APPENDIX D

HYDROLOGY STUDY

Jacques
Whitford

February 3, 2005 Project 6399

Ms. Janice Comeau
Jacques Whitford Limited
3 Spectacle Lake Drive
Dartmouth, NS
B3B 1W8

Re: Sovereign Resources Inc. Quarry

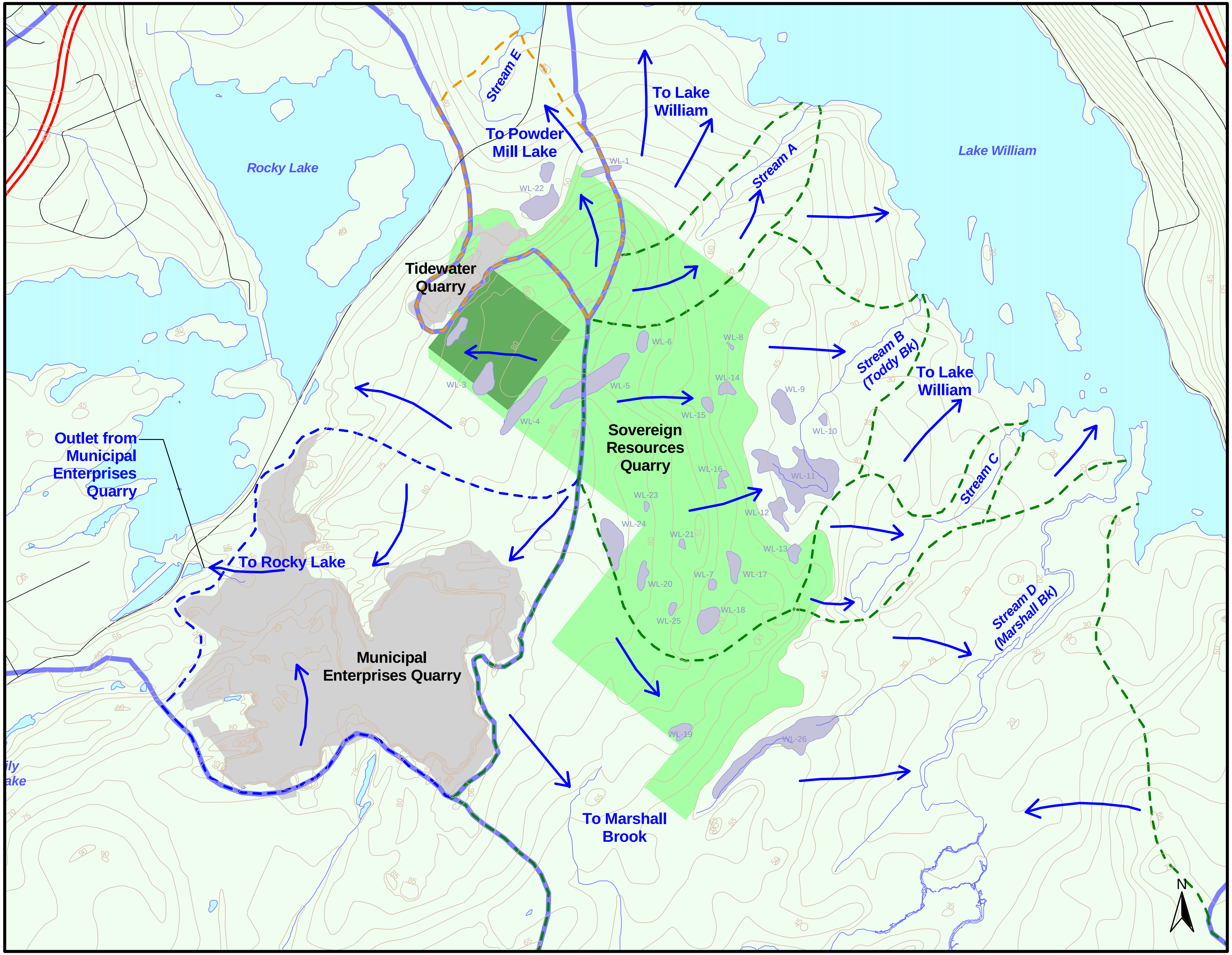
Dear Ms. Comeau:

Hydro-Com Technologies Limited, acting at your request, has performed a review of the *Sovereign Resources Inc.* Rocky Lake Drive Proposed Quarry Expansion. The objective of the review was to determine the hydrologic effects of this expansion. This report has been prepared solely for the project described above and contains a description of our methodologies and our findings.

Site Description

The plan view of the proposed quarry expansion area is presented in Figure 1. The quarry expansion area (*Sovereign Resources Quarry* indicated in green) is approximately 230 ha in size and includes the existing approved Sovereign Resources Quarry (labelled Tidewater Quarry on Figure 1) located in the northwest corner of the proposed site, while the previously approved *Municipal Enterprises* Quarry abuts the western boundary of the proposed expansion area. The proposed expansion area currently drains into three different lakes as shown by the watershed delineations in Figure 1. The largest drainage area (approximately 71% of the proposed expansion area) currently drains east toward Lake William by way of a number of watercourses, namely Stream A (unnnamed), Stream B (Toddy Brook), Stream C (unnamed), and Stream D (Marshall Brook). A smaller drainage area, located in the northwest corner of the property (representing approximately 18 % of the proposed expansion area) flows west directly into Rocky Lake. The smallest drainage area (representing approximately 11% of the proposed expansion area), located in the north corner of the property, flows north toward Powder Mill Lake by way of Stream E (unnamed) and includes the operating Tidewater Quarry.

It is our understanding that quarry development will progress from west to east, starting at the boundary with the approved Municipal Enterprises Quarry. Runoff from the entire proposed expansion area (including the existing Tidewater Quarry) will ultimately flow toward Municipal Enterprises Quarry and into Rocky Lake. Runoff from the site will be directed into one or more retention structures before entering the adjoining Municipal Enterprises properties.



Sovereign Resources Quarry Modification Project Environmental Assessment

Figure 1

Watershed Delineation and Wetland Locations at Proposed Modification Site

Watersheds

▭ Watershed Delineation

Sub-Watersheds

╱╲╱ Lake William Sub -Watershed
╱╲╱ Powder Mill Lake Sub-Watershed
╱╲╱ Rocky Lake Sub-Watershed

→ Runoff flow Direction

Project Features

🟩 Approved Sovereign Resources Quarry
🟩 Proposed Sovereign Resources Quarry Modification Boundary
⬜ Existing Quarry

Topographic Features

╱╲ Elevation Contour (m)
╱╲ Stream
⬜ Lake
⬜ Surveyed Wetland (Labeled by identifier)
☐ Property Boundary

Scale 1:15,000

0 250 500 750

Metres

Map Parameters
Projection: 3° MTM
Datum: ATS77
Zone: 5
Date: February 2005
Project: NSD17650

Jacques Whitford

Figure 1 also presents the locations of twenty (20) wetlands within the proposed expansion area and six (6) wetlands immediately adjacent to the expansion area boundaries. The majority of these wetlands are less than 2.0 ha in size, while only three (3) are larger than 2.0 ha; namely wetlands WL-05 (2.2 ha), WL-11 (4.6 ha), and WL-26 (3.9 ha).

Objectives

Based on our discussions, the objectives for this assignment are as follows:

- estimate the changes in mean annual surface runoff from the site's different drainage areas following ultimate level of quarry development,
- estimate the size and design discharge capacity of the flow retention/siltation structures required for the currently proposed ultimate level of quarry development,
- assess potential effects of the quarry on downstream flows and water quality for the currently proposed ultimate level of quarry development, and
- perform a hydrological evaluation of the wetlands affected by the development.

Methodology

The methodologies that were used to satisfy the above objectives were as follows:

- the expected changes in mean annual runoff volume associated with the ultimate development of the site were estimated using a proration of mean annual flows from a nearby hydrometric station and using values from the MacLaren Atlantic Limited (1980) study,
- the size and design discharge capacity of the required flow retention/siltation structures were determined using a HEC-1 runoff model and the Rational Method,
- the effects on downstream flows and water quality were assessed based on experience with similar developments, and
- the hydrological attributes of the wetlands were evaluated using the relevant sections of the Nova Scotia Department of Environment Wetlands Directive (for wetlands smaller than 2.0 ha) and the North American Wetlands Conservation Council Wetland Evaluation Guide (for wetlands larger than 2.0 ha).

The following physiographic parameters were obtained from the available project mapping:

- area within the proposed quarry development (including Tidewater Quarry): 2.23 km^2;
- drainage slope of the *Sovereign Resources* Quarry following ultimate development: 0.18%,
- time of concentration of the proposed expansion area following ultimate development: 2.15 hrs (129 minutes),
- coefficient of runoff of the proposed development area at the ultimate development condition: 0.65, and

magnitude and suggest that an average annual unit runoff of 951,000 m^3/km^2 or 30.2 $L/s/km^2$ is expected for pre-development conditions.

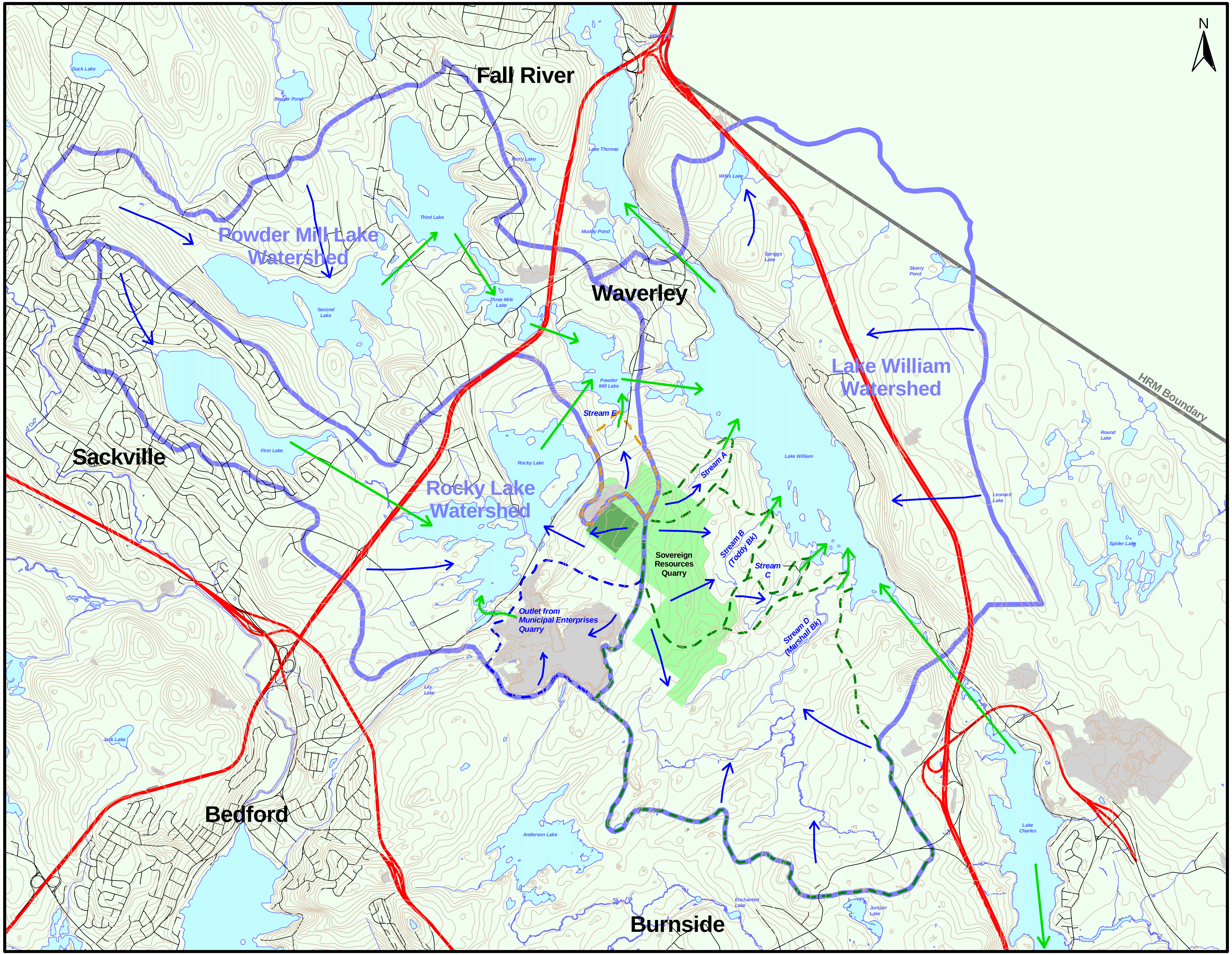
Finally, the expected flows following ultimate development were estimated by increasing the lower bound values by an appropriate amount. Full development of the quarry (without progressive reclamation) will involve the removal of vegetative cover and topsoil. Clearing the land of vegetative cover will reduce interception and temporary storage of precipitation. This hydrologic change will result in more direct runoff from the site, and result in less evapotranspiration (which encompasses both evaporation and transpiration from the soil-plant matrix). Average potential evapotranspiration rates in the area are approximately 500 to 600 mm (Dzikowski et al, 1984). By assuming a reduction in actual evapotranspiration rates of 250 mm, a direct increase in runoff to reflect the currently proposed ultimate level of development was computed. Increases in runoff from the lower bounds of average annual runoff as presented above resulted in an average expected annual unit runoff volume of 1,200,000 m^3/km^2 for ultimate development conditions, which corresponds to a mean annual flow of 38.1 $L/s/km^2$.

Based on the estimations presented above, the annual unit runoff of 951,000 m^3/km^2 or 30.2 $L/s/km^2$ is expected for pre-development conditions and the annual unit runoff of 1,200,000 m^3/km^2 or 38.1 $L/s/km^2$ is expected for ultimate development conditions. These values have been used in determining the expected changes in mean annual flows as presented below.

Changes in mean annual flows

The currently proposed ultimate level of quarry development is expected to reduce the amount of evapotranspiration from the quarry site and increase the volume of mean annual surface runoff. The mean annual runoff of the watercourses in proximity to the proposed expansion area for pre- and ultimate development conditions have been estimated based on the average annual unit runoff values described above. The mean annual runoff estimates following ultimate development assume that the total proposed expansion area (Sovereign Resources Quarry as presented in Figure 1) is fully impacted. Progressive development, involving the revegetation of impacted areas and mitigating increases in runoff has not been considered in this estimation. As such, the estimated changes presented below are likely conservative and overestimate the expected increases in runoff.

Figures 2 and 3 present the watershed delineations for pre- and ultimate development scenarios, respectively. As shown in these figures, the spatial distribution of flows will be impacted as they will be redirected toward Municipal Enterprises Quarry following development. The effects of these developments have been considered for the watercourses and lakes that currently receive flows from the proposed expansion area. As shown in Figures 2 & 3, the receiving watersheds constitute a major lake system, where Rocky Lake discharges into Powder Mill Lake which then discharges into Lake William. Figure 4 presents a schematic of the lake system.



Sovereign Resources
Quarry Modification Project
Environmental Assessment

Figure 2

Watershed Delineation for Pre-development Conditions

Watersheds

- Watershed Boundary

Sub-Watersheds

- Lake William Sub -Watershed
- Powder Mill Lake Sub-Watershed
- Rocky Lake Sub-Watershed

- → Runoff Flow Direction
- → Connection Between Bodies of Water

Project Features

- 🟩 Approved Sovereign Resources Quarry
- 🟩 Proposed Sovereign Resources Quarry Modification Boundary
- ▨ Existing Quarry

Topographic Features

- Elevation Contour (m)
- Stream
- Lake
- ☐ Property Boundary

Scale 1:40,000

0 500 1000 1500 2000

Metres

Map Parameters
Projection: 3° MTM
Datum: ATS77
Zone: 5
Date: February 2005
Project: NSD17650

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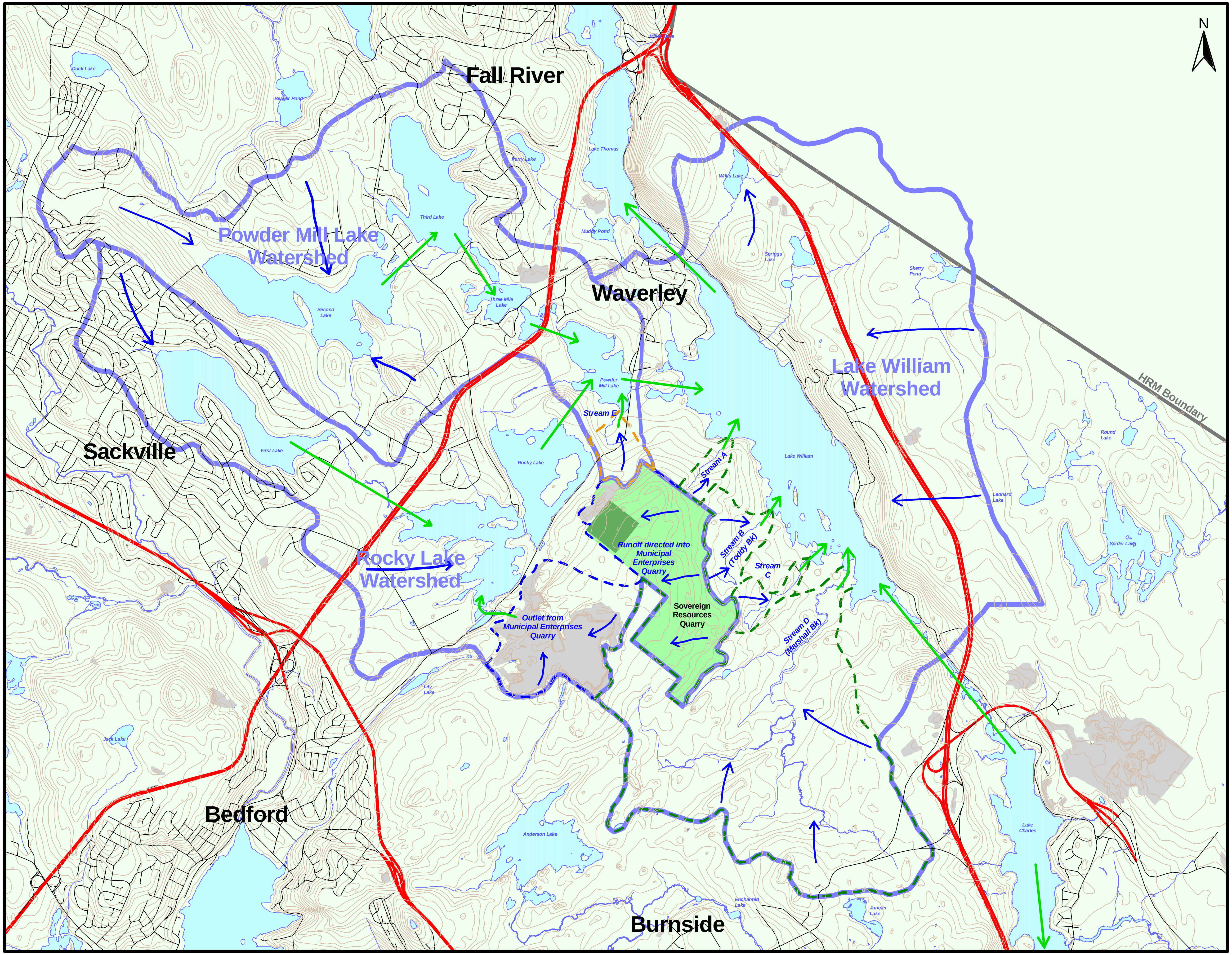

Sovereign Resources
Quarry Modification Project
Environmental Assessment

Figure 3

Watershed Delineations for Ultimate Development Conditions

Watersheds

- ▭ Watershed Boundary

Sub-Watersheds

- Lake William Sub -Watershed
- Powder Mill Lake Sub-Watershed
- Rocky Lake Sub-Watershed

- → Runoff Flow Direction
- → Connection Between Bodies of Water

Project Features

- 🟩 Approved Sovereign Resources Quarry
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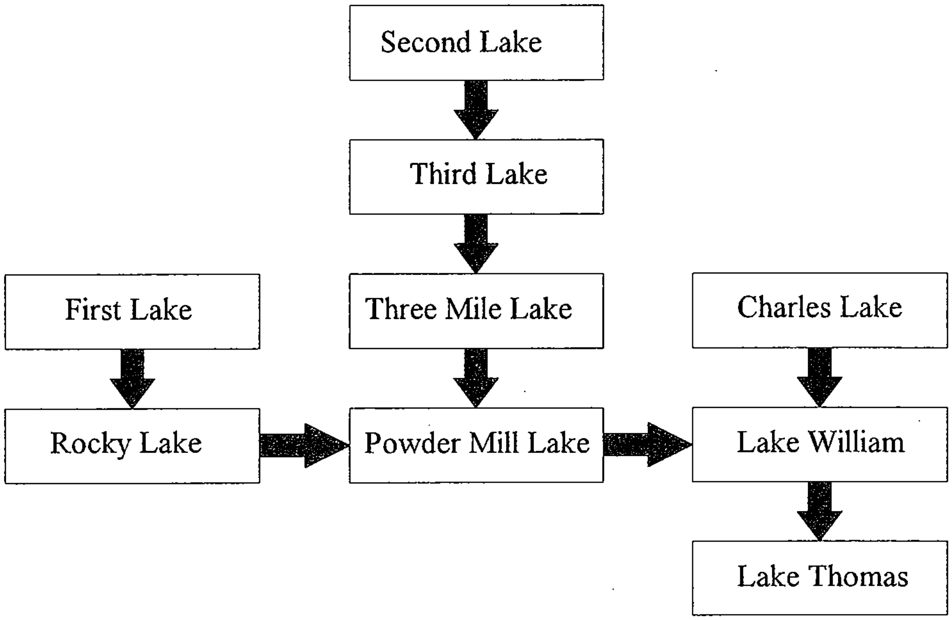

Figure 4 - Diagram of lake system connectivity

Please note that the northern portion of Lake Charles discharges into Lake William, while its southern portion discharges into Micmac Lake. Because of the uncertainty in estimating the drainage area contribution to Lake William, the drainage area associated with Lake Charles has been omitted from the estimation of Lake William's drainage area. This constitutes a conservative approach to estimating flow increases into Lake William associated with the proposed quarry expansion.

As shown in Figure 4, there is substantial surface water storage upstream of Rocky Lake, Powder Mill Lake and Lake William. As such, the drainage area of Lake William is substantially larger than that of Powder Mill Lake and Powder Mill Lake draws from a substantially larger drainage area than Rocky Lake. The absolute values and percent changes to the drainage areas and expected annual runoff volumes following ultimate development are presented in Table 1. Table 1 shows that increases in runoff volume in ultimate development conditions are attenuated in bodies of water with larger drainage areas.

Annual runoff into Rocky Lake from the proposed expansion area is expected to increase due to development of the quarry. During the pre-development conditions, a small portion of the proposed expansion area drained directly into Rocky Lake (approximately 39.6 ha). Following ultimate development, the proposed expansion area will entirely drain into Municipal Enterprises Quarry.

Annual flows at the outlet of Municipal Enterprises Quarry are expected to increase by 150% due to flow redistribution and higher runoff generating potential of the impacted surface area. This increase translates to an expected increase of 45% in annual flows at the outlet of Rocky Lake.

Table 1: Expected changes in drainage areas and annual runoff volumes following ultimate development of Sovereign Resources Quarry.

Watershed/ Subwatersheds	Drainage Areas (km^2)			Annual Runoff Volumes * (x1000 m^3)		
	Pre-Dev.	Ultimate Dev.	% Change	Pre-Dev.	Ultimate Dev.	% Change
Rocky Lake	5.11	6.94	+36	5,130	7,400	+45
Outlet from Municipal Enterprises Quarry	1.59	3.82	+140	1,780	4,460	+150
Powder Mill Lake	10.9	12.5	+15	10,700	12,700	+19
Stream E	0.635	0.386	-39	623	367	-41
Lake William	22.0	22.0	0	21,200	21,700	+3
Stream A	0.410	0.282	-31	390	268	-31
Stream B (Toddy Brook)	1.62	0.57	-65	1,540	542	-65
Stream C	0.357	0.332	-7	340	316	-7
Stream D (Marshall Brook)	3.10	2.72	-12	2,950	2,590	-12

* Volumes are based on Proration from East River and MacLaren Atlantic Ltd (1980).

Annual runoff volumes are expected to decrease at the outlet of Stream E, which discharges into Powder Mill Lake, due to the redirection of a portion of its drainage area toward Municipal Enterprises Quarry. This reduction in drainage area is expected to decrease its annual flows by 41%. However, due to the increased inflow from Rocky Lake, the annual flows at the outlet of Powder Mill Lake are expected to increase by 19%.

Annual runoff volumes are also expected to decrease at the outlets of Stream A, Stream B (Toddy Brook), Stream C, and Stream D (Marshall Brook) due to the redirection of a portion of their drainage areas toward Municipal Enterprises Quarry (see Figures 2 & 3). These decreases in drainage areas are expected to decrease annual flow volumes at Stream A, Stream B (Toddy Brook), Stream C, and Stream D (Marshall Brook) by 31%, 65%, 7% and 12%, respectively. The annual runoff volumes at the outlet of Lake William are expected to increase following ultimate development. Although its total drainage area does not change during development of the quarry expansion area, the annual runoff volumes are expected to increase slightly due the increased runoff generating potential of the impacted area. The increase in annual flows at the outlet of Lake William are however attenuated to 3% above pre-development conditions.

Flow Retention/Siltation Treatment Structures

The criteria that were used to determine the peak design flow and the retention volume associated with the flow retention/siltation structures at the outlet of the proposed expansion area at the currently proposed ultimate level of development are as follows. The peak design flow for one (1) centrally located structure consisted of the peak flow resulting from a 100 year return period storm event, while the minimum pond volume was to be equal to the runoff volume of a 6 hour duration storm event with a 25 year return period. Note that the low lying areas of the quarry floor can provide adequate retention/siltation treatment, provided it meets the runoff volume retention targets.

Based on the Rational Method and HEC-1 modelling, and using a time of concentration of 2.15 hours (129 minutes), the peak flow resulting from a 100 year return period storm event was estimated to have a magnitude of 15.1 m^3/s for the total area of the proposed quarry. Hydraulic control structures which receive total flows from the entire proposed development area at the currently proposed ultimate level of development should thus be designed for a peak flow magnitude of no less than 15.1 m^3/s at the outlet of the proposed expansion area.

Using HEC-1 modelling, the runoff volume resulting from a 6 hour duration storm event with a 25 year return period was estimated to be approximately 83,600 m^3 for the total expansion area . The flow retention/siltation structures (or capacity of quarry floor allowing for water accumulation between the interstices of porous media) should have a volume of no less than 83,600 m^3.

The above estimates are based on one (1) centrally located retention/siltation structure at the outlet of the proposed expansion area and assumes full development of the entire expansion area. The use of a number of retention/siltation structures upstream of the final outlet of the quarry would reduce the peak flow requirements of the retention/siltation structures. Progressive reclamation using revegetation of quarry sections that are no longer actively mined would also reduce the hydraulic requirements of these retention/siltation structures. These retention/siltation structures must be properly sized based on their location within the proposed expansion area and the maximum impacted quarry area within the proposed expansion area.

Effects on Downstream Flows and Water Quality

As previously presented, the removal of vegetation over the proposed expansion area and redirection of flow toward the Municipal Enterprises Quarry will impact annual runoff volumes of the receiving watercourses and lakes. The outlets of the Municipal Enterprises Quarry and Rocky Lake are expected to receive the highest increases in annual runoff volumes following ultimate development.

The quarry development will also result in an increase in the peak rates of surface runoff and potentially a reduction of the low flows at the outlet of Municipal Enterprises Quarry (i.e. without remedial measures, water will run off more quickly following additional quarry development). Considering the expected increases in mean annual runoff and design peak flows following ultimate development, downstream drainage infrastructure, channels and banks of receiving bodies of water may be impacted. Without implementation of remedial measures, a detailed investigation of the capacity of downstream drainage infrastructure and historical water levels would be required to assess the magnitude of the impacts associated with increasing the peak rates of surface runoff at the Municipal Enterprises Quarry outlet.

Remedial measures can however be implemented upstream of the outlet of the Municipal Enterprises Quarry to mitigate these increases in peak flows. These remedial measures include properly sized retention structures and reclamation of inactive quarry areas with vegetation. Retention structures can be sized to attenuate peak flows to pre-development conditions. Reclamation activities will also reduce peak rates and volumes of surface runoff. Either practice or a combination of both can mitigate the potential impact on downstream flows. However, detailed information regarding the quarry pit development and reclamation is required to determine the locations and sizes of the measures required to mitigated the potential impacts of the quarry expansion and operation on the downstream hydrology.

The potential effects of the quarry development on downstream water quality include an increase in the total sediment loading and an increase in chemical parameters associated with the rock being quarried. It is understood that the acid generating potential of the quarried rock will be considered prior to the commencement of the project if necessary. The placement of free-draining material over all disturbed areas and the use of properly sized flow retention/siltation structures (or holding areas along the quarry floor) is expected to fully mitigate the potential increase in downstream sediment loading. Because downstream water quality is most dependent on the amount of freshly exposed rock by quarry operations, rather than the overall quarry size, the effects of the quarry on downstream water quality are expected to be relatively minor and the downstream water quality should return to background levels following the termination of active quarrying operations.

In summary, the mean annual runoff volume and spatial distribution of flows into receiving bodies of water will be affected by quarry development. The expected temporal changes to flows entering Rocky Lake require analysis of the existing drainage capacity downstream or the implementation of proper mitigative measures upstream of the Municipal Enterprises Quarry outlet. However, we believe that the effects on the downstream flows and water quality associated with the currently proposed ultimate level of quarry development can be mitigated using a combination of the placement of free-draining material, implementation of properly sized flow retention/siltation structures and the reclamation of inactive quarry areas. Following the use of these mitigative measures, the remaining residual effects on downstream flows and water quality are expected to be minor.

Wetland evaluation

The wetlands within the proposed quarry development area were hydrologically evaluated using the appropriate guidelines. A total of twenty-six (26) wetlands will be impacted by the proposed development. The comments presented below related to the hydrology of these wetlands are based on mapping, wetland evaluation findings provided by Jacques Whitford Ltd, and observations from the October 5, 2004 field investigation.

Figure 1 shows that the network of wetlands located within the proposed development area is not well defined and lacks inter-connectivity. In addition, the streams drawing water from the two largest wetlands (WL-11 & WL-26) convey little flow. During the site visit, the streams on the eastern side of the proposed development area were discharging little flow following a heavy rainfall event (approximately 37 mm). The largest wetland (WL-11) will be impacted as approximately 76% of its drainage area is located within the proposed expansion area and will no longer contribute flows to the wetland during the ultimate quarry development conditions. The wetland bordering the southern corner of the expansion area (WL-26) will also be impacted by development as approximately 58% of its drainage area is located within the proposed expansion area and will no longer contribute flows to the wetland during the ultimate quarry development conditions. This wetland area includes the largest standing body of water of all impacted wetlands (approximately 0.70 ha). The 1.6 ha wetland bordering the northern side of the proposed expansion area (WL-22), which harbors a species of protected flora, will also be impacted by development as approximately 83% of its drainage area is located within the proposed expansion area and will no longer contribute flows to the wetland during the ultimate quarry development conditions.

Based on these observations, the hydrological and water treatment values of the wetlands are presented below:

Table 2: Wetland assessments based on Nova Scotia Department of Environment Wetland Directive (for wetlands smaller than 2.0 ha)

Wetland Numbers	WL-1, WL-2, WL-3, WL-4, WL-6, WL-7, WL-8, WL-9, WL-10, WL-12, WL-13, WL-14, WL-15, WL-16, WL-17, WL- 18, WL-19, WL-20, WL-21, WL-22, WL-23, WL-24, WL-25
Wetland sizes	Sizes range from 0.038 ha to 1.61 ha
Description	The location of these twenty-three (23) wetlands are presented in Figure 1.
Evaluation process used	NSDOE Wetland Directive
NSDOE Step 4: Surface Flow Regulation	Insignificant due to small size of wetlands and little inflow into wetlands.
NSDOE Step 6: Water Treatment	Insignificant due to lack of upstream development and little inflow into wetlands.

Table 3: Hydrological Evaluation of Wetland 5 based on the North American Wetlands Conservation Council Wetland Evaluation Guide (for wetlands larger than 2.0 ha)

Wetland Values (Wetland 5)				
	Are Criteria Present?	**Level of Criterion Significance**	**Expected Impact of Project upon Wetland Values**	**Describe Function (Provide Highlights only)**
LIFE SUPPORT VALUES: **<u>Hydrological Values</u>** Value of the wetland in contributing to surface and groundwater stocks				
* Does the wetland contribute to recharge of regional water supply aquifers?	N	NA	NA	No regional aquifer water supply.
* Does the wetland provide flood protection benefits?	N	NA	NA	No flood protection value due to minimal drainage area.
Does the wetland contribute to usable surface water?	N	NA	NA	No current water treatment value due to lack of upstream development and little drainage area.
Does the wetland provide erosion control?	N	NA	NA	There is currently little flow into and through wetland.
Does the wetland provide flow augmentation to users through a headwater position in the catchment basin?	N	NA	NA	Insignificant due to size of wetland and lack of downstream users.
*Does the wetland reduce tidal impacts?	N	NA	NA	No tidal influence.

Key:
* Critical Values

Are Criteria Present?
Y = Yes; confirmed presence
L = Likely: data suggests the presence but the presence is unconfirmed
P = Possibly: location and circumstance suggests presence but no data are available
N = No: not present
U = Unknown

Level of Criterion Significance:
N = National
P = Provincial
R = Regional
L = Local
NE = Negligible
NA = Not Applicable

Expected Impact of Project upon Wetland Values:
H = High
M = Moderate
L = Low
NA = Not Applicable

See Pages 52-53 of Wetland Evaluation Guide (NAWCC 1992) for guidance.

Table 4: Hydrological Evaluation of Wetland 11 based on the North American Wetlands Conservation Council Wetland Evaluation Guide (for wetlands larger than 2.0 ha)

Wetland Values (Wetland 11)				
	Are Criteria Present?	**Level of Criterion Significance**	**Expected Impact of Project upon Wetland Values**	**Describe Function (Provide Highlights only)**
LIFE SUPPORT VALUES: Hydrological Values Value of the wetland in contributing to surface and groundwater stocks				
* Does the wetland contribute to recharge of regional water supply aquifers?	N	NA	NA	No regional aquifer water supply.
* Does the wetland provide flood protection benefits?	P	NE	H	Negligible flood protection benefits due to lack of storage capacity of wetland.
Does the wetland contribute to usable surface water?	P	NE	H	Negligible benefits for current surface water usage due to lack of upstream development and of downstream users.
Does the wetland provide erosion control?	N	NA	NA	There is currently little flow into and through wetland.
Does the wetland provide flow augmentation to users through a headwater position in the catchment basin?	P	NE	H	Negligible flow augmentation benefits due to small size of wetland and lack of downstream users.
*Does the wetland reduce tidal impacts?	N	NA	NA	No tidal influence.

Key:
* Critical Values

Are Criteria Present?
Y = Yes; confirmed presence
L = Likely: data suggests the presence but the presence is unconfirmed
P = Possibly: location and circumstance suggests presence but no data are available
N = No: not present
U = Unknown

Level of Criterion Significance:
N = National
P = Provincial
R = Regional
L = Local
NE = Negligible
NA = Not Applicable

Expected Impact of Project upon Wetland Values:
H = High
M = Moderate
L = Low
NA = Not Applicable

See Pages 52-53 of Wetland Evaluation Guide (NAWCC 1992) for guidance.

Table 5: Hydrological Evaluation of Wetland 26 based on the North American Wetlands Conservation Council Wetland Evaluation Guide (for wetlands larger than 2.0 ha)

Wetland Values (Wetland 26)				
	Are Criteria Present?	**Level of Criterion Significance**	**Expected Impact of Project upon Wetland Values**	**Describe Function (Provide Highlights only)**
LIFE SUPPORT VALUES: <u>Hydrological Values</u> Value of the wetland in contributing to surface and groundwater stocks				
* Does the wetland contribute to recharge of regional water supply aquifers?	N	NA	NA	No regional aquifer water supply.
* Does the wetland provide flood protection benefits?	P	L	H	Minimal due to location of wetland in upper section of stream.
Does the wetland contribute to usable surface water?	P	NE	H	Negligible benefits for current surface water usage due to lack of upstream development and of downstream users.
Does the wetland provide erosion control?	N	NA	NA	There is currently little flow into and through wetland.
Does the wetland provide flow augmentation to users through a headwater position in the catchment basin?	P	NE	H	Negligible due to size of wetland and lack of downstream users.
*Does the wetland reduce tidal impacts?	N	NA	NA	No tidal influence.

Key:
* Critical Values

Are Criteria Present?
Y = Yes; confirmed presence
L = Likely: data suggests the presence but the presence is unconfirmed
P = Possibly: location and circumstance suggests presence but no data are available
N = No: not present
U = Unknown

Level of Criterion Significance:
N = National
P = Provincial
R = Regional
L = Local
NE = Negligible
NA = Not Applicable

Expected Impact of Project upon Wetland Values:
H = High
M = Moderate
L = Low
NA = Not Applicable

See Pages 52-53 of Wetland Evaluation Guide (NAWCC 1992) for guidance.

Quarry development within the expansion area is expected to impact all twenty-six (26) wetlands within and adjoining the proposed expansion area. The proposed ultimate development will also impact streams that receive surface water from the wetlands (WL-11 & WL-26). The drainage areas of Streams A, B, C & D are expected to decrease by 0.58%, 4.8%, 0.11%, and 1.7% of the Lake William watershed, respectively, during ultimate development conditions. However, due to the low flow volumes currently expected from the streams, the low storage capacity of the wetlands, and the lack of downstream users along the streams, all wetlands currently have minimal effects on local hydrology and their current water treatment value is minimal.

References

Dzikowski, P.A., G. Kirby, G. Read, W.G. Richards. 1984. *The Climate for Agriculture in Atlantic Canada.* Publication No. ACA 84-2-500. Agdex No. 070. 19 pp.

MacLaren Atlantic Limited. 1980. *Regional Flood Frequency Analysis for Mainland Nova Scotia Streams.* Canada- Nova Scotia Flood Reduction Program. Figure 3.1.

We trust that this satisfies your current requirements. If you have any questions or require additional information, please contact us at your convenience.

Yours truly,

Hydro-Com Technologies Limited

Neil McLaughlin
Neil McLaughlin, M.Sc.E., EIT

Hans Arisz, M.Sc.E., P.Eng.

Hydro-Com
Technologies
a division of R.V. Anderson Associates Limited

445 Urquhart Crescent
Fredericton New Brunswick E3B 8K4 Canada
Tel 506 455 2888 Fax 506 455 0193
Web www.hydro-com.com

June 10, 2005 Project 05-6399

Ms. Janice Ray
Jacques Whitford Limited
3 Spectacle Lake Drive
Dartmouth, NS
B3B 1W8

Re: Sovereign Resources Inc. Hydrology Report review questions

Dear Janice:

Hydro-Com Technologies, acting at your request, has provided additional information on the Sovereign Resources hydrological review report submitted February 3, 2005. This information is provided to clarify questions by environmental regulators (specifically comments from memos addressed by the Nova Scotia Department of Environment and Labour on April 6, 2005 and by Environment Canada on April 22, 2005). This report has been prepared solely for the project described above and addresses the questions indicated below.

1. Details of hydrologic modelling and predictions (NSDEL, point c)

1.1. Peak Runoff Flow

The Rational Method, a common approach, was used to estimate the 100 year design flow from quarry expansion area of 2.23 km^2. This method is based on the following equation:

$$\mathbf{q = 0.0028\ C\ i\ A}, \text{ where:}$$

q is the peak flow (m^3/s);
C is the runoff coefficient;
i is the peak rainfall intensity (mm/hr); and
A is the drainage area (ha).

The approach used in determining the design flow was conservative as it assumes the entire quarry expansion area fully developed. The runoff coefficient (C) used to represent ultimate development soil conditions at the quarry expansion area was 0.65, which is representative of light industrial conditions (Drainage Manual, 1982). This value reflects expected conditions at the quarry, as it is situated between the maximum crop value (0.55) and the value used for asphalt or concrete cover (0.83). The quarry floor is expected to be a hard compacted surface, but will provide some infiltration into the underlying bedrock and detention in uneven surface areas. In this exercise the C value was further increased by 25% to reflect the expected increase in peak flows during a 1:100 year rainfall event as is recommended by the Rational Method (Drainage Manual, 1982).

The rainfall intensity (i) is determined based on the expected time of concentration. The Bransby-Williams Formula was applied to determine this time of concentration:

$$\mathbf{T_c = 0.605\ L/(S^{0.2}\ A^{0.1})}\text{, where:}$$

T_c is the time of concentration (hrs)
L is the gross length of main channel head of basin (km)
S is the net slope of main channel (%)
A is the watershed area (km^2)

The time of concentration was estimated to be 2.15 hours (or 129 minutes). Using the intensity duration frequency data for Halifax (based on a record period of 23 years), the peak intensity of a 1:100 year rainfall event was estimated to be 29.9 mm/hr.

Using the parameters described above, the 1:100 year design flow was estimated to be 15.1 m^3/s.

1.2. Retention Structures

The runoff retention structures were sized based on the standard practice of determining the runoff volume generated from the 6 hour duration 25 year return period storm event. The HEC-1 runoff model (U.S. Army Corps of Engineers, 1981) with its SCS Curve Number runoff generation algorithm was used to determine the runoff volume from the quarry expansion zone. The model was calibrated to a CN value of 78 which is representative of hard surfaces over soils of Hydrological Groups "A" and "AB" (Drainage Manual, 1982). These soil groups include sands and coarse loams overlying limestone bedrock and represent the expected conditions at the site.

Using the parameters described above, the 6 hour duration storm event with a 25 year return period was estimated to be 83,600 m^3.

2. Sensitivity of the models (NSDEL, point d)

A sensitivity analysis of the model was not performed to address this point. Performance of sensitivity analysis on the model results without detailed knowledge of the actual pond sizing and development plans cannot be used for design purposes, and may not accurately reflect expected site conditions. A more refined modeling exercise is recommended during the construction phase of the project for proper sizing of the retention structures given adequate knowledge of the upstream development.

3. Nova Scotia Projections and Trends (NSDEL, point e & EC)

The Earth's climate system has demonstrably changed on both global and regional scales since the pre-industrial era, with some of these changes attributable to human activities. There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities (IPCC W.G. I, 2001). An increasing body of observations gives a collective picture of a warming world and other changes in the climate system. Globally averaged annual precipitation is projected to increase during the 21st century (IPCC W.G. I, 2001).

Hengeveld (2000) stated the results of experiments into future climate change with advanced models confirm what earlier models indicated: that the probability of extensive climate change was both real and imminent. He stated that the output of the Canadian general circulation model (CGCM1) indicated an increase in average global precipitation over the next century, although there was considerable variation from region to region. By 2090, precipitation over most of Canada and northern Eurasia was predicted to increase by 10% to 20%, with most of these increases occurring during winter. All regional projections are subject to considerable uncertainty and should be used with caution.

Precipitation is the main driver of variability in the water balance over space and time, and variations in precipitation over daily, seasonal, annual, and decadal time scales affect hydrological variability within a drainage basin (IPCC W.G. II, 2001) Changes in precipitation have important hydrologic implications. Climate variability from year-to-year affects the frequency of both high and low flows. High flows are also affected by changes in short-term rainfall intensity and duration. Generally, potential changes in intense rainfall frequency are difficult to infer from global climate models, but there are indications that the frequency of heavy rainfall events generally is likely to increase with global warming. The following paragraphs present findings from a number of research studies which address changes in hydrology in Atlantic Canada.

In cool temperate areas, such as Nova Scotia, a smaller proportion of winter precipitation will likely fall as snow, so there will be proportionately more runoff in winter and, as there will be less snowmelt, less runoff during spring (IPCC W.G. II, 2001).

Clair and Ehrman (1996) examined the implications of a 3°C rise in temperature coupled with various scenarios of precipitation using historical climate and hydrologic data for 15 wetland-influenced Atlantic Canada rivers. The temperature change combined with precipitation changes of –20%, 0% and +20% yielded discharge estimates of –29%, -10% and +9.5%, respectively.

Bruce (2002) stated there has been a small increase in precipitation throughout the Atlantic Provinces, mainly due to greater cold season snowfall, with a greater fraction of total precipitation since about 1940 falling in heavy rain and snow events. Since the trend of an increase in the frequency of shorter duration (one day or less) heavy rainfalls in spring and early summer is projected to continue, drainage facilities will be more frequently overtaxed. Bruce (2002) said that the costs of expanding drainage capacities must be weighed against projected costs of more frequent flooding, with return periods of severe events projected to be cut in half (e.g. 10-year storm becoming 5-year storm by the latter half of this century) and that soil erosion preventive measures should also be re-examined.

Swansburg et al. (2004) estimated that for a scenario of ~ 3 x CO_2 by 2100, annual precipitation in Atlantic Canada would increase by 9% to 48% in the 21st century. Average summer discharge, however, is expected to decrease at all stations, presumably due to increased evaporative loss. Swansburg et al. (2004) stated that precipitation is an inherently heterogeneous variable, where large differences in local precipitation patterns are common, and therefore is difficult to model on a large scale and as a result, precipitation scenarios have a greater degree of uncertainty associated with them.

Lines et al. (2005) utilized the Statistical Downscaling Model (SDSM, a regional modelling approach) to construct suites of downscaled climate variable projections at 14 selected sites in Atlantic Canada. The study examined SDSM downscaled values for daily maximum temperature, daily minimum temperature, and total daily precipitation, which were compared internally to synthesized data, as well as to non-downscaled values taken directly from the CGCM1 model output. Among the fourteen stations were Kentville and Shearwater in Nova Scotia. Downscaled projections show that a 5% to 15% increase in annual precipitation could occur in the tri-decadal periods centered on the 2020s and 2050s. The SDSM model results for Kentville show an increase in precipitation during the winter, summer and autumn seasons, but a decrease in precipitation during the spring season. Lines et al (2005) stated that monthly and seasonal projections for each climate variable showed considerable variability, and that the monthly or seasonal results at each station might be unique to that site.

The information about climatic change currently available generally indicates more precipitation including frequent high-intensity events, although uncertainties exist concerning the magnitude of precipitation and runoff changes due to climatic change. Nevertheless it seems that the design criteria should include provisions to handle greater precipitation, perhaps by equating future design flows for a specific recurrence interval to the flow with double that return period flow today, as suggested by Bruce (2002), or by applying a 15% increase to the design storm as suggested by Watt et al. (2003).

According to Kije Sipi Ltd (2001), increases in peak design flows associated with a 15% increase in rainfall intensities are a function of the design methodology used, and are estimated to be approximately 17% using the Rational Method and 27% using hydrograph based methods. Increases in runoff volumes associated with a 15% increase in rainfall intensities are a function of the design methodology used, and are estimated to be 15% using the Rational Method and approximately 20% using hydrograph based methods.

In this respect, during the 50-year lifetime of the Sovereign Resources Quarry project:

- high-intensity precipitation is expected to increase in frequency and magnitude,
- the 1:100 year design flows is expected to increase by 15% to 27%, and
- the 6 hour–25 year runoff design volume is expected to increase by 15% to 20%.

Considering the most current information regarding the effects of climate change on drainage infrastructure as discussed above, the effects of climate change on the increase in design flows and volumes should be considered when sizing permanent hydraulic and retention structures for the Sovereign Resources Quarry project. To be conservative, design flows will be increased by 27% and design volumes by 20% during the final design stage of the project.

4. Effects of Retention Structure Failure (NSDEL, point g)

The potential hydraulic consequences from failure of the retention structure were investigated by flood routing. The calculations assumed an instantaneous release of the entire 83,600 m^3 maximum storage volume of the retention structure into Rocky Lake. This discharge rate is considered a worst case scenario, as it is likely that the storage of 83,600 m^3 is distributed among a number of retention structures. A conceptual plan of the hydraulic network used for flood routing is presented in Figure 1.

The flow from the retention structure storage volume has been routed sequentially through Rocky Lake, Channel I, Powder Mill Lake, Channel II and finally into Lake William. The expected mean annual flows following ultimate development have been assumed as the initial flow and water level conditions. These mean annual flows into Rocky Lake and Powder Mill Lake, as previously presented in Table 1 of the February 3, 2005 report, are approximately 0.240 m^3/s and 0.403 m^3/s respectively for ultimate conditions. Because there is concern for remobilization of contaminants within Powder Mill Lake, the increase in peak flows at the outlet of Rocky Lake as a result of the retention structure failure is presented and compared to the range of existing flows using flow-duration analysis.

The following physiographic parameters used were obtained from available project mapping and from field survey information collected by Jacques Whitford personnel:

- Surface area of Rocky Lake: 0.565 km^2.
- Drainage area of Rocky Lake in pre-development conditions: 5.11 km^2.
- Length and slope of channel at outlet of Rocky Lake: 1,270 m @ 1.1% slope.
- Width of rectangular channel at outlet of Rocky Lake: 1.7 m
- Depth of rectangular channel (to top of bank) at outlet of Rocky Lake: 0.7 m

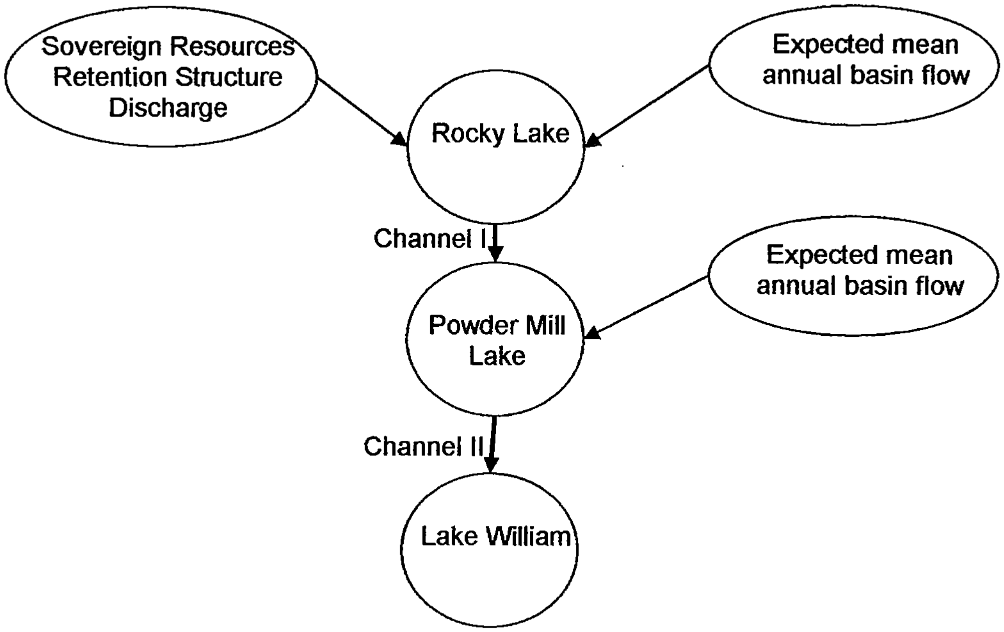

Figure 1: Conceptual Plan of Flood Routing

By means of the flow routing analysis described above, a peak flow of 0.66 m^3/s at the outlet and an increase in water level of 0.15 m within Rocky Lake were computed as worse-case scenario hydraulic effects following potential retention structure failure at ultimate development levels.

The expected peak flow at the Rocky Lake outlet following potential retention structure failure was compared to the current distribution of annual flows within Rocky Lake using flow-duration analysis (based on pre-development drainage areas). The ACFA (version 1.0) computer software was used to develop discharge frequency curves based on data sets of daily flows during the spring season (March 15 – June 15) and for the entire year at Rocky Lake (see Appendix A). The daily flow data sets were established by drainage-area based proration from a nearby hydrometric station (East River at St. Margaret's Bay, 01EH003 (1925-1995)), whose drainage area is 26.9 km^2.

Based on flow-duration analysis, it was found that the expected peak flow of 0.66 m^3/s at the Rocky Lake outlet following a breach of the retention structure is exceeded within the current range of flows approximately 2.6 % of the time (or 2.4 days) during the spring season and 1.8 % of the time (or 6.5 days) during the entire year.

Given the results of the flood routing exercise, a worse-case scenario failure of the retention structure may cause temporary increase in flows and water levels in Rocky Lake. However, the magnitude of the expected increases remain within the "normal" distribution of existing flows and water levels in the lakes. For this reason, a contingency plan to prepare for retention structure failure is not deemed necessary.

5. Options for hydrologic monitoring (NSDEL, point h)

Hydrologic monitoring is considered useful in long term studies for detailed modelling purposes or for quantifying contaminant loading within runoff discharge.

Models can be calibrated to closely mimic field collected flow data when large data sets of continuous flow data are available. A model can allow for investigation of effects of changes in local hydrological parameters. A large degree of effort is however required to properly calibrate and run these models and may not be relevant given the level of accuracy of runoff model predictions and uncertainty in determining the hydrologic parameters.

The changes in land use within the Sovereign Resource Quarry development area will be difficult to model as soil surface conditions are heterogeneous and difficult to accurately characterize. In addition, the expected changes in storage patterns and flow distribution within the quarry during its lifetime increase the complexity of the modelling exercise and its transient nature will require ongoing recalibration. As a result, models that do not require field calibration are expected to be as accurate in predicting changes in flow patterns following development of the quarry expansion area. Thus, collection of flow data is not expected to significantly improve the accuracy of the model results and we, accordingly, do not recommend flow data collection within the Sovereign Resources Expansion area.

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7. Signature

We trust that this satisfies your current requirements. If you have any questions or require additional information, please contact us at your convenience.

Yours truly,

Hydro-Com Technologies

Neil McLaughlin

Neil McLaughlin, M.Sc., P.Ag, EIT

Hans Arisz, M.Sc.E., P.Eng.

APPENDIX A: OUTPUT FLOW DURATION CURVES FROM ACFA COMPUTER SOFTWARE

Figure A-1: ACFA output file based on daily flows from Rocky Lake during spring season (March 15 – June 15)

ACFA Version 1.0

Analysis carried out : June 6th, 2005 at 3:04 PM
Transfer made from station East River at St. Margaret's Bay {area 26.90Km^2} to basin Rocky Lake {area 5.11Km^2}.
The DISCHARGES in the table are for a SPECIFIC PERIOD: Day ###. to Day ###. 75.000 166.0000

	discharge	frequency
1	0.010	100.000
2	0.011	99.953
3	0.013	99.938
4	0.015	99.922
5	0.018	99.891
6	0.021	99.767
7	0.024	99.643
8	0.028	99.348
9	0.032	98.665
10	0.038	97.655
11	0.044	96.025
12	0.051	94.348
13	0.059	91.304
14	0.068	87.314
15	0.080	82.686
16	0.092	76.227
17	0.107	69.860
18	0.125	62.857
19	0.145	55.404
20	0.169	47.360
21	0.196	38.416
22	0.228	30.792
23	0.264	22.748
24	0.307	17.143
25	0.357	11.941
26	0.415	8.230
27	0.482	5.885
28	0.561	3.789
29	0.651	2.655
30	0.757	1.755
31	0.880	1.102
32	1.022	0.792
33	1.188	0.606
34	1.381	0.373
35	1.604	0.217
36	1.864	0.093
37	2.167	0.078
38	2.518	0.047
39	2.926	0.047
40	3.400	0.031
41	3.951	0.000

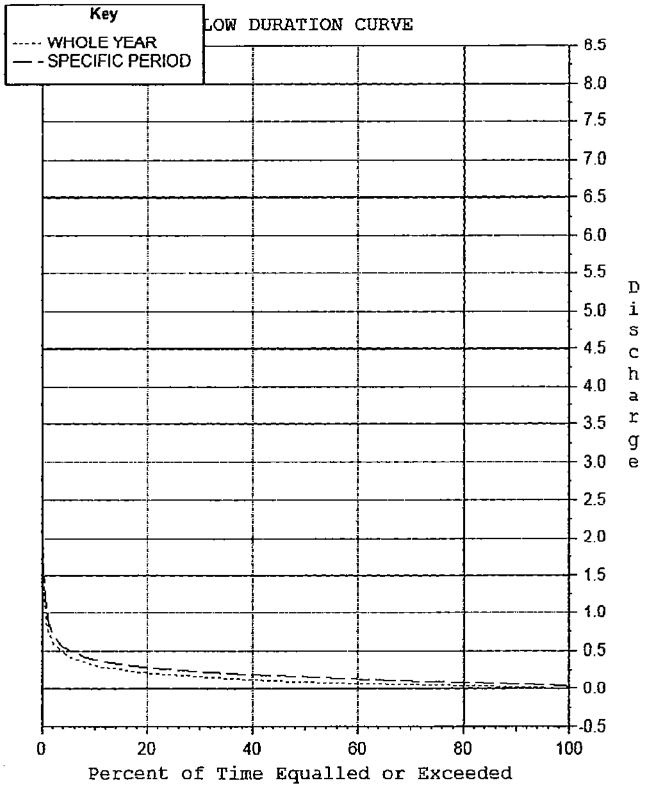

Figure A-2: ACFA output file based on daily flows from Rocky Lake during entire year

ACFA Version 1.0

Analysis carried out : June 6th, 2005 at 3:02 PM
Transfer made from station East River at St Margaret's Bay {area 20.90Km^2} to basin Rocky Lake {area 5.11Km^2}.
The DISCHARGES in the table are for a WHOLE YEAR

	discharge	frequency
1	0.000	100.000
2	0.000	99.981
3	0.000	99.981
4	0.000	99.981
5	0.000	99.981
6	0.000	99.981
7	0.000	99.981
8	0.000	99.981
9	0.000	99.969
10	0.000	99.969
11	0.000	99.961
12	0.001	99.942
13	0.001	99.926
14	0.001	99.727
15	0.002	99.536
16	0.002	99.330
17	0.003	98.959
18	0.005	98.336
19	0.006	97.455
20	0.009	95.776
21	0.012	93.164
22	0.017	90.195
23	0.023	87.140
24	0.032	82.237
25	0.044	75.296
26	0.061	67.237
27	0.084	56.181
28	0.116	43.741
29	0.161	31.551
30	0.222	18.835
31	0.307	10.296
32	0.424	5.082
33	0.585	2.241
34	0.808	0.963
35	1.116	0.429
36	1.542	0.156
37	2.129	0.055
38	2.941	0.019
39	4.063	0.004
40	5.611	0.004
41	7.750	0.000