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Nitrogen Prediction and Management at Brucejack Mine

BC MEND– December 7, 2021

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Brucejack Mine

Nitrogen (N) Prediction and Management

Overview

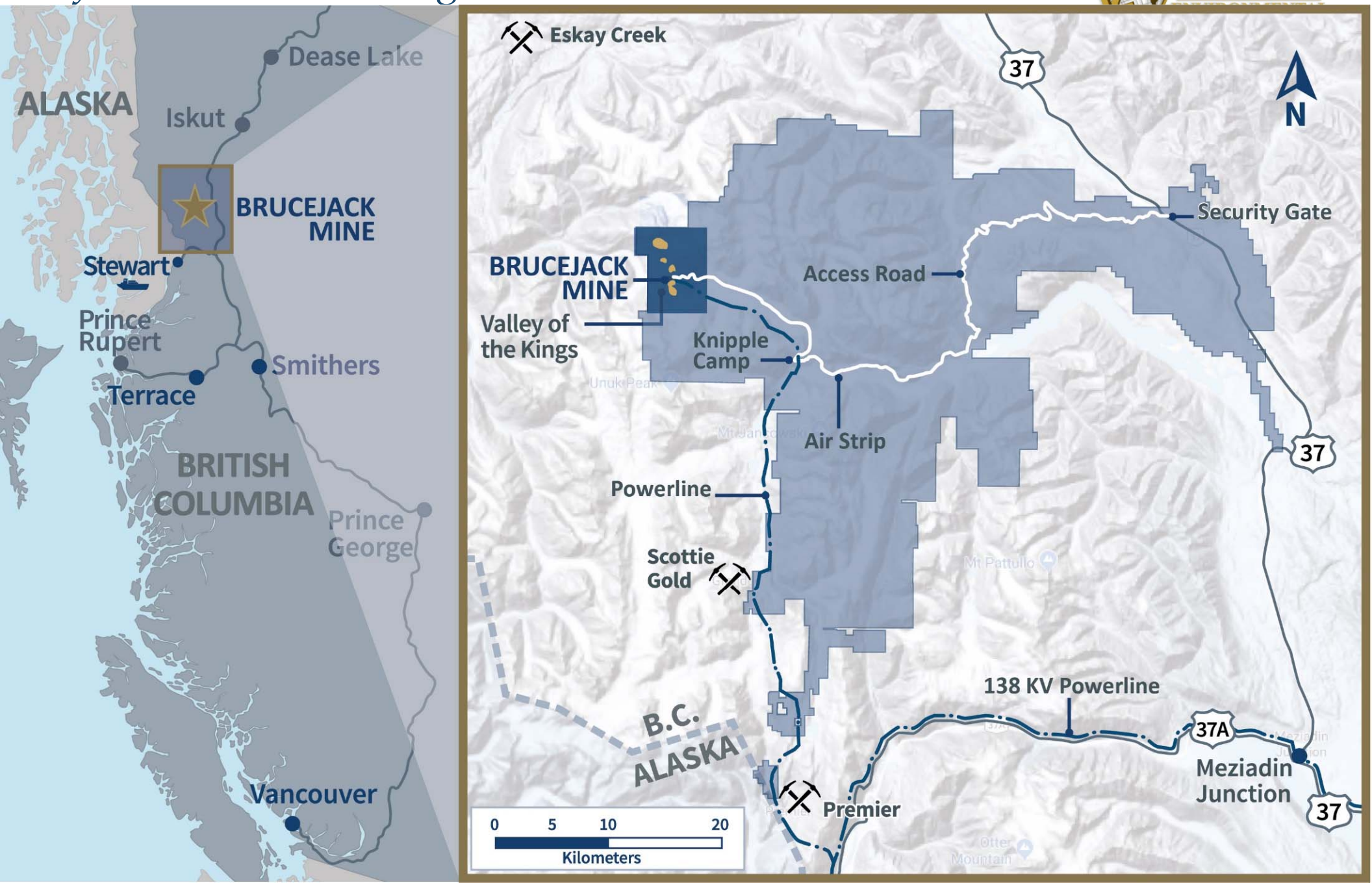
- N sources for mine water
- N modeling of mine water
- Model validation
- N management and source control procedures
- Management triggers

Why management?

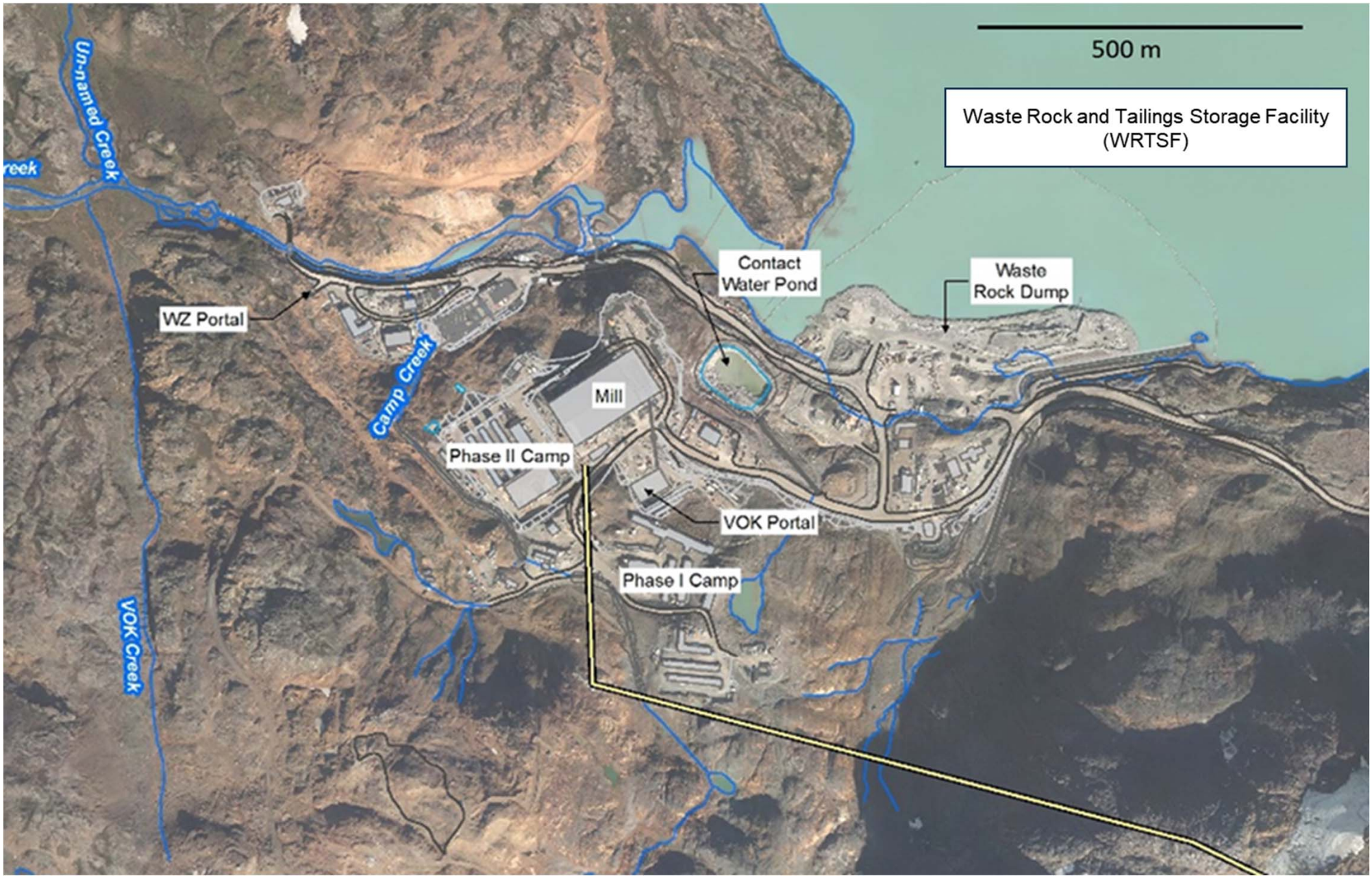
- N is regulated in the mine effluent permit

Brucejack Mine

Infrastructure and Logistics



Mine Site Surface Layout



Nitrogen Predictions

Background

- N is present in site waters as inorganic species:
  - Ammonia (NH_4^+ + NH_3)
  - Nitrate (NO_3^-)
  - Nitrite (NO_2^-)

- Explosives are the dominant source of N at Brucejack Mine
  - Ammonium nitrate (AN) emulsion explosives contain 25% – 30% N
  - Efficient blasting converts most of the N to nitrogen gas
  - Residues containing NH_4^+, NH_3, NO_3^- and NO_2^- are also produced
  - N is mobilized from the residues by contact water

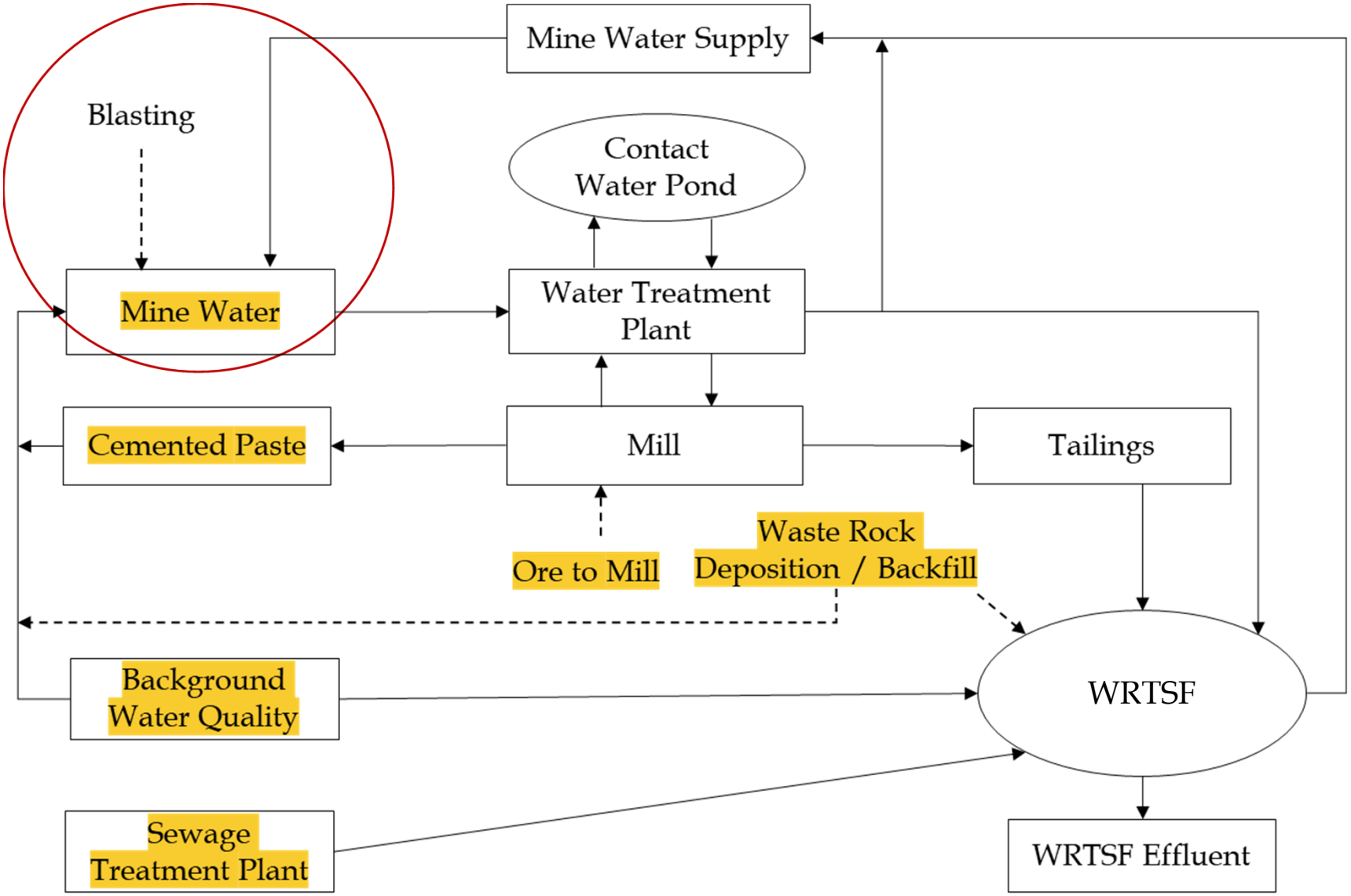
Nitrogen Predictions

Underground Mine Water – N sources

- January 2015 – September 2017:
  - Explosives residues (dominant)
  - Groundwater (negligible)
  - Water supply (minor)
  - Backfill (negligible, begin mid-2017)
- Assume all N is from explosives

Nitrogen Predictions

Water Quality Model



Conceptualization of the Brucejack Mine water balance nodes (outlined shapes). N source terms for the water quality model are highlighted.

Nitrogen Predictions

Underground Mine Water – Data Collection

- Jan 2015 – Sep 2017
  - Late exploration to early operations
  - Blasting ~10,000 t/month to ~140,000 t/month

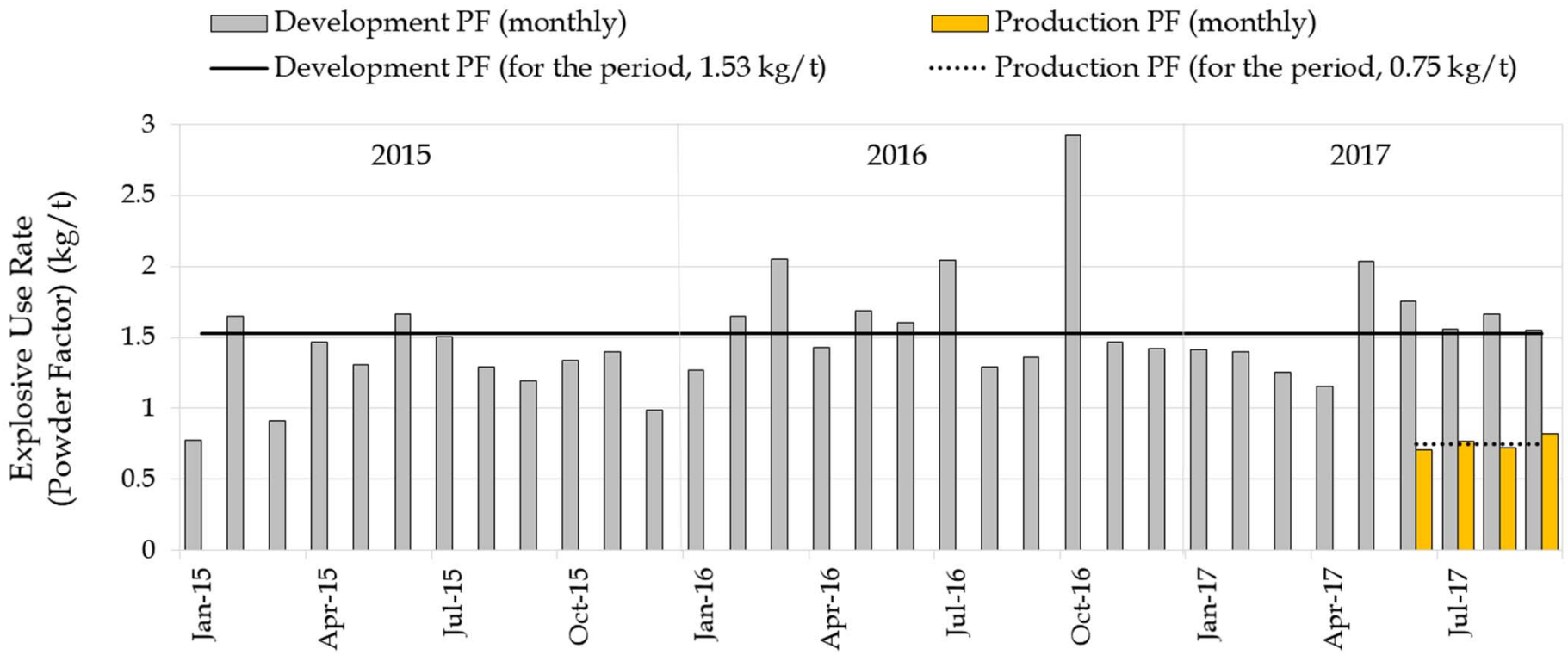
- Blasting records
  - Explosives use
  - Blasted tonnage
  - Powder factor (kg explosives used per tonne of blasted rock)

- Monitoring records
  - Water quality
  - Flow

- Source term derivations for mine water
  - Assume all N in mine water is from blasting residues
  - N speciation
  - N loading rate from explosives to mine water

Nitrogen Predictions

Blasting - Powder Factor

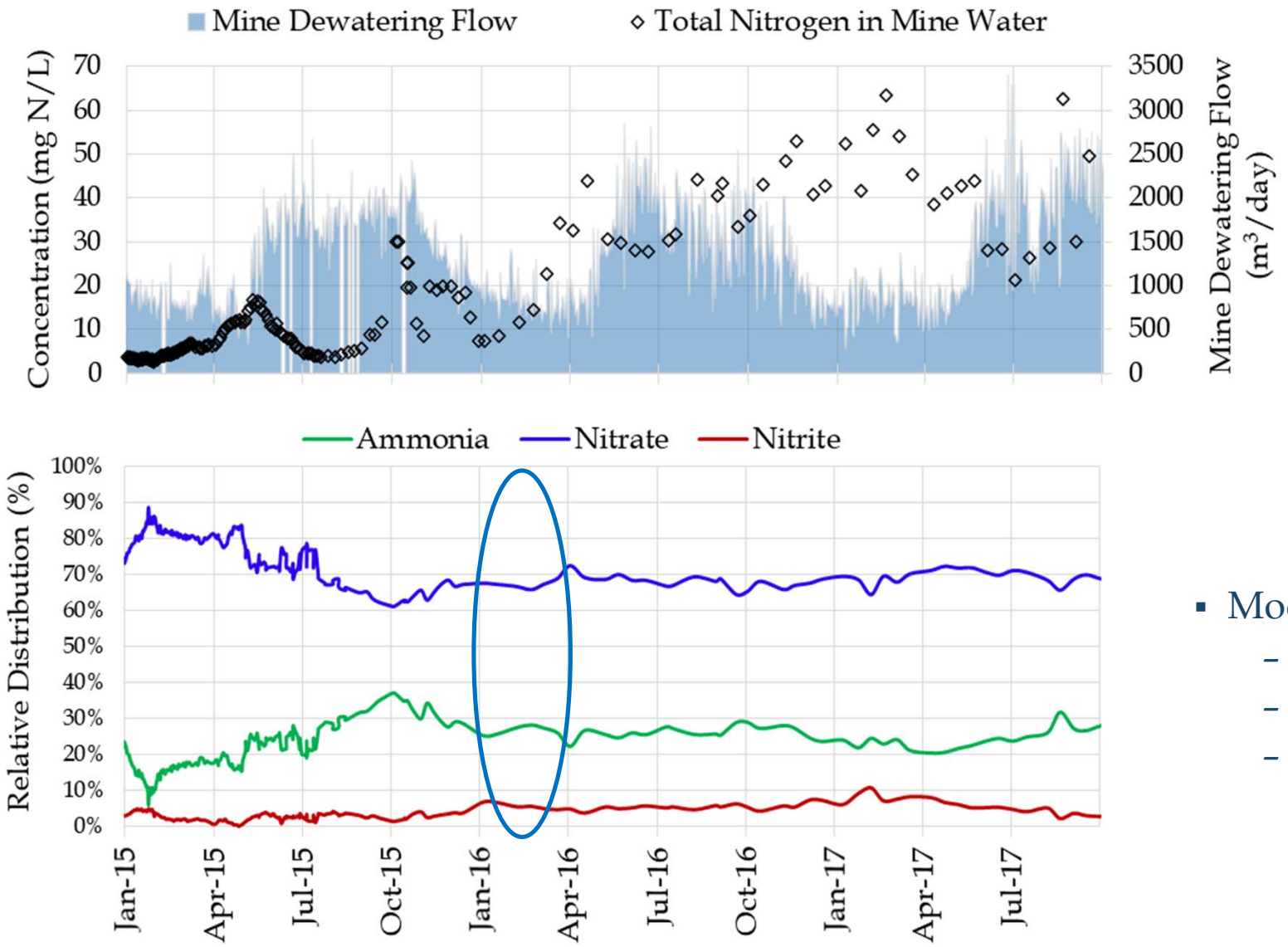


Powder factors (PF) for blasting from January 2015 to September 2017.

Development blasting = short-hole drifts for access tunnels (waste rock)
Production blasting = long-hole stope blasting (ore)

Nitrogen Predictions

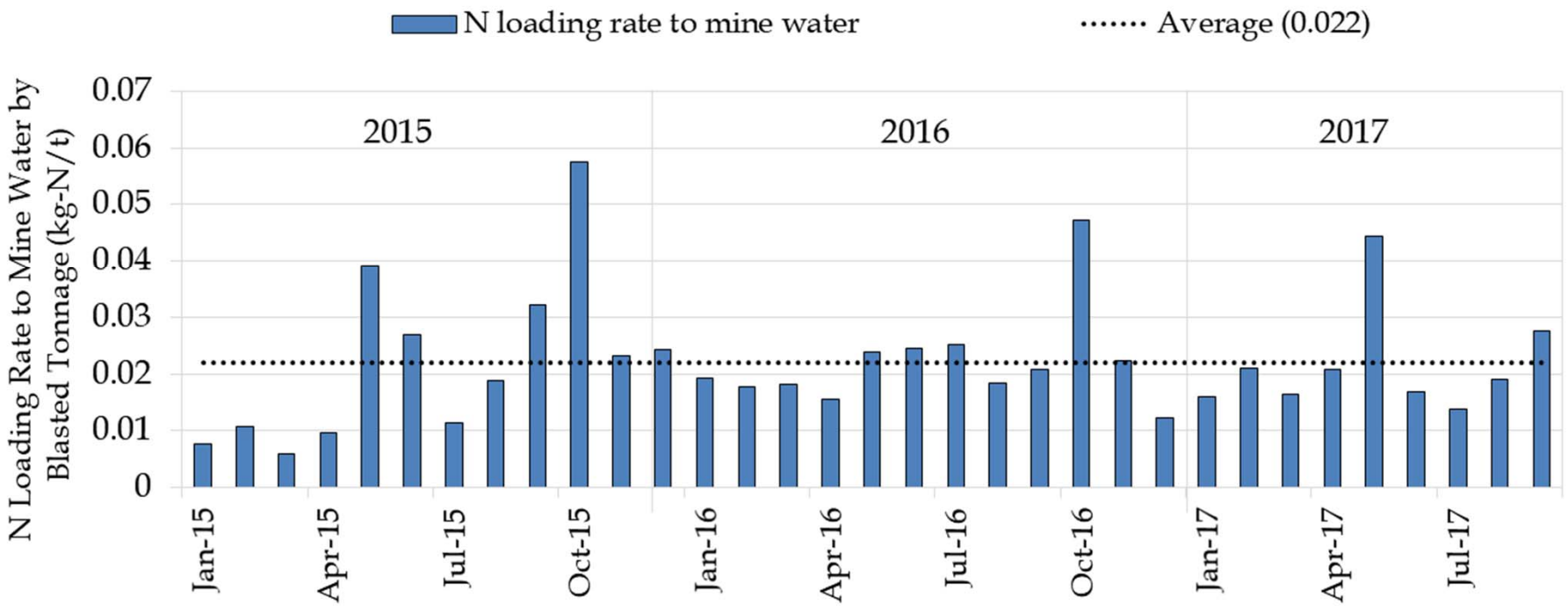
Mine Water Quality, Flow and N Speciation



- Modeled speciation
  - NH_3+NH_4: 28.8%
  - NO_3: 66%
  - NO_2: 5.2%

Nitrogen Predictions

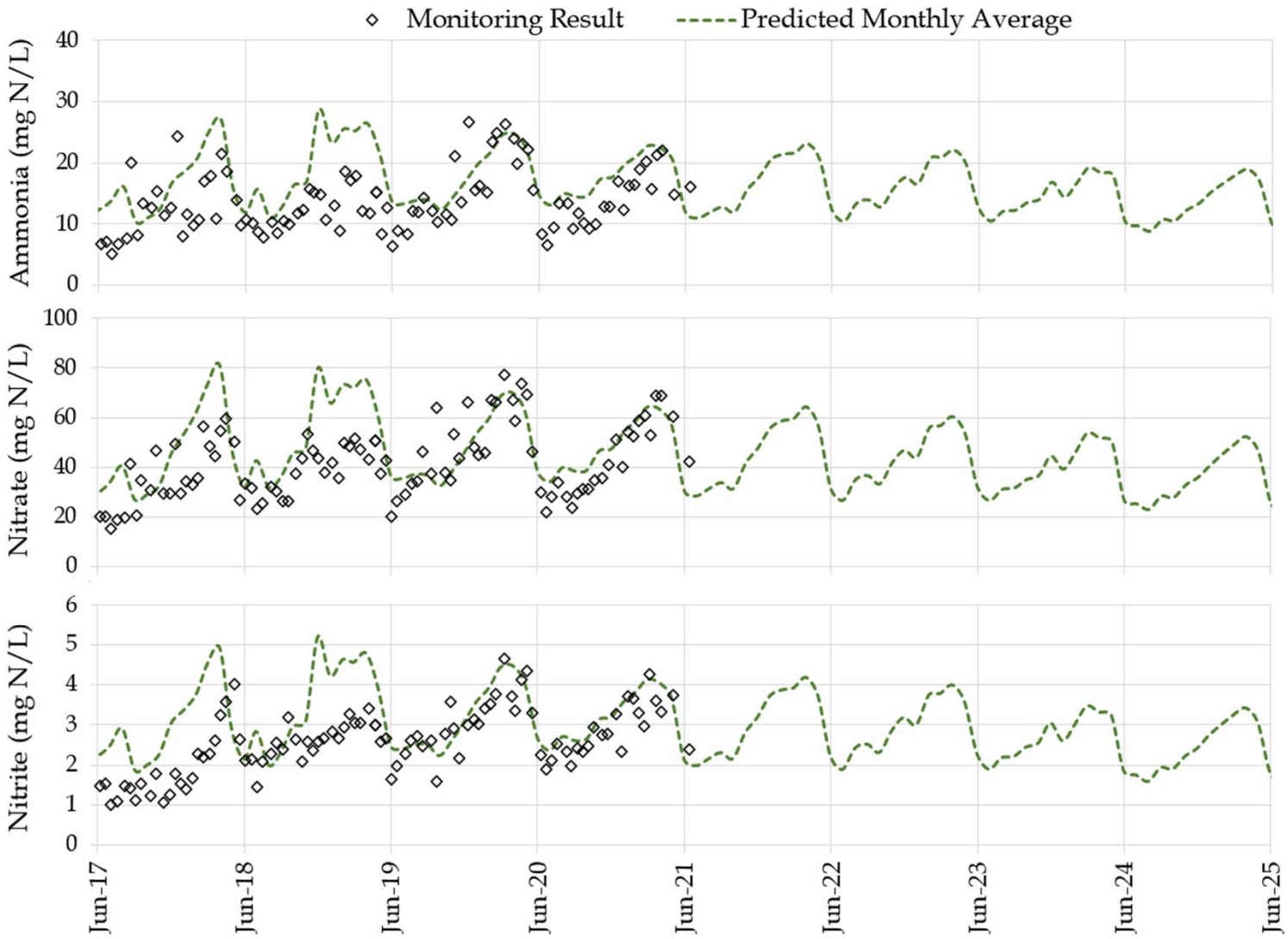
N Loading to Mine Water



- Modeled loading rates
  - Base Case: 0.022 kg N/t
  - Upper Case: 0.033 kg N/t (50% more than BC)

Nitrogen Predictions

Mine Water Quality – Model Validation

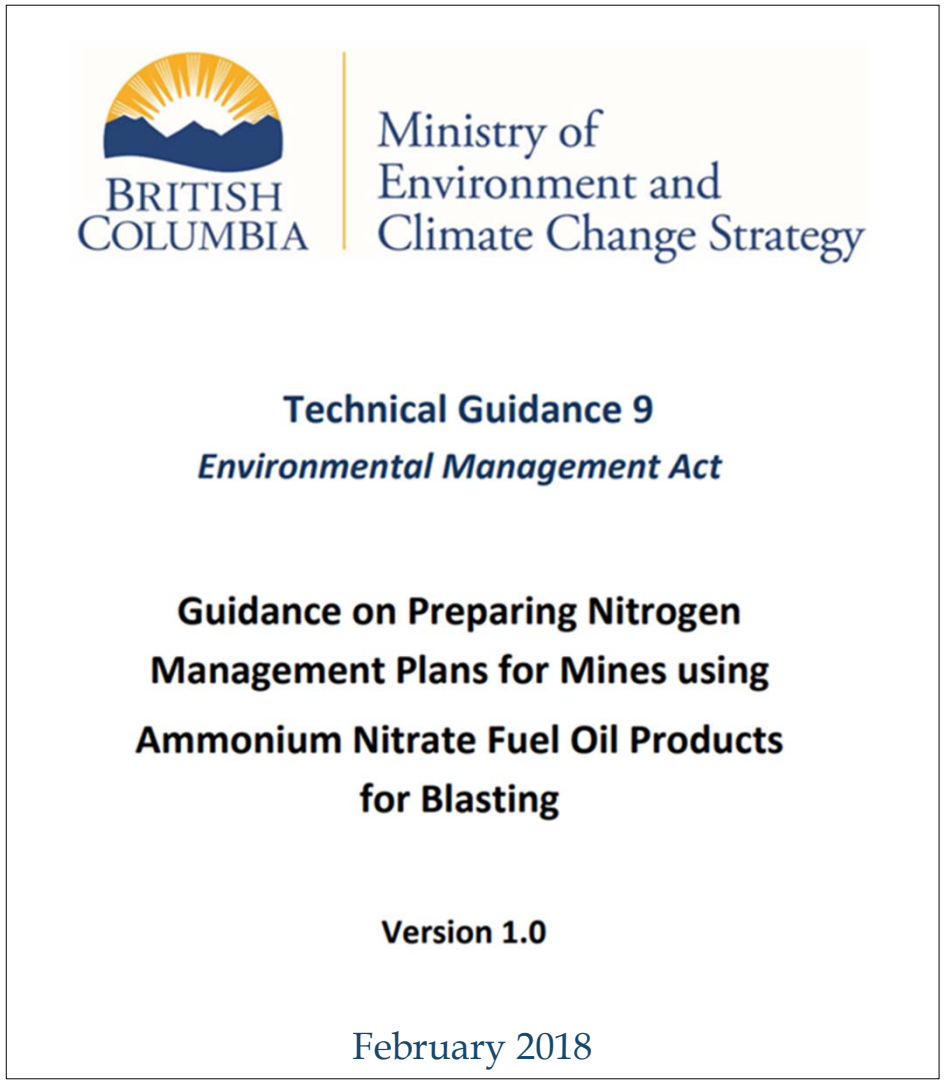


Measured and predicted concentrations for N species in mine water (Base Case). The predictions assume effective N source control measures are implemented.

Nitrogen Management

Site-specific Nitrogen Management Plan

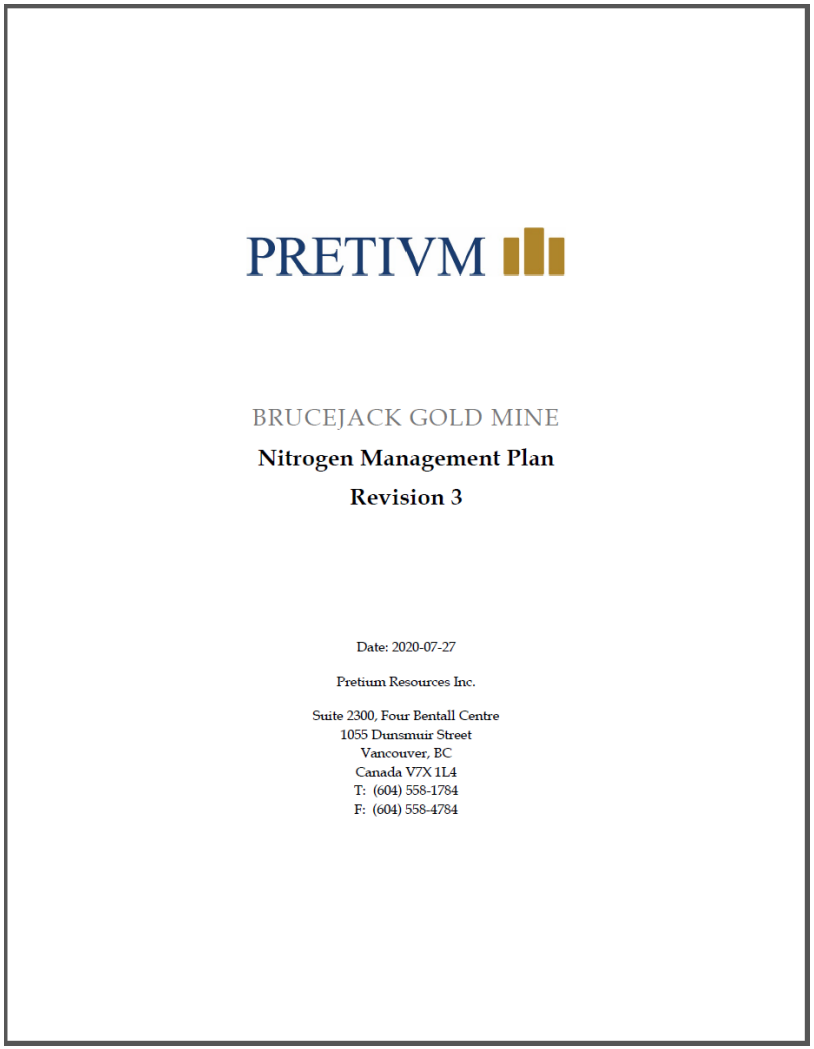
- Explosives storage, use and disposal procedures
- Predictive modeling and risk assessment
- Effluent discharges and permitting
- Source control and water management procedures
- Performance monitoring
- Environmental monitoring
- Contact water monitoring
- Continuous improvement



Nitrogen Management at Brucejack

Implementation

- How are we able to successfully implement the Nitrogen Management Plan?
  - Education and Training
  - Inspections
  - Monitoring and Reporting



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Nitrogen Management Plan

Revision 3

Date: 2020-07-27

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Nitrogen Management at Brucejack

Education and Training

- Presentations tailored to different departments
  - Technical vs. Non-Technical Groups
  - Periodic update presentations
- 1-on-1 discussions during audits

Nitrogen Management at Brucejack

Inspections

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PRETIVM **Underground Nitrogen Source Audit**

Inspector: **Date:**

OBSERVATION	GOOD	N.I.	COMMENTS
Emulsion Magazine			
General housekeeping	☐	☐	
Waste container/tote	☐	☐	
Spillage observed	☐	☐	
Hoses/totes capped	☐	☐	
Emulsion in wash bay	☐	☐	
Development Emulsion Loader			
Housekeeping	☐	☐	
Spillage observed	☐	☐	
Waste container on unit	☐	☐	
Pre-operation check	☐	☐	
General condition of equipment	☐	☐	
Development Loading			Location:
Blasting Crew:			
Loading complete/in progress			
Condition at face (water present, decline/incline)	☐	☐	
Nearest sump	☐	☐	
Loading of holes	☐	☐	

PRETIVM **Underground Nitrogen Source Audit**

OBSERVATION	GOOD	N.I.	COMMENTS
Spillage at face	☐	☐	
Clean up at face & waste emulsion disposal	☐	☐	
Operator(s) awareness of N2 plan	☐	☐	
Longhole Emulsion Loader			
Housekeeping	☐	☐	
Spillage observed	☐	☐	
Waste container on unit	☐	☐	
Pre-operation check	☐	☐	
General condition of equipment	☐	☐	
Longhole Loading			Location:
Blasting Crew:			
Loading complete/in progress			
Condition at face (water present, decline/incline)	☐	☐	
Nearest sump	☐	☐	
Loading holes	☐	☐	
Spillage at face	☐	☐	
Clean up at face & Waste emulsion disposal	☐	☐	
Operator(s) awareness of N2 plan	☐	☐	

Nitrogen Management at Brucejack

Inspections

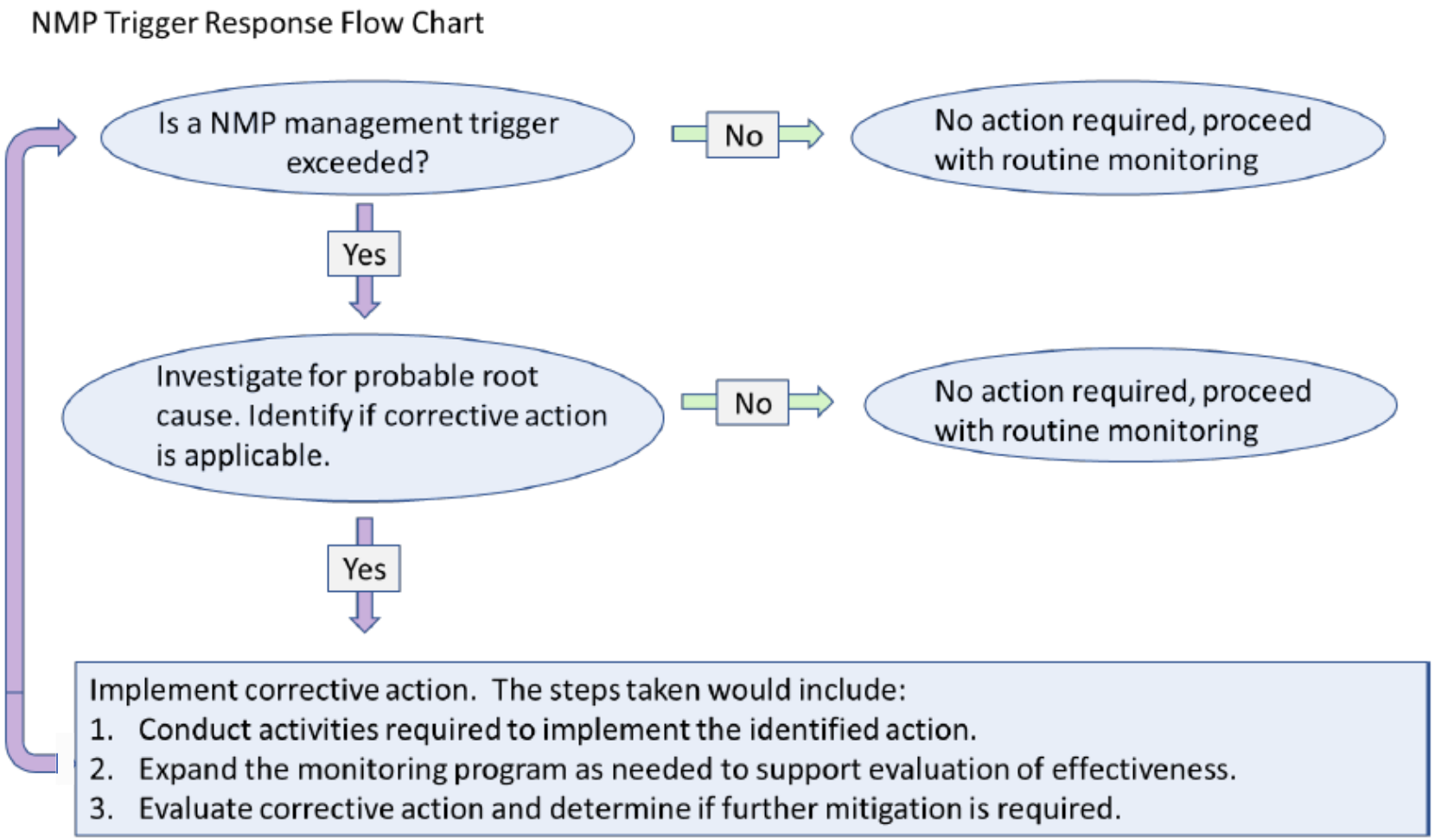
Nitrogen Management

Monitoring, Metrics and Management Triggers

Monitoring Programs	Metrics	Management Triggers
Blasted tonnage (ore and waste)	Powder factor (PF)	Powder factor (Development and Production blasting)
Explosives use	N loads to mine water, waste and ore	WRTSF effluent discharge quality
Waste placement records	Waste and tailings deposition tonnages	
Ore processing records	Effluent water quality	
Mine, mill and effluent discharge ▪ Water quality (T-N, NH_3+ NH_4, NO_3, NO_2) ▪ Flows	Measured values are compared to predicted values and management triggers	

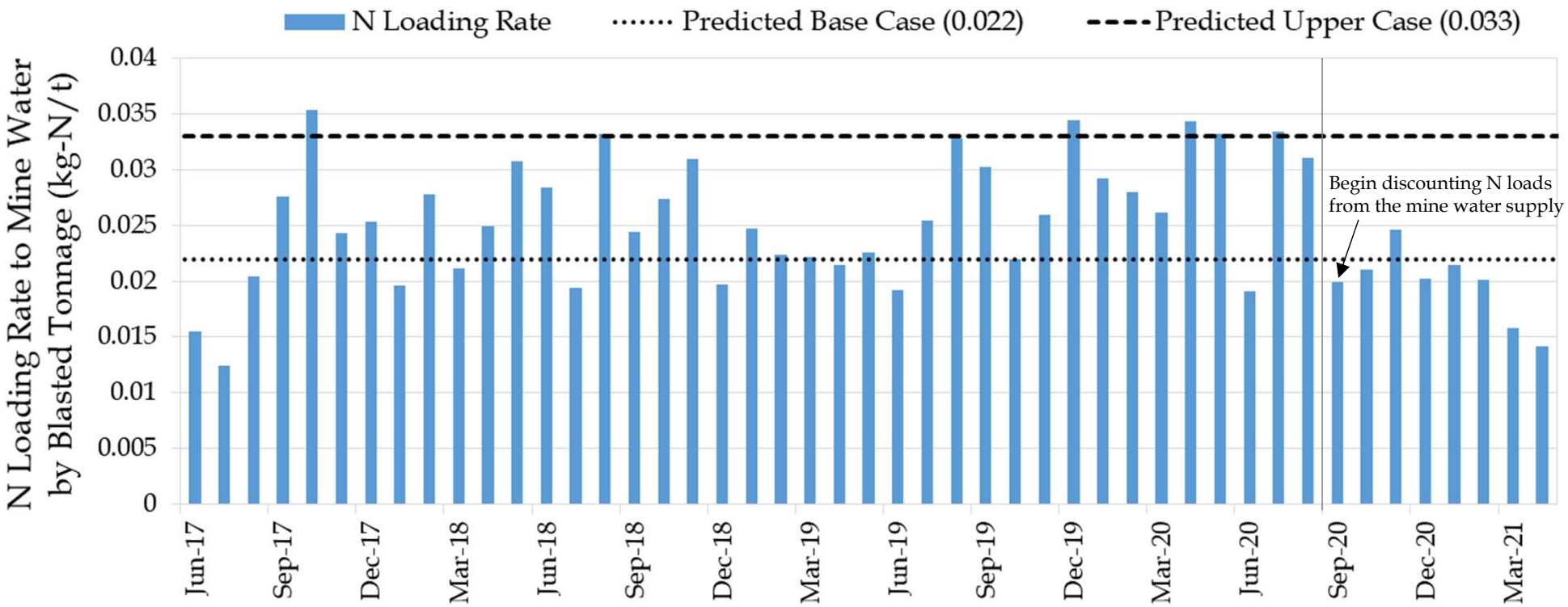
Nitrogen Management at Brucejack
Monitoring

- Trigger Values for Nitrogen Management



Nitrogen Management

Monitoring Metric – N Loading Rate to Mine Water



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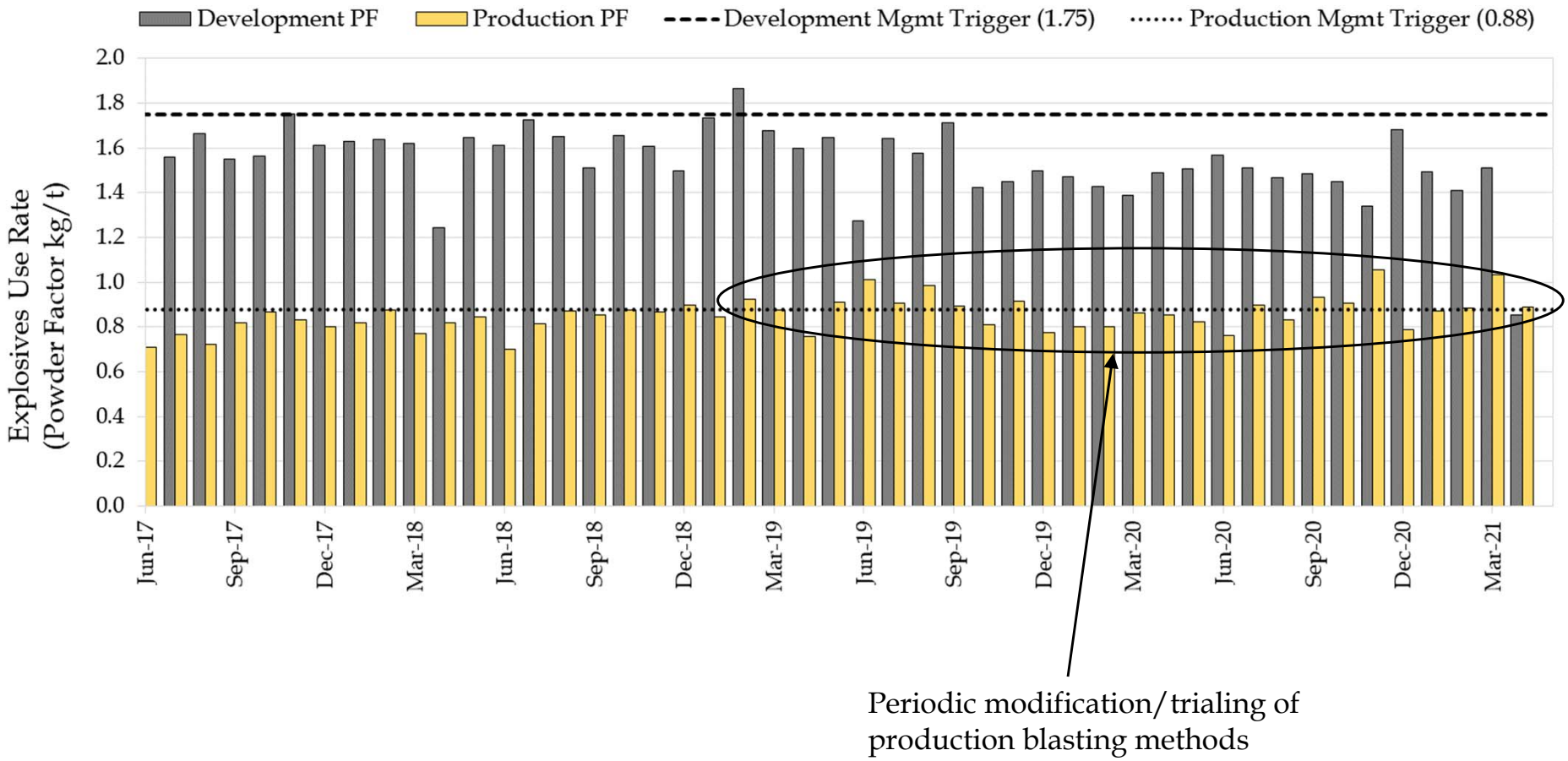
Management Triggers – Powder Factor



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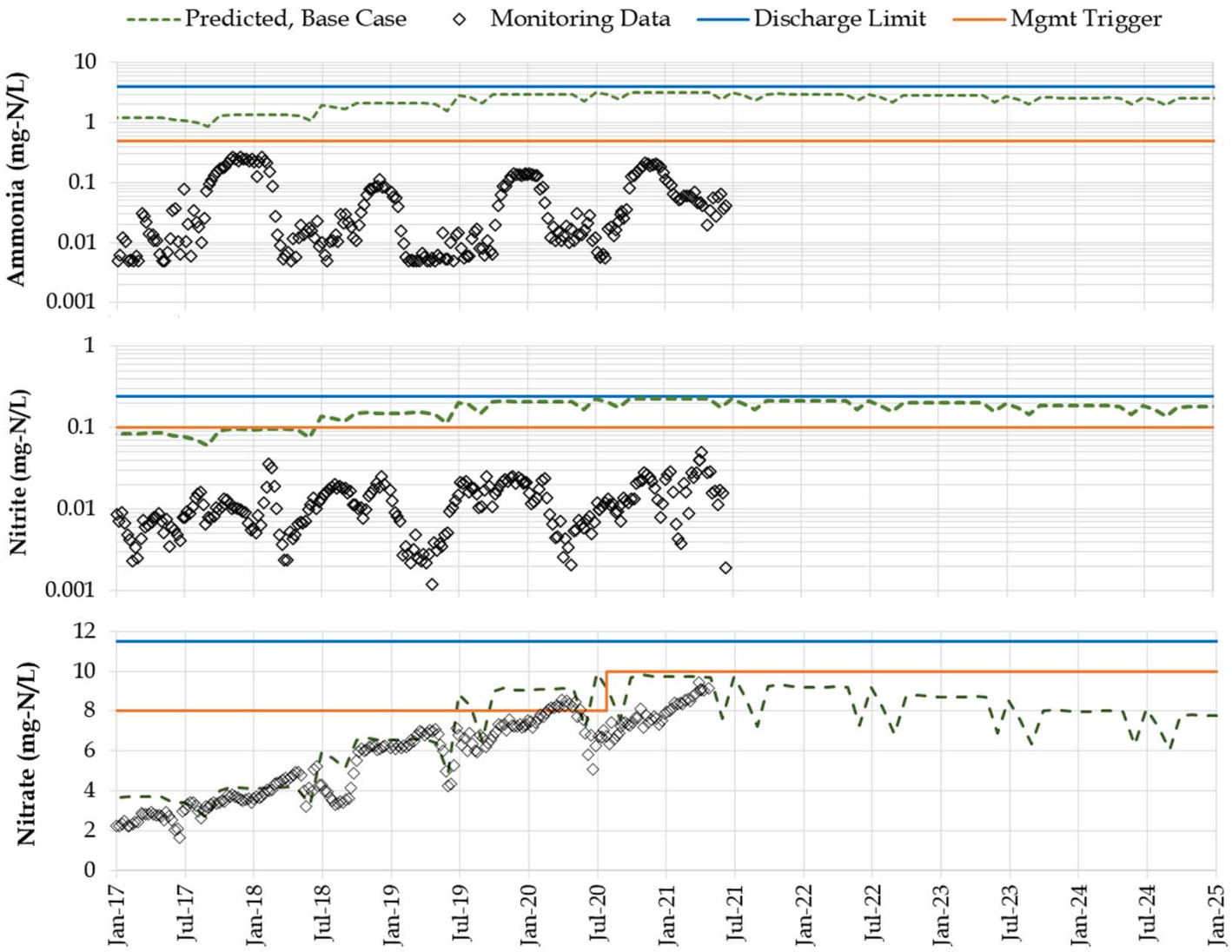
Management Triggers – WRTSF Effluent



Nitrogen Management at Brucejack

Reporting

Review/Report	What is monitored
Blast Report (Daily)	Drilling/blasting records for a given pattern • Hole depth, explosives use, blasted volume/advance • Other activities (i.e., shotcrete, water management, spills, etc.)
Waste Disposal Report (Daily)	Waste rock placement records • Underground rock volumes deposited to the WRTSF
WTP Report (Daily)	Daily performance and effluent quality • Metrics include nitrite monitoring
WTP Summary Review (Monthly)	Monthly performance review • Year to date summary of reagent usage, influent and effluent volumes, and internal water quality results
NMP Quarterly Review (Quarterly)	Year to date summary of NMP metrics • Informal internal review summarizing N loading rates, PF, BJ 3.10 results, external laboratory results for influent and effluent and black audit findings • Comparison of modelled to actual quantities for excavation, as well as the deposition of waste and tailings to the WRTSF • Flag emerging issues • Update progress on past issues
Annual Report	Annual summary of NMP monitoring metrics, N source control and loading rates • Annual summary of NMP monitoring data • Mine water, waste rock, ore, tailings, WTP Effluent and BJ 3.10 • Included in the annual water quality report

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