Coal Mine Planning and Selenium in British Columbia

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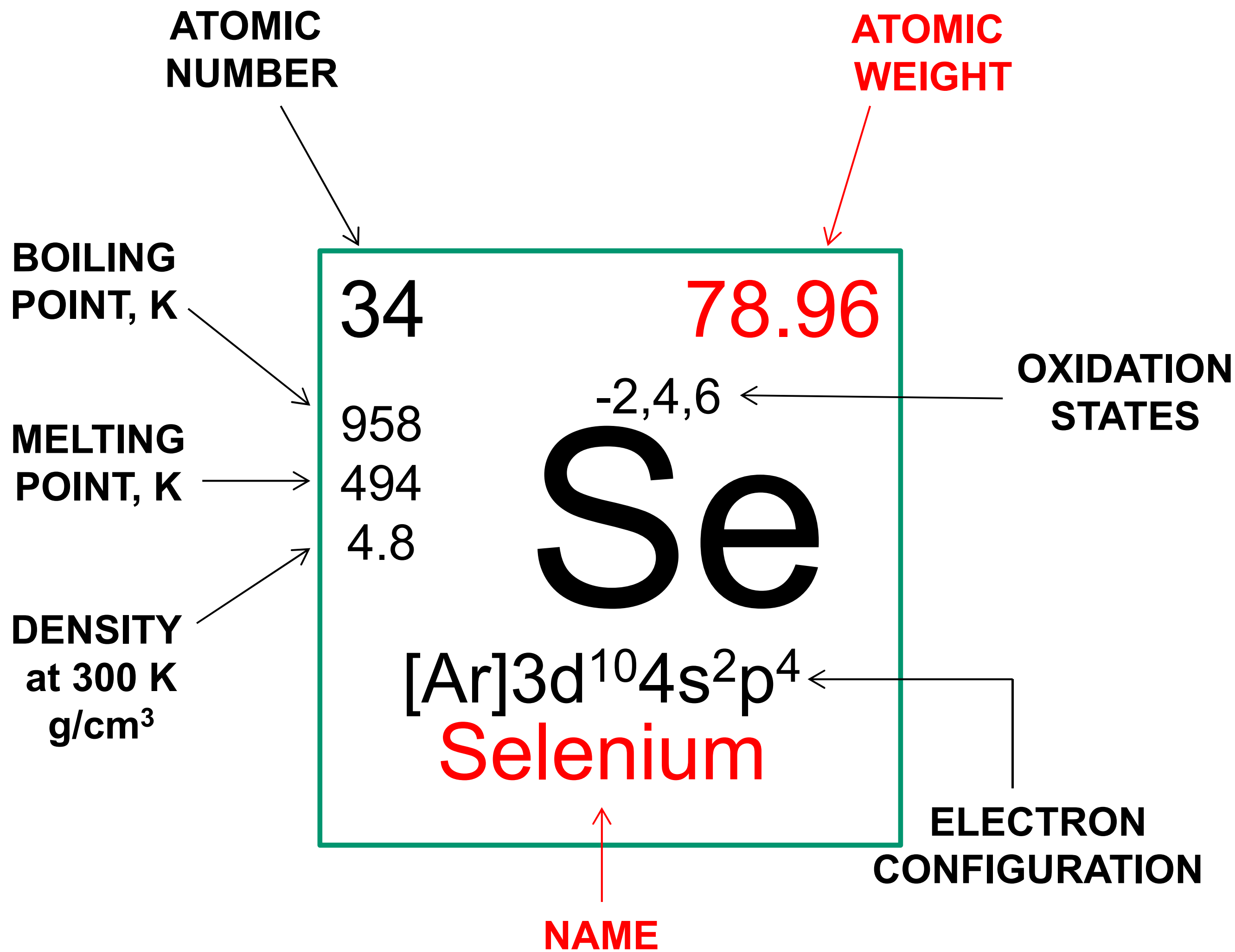
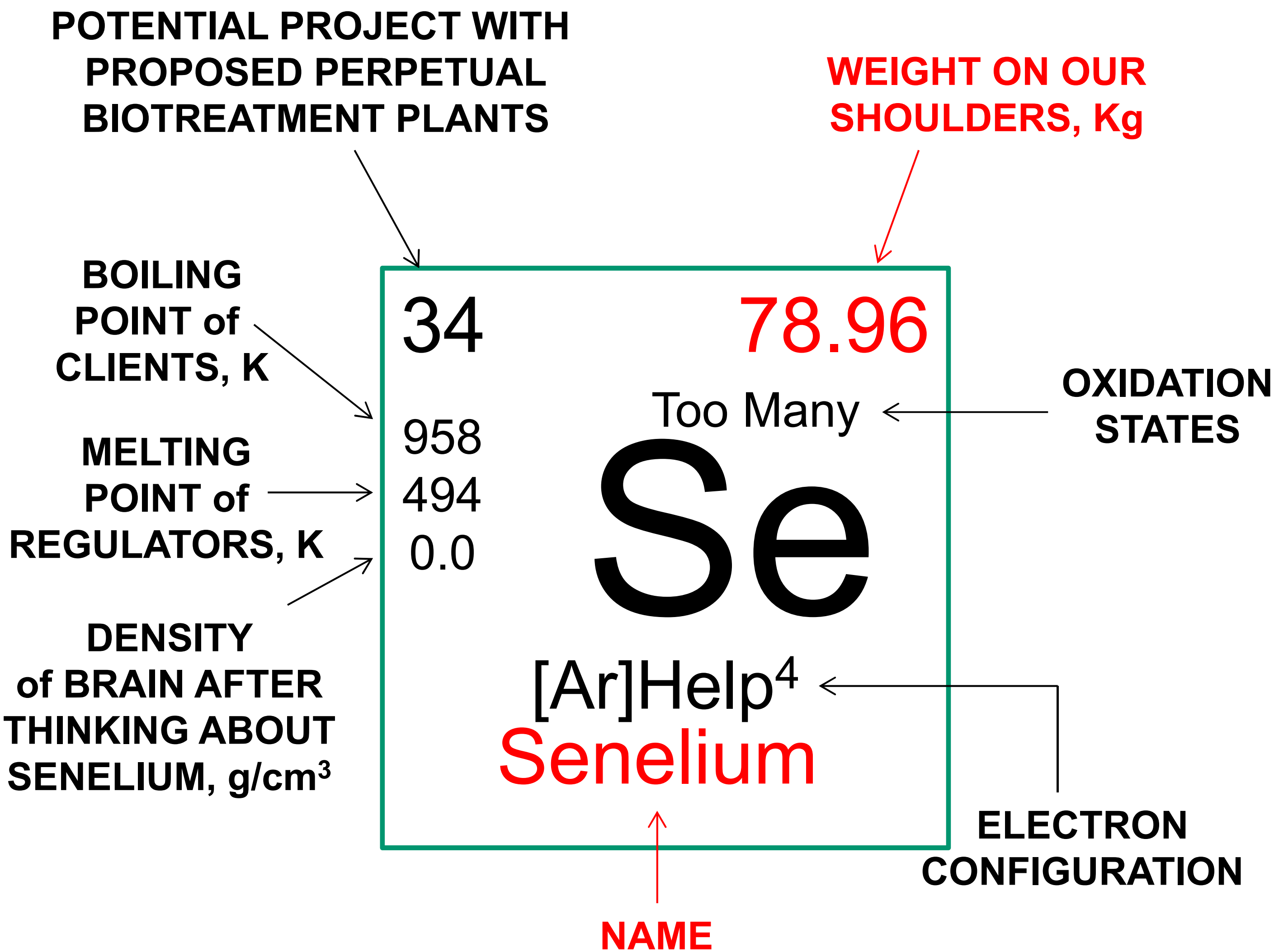

ATOMIC NUMBER
ATOMIC WEIGHT
BOILING POINT, K
34
78.96
OXIDATION STATES
-2,4,6
958
MELTING POINT, K
494
4.8
Se
DENSITY at 300 K g/cm^3
$[Ar]3d^{10}4s^2p^4$
Selenium
ELECTRON CONFIGURATION
NAME

Senelium

(səˈnē lē əm)

Noun: from Latin *senilis*,

to drive one crazy!



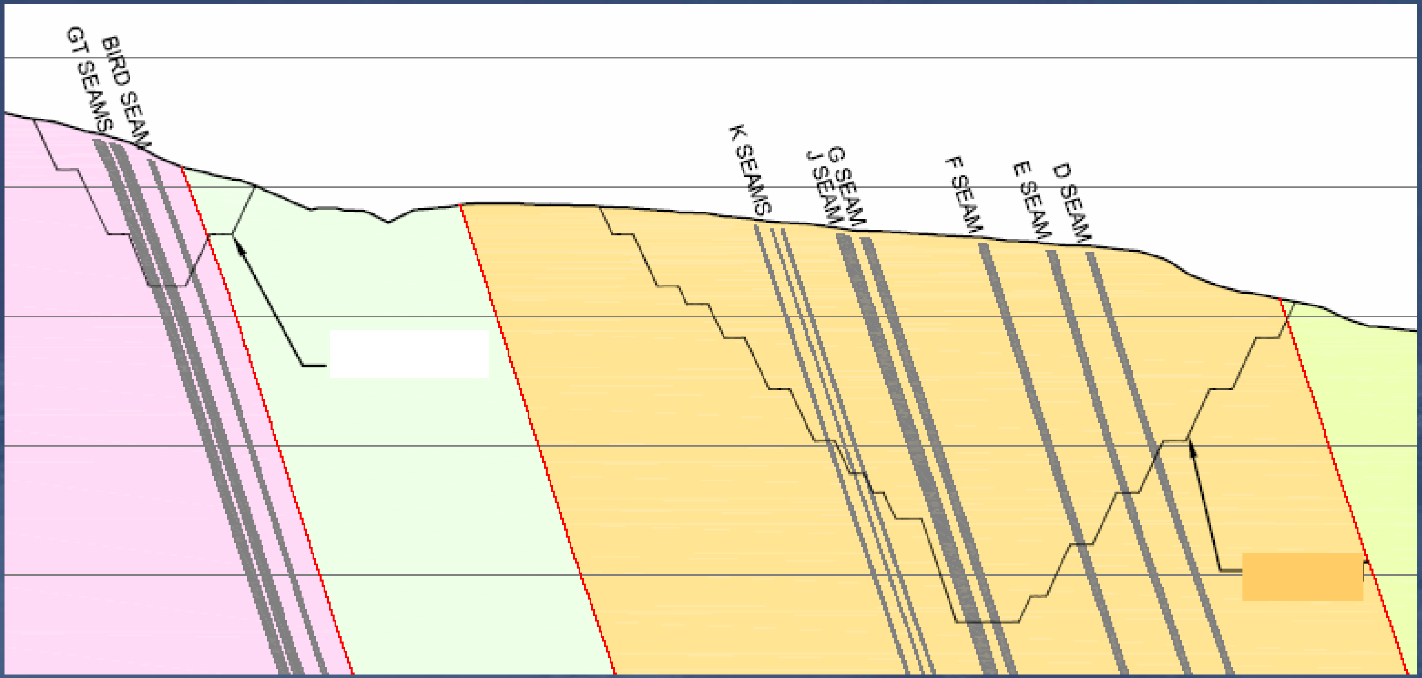
POTENTIAL PROJECT WITH PROPOSED PERPETUAL BIOTREATMENT PLANTS
WEIGHT ON OUR SHOULDERS, Kg
BOILING POINT of CLIENTS, K
MELTING POINT of REGULATORS, K
DENSITY of BRAIN AFTER THINKING ABOUT SENELIUM, g/cm3
OXIDATION STATES
ELECTRON CONFIGURATION
NAME
34
78.96
958
494
0.0
Too Many
Se
[Ar]Help4
Senelium

Outline

- BC coal
- Project effects on selenium water quality
- Mitigation
- Water treatment
- Considerations for mine planning

BC Coal

- Most coal mined in NE and SE BC is metallurgical coal
- BC is well known its high quality steel making met coal



Mine Effects on Selenium

- Primary driver for effects on selenium is from unsaturated spoils
- Loadings from exposed, open pit walls are typically much lower than spoils
- Saturated spoils and coal refuse (tailings and CCR) Se loadings are typically negligible

Mine Effects on Selenium

- Snowmelt driven hydrograph – highly variable flow

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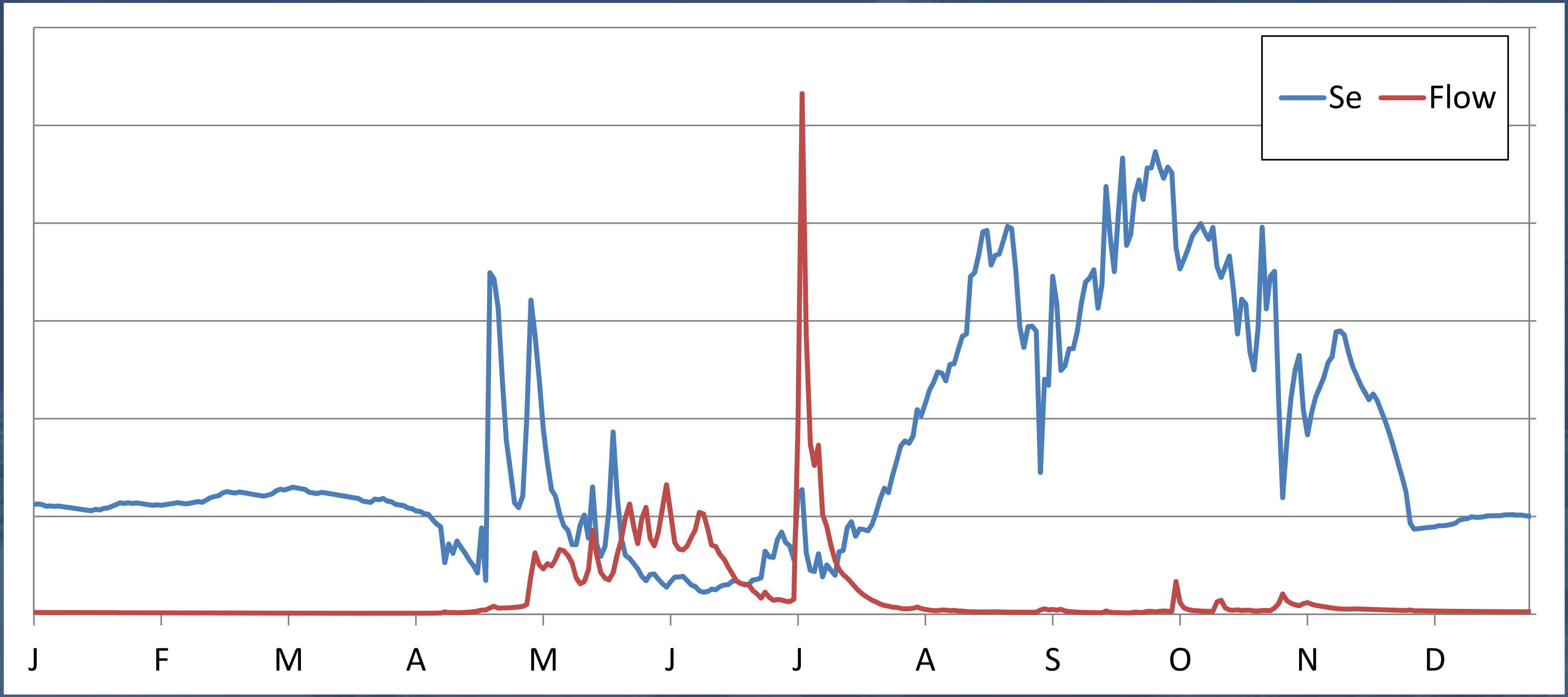
Mine Effects on Selenium

- Spoil Se signature typically inverse to flow



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Mine Effects on Selenium

- Bypass considerations
- Surface water management infrastructure typically designed to manage flow and TSS
- Should also consider leakage and long-term storage (closure)

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Mitigation Options
Diversions and storage

- Diversion of contact waters away from sensitive habitat or low flow drainages
- Strategic release during higher flow or to larger water bodies
- Discharges must be managed to avoid sensitive (lentic) habitat
  - Initial dilution zone regulations apply to fish bearing waters
- Flow reductions must be evaluated to determine serious harm (new DFO regulation supplants HADD)
  - Evaluating and determining serious harm is more complex
    - Decision-making uncertainty
  - Compensation should be considered in mitigation options

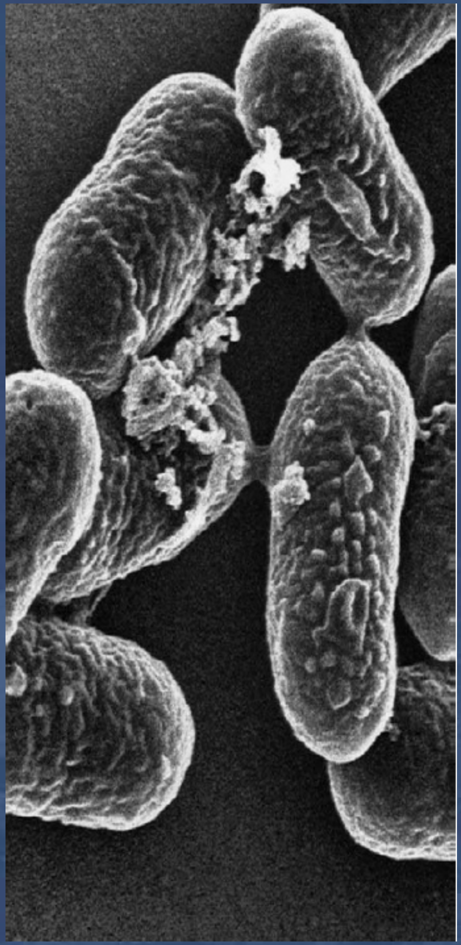
Mitigation Options
Attenuation by design

- Flooded pits
- Saturated backfill
- Permeable reactive barriers
- Engineered wetlands

- Design considerations:
    - residence time and flow rate;
    - nitrate and selenium removal rates

Mitigation Options Attenuation by design

- Selenium bioremediation is microbially mediated.
- Selenium speciation and removal strongly dependent on redox conditions.
- Suboxia is required for effective removal.



Mitigation Options
Attenuation by design

- Selenium attenuation is inhibited by nitrate

Decreasing Redox Potential

1. Oxygen (O_2) Consumption:

$$\boldsymbol{O_2} + 4H^+ + 4e^- \rightarrow 2H_2O$$

2. Nitrate (NO_3^-) Reduction (Denitrification)

$$2\boldsymbol{NO_3^-} + 12H^+ + 10e^- \rightarrow N_2 + 6H_2O$$

3. Selenate (SeO_4^{2-}) Reduction:

$$\boldsymbol{SeO_4^{2-}} + 3H^+ + 2e^- \rightarrow \boldsymbol{HSeO_3^-} + H_2O$$

4. Manganese Oxide (MnO_2) Reduction:

$$MnO_2(s) + 4H^+ + 2e^- \rightarrow \boldsymbol{Mn^{2+}} + 2H_2O$$

5. Fe Oxide (FeOOH) Reduction:

$$FeOOH(s) + 3H^+ + e^- \rightarrow \boldsymbol{Fe^{2+}} + 2H_2O$$

6. Sulfate (SO_4^{2-}) Reduction:

$$\boldsymbol{SO_4^{2-}} + 9H^+ + 8e^- \rightarrow \boldsymbol{HS^-} + 4H_2O$$

Increasing Free Energy Yield

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Mitigation Options
Flooded pits

- Flooded pits are facilities that commonly exist in mine environments following surface development.
- Large repositories of mine-influenced waters.
- Tendency for water column stratification and development of suboxic bottom waters.

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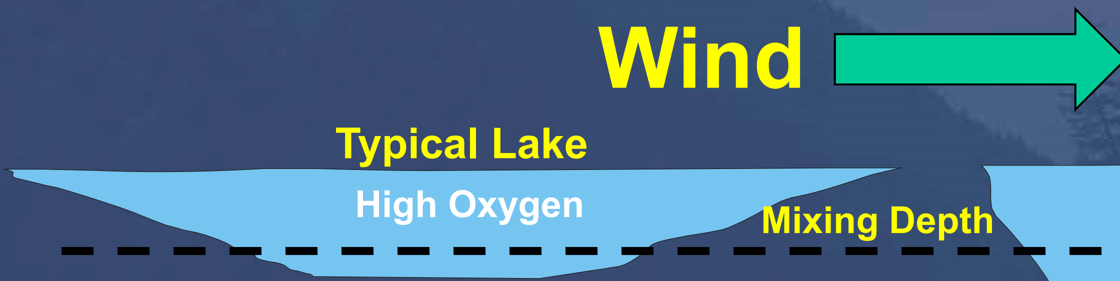
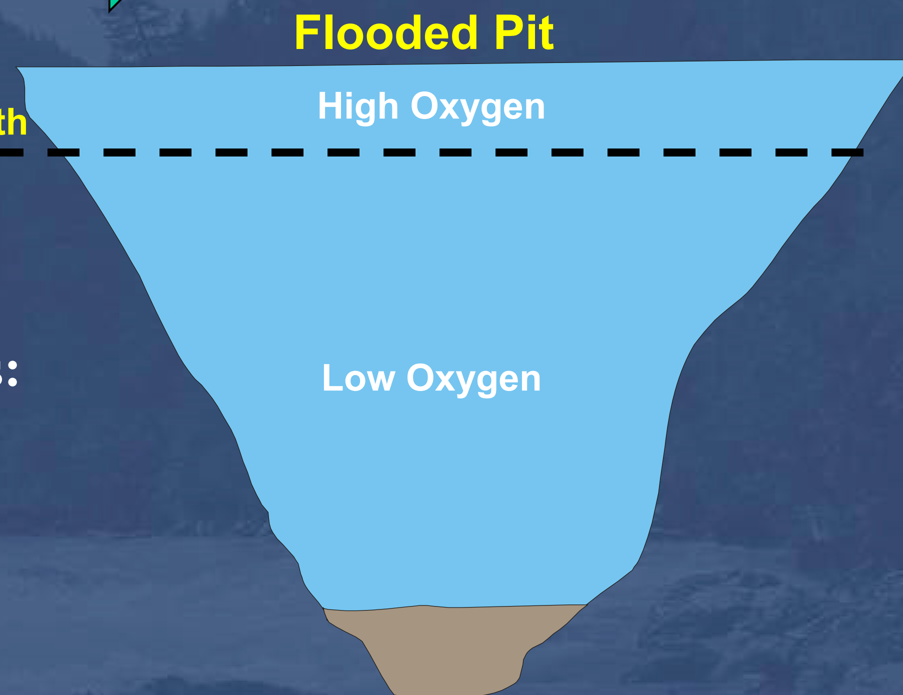
Mitigation Options
Flooded pits





Vertical mixing is restricted in flooded pits:

- deep water column
- short fetch
- topographic sheltering (pit walls)

- Tendency for seasonal and/or permanent stratification
- Natural tendency to develop suboxic bottom waters

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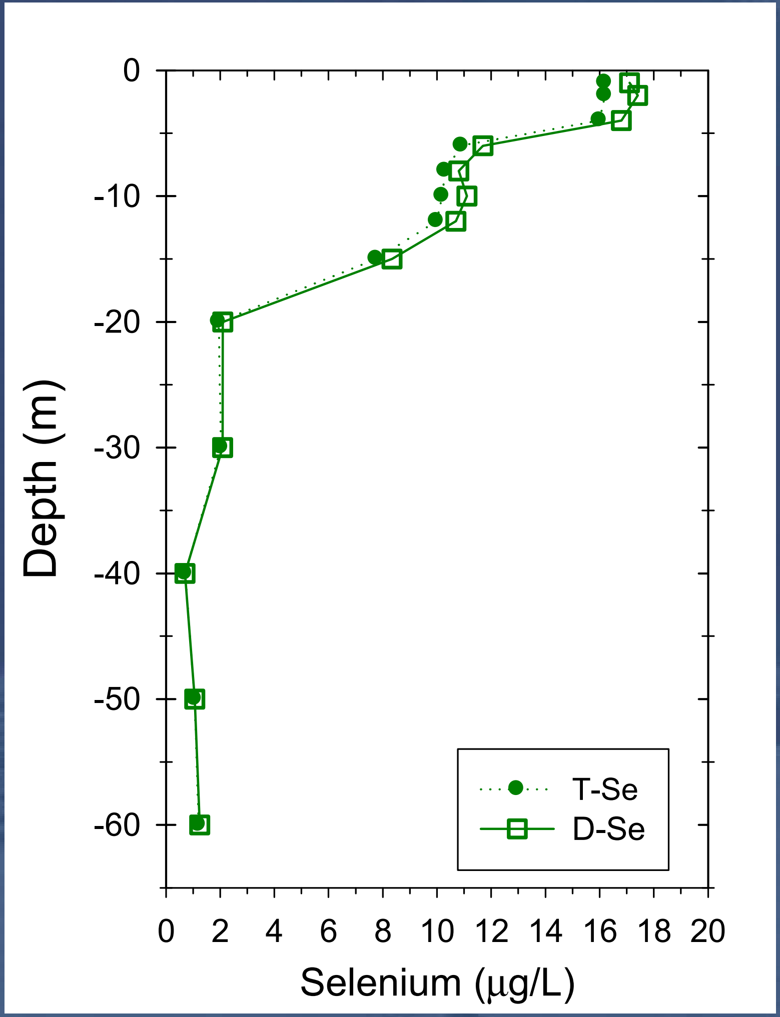
Mitigation Options
Flooded pits



Expected Se removal mechanisms:

- Dissimilatory reduction of Se oxyanions and precipitation as elemental Se [Se(0)].
- Reduction of selenate [Se(VI)] to selenite [Se(IV)] and adsorption of selenite to particles.

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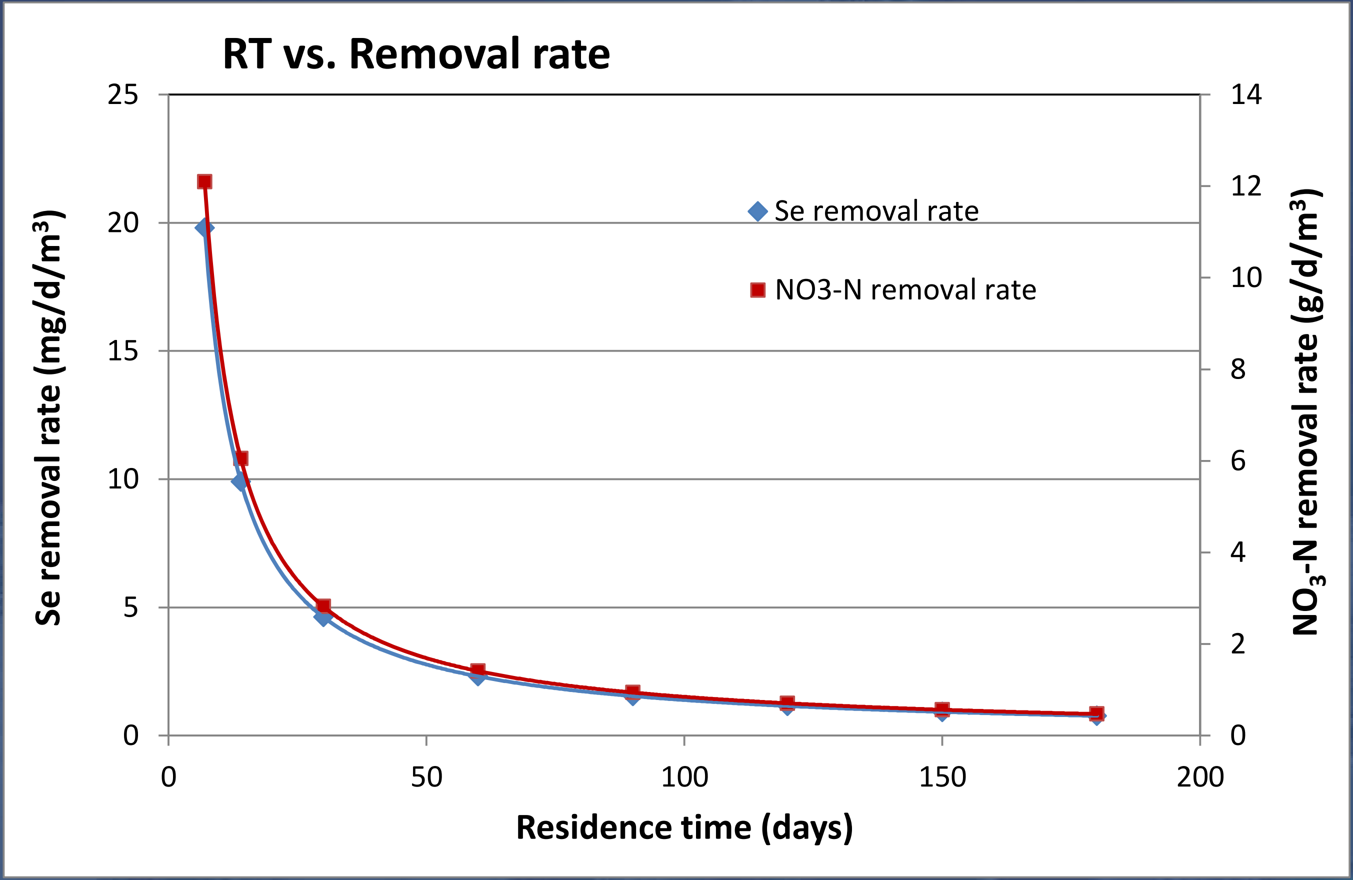
Mitigation Options
Saturated backfilled pit

- Design considerations
- Flow rate, removal rates, and residence time



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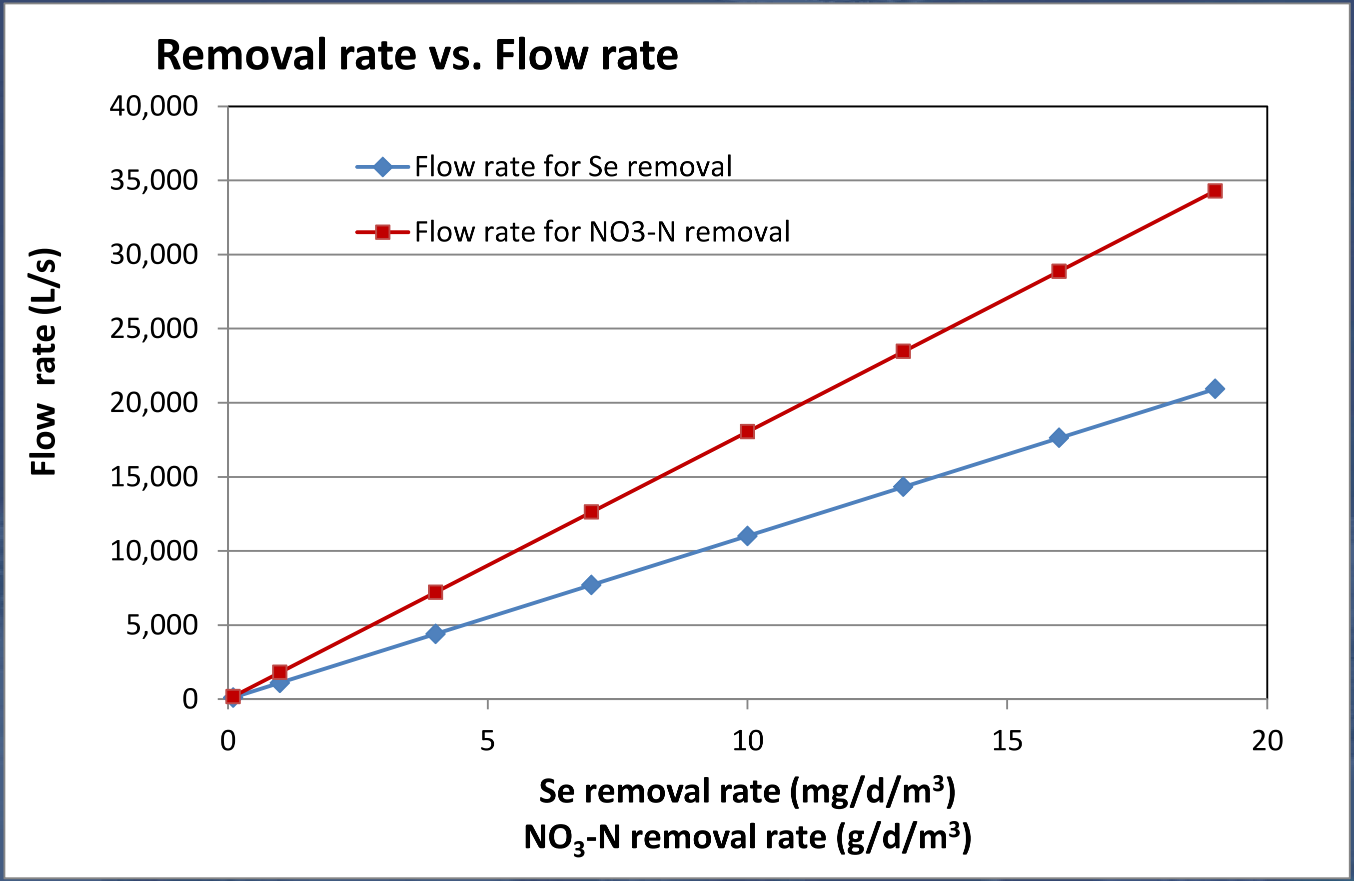
Mitigation Options
Saturated backfilled pit

- Increasing removal rates = higher treatment flow rates
- Nitrate removal considerations



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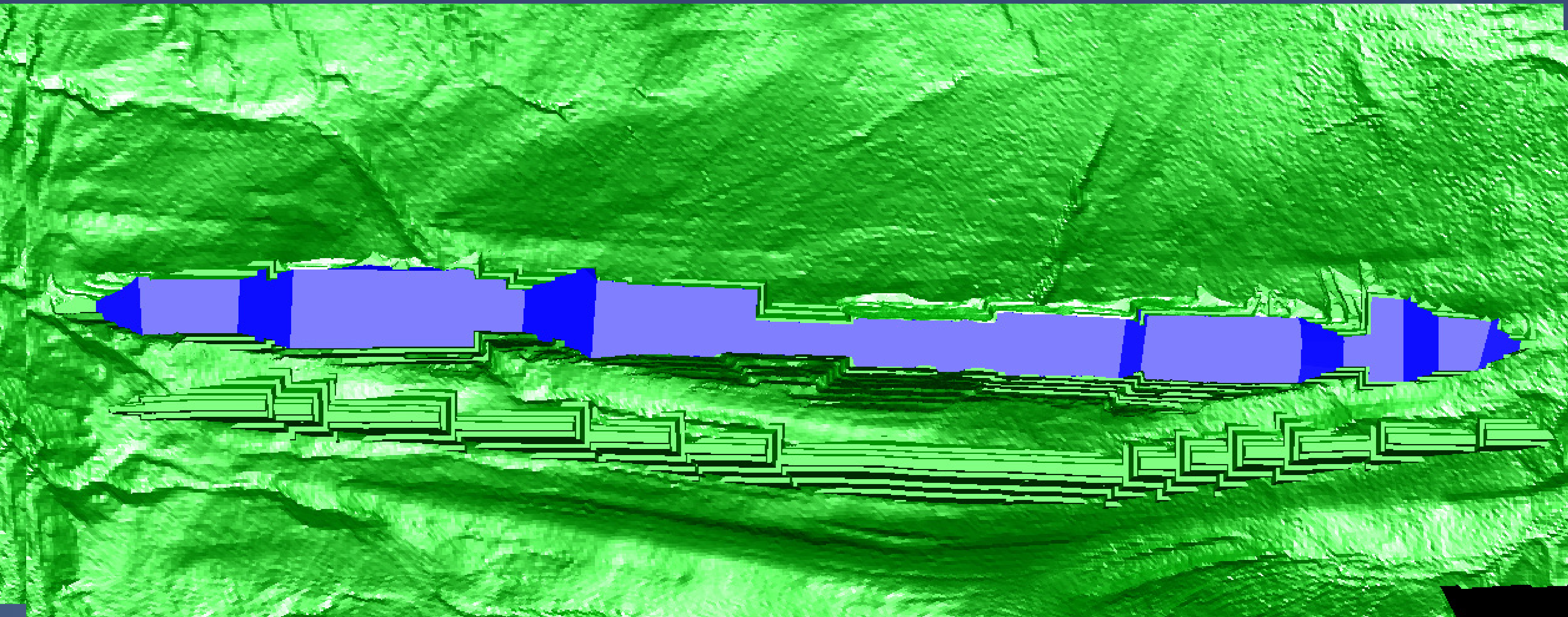
Mitigation Options
Flooded pits

- Flooded pits can be used as passive remediation cells
- Increased capacity results in increased RT and treatment potential



Mitigation Options
Flooded pits

- Flooded pits offer potential to treat large volumes of water at relatively low cost.
- Semi-passive attenuation and water management considerations:
  - Residence time, oxygen demand and nitrate/selenium removal rates.
  - Conveyance of contact flows to pit.
  - Withdrawal of treated water from pit.
  - Polishing prior to discharge to environment.

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Mitigation Options
Flooded pits

Flooded pits are well suited for bioremediation

- Typically ultra-oligotrophic
- Respond well to nutrient amendments
- Natural algal communities (Inoculation not required)
- Low cost and easy to implement
- Seasonality of primary production

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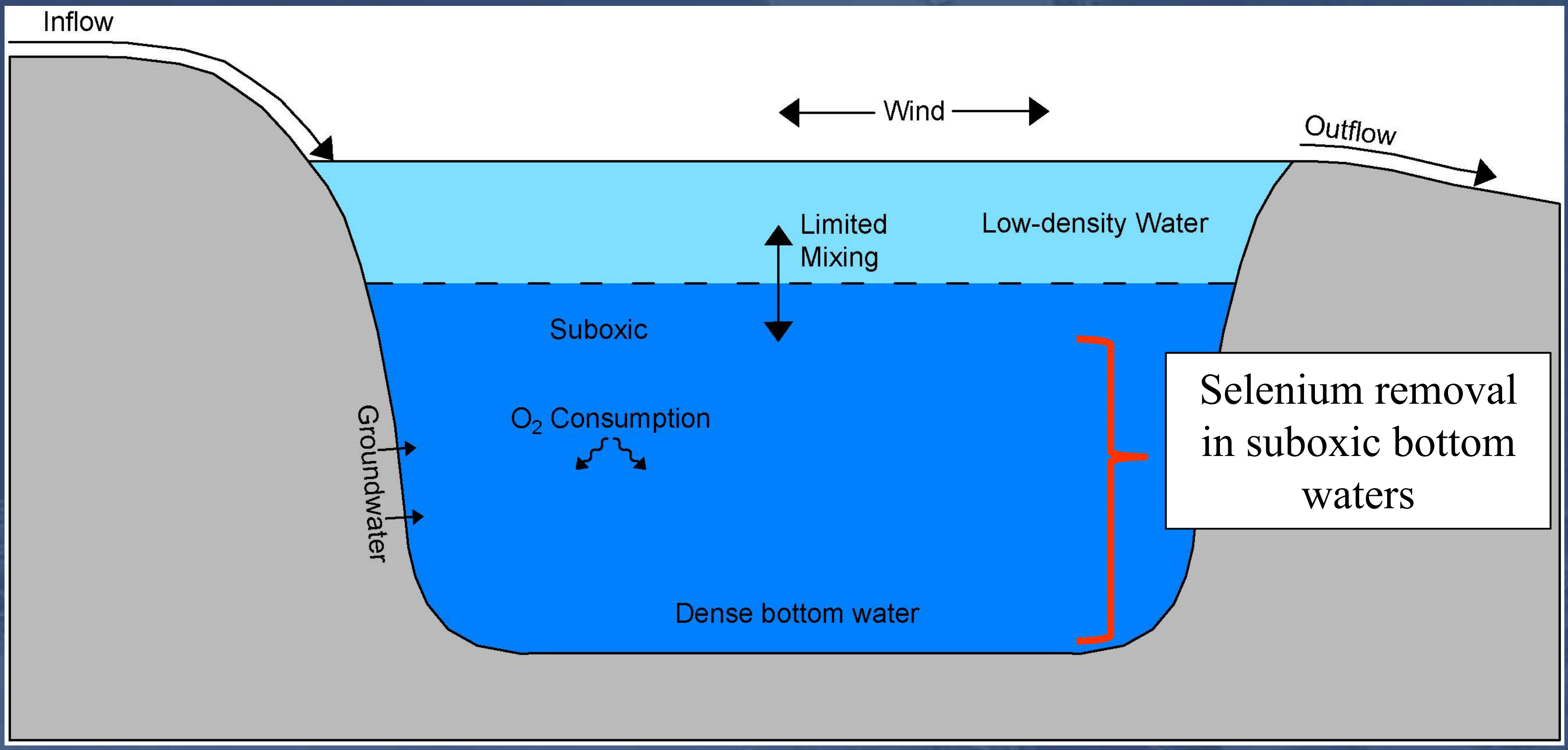
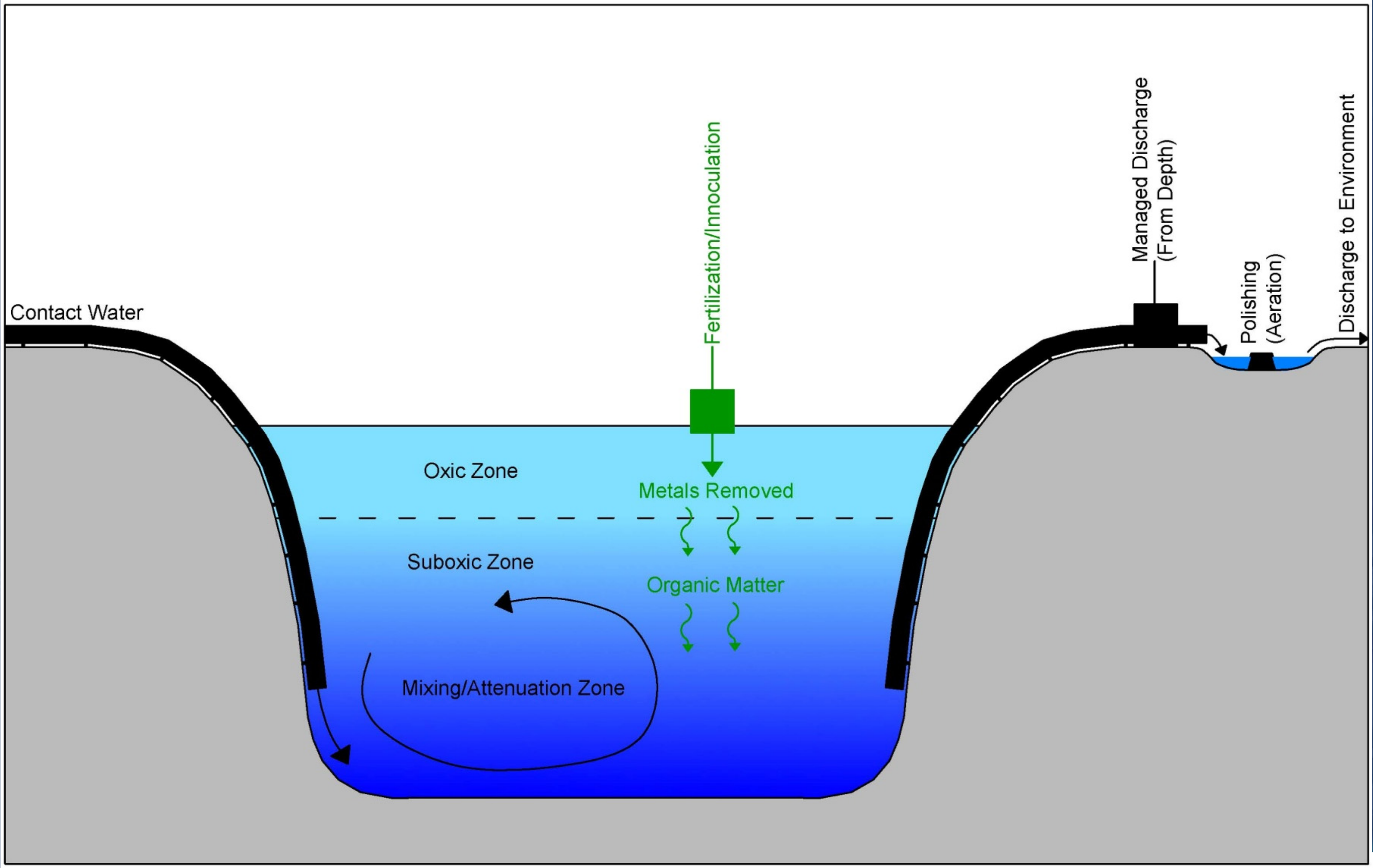
Mitigation Options
Flooded pits

Conceptual model for Se attenuation



Mitigation Options
Flooded pits

Mine water management – semi-passive treatment



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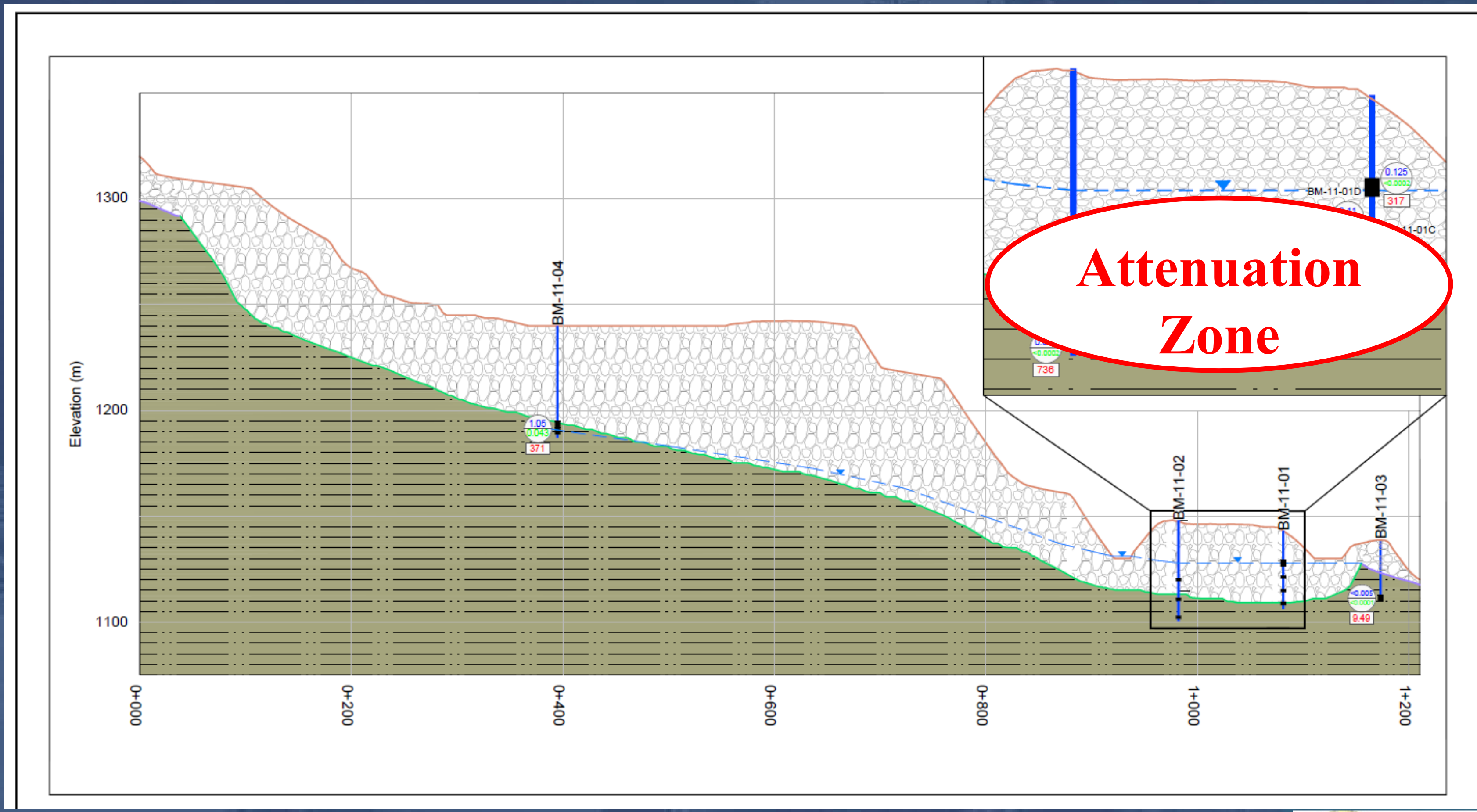
Mitigation Options
Saturated backfilled pit

- Saturated backfill may be designed and managed to treat contact water for Se and nitrate removal



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Mitigation Options
Attenuation in pits

Maximize saturated storage volumes

- Mine planning (pit morphometry and timing)
- In-pit berms
- Mine waste management – saturated backfill
- Water management

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Mitigation
Water Treatment

- Biotreatment
  - Nitrate and nitrate are reduced to nitrogen gas
  - Selenate and selenite are reduced to particulate elemental selenium
  - Nitrate inhibits selenium bioreduction
  - Biotreatment plants must be designed for denitrification

Mitigation
Water Treatment

- Biotreatment
  - Complicating factors include:
    - Storage and water management
    - Temperature – influent may require heating
    - Highly variable influent (Se, nitrate, TSS)
  - Potential effects from biotreatment effluent
    - Temperature
    - Ammonia
    - Phosphorous
    - TSS
    - BOD and dissolved oxygen

Mitigation
Water Treatment

- Biotreatment has been demonstrated at numerous industrial facilities
- Limited application in natural settings typical of BC coal mines
- Two facilities currently under construction in BC, scheduled to be commissioned in 2014

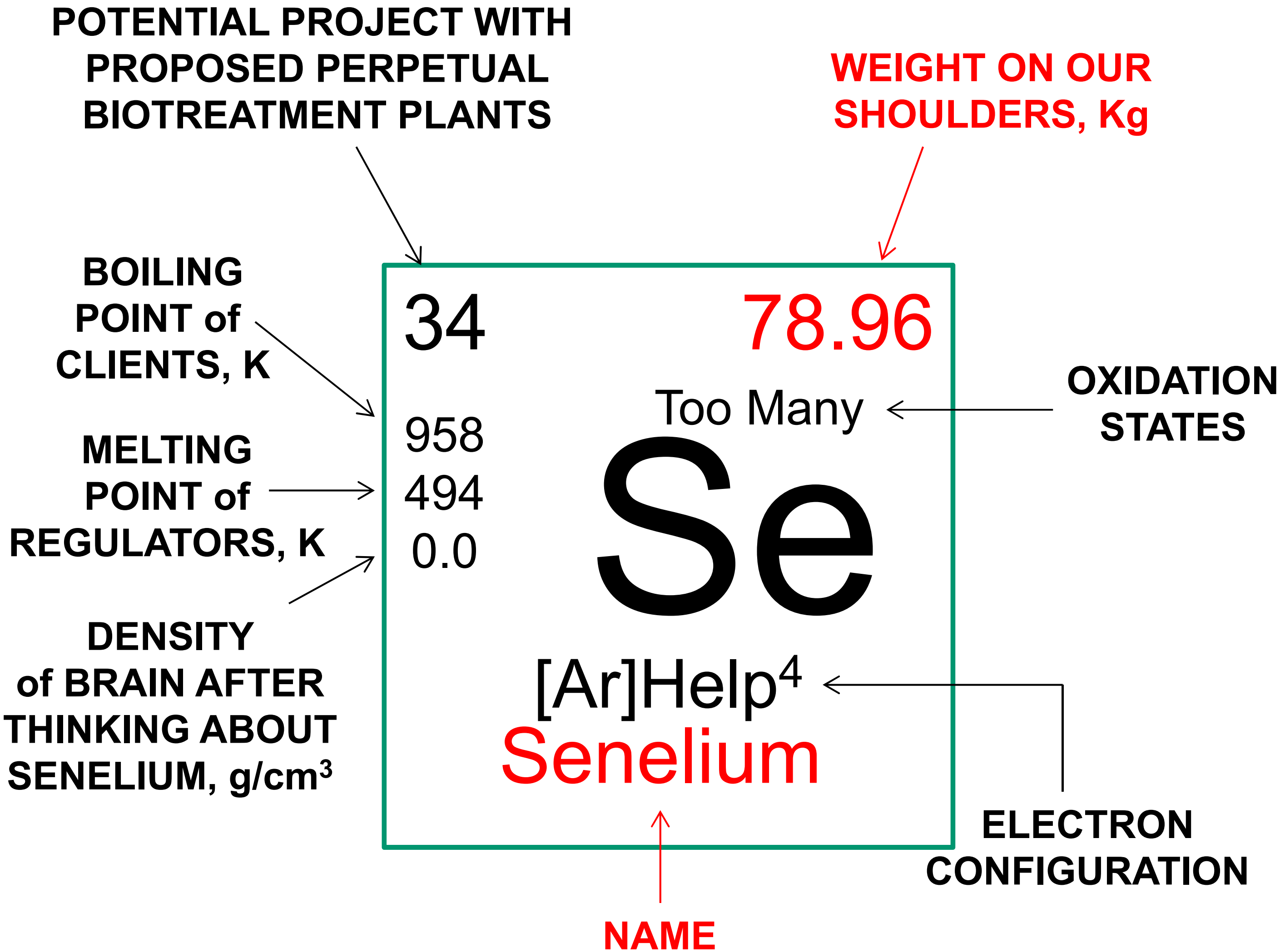
Summary

- Managing selenium is complex
  - Highly variable flow and concentrations
  - Flow reductions considerations
  - Nitrate inhibition

- Design for closure

- Understanding of passive attenuation continues to be refined
  - Further study necessary to inform mine planning and design

- Active treatment scheduled for commissioning in 2014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Thank you