

Acid-Base Accounting Methodology Comparison

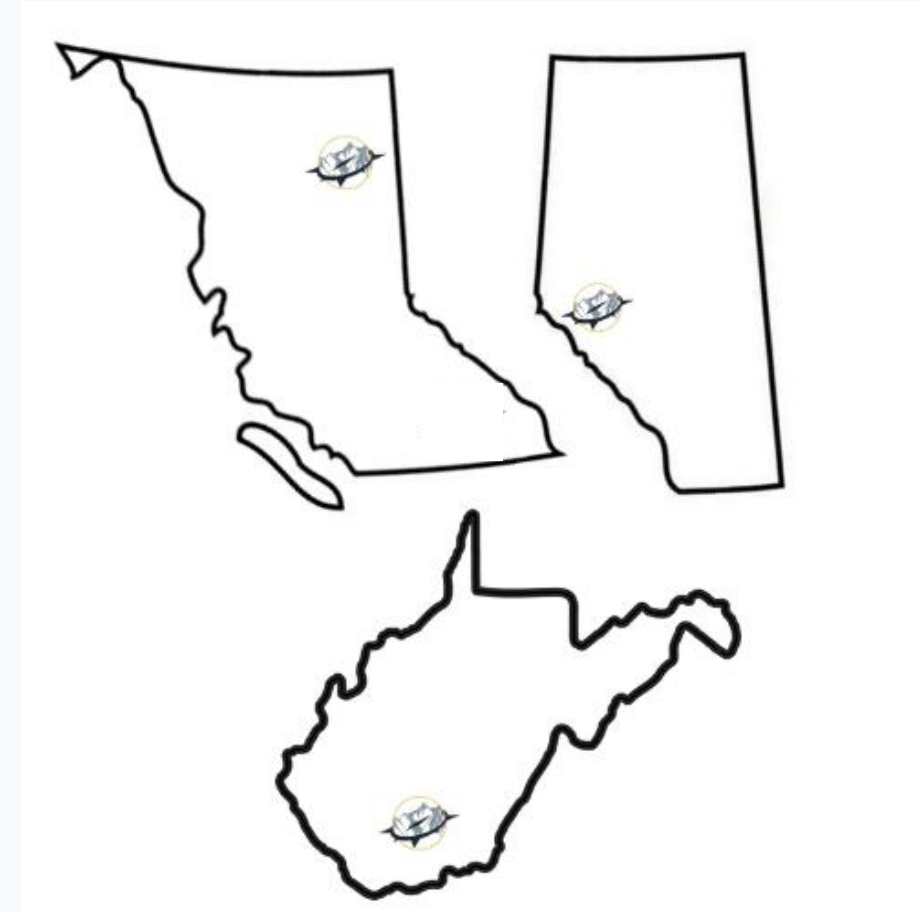
Looking into and beyond the Sobek / EPA-600 Baseline

**2026 West Virginia Mine Drainage Task Force Symposium
Morgantown, West Virginia**

NAVANA Labs | Flurina Deagle

NAVANA Labs

- 3 North American facilities
 - Hinton, Alberta – ISO17025 accredited
 - Chetwynd, British Columbia – ISO17025 accredited
 - Crab Orchard, West Virginia
- Coal (US and Canada Labs)
 - Full suite of thermal and metallurgical analysis
 - Gravity separation and plant testing
- Overburden (US and Canada Labs)
 - Acid base accounting
 - Topsoil substitute
- Water (Canada Labs)
 - Compliance monitoring
 - Surface and well water



NAVANA Labs- Leadership

- Thomas Cook
 - 30+ years of industry experience
 - Regulatory, coal industry, consulting, lab operations
- Greg Powers
 - 35+ years of coal industry experience
 - Geology, laboratory, preparation plant optimization, blending
- Tim Keeney
 - 45+ years of industry experience
 - Soil scientist
 - Leading expert on topsoil substitute analysis
- David Willson
 - 25+ years of industry experience
 - Biological, mitigation, environmental monitoring
- Flurina Deagle
 - 10 years of geology, laboratory operations and management
 - ISO17025 compliance



Agenda

- Acid Base Accounting
 - Acid Potential methods
 - Neutralization Potential methods
 - Different applications to coal, overburden, and refuse
- Topsoil substitute
 - Available plant nutrients and soluble salts
- Selenium
- Slake durability

Overburden Analysis - Current Baseline

WV Baseline

West Virginia practice remains anchored in acid-base accounting (ABA) and the Sobek / EPA-600 methods recognized by WVDEP

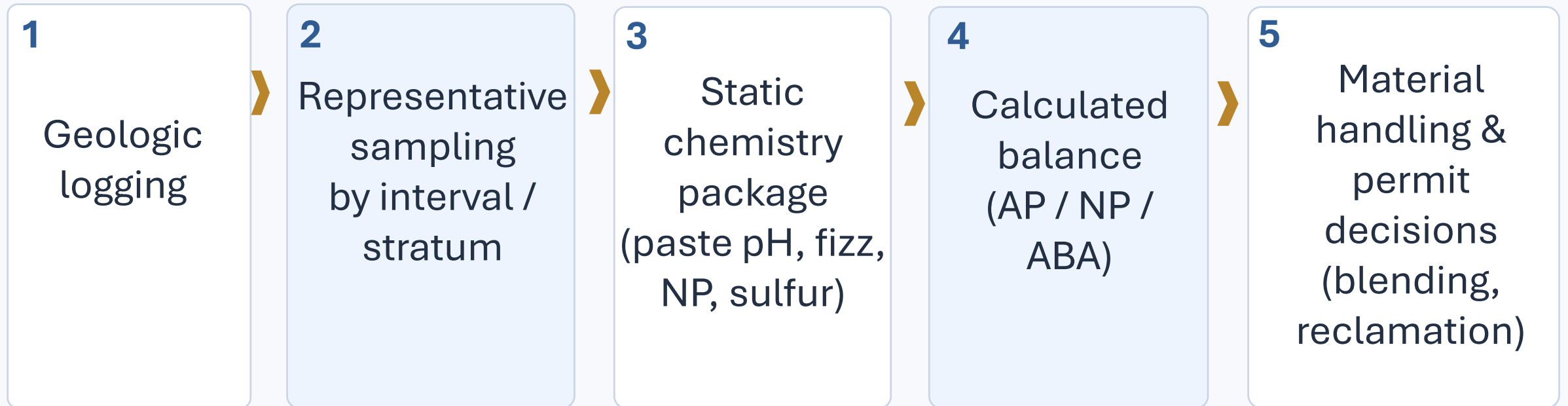
ABA

Series of analyses and calculations used to estimate the potential for mineral weathering to generate acidic drainage and the neutralizing abilities of materials

Technical challenge

The same rock unit can be interpreted differently when different analytical methods are used. Variable approaches to sulfur forms and neutralization potential can affect results and subsequent decisions

ABA workflow: from drill hole to permit conclusion



ABA chemistry package

Paste pH

Screens current acidity on unweathered samples. pH influences element mobility, including selenium behavior.

Fizz

Determines the acid volume and normality used in the Sobek NP digestion.

Neutralization Potential

A laboratory “best-case” measure of how much acid a pulverized sample neutralizes.

Sulfur Forms

Pyritic sulfur is commonly considered the acid producing form of sulfur.

Acid Potential (AP)

- Sulfur containing minerals are the primary source of acidity
- Sulfur species results will affect outcome of AP
- AP is determined via calculation from sulfur analysis
 - Low concentration samples use total sulfur
 - Higher sulfur samples use pyritic sulfur
- Used with Neutralization Potential to determine Acid Potential Ratio, and Net Neutralization Potential
- Acid drainage will occur when the rate of acid generation exceeds the rate of acid neutralization

Sulfur Forms

Pyritic Sulfur

- Primary reduced inorganic species
- Pyrite is the most common sulfide mineral contributing to AP and is assumed to be the source of AP in calculations
- Occurs with iron

Sulfate Sulfur

- Most oxidized inorganic sulfur species
- May be deposited by geological processes or precipitation of sulfate
- Most likely present in areas that were hydrothermally altered or formed under evaporative or marine conditions

Organic Sulfur

- Occurs in materials that contain organic materials
- Generally not significantly acid producing

Sulfur Forms – Analytical Methods

EPA600

- Cold acid digestion using HCl and NaOH
- Determines sulfate sulfur and pyritic sulfur

ASTM E1915

- Similar to EPA600
- Adds heat to reaction

ASTM D8214

- Designed for coal analysis
- Determines pyritic sulfur by calculation using iron values instead of directly analyzing sulfur

NAVANA Labs Aqua Regia Method

- Determines inorganic sulfur
- Useful in predicting post mining, AMD, sulfate concentrations

Sulfur Forms

EPA600

PROS

- Widely recognized and understood
- Uses existing instrumentation

CONS

- Short, cold reaction could result in incomplete reaction
- Uses calculations, so errors can compound

ASTM E1915

PROS

- Additional heat and increased exposure time allows more complete reaction

CONS

- Not widely recognized
- Uses calculations, so errors can compound

Sulfur Forms

ASTM D8214

PROS

- Reliable method for coal analysis

CONS

- Method specifies interpretation from iron result, not sulfur result
- Assumes all iron present is from pyrite
- Can overestimate acid potential
- Acceptable for coal, not for rock

NAVANA Labs Aqua Regia Method

PROS

- Shorter preparation and analysis time
- Fewer wet chemistry steps
- Includes all inorganic sulfur

CONS

- In house method – developed to meet customer specific permit requirements
- Not able to give separate sulfate vs pyritic results

Sulfur Forms Case Study

	Total Sulfur, %	Sulfate Sulfur, %	Pyritic Sulfur, %	Organic Sulfur, %
Sample A	0.07	<0.01	0.13	-0.06
Sample B	0.05	<0.01	0.08	-0.03
Sample C	0.19	<0.01	0.24	-0.05
Sample D	0.84	<0.01	0.91	-0.07

Sulfur forms using ASTM D8214

Neutralization Potential (NP)

- Measures the total acid a material can neutralize
- Most carbonates are soluble in acidic environments and neutralize quickly
- Carbonate solubility will increase to match increase in acid
- Bulk NP and carbonate NP can both be analyzed to determine how much of the NP is effective

Neutralization Potential (NP) – Sobek NP

- Tests bulk NP using strong acids
- Fizz test used to select HCl volume and normality.
- Heat acidified sample nearly to boiling until reaction is complete.
- Titrate to pH 7 end point with NaOH to measure acid consumed.

Neutralization Potential (NP) by TIC

- Commonly required in British Columbia framework and permits
- Direct measurement of carbon values
- Gives a carbonate NP
- Determines the capacity to neutralize if all the carbonate behaved like calcite
- Useful measure as calcite is commonly the only rapidly available NP source that matches rapid acid generation
- Uses either combustion or coulometry to determine TIC
- $NP = TIC \text{ carbon } \% * 83.33$

Sobek Neutralization Potential

Pros

- Widely recognized as the standard
- Uses widely available lab equipment

Cons

- Selected acid addition is a source of variability
- Strong-acid conditions that make the method practical also dissolve minerals that are not equally effective neutralizers in the field
- Labour intensive

Neutralization Potential by Total Inorganic Carbon

Pros

- More accurate assessment of readily available neutralizers
- Same procedure and method used across all concentration ranges
- Eliminates variability from different acid additions
- Less analyst time

Cons

- Not a recognized method in WV
- Utilizes specialized equipment
- Does not quantify non carbonate neutralizing components

Refuse Samples – case study

- Refuse sample is sent to a coal lab for analysis
- Sample is analyzed using the sulfur forms method for coal
- All iron present in the sample is assumed to be pyrite, which ends up overestimating the acid potential of the sample
- Overstates the neutralizing material requirements using an incorrect acid potential which results in unnecessary additional costs

	Total Sulfur, %	Pyritic Sulfur, %	AP	NP	Net NP
Coal Lab X	0.36	0.31	9.74	8.88	-0.86
EPA 600	0.36	0.16	5.06	8.88	3.82

ASTM D8215 vs EPA600 sulfur forms results comparison

WV topsoil substitute: overburden chemistry applied to revegetation

Key WV criteria

Topsoil substitute may be approved when topsoil is insufficient and the substitute meets the required acceptable parameter thresholds.

Laboratory requirement

The certification must be made by a qualified laboratory and must state that the substitute is equally suitable, best reasonably available, and tested using standard procedures.

Reviewer checklist

WVDEP's checklist asks whether the report is signed by a Certified Soil Scientist who works for an approved laboratory, and whether the SMA sections tie out to the chemistry and volumes.

Topsoil Substitute – NAVANA Labs

- Recognized by WVDEP as a qualified laboratory
 - NAVANA Labs Hinton is one of few ISO17025 accredited overburden testing labs in North America
- Tim Keeney is employed by NAVANA Labs
 - Oversaw and implemented overburden sampling, sample preparation, analysis, and reporting procedures
 - Issues topsoil substitute reports
- Samples are received and logged, if necessary, at Crab Orchard operation, prepared, and disseminated according to testing requirements. This makes the process traceable and seamless to the customer.



Selenium Testing

- NAVANA Labs completes analysis by AFS instead of ICPMS
 - Instrument is specific to selenium
 - Lower detection limits achievable
 - Fewer interferences
- NAVANA Labs Hinton has an ISO17025 accreditation specifically for selenium in overburden
- Facility is purpose built for overburden analysis
- Historically and currently provide these services to Western Canadian mining clients



Key takeaways

Critical decisions with substantial economic and environmental impacts are made off these analyses and interpretations

- Method choices matter
- Alternate methods should be considered where appropriate
- Decades of experience and ISO17025 accreditation specific to these services is crucial to ensuring reliable results