Forensic Approaches for Complex Soil Sources: How it can Impact your Approach to Risk Assessments

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Safety moment:

Sample Collection

We are talking about analysing soil samples but the sample collection is important as well!

Evaluate your sampling plan and look for hazards during sampling.

Collect samples in the correct container using appropriate tools.

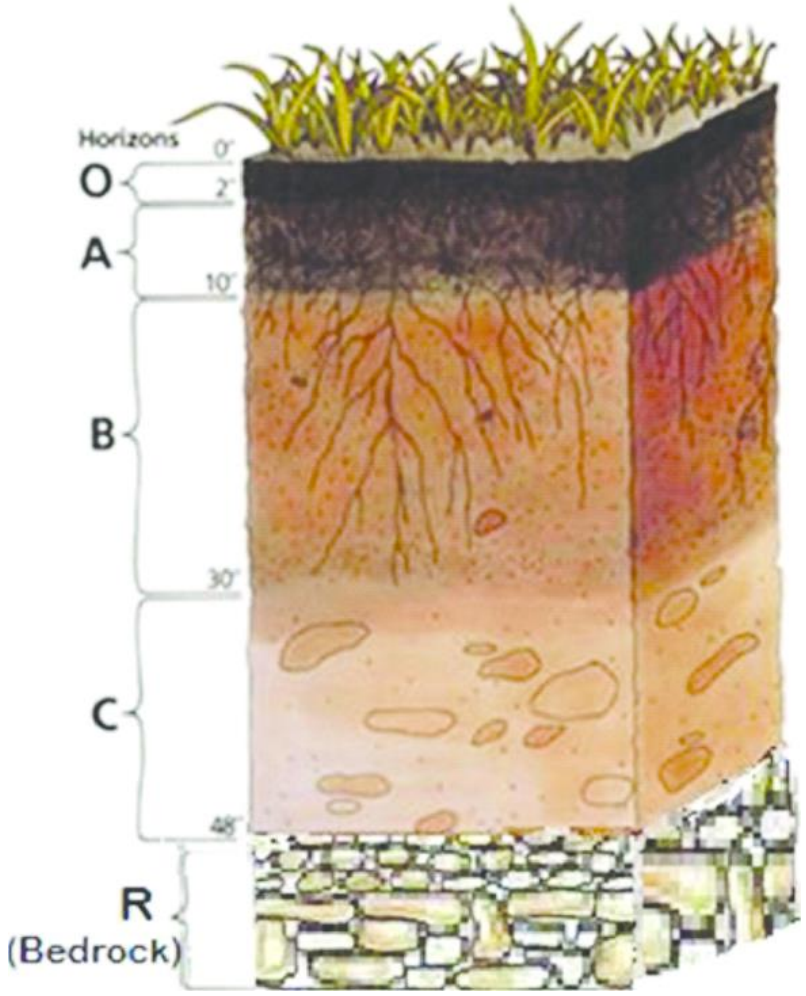
Reduce strain by utilizing smaller sampling containers (125mL jars instead of 500 mL jars) and smaller coolers for transport.

Overview

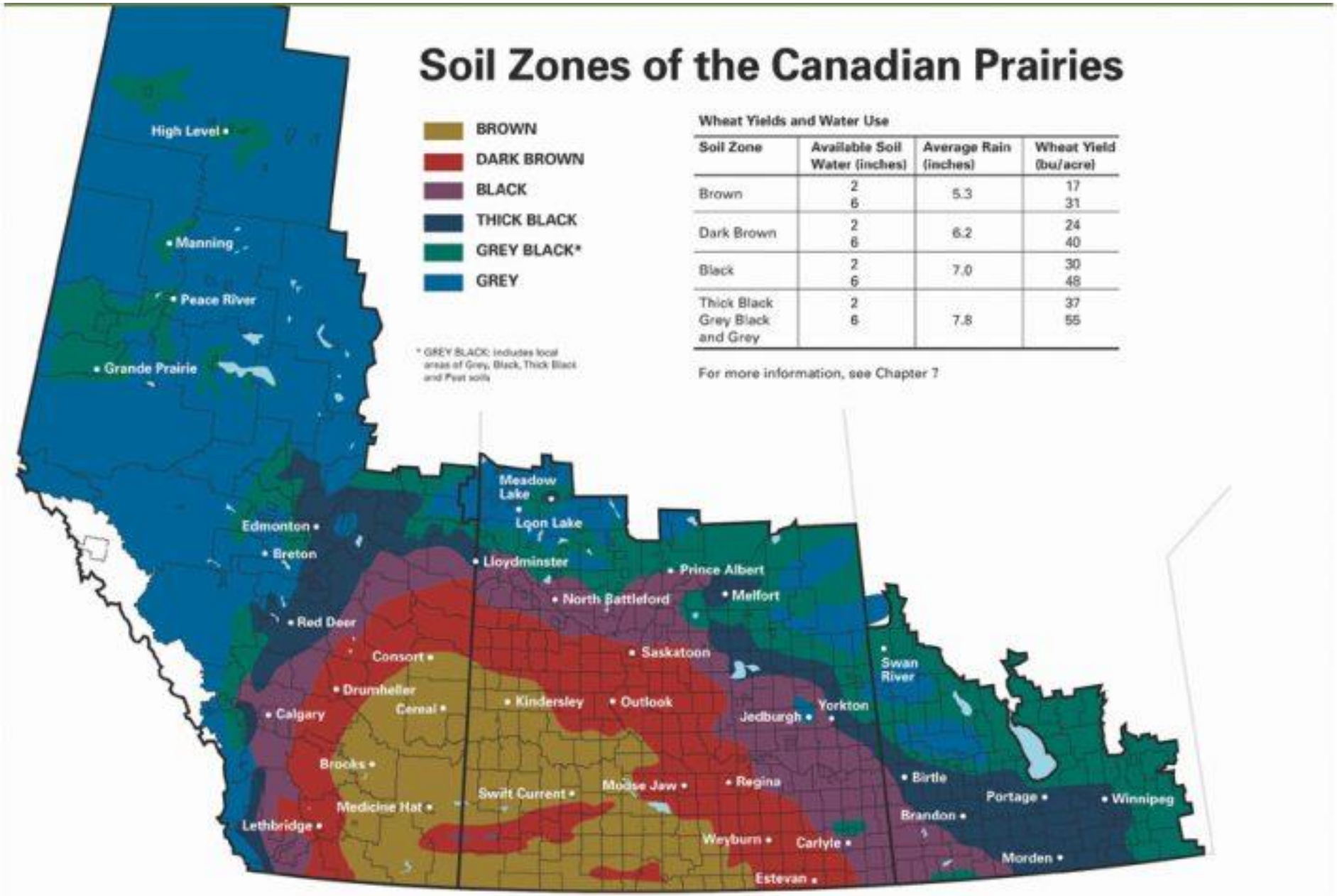
- Introduction to Forest Soils
- Challenges associated with Complex Matrices
- Method and regulatory adaptations
- Summary and Q&A

Introduction to Soil

- Soil is comprised of mineral particles interspersed with water and air.
- It is the top layer of the Earth's surface.
- Can be very variable based on the locality, depth, and environmental conditions.
- Can be composed of a mixture of loose minerals, and various states of organic matter.



Soil Zones of the Canadian Prairies



Wheat Yields and Water Use

Soil Zone	Available Soil Water (inches)	Average Rain (inches)	Wheat Yield (bu/acre)
Brown	2 6	5.3	17 31
Dark Brown	2 6	6.2	24 40
Black	2 6	7.0	30 48
Thick Black Grey Black and Grey	2 6	7.8	37 55

For more information, see Chapter 7

Forest Soil

- The most biologically active portion of the soil layer.
- Near the surface where water and oxygen levels are higher.
- Heavily influenced by incorporation of organic matter from grasses, shrubs, tree matter, forb, and root matter.
- Will contain physically uncomplexed organic matter.

Forest Soil

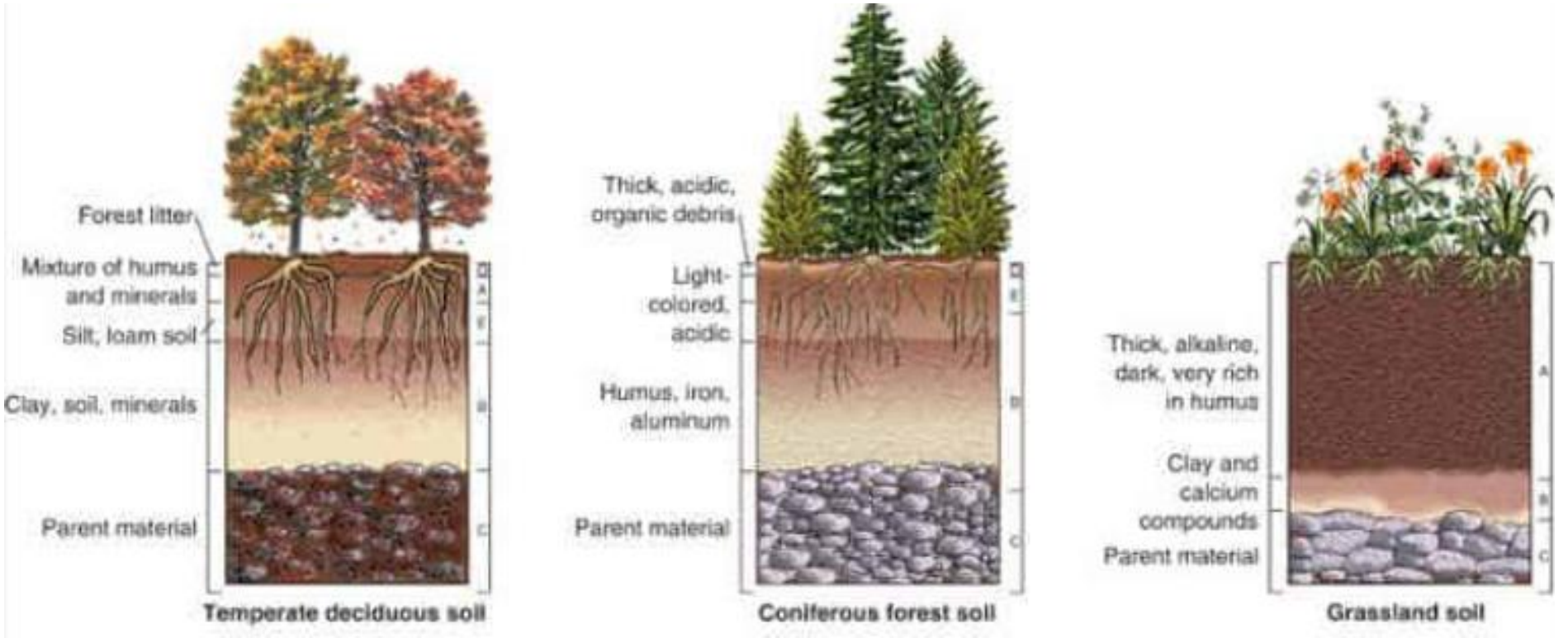


Image from: Lifescapecolorado.com

Forest Soil Analysis

- Soil is a complex matrix.
- Forest soils add an extra layer of complexity.
- Typical Soil Methods may not work!
- The data from analysis may be impacted in different ways.

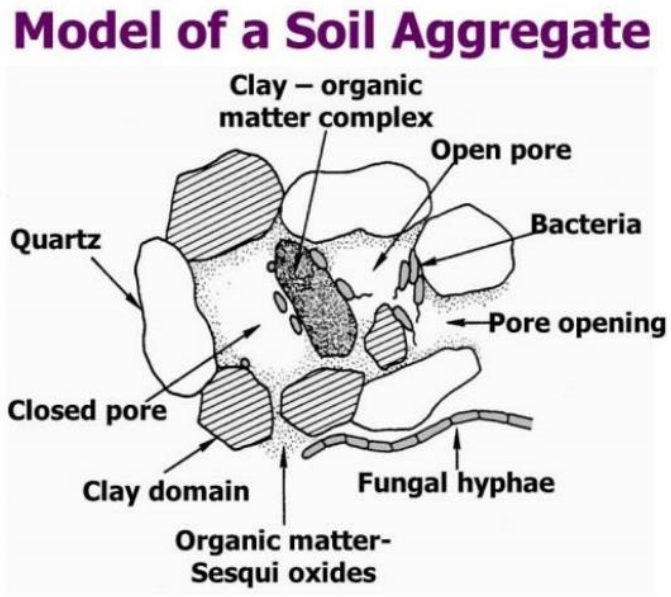


Image from USDA

Why is this important?

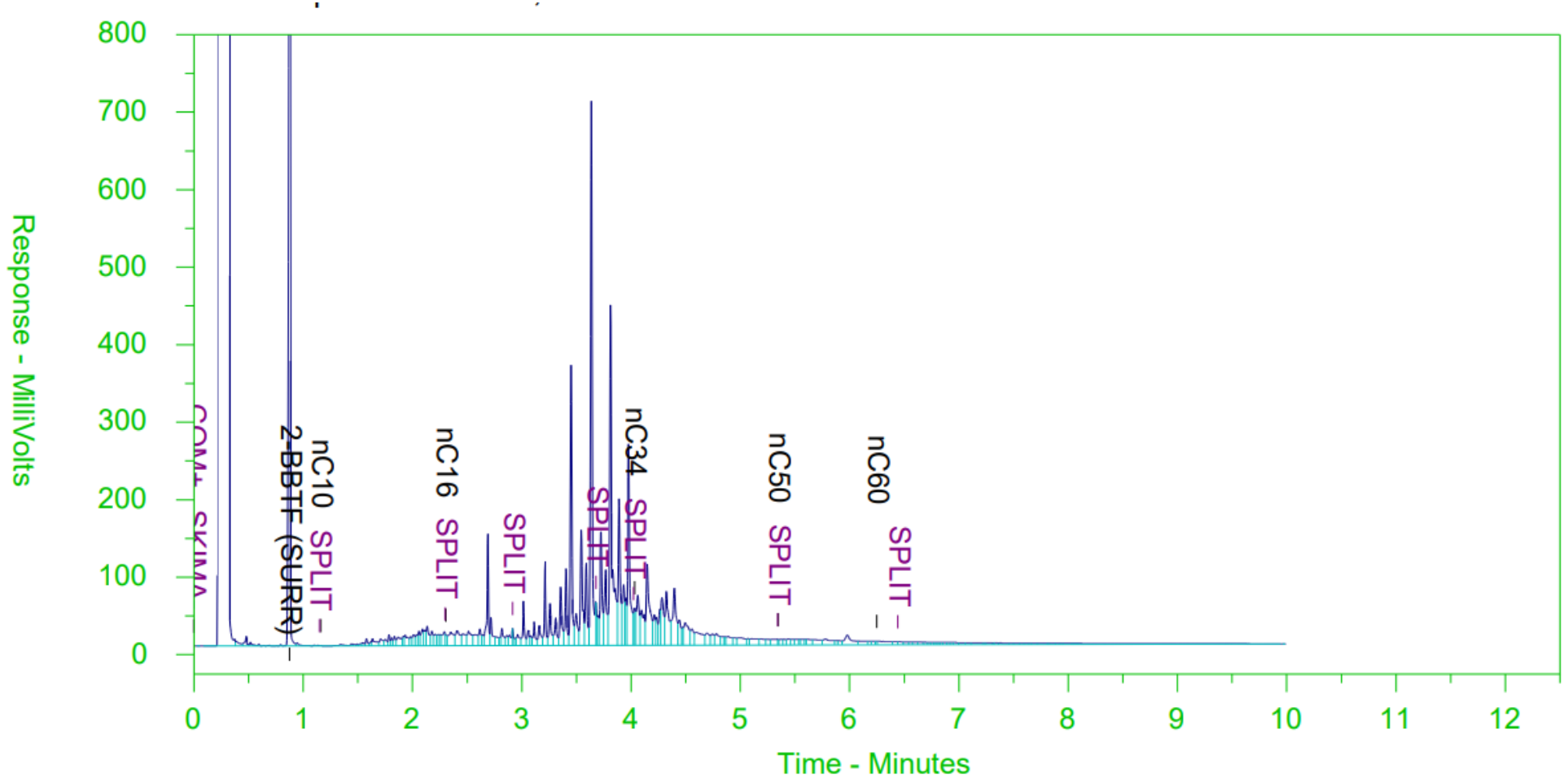
Alberta Tier 2 Guidelines

5.1 Conditions Triggering Tier 2

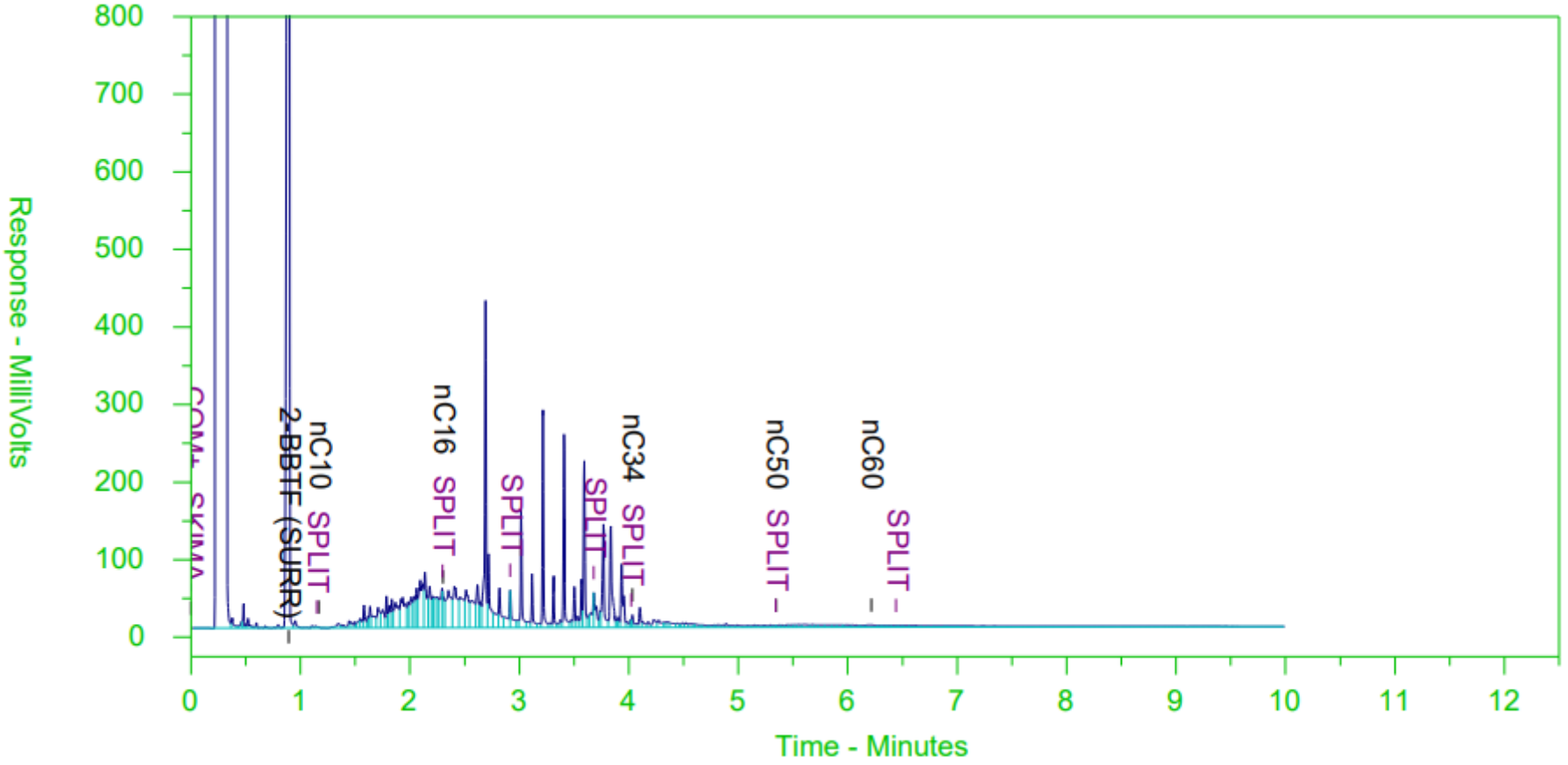
The use of Tier 1 guidelines is precluded when site-specific land and/or water use does not conform to a generic land or water use category, when site-specific factors invalidate the modeling used in the derivation of the generic guidelines, when a higher degree of exposure than considered in the generic scenario could result in more stringent guidelines, or when receptors may be more sensitive than considered in the default scenario and therefore result in more stringent guidelines. More detail on these exceptions are provided in the companion Tier 1. They are summarized as follows:

- Source of volatile contaminants present within 30 cm of a building foundation
- Unique building features, including earthen floors or unusually low air exchange rates
- Sensitive receptors that are present but not accounted for in the Tier 1 land use description
- Groundwater flow to stagnant water bodies
- Soil or groundwater contamination present within 10 m of a surface water body
- Very coarse textured materials enhancing groundwater or vapor transport
- Contamination in fractured bedrock
- Contaminant source length parallel to groundwater flow greater than 10 meters
- Organic soils

Hydrocarbon Analysis



Hydrocarbon Analysis – After Silica Gel Clean Up

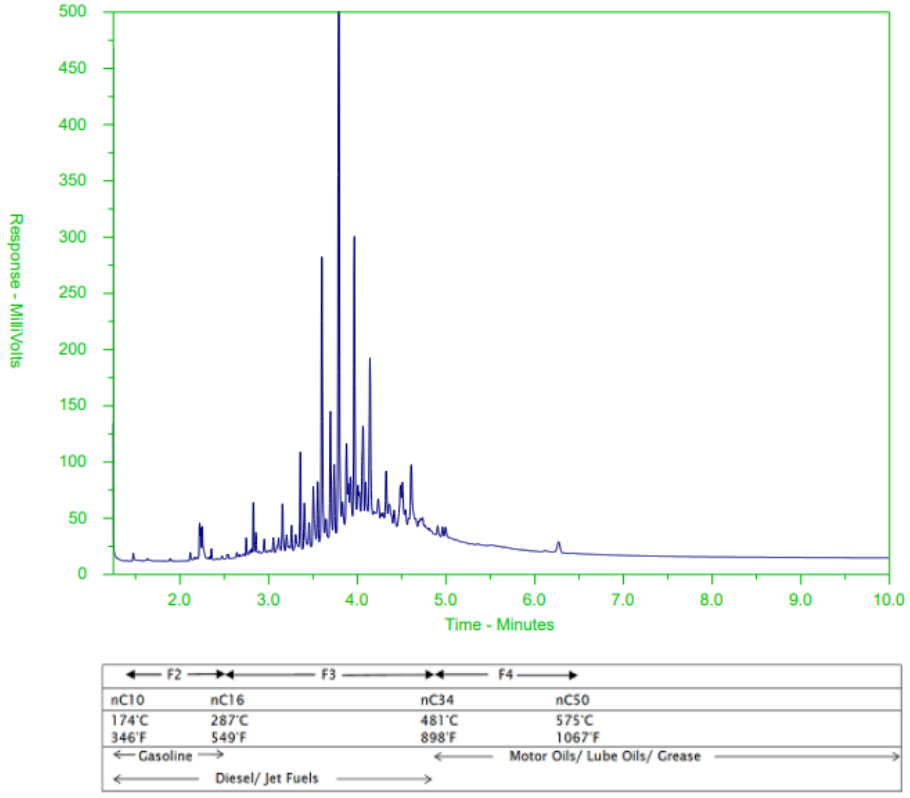


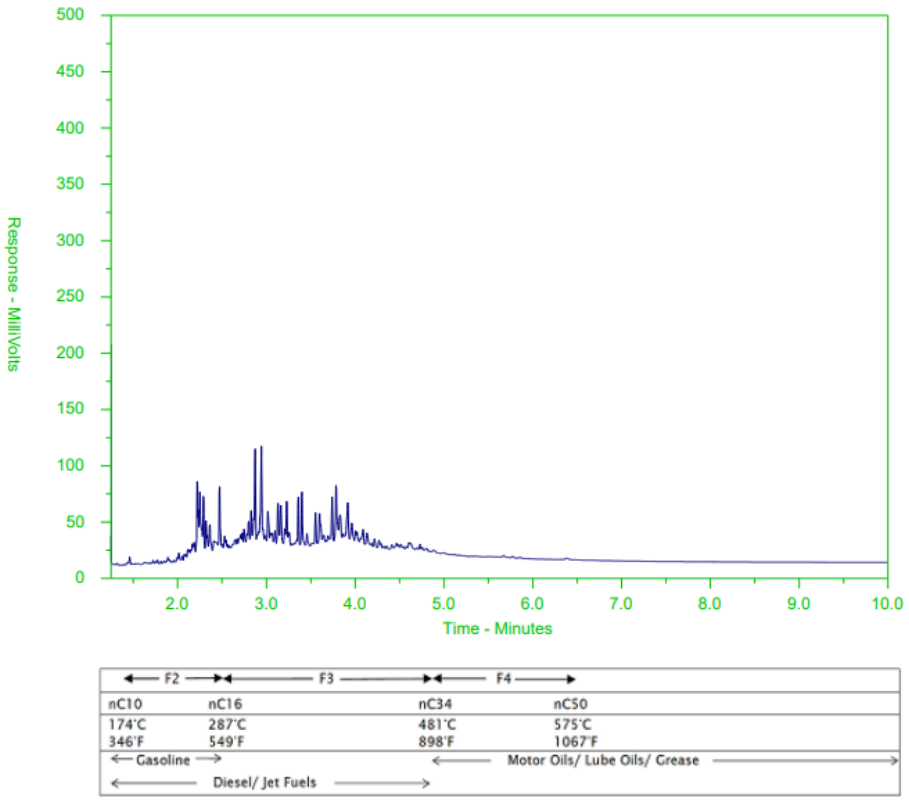
Coal

- Combustible, carbon-rich rock form from decomposed plant matter.
- Four main types:
  - Lignite, sub-bituminous, bituminous, and anthracite
- Forms in layers called seems.
- Can be exposed on the surface.
- Can impact analysis.

Coal Chromatography

- Coal will also appear as background on hydrocarbon distribution reports.
- Very similar to other PHC impacts.
- Can vary between different coal profiles.





PAHs (Source Evaluation)

- Polyaromatic Hydrocarbons (PAHs) are typically linked to energy production.
- Some occur within crude oil but many are formed through combustion processes.
- Can be split into three distinct groups:

Phytogenic derived from plants	Petrogenic derived from petroleum	Pyrogenic derived from combustion

Parks Canada

Forest Fires and PAH Analysis

- Three diagnostic ratios can be used to evaluate petrogenic vs. pyrogenic sources:
  - Fluoranthene /(Fluoranthene + Pyrene) Ratio
    - If this ratio is less than 0.4, this is generally indicative of a petrogenic source of PAHs. [Yunker 2002]
  - Phenanthrene / Anthracene Ratio
    - If this ratio is less than 10, this is generally indicative of a pyrogenic source of PAHs. [Tolosa 2003]
  - ∑ Methylated phenanthrenes / Phenanthene Ratio
    - If this ratio is less than 1, this is generally indicative of a pyrogenic source
  - [Yunker 2002; Elias 2007]
    - Requires Alkylated PAH Analysis to Evaluate.

References:

Tolosa, I., Stephen de M., Mohammad R. S., Jean-Pierre.V., Jean. B and Chantal. C., 2003. Aliphatic and aromatic hydrocarbon in coastal Caspian Sea sediments. Marine Pollution Bulletin Vol. 48, Issues 1-2, January 2004, Pages 44-60.

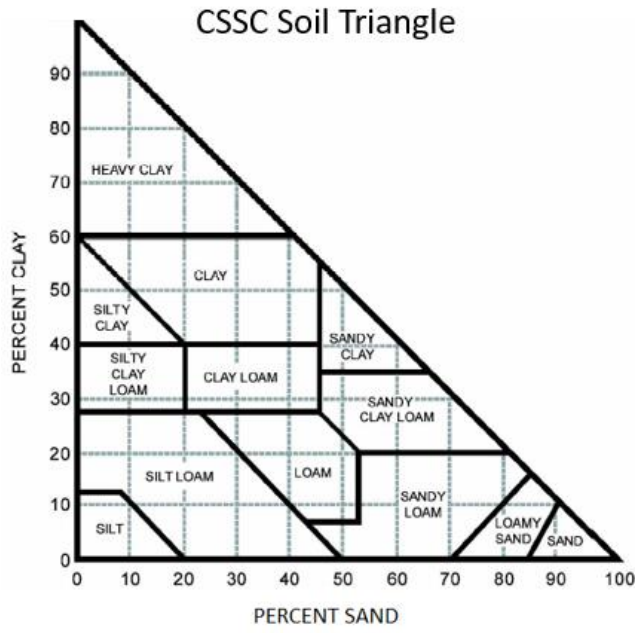
Yunker, M.B., Macdonald, R.W., Vingarzan, R., Mitchell, R.H., Goyette, D.S., Stephanie, 2002. PAHs in the Fraser River basin: a critical appraisal of PAH ratios as indicators of PAH source and composition. Organic Geochemistry 33, 489–515.

Md. Suhaimi Elias, and Ab. Khalik Wood, and Zaleha Hashim, and Wee, Boon Siong, and Mohd. Suhaimi Hamzah, and Shamsiah Abdul Rahman, and Nazaratul Ashifa Abdullah Salim, and Ariffin Talib, (2007) *Polycyclic Aromatic Hydrocarbon (PAH) Contamination in the Sediments of East Coast Peninsular Malaysia.* Malaysian Journal of Analytical Sciences, 11 (1). pp. 70-75. ISSN 13942506.

Particle Size Analysis

- Particle Size Analysis is based around several assumptions.
- Prairie soils typically will fall within these assumptions with minimal pre-treatment.
- Forest soils do not follow the same principles!

High OM!
>30%



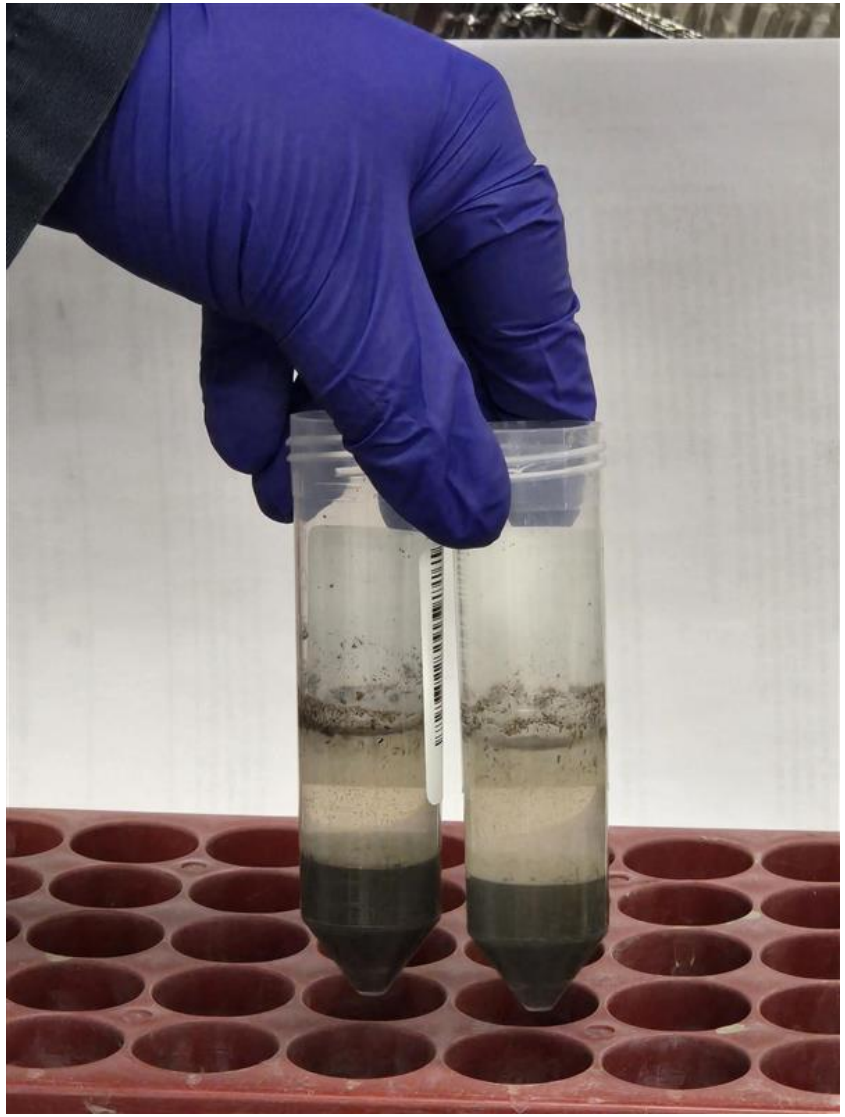
Courtesy of AAFC CSSC

Particle Size of Forest Soils

- Requires evaluation of degree of decomposition.
- Wet sieving process.
- Only can analyze samples to 0.075 mm.
- Sedimentation methods (for finer materials) may not apply.
- Other methods such as PSA-Laser Diffraction or highspeed photography can be applied.

Fixed Ratio Analysis

- Routine analysis for inorganic parameters.
- Most common tests:
  - Soil pH 1:2 CaCl2 extraction
  - VOC Methanol Vials (1:2)
- High organic matter samples become difficult as the samples will absorb your extraction liquid.
- Organic particles can be difficult to settle due to the buoyancy.
- For some analysis, Reporting limits must be adjusted due to moisture considerations.



Fixed Ratio Analysis

- For high OM samples, extraction ratios can be adjusted.
- Ratios from 1:5 to 1:9 can be expected depending on the sample type.
- Sphagnum mosses can absorb significant volumes of liquid, swelling up.
- Reporting limits may need to be adjusted based on the extraction ratio.

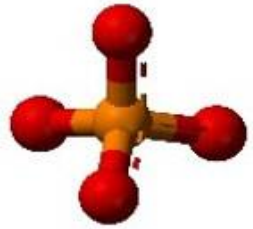
Metals Analysis

- Digesting soil samples for metals can be challenging with high organic matter.
- Higher temperatures can cause sample boil overs.
- Require extended cold digestion and reduced sample volumes.
- High carbon content can cause analytical interferences requiring careful considerations.
  - Dilutions
  - Matrix matching

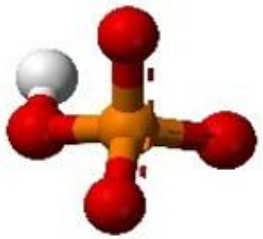
Case Study: Soil Phosphorus

- Critical Macronutrient in soil.
- Exists in various forms which change the state of availability.
- Not highly mobile.
- Forms:
  - Organic P
  - Soil Solution P
  - Sorbed P
  - Secondary P Minerals
  - Primary P Minerals

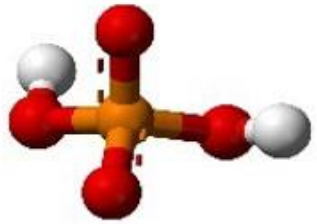
→ **Plant Available Phosphorus**



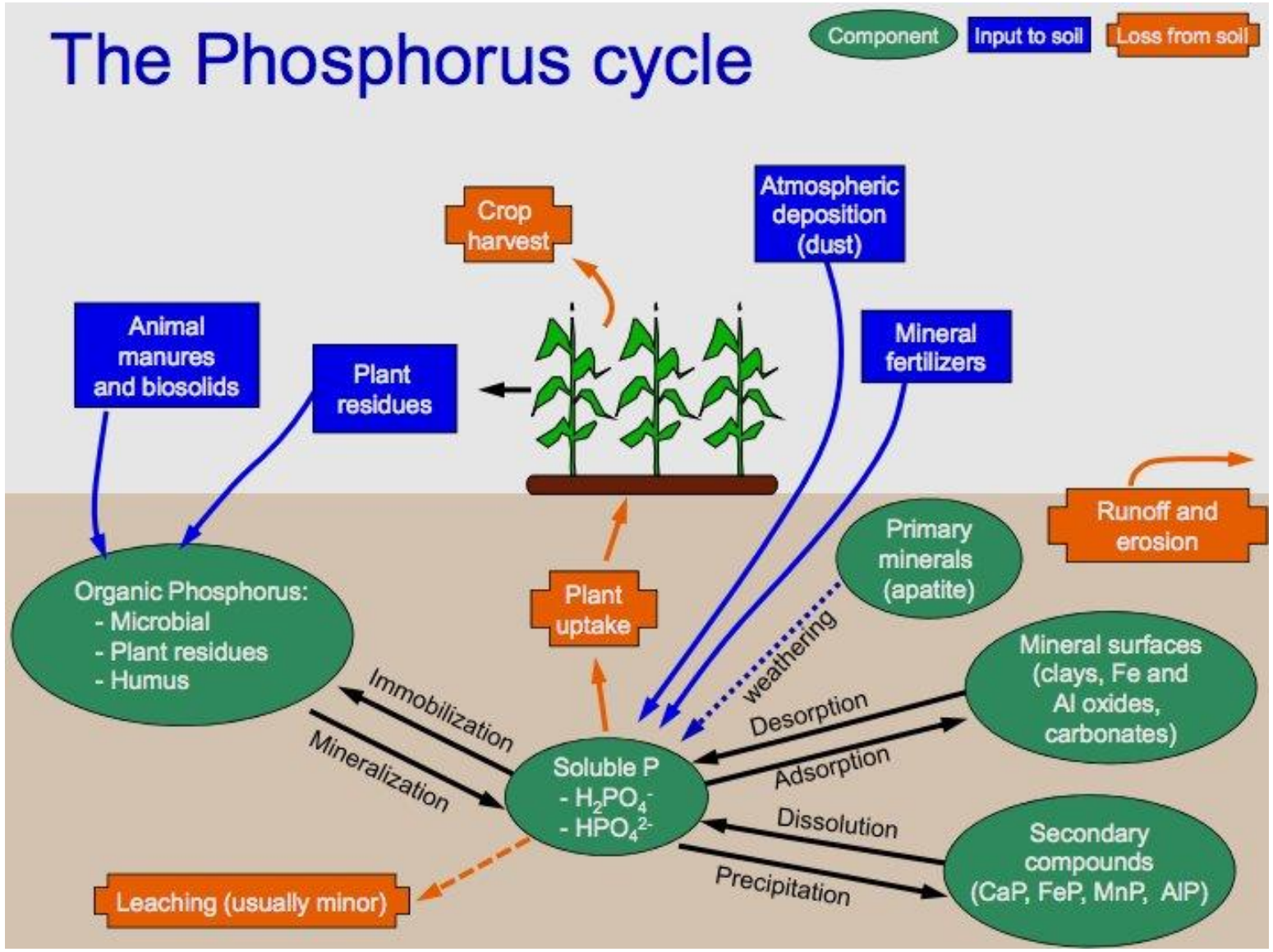
orthophosphate



hydrogen phosphate



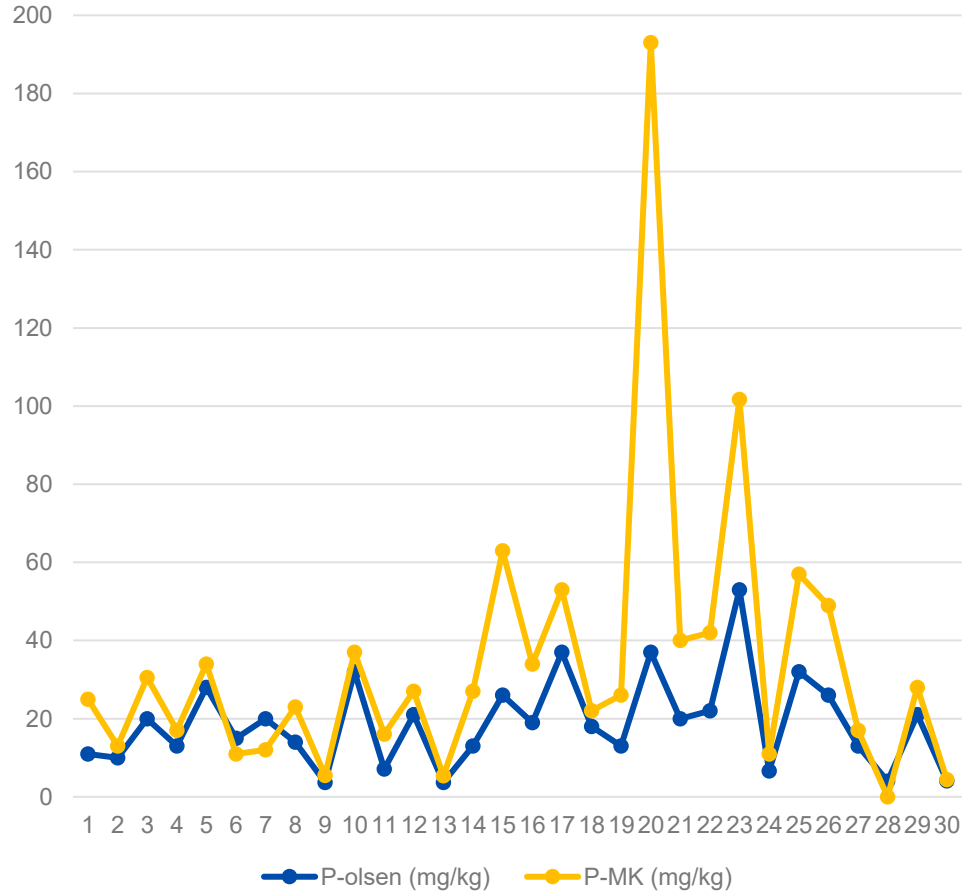
dihydrogen phosphate



https://commons.wikimedia.org/w/index.php?curid=48498089

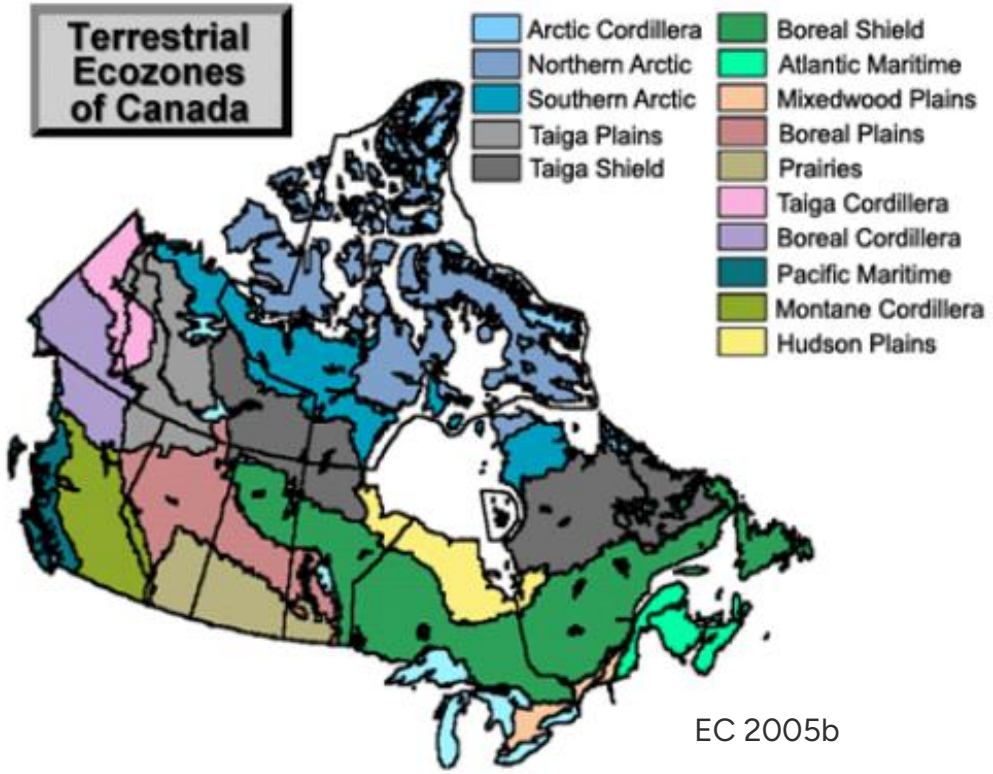
Phosphorus Testing

- It is important to know the form of phosphorus you are testing.
- Forest soils will have higher acidity compared to calcareous soils.
- In low pH samples, phosphates will bind with aluminum and iron.
- Analysis of available phosphorus for forest soils requires buffering conditions.
- Use of the Olsen method (Bicarbonate/Carbonate buffered) over conventional Kelowna/modified Kelowna.



Risk assessments

- Forest soils require specific considerations when performing risk assessments.
- Alberta considers organic soils as a vector for triggering tier 2.
- Thick organic surface horizons create challenges.
- Ecologically important.



EC 2005b

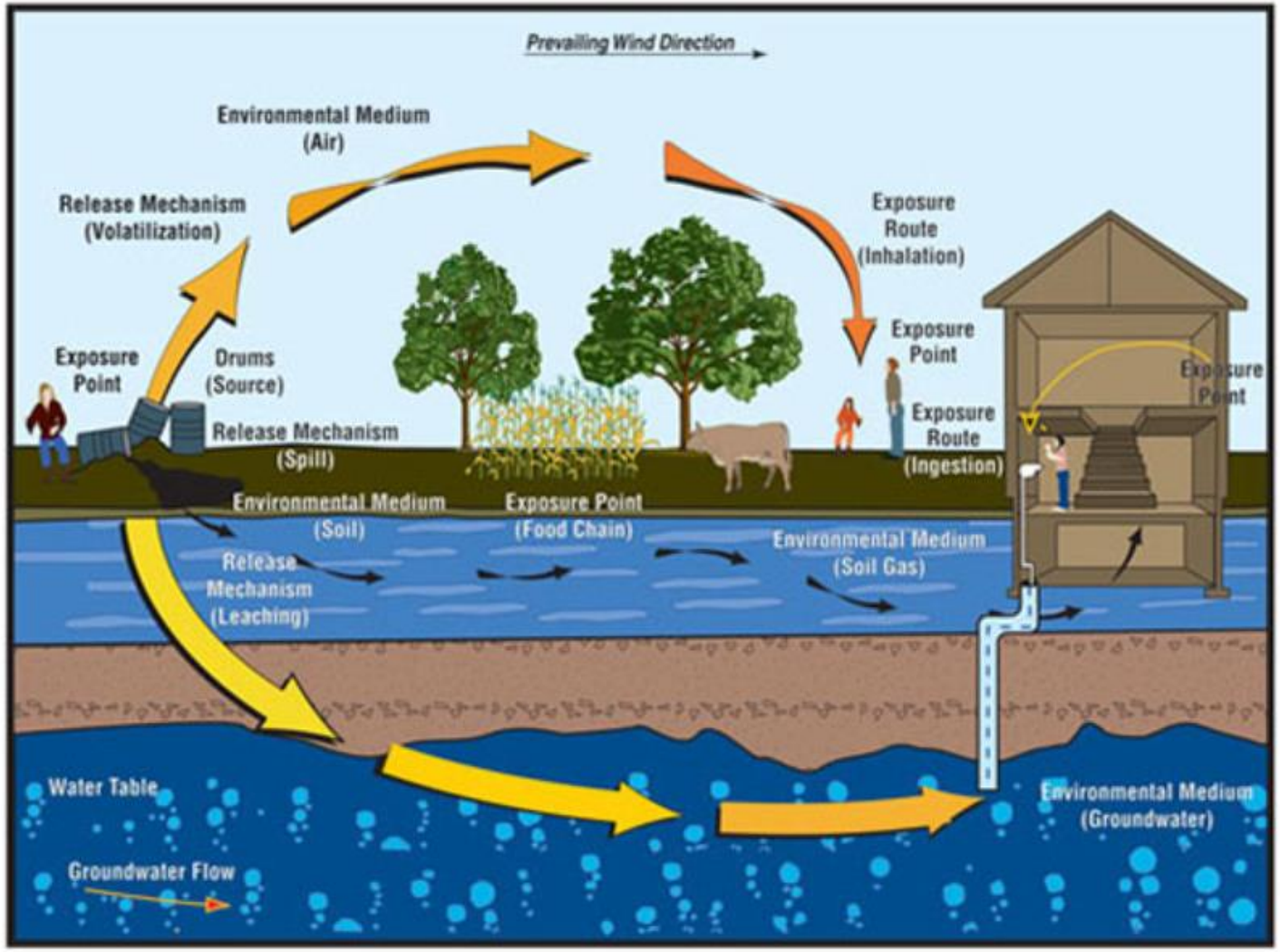
Risk Assessments

- Site assessments for contaminated forest sites requires additional considerations.
  - Surface vegetation and litter
  - Organic horizon contamination
  - Difficult to establish boundaries between organic and mineral horizons

- Hydrology through forest soils can lead to different behaviors.

- Biologically active. A living, growing system.
  - Ecological impacts
  - Microbiology can change site impact
  - Exposure pathways

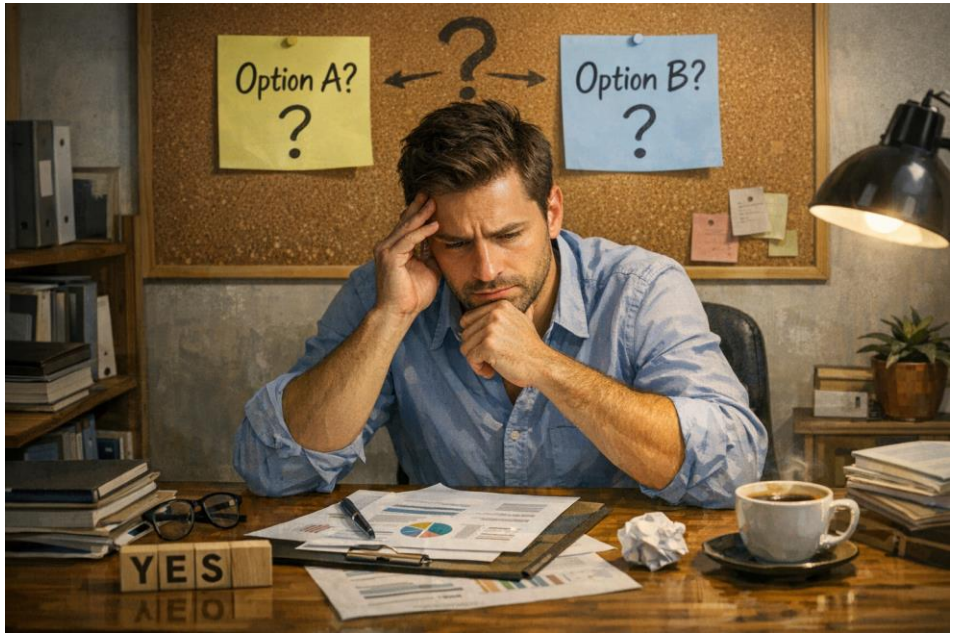
Exposure Routes



ATSDR CDC 2022

Decision Making

- What do you need the data to tell you?
- Some methods may not work as well based on high organic matter.
- Site history is important including environmental background. (Ex. Coal)
- Forest soil site impacts require you to evaluate that the right methods are selected and the data represents the right source.
- Sample collection when there are extraneous matter can be difficult.
- Sample heterogeneity is expected.



Summary

- The difference between ‘Prairie’ soil and Forest soil.
- Organic matter and the limitations of analytical techniques.
- Site history becoming an important component of evaluating site condition.
- Risk Assessments and how to evaluate pathways when looking at forest soils.

right solutions.
right partner.

Questions & Answers

right solutions.
right partner.

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