CAPE BRETON DEVELOPMENT CORPORATION (CBDC) was established as a Crown corporation in 1967 in order to reorganize and rehabilitate the coal industry on Cape Breton Island, Nova Scotia. In 2009, CBDC was dissolved, and its assets and liabilities were transferred to Enterprise Cape Breton Corporation (ECBC), a federal Crown corporation. Under the transfer arrangement, ECBC acquired stewardship obligations stemming from CBDC’s past operations, including land holdings and environmental remediation. Properties covered under the environmental remediation program stem from mining operations that began in 1685 and include more than 50 underground mines, which produced over 500 million tonnes of coal. The history of coal mining in the Sydney coal fields included 720 individual parcels of land on which there were 95 coal related operations covering more than 1,000 km². Some of the properties required remediation of waste rock piles (WRP) produced from the mining operations. In 2014, the operation of ECBC was transferred to Public Works and Government Services Canada.

The reclaimed Victoria Junction (VJ) WRP is located on the site of a historic coal preparation plant approximately 5 km northeast of Sydney, Nova Scotia, and has a footprint of approximately 26 ha and a height of 40 m. The coal preparation plant operated from the mid 1970s to 2000. During operations, the coal preparation plant washed up to 4 million tonnes of raw coal per year, of which 15–20% was placed into the WRP and 3% into fine tailings ponds. Several coal tailings ponds were constructed within the confines of the VJ WRP as required by processing and storage demands and were eventually covered with waste rock. Upwards of 10 million tonnes of potentially acid forming (PAF) waste was placed within the VJ WRP. The site is situated in the Northwest Brook watershed which flows into the Atlantic Ocean approximately 6 km north of the site. Northwest Brook flows from Grand Lake, located approximately 100 m south of the site, around the east side of the WRP and through the wetland to the north.

The long-term environmental concern is acid rock drainage and metal leaching (ARD/ML) emanating from the WRP as runoff and basal seepage. Hydraulic gradients in the WRP are downward, driving ARD/ML into groundwater which then flows north into the wetland. There is a reversal of hydraulic gradients in the wetland, allowing ARD/ML to migrate to the surface. As a result, loading from the pile to the receiving environment can be quantified north of the pile at MP2016. Several measures have been implemented to mitigate this issue, including the installation of a passive treatment system designed to intercept and treat seepage from the WRP.

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reclamation activities have been undertaken throughout the site’s history, the most notable include: the installation of a groundwater collection system to treat deep impacted groundwater in 2003, placement of an engineered low flux cover system in 2006, and the transition from active to passive water treatment in 2013. In 2010, at the request of ECBC, O’Kane Consultants (OKC) initiated a performance monitoring program to inform on long-term predictions of loading to the receiving environment.

Extensive monitoring implemented by ECBC at the site provided the opportunity to develop a conceptual model (i.e. an understanding for site conditions) to inform on loading to the receiving environment. Loading to the receiving environment has evolved over time and is characterized by three distinct periods:

- Phase 1 – pre-cover system with active treatment,
- Phase 2 – post-cover system with passive treatment, and
- Phase 3 – long-term post-cover system with passive treatment.

Acid load mass balances were developed for each phase, with the first two phases providing the basis for long-term predictions. The load to the receiving environment pre-cover system consists of three sources: basal seepage (groundwater mounding and net percolation) and runoff from the site. The active treatment system is the main sink, acting to reduce load to the receiving environment from both surface runoff and basal seepage. The total calculated acid load in Phase 1 at MP2016 is 147 t/year, and an error of 1% would suggest that the flow and geochemistry models closely represent site conditions. The total acid load generated from the site is 936 t/year, of which runoff is the largest contributor at 688 t/year. The active treatment system neutralized 788 t/year, while 2 t/year were neutralized by natural alkalinity in groundwater. In terms of basal seepage, approximately 40% is intercepted by the active treatment system, with the remaining reporting to groundwater flow, which is key in developing an understanding of loading to the receiving environment.

The mass balance changes substantially after installation of the low flux cover system and remediation of the site, both in terms of the load produced from surface runoff and basal seepage. The passive treatment system is introduced in this phase and replaces the active treatment system. A drain-down component is also introduced as a result of the decrease in net percolation following placement of the cover system. The total acid load generated from the site in Phase 2 is reduced from 936 t/year to 79 t/year. Approximately 13% of basal
Seepage is intercepted and treated before being discharged. The total calculated acid load at MP2016 is 68 t/year, compared to the current observed load of 66 t/year. While the total acid load generated from the site was reduced by approximately 92% (936 to 79 t/year), the acid load at MP2016 decreased by approximately 54%. The pre-cover system and current mass balances provide context for the observed water quality at MP2016 in that a proportional decrease in loading was not observed after changes in water collection and treatment.

Using the mass balances and conceptual model for pre-cover system and current conditions, a mass balance was developed to predict loadings to the receiving environment 100 years post-cover system. The most significant change in the 100 year post-cover system mass balance is the completion of drain-down. As a result, the load at MP2016 is estimated to decrease from 68 t/year to 11 t/year. Results of the acid load mass balance indicate that loading to the receiving environment has decreased substantially following placement of the cover system and will continue to decrease as drain-down diminishes. While an acid load of 66 t/year is observed at MP2016, the net acid load is negative given the alkalinity inputs to the system. Alkalinity is contributed through passive treatment discharge, an open limestone channel, and naturally from Grand Lake. Considering alkalinity inputs to the system, the net acid load at MP2016 is approximately -450 t/year.

The acid load mass balances provide a strong understanding for loading to the receiving environment as a function of reduced flux / seepage rates, and enabled long-term predictions 100 years post-cover system. Leapfrog Hydro was used to model the groundwater plume and provide a better understanding for how groundwater has evolved in conjunction with reclamation activities. Extensive groundwater sampling was conducted from 2002 to current, which permitted the generation of three-dimensional (3-D) groundwater plume models (sulfate) to illustrate how the groundwater has evolved.

There has been a steady improvement in water quality over the short term. Groundwater quality improvements observed in the modelled plumes are supported by the acid load mass balances. Pockets of high concentration appear to be dissipating and there is also less impact to deep groundwater as vertical gradients in the WRP have diminished as a result of the decreased flux through the cover system.

The mining industry is frequently challenged with the choice to either collect and treat in perpetuity or undergo reclamation activities to reduce the load to the receiving environment. This decision is often heavily influenced by net present value (NPV). There are many assumptions and variables in a NPV analysis such as discount rate, future cost of lime/polymer, and...
upgrades/maintenance. An NPV analysis was completed for the VJ site to investigate the decision to install the cover system. At a discount rate of 4%, treating in perpetuity and installing the cover system have NPVs of $11.2M and $13.8M, respectively. While the treatment scenario has a lower NPV, one must consider the risk (i.e. probability and impact) of each scenario, both from a financial and environmental stand point. For example, the loads generated from the site under each scenario are significantly different, each with their own unique financial and environmental risks. Under the active treatment scenario, it is important to note that approximately 40% of the basal seepage load was collected and treated before being discharged from the facility. As a result, water quality in the receiving environment would have taken a different trajectory than that observed in cover system scenario. The decision to install the cover system was obviously not solely dependent on NPV. The goal of site closure was to minimize cost while mitigating risk.

It is also important to note that if the discount rate was reduced to say 1%, the difference between NPVs for the two scenarios would be substantially different, with the collect and treat option being substantially higher. The key point to highlight in making this comparison is that hindsight perspective for the VJ WRP closure activities provides a good argument for discount rate being an output from an NPV analysis, and to use this understanding to inform risk, rather than how discount rate is typically utilized (i.e. as an input to NPV analysis).

The VJ site has transitioned from active to passive treatment following placement of a low flux cover system, with continued improvements observed in the receiving environment and continued reduction in loading. Extensive monitoring at the site enabled the development of a conceptual model to inform on long-term performance and impacts to the receiving environment without the use of numerical models. A well-designed monitoring program is critical to the conceptual model and requires sufficient information both spatially and temporally. This case study illustrates the importance and opportunity for using the conceptual model to communicate performance and risk, and ultimately inform management on decisions regarding site practices in order to meet closure objectives.

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