Agnico Eagle Mines Limited

Saline Water Management Trade-off

Meliadine, Nunavut

Calculation Note

Daily GHG Emissions Estimate

BBA Document No. / Rev. 5287170-000000-45-ENC-0001 / R00

October 9, 2020

BBA

Engineering
for a changing world

bba.ca

PERMIT TO PRACTICE
BBA INC.
Signature
Date 2020-10-09
PERMIT NUMBER: P 858
NT/NU Association of Professional Engineers and Geoscientists

Agnico Eagle Mines Limited

Saline Water Management Trade-off

Meliadine, Nunavut

Calculation Note

Daily GHG Emissions Estimate

BBA Document No. / Rev. 5287170-000000-45-ENC-0001 / R00

October 9, 2020

FINAL

REGISTERED PROFESSIONAL ENGINEER
2020-10-09
L.C. BOUCHARD-BOLDUC
LICENSEE

REGISTERED PROFESSIONAL ENGINEER
L.F. GAGNON
LICENSEE
NT/NU

2020-10-09

Prepared by:
Lee-Christophe Bouchard Bolduc, P.Eng.
OIQ No. 5036649
NAPEG No. L4351

Verified by:
Louis-François Gagnon, P.Eng.
OIQ No. 120444
NAPEG No. L3183

375 Sir-Wilfrid-Laurier Blvd.
Mont-Saint-Hilaire, QC J3H 6C3
T +1 450.464.2111 F +1 450.464.0901

REVISION HISTORY

Revision	Document Status – Revision Description	Date
R00	Final	2020-10-09

TABLE OF CONTENTS

LIST OF TABLES

APPENDICES

1. GENERAL

BBA was mandated to estimate the GHG emissions of the different scenarios considered for the treatment of saline water generated by the Meliadine underground mining activities. The three scenarios are:

- The construction of a water line from the Meliadine site to Ranking Inlet for disposal;
- The use of trucks to carry the saline water from the Meliadine site to Ranking Inlet for disposal;
- The use of a desalination plant to dispose of the treated water at site.

Five flow rates were studied for each scenario, namely:

- 800 m^3/day;
- 1,600 m^3/day;
- 6,000 m^3/day;
- 12,000 m^3/day;
- 20,000 m^3/day.

1.1 Scope of calculation note

The purpose of this document is to present the assumptions and calculations used for the GHG evaluation.

The results will help Agnico Eagle evaluate GHG emissions for the different alternatives related to Saline Water Management at the Meliadine site.

1.2 Units and symbols

All units of measurement must be in accordance with the International Systems of Units (SI). If exceptions need to be taken, SI shall be used as the primary dimensions, with the corresponding conversion to the other system of units in brackets.

All units used in this document are listed in the following table.

Table 1: Units and symbols

Unit / Symbol	Description
kW	Kilowatt
kWh	Kilowatt hour
Ton CO_2 eq.	Equivalent ton of CO_2
L	Litre
km	Kilometre
m	Metre
m^3	Cubic metre
HP	Horsepower
BHP	Break Horsepower
sg	Specific Gravity
USGPM	Us Gallon per Minute

2. REFERENCE DOCUMENTS

The following reference documents were used to prepare this calculation note.

Table 2: Reference documents

Reference	Document title
	2017, Canada's Greenhouse Gas Quantification Requirements
S.C. 2018, c.12, s.186, Schedule 3	Greenhouse Gas Pollution Pricing Act

3. ASSUMPTIONS

All scenarios mentioned above used the conversion factor of 0.002803525 equivalent ton of CO_2 per litre of diesel consumed as specified in *Canada's Greenhouse Gas Quantification Requirements* and *Greenhouse Gas Pollution Pricing Act (S.C. 2018, c.12, s.186, Schedule 3)*.

3.1 Water line

The following assumptions were made for the daily GHG emissions of the water line:

- HDPE pipe (DR 11) will be used;
- Agnico Eagle determined that two (2) 16-inch pipes were required for all scenarios;

- The distance between the mine and the highest point in the piping routing is 10 km;
- The Meliadine site is 100 feet lower than the highest point of the piping routing;
- Once the highest point is reached, no pumping power is required since water will run down by gravity toward Rankin Inlet;
- The total pipe length is 35 km;
- Pump efficiency is estimated at 70%;
- The drive efficiency is estimated at 99%;
- The electric motor efficiency is estimated at 90%;
- The power factor of the network is 0.9;
- The overall efficiency of the power plant is 0.24 L of fuel per kWh_{elec}.

3.2 Truck

For this option, two truck models were considered. The first one is a Caterpillar 773 off-highway water truck designed for the mining industry. The second one is a Kenworth tanker. Both trucks have a 40 m^3 capacity. The specific fuel consumption of the trucks is based on BBA's experience in previous projects:

- CAT 773 → 3.291 L/km;
- Kenworth → 0.4 L/km.

3.3 Desalination plant

The power consumption rate of the desalination plant was provided by Agnico Eagle directly and is 54.79 L of diesel per cubic metre of water treated.

4. DETAILED CALCULATIONS

4.1 Water line

The first step was to determine the pump head using piping diameter and material, flow, length, and inlet and outlet elevation difference. From those inputs, BBA was able to determine a required pump head as presented in appendix.

The following formulas are used to determine power consumption:

$$Power\ (bhp) = \frac{Flow\ (USGPM) * Head\ (Ft\ H_2O) * SG}{Conversion\ factor\ (3960)\ * Pump\ Efficiency}$$

$$Electrical\ Power\ (kW_{elec}) = \left(\frac{Power\ (kW) * System\ Effect}{Drive\ Efficiency * Motor\ Efficiency * Motor\ Efficiency}\right) * Conversion\ Factor\ (bhp\ to\ kW)$$

$$Daily\ Power\ consumption\ (kWh_{elec}/day) = Electrical\ Power\ (kW_{elec}) * 24h$$

$$Daily\ Fuel\ Consumption\ (L/day) = \frac{Daily\ Power\ consumption\ (kWh_{elec}/day)}{Power\ Plant\ Efficiency\ (kWh_{elec}/L)}$$

The following formula is used to determine GHG emissions:

$$Daily\ GHG\ emissions\ (ton\ CO_2\ eq./day) = Daily\ Fuel\ Consumption\ (L/day) * Conversion\ factor\ (0.0028)$$

4.2 Truck

The following formulas are used to determine GHG emissions:

$$Number\ of\ trips\ per\ day = \frac{Flow(m^3/day)}{Truck\ Capacity\ (m^3)}$$

$$Daily\ Fuel\ consumption\ \left(\frac{L}{day}\right) = Number\ of\ trips\ per\ day * distance\ between\ sites\ (km) * 2 * truck\ specific\ consumption$$

$$Daily\ GHG\ emissions\ (ton\ CO_2\ eq./day) = Daily\ Fuel\ Consumption\ (L/day) * Conversion\ factor\ (0.0028)$$

4.3 Desalination plant

The following formula is used to determine GHG emissions:

$$Daily\ GHG\ emissions\ \left(\frac{ton\ CO_2\ eq.}{day}\right) = Consumption\ rate\ \left(\frac{L}{m^3}\right) * Daily\ Flow\ \left(\frac{m^3}{day}\right) * Conversion\ factor\ (0.0028)$$

5. RESULTS

Table 3 below groups the results of the calculations shown above.

Table 3: Daily GHG emissions estimation results

		Daily GHG emissions estimate in equivalent tons of CO_2									
		Flow Rate (m^3/day)									
		800		1,600		6,000		12,000		20,000	
		Calculated	Rounded	Calculated	Rounded	Calculated	Rounded	Calculated	Rounded	Calculated	Rounded
Water Line	From Meliadine to Rankin	-	**-**	-	**-**	*0.8*	**1**	*2.1*	**2**	*4.9*	**5**
Truck	CAT 773	*13*	**13**	*25*	**25**	*94*	**94**	*188*	**188**	*314*	**314**
	Kenworth	*2*	**2**	*3*	**3**	*11*	**11**	*23*	**23**	*38*	**38**
Desalination Plant	On site	*123*	**123**	*246*	**246**	*922*	**922**	*1843*	**1843**	*3072*	**3072**

Appendix A: Print-out of water line head calculations (6,000 m^3/day)

Network calculation using equivalent length method

Project: PROJECT TITLE — BBA project no: XXXX-XXX

Type of liquid	Water at 60 F	Viscosity:	1.13	centistoke (mm²/s)	Specific gravity	1

Pressure loss in piping and fittings

Description	Type	Friction factor	Flow (usgpm)	Nominal diameter (in)	Quantity or length (ft)	Calculation diameter	Pressure loss per 100 ft (ft)	Velocity (ft/s)	equivalent length (ft)	total length (ft)	Pressure loss (ft H2O)
Pipe	Schedule 80	Plastic	550.4	16	35432	14.00	0.0	1.1	1.0	35432.0	10.9 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
Total											**10.9 ft**

Pressure loss in valves:

Description	Flow (usgpm)	Nominal diameter	Quantity	Calculation diameter	Pressure loss per 100 ft (ft)	Velocity (ft/s)	equivalent length (fti)	total length (ft)	Pressure loss (ft H2O)
				0.00	0.0	0.0	0.0	0.0	0.0 ft
				0.00	0.0	0.0	0.0	0.0	0.0 ft
				0.00	0.0	0.0	0.0	0.0	0.0 ft
				0.00	0.0	0.0	0.0	0.0	0.0 ft
				0.00	0.0	0.0	0.0	0.0	0.0 ft
				0.00	0.0	0.0	0.0	0.0	0.0 ft
				0.00	0.0	0.0	0.0	0.0	0.0 ft
Total									**0.0 ft**

Pressure loss in equipment (in ft H2O):

Description	Qty	Loss (ft)	Pressure loss (ft H2O)
Heat exchanger			0.0 ft
Coil			0.0 ft
Control valve			0.0 ft
Chiller			0.0 ft
Strainer			0.0 ft
Air eliminator			0.0 ft
Boiler			0.0 ft
			0.0 ft
Total			**0.0 ft**

Open system characteristics	Inlet elevation (ft)	225.1 ft
	Outlet elevation (ft)	325.1 ft
	Inlet pressure (psi)	
	Outlet pressure (psi)	
	Head loss for elevation	**100.0 ft H2O**
	Head loss for pressure differential	**0.0 ft H2O**
Head loss for friction		**10.9 ft H2O**
Total pump head		**110.9 ft H2O**
Safety factor (height difference included)		**20.0%**
Total design pump head		**133.0 ft H2O**

Centrifugal pump calculation

BHP calculation	
bhp=flowt x head x sg / 3960 x eff	
External head on pump	133.0 ft h2O
Flow	1101 usgpm
	Water at 60 F
Specific gravity	1.00
Pump efficiency	0.70
factor (US)	3960
bhp	52.82

6000 m3/day

Electrical power required	
System effects	1.05
Hydraulic bhp	55
Drive efficiency	0.99
Motor output (HP)	56
Motor efficiency	0.90
Power Factor	0.90
Electrical Power (kW)	**52 kW**
Time	24 hours
Energy	**1238 kWh**

Preliminary calculation for system design, for exact numbers see manufacturer's selection

Appendix B: Print-out of water line head calculations (12,000 m^3/day)

Network calculation using equivalent length method

Project: PROJECT TITLE — BBA project no: XXXX-XXX

Type of liquid	Water at 60 F	Viscosity:	1.13	centistoke (mm²/s)	Specific gravity	1

Pressure loss in piping and fittings

Description	Type	Friction factor	Flow (usgpm)	Nominal diameter (in)	Quantity or length (ft)	Calculation diameter	Pressure loss per 100 ft (ft)	Velocity (ft/s)	equivalent length (ft)	total length (ft)	Pressure loss (ft H2O)
Pipe	Schedule 80	Plastic	1101	16	35432	14.00	0.1	2.3	1.0	35432.0	37.9 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
Total											**37.9 ft**

Pressure loss in valves:

Description	Flow (usgpm)	Nominal diameter	Quantity	Calculation diameter	Pressure loss per 100 ft (ft)	Velocity (ft/s)	equivalent length (fti)	total length (ft)	Pressure loss (ft H2O)
				0.00	0.0	0.0	0.0	0.0	0.0 ft
				0.00	0.0	0.0	0.0	0.0	0.0 ft
				0.00	0.0	0.0	0.0	0.0	0.0 ft
				0.00	0.0	0.0	0.0	0.0	0.0 ft
				0.00	0.0	0.0	0.0	0.0	0.0 ft
				0.00	0.0	0.0	0.0	0.0	0.0 ft
				0.00	0.0	0.0	0.0	0.0	0.0 ft
Total									**0.0 ft**

Pressure loss in equipment (in ft H2O):

Description	Qty	Loss (ft)	Pressure loss (ft H2O)
Heat exchanger			0.0 ft
Coil			0.0 ft
Control valve			0.0 ft
Chiller			0.0 ft
Strainer			0.0 ft
Air eliminator			0.0 ft
Boiler			0.0 ft
			0.0 ft
Total			**0.0 ft**

Open system characteristics	Inlet elevation (ft)	225.1 ft
	Outlet elevation (ft)	325.1 ft
	Inlet pressure (psi)	
	Outlet pressure (psi)	
	Head loss for elevation	**100.0 ft H2O**
	Head loss for pressure differential	**0.0 ft H2O**
Head loss for friction		**37.9 ft H2O**
Total pump head		**137.8 ft H2O**
Safety factor (height difference included)		**20.0%**
Total design pump head		**165.4 ft H2O**

Centrifugal pump calculation

BHP calculation	
bhp=flowt x head x sg / 3960 x eff	
External head on pump	165.4 ft h2O
Flow	2201 usgpm
	Water at 60 F
Specific gravity	1.00
Pump efficiency	0.70
factor (US)	3960
bhp	131.37

12000 m3/day

Electrical power required	
System effects	1.05
Hydraulic bhp	138
Drive efficiency	0.99
Motor output (HP)	139
Motor efficiency	0.90
Power Factor	0.90
Electrical Power (kW)	**128 kW**
Time	24 hours
Energy	**3078 kWh**

Preliminary calculation for system design, for exact numbers see manufacturer's selection

Appendix C: Print-out of water line head calculations (20,000 m^3/day)

Network calculation using equivalent length method

Project: PROJECT TITLE | BBA project no: XXXX-XXX

Type of liquid	Water at 60 F	Viscosity:	1.13	centistoke (mm²/s)	Specific gravity	1

Pressure loss in piping and fittings

Description	Type	Friction factor	Flow (usgpm)	Nominal diameter (in)	Quantity or length (ft)	Calculation diameter	Pressure loss per 100 ft (ft)	Velocity (ft/s)	equivalent length (ft)	total length (ft)	Pressure loss (ft H2O)
Pipe	Schedule 80	Plastic	1835	16	35432	14.00	0.3	3.8	1.0	35432.0	95.6 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
						0.00	0.0	0.0	0.0	0.0	0.0 ft
Total											**95.6 ft**

Pressure loss in valves:

Description	Flow (usgpm)	Nominal diameter	Quantity	Calculation diameter	Pressure loss per 100 ft (ft)	Velocity (ft/s)	equivalent length (fti)	total length (ft)	Pressure loss (ft H2O)
				0.00	0.0	0.0	0.0	0.0	0.0 ft
				0.00	0.0	0.0	0.0	0.0	0.0 ft
				0.00	0.0	0.0	0.0	0.0	0.0 ft
				0.00	0.0	0.0	0.0	0.0	0.0 ft
				0.00	0.0	0.0	0.0	0.0	0.0 ft
				0.00	0.0	0.0	0.0	0.0	0.0 ft
				0.00	0.0	0.0	0.0	0.0	0.0 ft
Total									**0.0 ft**

Pressure loss in equipment (in ft H2O):

Description	Qty	Loss (ft)	Pressure loss (ft H2O)
Heat exchanger			0.0 ft
Coil			0.0 ft
Control valve			0.0 ft
Chiller			0.0 ft
Strainer			0.0 ft
Air eliminator			0.0 ft
Boiler			0.0 ft
			0.0 ft
Total			**0.0 ft**

Open system characteristics	Inlet elevation (ft)	225.1 ft
	Outlet elevation (ft)	325.1 ft
	Inlet pressure (psi)	
	Outlet pressure (psi)	
	Head loss for elevation	**100.0 ft H2O**
	Head loss for pressure differential	**0.0 ft H2O**
Head loss for friction		**95.6 ft H2O**
Total pump head		**195.6 ft H2O**
Safety factor (height difference included)		**20.0%**
Total design pump head		**234.7 ft H2O**

Centrifugal pump calculation

BHP calculation	
bhp=flowt x head x sg / 3960 x eff	
External head on pump	234.7 ft h2O
Flow	3669 usgpm
	Water at 60 F
Specific gravity	1.00
Pump efficiency	0.70
factor (US)	3960
bhp	310.67

20000 m3/day

Electrical power required	
System effects	1.05
Hydraulic bhp	326
Drive efficiency	0.99
Motor output (HP)	329
Motor efficiency	0.90
Power Factor	0.90
Electrical Power (kW)	**303 kW**
Time	24 hours
Energy	**7280 kWh**

Preliminary calculation for system design, for exact numbers see manufacturer's selection


BBA