Controlling Surface Water at One of Canada's Largest Base Metals Operations: From Legacy Challenges to Environmental Award Winner

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Abstract Vale Inco retained Klohn Crippen Berger to lead the design of a Water Management System to improve environmental performance at its large, 110-year-old integrated mining complex in Greater Sudbury, Ontario. The challenge was to manage ARD, process effluent, mine water and runoff from more than 52 square kilometres of land that was developed more than a half a century before the first environmental law was written in Canada. The solution is a $100M+ retrofit including a watershed wide fibre-optic control system to allow real time monitoring and flow control upstream of a central water treatment plant. The most notable accomplishments of this unprecedented Canadian-Mining collect-and-treat project include enhancing public safety, protecting the environment and lowering the life cycle cost of water management.

Key Words active water treatment, acid rock drainage (ARD), flow equalization, remote monitoring and control

Introduction
Surface water management is an increasingly important aspect of all mining projects regardless of what stage a project is at in the life-cycle, or where in the world it is located. As globalization continues, variables in the regulatory environment are being replaced by international standards in the areas of closure planning, reclamation, tailings management, discharge water quality, drinking water quality and groundwater quality.

Depending on climatic and process variables, mine water management falls into two basic categories: 1) managing a net-annual water surplus in a temperate or wet climate; or 2) managing a net-annual loss in an arid or semi-arid climate. Even in the case of perfect balance under average annual conditions, there may be droughts and wet periods when there is either not enough or too much water to handle without an integrated management plan and the appropriate infrastructure.

Background Information
Vale Inco and its predecessor companies have been mining, milling and smelting in the Sudbury area for more than a century. In 2008, Vale Inco was the second largest base metal producer in Canada.

During the advancement of the Canadian Pacific Railway in 1883, deposits of copper and nickel sulphide ore were first discovered in the Sudbury basin. By 1930, approximately 28 million tonnes of sulphide ore had been heap roasted near the present day communities of Copper Cliff, Coniston, O'Donnel and Victoria. The environmental effects of heap roasting and logging were profound at that time and are well documented. In 1930, the Copper Cliff Smelter Complex was brought into production, allowing the practice of heap roasting to end. About 40 years later, the first environmental laws were being drafted in Canada and soon after, the Copper Cliff Waste Water Treatment Plant (CCWWTP) was commissioned to manage effluent from the Sudbury basin operations.

Tailings are stored in the Copper Cliff Central Tailings (CCCT) Area which has been in operation since 1937. Since commissioning, tailings were deposited sequentially in the A-, CD-, M-, M1-, Q-, P-and R-Areas. Tailings disposal to R-Area began in 1985 in the R1-, R2-, and R3-Areas. The R4-Area development began in 1994 with continuous spigotting starting in 1995. The CCCT Area normally receives about 27,000 tonnes of tailings per day from the Clarabelle Mill (approximately 9,000 tonnes of tailings per day is used for backfill). The CCCT Area also receives other wastes including non-hazardous solid waste, potable water and wastewater treatment sludges, asbestos, and sewage sludge from the Region of Sudbury and Vale Inco operations.

To date, the CCCT facility contains more then 450 million tonnes of Potentially Acid Generating (PAG) tailings. The R-Area will provide tailings storage from Clarabelle Mill to year 2030 and possibly beyond and will impound an additional 300 million tonnes of PAG tailings. The average pyrrhotite content (FeS) of these tailings is about 7%. The residual sulphide present above the water table has the potential to produce low-pH, metal-contaminated seepage and runoff that will require long-term collection and treatment during the operating and post closure phases.

Problem Statement

Vale Inco employ a "collect and treat" strategy to manage process effluent, mine water, tailings transport water, waste dump seepage, perimeter dam seepage and runoff from approximately 48 km^2 of lands (11,900 acres) that drain directly to the CCWWTP. Pumped and diverted inflows, mine water and effluents from other Sudbury operations increase the collect and treat service area to more than 52 km^2 (12,850 acres), which is roughly four-fifths the land base of Manhattan, New York.

Hydraulic Overload

Not surprisingly, due to the size of the serviced area, the problem historically has been hydraulic overload at the CCWWTP during wet weather, in spite of a peak capacity of about 2,600 litres per second. Since about half of the drainage area to the plant is Canadian Shield watershed (25 km^2), runoff during spring melt or due to heavy rainstorms used to often cause hydraulic overload at the plant. Unless a release is due to an "extraordinary hydrologic event" a bypass at a water treatment plant in the mining sector is not compliant with current law in Ontario (i.e. Ontario Regulation 560/94). Note that a bypass is a release of non-compliant effluent, whether it is 100 litres over 10 minutes or the flow over Niagara Falls for 10 days.

Dependence on Water Recycling

Another complexity in this system is the need to recycle process water for operations at the Clarabelle Mill, in order to reduce potable water use. Operating continuously, the Clarabelle Mill reclaims between 950 – 1,250 L/s (i.e., 15,000 – 20,000 US gaL/min) from Copper Cliff Creek. Water used in the milling process is collected and pumped out to the CCCT Area in the form of slurry. The reliability and security of water recycle is therefore important from an environmental, economic and logistical point of view. When runoff conditions allow, treated effluent is recycled to the Mill to improve metallurgical recovery. During heavy runoff conditions, the flexibility to reclaim raw water from Copper Cliff Creek and retain tailings transport water in the R-Area, allows 950 – 1,250 L/s to be effectively removed from the influent hydrograph at the CCWWTP.

Operating the water recycle infrastructure in this manner produces the same result as an additional reactor clarifier, or the equivalent of 40% higher peak capacity at the plant. The cost to implement the operating strategy as part of the WMS was negligible. This was a classic example of optimization of existing infrastructure, a "low hanging fruit" that was ripe for picking.

Potential for Treatment Plant Upset or Power Supply Interruption

The CCWWTP has a rated capacity of 2,600 L/s (60 MGPD). The plant was commissioned in 1972 and has undergone a number of renovations to improve performance and reliability since that time. Like any water treatment plant, the system is a train of unit processes that work together to achieve effluent discharge criteria. The process train includes mechanical screening, raw water pumping, reagent addition (i.e., lime, flocculent and coagulant), settling and pH adjustment of the clarified effluent using sulphuric acid. Most CCWWTP systems require power for raw water pumping, mixing, reagent addition and process control.

Risks associated with non-compliant effluent include hydraulic overload during periods of heavy runoff, rapid changes in influent chemistry, power supply interruption, mechanical failure, instrumentation failure and the possibility of human error. In short, there are a plethora of things that can go wrong with a high capacity treatment, besides hydraulic overload.

Legal Change, Legacy and Compatibility with Closure

It is important to recognize that environmental law did not exist in Canada prior to about 1970, when the Canadian Environmental Law Association (CELA) and the Canadian Environmental Law and Research Foundation (CELRF) were initially founded. To meet the requirements associated with legal change, Vale Inco and its predecessor have implemented a series of air emission abatement projects, closure planning projects and water treatment and water management improvement projects. The net present value of these projects combined is in the rough order of two billion dollars. Future laws will be more stringent with respect to air and water releases. We believe this reality favours a modular approach to meet current and future challenges. Due to the long history of operations in the Vale Inco Sudbury Area, essentially all environmental and water management improvements have had to be retrofitted long after mining began in the Sudbury basin.

Project Objectives, Solutions and Achievements

This Water Management System (WMS) project is part of an initiative by Vale Inco to bring liquid effluents from this large, integrated mining complex from a legacy position to a leadership position. Building on the ancient Egyptian technology of using reservoirs to attenuate the flow of water, this system takes this basic concept further by incorporating state of the art instrumentation and control systems as well some innovations, thanks to the ongoing advances in material science and construction.

Since the preferred concept was developed in 1998, Vale Inco has committed more than $100,000,000 to design and construct the 22-reservoir, integrated WMS. This included the re-design of 19 of the existing reservoirs and lakes, re-design of four (4) seepage return pumping stations, the construction of two (2) new pumping stations, the construction of two (2) new tunnels and the expansion of two (2) existing tunnels.

The reservoir network allows central control of discharge to the treatment plant, by the use of touch screens that were customized for the operator-users. Fail-safe systems were also built-in, so if a particular reservoir level or set of them are outside of the normal operating parameters, the automatic call-out system can be enabled so the appropriate parties get paged to take appropriate action.

In the interest of public safety, impounding water near population centers needs to be done with great care. Accordingly, the redesigned reservoirs and associated embankment dams were engineered to meet relevant industry standards in order to function safely in the event of a catastrophic flood or earthquake. The new WMS complies with relevant Provincial and Federal legislation and relevant building codes and standards. It is also compatible with Vale Inco's stringent Environmental Policy and with Closure Plans for Sudbury basin sites which will depend on the long-term operation of the CCWWTP. Re-designed embankment dams and concrete dams forming many of the system components also comply with relevant legislation, good engineering practice, the Canadian Dam Association – Dam Safety Guidelines (CDA, 2007) and the Ministry of Natural Resources – Ontario Dam Safety Guidelines – Draft (MNR, 1999).

The concept of reservoir attenuation and even reservoir networks is not new, but this WMS is innovative in many ways. Some of the more note-worthy innovations associated with Vale Inco's WMS include: 1) the application of "best available technology" to protect the environment; 2) the selection of a number of "synthetic materials" for longevity and corrosion resistance (i.e., plastics, geo-synthetics and high strength fibres) in seepage control, contaminant barrier and rock support applications; 3) the creation of "custom user interfaces", tailored by the operations staff who rely on the infrastructure; 4) the application of "in-situ densification" technology to improve loose tailings foundations to resist liquefaction in the event of a strong earthquake (contributed by others); 5) the application of "trenchless technology" to rehabilitate decant pipelines that would be more expensive and risky to cut and fill; 6) the use of Global Positioning Satellite (GPS) guided earthwork equipment for deep tailings excavations that needed to meet exacting grade tolerances; and, 7) the operation of "existing" infrastructure in "new ways" to improve performance at no additional cost.

WMS Performance

Prior to implementation of the WMS, hydraulic overloading was a common problem at the CCWWTP and CCCT Area Seepage Return – Pumping Stations during heavy runoff periods. Since WMS improvements were completed at the seepage stations in 1999 and implementation of major components began in the CCWWTP basin, there have been no hydraulic overloading events in over a decade.

The WMS was designed to store runoff produced by a combination of rainfall and snowmelt. In the Sudbury area, this type of flood can produce more runoff volume over a longer period of time, as compared to runoff produced by rainfall only. Accordingly, the WMS was able to attenuate a severe flash flood on July 26, 2009 that produced about 90 mm of rain in an hour and a half (Sudbury Star, 2009). The flood caused extensive damage to parts of the city however, WMS operators we able to avoid spilling a drop of untreated effluent to the receiving waters.

While only about 85% operational to date, the WMS has eliminated the seasonal bypasses during spring runoff, as well as numerous short-term exceedances that resulted from a variety of things that can, and do go wrong, at a high capacity water treatment plant. Success of the project was recognized in 2009 by winning an environmental award from the Consulting Engineers of Ontario.

Conclusions

Vale Inco implemented a leading edge WMS for their 52 km^2 integrated mining, milling and smelting operations in Sudbury Ontario. While a remotely controlled system of lakes, ponds and reservoirs may seem elaborate at first glance, it is an operationally superior system, which allows blending of high and low strength effluents, and makes clear economic sense in the long-term.

It is important to note that this WMS is more than just infrastructure. Also critical to WMS success are the appropriate management systems with clear accountability, the implementation of Operations, Maintenance and Surveillance systems, fail-safe and risk analyses, preventative maintenance programs and commitment from all involved, especially the operators who make it all work, every day and night, without spilling a drop.

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