolostone quarry. On a regional basis, groundwater moves through the watershed in a north to south direction across the area encompassed by the quarry and the Carlisle municipal well field.

For preliminary discussion purposes the assessment of the potential effects of the quarry on the municipal wells was conducted using the groundwater model developed for this study. It is intended that additional model runs be undertaken using the City of Hamilton groundwater flow model once this is released to the public.

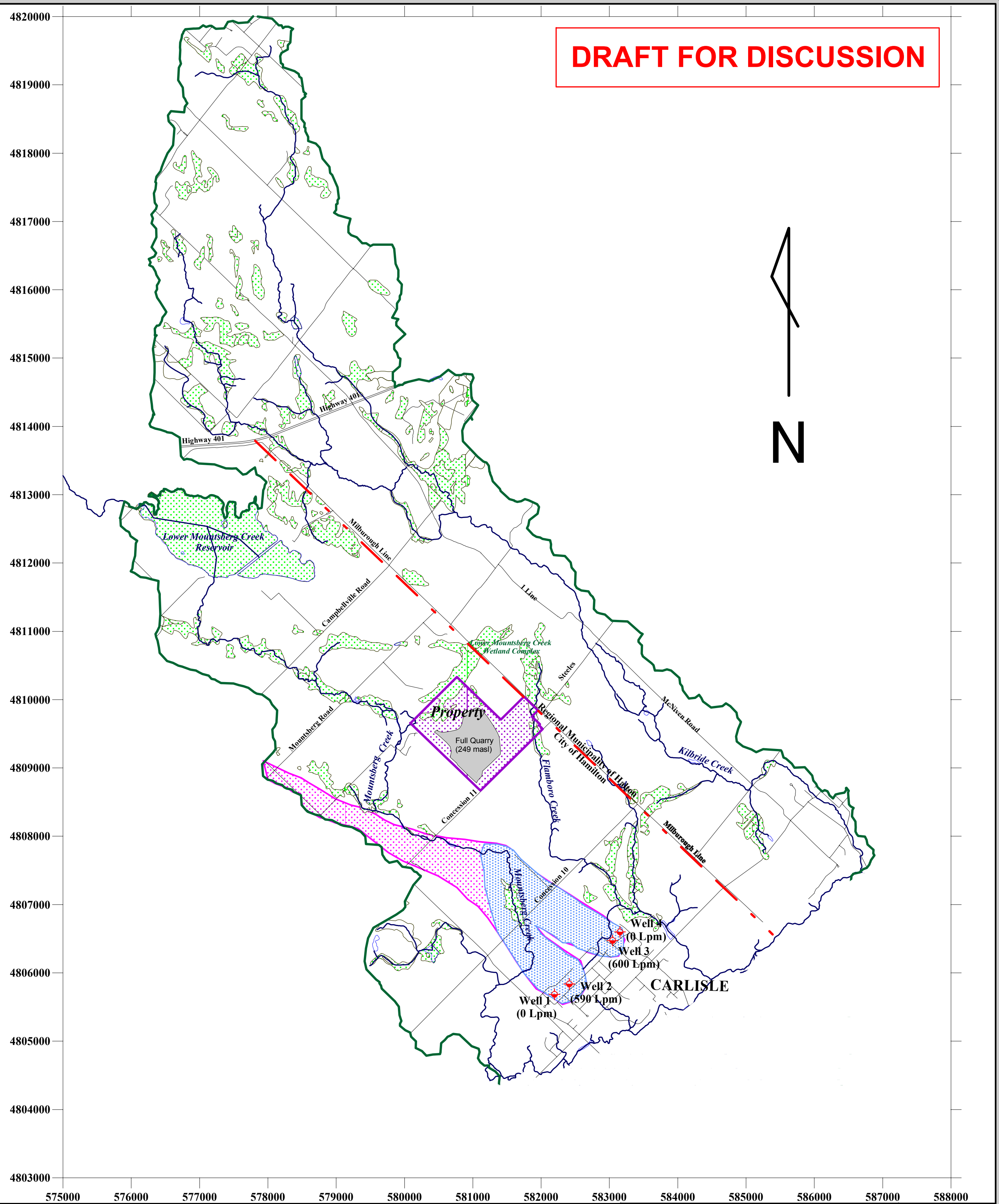
Results to date indicate that the quarry, even without mitigation, will not affect the Carlisle municipal wells. The drawdown induced by the Full Quarry dewatering extends approximately 1 km south of the quarry property, whereas the municipal wells are located more than 3.5 km away.

Particle tracking is commonly used to estimate the time of travel a particle of water will take to enter a well intake. By tracking a particle of water backward from a well intake upgradient through the groundwater system, it is possible to identify the approximate area where the water is recharged and the zone of influence of the well in question. Particle tracking is also employed to predict the distance groundwater will travel for a given period of time. Typically groundwater movement is slow and is measured in metres per day, month or even per year.

Reverse particle tracking was applied using the groundwater flow model developed for this investigation to assess the time of travel from the Carlisle municipal well field to the proposed dolostone quarry. Based on the permitted pumping rates, it will take over 20 years for a particle of water to move from the area of the quarry to the intake of the Carlisle production wells. The simulated zone of capture for the Carlisle municipal wells based on a 25-year time of travel (TOT) is illustrated in Figure 16.

The model output also suggests that there is a high probability that surface water features located between the quarry property and the Carlisle wells will effectively minimize the extent of the drawdown by "short-circuiting" the groundwater flow path. This will reduce the distance and time the source water will travel to the municipal wells.

The quarry is also not expected to be a potential source of contamination to the Carlisle municipal wells. When a quarry is dewatered, groundwater flows into the quarry, rather than away from the quarry. This would prevent any contamination from moving from the quarry to these wells. However, the first level of prevention is practiced at the quarry through the careful management of equipment fuels and lubricants, and blasting agents in accordance with government regulations. These are the only potential chemical contaminants used in aggregate production, since this is a mechanical process of crushing, screening and washing.



Legend

- Surface Drainage Features
- Water Bodies
- Wetlands
- Active Model Domain
- Property Boundary
- Roads
- Extraction Limits
- Capture Zone - 25 Years of Travel
- Capture Zone - Steady State

SOURCE: Base mapping produced by Gartner Lee Limited under license with the Ministry of Natural Resources, Queen's Printer 1997 - Reproduced 2004.

PROPOSED DOLOSTONE QUARRY

Figure 16

SIMULATED ZONE OF CAPTURE
FULL QUARRY - CARLISLE WELLS

Project # 23827, Hydrogeological Modeling Investigation

Gartner Lee Limited

Scale 1:80,000

:07/07/05:\ N:\Projects\2003\23827\2005\WIP\Data Interpretation\Level 2 Report\Figures\Figure 16.srf

3.3.4 Quarry Effects – Summary

In summary, it can be concluded that the un-mitigated development of the quarry will have an unacceptable impact on the Lower Mountsberg Creek Wetland Complex and on local residential wells, but will not affect the Carlisle water supply. This impact will be caused by quarry dewatering operations, which will result in the drawdown of groundwater levels and a reduction in the groundwater flux (baseflow) to the wetlands. The flow in Mountsberg Creek will also be affected by the discharge of groundwater/surface water from the quarry. The development of a quarry in this area will therefore require that mitigation measures be implemented to maintain the groundwater levels in the vicinity of the quarry and to reduce the volume of water that would be released to Mountsberg Creek. A description of the proposed measures is provided in Section 4.

4. Mitigation

4.1 Background

Dewatering impacts from the proposed dolostone quarry are expected to be significant requiring that some form of mitigation be applied. The primary objectives of this mitigation are to:

a) maintain residential water supplies; and,

b) maintain the existing groundwater flux to surface water features including streams and wetlands to sustain these components of the subwatershed [Note: these features are potentially more sensitive to the dewatering impacts than residential wells.]

The effects of quarry dewatering can be mitigated through the recirculation of the extracted water. This would involve the release of the groundwater and surface water collected within the quarry during the dewatering operations to a trench and/or line of boreholes (conduits) installed between the footprint of the quarry area and adjacent wetland features and residential wells. By re-circulating the extracted water, the groundwater level can be maintained at a pre-development condition. Provided the system operates as designed, the net water loss to the system would be limited to the volume of water lost to operations within the quarry proper. The balance of the extracted water would be re-circulated to the groundwater flow system and would in turn drain back into the quarry and again need to be extracted and re-circulated.

This mitigation measure is referred to herein as a ‘Groundwater Recirculation System’ or GRS. The GRS as initially envisioned for the quarry development was to consist of a shallow trench excavated through the overburden into the upper bedrock.

Groundwater and surface water collected within the quarry from dewatering would be discharged to the trench where it would infiltrate to sustain the groundwater level between the quarry and the adjacent wetland features and nearby water supplies.

A number of computer simulations were undertaken using the groundwater model to assess the effectiveness of this mitigation measure and to optimize the placement and design of the GRS. Because the re-circulated water drains back into the quarry and is again extracted and re-circulated, the actual volume of water extracted from the quarry increases until a steady state condition is realized.

The resulting volumes, at steady state, are presented in Table 12 below:

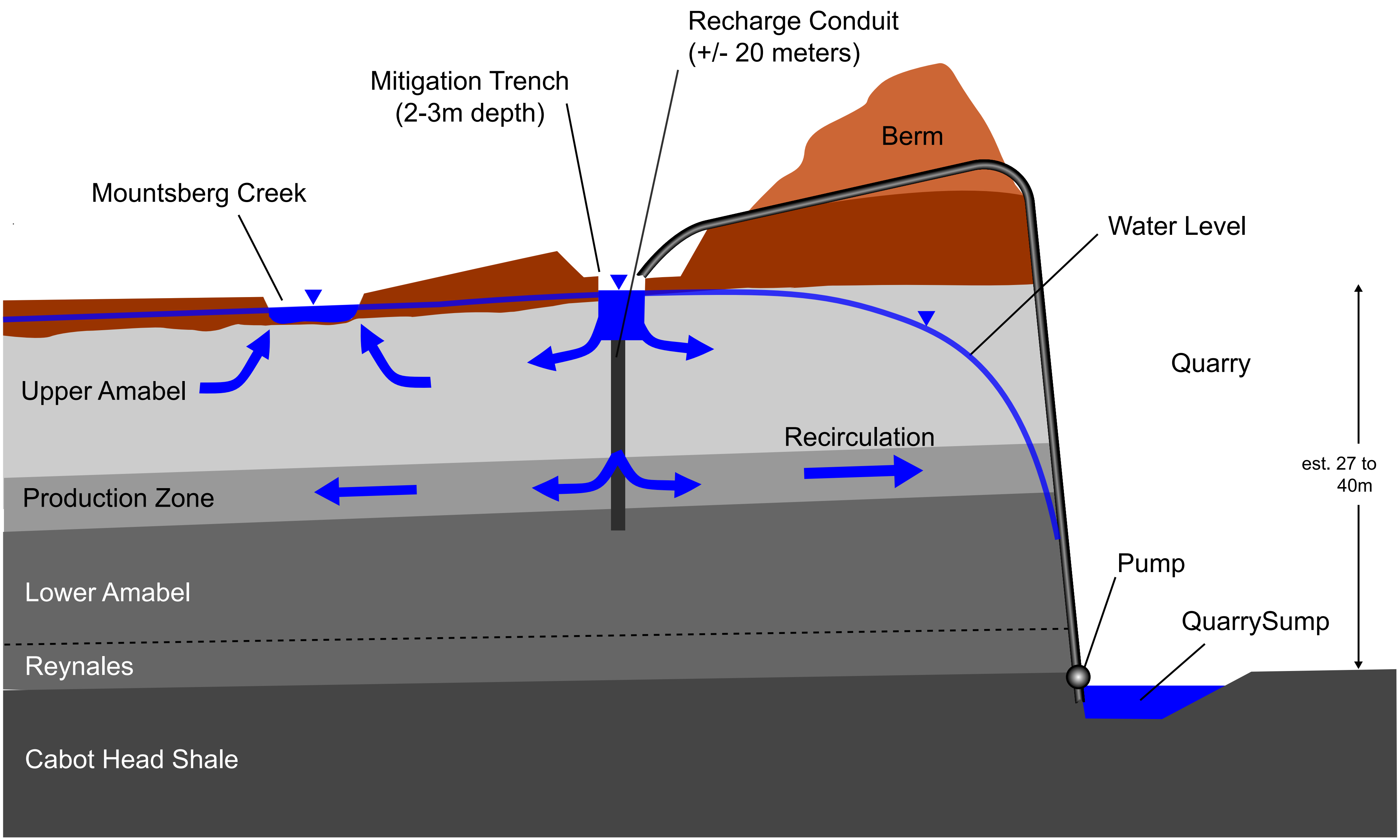
Table 12. Predicted Flows Required to Mitigate Quarry Dewatering

Computer Simulation	Predicted Flows Extracted from Quarry	GRS Discharge Required to Maintain Water Levels
Stage 1, 1st Lift (272 mASL), with mitigation	46.58 Lps (615 igpm)	43.12 Lps (570 igpm)
Full Quarry, final depth (249 mASL) with mitigation	338.82 Lps (4,472 igpm)	339.87 Lps (4,485 igpm)

A key finding of the predictive simulations was the need to accommodate the water loss through the hydraulically conductive zone encountered at mid-depth within the Amabel Formation. Specifically, it was determined that it is necessary to maintain the groundwater flux to this high conductivity zone otherwise the drawdown cone would expand outward beyond the GRS into the wetlands. This was addressed in the simulation by creating a hydraulic connection between the GRS at surface and this higher conductivity zone.

To achieve this hydraulic connection at the site, it will be necessary to drill conduits along the axis of the GRS trench, which extend into the productive zone within the Amabel Formation. Water discharged along the trench would be allowed to drain down the conduits to the higher conductive zone under gravity. [Note: These conduits would be drilled boreholes and should not to be confused with injection wells.] The resulting configuration of the GRS (trench and the conduits), as determined through the optimization efforts, is shown in Figure 17.

A continuous supply of water will be required to maintain the water level within the GRS. The source of this supply is the precipitation that accumulates in the quarry and the groundwater dewatering that will occur within the quarry.



Not to Scale

Gartner Lee

Conceptual Mitigation System

DRAFT FOR DISCUSSION

FIGURE
17

Project 23-827

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4.2 Feasibility of Proposed Mitigation

As noted, the groundwater model was employed to assess the feasibility of using the GRS at the site to mitigate the dewatering effects induced from quarry development. The goal of the GRS predictive simulation was to achieve no net losses to the wetland features.

This analysis was completed by a trial and error approach where the GRS configuration and the volumetric rates applied to the GRS were adjusted until the goal of no net loss to the wetland features was achieved. The resulting volumes were presented previously in Table 12. The water balance is summarized below:

- **Mitigated Quarry Water Balance**

  A key assumption used in determining the water volumes re-circulated back to the quarry from the GRS trench is the presence of the productive zone of the Amabel Formation discussed in Section 4.1 of the report. It is assumed that the productive zone is continuous throughout the site and will be encountered along the entire perimeter of the proposed quarry excavation. This is a *worse case* scenario and it is likely that there will be tighter zones where the productive zone is less productive and possibly not even present along the perimeter of the GRS trench. This will enhance the efficiency of the GRS system and will reduce the volume of water required to sustain the GRS system. Therefore, it is expected that the volumes discussed in this report are conservatively high and actual observed volumes will be somewhat less during field testing and operation of the GRS trench.

  The water balances for the mitigated Stage 1 Quarry and Full Quarry are presented in Table 13.

  For the mitigated Stage 1 Quarry condition, the combined groundwater and surface water input under the GRS is estimated as 1,596,475 m^3/year. A portion of this water would maintain the groundwater levels and groundwater discharge to wetlands and streams in proximity to the property, however, a large proportion of this water would re-circulated from the GRS trench and flow back to the quarry. This is reflected in the inflated volume of water observed to flow into the quarry in the *groundwater inflow* value. The total water loss from the quarry was calculated to be 1,430,737 m^3/year. However, as mentioned earlier, a large portion of this water (1,359,990 m^3/year) is re-distributed to the GRS system and is returned to the sub-watershed. The amount of water discharged to surface water after recharge to the GRS trench is estimated as 165,73 m^3/year. This water represents the net removal of water from the quarry due to accumulation of groundwater and losses from the GRS.

  The mitigated Full Quarry has a predicted combined groundwater and surface water input of approximately 11,150,262 m^3/year. As discussed in the Stage 1 Quarry scenario, a portion of this water is used to maintain groundwater levels and groundwater discharge to wetlands and streams in proximity to the property.

Table 13. Mitigated Quarry Water Balance

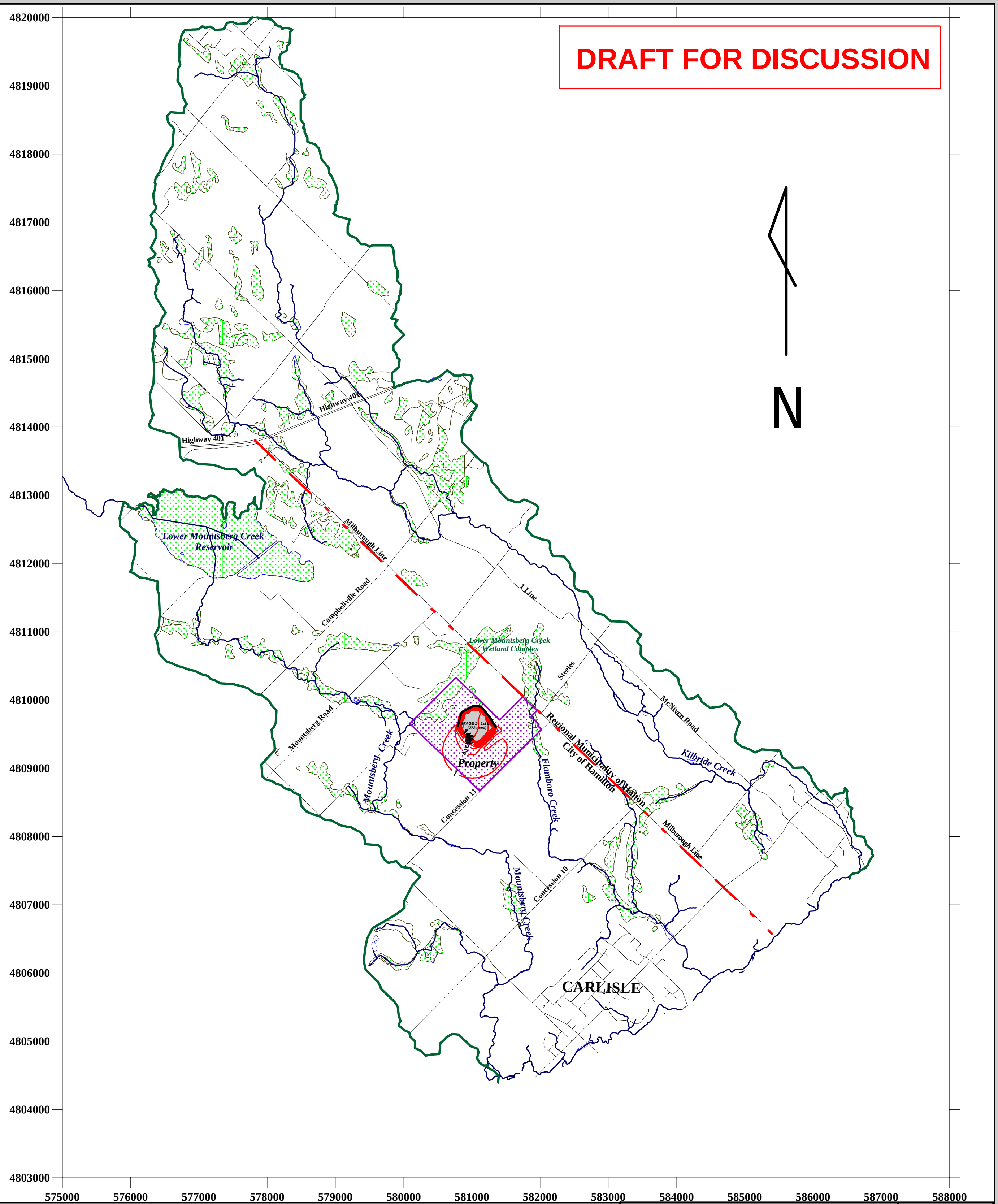
Mitigated Quarry Water Balance

Water Balance Components		Stage 1 (m^3/year)	Full Quarry (m^3/year)
A	**Water Input**		
I	Precipitation (849 mm average annual)	127,350	465,252
II	Groundwater inflow	1,469,125	10,685,010
Total		**1,596,475**	**11,150,262**
B	**Water Loss**		
I	Evaporation (Quarry Floor - 20% of 510 mm/yr evaporation = 102 mm/yr)	15,300	55,896
II	Evaporation (Pond Evaporation 710 mm/yr), from quarry sump ponds	459	1,677
III	Stone Shipments	54,000	54,000
IV	Dust Suppression	50	50
V	Ancillary Operations	938	938
VI	Groundwater Re-circulation System (GRS)	1,359,990	10,718,225
Total		**1,430,737**	**10, 830,786**
C	**Water Surplus for Discharge from Quarry (to river or surface water)**		
	C = A – B	**165,738**	**319,476**
	Lps conversion	5.26	10.13

A large proportion of this water is re-circulated from the GRS trench and flows back to the quarry. This is reflected in the inflated volume of water observed to flow into the quarry in the *groundwater inflow* value. The total water loss from the full quarry was calculated to be 10,830,786 m^3/year. As discussed, a large portion of this water is re-distributed to the GRS system and is returned to the sub-watershed. The amount of water removed from the quarry and discharged to surface water after recharge to the GRS trench is 319,476 m^3/yr (10.13 Lps).

- **<u>Effectiveness of GRS in Maintaining Groundwater Levels</u>**

The effectiveness of the infiltration system in reducing the zone of influence and associated drawdown of the groundwater level for the Stage 1 Quarry (excavation to 272 mASL) is illustrated in Figure 18 and Figure 19, for the regional and site scales respectively.



Legend

- Surface Drainage Features
- Water Bodies
- Wetlands
- Active Model Domain
- Property Boundary
- Roads
- Simulated Drawdown (m)
- Groundwater Recirculataion System
- Extraction Limit

SOURCE: Base mapping produced by Gartner Lee Limited under license with the Ministry of Natural Resources, Queen's Printer 1997 - Reproduced 2004.

NOTE:
STAGE 1 1st Lift With Groundwater Recirculation System
Quarry Extraction = 4025 m^3/d
Water Delivered to Trench = 3726 m^3/d

PROPOSED DOLOSTONE QUARRY | **Figure 18**

SIMULATED DRAWDOWN - WITH MITIGATION
STAGE 1 - 1st LIFT (272 masl) - REGIONAL SCALE

Project # 23827, Hydrogeological Modeling Investigation

Gartner Lee Limited

Scale
1:80,000

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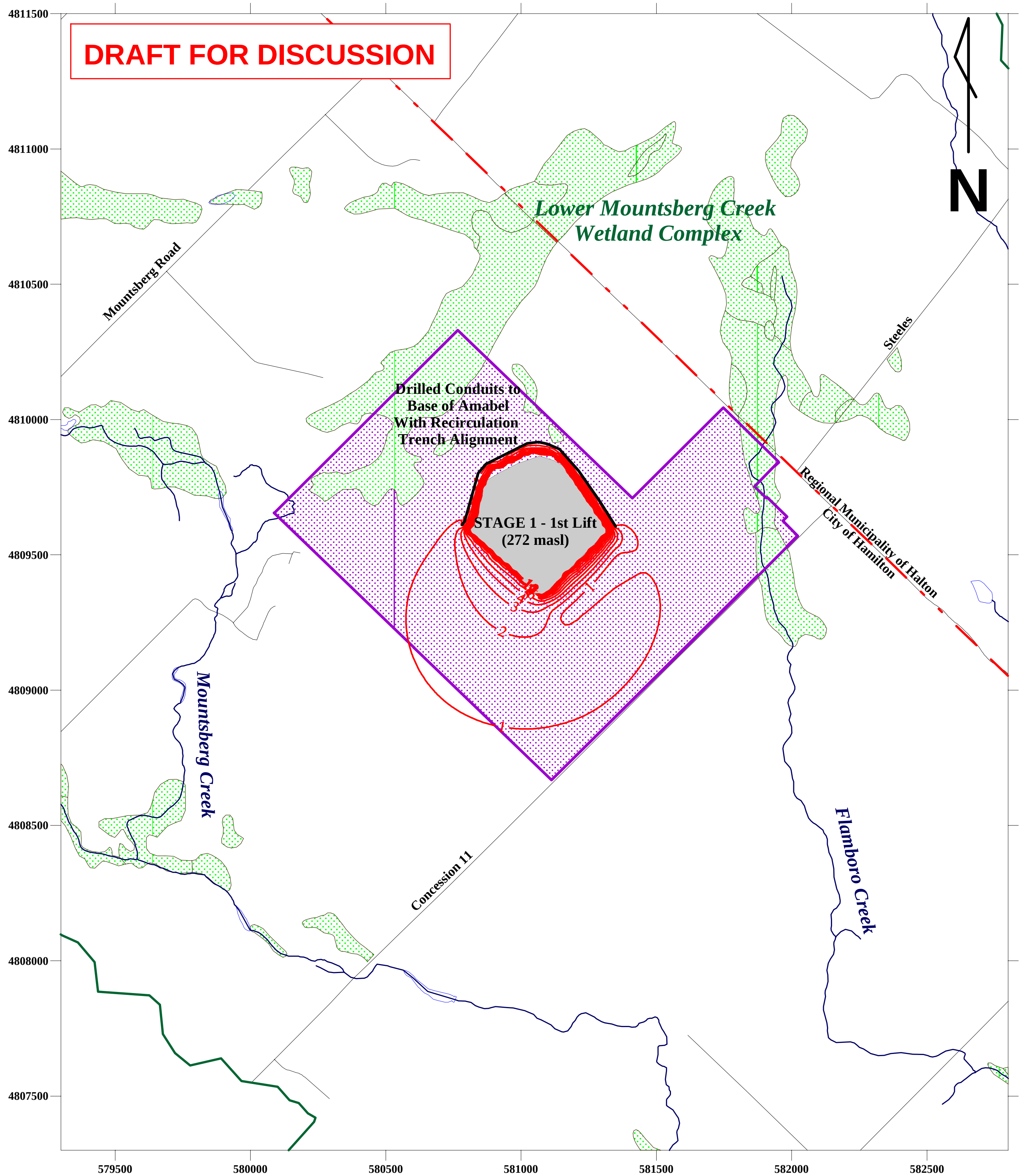

Legend

- Surface Drainage Features
- Water Bodies
- Wetlands
- Active Model Domain
- Property Boundary
- Roads
- Simulated Drawdown (m)
- Groundwater Recirculation System
- Extraction Limit

SOURCE: Base mapping produced by Gartner Lee Limited under license with the Ministry of Natural Resources, Queen's Printer 1997 - Reproduced 2004.

NOTE:
STAGE 1 1st Lift With Groundwater Recirculation System
Quarry Extraction = 4025 m^3/d
Water Delivered to Trench = 3726 m^3/d

PROPOSED DOLOSTONE QUARRY	Figure 19
SIMULATED DRAWDOWN - WITH MITIGATION STAGE 1 - 1st LIFT (272 masl) - SITE SCALE	
Project # 23827, Hydrogeological Modeling Investigation	
Gartner Lee Limited	Scale 1:20,000

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Through the optimization effort it was determined that effective mitigation of the Stage 1 Quarry dewatering effects could be achieved by the installation of a GRS along the north and northeast side of the quarry as shown in Figure 19. To maintain the discharge to the wetland and contain the drawdown effects within the development limits, it will be necessary to release 43.12 Lps (570 igpm) to the GRS.

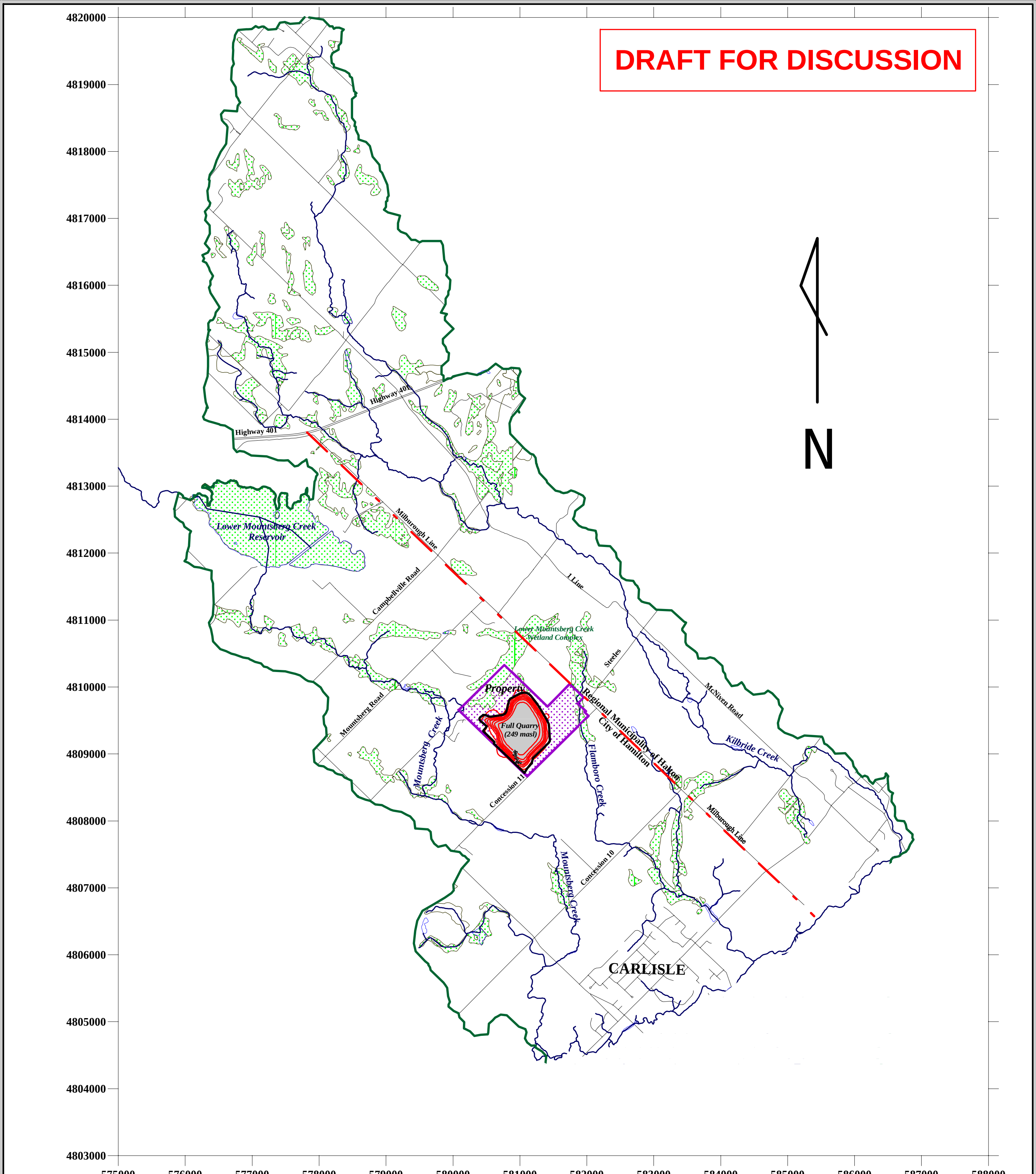
The mitigation simulation for the Full Quarry (base elevation of 249 mASL) is shown in Figure 20 and Figure 21. The mitigation scenario as formulated, involves the recharge of the extracted water along a GRS that extends fully around the perimeter of the quarry. As depicted, the drawdown is effectively contained within the area encompassed by the GRS. Groundwater levels along the outer perimeter of the GRS are maintained resulting in no net losses to the adjacent wetland features. The simulation requires that a large portion of the groundwater that drains into the quarry [339.87 (4,485 igpm)] be re-circulated. Any surplus water extracted from the quarry during development, above that required for the GRS, would be discharged to Mountsberg Creek.

As noted in Table 13, a water surplus of about 165,738 m^3/year (5.26 Lps) will occur during the initial Stage 1 Quarry development. The surplus for the Full Quarry is estimated as 319,476 m^3/year (10.13 Lps). This water would be discharged to Mountsberg Creek contributing to the creek flow. Considering the average flow in Mountsberg Creek (Station SWMC) is estimated as 595 Lps (Section 2.2), the Stage 1 Quarry and the Full Quarry contribution would represent an incremental increase of about 0.88% and 1.7%, respectively.

As noted in Section 3.2, the potential impact on the water quality of Mountsberg Creek would be proportionate to the quantity and quality of the discharge from the quarry. Three parameters (aluminum, iron and zinc) in the groundwater extracted during the November 2004 pumping test, approach or exceed the PWQO (Table 7). Assuming the groundwater extracted is representative of that which would be produced from the quarry, the average parameter concentrations after release and mixing in Mountsberg Creek are summarized below.

	Stage 1 Quarry	Full Quarry
Mountsberg Creek Flow	595 Lps	595 Lps
Quarry Discharge	5.26 Lps	10.13 Lps

Parameter (PWQO)	Predicted Concentration	Predicted Concentration
Aluminum (0.075 mg/L)	0.015	0.016
Iron (0.3 mg/l)	0.051	0.053
Zinc (0.02 mg/L)	0.011	0.0114



Legend

- Surface Drainage Features
- Water Bodies
- Wetlands
- Active Model Domain
- Property Boundary
- Roads
- Simulated Drawdown (m)
- Groundwater Recirculation System
- Extraction Limit

SOURCE: Base mapping produced by Gartner Lee Limited under license with the Ministry of Natural Resources, Queen's Printer 1997 - Reproduced 2004.

NOTE:
Full Quarry - With Groundwatre Recirculation System
Quarry dewatering: 29,274 m^3/d
Water delivered to Trench: 29,365 m^3/d

PROPOSED DOLOSTONE QUARRY	Figure 20
SIMULATED DRAWDOWN - WITH MITIGATION FULL QUARRY (249 masl) - REGIONAL SCALE	
Project # 23827, Hydrogeological Modeling Investigation	
Gartner Lee Limited	Scale 1:80,000

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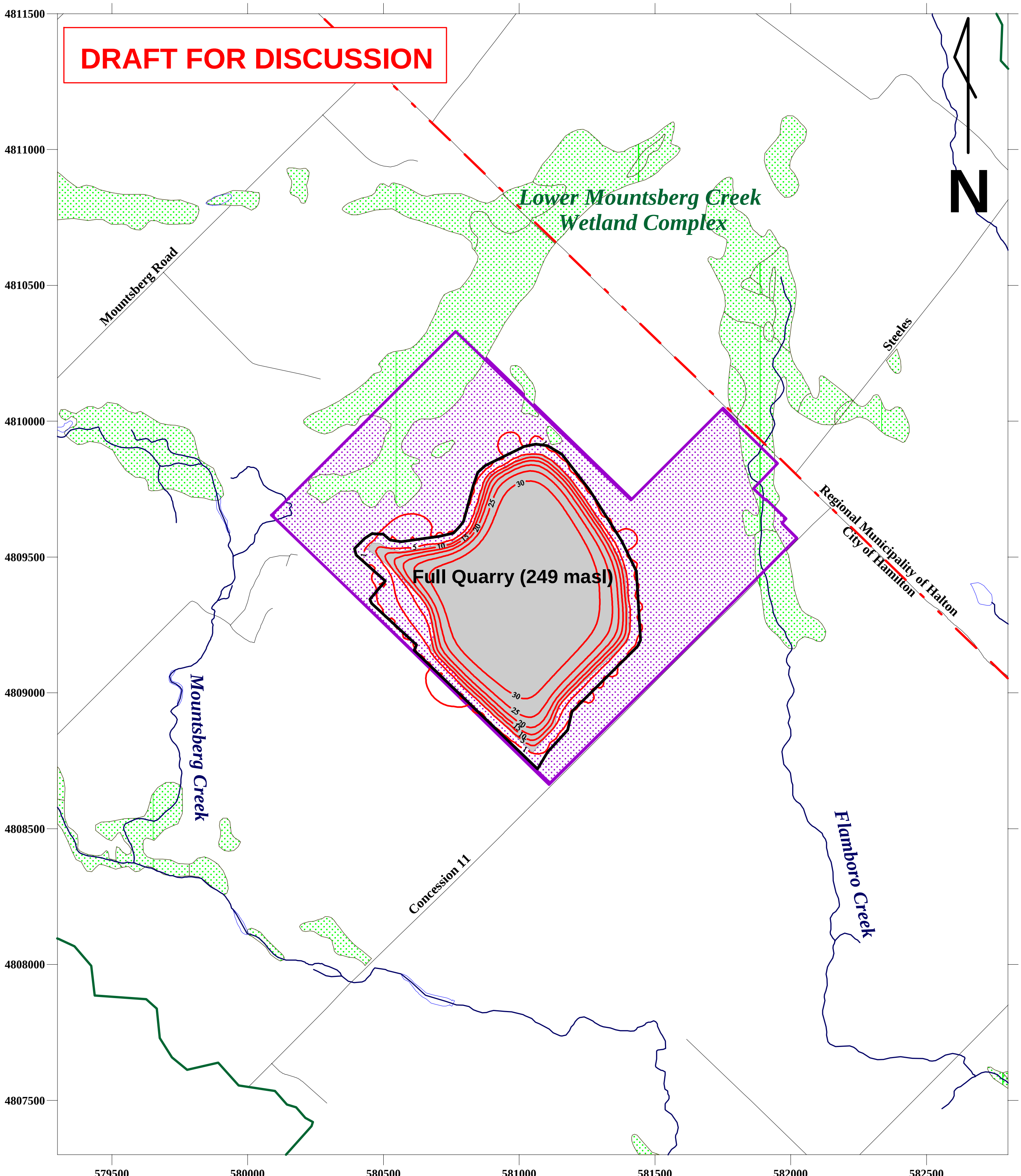

Legend

- Surface Drainage Features
- Water Bodies
- Wetlands
- Active Model Domain
- Property Boundary
- Roads
- Simulated Drawdown (m)
- Groundwater Recirculation System
- Extraction Limit

SOURCE: Base mapping produced by Gartner Lee Limited under license with the Ministry of Natural Resources, Queen's Printer 1997 - Reproduced 2004.

NOTES:
Full Quarry (249 masl) - With Groundwater Recirculation System
Quarry Dewatering = 29,274 m^3/d
Groundwater Recirculation System = 29,365 m^3/d

PROPOSED DOLOSTONE QUARRY	Figure 21
SIMULATED DRAWDOWN - WITH MITIGATION FULL QUARRY (249 masl) - SITE SCALE	
Project # 23827, Hydrogeological Modeling Investigation	
Gartner Lee Limited	Scale 1:20,000

:07/07/05:\ N:\Projects\2003\23827\2005\WIP\Data Interpretation\Level 2 Report\Figures\Figure 21.srf

After mixing, the concentrations of the three parameters (aluminum, iron and zinc) in the quarry discharge will be reduced to below the PWQO.

In summary, the feasibility of using the proposed GRS as a mitigation measure has been demonstrated through predictive simulation. As determined, the GRS can be expected to maintain groundwater levels along the perimeter of the quarry development area. This in turn would maintain the groundwater flux (i.e., recharge) to the critical wetlands. No impact to the residential wells is expected to occur.

4.3 Adaptive Management Plan

It is important to develop a means by which the effectiveness of the proposed mitigation can be demonstrated. This requires that the water resources be characterized from a quantity and quality perspective, and that the interrelationship between groundwater and surface water be established. Information provided in this Level 2 Hydrogeological Assessment goes a long way to addressing this requirement, although additional effort is required.

As part of this undertaking, the ‘baseline’ or ambient condition needs to be established through an extended period of monitoring. Comparing quarry dewatering induced changes in groundwater levels or surface water stage and flow to the baseline condition provides an indication of the nature and significance of impacts. The modeling investigation completed in this study has provided a reasonable understanding of the baseline groundwater conditions in this subwatershed. Simulation of quarry scenarios has demonstrated the influence of the quarry development under un-mitigated and mitigated conditions, and how the quarry will affect the baseline subwatershed condition.

The approach or process by which the effectiveness of the mitigation can be assessed is referred to as an Adaptive Management Plan (AMP) where a network of monitoring installations are established and a series of triggers are introduced that lead to the implementation of the mitigation measures or an adjustment or change to the mitigation. Although the scope of the AMP cannot be fully determined until input is realized from various agencies (including the Municipality, the Conservation Authorities, the MOE and the MNR), an outline of its components is provided below.

- **<u>Verification Monitoring and Evaluation</u>**

  It will be important to evaluate the performance of the GRS, as the quarry is developed, to ensure that water levels are maintained at a prescribed level. This would involve the active monitoring of water levels, temperatures, etc. at the monitoring network to identify any significant or short-term changes. Should such changes be observed, it will be necessary to establish their cause. If the changes are attributed to quarry development mechanisms to mitigate the impacts will be identified and implemented.

Although the full scope of this verification program cannot be established at this time, it is reasonable to conclude that monitoring will be more intensive during the initial stages of quarry development and less intensive once the effectiveness of the GRS is verified.

- **Routine Monitoring**

  Since quarry development is staged and various factors such as the depth of excavation will change with time, it will be necessary to continually monitor and if necessary to adjust (or adapt) the GRS as required. The monitoring program will similarly need to be updated as conditions and the hydrologic response to dewatering dictate.

- **Annual Reporting and Review**

  The annual reporting and review provides the 'adaptive' element. An annual report on quarry operations, monitoring and mitigation will be provided to the agencies having jurisdiction, with recommendations to adapt to changing circumstances, if necessary. Annual review will ensure accountability and relevance to environmental controls.

4.4 Fuel and Contingency Plan

Fuels and various lubricants will be stored and used on site. The storage facilities will need to comply with the Gasoline Handling Act and a Spill Contingency Program will need to be developed. Given that few details on the quarry infrastructure requirements are currently available, it is premature to speculate on the scope of the spills contingency program. It is reasonable to conclude that this program will be developed in consultation with the applicable agencies and will be in place when needed.

4.5 Permit to Take Water

Any water takings at the quarry exceeding 50,000 L/day will require a Permit to Take Water (PTTW). The water takings are governed by the Ontario Water Resources Act (Section 34) and the Water Taking and Transfer Regulation (2004), a regulation under the Act. The program is administered by the MOE. As part of the application process, Lowndes Holdings Corp. may be required to undertake additional testing of the aquifer and to undertake additional sampling of the discharge water and the receiving stream. Again, the scope of any additional work will need to be established following consultation with the MOE.

As a condition of its PTTW, Lowndes Holdings Corp. will be required to undertake routine monitoring of the water taken (volume), and of groundwater levels and surface flows. Normal practice is for a PTTW report to be submitted to the MOE on an annual basis.

4.6 Certificate of Approvals for Industrial Sewage Works

The quarry operation will involve the collection, transmission, treatment and disposal of water extracted from the quarry as well as water used in the processing of the stone. Although the 'effluent' generated will largely be made up of clean groundwater and storm runoff, the associated 'works' will need to be approved by the MOE. Lowndes Holdings Corp. will be required to apply for a Certificate of Approval of Industrial Sewage Works under Section 53 of the Ontario Water Resources Act R.S.O. 1990.

The process is comprehensive and requires that an application and supporting documentation be prepared, which fully describe the undertaking, the works to be constructed, and the quantity and quality of the water extracted and released. This will also include the development of a detailed surface water management plan and monitoring program. Reporting requirements will be directed by a condition in the Certificate of Approval.

5. Summary and Conclusions

This Hydrogeological Level 2 report has been prepared to supply the information required to support an application under The Aggregate Resources Act. The report has been prepared by qualified persons (Section 1.3) and addresses the following list of ARA requirements:

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 local geology, hydrogeology, and surface water systems;
i) water budget;
j) impact assessment;
k) mitigation measures including trigger mechanisms;
l) contingency plan; and,
m) monitoring plan.

Supporting data in the form of tables, graphs and figures are provided in Volume 2 Groundwater Flow Model and Volume 3 Appendices. Table 14 presents summary comments and observations regarding the requirements of the provincial Standards, under The Aggregate Resources Act.

Table 14. Summary of Requirements Under The Aggregate Resources Act

Requirements	Location Within Report	Summary Comments
Water Wells	Volume 1, Sections 2.5.3, 3.2 and 4.2, Volume 3, Appendix B	Water wells located in the general vicinity of the property were identified through a search of MOE Water Well Records. Additional information was developed through a reconnaissance survey. The potential impact of the quarry on the residential water wells was characterized and mitigation measures were identified.
Springs	Volume 1, Section 2.2	The Lower Mountsberg Creek Wetland Complex PSW extends onto the subject property. The wetland is fed by overland and shallow groundwater flow, and the water level is the surface expression of the water table in shallow bedrock. Identified springs are monitored.
Groundwater Aquifers	Volume 1, Sections 2.5, 2.6, and 3.1 Volume 3, Appendix G	The primary water-bearing geologic units were identified through a review of available reports and maps, and field investigations. The Amabel Formation is the primary aquifer both regionally and in the vicinity of the property. Pumping tests were undertaken to collect information on the hydrogeologic properties of the aquifer. Water samples were collected and analyzed, to characterize water quality.
Surface Water Courses and Bodies	Volume 1, Section 2.2, 2.6, 3.2 and 4.2, Volume 3, Appendix G	The surface water features were identified and instrumented with flow stations and mini piezometers. Water samples were collected and analyzed. The potential impact of the quarry on the wetlands was characterized and mitigation measures were identified.
Discharge to Surface Water	Volume 1, Sections 3 and 4	Without mitigation it will be necessary to discharge water from quarry dewatering to Mountsberg Creek. It is intended that mitigation measures be implement, which will involve the recirculation of the extracted groundwater via a trench and boreholes. A small portion of this cold groundwater will bleed off to Mountsberg Creek. The impact on the Creek flow and water quality has been assessed.
Proposed Water Diversion, Storage and Drainage Facilities On Site	To be developed	The location and nature of the water diversion, storage and drainage facilities onsite has yet to be defined. This will be undertaken consulting the applicable agencies, during quarry design.
Methodology	Volumes 1, 2 and 3	The methodologies employed are described throughout the three volumes of the report.
Description of the Physical Setting Including Local Geology, Hydrogeology and Surface Water Systems	Volume 1, Section 2	The physical setting was characterized through a review of available information, other Lowndes consultants' studies and field investigation.

Table 14. Summary of Requirements Under The Aggregate Resources Act

Requirements	Location Within Report	Summary Comments
Water Budget	Volume 1, Sections 2.3 and 3.2 and 4.2, Volume 2, Section 3	A detailed water budget was completed as part of the groundwater model. Additionally, water balances were completed to quantify the potential quarry impacts.
Impact Assessment	Volume 1, Sections 3.2 and 4.2, Volume 2	The potential impacts on the Mountsberg Creek PSW and on area wells was evaluated through the use of a groundwater flow model developed for this purpose. Without mitigation the proposed quarry will have an impact on both the PSW and local residential wells. With mitigation, the impacts beyond the development area of the quarry will be eliminated.
Mitigation Measures Including Trigger Mechanisms	Volume 1, Section 4 (trigger mechanisms are to be established)	It is intended that mitigation measures be implement as part of quarry development. These will involve the recirculation of the extracted groundwater via a trench and boreholes. Trigger mechanisms will be established in the Adaptive Management Plan, which is to be developed through consultation with the agencies and municipalities.
Contingency Plan	To be developed	A contingency plan will be included in the Adaptive Management Plan, which is to be developed through consultation with the agencies and municipalities, and a spill contingency plan, described in Section 4.4.
Monitoring Plan	To be developed	A monitoring plan will be included in the Adaptive Management Plan, which is to be developed through consultation with the agencies and municipalities.

Conclusions drawn from the Hydrogeological Level 2 assessment follow:

a) Lowndes Holdings Corp. business objective is to establish a quarry in the Amabel Formation dolostone to supply aggregate. The Amabel dolostone is a high quality aggregate resource, which at the site is overlain by a discontinuous cover (averaging 2.4 m thick) of overburden primarily silt till with local occurrences of organic soils and outwash gravel deposits. From boreholes advanced on the property the Amabel Formation is 27 m and 40 m thick, averaging 32.6 m. Quarrying the dolostone will result in an open excavation that will extend below the water table.

b) The site lies within the upper Bronte Creek Watershed, with the majority of the property falling within the Mountsberg Creek watershed except for the southeast corner, which is within the Flamboro Creek watershed. The Lower Mountsberg Creek Wetland Complex, a Provincially Significant Wetland extends onto the subject property. The wetlands appear to be fed by a combination of overland and shallow groundwater flow from adjacent uplands.

c) The Amabel Formation dolostone is a regionally significant aquifer. The aquifer potential is related to fractures and solution cavities along bedding planes within the rock. Groundwater is extensively used as a source of supply for residences located in the immediate area. The community of Carlisle located about 3.5 km south of the subject property also draws its supply from large capacity wells installed in the Amabel Formation. Pumping tests conducted on wells installed on the subject property confirmed the productivity of the aquifer.

d) The direction of groundwater movement in the shallow and deep portions of the bedrock is to the south. Hydraulic gradients observed in shallow and deep monitoring well pairs, vary across the property, but are for the most part downward.

e) The parker tests and pumping tests were conducted to establish the hydrogeologic properties (hydraulic conductivity and transmissivity) of the Amabel Formation. The horizontal hydraulic conductivity varied from a high of 5.27×10^{-3} m/s to a low of 9.14×10^{-9} m/s. The vertical hydraulic conductivity also varied with, with conductive zones (>10E-5 m/s) identified in many of the boreholes between the elevations of 279 mASL and 274 mASL, 271 mASL and 268 mASL, and 260 mASL and 251 mASL. The average bulk transmissivity and hydraulic conductivity determined for a pumping test conducted in April 2004 are 5.9×10^{-3} m^2/s and 1.4×10^{-4} m/s, respectively

f) Because the quarry excavation will extend below the water table, it will be necessary to dewater the quarry as the excavation expands. This would involve the placement of sumps in the quarry floor to capture seepage and storm runoff, and the use of pumps to extract the seepage water. This dewatering will produce a drawdown cone, the zone of influence of which will expand outward as the quarry is developed. The quarry has the potential to impact on groundwater levels in the area of the Lower Mountsberg Creek Wetland Complex and could reduce the groundwater flux (baseflow) to the wetlands. The flow in Mountsberg Creek will also be affected by the discharge of groundwater/surface water from the quarry.

g) Given the complexities of predicting impacts to a natural system from quarry dewatering, a computer model of the groundwater flow system was developed and employed. Two quarry development scenarios were initially simulated using the model. The initial scenarios were based on conceptual limits for quarry Stage 1 and full excavation, with Stage 1 excavated to an approximate elevation of 272 mASL and the Full Quarry to an approximate elevation of 249 mASL. Although the magnitude of the simulated impact is more pronounced for the full excavation, it was concluded that the un-mitigated development of the Stage 1 quarry, would have an unacceptable impact on the wetlands and on local residential wells. The impact on the Carlisle municipal wells is predicted to be negligible under either scenario.

h) On the basis of this conclusion, it was determined that measures would need to be implemented as the quarry is developed, to mitigate the effects of quarry dewatering. One commonly employed measure at other quarries is the controlled release of the water extracted from the quarry via a trench installed along the perimeter of the quarry development area. The goal would be to maintain groundwater levels at the trench at the predevelopment level. This would in turn maintain the groundwater flux (discharge) to the wetlands. This mitigation measure is referred to herein as a Groundwater Recirculation System or GRS.

i) The feasibility of using a GRS as a mitigation measure was evaluated using the same computer model. Based on the results of the initial simulation runs, it was determined that a trench would not be effective on its own. This is because the dewatering effects would propagate outward from the quarry through the hydraulically conductive zone encountered at mid-depth within the Amabel Formation. This would allow the drawdown cone to expand outward underneath the GRS into the wetlands inducing a downward gradient and loss of groundwater flux to the wetland. Measures to mitigate this effect were examined through additional simulation runs. It was concluded that it would be possible to mitigate the water loss through the conductive zone by maintaining a high hydraulic head in this zone. This was addressed in the simulation by creating a hydraulic connection between the GRS at surface and the conductive zone. In practice, to achieve this hydraulic connection at the site, it would be necessary to drill conduits along the axis of the GRS trench, which extend into the productive zone within the Amabel Formation. Water discharged along the trench would be allowed to drain down the conduits to the conductive zone under gravity. Additional computer simulations established that the GRS trench with drilled conduits would be effective in maintaining the groundwater levels at the perimeter of the property. This in turn would maintain the groundwater flux (discharge) in the wetlands.

j) A water balance was undertaken to account for the water inputs and outputs in the Mountsberg subwatershed and at the quarry. Most of the water discharged to the GRS will be re-circulated into the quarry where it will be extracted and again discharged. A portion of the extracted water would be released to Mountsberg Creek and would supplement flow in the Creek.

k) The discharge water from the quarry will have a distinctly different chemistry from that in the Mountsberg Creek. To assess the potential effect of releasing quarry water to the Creek, groundwater discharge samples and Creek water samples were collected during the November 2004 pumping test. Three parameters (aluminum, iron and zinc) in the groundwater discharge samples approached or exceeded the Provincial Water Quality Objectives (PWQO) that are applicable to surface water. The potential impact on the water quality of Mountsberg Creek would be proportionate to the quantity and quality of the discharge from the quarry. With mixing of the groundwater extracted from the quarry, the average parameter concentrations after release and mixing in Mountsberg Creek would be reduced to below the PWQO.

l) An Adaptive Management Plan (AMP) is to be developed. The AMP involves the installation of a network of monitoring installations and the introduction of a series of triggers that if exceeded would lead to the implementation of the mitigation measures or an adjustment or change to the mitigation. Although the scope of the AMP cannot be fully determined until input is realized from various agencies (including the Municipality, the Conservation Authorities, the MOE and the MNR), it would entail establishing the 'baseline' or ambient condition through an extended period of monitoring. Quarry dewatering induced changes in groundwater levels or surface water stage and flow is compared with the baseline condition to determine the nature and significance of the changes. Where the changes are deemed unacceptable, a contingency is implemented that could involve altering the quarry operation or enhancement of the mitigation measures. This monitoring, review and adjustment process is continuous, hence 'adaptive'.

m) The type of operation proposed for this quarry involves very few sources of potential contaminants. These are primarily limited to fuels and lubricants. If these are handled and stored with normal, reasonable precaution (according to regulations) the risk of a release to the environment is very low. A Spills Contingency Program will be prepared as a standard condition of the Aggregate Resources Act licence.

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