Risk Assessment of Upstream Coal Mining in the North Saskatchewan River Watershed on NSR Water Quality and Ecosystem Health

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1. Executive Summary

Coal mining has been shown to have negative effects on water quality, quantity, and aquatic ecosystems globally and within Alberta. The extent of the effects are difficult to quantify at both the local and regional scales, but one of the most clearly identified issues is bioaccumulation of selenium and impact on aquatic biota. Research has demonstrated that the amount of selenium-rich waste rock exposed and area of the watershed mines are critical factors in determining the extent of selenium contamination and effects. With 5% of the North Saskatchewan Watershed upstream of the City of Edmonton currently held by coal leases but currently undeveloped there is a risk to source water, aquatic ecosystem health, industrial users, and agricultural users should development occur. Although the science around selenium effects is continually developing, provincial and federal agencies have developed guidelines to help project these uses. These guidelines include both water quality and tissue loads for fish and benthic invertebrates as well as public health fish consumption guidelines, drinking water guidelines, and irrigation guidelines.

This Risk Assessment was undertaken in collaboration of the City of Edmonton who was concerned about the potential impacts of coal mining activities. It must be noted that this broad assessment focuses on NSR river health and does not consider other ecosystem heath metrics such as habitat loss and subsequent effects on terrestrial biota. It also focuses on effects within the City of Edmonton boundary which could cascade down from upstream effects, which could be significant. Lastly, there is currently little coal mining activity in the NSR basin and the assessment is based on the risk of future develop where current coal leases exist and makes assumptions that mine management will occur in accordance with current environmental regulations. Risks of upstream coal mining negatively affecting to source water for drinking and assimilative capacity is low. Risks to water quality for maintenance of aquatic ecosystem health in the Edmonton reach are medium-low, largely because although there is some potential for local effects in the headwaters to trickle down to lower reaches, the size of the disturbance to the watershed is expected to be low.

However, to best understand and manage risks to the users of the NSR within the City of Edmonton and local areas from mining activities it is necessary to quantify potential loads of mining parameters of concern (including selenium) from proposed mining activities at both the regional and local scale using modelling tools. Where data gaps exist in understanding the fate and transport of contaminants to allow accurate load assessments, these must be addressed before coal mining can proceed. This precautionary approach should be taken because despite advances in treatment technologies, exposing rock rich in selenium and other metals has been shown to affect water quality for decades in downstream waterbodies and mitigation is often cost prohibitive and difficult. Ultimately it is Government of Alberta's responsibility to protect water resources and manage cumulative effects and the role of stakeholders is to bring concerns forward and advocate for responsible resource management.

2. Coal Policy Changes

In 1976, Alberta enacted the Coal Policy and implemented a land-use classification system that divided the province into four categories dictating where and how coal leasing, exploration and development could occur (GoA 2021). Under this policy, no mining is allowed in Category 1 lands, surface mining is not normally permitted on Category 2 lands, exploration is allowed on Category 3 lands, but development is restricted, and mines are permitted on category 4 lands. Category 1 lands are located in the upper headwaters and encompass Banff and Jasper national parks and surrounding areas. Category 2 and 3 are located in the foothills. Category 4 lands are not located within the NSR watershed.

The Government of Alberta issues coal leases for 15-year terms that are renewable, which allow the holder of the lease the exclusive right to recover coal. A successful coal lease will result in either an agreement/lease being issued, or a competitive bidding. Coal agreements/leases are in place for a large portion of the Category 2 lands in the NSR watershed, despite the Coal Policy ban on surface mines. However, a coal agreement does not grant permission to develop a mine. In order to develop a mine, the holder of a coal agreement requires a mine permit and a mine license from the Alberta Energy Regulator (AER). Under the *Environmental Protection and Enhancement Act* (*EPEA*), an environmental impact assessment (EIA) would be required, which allows the AER to examine the effects that the proposed project may have on the environment, and determine if the project is in the public interest. An approval issued by the AER under *EPEA* outlines the obligations and responsibilities for design, construction, operation and reclamation of the coal mine. Following the completion of mining activities, reclamation certificates issued under *EPEA* certify that all reclamation requirements have been met and that companies have done everything they can to return land to a state functionally equivalent to what was there before development took place.

As of June 1, 2020, the Coal Policy was rescinded, and the restrictions on Category 2 and 3 lands were removed. This means that surface coal mining was permitted within these areas, and companies with existing coal agreements could begin the application process for a surface coal mine. All new coal development projects would be considered by the existing Alberta Energy Regulator review process which considers the economic, social and environmental impacts on a project-by-project basis. Lands that were formally category 1 lands "will continue to be protected from coal leasing, exploration and development on public lands . . . This will support critical watersheds, biodiversity (including numerous species at risk), as well as recreation and tourism activities along the eastern slopes" (GoA 2021).

In response to public pressure, the Government of Alberta cancelled 11 recently issued coal leases and pause future lease sales in January 2021. The cancelation of the leases did not reinstate the 1976 Coal Policy, and did not impact any coal projects that are currently under regulatory review. This means that surface coal mines were still permitted in Category 2 lands. On Feb 8th, 2021, under increasing public pressure reinstated the 1976 Coal Policy until a new coal policy can be developed, with adequate public consultation. It is not clear if, under new regulations, coal mining would be economically feasible for any areas in the NSR basin. However, there have been no new mining license applications in the NSR basin since the 1976 Coal Policy was rescinded in July 2020 and now reinstated, but that could change. In April, the Government of Alberta also halted all exploration on Category 2 lands until public coal consultation is complete.

3. Historic and Current Coal Activity in the NSR Including Coal Leases

There is a long history of coal mining in the North Saskatchewan River basin. Coal mining begin in Edmonton in the 1880s and continued until 1974. Coal mines near Nordegg operated from 1912 to 1955, and during the 1940s, Nordegg was one of top coal-producing areas in Alberta. Surface coal mines near Lake Wabamun began operation in the 1960s and remain in operation today.

There is currently relatively little coal mining activity in the NSR watershed; 54 km^2 of the watershed is categorized as active or recovered coal mine and of that 26.9 km^2 is categorized as open coal pit mine (0.3% of watershed). Coal mining is currently limited to the Wabamun Area and the waste stream drains into Wabamun Lake or pit lakes (1.5 km^2). Wabamun Lake connects to the NSR through Wabamun Creek; however, because of a weir at the outlet, water from Wabamun Lake does not overflow into the creek very often.

Although the active mine area is currently small, there are coal deposits, coal fields, and associated coal agreements that have not yet been developed. Specifically, there are 1510 km^2 (just over 5% of watershed) of coal agreements in place that are all located in Category 2. The coal in these areas is classified as high-volatile bituminous coal (Figure 1). These lease areas are largely forested with over 80% of the area in coniferous forest cover (Figures 4 and 5). Of the remaining agreements, 327 km^2 are under the normal Approval process and 15 km^2 are under Category 3.

There are 12 companies with leases in Category 2 lands and 19 total companies with lease holdings in the NSR watershed. Category 2 lands are of particular concern due to high water yields (Figure 6) and potential for waste rock runoff to contain heavy metals. The process of coal development includes exploration, establishing a mine, and remediation, all which require applications. For the NSR, in 2020 Black Eagle Mining Corporation applied and was approved for a coal exploration program as well as deep drilling permit for the Blackstone Coal Project Area. This Blackstone Project area is an 1120 km^2 area south-west of Rocky Mountain House in Clearwater County. Black Eagle Mining Corporation and Valory Resources Inc. are a business partnership on the Blackstone Coal Project in Clearwater County. The registered Business Associate and Licensee Agents with the AER for the partnership is Black Eagle Mining Corporation. There are no applications from Black Eagle and/or Black Eagle/Valory before AEP at the moment. The Blackstone Coal Property is directly south of the Ram Coal Ltd. Ram River Property which was extensively explored from 1914 to 1981, and during 2011- 2013.

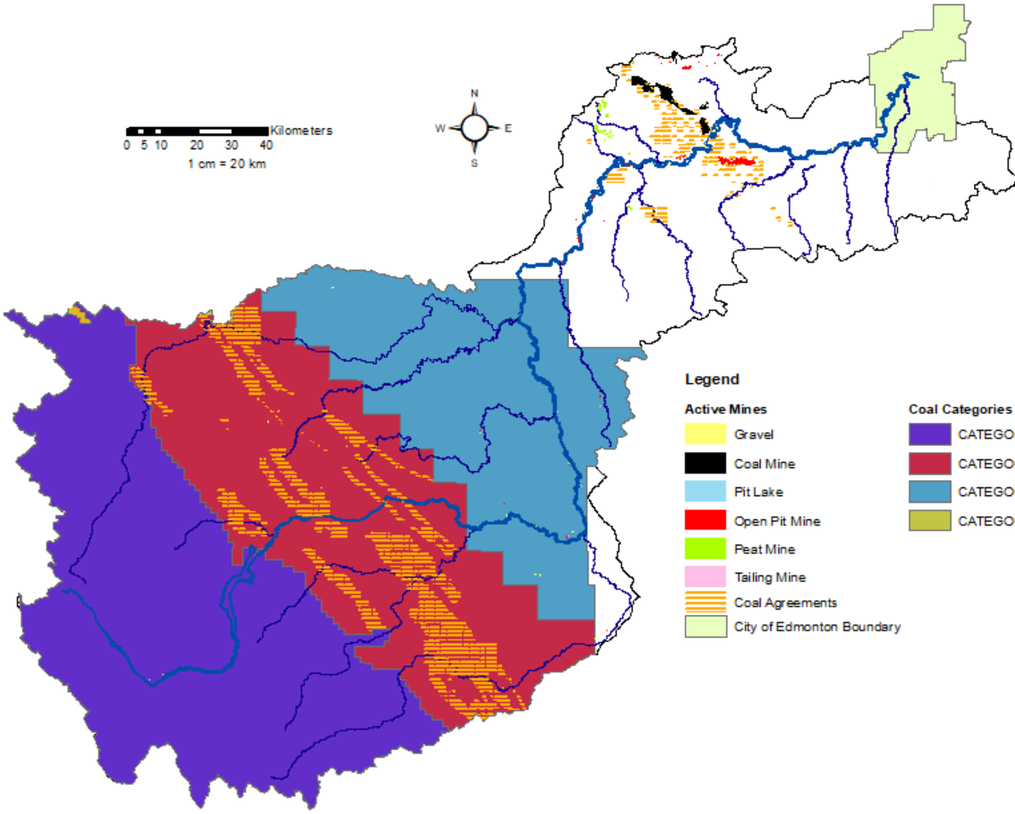

Figure 1. Active Mines, Current Coal Agreements, and Former Coal Categories Established Under the 1976 Coal Policy in the NSR Basin.

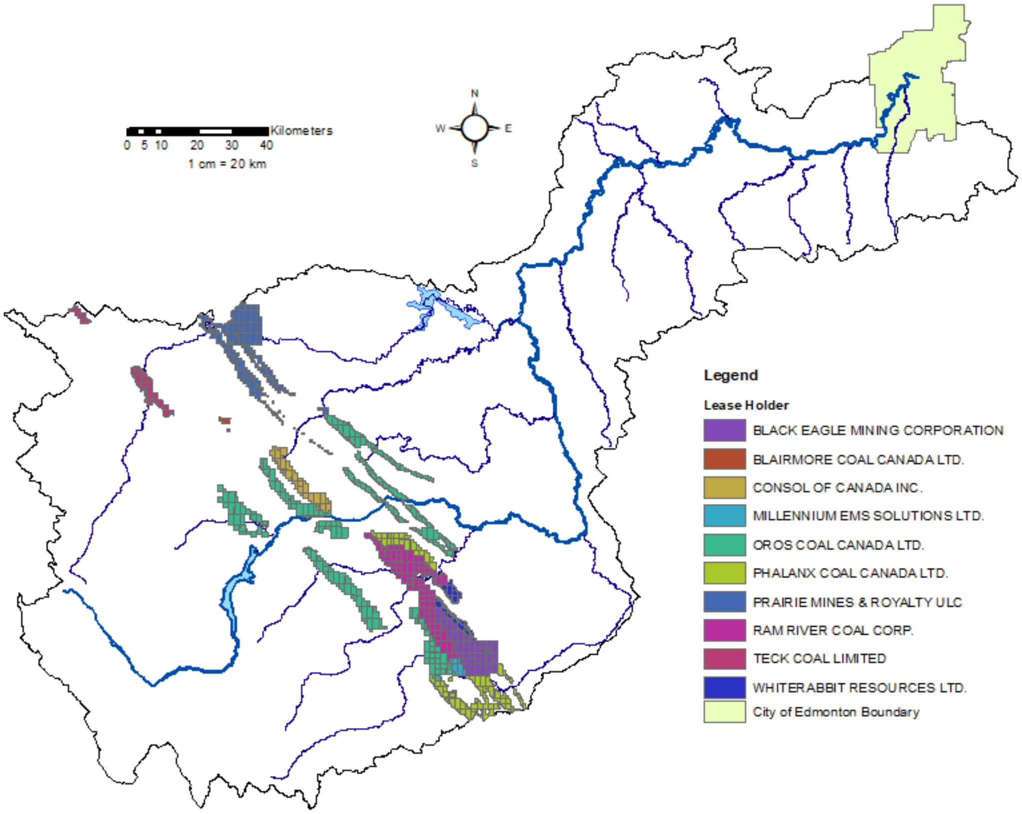

Figure 2. Companies with Leases in Category 2 Lands in the NSR Basin.

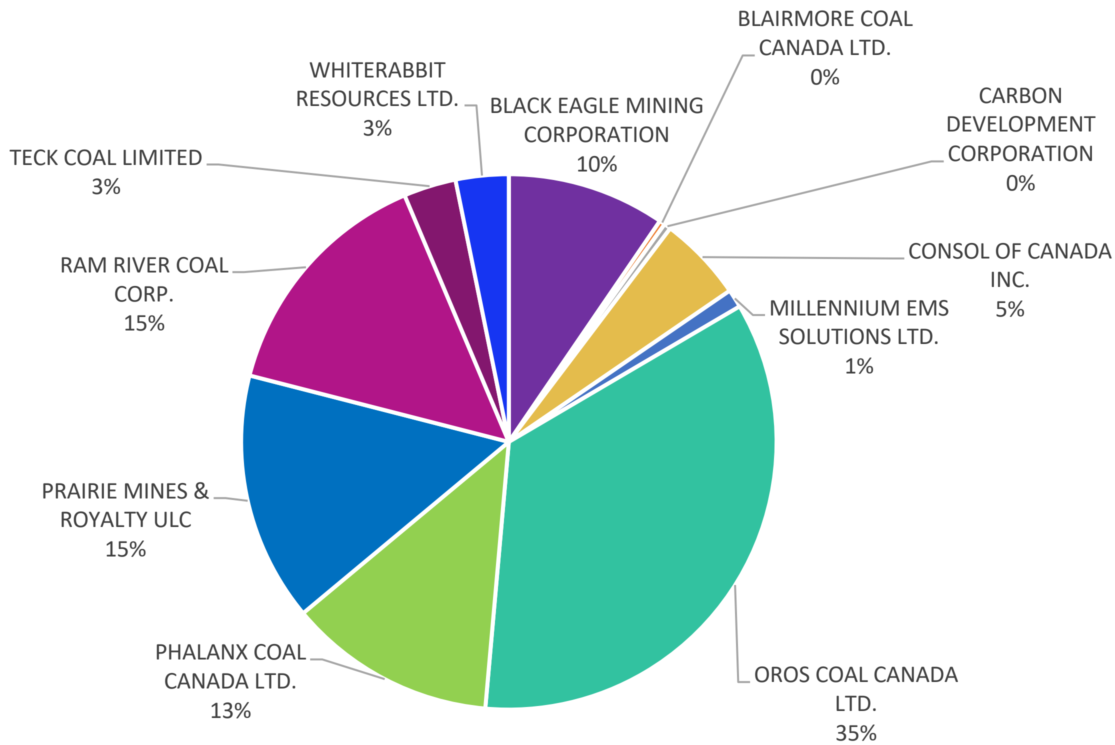

Figure 3. Pie Chart of the Percentage of Category 2 Leases Held by Each Company.

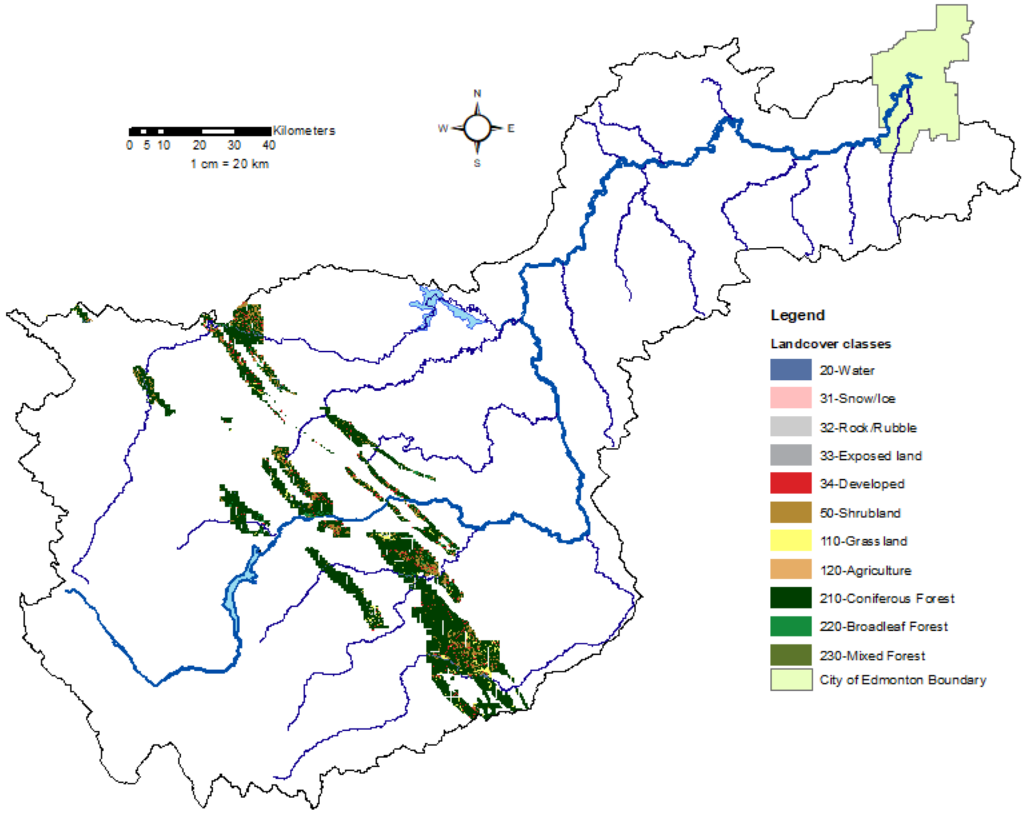

Figure 4. Current Land Cover (AMBI 2010 Land Cover) in Leases in Category 2 Lands.

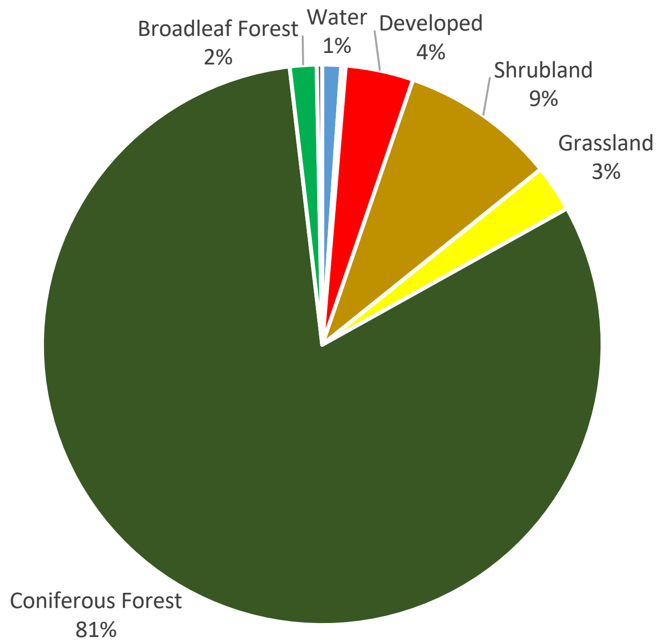

Figure 5. Pie Chart of the Land Cover in Category 2 Leases.

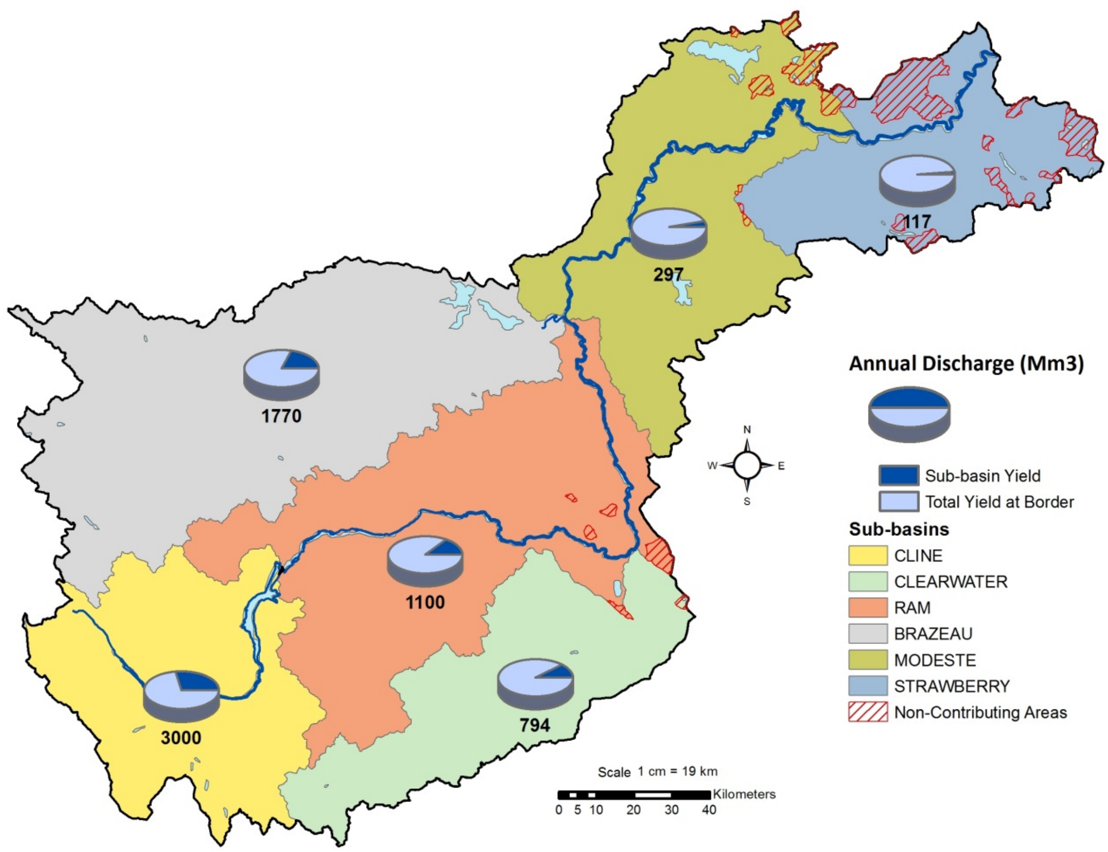

Figure 6. Water Yield Data for Sub-basins in the NSR watershed (modified from Golder 2008). Pie charts show the fraction of total water yield at the AB-SK border attributable to the sub-basin. The figure shows that the majority of the water yield is from upstream in the watershed.

4. Potential Effects of Coal Mining on the NSR and its Tributaries

Open pit or surface coal mines have the potential to affect aquatic ecosystems and water quality and quantity in a number of ways. The removal of surface vegetation and construction of roads have the potential to increase erosion, and therefore increase suspended solids, nutrient transport, and the volume of runoff. Mine waste can also result in acidification, elevated metals, and total dissolved solids. In mountainous areas, surface mining involves removal of several hundred meters of overburden with explosives and machinery, creating large areas of waste rock. When exposed to oxygen this waste rock can release selenium and other parameters through weathering processes.

In the Rocky Mountain and Foothills areas of Alberta and BC the effects of mining on fish, benthic algae, macroinvertebrates, and water quality is well studied. This is largely because coal mines require Environmental Assessments and Aquatic Effects Monitoring programs required by the Alberta Energy Regulator and Alberta Environment and Parks under the Environmental Protection and Enhancement Act. These assessments and programs are designed to limit downstream impacts to water quality and river and stream health. As well, because of problems with the bioaccumulation of selenium and potential effects on aquatic systems in the McLeod River and Smoky River systems (in Athabasca watershed), AEP, industry, and academia have advanced the state of knowledge of mining impacts over the last 30 years.

What We Know: Current State of Science

Streams and rivers with coal mines in their watersheds have exhibited elevated selenium, sodium, NO_3+NO_2, aluminum, sulfate, cadmium, arsenic, other trace metals, conductivity, and chlorine levels relative to reference streams (Casey and Siwik 2000; Holm et al. 2005). This trend is consistent across all mountain watersheds including the Appalachians (Lindberg et al. 2011, Griffith et al. 2012) and Elk Valley (Wellen et al. 2015, Teck Resources 2014). The relative concentrations for some parameters including sulphate, conductivity, and selenium have also been shown to be linearly related to the area of the watershed mined (Figure 7 from Lindberg 2011).

In June 2021, AEP released a report summarizing water quality data (2005 – 2016) in the McLeod River basin related to coal mining and reclamation activities (Redmond 2021). In the McLeod River downstream of mining activity there are increasing trends of total dissolved solids (TDS), NO_3+NO_2, selenium and other metals (i.e., antimony, arsenic, boron, cadmium, lithium, molybdenum, silver, strontium, uranium and zinc). Selenium concentration frequently exceeded water quality guidelines 40 km downstream of mining activity, but did not exceed guidelines 169 km downstream. While selenium concentrations exceeded guidelines over a large reach of the McLeod River, these impacts were not observed further downstream, presumably due to increased dilution from non-mined tributaries. In other words, the impacts of selenium from coal mines were relatively local, and not observed at distances farther downstream. In small tributaries where mining has stopped and reclamation activities have occurred, concentrations of TDS, metals, NO_3+NO_2, selenium and other metals were significantly higher compared to sample locations upstream of previous mining activity. In these reclaimed streams, NO_3+NO_2, selenium, antimony, molybdenum and uranium have decreased over time. However, concentrations of these parameters, and in particular selenium, still significantly exceed water quality guidelines over a decade after mining had stopped.

For selenium loading, the largest factor determining transport to downstream areas is the amount of waste rock present; in the Elk River watershed the amount of waste rock in the watershed accounts for 80% of the total instream selenium concentrations (Wellen et al.). More concerning is that research has shown that once waste rock is exposed selenium, leaching continues to occur for decades and that peak selenium loading can occur long after mining has stopped. Overall, it is well documented that selenium concentrations in streams draining mining operations are significantly higher than guideline values and concentrations in reference areas. For example, concentrations of selenium in Luscar Creek and Gregg River in Alberta, which are directly downstream of coal mining, are 17 µg/L (<2 ug/L upstream) and 7 µg/L (upstream <1 µg/L), respectively. In the Appalachians, concentrations draining the Lukey Fork tributary ranged from 5 to 13 µg/L and lead to average concentrations in downstream Mud River of 4 µg/L. Alberta Environment and Parks' water quality guideline is 2 µg/L for selenium for the protection of aquatic life, and there is an additional 'alert concentration' of 1 µg/L. The alert concentration indicates the need for increased water quality and aquatic ecosystem monitoring to support early detection of potential bioaccumulation of selenium. Ultimately, it is important to understand how much selenium can be dissolved in downstream water bodies before it moves through the aquatic food web and alters structure and function. This question is not easy to answer.

In 1999 a Selenium Working Group (ABSWG) was established to address the problems with high selenium and other parameters downstream of coal mining activity in Alberta. In addition, in 2005, the ABSWG commissioned the Selenium Science Panel (SeSP), comprising scientific experts in the field of selenium research, to obtain an independent assessment on the effects of selenium in Alberta mountain coal mines. This culminated with a final report that is publically available on the Government of Alberta's website. The critical takeaways from this assessment were that:

- Native rainbow trout populations are likely affected by high Se coupled with habitat change due to mining activities but because of the high natural variability in fish populations it was difficult to draw definitive conclusions: fish are not a good bioindicator.
- The SeFSP concludes that while the state of our knowledge concerning the population impacts on native rainbow trout is incomplete, the weight of the scientific evidence indicates that Se-rich inputs raise Se levels in streams to the point where egg Se concentrations exceed 7.5 µg egg Se/g ww (8.8-10.5 µg/g ww was found by Holm et al. 2005) and pose a serious teratogenicity risk for rainbow trout.
- Spatial structure of river salmonid populations makes small-scale impacts difficult to detect, exposing the population to the risk of large-scale cumulative impacts.
- There is evidence of this time-delayed loading effect leading to a large-scale concentration increase over time. For example, increases have been found in Gregg R (0.5µg/L/yr), Luscar Creek (1.3 µg/L/yr) (Alberta Environment data 2009), and 1 ug/L per decade in Elk River (Golder Associates 2007).

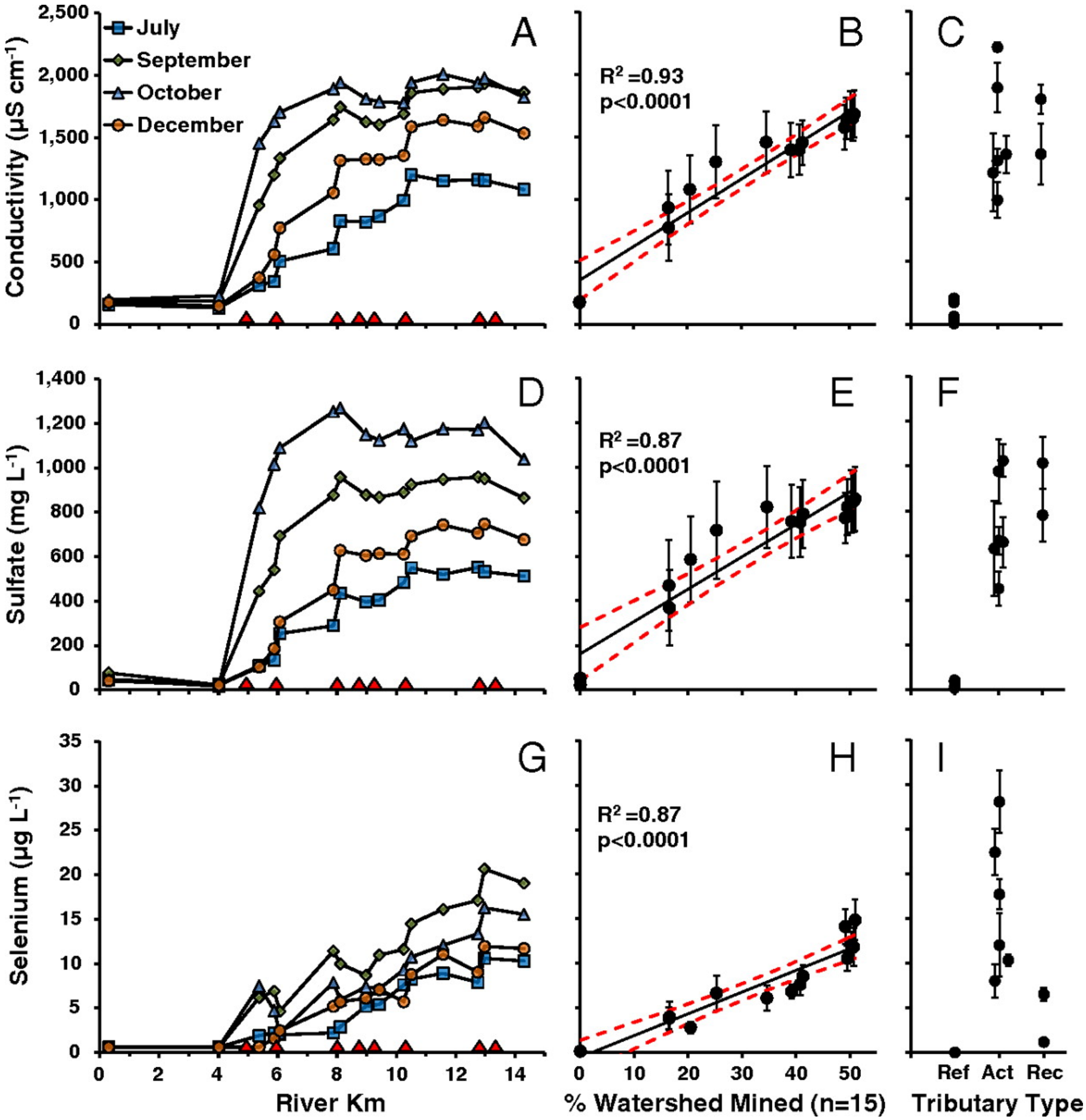

Figure 7. Showing watershed areas mined and concentrations of selenium, sulfate, and conductivity from Lindberg et al. 2011.

Again, it is difficult to determine concrete effect levels for benthos and fish and even more difficult to link those values to water column concentrations. Effects differ in benthos (ex. stream insects and algae living on the bottom of the waterbody) and are dependent on both acute and dietary pathways; but there is evidence of changes in community structure in areas with high mining activity (Golder 2007). Acute lethality is unlikely at concentrations seen in streams draining mines, but chronic toxicity has been observed. Lethality and sub-lethality targets that are based on tissue loads of selenium have been established in laboratory environments but for limited species. However, measured water column concentrations found in Alberta streams would be expected to produce dietary and internal selenium concentrations in the range associated with toxic effects to sensitive zoobenthic taxa. It is assumed that AEP's current Protection of Aquatic Life guideline takes into account these sensitive taxa and therefore is protective of the aquatic ecosystem.

Consideration should also be given the potential impacts to Lake Sturgeon, which in Alberta are ranked as Threatened under the provincial *Wildlife Act* due to the small number of reproducing adults, and their restricted distribution in the province. Despite their low numbers, the populations in the Saskatchewan River (which includes the North Saskatchewan River) are not currently listed under the federal *Species at Risk Act*. In 2011, the Alberta Lake Sturgeon Recovery Plan for the period of 2011 – 2016 was initiated; however, there have been no published updates regarding the status of this species since. In the North Saskatchewan River, it is estimated that the population of Lake Sturgeon consists of possibly fewer than 1,000 fish (Alberta Lake Sturgeon Recovery Team 2011). Their populations are located primarily in the mainstem of the North Saskatchewan River downstream of Drayton Valley; however, have been located as far upstream as Rocky Mountain House. Lake Sturgeon are a long-lived species and they have been identified as having a high likelihood of accumulating contaminants such as mercury and organochlorines in the Saskatchewan River. Selenium has been shown to accumulate in white sturgeon (a related species to Lake Sturgeon) in the San Francisco Bay enough to cause reproductive toxicity (Linares-Casenave et al. 2015). White sturgeon in B.C. are identified as having the highest risk of selenium accumulation, although accumulation rates depend greatly on site-specific conditions and how individuals use the habitat (BC MOE 2017). Additional studies and research is needed to better understand the potential risk of selenium bioaccumulation and reproductive toxicity in Lake Sturgeon in the Saskatchewan River Basin.

Water Quality Guidelines, Objectives and Triggers

Water quality guidelines published by AEP are based on guideline values from the BC Ministry of Environment who has done a comprehensive overview of selenium effects on aquatic ecosystems. Understanding that the science is uncertain, they have further adopted fish, invertebrate tissue and bird egg guidelines. Further information is available in their companion document that also summarizes guideline derivation (BC MOE 2014). This includes tissue values for human consumption screening values based on Health Canada's recommended equation for ingestion of selenium-contaminated fish (ex. high intake of 1.8 ug/g ww). BC also uses a source drinking water guideline of 10 µg/L which is adopted from and older Health Canada (2006) maximum acceptable concentration. Health Canada revised their maximum acceptable concentration of selenium to 50 µg/L in 2014.

Table 1. Summary of Selenium Guidelines

Category	Water Use	Guideline	Source
Water Quality	Protection of Aquatic Life - Alert Concentration	1 µg/L	AEP (2018), Based on BC MOE (2014)
	Protection of Aquatic Life - Guideline	2 µg/L	AEP (2018), Based on BC MOE (2014)
	Protection of Aquatic Life	1 µg/L	CCME 1987
Sediment Quality	Protection of Aquatic Life	2 µg/g (dw)	AEP (2018), Based on BC MOE (2014)
Aquatic Life and Wildlife	Invertebrate tissue (interim)	4 µg/g (dw)	BC MOE (2014)
	Fish - egg/ovary	11 µg/g (dw)	AEP (2018), Based on BC MOE (2014)
	Fish – whole body	4 µg/g (dw)	BC MOE (2014)

	Fish – muscle/muscle plug (interim)	4 µg/g (dw)	AEP (2018), Based on BC MOE (2014)
	Bird egg	6 µg/g (dw)	BC MOE (2014)
Agriculture	Continuous Irrigation	20 µg/L	AEP (2018), based on CCME (1987)
	Intermittent Irrigation	50 µg/L	AEP (2018), based on CCME (1987)
	Livestock	30 µg/L	BC MOE (2014)
Human Consumption Screening Values	High Fish Intake (0.22 kg/d)	1.8 µg/g (ww) 7.3 µg/g (dw)	BC MOE (2014)
	Moderate Fish Intake (0.11 kg/d)	3.6 µg/g (ww) 14.5 µg/g (dw)	BC MOE (2014)
	Low Fish Intake (0.3 kg/d)	18.7 µg/g (ww) 75.0 µg/g (dw)	BC MOE (2014)
Drinking Water	Drinking Water Quality Guideline	50 µg/L	Health Canada (2014)
	Drinking Water Quality Guideline	10 µg/L	Health Canada (2006), BC MOE (2020)

AEP's Water Management Framework for the Industrial Heartland and Capital Region (WMF IH/CR) has the strategic objective to maintain or improve water quality in the Devon to Pakan reach of the river. To achieve this AEP plans to implement maximum allowable pollutant loads, based on site-specific water quality objectives (WQOs) for variables of concern in the NSR. Selenium has been identified as a parameter of concern by AEP and there are Pilot WQOs and Maximum Allowable Loads (MALs) published for the Devon (30 km upstream of Edmonton) and Pakan (112 km downstream of Edmonton) sites. The 50th percentile WQO for Pakan is 0.375 µg/L during open water and 0.366 µg /L during ice cover, which are based on maintaining historical water quality and are most stringent objective. WQOs and MALs have also been published for parameters that have been shown to increase downstream of coal mines in Alberta such as: NO_3+NO_2, arsenic, cadmium, and zinc, as well as other major ions which are components of TDS. Given that the WMF IH/CR is based on the Devon to Pakan reach, it is unclear how management of upstream areas would be managed by the framework.

In addition, water quality objectives have been proposed by the North Saskatchewan Watershed Alliance, the Watershed Planning and Advisory Council for the basin, but these do not include selenium. The Master Agreement on Apportionment (MAA) established an intergovernmental framework to manage transboundary waters including establishing water quality objectives in the NSR reach from Lea Park to Lloydminster Ferry. For selenium the water quality objective mirrors AEP's protection of aquatic life guideline of 1 µg/L.

In June 2001, AEP announced stakeholder consultation for the North Saskatchewan Region Surface Water Quality Management Framework (NSR SWQMF). Similar to the WQF IH/CR, the NSR SWQMF proposes 50th and 90th percentile triggers for selenium and other parameters for the open water and winter seasons that are based on historical data. Trigger values are proposed for NO_3+NO_2, arsenic, cadmium, and zinc, as well as other major ions which are components of TDS. NSR SWQMF trigger values are similar to the WQOs published in the WMF IH/CR, but are slightly different as they are based on different periods of data. One significant difference is that the NSR SWQMF proposes trigger levels for the LTRN station near Rocky Mountain House, upstream of the Clearwater River. This LTRN station is located closer to many of the proposed mining areas, but would not capture any runoff from potential mines in the Brazeau, Nordegg, Baptiste or Clearwater sub-watersheds. Another difference is that the NSR SWQMF only proposes triggers for concentrations of water quality parameters, and does not seek to calculate loads or MALs of parameters.

Current Selenium Concentrations in the NSR

Selenium concentrations in the NSR in Edmonton are very low (Figure 8). They are below AEP's 'alert concentration' of 1 µg/L and guideline of 2 µg/L for the Protection of Aquatic Life; far below AEP's irrigation guidelines of 20 µg/L for continuous use and 50 µg/L for intermittent use; and far below the Health Canada drinking water quality guidelines of 50 µg/L.

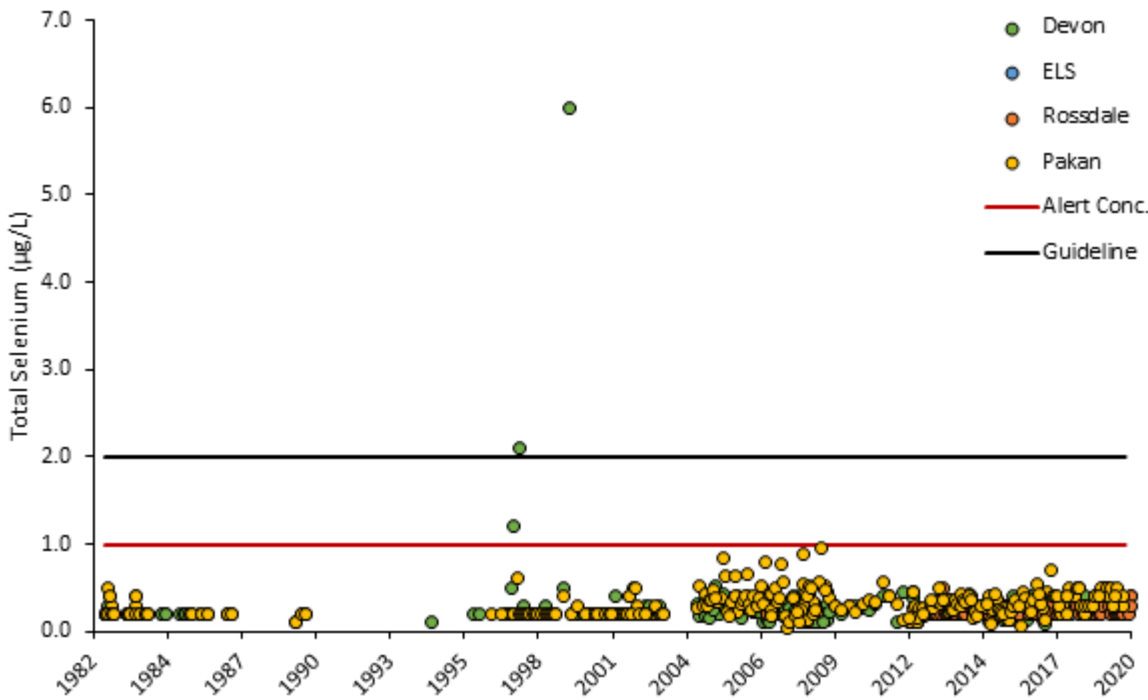

Figure 8. Selenium concentration (µg/L) in the NSR at Devon LTRN Site, Pakan LTRN site, and EPCOR's Water Treatment Plant intakes from 1980 to 2020.

Selenium concentrations in the NSR are low and generally below water quality guideline value for the Protection of Aquatic Life of 1 µg/L. EPCOR monitors selenium in the NSR at the WTP intakes monthly and of the 148 samples collected since 2013, 60% of samples have been at or below the detection limit of 0.2 µg/L; the highest recorded concentration was 0.5 µg/L; and the mean concentration was 0.25 µg/L. Similar results were found at AEP's sampling point at Devon, where of the 302 samples, 82% were at or below 0.2 µg/L; however, elevated selenium (i.e. 1.2 to 6 µg/L) was detected in three samples during the 1990s. The mean concentrations were 0.27 µg/L at the Devon LTRN. Upstream at the Rocky Mountain House LTRN, selenium concentrations were on average 0.23 µg/L from 1983 to 2019. At the downstream Pakan LTRN site of the 329 samples collected since 1982, the average concentration of selenium was 0.29 µg/L and no samples were above the Protection of Aquatic Life Guideline of 1 µg/L.

5. Water Quality Risks: Drinking and Irrigation Water Risks

Health Canada has set a maximum allowable concentration of selenium in drinking water of 50 µg/L and even in a watershed with very high proportions of coal mining values remain below this guideline value. In a small watershed (Lindberg 2011) data show that with less than 5% of the watershed area in active mines, selenium values would likely remain below 3 µg/L, but again this depends on the geochemical processes operating and amount of wasterock exposed. In more impacted streams draining directly from coal mine sites in Alberta, values remain below 50 µg/L and therefore the risk of exceeding a Health Canada guideline in the river at Edmonton is considered low. The same can be said for other parameters associated with waste rock weathering and mining activity where there are drinking water limits. Upstream of Edmonton, concentrations of metals, sodium, and nitrate plus nitrite are low, and typically well below water quality guidelines. Small increases in these parameters from upstream mines are unlikely to result in guidelines being exceeded at Devon, upstream of Edmonton but modelling would be needed to substantiate this.

An additional risk from an open-pit coal mine is the possibility of a mine disaster such as the failure of a tailings dam. Waste pits, end-pit lakes, and tailings dams are structures utilized to retain runoff and/or wastewater from mine operations. The volumes contained within these structures can be large, and typically are high in solids, metals and other parameters. In 2013, a tailings dam at the Obed Mountain coal mine near Hinton AB failed, releasing over 1 million cubic meters of waste water elevated in arsenic, metals and PAHs into the Athabasca River. In 2014, a tailings dam at the Mount Poly gold and copper mine (not a coal mine) in B.C. failed, releasing 24 million cubic meters of mine waste into Quesnel Lake. While the failure of tailings dams are rare occurrences, they can have an extreme impact to downstream water quality. Without a specific details of a proposed mine or tailings pond, it is not possible to make a definitive statement regarding the potential impacts of the failure of a tailings dam on the water quality however, water quality could remain significantly impaired for a number of days or for some parameters, months. Potential impacts of having to shut down the WTPs for an extended period could include implementing demand management, boil water advisories, or do-not-consume advisories. It would be important to characterize water quality and volumes in tailings ponds and their locations and quantify impacts to source water as they are built/maintained.

For irrigation, the most protective irrigation guideline for selenium is for continuous irrigation and is 20 µg/L. The risk of exceeding this guideline in Edmonton is very low. It is possible that values could read this high in upper tributaries depending on mining activity as values this high have been recorded at historical mine sites. However, it is expected that the application more stringent water quality guidelines and load apportionments would also project irrigation and other source water uses.

6. Water Quality Risks: Assimilative Capacity Risks

Streams and rivers with coal mines in their watersheds have exhibited elevated selenium, sodium, nitrate plus nitrite, aluminum, sulfate, cadmium, arsenic, and other trace metals. Upstream of Edmonton, concentrations of these parameters are low, and typically well below water quality guidelines. Small increases in these parameters from upstream mines are unlikely to result in guidelines being exceeded at Devon, upstream of Edmonton. Two possible exceptions would be cadmium and dissolved aluminum, where a concentrations at Devon have occasionally exceeded protection of aquatic life guidelines, which are generally the most protective.

Concentrations of these parameters increase in the NSR downstream of Edmonton due to loadings from storm water, waste water and water treatment plant waste streams. Alberta Environment and Parks has identified each of these parameters as parameters of concern for the North Saskatchewan River, and has issued pilot water quality objectives and maximum allowable loads to ensure that further degradation of water quality does not occur at Pakan, downstream of Edmonton. In other words, water quality needs to be maintained downstream of Edmonton, and coal mines may contribute to higher concentrations of these parameters in the NSR. Edmonton and EPCOR may risk losing assimilative capacity in the NSR. The parameter likely of highest concern is dissolved aluminum, which already approaches water quality guidelines upstream of Edmonton, is loaded to the NSR through water treatment plant waste streams and can exceed guidelines downstream of Edmonton.

7. Ecological and Aquatic Health Risks within the City of Edmonton Boundary

If all existing coal leases were to become active mines, 5% of the watershed would be in active mines. In this case, there would be potential for effects to resident fish populations that may migrate along river reaches and face high selenium exposure in tributaries. The state of knowledge of how 'bad' water quality would need to get before there were significant measureable effects on fish, zoobenthos, and algae is not definitive. However, based on work in other areas of Alberta whose watersheds are affected by mining, the PAL guideline of 2 μg/L would be protective if implemented across the watershed, including tributaries more directly affected by mining.

Mines would presumably install tailings dams/ponds in order to capture flows and reduce suspended solids and some adsorbed metals. With these control measures in place, it is assumed that impacts to water quality will be relatively small and localized. Given the anticipated government requirements, the distance downstream of EPCOR's WTPs, the small relative watershed area impacted, it is not expected that significant water quality impacts from mining activities would be observed in Edmonton. **However a basin-wide water quality model with appropriate loading exports would be needed to validate that assumption.** This should include a food web model where established tissue loads for fish and benthos are determined from expected concentrations change across the entire watershed. Environmental Impact Assessments are per project and do not necessarily account for basin wide impacts.

While the failure of tailings dams are rare occurrences (as described in Section 6), they can have an extreme impact to downstream water quality and aquatic health. Again, without a specific details of a proposed mine or tailings pond, it is not possible to make a definitive statement regarding the potential impacts of the failure of a tailings dam on the water quality or aquatic health in Edmonton; however, such a release would be a significant event and could result in fish kills and long-term effects on the overall ecosystem.

8. Risk Assessment Summary

This risk assessment was based on EPCOR Risk Matrix and based on professional judgement of the Watershed Team. This is difficult because it is based on theoretical mining activities and modelling work has not been completed.

Table 2. Risk Assessment Table for Effects of Coal Mining on the NSR in the City of Edmonton Boundary

Risk Area	Description	Liklihood	Consequence	Ranking	Mitigation and Management
Water Quality for Drinking Water	Given the small area of mine agreements (5% of upstream watershed, it is not expected that drinking water guidelines will be exceeded for mining parameters of concern. For selenium, which has been shown high values downstream	1	1	1-LOW	Basin wide modelling of expected selenium loading from all mining operations and expected change to water quality at Devon LTRN would be needed to confirm risk ranking.

	of mining in other watersheds, it is not expected to approach Health Canada Guideline value of 50 ug/L. Data from mined watersheds with values below 10% mining disturbance show Se values of less than 5 ug/L. Average Se values recorded in the literature in highly impacted streams Alberta streams remain below 20 ug/L. Catastrophic dam failure is possible but water quality impacts would expected to be short lived.				The ability to shutoff intakes for up to two days should a catastrophic tailings pond failure occur could mitigate some risk but this has never happened to date for any river quality reason.
Water Quality for Assimilative Capacity	For parameters of concern at Pakan (water quality monitoring site downstream of Edmonton) for which storm water, wastewater, and WTP residuals loads impact water quality there is a risk of losing assimilative capacity if background levels in the NSR increase from mining activities. These parameters include dissolved aluminum.	1	2	2-LOW	Basin wide modelling of expected loading of parameters of concern from all mining operations and expected change to water quality at Devon LTRN would be needed to confirm risk ranking.
Water Quality for Aquatic Health, Irrigation, and Industrial Use	Should water quality guidelines of 2 ug/L be met throughout the NSR and its tributaries risks to aquatic health, and water users for irrigation and industry would be very low. In other areas, mining activity has shown to regularly exceed water quality guidelines in small tributaries and, in some cases, larger downstream systems putting aquatic systems at risk. If selenium concentrations are elevated due to mining, mitigation is difficult.	2	3	MEDIUM-LOW_	Basin wide modelling of expected selenium loading from all mining operations and expected change to water quality at near-field sites, at the Rocky Mountain House LTRN site, and Devon LTRN site that would incorporate expected food web tissue concentrations would be required to assess risk. This would be needed if guidelines were expected to be exceeded.
Aquatic Health	The science on aquatic health impacts from mining are continuing to evolve despite a wide body of research. Effects vary widely across species but in general, selenium contamination is considered problematic for small stream systems draining coal mines. These effects can manifest themselves into larger systems, depending on exceedances. If water quality and tissue guidelines (BC guidelines) are met risk is low.	2	3	MEDIUM_ LOW	Basin wide modelling of expected selenium loading from all mining operations and expected change to water quality at the Rocky Mountain House and Devon LTRN sites as well as expected food web loads would be needed to confirm risk assumptions

9. What We Need to Know: Recommendations

Due to emerging science of selenium fate and transport; the long-term mining effects that can be set in motion by the physical alteration of the headwater areas; and costly and inconsistent remediation potential, it is critical that scientifically rigorous cumulative effects modelling assessments be completed before any mining activity is permitted. This should be completed at both the major basin scale (ex. North Saskatchewan Bain) and local scale (subwatershed, ex. Ram River) where the cumulative effects of mining need to be considered as multiple companies submit applications for mines on the same landscape.

For the North Saskatchewan Watershed we recommended that to protect long-term aquatic health, water quality, and quantity:

- For AEP to set Water Quality Objectives and Maximum Allowable Loads (MALs) at Rocky Mountain House and Devon Long-Term River Network Sites for mining parameters of concern including sulfate, aluminum, selenium, cadmium, arsenic, nitrate plus nitrite that align with PAL guidelines or Site Specific Water Quality Objectives.
- That the set objectives are included in the forthcoming North Saskatchewan Regional Plan and for parameters that leach over decades, such a selenium, that predictive modelling is used to manage future effects. This is because remediation is often not possible and reactive management (reacting once triggers or limits are exceeded) would not be an effective management strategy.
- AEP develop a large-scale spatially explicit modeling tool that can evaluate the downstream and cumulative impacts of different mining scenarios for the NSR basin at decadal time scales with the following considerations:
    - There is limited published quantitative knowledge of the loading rate of selenium or other constituents of interest and their transport downstream from mine-influenced watersheds
    - Little knowledge exists of how selenium loading changes with regard to factors that can be controlled during or after the mining process but Wellen et al. (2015) found that the amount of wasterock in the watershed is the critical factor determining selenium loads
    - There has been little published work focusing on regional scale modeling of Se sources, fate and transport. Wellen et al. (2015) use the USGS's SPARROW model and the GoldSim Model has also been used during individual mining applications (ex. Grassy Mountain)
    - Climate change models have shown the NSR is expecting increased precipitation which would increase runoff from headwaters areas and export from wasterock.
- AEP consider setting watershed wasterock and mined area limits that are linked to established MALs and Water Quality Objectives for parameters of concern and that those limits are incorporated into the forthcoming North Saskatchewan Regional Plan
- Mining proponents complete modelling work to determine effects using food web models (ex. GoldSim) but in the context of other mining operations/proposals and using Alberta based on tissue load effects for the most sensitive taxa. As well this should include loading models that predictions over the next 50 years. It is understood that there are treatment technologies at mine sites that can limit selenium transport downstream and these should be incorporated into load estimates.

10. Other Considerations beyond the NSR

The effects of coal mining and its benefits must be considered and balanced in relation to other activities and uses on the landscape. These include recreation, hunting, trapping, tourism, maintaining biodiversity, maintaining intactness of habitat for sensitive species (e.g. grizzly bear), and ensuring the overall health and resiliency of the watershed is maintained. As well there are intangible effects of allowing mining activities to proceed on the landscape in terms of Alberta's global reputation on climate change and stewardship of the environment which can cascade down and affect external investment in Alberta. For those reasons, coal development should be done in full and transparent discourse with Albertans, in part through the regional planning process. Coal development should also be based in science and should be precautionary in its approach as there is a threat of irreparable harm.

11. Current Watershed Management, Monitoring, and Modelling Initiatives

The City of Edmonton and EPCOR have had a long history of watershed management and have recognized that a watershed approach is a cost-effective and proactive approach to protecting source waters for drinking water and overall health. EPCOR has provided the City of Edmonton with a summary document on these initiatives but a brief description of governance roles are also included below. This information is important as it highlights the continued commitment of the City of Edmonton and EPCOR to understand and manage the watershed through collaborative, stakeholder based frameworks and initiatives. EPCOR also maintains a Drinking Water Source Water Protection Plan and an Integrated Watershed Management Strategy for the Edmonton drinking water and storm/wastewater collection system.

Organization	Current Role
North Saskatchewan Watershed Alliance	EPCOR: Board Member City of Edmonton: former Board Member and now on Advisory Panel
NSWA's Headwater Alliance	EPCOR a member
Alberta Water Council	City of Edmonton: Representing Large Urban
Alberta Water Council: Source Water Protection Project Team	EPCOR Watershed Manager is current co-chair
Industrial Heartland and Capital Region Water Management Framework	EPCOR: Advisory Committee Member and Stormwater Technical Working Group

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