The Way Forward:

A Strategic Plan for the Management of Selenium at Teck Coal Operations

The Strategic Advisory Panel on Selenium Management

6/30/2010

Teck is a diversified resource company whose commodity interests include copper, metallurgical coal, zinc, energy and gold. The coal business is significant – Teck Coal[1] is the world's second-largest producer of seaborne steelmaking coal, and operates six mines: five in south-eastern British Columbia and one in west-central Alberta. Coal sales were 20 million tonnes in 2009, and accounted for forty-six percent of company revenue and forty-seven percent of operating profit.

The mining of steel-making coal increases the release of selenium, a naturally occurring element, to the environment. While selenium is essential and beneficial to all animals, including humans, if present in elevated concentrations it can be toxic.

In recognition of this issue, Teck Coal commissioned an independent advisory panel to help forge a strategic plan for the sustainable management of selenium at the company's operations.

The Panel began its work in January 2010, and actively sought to meet with a cross-section of stakeholders[2] and First Nations representatives to better understand the perceptions and attitudes with respect to selenium management. This included field visits to Teck Coal's mine sites in British Columbia and Alberta, meetings with Teck Coal employees, and meetings and workshops with other stakeholders. The release of this report is an important milestone in the Panel's mandate, but it is not the completion of that mandate. The Panel will continue to provide advice on the translation of this report's findings and recommendations at individual Teck Coal operations throughout 2010. Stakeholder and First Nations' input will continue to be sought to further improve the Panel's recommendations.

A word about the content of this report
This report is a strategic document – it offers direction on how Teck Coal might define its overall strategy with respect to selenium management and allocate resources in this regard over an extended period. This report is not an operational plan that defines with clarity the short-term methods for achieving specific selenium management objectives at a specific operation. The next step in the Panel's work will be to offer advice on such operational requirements.

Stella Swanson, Ph.D., Chair
Strategic Advisory Panel on Selenium Management

[1] In this report, we refer to Teck Coal or "the company" to designate the coal business of Teck. In a limited number of places in the report we refer to Teck's sustainability commitments because Teck Coal should approach its selenium management efforts in a manner that is congruent with these commitments.
[2] The term "stakeholders" is used in this report to refer to all those who are affected by, and have the ability to affect, Teck Coal's business. They include Teck Coal employees and shareholders; residents and business operators in the communities where Teck Coal operates; local, provincial and federal regulatory agencies; non-government organizations; academics; and other interested parties.

The artwork in the report was done by Derrill Shuttleworth of Studio Two in Edmonton.

Strategic Advisory Panel on Selenium Management
3611 - 3rd Street SW
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June 30, 2010

Dr. Robin Johnstone
General Manager
Environmental Affairs
Teck Coal Limited
Suite 1000, 295 – 9th Ave. SE
Calgary, AB T2G 0R3

Dear Dr. Johnstone:

On behalf of the Strategic Advisory Panel on Selenium Management, I am pleased to present this report, which fulfills two of three objectives of the Panel as established in the Panel Charter.

It has been a distinct pleasure working with my fellow panelists, Dr. Rob Abbott, Mr. Wes Funk, Ms. Lisa Kirk, Dr. Gord McKenna, Dr. Harry Ohlendorf, and Mr. Tom Sandy. They have been generous with their time and their knowledge. I am also very grateful to the representatives of First Nations, provincial and federal regulatory agencies, elected officials and community members who gave their time and their own particular experience and knowledge during one-on-one interviews as well as during the two Workshops held in Fernie and in Hinton. The combination of the expertise of the highly qualified Panel members and the knowledge and insight of stakeholders in the Elk Valley and Yellowhead County produced a solid foundation for this strategic document.

I am confident that my fellow panelists share my view that the production of this strategic plan report has been interesting and personally rewarding. We hope that it will be a useful and immediately applicable contribution to the discussion and understanding of the issues associated with sustainable management of selenium at Teck Coal's operations.

Yours sincerely,

Stella Swanson, Chair

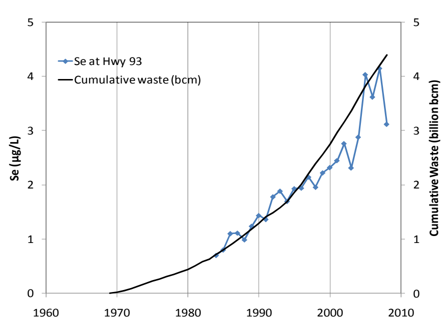
Executive Summary

Background

Teck Coal is the world's second largest producer of steel-making coal.

Coal mining creates large volumes of waste rock. Selenium is released from waste rock if exposed to air and water.

Selenium is a naturally-occurring element and is an essential nutrient; however, it can be toxic if present in elevated concentrations.



Correlation between Concentration of Selenium in the Elk River at Highway 93 and Waste Rock Volume

Teck Coal is the world's second largest producer of steelmaking coal, supplying one sixth of the global seaborne steelmaking coal market. The company's operations consist of six open-pit coal mines. The Coal Mountain, Elkview, Line Creek, Greenhills and Fording River Operations are located in southeastern British Columbia (Canada) near the communities of Elkford and Sparwood. The Cardinal River Operation is located in west-central Alberta near the town of Hinton.

Mining of coal creates large volumes of waste rock that, when exposed to water and air, accelerate the release of selenium into the environment. Selenium is a naturally occurring element that is essential and beneficial for all animals, including humans. It can be toxic if present in elevated concentrations.

While selenium is not the only environmental issue that Teck Coal must manage, the company has observed an increasing trend in the Elk River. The specific impacts of current selenium concentrations are not known, but a key management concern is the potential for selenium to cause population-level effects on fish and wildlife. An additional concern is that selenium concentrations occasionally exceed drinking water quality guidelines in the upstream portions of the Elk River watershed (including the area around Sparwood). Against this backdrop Teck Coal has sought to increase its understanding of selenium, and to identify technological solutions and management approaches to arrest the increasing trend in surface water concentrations.

The Panel

The seven-member Strategic Advisory Panel on Selenium Management (the Panel) was commissioned by Teck Coal.

The Panel worked independently of Teck Coal.

The Strategic Advisory Panel on Selenium Management (the Panel) was commissioned by Teck Coal in recognition of the need for a timely, sustainable approach to selenium management. Panel members represent the fields of reclamation engineering, microbial geochemistry, toxicology, ecological and human health risk assessment, water and wastewater treatment, ecological economics and decision analysis, and sustainable development. The Panel had its inaugural meeting in January, 2010. The goal of the Panel is to provide independent, expert advice and assistance by producing a strategic plan for the sustainable management of selenium at Teck Coal operations. The Panel has three objectives:

- Develop a selenium strategic management plan that integrates the environmental, social, and business opportunities and risks associated with selenium management by June 30, 2010.
- Develop a conceptual implementation plan for the strategy by June 30, 2010
- From June to the end of 2010, to further advise on the implementation of the strategic plan at individual operations.

The Panel during a tour of Teck Coal operations.

The Panel receives financial and logistic support from Teck Coal. The Panel recognizes the inherent contradiction between being commissioned and paid for by Teck and the provision of independent advice. With this in mind, the Panel worked independently of Teck (after receiving relevant information required for Panel deliberations), contacted stakeholders and hosted workshops directly and prepared this report with no review or revision by Teck Coal or other stakeholders. This report is being released simultaneously to all recipients, including Teck Coal, regulatory agencies, First Nations, and other stakeholder groups.

This report is a *strategic* document – it offers direction on how Teck Coal might define its overall strategy with respect to selenium management and allocate resources in this regard over an extended period. This report is *not* an operational plan that defines with clarity the short-term methods for achieving specific selenium management objectives at a specific operation. The next step in the Panel's work will be to offer advice on such operational requirements.

The Sustainability Framework

The Panel is committed to the use of a sustainability framework in all of its activities. The Panel has used the following definition of sustainability to guide its work:

> *"…a process in which the creation of financial and social wealth and wellbeing does not reduce the aesthetic and productive capacity of natural capital available for present and future generations"*

The Panel is committed to the use of a sustainability framework for all of its activities.

Several important concepts are embedded in this definition. The first is the reference to sustainability being a process rather than a utopian end state. The second is the explicit reference to the creation of both financial and social wealth or wellbeing. The third is the requirement that financial and social capital creation not be at the expense, either productively or aesthetically, of natural capital. Finally, this definition requires that the productive and aesthetic capacity of natural capital be maintained for future generations. The Panel has used this definition to guide its work.

Teck Coal's Position on Sustainability

Teck's vision of sustainability is:

Sustainability is a roadmap for Teck Coal as it aspires to integrate social, environmental and economic well-being.

> *While the scope of our activities may evolve, our mission is to find, extract and provide natural resources to society for the benefit of present and future generations – "Resource Stewardship for Generations." With this in mind, we work to identify the material ways in which our activities may impact sustainability and develop the strategies that will guide us as we maximize opportunities and minimize our impacts.*

Teck Coal's *2008 Sustainability Summary* adds to this vision the goal of "being a visionary corporate citizen" by establishing sustainability "as a core value driving our approach to business." Teck Coal has acknowledged selenium as one of the most material sustainability issues facing Teck as a whole.

Teck Coal's Selenium Management Efforts to Date

Teck Coal and previous owners have invested significant time and resources in the Elk Valley Selenium Task Force and the Alberta Working Group. A large body of relevant work has been carried out under the auspices of these and other groups.

Teck has invested considerable time and resources into selenium research over the past decade and continues a long-term commitment to the Elk Valley Selenium Task Force, a joint committee of government and industry representatives evaluating selenium monitoring and management in the Elk River Watershed, as well as the Alberta Working Group, a parallel committee of government and industry representatives working towards similar ends in Alberta. The work done by and for Teck and these task forces has provided a foundation for the Panel's work.

The Panel's review of the state-of-knowledge about selenium has shown that it's time to take action.

The Panel has reviewed and evaluated the current understanding of selenium at the source of its release from Teck Coal operations, along the pathways for selenium migration, and at the point where selenium interacts with aquatic life, wildlife, or humans. The Panel has also reviewed the current status of knowledge about selenium management options with a particular emphasis on water treatment. Although there are still several areas where more data are required, the Panel believes that these data needs are insufficient grounds for delay.

Teck Coal's current selenium management plans illustrate its intent. However, consistent and rigorous application of this intent is required at all operations.

The Panel recognizes Teck Coal's recent efforts to develop much of the knowledge base about selenium. The Panel also acknowledges that Teck has already begun to implement selenium management as described in its selenium management plans. These actions are a positive reflection of Teck Coal's commitment to sustainable selenium management.

Selenium management options will differ at legacy sites (such as historic waste dumps, current operations, and planned operations.

The Panel observes a need to apply (and amplify) this commitment in a consistent and rigorous fashion across all operating mines, and to consider the specific actions that are most appropriate to legacy sites (e.g., historic waste rock dumps), current or active operations, and planned future expansions. Certain management actions that are necessary and effective for legacy sites might not be needed for future activities if effective selenium management planning is embedded in current mine plans.

Selenium Management Objectives

Stakeholder input was vital to the Panel's work.

It is important to frame selenium management in a transparent fashion that incorporates the input of stakeholders. With this in mind, the Panel consulted one-on-one with stakeholders and then convened two Workshops, one in Fernie, British Columbia, the other in Hinton, Alberta. The Workshop agendas were developed to explore stakeholder perceptions and attitudes toward sustainability and the selenium management challenge, and to craft an objective for selenium that reflects broad stakeholder interest.

The objective statements that emerged from each Workshop are presented below. These objective statements capture the essence of sustainability.

Fernie Stakeholder Workshop Objective Statement for Selenium:

"Define, implement, monitor and communicate sustainable ways to stabilize and reverse the selenium trend in the Elk River water shed as soon as possible. 'Sustainable' implies the context of continued mining and growth as well as social and environmental values."

Hinton Stakeholder Workshop Objective Statement for Selenium:

Prologue:

Yellowhead County is home to unique and globally significant natural assets that support abundant recreational and tourism activities, and provide critical ecosystem goods and services.

The people who live, work and play in the County want to protect these assets and goods and services for their children and grandchildren.

Mining within the County produces significant economic and social benefits, but it can also accelerate the release of selenium, a potential contaminant, to the natural environment (and therefore place critical natural assets and services at risk)

Accordingly, the stakeholders' objective with respect to selenium is:

"To manage selenium at current and future Teck Coal mine sites in a way that optimizes the mitigation of environmental impacts, protects critical ecosystem goods and services, allows for the continued extraction of the resource, and ensures ongoing community and social well-being for generations in Yellowhead County."

Specific actions in support of this objective are:

1. *Decrease the loading to the receiving environment and establish a decreasing trend within three years.*
2. *Subsequent to item 1, manage selenium to a target that provides a sufficient margin of safety for humans, fish and aquatic life and wildlife.*
3. *Pioneer the use of selenium management practices that benefit the community both during and following mine life by positioning the community as a knowledge centre on selenium.*
4. *Engage Yellowhead County residents, and others who benefit from the assets of the County, in an ongoing dialogue about (1) selenium (so as not to cause alarm); (2) management actions; (3) progress; and (4) anticipated next steps.*

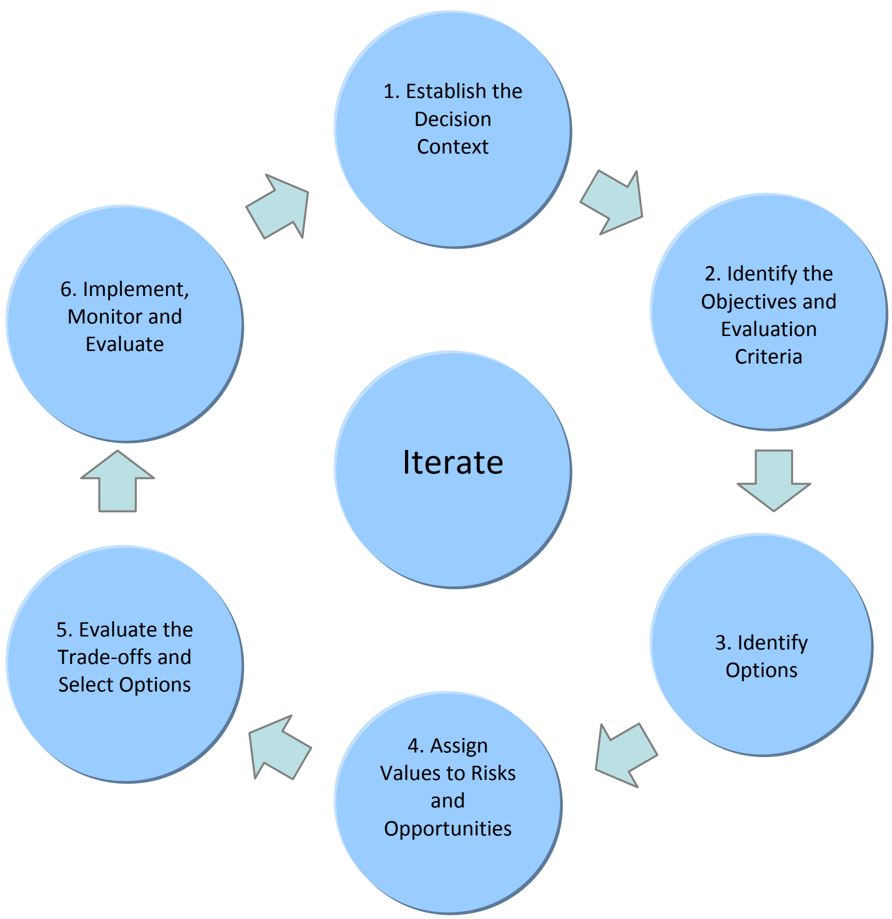
Option Identification and Evaluation

The Panel Used A Process Called Structured Decision-Making (SDM) to assist in the evaluation and selection of selenium management options.

SDM integrates science and policy, and offers a process for meaningful stakeholder involvement.

The Workshops also produced input for selenium mitigation option identification and evaluation. This information was used by the Panel within a Structured Decision Making Framework.

Structured Decision Making is a decision analysis technique. Decision analysis, and in particular, multiple criteria decision analysis (MCDA), has emerged as a technique to lend more transparency and greater rigour to the process and pursuit of sustainable decision-making.



The Multi-Criteria Decision Analysis (MCDA) identified the selenium management options that best fulfill evaluation criteria.

Structured Decision Making and the MCDA developed by the Panel is an iterative process. Solutions are often developed in the face of uncertainty, both with respect to data gaps and to ranges of opinions and values (these ranges are often very wide). Steps 1 to 3 in the above diagram were conducted during the individual stakeholder meetings and the Stakeholder Workshops. The Panel undertook Steps 4 and 5. It is expected that Teck Coal, its stakeholders, and the Panel will jointly undertake Step 6.

Ten selenium management options were ranked according to how well they scored against the evaluation criteria.

The MCDA conducted by the Panel produced the rankings shown below for each of the ten selenium management options selected for analysis. The lowest-scoring option (Passive Water Treatment) received a score of 125 while the highest-scoring option (Maximizing Pit Backfill), scored 172. The remainder of the options clustered, almost evenly, around scores of 130, 150 and 170. Within these groupings, the overall scores that produced these rankings were often very close. Furthermore, there was often substantial uncertainty associated with scoring the options against some of the criteria. Therefore, the rankings shown below should not be interpreted as a sequential preference list; rather, the rankings assist us in identifying the options that have the better chance of fulfilling economic, technical, environmental and social performance criteria, given what we know at this time. The actual order of deployment of the options will depend on many site-specific conditions at each of Teck Coal's operations because the risks and benefits accruing to each location will be altered by the economic, social, and environmental conditions influencing a given operation. Additionally, depending on site-specific circumstances, one or more of the options may not be feasibly deployed at a given mine site.

There was often substantial uncertainty associated with scoring the ten options. Therefore, the rankings are not a sequential preference list.

Rank	Option	Water Treatment	Water Management	Waste Management	Source Control
1	Maximize pit backfill			X	
2	New Dump design to limit oxygen and water infiltration			X	
3	Divert clean water from rock drains		X		
4	Avoid placement of waste in cross valley fills			X	
5	In situ microbial reduction as source control				X
6	Active Water Treatment - (e.g. biological FBR)	X			
7	Use only non-Se, massive rock in rock drains			X	
8	Existing dump reclamation to reduce Se mobilization			X	
9	Waste rock placement in constructed impoundment			X	
10	Passive Water Treatment-(e.g. passive biological reactor, permeable reactive barrier - iron)	X			

The order of deployment of the selenium management options will depend on site-specific conditions at each Teck Coal operation. Site-specific characteristics at individual operations and at legacy, current, or planned future sites will generate different combinations of the ten selenium management options.

The Panel will re-visit the sources of uncertainty in the next round of analysis in order to identify "high value of information" items that, when attained, may change the rankings of the management options.

The MCDA provided the Panel with key insights into the ability of each selenium management option to perform against triple bottom line (environment, economy, society) considerations. Uncertainty will be re-visited by the Panel during the next round of analysis in order to identify "high value of information" items that should be attained from site-specific monitoring and research. This does not mean that Teck is without sustainable selenium management options today; however, it does imply that in the presence of these knowledge gaps, it is difficult to optimize for sustainability through the use of the current MCDA findings. Indeed, as knowledge gaps close from targeted research and monitoring, a change in the rankings of the options could take place. The ten selenium management options reviewed are not mutually exclusive. Site-specific characteristics will generate the bundling of options (including high ranking and low ranking options). Optimum combinations of options will be different at legacy sites, current operations, and planned future operations.

The Way Forward

The Way Forward for Teck Coal's selenium management will require a step-change in the current program.

The Panel has concluded that the way forward will require that Teck Coal implement the following three pillars of a sustainable selenium management strategy.

The forward plan for selenium management at Teck Coal should be grounded in a transparent process informed by sound governance and operating principles.

Teck Coal should explicitly frame its approach to selenium management as a manifestation of its sustainability commitment.

Teck Coal should apply its experience with selenium management across all operations, to a higher standard, and with stronger management supported by additional technical specialists.

Robust decision tools, and a standardized approach for approval of selenium management projects are required within Teck Coal.

Selenium loadings can be reduced within three years; this will require swift action, based on a new way of thinking about mine planning.

The Panel recommends that Teck Coal adopt the following actions and operating principles as the basis for an effective, sustainable strategy for selenium management:

1. Make an immediate step change in its current selenium management program with a focus on significant changes to mine planning, water management, and waste management at all of its facilities and groups of facilities within the McLeod River and Elk River watersheds.
2. Adopt a framework of sustainability for management and decision making with respect to selenium that relies on robust decision tools and a standardized management approach for approval and implementation of selected options
3. Substantially reduce selenium loading within three years through a combination of water diversion, active water treatment, and avoidance of cross-valley fills, and keep loading rates below existing levels by adopting both remedial and operations measures to greatly reduce selenium loading rates from dumps and rock drains.

4. Identify and adopt portfolios of management options that offer synergies resulting in additional benefits (e.g., reduction in calcite formation or reduced nitrogen release to water).

Monitoring and R & D programs require re-designs.

5. Refocus-Teck Coal's research and development program to obtain critical design information in a timely manner.

6. Restructure the selenium and water quality monitoring program to improve data quality and availability, increase understanding of selenium loading, and facilitate measurement of reduced loading at the landform, site watershed, and regional watershed levels. The monitoring should be linked directly with a GIS-based database system, with further standardization of procedures and quality assurance.

Communications inside Teck Coal and engagement with stakeholders will be key components of the selenium management strategy.

7. Develop a selenium management communications plan within and among Teck Coal operations and other stakeholders to ensure that ideas, data, lessons learned, and key success stories are shared.

8. Continue and expand engagement with stakeholders on selenium issues.

A formal risk assessment framework will assist Teck Coal's recognition and management of emerging issues.

9. Develop a formal risk assessment and scanning framework to ensure emerging sustainability risks are recognized early on and framed appropriately against the portfolio of risks that Teck Coal is managing.

The Immediate Action Plan

The Panel recommends implementation of three of the options in order to reduce selenium loadings in three years.

Three options were deemed by the Panel to be capable of reducing selenium loadings within three years, with a high degree of certainty:[3]

- Active water treatment
- Diverting clean water from rock drains
- Avoiding the placement of waste rock in cross valley fills

Teck Coal should act immediately to identify and evaluate target locations for each of these three options.

We recommend that Teck Coal act immediately to identify and evaluate target locations for each of these three techniques, choosing areas where the reduction in loading rates are likely to be the greatest, and start design on these projects immediately thereafter so that the new facilities will be in place within three years. The selection process may also include evaluation of opportunities for staged implementation of these options in the following years.

The panel recognizes that there will be technical challenges and limitations associated with each of these options. There will also be uncertainty about the degree of reduction. Each of these is explored below.

Active water treatment should be targeted at areas with the largest legacy waste rock selenium loadings and the lowest volume of water to be treated.

With respect to active water treatment, site selection may be influenced by a desire to target areas with the largest legacy waste rock selenium load contributions and the lowest volume of water to be treated – West Line Creek is an obvious target to evaluate, as are Kilmarnock and Swift Creek. Other areas may be complicated by local flow conditions – especially where there is substantial subsurface water flow through porous foundations.

Diversion of clean water from rock drains can be applied more widely, but will only be effective where there are discrete and manageable streams upstream of the waste dump.

The diversion of clean water from rock drains can be applied more widely. However, diversion will only be effective where there are discrete and manageable streams upstream of the waste dump. Immediate consideration should be given to avoiding placement of waste in locations where clean water can be collected for subsequent diversion.

[3] Reduction here means both a stabilizing of the trend line with respect to selenium concentration in surface waters and a negative slope to the curve as the selenium concentrations begin to decline.

> **Geography can limit Teck Coal's ability to avoid cross valley fills and there may be a large and negative impact on mining costs. Therefore, an appropriate approach may be for Teck Coal to review its mine plans for opportunities to reduce the extent of future cross-valley fills.**

The Panel notes that geography can limit Teck Coal's ability to avoid cross-valley fills in some locations. Such avoidance would result in longer hauls. There may also be more land disturbance over a broader area (although placement of waste within the mined footprint would mitigate this). There may be a large and negative impact on mining costs, especially in the Elk Valley. Accordingly, an appropriate approach may be for the company to review its mine plans and look for opportunities to reduce the extent of future cross-valley fills and seek alternatives that allow more water diversion away from waste rock dumps and rock drains.

> **Method development and pilot scale testing of other options should begin right away.**

Other options, such as reducing oxygen availability within existing rock dumps to promote selenium reduction, could be considered but would require method development and pilot scale work, which should also begin right away.

> **The Line Creek expansion requires some redesigning for selenium management.**

The Line Creek expansion falls within the immediate action plan. The dumps for the expansion (including foundation preparation) need to be redesigned for selenium management. This redesign should include evaluation of opportunities for clean water capture, maximizing pit backfill, and avoidance of rock drains.

> **The immediate actions are not sustainable if applied widely across Teck Coal operations. The longer-term plan would deploy tailor-made suites of selenium management options at individual sites.**

An important caveat is that economic and social values will almost certainly be at risk if each of these options is used across Teck Coal operations. Widespread adoption of these options would be expensive and would require a high level of maintenance, leaving long-term sustainability in question. This is why, in the longer term, Teck Coal should deploy the recommended suite of ten management actions in a fashion that is tailored to specific site conditions. It is only by focussing on individual sites that the selenium management objectives will be achieved.

> **The recommended combinations of actions at legacy, existing and future sites will continue to be developed and refined, with the assistance of the Panel.**

The Panel will work with Teck Coal and its stakeholders over the balance of 2010 to begin the process of refining each option and determining which option (or combination of options) would be most effective at individual operations. In the main, however, it is recommended that the company commit to a combination of actions such as the following:

FOR AT LEAST ONE LEGACY ASSET WITH HIGH SELENIUM DISCHARGE	FOR ALL EXISTING OPERATIONS	FOR ALL FUTURE PLANNED MINE EXPANSION
▪ Active water treatment (e.g., biological fluidized bed reactor) ▪ Passive water treatment (e.g., passive biological reactor, permeable reactive barrier)	▪ Divert clean water from rock drains ▪ Maximize pit backfill ▪ Promote in-situ microbial reduction as source control ▪ Reclaim existing dumps to reduce selenium mobilization ▪ Hire needed personnel ▪ Implement site investigations and pilot scale development actions	▪ Avoid placement of waste in cross valley fills ▪ Use only low-selenium, massive rock in rock drains ▪ Design new dumps to limit oxygen and water infiltration ▪ Evaluate opportunities to place waste rock under water in a constructed impoundment

Conclusion

Teck Coal's willingness to commit to the above recommendations will be a defining feature of a new approach to selenium management. Support of specific changes in practice for particular legacy, operating, and planned assets is a worthy expression of Teck's sustainability commitment. In particular, if the company is to genuinely "take into consideration the current needs of society and the ability of future generations to meet their own needs", and "*find, extract and provide natural resources to society for the benefit of present and future generations"* as their sustainability commitment suggests, the principles and actions identified above represent a necessary and required evolution in selenium management and practice.

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Setting the Stage

The Business of Teck Coal

For us, sustainability means ensuring that we consider people, the environment and our communities of interest, now and in the future, with every decision we make. We are creating a culture in the company where everyone is empowered to look at their decisions through a sustainability lens and to do so in a way that respects the physical and human environment.

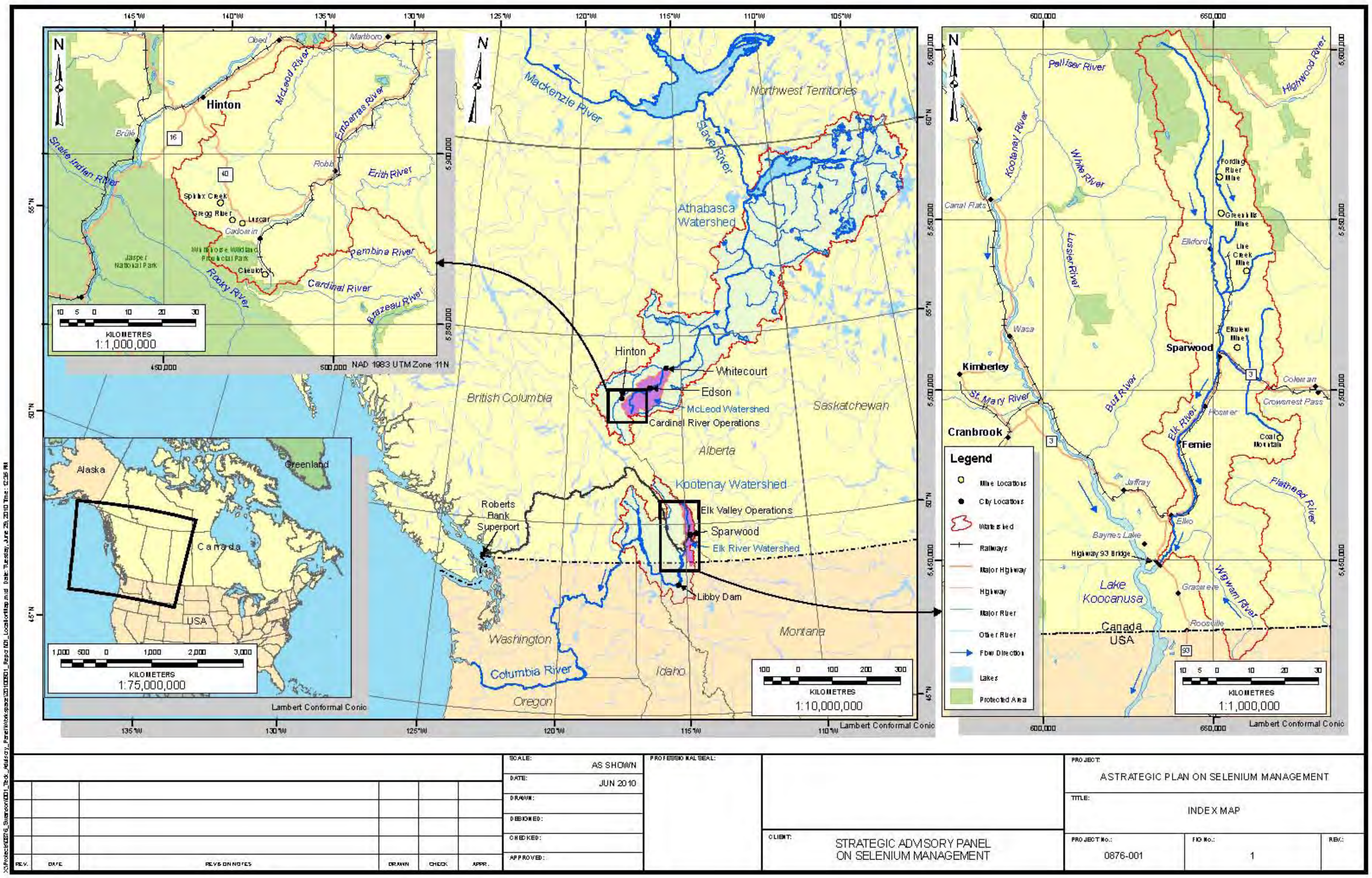
- Teck 2009 Annual Report, p. 24

Teck Coal is the world's second-largest producer of steel-making coal, with five mines in southeastern B.C., and one mine in west-central Alberta.

Teck Coal is the world's second-largest producer of steelmaking coal, supplying one sixth of the global seaborne steelmaking coal market. The company's operations consist of six open-pit mines. The Coal Mountain, Elkview, Line Creek, Greenhills and Fording River Operations are located in in south-eastern British Columbia, near the communities of Elkford and Sparwood, about 1,100 kilometres from tidewater near Vancouver. The Cardinal River Operation is located in west-central Alberta near the town of Hinton (Figure 1). Additional maps highlighting specific features of the mines are included in Appendix A. In addition to the company's abundant coal resources it has a 46 percent interest in Neptune Bulk Terminals, a coal loading facility located in Vancouver.

Loading a Haul Truck.

Figure 1: Location of Teck Coal's Mining Operations in British Columbia and Alberta



The company's core product is coking coal, used to make steel. The company also produces small amounts of thermal coal. The mines employ conventional open-pit truck and shovel mining methods. Following mining, the coal is washed and conveyed to dryers. The coal preparation plants are conventional wash plants using cycloning and heavy media flotation technologies.

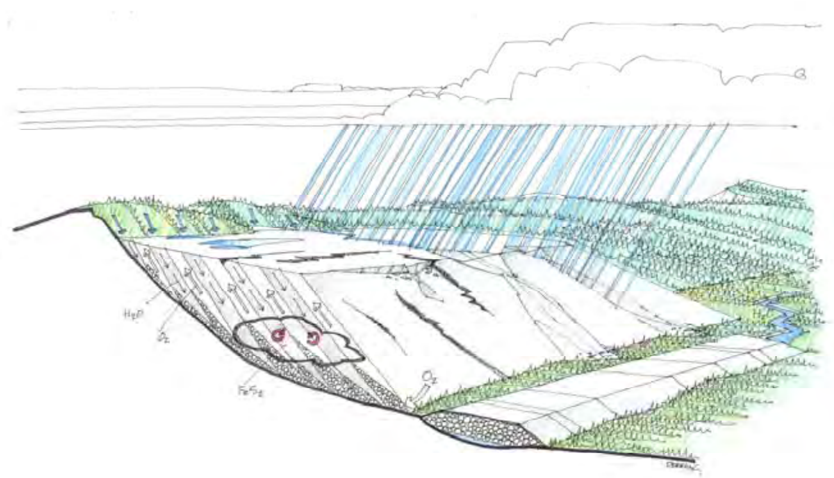
Most of the clean coal is shipped by rail to Westshore Terminals and Neptune Terminals near Vancouver for shipment to overseas customers in Asia,[4] Europe and South America. The balance is shipped east by rail or by rail and ship to Thunder Bay Terminals in Ontario to customers in eastern North America.

Selenium as a Strategic Business Issue for Teck

Selenium is a naturally-occurring element and is an essential nutrient; however, it can be toxic if concentrations are too high.

Selenium[5] is a naturally occurring element that is essential for all animals, including humans. It can be toxic if concentrations are too high. Mining of coal creates large volumes of waste rock that, when exposed to water and air, accelerate the release of selenium into the environment (Figure 2).

Figure 2 Existing Waste Rock Dump Practices at Teck Coal Operations, and Release of Selenium



[4] Historically, nearly half of the company's coal production was shipped to Japan, Korea and Taiwan, but in 2009 China emerged as a significant customer; the country is currently undergoing the largest process of urbanization and industrialization in human history, a process that is elevating millions of people out of poverty. This process requires large volumes of steel to support the construction activities taking place.

[5] The chemical symbol for selenium is Se. While this report generally uses the term selenium, in tables and figures the symbol Se is occasionally used as well.

Teck Coal's *2008 Sustainability Summary* highlights the relative proportions of coal and waste rock produced between 2006 and 2008. The ratio of waste rock to coal produced is about 18:1 (by mass) (Table 1).

Table 1: Ratio of Total Waste Rock to Coal at Teck Coal Operations, 2006-2008

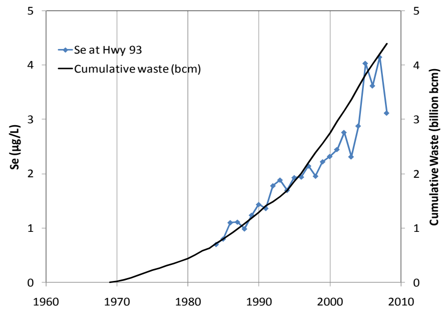
PRODUCTION (kt)	**2006**	**2007**	**2008**
Coal	22,564	23,401	23,964
MINED MATERIALS (kt)	**2006**	**2007**	**2008**
Total Waste Rock	430,884	422,178	449,883
Total Tailings Dry	5,148	5,504	7,433

Source: Teck Coal. *2008 Sustainability Summary*, p. 11.
kt = thousand tonnes

There has been an increasing trend in surface water concentrations of selenium for the past several years.

While selenium is not the only environmental issue that Teck Coal must manage,[6] for several years the company has observed an increasing trend in the surface water concentration of the element. The exact impact is not known, but a key management concern is the potential for selenium to cause population-level effects on fish and wildlife. Against this backdrop, Teck Coal has sought to both increase its understanding of selenium release and to identify solutions that might arrest the increasing trend in surface water concentrations. To date, however, the company has not been able to demonstrate that it has *proven* management methods to resolve the issue. This creates business risk because Teck Coal must receive permits for several upcoming mine expansions to continue operations. Regulators in British Columbia and Alberta may be reluctant to issue such permits

[6] Other environmental issues include biodiversity and land management; waste management; energy and greenhouse gas management; climate change; and spills. Other water quality issues include calcite deposition; total dissolved solids (TDS); sulphates; and metals. Current efforts by Teck Coal focus on managing total suspended solids. Ultimately, Teck Coal needs to address all of these issues. Ideally, selenium management should assist in the management of these issues; at a minimum, selenium management must not make these issues worse.



Correlation between Concentration of Selenium in the Elk River at Highway 93 and Waste Rock Volume

in the absence of proven management[7] techniques for selenium. Accordingly, the company's business viability depends on finding such techniques in a timely fashion.

Conceptually, the business risk associated with selenium can be framed as one that affects the company's existing license to operate, with a primary focus on value protection, as well as its future license to grow, with a primary focus on new value creation. While it is a truism within the mining industry that company value is a function of ore reserves, this applies only if the company is able to secure and protect the social license to operate, and the social license to grow.

The Strategic Advisory Panel on Selenium Management

The seven-member Strategic Advisory Panel on Selenium Management (the Panel) was commissioned by Teck.

The Strategic Advisory Panel on Selenium Management (the Panel) was commissioned by Teck Coal to create a strategic plan for the sustainable management of selenium at its six mines. Panel members represent the fields of reclamation engineering, microbial geochemistry, toxicology, ecological and human health risk assessment, water and wastewater treatment, ecological economics, and sustainable development. The Panel had its inaugural meeting in January of 2010.

The Panel during a tour of Teck Coal operations.

The Panel has three objectives:

- Develop a strategic management plan for selenium that integrates the environmental, social, and business opportunities and risks associated with selenium management by June 30, 2010.
- Develop a conceptual implementation plan for the strategy by June 30, 2010
- From June 30, 2010 to the end of 2010, to further advise on the implementation of the strategic plan at individual operations.

The Panel Charter is included here as Appendix B.

[7] The ability of Teck Coal to obtain permits for its anticipated mine expansions is affected by the fact that the increasing trend in surface water concentrations of selenium is such that concentrations are exceeding the Canadian Council of Ministers of the Environment (CCME) guideline for the protection of aquatic life and, occasionally, the CCME drinking water quality guideline.

The Panel worked independently of Teck, including meetings and workshops with stakeholders and the preparation and release of this report.

The Panel receives financial and logistical support from Teck Coal. The Panel recognizes the inherent contradiction between being commissioned and paid for by Teck Coal and the provision of independent advice. With this in mind, the Panel worked independently of Teck (after receiving relevant information required for Panel deliberations), contacted stakeholders and hosted workshops directly and prepared the report with no review or revision by Teck Coal or other stakeholders. This report is being released simultaneously to all recipients, including Teck Coal, regulatory agencies, First Nations, and other stakeholder groups.

A record of Panel activities is included as Appendix C.

The Panel is committed to the use of a sustainability framework in all of its activities.

The Panel is committed to the use of a sustainability framework in all of its activities. The Panel's understanding of sustainability is reviewed in the following chapter.

The Sustainability Lens

The Emergence of an Idea

The concept of sustainability was first cited in 1980 and introduced to a wide audience through the publication of *Our Common Future* in 1987

At the onset of the 21st century, the relationships between environmental protection, economic development, and social welfare are being explored and debated with great fervour around the world. These relationships, commonly called sustainable development or sustainability, were first cited in the World Conservation Strategy in 1980, and introduced to a wide audience in the report of the World Commission on Environment and Development (WCED), Our Common Future, in 1987. Since that time, government, non-government, and other groups around the world have increasingly sought to understand sustainability. In 1989, the then Group of Seven leading industrial countries made explicit reference to sustainability in an economic statement:[8]

[8] Ruth Eblen and William Eblen (eds.), *The Encyclopedia of the Environment*, 1994, p. 680.

In order to achieve sustainable development, we shall ensure the compatibility of economic growth and development with the protection of the environment.

Sustainability is a roadmap for human development that integrates environmental, social and economic wellbeing.

A synthesis of sustainability initiatives throughout the world suggests that it is now generally understood to be a roadmap for human development that recognizes the importance and interdependence of environmental, social and economic wellbeing. Put another way, sustainability can be defined as:

"…a process in which the creation of financial and social wealth and wellbeing does not reduce the aesthetic and productive capacity of natural capital available for present and future generations."[9]

Several important concepts are embedded in this definition. The first is the reference to sustainability being a process rather than a utopian end state. The second is the explicit reference to the creation of financial and social wealth or wellbeing. The third is the requirement that financial and social capital creation not be at the expense, either productively or aesthetically, of natural capital. Finally, this definition requires that the productive and aesthetic capacity of natural capital be maintained for future generations. The Panel has used this definition to guide its work.

Sustainability and the Mining Industry

Today's mining industry is actively seeking to embed sustainability in everyday operations.

The application of sustainability to the mining industry has its roots in the social and economic impacts long associated with extractive industries and the communities in which they work. Extreme working conditions, worker exposure to hazardous materials, and conspicuous environmental impacts were for many years the signature of mining and other extractive resource activities.[10] Today, the mining industry is actively seeking to embed sustainability in its organizational DNA. Among other activities, the chief executive officers of many of the world's largest mining companies formed the Global

[9] Robert M. Abbott, *Uncommon Cents: Thoreau and the Nature of Business*, 2008, p. 122.
[10] Andrew Watson describes this history well in a recent article, "Incorporating Sustainability into Mining Services," in Engineering and Mining Journal, September 2008.

A coal pit high wall and waste rock dump.

Mining Initiative (GMI) through the World Business Council for Sustainable Development in 1999. The GMI commissioned a review of sustainability within the industry, which led to the formation of the Mining, Minerals and Sustainable Development (MMSD) Project, an initiative dedicated to the development of a framework and strategy for sustainable mining. The International Council on Mining and Metals (ICMM) was formed in 2002 to implement the findings of the MMSD Project. One of the signal achievements of the ICMM has been the articulation of sustainability principles for the industry (Table 2).

Table 2: Sustainability Principles of the International Council on Mining and Metals

- **Implement** and maintain ethical business practices and sound systems of corporate governance
- **Integrate** sustainable development considerations within the corporate decision-making process
- **Uphold** fundamental human rights and respect cultures, customs and values in dealings with employees and others who are affected by our activities
- **Implement** risk management strategies based on valid data and sound science
- **Seek** continual improvement of our health and safety performance
- **Seek** continual improvement of our environmental performance
- **Contribute** to conservation of biodiversity and integrated approaches to land use planning
- **Facilitate** and encourage responsible product design, use, re-use, recycling and disposal of our products
- **Contribute** to the social, economic and institutional development of the communities in which we operate
- **Implement** effective and transparent engagement, communication and independently verified reporting arrangements with our stakeholders

The Mining Association of Canada has made endorsement of the "Towards Sustainable Mining" (TSM) Principles a condition of membership and requires all members to report on key performance areas within three years.

In a Canadian context, the Mining Association of Canada (MAC) began developing a "Towards Sustainable Mining (TSM)" initiative in 2000 to enhance the industry's reputation by spurring improvements in its environmental, social, and economic performance. On May 10, 2004, TSM was launched publicly, and on November 24, 2004, MAC's Board of Directors made TSM a condition of membership. The condition requires that MAC members endorse the TSM guiding principles (Table 3), a set of commitments that address all areas of the industry's performance. It also requires all members to report on key performance areas within three years at all Canadian operating facilities.[11] Teck is a member of MAC and is therefore bound by these conditions.

Table 3: Mining Association of Canada TSM Guiding Principles

As members of the Mining Association of Canada, our role is to responsibly meet society's needs for minerals, metals and energy products. To achieve this we engage in the exploration, discovery, development, production, distribution and recycling of these products. We believe that our opportunities to contribute to and thrive in the economies in which we operate must be earned through a demonstrated commitment to sustainable development.

Accordingly, our actions must demonstrate a responsible approach to social, economic and environmental performance that is aligned with the evolving priorities of our communities of interest. Our actions must reflect a broad spectrum of values that we share with our employees and communities of interest, including honesty, transparency and integrity. And they must underscore our ongoing efforts to protect our employees, communities, customers and the natural environment.

We will demonstrate leadership worldwide by:

- Involving communities of interest in the design and implementation of our Towards Sustainable Mining initiative;
- Proactively seeking, engaging and supporting dialogue regarding our operations;
- Fostering leadership throughout our companies to achieve sustainable resource stewardship wherever we operate;
- Conducting all facets of our business with excellence, transparency and accountability;
- Protecting the health and safety of our employees, contractors and communities;
- Contributing to global initiatives to promote the production, use and recycling of metals and minerals in a safe and environmentally responsible manner;
- Seeking to minimize the impact of our operations on the environment and biodiversity**,** through all stages of development, from exploration to closure;
- Working with our communities of interest to address legacy issues, such as orphaned and abandoned mines; and,
- Practicing continuous improvement through the application of new technology, innovation and best practices in all facets of our operations.

[11] The TSM performance areas are tailings management; crisis communications; Aboriginal relations; energy management, including GHG emissions management; external stakeholder engagement; biodiversity; and mine closure.

Table 3 (continued)

In all aspects of our business and operations, we will:

- Respect human rights and treat those with whom we deal fairly and with dignity;
- Respect the cultures, customs and values of people with whom our operations interact;
- Recognize and respect the unique role, contribution and concerns of Aboriginal peoples (First Nations, Inuit and Métis) and indigenous peoples worldwide;
- Obtain and maintain business through ethical conduct;
- Comply with all laws and regulations in each country where we operate and apply the standards reflecting our adherence to these Guiding Principles and our adherence to best international practices;
- Support the capability of communities to participate in opportunities provided by new mining projects and existing operations;
- Be responsive to community priorities, needs and interests through all stages of mining exploration, development, operations and closure; and,
- Provide lasting benefits to local communities through self-sustaining programs to enhance the economic, environmental, social, educational and health care standards they enjoy.

Teck Coal's Position on Sustainability

Teck has published its understanding of, and commitment to, sustainability in the Teck Sustainability Report and the Teck Coal Sustainability Summary

Teck's 2008 *Sustainability Report (Volume 2)* describes the process through which the company has continued to mature its thought and action with respect to sustainability:[12]

> *As our understanding of sustainability has evolved – the notion that our actions today must take into consideration the current needs of society and the ability of future generations to meet their own needs – it has become clear that natural resource extraction, more than most other forms of enterprise, has the ability to foster or hinder the pursuit of sustainability on a grand scale.*

In particular, the company has engaged with internal and external stakeholders to learn how it can more clearly articulate the linkages between vision, issues, and strategy. Against this backdrop, Teck's vision of sustainability is:

[12] Teck 2008 *Sustainability Report (Volume Two)*, p. 3.

> *While the scope of our activities may evolve, our mission is to find, extract and provide natural resources to society for the benefit of present and future generations – "Resource Stewardship for Generations". With this in mind, we work to identify the material ways in which our activities may impact sustainability and develop the strategies that will guide us as we maximize opportunities and minimize our impacts.*[13]

Teck Coal's *2008 Sustainability Summary* adds to this vision the goal of "being a visionary corporate citizen" by establishing sustainability "as a core value driving our approach to business."

While selenium was not specifically highlighted as one of the most material sustainability issues facing Teck as a whole in 2008, the coal business did so:[14]

Teck Coal has recognized that selenium is a sustainability issue

> *The enhanced levels of selenium discharge that result from mining activity, and the potentially adverse impact upon human health are key sustainability challenges.*

Teck Coal further acknowledged that "the pursuit of sustainability is never ending" and that a key initiative for 2009 would be to "advance selenium management strategies."

Teck has demonstrated a strong strategic intent with respect to sustainability

Collectively, the above speaks to a strong statement of strategic intent with respect to sustainability – an intent that was recognized in 2008 and 2009 when Teck was named to the Dow Jones Sustainability Index (DJSI), North America.[15]

[13] All of Teck Coal operations are registered to the ISO 14001 international environmental management standard.
[14] Teck Coal 2008 Sustainability Summary, p. 3.
[15] The DJSI is the first global index tracking the performance of sustainability-driven companies worldwide.

Looking at Selenium through the Sustainability Lens

The management of selenium is, in many respects, an object lesson in the implementation of sustainability "on the ground" because it tests the extent to which Teck has created a culture that truly considers "*people, the environment and communities of interest, now and in the future, with every decision.*" While there are management approaches that might be effective in reducing selenium concentrations in surface water (active water treatment, for example), some of these approaches may not be economically viable. Conversely, if selenium concentrations continue to increase, invertebrates, the fish that feed on invertebrates, aquatic birds, other wildlife, and potentially people could be negatively affected. The challenge, therefore, is to shift management thinking from maximizing one dimension of sustainability and minimizing "losses" in the others, to simultaneously holding the economic, social, and environmental dimensions, recognizing the interplay among them, and looking for opportunities to optimize performance across them. This is not easy. Teck Coal has itself underscored the magnitude of the sustainability challenge with its observation that "the pursuit of sustainability is never ending," and that the company strives to be a "visionary corporate citizen" with "sustainability as a core value driving our approach to business."

The challenge for Teck Coal is to shift management thinking from a focus on maximizing economic value while minimizing "losses" to simultaneously holding economic, environmental and social dimensions and looking for opportunities to optimize across all three.

Implementing sustainable management of selenium will require a weaving of economic, social, and environmental considerations into every decision. At present this is not happening consistently at Teck Coal. For example, mine planning (for ore production and waste rock management) does not incorporate selenium management as a key objective and performance metric. A set of formal selenium management "rules" may therefore be called for – rules that could be incorporated into mine planning and decision making to explicitly address selenium. Among other considerations, these rules might guide new ways of thinking about cut-off strip ratios, waste rock dump construction, the use or re-use of selenium-affected water, and the management of clean water. They might also influence the shape of mined out pits, the

Weaving of the three sustainability dimensions into every decision is not happening consistently at Teck Coal

sequencing of ore development, and even plans to mine certain areas.

Ultimately, if Teck is to look at selenium management through a sustainability lens, there will need to be a step-change in the way the issue has been framed strategically within the company. In particular, the way in which different aspects or "parts" of the selenium problem are considered at each mine site and corporately will need to change.

A Conventional Waste Rock Dump

A step-change is needed in the way the selenium management issue is framed strategically within Teck Coal to ensure integration of all of the "parts" of the selenium issue into a sustainable whole.

This approach is consistent with the models of ecosystem science and management advocated by C.S. (Buzz) Holling, one of the pioneers of adaptive ecosystem management, who talks of two kinds of science that should shape effective resource and environmental management. The first is a science of parts; the second is a science of the *integration* of parts: "It uses the results of the first, but identifies gaps, invents alternatives and evaluates the integrated consequences against planned and unplanned interventions in the whole system that occur in nature." *This* is the essence of what it means to look at selenium through a sustainability lens.

The integration of the "parts" regarding selenium management must address the "integrated whole" in terms of cumulative effects on a landscape scale over long time periods. Furthermore, the cumulative effects of selenium must be integrated with the effects of many other stressors acting on the same landscape. These stressors are associated not only with Teck Coal operations but with other activities such as forestry, oil and gas development, and recreational use of resources.

Teck Coal's Selenium Management Efforts to Date

Teck Coal and previous owners have invested significant time and resources in the Elk Valley Selenium Task Force and the Alberta Working Group. A large body of relevant work has been carried out under the auspices of these and other groups and individuals.

Teck Coal and previous owners of the British Columbia and Alberta operations have invested considerable time and resources into selenium research over the past decade. Teck Coal continues a long-term commitment to the Elk Valley Selenium Task Force, a joint committee of government and industry representatives evaluating selenium monitoring and management in the Elk River Watershed, as well as the Alberta Working Group, a parallel committee of government and industry representatives working toward similar ends in Alberta. The nature of the work carried out under the auspices of these groups, and additional work carried out by or on behalf of Teck Coal, can be characterized as falling into one or more of the following categories:

- Biological effects studies
- Hydrogeochemistry studies
- Water quality monitoring
- Selenium management options
- Water treatment options

Teck chairs the Canadian Industry Selenium Working Group (CISWG) and co-chairs the North American Metals Council Selenium Working Group. CISWG recently helped fund and participated in a workshop that produced a book summarizing knowledge about selenium in the aquatic environment.

In addition to the above, Teck chairs the Canadian Industry Selenium Working Group (CISWG). The CISWG members were a significant funder, organizer and participant in the Society of Environmental Toxicology and Chemistry (SETAC) Pellston workshop in 2009. The SETAC Pellston was an international workshop with leading scientists from academia, government and industry who reviewed the current state of knowledge on selenium.[16]

Teck also co-chairs the North American Metals Council – Selenium Working Group (NAMC – SWG), an international group formed to advance knowledge on selenium and to promote research on this element and its effects on the environment.[17]

[16] A summary of the workshop's ecological assessment of selenium in the aquatic environment is available for review at http://www.setac.org/node/265.

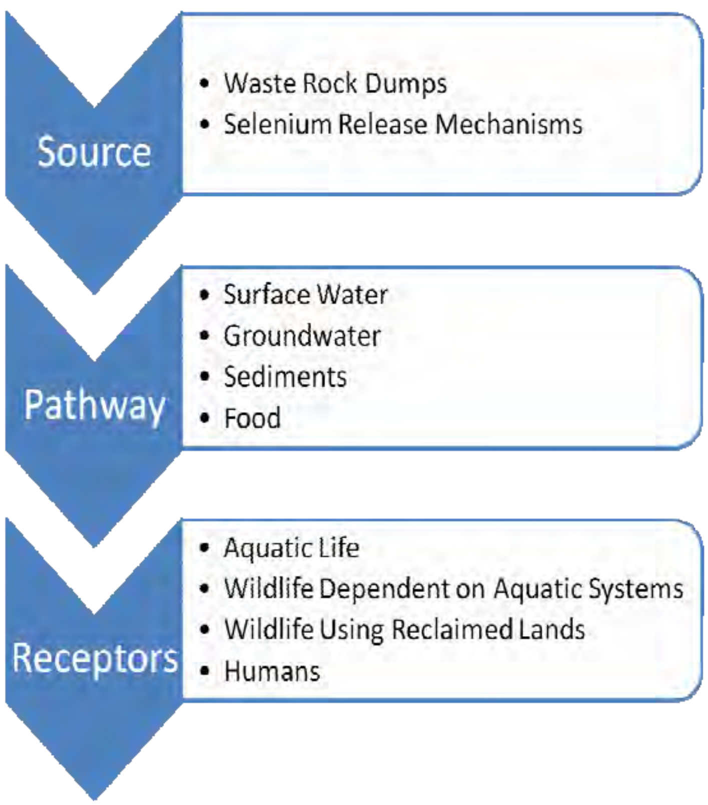
[17] White papers on the current state of selenium research prepared by this group are available for review at http://www.namc.org/selenium.html.

There are still gaps in our knowledge of selenium effects in the environment, but the focus can now shift towards an integrated mix of research and translation of that research into action.

The above work has provided a foundation for the Panel's development of this strategic plan. While there are still gaps in the state of knowledge on the effects of selenium in the environment, much has been learned. The focus of additional work can now shift toward an integrated mix of targeted research, the translation of that research into specific pilot projects, other management interventions, and monitoring to gather feedback and make corrective adjustments in the management path.

A Source-Pathway-Receptor framework was used by the Panel as a method of organizing information about selenium.

The Panel decided that a "source-pathway-receptor" framework was useful for organizing existing knowledge about selenium as well as potential selenium management options (Figure 3). The source of selenium is the rock from which coal is mined. This rock influences background concentrations, and where disturbed and placed as waste rock, releases elevated levels of selenium to the receiving environment. Release mechanisms from the waste rock include transformation of selenium to soluble forms (primarily as selenate) via contact with oxygen and water.

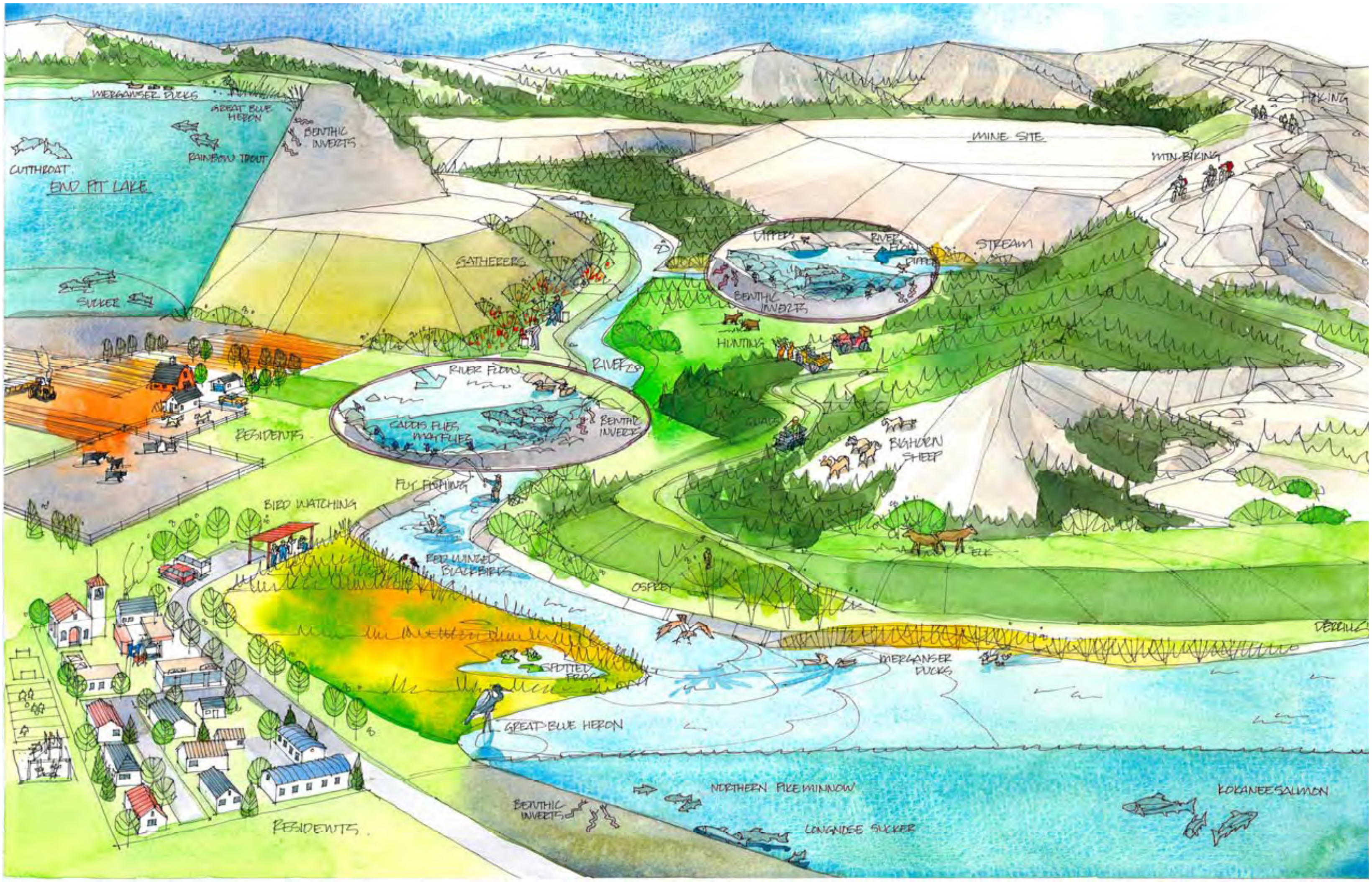


Selenium is released to streams or groundwater unless it is attenuated through reduction to less mobile forms in low flow, low oxygen environments.

Receptors such as algae, bottom-dwelling invertebrates, and fish can take selenium up into their tissues from water, sediment, or food.

Once released, selenium follows pathways (streams, near-surface groundwater) to the receiving environment, unless it is attenuated through reduction to less mobile forms (selenite, elemental selenium or selenide) in low flow, low oxygen environments (such as marshes and saturated sediments). Receptors in the receiving environment include aquatic organisms such as algae, bottom-dwelling and water-column invertebrates, and fish. These receptors can take selenium up into their tissues directly from water or sediment, or from food. Wildlife (including amphibians, birds, and mammals) that eat aquatic organisms are part of the aquatic-based pathways, and can also be exposed to selenium via water, sediment, or food. Other wildlife such as elk and bighorn sheep are part of terrestrial-based pathways where selenium is taken up by plants growing on waste rock. The plants are, in turn, consumed by wildlife. Humans are receptors in both aquatic and terrestrial systems; exposure may be via drinking water, consumption of fish, or consumption of plants or wildlife.

Figure 3: Conceptual Model of Selenium Sources, Pathways and Receptors



Elk on reclaimed land – an example of a wildlife receptor.

A stonefly nymph – an example of an aquatic receptor

The current understanding of selenium at the source (Table 4), along pathways (Table 5), or at the point where selenium interacts with one or more receptors (Table 6) has guided the Panel in the development of this strategic plan.

Risk assessment will be an important tool for use in adaptive management of selenium. Table 6 highlights the need for ecological risk assessments that, in turn, can inform risk management decisions. Ecological risk assessment involves the determination of the amount of risk (in this case from selenium exposure) to populations and communities of organisms. Laboratory studies (and to some extent field studies) have shown thresholds for effect in individual organisms; however, there is still controversy regarding when effects at the population level will occur. Thus, there is uncertainty about how much risk management will be enough to protect populations. Once the risk associated with selenium is better understood, management of that risk can proceed with more confidence.

Although there are still many unknowns, the Panel believes that these unknowns are insufficient grounds for delay. For example, water treatment technology is at the stage where some methods are applicable, when properly configured with primary, tertiary and residuals treatment (Table 7).

The summaries of "knowns", "unknowns", and "implications for management" in Tables 4-7 are based upon extensive literature reviews as well as the knowledge and experience of Panel members.

References to the literature upon which Tables 4-7 are based will be provided upon request.

Table 4: Selenium Sources: Knowns and Unknowns and Implications for Management

	KNOWN	UNKNOWN
Release	• Se load to the Elk River increasing 6-8%/year, based on concentration in receiving water • Rate of release at Elk River watershed scale is proportional to tonnage • Rate varies by 10X and is highest from dry, out-of-pit waste rock with rock drains • Rock that is backfilled and/or partially saturated has lower Se release • Se release associated with elevated SO_4 (sulfide oxidation), NO_3 (blasting residue) • Se released by weathering of Se-sulfide and dissolution of Se-SO_4 minerals • In Elk River (Mist Mtn Formation), no one lithotype contributes dominant load • In Cardinal River (Gates Formation), Moosebar shale has higher Se/surface area, so loading is higher • Reduced Se (Se^{2}-, Se_o) is oxidized to the mobile and toxic SeO^3 and SeO_4 forms	• Continuity of rate of release (anticipate increase, then long-term decrease) • Lag time in sulfide oxidation rate controlling Se release typical in dumps, depending on wetting requirements and buffering of pyrite oxidation • Relative distribution and rate of depletion of Se between mineral sources • Influence of local mineralogical variation • Potential increase of low level trace metals associated with sulfide oxidation

IMPLICATIONS FOR MANAGEMENT

- Divert and treat water
- Selective handling of high-Se rock not feasible at Elk Valley operations
- Selective handling of Moose Mtn Shale is feasible at Cardinal River operations (CRO)
- Selectively handle clean, low-Se rock for drains, construction
- Monitoring and trend analysis required
- Monitor for solutes other than Se, SO_4, NO_3
- Likely reduced if sulfide oxidation and secondary acid neutralizaton is reduced

	KNOWN	UNKNOWN
Attenuation	• Reduced Se is less soluble and more likely to remain at source • Bacteria reduce Se when oxygen is low and carbon and water are available • Abiotic reduction is less common than biological reduction • Facultative bacteria can reduce oxygen and then switch to selenate reduction • Oxidized SeO_3 and SeO_4 adsorb to the surface of iron and manganese oxide minerals • Selenide gas and methylated Se compounds are volatile and can dissipate into the air • Methylated Se compounds are less toxic but more available for bioaccumulation	• Oxygen consumption factors within waste • Moisture and bioavailable carbon contents of facilities • Availability of sorptive substrate for Se attenuation • Ability to use native carbon vs. process reagents added to tailings, Coarse Coal Projects (CCR)
IMPLICATIONS FOR MANAGEMENT		
• Design for low flux, prolonged residence time		

	KNOWN	UNKNOWN
Dumps	• Variable Se release, ranging from 4E^{-7} to 6E^{-6} kg/year/bank cubic metre between facilities in 2009 • Rate of Se release varies seasonally and from year to year • Large end-dumped, angle-of-repose piles, partial reclamation, many partial or cross valley fills • Temperature increasing with depth at Line Creek in situ monitored wells in waste rock • Variable O_2 content, 5 to 20%, decreasing at lower depth • Carbon dioxide accumulation with increasing temperature at depth indicates biological activity • Increasing temperature suggests exothermic biological or mineral oxidation process • Geotechnical instability with potential for flowslide • Direct reseeding of run-of-mine rock, limited use of store and release covers, no synthetics • Use of loose material placement on compacted surface for revegetation • Development of dendritic drainage to enhance runoff term	• Pore water chemistry • Water balance at facility, mine and watershed scale • Evaporation data • Insitu monitoring of gases, temperature at Greenhills Line Creek - ongoing study • Relative influence of microbial activity vs. abiotic sulfide oxidation/acid neutralization • Capacity of attenuation mechanisms • Influence on moisture and gas content, microbial activity, Se release • Influence on infiltration and water balance • Relative effectiveness is unclear

IMPLICATIONS FOR MANAGEMENT

- Investigate whether covers, reconstruction can be accomplished on existing large dumps
- Identify locations to pull material back from drainage and cap (e.g., Harmer)
- Monitor evaporation and adjust water balances
- Evaluate response of these factors to dump design at pilot scale
- Design facilities to promote in situ source control
- Manage dumps to minimize Se release through source control
- Manage dumps to minimize oxidation - limit all solutes, calcite, exc. NO_3

<table>
<tr><td rowspan="2">Rock Drains</td><td>KNOWN</td><td>UNKNOWN</td></tr>
<tr><td>• Variable magnitudes of Se release
• Some water running into drains contains Se already, some does not
• Release rate is higher for dry dump complexes with drains, $9E^{-7}$ to $6E^{-6}$ kg/yr/bank cubic metre
• Se load from dumps discharging through drains is highest at Kilmarnock, West Line Creek, Cataract, Erickson</td><td>• Relative contribution of rock above, and rock within, drains to discharge
• Lithologic composition of drains</td></tr>
<tr><td colspan="3">IMPLICATIONS FOR MANAGEMENT
• Variable potential to divert clean water
• Avoid cross-valley fill, rock drain construction
• If unavoidable, construct with select clean, massive rock
• Determine probable mass removal and validate through monitoring</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="2">Tailings</td><td>KNOWN</td><td>UNKNOWN</td></tr>
<tr><td>• Elkview, Fording R., Cardinal R. tailings ponds have low Se release
• In situ evidence that O_2 concentration is low, water content is high
• Microbial community capable of Se reduction has been identified in situ at Elkview
• Reagents MIBC and kerosene added in flotation are bioavailable for some bacteria</td><td>• Consistency across tailing ponds at different mine sites
• Long-term stability of reduced Se phases? Source of other solutes?
• Physical characteristics (particle size, O_2, iron minerals) driving Se reduction?
• Native carbon or flotation reagents driving Se reduction?
• Is microbial community consistent at operations other than Elkview, also coarse coal rejects?</td></tr>
<tr><td colspan="3">IMPLICATIONS FOR MANAGEMENT
• Support oxygen reduction, subaqueous waste management
• Co-disposal potential of coarse coal rejects and/or tailings with waste rock to enhance source control
• Evaluate abiotic and biotic rates, with and without process additives
• Divert water to tailings impoundment for Se removal</td></tr>
<tr><td colspan="3"></td></tr>
</table>

<table>
<tr><td rowspan="2">Coarse Coal Reject Piles</td><td>KNOWN</td><td>UNKNOWN</td></tr>
<tr><td>CCR piles demonstrate reduced Se release
Insitu evidence from Greenhills of increasing CO_2 and temperature with decreasing O_2 in upper pile
O_2 variable but consistently below detect for between 20-60 feet in monitored wells
Temperature decreases with depth (as opposed to waste rock, which increases)</td><td>Consistency across CCR at different mine sites, under different hydrodynamic conditions
Long-term stability of reduced Se phases? Source of other solutes?
Physical characteristics (particle size, O_2, iron minerals) driving Se reduction?
Native carbon or flotation reagents driving Se reduction?
Microbial community consistent at operations ?</td></tr>
<tr><td colspan="3">IMPLICATIONS FOR MANAGEMENT
Supports oxygen reduction, subaqueous waste management
Co-disposal potential with waste rock to enhance source control
Evaluate abiotic and biotic rates, with and without process additives
Use CCR in reactors (based on Golder Research) to reduce Se</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="2">Sediment Ponds</td><td>KNOWN</td><td>UNKNOWN</td></tr>
<tr><td>Se-rich sediment accumulates in the ponds</td><td>Factors controlling Se sequestration - sorption, precipitation, biological activity</td></tr>
<tr><td colspan="3">IMPLICATIONS FOR MANAGEMENT
Manage sediment when removed to prevent remobilization of Se</td></tr>
<tr><td colspan="3"></td></tr>
</table>

Pits	KNOWN	UNKNOWN
Open Pits	• Se discharges from some exposed highwalls and surrounding waste rock dumps • Many affected drainages headwater in the pits • Difficult to collect water in open pits	• Is the reduction process biotic? Abiotic? • Water balance for pit lakes including groundwater flux
Backfilled Pits	• At Cardinal River, Se load is reduced under backfill conditions where saturation exists • Backfilling reduces footprint of disturbance, of external dumps, and need for rock drains	
End Pit Lakes	• Se can be elevated to 50-70 µg/L • Still water enhances potential for bioaccumulation • Dilution by groundwater contribution at Cardinal River	• Potential for meromixis in designed end pit lakes in order to sequester Se in anaerobic and permanently stratified bottom water layer • Se reduction in meromictic lake relative to in situ biological reduction in passive barrier

IMPLICATIONS FOR MANAGEMENT

- Dewater pits before mining; restore groundwater at closure
- Value of more systematic comprehensive mine planning that integrates pit design for both coal extraction and waste placement avoids rehauls and distance hauls by consolidating operational focus
- Design passive biological reduction barriers into backfill, dump designs
- Use end pit lakes as biological treatment reactors or design for meromixis

	KNOWN	UNKNOWN
Deep Groundwater	• Se in deep groundwater monitored at Cardinal River is at or below detection limit	• Attenuation limiting impacts to groundwater? Lag time? Dilution?

Table 5: Selenium Pathways: Knowns and Unknowns and Implications for Management

	KNOWN	UNKNOWN
Source	• Water running into, onto, precipitating onto waste picks up Se • Se acquisition is greater in fine materials with large surface area • Headwaters are often buried or in pit areas • Rock drains downgradient of large dry dumps associated with high Se load	• Groundwater hydrology and chemistry
IMPLICATIONS FOR MANAGEMENT		
• Consider nested management options at watershed scale (divert clean water to reduce volume for treatment) • Design new facilities to collect impacted water - slope pit floor toward collection point • Design new facilities to protect headwaters, emphasize diversion of clean water • Reuse selenium impacted water in processing coal		
	KNOWN	**UNKNOWN**
Sinks	• Groundwater environment seems to support reduction of soluble Se • Slow flow under low oxygen conditions promotes Se reduction	• Extent and influence of losing and gaining reaches in affected drainages
IMPLICATIONS FOR MANAGEMENT		
• Design mines to develop adequate subsurface placement for waste - in situ source control		

Dumps

	KNOWN	UNKNOWN
Engineered Dumps	• Se elevated in toe-seep discharges, rock drains • Ponded water, operational discharges, snow contribute water • Surface water in drainages that are filled with waste rock • Efforts to construct cover on large run-of-mine dump at Coal Mountain unsuccessful	• Magnitude of groundwater run-on • Magnitude of evaporation • Water content of dumps as function of depth, management, setting • Magnitude of discharge to groundwater • Rock:Water % interaction - extent of preferential flow? • Geotechnical construction limits to cover placement • Influence of reduced water flux, reduced oxygen available on Se mobility • Geotechnical limitations to design of wet intra-dump barriers

IMPLICATIONS FOR MANAGEMENT

- Dumps should be designed and managed to reduce solute transport: Change water infiltration through design, limit O_2 flux, and manage water to promote insitu reduction
- Divert clean water around mined rock
- Collect and reuse selenium impacted water
- Seasonal diversions - pump only when needed

	KNOWN	UNKNOWN
Rock Drains	• Water runs into drains along established channels • Water seeps into drains from overlying rock	• Water balance and mass load calculations for rock drains • Relative saturation of overlying rock • Pore water chemistry of overlying rock

IMPLICATIONS FOR MANAGEMENT

- Do synoptic monitoring, in situ characterization of waste moisture/chemistry
- Do a diversion test - monitor downgradient changes as result of diversion
- Dewater or divert during construction, reconstruct in controlled channel on dump later
- Tracer study

	KNOWN	UNKNOWN
Tailings	• Groundwater flow into dumps via buried seeps/springs likely • Saturated conditions dominate during operations	• Change in reduction capacity with consolidation, dewatering • Required conditions, residence time for Se removal
IMPLICATIONS FOR MANAGEMENT		
• Offers change in flow characteristics for co-disposal • Change in saturation at closure?		
Coarse Coal Reject Piles	**KNOWN**	**UNKNOWN**
	• Coarse-grained coaly rock is placed as wet rock following process • Magnetite added to enhance separation during beneficiation	• Change in reduction capacity with consolidation, dewatering • Required conditions and residence time for Se removal
IMPLICATIONS FOR MANAGEMENT		
• Evaluate influence of CCR co-disposal on water flow		
Sediment Ponds	**KNOWN**	**UNKNOWN**
	• Sediment traps very useful in reducing load • Ponds may function as Se-reducing environments under slow flow	• Required residence time for optimum Se removal as function of flow • Geochemical stability of recovered sediment
IMPLICATIONS FOR MANAGEMENT		
• Se accumulation - sludge disposal?		

Pits	KNOWN	UNKNOWN
Open Pits	• Mountain-top and side-hill pit configurations make water collection difficult	
Backfilled Pits	• Backfilled pits developed at water table support Se reduction • Rock above water table will need design support to facilitate biotic reduction	• Effectiveness of designs to enhance water availability in backfilled bioreactor
End Pit Lakes	• Seasonal overturn relative to water discharge, groundwater inflow affect Se	• Does meromixis support sufficient limitation of Se in biotic zone?

IMPLICATIONS FOR MANAGEMENT

- Promote meromixis to limit Se accumulation in biologically active zones
- Maximize opportunities for backfill at water table through design of pits, haul patterns
- Consider leaving some mountaintop resource in place to reduce volume of out-of-pit placement required
- Design to avoid biological accumulation at primary productivity level

Table 6: Selenium Receptors: Knowns and Unknowns and Implications for Management

WATER AND SEDIMENT	
KNOWN	**UNKNOWN**
• Se is mobilized from waste rock primarily in the selenate form (which is the most water-soluble but least bioavailable form of Se) and generally remains mainly as selenate in lotic (flowing-water) systems. • In wetlands (lentic systems), Se cycling is enhanced because of chemical reduction of Se to more bioaccumulative forms (e.g., selenite and organic Se), especially in the detrital-sediment pathway of vegetated wetlands. • Organic-rich fractions of sediment and associated periphyton (sessile organisms, such as algae and small invertebrates, that live attached to surfaces projecting from the bottom of a freshwater aquatic environment) have higher Se concentrations than mineral sediment and are available for ingestion by benthic (bottom-dwelling) invertebrates. • Wetland sediment serves as a reservoir for cycling of Se long after discharges of Se to that habitat have ended (based on information from other areas).	• Although it is clear that oxygen and water in contact with waste rock (along with associated microbial activity) contribute to mobilization, rates of mobilization and the expected duration for such mobilization from rock are not well established. • Details of the processes contributing to Se cycling are not clearly established for all kinds of wetlands in the mining-affected watersheds. • Details of the processes affecting Se uptake from organic-rich sediments are not clearly established for all kinds of wetlands in the mining-affected watersheds. • Expected duration of continued recycling of Se from sediment through wetland food webs in the mining-affected watersheds is not known.
IMPLICATIONS FOR MANAGEMENT 1. Minimize the availability of oxygen and water to waste rock where Se may be mobilized. 2. Avoid creating wetlands as receiving environments for drainage from mines, because of their potential to become "attractive nuisances;" i.e., habitats that attract wildlife but with elevated ecological risk caused by enhanced Se uptake and transfer in food chains. 3. Weigh habitat values of existing wetlands; i.e., their value as habitat versus their attractive nuisance conditions, in order to determine if they should be removed. Consider developing off-site wetlands using water from clean sources as mitigation for Se-affected habitats such as Clode Pond and Goddard Marsh.	

INVERTEBRATES

KNOWN	UNKNOWN
• Invertebrates accumulate Se from water and their food; food-chain length and different feeding habits of invertebrates contribute to variable bioaccumulation and varying amounts of organic vs. inorganic Se in their tissues (which would affect bioaccumulation rates in fish or birds that eat them). • Bioaccumulation factors (tissue Se divided by waterborne Se) are highest when waterborne Se concentrations are lower, probably because Se is an essential nutrient and animals sequester it when concentrations are lower. • Benthic invertebrates in lentic (still-water) systems accumulate more Se than those in the water column or in lotic (flowing-water) systems. • Se concentrations in invertebrates in lentic habitats are often greater than 20 mg/kg dw, whereas dietary effect levels for some fish and birds are less than half that concentration.	• • Effects of Se on invertebrate diversity and abundance in mining-affected portions of the watersheds are unclear, although fish and birds are generally considered to be capable of changing their food preference if there are shifts to more Se-tolerant invertebrate taxa. • The trophic relationships (who eats whom) of invertebrates and the interactions between trophic position and chemical forms of Se in invertebrate tissues in mining-affected watersheds are not well understood. This makes accurate prediction of Se transfer in food chains difficult. • The degree to which different chemical forms of Se bioaccumulate in invertebrates in the mining-affected watersheds is not well known, though overall bioaccumulation rates are being determined through continued co-located sampling of water and invertebrates. • Although there is a general understanding of the processes involved (e.g., residence time of water, chemical forms of waterborne Se, ecological productivity), specific factors that might be controllable for wetlands so that Se is not as available for uptake are not well known.

IMPLICATIONS FOR MANAGEMENT

1. Continue to refine understanding of Se relationships in food webs for fish and birds in the mining-affected watersheds so that ecological risk assessments can develop risk-based information to make management decisions.
2. Use of simple bioaccumulation factors to estimate invertebrate tissue Se based on waterborne Se regardless of concentrations in water can give misleading results and should be avoided.

FISH	
KNOWN	**UNKNOWN**
• Fish accumulate Se primarily from their food; differences in feeding habitats and food preferences of individuals, as well as among species, affect tissue Se in fish; as for invertebrates, bioaccumulation factors are higher when waterborne Se concentrations are lower. • Se concentrations in fish from lotic habitats are more variable than those from lentic habitats because fish may move from exposed to reference sites and vice-versa. • Se is transferred to eggs primarily from body reserves (endogenous source); exposures to selenium during the time eggs are developing determine Se transfer to eggs; larval deformities are the most sensitive endpoint for Se effects in fish. • Laboratory and field studies have shown that EC10 Se concentrations (the concentration that affects 10% of offspring) in eggs-ovaries vary widely (and these are being used by USEPA in the new proposed draft ambient water quality criteria). For coldwater species, including species that may be in the Elk River and Gregg/McLeod rivers systems, EC10 values (mg/kg, dw) are as follows: o *Salmo* (brown trout) 17.8 o *Oncorhynchus* (rainbow & cutthroat trout) 22.6 o *Esox* (northern pike) 34.0 o *Salvelinus* (brook trout & Dolly Varden) 56.2 • Cutthroat, rainbow, and brook trout studies used by USEPA included lab-field studies from the watersheds of the Elk or Gregg/McLeod rivers. Eggs of some trout from these watersheds, especially from lentic habitats exceed the EC10 for the respective species.	• There is limited information about the relationships between Se concentrations in invertebrates (as diet) and in fish tissue, although information from the 2009 monitoring in the Elk River watershed suggests high variability but potential relationships between individual food preferences and tissue Se. • Fish movement patterns in the mining-affected watersheds have been documented through tagging studies and use of otoliths to determine exposure patterns throughout the fish's life, but the extent of movement between affected and unaffected areas is still somewhat unclear in some portions of the watersheds. • The population-level significance of increased incidence of larval deformities alone (though a sensitive indicator of Se-related effects) is unclear if mortality is not severe; threshold effect levels are based on a combination of incidence of deformities and larval survival. • Toxicity to many species (e.g., bull trout, mountain whitefish, sculpins) has not been tested, and effect levels for other species are used to estimate potential for effects in these species. Effects at the population level are difficult to determine in stream environments, because of fish movement. Relative significance of Se toxicity in comparison to other factors (e.g., food availability, habitat linkages, and refugia) is not clearly established. • Egg-ovary Se concentrations in some other species (especially mountain whitefish from the Elk River watershed and longnose suckers in lentic habitats of the Elk River watershed) are substantially higher than the expected USEPA water quality criterion for fish egg-ovary tissue, but effect levels in these species are not known.

IMPLICATIONS FOR MANAGEMENT

To assist in the development and refinement of ecological risk assessments that, in turn, will inform risk management decisions:

1. Continue to refine our understanding of Se relationships in food webs for fish in the mining-affected watersheds (e.g., by collecting co-located invertebrates and fish).
2. Avoid use of simple bioaccumulation factors to estimate invertebrate tissue Se based on waterborne Se because results can be misleading.
3. Continue to refine our understanding of movement patterns for fish in the mining-affected watersheds.
4. Increase our understanding of the ecological significance of deformity rates for fish in the mining-affected watersheds.
5. Develop effect threshold concentrations for mountain whitefish, in particular, because of the very high concentrations found in ovaries of fish from the Elk River watershed (relative to other fish species).

<table>
<tr><th colspan="2">AMPHIBIANS</th></tr>
<tr><th>KNOWN</th><th>UNKNOWN</th></tr>
<tr><td>▪ Amphibians (e.g., Columbia spotted frog) are sensitive to the adverse effects of elevated Se; there is an apparent association of Se concentrations in eggs with impaired reproduction (reflected as embryo mortality and deformities).</td><td>▪ The threshold for reproductive effects is not clear, though it is apparently similar to that for some of the more sensitive fish species.</td></tr>
<tr><th colspan="2">IMPLICATIONS FOR MANAGEMENT</th></tr>
<tr><td colspan="2">To assist in the development and refinement of ecological risk assessments that, in turn, will inform risk management decisions:

1. Continue to investigate the effects of Se on frog reproduction and, in turn, on frog populations in lentic habitats of the mining-affected watersheds.</td></tr>
</table>

BIRDS	
KNOWN	**UNKNOWN**

▪ Birds accumulate Se primarily from their food; Se is transferred to eggs primarily from current dietary exposure (i.e., exogenous source), so Se concentrations in eggs quickly reflect local exposure; egg hatchability is the most sensitive endpoint for birds.
▪ Laboratory and field studies have shown that EC_{10} Se concentrations (the concentration that reduces hatching success by 10%) in eggs vary widely (even between closely related species). For species such as those that may be found in the Elk River and Gregg/McLeod watersheds, threshold values (mg/kg dw) are as follows:
  o Mallard (a sensitive species considered a surrogate for other duck species) 7.7-12.0 depending on the study and statistical approach used
  o Dipper 8.4; 15% depression in egg viability
  o Red-winged blackbird 22; threshold for reduced egg hatchability
▪ Teratogenic effects (i.e., embryo deformities) occur when dietary exposures are higher than those that affect egg hatchability; for example, the EC_{10} for mallards (considered a "sensitive" species) is 23 mg/kg dw.
	▪ Bird movements between some mine-affected areas and reference sites (or some other unknown factors) result in egg Se concentrations that sometimes are not markedly different between exposure and reference sites.
	▪ Studies of waterfowl have had very limited success, primarily because of the difficulty in locating and monitoring nests. Similarly, although studies of other species have been conducted in mining-affected watersheds, those studies may be difficult to complete (e.g., due to environmental factors such as weather-related effects on nesting) with adequate sample sizes for robust assessment of effects, and population-level effects must be extrapolated from effects on egg hatchability or nestling survival.
	▪ Sensitivity of the aquatic-dependent species in mining-affected portions of watersheds to Se-related deformities is not known.

IMPLICATIONS FOR MANAGEMENT

To assist in the development and refinement of ecological risk assessments that, in turn, will inform risk management decisions:

1. Continue to refine our understanding of Se relationships in food webs for aquatic-dependent birds in the mining-affected watersheds (e.g., by collecting co-located invertebrates and bird eggs).
2. Avoid use of simple bioaccumulation factors to estimate egg Se based on invertebrate tissue Se (except in initial risk screening steps) because this can give misleading results. Continue to refine our understanding of relationships (spatial and temporal) and significance of Se in eggs for aquatic-dependent birds in the mining-affected watersheds (e.g., by collecting co-located invertebrates and bird eggs).
3. Avoid use of effect levels for other species or locations to estimate effects of Se on bird nesting success (except in initial risk screening) because this can give misleading results.
4. Continue to examine embryos in field-collected bird eggs for Se-related deformities, though incidence is expected to be low.
5. Conduct longer-term research and/or population modelling for birds exposed to elevated selenium in their diet and with increased embryo deformities in order to allow for more confident prediction of risk to bird populations.

<table>
<tr><th colspan="2">MAMMALS (NON-HUMAN)</th></tr>
<tr><th>KNOWN</th><th>UNKNOWN</th></tr>
<tr><td>

- Like other animals, mammals accumulate Se primarily from their food; in general, more information is available about exposure levels and potential effects for ungulates (e.g., domestic livestock, bighorn sheep) and small mammals than for most other species. Mean Se concentrations in livers, blood, and hair of bighorn sheep from Alberta mines were within normal ranges, though some individuals exceeded the normal range for liver or blood serum. Se concentrations in forage did not exceed the "adequate" range for sheep.

</td><td>

- Little information is available for carnivores/piscivores in general; those species have not been sampled in the Elk or Gregg/McLeod rivers watersheds, and small mammals have not been sampled on reclaimed mine areas. Se concentrations have not been reported for Elk Valley bighorn sheep using the reclaimed mine areas.
- Do reclaimed areas represent a net benefit for bighorn sheep and elk, or do they represent a "sink" that subjects the animals to greater predation than would exist under natural conditions?

</td></tr>
<tr><th colspan="2">IMPLICATIONS FOR MANAGEMENT</th></tr>
<tr><td colspan="2">

1. Determine Se concentrations in bighorn sheep using Elk Valley mines (as proposed in 2008, but report not seen); continue to monitor bighorn sheep for Se in liver (periodically, to determine relationship to blood Se), blood, and hair, and monitor health status and population levels of bighorn sheep on the reclaimed mine habitats.
2. Periodically determine overall population distribution and status of bighorn sheep populations in the Elk Valley and vicinity of the Alberta mines to determine whether populations are stable, increasing, or decreasing.
3. Avoid planting of hyper-accumulating vegetation on waste rock dumps, and seek to reduce the available selenium in the root zone of reclaimed areas.

</td></tr>
</table>

HUMANS	
KNOWN	**UNKNOWN**
▪ People use areas in the Elk and Gregg/McLeod rivers watersheds for many forms of recreation, including fishing, hunting, mountain biking, hiking, off-road (ATV) travel, back-country camping, and there is a strong desire in the communities to maintain or expand recreational opportunities. ▪ Proximal communities to mine operations affecting the Elk and Gregg/McLeod Rivers including Sparwood, Cadomin and Edson use groundwater for some or all of their drinking water supply. ▪ A human health risk assessment conducted in 2000 using fish data from the Elk River and Fording River (assuming "catch-and-consume" cutthroat trout fishery despite the existence of size restrictions and primarily catch-and-release fisheries in the basin) concluded there was a negligible human health risk from eating fish from the Elk River watershed. Scenarios evaluated included native fishers as well as recreational fishers, though no native subsistence fishery is known to exist in the basin. The risk assessment compared exposure via fish consumption with exposure limits set by regulatory agencies. Health Canada has defined "the highest average daily nutrient intake level likely to pose no risk of adverse effects to almost all individuals in a given life-stage and gender group" as a daily intake of about 5.5 µg/kg body weight. The United States Environmental Protection Agency (U.S. EPA) and the U.S. Agency for Toxic Substances and Disease Registry (ATSDR) have set the selenium exposure limit at 5 µg/kg body weight/day. The estimated exposure via fish consumption was much less than 5 µg/kg body weight/day.	▪ There has not been a human health risk assessment conducted that evaluates the risk of selenium exposure via all exposure pathways (drinking water, inhalation, bathing and incidental skin contact with water or sediment, and food) in the Elk Valley or in the Gregg/McLeod watersheds. ▪ The potential connectivity between selenium-affected water and its fate regarding groundwater presence or influence, especially as it may affect drinking water supplies.

Selenium concentrations have to be several thousand times higher than normal in drinking water or food to cause effects from a short exposure (hours to days) and 10-20 times higher than normal to cause longer-term effects (over several years).	

IMPLICATIONS FOR MANAGEMENT

1. Identify and delineate zones within the Elk River and its tributaries as well as the Gregg/McLeod Rivers where Se concentrations exceed the drinking water quality guideline of 10 µg/L.
2. Conduct a human health risk assessment that assumes consumption of drinking water from zones that exceed the drinking water guideline as well as exposure via skin contact and via eating of fish. Respond to the results of the human health risk assessment according to its results. Communicate the results of the risk assessment to stakeholders in the Elk Valley and in the Hinton area.

Table 7: Selenium Treatment: Knowns and Unknowns and Implications for Management

KNOWN	UNKNOWN
• There are several biological, chemical, and physical treatment processes that can treat Se to 5 µg/L or less when properly configured with primary, tertiary and residuals treatment.	• The specific primary, tertiary, and by-product treatment process to be used depend upon the water source and selected core Se treatment technology.
• The primary design basis for each Se treatment system is hydraulic or flow based, thereby requiring equalization or diversion systems when flows exceed the design flow capacity.	• An appropriate configuration of the Se treatment system to address other future surface water quality issues (e.g., calcite).
• Other water matrix parameters (e.g., temperature, pH, ionic strength, hardness, etc.) will affect the performance of the Se treatment technology if not addressed in design.	• The specific tertiary treatment configuration to meet conventional discharge requirements.
• The mass of Se has little effect on the treatment system size, and the performance generally improves with increase in mass of Se.	• Startup, shutdown and operation procedures during a potential seasonal event when the water source freezes and power may be lost.
• Controlling the environment in which the biological, chemical, and physical treatment of Se occurs greatly improves the Se treatment system performance thereby favouring a more process-oriented system versus a passive system for low-level Se treatment.	• An appropriate equalization and diversion system, if any, to maximize the volume treated versus designing the Se treatment system to handle 6 to 12 times the base flow during dry weather months.
• Treatment of Se to levels of 5 µg/L or less with the core treatment technology results in a discharge that will require tertiary treatment for other regulated discharge parameters (e.g., total suspended solids, dissolved oxygen, pH, biochemical oxygen demand, etc.)	• Instrumentation and control systems to automate the Se treatment systems that are located in extremely remote areas.
• Treatment system costs considering the Se mass removed compared to other conventional pollutant parameters are excessive, with the biological based systems having the lower cost systems.	• Security systems to protect Se treatment infrastructure located in remote locations.

IMPLICATIONS FOR MANAGEMENT

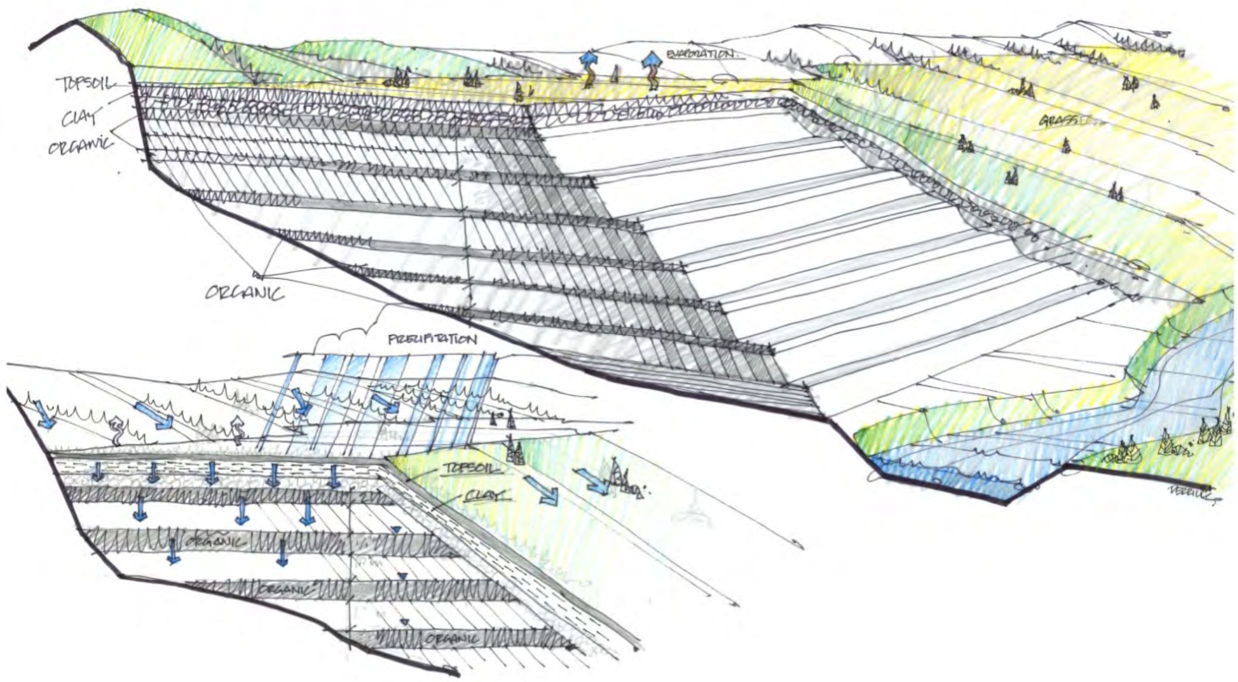
- Additional treatability testing may be merited to better define the primary, tertiary, and by-products treatment requirements around a given core Se treatment process.
- A comprehensive understanding of the seasonal flow rates and other water matrix parameters is required to design a Se treatment system where performance guarantees are desired.
- While passive systems are more sustainable, they do not completely control the environment, therefore resulting in lower Se treatment performance at times as well as requiring tertiary treatment facilities with relatively large footprints for treatment of conventional parameters.
- Most locations do not have a large enough area to accommodate large flow equalization or flow diversion infrastructure, thereby requiring a system to be over sized during the dry weather periods.
- Resource requirements, access roads and security systems are an important consideration for water treatment, especially in remote areas.
- Equipment, instrumentation, and power redundancy requirements for continuous operation.
- On-site disposal structures for management of concentrated Se residuals or by-products with a potential for ultimate Se resource recovery.

Examples of Teck Selenium Management Actions

The Panel recognizes Teck Coal's recent efforts to develop much of the information summarized above. The company has already begun to act on many of the "implications for management" within the source-pathway-receptor framework, and has developed selenium management plans for each operation. Examples of specific selenium management measures taken by Teck Coal include the following:

- Some waste rock dumps are being built in lifts, similar to the design shown in Figure 4 (addressing the source of selenium by reducing mechanisms for release).

Figure 4: Conceptual Illustration of New Waste Rock Dump Design



Example of reclaimed waste dump with soil cap, hummocky landform design and vegetation.

- Landform grading and landform design (including revegetation) for water management are underway at several waste rock dumps (thus reducing water running onto waste dumps, which, in turn, would contribute to selenium release).

- Existing Coarse Coal Rejects and Tailings management practices appear to limit selenium release to the aquatic and terrestrial environments, and some research is focused on understanding that sequestration.
- Some rock drains have been constructed with clean rock to reduce the potential for the drains to accelerate oxidation (oxidation creates the selenate form of selenium, which is the form that is released via surface water and groundwater).

Coarse Coal Rejects.

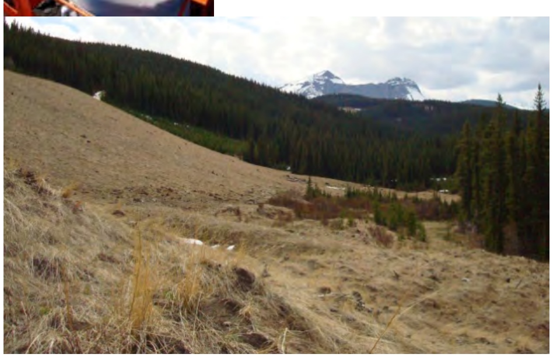
Diverting water into a rock drain.

- Water diversions have been constructed around some active pits (thus reducing water running onto or through waste dumps which, in turn, reduces the potential for selenium release).
- Water flows and water chemistry are being measured with greater frequency and accuracy, evaluated for quality, assessed using load models, and more clearly reported to a broader audience, thus increasing the understanding of selenium sources, release mechanisms, and pathways.
- Mine plans are including backfilling into pits, with the aim of reducing out-of-pit waste dumps (which have associated problems of high oxygen content plus water exposure creating selenium release); backfilling creates a waste environment that decreases selenium release by placing waste rock below the water table where low oxygen limits oxidation and promotes selenium reduction to insoluble forms.

Pit with backfill.

- Scale-dependent hydro-geochemical evaluations of selenium release mechanisms are underway that will provide important understanding of how much selenium control will be possible under different management strategies.

Field evaluations of hydro-geochemical mechanisms of selenium release.



- Covers are being constructed on some waste rock piles to reduce water and oxygen flux into the dumps. Thus, less selenium is converted to mobile forms and potential is created for immobilization of selenium.

Cover plus vegetation on an historic waste dump.

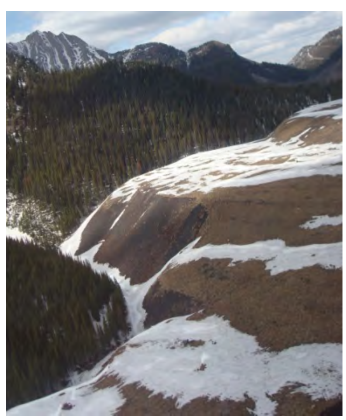
Construction of pilot passive treatment system.

- Research and development into passive treatment of selenium-affected waters is underway, including pilot scale field trials
- There are selenium management teams and management plans at each mine, being directed corporately.
- Mine planning and construction focused on development of comprehensive and effective selenium management has begun, albeit at varying levels of intensity.
- There is an active community and regulatory affairs program within Teck Coal.

The above actions are a positive reflection of Teck's commitment to sustainable selenium management.

The Panel observes a need to apply and amplify Teck Coal's current commitment to selenium management across all operations and to tailor actions to legacy, current and planned sites.

The Panel observes a need to apply (and amplify) this commitment in a consistent and rigorous fashion across all operating mines, and to consider the specific actions that are most appropriate to legacy assets,[18] current or active operations, and planned future expansions. Certain management actions that are necessary and effective for legacy assets might not be needed for future activities if effective selenium management planning is embedded in current mine plans.



Two examples of legacy waste rock dumps.

[18] Legacy assets refers to mine components such as pits, waste rock dumps, tailings ponds, or impoundments that remain from historic operations.

Objectives for Selenium Management

Teck's objectives with respect to selenium management are two-fold:

a. To build a toolbox of proven management solutions; and

b. To reduce the loading of selenium from its operations to the environment.

Teck has indicated that the time-frame for these objectives is 5-10 years.

The Panel decided to keep the two Objectives statements developed at the Fernie and Hinton Workshops because they highlight different, but related aspects of the sustainability challenge associated with selenium management.

Success against either of these objectives may not be immediately apparent or measurable – it may take time to achieve proven management solutions, much less see an actual reduction in selenium release. It is therefore important to frame the selenium management objective in a transparent fashion with the input of stakeholders. With this in mind, the Panel convened two workshops, one in Fernie, British Columbia, the other in Hinton, Alberta, to explore stakeholder perceptions and attitudes toward sustainability and the selenium management challenge, and to craft an objective for selenium that reflects broad stakeholder interest.[19] The objective statements that emerged from each workshop are presented below. The Panel has left them as two statements rather than combining them into one because they highlight different, but related, aspects of the sustainability challenge associated with selenium management. Both perspectives are valuable in forging a strategic path forward.

Fernie Stakeholder Workshop Objective Statement for Selenium:

"Define, implement, monitor and communicate sustainable ways to stabilize and reverse the selenium trend in the Elk River watershed as soon as possible. 'Sustainable' implies the context of continued mining and growth as well as social and environmental values."

[19] Appendix D provides a roster of those stakeholders who attended each workshop, as well as a summary of the discussion, but it is worth noting that regulatory officials, non-government organizations, First Nations (Fernie only), Teck Coal employees, and local residents were represented.

The Objective developed at the Fernie Workshop captures the essence of an adaptive management approach

This objective statement succinctly captures the essence of an adaptive management approach to selenium – define the management actions to be taken, implement, monitor the efficacy of the actions (and make corrective adjustments as necessary in light of the monitoring), and communicate with stakeholders. As well, this statement acknowledges that a sustainable solution must be one in which social and environmental values are protected within a frame that also includes continued mining and growth – no single value is maximized; an attempt is made to work with all three value sets simultaneously.

Hinton Stakeholder Workshop Objective Statement for Selenium:

Prologue:

Yellowhead County is home to unique and globally significant natural assets that support abundant recreational and tourism activities, and provide critical ecosystem goods and services.

The people who live, work and play in the County want to protect these assets and goods and services for their children and grandchildren.

Mining within the County produces significant economic and social benefits, but it can also accelerate the release of selenium, a potential contaminant, to the natural environment (and therefore place critical natural assets and services at risk).

Accordingly, the stakeholders' objective with respect to selenium is:

"To manage selenium at current and future Teck Coal mine sites in a way that optimizes the mitigation of environmental impacts, protects critical ecosystem goods and services, allows for the continued extraction of the resource, and ensures ongoing community and social well-being for generations in Yellowhead County."

Specific actions in support of this objective are:

1) *Decrease the loading to the receiving environment and establish a decreasing trend within three years.*
2) *Subsequent to item 1, manage selenium to a target that provides a sufficient margin of safety for humans, fish and aquatic life and wildlife.*
3) *Pioneer the use of selenium management practices that benefit the community both during and following mine life by positioning the community as a knowledge centre on selenium.*
4) *Engage Yellowhead County residents, and others who benefit from the assets of the County, in an ongoing dialogue about (1) selenium (so as not to cause alarm); (2) management actions; (3) progress; and (4) anticipated next steps.*

The Objective developed at the Hinton Workshop provides explicit guidance for achieving an outcome that optimizes across multiple values.

This statement captures the essence of sustainability – it looks for an outcome that optimizes across multiple values:

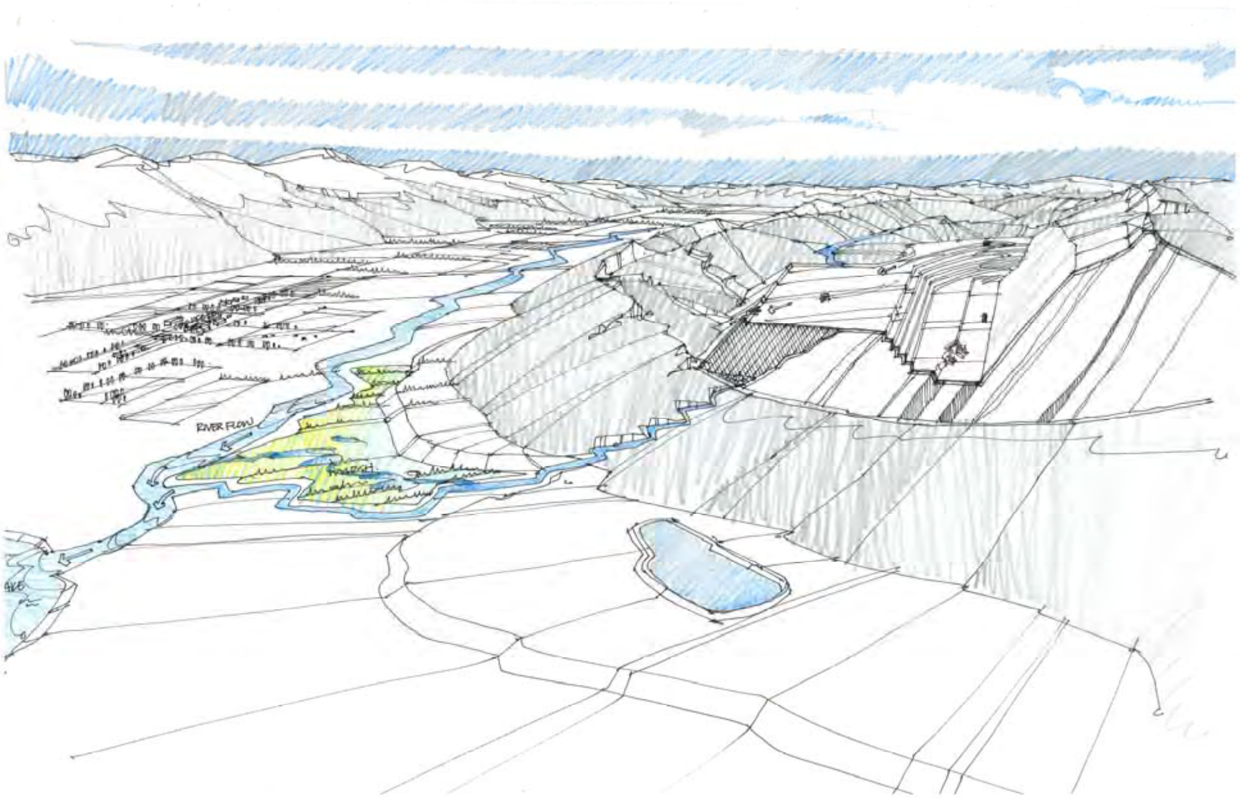
- The mitigation of environmental impacts
- The protection of ecosystem goods and services
- The continued presence of mining in the community/region
- The continued community and social wellbeing – for generations

The Virtual Mine

To explore how these aspirations with respect to selenium management might be achieved across six mines – each with unique watershed characteristics, several waste rock dumps, tailings deposits, and other attributes – the Panel created a "virtual mine" and "virtual watershed" against which different management approaches could be tested for practicality and efficacy (Figures 5 and 6).[20]

[20] While we tested a variety of ideas and approaches against the virtual mine, the Panel also tested these ideas against our understanding of the six "real" mines.

Figure 5: The Virtual Mine



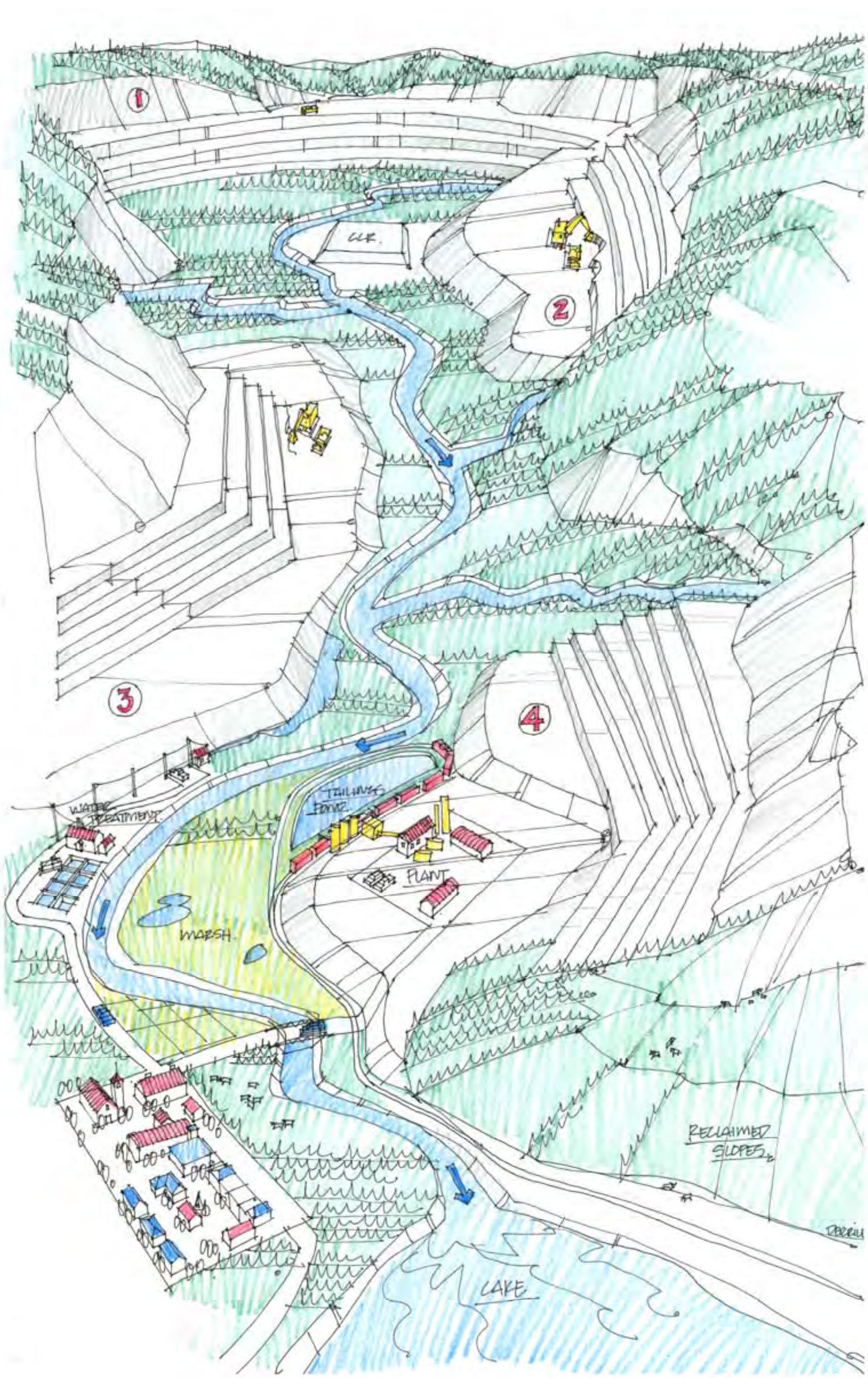
The virtual mine follows existing mining practices and has one pit, one waste rock dump, one rock drain, one through-going mountain stream, one tailings pond, one Coarse Coal Rejects (CCR) pile, one marsh ("lentic" habitat), and one river ("lotic" habitat) feeding into a lake. A small mining town and some fields are located nearby.

A conceptual design was developed for the virtual mine, as a basis for considering the volumes of rock and water to be managed as well as the costs for various selenium management scenarios. To help ground the virtual mine in real-world conditions, the geography is loosely based on Line Creek. The stream discharges from the virtual mine are similar to those of Line Creek (10,000 cubic metres per day), and the production rates and strip ratios are similar to those of Elkview (6 million tonnes of clean coal per year, with similar waste rock, tailings, and CCR multiplier factors, and similar mining unit costs). The virtual mine generates 75 million cubic metres of waste rock per year and is shown here after its third year of full production. It is expected to have a 20-year life.

While useful for analytical purposes, the Panel acknowledges that the virtual mine is not without limitations – chief among these is the fact that it has just one pit and a single waste rock dump. Much of the nuance in decision making regarding selenium management strategies stems from the fact that all six mines in the Teck portfolio have multiple pits and waste rock dumps of various ages, constructed in different ways in different geographical settings, in multiple watersheds, with many more waste rock dumps to come. This complexity is partially addressed by the virtual watershed.

In the next phase of the Panel's work, the methodology used in assessing various technologies and strategies in the virtual mine will be adapted for the real mine sites. As noted on the inside cover of this report, the Panel's work to date has not been focused on individual mines. The development of selenium management plans tailored to the unique characteristics of each mine will occupy the Panel for the balance of 2010.

Figure 6: The Virtual Watershed



Option Identification and Evaluation

The Panel chose the Structured Decision Making process as its overall framework for development of the Strategic Plan

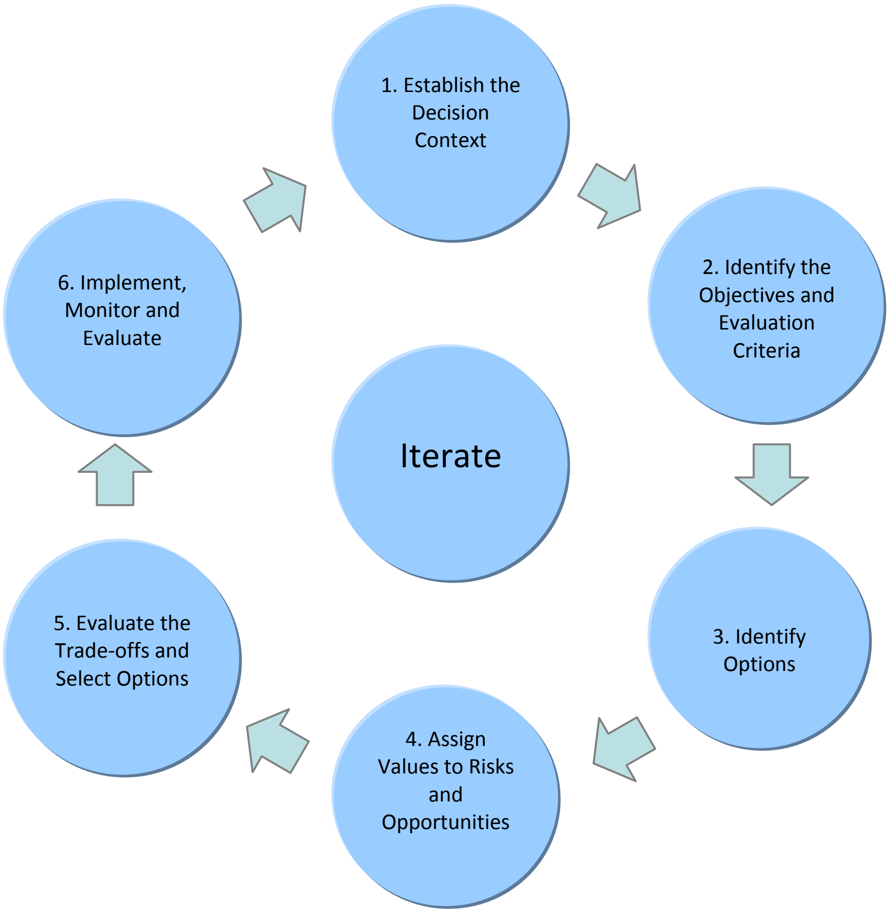
The Charter for the Panel highlights the importance of adopting a sustainability lens in identifying and evaluating selenium management options. The recommendations that flow from the Panel's work (Section 7.0) must be transparent, technically sound and give due consideration to the "triple bottom line" of social, environmental, and economic factors. To meet this mandate, the Panel chose the Structured Decision Making process as its overall framework for development of the strategic plan for selenium management.

Structured Decision Making integrates science and policy and offers a process for meaningful stakeholder involvement.

Structured decision making (SDM) is a general term for carefully organized analysis of problems in order to reach decisions that are focused clearly on achieving fundamental objectives. SDM encompasses a simple set of concepts and helpful steps. Key SDM concepts include making decisions based on clearly articulated fundamental objectives, dealing explicitly with uncertainty, and responding transparently to legal mandates and public preferences or values in decision making; thus, SDM integrates science and policy explicitly.[21]

[21] This description of SDM is from the Structured Decision Making Factsheet (http://www.fws.gov/science/doc/structured_decision_making_factsheet.pdf).

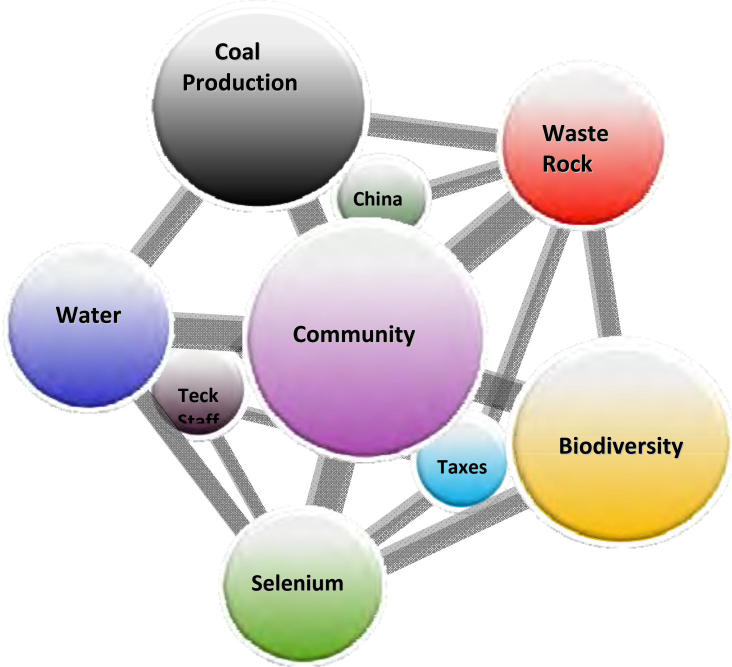
Figure 7: Structured Decision Making Process



The Panel used multi-criteria decision analysis (MCDA) within the Structured Decision Making Framework. The Panel adopted the consensus-driven objectives developed during the Fernie and Hinton Workshops as the basis for the MCDA. The Panel also made use of options and evaluation criteria suggested by workshop participants.

The Panel chose multi-criteria decision analysis (MCDA) for use within the Structured Decision Making framework. Central components of the MCDA adopted by the Panel were the consensus-derived objective statements, options, and evaluation criteria that were developed during two Stakeholder Workshops in Fernie on May 13, 2010 and Hinton on June 2, 2010 (see Appendix D). The stakeholders attending the Workshops included representatives from First Nations, federal and provincial regulators, elected county and municipal officials, municipal employees, non-governmental organizations, community and special interest groups, local business operators and Teck Coal operations and corporate staff. The triple bottom line focus of the workshops allowed participants to recognize the relationships between the environmental, social, and economic risks and opportunities associated with selenium management (Figure 8).

Figure 8: Selenium and Its Many Relationships



Methodology

Steps 1 to 3 of the SDM framework (Figure 7) were conducted during the individual stakeholder meetings and the Stakeholder Workshops. The Panel undertook Steps 4 and 5. It is expected that Teck Coal, its stakeholders and the Panel will jointly undertake Step 6.

The following activities were undertaken to complete Steps 1 to 3:

- One-on-one and group meetings with stakeholders in the Elk Valley and in Yellowhead County;
- Stakeholder Workshops in Fernie, British Columbia and Hinton, Alberta;
- Presentations on Structured Decision Making to Teck Coal as well as during the two Workshops;
- Adoption of the Objective Statements for selenium management developed during the two Workshops;
- Identification of potential options for selenium management at Teck Coal operations; and,
- Development of the key environmental, social, economic and technical considerations to be used in the evaluation of the selenium management options.

Following the Stakeholder Workshops, the Panel undertook the following activities in order to complete Steps 4 and 5:

- Development of business rules for the grouping and selection of selenium management options to be evaluated in the MCDA;
- Establishment of a short-list of selenium management options for evaluation;
- Adoption of environmental, social and economic criteria for the evaluation of the short- listed selenium management options (by reviewing and refining criteria suggested during the two Workshops as well as from published guidance regarding selection of remediation options);
- Assessment of each option against the criteria with respect to the risk or opportunity the option presented to the objective statements;
- Evaluation of the trade-offs (balance between risk and benefit) among the selenium management options; and,
- Selection of the options to be recommended for deployment at legacy assets (e.g., historic waste rock dumps), current operations and new operations.

Step One: Establishing the Decision Context

The Panel accomplished Step One by reviewing and integrating selenium data, information about Teck Coal operations, and stakeholder input.

Since January 2010, the Panel has been reviewing, interpreting and consolidating selenium data as well as information about Teck Coal's operations. This information, together with stakeholder input during the Fernie and Hinton Workshops was integrated and summarized to establish the decision context. The decision context includes the specific decision to be made, the spatial and temporal scope of the decision and whether the decision will be iterated over time.

The decision context includes the decision to be made, spatial and temporal scope, and whether the decision will be iterated over time.

The decision to be made is the set of selenium management options that best fulfill evaluation criteria based upon the triple bottom line of social, environmental and economic factors. This decision has two geographic scopes. The first geographic scope is the Elk River watershed including the communities of Elkford, Sparwood and Fernie as well as the East Kootenay Regional District and the traditional territory of the Ktunaxa First Nation. This scope extends to the Lake Koocanusa. Consideration of far-field effects into the Kootenay River system is also included. The second geographic scope is the the Gregg/McLeod River watershed including the communities of Cadomin, Hinton, and Edson as well as Yellowhead County and the traditional territory of the Mountain Cree and the Alexis Nakota Sioux First Nation. Consideration of far-field effects into the Athabasca River

The Elk River at the confluence of Coal Creek

system is also included. The temporal scope is “generations”. The decision will be iterated over time.

Luscar Creek, a tributary of the McLeod River

Step Two: Objective Statement and Evaluation Criteria

Workshop participants at Fernie and Hinton achieved consensus on objective statements and also provided evaluation criteria.

The Panel chose to use both objective statements developed during the Fernie and Hinton Workshops because they were complementary and represented the collective will of all stakeholders.

The evaluation criteria were divided into environmental, social, technical and economic categories.

To develop the selenium management objective statements for both the British Columbia and Alberta-based Teck Coal operations, the Workshop participants at Fernie and Hinton provided their individual inputs to the objectives for selenium management at the Teck Coal operations. Following the individual inputs, a group discussion was used to achieve consensus on an Objective Statement for selenium management. Importantly, this discussion drew heavily upon the stakeholders’ contributions regarding their definitions of sustainability and the importance of selenium as an economic, environmental, and social issue.

The objective statements derived from the Stakeholder Workshops and used for the MCDA were discussed in Section 5. The full discussion surrounding the development of these statements is found in Appendix D. The Panel chose to use both objective statements to guide the MCDA as they were complementary, posed no dissonance regarding direction and represented the collective will of both Teck Coal’s Fernie and Hinton stakeholders.

The evaluation criteria used to analyze the selenium management options were divided into the following categories:

- Environmental;
- Social;
- Technical; and,
- Economic.

Environmental, social, and economic criteria represent the three pillars of sustainability (to which was added technical feasibility – a key constraint) and were designed to prompt the Workshop participants and Panel to recognize the opportunities and risks associated with each selenium management option.

Evaluation criteria were derived from input obtained during the Workshops as well as from Panel experience and selected guidance available from the literature.

The development of sub-criteria for each of the evaluation criteria was critical to the MCDA. To derive these sub-criteria, the Stakeholder Workshop participants were asked to provide environmental, social, economic, and technical considerations against which to review the selenium management options. These considerations were either overtly included in the MCDA matrix as sub-criteria under the main criteria headings (i.e., environment, social, economic and technical) or were amalgamated by the Panel to be one or more representative sub-criteria. Additional sub-criteria were developed using the following sources: the United States Environmental Protection Agency (USEPA) Record of Decision Guidance[22], sustainability criteria from the Global Reporting Initiative's Sustainability Reporting Guidelines[23] and analogous criteria from other MCDAs conducted by Panel members.

The main criteria headings of Environmental, Social, and Economic and Technical are found along the left side of the decision matrix shown in Table 8. Ten to 12 sub-criteria were assigned under these headings.

[22] United States Environmental Protection Agency. 1999. A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision documents. USEPA. Washington, DC: pp. 3-8 to 3-9.
[23] Global Reporting Initiative (GRI). 2006. Sustainability Reporting Guidelines Version 3 (G3). GRI. Amsterdam. 44 pp.

Step Three: Selenium Management Options Identification

Selenium management options were developed from Teck Coal reports, other mining jurisdictions and stakeholder ideas presented at the Fernie and Hinton Workshops.

The selenium management options considered by the Panel for the MCDA were developed from three key sources: 1) options put forward in Teck Coal-derived reports, 2) options representing selenium management practices in other mining jurisdictions, and 3) options put forward by participants at the Stakeholder Workshops.

The Panel followed a series of business rules to reduce a long list of selenium management options down to ten.

The Panel followed "ad hoc" business rules to reduce a long list of selenium management options (Appendix E) down to ten (Appendix F). These business rules included technical feasibility, the time-frame for the option to become technically feasible, requirements for perpetual maintenance, the timeframe for demonstrated results, relative cost, and effectiveness in reducing selenium (Appendix E). The ten selected options have the potential to include many of the more detailed options that were set aside for future consideration. Several options were pulled out because they were "additive" to the ten selected options and could not stand on their own.

The ten selected options represent a range, from high-level categories that potentially include several different technologies (e.g. Active Treatment) to specific actions deemed to be the most likely to materially affect selenium loadings.

Ultimately, a high-level definition was used for some of the options (i.e., active and passive treatment); these two options include a number of potential technologies which would be selected on the basis of a technology review by Teck Coal. The water management option was reduced to one measure that was deemed by the Panel to be the single most important action that would be likely to materially affect selenium release in the short term. Several waste management options were evaluated; they were selected on the basis of the likelihood of substantial effects on selenium release from waste rock dumps. In situ microbial source control was included by the Panel because of its high potential effectiveness and moderate cost.

Appendix F provides short descriptions of each of the ten selenium management options evaluated by the Panel using the MCDA matrix. The ten options are grouped under the following headings:

- Water Treatment,
- Water Management,

- Waste Management, and
- Source Control.

The full set of selenium management options in Appendix E will be re-visited as the Panel moves to the next stage of decision analysis.

The options are presented from left to right along the top row of the MCDA Matrix shown in Table 8

The selection of ten options for the MCDA does not imply that other options in Appendix E are discarded. The full list of options in Appendix E serves as an excellent resource for consideration when developing implementation plans at individual operations. As the Panel moves into the next stage of the decision making process, some of the discounted options will be revisited. The "additive" options can be run as a secondary series in future analyses.

Step Four: Assigning Values to the Risk and Opportunities of the Selenium Management Options

A qualitative ranking scheme was developed by the Panel.

To complete Step 4, a qualitative ranking scheme ranging from significant risk to significant benefit relative to the Objective Statement for the selenium management options was applied to the MCDA matrix. The ranking scheme was developed based on consensus among members of the Panel.

The risks were categorized as Null (no risk), Minor Risk, Moderate Risk, or Significant Risk. If a technical option posed a threat to meeting the selenium management objective in terms of cost or risk relative to the business as usual case (i.e., the generic Teck Coal mining practices at the Virtual Mine developed by the Panel), the severity of the risk was agreed upon by the Panel and used in the MCDA matrix. The following colours were applied to the risk spectrum:

Significant Risk	Moderate Risk	Minor Risk	Null

Similarly, a benefits spectrum was developed to reflect an opportunity or benefit to the selenium management Objective Statements posed by a technical option/criterion. By consensus, the Panel decided on the degree of the benefit, categorized as Null (no benefit), Minor Benefit, Moderate Benefit, or Significant Benefit. The corresponding cells were shaded and scored as follows:

Null	Moderate Benefit	Major Benefit	Significant Benefit

Step Five: Evaluate the Trade-Offs and Select Options

The qualitative ranking scheme was applied to all option/criteria combinations. This produced a large matrix of results. Numeric scores were assigned to the qualitative ranks to facilitate interpretation of results.

The qualitative ranking scheme was used throughout the MCDA to populate the matrix (Table 8). The Panel subsequently created a numerical ranking scheme to facilitate a ready review of the technical options/criteria. Recognizing the ability to render technical options null using an additive system that assigned negative values to risks and positive values to benefits, the following numerical scheme was used (i.e., only positive values were assigned to both risks and benefits, the assumption being that the highest final score reflected the option possessing the greatest benefit):

Significant Risk	Medium Risk	Minor Risk	Null	Minor Benefit	Moderate Benefit	Significant Benefit
1	2	3	4	5	6	7

The shadings in Table 8 make the trade-offs between risks and benefits readily visible.

The shading convention used in the MCDA allows for the ready discernment of the benefits and risks (or trade-offs) associated with the evaluation criteria as applied to the selenium management options (Table 8). For example, Active Water Treatment was deemed to present significant environmental benefit owing to its ability to greatly reduce selenium loads from the water course it treated in a short period of time. However, it is expected this will come at significant capital and operating expense (i.e., ranging from $20 million to $200 million). It will also create an ongoing visual disturbance (or social cost) at the mine site post-reclamation owing to the long term need to operate such a system.

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Significant Risk	Moderate Risk	Minor Risk	Null	Minor Benefit	Moderate Benefit	Significant Benefit
1	2	3	4	5	6	7

Evaluation Criteria																									
Criteria Heading	**Criteria Subheading (Shading denotes criteria identified by stakeholders)**	**Considerations for Criteria**	**Internal / GRI Reference**	**Active water treatment (biological FBR)**		**Passive water treatment (passive biological reactor, permeable reactive barrier - iron)**		**Water Management - Divert clean water from rock drains**		**Waste Management Avoid placement of waste in cross valley Fills**		**Waste Management Use only non-Se massive rock in rock drains**		**Waste Management New dump design to limit oxygen and water infiltration**		**Waste Management Existing dump reclamation to reduce Se mobilisation**		**Waste Management Waste rock placement in constructed impoundment**		**Waste Management Maximise pit backfill**		**In situ microbial reduction as source control**	
					Comments		Comments		Comments		Comments		Comments		Comments		Comments		Comments		Comments		Comments
Environmental																									
Energy																									
	Energy Consumption (C02)	Consider energy use from each option; direct/indirect and CO2 (0-35,35-70,70 -100)	EN3/EN4	3	20% even for the biggest WT plant - 4 500 hp pumps v 5 trucks 250 hp	3	Construction of dam; using dozer to push hay or compacting rock (10 ha); equipment use	2	Pumping water to divert can be pricy - gradients can be used for natural flow	2	Assumes no drain. Owing to additional equipment	2	In virtual mine, within the mine lease area	3	Building in dumps; Jensen advise (driving downhill) - 5 more dozers (pitch geometry - try to stay on the level)	2	$20M/yr	2	Trucks etc. building of dam (not fussed about waste, keeping water in)	3	Assume coal left behind is worth leaving behind to get the benefit. Assume short haul and virtual mine. Haul to legacy pits could be longer with higher energy	3	Selectively handling material, etc. Little more truck
Air and Climate																									
	Air quality	Dust and particulates	LARP	3	Power from coal fired grid (emissions factor); truck sludge - residuals is one dump truck of month; CO_2 production; HS production	3	Trucking: hydrogen sulphide, methane, controlled venting given size and dilution	3	Acute impact phase during construction	2		2		3	Proportional to trucks	2	Many trucks.	2		3	Dusting, etc.	5	Taking tailings and CCR away from valley and burying
Water (Total economic value of water)																									
	Water Quality			6	Water Quality significantly improves - aligns with objective; treating for Se, the biological process can contravene other water qualities	5	Golder data shows modest removal - polish at the end - might have to put an active system at back end before	6	Clean water not exposed; prevents Se loading	6	Need water balance to confirm.	5		6	50-70% reduction in water; 50-70% reduction in rate - 60 - 80% in reduction	5	Already exists harder to effect	6	Would catch all the loading from Ericson (say) - all old and new dumps	7	90%+	6	80% reduction

Evaluation Criteria																							
Criteria Heading	**Criteria Subheading (Shading denotes criteria identified by stakeholders)**	**Considerations for Criteria**	**Internal / GRI Reference**	**Active water treatment (biological FBR)**		**Passive water treatment (passive biological reactor, permeable reactive barrier - iron)**		**Water Management Divert clean water from rock drains**		**Waste Management Avoid placement of waste in cross valley Fills**		**Waste Management Use only non-Se massive rock in rock drains**		**Waste Management New dump design to limit oxygen and water infiltration**		**Waste Management Existing dump reclamation to reduce Se mobilisation**		**Waste Management Waste rock placement in constructed impoundment**		**Waste Management Maximise pit backfill**		**In situ microbial reduction as source control**	
					Comments		Comments		Comments		Comments		Comments		Comments		Comments		Comments		Comments		Comments
	Water Quantity (Beneficial use)			5	Supply water that is greater commodity as better quality but may effect water shed; DFO in stream flow needs would ok temporary diminishment	4	Polishing step would ensure (beneficial) water quantity	6	Maintains larger volume of unaffected water	4		4		5	Diverting around on run-off run-on control	4		4		4	Would probably go to groundwater	4	
Ecosystem Service Value (Terrestrial and aquatic)				5	Although, Se effect on system neutralized; fish may suffer risk associated with nutrient enrichment - increase some services and decrease others, hard to quantify full effect.	4	Proxy study shows as much as 98% Se elimination - but unreliable. Unclear if side specific conditions are tech feasible. Could be part of bundled strategies?	5		6		5		6	Commensurate w/ water quality; dumps are better designed (taller Cardinal river dumps); disturbing larger footprint otherwise	5		6	Protect downstream; can destroy habitat as large scale.	6	Less water in surface system.	6	Protecting
Reclamation																							
	Ability to protect or restore habitats	Relative ease and timeline of reclamation	EN13	3	Intervention encumbers habitat - but less damaging than 15 dams or footprint of passive treatment.	2	Physical footprint is 15 ha+	6	Protects water	6		5	Clean water quality.	6	Diverting clean water; lower volume of water effected; lower concentration in effected water	6	More forests and more grass.	2	Sheer scale destroys habitat. Optimize.	6		6	
	Ensures multiple and traditional land uses over long term			6	Should match to eco-services - but perception overall is good, roads good, fish eating good.	5	Minor benefit - huge disturbing land - big footprint	6	Linear feature constraining movement (buried features)	6		3	New disturbance	6		6	More forests and grass.	2		5		6	
Biodiversity																							
	Species at Risk Sensitive Receptor)	Athabasca rainbow trout	LARP/EN12/EN15	3	Se is down with increase in BOD and phosphorous.	2	Se is down with increase in BOD and phosphorous, which is uncontrolled	6	Diverted water protected = receiving body protected.	6		5	Clean water	6		5		4	Saves downstream but destroys habitat	5		6	
	Terrestrial ecosystem health	Does not encourage wildlife, does not become ecological sink, doesn't create an attractive nuisance. Includes waterfowl.	LARP/EN12/EN15	4	No impact.	3	Footprint encumbers - every 5 yrs need to redevelop treatment basin	4	Diverted water protected = receiving body protected	6		4		6		6	See Cardinal	3		5	Less Se but slightly less water in creeks	4	

Evaluation Criteria																							
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					Comments		Comments		Comments		Comments		Comments		Comments		Comments		Comments		Comments		Comments
	Aquatic ecosystem health	Maintain fish population and structure	LARP/EN25	5	Se decreased.	2		6	Diverted water protected = receiving body protected	6		5	Mass water balance	5		5		5	Se reduction	5		6	
	% Disturbed, location wrt protected areas and areas of high biodiversity value outside protected areas		LARP/EN11	3	WT plant approximately 1 ha.	2	Corridor land imperilled	4		6		3		5	Bigger footprint but kinder and gentler to landscape	3	Borrow material from elsewhere	2	Large scale.	6	Protect down gradient	3	extend toe
Se Management																							
	Degree of Se reduction			7	Method 98%/ Drainage 80%	7	Significant (use PBR trial as per Golder build it big enough get 80% in stream); 98/80%	6	50% reduction (protection vs. contamination)	6	Doesn't prevent all release.	5	Could be factor of 3 - or could be Oxygen in, can it be contributing load to volume	6	70 - 90%	5	Slows infiltration 50%	6	70 - 90%	7	70 - 90%	7	70 - 90%
	Timeline to demonstrate Selenium Reduction (at compliance point to be defined)			7	Immediate.	3	Data gap	7	Immediate	7	For new mines	6	10 years and only applies to new mines or brand new dumps (3 years new dumps)	5	10 yrs	5	10+ years	5	10+ year	5		5	
Social																							
Social Gain																							
	Opportunity for new economic development			6	Skilled long-term (6) jobs, new construction; local and regional suppliers; 10 yr construction frame.	5	Uses local resources	5	1.5 FTE	6		4		5	4 FTE	6		5	1.5 FTE	4		4	New mining standard in future
	Quality of life index			6	Better quality water; more public/corporate trust; Note: drive definition from both workshops.	6		6		6		5	Less Se	6		5		3	Moderate decline in Se big disturbance in view shed	5		6	
Regulatory Affairs	Compliance with permit or potential permit requirements		EN28/SO8/PR9	7	Se impact not meeting reg. guidelines - WT process moves toward goal.	6	Reliability and availability could be called into question; potential downstream issues	6		5		5	Buying time? Too uncertain	6	Easy to demonstrate for vegetation, erosion, geotech, ...(down side bigger footprint)	5		5		6		6	

Evaluation Criteria																							
Criteria Heading	**Criteria Subheading (Shading denotes criteria identified by stakeholders)**	**Considerations for Criteria**	**Internal / GRI Reference**	**Active water treatment (biological FBR)**		**Passive water treatment (passive biological reactor, permeable reactive barrier - iron)**		**Water Management Divert clean water from rock drains**		**Waste Management Avoid placement of waste in cross valley Fills**		**Waste Management Use only non-Se massive rock in rock drains**		**Waste Management New dump design to limit oxygen and water infiltration**		**Waste Management Existing dump reclamation to reduce Se mobilisation**		**Waste Management Waste rock placement in constructed impoundment**		**Waste Management Maximise pit backfill**		**In situ microbial reduction as source control**	
					Comments		Comments		Comments		Comments		Comments		Comments		Comments		Comments		Comments		Comments
	Ability to readily secure regulatory acceptance of Se management action			7	Se impact not meeting reg. guidelines - WT process moves toward goal.	5	Can make agencies nervous	7		6		3	Further information will change this	6		5		3	Concept should be explained in terms of tailings dam construction.	6		5	
	Ease of performance monitoring			7	Monitoring only Se is simple. Note: what is the standard for analyzing Se - huge ranges of sensitivity per method.	6	Can be difficult (based on compliance point)	7		5		5		5	Safely	5		5	If it saturates up, easy to catch	5	Groundwater monitoring	3	Need more rationale on performance
Internal Stakeholders		Teck management, staff and contractors	SO1	3	Teck wants to solve problems with existing skill sets - this would not apply. Would not increases job sat/MBOs performance.	5	No new skill set development required	7		2		3		3	Changes business	2		5	Existing skill sets	6	Depending on length of haul	2	R&D (risk)
Health and Safety																							
	Maintain human health			6	Definition: to ensure that the receiving water quality meets 10 microgram/L.	5	Seasonality can impact effectiveness	6		6		5		6	Longer term (10 yrs)	2		5	Dam failure? If water in waste rock, no, plus Se reduction	6		6	
	Protection of workers during remedial actions (operational safety)		LA6/LA7/LA8	3	All plants (and plant construction) can be deemed risky.	3	Asphyxiation risk	3		1		4		5	1 more dozer (4 more drivers)	2		4		4		4	
Local Impacts	Nuisance Impacts (odours, light, noise, visual); Traffic volume	Aesthetic, odours, social sink		2	Proximity.	3		4		2		3	Longer hauls	4		2		2	View Shed compromised; more traffic	4	Depends on the haul	4	
	Infrastructure Impacts	Cost of infrastructure etc. Does not become economic sink.		3	Relatively modest to others pressures.	3		4		2		4		3	Dozer; 4 trucks; shop	2		3		4		4	
Technical and Economic																							
Implementability																							
	Constructability	Building on time on schedule with minimum time wasted	US EPA ROD	6	Not easy to build (geotech issues; seasonality, keying into bedrock; dumps).	2	Space required; transport of materials; remote areas	6	Need to bury; jack and bore; can't always grade and must use pumps	3		3		5	Smarter not necessarily harder (good on reclamation)	3	This is driven by conditions similar to Elk Valley	3		6		5	

Evaluation Criteria																							
Criteria Heading	**Criteria Subheading (Shading denotes criteria identified by stakeholders)**	**Considerations for Criteria**	**Internal / GRI Reference**	**Active water treatment (biological FBR)**		**Passive water treatment (passive biological reactor, permeable reactive barrier - iron)**		**Water Management - Divert clean water from rock drains**		**Waste Management - Avoid placement of waste in cross valley Fills**		**Waste Management - Use only non-Se massive rock in rock drains**		**Waste Management - New dump design to limit oxygen and water infiltration**		**Waste Management - Existing dump reclamation to reduce Se mobilisation**		**Waste Management - Waste rock placement in constructed impoundment**		**Waste Management - Maximise pit backfill**		**In situ microbial reduction as source control**	
					Comments		Comments		Comments		Comments		Comments		Comments		Comments		Comments		Comments		Comments
	Proven methodology or technology			6	Proven.	5	Site specific	7		7		6		6		5	Original dumps not built with an idea to be compacted (small incremental benefit as proven but small also risk as proven to have failed)	6		6		2	R&D
	Flexibility	Ability of system to adapt to changing economic environmental and operating conditions.		5	Finite flow (not very flexible); other constituents could be managed with this system.	3	Not inflexible	6		5		5		6		5		5	Put waste any where you want	4		4	Good dump design
Operability																							
	Ease of operation			2	Problematic - new skill sets, site specific learning curve.	3		3	Designed not to freeze; potential for scale	6		5	Less potential for backing up. Clean rock	6		5	Cracks hard to close	3	Maintain discharge and dam stability	5		6	
	Reliability of the operation		US EPA ROD	2	Hard to get down to concentrations promised.	2		4		6		5		6	May need to fill cracks from time to time	3		6		6		2	
	Infrastructure Needs		EN29	3	New substation? Back up power required if end of pipe hard limit.	3	Day to day consistent; turbidity potential.	3	Power to run pumps	4		4		4		3		3		4		4	
Perpetual care		Ensure no double count with OPEX		1	How long is forever?	2		2	When problem, it is a big problem	5		5		3	Monitor, maintain erosion - can get to a reclaimed state?	3		3		6	Reduce what needs to be cared for	3	
Economic Performance																							
	Operational resource demands	Human and equipment resources		2	New skill sets required.	3		3	Mechanics; checking it	2		3	Should try 1 yr special project for a yr	3	The 1st will take heavy instrumentation, after that routine	2	50 trucks (highway trucks)	3		3	More hauling	3	
	Alternative revenue streams	Sell Selenium, potable water from waste treatment plants.		5	Can we sell Se? Quality processed water as a commodity? (modest) - could attract other industry.	4	Less than $100M	4		4		4		4		4		4		4		4	
	CAPEX	Low $0-$20M, Med $20 -$100M, High >$100M		1	$100M+	2		2	Handles all the flow	1		3	$10M-$30M/yr	3	Dozer ($2M); instrumentation $3M	2		2		2	May cost sterilized reserve $50M left in ground	2	$20M+

Evaluation Criteria																							
Criteria Heading	**Criteria Subheading (Shading denotes criteria identified by stakeholders)**	**Considerations for Criteria**	**Internal / GRI Reference**	**Active water treatment (biological FBR)**		**Passive water treatment (passive biological reactor, permeable reactive barrier - iron)**		**Water Management - Divert clean water from rock drains**		**Waste Management Avoid placement of waste in cross valley Fills**		**Waste Management Use only non-Se massive rock in rock drains**		**Waste Management New dump design to limit oxygen and water infiltration**		**Waste Management Existing dump reclamation to reduce Se mobilisation**		**Waste Management Waste rock placement in constructed impoundment**		**Waste Management Maximise pit backfill**		**In situ microbial reduction as source control**	
					Comments		Comments		Comments		Comments		Comments		Comments		Comments		Comments		Comments		Comments
	OPEX			1		2		2	$2M/yr	1		1		2		2	Hauling in clay from offsite can lead to a $100M plus expenditure. This is normal practice everywhere and at Cardinal. Teck will have to find better growth mediums (Feed Lot Manure!)	2		3		2	
	Potential future liability			3	Closure liability; backend process outfall - plant could be repurposed.	2	Closure cost.	4	Abandon in place	6		5		5	Closure liability - reclamation certificate off books but Se source control needs review	5	Cracks	5		6		6	Control sulphide oxidation
Total (Unweighted Score)				**147**		**125**		**168**		**166**		**144**		**170**		**137**		**134**		**172**		**160**	
Rank				**6**		**10**		**3**		**4**		**7**		**2**		**8**		**9**		**1**		**5**	

NOTE 1: Criteria were developed from the following sources:

- Analogous MCDA matrices developed by SAPSM members using Global Reporting Initiative (GRI G3) sustainability indicators and key features of the Lower Athabasca Regional Plan
- US EPA Criteria for Detailed Analysis of Alternatives for Superfund Record of Decision (ROD) Documents

The ten options were ranked using a simple scoring system.

Beyond the shading conventions to depict risk and benefit, these options were also ranked in accordance with the simple numerical scoring system discussed above; #1 is the highest-ranked option and #10 the lowest (Table 9). The lowest scoring option (Passive Water Treatment) received a score of 125 while the highest scoring option (Maximizing Pit Backfill) scored 172. The remainder of the options clustered, almost evenly, around scores of 130, 150 and 170. Within these groupings, the overall scores that produced these rankings were often very close (Table 8).

There was often substantial uncertainty associated with scoring the ten options. Therefore, the rankings should not be interpreted as a sequential preference list.

The Panel had insufficient time to assign uncertainty scores for each of the option/criteria combinations. However, the Panel recognized that there was often substantial uncertainty associated with scoring some of the options against the criteria. Therefore, the rankings shown in Table 9 should not be interpreted as a sequential preference list; rather, the rankings assist us in identifying the options that have the better chance of fulfilling economic, technical, environmental, and social performance criteria, given what we know at this time.

The order of deployment of the options will depend on site-specific conditions at each of Teck Coal's operations.

The actual order of deployment of the options will depend on site-specific conditions at each of Teck Coal's operations because the risks and benefits accruing to each location will be altered by the economic, social, and environmental conditions influencing a given operation. Additionally, depending on site-specific circumstances one or more of the options may not be feasibly deployed at a given mine site.

The MCDA provided key insights into the performance of the ten selenium management options against evaluation criteria.

The Panel will re-visit the sources of uncertainty in the next round of analysis in order to identify "high value of information" items that, when attained, may change the rankings of the selenium management options.

The MCDA provided the Panel with key insights into the ability of each selenium management option to perform against triple bottom line considerations. The Panel also noted the uncertainty that surrounds the actual operating conditions at the sites owing to a lack of key data (e.g., water balance data and monitoring data to reflect the performance of existing selenium management measures). These data gaps, coupled with the uncertainty around the potential efficacy of several of selenium management options, will be re-visited by the Panel during the next round of analysis in order to identify "high value of information" items that should be attained from site-specific monitoring and research. This does not mean that Teck is without sustainable selenium management options today; however, it does imply that in the presence of these knowledge gaps, it is difficult to optimize for sustainability through the use of the current MCDA findings. Indeed, as knowledge gaps close from targeted research and monitoring and the uncertainty scores in the MCDA are diminished, a change in the rankings of the options could take place.

The ten selenium management options reviewed are not mutually exclusive. Site-specific characteristics will encourage the bundling of options (including high ranking and low ranking options) to maximize the effectiveness of any one operation to sustainably manage selenium.

Table 9: Selenium Management Options - Ranked

Rank	Option	Water Treatment	Water Management	Waste Management	Source Control
1	Maximize pit backfill			X	
2	New dump design to limit oxygen and water infiltration			X	
3	Divert clean water from rock drains		X		
4	Avoid placement of waste in cross valley fills			X	
5	In situ microbial reduction as source control				X
6	Active water treatment (e.g., biological fluidized bed reactor)	X			
7	Use only low-Se, massive rock in rock drains			X	
8	Existing dump reclamation to reduce Se mobilization			X	
9	Waste rock placement in constructed impoundment			X	
10	Passive Water Treatment (e.g., passive biological reactor, permeable reactive barrier)	X			

The Plan for Selenium Management at Teck Coal

The Panel has concluded that the way forward will require that Teck Coal implement the following three pillars of a sustainable selenium management strategy.

The forward plan for selenium management at Teck Coal should be grounded in a transparent process informed by sound governance and operating principles.

Teck Coal should explicitly frame its approach to selenium management as a manifestation of its sustainability commitment.

Teck Coal should apply its experience with selenium management across all operations, to a higher standard, and with stronger management supported by additional technical specialists.

Recommendations for Selenium Management

The Panel recommends that Teck Coal adopt the actions and operating principles listed below as the basis for an effective, sustainable strategy for selenium management.

1. Make an immediate step change in its current selenium management program with a focus on significant changes to mine planning, water management, and waste management at all of its facilities and groups of facilities within the McLeod River and Elk River watersheds.

2. Adopt a framework of sustainability for management and decision making with respect to selenium, that relies on robust decision tools and a standardized management approach for approval and implementation of selected options.

3. Substantially reduce selenium loading within three years through a combination of water diversion, active water treatment, and avoidance of cross-valley fills; and, keep loading rates below existing levels after that by adopting both remedial and operations measures to greatly reduce selenium loading rates from dumps and rock drains.

4. Identify and adopt strategies that offer synergies resulting in additional benefits from adoption of selenium management measures (e.g., reduction in calcite formation or nitrogen release to air and water).

5. Refocus Teck Coal's research and development (R&D) program to obtain critical design information in a timely manner.

6. Restructure the selenium and water quality monitoring program to improve data quality and availability, increase understanding of loading, and facilitate measurement of reduced loading selenium at the landform, site watershed, and regional watershed level. The monitoring should be linked directly with a GIS-based database system, with further standardization of procedures and quality assurance.

7. Develop a selenium management communications plan within and among Teck Coal operations and other stakeholders to ensure that ideas, data, lessons learned, and key success stories are shared.

8. Continue and expand engagement with stakeholders on selenium issues.

9. Develop a formal risk assessment and scanning framework to ensure emerging sustainability risks are recognized early on and framed appropriately against the portfolio of risks that Teck Coal is managing.

10. Create a funding mechanism to ensure the continuance of long-term or perpetual care selenium management options.

Recommendation #1:

Make an immediate step change in Teck's current selenium management program with a focus on significant changes to mine planning, water management, and waste management at all of its facilities and groups of facilities within the McLeod River and Elk River watersheds.

> **There is a sense of urgency to initiate meaningful change in selenium management practices.**

There is a sense of urgency to initiate meaningful change in selenium management practices in Teck Coal. This urgency is driven by the risk of losing the social license to operate as well as the social license to grow. Within the community of Teck stakeholders, this urgency is driven by concerns about effects on quality of life associated with impacts on water quality, aquatic life, and wildlife. Stakeholders are also concerned about impacts on economic viability caused by the potential reduction in either Teck Coal business or businesses that rely on the health of ecosystems. Additional sources of urgency include the present economic ability of Teck Coal to make changes and act quickly, due to the high price of metallurgical coal as well as the recognition that continued placement of waste rock using present methods may eventually preclude viable solutions for reducing selenium loading to acceptable levels. Every day lost on starting real change has a "triple bottom line" cost and risk.

Westslope cutthroat trout – a valuable eco-tourism resource in the Elk River

Good selenium management practices are already in place at some Teck Coal operations but implementation is not universal nor consistent.

Some good selenium management practices are already in place at some Teck Coal operations. However, their implementation is not universal and their effectiveness is not tracked consistently, so that their ability to meaningfully address stakeholder concerns and management objectives cannot be evaluated. Corporate commitment will require a step change in the level of technical effort and resources currently devoted to managing selenium. A combination of management, staff, contractors, consultants, and academics will be needed to meet this call. Engagement with stakeholders will also be required.

Conventional Active Dump into Valley

Active Pit Where Backfilling is Occurring

Selenium management practices that align with this principle will include:

Mine Planning:

- Include selenium management in mine planning decisions, with a set of formal selenium management rules that can be adjusted as operations proceed. These considerations are likely to change cut-off strip ratios, waste rock dump construction, fleet sizes and mixes, and may also affect the shape of mined out pits, sequencing of ore development and, potentially, even plans to mine certain areas.
- Identify opportunities and not just costs; for example, sell clean water produced by treatment and actively promote use of higher-value reclaimed landscapes

Coal Plant

Goddard Marsh – a still-water habitat which receives selenium-affected waters.

Ponding of creek upstream of a rock drain.

Water Management:

- Use/re-use as much selenium-affected water in coal plants as practical
- Avoid discharging selenium-affected waters that are already in a pipe back into the environment; in particular, avoid discharging into rock drains that contain selenium-bearing rock
- Develop separate systems for clean water and selenium-affected waters – keep clean water clean
- Avoid creating lentic (still-water) habitats that receive selenium-affected water

Waste Management:

- Avoid placing selenium-bearing rock into drains
- Ensure that new valley fills use clear under-drainage, soil salvage, and construction in lifts to limit post-reclamation settlement and subsequent airflow through the dump
- Re-slope existing dumps to a manageable angle and have a revegetated "store and release" type cover on these dumps to control water flux. For legacy dumps, examine methods to reduce percolation of waters; recognize that these dumps will exhibit considerable settlement that may affect the integrity of any cover.
- Where practical and useful, pull back rock from

Converging rock dumps

drainages in areas where dump failure has created local landslides into riparian areas

- Construct new dumps from the bottom up wherever possible, using capillary breaks, compaction, covers, and organic amendments to consume oxygen and prevent infiltration of oxygen
- Design dumps to promote moisture, oxygen, and lithology conditions to support in situ microbial source control through selenium reduction
- Maximize pit backfill

Recommendation #2:

Adopt a framework of sustainability for management and decision making with respect to selenium that relies on robust decision tools and a standardized management approach for approval and implementation of selected options.

The Panel recommends the use of a thorough cost-benefit analysis that equitably incorporates the value of the many resources identified by stakeholders.

The Panel recommends that the selection of optimal combinations (or portfolios) of options for individual operations and for legacy, current and future sites within these operations be evaluated relative to the triple bottom line using a thorough cost-benefit analysis that equitably incorporates the value of the many resources identified by stakeholders in the management objectives.

A thorough cost-benefit analysis would place dollar values on assets that are not normally included such as water, carbon, biodiversity and community amenity.

A thorough cost-benefit analysis would examine the financial, social, and environmental implications of different selenium management options by providing quantification or valuation in monetary terms of the economic sustainability of each option. By explicitly placing dollar values on assets that are not normally included in a cost-benefit analysis or financial Net Present Value (NPV) calculation, such as water, carbon, biodiversity, and community amenity, the effect of these issues on selenium management can be compared with more conventional cost-benefit factors such as construction costs and health/safety and assessed in monetary terms. Such an assessment would require a sophisticated economic model that can incorporate Teck's financial considerations with the social and environmental external costs and benefits associated with different selenium management options. It should also allow for the examination of the effects of a range of possible future outcomes for all sensitive parameters. This analysis would allow the economic viability of an option (measured as NPV positive when all issues are included) to illustrate its true sustainability. Uneconomic options are not sustainable because society does not receive enough overall benefit to justify the costs involved.

Bighorn sheep at Cardinal River Operations

Ultimately, the results of a thorough cost-benefit analysis will assist Teck Coal and its stakeholders in thoughtful development of a portfolio of selenium management options for each mine operation.

Closure costs should be considered in cost-benefit analyses. The Panel is aware that there is a strong desire to avoid perpetual care; however there will be some kind of maintenance on each site for the foreseeable future.

The Panel notes that closure costs, as well as any anticipated need for perpetual or long-term maintenance on individual mine properties, should be considered in cost-benefit analyses. The Panel is aware that there is a strong desire to avoid perpetual or long-term maintenance on individual mine properties. However, there will be some kind of maintenance on each site for the foreseeable future.

The Panel recommends that Teck Coal adopt a suite of decision making tools that follow the Structured Decision Making process.

The Panel further recommends that Teck Coal adopt a scalable suite of sustainability decision-making tools that follow the Structured Decision Making Process illustrated in Section 6 (Figure 7) for future operational and strategic decision making. This suite could include the MCDA approach used by the Panel and the aforementioned cost-benefit analysis. The use of a scalable suite of tools would ensure that Teck Coal can continue to make timely and effective decisions at an operational and strategic level while balancing their many environmental, social, and economic goals and objectives.

The Panel suggests that Teck Coal consider opportunities for habitat mitigation.

Natural resource values are a critical component of sustainability, and the Panel recommends that Teck Coal consider further opportunities for habitat mitigation. In addition to the on-site reclamation of waste rock dumps to create favourable habitat for terrestrial wildlife and human use and the restoration of disturbed streams, the Panel recommends additional off-site mitigation of effects on lotic and lentic aquatic habitats that receive mine drainage. Commendable efforts are underway in the upper Elk River Valley and at Cardinal River for fisheries enhancement, and they should be continued. The Panel recommends that Teck Coal also consider the feasibility of mitigation of effects on lentic habitats (such as Goddard Marsh) for the benefit of species using those affected areas. (As noted earlier, selenium bioaccumulation and associated risk are greater in lentic environments than in the lotic habitat.)

Sphinx Creek reconstruction

A formal Teck Coal process for the review and approval of selenium management options is recommended.

The Panel recommends that Teck adopt a formal corporate process for the review and approval of the portfolio of selenium management options identified for each operation. The Panel has observed that current selenium management plans are not consistent among operations, and in spite of recent, focused efforts to improve, there does not yet appear to be a uniform, formalized management review and approval process. While the Panel does not wish to introduce unnecessary levels of review or bureaucracy, a clear, consistent, and standardized approach to the review and deployment of management options is warranted.

Recommendation #3:

Substantially reduce selenium loading within three years through a combination of water diversion and active water treatment, and keep loading rates below existing levels after that by adopting both remedial and operations measures to greatly reduce selenium loading rates from dumps and rock drains.

> **The objective statements require results in three years – an aggressive timeline that requires immediate attention.**

The objective statements developed with Teck stakeholders in Fernie and Hinton require results "as soon as possible," which was defined as three years by the Hinton Workshop participants. This is an aggressive timeline that requires immediate attention. The Panel suggests the following sequence of activities for the remainder of 2010 as a demonstration of Teck's willingness and ability to meet this timeline:

1. Adopt the recommendations as outlined in this report and amended (as required by the Panel charter) via consultation within Teck Coal and with stakeholders
2. Work with the Panel to identify and optimize selenium management portfolios at each operation for legacy, current, and planned sites by:
   a. Identifying highest-priority locations based on the greatest selenium loads
   b. Review/compile available data to develop cost and benefit estimates
   c. Run the cost-benefit analysis
   d. Identify money and staff required to implement the first set of selenium management actions as identified by the cost-benefit analysis
   e. Devise an active water treatment plan for legacy load reduction based upon available data, and implement pilot testing for the fall of 2010. If possible, integrate water diversion, water reuse, and waste facility designs to reduce the cost of active treatment.
   f. Revise mine plans and dump designs to increase pit backfill, limit water and oxygen flux, and promote selenium reduction.
3. Develop a comprehensive and consistent monitoring program that includes a QA/QC plan and directly link this with a GIS database that addresses cumulative effects.
   a. Implement data collection programs, with priority assigned to high-uncertainty issues that affect the confidence in the selection of selenium management portfolios
4. Modify the existing R&D program to focus on reduction of critical uncertainty attached to the performance of key selenium management options
5. Re-evaluate mine plans for current operations and expansions given the results of cost-benefit analysis and progress on legacy impacts
6. Consider synergistic options to address multiple objectives, or to reduce remedial action costs, by developing strategies in series within watersheds

The longer-term selenium management plan should identify clearly the selenium load reduction targets.

A simplified anlaysis conducted by the Panel shows that continued growth in coal production would result in an increasing trend in selenium even with considerable short-term loading reductions.

Selenium concentrations likely will stay below current levels for most loading reduction scenarios and would not exceed guidelines for drinking water under any scenario.

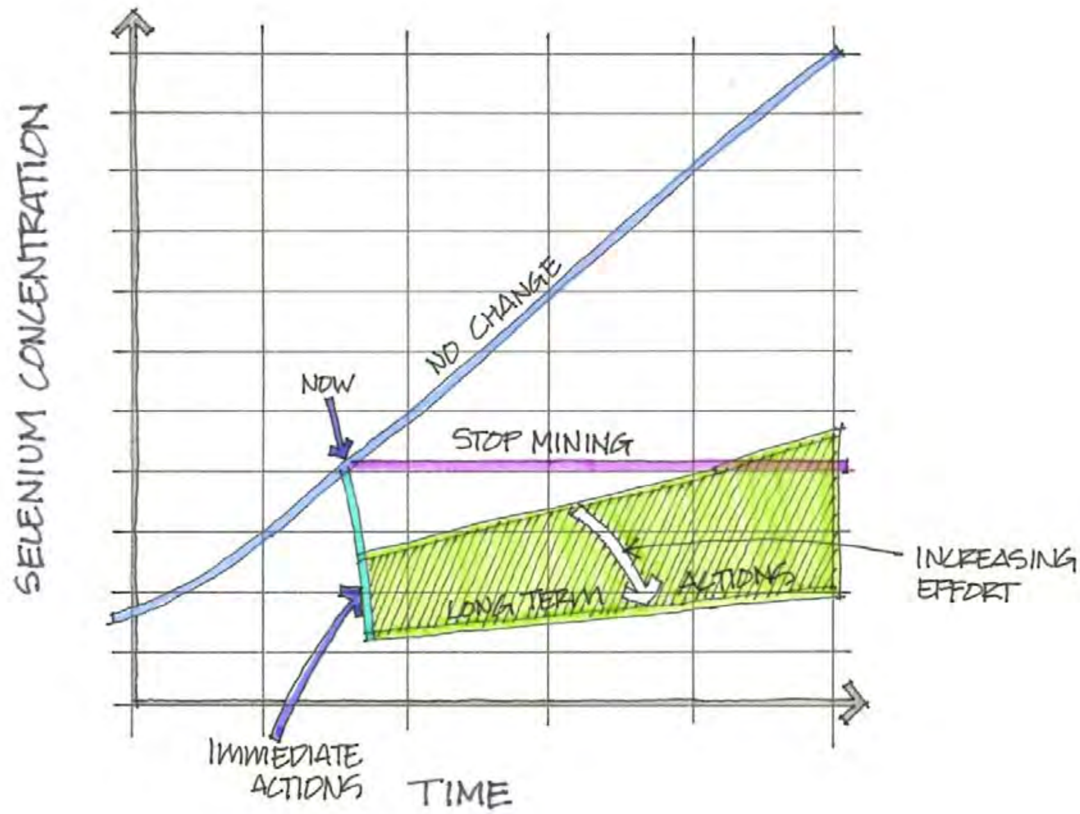
The Panel's analysis indicates that selenium concentrations could be prevented from reaching thresholds for population-level effects on fish and other aquatic life.

Maintaining selenium concentrations below existing levels will require high levels of effort.

The specific sequence of selenium management activities for 2011-2013 would depend upon the priorities identified during the analyses to be conducted later in 2010. The longer-term selenium management plan should identify clearly the load reduction targets, because the Stakeholder Objective statements require a reversal in the selenium trend. A simplified analysis conducted by the Panel and illustrated below (Figure 9) has shown that continued growth in coal production would result in an increasing trend in selenium even with considerable short-term loading reductions. This is unavoidable because no selenium management strategies are 100 percent effective. These generalized estimates reflect the net ability of combinations of management strategies to reduce selenium loading. The "business as usual" or "no change" scenario produces an increasing trend consistent with loading observed in recent years. The "stop mining" scenario would hold concentrations at current levels. A range of other scenarios would produce a short-term decrease followed by an increase in selenium concentrations at different rates reflecting management effectiveness. Selenium concentrations likely will stay below current levels for most scenarios and would not exceed guidelines for drinking water under any scenario. This analysis indicates that selenium concentrations will increase slowly over time with continued mining but could be prevented from reaching thresholds for population-level effects on fish and other aquatic life. This model should be refined and made more robust as more specific data on loading and treatment options become available.

The Panel notes that maintaining selenium concentrations in receiving waters below existing concentrations, given the existing as well as the planned volumes of waste rock, will require high levels of effort in reducing the production of selenium from all waste rock piles.

Figure 9: Selenium Concentration Plotted Against Time and Mine Growth



Recommendation #4:

Identify and adopt portfolios of management options that offer synergies resulting in additional benefits (e.g., more efficient selenium load reduction, reduction in calcite formation or reduced nitrogen release to water).

> **There are opportunities to use selenium management options synergistically to achieve efficient selenium load reduction.**

There are opportunities to use management options synergistically so they would reduce demand for more expensive management options and accomplish efficient selenium load reduction. For example, reuse of selenium-impacted water and diversion of clean water would reduce the volume of water requiring active treatment.

Water and waste management, as well as source-control related to selenium reduction, offer potential additional improvements to both terrestrial and aquatic ecosystems associated with Teck Coal operations. Improved water quality would enhance biodiversity in receiving streams. Integrated water quality management would reduce total dissolved solids,

An integrated program of water and waste management would have benefits extending beyond selenium reduction to issues such as calcite formation, total dissolved solids, sulphates and nitrates, and the quality of wildlife habitat.

sulphates and nitrates in streams and rivers. Improved waste management and reclamation practices can reduce concerns regarding wildlife health and management of wildlife populations. Improved water management can reduce loadings of all chemicals of concern, not just selenium. A combination of waste and water management practices can be used to prevent calcite deposition. The additional benefits of selenium management options should be evaluated explicitly in future analyses.

Recommendation #5:

Refocus Teck's R&D program to obtain critical design information in a timely manner.

Teck has an extensive R&D program that is focussed on biological effects monitoring, laboratory and small-scale geochemical field experiments on selenium oxidation and leaching, and small-scale, semi-passive water treatment pilots.

Teck Coal's R&D program needs to be re-designed. The program should distinguish between performance and effects monitoring, site investigation, technical development / piloting and research.

The Panel recommends that the R&D program be re-visited and re-designed. The new program would distinguish between "performance and effects monitoring;' "site investigation;" "development / piloting" of treatment technologies; and "research." Much of the near-term work will involve "development and piloting" and "site investigation" as Teck moves into development and full-scale application of management strategies that have been the focus of ongoing research and development activities. Specific development and pilot-scale process development goals will involve scale up of active water treatment options and determination of options for reducing water and oxygen entry into existing rock dumps. Site investigation of hydro-geochemical and biogeochemical processes will lead to pilot-scale testing of new dump designs for control of oxygen and water within rock dumps.

> **The R&D program should identify near-term studies that are required to reduce critical areas of uncertainty related to ranking of selenium management options.**

The R&D program should identify near-term investigations that are required to reduce critical uncertainty and confirm that the first set of selenium management measures to be implemented will, indeed, have a high likelihood of achieving a selenium loading reduction in three years. For example, a likely component of the program in the near future would be to establish the physical/chemical mechanics of selenium loading from rock drains, so that Teck can quantify the benefit of diverting water or changing dump construction practices to avoid rock drains. Another would be definition of factors that drive the observed selenium sequestration in tailings and CCR facilities. Much more information on water balance is required; this information is vital for design of active water treatment at the high-priority, highest-selenium-loading locations.

The longer-term R&D program may benefit from partnering with universities and colleges.

Recommendation #6:

Restructure the selenium and water quality monitoring program to improve data quality and availability, increase understanding of loading, and facilitate measurement of reduced loading as selenium management measures are implemented at the landform, site watershed, and regional watershed level. The monitoring should be linked directly with a GIS-based database system, with further standardization of procedures and quality assurance.

> **A comprehensive and consistent monitoring program is an urgent requirement.**

A comprehensive and consistent monitoring program is an urgent requirement. In spite of focused recent efforts by Teck Coal, the Panel has noted a number of inadequacies in the current monitoring. This program should be redesigned and made more comprehensive. Additional steps to standardize methods, data quality objectives, data reduction and evaluation, and data archives are required. A GIS-based system is recommended.

> **There is an almost immediate need for improved understanding of surface water and groundwater flows and their interaction with seepage in and around waste rock dumps.**

There is an almost immediate need for improved understanding of surface water and groundwater flows and their interaction with seepage in and around waste rock dumps. This is an important limitation of the work completed to date. Also, there are no climate stations in the mine areas; instead, there is reliance on measurements in Sparwood, which is far from most of the operations and at a much lower elevation. Appropriate climatic monitoring should be established, including efforts to monitor snow and evaporation. Data currently being collected are not stored in an easily retrievable format and the data quality objectives are not clearly defined, although work is underway to address these concerns. While the data are sufficient to make strategic recommendations, they are insufficient for operational decisions and detailed design/monitoring.

Laboratory methods should be reviewed and standardized.

There is also considerable uncertainty about the sampling and laboratory methods currently used to measure selenium concentrations and loads in creeks and rivers, as well as in monitoring wells. A review and standardization of methods for the entire watershed system at each mine operating area (Elk Valley and Cardinal River) is needed. Additionally, the frequency of sampling needs to be reviewed – automated composite samplers and continuous flow measurements will likely be required in key locations.

Monitoring locations for confirmation of reductions in selenium concentrations should be identified and incorporated into the monitoring program.

The monitoring program should be able to validate previous measurements of selenium concentrations and trends at a number of important geographic locations, including the following "confirmatory" locations:

- Elk River at Highway 93;
- Elk River at Sparwood;
- McLeod River where it is met by Luscar Creek;
- Fording River where it joins the Elk; and
- Specific lentic areas such as Goddard Marsh.

Elk River near Elko (also near Highway 93)

This validation is needed as a basis for confirming reductions in selenium loadings at upstream locations closer to (or on) the mine sites. These monitoring locations would include "last point of control" monitoring stations at locations such as West Line Creek below the weir. In addition, the first point at which fish habitat is known to occur should be monitored for water quality in each tributary leaving the mine property. The specific locations of these "last point of control" and "first fish habitat" monitoring stations and the frequency of sampling should be identified as part of the monitoring program design.

Monitoring for cumulative effects is a requirement and must include concurrent measurement of selenium exposure and effects.

Cumulative effects data should be collected in any monitoring program. The current aquatic effects monitoring program should be rolled into the overall program, with particular attention paid to collection of biological response data from the same locations as water and sediment data. The goal of cumulative effects monitoring would be to document selenium-loading reductions with resultant decreases in receiving water selenium concentrations, tissue concentrations and the response of key biological indicators. Cumulative effects monitoring provides an opportunity to involve and inform stakeholders.

Recommendation #7:

Develop a selenium management communications plan within and among Teck Coal operations and other stakeholders to ensure that ideas, data, lessons learned, and key success stories are shared.

Current communication about selenium within and among Teck Coal operations is inconsistent and does not produce a broadly-based understanding of the selenium issue.

The Panel has observed that current communication about selenium within and among Teck Coal operations is inconsistent and does not produce a broadly based and accurate understanding of the selenium issue and its management among Teck employees. This is a key issue because successful implementation of the selenium management program will depend upon the understanding and collaborative effort of all employees.

A plan and adequate resources are required to produce effective internal stakeholder engagement and communication.

Effective internal stakeholder engagement and communication will require not only a plan, but also adequate resources. It is likely that additional staff will be needed to implement the plan within Teck. As this is a strategic plan, the value and means of changing “the way things are done” will need to be made clear to Teck employees and other stakeholders. Equally important, the way in which these changes will affect individual employees, or groups of employees, should be made clear. Finally, the reward and incentive programs that will be put into place to recognize compliance with the desired changes should be communicated.

Recommendation #8:

Continue and expand engagement with stakeholders on selenium issues.

An expanded stakeholder engagement program is recommended.

The Panel will continue to consult with stakeholders during the development of specific plans for each of the Teck Coal operations. However, the Panel suggests that an expanded stakeholder engagement program with a concomitant increase in staffing will be valuable to Teck Coal's efforts.

An expanded stakeholder engagement program could include participation in and/or sponsorship of community-based monitoring programs. The proposed "Elk River Alliance" is an example of such a program.

Recommendation #9:

Develop a formal risk assessment and scanning framework to ensure emerging sustainability risks are recognized early on and framed appropriately against the current portfolio of risks Teck Coal is currently managing.

A formal corporate risk assessment and scanning framework will help identify and prioritize emerging risks.

The development of a formal risk assessment and scanning framework will help to ensure that current and future selenium management actions do not catalyze or exacerbate emerging sustainability risks. This same framework will assist Teck Coal with minimizing potential future consequences associated with past, current, and future mining operational practices. At the same time it can provide Teck Coal with the ability to generate measured responses that are commensurate with the potential likelihood and consequence of the emerging risk to its operations.

Continued engagement with Teck Coal's stakeholders will be a valuable component of the risk-scanning framework. These stakeholders may offer additional information regarding environmental conditions surrounding Teck Coal's operations or key findings regarding emerging risks from other mining and industrial jurisdictions.

The Building Blocks (or Tool-Box) for Selenium Management

Section 6 described the process of scoring and ranking the ten primary selenium management options and presented the results of this process (Table 9). These ten management options compose the primary building blocks (or Tool-Box to use Teck Coal's terminology) for building selenium management portfolios at each Teck Coal operation. There is no single option that will provide "the answer." The top-ranked option may not be the #1 choice at all operations or all locations within particular operations. Rather, a combination of options will be required to meet the selenium management objectives.

The Immediate Action Plan

The Panel recommends implementation of three of the options in order to reduce selenium loadings in three years.

Three options were deemed by the Panel to be capable of reducing selenium loadings within three years, with a high degree of certainty:[24]

- Active water treatment
- Diverting clean water from rock drains
- Avoiding the placement of waste rock in cross valley fills

Teck Coal should act immediately to identify and evaluate target locations for each of these three options.

We recommend that Teck Coal act immediately to identify and evaluate target locations for each of these three techniques, choosing areas where the reduction in loading rates are likely to be the greatest, and start design on these projects immediately thereafter so that the new facilities will be in place within three years. The selection process may also include evaluation of opportunities for staged implementation of these options in the following years.

Active water treatment should be targeted at areas with the largest legacy waste rock selenium loadings and the lowest volume of water to be treated.

The panel recognizes that there will be technical challenges and limitations associated with each of these options. There will also be uncertainty about the degree of reduction. Each of these is explored below.

With respect to active water treatment, site selection may be influenced by a desire to target areas with the largest legacy

[24] Reduction here means both a stabilizing of the trend line with respect to selenium concentration in surface waters and a negative slope to the curve as the selenium concentrations begin to decline.

waste rock selenium load contributions and the lowest volume of water to be treated – West Line Creek is an obvious target to evaluate, as are Kilmarnock and Swift Creek. Other areas may be complicated by local flow conditions – especially where there is substantial subsurface water flow through porous foundations.

Diversion of clean water from rock drains can be applied more widely, but will only be effective where there are discrete and manageable streams upstream of the waste dump.

The diversion of clean water from rock drains can be applied more widely. However, diversion will only be effective where there are discrete and manageable streams upstream of the waste dump. Immediate consideration should be given to avoiding placement of waste in locations where clean water can be collected for subsequent diversion.

Geography can limit Teck Coal's ability to avoid cross valley fills and there may be a large and negative impact on mining costs. Therefore, an appropriate approach may be for Teck Coal to review its mine plans for opportunities to reduce the extent of future cross-valley fills.

The Panel notes that geography can limit Teck Coal's ability to avoid cross-valley fills in some locations. Such avoidance would result in longer hauls. There may also be more land disturbance over a broader area (although placement of waste within the mined footprint would mitigate this). There may be a large and negative impact on mining costs, especially in the Elk Valley. Accordingly, an appropriate approach may be for the company to review its mine plans and look for opportunities to reduce the extent of future cross-valley fills and seek alternatives that allow more water diversion away from waste rock dumps and rock drains.

Method development and pilot scale testing of other options should begin right away.

Other options, such as reducing oxygen availability within existing rock dumps to promote selenium reduction, could be considered but would require method development and pilot scale work, which should also begin right away.

The Line Creek expansion requires some redesigning for selenium management.

The Line Creek expansion falls within the immediate action plan. The dumps for the expansion (including foundation preparation) need to be redesigned for selenium management. This redesign should include evaluation of opportunities for clean water capture, maximizing pit backfill, and avoidance of rock drains.

An important caveat is that economic and social values will almost certainly be at risk if each of these options is used across Teck Coal operations. Widespread adoption of these options would be expensive and would require a high level of maintenance, leaving long-term sustainability in question. This

The immediate actions are not sustainable if applied widely across Teck Coal operations. The longer-term plan would deploy tailor-made suites of selenium management options at individual sites.

The recommended combinations of actions at legacy, existing and future sites will continue to be developed and refined, with the assistance of the Panel.

is why, in the longer term, Teck Coal should deploy the recommended suite of ten management actions in a fashion that is tailored to specific site conditions. It is only by focussing on individual sites that the selenium management objectives will be achieved.

The Panel will work with Teck Coal and its stakeholders over the balance of 2010 to begin the process of refining each option and determining which option (or combination of options) would be most effective at individual operations. In the main, however, it is recommended that the company commit to a combination of actions such as the following:

FOR AT LEAST ONE LEGACY ASSET WITH HIGH SELENIUM DISCHARGE	FOR ALL EXISTING OPERATIONS	FOR ALL FUTURE PLANNED MINE EXPANSION
▪ Active water treatment (e.g., biological fluidized bed reactor) ▪ Passive water treatment (e.g., passive biological reactor, permeable reactive barrier)	▪ Divert clean water from rock drains ▪ Maximize pit backfill ▪ Promote in-situ microbial reduction as source control ▪ Reclaim existing dumps to reduce selenium mobilization ▪ Hire needed personnel ▪ Implement site investigations and pilot scale development actions	▪ Avoid placement of waste in cross valley fills ▪ Use only low-selenium, massive rock in rock drains ▪ Design new dumps to limit oxygen and water infiltration ▪ Evaluate opportunities to place waste rock under water in a constructed impoundment

Conclusion

Teck's willingness to commit to the principles identified above is a defining feature of a new approach to selenium management. Support of specific changes in practice for particularlegacy, operating, and planned assets is a worthy expression of Teck's sustainability commitment. In particular, if the company is to genuinely "take into consideration the current needs of society and the ability of future generations to meet their own needs," and "*find, extract and provide natural resources to society for the benefit of present and future generations"* as their sustainability commitment suggests, the principles and actions identified above represent a fundamental and required evolution in selenium management and practice.

Appendix A

Maps of Teck Coal Operations

SCALE:	1:400,000
DATE:	JUN 2010
DRAWN:	
DESIGNED:	
CHECKED:	
APPROVED:	

PROFESSIONAL SEAL:

REV. | DATE | REVISION NOTES | DRAWN | CHECK | APPR.

CLIENT: STRATEGIC ADVISORY PANEL ON SELENIUM MANAGEMENT

PROJECT: A STRATEGIC PLAN ON SELENIUM MANAGEMENT

TITLE: CARDINAL RIVER OPERATION AREA
ELK RIVER OPERATION AREA

PROJECT No.: 0876-001 | FIG No.: 2 | REV.:

FIG TO BE READ WITH REPORT TITLED "WAY AHEAD: A STRATEGIC PLAN FOR SELENIUM MANAGEMENT AT TECK COAL OPERATIONS"

REV.	DATE	REVISION NOTES	DRAWN	CHECK	APPR.

SCALE: 1:100,000

DATE: JUN 2010

DRAWN:

DESIGNED:

CHECKED:

APPROVED:

PROFESSIONAL SEAL:

CLIENT: STRATEGIC ADVISORY PANEL ON SELENIUM MANAGEMENT

PROJECT: A STRATEGIC PLAN ON SELENIUM MANAGEMENT

TITLE: CARDINAL RIVER OPERATION AREA

PROJECT No.: 0876-001

FIG No.: 3

REV.:

FIG TO BE READ WITH REPORT TITLED "WAY AHEAD: A STRATEGIC PLAN FOR SELENIUM MANAGEMENT AT TECK COAL OPERATIONS"

REV.	DATE	REVISION NOTES	DRAWN	CHECK	APPR.

SCALE: 1:125,000
DATE: JUNE 2010
DRAWN:
DESIGNED:
CHECKED:
APPROVED:
PROFESSIONAL SEAL:
CLIENT: STRATEGIC ADVISORY PANEL ON SELENIUM MANAGEMENT
PROJECT: A STRATEGIC PLAN ON SELENIUM MANAGEMENT
TITLE: ELK RIVER OPERATION AREA
PROJECT No.: 0876-001
FIG No.: 4
REV.:

FIG TO BE READ WITH REPORT TITLED "WAY AHEAD: A STRATEGIC PLAN FOR SELLENIUM MANAGEMENT AT TECK COAL OPERATIONS"

Appendix B

Panel Charter

Strategic Advisory Panel on Selenium Management

Introduction

The mining of steel-making coal increases the release of selenium, a naturally occurring element, to the environment. In recognition of this, Teck Coal has commissioned an independent advisory panel to help forge a selenium management strategy and implementation plan.

This Charter establishes the Panel name, authority, membership and mandate. In the absence of any guidance for scientific advisory panels in Canada, this Charter follows guidance provided under the U.S. Federal Advisory Committee Act (FACA).

Panel Charter

Panel Name

Strategic Advisory Panel on Selenium Management

Authority

The Panel has been established under the authority of Robin Johnstone, General Manager of Environmental Affairs, Teck Coal.

Goal and Objectives

Goal

Provide independent, expert advice and assistance by producing a strategic plan for the sustainable management of selenium at Teck Coal operations.

Objectives

- Develop a selenium strategic management plan that integrates the environmental, social and business opportunities and risks associated with selenium management by June 30, 2010.
- Develop a conceptual implementation plan for the strategy by June 30, 2010
- From June to the end of 2010, to further advise on the implementation of the strategic plan at individual operations.

Description of Duties

The Panel will define and commit to tasks and activities along a critical path that results in the achievement of Panel objectives. Related activities will include the production and execution of a Communication Plan for the Panel. Panel members are required to attend all scheduled meetings. Panel members are required to participate actively in Panel tasks. Panel performance measures will be used to evaluate Panel progress and value.

Official to Whom the Panel Reports

The Panel provides its advice to Robin Johnstone, General Manager of Environmental Affairs, Teck Coal.

Support

The Panel receives financial and logistic support from Teck Coal.

Estimated Number and Frequency of Meetings

The Panel will meet monthly from January to June, 2010. There will be three Panel meetings for the period July-December, 2010.

Duration

The Panel will serve for one year, spanning the period January-December, 2010. The Panel's duration may be extended at the discretion of Teck Coal

Membership and Designation

Chair: Stella Swanson, Swanson Environmental Strategies Ltd.

Stella Swanson [Aquatic Biologist/Risk Assessment]. As chair, responsible for strategic direction of the Panel; liaison with Teck Coal and voice of the Panel with Teck Coal; performance of the Panel; adherence to the Panel Charter; communication lead; governance of the Panel.

Members:

Rob Abbott, Abbott Strategies [Sustainability and Stakeholder Strategist]
Wes Funk, Worley Parsons [Sustainability Evaluation]
Gord McKenna, BGC Engineering [Reclamation and Landform Design]
Harry Ohlendorf, CH2M Hill [Ecological Risk Management; Selenium Ecotoxicology]
Tom Sandy, CH2M Hill [Industrial Wastewater Treatment]
Lisa Kirk, Enviromin [Geochemist]

Teck Coal Liaison

John Pumphrey, Environmental Administrator, Teck Coal

Panel Independence

The Panel recognizes the inherent contradiction between being commissioned and paid for by Teck and the provision of independent advice. The intent of forming the Panel is to obtain objective, unfettered opinion.

Panel Membership

"To be effective, peer review panels must be—and also be perceived to be—free of any significant conflict of interest and uncompromised by bias. Peer review panels should also be properly balanced, allowing for a spectrum of views and appropriate expertise." (GAO 2009)

In light of the above statement, the following applies to membership on the Selenium Advisory Panel:

- Panel members should be free of financial conflicts of interest.
- If Panel members have a financial conflict of interest (e.g. they are Teck shareholders), they can be granted a waiver to serve on the Panel but the existence of the conflict and the waiver document shall both be made public.
- The term of Panel membership shall be made public
- Requirements for remaining a Panel member "in good standing" are:
  - Attendance at all Panel meetings;
  - Active participation in Panel discussions, deliberations and decisions
  - Acceptance of accountability for the quality and value of Panel deliberations and decisions

Transparency

- Teck shall ensure the process for selecting Panel members is transparent by:
  - publicly announcing the formation of the Panel,
  - publishing criteria for selecting Panel members,
  - publishing the Panel Terms of Reference and timeline for Panel output,
  - making basic information on Panel members easily available to the public. This information will describe each member's qualifications and background, and disclose past employers and Advisory Committee membership.
- Teck will publish Panel output such as the Selenium Management Strategy report and respond to their findings and recommendations.
- Teck will pay the expenses associated with Panel meetings with regulators, stakeholder groups and aboriginal groups
- If a Panel member's organization has patented or otherwise proprietary technology and/or tools that may be included in Panel recommendations, the Panel member shall declare a conflict of interest during consideration of the technology or tool and recuse themselves from Panel discussions involving any recommendation relating to that technology or tool

Demonstration and Maintenance of Panel Independence

- Panel meetings will be for Panel members only, except when:
  - the Panel has determined that it requires information to be presented by Teck;
  - the Panel has questions for Teck or its consultants; and
  - the results of Panel deliberations are presented to Teck.
- Panel meetings will not be held at Teck offices except during tours of Teck mining operations, when practical considerations may dictate the location of meetings.
- The Panel will communicate independently with regulators and stakeholders. Teck will be copied on materials to be presented as well as minutes of such meetings; however, Teck will not have authority to change or edit those materials, except when factual errors regarding Teck operations are identified.
- Having a point of view does not preclude an objective assessment of the information presented to the Panel. A Panel member's membership in a scientific association or non-government association shall not be considered evidence of bias, even if that association has a stated policy agenda.

Sources of Information

The Charter follows guidance prepared in support of the U.S. Federal Advisory Committees Act (http://www.gsa.gov/Portal/gsa/ep/).

The Charter includes measures recommended by the Union of Concerned Scientists (http://www.ucsusa.org/scientific_integrity/solutions/big_picture_solutions/scientific-advisory-committees.html) as well as by the US Government Accountability Office (http://www.gao.gov/new.items/d09773t.pdf). The concerns and recommendations of NGOs were noted and reflected by reviewing documents such as the Natural Resources Defence Council comments on the Presidential Memo on Scientific Integrity (http://docs.nrdc.org/health/files/hea_09051401a.pdf).

Appendix C

Panel Activities

APPENDIX C: PANEL ACTIVITIES CONDUCTED FROM JANUARY 2010 TO JUNE 2010

Panel Meetings

- January 14-15 (Inaugural Meeting)
- February 1-2
- March 16-17
- April 18-20: Tour of Elk Valley mine operations and Panel Meeting in Fernie
- May 16-19: Tour of Cardinal River Operation and Panel Meeting in Edmonton
- June 8-10: Multi-Criteria Decision Analysis conducted by the Panel
- June 24: Conference Call regarding the Strategic Plan report

Stakeholder Meetings

- January 25 (Stella Swanson and Teck Coal)
- February 19 (Stella Swanson and Teck Coal)
- March 9: (Stella Swanson, Wes Funk, Rob Abbott of Panel and Teck Coal)
- March 10: (Stella Swanson, Wes Funk, Gord McKenna of Panel and Teck Coal)
- March 15: (Stella Swanson, Wes Funk and Rob Abbott of Panel and Teck Coal)
- March 18: (Stella Swanson and Rob Abbott of Panel and Alberta Environment, Sustainable Resource Development, Fisheries and Oceans Canada)
- April 20: (Entire Panel and Area A Representative, Regional District East Kootenay)
- April 21: (Entire Panel and representatives of individual Teck Coal operations)
- April 21: (Stella Swanson and representative of Fernie community regarding establishment of Elk River Alliance)
- April 22: (Stella Swanson, Mayor and Councillor of Elkford)
- April 23: (Stella Swanson and representatives of Wildsight)
- April 26: (Stella Swanson, Mayor and Council of Fernie)
- April 27: (Stella Swanson and representative of fly fishing guides)
- April 27: (Rob Abbott and Wes Funk of Panel and representatives of Energy Resources Conservation Board of Alberta)
- April 28: (Stella Swanson, Rob Abbott and Wes Funk of the Panel and representatives of BC Ministry of Environment and Fisheries and Oceans Canada)
- April 29: (Stella Swanson, Rob Abbott and Wes Funk of the Panel and the Mayor of Sparwood)
- May 13: Fernie Workshop
- May 17: (Rob Abbott and representative of Alberta Trapper's Association)
- May 17: (Rob Abbott and representative of Athabasca Bioregional Society)
- May 17: Rob Abbott and representative of Yellowhead County)
- May 18: (Rob Abbott and retired CRO mine employee)
- May 18: (Rob Abbott and representative of Foothills Research Institute)
- May 18: (Rob Abbott and representative of Town of Hinton)

- May 18: (Rob Abbott and representative of Hinton Fish & Game Club)
- May 18: (Rob Abbott and Alberta MLA for Yellowhead)
- May 28: (Rob Abbott and representatives of Alberta Ministry of Sustainable Resource Development)
- June 2: Hinton Workshop

Appendix D

Workshop Reports

Teck Coal Limited
Stakeholder Engagement Workshop
Fernie, British Columbia

C70940000

25 June 2010

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WorleyParsons

resources & energy

TECK COAL LIMITED
STAKEHOLDER ENGAGEMENT WORKSHOP
FERNIE, BRITISH COLUMBIA

PROJECT - STAKEHOLDER ENGAGEMENT WORKSHOP
FILE LOC.: CALGARY

REV	DESCRIPTION	ORIG	REVIEW	WORLEY-PARSONS APPROVAL	DATE	CLIENT APPROVAL	DATE
A	Issued for review	O. Ogrodnik	S. Ferner	A. MacDonald	21-May-10		
B	Issued as draft	O. Ogrodnik	S. Ferner	A. MacDonald	22-Jun-10		
0	Issued as final	O. Ogrodnik	S. Ferner	A. MacDonald	25-Jun-10		

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Teck Coal Stakeholder Engagement Workshop
Potential Selenium Management Solutions
Fernie, British Columbia

1. OVERVIEW

1.1 Introduction

The Strategic Advisory Panel on Selenium Management (SAPSM) – "the Panel" - hosted its first workshop on selenium management in Fernie, British Columbia on Thursday, May 13, 2010. Teck Coal Limited (Teck Coal) has large operating mines in the area that are associated with selenium release. Facilitation and logistical support was provided by Swanson Environmental Strategies Limited and WorleyParsons Canada Limited. The agenda for the workshop and a list of participants are provided in Appendix A and B, respectively.

The focus of the one-day workshop was to review potential selenium management options. The workshop provided a venue for various stakeholders to acquire a better understanding of the selenium issue, to talk about sustainability as it pertains to selenium, and to gain feedback from stakeholders about various management options. The workshop provided an opportunity for participants to talk openly about their concerns and to ask questions about the rising selenium concentrations in the Elk River Valley.

The workshop provided valuable information for the Panel, as it allowed for a better understanding of the stakeholders' concerns, which will assist the Panel and Teck Coal in making informed decisions regarding selenium management.

1.2 Background

The Panel was established in January 2010 to provide an independent third party review of management efforts to reduce selenium concentrations downstream of Teck Coal's mining operations within Alberta and British Columbia. In the Elk River Valley, selenium concentrations are above the Canadian Council of Ministers of the Environment (CCME) Water Quality Guideline (WQG) values and are increasing annually.

The Panel's objective is to develop a selenium strategic management plan (Strategic Plan) that integrates the environmental, social and economic opportunities and risks associated with selenium management. The Strategic Plan will be tabled on June 30, 2010 and will be provided to all stakeholders and Teck Coal on this day, simultaneously. There will be no prior release of the Strategic Plan to Teck Coal. The Strategic Plan is not intended to provide a fixed solution for selenium management in all locations, but rather to provide a framework for sustainable operation-specific and watershed scale decisions. The Strategic Plan will consider the key elements of sustainability (environmental, economic and social factors). It will also take into consideration the stakeholders' input from this workshop and an additional workshop, which was conducted in Hinton, Alberta on June 2, 2010.

The following is a summary of the topics that were discussed in the Fernie workshop on May 13, 2010. Comments, inputs and questions from all workshop participants (stakeholders and the Panel) have been noted throughout the report in *italics*.

2. OBJECTIVES

2.1 Purpose of the Workshop

WorleyParsons were commissioned by the Panel to pursue the following objectives in a collaborative workshop format:

1) Engage, solicit and document comments from external stakeholders with respect to the work of the Panel, including an objective statement, sustainability criteria and potential selenium management options.

2) Document any issues, ideas and questions associated with each option from a sustainability perspective.

3) Engage and receive comments from stakeholders on recommendations for the next steps in the decision making process.

2.2 Workshop Structure

The workshop was designed to provide opportunities for stakeholder input. The day began with Stella Swanson, the chair of the Panel, welcoming all participants and explaining that several members of the Panel were at the meeting to listen to feedback and to answer any technical questions. She stated that *"the management of selenium will be strongly rooted in opinions and views of the community".* Community feedback would be taken into consideration in the Strategic Plan, which will be released on June 30, 2010.

Alan MacDonald, the Lead Facilitator from WorleyParsons, outlined ground rules for the discussion. Respect for others' opinions was crucial. It was made clear that the names of the stakeholders would not be mentioned in this report, which is in accordance with the Personal Information Protection Act.

The workshop addressed the following topics: sustainability, the objective statement, sustainable decision making, and potential management options for selenium. Both small and large group discussion sessions were held.

2.3 Sustainability Definition

The term "sustainability" was discussed by the participants during the opening ice-breaker portion of the workshop. The results of the ice-breaker are provided in Appendix C. Participants were asked to work in small break-out groups to discuss "what sustainability means to you". In all groups, sustainability was defined in relation to a balance of economic, environmental and social viability in both the short and long term. These definitions were utilized as a basis in creating sustainability evaluation criteria for evaluating potential selenium management options. The sustainability evaluation criteria are further discussed in Section 4 of this report.

2.4 Selenium Management Objective Statement

The next session of the workshop was a group discussion with all present individuals, with the purpose of defining a Selenium Management Objective for Teck Coal's operations in the Elk River Valley. The Panel's Selenium Management Objective Statements were introduced to initiate the discussion, which included the following:

- Develop a Selenium Strategic Management Plan that integrates the environmental, social and business opportunities and risks associated with selenium management by June 30, 2010.
- Develop a conceptual implementation plan for use at the individual operating mines that accurately reflects the strategic plan.
- Develop detailed implementation plans for each Teck Coal operating mine.

The Facilitator asked the group to come up with their own objective(s). Guiding the discussion were the "five W's"... who, what, where, when and why. A lively discussion ensued (see Appendix D for the minutes on this section of the workshop).

The group arrived at the following Objective Statement:

"Define, implement, monitor and communicate sustainable ways to stabilize and reverse the selenium trend in the Elk River watershed as soon as possible. 'Sustainable' implies the context of continued mining and growth as well as social and environmental values."

3. POTENTIAL SELENIUM MANAGEMENT OPTIONS

Participants asked the Panel's technical experts to provide some information about selenium management options. Stella Swanson, Lisa Kirk and Tom Sandy of the Panel briefly summarized the management options that were under consideration. The Panel believes that a portfolio of management solutions may be required for each site, particularly when looking at legacy waste dumps compared to future dumps. Participants were told that the management report will initially be based on a virtual mine, with a focus on rock dumps and hydrogeochemistry.

Stakeholders were asked to provide input and suggestions for additional selenium management options. All suggestions were considered and a number of new ideas were brought forward. A summary of the ideas discussed during the workshop is provided in Table 1. The following comments were made during the options discussion.

3.1 Water Treatment

- *Q. Would the water treatment option be able to handle more than selenium (i.e. other contaminants)?*

  A. Treatment can remove other solutes depending on which method is used. It is possible to remove a lot of pollutants with biological and membrane filtration methods, but membrane systems work on percent efficiencies, so it is progressively harder to remove low concentrations. There will also be by-product (e.g. filters, filter cake) which will need to be managed. Could end up with a pretty complex and high cost system if the goal was to remove multiple compounds to low concentrations.

Sparwood Water Treatment Plant:

- *Q. The Sparwood community is going to build a water treatment plant. Is there a possibility to incorporate selenium extraction at this Water Treatment Plant to create synergy between Sparwood and Teck Coal?*

  A. The idea would be that while Teck Coal is dealing with source at the mine sites, the company could work with the city to protect end-users using a municipal water treatment process.

  Teck Coal needs to consider not only drinking water but also the watershed, and so must consider high selenium flows close to the mines. This would require piping the water to the treatment plant.

  We will also need to look at volume for treatment processes as the volume of impacted water high in the watershed is smaller than the volume at the watershed scale.

We could also place a biological system within the sewage treatment plant. This could use the same process as removing nitrogen to remove selenium. It would be a co-treatment of sewage and selenium through a public operated treatment works or potentially privately operated works.

- *Q. What is the potential for selenium to enter Sparwood's aquifer drinking water source due to this type of treatment? If contamination happened to Sparwood's drinking water, what is the process to treat it?*

  A. Concentrations have been detected intermittently in the Sparwood drinking supply. There is considerable variation observed in concentration in surface water, and we do not have a well defined mass load model for the system that allows us to understand where selenium is added to, and lost from, the affected drainages. This is also affected by portions of drainages which lose water to (and gain water from) alluvium. Data is being collected to better understand the hydrogeology of the area. Recommend more detail and understanding of this issue.

  If the community's water supply was impacted, one could treat the water. The most widely used mitigation strategy for preventing the contamination of drinking water are water-control covers for waste rock facilities, often in constructed dumps or impoundments, which could include use of pit-lakes to develop reducing conditions.

  If one decides to treat with a membrane to remove all constituents down-gradient of the mine, one would create a very high quality water source that would be difficult to put it back into natural waters because it would influence that chemistry.

  Regarding the time frame, surface water and shallow groundwater can be treated easily and quickly, but depending on the type of hydro-geology and groundwater contamination, it could take a very long time to treat deeper groundwater sources.

Protected Bio-treatment System (Engineered):

- *Q. Is there only the microbial level treatment, or are there other plant-based treatments that can be used?*

  A. Wetland treatment is common for polishing, although plant-based treatment is often not useful. Plants are good at taking up selenium, they bio-accumulate the selenium, making it possible for accumulation up the food chain when selenium-rich vegetation is eaten by grazing animals.

- *Q. What about sequestering in a wetland which is not accessible, isolate it, then take it and dispose of it as biofuel, or even recapture selenium as a product? Could create business opportunities, i.e. vitamins.*

A. *Wetlands are an option, but may promote bioavailability.*

Selenium recovery is an economic option, but removal of sequestered selenium from a wetland is impractical.

Fungi Treatment:

- *Some promising examples from the Kesterson Reservoir Studies by Dungan and Frankenberger.*
- *Fungi have been shown to transform selenium to a gas that is volatile and mixes into the atmosphere.*

Activated Charcoal:

- *Activated carbon and charcoal are used in water treatment to provide a substrate for sorption of constituents. Coal mine operations on the prairies are selling activated charcoal. However, selenium sorption is not very efficient.*

3.2 Water Management

- *Water management seems to be the key issue in mobilizing selenium. Therefore, increased understanding and improved practices should be of high priority.*

Water Diversion:

- *Divert water to the tailings or CCR dumps. Easier to bring the source to the materials.*

Stormwater Management:

- *Stormwater management and grey water are big issues for urban development. Teck Coal will probably come across similar issues. Stormwater management has a lot of parallels with selenium management, and would probably provide some good information.*
- *Stormwater is multiple discharge, looking at concentrating in one location or multiple treatment locations and processes.*

Monitoring:

- *Teck Coal should identify what the patterns are and then use this information for placing the locations of the dumps.*

Permeable Reactive Barriers:

- *May be a possibility to put these in existing rock drains, e.g. could carve a ditch.*
- *Consider design of waste facilities to incorporate reactive barriers.*

- *Difficult to integrate reactive barriers into existing waste rock dumps as they are very steep and there may be safety problems. Will need to increase the stability of slope before remediation will be very effective.*
- *Assumes the use of dendritic drainage on dumps. Not doing much of it, currently, due to stability problems. Teck Coal is increasing this practice.*

Water Utilization:

- *Use water for irrigation.*
- *Once there is water with high concentrations, Teck Coal could possibly use the highly contaminated water for other purposes.*

Hydrologic Management:

- *For other parts of mining industry, a part of the groundwater plan is to build pervious surrounds, so that we are directing groundwater away from tailings ponds or pit lakes. This can be engineered ahead of time.*

Collection of Seepage:

- *Interception system.*

Using a Culvert to Replace Waste Rock Drains:

- *Prevent water from contacting the waste rock.*
- *Consider the use of impoundment to control water flow seasonally. However, in small drainages, the mine cannot hold it back and stop the flow entirely with a dam. Teck Coal will still have the surface water going through the area above the rock dump.*
- *Also, would have to watch out that Teck Coal does not change water flow in the Elk River through use of impoundments or changing pumping rates.*
- *Stop the water flow entirely by creating an upstream hydro plant.*

Impoundment (Subsurface Reactor):

- *Selenium is reduced from mobile and toxic compounds in water to insoluble and non-toxic forms under low oxygen conditions. Placement of waste into a subsurface reactor would facilitate isolation of rock from oxygen.*

Geochemical System (Ways to Manipulate the System):

- *Create physical geo-chemical conditions to increase the rate of mobilization of selenium, in order to shorten the active treatment window.*

- *Manage on a temporal scale. Optimize oxidation to remove selenium at the highest possible rate when operational treatment resources are available to collect water and remove selenium.*

3.3 Dump Design to Reduce Selenium Loading

Multi-purpose dumps and treatment facilities:

- *Taking what we learned from the issues in Sullivan, a lot of dumps and treatment facilities are designed for single purpose, but sometime the products we get are not foreseen. In terms of design for dumps, the design needs to be more flexible to identify these issues and resolve them, while still meeting the treatment focuses. The design needs to be multi-purpose.*

Dump Design (Cross-Valley):

- *Q. A lot of dumps are cross-valley – would you want to shift away from that?*

  A. The problem is that we do not understand high flux rates of water and how it promotes selenium release. The rocks we need for rock drains contain selenium, so it is confusing. Limited available data suggest that selenium may come from rock in the drains themselves or from rock overlying the drains. This question needs to be resolved. Current information on water-balance suggests loading is not from rock drains at one location but get opposite results at another location. The Panel is also looking at co-depositing materials (e.g. tails with waste rock) but need to review the carbon source first.

Oxygen Barrier-Type Systems:

- *We have learned that gas moves readily through rock dumps respire. This is temperature, chemistry and pressure dependent. Under unsaturated conditions, when oxygen consumption by minerals or organic matter is low, oxygen can move through the well constructed rock dumps. In other cases, where rock is oxygen consuming or where local zones of changing texture or moisture content are developed, less gas flux is observed. Minimizing infiltration is an important part of developing an oxygen barrier system.*
- *Teck Coal could also think about keeping oxygen out with different types of covers. Should address the question of what those microbes are doing under that cover (e.g. oxygen consumption by microbes).*
- *It is hard to keep water or oxygen out forever. If Teck Coal can use oxygen and water reduction to limit that flux rate, the bugs will use up the oxygen left. Unable to keep all oxygen or all water out of any rock pile, but there is a middle ground that could be beneficial.*
- *If Teck Coal could use an oxygen control cover with water control strategies, the company can slow the rate of water moving through, as well as oxygen. We are not getting all of it but some of it - the microbes can then use up the oxygen that is left. This method will be difficult on legacy*

sites; however, there are some strategies that can be incorporated in the dump design if the load and volume of the scenario can be lowered.

- *If Teck Coal can avoid dumping rock on a steep valley fill but build the fill from the bottom up, we are less likely to have a lot of oxygen and water moving through.*
- *Perhaps used more in CCR and tailings? –Two hypothesis; cannot rule anything out.*

Legacy Dumps:

- *Q. Is there a way that legacy dumps can be drilled and injected with materials that might reduce selenium?*

  A. Could promote fouling of pore spaces by feeding organisms that live there, which is essentially a barrier. Could inject with microbes and/or carbon, to promote biofilm formation that restricts oxygen and water flow and promotes development of anaerobic conditions, although there may be geotechnical risks to consider.

  Anything we inject can affect these steep, large dumps, thereby creating safety issues. Some are dynamic, landforms with high potential for failure if friction is reduced between rocks within the dump.

- *With respect to the dump design option, it is not practical to rebuild the legacy dumps, but as Teck Coal develops a selenium management strategy, this option is under consideration.*

3.4 In Situ Microbial Source Control

- *Explicitly promote the conditions in dump design that support biological reduction processes, which transform the selenium from a toxic and soluble compound to an immobile mineral that is not biologically available. These designs need to consider lithology, oxygen availability, water flux, and carbon availability.*

3.5 Mine Planning

Underground and Surface Mining:

- *Changes to underground mining and changes in surface mining in order to generate less waste. Looking at IE strip ratios, which may require phasing. Focusing on both the ore and waste management.*

Rock Drain Location:

- *Where the rock drain is located is critical. Moving water around is fine, but mine planning has to address the large scale mountain top mining and mid-scale rock drains, in terms of whether they are suitable to construct. If the movement of surface water can be manipulated, then it is less of* *a concern than potential affects of groundwater and interconnection between surface and groundwater.*

- *Mid-channel rock drains create moderate flow. There is a need to optimize the design and location of the rock drains to maximize efficiency.*
- *Use of a diversion scenario is dependent on others.*

3.6 Waste Management

Mine Planning:

- *"Where are we going to place the waste?" Suitable locations for waste placement need to look beyond valley fills. Teck Coal may not be able to completely get away from these fills, due to the topography at the mine sites, but should consider a significant move away from this waste management method which places rock into high water and oxygen flux settings.*
- *For Line Creek Expansion, are there different ways to control the waste?*

New Technologies:

- *Presently, waste management strategies may change in the future. Other industries have gone back and reprocessed waste materials using new and improved technologies. There may be an opportunity to reprocess waste material to recover additional elements in the dumps. Likely to have innovative opportunities fifty years down the road.*
- *As coal increases in value, things that have not been economical may begin to become economic. Current mine designs need to look into the amount of waste that is produced.*

Strip Ratio Management:

- *Teck Coal is not going to increase its strip ratios in the foreseeable future; there is nowhere to put the waste. Currently the ratio is 10:1 and Teck Coal is limited by topography.*

Business Opportunities:

- *Looking at waste dumps, there may be opportunities for other businesses to harvest them. Something that can be waste could also be a revenue generator e.g. used in uranium disposal.*

Atmospheric Release of Selenium:

- *Q. Could we use atmospheric release as an option?*

  A. This would result in the release of methylated selenium or selenide – a biologically available form of selenium.

Syngas Plant:

- *Full operation in Sioux Sainte-Marie. Looking at putting in a waste-to-energy plant using municipal solid waste and a syngas plant. Consultants have been hired to investigate this for the community of Sparwood.*
- *If we were to do this, could we supplement with coal, is there some way of dealing with selenium through that kind of process? (e.g. Elemental Group).*

3.7 Other

Progressive Reclamation:

- *In terms of legacy, there is only 20% reclamation, have we rationalized current mine operations to not have a higher reclamation rate? How much of this can be treated by an increased rate of reclamation and restoration? Revisit the rate of progressive reclamation, and the amount of legacy dumps that are being actively reclaimed and are successfully reclaimed.*

Administrative Controls:

- *Q. What about the receptor level on a watershed scale? In the near future, there will be parts of the watershed that are not fishable or swimmable. Need to use management. Do we say that you cannot fish here because there is too much selenium in them or "please do not draw water from this area"? These are some administrative option examples.*

  A. I do not think this is on the table, as a regulator, you do this if you have no other choice. This is management of residual risk when all else fails. It is not a goal. This is a management tool that is only used when you have no other options. It is a by-law that we cannot police.

Habitat compensation:

- *Creating robust compensation schemes. If effects are currently being felt, could we use a compensation scheme to bide time? Could look at financial and habitat compensation.*

3.8 Summary

Table 1 provides a summary of selenium management options, broken-down by categories. The table indicates if an option was provided by the Panel or stakeholder participant.

Table 1 Selenium Management Options Identified by the Panel and Stakeholders

Category	Option	Panel	Stakeholder
Water Treatment			
	Treat mine effluent waters	x	
	Water treatment plant at neighbouring community		x
	Protected Bio-treatment system (Engineered)		x
	Fungi Treatment		x
	Activated Coal		x
Water Management			
	Divert water from rock drains	x	
	Divert water to tailings or to CCR dumps		x
	Stormwater Management		x
	Monitor water patterns for determining location of dumps		x
	Permeable reactive barriers (i.e. ditch in the rock drain)		x
	Water for irrigation; reclaiming water		x
	Water utilization - use highly contaminated water for other purposes		x
	Hydrological management engineered as part of the groundwater plan		x
	Collection of seepage; interception system		x
	Culvert; Upstream hydro plant		x
	Impoundment (subsurface reactor)		x
	Geotechnical system to increase rate of mobilization of selenium (shorten active treatment window)		x

Category	Option	Panel	Stakeholder
Dump Design to Reduce Selenium Loading			
	Selectively handle and encapsulate selenium material	x	
	Multi-purpose dumps and treatment facilities		x
	Shift away from cross-valley dumps		x
	Oxygen barrier-type systems		x
	Drill and inject into legacy dumps		x
	Rebuild legacy dumps		x
In Situ Microbial Source Control			
	Use native microbial technology	x	x
Mine Planning			
	Changes to underground mining	x	x
	Changes to surface mining	x	x
	Changes to / management of rock drain location		x
Waste Management			
	Dump covers	x	
	Mine planning	x	x
	New technologies with reduced waste		x
	Strip ratio management		x
	Business opportunities for waste dumps (e.g. uranium disposal)		x
	Atmospheric release of selenium		x
	Syngas plant		x

Category	Option	Panel	Stakeholder
Other			
	Progressive Reclamation		x
	Administrative Controls	x	
	Habitat compensation	x	

3.9 Additional Comments

Additional comments pertaining to the selenium management options discussed in the workshop include:

- *The important thing is that there are a number of strategies and we need to address all of them, some of them are more do-able, some produce more immediate results, some are longer term and some do not have measureable results. Teck Coal is going to have to decide how much they are willing to spend on strategies that are not measurable and how to make sure that they are actually successful.*
- *The list of technologies needs to be reviewed to see what their local applicability is here in the Valley. Identify if there are any commercial operations that could be used (conventional methods).*
  - *Address the existing technology that might be applicable here if there is nothing else, in order to bide time for the other systems to come into play.*
- *Finding the best route. There are three areas that discharge 10,000 to 12,000 cubic metres of wastewater a day. All three are in sensitive fishery habitants; therefore, they appear to be good candidates. The concentrations are the highest at these three sites and they account for 52% of the problem.*
  - *Focus on the highest loading and sensitive receiving environment - start there.*
- *Looking at bundles of options: sets of selenium management options. We are trying to identify the combinations that will work the best at the individual sites.*
- *Temporal: Options can be phased in and out throughout the management process.*

4. SUSTAINABILITY EVALUATION CRITERIA

The Facilitator asked the participants to provide sustainability evaluation criteria under the categories of environmental, social, economic and technical criteria. The Panel will take these criteria into consideration when evaluating selenium management options. The question "what is important to you?" was asked. Based on the participants' input, Table 2 outlines the sustainability criteria which were recommended to evaluate potential selenium management options.

Table 2 Sustainability Evaluation Criteria

Sustainability Criteria	
Environmental	
- Healthy aquatic eco-systems	*- Economical value on eco-system services*
- Minimize secondary environmental impacts	*- Energy use*
- Timeline of impacts to selenium reduction	*- Protection of groundwater*
- Protection and improvement of water quality	*- Protect , reclaim and restore habitat*
- Maintain cohort fish population and structure	*- Air quality*
- Safe drinking water	*- Enhance and protect ecological productivity*
- Protection of biodiversity (terrestrial)	*- Physical and visible footprint of the solution*
- Quality and continuation of monitoring	*- Successful reclamation*
- Greenhouse gases (CO_2)	*- Change end-use of land*
- Permits	
Social	
- Jobs	*- Educate and inform the public and stewardship*
- Enhance or maintain the quality of life for the residents of the Elk Valley	*- Effects to downstream businesses (e.g. tourism)*
- Accountability and transparency for discussion, by building confidence and legacy approach	*- Operational safety*
- Maintain human health	*- Community benefits*
- Good neighbour policy	*- New skills development*

Sustainability Criteria

Social	
- Alignment with goals of the local community	*- Transparency creating community empowerment*
- Community confidence leading to social license	*- Worker empowerment, employee satisfaction, stimulating workplace*
- Community consultation	*- Corporate reputation*
- Cultural values	*- Community amenity value*
- Local impacts (i.e. traffic, noise, dust, odours, infrastructure pressures)	*- Property values*
Economic	
- Cost effective: both capital and operating costs	*- Additional economic benefits*
- Solution feasible and justifiable to the shareholders - protect shareholders	*- Operational resource management requirements (people)*
- Opportunity for new economies: create new business opportunities, develop new technologies	*- Best practice (opportunity to showcase): multiplier effect in the economy*
- Revenue development	*- Tax revenue*
- Increase or maintain coal production	*- Risk of capital investment versus potential of success for management option; risk benefit ratio*
- Requirement for perpetual care	
Technical	
- Mining-based solution, utilize our technical skills, mining technology and know-how	*- Immediate magnitude of reduction; significant or substantial reduction in loading to bide time for future plans*
- Holistic approach to risk	*- Optimization*
- Reduce the greatest negative impacts	*- Degree of effectiveness of treatment/management strategy*
- Practicality: ensure solutions can be implemented	*- Timeline of implementation*
- Constructability and reliability: geo-technical stability	*- Scale: replicable and adaptive*
- Proven methodology or technology	*- Flexibility*

5. ADDITIONAL QUESTIONS AND COMMENTS

The following comments and questions were raised, which were general and outside the themes mentioned above. They are provided here for the Panel's consideration.

- *Look at sites as receptors and fish types. Some creek systems will respond very differently in terms of source (groundwater versus surface) which impacts selenium uptake. One solution may not be sensible for all discharge areas. Look at areas that have receptors that could potentially be greatly affected by selenium. Focus on Fording and Line Creek.*
- *Education and communication: the general public need to understand the issue and why it is important.*
- *Q. Hypothesis on why CCR and tailings ponds do not have the same concentrations of selenium. Is it a result of it being stripped out of the tailings pond, or is it there to begin with?*

  A. Coarse coal rejects and tailings both come from processes in beneficiation and washing. Material is sorted by size and uses reagents, which changes the flotation capacity of material. Some of these materials have carbon in them and allow microbes to grow. Biotic reduction is occurring, due to carbon or less oxygen present. Do not know whether it is due to carbon being added into plants, or if it characteristic of material size and the way it is placed, which is anaerobic. Two possibilities: physical properties of material or carbon content due to its treatment.

  Rock drains themselves are full of oxygen, and create conditions which enhance release and transport of selenium. The Panel has been looking at the amount of water coming into rock drains and whether it can be managed. Water is usually not a well defined channel - it often disappears to the alluvium and reappears down-gradient. One of the challenges is controlling the volume of water coming into the rock dumps.
- *Q. Does some of the work consider selenium speciation?*

  A. There are a number of chemical forms of selenium, the most oxidized form is not the most toxic, but it is the most mobile. The other form is more toxic but less mobile. Insoluble mineral is non-soluble and non-toxic. Must design a process that does not enhance bio-accumulation.

  There are higher accumulations of bio-available selenium compounds (e.g. methylated selenium) in lakes and in still water than in flowing water.

6. NEXT STEPS

Overall, the participants were pleased with the outcome of the workshop. Many expressed that good information was shared and that the session was informative. They mentioned that the workshop brought a diverse group together which allowed for beneficial interaction between various stakeholders. All comments are found in Appendix E. The following are a few examples of the thoughts and feedback expressed by the participants.

Thoughts About the Workshop

"I appreciated hearing input from people with whom I don't normally interact with. Having worked with this issue for a few years, it has been validation for many of the things we have been discussing."

"*Pleased to be a part of the discussions. The depth of the discussions and expertise evident is extremely reassuring. I look forward to hearing the decisions and my interest as a community person has been sparked by selenium in the Elk Valley. It is concerning regarding possible effects, and I'm very pleased that Teck Coal has initiated these discussions."*

"Really interesting as a politician to hear such a diverse group of individuals come to a collective agreement."

"Learned a ton. Encouraged to see the process moving forward and a corporate philosophy which involves an inclusive involvement. As an educator, I would like to see how we can take higher level knowledge and translate it into Selenium 101 to roll out community education and avoid selenium hysteria."

Ktunaxa have been here for thousands of years. It is important to aboriginal people here, for aboriginal interests and resources. Being able to have meaningful engagement with Teck Coal is very important, as well as being able to make informed decisions based on good information and science, and being able to communicate that to the people who use the resources. As someone who has spent a lot of time in the Elk Valley, this workshop exceeded my expectations. Everyone here has different interests but there is a lot of common ground and a lot of the things that are good for Teck Coal and the community. We can all benefit by working together or all lose by not contributing to the process. If there is anything we can do to help or be engaged we are more than willing to do that.

Going Forward

Individuals and representatives from Teck Coal stated that they are interested in seeing the Strategic Plan at the end of June. Participants expressed that they look forward to ongoing stakeholder engagement and data sharing. Some expressed that this is a great start, and now there is a need to continue the process and see how it evolves. Individuals expressed a need to:

- *See the Strategic Plan at the end of June.*
- *Keep an eye on water quality monitoring data.*
- *Maintain community and stakeholder involvement throughout the process.*
- *Provide more research on the effects of selenium.*
- *Translate higher level knowledge for community wide education.*
- *Establish one source: manage the message at Teck Coal for the media, to avoid misinformation.*

Appendices

Appendix A Workshop Agenda

Workshop on Selenium Management at Teck Coal Operations
Best Western Fernie Mountain Lodge
Fernie, British Columbia
May 13, 2010

PURPOSE OF THE WORKSHOP

1. Engage, solicit and document comments from external stakeholders with respect to the work of the Strategic Advisory Panel on Selenium Management (SAPSM), including the objective statement, sustainability criteria and potential selenium management options.

2. Document any issues, ideas and questions associated with each option from a sustainability perspective.

3. Engage and receive comments from stakeholders on preferences for the next steps in the decision making process.

AGENDA

8:00 – 8:30

Continental Breakfast
- Informal introductions

8:30 – 9:00 (Welcome)

Plan for the Day by Stella Swanson, Chair, SAPSM & Alan MacDonald, Facilitator
- Welcome and recognition
- Workshop purpose and goals
- House rules

9:00 – 9:30 (Small Groups)

Ice-Breaker Small Group Exercise
- What does Sustainability mean to you?
- What do you think are the most pressing sustainability challenges associated with selenium management at Teck Coal's operations in the Elk Valley? Why?
- Share your thoughts with your table. Are there common points of thinking? Are there differences of opinion?
- Be prepared to share your table's results with the whole group.

9:30 – 10:00 (Large Group)

Present Sustainability ideas in the large group

10:00 – 10:15

Coffee Break

10:15 – 12:00

The Objective Statement
- Review Objective Statement in breakout groups
- Identify show-stoppers and major issues
- Review major issues as a larger group

12:00 – 12:45

Lunch

12:45 – 1:00 (Presentation)

The Sustainable Decision Making Process by Wes Funk, Panel Member, SAPSM
- What is Sustainable Decision Making?
- Examples of Sustainable Decision Making (Multi-Criteria Analysis) in the mining and energy sectors
- Today's workshop in context of Structured Decision Making

1:00 – 2:30 (Discussion)

Ideas for Potential Management Options for Selenium, Alan MacDonald, Facilitator & Stella Swanson, Chair, SAPSM

2:30 -2:45 (Coffee Break)

2:45 – 3:15 (Large Group)

Synopsis of the options

3:15– 4:00 (Large Group)

Next steps and evaluation of the day

4:00 (Adjourn)

Appendix B Workshop Participants

Workshop Participants List

Name	Organization
Walter Conibear	District of Elkford
Lee-Anne Walker	Wildsight
Jon Bisset	KNC First Nation
Pat Shaw	Environment Canada
Mark Strosher	BC MOE
Jody Frenette	BC MOE
Cindy Corrigan	Mayor of Fernie
Paul Samycia	Elk River Guiding Company
Ian Anderson	Teck Coal
Robin Johnstone	Teck Coal
Nick Milligan	Teck Coal
John Pumphrey	Teck Coal
Councillor Lois Halko	District of Sparwood
Danny Dwyer	District of Sparwood Director of Planning and Engineering Services (Mayor of Sparwood)
Casey Brennan	Wildsight
Ryland Nelson	Wildsight
Kim Bellefontaine	BC MOE
Mike Sosnowski	Director of Area A
Stella Swanson	Chair - SAPSM
Wes Funk	SAPSM
Tom Sandy	SAPSM
Lisa Kirk	SAPSM
Rob Abbott	SAPSM

Name	**Organization**
Alan MacDonald	WorleyParsons – Lead Facilitator
Susan Ferner	WorleyParsons – Co-Facilitator
Paul Hardisty	WorleyParsons – Co-Facilitator
Ashley Kirvan	WorleyParsons – Scribe
Oksana Ogrodnik	WorleyParsons – Scribe
Rowena Peñaranda	WorleyParsons – Scribe
Jason Swanson	Swanson Environmental Strategies Ltd – Scribe

Appendix C Sustainability Definitions

Sustainability

Defining Sustainability

The participants were asked to define the term “sustainability” during the ice-breaker portion of the workshop. These definitions were characterized based on environmental, social, economical and temporal issues and were documented below.

Environmental Sustainability

- *While the resource is not infinite the industry could operate in a low-impact way.*
- *We have to get back to being in harmony with the environment and make sure we live and prosper in conjunction with the world.*
- *“We are the only species on earth that causes so much waste and destruction and we are on the cusp of making the change.”*
- *“Whether mining is fundamentally sustainable? If one mines all the coal, and there is none left, how is this sustainable in the future? – It is a finite resource.”*
- *“Is it not a mining issue? Does not mining and depleting the resource not all of the sudden make it unsustainable?”*
- *The real problem is the river and the fish itself.*
- *Managing impact on the environment, based on geological terms, i.e. choose to modify an area.*
- *Balance between resources. Balance between protecting water and the environment and the coal resource.*
- *There are indirect impacts. Focusing on the valley, but the air moves around the world.*
- *Do not have to give up the environment for the economy.*

Social Sustainability

- *Everything man does has a cause and effect and as a society we evolve, so does the word ‘sustainability’. So we have to manage. The management of where you want to be has to be managed all together. To manage things to be as good as they can, knowing that there will be tradeoffs.*
- *A social license, which requires more transparency and accountability in the process of maximizing the economic benefits. Where people are not willing to make trade-offs. The social community has a threshold that I would not be willing to compromise.*

- *More transparency and accountability as a business model on the social continuum, which is a changing business model.*
- *Health and welfare needs, unique cultures in the different towns.*
- *Balance, the word is quite important to the discussion and as a corporation we have evolved to a more open and transparent model in community engagement. We manage, we meet everyone's' needs, it is about communication.*
- *"I want my kids to have the river available."*
- *Personal connection to the industry and the community that we live in.*
- *Sustainability for the community is to make sure our future community has the same resources. Ensuring that our road structure, infrastructure is set up for years to come.*
- *"Sustainability is the capacity to endure."*
- *Improving quality of life.*
- *Need to be able to sustain employment, lifestyle, so that we have resources and the ability to care about protecting the environment. Association between having quality of life to give you the ability to care.*
- *Cultural resources.*

Economic Sustainability

- *We need to ensure the viability of the coal mining industry, the communities in this valley would not exist without the mines.*
- *Jobs are critical. The economic generation of the mines is essential but in the whole business model, what is the real cost of mining?*
- *Full cost accounting of the whole thing. The life-cycle consideration of coal and mining is not sustainable if you cannot make coal. Maybe we can work towards more integrated thinking?*
- *The coal reserves are resource inferred out over 100 years over 4 or 5 generations and those jobs do sustain the community and will continue to do so.*
- *Coal has been around since 1968 – that is why the community is here. 56% of the tax base is supplemented by coal. This is the community's life. The sustainability point is to maintain these levels to come. There are huge demands for steel.*
- *Viability. Maintaining or improving status quo.*

Temporal

- *Sustainability is a process – we cannot put our finger on it. It is the process and the art of the long view – looking way out there.*
- *“My grandchildren and their children – that they can be assured of swimmable, drinkable and fishable water.”*
- *Long view, local, regional and global picture.*
- *Classic definition: “operating today in such a manner that future generations can meet their own needs, in terms of personal connection – move here.”*
- *It is an issue of short term versus long term thinking. The current thinking is the shorter term, which is that we have to manage risk. We have to find a balance because we are evolving into this change.*
- *The concept of the full life cycle, its cradle to cradle not cradle to grave. Making sure we re-use everything - what we do and what we have done for the last century. I believe it is changing. It is not sustainability but something different.*
- *“How do we maintain the values that we value today in perpetuity?”*
- *“Sustainability is what we have today and what we value - social, environmental - and having that for the future. Not taking advantage of it.”*
- *To be able to continue doing what one has been doing? To keep going.*
- *Not compromising future generations or other inhabitants of the planet.*
- *Balancing or considering environment and community in every business decision (day to day basis).*
- *Last a long time with benefits along the way.*

Balance Between Environmental, Social and Economic Pillars

- *“Looking at how we can manage risks so that the Elk River is fishable, drinkable and swimmable. It will require a business model that is maximizing the economic potential which supports jobs, community and well-being.”*
- *“In the broader term, manageable risk and sustainability is economic and environmental. I have a real problem defining sustainability. For every cause there is an effect. Sustainability is all of those things. What is manageable sustainability?”*
- *“Need to mitigate the selenium; I think it’s important that we look at all of the aspects, social, economic and environmental aspects.”*

- *"The balance is what I would be looking for; I would suggest more balance than trade-offs."*
- *As we move forward as a society, we have to keep the balance but ensure that the mining industry in this valley stays sustainable.*
- *Inter-dependent relationship, each dependent on each other. Something balanced and somehow linked.*
- *Sustainability really is the combinations of the three pillars. It is something that allows things to proceed as they are.*
- *"Make sure the three pillars come to some balance, my view of sustainability goes way beyond that, words are not good enough anymore."*
- *The growth in our ability to be in harmony to be in concert with everything around us, way beyond the current definition of sustainability.*
- *Financial wealth and social well-being. A wealth component and a well-being component. Cannot affect the productive capacity of the environment.*
- *Sustainability comes from the environment and community.*
- *Must be a balance, hope that actions today work towards actions for the future. A real systemic balance.*
- *Understanding the whole and managing all of it.*
- *Making choices.*
- *People are greedy. It is being able to understand management and mitigation of our impacts.*
- *We live in a place with world class nature, air, wildlife etc, and we can have world-class mining as well. We are still learning that some things are not in balance, and we are trying to adapt and improve and aspire to excellence, so that mining can be as good as it possibility can be.*
- *When man and environment can survive with good health over a long period of time, economically.*
- *Balance of functional eco system, robust economy, and healthy community.*
- *Balance and harmony between economic, social and environmental aspects. Sustainable development - development that meets the needs of today's society without taking away future generations' abilities to sustain (Brundtland Commission).*
- *A process in which the criteria of financial and social wealth or well being does not undermine or otherwise damage the aesthetic and productive capacity of natural capital for present and future generations.*

Defining Challenges

The following question was also presented to the participants by the Facilitator:

"What do you think are the most pressing sustainability challenges associated with selenium management at Teck Coal's operations in the Elk Valley? Why?"

The answers were characterized based on environmental, social, economical and temporal issues and were documented below.

Environmental

- *Cumulative impact of all five mines. Now, more proposed expansions and potential for a new mine. This is cumulating and is getting bigger but at the same time the solutions to the problems will require a collective effort to solve it.*
- *"No doubt, decreased levels are the main focus. How do we get to these levels?"*
- *Not enough regeneration of the fish within Elk River Valley.*
- *Water issues – long term issue.*
- *Aquatic ecosystem (water birds and fish). Birds of prey consuming fish (food chain impacts).*
- *Steel is the most recycled industrial good on the planet.*
- *There is going to be a carbon footprint somewhere, we need to accept that where we are economically and socially, we are in a better position to manage our carbon footprint than other places like China. If we were to export mining activity to developing world, the carbon footprint would be even greater.*
- *In a single pile of rock, there would be a plateau and reduction; however with increasing volumes of rock, it is impossible for scientists to say when a reduction would be.*
- *After 50 to 100 years, even if concentrations are reduced, some volume has been released which were not there before.*
- *Bioaccumulation.*
- *Large footprint within context of valley, and can contribute to make major impacts.*
- *Issues like water quality, habitat, continuity, landscape and reclamation.*
- *Biological should be the foundation, but need to assign some value and put into context in the short term.*
- *Use of lakes and rivers as an outlet and replace fish later. Cost in the long term is orders of magnitude higher than maintaining the system now.*

- *What is the threshold that changes selenium and its various forms from maintaining a functional healthy system? At primary production, or critical bottleneck? For fish, is it for embryo development?*
- *Affects on biodiversity.*
- *Technology in the mines. Wish I could drive an electric car that worked in -40 but we do not have that technology. I wish we could make cars without coal but we cannot. I wish I could recycle for less than 285 dollars a tonne but we cannot yet, yet we should always work towards this goal.*
- *"I do not know if the infrastructure is in place for the collective effort."*
- *What can Teck Coal do? Starting as soon as they can to put ponds in there? Can you trap this stuff?*
- *Challenges to measure the reductions, apply control measures.*
- *Changing mine plans, changing mining strategy, where to put the waste rock and water. What if we cannot measure those changes?*
- *Application of control technology that is on the cutting edge of being applicable, potentially to this area.*
- *Are there ways of capturing selenium? Is there a scientific way of trying to capture selenium?*
- *Legacy issue and future development. Elements of the engineering practice can be looked at but the practices themselves have not changes.*
- *How long could we continue to mine? Have 30 to 50 years of reserves. Probably more than 100 years worth of resources.*
- *Avalanches example - rule about decision making "Don't know, don't go". Precautionary, but also ask better questions.*
- *So many layers for decision making and planning, but sometimes it needs to be looked at individually. Do not just compartmentalize issues. Need good communication between various disciplines.*
- *What technology or tools are going to stabilize and change the trend? And when?*
- *What levels of selenium should be focused on? Can we maintain the baseline?*
- *What other processes besides mining affect selenium? How do other processes interact with selenium?*
- *What changes to the process does mining make to the release of selenium, and what are the differences?*

- *If science is not established, how do we establish whether there are legitimate concerns or not, compared to other factors?*

Social

- *Awareness and raising the issue – need to get people aware.*
- *Internally, we manage for safety. We have a strong focus on safety and people understand the cause and effect. We are willing to shut down operations for a shift. We accept it. We begin to make managing the environment a core value, and are willing to shut down a shift for a health and safety issues.*
- *Core business value at Teck Coal, along the same lines with Health and Safety.*
- *"Initially, Elk River toxicity was never an issue ... (but it is now, especially because)... Elk River has become a world-class place to fish."*
- *"Will be interesting to see how the Ministry and community will get involved."*
- *Do not know the human health issues. Fish consumption is an issue as well. Reaches a tipping point. Initially fine to consume but then can become toxic.*
- *Drinking water. Cannot guarantee that underground aquifer will not move. All aquifers are connected.*
- *On a community side, scale is also an issue. Teck Coal has a large number of employees, with potential to require balance in the community.*

Economic

- *Every option has a cost.*
- *Seems like a big liability for Teck Coal. Future practices are a lot like the past practices. Do not have many options.*
- *Provide positive economic impacts by providing our steel around the world.*
- *Do not have a lot of answers, so making best guesses to informed decisions. Different economies of scale. Application of new science and information, as well as learning. What about unknown uncertainties?*
- *Sheer scale of activities within Elk River Valley. Massive contributor to the economy.*
- *Sometimes take risks without the proper capital to support. Precautionary principle.*
- *Functionality and values may be different from the future, but need to keep them separate.*
- *Major tourism due to fish guiding (lost revenue for businesses).*

Temporal

- *We need to start making conscious changes. Hopefully the changes will come quicker than two generations but it is the understanding and knowledge to make the changes.*
- *Multi-generational impacts (need to be taken into consideration).*
- *How do you know what the best thing to do at one time is, when it is going to change? For now, have to take the pieces you know and make a decision.*
- *Planning horizon is important (ecological and geological versus human).*
- *Look further ahead –- not just today. How will the overall environment be affected? Is reclamation today good enough for the future? What happens at the end of life? Who is there to control the end product of the mine?*
- *Time scale and intergenerational (impacts) are important to consider.*
- *Future science may not solve today's problems, but this is a perception that is risky.*
- *Good decision making in the face of uncertainty.*
- *Currently plan for the present and think for the future, rather than reverse. Need to think and plan for the future.*

Appendix D Stakeholders' Objective Statement

Objective Statement

Defining the Objective

"Define, implement, monitor and communicate sustainable ways to stabilize and reverse the selenium trend in the Elk River watershed as soon as possible. 'Sustainable' implies the context of continued mining and growth as well as social and environmental values."

This Objective Statement was formulated by all participants by addressing the "5 W's" - who, what, where, when and why. A lively discussion ensued, and only the first 2 W's were discussed. An Objective Statement was suggested early into the discussion, and the group responded to it and modified it. The following is essentially the 'conversation train' that was captured by the scribes.

Who? – Who's problem? Who will manage selenium? Who is affected or influenced by the decision? (Manage within the geography of the mines).

- *Teck Coal.*
- *Communities in the Elk River Valley.*
- *Everyone who lives downstream (i.e. Kootenay, Kookanusa, United States, etc.) Do we know how far it travels?*
- *Animals that use the affected area.*
- *Proposed new coal mines (e.g. Centre Mount).*
- *Difference between effects of selenium and selenium management - need to be distinguished. Management involves a wider group.*
- *People of British Columbia: shared resource equates to shared responsibility (collective governance).*
- *First Nations.*
- *Ktunaxa traditional territory covers entire Elk watershed, Kootenay, parts of Idaho, southwest Alberta etc.*
- *Legacy – "Who is going to inherit this issue from us?" Future generations will continue to deal with the issue, and may be faced with greater impacts if they are left unsolved.*
- *People who visit the Elk Valley (e.g. tourists).*
- *Connections: recognizing the link to global customers and other communities; global leadership opportunity for world class mining (Do not lose sight of the need to manage selenium locally):*

- *Metallurgical coal is intensely scarce; there are 7-8 known reserves outside of western Canada.*
- *Have the opportunity to manage these resources and issues, which might not occur if forced to be managed somewhere else.*
- *"It may seem like a local issue, but it affects a broad range of people and we have to be aware of that through the process." We are part of the global system.*
- *We have some world class water, air, wildlife etc, and world class mining can fit into that picture. We can send a message that this can be done in a responsible way.*
- *Issue of connections is an issue whether we continue making product or not. We need to keep in mind that even if Teck Coal stops mining coal, the selenium does not go away. If we are looking at keeping our focus, whether Teck Coal mines or not, there is a need to manage that issue.*

What is the issue? What are we trying to accomplish with respect to selenium management?

- *Real strategy that shows leadership in world class mining operations– not just "random acts of greenness" – Commitment is on a bigger level. Strategic level of thinking.*
- *Stabilize and reverse the selenium trend in the Elk River watershed as soon as possible.*
- *Continue to refine the science – do something that is real.*
- *Monitoring and refinement of the system and processes. This is the foundation of the decision-making process and can often be forgotten and lost.*
- *Embrace the whole issue of mining – not just selenium. Managing this issue may cause other issues (i.e. huge energy requirement to treat selenium). There needs to be a balance - conducted in a holistic way.*
- *With minimal additional economic, social and environmental impacts.*
- *"Optimal" – so that you get the best balance between environment, social and economic?*
- *Need to keep all discussions in mind, but in a "sustainable way to stabilize and reverse the selenium trend in the Elk River as soon as possible":*
  - *Define "reverse" – is this possible or realistic without shutting down the mine? (Given the legacy of waste piles leaching for a long time) – Given that coal mining will continue? Wants to hear the scientists explain how that's going to happen.*
  - *"The definition of reverse? – how is that sustainable?"*
  - *Reverse: like this term, as you need to have a goal, in order to strive to something.*

- *Objective is: "what do you want to end up with when this is all done?"*
- *Is it important to capture the 'sustainable' concept in objective?*
- *First goal is to stop the increased loading:*
  - *Rate to accomplish stopping the increased loading can be achieved with many possible approaches. This is being reviewed by the Panel. Specific characteristics can result in options between 2-10 years.*
  - *If we do this well enough then there is the potential to decrease some concentrations. Rate at which you can accomplish that depends on what approach you use.*
  - *One option is treatment at the source. Is expensive and trades off with carbon and must be done forever. Alternative is in-situ source control (which are longer term), design of dumps to reduce contact with water, re-use of water in process, and diversion of water away from the facilities. There are a number of ways to reduce the loading to the water treatment plant, but it would need to be operated indefinitely. Then there is a question as to how long it takes to be efficacious. So the "as soon as possible" is very important to key in on, because how we define 'possible'?*
  - *Rate of decline depends on the specific management options – can be done in a relatively short timeframe – but will be trade-offs.*
- *"As soon as possible" – how we define possible will determine how quickly and what option is utilized.*
- *Define selenium management – not just technical methods but also broader measures.*
- *Which mechanism to use to measure the trend – in the water versus accumulation in the food chain and sediments.*
- *Declining to what point and how long will it take?*
- *Allow for increased tonnage of coal production – still stabilize and decrease selenium (should be to maintain and reduce in the context of continued mining and growth). Increased tonnage is sustainable mining. The objective is projection of where we are going with increasing mining tonnages, while decreasing selenium levels.*
- *Different background concentrations of selenium – i.e. some of the reference locations have elevated selenium.*
- *Q. Is the impact from each mine equal?*

  A. Some impacts are more than others. The Panel has identified the main loading of selenium and is focusing on these first – i.e. highest loading is in Fording.

Q. *Does this have anything to do with the footprint of the mine?*

A. It is partly to do with the footprint of the mine.

- *Ensure that other chemicals of concern and other environmental issues are not neglected and are captured within the "sustainable" definition. Can possibly be updated to "impacts of mine drainage" instead of selenium.*
- *Q. Recall discussion of other contaminants other than selenium - perhaps in the context of mining and growth, and protecting values. How will the other contaminant issues be addressed?*

  A. What selenium management would not address is the air quality issue. Sustainable will be defined to include other contaminants in the notes. Some things will remain implicit in the word sustainable. One of the reasons the Panel is asking this question is that we have so much focus on selenium that we ignore other problems which we are potentially worse.

  Do not want to focus specifically on selenium as there may be other issues that are equally or more important.
- *We should say "sustainable ways' not 'sustainable way', because this is a multi-effect problem which will probably have a suite of solutions.*
- *Concept of Growth/Targets:*
  - *In this statement there is an objective and a constraint. Because there is a constraint, there is a whole bunch of options which we may have excluded before having the ability to examine them.*
  - *Should not set a target. Do not add a constraint i.e. we need to grow at the same or progressive way. If you want to get the more sustainable, it might mean changing the growth target. For instance, mining growth is a constraint if you best reach that solution through a 20 percent reduction of growth.*
  - *We are not enshrining the fact that we need to have continued growth. The Panel has the opportunity to advise on all mining operations, as well as growth. Recognising there is an intrinsic conflict between mining and reducing selenium.*
  - *"What is reasonable growth? What is reasonable growth for our shareholders, for the community? How do we balance that?"*
  - *"I think it is a goal that everyone is happy with."*
  - *Sustainable means you have business here and it is providing jobs, to become the most sustainable, playing around with a growth target might help.*

  - *There is no growth target.*
  - *Growth – would eliminate this from the objective. Do not believe that needs to be reflected in the statement.*
  - *This is a challenge we need to keep in mind. As an objective statement, we could do without it, but we need to understand the context of continued mining. There is a reality of expansion plans at the mines; we need Teck Coal here mining, to find a solution to this, and shutting Teck Coal down is not going to shut out selenium. Teck Coal provides a valuable resource, is a capable company, it is going to potentially work but only if they are still here.*
  - *"Do we need the word 'and growth'?"*
- *We need to mention the social aspects, the environmental aspects; we are not giving equal time to all of the circles. If we are going to nominate mining, that we need to nominate social and environmental issues.*
- *"As soon as possible" is a constraint, we need to ACT immediately, but we need to act in a way that is best for the long term, in the best manner possible.*
- *"As soon as possible" is appropriate, because of the urgency of the issue.*
- *The sustainability issue addresses all the other issues of what is possible and/or realistic, as long as we are communicating, implementing and monitoring and doing that "As soon as possible" we are going to get new definitions. By focusing on the "definition"- means that we are only focusing on what we know right now.*
- *Have to keep in mind that not everybody impacted by this issue is in attendance right now. Needs to be a definition and explanation of the word sustainability so that all those not included in this discussion understand the concept.*
- *Without the economy working, nothing else works.*
- *With Elk River or is it the tributaries as well? Should add the word 'watershed' to the objective statement.*

Additional Comments

Additional issues and concerns were expressed by the participants during the objective generation process. These issues and concerns are listed below.

Improving Baseline Data and Data Available

- *Looking for reasonable base line data for selenium concentrations:*
  - *Need baseline data from truly pristine areas.*

- *How are we going to monitor if we do not know against what?*

- *Lack of Understanding: As a community, we as citizens do not have a great understanding of baseline:*
  - *"I do not have the confidence that the monitoring is going to be open and transparent."*
  - *Do not have the ability to detect symptoms – how do we know when we have past the threshold, how do we know if anything has been done to prevent, protect the citizens?*
  - *Do not understand the tracking and the monitoring, the red flags.*
  - *"How to validate progress, track it, build it in your community, that it is achievable, measurable, do-able. Has to be specific."*
  - *Important to define, monitor, communicate, and implement.*
- *Minimal data available:*
  - *There seems to be a bit of a gap in understanding in most recent work, in particular to answer geochemical and baseline type questions (i.e. water flow, contamination).*
  - *EVSTF has produced a number of status reports and studies in the Elk Valley (from Elk Valley and water task force), first one completed in 2003-04, last one in 2007 and another to be released soon. There are reports staring from 1996. These sources can be found in the local libraries.*
- *Background information has been collected by Teck Coal. As part of effluent permit, Teck Coal is required to collect upstream samples:*
  - *Status reports would explain, but would not go into detail.*
  - *Frustration regarding communication and open sharing. Should be in a format that is not a "data dump". Will capture open sharing of information (Discussed in section "Next Steps").*

Threshold for Aquatic and Human Life

- *There are no human health experts involved in the meetings.*
- *Q. Human Health does not seem to be enough of an issue and is not represented in the Panel. Is there scientific consensus that there is no risk to human health?*

  A. Because aquatic life has been further studied, there is more of a consensus that aquatic life might be threatened but not sure about human health.

  Nowhere near the threshold on humans, as we are on fish. We will get back to you on human health questions that cannot be answered today.

- *Q. Do we know what the threshold level for protecting aquatic and human health?*

  A. Yes, there is a difference between guidelines and thresholds. Guidelines are set by regulatory (ministry). The ministry always builds in a layer of safety, to flag issues, but this does not mean that kids or fish are getting sick - that this is the threshold. Guidelines are more of a warning, while a threshold becomes harmful. Between the guideline and threshold there is an order of magnitude, which is still in debate.

  Not sure of the exact value of the threshold. We are past the guideline but not sure where the threshold is exactly.

  It is easy to know what fish populations do, because there are experiments which can be done. Not so for humans. There are more uncertainties in humans than aquatics as there is less data for toxicology affecting humans.

  Have been spending a lot of time in the last 10 years discussing what the threshold is at the population level. There is a huge debate on the threshold on population. There is a close affect on reproduction, but higher on a whole population of fish. Let's stop debating the threshold. The guideline has already been passed. We are already above guidelines and rising.

- *Q. There is also a drinking water quality guideline?*

  A. The drinking water guideline is 10 µg/L (i.e. ppb), and sometimes in Sparwood we go above. Human health guidelines are set to protect the weakest, which gives a layer of protection.

  Near Elkwood there are some instances where there is an exceedance.

Appendix E Next Steps

Next Steps

Participants were asked for feedback and their thoughts about the workshop:

- *"I appreciated hearing input from people with whom I don't normally interact with. Having worked with this issue for a few years it has been validation for many of the things we have been discussing."*
- *"Expertise at the table is exceptional, will be able to tell Council some interesting things and would like to be kept in the loop."*
- *"Pleased to be a part of the discussions. The depth of the discussions and expertise evident is extremely reassuring. I look forward to hearing the decisions and my interest as a community person has been sparked by selenium in the Elk Valley. It is concerning regarding possible effects, and I am very pleased that Teck Coal has initiated these discussions."*
- *"Very informative. Teck Coal being proactive is excellent. Learned a lot. Discovered that there may be more impacts then I thought – perhaps in our groundwater as well."*
- *"Really interesting as a politician to hear such a diverse group of individuals come to a collective agreement."*
- *"Pleasant surprise, a refreshing environment with many different viewpoints. People are coming together to find agreement at a high level, instead of disagreeing on fine points. It is a broader issue that everyone has to be a part of."*
- *"Came expecting to hear viewpoints that I do not normally receive - normally very focused on science. Great to hear other view-points."*
- *"The importance of stakeholder and community involvement early in the process, and importance of continuing to do so."*
- *"Selenium management is important to many people. Mining is important to a number of groups."*
- *"Are making a lot of assumptions which may or may not be necessary, but which are definitely proactive – more research required."*
- *"Learned a ton. Encourage to see process moving forward and a corporate philosophy which involves an inclusive involvement. As an educator, would like to see how we can take this to a higher level knowledge and translate it into Selenium 101 to roll out community education and avoid "selenium hysteria"."*
- *"Grateful to the Panel for allowing this process to occur. For creating a safe environment for people to speak their minds- this is very important."*

- *"Reinforce the immense value in tackling issues of this substance in a stakeholder setting. Companies in the past have believed that a venue like this would create a great amount of anxiety. The more often we do these things the better we will get at it. Incredible alignment as to where we want to get to."*
- *"Getting much better at having these, I think we are really aligned in here but we need one source of media to manage the message and community fear. We need selenium 101 and we need one source for this information. The Panel members are extremely astute."*
- *"A measure of success, when items come up on the economic side from environment people, and the other way around. A process that is worth modelling more. Being proactive is very positive. Important to me personally. Discovered it was an issue in 1995. We are closer to solving this problem than ever before because of the commonality."*
- *Ktunaxa have been here for thousands of years. It is important to aboriginal people here, for aboriginal interests and resources. Being able to have meaningful engagement with Teck Coal is very important, as well as being able to make informed decisions based on good information and science, and being able to communicate that to the people who use the resources. As someone who has spent a lot of time in the Elk valley. "This workshop exceeded my expectations". Everyone here has different interests but there is a lot of common ground and a lot of the things that are good for Teck Coal and the community and we can all benefit by working together or all lose by not contributing to the process. If there is anything we can do to help or be engaged we are more than willing to do that.*

Going Forward

Participants were what they would like to see as the Panel and Teck Coal move forward:

- *Anticipate seeing the plan.*
  - *"This will be interesting, the solutions in that, the HOW is very important. I think part of the reason they will emerge balanced is because of this group."*
- *See these matrix tables – how things are ranked.*
- *To continued stakeholder engagement.*
- *Continued approved data sharing.*
- *Participant member would like to stay involved in the group discussions.*
- *Deliberations and Decisions.*
- *Articles regarding current levels.*
- *Future viability between Teck Coal and communities.*

- *Observe water quality monitoring data.*
- *Objective is a great starting point – would like to see how it evolves.*
- *Timeline for action is important.*
- *Community and stakeholder involvement throughout the process.*
- *Interested in seeing the next steps of the structured decision making process - steps 4, 5 and 6.*
- *More research on the effects of selenium.*
- *Translate higher level knowledge for community wide education (community confidence in potential solutions). They can be a part of the dialogue.*
- *Engage communities.*
- *One source for media to manage the message.*
  - *The more conflict created the more papers you will sell; this is a difficult thing to overcome.*
- *Publish a List of Attendees.*
- *Stay involved in the process – ties in with new mining applications that the Fist Nations has currently (governance role that the Ktunaxa have in mine expansions and fish populations).*

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Stakeholder Engagement Workshop

Hinton, Alberta

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STAKEHOLDER ENGAGEMENT WORKSHOP
HINTON, ALBERTA

PROJECT - STAKEHOLDER ENGAGEMENT WORKSHOP

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Hinton, Alberta

1. OVERVIEW

1.1 Introduction

The Strategic Advisory Panel on Selenium Management (SAPSM) – "the Panel" – hosted its first Alberta workshop on selenium management in Hinton, Alberta on Wednesday, June 2, 2010. Teck Coal Limited (Teck Coal) operates a large mine in the area that is associated with selenium release. Facilitation and logistical support was provided by Swanson Environmental Strategies Limited and WorleyParsons Canada Limited. The agenda for the workshop and a list of participants are provided in Appendix A and B, respectively.

The workshop was held in Hinton for the following reasons:

- Selenium concentrations are above guidelines in Luscar Creek, Gregg River, McLeod River, and downstream of Luscar and Gregg Rivers.
- Scientific evidence shows risk to rainbow trout in Luscar Creek watershed.
- While scientific debate about selenium effects goes on, there is wide consensus that management of selenium is required.

The focus of the one-day workshop was to review potential selenium management options. The workshop provided a venue for various stakeholders to acquire a better understanding of the selenium issue, to talk about sustainability as it pertains to selenium, and to gain feedback from stakeholders about various management options. The workshop provided an opportunity for participants to talk openly about their concerns and to ask questions about the rising selenium concentrations in Yellowhead County, specifically in Luscar Creek, Gregg River and McLeod River.

The workshop provided valuable information for the Panel, as it allowed for a better understanding of the stakeholders' concerns, which will assist the Panel and Teck Coal in making informed decisions regarding selenium management.

1.2 Background

The Panel was established in January 2010 to provide an independent third party review of management efforts to reduce selenium concentrations downstream of Teck Coal's mining operations within Alberta and British Columbia. Although selenium concentrations in Luscar Creek, Gregg River and McLeod River do not demonstrate any observed trends, the concentrations are above the Canadian Council of Ministers of the Environment (CCME) Water Quality Guideline (WQG) values and need to be managed.

The Panel's objective is to develop a selenium strategic management plan (Strategic Plan) that integrates the environmental, social and economic opportunities and risks associated with selenium management. The Strategic Plan will be tabled on June 30, 2010 and will be provided to all stakeholders and Teck Coal on this day, simultaneously. There will be no prior release of the Strategic Plan to Teck Coal. The Strategic Plan is not intended to provide a fixed solution for selenium management in all locations, but rather to provide a framework for sustainable operation-specific and watershed scale decisions. The Strategic Plan will consider the key elements of sustainability (environmental, economic and social factors). It will also take into consideration the stakeholders' input from this workshop and an additional workshop, which was conducted in Fernie, British Columbia on May 13, 2010.

The following is a summary of the topics that were discussed in the Hinton workshop on June 2, 2010. Comments, inputs and questions from all workshop participants (stakeholders and the Panel) have been noted throughout the report in *italics*.

2. OBJECTIVES

2.1 Purpose of the Workshop

WorleyParsons was commissioned by the Panel to pursue the following objectives in a collaborative workshop format:

1) Engage, solicit and document comments from external stakeholders with respect to the work of the Panel, including an objective statement, sustainability criteria and potential selenium management options.

2) Document any issues, ideas and questions associated with each option from a sustainability perspective.

3) Engage and receive comments from stakeholders on recommendations for the next steps in the decision making process.

2.2 Workshop Structure

The workshop was designed to provide opportunities for stakeholder input. Open discussion was encouraged in both the small break-out sessions and large group discussions. Several members of the Panel attended the workshop, and their role was to listen to stakeholders and to answer any technical questions.

Stella Swanson, the chair of the Panel, welcomed all participants and briefly explained the situation regarding selenium exceedances in Luscar Creek, Gregg River and McLeod River. Susan Ferner, the Facilitator from WorleyParsons, outlined ground rules for the discussion. Respect for others' opinions was crucial. It was made clear that the names of the stakeholders would not be mentioned in this report, which is in accordance with the Personal Information Protection Act.

The workshop addressed the following topics: sustainability, the objective statement, sustainable decision-making and potential management options for selenium.

2.3 Sustainability Definition

The term "sustainability" was discussed by the participants during the opening ice-breaker portion of the workshop. The results of the ice-breaker are provided in Appendix C. Participants were asked to work in small break-out groups to discuss "what sustainability means to you". In all groups, sustainability was defined in relation to a balance of economic, environmental and social viability in both the short and long term. Examples of the definitions of sustainability that were discussed include:

- *Considering the environment and community (society) in every business decision. It is a triple bottom line; therefore, reconciling environmental, community, business issues on a daily basis.*

- *Clean environment for future generations, with economic opportunities available to enjoy life.*
- *Balance of social, economic and environmental considerations, resulting in informed, responsible decision-making.*

In addition to the discussion about the definition of sustainability, participants were asked: "What do you think are the most pressing sustainability challenges associated with selenium management at Teck Coal's operations in Luscar Creek, Gregg River and McLeod River? Why?"

The answers reflected concerns about environmental, social and economic issues. Examples under each of these areas are:

Environmental

- *Control the industrial operation to be site-specific (i.e. ensure that no wildlife and surrounding areas are being affected); keep selenium or any other industrial contamination within the industrial setting.*
- *Industry affects the environment. Need to put environment back into a state that is useable.*
- *There are naturally occurring streams that have a high concentration of selenium, which could result in a cumulative effect.*

Social

- *Alberta Environment manages point sources currently, but there is no understanding of duration of the problem following the end of mining (post mining / reclamation). There is concern over who will assume the liability, i.e. province, company, stakeholders in the region?*
- *Living within our limits. Society is currently taking too much.*
- *Challenge to have everyone see their share of the responsibility.*

Economic

- *What does the community do after mining is finished? Not just this mine here, but other panels around the world have studied and are implementing solutions in industrial settings.*
- *Research and development and clearly defined objectives. Life after mining and technological advances (i.e. United States set objectives and technology).*
- *80/20 Rule: Lower effort with higher gain.*
- *What is profitable?*
- *Cost of prevention. Fixing what has already occurred.*

2.4 Selenium Management Objective Statement

The next session of the workshop was a group discussion with all present individuals, with the purpose of defining a Selenium Management Objective for Teck Coal's operations within Yellowhead County. A lively discussion ensued (see Appendix D for the minutes on this section of the workshop) and many different ideas were presented. Based on the stakeholders' objectives and ideas, two members from the Panel and the Facilitator developed a draft Objective Statement. This was presented to the stakeholder group who provided final minor changes. The following Selenium Management Objective Statement was tabled:

Prologue:

- ***Yellowhead County is home to unique and globally significant natural assets that support abundant recreational and tourism activities, and provide critical ecosystem goods and services.***
- ***The people who live, work and play in the County want to protect these assets and goods and services for their children and grandchildren.***
- ***Mining within the County produces significant economic and social benefits, but it can also accelerate the release of selenium, a potential contaminant, to the natural environment (and therefore place critical natural assets and services at risk).***

Accordingly, the stakeholders' objective with respect to selenium is:

"To manage selenium at current and future Teck Coal mine sites in a way that optimizes the mitigation of environmental impacts, protects critical ecosystem goods and services, allows for the continued extraction of the resource, and ensures ongoing community and social well-being for generations in Yellowhead County."

Specific actions in support of this objective are:

1) ***Decrease the loading to the receiving environment and establish a decreasing trend within three years.***
2) ***Subsequent to item 1, manage selenium to a target that provides a sufficient margin of safety for humans, fish and aquatic life and wildlife.***
3) ***Pioneer the use of selenium management practices that benefit the community both during and following mine life by positioning the community as a knowledge centre on selenium.***
4) ***Engage Yellowhead County residents, and others who benefit from the assets of the County, in an ongoing dialogue about:***

i) ***Selenium (so as not to cause alarm).***

ii) ***Management actions.***

iii) ***Progress.***

iv) ***Anticipated next steps.***

3. POTENTIAL SELENIUM MANAGEMENT OPTIONS

Participants asked the Panel's technical experts to provide some information about selenium management options. Dr. Swanson briefly summarized the management options that were under consideration. The Panel believes that a portfolio of management solutions may be required for each site, particularly when looking at legacy waste dumps compared to future dumps. The management report will initially be based on a virtual mine, with a focus on rock dumps and hydrogeochemistry.

Stakeholders were asked to provide input and suggestions for additional selenium management options. All suggestions were considered and a number of new ideas were brought forward. A summary of the ideas discussed during the workshop is provided in Table 1. The following comments were made during the options discussion:

3.1 Water Treatment

- *Water treatment can be active or passive. Teck Coal has already initiated water treatment throughout the mines.*
- *Treat mine effluent waters.*

Multiple Water Treatment Systems:

- *Run-off from all the streams would make a single treatment plant unfeasible.*

Water Treatment Facility (attached to an End-pit Lake):

- *Create a small (water treatment) facility off of an end-pit lake opposed to a large facility in the mine.*

Combining Iron with Selenium:

- *A workshop participant asked if there was another chemical to combine with selenium.*
  Dr. Swanson explained that the Panel is looking at the possibility of combining another element with selenium; iron may be a favourable additive. Iron can serve as a substrate for sorption of selenium in the form selenite and can complex the most strongly reduced selenide form, resulting in the precipitation of an insoluble iron selenide mineral.

3.2 Water Management

- *Dr. Swanson explained that there are water management technologies available. The main question is whether these can be scaled up to treat the issues of selenium at Teck Coal. The challenge is to get volumes down for easier and better treatment.*

Water Diversion:

- *Divert clean water around rock drains.*
- *Divert water around fresh water sources before the problem occurs.*
- *Water diversion around the dumpsite.*

Water Utilization:

- *Reuse selenium impacted water – capture selenium and send to market.*

Infiltration with Dump Covers:

- *Control infiltration of water and/or oxygen with dump covers.*

End-pit Lakes:

- *Use end-pit lakes to lower the concentration and reduce cumulative impact over time. End-pit lakes can be an opportunity and a detriment. They are an “attractive nuisance” and can increase selenium bioavailability since it is still water. Methods can work by manipulating the mixing behaviour of the end-pit lake, to create an anaerobic zone at depth in order to trap reduced selenium. First, need to understand the hydrochemistry and geometry of the end-pit lake.*

3.3 Dump Design to Reduce Selenium Loading

Dump Design (Cross-Valley):

- *Eliminate selenium material in rock drain cross-valley fills.*

Capping:

- *Capping dump options are being looked into as a favourable option.*
- *Use covers as soon as able – quicker reclamation. Mitigate before the stage where leaching occurs.*

3.4 In Situ Microbial Source Control

- *Creating conditions where oxygen is limited in waste rock is being considered as a favourable option.*
- *Microbes can grow in natural settings with or without oxygen. Some microbes can only grow with oxygen, others can only grow without it, and a third group can flex between aerobic and anaerobic metabolism as conditions warrant. When oxygen flux into a rock pile is limited, microbes can deplete oxygen and switch to anaerobic metabolism, which allows selenate*

reduction to occur. Building facilities to support this transition would facilitate microbial reduction of selenium to immobile and non-toxic forms.

- *Microbial reduction appears to occur in CCR and tailing and could potentially be promoted in waste rock dumps and backfills through design.*

3.5 Mine Planning

- *Mine planning is likely the most economic method, i.e. source control (versus options such as water treatment as it speaks to "after-the-fact.").*

Underground Mining:

- *Conditions at the Cardinal River Operations are not suitable for underground mining for the following reasons: the slope needs to be less than 20 degrees, it is relatively unsafe compared to open pit mining and the initial start up costs are quite substantial. Furthermore, conditions on both the floor and the ceiling need to be absolutely perfect for the mine to operate at maximize efficiency, which does not exist at the Cardinal River Operations.*
- *Do not have to go far to see some of the disasters that can happen with underground mining, safety is a core value at Teck Coal; therefore, this is not a feasible option.*

Surface Mining:

- *Assess and evaluate existing problems to develop future mining practices to be effective at a loading production stage.*
- *Change the mining process to become more environmentally friendly, e.g. change the way explosives are used in mining to minimize the reactive surface area of broken rock. Adaptation of new technologies.*

Avoid "Attractive Nuisance":

- *The issue of wetlands, shallow lakes and marshes along the pathway will be addressed. These areas may become an "attractive nuisance" where animals congregate around the water, and may become an unintended way for selenium to enter the food chain. Production of more bio-available forms of selenium is higher in this type of environment.*

Waste Management:

- *Proper placement of waste material.*

Hybrid Mine:

- *Hybrid mine with an advanced open pit and seams. At least one of Teck Coal's operations has hybrid operations. It is possible, but there are very few people that are trained underground.*

3.6 Other

Progressive Reclamation:

- *Progressive reclamation to minimize the release of selenium.*

Administrative Controls:

- *Q. A Panel member asked if there is any level of acceptance for management at the receptor source. For example, administrative controls such as restricted use for fishing and swimming in certain areas and not being able to eat fish or swim in the lakes.*

  A. Sometimes the sustainable solution is to take a portion of a stream or lake and restrict the use of that portion of water.

  Go to this option when there are no other options. Perhaps this is only a last case scenario after all other options have been explored. Need an implementation or culture shift. This is not off the table; however, it is lower on the hierarchy.

3.7 Summary

Table 1 provides a summary of selenium management options, broken down by categories. The table indicates if an option was provided by the Panel or stakeholder participant.

Table 1 Selenium Management Options Identified by the Panel and Stakeholders

Category	Option	Panel	Stakeholder
Water Treatment			
	Treat mine effluent waters through water treatment facilities	x	x
	Multiple water treatment systems		x
	Attach a treatment system to an end-pit lake		x
	Combining iron with selenium		x
Water Management			
	Divert water from rock drains	x	
	Divert clean run-on water away from dumps	x	x
	Divert water around fresh water sources		x
	Reuse selenium impacted water - capture selenium and send to market	x	x
	Infiltration with dump covers	x	x
	End-pit lakes		x
Dump Design to Reduce Selenium Loading			
	Eliminate selenium material in rock drain cross valley fills	x	
	Selectively handle and encapsulate selenium material	x	x
	Capping – progressive reclamation		x
In Situ Microbial Source Control			
	Use native microbial technology	x	x

Category	Option	Panel	Stakeholder
Mine Planning			
	Changes to underground mining	x	x
	Changes to surface mining	x	x
	Avoid "Attractive Nuisance" - wetlands, shallow lakes and marshes		x
	Proper placement of waste material	x	x
	Hybrid Mining		x
Other			
	Progressive Reclamation		x
	Administrative Controls	x	

3.8 Additional Comments

Additional comments pertaining to the selenium management options discussed in the workshop include:

- *Verification of the efficiency of the options, need to ensure this is effective over the long time.*
- *When recommendations go forward, a way to implement a culture or behaviour shift should be addressed.*
- *Verification of mine efficacy on Best Mining Practices (BMP) to ensure that BMPs are effective in the long term. This is part of monitoring, performance evaluation and adaptive management in the structured decision making model. Useful exercise would be to prioritize options and strategies in relation to ecological effects and what is manageable. Look at existing management strategies and see if they are effective – could identify the best "bang for the buck".*
    - *The Panel is aware that there will be a lag between application and best management practices. It may take up to 10 years to see the effects of the solutions.*
- *Look at concurrent activity to analyze current and future.*
- *No pool of underground miners available in the west.*
- *Need more testing of the water outside the mine and downstream of the mine, in order to feel reassured.*

4. SUSTAINABILITY EVALUATION CRITERIA

The Facilitator asked the participants to provide sustainability evaluation criteria under the categories of environmental, social, economic and technical criteria. The Panel will take these criteria into consideration when evaluating selenium management options. The question "what is important to you?" was asked. Based on the participants' input, Table 2 outlines the sustainability criteria, which were recommended to evaluate potential selenium management options.

Table 2 Sustainability Evaluation Criteria

Sustainability Criteria	
Environmental	
- Water quality	*- Do not encourage wildlife in the industrial site*
- Timeline to success	*- Total Economic Value (TEV) of Water*
- Fisheries health	*- Minimize invasive species*
- All Wildlife (i.e. bighorn sheep) Health	*- Assure area does not become an ecological sink*
- Controlling adverse effects on the environment	*- Prioritization based on ecological risks*
- Athabasca rainbow trout as a sensitive receptor	*- Biodiversity (no shift in species of importance)*
- Selenium management with past, current and future mining operations would assure ecosystem health	*- Clear environmental cost benefit, not just energy use; trade-off with air quality; lifecycle*
- Avoid perpetual maintenance	
Social	
- Ensure multi-use of land over long term	*- Teck Coal to be viewed as operator of choice*
- Maintain or enhance quality of life for residence of region	*- Assure area does not become a social sink*
- Values of area need to be balanced between all aspects	*- Flexibility in the regulatory framework; no net loss efficacy*
- Transparency	*- Availability of trained personnel*
- Multi-stakeholder engagement	*- Safety (Health, Safety and Environment)*

Sustainability Criteria	
Social	
- First Nations support for options	*- Secure and consistent application of regulation*
- Quality of life	*- Employment*
- Focused efficient use of resources to meet social and environmental needs	
Economic	
- Resilience; enhance through time	*- Property prices*
- Adapt to economic change	*- Opportunities for local business*
- Think aspirationally about the global market as a best practice	*- Profit-making with social responsibility*
- Teck Coal operations keep running	*- Acceptable to board and shareholders*
- Cost feasible	*- Clear environmental cost benefit*
- Reflects needs specific to site	*- Assure area does not become a economic sink*
Technical	
- Technically feasible	*- Active management; checks and balances*
- Evaluation and verification of BMP and planning tools for mine development	*- Results are measurable, but measure the right things*
- Proven technologies	*- Reliability and availability*
- Adverse effects of each option	*- Best available technology*

Additional Comments

- *Past, current and future mining operations do not incur significant environmental impacts due to these selenium management solutions. Selenium management is successful if it is manageable over the long term.*
- *Profit making with social responsibility (social and economic).*
- *Several stakeholders expressed concern over wildlife in the mine site and the effects on them, one participant said that bighorn sheep are being crippled by the growth of nine-inch hooves. He has spoken to some people (scientists), who think it may be caused by excess selenium. There are also examples sheep losing their horns. “There may already be indicators of what is going on with the wildlife. Someone has to look into this but no one has an idea. Why are you taking the*

environmental risk, where sheep and other wildlife are able to walk around the mines?" It was recommended that habitat that encourages more wildlife to feed within the mining area should not be introduced. It creates an attractive nuisance that needs to be mitigated.

- *Another stakeholder mentioned that grizzly bears are also a concern, perhaps more than the bighorn Sheep. She said that "those grizzly bears will eat your sheep up and spit them out."*

5. ADDITIONAL QUESTIONS AND COMMENTS

The following comments and questions were raised, which were general and outside the themes mentioned above. They are provided here for the Panel's consideration:

- Q. *Is selenium above guidelines?*

  A. *Yes, but CCME guidelines are NOT the level above which fish will get sick. It is a warning - a conservative safety factor.*

- Q. *Why is selenium an issue?*

  A. *Luscar Creek Watershed study area: trends show a range of selenium concentrations, all above guidelines, regardless of how the trend line is shown.*

  Lower McLeod River study area: Spikes in concentrations follow mining events.

  Gregg River was shut down (now catch and release for fish) in early 2006.

- Q. *Have the criteria for selenium changed over the last few years?*

  A. *The whole philosophy on selenium has changed, but not the criteria. It has changed from selenium concentrations in water to concentrations in fish tissue. Current US EPA discussions are not much different from Canada. Criteria are based on back calculation.*

- Q. *Do we understand where the toxicity line is located?*

  A. *Depending to who one talks to, the toxicity line may be as low as 5% - 6% and as high as 20% - 30%. The toxic amounts of selenium are best evaluated in the amount that is injected in fish and wildlife.*

- Q. *At the elevated levels, is anything happening?*

  A. *Rainbow trout are being affected, as seen by embryo deformities and reproductive tissue of fish. This is a convincing argument that something needs to be done about selenium. There is Broad consensus that now is the time to act.*

  Selenium is the type of chemical that accumulates in food chains; therefore, we should err on the side of caution.

- Q. *Is there a possible risk assessment associated with the selenium concentrations? Is there a possibility of killing something due to production?*

  A. *There is no risk that sheep will be killed due to the exposure of selenium. This is a different type of toxicity, it is in the ground and we have knowledge of where it is located. We know the amount of selenium that affects sheep. The management of selenium is* *currently to protect the aquatic life, as there is more research on the affects of selenium on these species at this point.*

- *Q. How persistent is selenium in the water, is it going to be in Fort Chip? How far downstream will the problem go?*

  A. Selenium is not something that degrades, but can add to the other selenium sources, which can then accumulate, causing a cumulative effect. Selenium is currently in Luscar Creek and McLeod River. The Athabasca River is not affected, but it is very important. We have to ensure that we are not affecting the Athabasca in the future.

- *Q. Should people downstream of McLeod Lake be testing the water for selenium?*

  A. That would be prudent. Far downstream concern is less. If taking surface water for drinking use in any body of water, it should always be tested, not only for selenium, but for other contaminants.

- *Q. Are there pockets of areas with high selenium?*

  A. No. Pockets and hot spots would be easier to treat but the selenium problem is more general. Very small range of selenium in waste rock, which does not vary much. The volume of waste rock and geochemical conditions will effect how much selenium is getting out.

- *Q. Is surface level disturbance not as great in deeper mining due to shear volume?*

  A. Correct, due to shear rock. Shallow groundwater that moves into deeper groundwater is the problem. The big challenge is to get the volume down, even if at higher concentration, in order to help treat the problem. Treatment is not the only option.

- *Q. Does the quarry in Cadomin have selenium?*

  A. The rock is limestone, so that area does not have the same problem.

- *Q. Can Highway 40 South be the dividing line, because there is a coal mine proposed there? Or is selenium in the metallurgical coal only?*

  A. In the overburden, there is different rock. The Coal Valley is a different type of rock and formation, therefore it possess different selenium concentrations. This issue is not necessarily limited to the Foothills. Selenium is not associated with coal but the host rock. Cannot say that coal itself has selenium in it.

  In the United States, the selenium content was caused by agriculture. It is not only a coalmine problem.

- *Q. Is livestock watering a common practice in McLeod?*

  A. Yes, although there are no house leases along the river.

- *Q. Does selenium get into the vegetation?*

  A. Yes it does.

- *Some agriculture areas are selenium deficient. Need to inoculate animals against white muscle disease.*

- *There is a new application for expansions within Teck Coal's mine. The planning for the mines is currently underway.*

6. NEXT STEPS

Overall, the participants were pleased with the outcome of the workshop. Many expressed that good information was shared and that the session was informative. They mentioned that the workshop brought a diverse group together which allowed for beneficial interaction between various stakeholders. The following are a few examples of the thoughts and feedback expressed by the participants:

6.1 Thoughts about the Workshop

- *"Enjoyable. I learned a lot."*
- *"Made a lot of progress. Have a different position now compared to 9 am this morning."*
- *"Extremely useful in terms of strategy."*
- *"Refreshing that all come from different backgrounds. Everyone is looking at it not just from their own point of view."*
- *"Learned a lot; feel privileged to be sitting here. I commend Teck Coal for all that they have done in other parts of reclamation."*
- *"Good exchange of ideas."*
- *"Exciting to hear support from stakeholders as it creates energy and optimism. If we can put our minds together we can get a lot done efficiently."*
- *"Comment on the process, Teck Coal is going out and taking a chance, Teck Coal has been extremely open and upfront with the stakeholders. This is not out of the norm and I want to commend them for that, it is a continuation of the company philosophy."*
- *"Humbled by the capacity of people that come to the table to volunteer and make the effort to come here."*

6.2 Going Forward

Individuals and representatives from Teck Coal stated that they are interested in seeing the Plan at the end of June. Participants expressed that they look forward to ongoing stakeholder engagement and data sharing. Some expressed that this is a great start, and now there is a need to continue the process, and see how it evolves. Individuals expressed a need to see the following going forward:

- *Report at the end of the month (June 30, 5 pm MDT).*
- *Scheduled open houses after the report is issued.*
- *Further one-on-one meetings anytime (before or after report).*

- *Consultation with missed stakeholders (once identified).*
- *Communication plan required (to be started immediately), including local media releases with fact sheets.*
- *Teck Coal's solutions or implementation of recommendations to be transparent, though formal process not yet identified.*
- *Incorporate recommendations and actions into site-specific plans and community reporting.*
- *Continuing communication and education (information ladder).*
- *Cardinal River operations approach to be kept in mind.*

.

Appendices

Appendix A Workshop Agenda

Workshop on Selenium Management at Teck Coal Operations
Hinton Training Centre, 1176 Switzer Drive
Hinton, Alberta
June 2, 2010

PURPOSE OF THE WORKSHOP

1. Engage, solicit and document comments from external stakeholders with respect to the work of the Strategic Advisory Panel on Selenium Management (SAPSM), including the objective statement, sustainability criteria and potential selenium management options.
2. Document any issues, ideas and questions associated with each option from a sustainability perspective.
3. Engage and receive comments from stakeholders on preferences for the next steps in the decision making process.

AGENDA

8:00 – 8:30

Continental Breakfast
- Informal introductions

8:30 – 9:00 (Welcome)

Plan for the Day by Stella Swanson, Chair, SAPSM & Susan Ferner, Facilitator
- Welcome and recognition
- Workshop purpose and goals
- House rules

9:00 – 9:30 (Small Groups)

Ice-Breaker Small Group Exercise
- What does Sustainability mean to you?
- What do you think are the most pressing sustainability challenges associated with selenium management at Teck Coal's operations in Yellowhead County? Why?
- Share your thoughts with your table. Are there common points of thinking? Are there differences of opinion?
- Be prepared to share your table's results with the whole group.

9:30 – 10:00 (Large Group)

Present Sustainability ideas in the large group

10:00 – 10:15

Coffee Break

10:15 – 12:00

The Objective Statement

- Review Objective Statement in breakout groups
- Identify show-stoppers and major issues
- Review major issues as a larger group

12:00 – 12:45

Lunch

12:45 – 1:00 (Presentation)

The Sustainable Decision Making Process by Wes Funk, Panel Member, SAPSM

- What is Sustainable Decision Making?
- Examples of Sustainable Decision Making (Multi-Criteria Analysis) in the mining and energy sectors
- Today's workshop in context of Structured Decision Making

1:00 – 2:30 (Discussion)

Ideas for Potential Management Options for Selenium, Susan Ferner, Facilitator & Stella Swanson, Chair, SAPSM

2:30 – 2:45 (Coffee Break)

2:45 – 3:15 (Large Group)

Synopsis of the options

3:15 – 4:00 (Large Group)

Next steps and evaluation of the day

4:00 (Adjourn)

Appendix B Workshop Participants

WorleyParsons

resources & energy

TECK COAL LIMITED
STAKEHOLDER ENGAGEMENT WORKSHOP
HINTON, ALBERTA

Workshop Participants List

Name	**Organization**	**Comments**
Crystal Kereliuk	Planner - Town of Hinton	Left at 12:00 pm
Bill Bulger	Counselor with Town of Hinton	
David Robson	Fishery and Game, Hinton	
Nic Milligan	Teck Coal	
Robin Johnstone	General Manager - Teck Coal	
Bernie Kreiner	Town Manager in Hinton	Left at 12:00 pm
Curtis Brock	Alberta Environment	
Ryan Adumard	Teck Coal	
Margaret Kidner	Alberta Trappers Association – Zone Director - Zone 2	
Lori Burndred	Alberta Environment	Left at 2:30 pm
Nicole Lawrence	Teck Coal	
David Helmer	Alberta Environment	Left at 2:30 pm
Cal Rakach	President, Alberta OHV	
Marc Symbalak	Teck Coal	
Jack Williams	Rep. for MLA Robin Campbell, County Resident	Left at 2:30 pm
Stella Swanson	Chair - SAPSM	
Wes Funk	SAPSM	
Rob Abbott	SAPSM	
Susan Ferner	WorleyParsons – Co-Facilitator	
Vernon Betts	WorleyParsons – Scribe	
Oksana Ogrodnik	WorleyParsons – Scribe	
Rowena Peñaranda	WorleyParsons – Scribe	
Jason Swanson	Swanson Environmental Strategies Ltd – Scribe	

Appendix C Sustainability Definitions

Sustainability

Defining Sustainability

The participants were asked to define the term "sustainability" during the ice-breaker portion of the workshop. These definitions encompassed environmental, social, economical and temporal issues. Questions regarding selenium were also asked throughout this session.

Environmental Sustainability

- *Clean environment for future generations.*
- *Longevity of resources.*
- *Keeping nature's balance.*
- *Water quantity and quality.*
- *Sufficient resources.*
- *Impacts – healthy environment.*
- *Measure of success: what is drinkable, swimmable, and fishable.*
- *Clean water – keep it clean.*
- *No footprint.*
- *Healthy air.*

Social Sustainability

- *Community level.*
- *Community and society must exist in every business decision.*
- *Municipality as a whole i.e. industry, business, communities.*
- *Quality of Life – enough interest in area that people want to live in.*
- *Social licence.*

Economic Sustainability

- *Lease agreements – get product out then get areas "back to normal".*
- *Bring businesses into the region.*
- *People have jobs.*

- *The industries along the river and downstream are employed.*
- *Land use productivity.*

Temporal

- *Clean environment for future generations, with economic opportunities available to enjoy life.*
- *Operating in such a manner today that does not compromise the future.*
- *Leave as much for future generations as our society has currently.*

Balance between Environmental, Social and Economic Pillars

- *Consider the environment and community (society) in every business decision. It is a triple bottom line, therefore, reconciling environmental, community, business issues on a daily basis.*
- *Balance of social, economic and environmental considerations, resulting in informed responsible decision-making.*
- *Holistic approach: the use of resources, people, money, environment. Manage use that permits the ongoing use until perpetuity.*
- *Triple Bottom Line.*
- *Continue growth without significant impacts to the environment and quality of life.*
- *"Trust fund" – maintaining the value, trying to attach a value to those 'softer' aspects.*

Defining Challenges

The following question was also presented to the participants by the Facilitator:

"What do you think are the most pressing sustainability challenges associated with selenium management at Teck Coal's operations in Luscar Creek, Gregg River and McLeod River? Why?"

The answers were characterized based on environmental, social, economical and temporal issues and were documented below.

Environmental

- *Mining activity accelerates the release of selenium into the environment, which can be toxic.*
- *Uptake by algae, invertebrates, fish (most of attention to date) and animals (aquatic and terrestrial).*
- *Potential for cumulative effects.*
- *Sheep on mine site is "ludicrous".*

- *Control the industrial operation to be site-specific (i.e. ensure that no wildlife and surrounding areas are being affected); keep selenium or any other industrial contamination within the industrial setting.*
- *Industry affects the environment. Need to put environment back into a state that is useable.*
- *Continue to keep the beauty of the area.*
- *Be aware of the dynamics in water as operations are expended.*
- *Legacy issues.*
- *Physical limits of selenium and regulatory limits of selenium can be two different things.*
- *Footprint being affected. Is it mine or region?*
- *Fish – how readily selenium can be absorbed.*
- *There are naturally occurring streams that have a high concentration of selenium, which could result in a cumulative effect.*
- *Provide a robust and stable closure plan – "health landscape".*
- *Wants selenium downstream, as it is needed to feed animals.*
- *In terms of regional planning, goals or outcomes are unclear (i.e. Upper McLeod); therefore a new approach to management is required for regional planning. Cumulative discharge of selenium necessitates a "no go" to manage back to under a cumulative effects paradigm.*
- *Making good decisions in the face of uncertainty; informed and responsible decision-making. Uncertainty comes in many different forms and there is great uncertainty regarding selenium impacts and efficacy. The selenium issue is not as simple as a sewage issue. Despite the uncertainty, this issue needs to be managed. Teck Coal cannot wait for science.*
- *Scale of mining has increased over time, therefore more waste rock on an annual basis.*
- *Set limits and manage the landscape to meet the needs of the industry.*
- *Closed circuit. Settling ponds are good.*

Social

- *Alberta Environment manages point sources currently, but there is no understanding of duration of the problem following the end of mining (post mining/reclamation). There is concern over who will assume the liability, i.e. province, company, stakeholders in the region?*
- *Living within our limits. Society is currently taking too much.*
- *Challenge to have everyone see their share of the responsibility.*

- *Debate over whether society is living within their means; this is a matter of perspective.*
- *Understanding what communities and geographical area is affected.*
- *Confidence that selenium management objectives can be achieved.*

Economic

- *What does the community do after mining is finished? Not just this mine here, but other panels around the world have studied and are implementing solutions in industrial settings.*
- *Research and development and clearly defined objectives. Life after mining and technological advances (i.e. United States set objectives and technology).*
- *Industry as a stabilizing force.*
- *Technology that can assist in water management and treatment (mitigation) but does not slow down the production of the mining.*
- *80/20 Rule: Lower effort with higher gain.*
- *"What is profitable?"*
- *Cost of prevention. Fixing what has already occurred.*
- *Hard costs (Capital and Operations Expenditure).*
- *Cannot wait for science. Adaptive management must occur.*
- *Bringing selenium back to appropriate guidelines is important relative to cumulative impacts and effects on future development. If selenium is above that threshold, than it will make it difficult to bring on new industry and new activities that may also increase selenium.*
- *Need continuous improvements to achieve true reduction in the face of growth.*
- *Making the most of resources currently available. Must find a common ground that maximizes these resources.*
- *Need to go ahead and try something new.*
- *Provide a solution that is effective.*
- *Timely action.*
- *Turn this into an opportunity.*

Balance

- *How do we get the coal out while keeping people's jobs, while protecting the environment and social values (economic, environment, and social)?*
- *"Look at the WHOLE picture."*
- *There are gong to be trade-offs and these will need to be balanced.*
- *How to measure balance?*
- *Benefits matching or exceeding the costs.*
- *Solution for selenium should not create other issues.*

Temporal

- *Need to adaptively manage to reduce the uncertainty over time.*
- *Adopt appropriate geographic and temporal perspectives. Solutions for selenium cannot be at the expense of creating other issues.*
- *Panel is an indication of how things will move and operate in the future.*
- *Balance of selenium management within mine lifecycle.*

Questions Addressed:

- *How is selenium going to affect the community in the future?*
- *Have not been following, so do not know about the issues regarding selenium. What is the issue?*
- *What is the difference between how selenium affects fish and how it affects wildlife?*
- *Q. Is there a baseline? Is it escalating because of the mining?*

  A. There is naturally occurring selenium due to geology. Although there are no solid baselines as there has been no monitoring until the 1950s, over the last 15 years the trend has been increasing.
- *Q. Oil sands tar release is not necessarily higher (some is natural). Is selenium the same?*

  A. No, this is not the same but it is the same kind of sustainability questions. Science is not rock solid on this point; however, there is a good understanding of the problem.

Appendix D Stakeholders' Objective Statement

Objective Statement

Defining the Objective

Prologue:

- ***Yellowhead County is home to unique and globally significant natural assets that support abundant recreational and tourism activities, and provide critical ecosystem goods and services.***
- ***The people who live, work and play in the County want to protect these assets and goods and services for their children and grandchildren.***
- ***Mining within the County produces significant economic and social benefits, but it can also accelerate the release of selenium, a potential contaminant, to the natural environment (and therefore place critical natural assets and services at risk).***

Accordingly, the stakeholders' objective with respect to selenium is:

"To manage selenium at current and future Teck Coal mine sites in a way that optimizes the mitigation of environmental impacts, protects critical ecosystem goods and services, allows for the continued extraction of the resource, and ensures ongoing community and social well-being for generations in Yellowhead County."

Specific actions in support of this objective are:

1) ***Decrease the loading to the receiving environment and establish a decreasing trend within three years.***
2) ***Subsequent to item 1, manage selenium to a target that provides a sufficient margin of safety for humans, fish and aquatic life and wildlife.***
3) ***Pioneer the use of selenium management practices that benefit the community both during and following mine life by positioning the community as a knowledge centre on selenium.***
4) ***Engage Yellowhead County residents, and others who benefit from the assets of the County, in an ongoing dialogue about:***
   - i) ***Selenium (so as not to cause alarm).***
   - ii) ***Management actions.***
   - iii) ***Progress.***
   - iv) ***Anticipated next steps.***

This Objective Statement was formulated by all participants, see Section 2.4. The questions of "Who will manage selenium?", "What is the target?" "By when will this be achieved?" and "Where? What is the geographical area?" were asked by the Facilitator in order to stimulate stakeholder input. A lively discussion ensued, which was captured in the following section by the scribes.

- *Attempt to keep selenium within the boundaries of the leases that are being mined. Keep it in contained sites as much as possible with the technologies that are being used.*
- *Capture selenium and sell it to places that are deficient.*
- *Water treatment – remove the selenium.*
- *Uncertainties exist but need to keep the solution economic. Recognize the trade-off between the objective and economic barriers. Look to find a balanced means of managing selenium.*
- *In the future, be mindful of where the waste rock is stored, and where run-off of rain and snow would come off the waste rock.*
- *Do not know how to handle or contain the selenium. Need to understand where the issue is before moving to the "how". What is trying to be achieved, over what time frame, over what scale? To what extent will the concentrations be managed? Why and to protect what?*
- *How can the stakeholder provide an objective if they do not know the "how"? Is the Panel holding back some information?*
- *Example provided by the Panel: "Being mindful of desire for continued mining in Hinton, while taking social and environmental values into consideration and ultimately reversing the trend of selenium concentrations to acceptable levels."*
- *Start of the initial objective: The community management of selenium at the mine site, being mindful of environmental impacts, efficient extraction of the resource, corporate profitability – remain within the community and provide social support within the community – and community and social sustainability.*
- *This is an environmental problem; therefore, this objective should be set in environmental terms. Typically, set the target typically around the problem, which in this case is environmental and then set the context.*
- *Do not have the right and social license to kill something in order to continue economically – no dead fish. "Environmental target that will stabilize selenium levels such that there is a sufficient margin of safety" – never to exceed toxicity thresholds in the future.*
- *Short term reversal of the loading trend – three years. Secondly, manage the target; there are several different targets but the first one should be to get the reversal trend started and then work from this point. Look separately at existing and future loadings, since future loading will be*

harder to deal with than current loading. Perhaps will need two objectives, which take time frame into consideration.

- *Manage selenium on the onset rather than attempt to fix the problem in the future.*
- *Require a much more specific environmental objective. Then can move forward with specific social and economical objectives.*
- *Ultimate end-source is aquatic and human life.*
- *Habitat and wildlife. Be mindful of attracting wildlife to the region by managing wildlife risk.*
  - *Objective should be – "manage selenium such that toxicity would not affect wildlife and fishery".*
  - *Previously looking at planting species to attract grizzly bears and other species. Need to be mindful of plating greenery that will attract animals.*
  - *Do not want to have a closed coal mine that is an "attractive nuisance" – where wildlife gets attracted to alterations that have been created through reclamation, mine planning etc. i.e. planting marshes within the mining area that attract wildlife. Do not want animals to get attracted to selenium areas and inject this contamination to the point where the animals get sick.*
  - *Ensure that risk management and assessment takes into consideration wildlife, fishery, etc.*
- *Nothing wrong with having an environmental endpoint. In order to get to this endpoint, there needs to be a balance. Want to optimize the trend of social, economical and environmental as we optimize the management of selenium.*
- *As an employee, one wants to know that they are contributing to society, that they are doing their job. There is the understanding that the community has a certain amount of time to use a resource with the assumption that it will be returned back to its natural source at the end of the mine life. That future generation will enjoy it exactly the way that this current generation intended it to be, by returning the mine to its natural state.*
- *Talking about long term, 20-25 years down the road when the coal begins drying up. Long term plan to remediate mine to as close to original state as can be achieved. There is an objective for children and grandchildren to enjoy the landscape as envisioned today.*
- *How do you best plan for closure that provides this landscape and provides this objective?*
- *What if the studies show that it is not going to be economically feasible to treat selenium? What type of accountability is there that Teck Coal will do anything possible to manage it? Could be a long term and short term goal. That Teck Coal is accountable for managing short term and*

long term selenium issues, dependent on the outcome of the study, until it is turned back into the government.

- *There needs to be transparency of impacts. Selenium management strategy must be transparent in its impacts, i.e. disclosure, ongoing monitoring. The economic and social impacts during management is a make or break, either you can sell coal or you cannot, in a lot of ways, the objective statement and balance piece is very difficult to arrive at.*
- *Economic objective is to preserve the employment that is currently in place. That provides the community with the best selenium management practice in the world (pioneer use of these practices) and creates employment. Become leaders in selenium management, and the economy can change from a resource one to one of management. Become an intellectual community as opposed to a resource extraction one. If the coal runs out, this is the opportunity to be sustainable.*

Where?

- *This is a porous site, but do not have an answer to the question of "where". The more that I am listening the more I realize that it is forestry and that there cannot really be boundaries.*
- *If the standards are set in Alberta and British Columbia, what happens to the rest of the world? What trade-offs are communities willing to make to stay competitive? What is done here is not going to be happening in China, it is all about the trade-offs.*
- *Maintain and improve aquatic ecosystems: safe and secure drinking water and for life-stock, water quality that sustains a healthy economy, and healthy eco-systems services. Cannot set objectives if one does not understand the uses. Drinking water is utilized for tourism, recreation, life stock.*
- *Whitehorse Creek and Park brings people into Cadomin, water is very important as this makes the area attractive. Maybe identifying uses and then categorizing these based on the trade-offs. This comes back to the geographic scope. To identify the areas that are affected, i.e. water drainage areas, all tributary but the main steam from McLeod and Athabasca.*
- *This issue is geographic; from an economic and social perspective include the economic and social trading area. From a recreation/tourism area it is huge; Europeans flock to the region and hunters come in the fall and spring from all over the world. It is an employment base, as some of the people employed in the mines are from British Columbia.*
- *Trusteeship and stewardship: geographically this area is important. This community is closer to it so it should care for it for the world. The main trustees are Hinton, Yellowhead County (mine is within the municipality of this county), and Edson.*

- *Collectively make decisions in a defined geographical scope but we are making decisions that have ramifications globally. The natural assets of the region create the potential for significant social and economic wealth and this wealth is tied to this defined area.*
- *The Panel has avoided Yellowhead County in all the design. They need to be included.*
  - *Yellowhead County were included in discussions and invited.*
- *Edson is most affected for they draw their water out of the McLeod River.*

When?

- *Teck Coal is accountable for the management of selenium on a short term and long term basis.*
- *Need more timeline objectives. It appears that a three-year objective is being defined as "as soon as possible".*
  - *Address the selenium issue within the three year timeframe, but do not drop the ball when things, like technology, changes. Do not say in three years that selenium is not an issue anymore. Depend on the mitigation strategy, keep this ongoing and do not stop after several years, continue to monitor even after the issue is "resolved".*
  - *What does address mean? Cannot determine the timeframe if one does not know what address means.*
- *Educate mine employees so that they can communicate the ideas properly; keep everybody informed and use the resources available. Informed people make informed decisions. Receiving selenium management suggestion from employees i.e. contest or incentives.*
- *Transparency is very important. Increase social awareness around the selenium issue in a responsible manner so that it does not create an alarming issue (i.e. Waterton and Drayton Valley) and does not result in someone else trying to solve the problem for us.*
- *Communication is a key component of this issue and the Panel is very sensitive about how to communicate this to the society.*
- *One problem is the ability to measure in smaller and smaller increments: parts-per-million versus parts-per-billion. Increasing the ability to measure the concentrations results in more issues. For example: The town spent millions ($) to treat water to parts per million, which resulted in a large effort for minor change.*
- *Selenium is toxic at very low concentrations. It is something that legitimately needs attention.*

Objective Statement Changes

As mentioned in Section 2.4, once all objectives and ideas were gathered from the stakeholders, two members from the Panel and the Facilitator used the information to develop a draft Objective

Statement. This was then re-visited by the stakeholder group, and minor changes were made. The discussion is documented below:

- *What does "rare" mean? Change rare to unique.*
- *Eliminate "stabilize" and "stabilize" in the first action plan point, "Decrease the loading to the receiving…"*
- *Issues regarding the trend. Seems to be a lot of discussion of whether or not there is a trend. Look at a median, or percentile opposed to a baseline trade line.*
- *What should Teck Coal's management ambition be? Reduce the loading in three years is a greater effort than deceasing selenium concentrations.*
- *Second point in the action plan: What are the immediate actions if we cannot at this time accomplish a sufficient margin of safety?*
- *Have an existing site that has existing issues. Hate to think of the problems the same way that has been done previously. Must understand that "business as usual" for future mining operations is not acceptable.*
- *Q. Should there not be an actual amount that is being targeted?*

  A. No, not sure what the threshold is at this time.
- *Q. Referring to all mine sites or just Teck Coal's mine site?*

  A. Referring to Teck Coal's mines specifically.

Appendix E

Options for Selenium Management

Category	Option	Teck	Panel	Stakeholder	Feasible Y or N	Is it technically feasible within 3 years	Is it technically feasible 3-40 years	Perpetual Maintenance	Time Frame to Demonstrated Results	Cost Cap-Ex	Op-Ex	Cost	Se Reduction Effectiveness	Comments
Active Water Treatment														
	Reverse Osmosis			x	Y	Y	Y	Y	3 years	TBD	TBD	High	TBD	
	Nanofiltration			x	Y	Y	Y	Y	3 years	TBD	TBD	High	TBD	
	Ion exchange			x	Y	Y	Y	Y	3 years	TBD	TBD	High	TBD	
	Catalyzed Cementation			x	Y	Y	Y	Y	3 years	TBD	TBD	High	TBD	
	Iron precipitation or sorption			x	Y	Y	Y	Y	3 years	100 Million	26 Million	High	85%	Depends on source of iron
	Sorption to Activated Coal/ Filtration			x	N									
	Bacterial Reduction	x	x											
at key loading locations	Fluidized Bed Reactor biological reduction system		x		Y	Y	Y	Y	3 years	133 Million	35 Million	High	98%	Costs estimated to achieve 60% reduction at Elk Valley operations (80% in 4 highest loading drainages)
at multiple locations	Fluidized Bed Reactor biological reduction system		x		Y	Y	Y	Y	3 years	540 Million	145 Million	High	98%	Treat everything
at community treatment plant	Fluidized Bed Reactor biological reduction system			x	Y	Y	Y	Y	3 years	133+ Million	35+ Million	High	98%	Contingent on location, volume, other objectives
water from end pit lake	Attach FBR treatment system to an end-pit lake			x	Y	Y	Y	Y	3 years	TBD	TBD	High	98%	Cost for 3 lakes - with flows like at Line Creek Operation
	AB Met Process	x			Y	Y	Y	Y	1 years	TBD	TBD	High	98%	
Passive Water Treatment														
	Attached growth - ICB or Coarse Coal Biological Reactor	x			Y	N	Y	Y	5+ years	TBD	TBD	Mod	95%	
	Engineered Passive Bioreactor - organic substrate	x		x	Y	N	Y	Y	5+	TBD	TBD	Mod	95%	Requires large footprint
	Engineered Passive Bioreactor - CCR or tailing substrate	x			Y	N	Y	Y	5+	TBD	TBD	Mod	95%	Requires large footprint
ponds or wetlands	**Fungal volatilization**			x	N									
in situ end pit lake	**Algal Volatilization**	x			Y	Y	Y	Y	1 year	TBD	TBD	Low	30%	Concerns with creating nuisance algal growth and also cyanbacterial blooms with associated toxicity
	Permeable Reactive Barrier- iron			x	Y	Y	Y	Y	10+ years	TBD	TBD	Hi	80%?	Source iron, may need replacement
	Permeable Reactive Barrier - organic	x			Y	Y	Y	Y	10+ years	TBD	TBD	Mod	80-90%	May require substrate replacement
	Permeable Reactive Barrier - native carbon		x		Y	N	Y	N	10+ years	TBD	TBD	Low	80-90%	Requires characterization native carbon
	Wetland biological reduction	x			Y	Y	Y	N	3 year	TBD	TBD	Low	TBD	Concerns with bioaccumulation and creation of an attractive nuisance
	End Pit lake biological reduction - add carbon + nutrients	x			Y	Y	Y	Y	1 year	TBD	TBD	Low	TBD	Concerns with bioaccumulation and creation of an attractive nuisance
Water Management														
	Control erosion and collect sediment	x			Y	Y	Y	Y	1 yr	TBD	TBD	Low	TBD	How much Se removed with pond sediment?
	Divert water from rock drains		x	x	Y	Y	Y	Y	1 year	20-50 million per drainage			Unknown	Need mass and water balance
	Design to collect water in end pit lake	x			Y	Y	Y	Y	1 year	TBD	TBD	Mod	Unknown	Depends on relative volume
	Stormwater Management			x	Y	Y	Y	Y	1 year	TBD	TBD	Low	Unknown	Need mass and water balance
	Avoid waste rock placement in cross valley fills			x	Y	Y	Y	N	10+ years	TBD	TBD	Low		Site specific
	Divert impacted water to tailings or CCR dumps			x	Y	Y	Y	Y	5 years	TBD	TBD	Mod		Dependent on capacity
	Divert impacted water around clean water			x	Y	Y	Y	Y	1 year	TBD	TBD	Mod	Unknown	Dependent on volume
	Divert clean surface water around rock drains				Y	Y	Y	Y	1 years	TBD	TBD	Mod		
	Divert clean surface water around mined rock/ away dirty water		x	x	Y	Y	Y	Y	1 year	TBD	TBD	Mod	Unknown	
	Divert clean groundwater				Y	N	Y	Y	3-5 yrs	TBD	TBD	Mod	Unknown	Need groundwater data, water balance.
	Collect and divert impacted water to treatment				Y	Y	Y	Y	1-3 yrs	TBD	TBD	Mod	Unknown	Site specific
	Divert impacted water away from lentic systems				Y	Y	Y	Y	3-5 yrs	TBD	TBD	Mod	Unknown	Site specific
	Seasonal diversion to accommodate hydrograph				Y	N	Y	Y	3-5 yrs	TBD	TBD	Mod	Unknown	Need hydrograph
	Remove snow to prevent infiltration				Y	Y	Y	Y	1 yrs	TBD	TBD	Mod	Unknown	Need water balance.
	Constructed wetlands/ move wetland resources				Y	Y	Y	N	5	TBD	TBD	Mod	na	
	Permeable reactive barriers (i.e. ditch in the rock drain)			x	Y	N	Y	Y	5-10 yrs	TBD	TBD	Mod	80	Covered elsewhere
	Dilute impacted water with low selenium water	x			Y	Y	Y	Y	1	TBD	TBD	Low	Unknown	Depends on relative volumes
	Water for irrigation; reclaiming water			x	N									
	Water utilization - use highly contaminated water for other purposes			x	N/A									Combine with divert dirty around clean
	Hydrological management engineered as part of the groundwater plan			x	N/A									Have not received ground water plan
	Collection of seepage; interception system			x	N/A									Covered elsewhere
	Engineer a culvert			x	N									
	Impoundment (subsurface reactor)			x	Y	N	Y	N	10+ years	TBD	TBD	High	80%	Anaerobic
	Geotechnical system to increase rate of mobilization of selenium (shorten active treatment window)			x	Y?	N	Y	Y	20+ years	TBD	TBD	Low	Unknown	Heap leach mining, increaes loading rates during operations

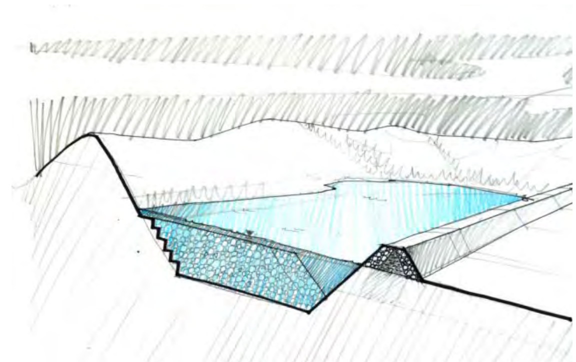
Category	Option	Teck	Panel	Stakeholder	Feasible Y or N	Is it technically feasible within 3 years	Is it technically feasible 3-40 years	Perpetual Maintenance	Time Frame to Demonstrated Results	Cost Cap-Ex	Op-Ex	Cost	Se Reduction Effectiveness	Comments
Dump Design to Reduce Selenium Loading														
	Dump design to limit ponding and infiltration through channel design and revegetation	x			Y	Y	Y	N	5 years	TBD	TBD	Mod		
	Limit formation of wetlands that receive Se-rich water	x			Y	Y	Y	Y		TBD	TBD	Low		
	Selectively handle and encapsulate selenium material		x		Y	Y	Y	N	5-10 years	TBD	TBD	Mod	Minimal	Cardinal River Operations Mooseshale ONLY
	Use biocide to reduce bacterial sulfide oxidation	x			N					TBD	TBD			
	Eliminate selenium material in rock drain cross valley fills		x		Y	Y	Y	N	3-5 years	TBD	TBD	High	Unknown	New Dumps only
	Oxygen barrier-type systems to reduce oxygen flux			x	Y	N	Y	Y	10+ years	TBD	TBD	Mod	Unknown	Reduce Sulfide oxidation, promote Se reduction
	Blend with oxygen consuming materials	x			Y	Y	Y	Y	5-10 years	TBD	TBD	Mod	70-80%	
	Saturate waste and/or cover soil to reduce oxygen	x			Y	Y	Y	Y	10 years	TBD	TBD	Mod	70-80%	Must maintain low flux of oxygen
	Multi-purpose dumps and treatment facilities			x	N/A					TBD	TBD			Covered elsewhere
	Shift away from cross-valley dumps			x	N/A					TBD	TBD			Covered elsewhere
	Drill and inject into legacy dumps			x	Y	Y	Y	Y	5 years	TBD	TBD	Mod	50%	Inject Carbon or reductant
	Capping to reduce erosion and limit infiltration– concurrent reclamation			x	Y	Y	Y	N	10+ years	TBD	TBD	High	50%	More applicable to new dumps
	Revegetate with high ET species	x			Y	Y	Y	N	10+	TBD	TBD	Low	50%	
	Isolate vegetation from Se-rich rock / use non-accumulator veg	x			Y	Y	Y	N	1 yrs	TBD	TBD	Low	20%	
In-Situ Microbial Source Control														
	design dumps to promote microbial reduction as source control		x	x	Y	N	Y	N	10+ years	TBD	TBD	Mod	80%	Manage O2, water to promote insitu reduction
Mine Planning														
	Selectively handle and encapsulate selenium material	x			Y/N	Y	Y	Y	1yr	TBD	TBD	Low	unknown	Possible Cardinal River Operations but not at Elk Valley operations
	Footprint reduction -maximize inpit fill	x			Y	Y	Y	N	3 yrs	TBD	TBD	Low	unknown	
	Changes to underground mining		x	x	N					TBD	TBD			
	Changes to surface mining		x	x	Y	Y	Y	N	3-5 years	TBD	TBD	Mod	Unknown	Lots of opportunities from small to large
	Avoid “Attractive Nuisance” - wetlands, shallow lakes and marshes			x	Y	Y	Y	N	1 year	TBD	TBD	Low	Unknown	Future only
	Proper placement of waste material		x	x	N/A					TBD	TBD			Covered elsewhere
	Hybrid Mining - Open pit and underground			x	N					TBD	TBD			
	Changes to / management of rock drain location			x	N/A					TBD	TBD			Covered elsewhere
Waste Management														
	Mine planning		x		N/A					TBD	TBD			Covered
	Dump covers		x		N/A					TBD	TBD			Covered
	New Mining Methods that produce less waste (e.g. Different blasting patterns)			x	?					TBD	TBD			Requires further discussion
	Management of strip ratio			x	N/A					TBD	TBD			Covered under Mine Planning
	Business opportunities for waste dumps (i.e. uranium disposal)			x	N					TBD	TBD			
	Atmospheric release of selenium			x	Y	N	Y	Y	5+ yrs	TBD	TBD	Low	Unknown	Requires high Se concentrations
	Syngas plant			x	?					TBD	TBD		Unknown	Might purchase treated water?
	Infiltration with dump covers		x	x	N/A					TBD	TBD			Covered elsewhere
	End pit lakes placement			x	Y	Y	Y	N	1 year	TBD	TBD	Low	Moderate	Acceptability to regulators of somewhat elevated Se, Attractive nuisance, losing capacity for sub-surface placement of rock
Other														
	Administrative Controls		x		Y	Y	Y	Y	Immed.			Low	Unknown	Administrative controls are not acceptable to stakeholders attending Workshops
	Progressive Reclamation			x	N/A									Covered
	Minimize Se Loadings and concentrations during reproductive periods	x				Y	N	Y	3-5+ yrs	TBD	TBD	High	Unknown	Site specific
	Improve habitat and productivity to offset selenium stress in ecosystems	x			Y	Y	Y	N	1-3 yrs	$6-40/m2	TBD	Mod	Offset rather than reduction	Would require adherence to Fisheries and Oceans Canada Habitat Compensation Planning Requirements and the No Net Loss policy
	Increase flow in lentic systems to increase O2, limit Se reduction and bioavailability	x			Y	Y	Y	Y	1 year	TBD	TBD			
	Cash compensation to affected landowners	x								TBD	TBD			
	Create habitat in unaffected areas	x			Y	Y	Y	N	3-5 yrs	$6-40/m2	TBD	Mod	Offset rather than reduction	Would require adherence to Fisheries and Oceans Canada Habitat Compensation Planning Requirements and the No Net Loss policy
	Stock fisheries	x			Y	Y	Y	Y	1 year	TBD	TBD		Offset rather than reduction	Would require approval by federal and provincial fisheries management authorities

TBD = To Be Determined

Appendix F

Descriptions of the Selenium Management Options Selected for Multi-Criteria Decision Analysis

Waste Rock Placement
in Constructed Impoundments or Backfilled Pits



One of the most common methods for controlling the oxidation of waste rock (and tailings) is simple submergence of the materials in a reservoir held by a dam, or within an end pit lake with geologic containment. In the case of dams, perpetual maintenance is indicated. The water nearly eliminates the contact of oxygen with the waste rock, essentially shutting down oxidation. In the case of selenium management at the coal mines, such flooding is expected to create reducing conditions, helping to chemically reduce and immobilize dissolved selenium migrating through the flooded zone.

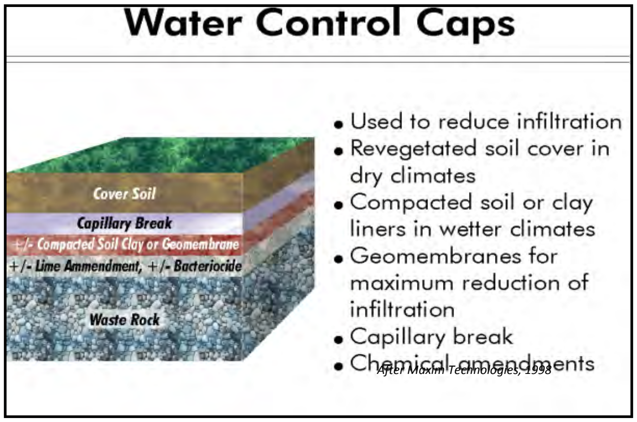
One of the best ways to create these conditions is through placement of backfill in mined-out pits, allowing these areas to flood. The risk of a breach / sudden outflow of water is minimal, as there is geologic (bedrock) containment of the submerged rock. The flux of oxygen is also typically lower, as dumped rock is stable within the backfilled pit. The volume of rock that can be submerged in such a scenario can be enhanced through changes to the pit configuration during mining.

The present recommendation, however, calls for a novel design of waste rock piles to trap more water within them, submerging some of the waste rock, helping to limit oxygen access to the waste rock, and potentially creating a reducing zone. In keeping with a desire to avoid maintenance-intensive dams in the long term, such designs would likely be limited to submerging the base of the some of the cross-valley fills, with dam-like shells that would have very conservative geotechnical designs, shallow downstream slopes, and would be designed to become maintenance free structures. The Canadian Dam Association has two committees evaluating methods to declassify dam-like structures – the results of their work will be applicable to the present discussion.

One option would be to completely flood the waste rock dump, allowing a lake to form on top. A second option is described below. It may be useful to think of the Erickson Creek valley as a potential location. At the downstream end of a cross-valley fill, the rock drain would be partially blocked with low permeability fill, thus raising the water table and flooding the base of the dump. This downstream dyke-like structure would need to be constructed to be geotechnically stable (even with the rising water table) and non-eroding even in extreme flood events. Whether this type of structure would need to be constructed before the waste rock is dumped, or whether it could be constructed to retrofit legacy settings is unclear. For the typical stream gradients in the region, it would need to be tens of metres high to store enough water to be worthwhile.

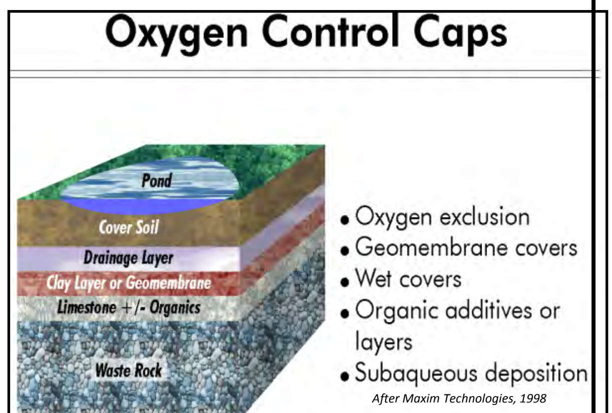
Another option would be to design this structure internally within a waste rock dam, backing up water within the dump, without affecting the downstream slope. This internal dam could likely be made quite high without affecting the downstream geotechnical or erosional stability.

The idea of constructing an impoundment for placement of waste rock is best explored on a case-by-case basis. While this method is likely to have only limited applicability (governed mostly by geography), each dump should be evaluated for the potential to submerge at least some of the lower waste rock, to create a zone capable of selenium reduction within the seepage flow path.



New Waste Rock Dump Construction to Minimize Oxygen and Water Flux

Minimizing oxygen concentrations and water flux in coal waste will reduce sulphide oxidation rates, thereby reducing release of selenium and sulfate. It very likely would also reduce saturation of dump seepage with carbon dioxide gas, which can lead to precipitation of calcite downgradient of waste rock facilities. Lower oxygen flux would also support the development of anaerobic zones where biological reduction can promote *in situ* reduction of selenium to insoluble and non-toxic forms. Low rates of water flow would reduce transport of dissolved selenium away from rock dumps. It is important to note that the goals of dump design to reduce sulphide oxidation (low oxygen, minimal water or saturated anaerobic conditions) differ subtly from those of promoting *in situ* selenium reduction (low oxygen, slow flux of anaerobic water).



Engineered control of oxygen and water flux into waste rock is most effective when dumps or backfills are intentionally constructed for this purpose. Deliberate design prevents development of oxidation-related heating that drives convective flow of oxygen into waste, and prevents generation of acidity that promotes accelerated microbial sulfate oxidation. Prevention of impact through source control in mining is really worth a ton of cure!!

Effective methods depend on *site-specific* hydrological, geochemical, and geotechnical conditions, but often include:

- Construction of piles from the ground up (rather than by end dumping) to promote geotechnical stability and facilitate compaction, grade control, and cover design
- Avoidance of cross-valley fills will reduce potential for sulphide oxidation and selenium release in rock drains
- Engineered diversion structures to convey away from dump facilities
- Grade control to divert water running onto rock and promote runoff before infiltration
- Construction of a vegetated soil cover to promote evapo-transpiration and reduce infiltration of seepage
- Use of changes in grain size and compaction to create discontinuities that reduce large-scale air flux, to limit sulphide oxidation and promote selenium reduction in the dump
- Construction of capillary breaks using fine layers of compacted material overlying coarser material to enhance water storage in select zones (e.g., reactive permeable barriers or evapotranspiration cover soils)
- Encapsulation of reactive rock within oxygen consuming or acid neutralizing zones
- Placement of rock below the water table to limit oxygen availability
- Construction of backfills within mined-out pits to isolate rock from the atmosphere
- Addition of oxygen-consuming organic material to promote selenate reduction (CCR/tailings)
- Construction of wet covers to limit oxygen flux to reactive waste rock, thus reducing oxidation

The effectiveness of designed rock dumps in reducing oxidation rates and selenium release will vary from 50 to 95%, depending upon site-specific conditions.

Additional information on waste rock design options is available at http://www.gardguide.com, http://aciddrainage.com/, http://www.nrcan.gc.ca/mms-smm/tect-tech/sat-set/med-ndd-eng.htm or http://www.inap.com.au/.

Effective Use of Water Diversion – Keeping Clean Water Clean

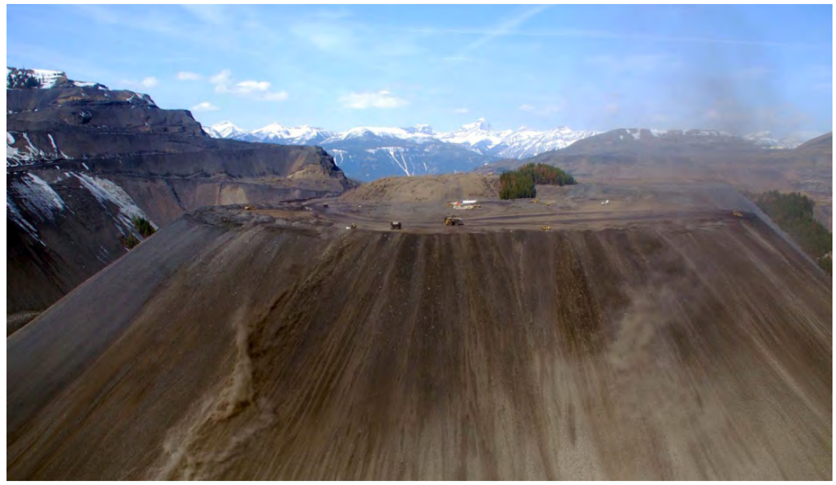
Diversion of surface flow and groundwater away from waste rock piles and rock drains limits selenium dissolution and oxidation, thereby reducing selenium loading. Keeping clean water away from selenium-bearing materials reduces the volume of water requiring further management (e.g., treatment), but it can be challenging where sources are diffuse (e.g., discharge of groundwater through seeps and springs developed on pit high-walls or into gravel deposits in existing drainages) or where waste rock or pit facilities are developed in the headwaters of watersheds. Where water can be collected, pumping stations and pipe (or tunnels/channels) can be used to transfer water around waste rock (or rock drains) to down-gradient locations to minimize loading.

One important concern with this approach is seasonal fluctuation in the volume of up-gradient run-on to waste rock facilities, which could require installation of considerable pumping capacity to adequately control flow in some seasons on the year. This could be minimized if room were available to develop ponds for water storage under peak flow conditions. A second concern is maintenance of adequate flow within existing drainages, to minimize effects on biological resources.

The value of keeping clean water clean is obvious, and there are conditions at some mines that indicate diversions are warranted, although it is difficult to predict the magnitude of selenium load reduction for rock drain settings without additional information about relative load contribution from rock within drains, relative to that deposited in piles that overlie the drains. Diversion would reduce only the loading contributions from rock within the drains, not from rock that overlies the drains. Due to the long-term operation and maintenance costs of pumps and diversion works, Teck would need to monitor changes in down-gradient water quality resulting from diversion, to demonstrate that this approach offers sufficient selenium reduction to warrant its cost.

Water diversions would help to control water treatment costs and enable use of a wider range of water treatment technologies during mining operations. Diversion structures would require ongoing maintenance; however, in the active geologic environment present in the mine areas. Closure strategies that minimize the need for water diversion will, therefore, need careful consideration.

Avoid Placement of Waste Rock in Cross-Valley Fills



Handling the large volume of waste rock at Teck Coal operations is by far the largest mining cost. Efficient transport and placement of this waste rock is central to the viability of all operations. From a traditional mining perspective, the most efficient disposal method is to design the mine and the waste rock dumps so that trucks hauling the waste rock drive the shortest distance, at constant elevation (neither uphill nor downhill), and dump over a high angle of repose dump slope. At Teck Coal, some of this waste rock is dumped back in the mined out pit, but the majority is dumped into adjacent valleys for permanent storage. For rock dumps that block creeks, engineered rock drains are used to transmit this water, which allows clean, oxygenated water to flow through the base of the dumps, leading to increased selenium loading and increased water treatment costs (due to dilution), as discussed elsewhere in this document.

Most mine dumps are one of four types: flat land pile dumps, head-of-valley fills, cross-valley fills, and side-hill dumps (Hustrulid and Kuchta, 2006). Teck Coal uses flat land pile dumps when backfilling mined-out pits. This style of dump minimizes water entry into the waste rock. Head-of-valley dumps, which are used extensively at Teck Coal, have limited upstream surface water catchment but can still generate high flows of water through their integral rock drains, most likely due to groundwater flow through talus in the valley.

The photo to the left shows a cross-valley fill at Line Creek and the outlet of a rock drain. Temporary diversion of surface water around this type of dump is expensive, but quite important to overall reduction of loading and water treatment costs unless it can be shown through *in situ* study that rock drain loading is not significant. It can also be difficult to design a sustainable permanent diversion because the entire valley floor is filled with waste rock, and the valley slopes are subject to ongoing natural geological instabilities (such as snow avalanches and debris flows) that can block flows in diversion channels.

Side-hill dumps, as in the Erickson Creek example in the photo below, do not rely on rockdrains for temporary or permanent conveyance of water through the valley, but have much less storage capacity than cross-valley dumps. In-depth evaluations of flow through existing drains built with run-of-mine rock, as well as rock drains built of clean rock, are needed to confirm acceptable selenium loadings to support future waste rock placement in cross-valley fills.

The Panel recommends that Teck Coal favour the use of flat-pile dumps and side-hill dumps over cross-valley fills, recognizing that there are economic and land disturbance tradeoffs. Head-of-valley fills lie somewhere between these two options – additional efforts to control the contact of clean water with selenium-bearing rock at the base of these fills (perhaps through construction of drain pipes set into the bedrock foundation) beneath the dump is warranted.

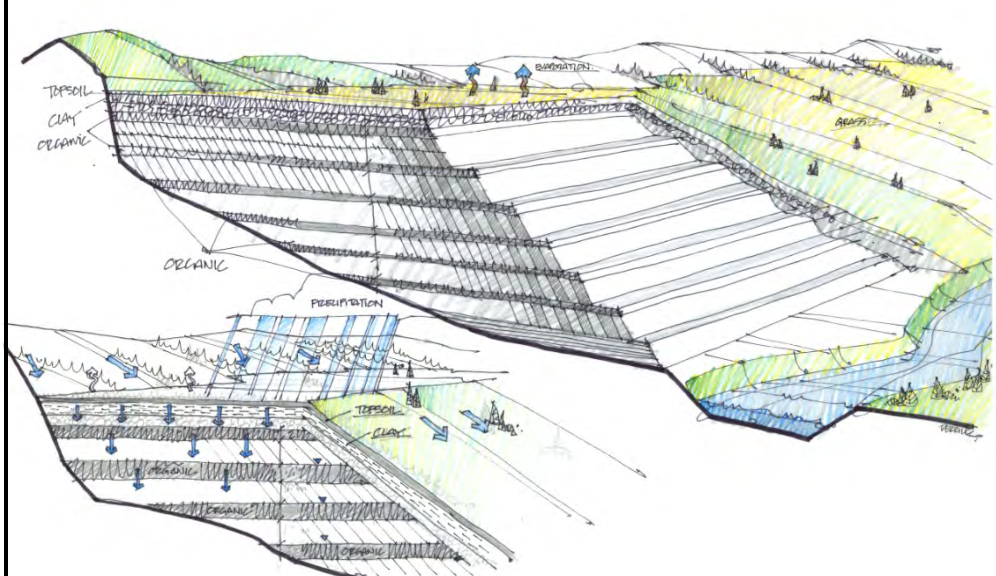
Hustrulid, W and Kuchta, M. 2006. Pit Mine Planning and Design, Second Edition, Taylor & Francis, 991p.

Microbial Source Control

Recent advances in biotechnology offer important strategies for operational management of selenium release from mine waste. Mobile selenium can be reduced to immobile and non-toxic forms by a surprising variety of bacteria, fungi, and algae (Lenz and Les, 2008). Selenate reduction to the less soluble selenite, elemental selenium, and selenide compounds can result from microbial growth under anaerobic conditions or from transformation by microbes for detoxification purposes. Fungi and algae can volatilize selenium as methylated or selenide gas forms as well, thus releasing it to the atmosphere (Dungan and Frankenberger, 1999). Once reduced, selenite can sorb to minerals like iron oxide or selenium minerals can precipitate within the waste rock itself, thus providing a relatively rapid means of *in situ* source control (Kirk et al., 2009).

Biological reduction of selenium is most efficient at low oxygen concentrations, when moisture and carbon are present. Active water treatment methods make use of these natural microbial processes (Sandy, 2010; see discussion this appendix), and microbial reduction of selenium in permeable reactive barriers has been demonstrated at multiple bioremediation sites (USEPA 2010). R&D work on passive bioreactor designs for Teck Coal has demonstrated significant capacity for microbial selenium reduction. Although microbial selenium reduction strategies have been applied more to remediation or treatment objectives than to operational waste management at mine sites, there is substantial evidence that they can be effectively promoted within the mined waste itself. Promotion of *in situ* microbial reduction within waste rock piles or backfills, through control of oxygen and water, is under study for the purpose of managing selenium in phosphate mine waste in SE Idaho (Kirk, 2009, http://www.scgcorp.com/fellowship2009/PosterList.aspx). Options for integrating microbial ecology into operational management through deliberate design of waste management facilities offer sustainable, low-maintenance and cost-effective means of controlling mine drainage impacts.

In the carbon-rich shales mined by Teck Coal, it is likely that native microbes present in the waste are capable of using the natural carbon to reduce selenium to immobile forms under appropriate moisture and gas conditions. In fact, reduction of selenium has been observed in tailings and coarse coal reject (CCR) deposits at Teck mine sites and there is evidence that this reduction is microbially mediated (Siddique et al., 2007). Teck (and their consultant, Golder, 2010) has completed experiments that show selenium reduction in CCR, with and without addition of carbon, over relatively short periods of time (Teck Cominco, 2007).



Creating low oxygen conditions in full-scale rock dumps is challenging, but has been approached in various ways at mine sites through injection of oxygen-consuming compounds, subaqueous placement of rock, and/or use of oxygen control cap designs (see figure). Use of differential compaction and capillary breaks to limit oxygen and water flux may also be of value. Facultative microbes, which will grow using oxygen until it is depleted and then switch to anaerobic metabolism, also can create low oxygen conditions and are known to reduce selenium.

Implementation of operational in situ selenate reduction would require further understanding of the native microbes involved in selenate reduction in coal waste, CCR, and tailings at Teck sites; better understanding of the available carbon supply and microbial demand; design of facilities to promote the moisture and low oxygen conditions needed to drive selenate reduction; and understanding of hydrology within mine facilities.

The concept of *in situ* microbial source control complements other selenium management strategies available to Teck, including placement of waste as backfill; engineered dumps that limit oxygen and water flux; subaqueous rock management; and construction of reactive permeable barriers in the path of selenium-bearing water. Due to the site-specific aspect of these strategies, *in situ* validation at the pilot scale and research to address key parameters such as carbon availability will be required.

Brienne, S.H. and S.E. Jensen, 2007. Microbial Selenium Removal from EVCC Water: Mechanism. Teck Cominco Applied Research & Technology Report No. 2007RR22.

Dugan, R.S., Frankenberger Jr., W.T. 1999. Microbial Transformations of Selenium and the Bioremediation of Seleniferous Environments. Bioremediation Journal 3(3): 171-188.

Golder, 2010. Draft Interim Selenium Research and Development Project. Report No. 09-1324-1039 prepared for Teck Coal, February 2010.

Kirk, L.B., S.E. Childers, B. Peyton, T. McDermott, R. Gerlach, and T.M. Johnson, 2009. Geomicrobiological Control of Selenium Solubility in Subsurface Phosphate Overburden Deposits. Talk presented at Goldschmidt Geochemistry Conference, June 2009. In Goldschmidt Abstracts – K, Abstract A661, Geochimica et Cosmochimica Acta, Vol.73, No.13, Supplement June, 2009.

Lenz, M., Lens, P.N.L. 2009. The Essential Toxin: The Changing Perception of Selenium in Environmental Sciences. Science of the Total Environment. 407. P. 3620-3633.

Naftz, D.L., Morrison, S.J., Davis, J.A., Fuller, C.C. 2002. *Ground Water Remediation using Permeable Reactive Barriers(Chapter 13). Academic Press. Boston, MA.*

Sandy, T. and DiSante, C., 2010. Review of Available Technologies for the Removal of Selenium from Water. Report prepared for North American Metals Council, June 2010

Siddique, T., Arocena, J.M., Thring, R.W., Zhang, Y. 2007. Bacterial Reduction of Selenium in Coal Mine Tailings Pond Sediment. Journal of Environmental Quality. P. 621-627.

USEPA, 2010. Permeable Reactive Barriers, Permeable Treatment Zones, and Application of Zero-Valent Iron: An Overview, **http://clu-in.org/techfocus/default.focus/sec/Permeable_Reactive_Barriers%2C_Permeable_Treatment_Zones%2C_and_Application_of_Zero-Valent_Iron/cat/Overview/**

Selenium Water Treatment

Water treatment for the removal of selenium will likely be a component of a successful selenium management strategy for Teck Coal (Teck). As discussed below, Teck should consider selenium treatment on a site-specific basis in conjunction with water reuse, measures to prevent contamination, and source control measures.

Reuse

Reuse of water associated with mining activities as process make-up water for coal handling and processing plants that are currently using other sources (e.g., potable water or Elk River water) should be a priority for Teck. Teck reviews indicate these plants reduce the concentration of selenium in the discharges either through the magnetite and dissolved carbon used in the coal separation processes, or the tailings management ponds. These do seem to be plausible explanations, as both ferrous and ferric iron that make up magnetite used to enhance separation in the flotation processes have been shown to chemically reduce and adsorb selenium, and soluble carbon available under anaerobic conditions that exist in the tailings ponds will result in heterotrophic biological activity that can biochemically reduce selenium. **Before implementation of reuse in the coal handling and processing plants, Teck should better confirm the mechanism, complete rigorous material mass balances for selenium, and address potential challenges with the collector (e.g., kerosene) and frother (e.g., methyl isobutyl carbon) chemistry as well as other surfactants/polymers used in the processing facility.** One certainty is that the Cardinal River Operation coal handling and processing plant does reuse water affected by mining activities without too much difficulty and their selenium levels in the discharges from the plant through tailings ponds are relatively low in selenium. Teck currently reuses water for dust control at each operation.

Treatment Challenges

Achieving selenium levels less than 5 µg/L in surface water discharges from the rock drains from the Teck operations poses a challenge given that selenium:

- Removal is limited by the minimum and maximum feasible ranges of design flows that can vary greatly over time;
- Predominantly exists in the selenate form;
- Is relatively dilute in concentration (e.g., less than 500 µg/L);
- Removal from water is confounded by the water matrix (e.g., temperature, pH, and other chemicals);
- Treatment generally results in a concentrated by-product or residual; and
- Re-release from the residuals can occur.

Significant variation in selenium levels and flows exists among the different Teck operations. This increases the complexity of identifying the best locations for active treatment to remove selenium. Generally, all the selenium treatment technologies are hydraulic-dependent rather than selenium mass-dependent. **Teck should prioritize treatment at discharge locations that are highest in mass and concentration of selenium, and lowest in volumetric flowrate to obtain the most selenium removal per unit cost. This is especially true when considering a mass-based approach to reduce the selenium concentration of the resulting discharges from the watershed (i.e., Elk River).**

Basis of Design

Adequate characterization of targeted water discharges from the various Teck operations should capture seasonal variation, and speciation should be performed to establish a basis of design for the applicable technology for removal. Understanding not only the selenium concentrations but the competing and interfering water chemistry (e.g., complete major ion and trace element chemistry) is key to designing the treatment system for selenium removal. **Seasonal snow melt increases the base flow of a given discharge in April and continues to increase to peak flows in June, followed by a steady decrease back to the base flow in late September early October. Given this, Teck should consider applying best practices for open channel flow measurement at targeted surface water discharges for selenium treatment as**

well as flow-weighted composite sampling for key parameters. Typically the peak June month daily flow rates may be 6 to 12 times the baseline flow from November through March.

The selenium treatment technologies have a very limited capacity for increased flows and can be more easily designed to operate without impact on performance under low-flow conditions. Selecting the dry weather base flow as a basis of design will limit the mass that can be removed annually, however. Selecting a portion, if not all, of the wet weather flow will increase the mass/load that can be removed annually from the discharge, but could significantly increase cost due to large increases in volume at those times. Because the performance of each technology is flow based, the system may require flow equalization infrastructure. However, most locations at Teck mine sites are constrained by geography that would limit installation of large impoundments or in-ground basins for equalization/diversion. The end result is a treatment plant that could have significant total installed and operations and maintenance costs.

Core Selenium Treatment

Recently, Teck has made a significant investment in evaluation of treatment technologies for selenium reduction. Teck has focused on core selenium treatment technologies that are primarily biologically based. These include the passive Biochemical Reactor (BCR) application to rock drain discharges and algal-based systems for end pit lakes. Teck has also evaluated down-flow attached growth systems applying two types of media: ICB™ (a Golder Associates proprietary foam medium) and coarse coal rejects (CCR). These attached growth systems would operate in a similar fashion as the commercially available General Electric ABMet® system.

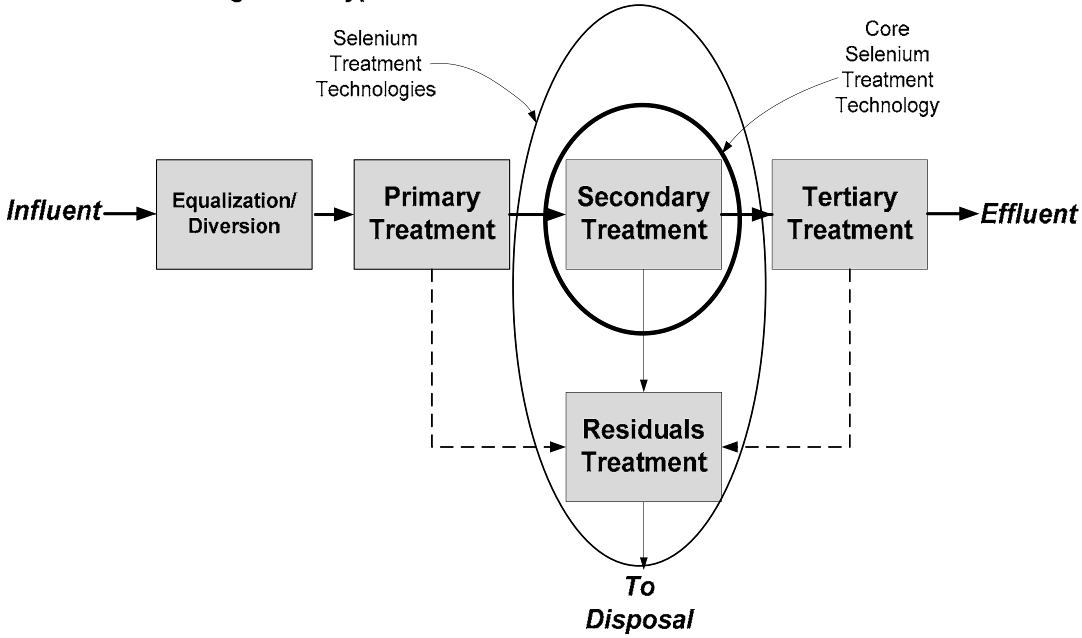
While the BCR is a passive system that can provide selenium reduction through both biological and chemical pathways in the reactor, it and other passive systems (e.g., constructed vertical flow wetlands) require a relatively large footprint and can require tertiary treatment in the early stages of operation. Algae have been shown in pilot tests to remove selenium from water; however, application of this technology is seasonally limited and can create other issues as a result of the high levels of nutrients required to sustain the algal population. Application of the ICB™ and CCR media are novel applications of the media types in attached growth biological treatment. While Teck should consider passive and novel applications that may be more sustainable in the long term, **Teck should focus on core selenium treatment technologies that are most cost effective and can provide the highest level of successful selenium reduction at full scale under similar conditions.**

Systems Approach

A variety of physical, chemical and biological treatment technologies have been shown to remove selenium from water. Decisions to apply these treatment technologies must consider the aforementioned challenges. This typically means that the treatment technology must be configured as a “system” that includes primary, tertiary, and residual treatment processes in addition to the core treatment technology process. Figure 1 provides an overview of the elements of a typical selenium treatment system. **Teck should consider both the core selenium treatment technology and the ancillary unit processes (e.g., primary, residuals, and tertiary treatment) required for compliance with other parameters. Additional treatability testing may have merit, especially to address tertiary treatment needs related to compliance with conventional discharge parameters (e.g., dissolved oxygen, total suspended solids, biochemical oxygen demand, etc.). Additionally, Teck should consider other water quality parameters that have been recently identified as creating issues in the surface water (e.g., calcite) that could also be treated through the selenium treatment system or be addressed through add-on treatment technologies in the future.**

Primary treatment to remove suspended solids and/or inorganic scale (e.g., calcium carbonate) may be required for certain of the core selenium treatment technologies. Tertiary treatment will generally be required to meet both the selenium and other conventional surface water discharge parameter guidelines or criteria. Residuals or by-product treatment will be required for most systems. The residuals will contain concentrated levels of selenium that, if disposed of as a solid or liquid waste, will need to comply with other disposal regulations. By-products may require further treatment to ultimately reduce the selenium to a less hazardous form.

Figure 1. Typical Selenium Treatment Unit Processes

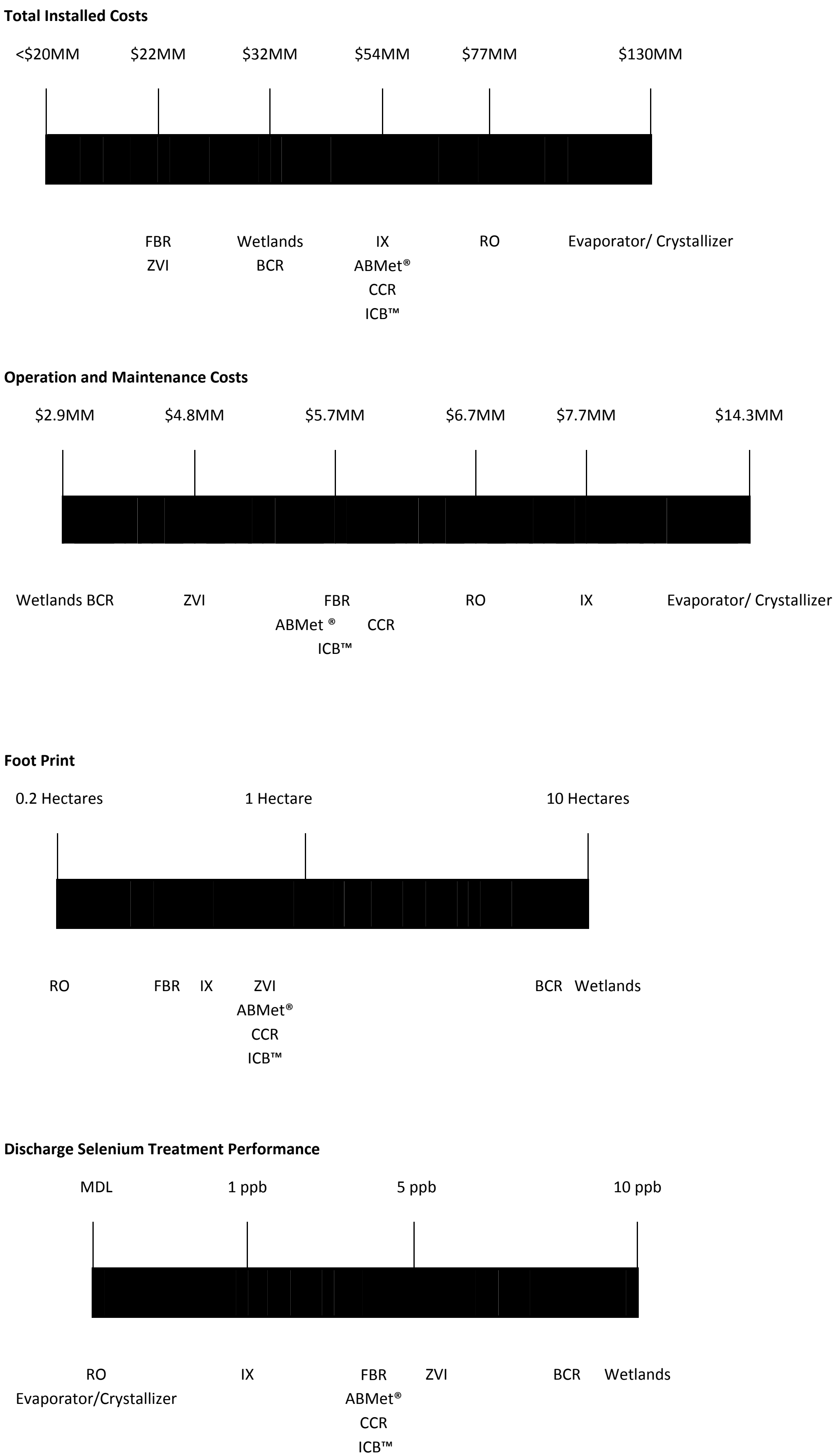


Selection of a System

Consistent with the ***Final Report Review of Available Technologies for the Removal of Selenium from Water for the North American Metals Council*, June 2010**, attached growth biological (e.g., fluidized bed reactor (FBR), ABMet®, CCR and ICB™), evaporation/crystallization, ion exchange(IX), passive (e.g., BCR and constructed wetlands), and zero valent iron (ZVI) are the technologies that have been shown to provide the most consistent removal of selenium down to the 5 µg/L levels. Reverse osmosis (RO) can remove selenium down to less than 1 µg/L. Figure 2 provides a relative comparison of these technologies for an 11,000 cubic meter per day (m^3/d) selenium treatment system (i.e., the volume of water moving through the virtual mine). The costs provided are Class 5 cost estimates with an accuracy of +100%, -50% as defined by the American Association of Cost Engineers.

There are many factors (e.g., sustainability, safety, business impacts, etc.) beyond these key indicators that must be considered when selecting the ultimate treatment system for selenium removal. **Teck should consider all objectives, preferences, and critical success factors when making a decision on a selenium treatment system as well as a stage-gated process for implementation.**

Figure 2. Relative Comparison of Technologies

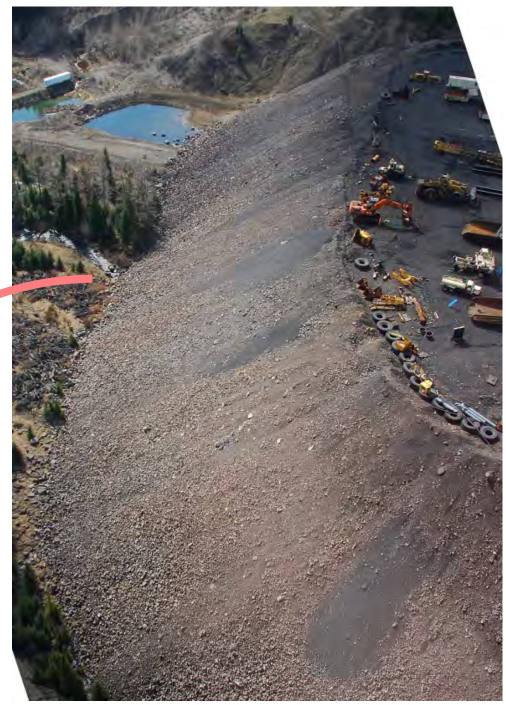


Use Massive, Low-selenium (Non-seleniferous) Rock in Drains

The use of engineered rock drains for coal mining is a relatively new innovation (see for example, Symons, 1987; Mine Waste Rock Pile Research Committee, 1999) but became common in Rocky Mountain coal mining before selenium leaching from waste rock dumps was recognized as an issue. Concern about the drains arises from their capacity to rapidly convey oxygen and water to rock that leaches selenium upon weathering.

A rock drain is “a valley or head of hollow fill constructed through the placement of mine waste rock in and about water courses, whether permanent or ephemeral, in such a manner that stream-flow will pass through the mine waste rock” (MEMP & MOE, 2001), thereby reducing geotechnical instability issues. The rock drain design involves prediction of the probable maximum flood for the upstream drainage, so that the cross-sectional area of the drain and the minimum rock diameter for drain rock can be specified to transmit the needed volume of water. The required durability of the drain rock, the source of the rock (and criteria for its selection so that rock will not leach unwanted solutes into the water), and construction details are also typical components of rock drain designs.

Some rock drains are constructed through placement of quarried rock in the stream channel in advance of mine waste rock dumping. This method allows good construction control, but can be expensive. A more common approach is to build the waste rock dump across the valley using a sufficiently high lift that the largest and strongest boulders roll to the base of the pile, forming the rock drain with minimal controls (see segregation of rocks at the toe of the slope in the photos).



The Panel is unaware of any data on the performance of the Teck Coal rock drains with respect to physical or chemical stability, apart from some general up-gradient and down-gradient measurements of selenium concentrations that suggest selenium release to water moving through the drain in several (but not all) monitored locations. It is unclear whether most of this selenium comes from leaching of boulders within the rock drains, which may physically disaggregate during weathering and thereby increase surface area, or if most of the loading comes from seepage through rock that overlies the drain. Also, there may be finer material co-deposited with the boulders or migrating into the rock drains, leading to additional selenium leaching in this aggressive high-oxygen and water-flux environment. The relative contribution of rock within, and above, the drain itself is unknown.

The Panel recommends that existing rock drains should be tested to determine if materials in the rock drains are leaching selenium. Moreover, the Panel recommends that all future rock drains (both for head-of-valley and cross-valley fills) be constructed of durable rock with low potential to release soluble selenium. This approach may require placement of clean quarried rock (or selectively handled, non-reactive waste rock) before dump construction. This is an approach that has been previously used at some of the mines. A graded gravel filter to reduce fines migration from the waste rock into the rock drain should also be considered.

There may be an option to control water through the base of dumps using one or more buried pipes, to either aid in the diversion of clean surface water and groundwater away from the rock drain, or as a method of minimizing water contact with the rock drain. While likely long-lived, this approach could not be considered a permanent solution. Stresses in the dump are too high for conventional culvert/pipe, but a cut-and-cover culvert set into bedrock (or a tunnel in the bedrock), may be a useful additional design element.

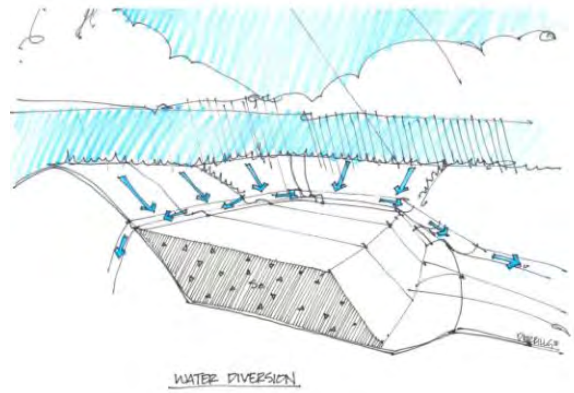
Symons G, ed. 1987. Proceedings of the International Symposium on Flow-through Rock Drains: Victoria, BC: Technical and Research Committee on Reclamation. 206 pp.

Mine Waste Rock Pile Research Committee. 1999. Rock drain research program: final report, Waste Dump Research Committee, Victoria, BC.

Ministry of Energy Mines and Petroleum, Ministry of Environment. 2001. Rock drain agreement regarding the joint administration and regulation of the mining industry. Government of British Columbia, Victoria, BC, 7 p.

Existing Dump Reclamation to Limit Sulphide Oxidation

Reclamation of existing dumps to limit selenium release is more difficult than design of new dumps, as remedial action must reverse (rather than prevent) active weathering processes. Selenium is released from Teck waste rock dumps through dissolution of selenium-bearing sulphate minerals (such as gypsum, $Ca(SeO_4,SO_4)\text{-}2H_2O$) or by oxidation of seleniferous pyrite ($Fe(Se,S)_2$) in the presence of oxygen and water (SRK, 2007). Heat from sulphide oxidation causes air to rise within the dump, pulling fresh oxygen into the lower rock pile and creating a self-aerating, chimney-like oxidation environment. This is especially true for rock that has been end-dumped along steep terrain, so that coarse rock accumulates to create porous conditions in the dump toe. Remedial designs for existing dumps must (1) reduce oxygen and water concentrations to prevent oxidation reactions (by consuming the reactants and/or limiting their replacement) or (2) limit the flow of water that dissolves and mobilizes selenium. Strategies that rely on changes in compaction or particle size of rock to control gas or water flux within rock piles are not possible for existing facilities. Options that were considered by the panel for modification of existing dumps to control of the selenium release process are discussed below.



Infiltration can be reduced by recontouring piles to stable slope configurations that promote runoff while allowing vegetation to grow (between 2:1 and 3:1); construction of effective surface water diversions (see figure at right); and establishment of drainage on dump surfaces to prevent ponding or erosion. Reworking the surfaces of dumps to reduce the grade and increase stability to support capping is possible in some locations, but could expand the footprint of existing dumps further into drainages. Removal of smaller quantities of rock from drainages would also be possible in a few locations. The impact of these strategies in reducing selenium release will be highly site specific. Construction of high evapotranspiration or low transmissivity covers to physically limit infiltration or gas exchange is also an option. Some water control cap designs are shown in the figure below; these can include revegetated "store-and-release" covers (50 to 80% effective), compacted soil or clay layers (50 to 90% effective), or geomembrane caps (as much as 95% effective) in reducing infiltration. Designs that incorporate oxygen-consuming materials (such as organics), or create saturated zones to limit oxygen access to material (e.g., saturated backfills or "wet covers") are shown in the appendix describing new dump designs***.*** Successful use of any cover requires a geotechnically stable waste dump (e.g., not overly steep), which could be difficult for some existing dumps.

To meet selenium reduction targets, covers will likely be required for all dumps. Resloping would help to reduce cracking near the dump crests. Net percolation rates would still be reduced by vegetated covers in spite of settling and cracking of legacy dumps, albeit with some reduced efficiency. Finding a cost-effective growth media that will support lush vegetation will be a significant issue for all covers.

Oxygen within existing end-dumps is difficult to control, especially if sulphide oxidation is occurring. Injection of carbon or other oxygen-consuming compounds into rock dumps or heaps has been used at some mine sites, but success is variable and limited by the ability to distribute injected reactants within the rock piles.

Effective design must consider the site-specific nature of water flux and oxygen consumption within waste. An excellent discussion on facility and cover design to control sulphide oxidation (and thus, associated selenium release) is available at http://www.gardguide.com.