Simulation of Recipient Water Quality for Closure Planning at the Aitik Mine, Sweden

GoldSim User Conference 2018

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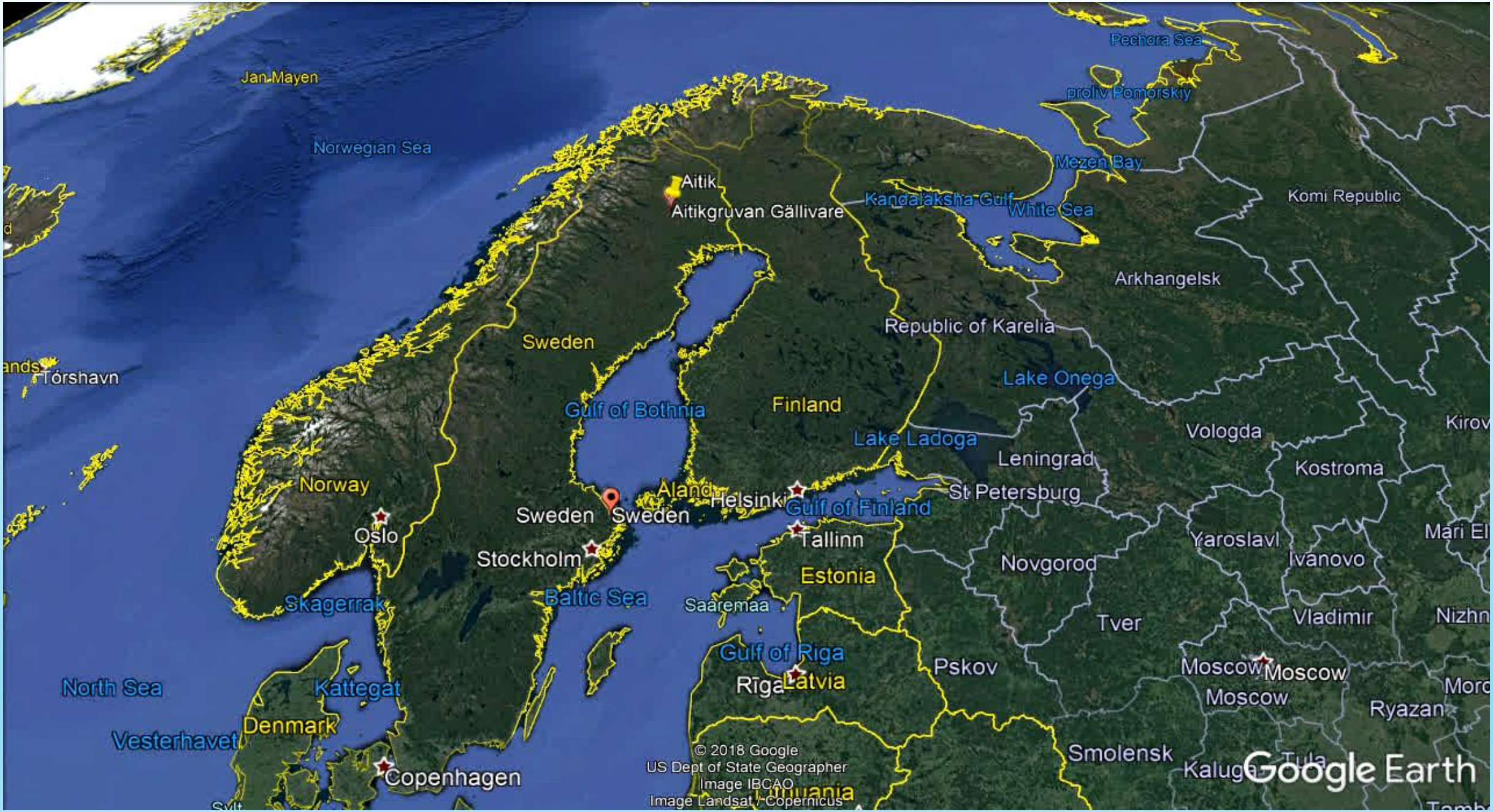
Topics

- Background
  - Mine location and operations
  - Configuration of existing water management systems
- Closure planning
  - Remediation measures
  - Closure configuration and conceptualization
- Model development approach
  - Model setup and structure
  - Checks of model results compared to measured data
- Predictions for closure and identification of liabilities


Jan Mayen
Norwegian Sea
Pechora Sea
proliv Pomorskiy
Mezen Bay
Kandalaksha Gulf
White Sea
Komi Republic
Aitik
Aitikgruvan Gällivare
Arkhangelsk
Republic of Karelia
Sweden
Tórshavn
Lake Onega
Gulf of Bothnia
Finland
Lake Ladoga
Vologda
Kirov
Leningrad
Kostroma
Norway
Aland
Helsinki
St Petersburg
Gulf of Finland
Sweden
Sweden
Oslo
Tallinn
Mari El
Yaroslavl
Ivanovo
Stockholm
Novgorod
Estonia
Baltic Sea
Skagerrak
Saaremaa
Tver
Vladimir
Nizhn
Gulf of Riga
Pskov
Moscow
Moscow
Moscow
Riga
Latvia
North Sea
Kattegat
Moro
Ryazan
Denmark
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Aitik Mine

- Established 1968
- 650 Employees
- Sweden's largest copper mine
- 39 Mtonne/yr in 2017
- Increasing to 45 Mtonne/yr in 2020
- Ore grades ≈ 0.25% Cu

Permitting for Expansion and Continued Operation

Detailed (conceptual) closure plan

- Reclamation Plan
  - Tailings and Waste Rock
    - Landforms
    - Cover systems (moraine and moraine + bentonite)
    - Vegetation
- Water management plan
  - Clarification pond
  - Runoff and seepage control
  - Pit lakes filling and discharge

Requirements

- Covers must limit O_2 flux < 1 mol/m^2/yr
- Meet applicable water quality criteria in rivers (Excess water balance environment so there will always be water moving from the mine areas to the rivers.)
- Account for future climate change (to year 2200)

Multi-Company Effort

Boliden AB

- Project management
- Legal
- Permitting
- Technical review

Lorax Environmental

- Pit lake hydrology & water chemistry
- Future climate

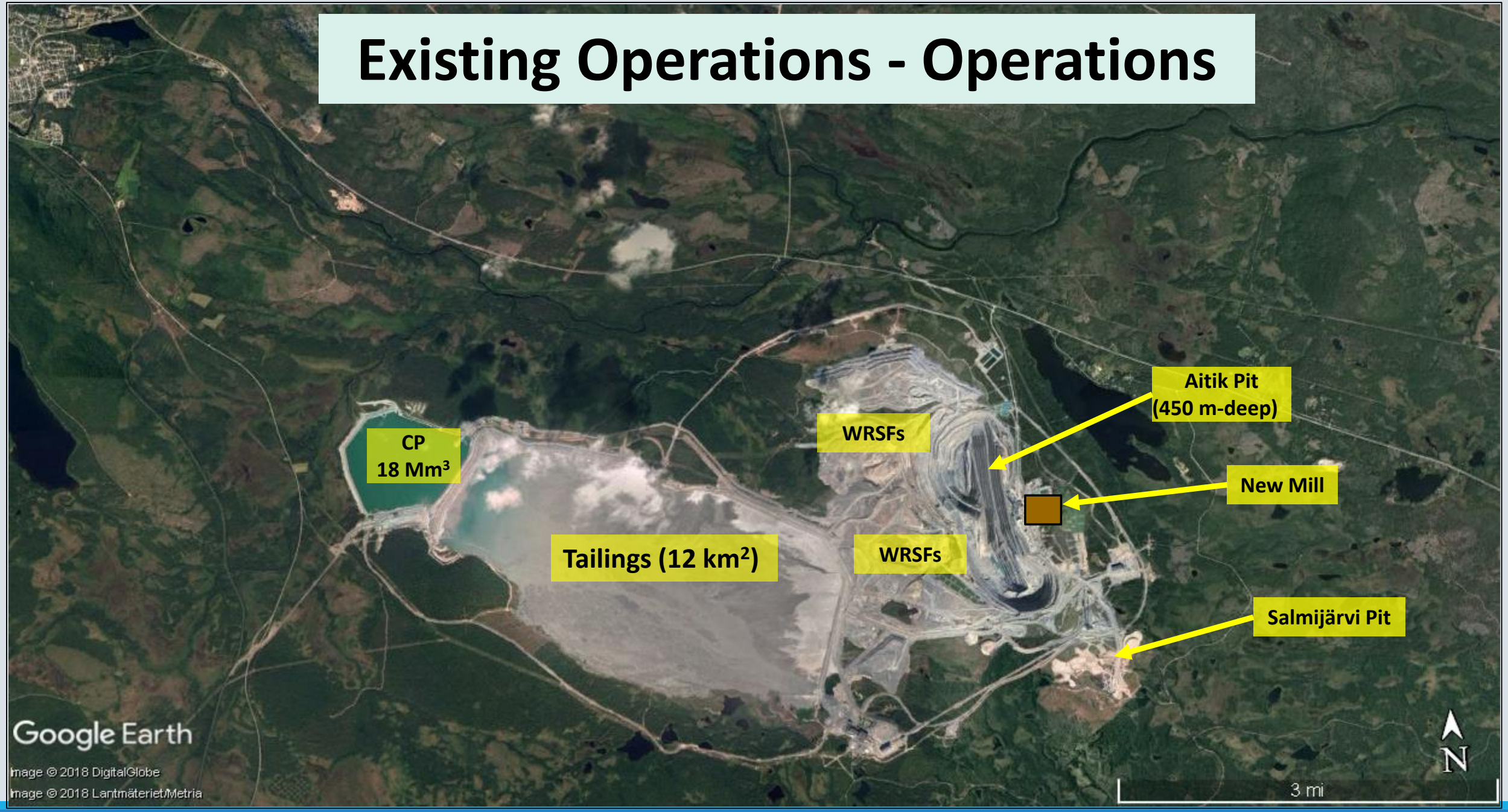
Interralogic/Enchemica, LLC

- Tailings geochemistry & seepage water chemistry
- Site-wide water balance
- River Modeling

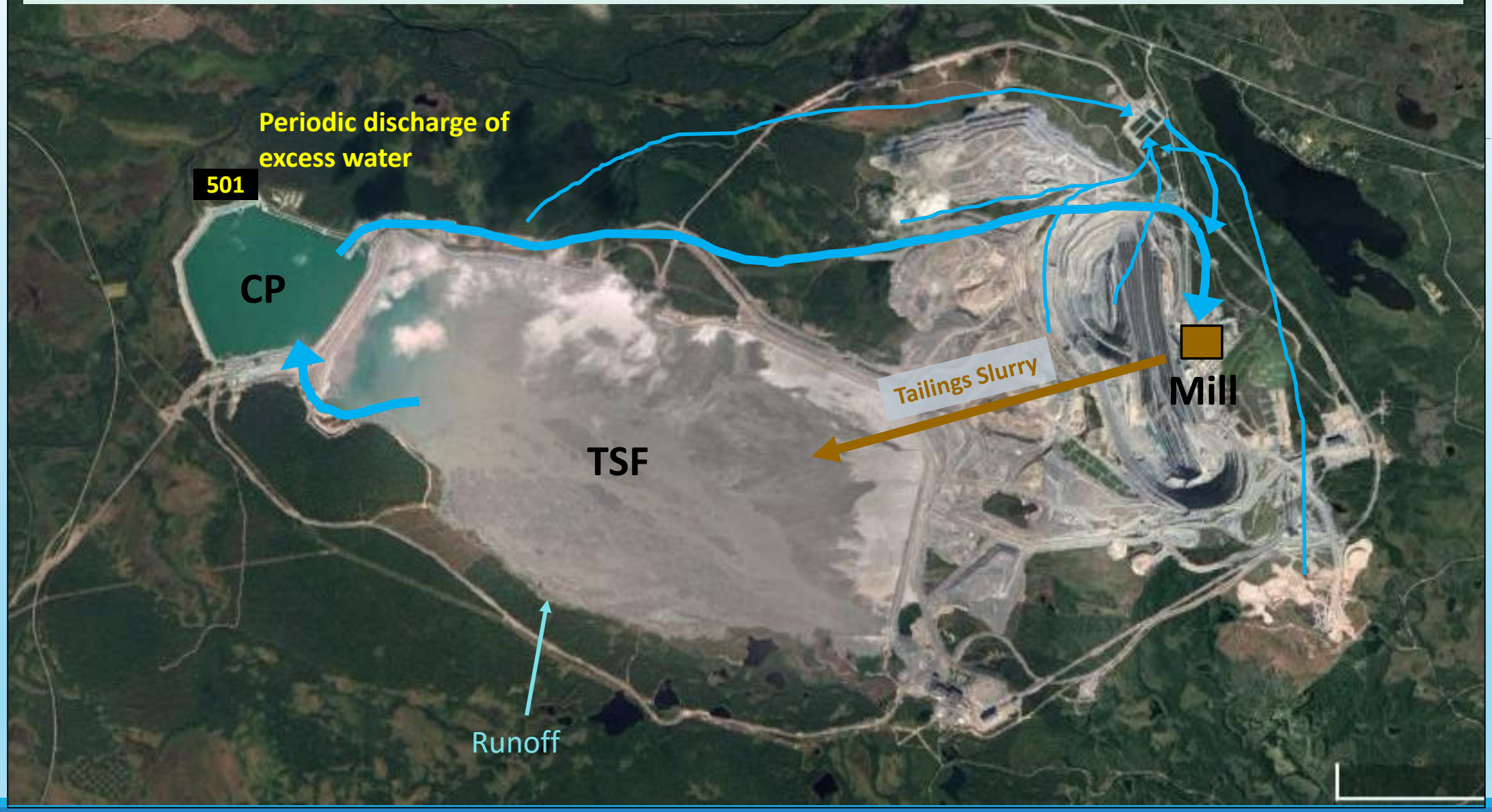
O'Kane Associates

- Reclamation Planning (tailings, waste rock)
- Cover designs (tailings, waste rock)
- Waste rock geochemistry & seepage water chemistry
- Base Case closure plan
- Failure Modes & Effects Analysis

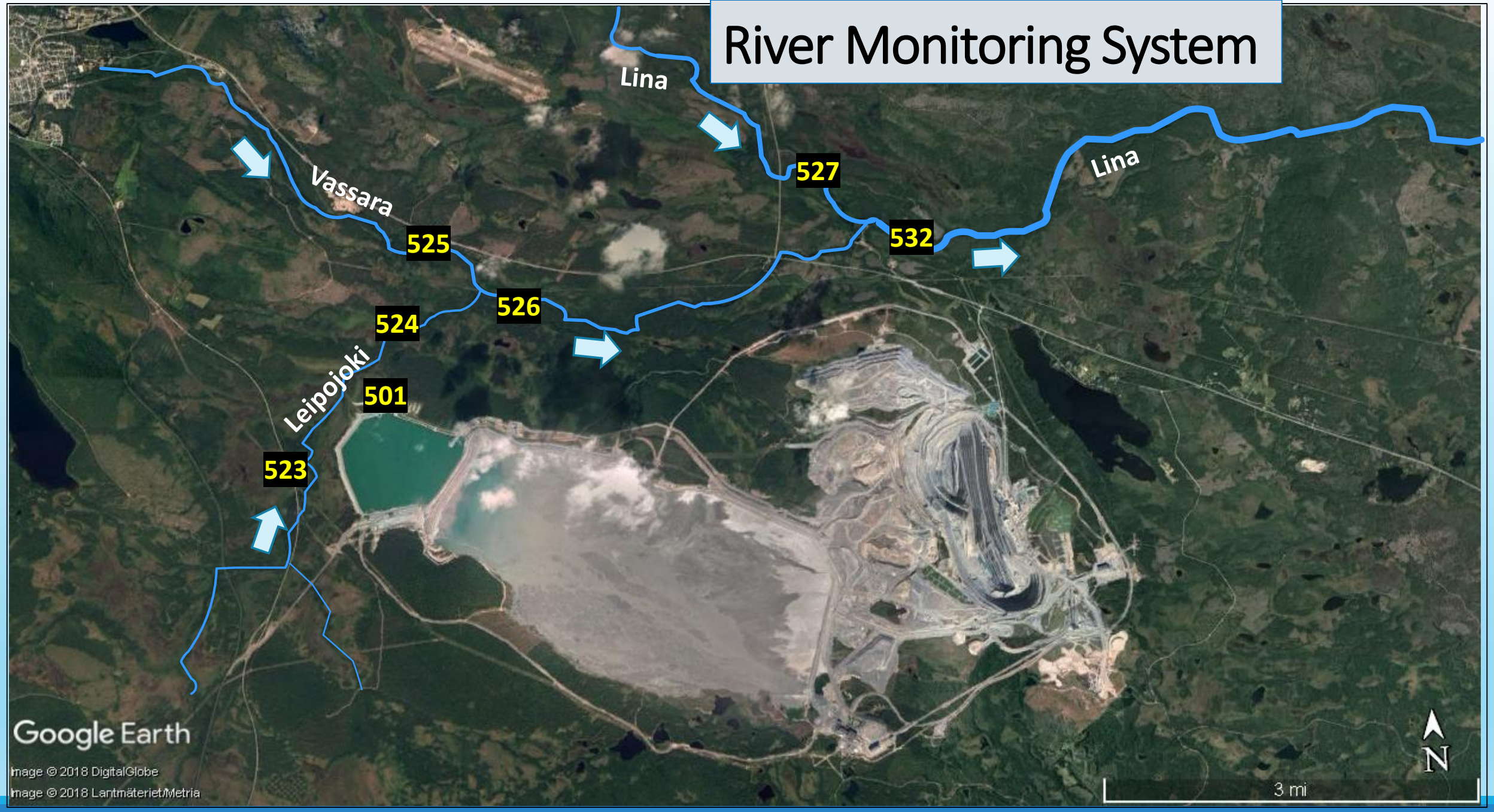
Existing Operations - Operations



Existing Operations – Water Management

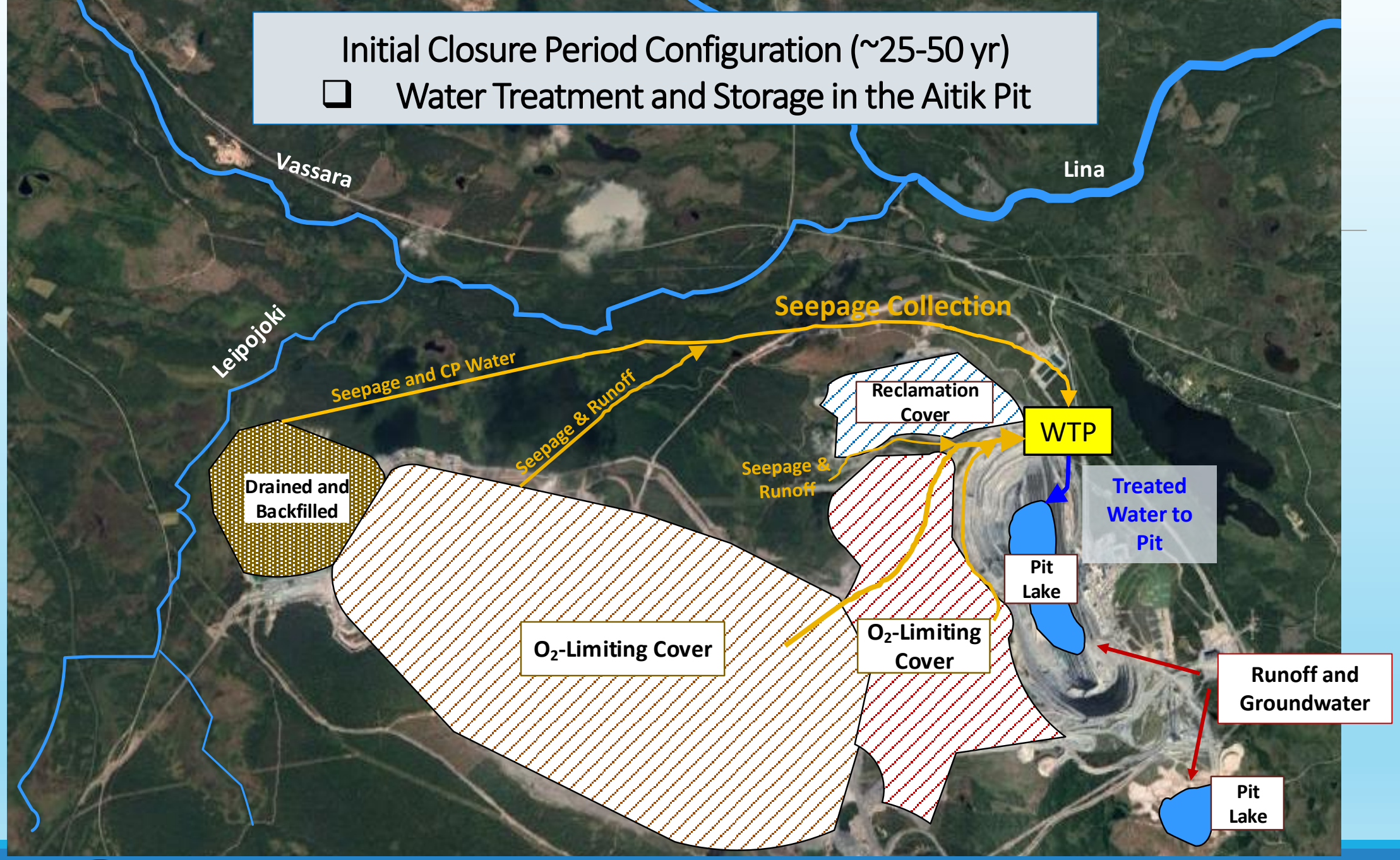


River Monitoring System



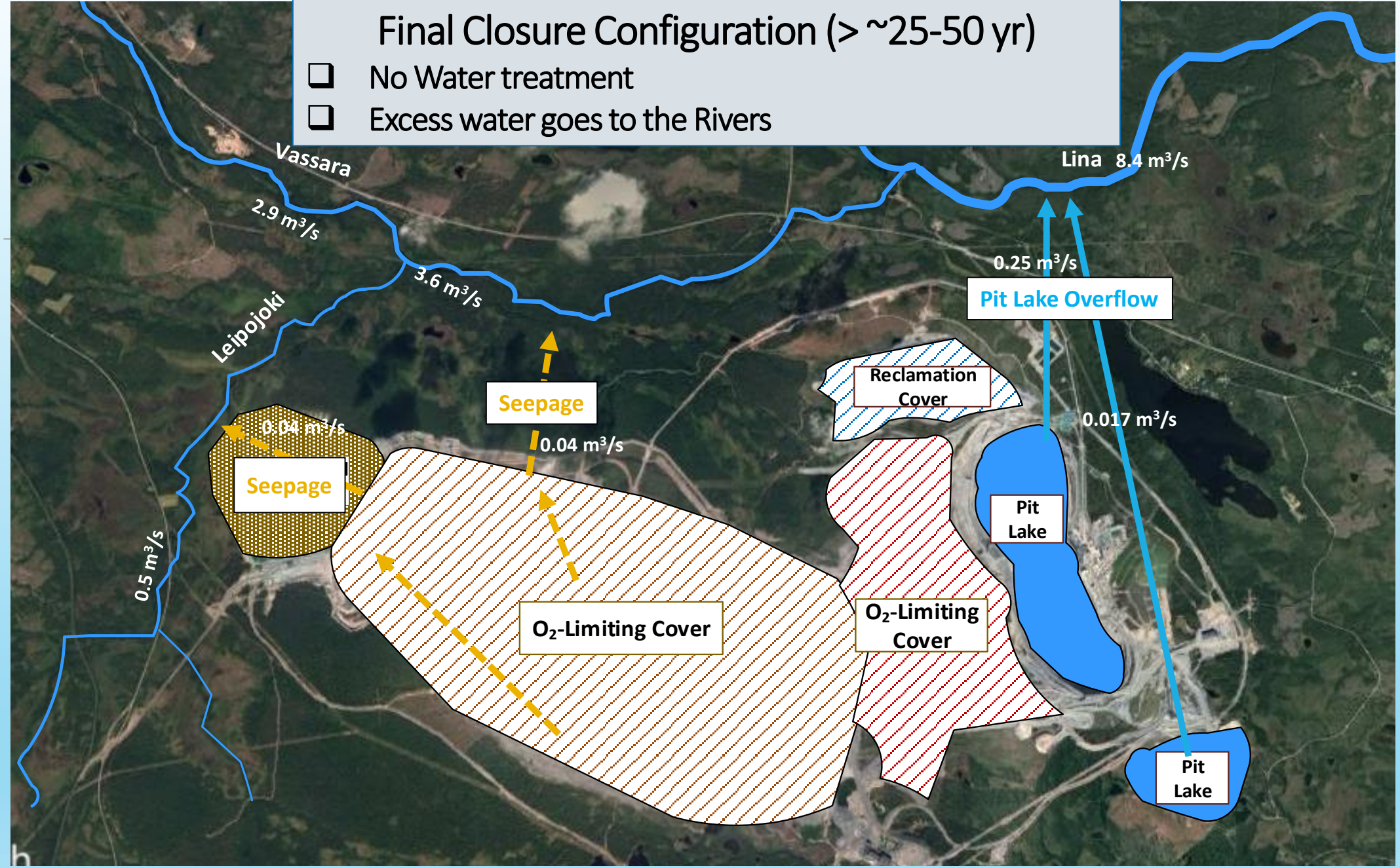
Initial Closure Period Configuration (~25-50 yr)

- Water Treatment and Storage in the Aitik Pit



Final Closure Configuration (> ~25-50 yr)

- ❑ No Water treatment
- ❑ Excess water goes to the Rivers



Model Development Approach – Two Step Process

Step 1: Comparison (Calibration) Period

- Build model and check results against measured data for the Rivers
  - Discharge rate and concentrations at location 501 (Clarification Pond)
  - Flow rate and concentrations in the rivers (Locations 524, 526, and 532)

Step 2: Future Prediction Period

- Extend to the future after Mine closure (to year 2200) to include
  - Predictions of future river flows and background chemistry
    - Climate change (Scenario RCP 4.5) (Predicts 20% to 25% increase in annual average precipitation and river flow by year 2100)
  - Predictions of flows and chemistry from the closed mine for:
    - Tailings
    - Waste rock storage facilities (WRSFs)
    - Pit Lake overflows
  - Scenarios
    - 5 Different tailings sulfide contents
    - Base Case Reclamation Cover (till/compacted till)
    - Bentonite Reclamation Cover (till/compacted till+bentonite)

Calculation Methods

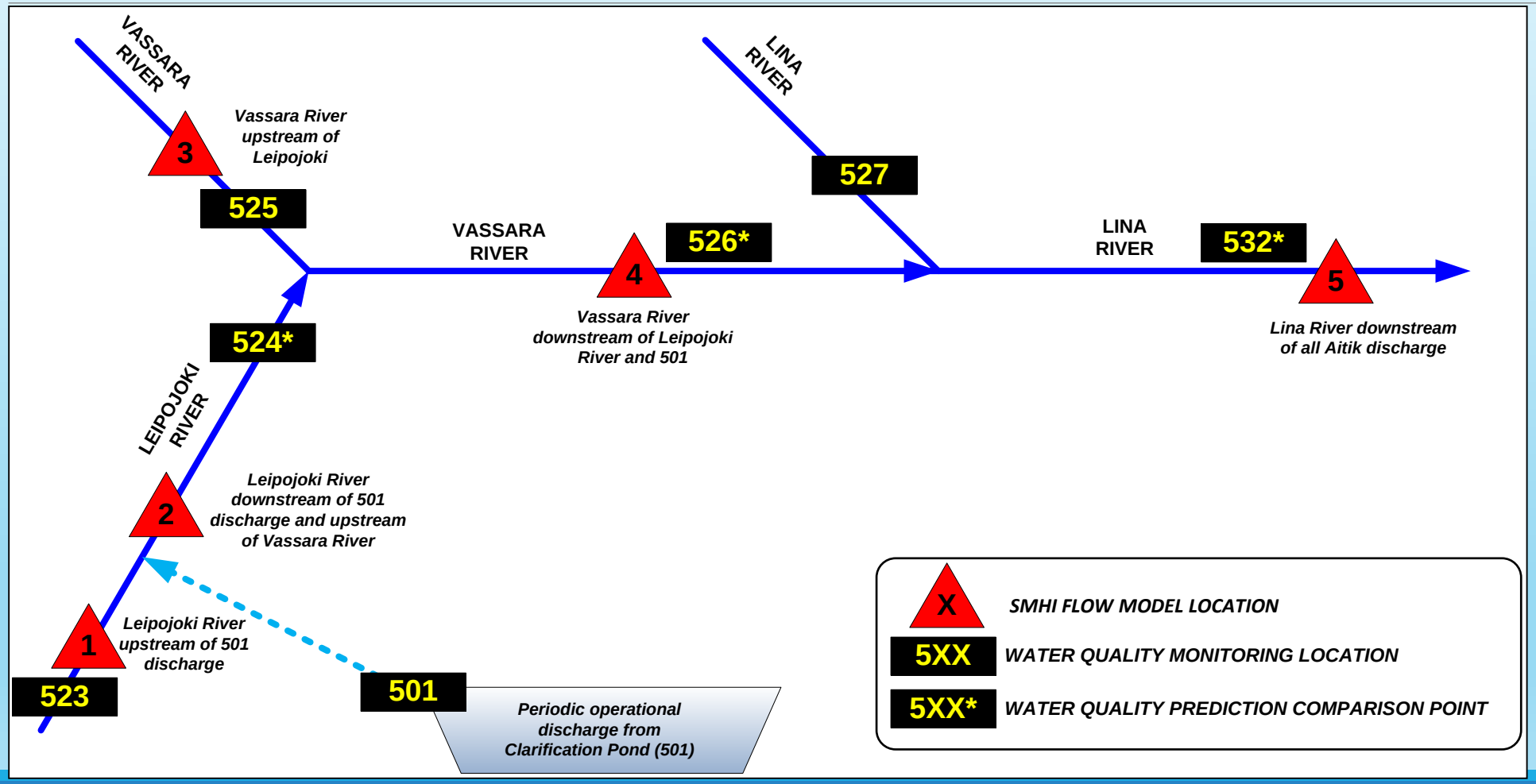
- Contaminant Transport Module
  - Cell Pathways used for mixing calculations
  - No attenuation or release (solubility, adsorption, redox, biological uptake, etc.)

- Water Chemistry
  - Al, HCO_3, As, Ba, Ca, Cd, Cl, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, Pb, SO_4, Sb, Si, Sr, V, Zn, NH_4-N, NH_3-N, NO_3-N, P, V, U, pH

- Input Data
  - Excel for Flow Rates and Water Chemistry

Step 1 (Comparison Period) – Data Sources for the Existing Operations and Rivers

- Flow Rates: SMHI daily river flows (http://vattenweb.smhi.se/modelarea/)
- Chemistry: Aitik chemistry monitoring network



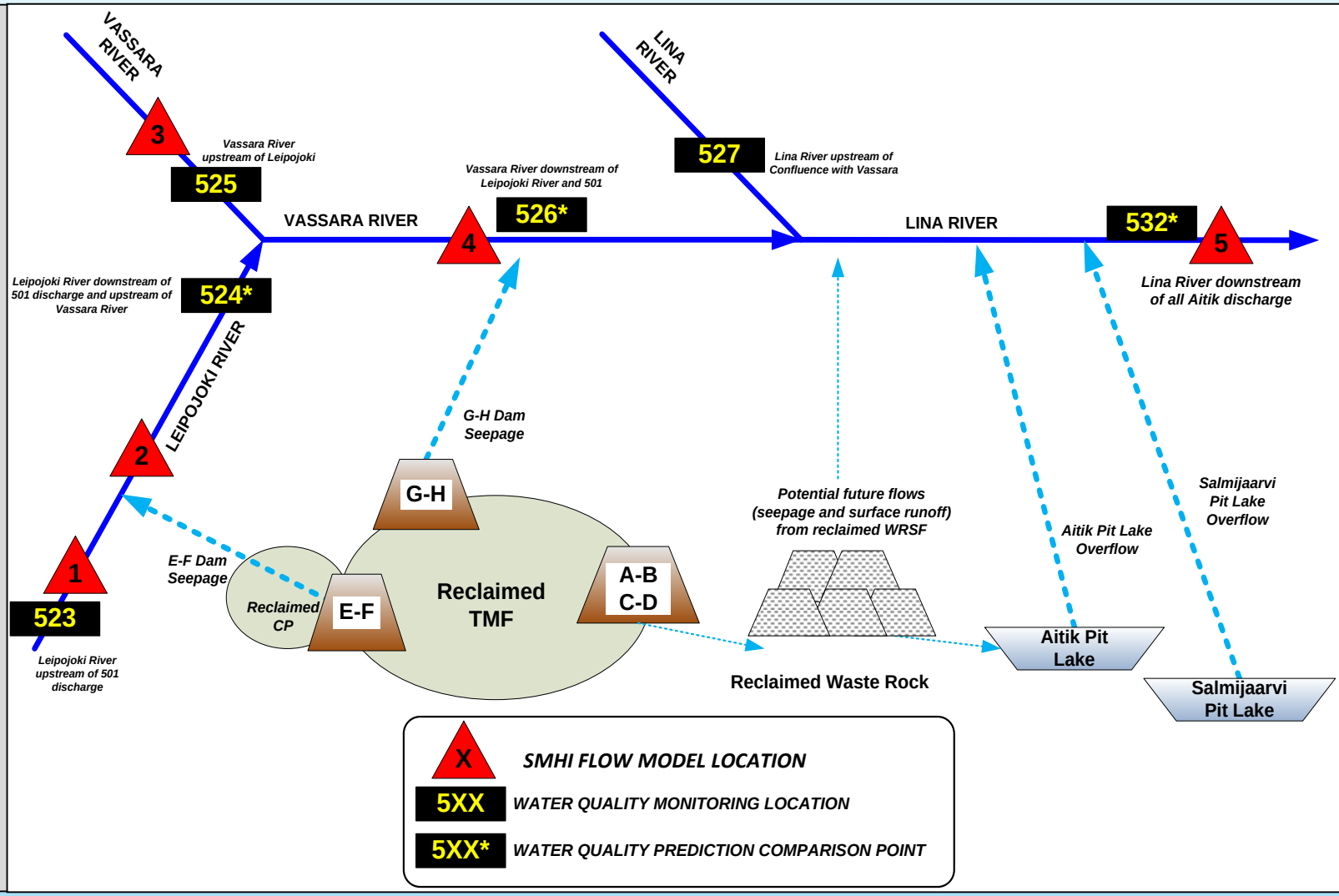
Step 2 (Future Prediction Period) – Data Sources for the closed operations and rivers

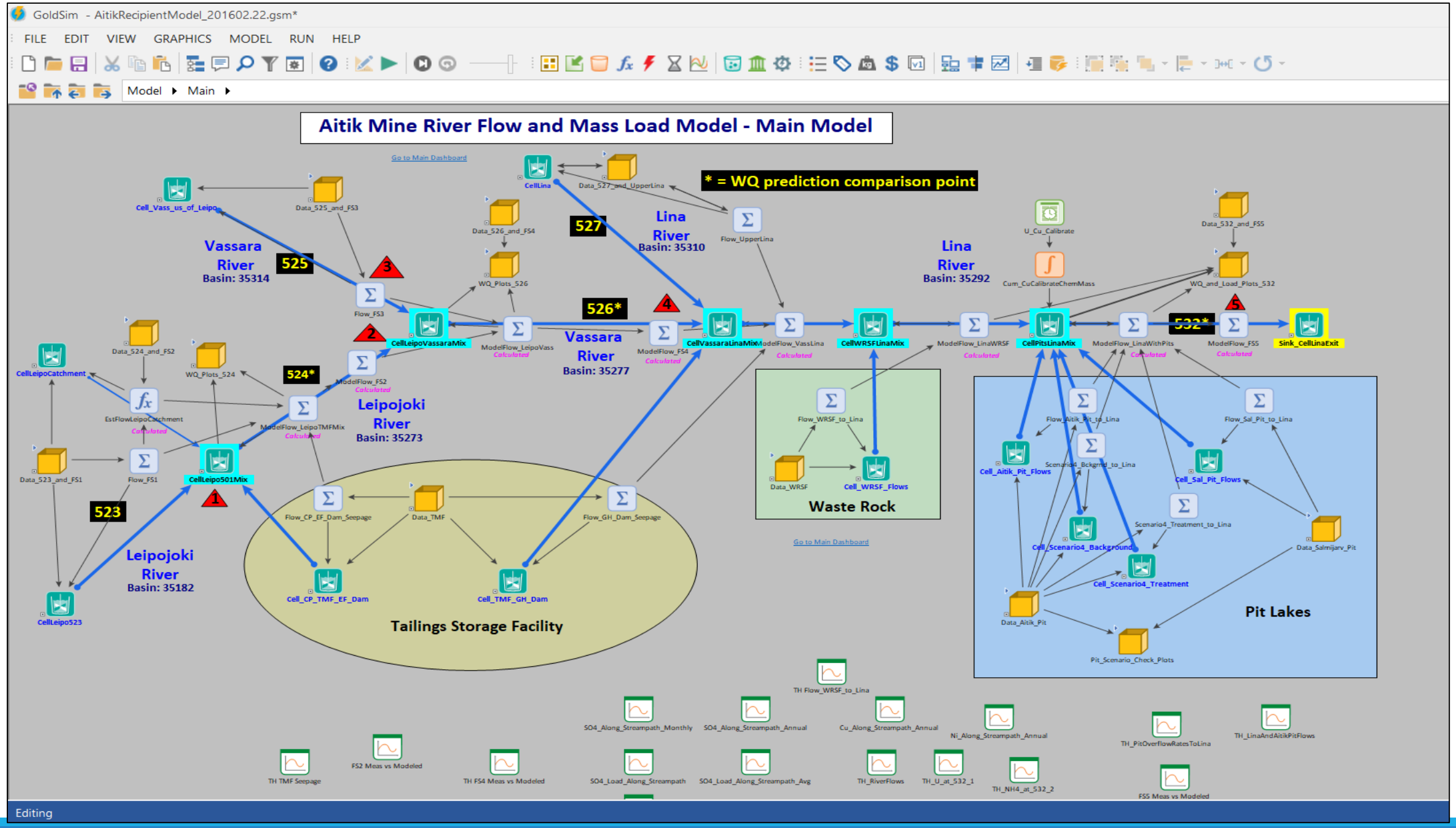
River System

- **Flow Rates**
  - Watershed modeling by SMHI including future climate change (RCP 4.5)
- **Background Water Chemistry**
  - Monthly medians of current chemistry measurements

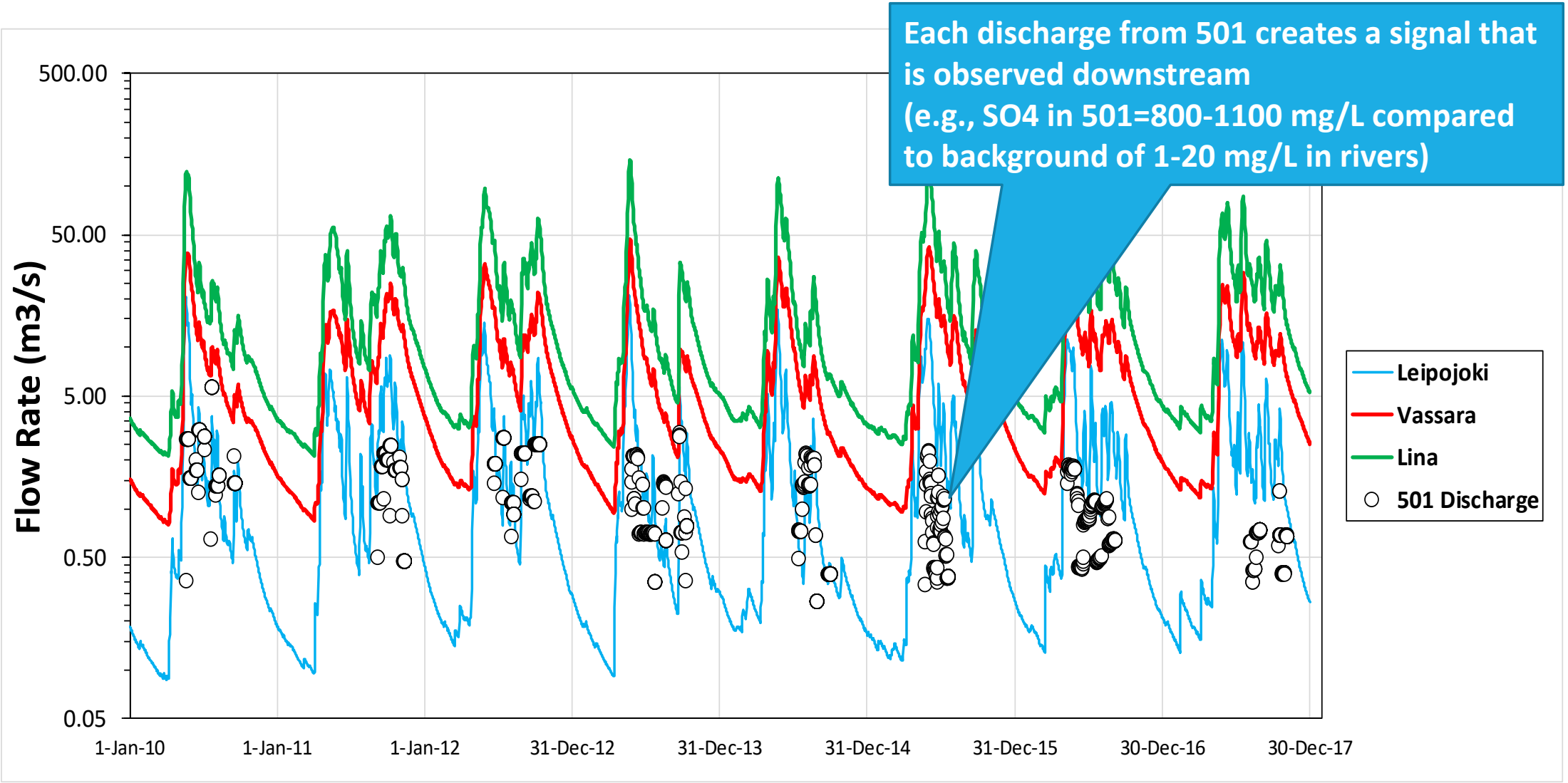
Mine Areas

- **Flow Rates**
  - Hydrologic modeling for TMF seepage (Hatch)
  - Hydrologic modeling for WRSF seepage (O'Kane)
  - Pit lake hydrologic modeling (Lorax)
    - 2080 Aitik overflows
    - 2123 Salmijärvi overflows
- **Chemistry**
  - TMF geochemical modeling (Enchemica)
  - WRSF geochemical modeling (O'Kane)
  - Pit lake limnological/geochemical modeling (Lorax)

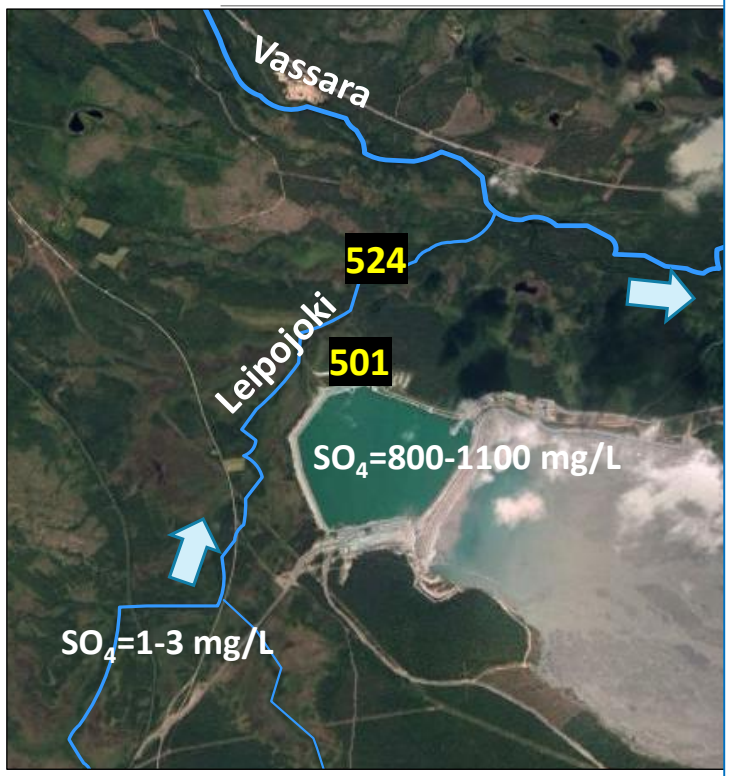


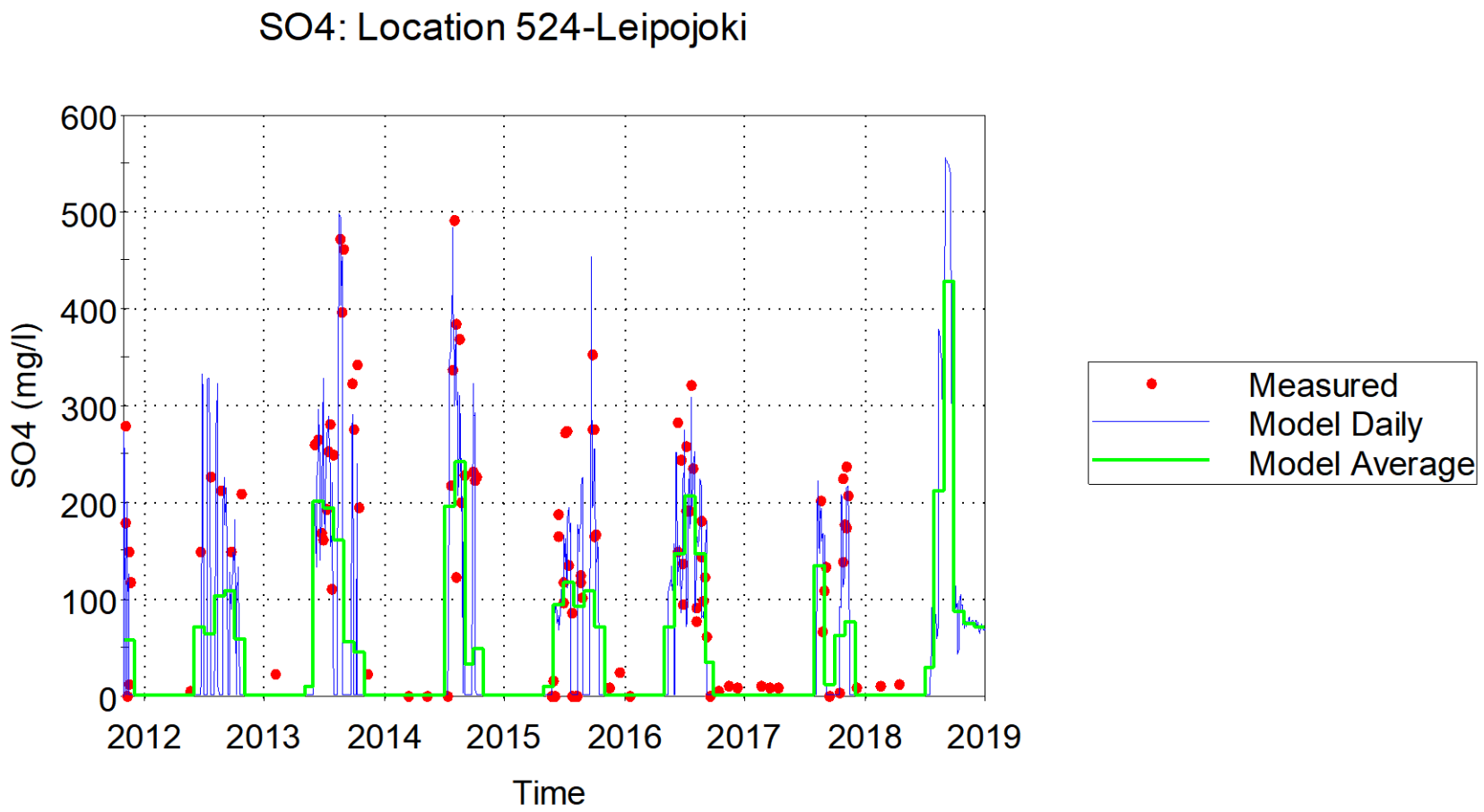

GoldSim - AitikRecipientModel_201602.22.gsm*
FILE EDIT VIEW GRAPHICS MODEL RUN HELP
Model ▸ Main ▸
Aitik Mine River Flow and Mass Load Model - Main Model
* = WQ prediction comparison point
Vassara River Basin: 35314
Lina River Basin: 35310
Lina River Basin: 35292
Vassara River Basin: 35277
Leipojoki River Basin: 35273
Leipojoki River Basin: 35182
525
527
526*
524*
523
532*
Waste Rock
Pit Lakes
Tailings Storage Facility
Editing

Comparison Period: River Flows and 501 Discharges

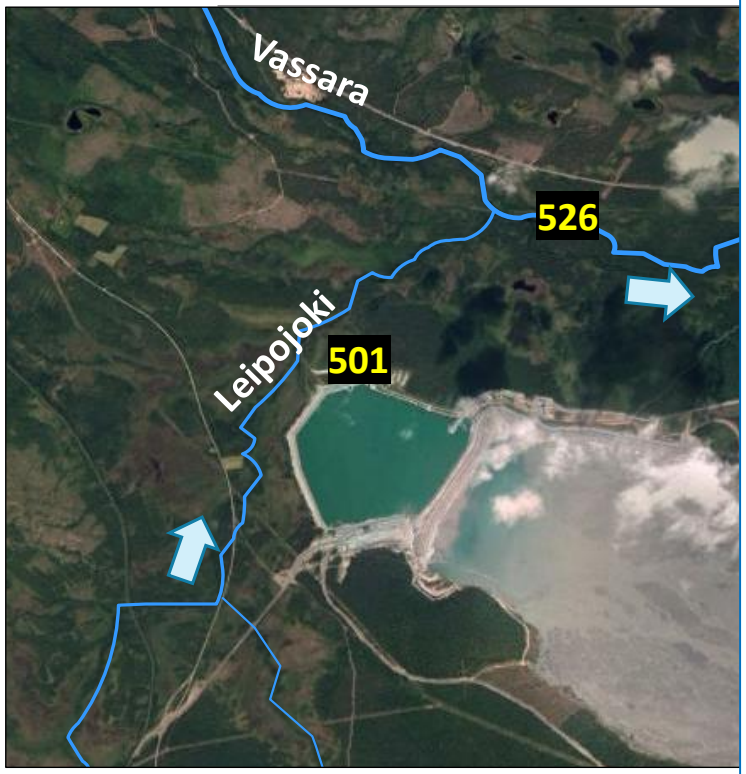


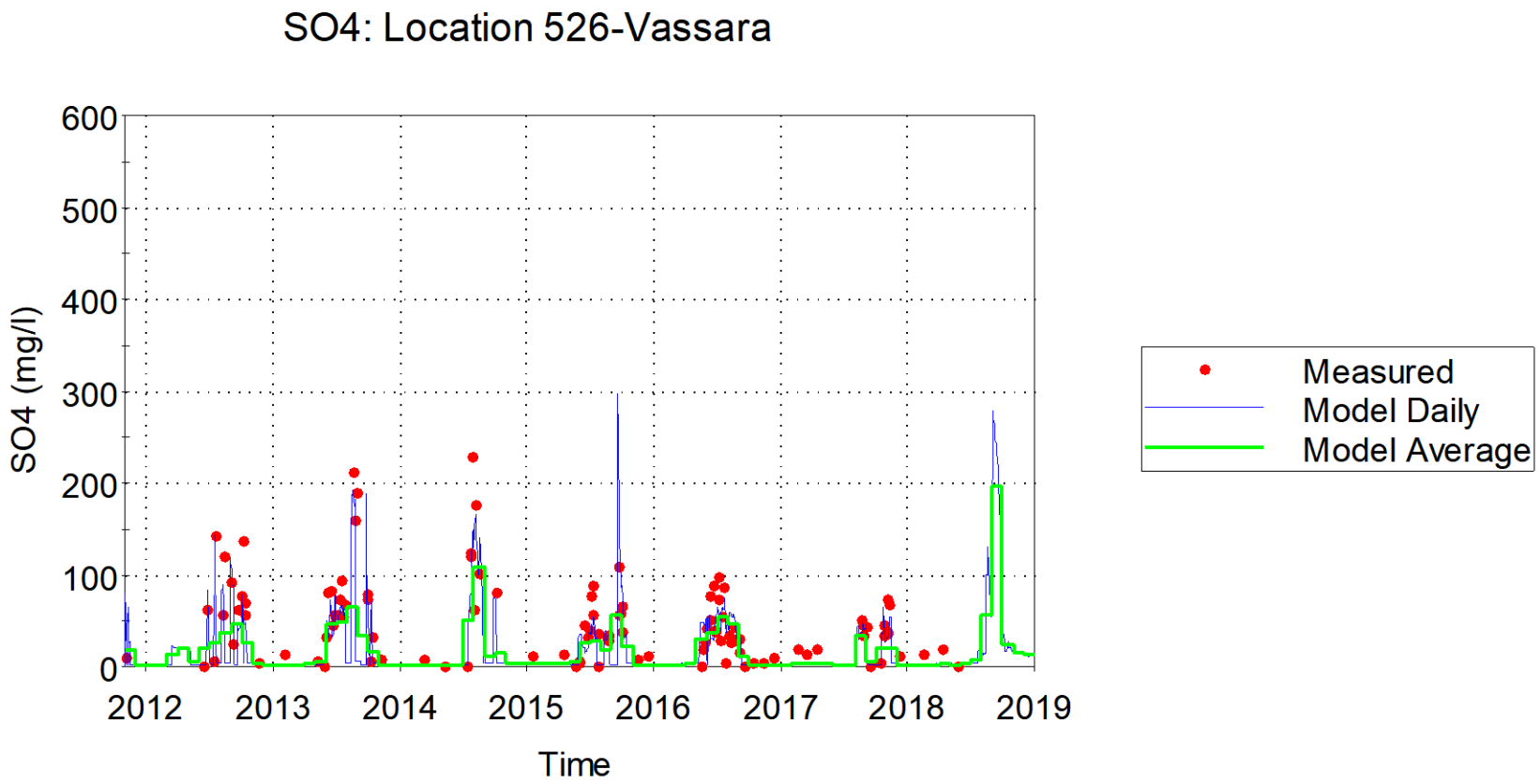
Comparison Period: Example of measured and modeled sulfate results for Location 524



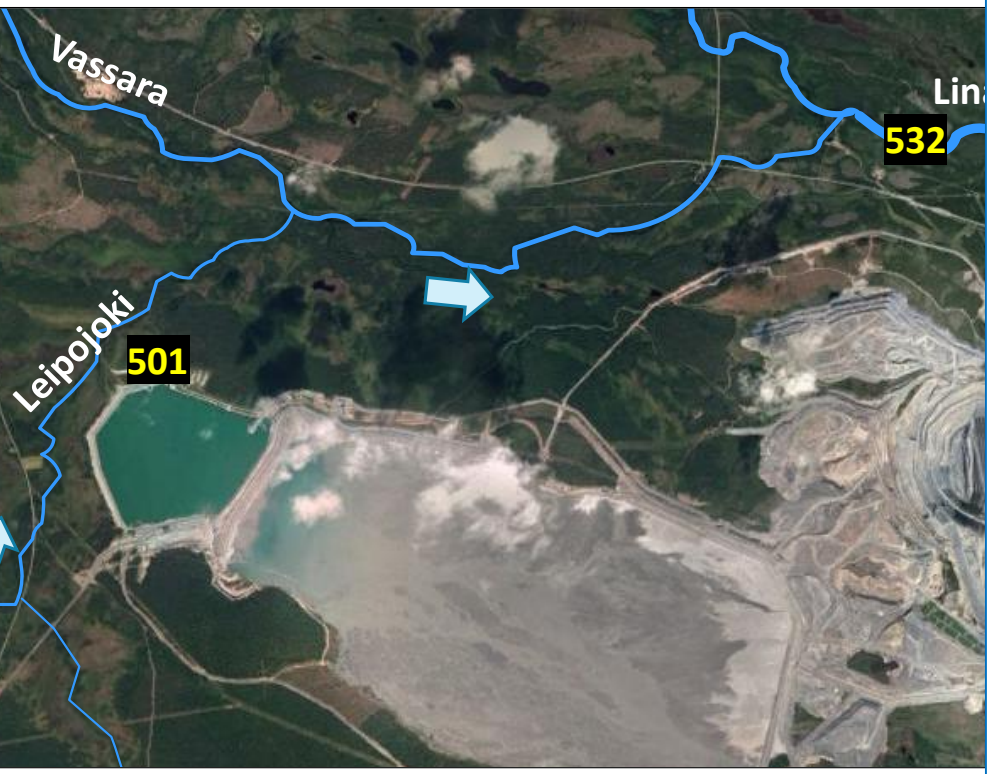


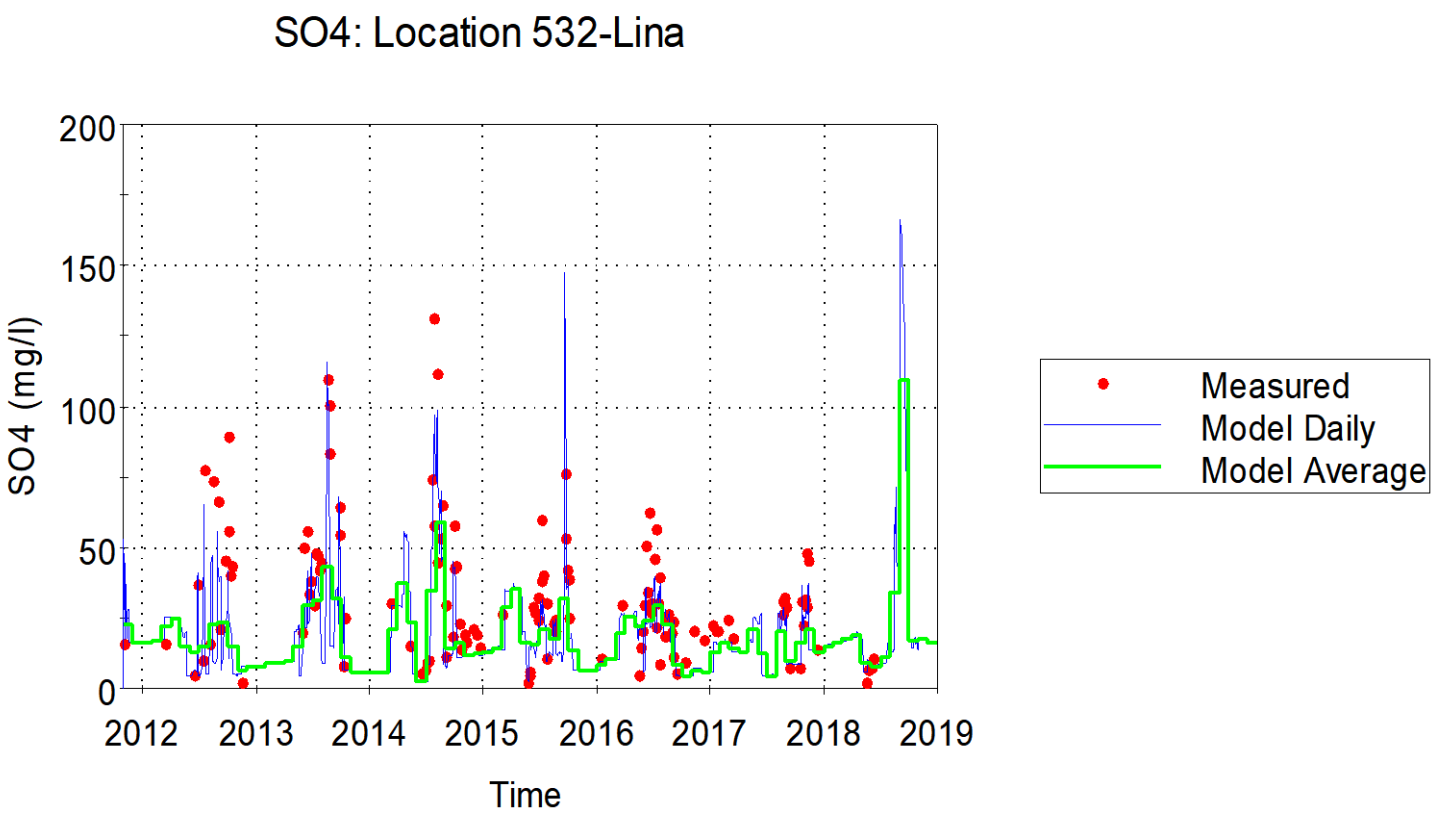
Comparison Period: Example measured and modeled sulfate results for Location 526





Comparison Period: Example of measured and modeled sulfate results for Location 532



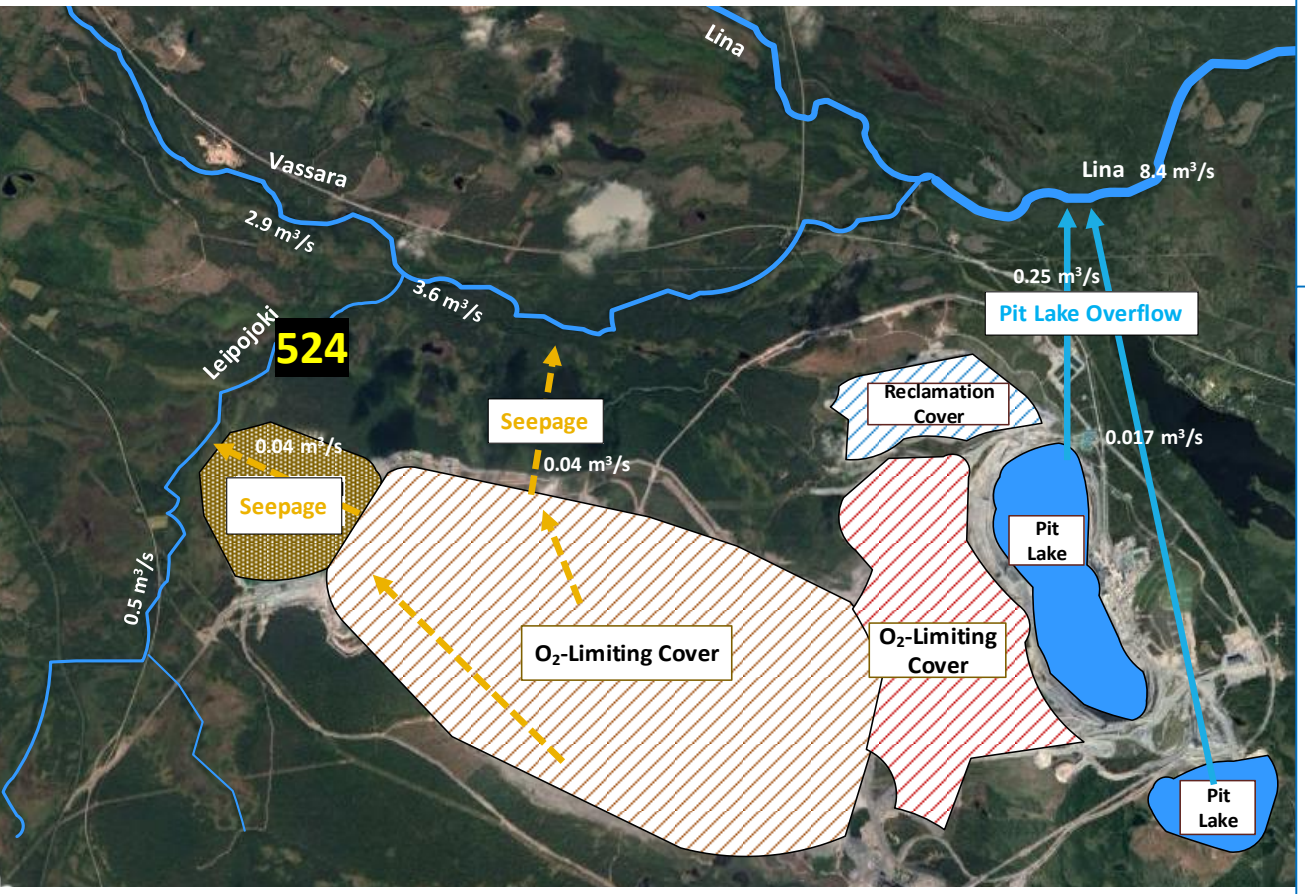


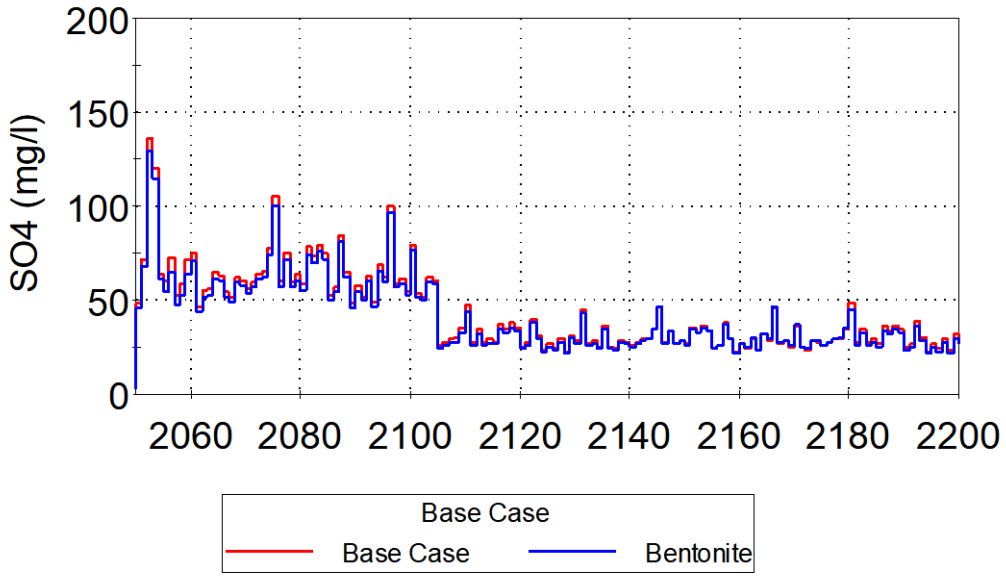
Modeling Data used for Future Predictions (2050-2200)

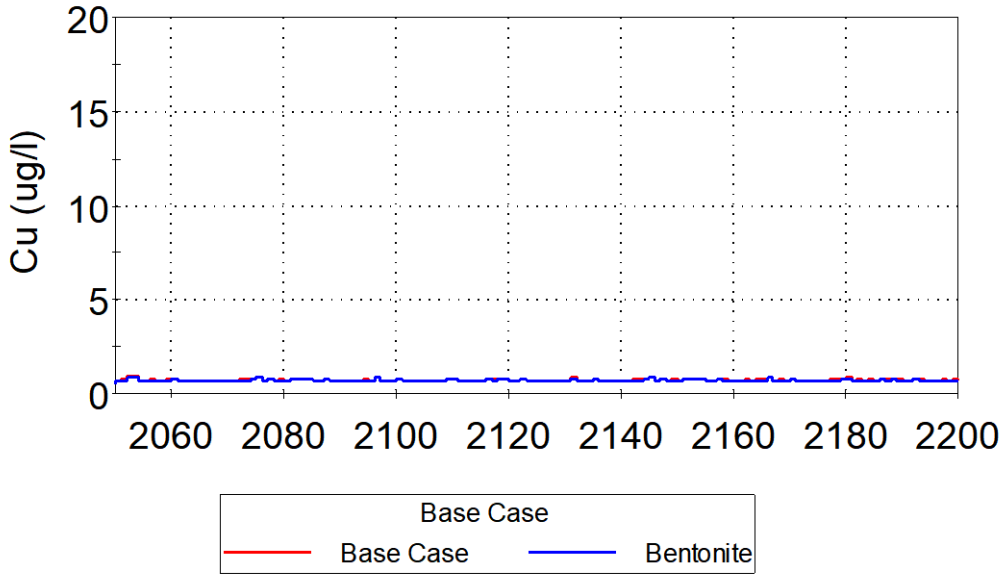
Recipient Model Inputs	Data Input Frequency
Future climate for RCP 4.5 (SMHI)	Day
Pit Lake chemistry and flow (Lorax)	Month
TMF chemistry and flow (Enchemica)	Year
WRSF chemistry and flow (OKC)	Year to multi-year
River chemistry (Boliden)	Monthly medians

Outputs: Annual average concentrations

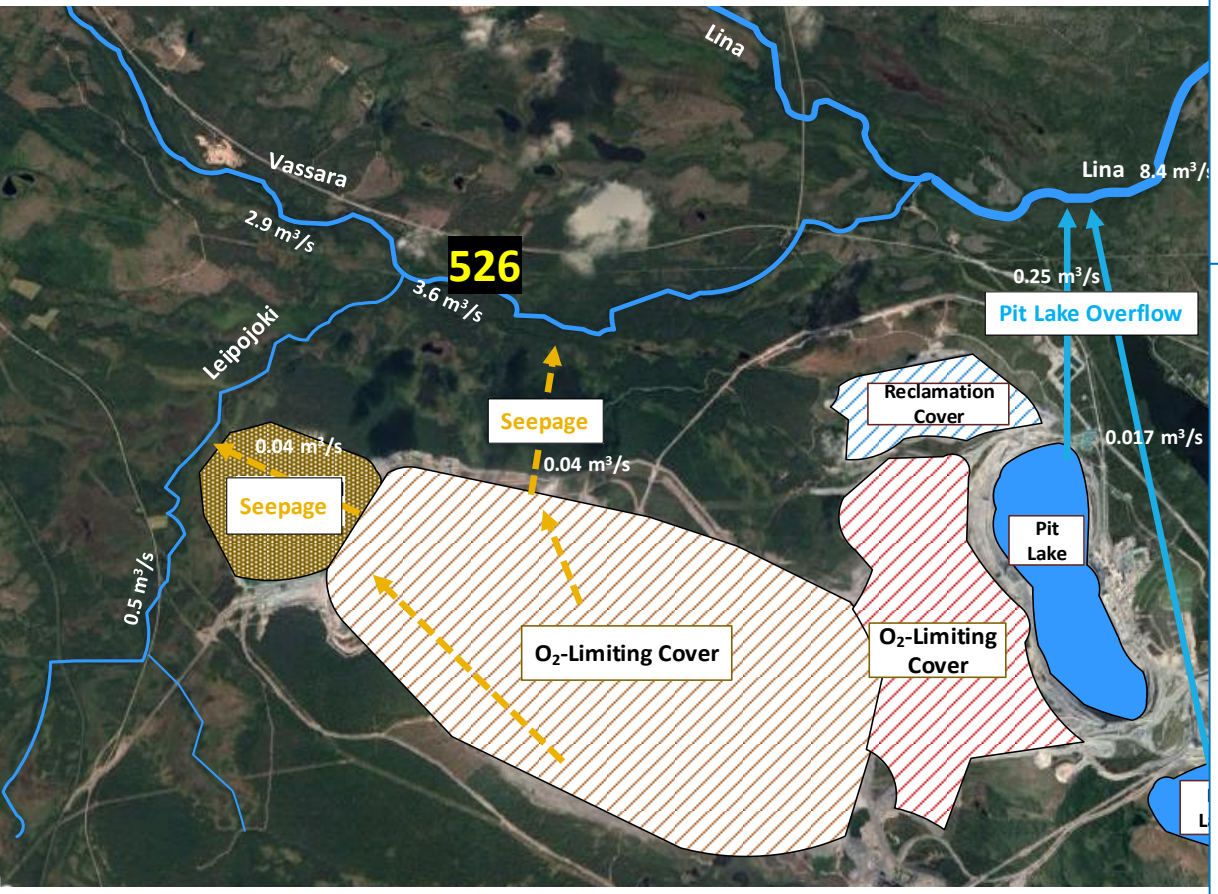
Future Prediction Period: Example results for location 524 for sulfate and copper (annual averages)

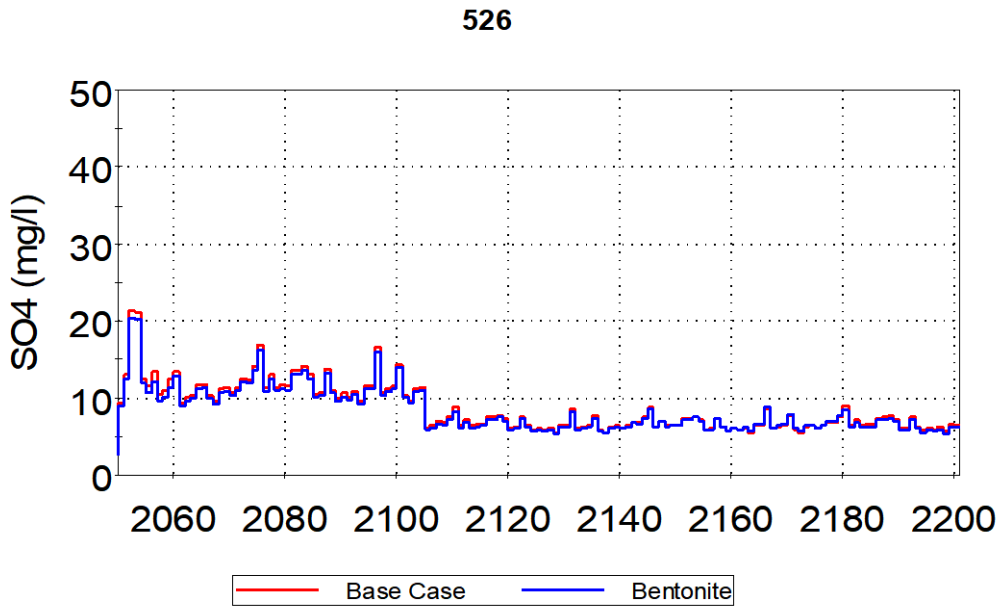


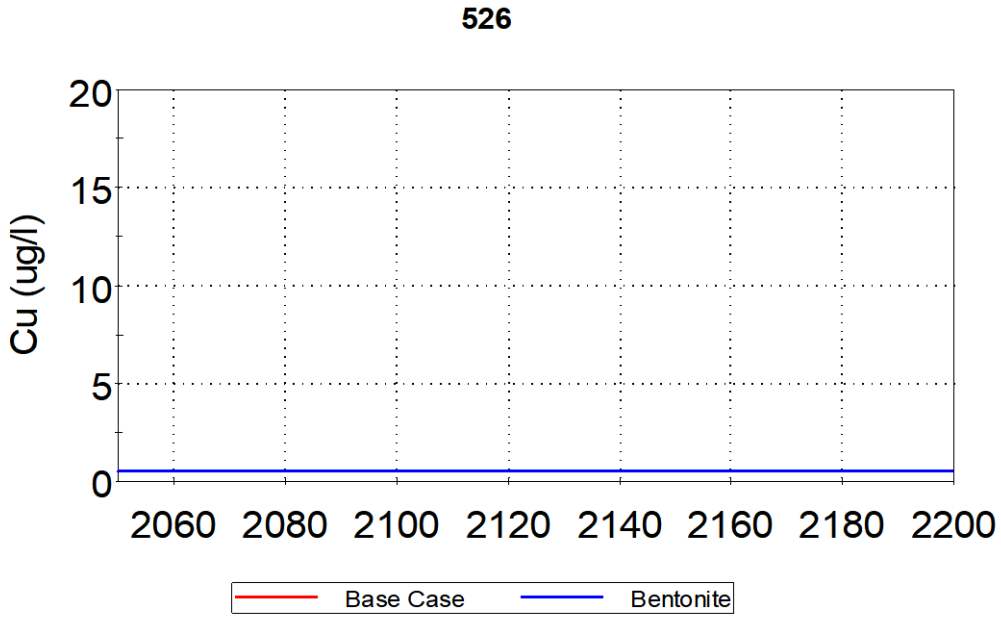




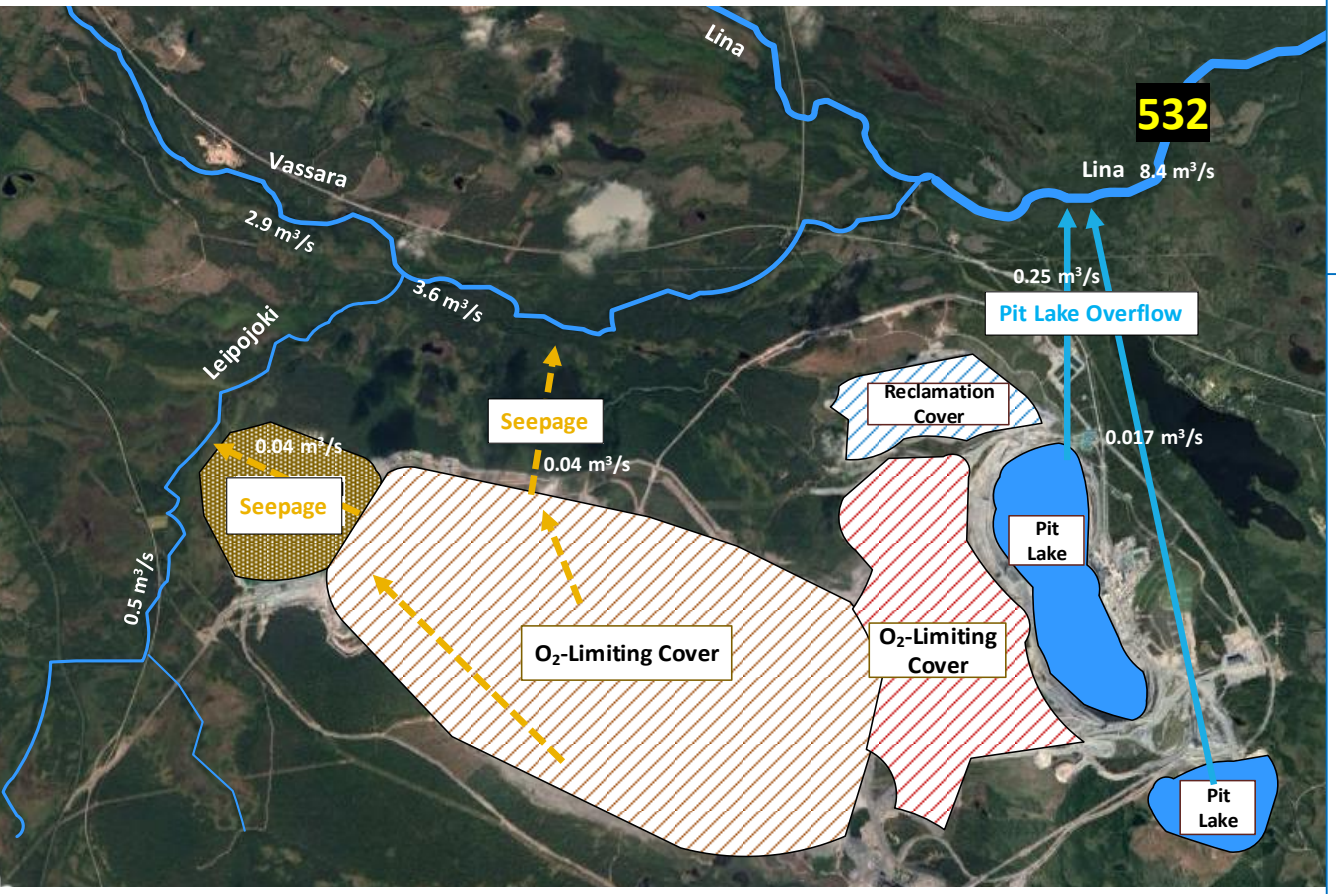
Future Prediction Period: Example results for location 526 for sulfate and copper (annual averages)

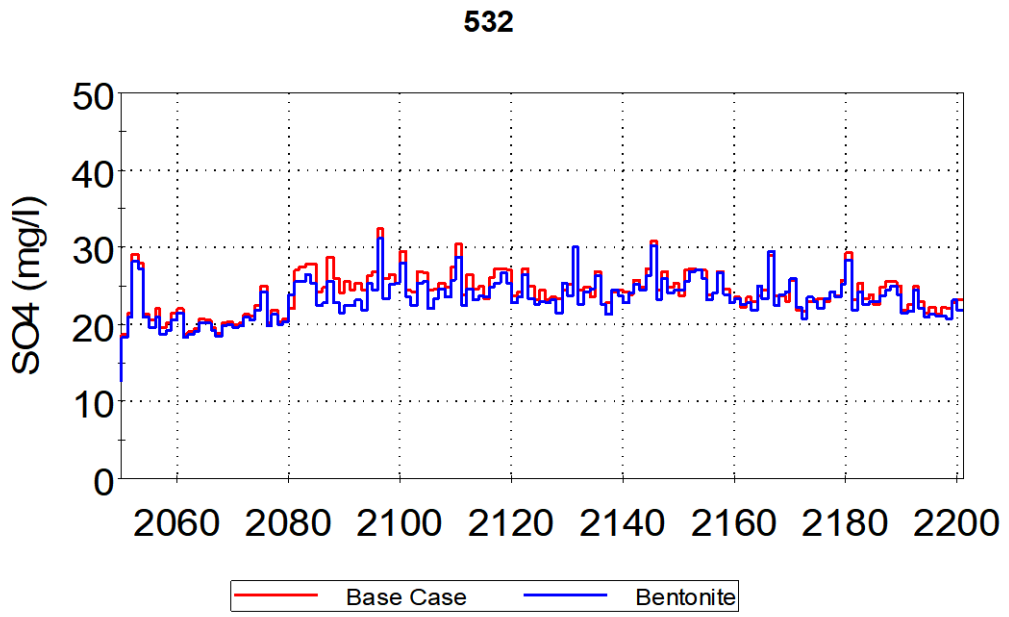


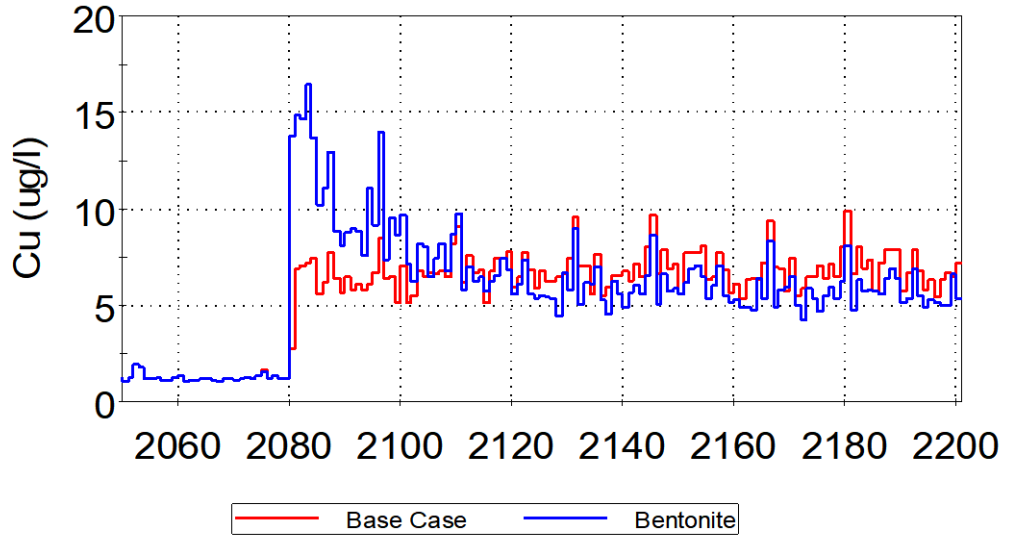




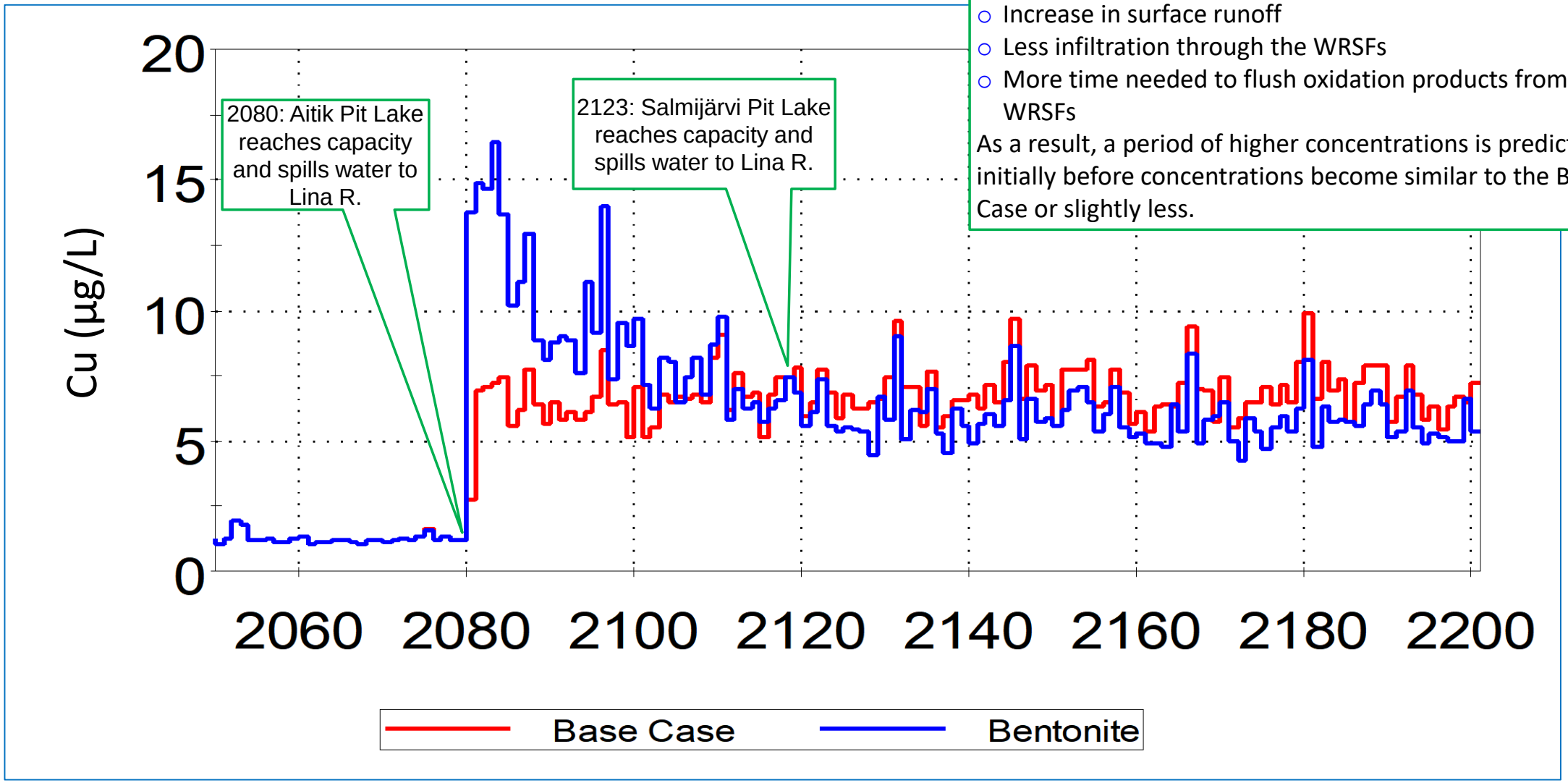
Future Prediction Period: Example results for location 532 for sulfate and copper (annual averages)







Lina River Location 532 - Copper



The Bentonite Scenario predicted to have

- Increase in surface runoff
- Less infiltration through the WRSFs
- More time needed to flush oxidation products from the WRSFs

As a result, a period of higher concentrations is predicted initially before concentrations become similar to the Base Case or slightly less.

Summary - GoldSim

- Ideal simulation platform for combining water flows and chemistry systems
  - Fast development
  - Easy to integrate data collected on different time frequencies from different types of hydrogeochemical models
  - Fast models
  - Multitude of results for different locations, times, scenarios, etc.

- Excellent tool for risk management because it integrates data from all relevant studies into a single model with consideration of:
  - Operational scenarios
  - Closure scenarios
  - Climate scenarios

Google Earth
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Thank you