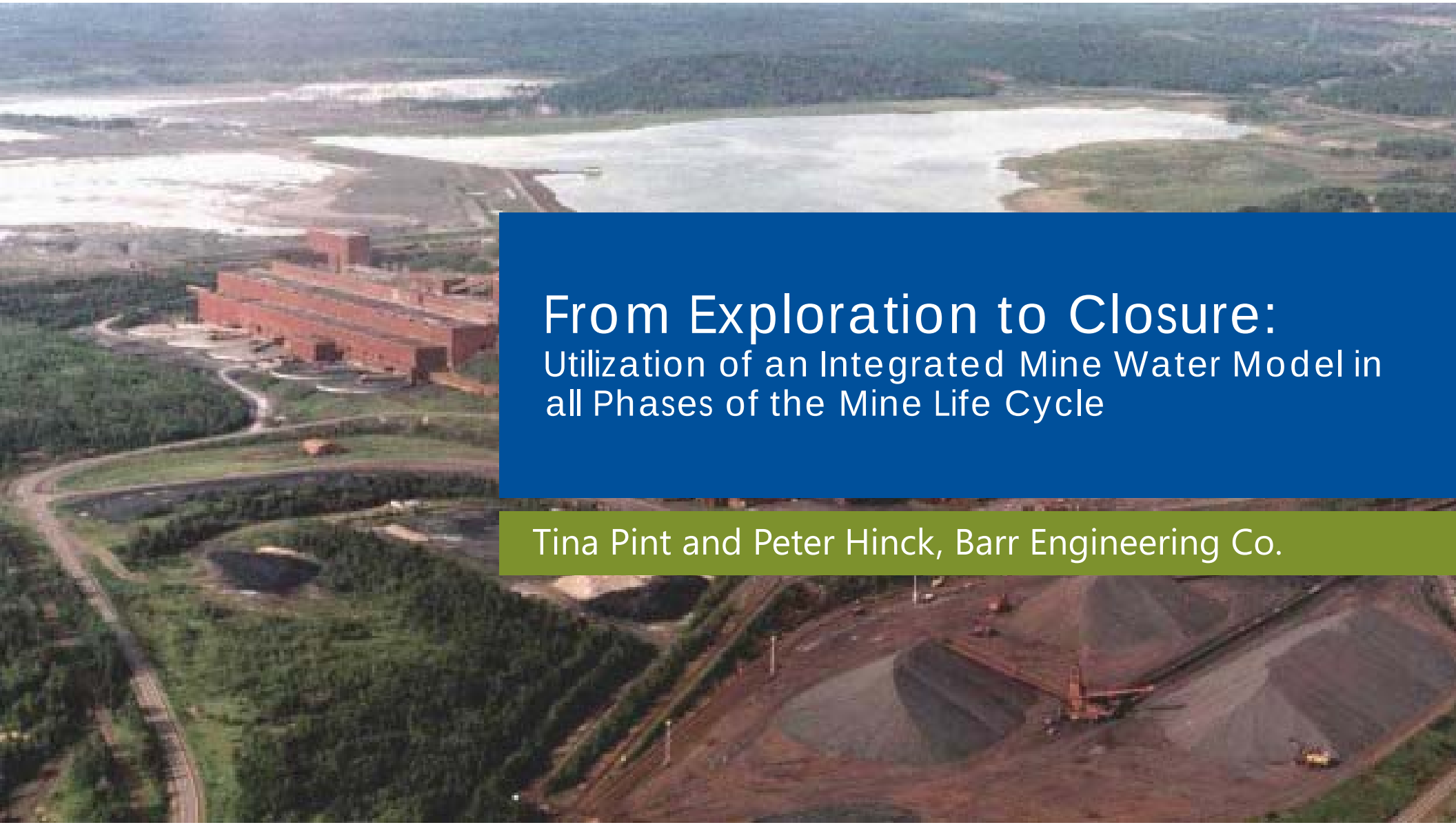


From Exploration to Closure:
Utilization of an Integrated Mine Water Model in all Phases of the Mine Life Cycle

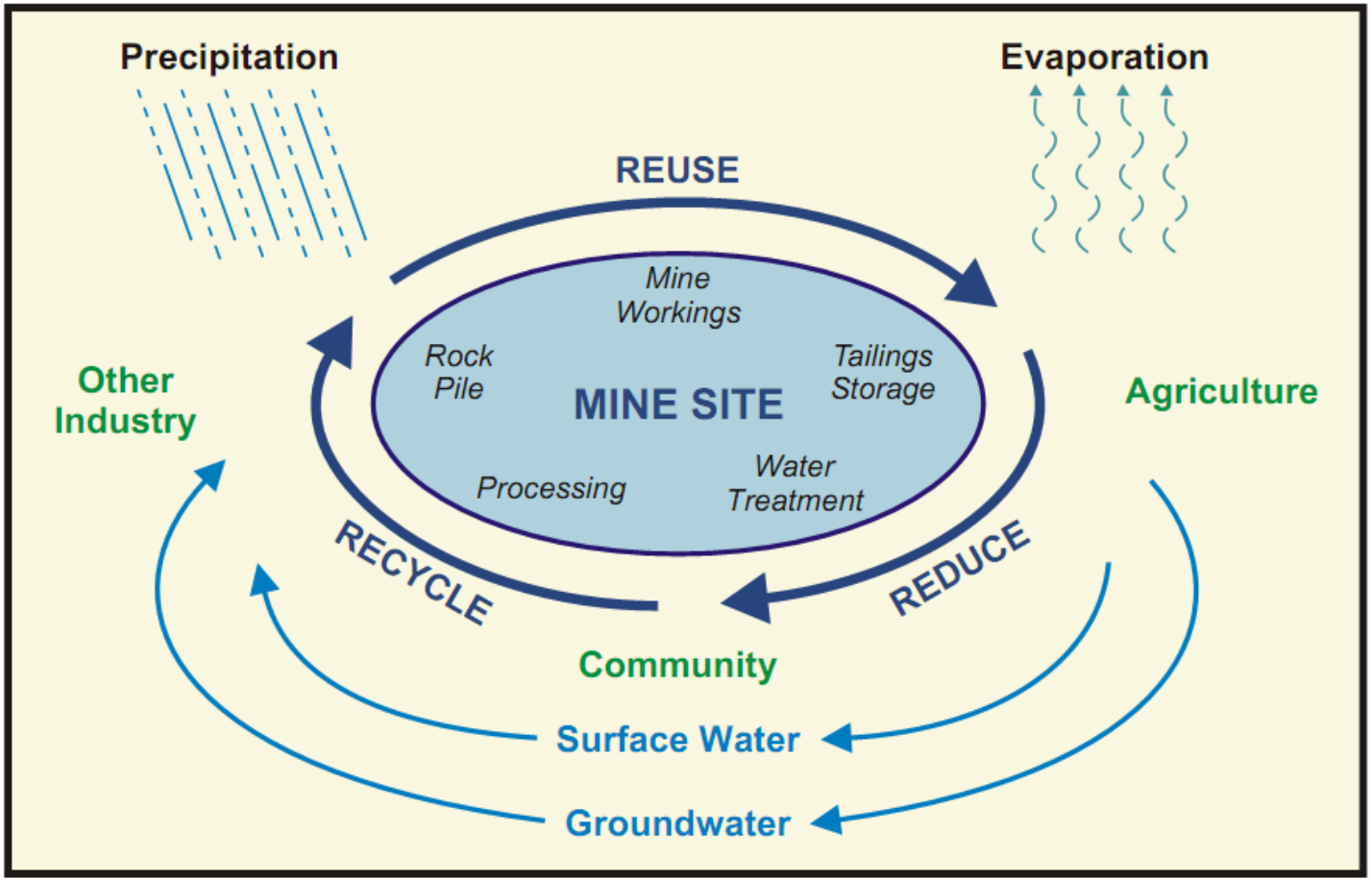
Tina Pint and Peter Hinck, Barr Engineering Co.

outline

High level discussion of why an integrated mine water model is beneficial

Project example of the use of an integrated model for mine planning

mining and water management



modeling of complex systems

The complexity in water management strategies and the iterative nature of mine planning necessitates integrated water models during all phases of the mine life cycle

integrated mine water models

- a model that includes key mine features or processes that could effect water quantity or quality and the eventual receptors of the water
- the more you can get into a single model the better

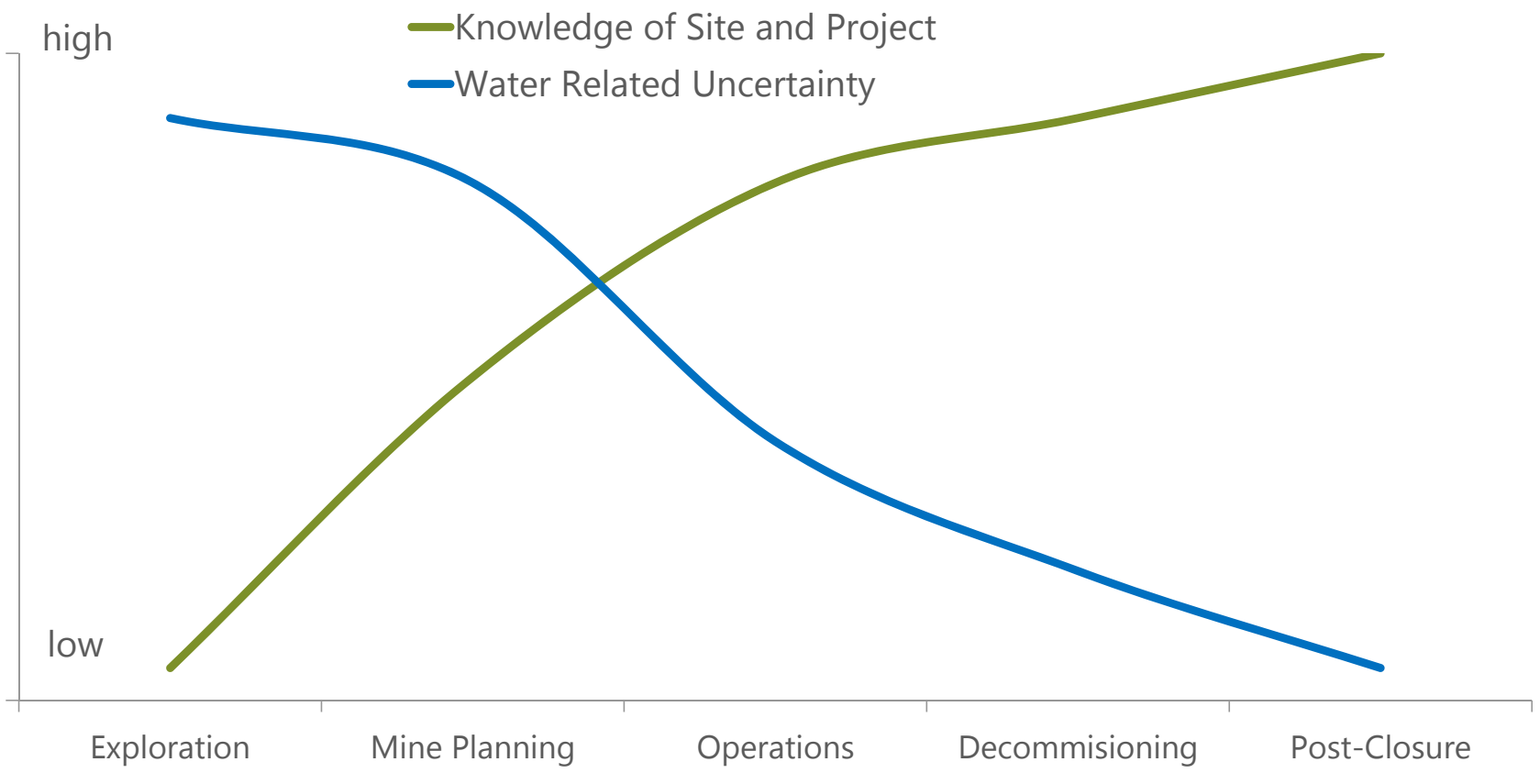
aspects included in a integrated water model

- sources:
  - pits
  - stockpiles
  - TSF
  - plant
  - natural watershed
- receptors:
  - groundwater
  - surface water

and everything in between!

mine life cycle

knowledge and uncertainty through the mine cycle

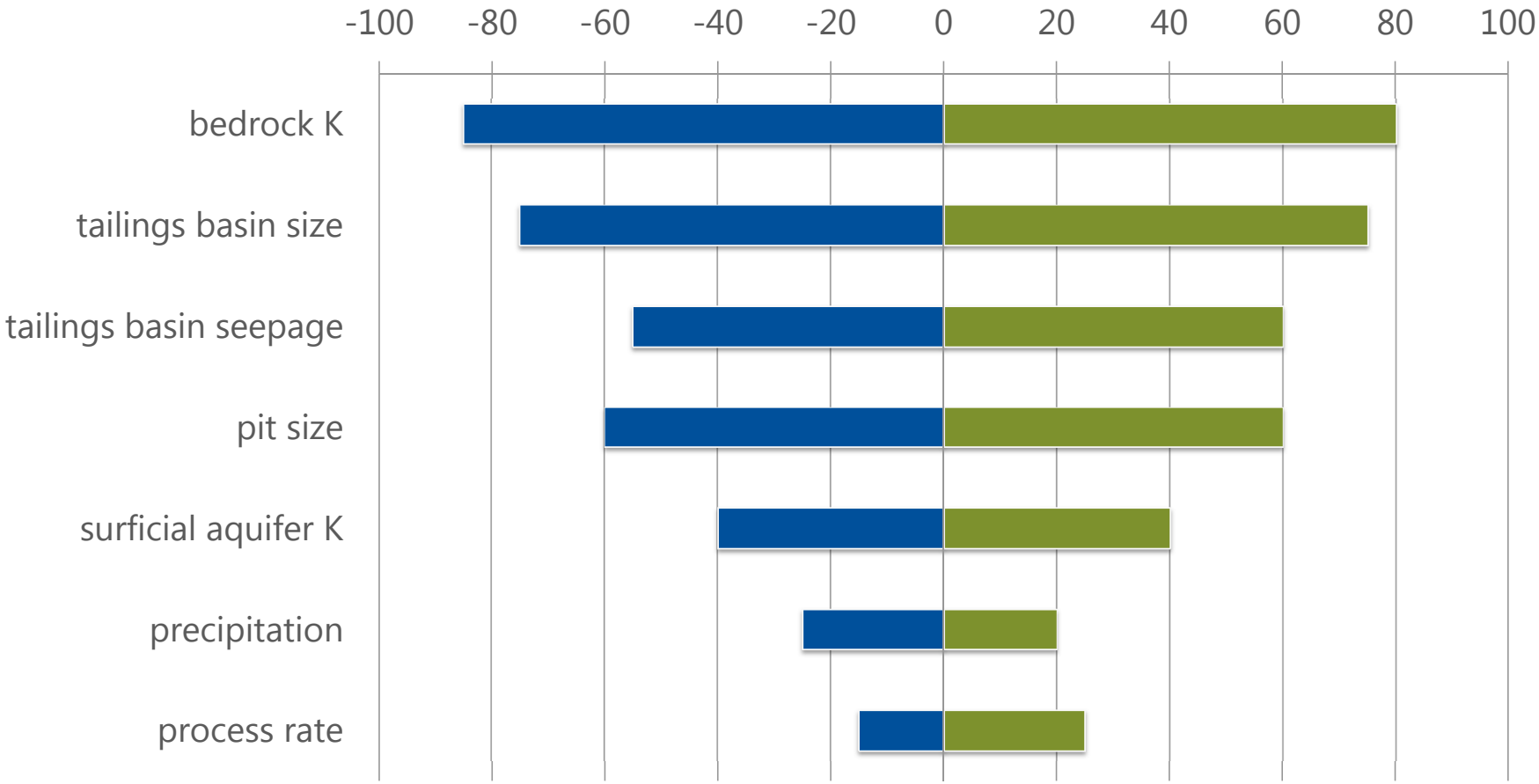


mine life cycle

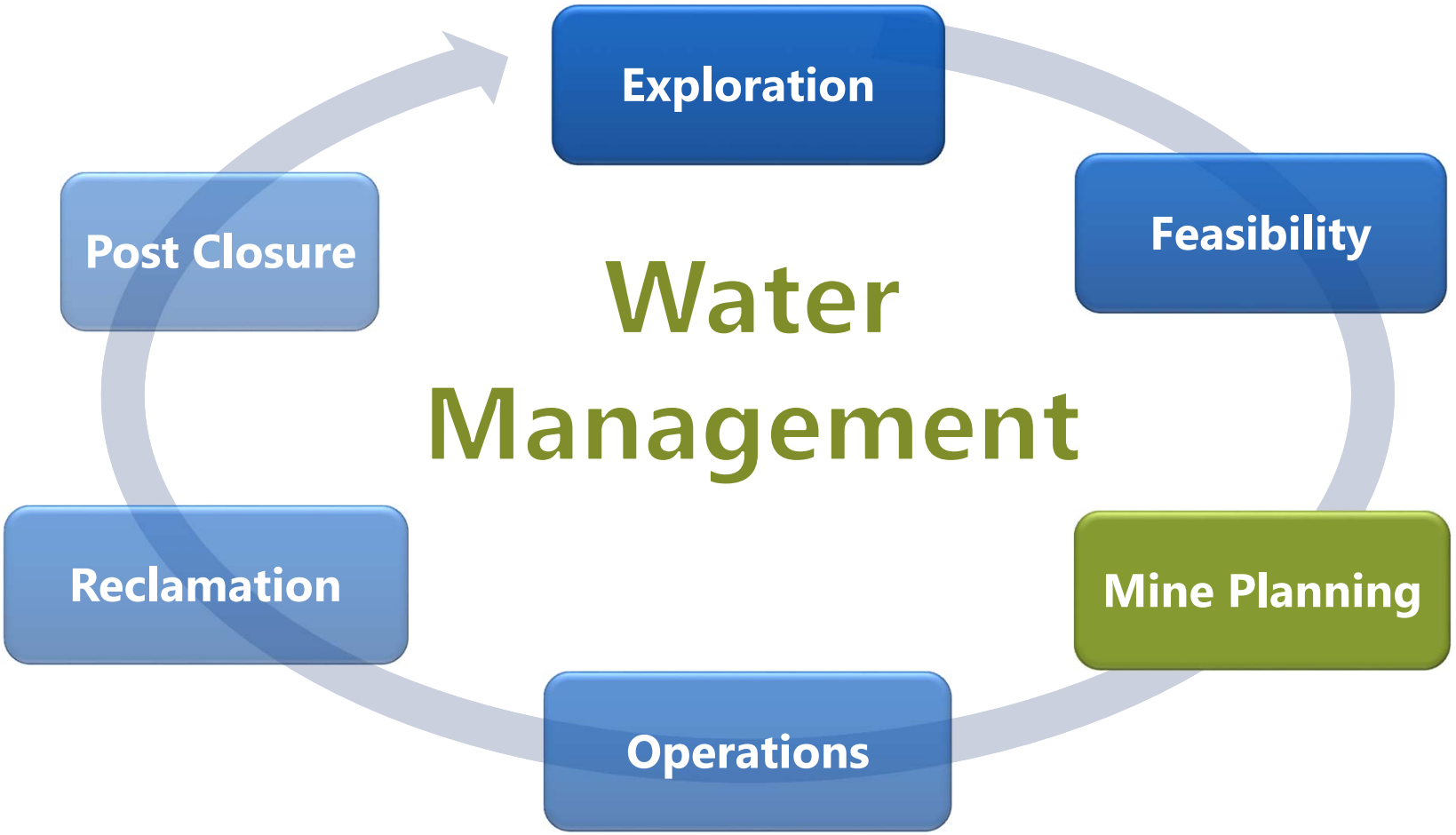
water modeling in feasibility – start simple

- data to support NI43-101 reports
- preliminary water balance and geochemical assessment
- what are the key drivers of desired outcomes?
- what water related controls are likely to be needed?
- where will collecting additional data significantly reduce uncertainty?

modeling to guide data collection



mine life cycle



water management modeling – mine planning

- Refining the water management plan
- Support environmental review
- Demonstrate regulatory compliance
- Provide data for permitting

mine life cycle

water management in operations

- How do you manage water to maintain operations?
- How do you manage water to meet permit conditions?

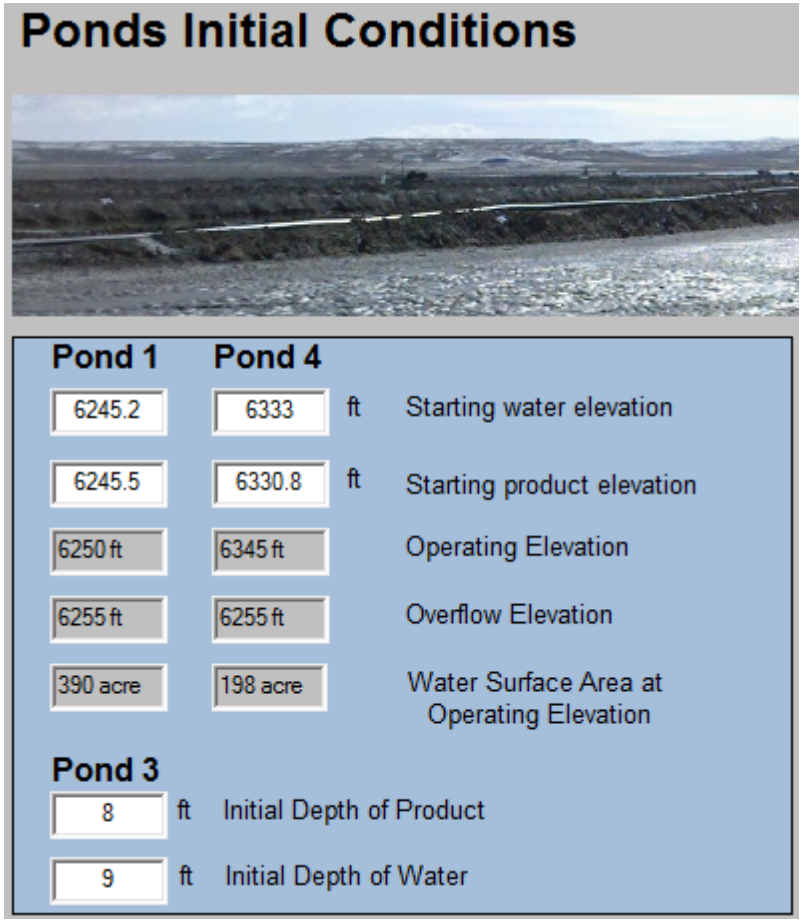
operating mine – Western US

operating mine – Western US

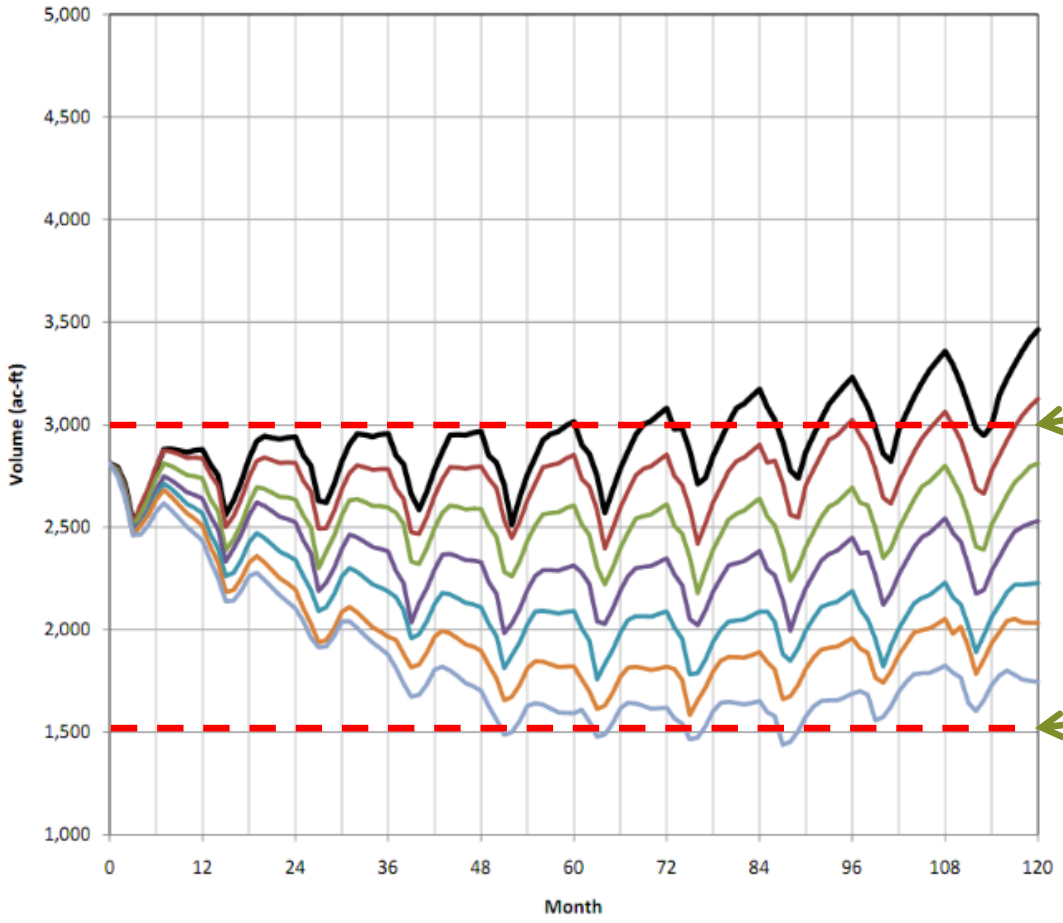
- operating facility in need of tool to help to manage water on a month-by-month and annual basis
- two primary objectives
  - maintain zero discharge
  - be able to recover product in the tailings basin pond

Ponds Management Tool – setup

- built a tool that incorporates plant production, tailings management, water management, and ponds
- used to help determine when, where and at what rate to pump



Ponds Management Tool – output



Maximum volume

Minimum volume

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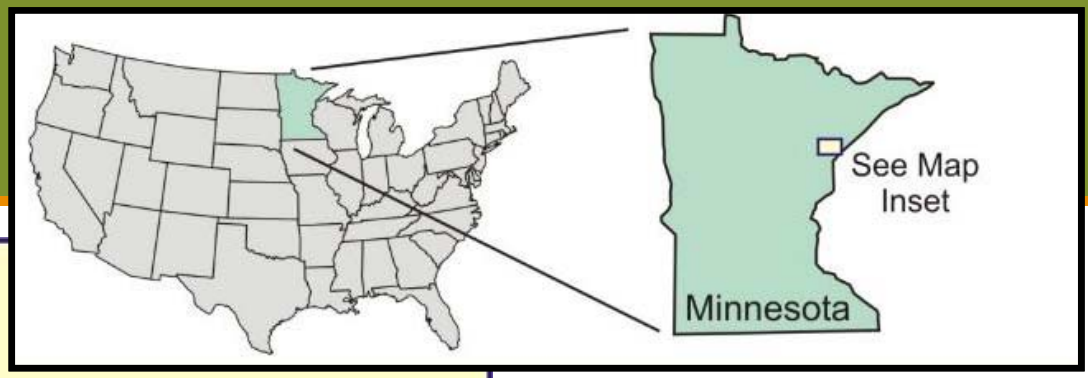
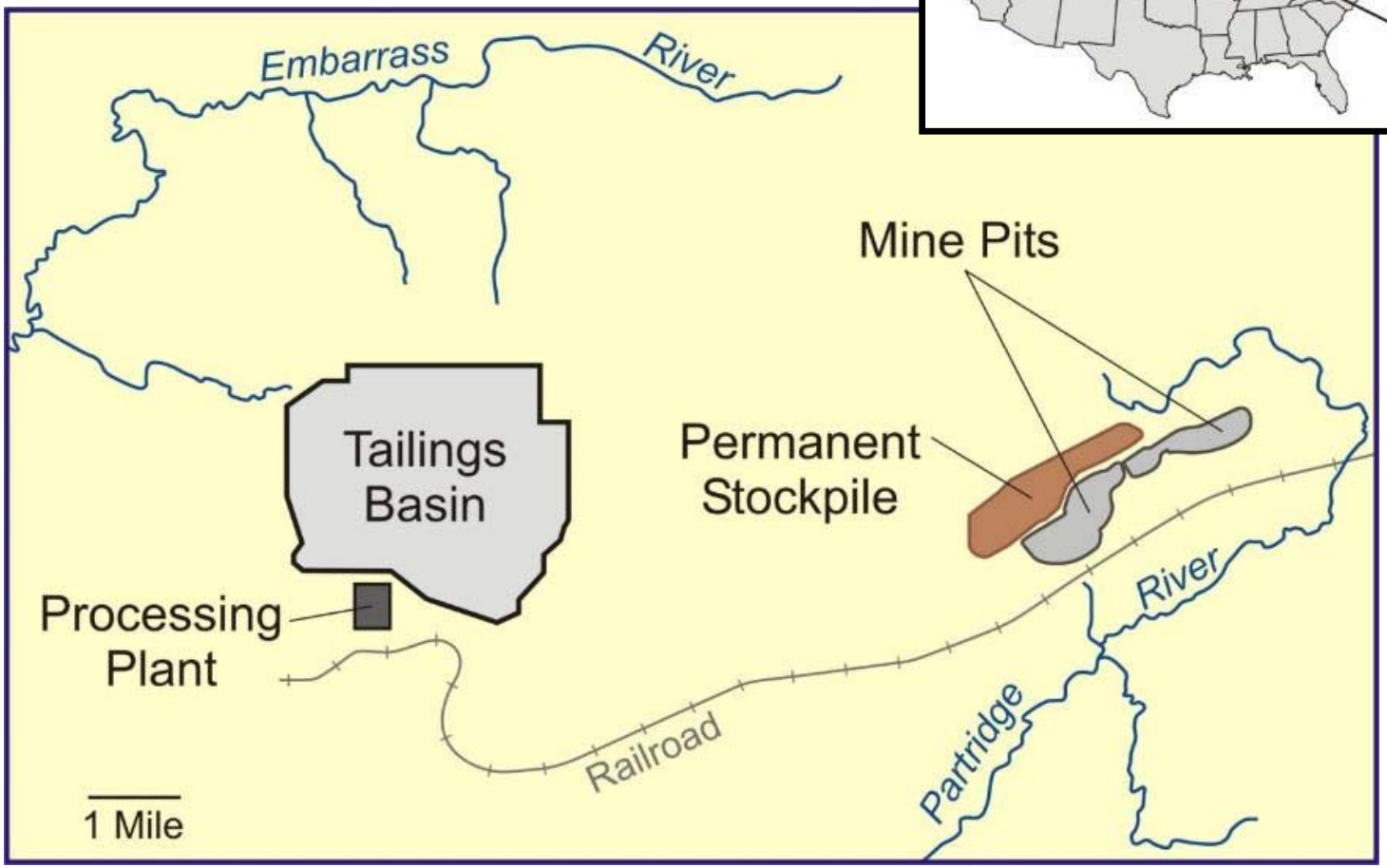
mine life cycle

water management in reclamation

how can you manage water to reduce liability and long term maintenance

mine planning example





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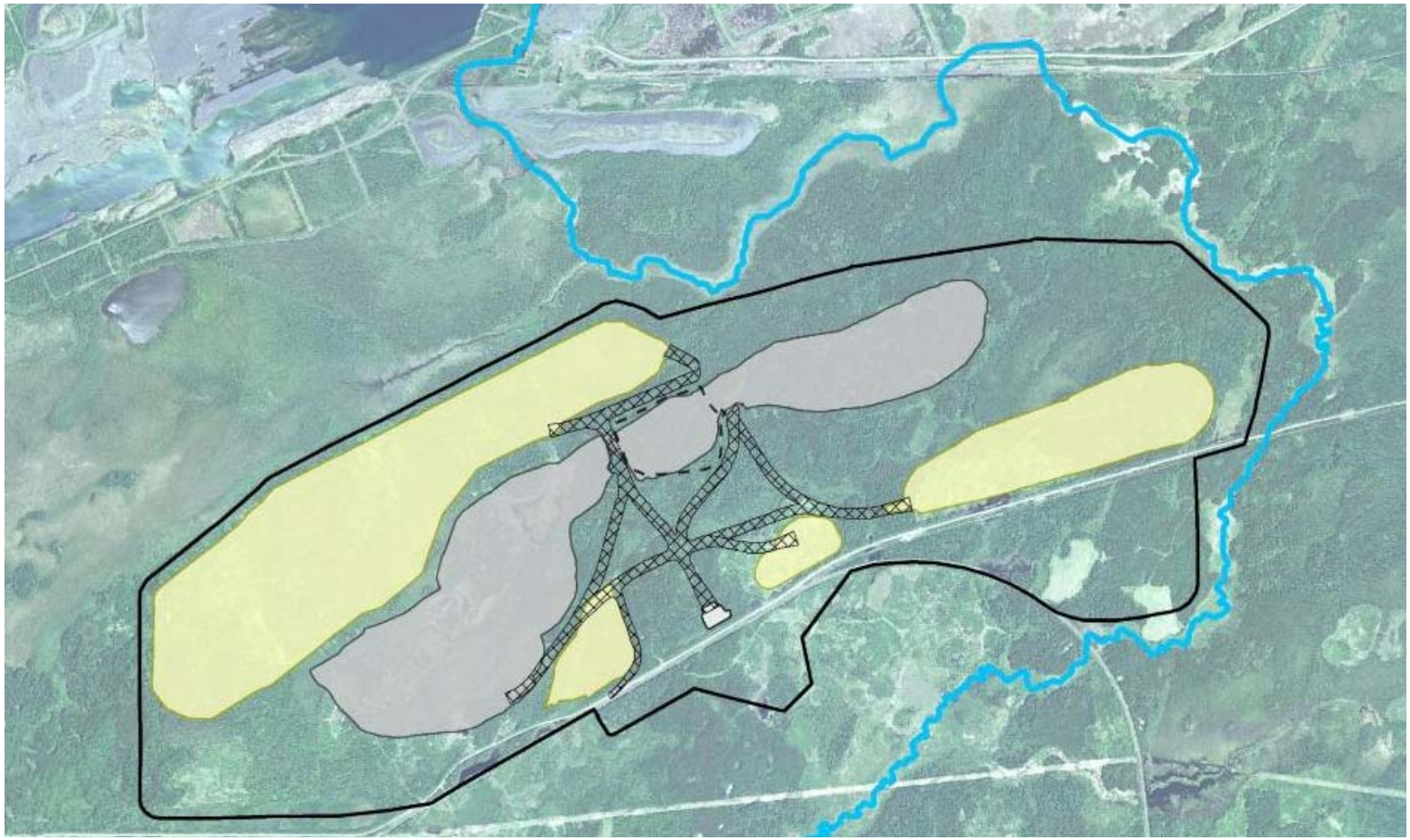
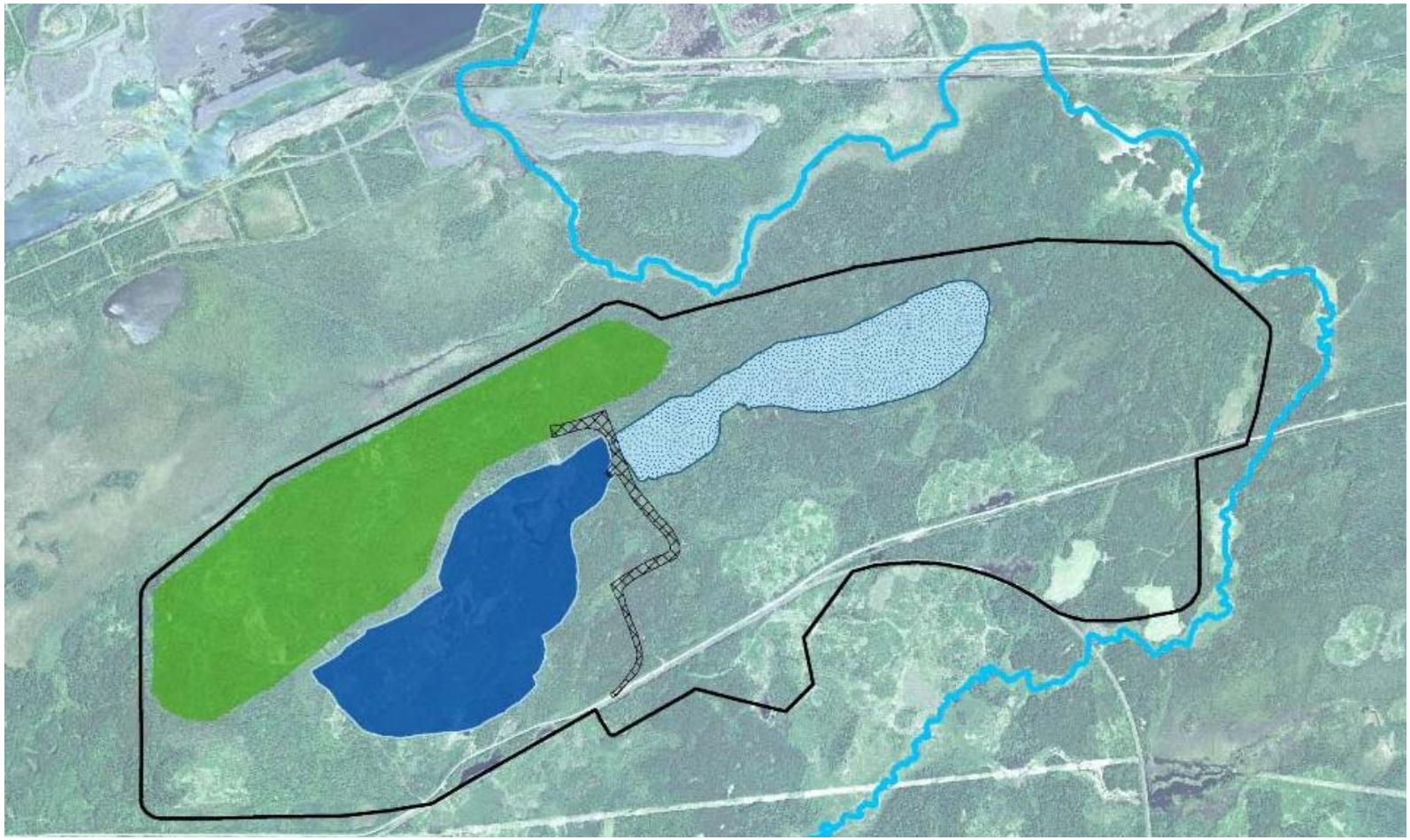
NorthMet mine site - operations



NorthMet mine site – closure



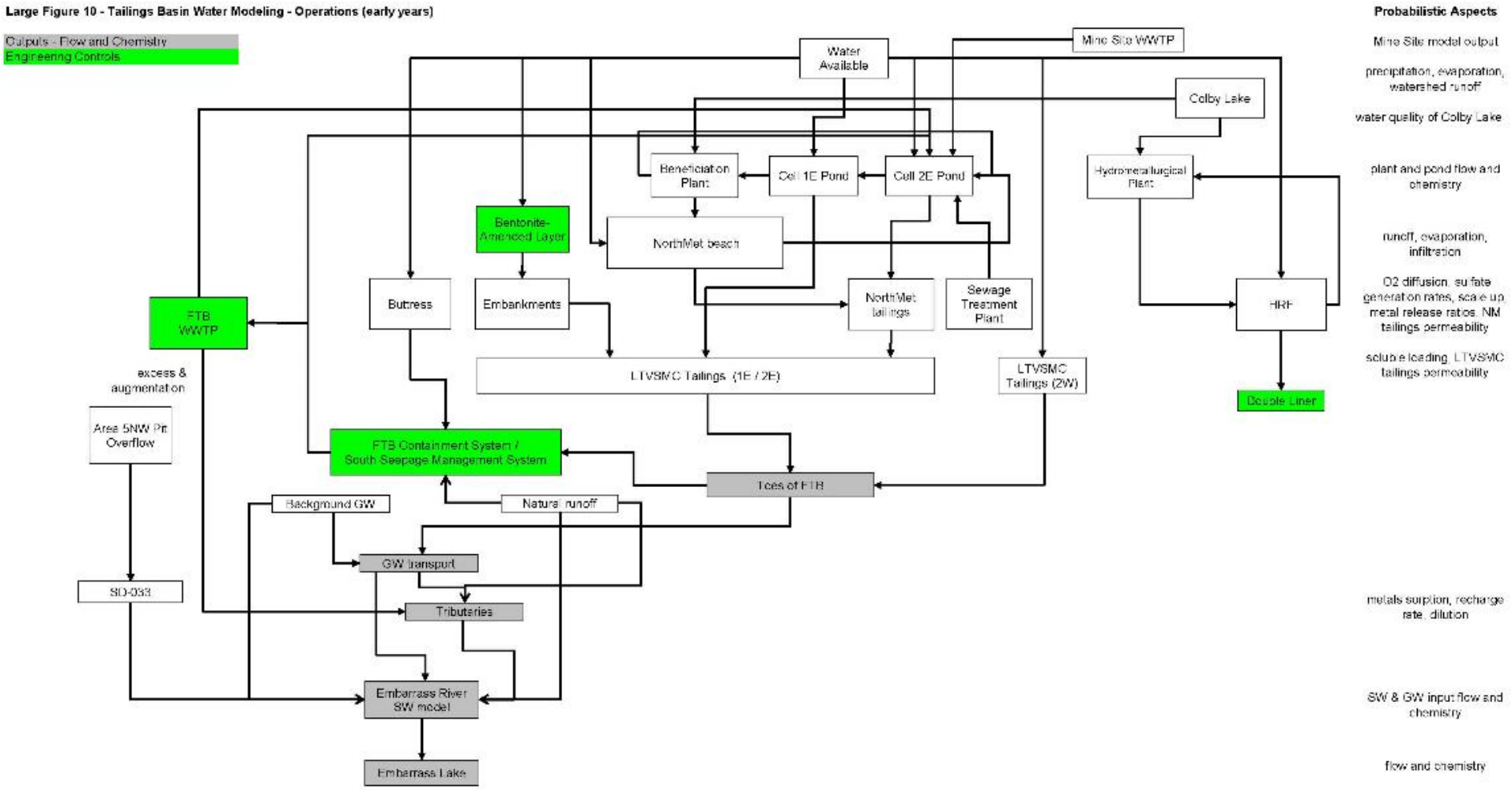
NorthMet plant site

- processing plant
- tailings storage
- hydrometallurgical residue storage
- water treatment

Water management strategy

- Collect water from the mine site (pits and stockpiles) and pump to the plant site for use in processing
- All seepage from the TSF will be collected and reused to the extent possible
- Additional make-up water will come from nearby lake as required

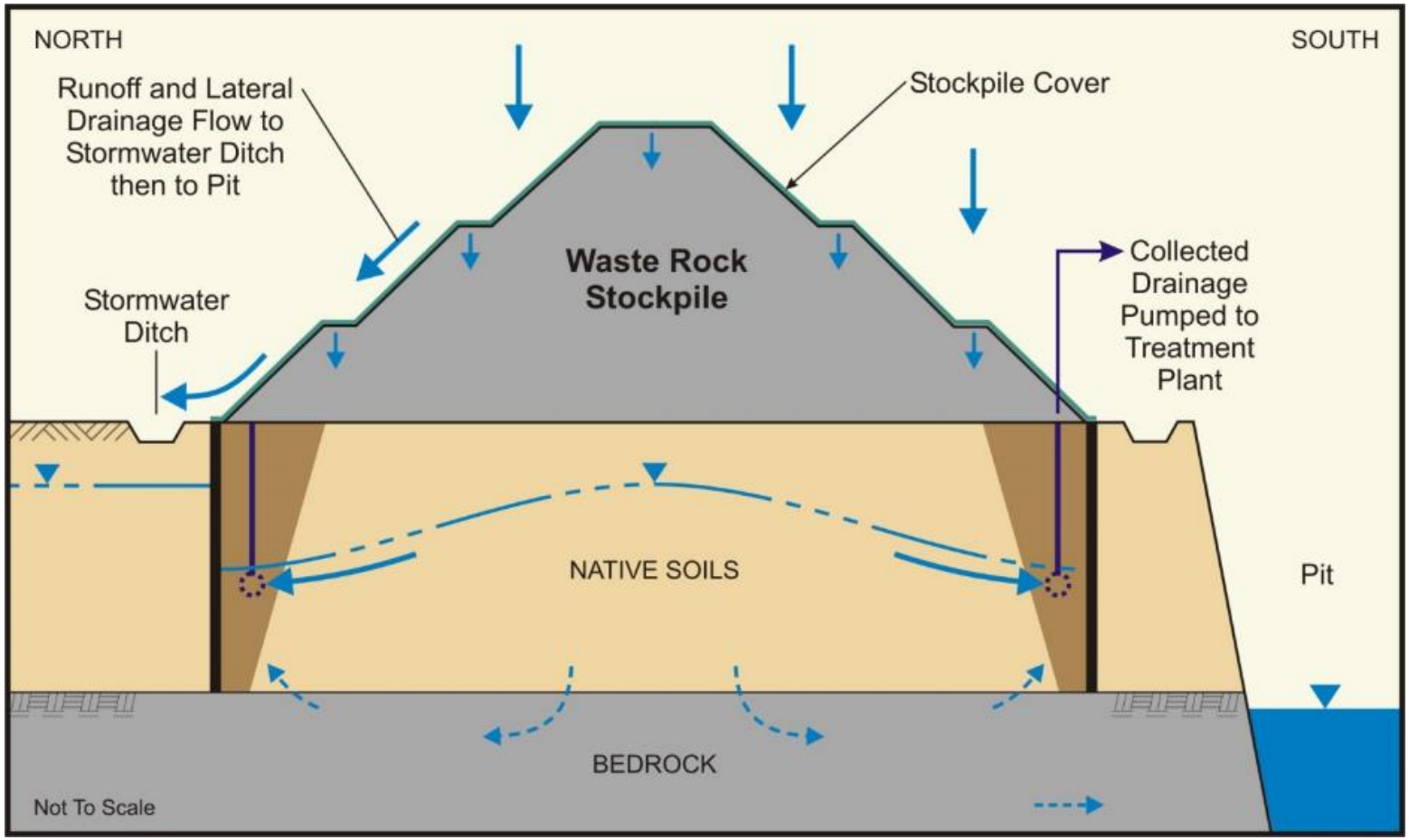
integrated water balance



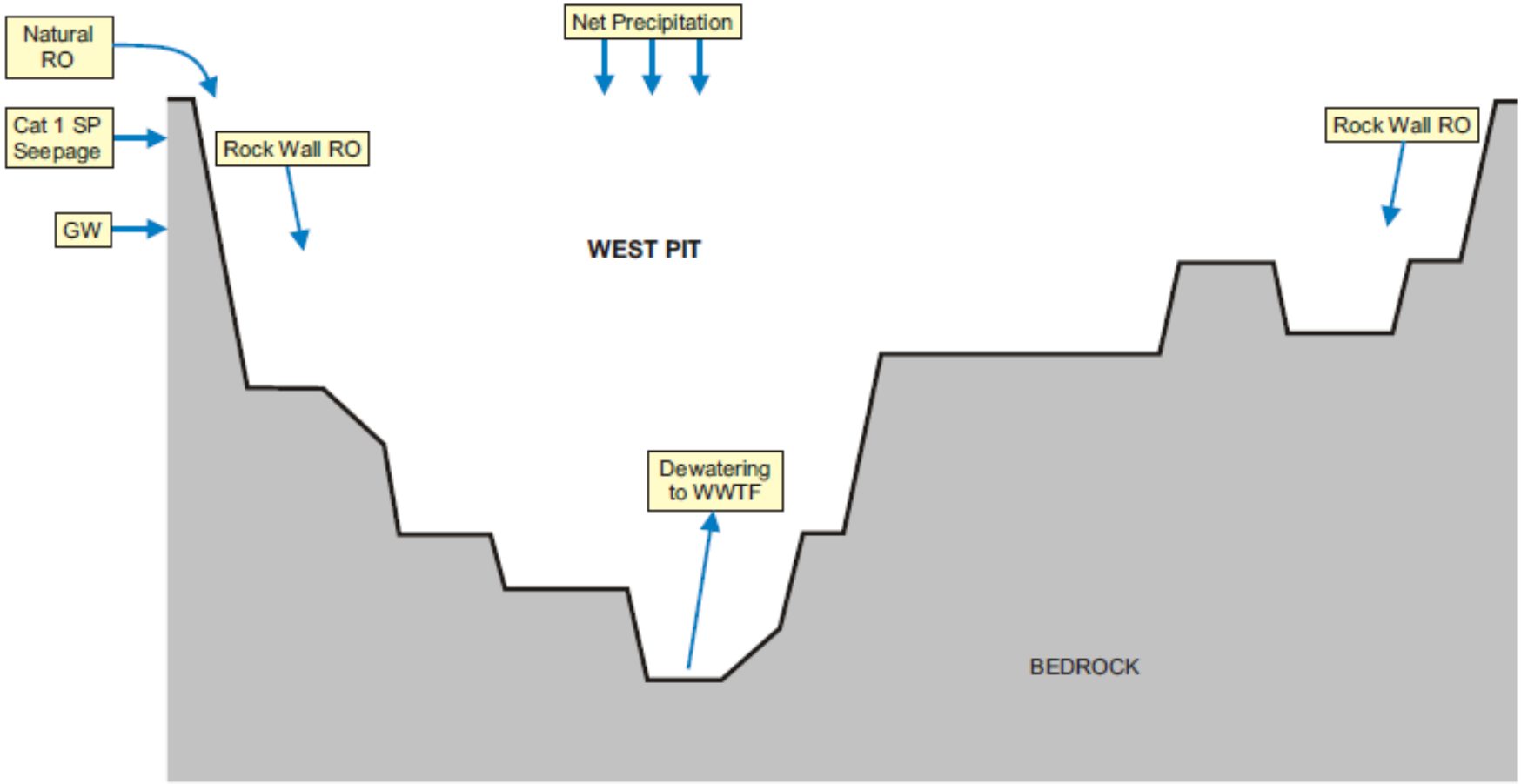
modeling overview

- two linked GoldSim models that go from source to receptor
- transient through time from operations through post closure
- simulate water quantity and quality (20+ constituents)

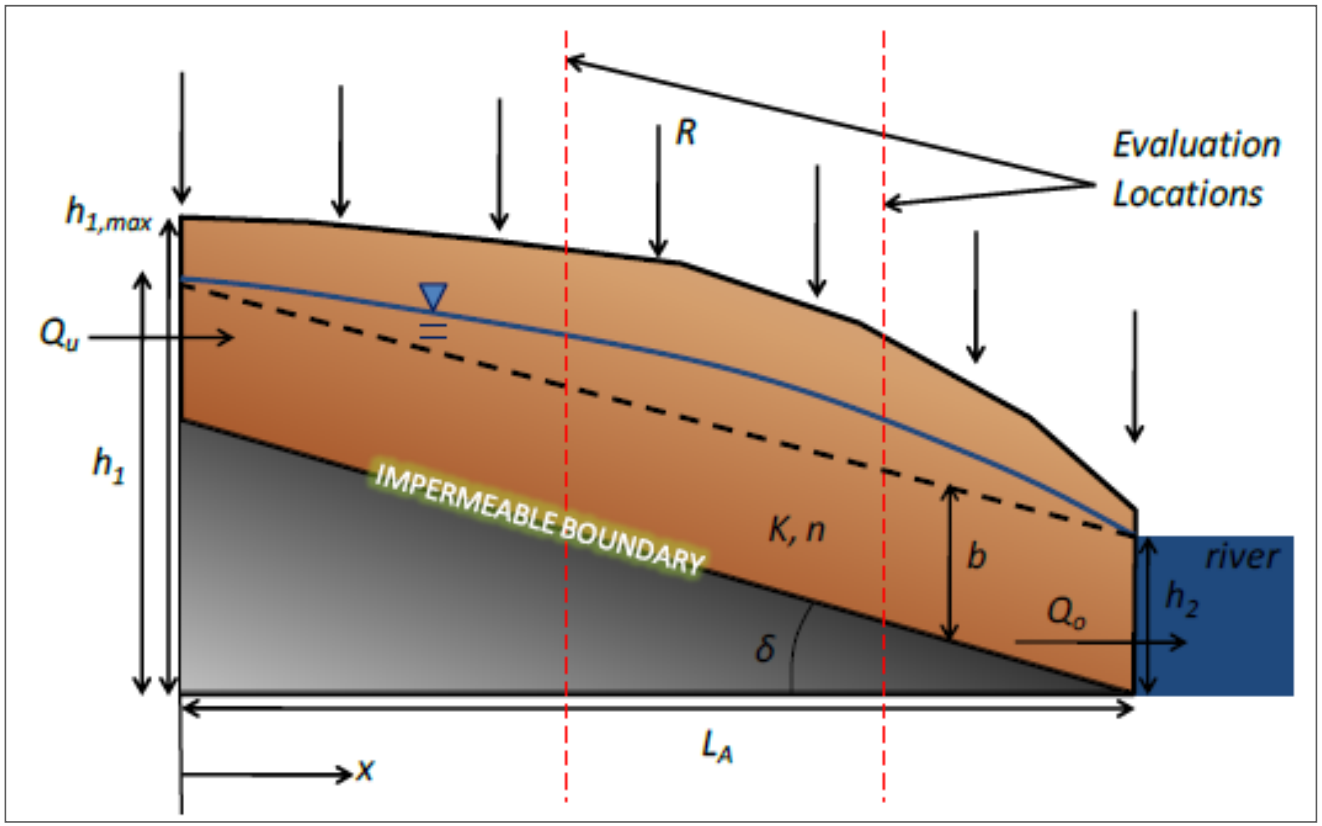
waste rock submodel



mine pit submodel



groundwater transport



Simulate 1D flow with:

- advection
- dispersion
- sorption
- aquifer recharge

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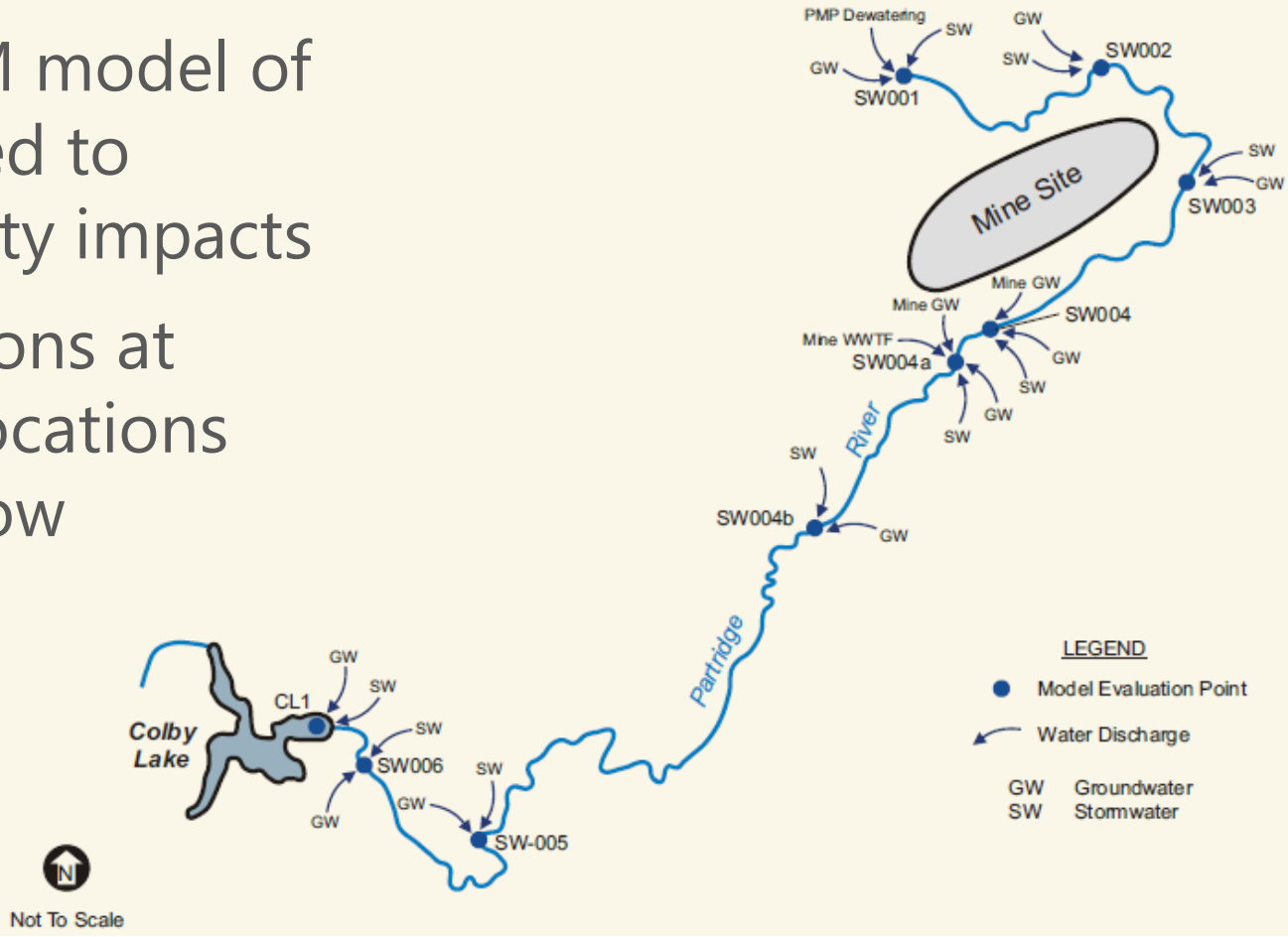
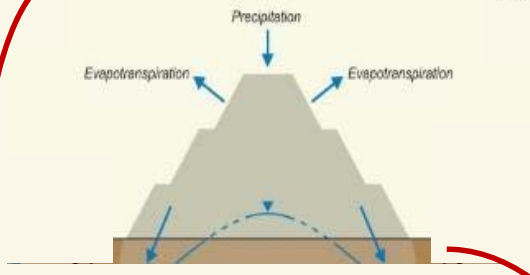
surface water submodel

- based on XP-SWMM model of river system designed to predict water quantity impacts
- predicts concentrations at various evaluation locations under a variety of flow conditions

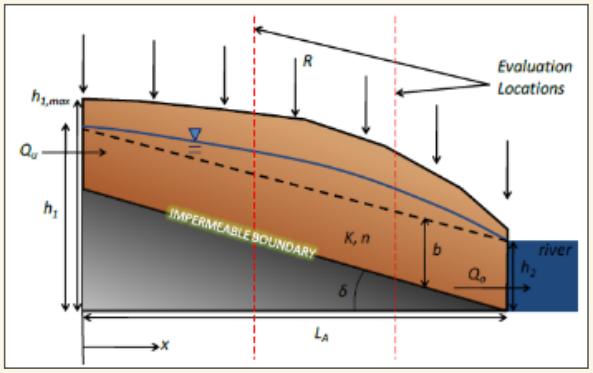


linked source-to-receptor model

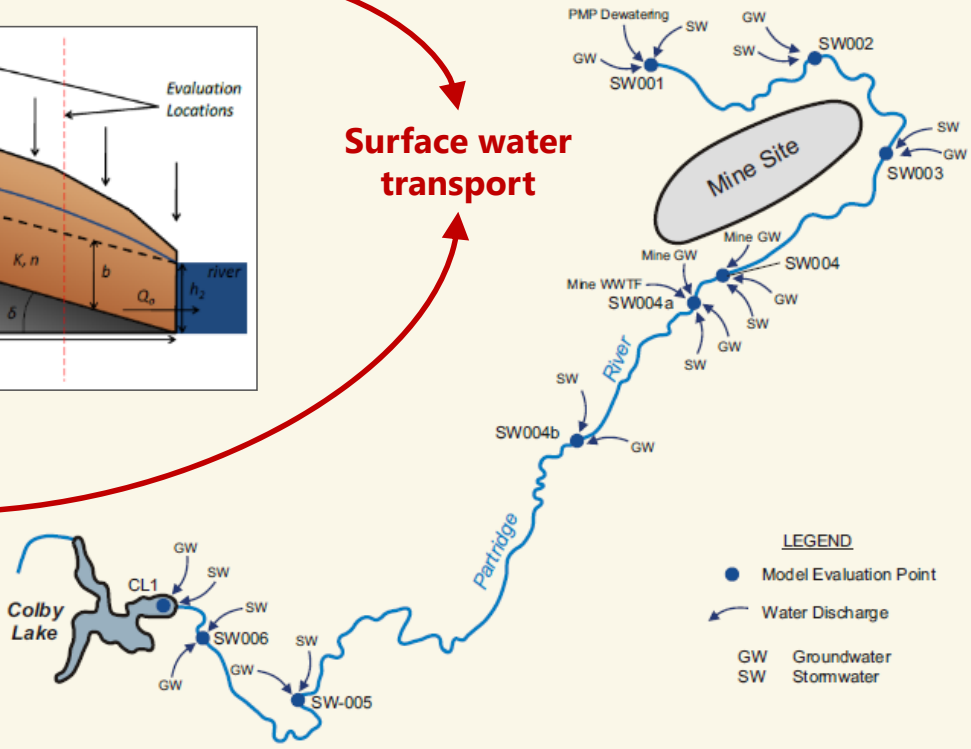
Waste rock geochemistry



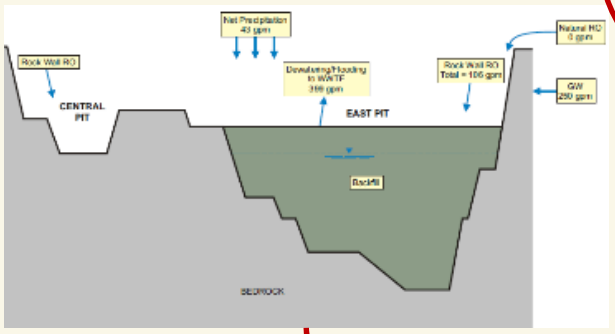
Groundwater transport



Surface water transport



Pit water/mass balance



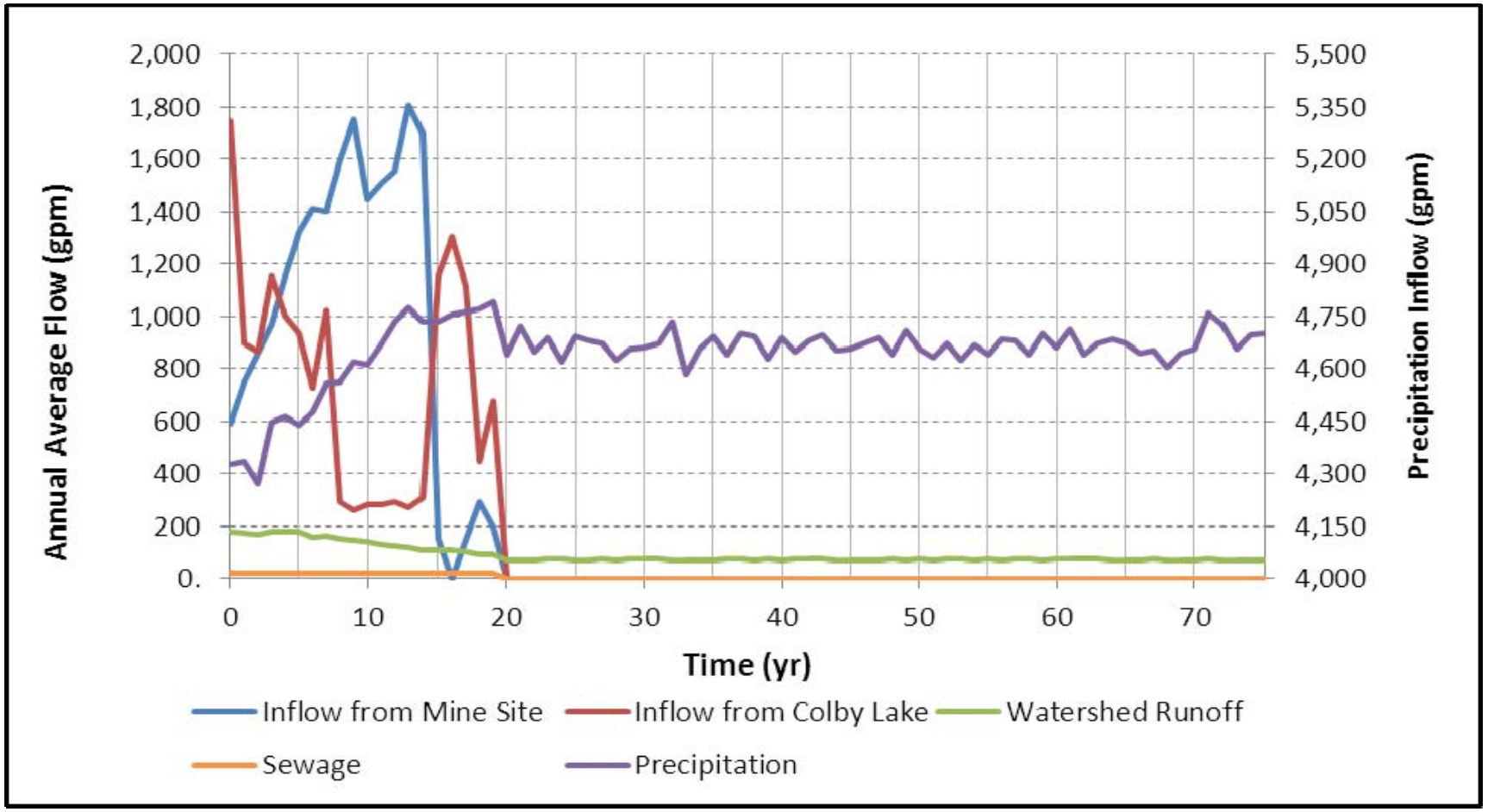
Not To Scale

Flows & loads to treatment

advantages of this approach

- holistic view of the water balance and how it changes
- rapid evaluation of design changes or changes in model assumptions – what-ifs
- conduct site-wide culpability and sensitivity analyses
- continuity of mass
- flexibility to address additional questions and evolving issues though the mine life cycle

water balance example

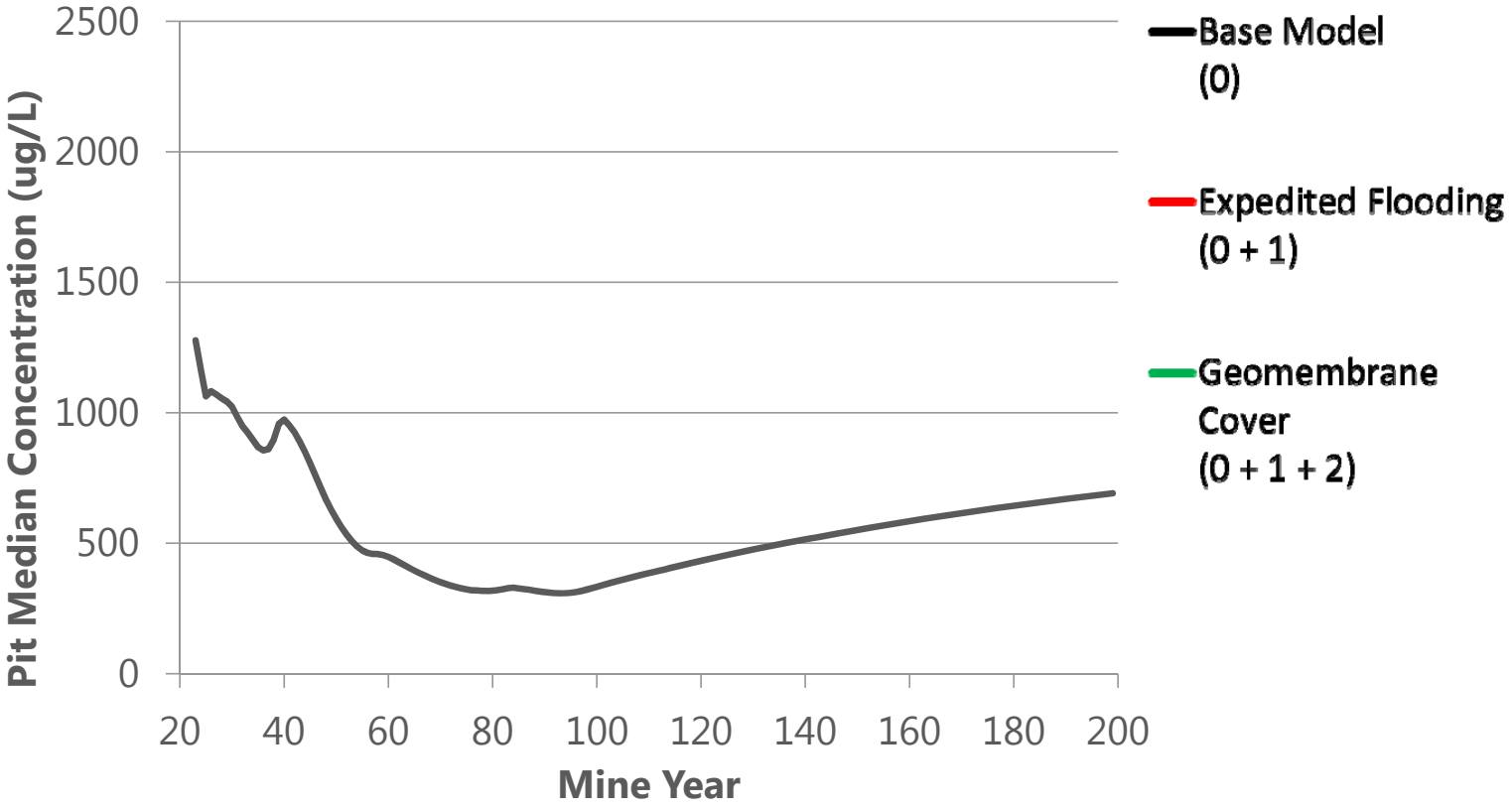


example of evaluation of design options

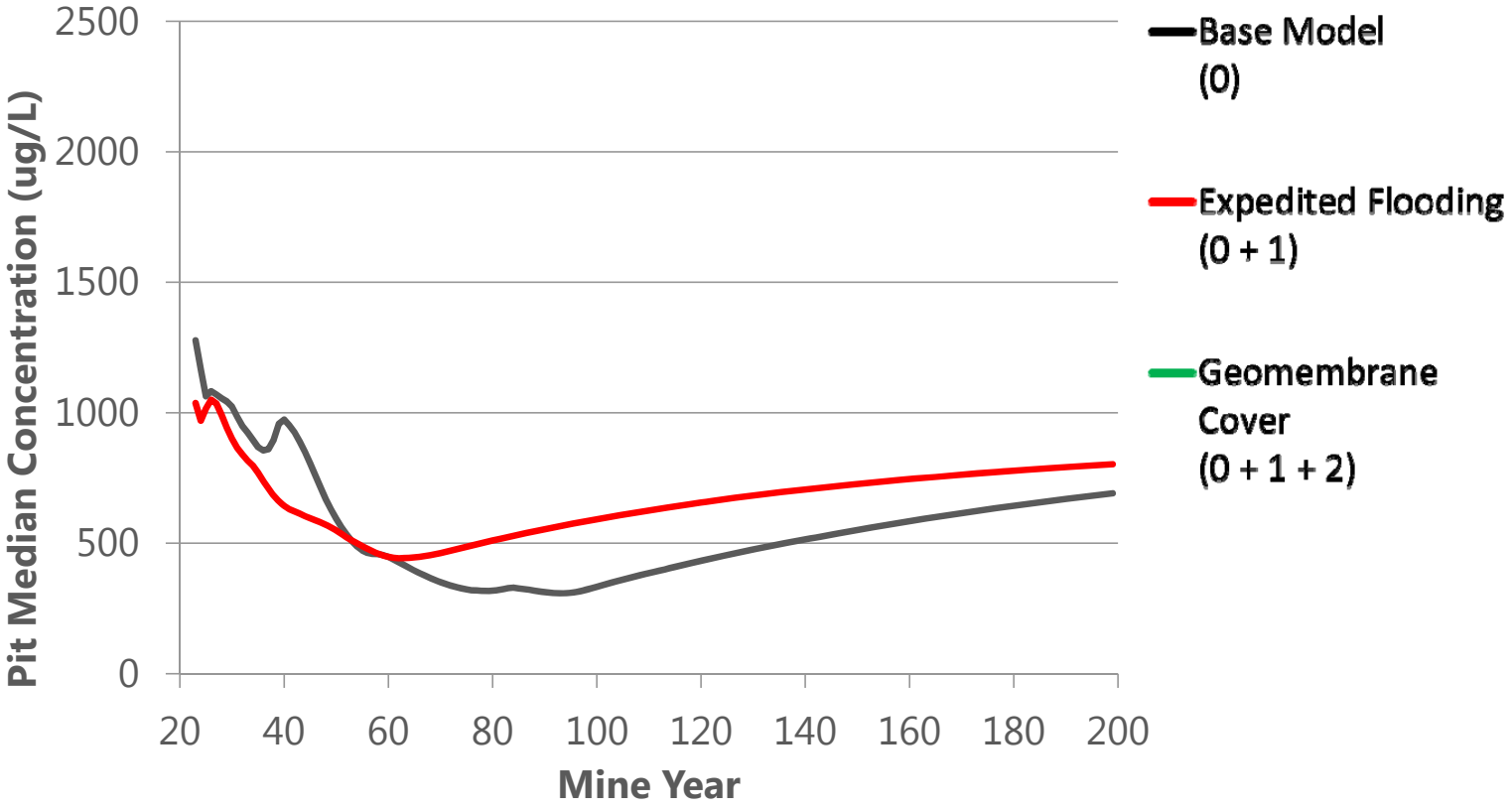
NorthMet Mine Site design options considered

1) expedited pit flooding
2) stockpile geomembrane cover

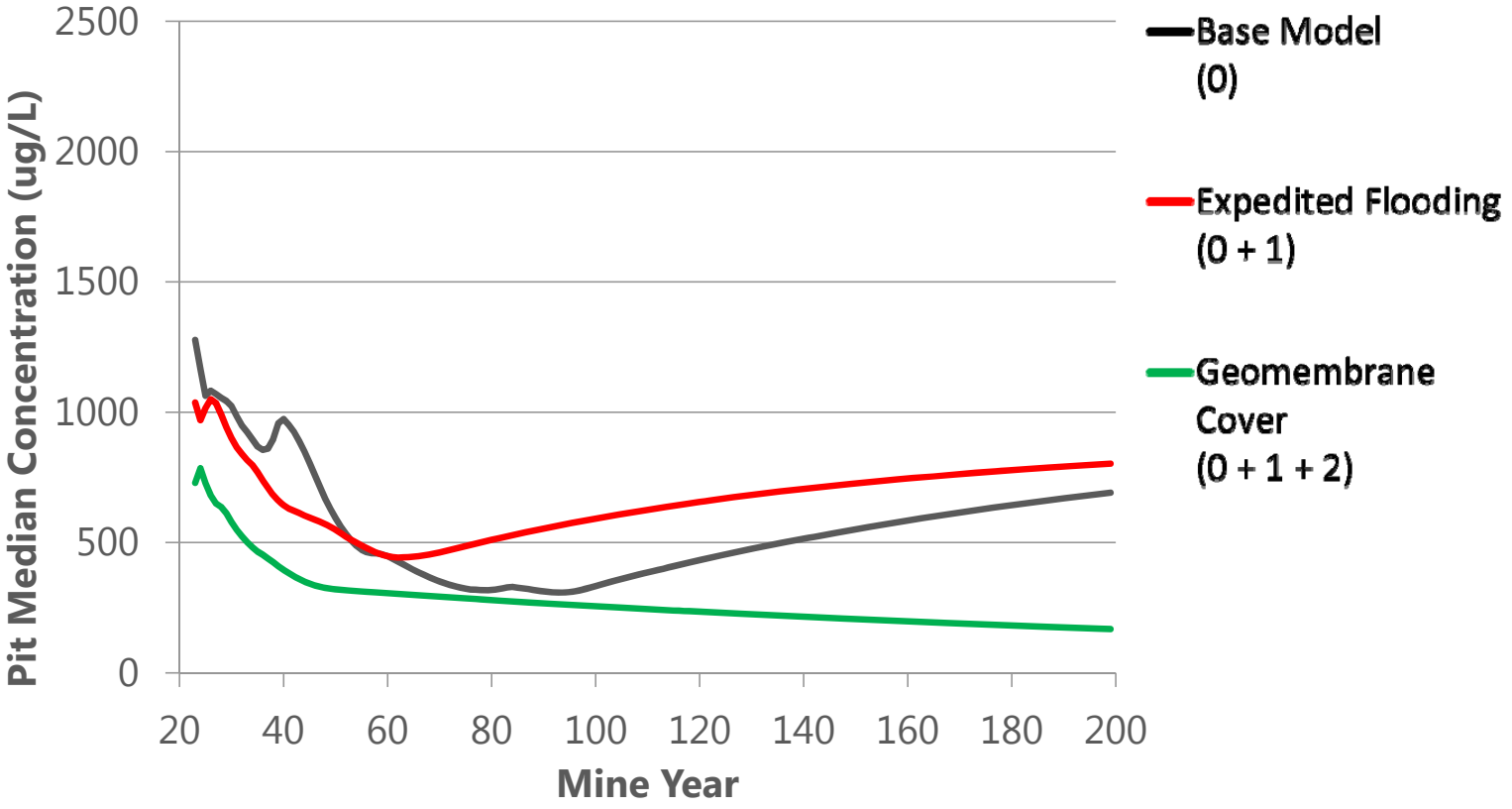
mine pit water quality



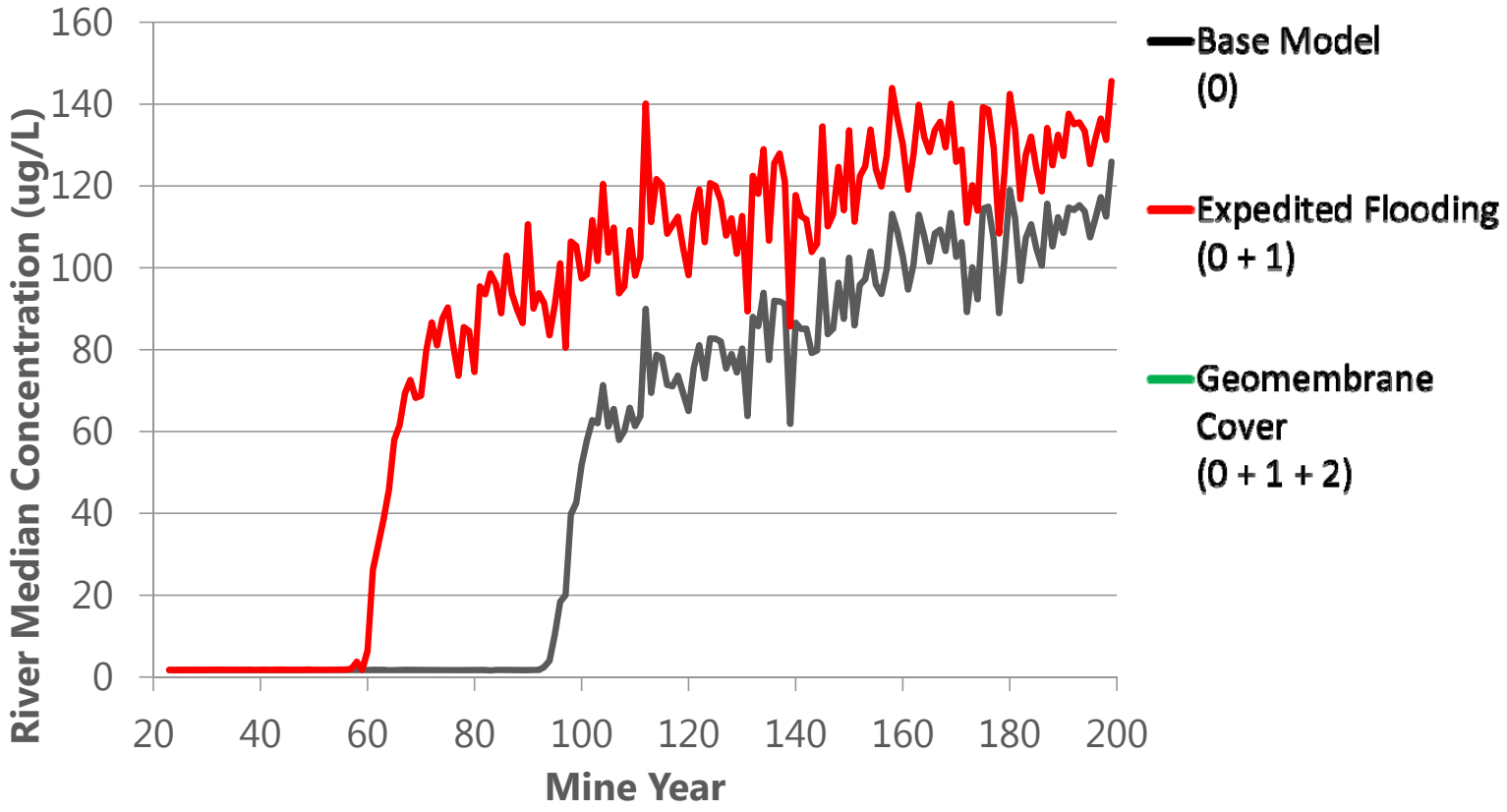
mine pit water quality



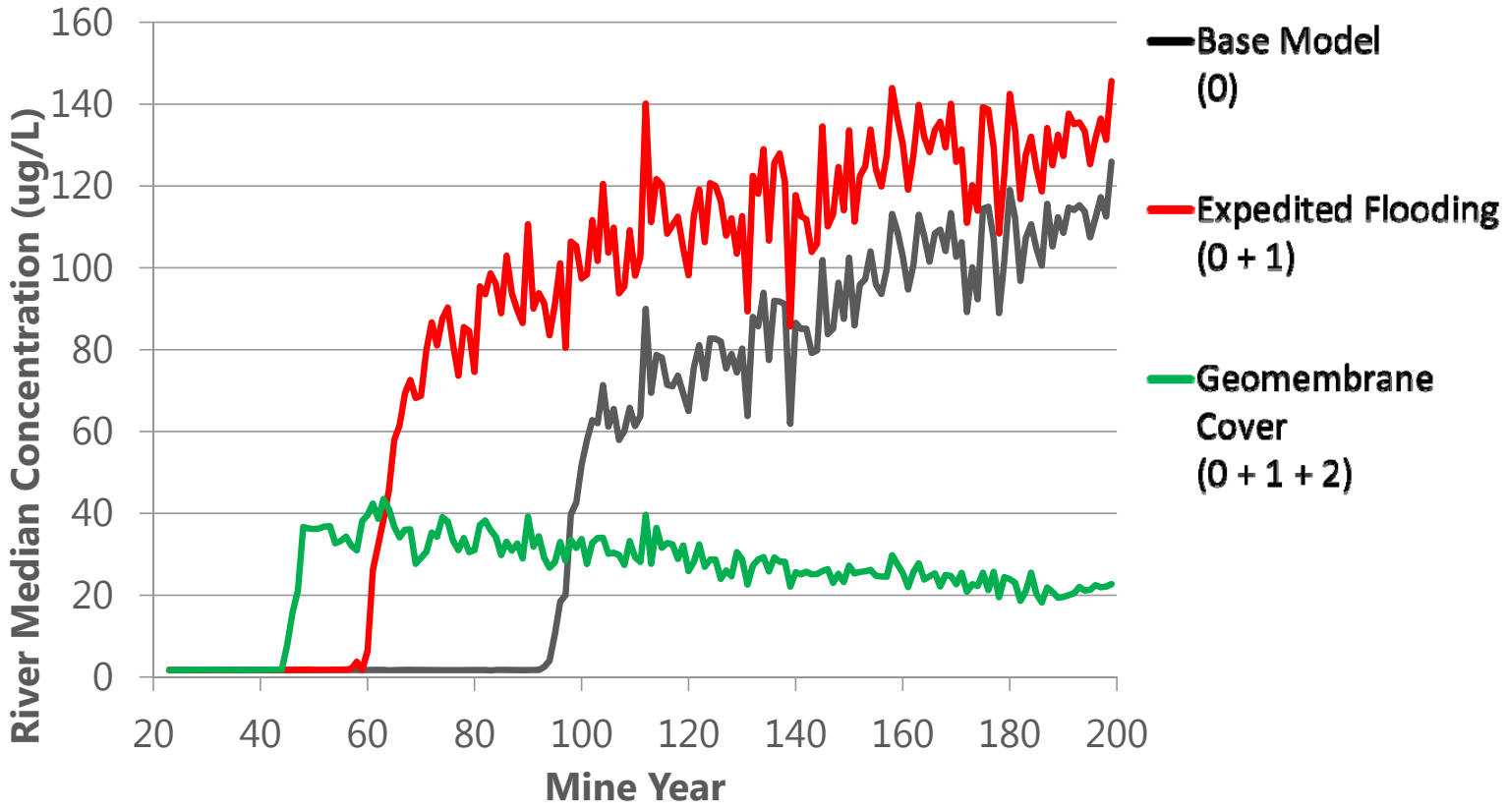
mine pit water quality



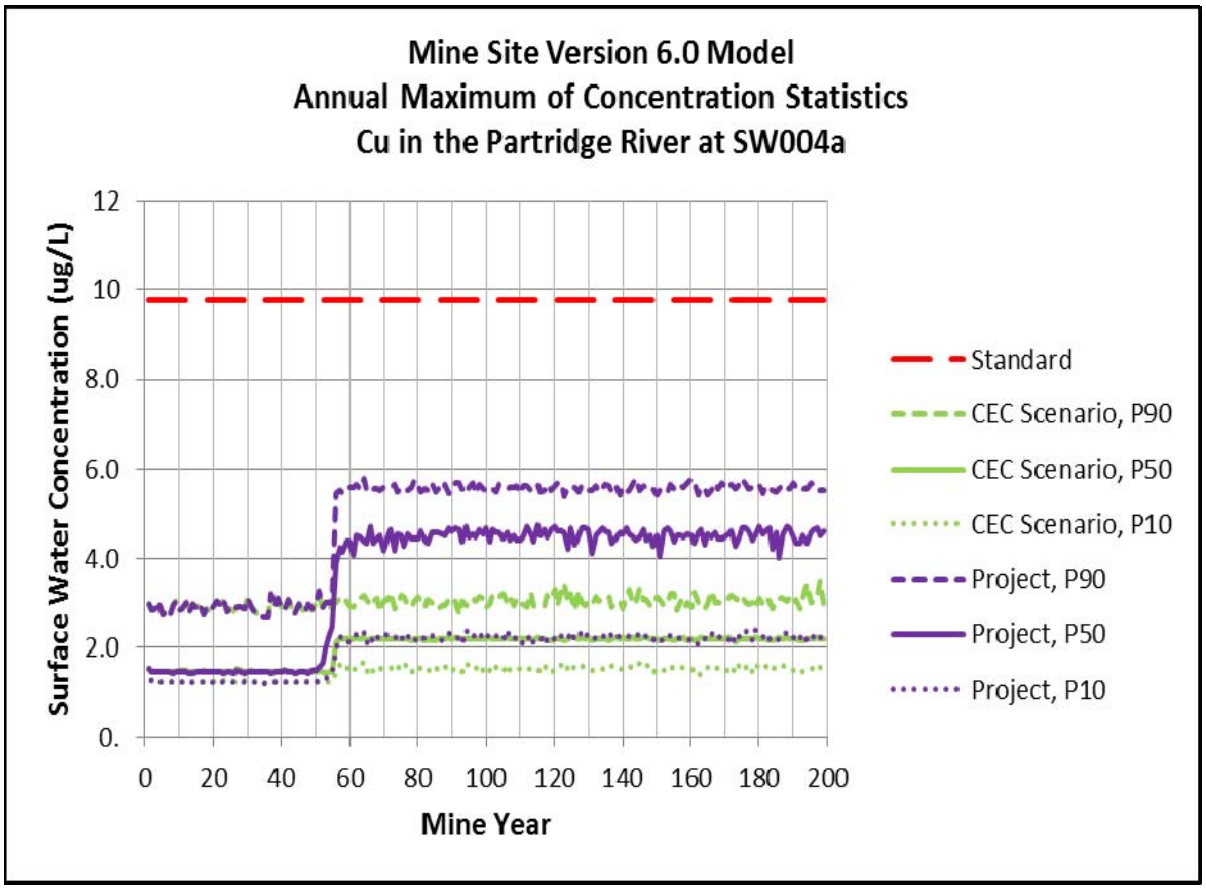
surface water receptor water quality



surface water receptor water quality



assess regulatory compliance considering uncertainty



- Predicted concentrations relative to water quality standards
- Presenting P10, P50 and P90 results
- Comparing No Action to Project

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take home points

- mine water management plans can be complex and hard to understand if not looked at holistically
- the sooner you start to model the mine water, the more benefit you can get out of the model
- these don't have to be really complex, just right sized for the questions being asked
- mine water models are not just for regulatory compliance, they can be a useful tool for operators

the end.