

**Canadian Land Reclamation Association (CLRA)
Atlantic Reclamation Conference (ARC) 2015
Wu Centre
University of New Brunswick
Fredericton NB**

11:45 – 12:15 (incl. Q&A) – October 20, 2015

Calculating Changing Compound Concentrations in Groundwater using Atlantic RBCA Version 3

Cameron Ells, P.Eng.

cells@CameronConsulting.ca

Cameron Consulting Incorporated

**Cameron
Consulting**



Full Title

Cameron
Consulting

Atlantic RBCA Version 3
Example Application:
Calculating changing compound
concentrations in groundwater
between a source area and a
surface water receptor



Presentation Outline

- 1) The Context and the Questions
- 2) Atlantic RBCA Version 3 steps
- 3) Comments and Lessons Learned

**Cameron
Consulting**



The CONTEXT and the Questions

- 1) A maturing “Contaminated Sites” market
- 2) Focus is on long term Site Management, Risk Management, and Reclamation
- 3) Sites often without unacceptable risk or hazard to current on site receptors
- 4) Some site decision making is based on down gradient surface water receptor
- 5) Along the rational road to “enough”



The Context and the QUESTIONS

- 1) What concentration change contingency should be planned for, from an on-site groundwater plume migrating to off-site surface water receptor?
- 2) How does concentration change or vary in groundwater along the distance to the surface water? and over time?
- 3) For an edge of property monitor well, what concentration trend can justify the protection of surface water receptor?



Atlantic RBCA Version 3 and Responding to the Questions

- 1) Atlantic RBCA Version 3 can contribute to responding to these questions
- 2) Example of straight, down gradient dispersion, using built in Dominico Modelling, and Transient Analysis
- 3) Simplifications, information gaps, and preparing a decision making approach

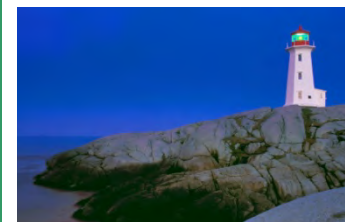
**Cameron
Consulting**



Atlantic RBCA Version 3 and Exposure Pathway Scenario

- 1) Benzene, Napthalene, and TPH C08-10 aliphatic and aromatic fractions
- 2) Nominal concentrations of 0.1 mg/litre in on site plume (5 m wide and 2 m deep) to Surface Water receptor 30 m away
- 3) Input Aquatic Life Protection Criteria as nominal concentrations of 0.001 mg/litre

**Cameron
Consulting**



Atlantic RBCA Version 3, the Compounds of Concern, and Concentrations



RBCA Tool Kit for Atlantic Canada, Version 3.1

Site Name: 1815 Waterloo ARC Job ID: CLRA ARC 2015 Commands and Options
 Location: Fredericton NB Date: 2015.10.20 Main Screen Print Sheet Help
 Compl. By: Cameron

Source Media Constituents of Concern (COCs)

Apply Raoult's Law

Selected COCs *Representative COC Concentration*

COC Select:	Sort List: ?	Groundwater Source Zone		Soil Source Zone		Mole Fraction in Source Material
		Calculate	Enter Site Data	Calculate	Enter Site Data	
Add/Insert Top MoveUp Delete Bottom MoveDown		(mg/L)	note	(mg/kg)	note	(?)
Benzene		1.0E-1	nominal but still soluble			
Naphthalene		1.0E-1	nominal but still soluble			
TPH - Aliph >C08-C10		1.0E-1	nominal but still soluble			
TPH - Arom >C08-C10		1.0E-1	nominal but still soluble			

Atlantic RBCA Version 3 and Main Screen for Example

Main Screen RBCA Tool Kit for Atlantic Canada
Version 3.1 © 2011

1. Project Information

Site Name: 1815 Waterloo ARC
 Location: Fredericton NB
 Compl. By: Cameron
 Date: 2015.10.20 Job ID: CLRA ARC 2015

2. Which Type of RBCA Analysis?

Tier 1
Risk-Based Screening Levels

Tier 2/3
Site-Specific Target Levels

3. Calculation Options

Affects which input data are required.

Baseline Risks (Forward mode)
 RBCA Cleanup Standards (Backward mode)

Individual and Cumulative Risk Goals: [Dropdown]

Receptor Types: Residential [Dropdown] and Commercial [Dropdown]

Apply Source Depletion Algorithm

4. RBCA Evaluation Process

Prepare Input Data
Data Complete? (yes, no)

Exposure Pathways
↓
 Constituents of Concern (COCs)
↓
 Fate and Transport
↓
 Soil Parameters
↓
 GW Parameters
↓
 Air Parameters

Review Output

Exposure Flowchart
 COC Chem. Parameters
 Input Data Summary
 User-Spec. COC Data...
 Transient Domenico Analysis...
 Baseline Risks...
 Cleanup Standards...

5. Commands and Options


New Site Load Data... Save Data As... Quit
 Print Sheet Set Units Custom Chem. Data... Help

Atlantic RBCA Version 3 and Exposure Path Identification

RBCA Tool Kit for Atlantic Canada, Version 3.1

Exposure Pathway Identification

1. Groundwater Exposure Groundwater Ingestion/ Surface Water Impact ?



Receptor: None None S.W.

On-site Off-site1 Off-site2

Apply CDWQG values

Affected Groundwater

Downgradient distance: 0 0 30 (m)

Lateral distance off centreline: 0 0 0 (m)


Affected Soils Leaching to Groundwater

Downgradient distance: 0 0 0 (m)

Lateral distance off centreline: 0 0 0 (m)

Depth below top of water-bearing unit: 0 0 0 (m)

GW Discharge to Surface Water Exposure




Swimming

Fish Consumption

Aquatic Life Protection

Enter ALP Criteria

2. Surface Soil Exposure Direct Ingestion and Dermal Contact ?




Receptor: None No off-site receptors

On-site

Construction Worker

Site Name: 1815 Waterloo ARC
 Location: Fredericton NB
 Compl. By: Cameron
 Job ID: CLRA ARC 2015
 Date: 2015.10.20

3. Air Exposure Volatilization and Particulates to Outdoor Air Inhalation ?



Receptor: None None None

On-site Off-site1 Off-site2

Downwind dist.: 0 0 0 (m)


Construction Worker

Affected Soils - Volatilization to Ambient Outdoor Air

Affected Groundwater - Volatilization to Ambient Outdoor Air

Affected Surface Soils - Partitioning to Ambient Outdoor Air

Volatilization to Indoor Air Inhalation



Receptor: None No off-site receptors

On-site

Affected Soils - Volatilization to Enclosed Space

Affected Groundwater - Volatilization to Enclosed Space

4. Commands and Options

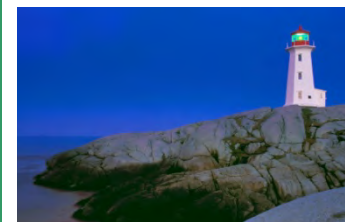
Main Screen Print Sheet Set Units Help

Exposure Factors & Target Risks Exposure Flowchart

Atlantic RBCA Version 3 and Exposure Path Identification

- 1) Off Site 2 Receptor has the Surface Water Receptor Option
- 2) When 0 m is lateral distance off centreline and depth 0 m is depth below top of water bearing unit, the Dominico Transient Analysis is calculated (later).
- 3) Also used in calc is Surface Water flow rate at GW/SW (m³/s GW Parameters)

**Cameron
Consulting**



Atlantic RBCA Version 3 and Aquatic Life Protection Input

RBCA Tool Kit for Atlantic Canada, Version 3.1

Site Name: 1815 Waterloo ARC	Job ID: CLRA ARC 2015	Commands and Options	
Location: Fredericton NB	Date: 2015.10.20	<input type="button" value="Return"/>	<input type="button" value="Print Sheet"/>
Compl. By: Cameron		<input type="button" value="Paste Default Values"/>	<input type="button" value="Help"/>
Surface Water Aquatic Life Protection Criteria			
	Constituent	Concentration	
		(mg/L)	
	Benzene	1.0E-3	
	Naphthalene	1.0E-3	
	TPH - Aliph >C08-C10	1.0E-3	
	TPH - Arom >C08-C10	1.0E-3	

Atlantic RBCA Version 3 and Aquatic Life Protection Input

- 1) Aquatic Life Protection (ALP) criteria concentrations (mg/litre) for each compound from other sources (no defaults)
- 2) Atlantic RBCA uses this in calculating the Groundwater Discharge to Surface Water SSTL (mg/L Clean up Standards)
- 3) Also used in calc is Surface Water flow rate at GW/SW (m³/s GW Parameters)

**Cameron
Consulting**



Atlantic RBCA Version 3 and Exposure Factors

Exposure Factors and Target Risk Limits

1. Exposure Parameters

Specified receptor for non-carcinogens:

Residential **Toddler (age 1-4)** ▼
 Commercial **Toddler (age 1-4)** ▼

Averaging time, carcinogens (yr)
 Averaging time, non-carcinogens (yr)
 Body weight (kg)
 Exposure duration (yr)
 Exposure frequency (days/yr)*
 Soil ingest./dermal exposure freq. (days/yr)
 Skin surface area, soil contact (cm²)
 Soil dermal adherence factor (mg/cm²/day)
 Water ingestion rate (L/day)
 Soil ingestion rate (mg/day)
 Swimming exposure time (hr/event)
 Swimming event frequency (events/yr)
 Swimming water ingestion rate (L/hr)
 Skin surface area, swimming (cm²)
 Fish consumption rate (kg/day)
 Contaminated fish fraction (unitless)

Residential Receptors			Commercial Receptors	
Adult	Toddler	Child	Adult	Construc
78				
25	4	7	25	1
70.7	16.5	33	70.7	
25	4	7	25	1
365			100	100
365			240	
3400	3000	5000	3400	3400
0.1				
1.5	0.6	0.9	1.5	
20	80	20	20	100
1				
12	12	12		
0.05	0.5	0.5		
23000	4400	8100		
0.05				
1				



Site Name: 1815 Waterloo ARC
 Location: Fredericton NB
 Compl. By: Cameron
 Job ID: CLRA ARC 2015
 Date: 2015.10.20

2. Age Adjustment

Applies for carcinogens only.

Adjustment Factor

Skin surface area, soil contact
 Water ingestion
 Soil ingestion
 Swimming water ingestion
 Skin surface area, swimming

4.12E+0 (mg-yr/L-day)
 8.81E+4 (cm2-yr/kg)

3. Target Health Risk Limits

	Individual	Cumulative
Target Risk (Class A/B carcins.)	1.0E-5	1.0E-5
Target Risk (Class C carcinogens)	1.0E-5	
Target Hazard Quotient	1.0E+0	
Target Hazard Index		1.0E+0

4. Commands and Options

[Return to Exposure Pathways](#)

[Use Default Values](#) [Print Sheet](#)

[Help](#)

*For groundwater ingestion pathways, Residential exposure frequency applies for all receptor types.

Atlantic RBCA Version 3 and Chemical Fate and Transport

Chemical Fate and Transport

1. Vertical Transport, Surface Soil Column

Soil/GW Volatilization to Outdoor Air

Calculate (ASTM models)

Use VF values:

Thickness of surface soil zone: (m)

Use specified VF from other model

Soil/GW Volatilization to Indoor Air

Calculate (Johnson & Ettinger model)

Use specified VF from other model

Soil-to-Groundwater Leachino Factor

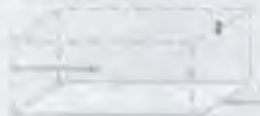
ASTM Model

Apply Soil Attenuation Model (SAM)

Allow first-order biodegradation

Use specified LF from other model

2. Lateral Air Dispersion



Calculate pH-D Equations (Domenico)

Off-site 1: Off-site 2: (-)

Use Specified ADF

Site Name: 1815 Waterloo ARC Job ID: CLRA ARC 2015
 Location: Fredericton NB Date: 2015.10.20
 Compl. By: Cameron

3. Groundwater Dilution Attenuation

Calculate Well Dilution Factor

Apply Well Dilution Factor (WDF) in lieu of lateral DAF

Use the value: (Entry)

Calculate DAF using Domenico Model

Domenico equation with dispersion only (no biodegradation)

Domenico equation first-order decay

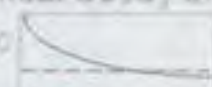
Modified Domenico equation using electron acceptor superposition

Enter Directly: Biodegradation Capacity: (mg/L)

User-Specified WDF or DAF Values

DAF or WDF values from other model or site data

4. Chemical Decay and Source Depletion



5. Commands and Options

Atlantic RBCA Version 3 and Groundwater Parameters

Site-Specific Groundwater Parameters

1. Water-Bearing Unit ?

Hydrogeology

Groundwater Darcy velocity: (cm/s)

Groundwater seepage velocity: (cm/s)

or ↑ or ↓

Hydraulic conductivity: (cm/s)

Hydraulic gradient: (-)

Effective porosity: (-)

Sorption

Fraction organic carbon-saturated zone: (-)

Groundwater pH: (-)

2. Groundwater Source Zone ?


Groundwater plume width at source: (m)

Plume (mixing zone) thickness at source: (m)

or ↑ or ↓

Saturated thickness: (m)

Length of source zone: (m)



Site Name: 1815 Waterloo ARC Job ID: CLRA ARC 2015
 Location: Fredericton NB Date: 2015.10.20
 Compl. By: Cameron

3. Groundwater Dispersion ?

Model: Xu and Eckstein GW Ingestion Soil Leaching to GW

Distance to GW receptors: (m) Off-site 2

or ↓ or ↓

Longitudinal dispersivity: (m)

Transverse dispersivity: (m)

Vertical dispersivity: (m)

4. Groundwater Discharge to Surface Water ?

Distance to GW/SW discharge point: (m) Off-site 2

Plume width at GW/SW discharge: (m)

Plume thickness at GW/SW discharge: (m)

Surface water flowrate at GW/SW discharge: (m³/s)

5. Commands and Options

Main Screen Use Default Values Print Sheet

Set Units Help

Atlantic RBCA Version 3 and Groundwater Parameters

- 1) Distance (e.g. 30 m) to GW/SW Discharge Point (longer lowers steady state point of exposure concentration, and increases NAF and SSTL values)
- 2) Plume width (e.g. 5 m) and thickness (e.g. 2 m) at GW/SW Discharge Point (smaller area reduces total mass transfer, increases NAF, and reduces point of exposure concentration)



Atlantic RBCA Version 3 and Groundwater Parameters

- 1) Surface Water Flow Rate (e.g. 1 m³/s) at GW/SW Discharge Point (larger flow rate reduces the point of exposure concentration in the receiving water from the total mass being transferred; and increases the NAF and SSTL values)

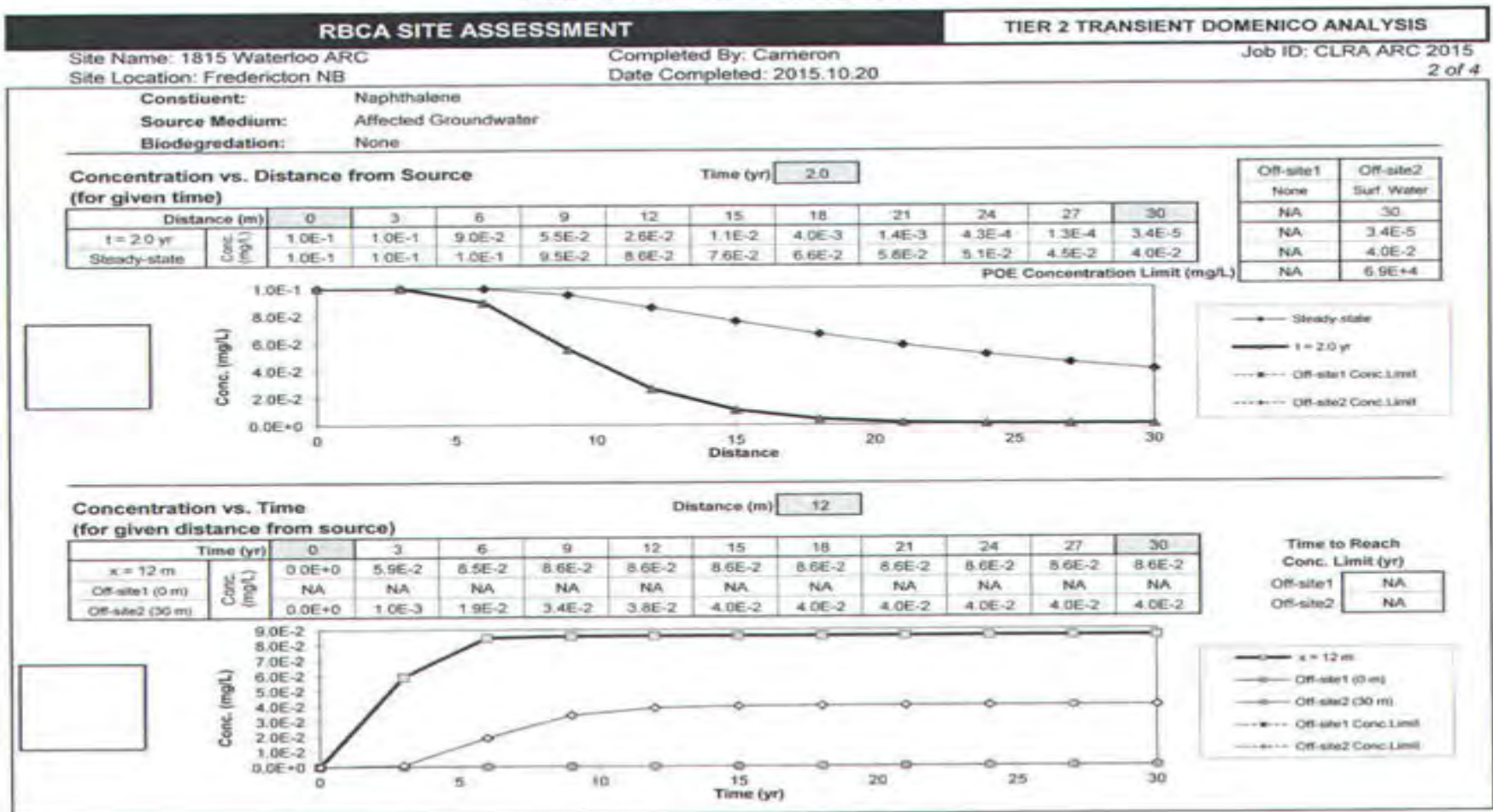
Cameron
Consulting



Atlantic RBCA Version 3 and Domineco Model Summary

RBCA SITE ASSESSMENT		Tier 2 Domineco Groundwater modelling Summary						
Site Name: 1815 Waterloo ARC		Site Location: Fredericton NB		Completed By: Cameron		Date Completed: 2015.10.20		3 OF 3
DOMINECO GROUNDWATER modelling SUMMARY								
OFF-SITE GROUNDWATER EXPOSURE PATHWAYS <input checked="" type="checkbox"/> (CHECKED IF PATHWAY IS ACTIVE)								
GROUNDWATER:								
SURFACE WATER IMPACT	1) Source Median	2) Steady-state Exposure Concentration Groundwater POE Conc. (mg/L)		3) POE Concentration Limit Groundwater POE Conc. (mg/L)		4) Time to Reach POE Conc. Limit Conc. reaches limit? (☐ if yes), Time (yr)		
	Groundwater Conc. (mg/L)	Off-site 1 (0 m) None	Off-site 2 (30 m) Surf. Water	Off-site 1 (0 m) None	Off-site 2 (30 m) Surf. Water	Off-site 1 (0 m) None	Off-site 2 (30 m) Surf. Water	
Constituents of Concern								
Benzene	1.0E-1		4.0E-2		7.1E+4	NA	<input type="checkbox"/>	NA
Naphthalene	1.0E-1		4.0E-2		6.9E+4	NA	<input type="checkbox"/>	NA
TPH - Aliph >C08-C10	1.0E-1		4.0E-2		NC	NA	<input type="checkbox"/>	NA
TPH - Arom >C08-C10	1.0E-1		4.0E-2		NC	NA	<input type="checkbox"/>	NA
NOTE: POE = Point of exposure								

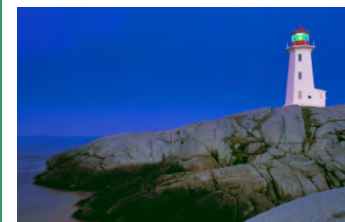
Atlantic RBCA Version 3 and Domineco Transient Analysis



Atlantic RBCA Version 3 and Baseline Risk Individual and Cumulative Risk Worksheets

- 1) For Surface Water exposure - receptors, it does not calculate risks for Aquatic Life Protection but can for Swimming and Fish Consumption by humans.
- 2) Even if Swimming and Fish Consumption are not exposure routes of interest, it can be useful to “turn them on” for their intermediate calculation of Point of Exposure Concentrations, at the GW / SW interface

**Cameron
Consulting**



Atlantic RBCA Version 3 and Baseline Risk Surface Water

RBCA SITE ASSESSMENT

8 OF 8

TIER 2 EXPOSURE CONCENTRATION AND INTAKE CALCULATION

SURFACE WATER EXPOSURE PATHWAYS

(CHECKED IF PATHWAY IS ACTIVE)

GROUNDWATER: DISCHARGE TO SURFACE

WATER / DERMAL CONTACT & INGESTION
VIA SWIMMING

Constituents of Concern

Constituents of Concern	1) Source Medium		2) NAF Value (unitless) Receptor	3) Exposure Medium Surface Water: POE Conc. (mg/L) (1/10)
	Groundwater Conc. (µg/L)	Solubility mg/L	Off-site 2 (30 m) Surface Water	Off-site 2 (30 m) Surface Water
Benzene	1.0E-1	1.8E+3	9.0E+5	1.1E-7
Naphthalene	1.0E-1	3.1E+1	9.0E+5	1.1E-7
TPH - Aliph >C08-C10	1.0E-1	4.3E-1	9.0E+5	1.1E-7
TPH - Arom >C08-C10	1.0E-1	6.5E+1	9.0E+5	1.1E-7

NOTE: NAF = Natural attenuation factor POE = Point of exposure

Site Name: 1515 Waterloo ARC

Site Location: Fredericton NB

Completed By: Cameron

Date Completed: 2015-10-20

Job ID: CLRA ARC 2015

Atlantic RBCA Version 3 and Baseline Risk Surface Water

- 1) For Surface Water exposures, it does not calculate for Aquatic Life Protection but for Fish Consumption, Swimming
- 2) ALP criteria (mg/L) influences SSTL Groundwater calc at GW/SW . ALP criteria may be based on CCME or similar types of performance goals
- 3) Decisions can be made after comparing Point of Exposure concentrations (outside of mixing zone?) to ALP criteria

**Cameron
Consulting**



Atlantic RBCA Version 3 and Cleanup Standard Groundwater

RBCA SITE ASSESSMENT

Site Name: 1815 Waterloo ARC

Compiled By: Cameron

Job ID: CLRA-ARC 2015

Site Location: Fredericton NB

Date Compiled: 2015-10-20

1 OF 1

GROUNDWATER SSTL VALUES

Target Risk (Class A & B): 1.0E-4

Source Dependent Option: No

Target Risk (Class C): 1.0E-5

Time to Future Exposure: 0 years

Target Hazard Quotient: 1.0E+0

Groundwater Dilution-Attenuation Factor: Generic - No Decay

SSTL Results For Complete Exposure Pathways ("X" if Complete)

CONSTITUENTS OF CONCERN		Representative Concentration (mg/L)	Groundwater Discharge to Surface Water			GW Vol. to Indoor Air (0 m)	Groundwater Volatilization to Outdoor Air			Applicable SSTL (mg/L)	SSTL Exceeded? "X" if yes	Remedial CDF Only if "yes" left
			On-site (0 m)	Off-site 1 (0 m)	Off-site 2 (30 m)		On-site (0 m)	Off-site (0 m)	Off-site 1 (0 m)			
71-43-2	Benzene	1.0E-1	None	None	Surf. Water	None	None	None	None	9.0E+2	<input type="checkbox"/>	<1
91-20-3	Naphthalene	1.0E-1	None	None	>3.1E+1	None	None	None	None	>3.1E+1	<input type="checkbox"/>	NA
108-10-0	TPH - Aliph >C08-C10	1.0E-1	None	None	NC	None	None	None	None	NC	<input type="checkbox"/>	NA
208-10-0	TPH - Arom >C08-C10	1.0E-1	None	None	NC	None	None	None	None	NC	<input type="checkbox"/>	NA

* indicates risk-based target concentration greater than constituent toxicity value NA = Not applicable NC = Not calculated

Atlantic RBCA Version 3 and Cleanup Levels for TPH (Water)

RBCA SITE ASSESSMENT						TPH Criteria SSTL Worksheet			
Site Name: 1815 Waterloo ARC		Completed By: Cameron			Job ID: CLRA ARC 2015				
Site Location: Fredericton NB		Date Completed: 2015.10.20			1 OF 1				
SSTL VALUES FOR TPH		Target Hazard Index: 1.0E+0			Source Depletion Option: No				
					Time to Future Exposure: 0 years				
					Groundwater Dilution-Attenuation Factor: Domenico - No Decay				
CONSTITUENTS OF CONCERN		Mass Fractions		Representative Concentrations		Calculated Concentration Limits		Applicable SSTL Values	
		Soil	Groundwater	Soil	Groundwater	Residual Soil Concentration	Solubility	Soil	Groundwater
CAS No.	Name	(-)	(-)	(mg/kg)	(mg/L)	(mg/kg)	(mg/L)	(mg/kg)	(mg/L)
108-10-0	TPH - Aliph >C08-C10		5.0E-1		1.0E-1		4.3E-1		NC
208-10-0	TPH - Arom >C08-C10		5.0E-1		1.0E-1		6.5E-1		NC
Total		0.0E+0	1.0E+0	0.0E+0	2.0E-1	Total TPH SSTL			>Sol

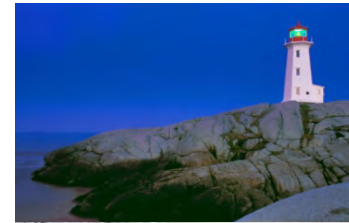
> indicates risk-based target concentration greater than constituent residual saturation value. NC = Not calculated.

Atlantic RBCA Version 3 and those Original Questions

What concentration change contingency should be planned for, from an on-site groundwater plume migrating to off-site surface water receptor?

The point of exposure steady state concentration at the GW / SW interface, is from Domineco (e.g. 0.04 mg/Litre in GW) and in baseline risk calculations (e.g. 1 E-07 mg/Litre in mixed SW).

**Cameron
Consulting**



Atlantic RBCA Version 3 and those Original Questions

How does concentration change or vary in groundwater along the distance to the surface water? and over time?

Dominico Transient Analysis results, for steady state conditions, give changing concentrations over distance, to GW / SW point of exposure; and over time until steady state conditions exist. At some point, natural decay will begin.



Atlantic RBCA Version 3 and those Original Questions

For an edge of property monitor well,
what concentration trend can justify the
protection of surface water receptor?

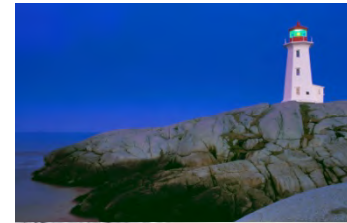
Dominico Transient Analysis results, for
acceptable steady state conditions, at
(e.g. 12 m) an intermediate distance,
give a changing concentration result. If
they are less than steady state values,
this can justify a “protection” conclusion.



Closing Comments and Lessons Learned

- 1) Atlantic RBCA 3 can be useful in evaluating potential for an impacted groundwater plume, to result in an unacceptable risk or hazard to Surface Water receptors.
- 2) It does not provide “off the shelf” results, but can be used with other calculations.
- 3) Atlantic RBCA is a useful tool, but the fuel it runs on is good science, from a good team.

**Cameron
Consulting**



Thank You ARC 2015

Thank you for this opportunity.

For further discussions, please contact:

Cameron Consulting Incorporated

1778 Cambridge Street

Halifax NS B3H 4A9

Canada

902.422.3985

Cameron Ells, P.Eng.

Cells@CameronConsulting.ca

**Cameron
Consulting**

