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Review of Analytical Methodologies and Interpretation of Analytical Results in Peat: Overcoming Alberta Challenges 25-RRRC-02

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October 15, 2026

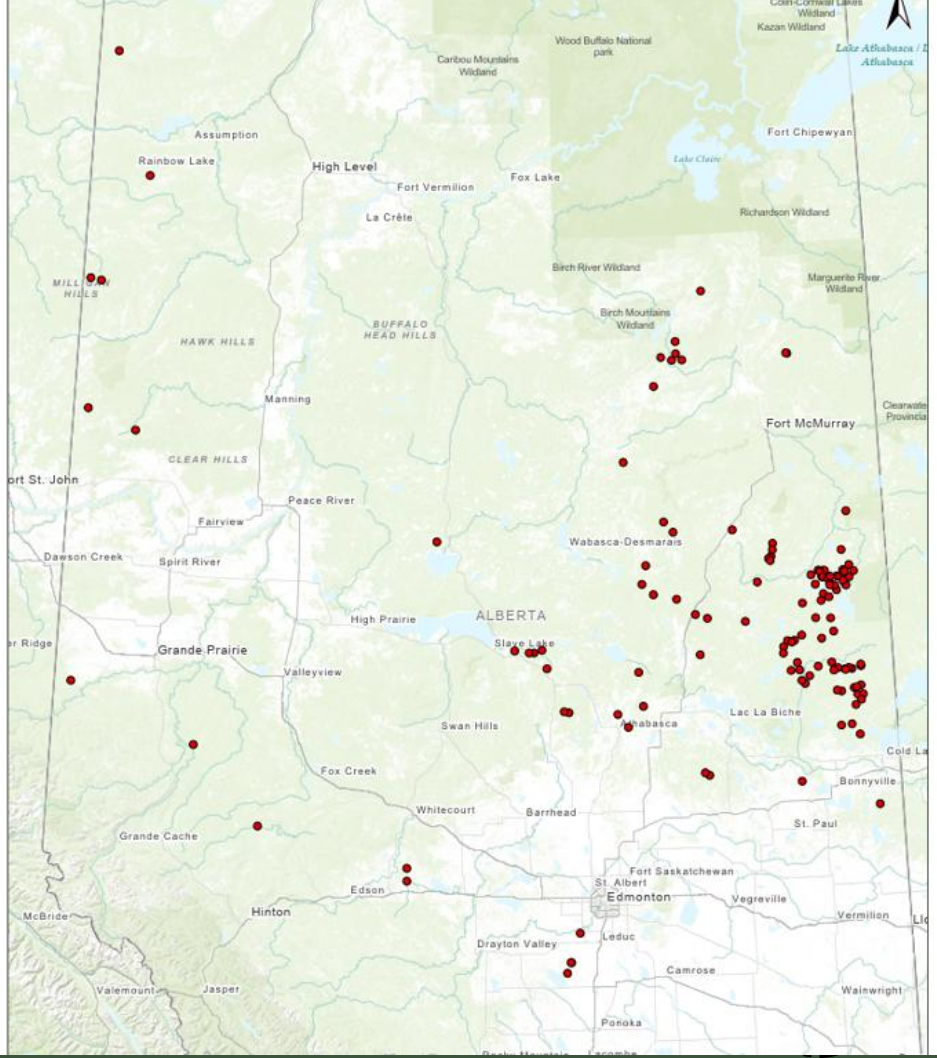
Executive Summary

- **AB guidelines** are based on 2 types of mineral soil (coarse and fine). However, they do not consider peatlands, which occupy 16% of the total Alberta land base and between 30–40% of northern boreal areas, where most of the oil and gas development occurs.
- **Regulatory requirements** governing the Phase 2 ESA process **impose considerable cost** on industry, especially at peatland sites, where natural concentrations exceeding regulatory guidelines are common and require use of professional judgement.
- This **study provides an overview and limitations** of current sampling and analytical methodologies, regulatory framework in AB, and **outlines best industry practices** on how to interpret analytical results from peat material to help differentiate naturally occurring concentrations from anthropogenic impacts for various CoC.
- Intent of the study is to provide a clear tool on **closure process** for assets located in peatlands.



Methodology

- **Literature review** and **regulatory review** of various jurisdictions (AB, BC, SK, Alaska).
- Connected with **Industry partners** (Cenovus Energy Inc., MEG Energy., Imperial Oil and others) and built custom AER OneStop queries to mine AER OneStop for relevant reports.
- **Reviewed 131 Record of Site Condition Forms (RoSC)** to identify most common parameters exceeding regulatory guidelines in peat.
- Requested **AER feedback** and incorporated most common “pain points” from AER when reviewing RoSC applications and justifications for concentrations exceeding the guidelines.





Findings & Conclusions

1. It is important to consider the natural ranges in PHC, pH and metals concentrations for both soil and water when interpreting assessment data for disturbed peatlands, as natural background concentrations of these parameters have the potential to exceed assessment standards and remediation criteria.
2. Typical parameters naturally exceeding in peatlands: F2, F3, F4, toluene, xylene, pH, SAR, EC, arsenic, boron, cadmium, molybdenum, nickel, selenium, uranium, zinc.
3. Methanol – not known to naturally occur in peatlands and usually is a result of sampling cross-contamination or methanol spills / drained methanol tanks.
4. Consider reviewing predevelopment reports and background databases to determine background conditions (i.e. OneStop reports, StaVis, site specific or regional background information).
5. A multiple lines of evidence approach is required due to the complexities of the peatland environment.

Biogenic interference in PHC analysis…

Phil Richards
PR enviroforensics

RemTech
Oct 15, 2026

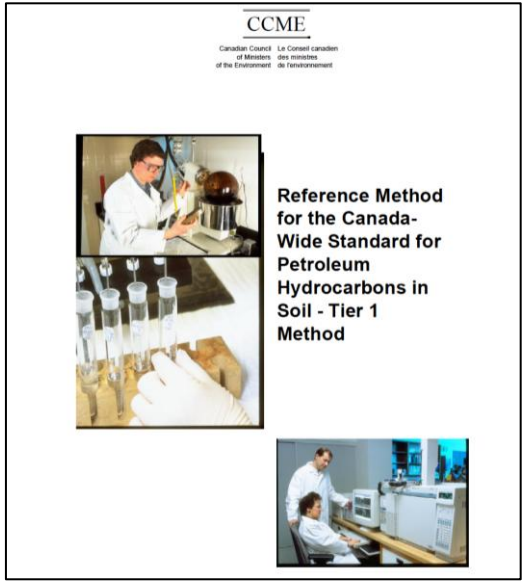
Petroleum Hydrocarbons Analysis is not specific for Petroleum Hydrocarbons

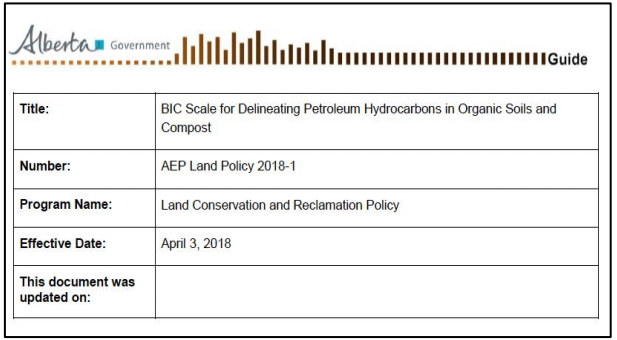
- PHCs are not a chemical.
- PHCs results can include biogenics.
- So, we have to see them… remove them… deduct them…

Regulatory basis

CSPF considers that biogenic PHCs are natural, background conditions, and specifically for peat directs us to two documents:

1. Reference Method for the Canada-Wide Standard for Petroleum Hydrocarbons in Soil (2001)
2. Biogenic Interference Calculation (BIC) Scale (2018)





Regulatory basis

CCME Reference Method provides two options:

1. Analyze by GC-MS to confirm the presence of hydrocarbons
2. Compare against a background soil sample

CSPF (see BIC guidance doc) provides four options:

1. Silica Gel Cleanup
2. Subtraction of Background PHC Concentrations
3. Biomarker Forensic Analysis
4. Biogenic Interference Calculation (BIC) Scale

Review of PHC chroms is an additional option, and simple.

Option	Pros	Cons
Silica gel clean-up	• No interpretation needed • Well established practice • Quantitative • The option of preparing a sub-sample is likely under-utilized	• Unlikely to account for higher concentrations of biogenic hydrocarbons
Background subtraction	• Relatively simple approach • Quantitative	• Statistically-relevant background dataset • Statistics may misrepresent results for biogenic hydrocarbons as above background • Biogenics do not present acceptably comparable risk to PHCs
Biomarker assessment	• Potentially very definitive	• Requires a clear framework to be suitable • Likely expensive • Requires potentially complex interpretation • Qualitative

Option	Pros	Cons
BIC Scale	• Interpretation expectations clearly outlined • Can be provided by commercial laboratories as part of a laboratory report	• Situations where this approach is not allowed • May misrepresent results for biogenic hydrocarbons that do not align with the flowchart as PHCs • Relies heavily on chromatogram assessment for decisions for identification of biogenic PHCs • Qualitative
Chromatogram assessment	• Interpretation can be provided by commercial laboratories as part of a laboratory report	• Requires specialist interpretation • Qualitative

Summary

Be aware of the options available and where each is best used.

- Consider silica-gel clean up of sub-samples for peat samples to prevent saturation of silica by biogenics.

- Chromatogram assessment is simple and fast, and can be provided by a commercial lab or a contaminated sites professional.



UTILIZATION OF BIOGENIC HYDROCARBON ASSESSMENTS TO DETERMINE EXTENT OF PETROLEUM HYDROCARBON CONTAMINATION

2026

BUREAU VERITAS
A GLOBAL LEADER IN TESTING, INSPECTION & CERTIFICATION SERVICES

BUREAU VERITAS
1828

LEVELS

Benzene	<0.041	<0.046	<0.063	<0.055	<0.038	<0.040	0.12
Toluene	0.67	<0.12	<0.12	2.7	<0.12	0.69	1.0
Ethylbenzene	<0.073	<0.073	<0.073	<0.073	<0.073	<0.073	0.21
m- & p-Xylene	<0.33	<0.38	<0.55	<0.48	<0.34	<0.32	1.0
o-Xylene	<0.17	<0.19	<0.28	<0.24	<0.17	<0.16	0.3
F1	<45	<51	<74	<65	<46	<43	<41
F1-BTEX	<45	<51	<74	<65	<46	<43	<41
F2	<52	69	100	120	120	140	160
F3	2600	3600	3300	1900	4000	4200	5200
F4	1100	1700	1800	1100	1700	2100	3100
Moisture	81	84	87	84	82	80	78

BTEX RATIOS

$$Toluene\ Ratio = \frac{[Toluene]}{[\sum BTEX]}$$

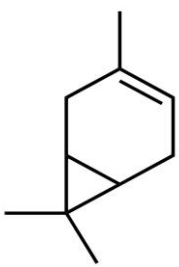
Toluene is a common terminal point for degradation in metabolic pathways, and thus detected toluene with low concentrations of benzene, ethylbenzene and xylene isomers is often linked to a biogenic source.

Toluene >> Ethylbenzene > Benzene > Xylenes

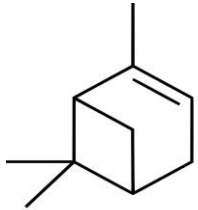
Ideal T-ratio ≥ 0.7

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T-Ratio	0.94	NC	NC	0.98	NC	0.94	0.61
Biogenic Conclusion							

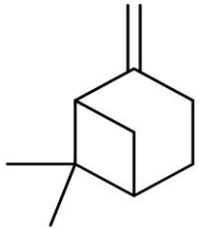
MONOTERPENES



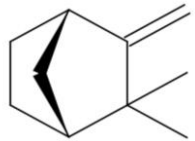
3-Carene
$C_{10}H_{16}$



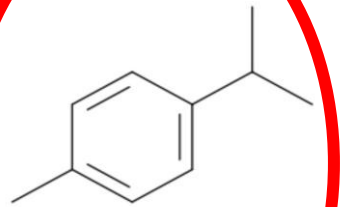
α-Pinene
$C_{10}H_{16}$



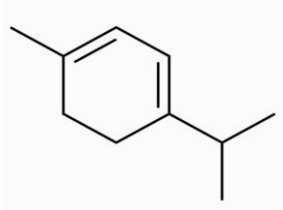
β-Pinene
$C_{10}H_{16}$



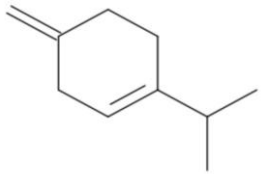
Camphene
$C_{10}H_{16}$



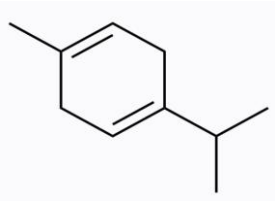
p-Cymene
$C_{10}H_{14}$



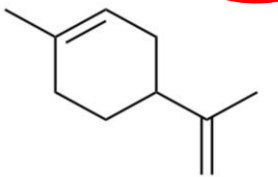
α-Terpinene
$C_{10}H_{16}$



β-Terpinene
$C_{10}H_{16}$



γ-Terpinene
$C_{10}H_{16}$



Limonene
$C_{10}H_{16}$

CYMENE RATIOS

$$Cymene\ Ratio = \frac{[p - Cymene]}{[o - Cymene] + [m - Cymene]}$$

p-Cymene is commonly found in peat due to the decomposition of wood materials, whereas m- and o-cymene are more associated with petroleum.

Ideal C-ratio ≥ 0.8

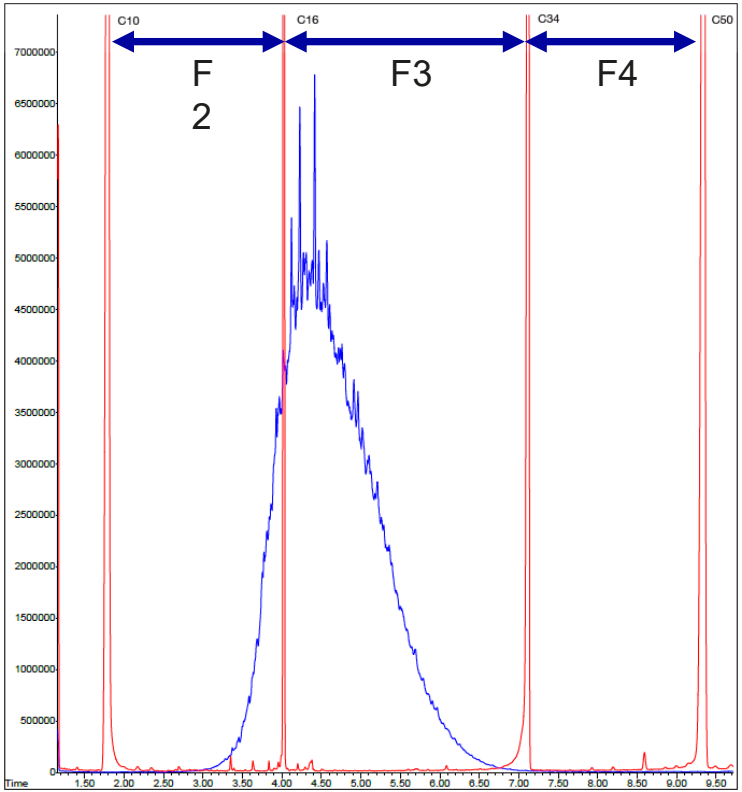
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C-Ratio	0.87	0.84	NC	0.90	0.84	0.83	0.49
Biogenic Conclusion							

MOISTURE CONTENT

- Water is critical resource in peatland regions.
- High moisture content is exceedingly common in soils with biogenic hydrocarbons.
  - Soils with ≥ 70% moisture classified as high moisture and is typical association with biogenics
  - Soils with moisture between 20-70% classified as mid-range moisture and can be associated with biogenic source
    - Mid-range moisture content doesn't nullify biogenic conclusion if other lines of evidence in support

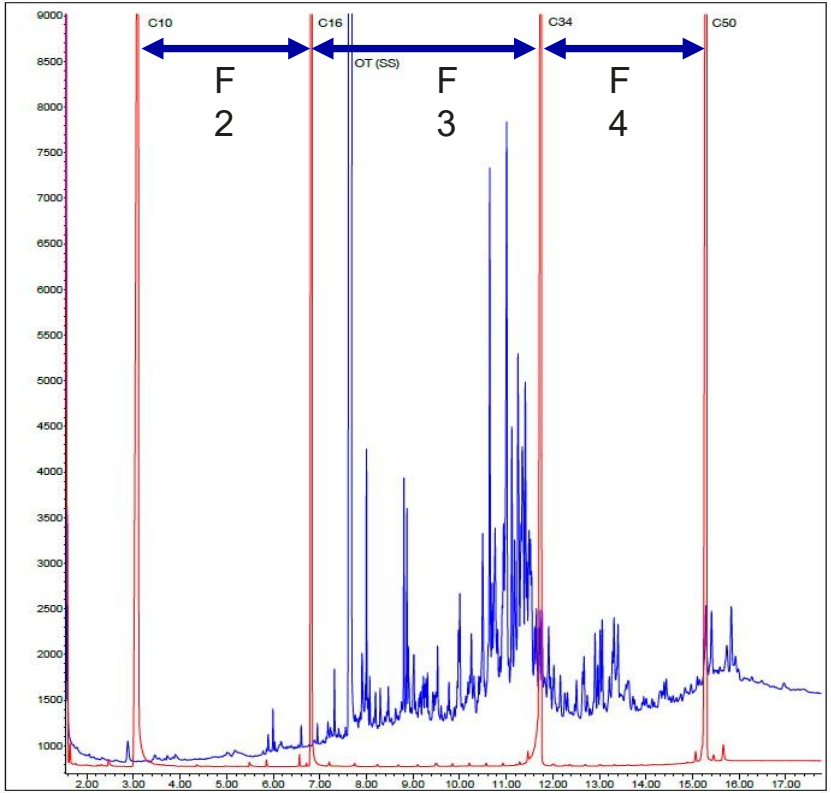
UNRESOLVED COMPLEX MIXTURE

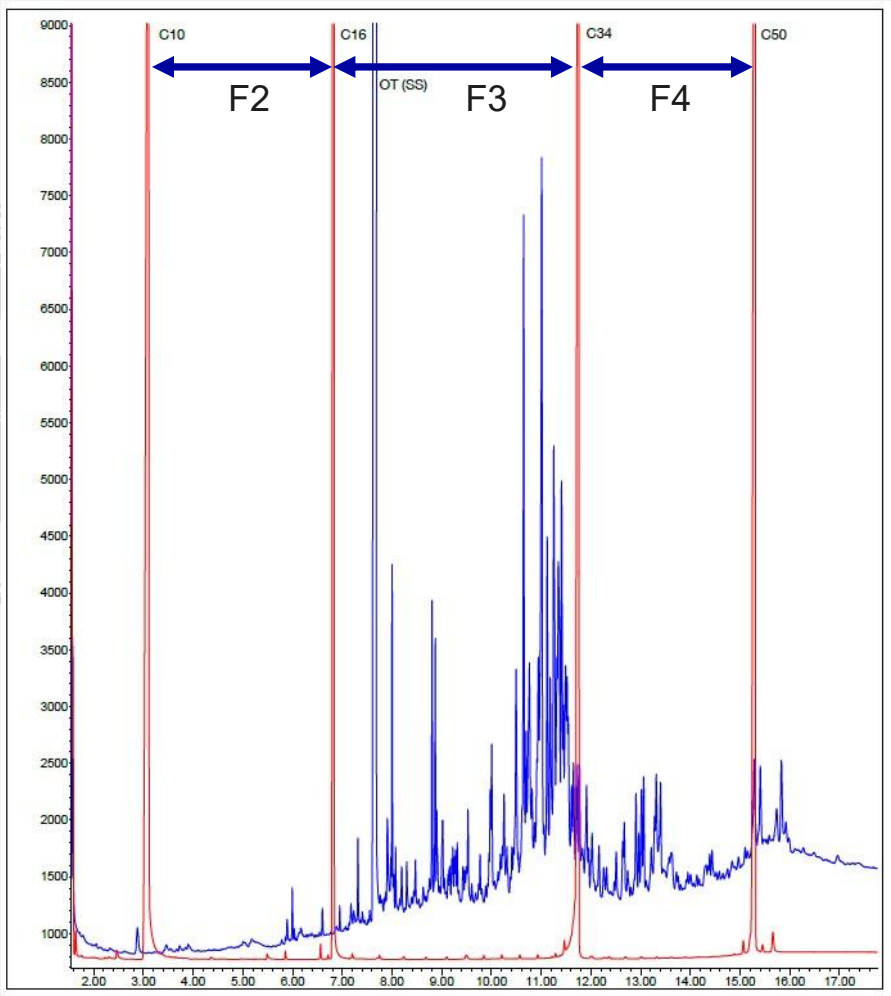
- Biogenic hydrocarbons do not have hundreds of individual compounds contributing to the chromatogram.
- Presence of individual compound peaks less likely to come from petroleum
- F2 (nC_{10}-nC_{16}) fraction and F3 (nC_{16}-nC_{34}) fraction are critical diagnostic ranges
- Ideally, low detections in F2 fraction

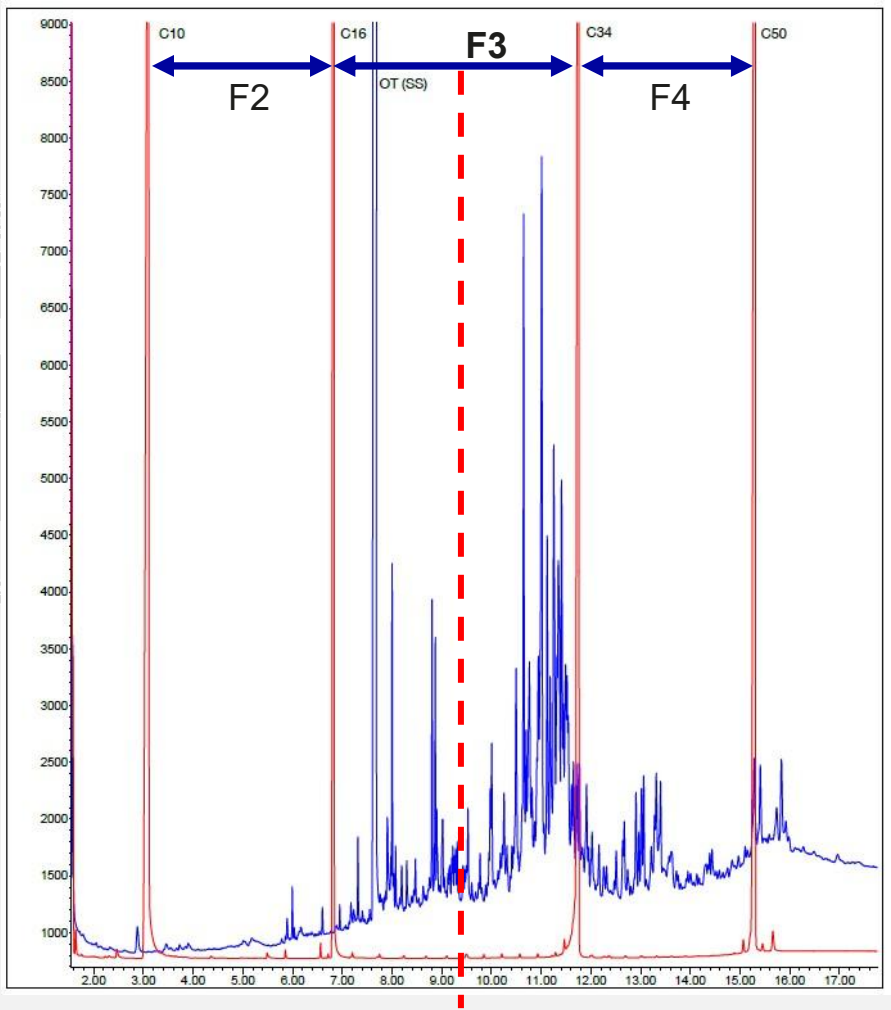


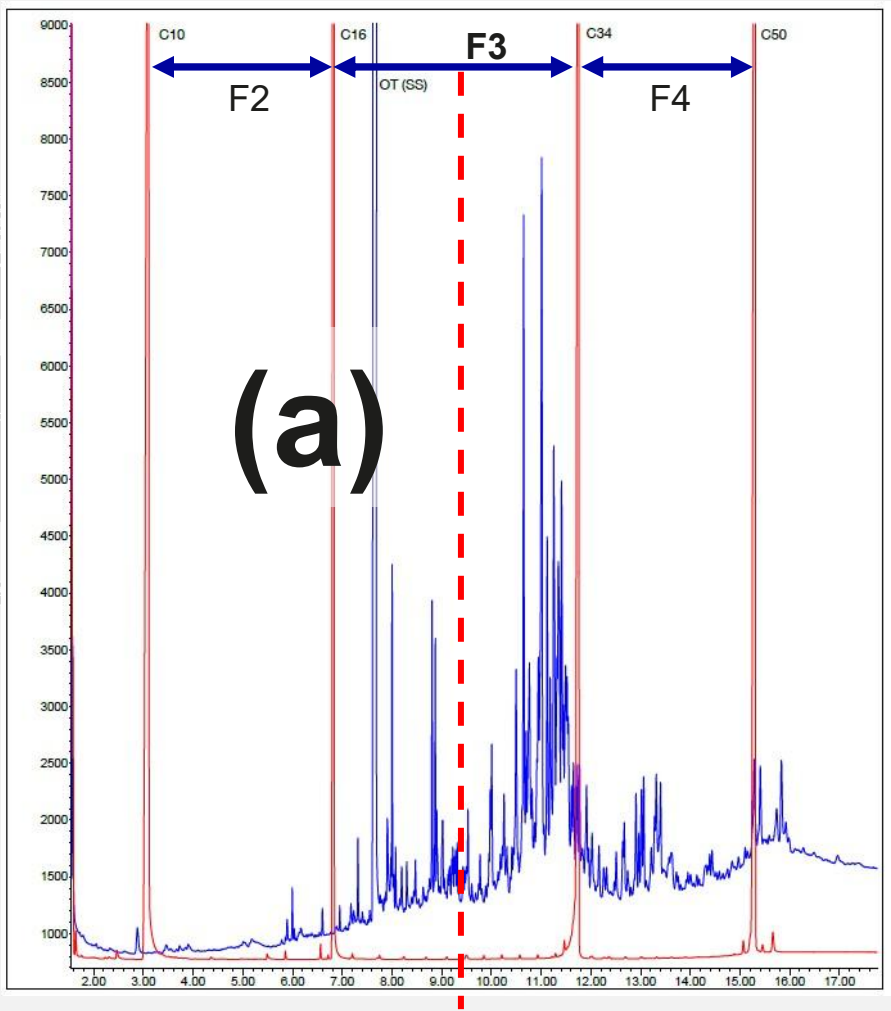
BIOGENIC CLUSTER

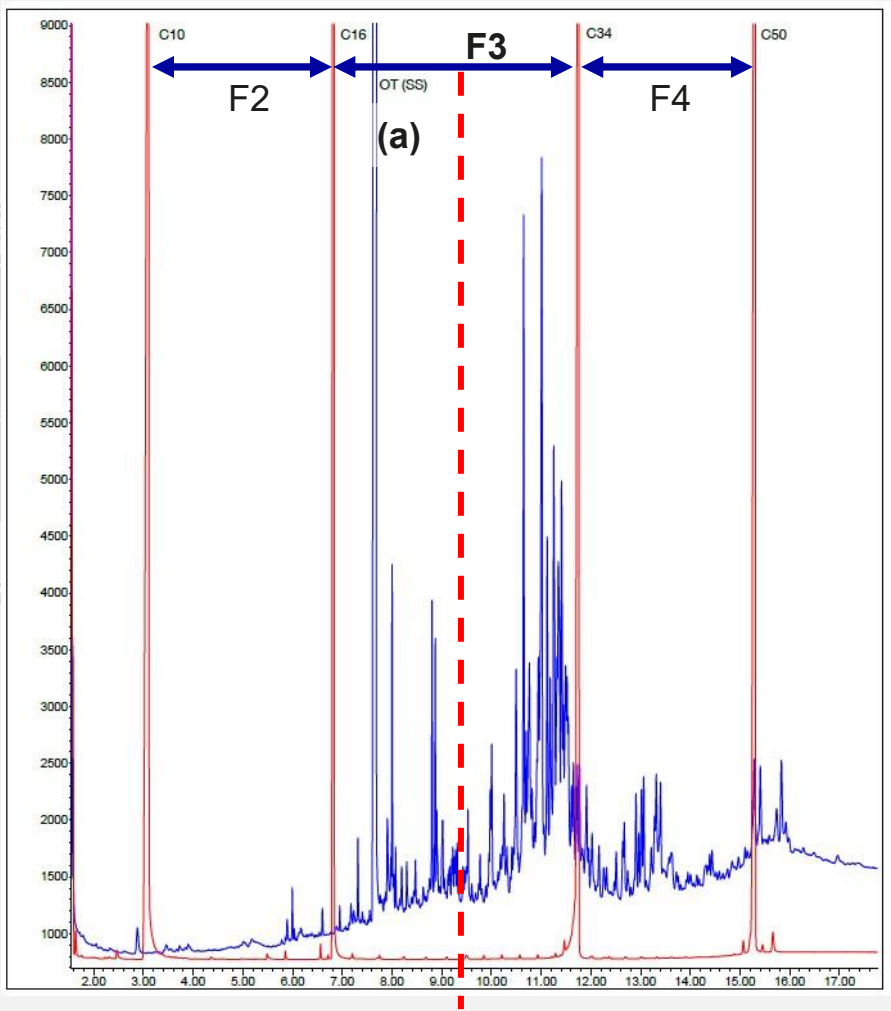
- Detections can be found in the F3 (nC_{16}-nC_{34}) fraction
- Plant-derived lipids that can appear like petroleum hydrocarbons
- Ex-situ silica gel column clean-up can remove, but often simple to identify without cleaning process
- Occurs in the latter half of the F3 fraction, often referred to as F3b
  - Alberta Environment recognizes as “Biogenic Interference Calculation” from Dr. Francine Kelly-Hooper
  - Requires F2 < 300 mg/kg in soils

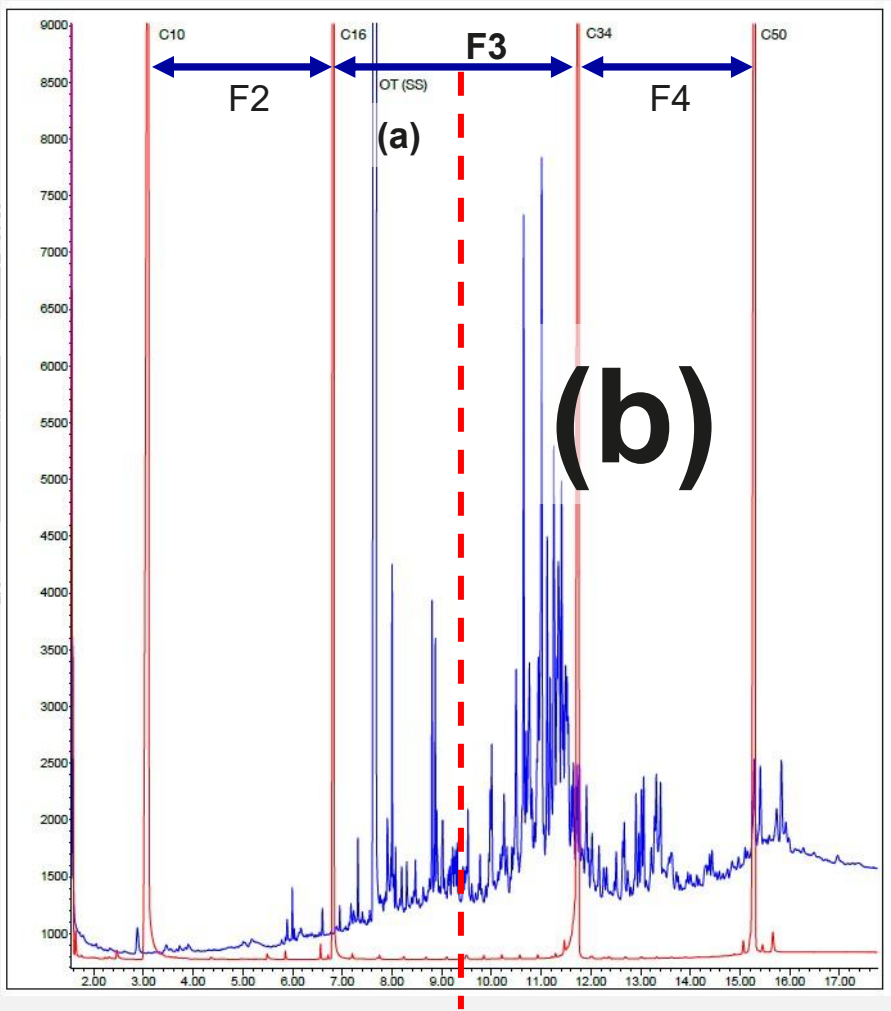


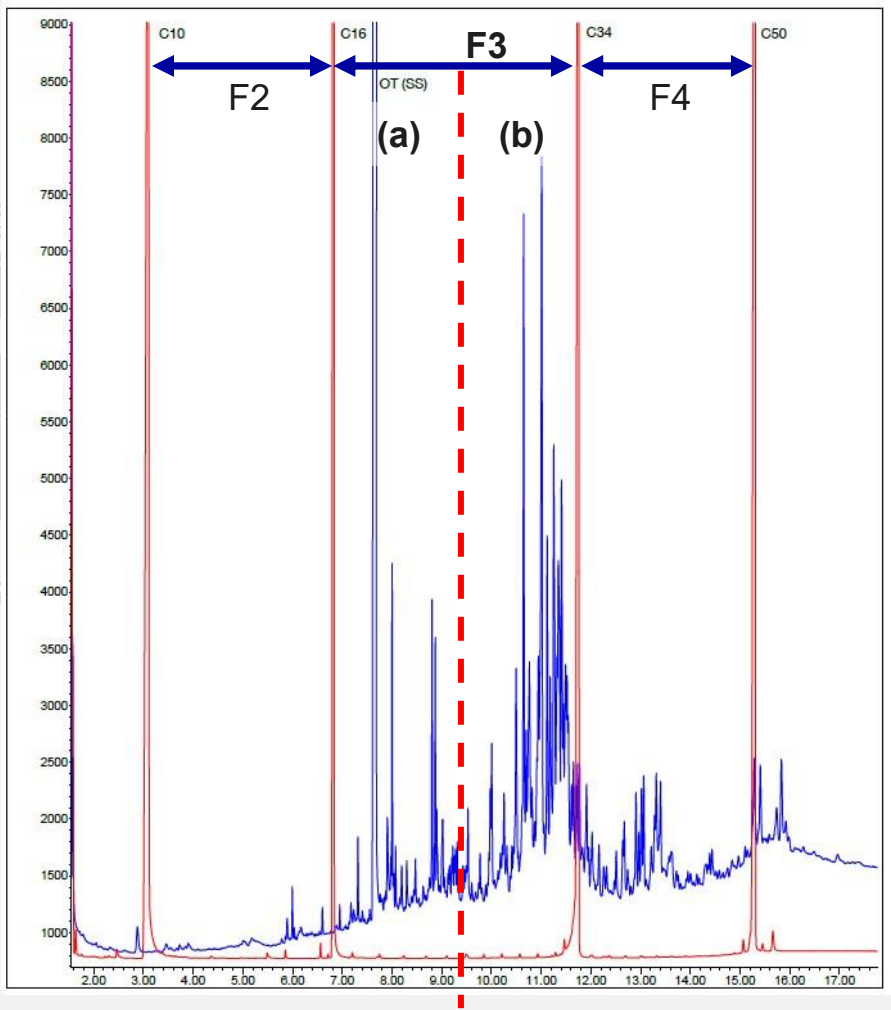

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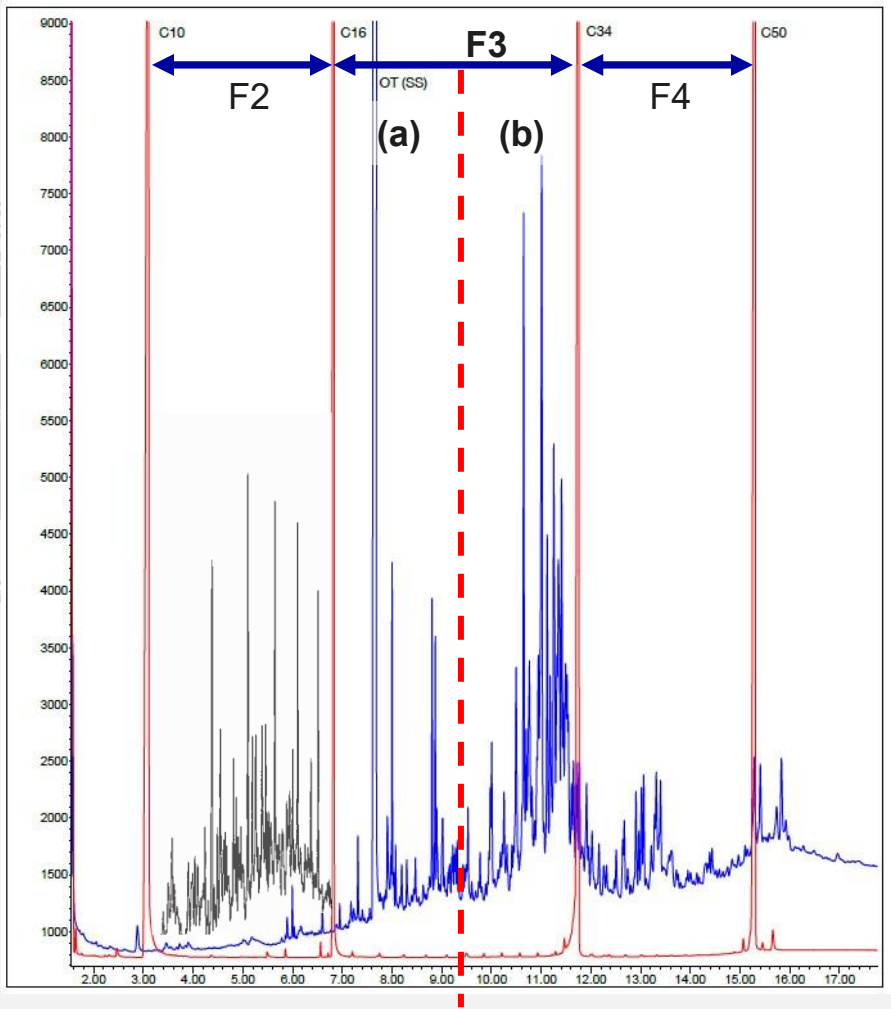

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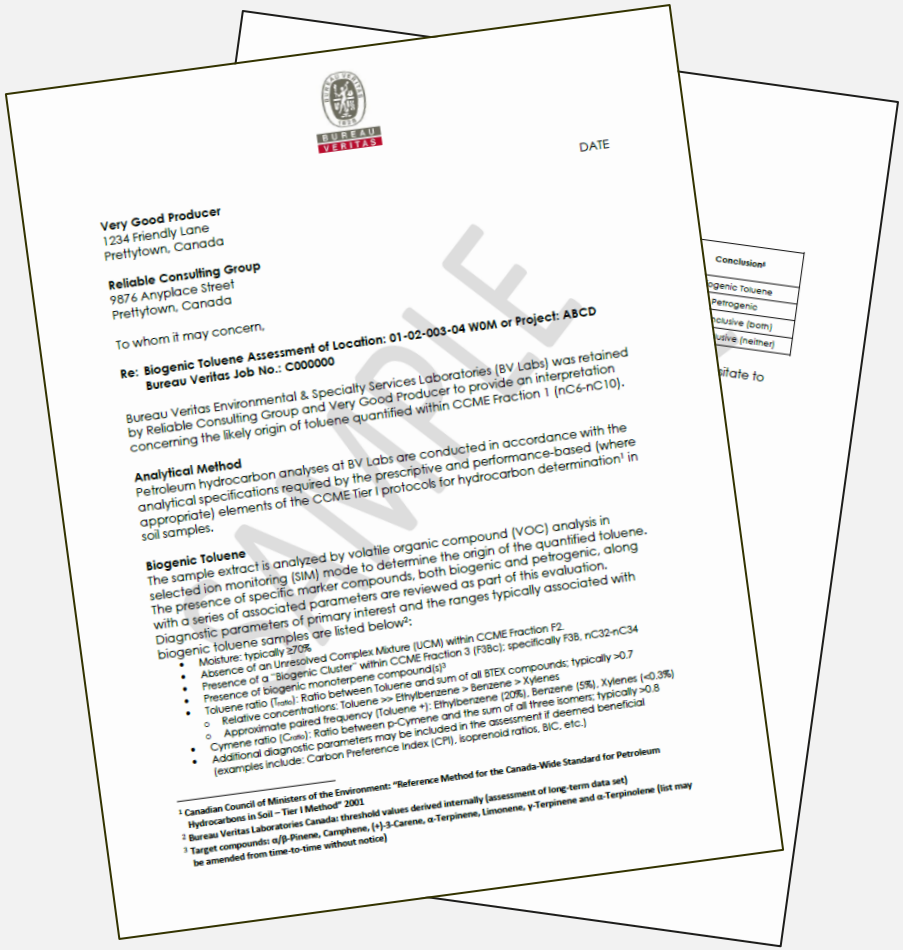
LINES OF DEFENSE

- High moisture content
  - High – ≥70%
  - Medium – <70% but ≥20%
- Unresolved complex mixture
- F3b biogenic cluster
- Biogenic monoterpenes
- Toluene ratio
  - [Toluene] / [Σ BTEX]
- Cymene ratio
  - [p-Cymene] / [Σ Cymene isomers]
- Carbon stable isotope analysis on $\delta^{13}C$ of toluene

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T-Ratio	0.94	NC	NC	0.98	NC	0.94	0.61
C-Ratio	0.87	0.84	NC	0.90	0.84	0.83	0.49
Biogenic Conclusion	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	

Benzene	<0.041	<0.046	<0.063	<0.055	<0.038	<0.040	0.12
Toluene	0.67	<0.12	<0.12	2.7	<0.12	0.69	1.0
Ethylbenzene	<0.073	<0.073	<0.073	<0.073	<0.073	<0.073	0.21
m- & p-Xylene	<0.33	<0.38	<0.55	<0.48	<0.34	<0.32	1.0
o-Xylene	<0.17	<0.19	<0.28	<0.24	<0.17	<0.16	0.3
F1	<45	<51	<74	<65	<46	<43	<41
F1-BTEX	<45	<51	<74	<65	<46	<43	<41
F2	<52	69	100	120	120	140	160
F3	2600	3600	3300	1900	4000	4200	5200
F4	1100	1700	1800	1100	1700	2100	3100
Moisture	81	84	87	84	82	80	78
T-Ratio	0.94	NC	NC	0.98	NC	0.94	0.61
C-Ratio	0.87	0.84	NC	0.90	0.84	0.83	0.49
Biogenic Conclusion	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**No**



DATE

Very Good Producer
1234 Friendly Lane
Prettytown, Canada

Reliable Consulting Group
9876 Anyplace Street
Prettytown, Canada

To whom it may concern,

Re: Biogenic Toluene Assessment of Location: 01-02-003-04 WOM or Project: ABCD
Bureau Veritas Job No.: C000000

Bureau Veritas Environmental & Specialty Services Laboratories (BV Labs) was retained by Reliable Consulting Group and Very Good Producer to provide an interpretation concerning the likely origin of toluene quantified within CCME Fraction 1 (nC6-nC10).

Analytical Method
Petroleum hydrocarbon analyses at BV Labs are conducted in accordance with the analytical specifications required by the prescriptive and performance-based (where appropriate) elements of the CCME Tier I protocols for hydrocarbon determination[1] in soil samples.

Biogenic Toluene
The sample extract is analyzed by volatile organic compound (VOC) analysis in selected ion monitoring (SIM) mode to determine the origin of the quantified toluene. The presence of specific marker compounds, both biogenic and petrogenic, along with a series of associated parameters are reviewed as part of this evaluation. Diagnostic parameters of primary interest and the ranges typically associated with biogenic toluene samples are listed below[2]:

- Moisture: typically ≥70%
- Absence of an Unresolved Complex Mixture (UCM) within CCME Fraction F2.
- Presence of a "Biogenic Cluster" within CCME Fraction 3 (F3Bc); specifically F3B, nC32-nC34
- Presence of biogenic monoterpene compound(s)[3]
- Toluene ratio (T_{ratio}): Ratio between Toluene and sum of all BTEX compounds: typically >0.7
  - Relative concentrations: Toluene >> Ethylbenzene > Benzene > Xylenes
  - Approximate paired frequency (Toluene +): Ethylbenzene (20%), Benzene (5%), Xylenes (<0.3%)
- Cymene ratio (C_{ratio}): Ratio between p-Cymene and the sum of all three isomers; typically >0.8
- Additional diagnostic parameters may be included in the assessment if deemed beneficial (examples include: Carbon Preference Index (CPI), Isoprenoid ratios, BIC, etc.)

[1] Canadian Council of Ministers of the Environment: "Reference Method for the Canada-Wide Standard for Petroleum Hydrocarbons in Soil – Tier I Method" 2001
[2] Bureau Veritas Laboratories Canada: threshold values derived internally (assessment of long-term data set)
[3] Target compounds: α/β-Pinene, Camphene, (+)-3-Carene, α-Terpinene, Limonene, γ-Terpinene and α-Terpinolene (list may be amended from time-to-time without notice)

SAMPLE

Conclusion[4]
ogenic Toluene
Petrogenic
clusive (both)
clusive (neither)

itate to

Data Interpretation

Table 1. Data Summary – Biogenic Toluene Evaluation

Lab ID	Sample ID	Diagnostic Parameters[4]						Conclusion[5]
		Moist	UCM	F3Bc	Mono	T_{ratio}	C_{ratio}	
	Example 1	H	No	Yes	Yes	0.92	0.89	Biogenic Toluene
	Example 2	L	F2	No	No	0.41	0.32	Petrogenic
	Example 3	H	F2/3/4	Yes	Yes	0.63	0.51	Inconclusive (both)
	Example 4	M	No	No	No	0.87	NC	Inconclusive (neither)

NA: Not Applicable; NC: Unable to Calculate (no cymene isomers detected)

If you have any questions or require additional information, please do not hesitate to contact the undersigned.

Sincerely,
Bureau Veritas Environmental & Specialty Services Laboratories

SAMPLE

Data Interpretation

Table 1. Data Summary – Biogenic Toluene Evaluation

Lab ID	Sample ID	Diagnostic Parameters[4]						Conclusion[5]
		Moist	UCM	F3B$_c$	Mono	T$_{ratio}$	C$_{ratio}$	
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	Example 3	H	F2/3/4	Yes	Yes	0.63	0.51	Inconclusive (both)
	Example 4	M	No	No	No	0.87	NC	Inconclusive (neither)

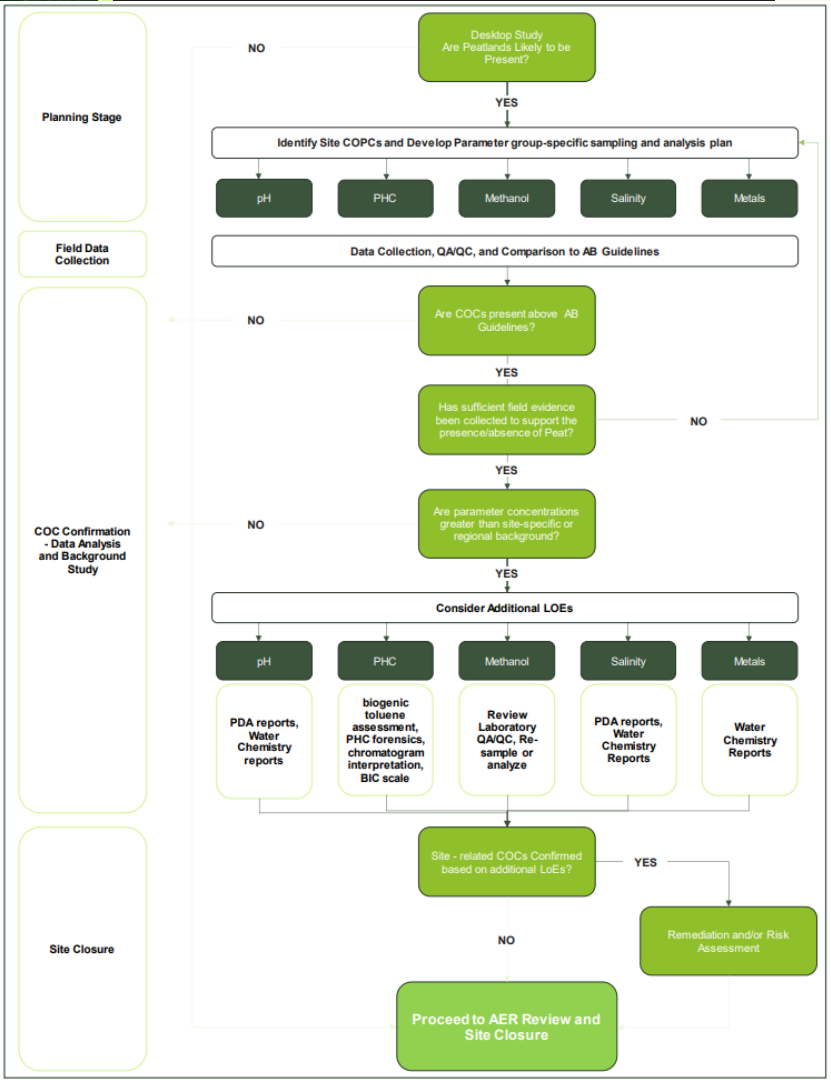
NA: Not Applicable; NC: Unable to Calculate (no cymene isomers detected)

If you have any questions or require additional information, please do not hesitate to contact the undersigned.

Sincerely,
Bureau Veritas Environmental & Specialty Services Laboratories



Shaping a World of Trust



Summary

- **Peat is a different matrix from mineral soil**, as it's comprised of organics and water and therefore **should be recognized as its own media in the regulations for assessment** and remediation of peatlands.
- The study provides **an improved approach for assessing contamination in peatlands** to support a more efficient evidence-based closure process of contaminated oil and gas sites in Alberta.
- The methods and best practices described in this Study are not meant to replace professional judgement. **Additional information regarding site settings and history**, including consideration of the surrounding properties, **must be evaluated in the context of CSM** in combination with the analytical data.

What's next?

- Development of peatland guidelines.
- Background database (like StatVis) specific to peatlands.
- AER OneStop RoSC submission checkmark for peat samples.
- Additional toxicity studies using peat soil and relevant biological terrestrial and aquatic species common to peatlands.



Questions? Please contact:

Maria Kudienko, *SLR Consulting*

Brody Andersen, *BV Labs*

Phil Richards, *PR Enviro Forensics*