CANADIAN CENTRE FOR POLICY ALTERNATIVES-SK

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# The Government of Canada's Legacy of Contamination in Northern Saskatchewan Watersheds

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**Introduction**

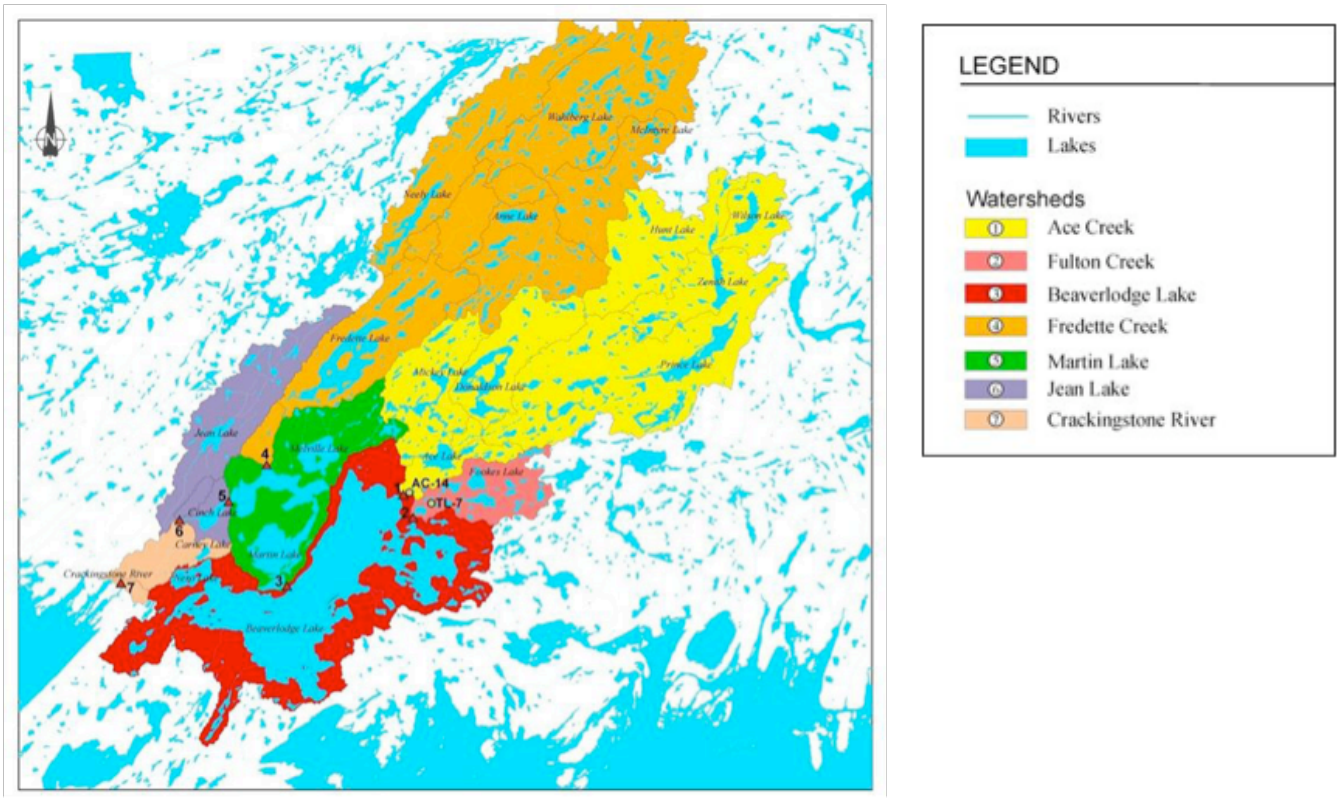
Beaverlodge Lake and three adjacent watersheds in the Uranium City area of northern Saskatchewan are seriously contaminated with uranium and selenium. Most of the contamination dates back to the 1952-1982 period when Eldorado Nuclear Ltd., a federal crown corporation, operated numerous mining properties east of Uranium City and northeast of Beaverlodge Lake. Operating on behalf of the Government of Canada, Eldorado Nuclear opened its uranium mines and mill in 1952 to serve military contracts. It sold uranium to the United States Atomic Energy Commission in large quantities, and did so for the purpose of supplying the US military with uranium for the production of atomic weapons.[1] It was a dark legacy to leave to future generations. When those military contracts ultimately ended in the early 1960's, Eldorado Nuclear turned to selling uranium to a growing number of civilian nuclear power programs around the world.

Less well known than Eldorado Nuclear Ltd.'s uranium export record are the enduring local impacts that resulted from its uranium mining operations. Thirty one years after Eldorado Nuclear ceased all uranium mining activity, and 28 years after it decommissioned its mines and mill with the approval of the Atomic Energy Control Board,[2] the watersheds in which it mined uranium and stored radioactive tailings are still highly contaminated from those mining operations, as are other important watersheds downstream.


*Uranium City intersection (1977).*

The four watersheds most affected include the Ace Creek watershed, the Fulton Creek watershed, the Beaverlodge Lake watershed, and the Martin Lake watershed. A fifth watershed – the Crackingstone River – also suffers less serious, but still notable levels of contamination.

**Watersheds in the Uranium City Area of Northern Saskatchewan**




Eldorado Nuclear Ltd.'s mining operations were centered in the Ace Creek watershed, while its tailings disposal was primarily in the Fulton Creek watershed.

*Map Source: Canadian Nuclear Safety Commission Staff Submission, February 1, 2013 (Presentation to the Board of the Canadian Nuclear Safety Commission).*

**Current Responsibilities At The Mined-Out Eldorado Sites**

Eldorado Nuclear no longer exists as a corporate entity. However, its financial obligations continue to be looked after by another federal crown corporation known as Canada Eldor Inc.[3] In effect, Canada Eldor Inc. was established by the Government of Canada to assume the remaining financial liabilities of Eldorado Nuclear Ltd.[4] Canada Eldor Inc. thus has ultimate responsibility for the decommissioned uranium mine properties under discussion. The mined-out sites and other sites on which Eldorado Nuclear conducted its operations are collectively known as the Beaverlodge properties, because of their proximity to Beaverlodge Lake. There are 62 Beaverlodge properties in all.

Today, monitoring and maintenance of the decommissioned Beaverlodge properties is carried out by Cameco on behalf of Canada Eldor Inc. and the Government of Canada.[5] Cameco was created in 1988 when Eldorado Nuclear and Saskatchewan Mining Development Corporation were merged, after both were privatized by their respective governments.[6] The licence for the

decommissioned Beaverlodge properties is now held by Cameco and is issued by the Canadian Nuclear Safety Commission, the federal regulator of the nuclear industry in Canada.

Cameco is not responsible for the serious levels of contamination present on the Beaverlodge properties. That responsibility lies squarely with Eldorado Nuclear and the Government of Canada. However, Cameco, Canada Eldor Inc., and the federal government could all do far more than is currently planned with respect to decontaminating and remediating the Beaverlodge properties and the water bodies downstream of them.

**The Plan For Transfer Of Mined-Out Properties Back To The Province Of Saskatchewan**

It is clear from the April 2013 hearings of the Canadian Nuclear Safety Commission held in Saskatoon, Saskatchewan that Canada Eldor Inc. and the Government of Canada hope to be relieved of their responsibilities for most mined-out Beaverlodge properties over the course of the next decade. To achieve that goal, Canada Eldor Inc. and Cameco plan to transfer the mined-out properties back to the Government of Saskatchewan.[7] They plan to do this via Saskatchewan's Institutional Control program, and fully intend to return these properties to the Province of Saskatchewan in a very contaminated state.[8] They will seek approval from the Canadian Nuclear Safety Commission to do so.

The transfer back to the Province presumes that only minimal costs in the future will need to be incurred with respect to the transferred properties. Canada Eldor Inc. would be required to post a one-time bond to cover the cost of occasional monitoring and maintenance, plus an additional sum to take account of unexpected events.

In fact, the transfer process for some of the small properties has already begun. To date, the amount of the bonds posted when mined-out properties are returned to Saskatchewan's Institutional Control Program has been modest, especially in light of the significant cost of travelling to and accessing the sites for monitoring purposes, and the high costs of assembling equipment to undertake future work that might be required.[9]

**The State of Contamination In Northern Saskatchewan Watersheds Where The Government of Canada Mined And Milled Uranium**

Eldorado Nuclear's Beaverlodge mining properties were located in the Ace Creek watershed; while its mill tailings disposal sites were located in the smaller Fulton Creek watershed.[10] These two watersheds are now home to many lakes with excessive uranium concentrations in surface waters.

One would expect uranium mill tailings disposal sites to exceed Saskatchewan Surface Water Quality Objectives for Aquatic Life, but the state of contamination extends far beyond the tailings ponds. In fact, the contamination spans large areas of both watersheds.

By way of example, discharge from Dubyna Lake in the Ace Creek watershed has uranium concentrations that are 16 times higher than Saskatchewan Surface Water Quality Objectives for the Protection of Aquatic Life. A location known as the Hab site, upstream of the confluence of Hab and Pistol Lakes, in the Ace Creek watershed, has uranium concentrations that exceed Saskatchewan Surface Water Quality Objectives by a factor of 9. Verna Lake discharge to Ace Lake exceeds Saskatchewan Surface Water Quality Objectives for uranium by a factor of 11.[11]

Meanwhile, in the Fulton Creek watershed, Greer Lake, located downstream of lakes that were used for disposal of uranium mill tailings, discharges water with uranium concentrations 24 times higher than Saskatchewan Surface Water Quality Objectives. Radium and selenium contamination are also a problem. For example, radium concentrations in Greer Lake discharge are 24 times above the provincial guideline, and selenium levels are at least 4 times higher than Saskatchewan Surface Water Quality Objectives.[12]

These contaminant concentrations in surface waters of Saskatchewan lands that were mined by the Government of Canada contrast sharply with the current Saskatchewan Guidelines for Northern Mine Decommissioning and Reclamation. These guidelines state that areas disturbed by mining operations "should be reclaimed to an ecological (physical and biological) condition that will be similar to what was observed in the area prior to disturbance". The guidelines go on to say that "lake shorelines and river banks should be reclaimed to their pre-disturbed condition". Moreover, "surface water quality should be within the natural range of variation for the area."[13] With respect to tailings facilities, the guidelines recognize that some areas cannot be reclaimed to their original ecological condition, but state that the potential for contaminants to "migrate from impacted areas within the project sites to ecosystems outside of the project area ….should be minimized through site specific mitigation measures…"[14]

Today's Saskatchewan Guidelines for Northern Mine Decommissioning and Reclamation were drawn up many years after the Eldorado Nuclear operations in the Ace Creek and Fulton Creek watersheds were closed, and one would not expect that the guidelines could be fully complied with. However, what one would expect is that the Government of Canada would make a reasonable effort to comply wherever possible, and to set an example of how remediation of an older mine site can be properly carried out. Unfortunately, there is little evidence to date that the Government of Canada plans to move in this direction.

**Downstream Contamination**

Both the Ace Creek and Fulton Creek watersheds drain into Beaverlodge Lake, a water body with a surface area of 57 square kilometres,[15] and water depths commonly in the 40 to 60 metre range. Beaverlodge Lake suffered the consequences of Eldorado Nuclear Ltd.'s decision not to install a proper effluent treatment system for the first 25 years of its mining and milling operation.[16]

*Outlet pipe from the Beaverlodge uranium mill near Uranium City, where vast quantities of radioactive waste were dumped into Fookes Lake, converting it into a tailings reservoir. The tailings reservoir lies in the Fulton Creek watershed (early 1980s).*

Under normal conditions, the large size of Beaverlodge Lake would quickly dilute pollution. However, Beaverlodge Lake has been so badly contaminated by the polluted discharge from the Ace Creek and Fulton Creek watersheds that concentrations of uranium in surface waters in Beaverlodge Lake are now 7 times higher than

Saskatchewan Municipal Drinking Water Quality Objectives.[17] Depending on sampling locations within the lake, uranium concentrations in surface waters are 8 to 9 times higher than Saskatchewan Surface Water Quality Objectives for the Protection of Aquatic Life.[18]

Meanwhile, selenium concentrations in Beaverlodge Lake surface waters are two and one half times higher than Saskatchewan Surface Water Quality Objectives for the Protection of Aquatic Life.[19] Not surprisingly, elevated levels of selenium have been found in fish tissue.

Over time the sediment in the bottom of Beaverlodge Lake has suffered a serious build-up of pollutants. Beaverlodge Lake sediment has become so heavily loaded with selenium and uranium that the sediment at the bottom of the lake is becoming a source of on-going contamination to the lake's surface waters.

In effect, the federal government's uranium mining operations have left Beaverlodge Lake in a badly damaged state. As a result, limits have had to be placed on weekly fish consumption from the lake. Saskatchewan's Ministry of Environment has issued a drinking water advisory and an advisory on fish consumption.[20]

The damage to downstream watersheds from federal government uranium mining activities is not limited to Beaverlodge Lake. The Martin Lake watershed is immediately south of Uranium City and is used as a recreational site by the community. In 2011 the sampling station at the outlet of Martin Lake recorded uranium concentrations over 4 times higher than Saskatchewan Surface Water Quality Objectives for the Protection of Aquatic Life and selenium concentrations approximately one and a half times higher.[21]

Martin Lake and Cinch Lake in turn drain into the Crackingstone River. While radium and selenium concentrations are within accepted guidelines in the Crackingstone River, uranium concentrations are still 3 times higher than Saskatchewan Surface Water Quality Objectives.[22] The Crackingstone River ultimately flows into Lake Athabasca. It is only when it reaches Lake Athabasca, where the vastness of the water body results in a rapid dilution of pollution, that Saskatchewan Surface Water Quality Objectives for uranium are finally met.

**Other Sources Of Pollution In Beaverlodge Lake**

While Beaverlodge Lake has been very badly contaminated by the polluted waters from the decommissioned Beaverlodge properties, it is also the receiving environment for contaminants discharged from nine other, non-Eldorado, abandoned uranium mine sites, and one former uranium mill tailings area (Lorado Uranium Mining Ltd. mill site).[23]

Today, these non-Eldorado abandoned sites are managed by the Saskatchewan Research Council (SRC), which is currently engaged in decommissioning work on them. They are likely contributing some level of contamination to Beaverlodge Lake and Martin Lake, especially during spring runoff and periods of heavy rainfall.

However, the Beaverlodge properties have been by far the most significant source of contaminants.

**Limited Plans for Site Cleanup and Remediation**

As site manager, Cameco does plan to undertake a limited set of remediation activities to some of the Beaverlodge properties in the Ace Creek and Fulton Creek watersheds. These plans were formulated after a comprehensive set of studies was undertaken. Cameco will divert a creek (Zora Creek) around one of the waste rock piles (Bolger waste rock pile). It will plug flowing and non-flowing bore-holes at decommissioned

uranium mine properties to prevent potential groundwater outflow. It will replace caps on all vertical mine openings. And it will perform a gamma survey of waste rock and tailings areas, and then cover easily accessible areas that display elevated gamma radiation fields. Beyond that, however, its focus will only be on monitoring. It will continue monitoring water quality on the Beaverlodge properties and on Beaverlodge Lake in the decade ahead, and will seek to co-operate with the Saskatchewan Research Council on implementing a regional monitoring program.[24]

The completion of these measures will still leave Canada Eldor Inc., the Government of Canada, and Cameco with many mined-out Beaverlodge properties that have extremely high levels of contamination. Moreover, nothing whatsoever is planned to actually remediate Beaverlodge Lake, Martin Lake or other downstream water bodies, which will therefore continue to remain polluted over the long term.

Cameco has presented surface water quality environmental performance objectives to the Canadian Nuclear Safety Commission (CNSC) for the mined out properties in the Ace Creek and Fulton Creek watersheds, as well as for Beaverlodge Lake. Acting on behalf of Canada Eldor Inc., Cameco has proposed to the Commission that - after the planned remediation activities are completed - CNSC should deem it acceptable to have uranium contamination levels that are frequently 8 to 20 times higher than Saskatchewan Surface Water Quality Objectives, in many of the lakes and discharge points in the watersheds.[25] These pollution levels do not include the tailings ponds in the Fulton Creek watershed, where Cameco's performance objectives would permit even higher contaminant levels. If these performance objectives are met over the course of this next decade, Cameco and Canada Eldor Inc. have proposed to CNSC that the mined-out properties would be ready to be returned to the Government of Saskatchewan to manage.

**Heavily Contaminated Properties Should Not Be Deemed Acceptable For Saskatchewan's Institutional Control Program**

For mined-out properties with this level of contamination to be accepted back into the Saskatchewan Institutional Control Program would set a dangerous precedent. One naturally expects that some contamination will remain on mined-out properties that are accepted into Institutional Control. However, there need to be limits on just how contaminated the properties can be. Accepting the Beaverlodge properties back into Institutional Control would in effect forgive the Government of Canada from needing to take managerial oversight responsibilities for the large scale pollution problems it has created. In addition, it is unclear whether federal financing for de-contamination of the properties and downstream watersheds could easily be negotiated after the return to Institutional Control takes place.

The authors suggest that the Government of Canada, having contaminated these sites, should assume full responsibility for their remediation, prior to turning the properties back to the Province of Saskatchewan. The cost of remediation is likely to exceed $100 million. The burden of future site remediation should not fall on Saskatchewan taxpayers.

Moreover, as a matter of public policy, the Government of Saskatchewan should not accept highly contaminated mining properties back into the Institutional Control Program. If it were to do so, a signal would be sent to other mining companies that their properties might also be accepted back in a badly polluted state.

Similarly, the Canadian Nuclear Safety Commission, as the prime regulator of Canada's nuclear industry, should not forgo its regulatory responsibility for uranium properties it has responsibility for overseeing, until those properties have been properly cleaned up, and until downstream properties that have been polluted are properly restored.

**A Regional Approach To De-contamination And Remediation Is Needed**

In the judgement of the authors, many surface water bodies in the Ace Creek watershed, the Fulton Creek watershed, the Martin Lake watershed and Crackingstone River watershed could be significantly decontaminated. If real progress is to be made, however, it is essential that those responsible for each mined-out uranium property collaborate, and plan to move forward with cleanup and remediation endeavours beyond the mined-out sites for which they are specifically responsible. In effect, a regional approach to remediation needs to be taken in which contamination downstream of the mined-out properties is addressed. This would involve Cameco, Canada Eldor Inc., the Saskatchewan Research Council, the Government of Saskatchewan and the Government of Canada all collaborating to launch a remediation program in each negatively impacted downstream watershed. As the primary polluter, the vast bulk of the funding for this regional cleanup initiative should come from the Government of Canada. Residents of the Uranium City area should have the opportunity to be fully engaged in the planning process, and should have the opportunity to benefit in concrete ways from the jobs that are created.

The authors believe that progress can be made by using at least two approaches that have not yet been applied by Cameco, Canada Eldor Inc. and the relevant government departments.

The most promising approach is Permeable Reactive Barrier technology. Numerous studies carried out by, or for, the United States Environmental Protection Agency over the past decade indicate the serious potential for management and removal of uranium contamination in flowing surface or ground water, using vertical permeable reactive barriers. In some cases, uranium concentrations have been reduced by 99%.[26]

Permeable reactive barriers are well suited to application at geographical points where waters narrow, including outlet points of lakes, along streams and rivers, or in excavated groundwater flow channels. Permeable reactive barriers can also be used to cover radioactive tailings, cap sediment bottoms in lakes, or intercept leachate coming off waste rock piles.[27]

A second approach that merits application in several watersheds in the Uranium City area is ecological polishing. For example, significant experience has been gained with the use of macrophytes, particularly the alga Chara (stonewort) to remove uranium and radium from solution.[28] In fact, some of this work was carried out years ago in collaboration with Cameco at the Rabbit Lake uranium mine site in northern Saskatchewan. At the time it was observed that stonewort, naturally occurring in Lower Link Lake, was effectively converting dissolved uranium into a mineralized format which sank into sediment. Similar experience has been documented for locations in Germany and the United States. Progress in this area is sufficient to justify its application on the decommissioned Beaverlodge properties.

The authors are of the view that these approaches have a serious chance of success in four of the five watersheds in question. Permeable reactive barriers and the use of macrophytes have potential to help remediate

many smaller lakes, creeks and other water bodies. However, these approaches would be more difficult to successfully apply in Beaverlodge Lake. The vast area of Beaverlodge Lake simply provides less opportunity for strategic application of these remediation approaches. Sadly, the reality may be that properly remediating Beaverlodge Lake with today's technologies might not be possible. More advances in environmental remediation technology may be required before Beaverlodge Lake can be restored, and this is yet one more reason why the Province of Saskatchewan should be in no rush to absolve the Government of Canada of its responsibilities in the Uranium City area.

**Conclusion**

The contamination that exists today in the Uranium City area is a grim reminder that the mining of uranium in this part of northern Saskatchewan has been done at a very high cost. Several watersheds have suffered environmental damage that will continue for more than a century into the future, unless a comprehensive remediation initiative is launched. The cleanup and remediation work that is required should be undertaken on a regional basis.

The environmental legacy of Uranium City is an unfortunate chapter in Canadian history, and a sad reminder of the Government of Canada's unwillingness to take full responsibility for its actions. The time has come for the Government of Saskatchewan to hold the national government accountable for the widespread pollution it has caused.

This Beaverlodge case study also underlines the high cost of inadequate environmental regulation, and the enormous challenges that are then posed when cleanup and remediation discussions finally get underway. In that context, it is a lesson with applicability to other economic sectors that are still poorly regulated in many parts of Canada, but in which companies are rushing to extract resources for economic gain. Examples that come to mind include venting and flaring of methane into the atmosphere by the oil and gas industry, hydraulic fracking by the oil and gas industry, and the widespread creation of toxic tailings ponds in the Alberta oil sands.

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**ABOUT THE AUTHORS**

Peter Prebble is Director of Environmental Policy for the Saskatchewan Environmental Society. He holds a Master's Degree in Sustainable Environmental Management and a Master's Degree in Education from the University of Saskatchewan. In addition to his environmental work, he served as a Member of the Saskatchewan Legislature for 16 years. He held several Cabinet portfolios and was the Premier's Legislative Secretary for Renewable Energy Development and Conservation.

Ann Coxworth is a long-time volunteer researcher and board member with the Saskatchewan Environmental Society. She has a Master's Degree in Nuclear Chemistry from the University of California, and was a founding member of Canada's Climate Action Network. Currently she serves on Saskatchewan's Environmental Code Development Committee.

## NOTES

[1] Robert Bothwell, *Eldorado: Canada's National Uranium Company* (The official history of Eldorado Nuclear Ltd. Commissioned by Eldorado Nuclear Ltd.) Refer to pages 315-386.

The contracts negotiated between Eldorado Nuclear and the US Atomic Energy Commission were intended to deliver uranium to the United States up to March 31, 1962, a date that was later revised to March 1963. (Bothwell, ibid, p. 386)

[2] Eldorado Nuclear completed decommissioning of the properties in 1985 under the supervision of the Atomic Energy Control Board of Canada. (Submission from Canada Eldor Inc. to the Canadian Nuclear Safety Commission, April 4, 2013 In the Matter of an Application by Cameco Corporation for the Decommissioned Beaverlodge Mine and Mill Site License Renewal).

[3] Beaverlodge Project Annual Report – Year 25 (January 1, 2010 to June 30, 2011, page 2-3). The Annual Report notes: "the Government of Canada, through Canada Eldor Inc. (CEI) retained responsibility for the financial liabilities associated with the properties."

[4] Submission from Canada Eldor Inc. to the Canadian Nuclear Safety Commission, April 4, 2013 (In the Matter of an Application by Cameco Corporation for the Decommissioned Beaverlodge Mine and Mill Site License Renewal).

[5] Beaverlodge Project Annual Report – Year 25 (January 1, 2010 to June 30, 2011, page 2-3).

[6] Ibid, page 2-3. In February of 1988 the Government of Canada and the Government of Saskatchewan announced their intent to create an integrated uranium company as a first step in privatizing their respective investments in uranium. In October 1988 Cameco Corporation was established from the merger of the assets of the Saskatchewan Mining Development Corporation and Eldorado Nuclear Ltd.

[7] Canada Eldor Inc. notes in their April 4, 2013 submission to the Canadian Nuclear Safety Commission that work continues to "prepare the properties for custodial transfer to the Government of Saskatchewan under the Reclaimed Industrial Sites Act." This act created a provincial Institutional Control program, under which the Saskatchewan government can continue to monitor mined-out properties that are returned to it, and can place restrictions, if it wishes to, on future land use on those properties.

[8] Cameco, *Beaverlodge Mine Site Path Forward*, December 2012, p. 4-18 and p. 4-19. Refer to Table 4.2-2 entitled 'Annual Water Quality Performance Objectives for Selenium' and Table 4.3-3 entitled 'Annual Water Quality Performance Objectives for Uranium'.

[9] Government of Saskatchewan, Ministry of Energy and Resources, 2012 Institutional Control Report (The Reclaimed Industrial Sites Act), For the period April 1, 2007 to March 31, 2012 .

As of March 31, 2012, a total of six sites have been accepted into Saskatchewan's Institutional Control Program: one decommissioned gold mine, and five decommissioned uranium mines. The decommissioned uranium mines are all Beaverlodge properties. For each property a sum of $137,895 has been set aside for the Monitoring and Maintenance Fund. An additional sum of $21,471.36 has been set aside for the Unforseen Events Fund.

[10] During the mill operating period approximately 60% of the radioactive tailings were placed into small water bodies within the Fulton Creek watershed, while the remainder were deposited underground. (Source: Beaverlodge Project Annual Report – Year 25 (January 1, 2010 to June 30, 2011, page 2-3).

[11] Beaverlodge Project Annual Report for January 1, 2011 to June 30, 2012, Table 4.1.1

[12] Beaverlodge Project Annual Report for January 1, 2011 to June 30, 2012, Table 4.1.1

[13] *Guidelines for Northern Mine Decommissioning and Reclamation*, November 30, 2008, Version 6, EPB 381. Refer to section 3.0 'Final Mine Closure Objectives and Criteria' and to section 3.1 'General Site Objectives'.

[14] *Guidelines for Northern Mine Decommissioning and Reclamation,* November 30, 2008, ibid. Refer to section 3.1 'General Site Objectives'.

[15] SENES Consultants Ltd., Beaverlodge Quantitative Site Model (Prepared for Cameco Corporation), May 2012. Refer to Part A, Table 5.1-1 Summary of Limnological Characteristics of Modeled Lakes in the Beaverlodge Study Area. SENES reports the area of Beaverlodge Lake to be $5.7 \times 10^7$ $m^2$. The reported volume of water is $1.2 \times 10^9$ $m^3$.

[16] CNSC Staff Submission to a One-Day Public Hearing Audience Scheduled for April 4, 2013 on the matter of "Cameco Corporation, The Decommissioned Beaverlodge Mine and Mill Site License Renewal", February 1, 2013. CNSC staff do not comment on Eldorado Nuclear's decision making process, but note that "…the site operated without an effluent treatment process for approximately 25 years." Proper water treatment was ultimately installed in 1977 to adhere to the federal Metal Mine Liquid Effluent Regulations.

[17] Beaverlodge Project Annual Report for January 1, 2011 to June 30, 2012, Table 4.3.3-1 to Table 4.3.3.-2; Table 4.1.1. Prepared by Cameco.

[18] Annual Report for the Beaverlodge Project, January 1, 2011 to June 30, 2012, Section 4. This Annual Report was prepared by Cameco. For example, in 2011 the Beaverlodge Lake outlet (Sampling Station BL5) recorded uranium concentrations approximately 9 times higher than Saskatchewan Surface Water Quality Objectives and selenium concentrations approximately 2 times higher than Saskatchewan Surface Water Quality Objectives. Radium concentrations were below current guidelines.

[19] Annual Report for the Beaverlodge Project, January 1, 2011 to June 30, 2012, Section 4, ibid.

[20] Canadian Nuclear Safety Commission Meeting, November 3, 2010, #21

Canadian Nuclear Safety Commission, Record of Proceedings Including Reason for Decision in the Matter of Cameco Corporation's Application to Renew the Beaverlodge Mine and Mill Site Waste Facility Operating License, Hearing Dates: February 18, 2009 and November 5, 2009.

[21] Annual Report for the Beaverlodge Project, January 1, 2011 to June 30, 2012, Section 4, ibid. Refer to data for monitoring station ML1.

[22] Annual Report for the Beaverlodge Project, January 1, 2011 to June 30, 2012, Section 4, ibid. Refer to data for monitoring station CS1.

[23] Cameco Corporation, *Beaverlodge Project Annual Report, Year 25* (January 1, 2010 to June 30, 2011), page 2-4.

[24] Cameco, *Beaverlodge Mine Site Path Forward,* December 2012, page 5-1.

[25] For example, in setting its performance objectives, Cameco is asking CNSC to accept uranium concentrations in Greer Lake that are 20 times higher than Saskatchewan Surface Water Quality Objectives (SSWQO) in 2020 and 18 times higher than SSWQO in 2050. Performance objectives for Radium for 2050 in Greer Lake are proposed to be 18 times higher than current guidelines. This lake will clearly be an ongoing source of contamination that extends beyond the Beaverlodge properties themselves and directly affects Beaverlodge Lake. (Data source: Written submission from Cameco Corporation for the License Renewal for Beaverlodge, February 2013, Addendum A).

[26] Dr. G. Lakshman, System Ecotechnologies Inc. "Options for Remedial Technologies: Beaverlodge Lake Uranium Mining Area". This document was part of a larger Saskatchewan Environmental Society submission to the Canadian Nuclear Safety Commission dated March 2013 and entitled "Comments from the Saskatchewan Environmental Society on Cameco's Proposal for the Re-licensing of the Decommissioned Beaverlodge Mine and Mill Site". For further detail refer also to: Permeable Reactive Barriers for Inorganic and Radionuclide Contamination, August 25, US EPA, http://www.clu-in.org and "Field Demonstration of Permeable Reactive Barriers to Control Radionuclide and Trace-element Contamination in Groundwater from Abandoned Mine Lands." Nafts et al, 1999.

A permeable reactive barrier (PRB) is defined by the US Environmental Protection Agency as 'an emplacement of reactive media in the subsurface designed to intercept a continuous plume, provide flow path through the reactive media and transform the contaminant (s) into environmentally acceptable forms to attain remediation concentration goals down-gradient of the barrier.' PRBs can be installed as replaceable units, or as permanent or semi-permanent units.

[27] Dr. G. Lakshman, System Ecotechnologies Inc. "Options for Remedial Technologies: Beaverlodge Lake Uranium Mining Area", ibid.

[28] M. Kalin, W.N. Wheeler and G. Meinrath, "Removal of Uranium from Mining Waste Water Using Algal/Microbial Biomass," *Journal of Environmental Radioactivity,* 01/2005, 78 (2), pp. 151-177.

M. Kalin, M.P. Smith and M.B. Wittrup, "Ecosystem Restoration Incorporating Mineotrophic Ecology and Stoneworts that Accumulate Ra226." *Proceedings of the Uranium Mining and Hydrogeology III Conference*, Freiberg, Germany, September 15-21, 2002, pp. 499-508

M. Kalin, G. Meinrath, W.N. Wheeler and M.P. Smith. 'Sustainable Removal of Radium226 and Uranium from Mine Effluents: A Review of Field Work in Northern Saskatchewan, Canada and Saxony, Germany' in International Atomic Energy, *Low Environmental Impact Uranium Mining and Remediation: 15 Years of Multinational Experience through Uranium.* Mine Remediation Exchange Group.