SELENIUM ASSESSMENT AND MANAGEMENT IN THE NORTH AMERICAN COAL MINING SECTOR: UNIQUE ASPECTS OF SETTING BENCHMARKS AND PROJECT DEVELOPMENT CONSIDERATIONS

OR

“EVERYTHING YOU ALWAYS WANTED TO KNOW ABOUT SELENIUM*”

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Senior Environmental Scientist
Borealis Environmental Consulting Inc.

*But were afraid to ask.”

Acknowledgements: Michael Patterson (AngloAmerican); Al Martin, Justin Stockwell (Lorax Environmental), Marko Adzic (Teck Resources), Stella Swanson (Swanson Strategies)
PRESENTATION OVERVIEW

- Introduction
  - What is Selenium and Why is it different? What is at Issue?

- Selenium Assessment
  - Aquatic Life Criteria/Water Quality Guidelines
    - Canada
    - United States
    - Proposal for a Canadian Aquatic Life Guideline for Selenium – NAMC-SWG

- Selenium Management
  - General Considerations
  - Mine and Facility Design Considerations
  - An Adaptive Approach to Selenium Management

- Summary and Conclusions

- Questions?
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- M.Sc., Marine Ecology, University of Guelph; Thesis: Plankton Ecology
- Registered Professional Biologist (R.P. Bio.) (British Columbia)
- 18 years environmental consulting (ON, BC) - ecotoxicology, environmental effects monitoring, ecological and human health risk assessment, First Nations consultation, regulatory liaison
- 9 years in the mining industry as Director, Environment (Teck) and VP Environment, Community and Regulatory Affairs (Cardero)
- Member, SETAC; Past-President of SETAC Laurentian
- Member, North American Metals Council – Selenium Working Group
- Member, Elk Valley Selenium Task Force (previously)
- Board of Directors, Canadian Ecotoxicity Workshop
- Editorial Board, *Integrated Environmental Assessment and Management*
Borealis Environmental Consulting Inc.

- based in North Vancouver, BC; work with a variety of associates
- specialize in environmental impact and risk assessments, due diligence evaluations, for clients across industry sectors:
  - mining (metal and coal), oil and gas, chemical products
- recent work with various industry associations and multi-stakeholder forums, focus on the integration of science, policy, environmental management and regulatory decision-making
- expertise in the area of Selenium fate, effects, and management; work across North America
WHAT IS SELENIUM AND WHY IS IT DIFFERENT?

- Selenium (Se) – a naturally-occurring metalloid
- Increased [Se] have been monitored as a result of anthropogenic activities, e.g., mining, power generation, agriculture/animal husbandry
- Waste rock spoils associated with coal mining have the potential to increase leaching rates of Se, especially when it comes into contact with H\textsubscript{2}O and O\textsubscript{2}
- Essentaility/Toxicology:
  - essential for health of people, other animals, some plants (soils in BC deficient in Se)
  - in excess and in critical chemical species in diet can cause reproductive failures / abnormalities in egg-laying vertebrates (i.e., fish, birds, amphibians, reptiles)
- Reproductive/developmental effects likely due to Se replacing S in amino acid synthesis
WHAT IS AT ISSUE?

- Stakeholder concerns regarding elevated Se in effluent discharged from industrial operations (coal mines, specifically) has placed increased focus on Se assessment, mitigation and management.

- Se is a complex chemical of concern which varies site-specifically:
  - potential effects are chronic, rarely acute
  - tissue threshold (of egg-laying vertebrates) vs. water concentration better correlate of effects
  - offspring of exposed individuals affected (not classic response)
  - lentic vs. lotic systems differ

- Dealing with Se must recognize the difference between existing and developing mines – reactive vs. proactive/preventative actions

This presentation: focus on considerations related to Se assessment and management during the project development phase.
SELENIUM ASSESSMENT
AQUATIC LIFE CRITERIA / WATER QUALITY GUIDELINES

Current State-of-Science

• often in the primary literature, has not been incorporated into regulatory guidelines to keep up with science
• based on chronic reproductive effects on 2nd generation fish/birds/amphibians
• need to be based on controlled, long-term, chronic exposure, multi-generational lab experiments
• criteria should be derived on tissue concentration basis
AQUATIC LIFE CRITERIA / WATER QUALITY GUIDELINES, CONT’D.

- Hierarchy (less certain ---> more certain)
  - Water Concentrations
  - Whole Body/Muscle Tissue Concentrations
  - Ovary/Egg Tissue Concentrations
Canada

- National Guidelines – Canadian Council of Ministers of Environment (CCME)
- Provincial Guidelines – most default to CCME value, only BC has a ‘different’ guideline
- Canadian Nuclear Safety Commission (CNSC) – based on CCME, but currently applying tissue-based thresholds (where applicable/appropriate)

Note: most guidelines derived using the Species Sensitivity Distribution (SSD) approach, not the Safety Factor (SF) approach (still used by BC)
SAFETY FACTOR METHOD VS. SSD APPROACH

SAFETY FACTOR

- Guideline divided by an arbitrary safety factor
- Depends on type of key study (most based on one study)
- CCME Protocol (only when not enough data):
  - 10, 20, 100, etc.
  - (other jurisdictions: as above, and 1000, …)
- Extrapolation from the KNOWN (measured toxic impact) to the UNKNOWN (the protective threshold value)
SAFETY FACTOR METHOD VS. SSD APPROACH

SPECIES SENSITIVITY DISTRIBUTION (EXAMPLE)
AQUATIC LIFE CRITERIA / WATER QUALITY GUIDELINES, CONT’D.

Canada

- historical basis for the current Canadian national (CCME) Se guideline - 1 µg/L to protect aquatic life
  - based on field studies:
    - historical fish kills (Belews Lake/Hyco Reservoir), and not using traditional methods (i.e., toxicity test data)
    - indicated that waterborne [Se] of 5-10 µg/L associated with food web “contamination” caused predatory fish mortalities

- no current plans for revision to current guideline, despite high profile of Se; more on this later……
### Aquatic Life Criteria / Water Quality Guidelines, Cont’d.

**British Columbia (2014)**

<table>
<thead>
<tr>
<th>Medium</th>
<th>Category</th>
<th>Previous (2001)</th>
<th>2014</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater</td>
<td>Alert</td>
<td>N/A</td>
<td>1 μg/L</td>
<td>Not science-based (1/2 of guideline)</td>
</tr>
<tr>
<td></td>
<td>Guideline</td>
<td>2 μg/L</td>
<td>2 μg/L</td>
<td>Based on SF approach (not SSD)</td>
</tr>
<tr>
<td>Dietary</td>
<td>INTERIM</td>
<td>N/A</td>
<td>4 μg/g (dw)</td>
<td>Weight of evidence; lowest published thresholds, no UF applied; insufficient data for full guidelines.</td>
</tr>
<tr>
<td>(Invertebrate tissue)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sediment</td>
<td>INTERIM</td>
<td>2 μg/g (dw)</td>
<td>2 μg/g (dw)</td>
<td></td>
</tr>
<tr>
<td>Tissue (fish)</td>
<td>Egg/Ovary</td>
<td>N/A</td>
<td>11 μg/g (dw)</td>
<td>SSD derived = 20 μg/g (dw) (DeForest et al., 2012)</td>
</tr>
<tr>
<td></td>
<td>Whole Body</td>
<td>4 μg/g (dw)</td>
<td>4 μg/g (dw)</td>
<td>50% of Draft USEPA criterion</td>
</tr>
</tbody>
</table>
AQUATIC LIFE CRITERIA / WATER QUALITY GUIDELINES, CONT’D.

United States

- States:
  - Utah (2011; based on bird egg tissue)
  - Kentucky (2013; tiered approach)
  - West Virginia, Colorado, others pending, awaiting USEPA

- National/Federal
  - USEPA (DRAFT) – currently in expert & public review
AQUATIC LIFE CRITERIA / WATER QUALITY GUIDELINES, CONT’D.

Utah (2011) – based on water bird tissue (eggs) dw for Great Salt Lake

- **< 5.0 mg/kg:** routine monitoring with sufficient intensity to determine if [Se] within the Great Salt Lake ecosystem are increasing.
- **5.0 mg/kg:** increased monitoring to address data gaps, loadings, and areas of uncertainty identified from initial Great Salt Lake Se studies.
- **6.4 mg/kg:** Initiation of a Level II Anti-degradation review by the State for all discharge permit renewals or new discharge permits to Great Salt Lake (may include an analysis of loading reductions).
- **9.8 mg/kg:** Initiation of preliminary TMDL* studies to evaluate selenium loading sources.
- **> 12.5 mg/kg:** Declare impairment. Formalize and implement TMDL*.

*TMDL = total maximum daily load
AQUATIC LIFE CRITERIA / WATER QUALITY GUIDELINES, CONT’D.

Kentucky (2013) – based on [water] and [fish tissue], uses a tiered approach

- **Step/Tier 1.** Water column Se$_{\text{total}}$ concentration $> 5.0$ $\mu$g/L threshold?
  - if [water column] for Se$_{\text{total}}$ is $\leq 5.0$ $\mu$g/L the water body is meeting its aquatic life use.
  - if [water column] for Se$_{\text{total}}$ is $> 5.0$ $\mu$g/L, proceed to Step/Tier 2.

- **Step/Tier 2.** Site is in attainment of fish tissue criterion? (i.e., whole body $[8.6 \ \mu$g/g Se$_{\text{total}}$ dw] or egg/ovary tissue $[19.3 \ \mu$g/g Se$_{\text{total}}$ dw]).
  - if each species-composite fish tissue has concentration $<$ the appropriate tissue-based criterion, water body meets chronic standard.
  - if a species-composite fish tissue has concentration exceeding tissue criterion, the site is considered in non-attainment of the water quality standard.
AQUATIC LIFE CRITERIA / WATER QUALITY GUIDELINES, CONT’D.
U.S. EPA – 2015 (2nd DRAFT; Public Comment period closed)

<table>
<thead>
<tr>
<th>Medium</th>
<th>Category</th>
<th>Previous (Interim)</th>
<th>Proposed (2015?)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater</td>
<td>Lentic (slow-moving waters)</td>
<td>5 μg/L</td>
<td>1.2 μg/L</td>
</tr>
<tr>
<td></td>
<td>Lotic (fast-moving waters)</td>
<td>5 μg/L</td>
<td>3.1 μg/L</td>
</tr>
<tr>
<td>Tissue (fish)</td>
<td>Whole Body</td>
<td>7.91 μg/g (dw)</td>
<td>8.0 μg/g (dw)</td>
</tr>
<tr>
<td></td>
<td>Muscle Tissue</td>
<td>N/A</td>
<td>11.3 μg/g (dw)</td>
</tr>
<tr>
<td></td>
<td>Egg / Ovary</td>
<td>N/A</td>
<td>15.8 μg/g (dw)</td>
</tr>
</tbody>
</table>
Overview of the North American Metals Council - Selenium Work Group (NAMC-SWG)

Industry-funded, engaged in technical research on issues pertaining to Se (NOTE: not exclusive to metal mining)

Activities include:

- sharing of information on Se impacts, guidelines/criteria, mitigation, and treatment technologies
- development of Se effects thresholds, water quality tissue-based standards
- identification of field programs and analytical methods

As part of its ongoing efforts, the NAMC-SWG develops papers on these topics and shares them publicly:

http://www.namc.org/selenium.html
PROPOSAL FOR A CANADIAN AQUATIC LIFE GUIDELINE FOR SELENIUM

- History of Initiative
  - 2008: CCME Subcommittee of NAMC-SWG established direct and coordinate research aimed at developing/deriving a Third-Party Contributed Guideline force consideration.
  - 2009: BCMOE provided an update regarding Se WQG revision; CCME likely to consider a provincial guideline over a Third-Party Contributed Guideline, should Se be prioritized for guideline revision.

- Subsequently:
  - NAMC-SWG continued with initiative
  - BCMOE developed a revised guideline document (now finalized, and published)
History of Initiative, cont’d.

How could NAMC-SWG work to contribute to CCME’s future revision of a freshwater aquatic life guideline for Se?

BC Se guideline based on the “Safety Factor” approach (not used by CCME, when there are sufficient data).

CCME – and most other international jurisdictions - recommends the Species Sensitivity Distribution (SSD) approach in the development of WQGs.
PROPOSAL FOR A CANADIAN AQUATIC LIFE GUIDELINE FOR SELENIUM

Summary of Work Completed to Date

- **Phase I** - Development of a tissue-based threshold, developed according to CCME protocols (DeForest et al., 2012).

- **Phase II** - Derivation of a water-based guideline, 'back-calculated' from the tissue-based guideline, using data generated by project team, and using statistically-derived bioaccumulation factors (DeForest et al., 2015; in press).
PHASE I

- Development of a tissue-based threshold
SELENIUM TISSUE-BASED WQG BASED ON THE SSD APPROACH

- Used CCME toxicity endpoint hierarchy:
  - $EC_{10} > EC_{11-25} > MATC > NOEC > LOEC > EC_{26-49} > nonlethal EC_{50}$

- SSDs developed for:
  - all species, Canadian species, Canadian “coldwater” species, excluding “uncertain” thresholds (i.e., brook trout, white sucker)

- Sensitivity Analysis:
  - Regardless of data set (above), 5th percentile of SSDs = 20 µg/g dw

- Paper published in IEAM journal in June 2012:
Figure 1. Species sensitivity distributions (SSDs) based on all egg or ovary Se toxicity thresholds for fish species that occur in Canada. See Table 1 for sources of toxicity thresholds.
PHASE II

- Derivation of a water-based guidelines
Table 1. Summary of possible waterborne selenium screening guidelines from the approaches evaluated.

<table>
<thead>
<tr>
<th>Approach</th>
<th>Description</th>
<th>Water Se (µg/L)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lotic or Selenate</td>
<td>Lentic or Selenite</td>
<td></td>
</tr>
<tr>
<td>Quantile regression</td>
<td>Field-based water-to-particulate Se data</td>
<td>6.5</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Laboratory-based water-to-particulate selenate or selenite data</td>
<td>5.1</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pooled laboratory selenate/field lotic and laboratory selenite/field lentic</td>
<td>4.7</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Mean of all quantile regression approaches:</strong></td>
<td><strong>5.4</strong></td>
<td><strong>2.1</strong></td>
<td></td>
</tr>
</tbody>
</table>

1 Assuming that selenate data are representative of lotic conditions and selenite data are representative of lentic conditions.
SE WQG PROPOSED TIERED APPROACH

Water Screening Guideline:
Lentic (2.1 µg/L*) and Lotic (5.4 µg/L*)

Below?

No Se Toxicity

Above?

Fish Tissue** Guideline 20 µg/g dw

Below?

No Se Toxicity

Above?

Se Toxicity Potential

*total Se

**egg/ovary
### AQUATIC LIFE CRITERIA / WATER QUALITY GUIDELINES, CONT’D.

**U.S. EPA (2\textsuperscript{nd} DRAFT) 2015 vs. NAMC-SWG (DeForest et al., 2012, 2015)**

<table>
<thead>
<tr>
<th>Medium</th>
<th>Category</th>
<th>Previous</th>
<th>USEPA DRAFT (2015)</th>
<th>DeForest et al. 2012 (IEAM)</th>
<th>DeForest et al., 2015 (EST)</th>
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<tr>
<td>Freshwater</td>
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<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Egg / Ovary</td>
<td>N/A</td>
<td>15.8 $\mu$g/g (dw)</td>
<td></td>
<td>20 $\mu$g/g (dw) – based on extensive bioaccumulation studies</td>
</tr>
</tbody>
</table>
NEXT STEPS

- NAMC-SWG:
  - requesting consideration of a Third-Party Contributed Guideline [revision] for Se.
  - contacting provincial representatives in order to obtain a “champion/sponsor” for this initiative.

- Guidelines Development Project Team of the CCME Water Management Committee
  - consider need for revision of the current Se Guideline for the Protection of Aquatic Life (Freshwater) (i.e., 1 μg/L)
INTERMISSION

We are here...

% of audience paying full attention

Time (mins)

Mills HR, 1977
“Senelium”
(səˈneɪ lə əm): Noun: from Latin *senilis*, to be driven crazy!
Back to Sleep!
SELENIUM MANAGEMENT
GENERAL CONSIDERATIONS

- Where does Se assessment/management fit into coal mine project development?

- The Mining Life Cycle
  - Project Development in context

- Project Development Phases:
  - Exploration and Mine Planning
  - Environmental Assessment and Permitting
  - Construction
GENERAL CONSIDERATIONS - CONT’D.

Where does Se assessment/management fit into coal mine project development? – cont’d.

Project Development Phases:

Exploration and Mine Planning (NI 43-101 – compliant)

- Preliminary Economic Assessment (PEA)
- Pre-Feasibility Study (PFS)
- Bankable Feasibility Study (BFS)*
GENERAL CONSIDERATIONS - CONT’D.

- Project Development Phases, cont’d.:
  - Environmental Assessment and Permitting*
    - Environmental Assessment Report (and Certificate)
      - Based on a comprehensive EA (incl. baseline studies, effects assessments and management plans – to deal with impact mitigations)
  - Permitting
    - permits related to discharge (air, water)
    - *Mines Act* Permit (BC) – including reclamation bonding.

*Note: EA and Permitting often initiated prior to BFS*
SELENIUM IN ENVIRONMENTAL ASSESSMENT – KEY ELEMENTS

- **Baseline studies**
  - **Hydrology/Limnology** – climate, design events, flow
  - **Hydrogeology** – groundwater flow, quality
  - **Geochemistry** – ‘source terms’ from waste rock
  - **Water quality** – receiving environment, predicted effluent quality
  - **Fish/Aquatic Biota** – ecological receptors

- **Effects Assessment**
  - **Water Balance, Aquatic Effects Assessment (including assimilative capacity)**
  - **Ecotoxicity Evaluations/Modelling/Risk Assessment**
  - **Human Health**
  - **Management Plan(s)**
    - **Water Management Plan**
    - **Se Management Plan**
    - **Environmental Management System**
Feasibility
Mine Plan
Water Management Plan

Water Quality Predictions/Projections
- Water Balance (modelling)
- Groundwater Modelling/Assessment Feeds into Water Balance
  - Geochemical Source Term Development
- Draft Water Quality Predictions/Projections, Screening, Reporting
  - (not just for Se, but requires multi-element analysis)

Effects Assessment
(water quality, flow, aquatic biota)

Model final mitigation

EA Submission

Parallel Processes

- Scenarios to Model
- (End of Mine Closure scenarios)

- Environmental Management Levels (EMLs)/ Site Performance Objectives (SPOs)
- Hydrodynamic modelling

Mine Permits (effluent discharge)

Modified from Lorax Environmental (2013)
SELENIUM ASSESSMENT / MANAGEMENT
KEY ELEMENTS

- **Engage** early with applicable regulatory agencies

- **Understand** stakeholder concerns

- **Establish** appropriate benchmarks, thresholds

- **Ensure** that predictions/projections are based on current/recent, best available, quantitative information

- e.g., Environment, Mines, Natural Resources, DFO

- What are communities and FNs concerned about? How can concerns be addressed?

- Are EMLs/SPOs appropriate due to site-specificity? Will regulators accept these?

- What is the quality of baseline data? How can uncertainty be reduced?
SELENIUM MANAGEMENT CONSIDERATIONS

- **Understand** the assimilative capacity of receiving environment
- **Research** available technologies to assure their efficacy
- **Evaluate** cost-benefit of any/all technologies

- What is the size of the Initial Dilution Zone (IDZ)?
- What impact does dilution have on [Se] in receiver?
- How will full-scale treatment plant deal with final effluent volumes? How efficient will a treatment system be?
- Design for in-stream concentrations (vs. traditional ‘end-of-pipe’)
MINE AND FACILITY DESIGN PRINCIPLES

- Ensure that “clean”* water is kept clean
  - Optimize the volume of water reused and recycled on site
  - Minimize clean water coming into contact with waste rock, coarse coal refuse

- Ensure aquatic effects assessment results (e.g., water quality predictions, water balance) feed back to mine design engineers early in FS → water management diversions and structures (e.g., sedimentation ponds)

*“Clean” = not impacted by on-site activities
MINE AND FACILITY DESIGN PRINCIPLES – CONT’D.

- Progressive Reclamation throughout life of mine – standard practice
- Maximize potential use of:
  - innovative design and siting of waste rock dumps
  - backfilling (above ground, underground)
  - end pit lakes (surface)

Overall..........”Design for Closure”
AN ADAPTIVE APPROACH TO SELENIUM MANAGEMENT

The Adaptive Approach:

Throughout the EA and Permitting phase(s), need to consider various options so as to anticipate the various potential outcomes of aquatic effects assessment (impacts and mitigations)

“Fine-tune” as you go through EA and permitting
AN ADAPTIVE APPROACH TO SELENIUM MANAGEMENT – CONT’D.

- **Option 1.** No constraints, mitigations unnecessary
- **Option 2.** Diversion of mine-influenced waters
- **Option 3.** On-site utilization of affected waters (‘Reuse and Recycle’)
- **Option 4.** Active management of mine-influenced waters
- **Option 5.** *In situ* treatment
- **Option 6.** Active treatment
Option 1. No constraints, mitigations unnecessary

- Based on geochemical source terms (from static and kinetic tests), water quality modelling predictions, overall water balance
- This option would be based on $[\text{Se}]$ not exceeding applicable risk thresholds such as:
  - generic aquatic life criteria (e.g., BCMOE, CCME, USEPA)
  - Site Specific Water Quality Objectives (SSWQO) – existing mines
  - Environmental Management Levels (EMLs)/Site Performance Objectives (SPOs) – developing mines
    - Latter two – based on multi-generational toxicity tests and/or bioaccumulation modelling; requires monitoring to validate

- In all cases, need to consider the potential for elevated background concentrations
Option 2. Diversion of mine-influenced waters

- Based on the principle that clean water is diverted from waste water

- In cases of moderate Se exceedances of the above-mentioned risk thresholds (e.g., an order of magnitude), mine-influenced waters could be diverted from sedimentation ponds located at various points on the property to:
  - non-fish bearing waters
  - waters of low habitat quality
    - [reduces risk to potential receiving water receptors]

- This option may require habitat compensation
Option 3. On-site utilization of affected waters (‘Reuse and Recycle’)

Se-impacted waters may be suitable for use on site for activities such as:

- Coal washing and processing in a Coal Handling and Processing Plant (CHPP)
- Dust suppression on roads and stockpiles

In the case that partial or full treatment is implemented, this option reduced the volume of discharge water to be treated.
Option 4. Active management of mine-influenced waters

- The release of Se-impacted waters could be restricted by the assimilative capacity of the receiving environment.
- Active management, through the use of water storage and timed release could be used to match site loads with assimilative capacity of the receiver.
AN ADAPTIVE APPROACH TO SELENIUM MANAGEMENT – CONT’D.

- Option 5. *In situ* / passive treatment
  - In cases whereby [Se] in effluent would be significantly higher than those discussed above (i.e., nearing 2 orders of magnitude)
  - A number of *in situ* treatment approaches can be considered, including: passive systems (bioreactors)*/ in situ treatment approaches (e.g., engineered wetlands).
Option 6. Active treatment

Also in cases where \([\text{Se}]\) in effluent would be significantly higher than those discussed above (i.e., nearing 2 orders of magnitude)

Active treatment technologies – either total or partial - may to be considered, depending on:

(a) the magnitude of \([\text{Se}]\) above benchmarks; and,

(b) the volume of water requiring treatment.
SUMMARY AND CONCLUSIONS

- Se – unique characteristics, unique regulations/guidelines
  - challenge of keeping guidelines current with rapidly-changing science

- 2014/2015 – the year of changing Aquatic Life guidelines/regulations?
  - BC (finalized; 2014)
  - USEPA (draft; 2015)
    - {note: Health Canada just revised DWQG from 10 to 50 ppb}

- NAMC Proposal for new CCME Guideline (Canada)
- News to follow............
SUMMARY AND CONCLUSIONS

- Recently, greater focus on the potential effect(s) of Se in effluent discharged from coal mines (mostly in North America)

- Se is a complex chemical of concern; site-specific issues (site receptors, lentic vs. lotic receiving waters) need to be considered

- Coal mines going through project development have an opportunity to proactively assess, mitigate and manage Se using a range of tools, including mine design parameters, mitigation principles and treatment technologies

- There are a number of mitigation/management options to be considered using an adaptive approach
THANK YOU

QUESTIONS?