APPENDIX E. WATER BALANCE

Memorandum

December 13, 2019

To:	Andy Walters	Ref. No.:	11204334
	AJB		
From:	Andrew Betts/aj	Tel:	519-340-4101

Subject: Gillis Lake Quarry – Water Balance Analysis

1. Background

The following technical memorandum summarizes the water balance assessment completed for the proposed Gillis Lake Quarry Expansion (Project) located near Portage, Nova Scotia. The proposed quarry expansion are (i.e. the Quarry Development Area) includes an additional 9.34 hectares (ha) of land. There are two streams (Watercourse 4 and Watercourse 5) and extensive drainage system within the Quarry Development Area, with the majority of the drainage heading off site to the south. A portion of the drainage flows west to road drainage, and a small amount of drainage from the north flows east. MacDonalds Brook is the watercourse located to the east of the Project Site that receives a small portion of flow from Watercourse 4 and Watercourse 5.

The water balance presented here is a preliminary assessment of the predicted effects on surrounding surface waterbodies caused by development of the quarry area expansion. Two site conditions were analyzed; existing (baseline) conditions and end-of-quarry (EOQ) conditions. EOQ conditions consider the quarry expansion at full development of approximately 41 ha.

Due to the range of infiltration rates possible and associated changes in surface water movement caused by quarry development, the water balance assessment was completed for two infiltration potential scenarios for the EOQ situation. The two infiltration scenarios represent the range of possible outcomes from existing infiltration (most likely infiltration) to 100% impervious.

1.1 Data Collection

1.1.1 Climate Data

Precipitation totals were obtained from the Environment Canada Sydney A Climate Station (Climate ID 8205700) from 1981-2010. This station was selected based on its proximity to the Project Study Area, approximately 31 km from the Study Area, and relatively long record. Monthly potential evapotranspiration normals were calculated using the Hamon equation (1961) (Lu et al., 2005). The Hamon equation requires monthly average hours of daylight and monthly average temperature as input. Monthly average hours of daylight were calculated for the Study Area using the Sunrise and Sunset Calculator (https://www.timeanddate.com/sun/, last accessed 24 September 2019). Monthly average temperature

values were obtained from the Environment Canada Sydney A Climate Station. Table 1.1 presents temperature, total precipitation and evaporation rates that are used in the analysis.

Table 1.1 Climate Normals (Data taken from Sydney Environment Canada Climate Station)

	January	February	March	April	May	June	July	August	September	October	November	December
Temperature[1] (°C)	-5.4	-5.9	-2.6	2.5	7.9	13.2	17.9	18	14	8.5	3.8	-1.5
Precipitation[1] (mm)	152.5	128.1	130	133.3	103.2	96.9	88.5	100.2	118.7	142.9	156	167
Evaporation[2] (mm)	0.0	0.0	0.0	0.0	89.9	102.0	117.8	96.1	69.0	40.3	0.0	0.0
Potential Evapotranspiration	0.0	0.0	0.0	33.7	52.5	73.4	97.6	90.0	60.9	39.1	25.4	0.00

Notes:

1 Values obtained from the Sydney climate station 8205700

2 Evaporation was determined using the Hamon equation (1961), (Lu et al., 2005) for Potential Evapotranspiration

2. Methodology

GHD developed a preliminary water balance assessment to assess the potential environmental impacts of the proposed Project expansion from existing conditions to EOQ conditions. The assessment was developed to determine the yearly changes to flow composition during an average year for the two site conditions, and two impervious scenarios mentioned previously.

2.1 Watershed Delineation

The area surrounding the Study Area was delineated into three (3) watersheds: Outfall 1 (177.5 ha), Outfall 2 (71.0 ha) and Outfall 3 (144.8 ha) using a combination of aerial imagery, field investigation and topographical data sourced from GeoNova Scotia Elevation Dataset. Watershed delineations are presented based on two life-cycle phases of the proposed quarry: Figure 1, Baseline Watershed Delineation and Figure 2, End of Quarry Watershed Delineation. During EOQ, water which falls on the quarry is discharged to the Outfall 2 and downstream receiver (Outfall 1).

2.2 Evaporation & Evapotranspiration Potential

Evaporation describes the process of the return of moisture to the atmosphere from open water and land surfaces. The magnitude of evaporation or evapotranspiration over time is a function of the climate, soil and the vegetation in the area. Evaporation rates tend to peak in the summer months when temperatures are highest, daylight hours are longest, sun intensity is greatest and the growing season is at its peak.

Evapotranspiration rates were calculated using the Hamon equation (1961) as described in Section 1.1.1 based on average monthly temperature and daylight hours. The total potential evapotranspiration rate used for this water balance is 472.57 mm per year. Table 1-1 provides a summary of the potential evaporation rates used as a water loss parameter in the water balance assessment on a monthly basis.

2.3 Infiltration Factor

The water storage/infiltration has been estimated using the infiltration factors taken from Table 3.1 from the Ontario Ministry of Environment, Conservation and Parks (OMECP) SWM planning and Design Manual (2003). The infiltration factors are used to determine the fraction of water surplus that infiltrates into the ground and the fraction that runs off to nearby streams. The infiltration factors cover a wide range of soil types, topography and land cover that is applicable for use in Nova Scotia and the Study Area. Each watershed was individually analyzed to determine the slope, land use and soil type drainage factors. If multiple slope or land use segments existed within a watershed an area-ratio method was used to determine the appropriate infiltration factor. During existing conditions the watersheds in the Study Area were determined to be hilly land (0.1 infiltration factor) with woodland (0.2) and open Sandy Loam soil (0.4). The soil in the area was determined through the Nova Scotia Soil Survey of Cape Breton Island and is classified as Thom, a sandy loam till with good drainage (Soil Survey Reports for Nova Scotia, Reprinted 1981).

Two scenarios were assessed for the infiltration conditions during baseline and EOQ conditions; an impervious quarry floor where no infiltration occurred through the bed of the quarry; and a pervious quarry floor consisting of similar infiltration capabilities to existing surficial soils (Sandy Loam). Due to the well-drained nature of the surficial soils it is unlikely the soil will have greater infiltration at the base of the quarry than the existing surface. As such, these two scenarios present the maximum and minimum values for expected infiltration in the quarry. These two scenarios provide a range of potential outcomes as a result of quarry development. New infiltration parameters for these scenarios were computed based on an area-ratio method.

End of Quarry conditions were expected to be similar to existing conditions with the exception of Flat Land (0.3) and Cultivated Land (0.1) in the area where the quarry was located. An area-ratio method was applied to determine the appropriate infiltration factor for slope and land use in the watersheds with multiple different slope and land use segments. This was mostly used for the watersheds containing the proposed quarry.

Runoff volumes for this water balance were assumed to equal the total precipitation less the evaporation and infiltration. Groundwater recharge was not included in this water balance.

3. Results

Table 3.1, Table 3.2, and Table 3.3 present the annual water balance analysis during existing and EOQ conditions (Pervious and Impervious) respectively. Table 3.6 and Table 3.7 display the percentage change in area, runoff and infiltration from existing conditions to EOQ conditions respectively. A negative represents a decrease in the value compared to existing condition and a positive value represents an increase in the value compared to existing conditions.

Table 3.1 Existing Condition Annual Water Balance

Catchment	Area (ha)	Runoff (m^3)	Evaporation (m^3)	Potential Evaporation (m^3)	Infiltration (m^3)
Outfall 1	177.50	500,061	6,387	832,949	1,046,538
Outfall 2	71.00	175,275	0	335,524	443,364
Outfall 3	144.80	441,587	66,963	622,845	820,089

Table 3.2 End-of-Quarry (Impervious) Annual Water Balance

Catchment	Area (ha)	Runoff (m^3)	Evaporation (m^3)	Potential Evaporation (m^3)	Infiltration (m^3)
Outfall 1	187.40	564,784	6,387	910,007	1,000,093
Outfall 2	80.90	218,991	0	395,464	456,562
Outfall 3	135.00	394,559	66,963	596,373	732,753

Table 3.3End-of-Mine (Pervious) Annual Water Balance

Catchment	Area (ha)	Runoff (m^3)	Evaporation (m^3)	Potential Evaporation (m^3)	Infiltration (m^3)
Outfall 1	187.40	496,477	6,387	910,007	1,068,400
Outfall 2	80.90	185,213	0	395,464	490,339
Outfall 3	135.00	394,559	66,963	596,373	732,753

Table 3.4 End of Quarry Impervious Conditions comparison to Existing Conditions

Catchment	% Area Change	% Runoff Change	% Infiltration Change
Outfall 1	5.58%	12.94%	-4.44%
Outfall 2	13.94%	24.94%	2.98%
Outfall 3	-6.77%	-10.65%	-10.65%

Table 3.5 End of Quarry Pervious Conditions comparison to Existing Conditions

Catchment	% Area Change	% Runoff Change	% Infiltration Change
Outfall 1	5.58%	-0.72%	2.09%
Outfall 2	13.94%	5.67%	10.60%
Outfall 3	-6.77%	-10.65%	-10.65%

4. Conclusions

The results from the water balance analysis can be used to assess the potential impact of the proposed quarry development on the receiving environment in terms of the change in runoff volume discharged to the surrounding watercourses.

Outfall 1 is the largest catchment and includes all of Outfall 2 subcatchment (Quarry) within its boundaries. The catchment increases in contributing area with the quarry expansion by approximately 5.58%. Due to the increase in area and land use type there is a corresponding change in annual runoff and infiltration for both EOQ scenarios. An increase of 12.94% for runoff and a decrease of 4.44% of infiltration is seen during Impervious-EOQ conditions. A decrease of 0.72% for runoff and an increase of 2.09% of infiltration is seen during Pervious-EOQ conditions. It is likely that the actual changes to runoff and infiltration will be somewhere within the range estimated for Impervious-EOQ and Pervious-EOQ. As the increases and decreases are relatively small (other than the increase in runoff during Impervious-EOQ) it is unlikely there will be an adverse impact to the Outfall 1 watershed. A mitigation option for the potential increase in runoff of 12.94% during Impervious-EOQ scenario would include settling pond outlet controls at the downstream portion of the Quarry.

Outfall 2 is comprised of the Quarry footprint and an off-site drainage area upstream of the Quarry. The catchment increases in contributing area with the quarry expansion by approximately 13.94%. Due to the increase in area and land use type there is a corresponding change in annual runoff and infiltration for both EOQ scenarios. An increase of 24.94% for runoff and an increase of 2.98% of infiltration is seen during Impervious-EOQ conditions. An increase of 5.67% for runoff and an increase of 10.60% of infiltration is seen during Pervious-EOQ conditions. It is likely that the actual changes to runoff and infiltration will be somewhere within the range estimated for Impervious-EOQ and Pervious-EOQ. As the increases and decreases are relatively small (other than the increase in runoff during Impervious-EOQ) it is unlikely there will be an adverse impact to the Outfall 2 watershed. A mitigation option for the potential increase in runoff of

24.94% during Impervious-EOQ scenario would include settling pond outlet controls at the downstream portion of the Quarry.

Outfall 3 catchment area is mainly located outside of the Project Site. This catchment contains numerous watercourses and contributes the vast majority of the water to the main receiver to the east of the Study Area, MacDonalds Brook. The changes to Outfall 3 are a direct result of the quarry expansion removing contributing drainage area. As such, Outfall 3 experiences a decrease in watershed area of 6.77%. Additionally, since none of Outfall 3 is wilthin the Quarry area infiltration parameters do not change from existing conditions and a decrease of infiltration volume by approximately 10.65% is estimated to occur during both EOQ scenarios. A potential decrease of 10.65% in runoff volume is estimated to occur during both EOQ scenarios.

5. References

Lu et al. (2005). A comparison of six potential evapotranspiration methods for regional use in the southeastern United States. Journal of the American Water Resources Association, 41, 621-633

Ministry of the Environment. (2003). Stormwater Management Planning and Design Manual.

Soil Survey Reports for Nova Scotia. Soil Survey of Cape Breton Island (Reprinted 1981) (1963). http://sis.agr.gc.ca/cansis/publications/surveys/ns/index.html

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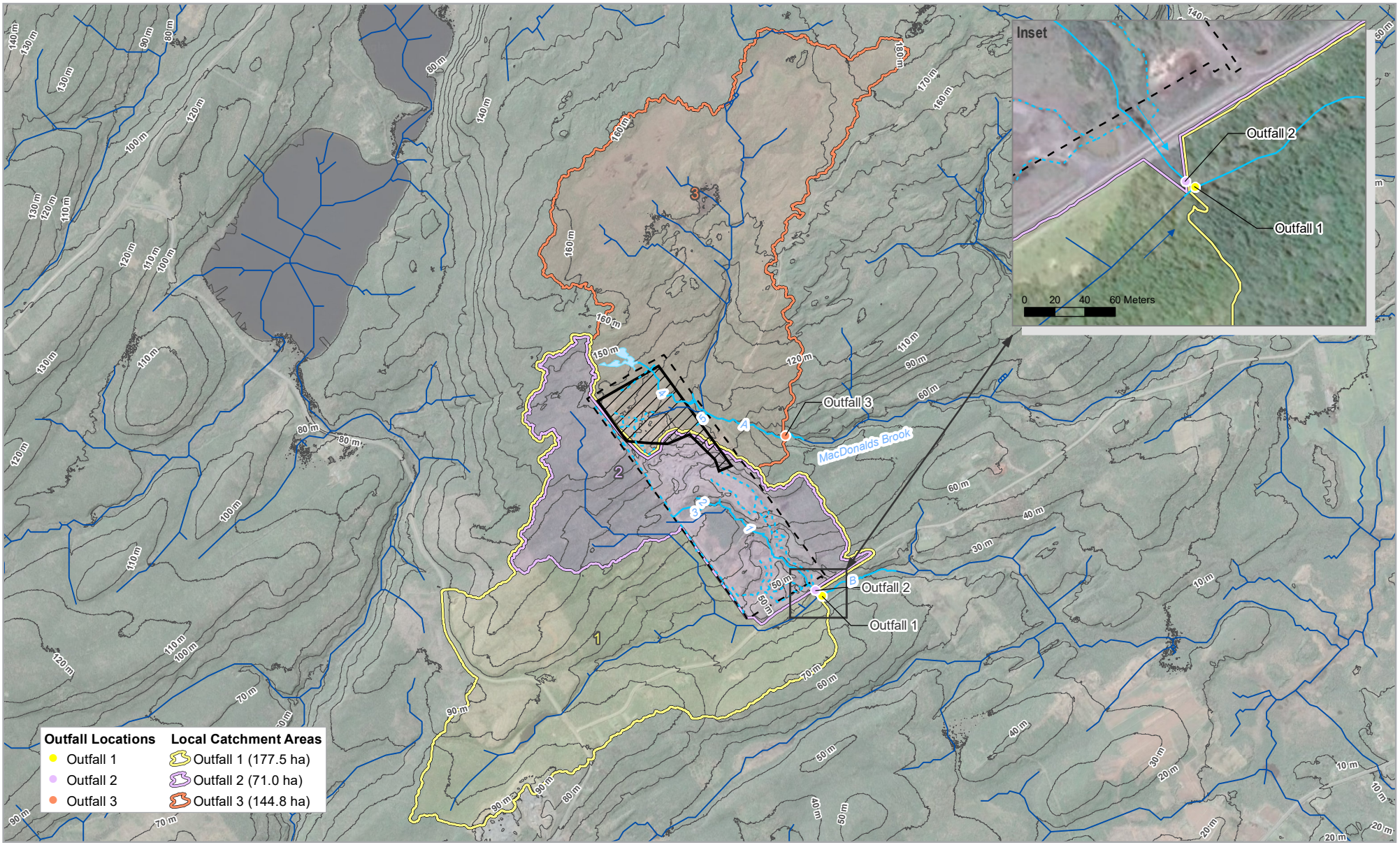

Legend

- Study Area
- Development Area
- Elevation Contour (10m)
- Mapped Watercourse
- Field Identified Watercourse
- Field Identified Drainage
- Field Identified Wetland

Paper Size ANSI A

0 100 200 300 400

Meters

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983
Grid: NAD 1983 UTM Zone 20N

N

GHD

GILLIS LAKE, NOVA SCOTIA
LOCAL CATCHEMENT AREAS

BASELINE
WATERSHED DELINEATION

Project No. **11204334**
Revision No. **-**
Date **Dec 12, 2019**

FIGURE 1

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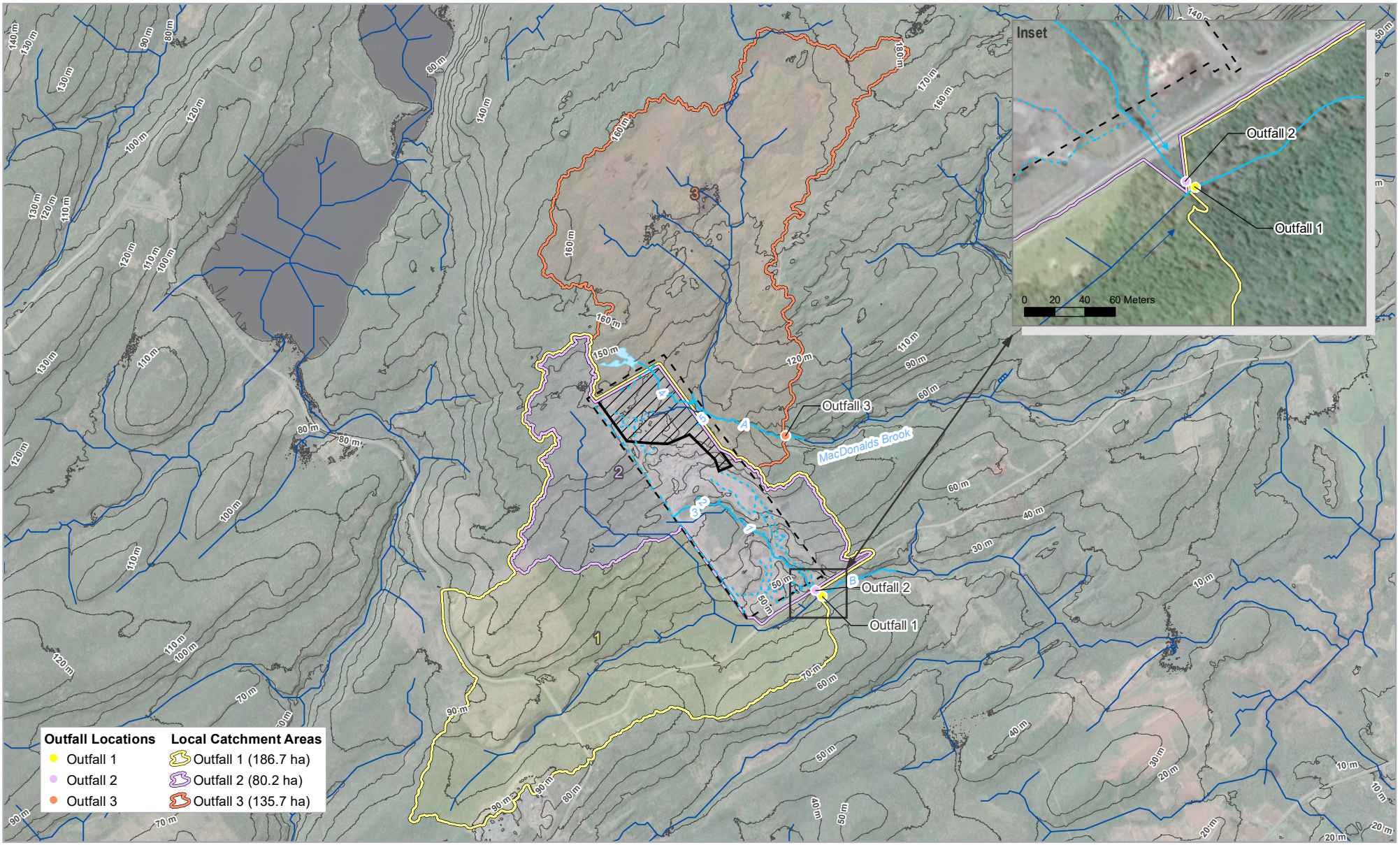
Data source: Image ©2019 Google, Imagery date 6/6/2019. Nova Scotia Department of Natural Resources. GeoNOVA Nova Scotia Elevation Dataset 1m Resolution DEM downloaded from DataLocator Elevation Explorer. Her Majesty the Queen in Right of the Province of Nova Scotia, as represented by the Minister of Internal Services (ISD). Reproduced and distributed with the permission of Internal Services.



Legend

- Study Area
- Development Area
- Elevation Contour (10m)
- Mapped Watercourse
- Field Identified Watercourse
- Field Identified Drainage
- Field Identified Wetland

Paper Size ANSI A

0 100 200 300 400

Meters

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983
Grid: NAD 1983 UTM Zone 20N

N

GHD

GILLIS LAKE, NOVA SCOTIA
LOCAL CATCHEMENT AREAS

END OF MINE WATERSHED DELINEATION

Project No. **11204334**
Revision No. **-**
Date **Dec 12, 2019**

FIGURE 2

Q:\GIS\PROJECTS\11204000s\11204334\Layouts\WatershedDelineation_2\11204334_201911_EOMWatershedDelineation_GIS002.mxd

Data source: Image ©2019 Google, Imagery date 6/6/2019. Nova Scotia Department of Natural Resources. GeoNOVA Nova Scotia Elevation Dataset 1m Resolution DEM downloaded from DataLocator Elevation Explorer. Her Majesty the Queen in Right of the Province of Nova Scotia, as represented by the Minister of Internal Services (ISD). Reproduced and distributed with the permission of Internal Services.

APPENDIX F. WATER QUALITY RESULTS

Gillis Lake Quarry Expansion Project
Surface Water Samples Results

McCallum Environmental Ltd.

Sample				**WQ1**		**WQ2**		**WQ3**		**WQ4**		**WQ5**	
Sample Date				09/25/19	11/06/19	09/25/19	11/06/19	09/25/19	11/06/19	09/25/19	11/06/19	09/25/19	11/06/19
Parameters	**CCME Guidelines**	**Units**	**Reportable Detection Limit**										
TSS	Maximun increase of 25mg/L (short-term) or 5mg/L (long-term) from baseline levels	mg/L	2.5	Not sampled	73	Not sampled	Not sampled	Not sampled	7.5	Not sampled	Not sampled	Not sampled	Not sampled
	CALCULATED PARAMETERS												
Anion Sum	NV	me/L	N/A	4.91	2.66	4.26	4.10	4.27	1.67	0.370	0.220	0.390	0.340
Bicarb. Alkalinity (calc. as CaCO3)	NV	mg/L	1.0	91	58	110	110	57	25	11	ND	11	6.1
Calculated TDS	NV	mg/L	1.0	270	140	240	220	240	99	25	18	25	22
Carb. Alkalinity (calc. as CaCO3)	NV	mg/L	1.0	ND	ND	1.6	ND	ND	ND	ND	ND	ND	ND
Cation Sum	NV	me/L	N/A	4.71	2.36	4.23	3.94	4.02	1.62	0.470	0.380	0.470	0.390
Hardness (CaCO3)	NV	mg/L	1.0	110	68	150	150	41	26	14	9.3	13	9.9
Ion Balance (% Difference)	NV	%	N/A	2.08	5.98	0.350	1.99	3.02	1.52	11.9	26.7	9.30	6.85
Langelier Index (@ 20C)	NV	N/A		-0.174	-0.588	0.521	0.239	-0.669	-1.81	-2.85	NC	-2.83	-3.77
Langelier Index (@ 4C)	NV	N/A		-0.423	-0.838	0.271	-0.0100	-0.919	-2.06	-3.10	NC	-3.09	-4.02
Nitrate (N)	550 (long-term) or 13 (short-term)	mg/L	0.050	0.96	0.44	1.8	1.3	0.10	0.67	0.11	ND	0.17	ND
Saturation pH (@ 20C)	NV	N/A		7.90	8.26	7.68	7.66	8.53	9.06	9.71	NC	9.73	10.1
Saturation pH (@ 4C)	NV	N/A		8.15	8.51	7.93	7.91	8.78	9.31	9.96	NC	9.98	10.3
	INORGANICS												

Gillis Lake Quarry Expansion Project
Surface Water Samples Results

Sample				WQ1		WQ2		WQ3		WQ4		WQ5	
Total Alkalinity (Total as CaCO3)	NV	mg/L	5.0	92 (1)	58	110	110	57	25	11	ND	11	6.1
Dissolved Chloride (Cl)	640 (short-term) or 120 (long-term)	mg/L	1.0	99	47	64	57	100	36	5.5	7.7	5.7	7.6
Colour	Shall not be significantly higher than the seasonally adjusted expected value	TCU	25	6.2	26	ND	7.2	14	39	87	100	63	80
Nitrate + Nitrite (N)	NV	mg/L	0.050	0.96	0.45	1.8	1.3	0.10	0.67	0.11	ND	0.17	ND
Nitrite (N)	60	mg/L	0.010	ND	0.011	ND	ND	ND	ND	ND	ND	ND	ND
Nitrogen (Ammonia Nitrogen)	NV	mg/L	0.050	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Organic Carbon (C)	NV	mg/L	0.50	1.3	3.8	0.89	1.7	2.5	5.6	15	14	11	13
Orthophosphate (P)	NV	mg/L	0.010	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
pH	6.5 to 9.0	pH	N/A	7.73	7.67	8.20	7.90	7.86	7.25	6.86	6.10	6.89	6.32
Reactive Silica (SiO2)	NV	mg/L	0.50	6.7	4.7	6.4	5.3	6.7	4.4	2.7	2.6	2.8	2.7
Dissolved Sulphate (SO4)	NV	mg/L	2.0	10	7.2	8.0	11	11	5.2	ND	ND	ND	ND
Turbidity	Maximum increased of 8 NTUs (short-term) or 2 NTUs (long-term) from background levels	NTU	0.10	0.27	7.6	0.24	1.9	2.2	14	0.59	0.62	0.18	0.29
Conductivity	NV	uS/cm	1.0	540	270	460	410	510	170	43	38	45	38
	METALS												

Gillis Lake Quarry Expansion Project
Surface Water Samples Results

McCallum Environmental Ltd.

Sample				WQ1		WQ2		WQ3		WQ4		WQ5	
Total Aluminum (Al)	5	ug/L	5.0	16	470	20	110	32	730	220	220	140	190
Total Antimony (Sb)	NV	ug/L	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Arsenic (As)	5	ug/L	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Barium (Ba)	NV	ug/L	1.0	180	78	230	150	24	19	5.4	5.4	4.7	5.5
Total Beryllium (Be)	NV	ug/L	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Bismuth (Bi)	NV	ug/L	2.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Boron (B)	1,500 (long-term) or 29,000 (short-term)	ug/L	50	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Cadmium (Cd)	0.09 (long-term) or 1 (short-term)	ug/L	0.010	ND	ND	ND	ND	ND	ND	0.018	0.019	ND	ND
Total Calcium (Ca)	NV	ug/L	100	35000	22000	49000	50000	13000	7800	3600	2400	3300	2600
Total Chromium (Cr)	1 (hexavalent) or 8.9 (trivalent)	ug/L	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Cobalt (Co)	NV	ug/L	0.40	ND	ND	ND	ND	ND	ND	0.44	ND	ND	ND
Total Copper (Cu)	2	ug/L	0.50	0.55	1.2	0.88	0.93	0.72	1.8	0.87	0.55	0.73	0.51
Total Iron (Fe)	300	ug/L	50	ND	380	ND	89	63	710	780	430	230	280
Total Lead (Pb)	1	ug/L	0.50	ND	ND	ND	ND	ND	ND	0.54	ND	ND	ND
Total Magnesium (Mg)	NV	ug/L	100	5000	3200	7100	6700	2100	1700	1100	830	1100	870
Total Manganese (Mn)	NV	ug/L	2.0	9.6	24	6.1	19	7.4	33	230	92	51	23
Total Molybdenum (Mo)	73	ug/L	2.0	4.8	2.1	6.4	4.7	3.9	ND	ND	ND	ND	ND
Total Nickel (Ni)	25	ug/L	2.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Phosphorus (P)	NV	ug/L	100	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Potassium (K)	NV	ug/L	100	930	800	1200	1300	600	640	310	260	340	270
Total Selenium (Se)	1	ug/L	0.50	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Silver (Ag)	0.25	ug/L	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Gillis Lake Quarry Expansion Project
Surface Water Samples Results

McCallum Environmental Ltd.

Sample				WQ1		WQ2		WQ3		WQ4		WQ5	
Total Sodium (Na)	NV	ug/L	100	58000	22000	27000	19000	73000	24000	3700	3800	4500	4000
Total Strontium (Sr)	NV	ug/L	2.0	230	97	320	210	87	39	13	9.5	15	11
Total Thallium (Tl)	0.8	ug/L	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Tin (Sn)	NV	ug/L	2.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Titanium (Ti)	NV	ug/L	2.0	ND	8.8	ND	6.7	ND	16	3.7	2.3	2.4	2.2
Total Uranium (U)	15 (long-term) or 33 (short-term)	ug/L	0.10	1.6	0.86	2.8	2.2	0.42	0.25	ND	ND	ND	ND
Total Vanadium (V)	NV	ug/L	2.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Zinc (Zn)	7 (long-term) or 37 (short-term)	ug/L	5.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	PETROLEUM HYDROCARBONS												
Benzene	0.37	mg/L	0.0010	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	0.002	mg/L	0.0010	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	0.09	mg/L	0.0010	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Xylenes	NV	mg/L	0.0020	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C6 - C10 (less BTEX)	NV	mg/L	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
>C10-C16 Hydrocarbons	NV	mg/L	0.050	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
>C16-C21 Hydrocarbons	NV	mg/L	0.050	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
>C21-<C32 Hydrocarbons	NV	mg/L	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Modified TPH (Tier1)	NV	mg/L	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Reached Baseline at C32	NV	mg/L	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hydrocarbon Resemblance	NV	mg/L	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

ND= Not detected, N/A= Not Applicable, NV= No value, NC = Not calculated, due to no detection of an alkalinity value, (1) = Elevated reporting limit due to sample matrix
Highlighted values exceed the CCME FWAL Guidelines