CLRA/OMA/MNDM 11th annual Ontario Mine Reclamation

Symposium and Field Trip

June 19 and 20, 2018

Michipicoten Memorial Community Centre, Wawa, Ontario

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TECHNICAL PROGRAM (Tuesday June 19)

08:00 – 09:00	Registration
09:00 – 09:15	Welcome, overview of CLRA and Tom Peters Memorial award. (Peter Beckett and Bill Mackasey)
09:15 – 09:30	Delegate welcome (His Worship Ron Rody, Mayor of Wawa)
09:30 – 10:10	Geology and history of mining in the Wawa area. Anthony Pace (MNDM)
10:10 – 10:30	The ABCs of PWQOs and CWQGs. Maria Story (Story Environmental)
10:30 – 10:50	**Health Break**
10:50 – 11:10	Implementation of post closure water treatment at MacLeod Mine, Wawa. Steve Reitzel (MNDM) and Fred Post (Algoma Inc.)
11:10 - 11:30	Environmental intelligence in mine closure and reclamation. Elizabeth Haack and Sarah Barabash (EcoMetrix Incorporated)

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11:30 – 11:50	An overview of the NRC's research on acid rock drainage and metal leaching. Dr. Zhong-Sheng (Simon) Liu (National Research Council Canada, Vancouver, BC)
11:50 – 1:00	**Lunch Break**
1:00 – 1:20	A web site for collecting wild seed to support mine reclamation in northern Ontario. Brittany Rantala-Sykes (Laurentian University) and Daniel Campbell (Birchbark Environmental)
1:20 – 1:40	Bat friendly progressive rehabilitation of the historic Edison Mine. Josip Balaban, Paul Palmer (Golder Associates Ltd., Canada) and Jeff Allen (Eaton Corporation, United States)
1:40 – 2:00	Growth and metal uptake of canola and sunflower along a thickness gradient of organic-rich covers over Ni-Cu mine tailings. Daniel Campbell (Birchbark Environmental) and Kayla Stewart, Graeme Spiers and Peter Beckett (Laurentian University)
2:00 – 2:20	Developing pulp & paper mill residuals for land application. Leyland Johnston, Nathan Basiliko, Graeme Spires, and Peter Beckett (Laurentian University)
2:20 – 2:40	Effects of emission reduction, lime application, and tree planting on carbon accumulation in an acidified and metal-polluted boreal shield watershed. Robyn Rumney, John Gunn, Nathan Basiliko (Laurentian University)
2:40 – 3:00	**Health Break**
3:00 – 3:20	An evaluation of natural char and wood ash for mine tailings reclamation in a northern boreal forest. Jillian Bieser, 2017 (University of Toronto)
3:20 – 3:40	Rehabilitation plans for the Goudreau open pits: Part 1 – History and the way forward. Steven Aiken, Ryan Tibbles, and Andy Phillips (Knight Piesold Ltd.) and Fred Post (Algoma Inc.)

3:40 – 4:00	Rehabilitation plans for the Goudreau open pits: Part 2 – Water quality issues and management. Derek Amores, Daniel Skruch, Sarah Barabash and Ron Nicholson (EcoMetrix Incorporated) and Fred Post (Algoma Inc.)
4:00 – 4:20	Rehabilitation of orphan tailings and soil cover construction at a decommissioned copper mine site. Michael Gunsinger, Ken Bocking, George Schneider, Andrew Forbes, and Ken De Vos (Golder)
4:20 – 4:40	Construction of a capillary barrier cover for reactive mine waste management utilizing municipal biosolids. Christopher Hey and Paul Simms (Carleton University)
4:40 – 5:00	Workshop Discussion and Wrap Up
5:00 – 6:30	Cocktails
6:30 – 10:00	Banquet and Awards
8:00 – 8:20	Heart of a mountain – Soul of a town: The Story of Algoma Ore and the town of Wawa. Joanna Rowe

POSTER

Effect of *Typha latifolia*, *Carex lacustris* & *Juncus canadensis* on iron and sulfur dynamics and associated microbial community in a floating treatment wetland. Varun Gupta, John Gunn, and Nadia Mykytczuk (Vale Living the Lakes Centre, Laurentian University)

BANQUET (Tuesday June 19)

A banquet will be held at the Wawa Michipicoten Memorial Community Centre from 6:30 pm to 10:00 pm. The Tom Peters Memorial Mine Reclamation Awards will be presented and Johanna Rowe, author of "***Heart of a Mountain – Soul of a Town, The Story of Algoma Ore and the Town of Wawa***" will be the after-dinner guest speaker.

FIELD TRIP (Wednesday June 20)

The field trip is an eight hour tour highlighting Wawa historical mining and reclamation sites including the decommissioned Algoma Ore Sinter Plant site and the former MacLeod Mine. The site visit will include a tour of the recently constructed high density sludge water treatment plant. The tour will then travel to the former Goudreau iron ore pits approximately 90 km north of Wawa. These small open pits were mined in the 1950s and 60s. Of the 5 pits, one has been reclaimed and the others remain in their abandoned state.

The field trip will depart from the Wawa Motor Inn at 8:30 am. Lunch will be provided and personal protective equipment is required for the field trip participants. If you plan on participating in the field trip please arrive prepared with safety boots and glasses. Tour personnel include Fred Post (Algoma Inc.); Steve Aiken (Knight Piesold Ltd.); Steve Reitzel (MNDM); Dawn Spires (CLRA) and Bill Mackasey (CLRA).

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ABSTRACTS

Geology and history of mining in the Wawa area.

Anthony Pace (MNDM)

The present town site of Wawa, formally of the township of Michipicoten was first occupied by the Anishnabe. It was first developed for fur trading, where it was the main fur trade route from Montreal westward and the route to James Bay via the Missinaibi River. In the late 19th century, the discovery of both gold and iron ore established Wawa's future as a mining town. Gold was first discovered by a local Ojibway, Louise Towab and her husband William Teddy in 1897 on the south shore of Wawa Lake. This set off Ontario's first gold rush and by the fall of 1897 some 1,700 claims were staked (Rowe, J., 1999). The early gold mines that developed as a result of the rush included the Grace, Norwalk, Diamond Jubilee, Kitchegami and the Golden Reed. Through a series of boom and bust cycles there were a number of gold mines that operated in the region from the early 1900's to today with varying success. Gold continues to be the commodity of interest in the region, where there are 44 active exploration projects and 3 producing gold mines with past and current production of approximately 3.7 million ounces of gold. The search for gold during the boom led to the unexpected discovery of iron ore by prospectors Ben Boyer, Jim Sayers and Alois Goetz in 1898. Francis Hector Clergue, an American entrepreneur, immediately recognized the iron ore for its potential (Rowe, J. 1999). As a result of this discovery, the Helen Mine began operations in 1900 and continued until 1918. The Magpie mine a second iron ore producer began operation in 1902 and continued until 1918. The iron ore from both mines were shipped to blast furnaces at steel mills in Sault Ste. Marie and Midland, Ontario. The discovery and development of these mines ignited a wave of industrial growth in the region. The Helen mine, until its closure in 1918 was the largest source of iron ore in Ontario and produced higher grade iron ore than any other iron mine in Canada at that time (Rowe, J., 1999). In 1939, Sir James Dunn, chairman of Algoma Steel Corporation re-opened the Helen Mine and created the Algoma Ore Properties. The inexhaustible amount of siderite ore led to the construction of a Sinter plant where it was treated to produce sinter and shipped to blast furnaces around the continent as well as Algoma Steel in Sault Ste. Marie. Algoma Ore Properties operated a series of other open pit

iron mines including the Victoria, Sir James Dunn, Ruth, Lucy and the Goudreau iron ranges. The Helen Mine exhausted its open pit operations and began mining its ore with underground methods. In 1960, the Algoma Ore Division was formed as the parent company of Algoma Steel Corp. and the mine entered a new stage of underground operations and changed its name to the George W. MacLeod Mine. The Michipicoten Iron formation had been the sole source of iron ore from the area and had played an intimate role in the economic development of the Wawa region. The iron formation is part of the Michipicoten Greenstone Belt that consists of successions of Archean metavolcanic and metasedimentary rocks intruded by Archean granitic rocks and later Proterozoic dikes (Turek, Smith and Van Schmus 1982). The metavolcanic rocks in the belt have been subdivided into 3 distinct volcanic cycles: 2900 Ma, 2750 Ma and 2700 Ma (Sage and Heather 1991; Heather and Arias 1992; Turek, Smith and Van Schmus 1982, 1984, Turek, Van Schmus and Sage 1988). The iron formation, composed dominantly of carbonate and sulphides, if unfolded and unfaulted would probably have a strike length of 100 km or more, capping the 2750 Ma cycle of volcanism (Sage and Heather 1991). Since the start of operations in the early 1900's approximately 100 million tons of iron ore was produced in the Wawa region (Mineral Deposit Inventory, 2015). At its closure in 1998, the MacLeod Mine was the oldest iron mine in Ontario and the only operating underground iron ore mine in North America.

References:

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The ABCs of PWQOs and CWQGs.

Maria Story (Story Environmental)

Provincial Water Quality Objectives ("PWQOs") and Canadian Water Quality Guidelines for the Protection of Aquatic Life ("CWQGs") are routinely used by regulators, mining engineers/scientists, and environmental consultants to characterize surface water quality. More recently, they are also being used as effluent objectives (and sometimes effluent limits) for mining facilities. What are PWQOs and CWQGs? How are these objectives/guidelines developed? When should they be used? These questions will be discussed and related to a case study in the historic Cobalt Mining Camp.

Implementation of post closure water treatment at MacLeod Mine, Wawa.

Steve Reitzel (MNDM) and Fred Post (Algoma Inc.)

Iron ore mining on the former Algoma Ore property started in 1900 as an open pit operation, before moving underground at the MacLeod Mine in 1960. In June 1998, mining at the MacLeod Mine was shut down and the mine workings immediately began to flood. The MacLeod Mine Closure Plan involved allowing the underground workings to flood to the maximum elevation, without discharging to surface, to submerge sulphidic mineralization within the mine workings. Sulphide oxidation has resulted in mine water quality that is acidic with elevated metals, particularly iron. The mine water level was predicted to reach its maximum allowable water level in 2019, at which time there is the potential for mine water to migrate through the Walbank fault zone to Wawa Lake. To prevent the mine water from migrating into Wawa Lake, the Closure Plan identified the need to construct a water treatment plant to maintain the mine water level below the spill elevation. In 2016, bench scale and pilot testing were completed and high density sludge (HDS) lime treatment was identified as the preferred treatment technology. In 2017, a 7,100 m3/day HDS lime treatment plant was constructed at the former No. 5 Shaft of the MacLeod Mine. The WTP will be commissioned and operational in the spring of 2018.

Environmental intelligence in mine closure and reclamation. Elizabeth Haack and Sarah Barabash (EcoMetrix Incorporated)

For the last number of years, we have been advocating an integrative approach to mine life cycle risk management to mining practitioners at venues such as the annual Canadian Land Reclamation Association (Ontario Chapter) and technical workshops sponsored by the Ontario Mining Association, among others. Our approach brings together site-wide constituent loadings modelling with quantitative human health and ecological risk assessment. We believe this approach is one that is consistent with, and supportive of the holistic, risk management-focused business strategy that many of our clients have adopted to ensure their sustainability. Case studies are presented that demonstrate the environmental intelligence gained by application of our approach, including recent experience in support of mine closure planning. The source term model, developed in-house, established current conditions and provides a flexible and intuitive real-time platform for evaluating reclamation options. HHERA identified site aspects that contribute meaningfully to risks and key areas of regulatory and public interest. Closure and reclamation options were ranked/prioritized on the basis of the predicted risk profile. Specific design criteria and targeted mitigation strategies were then developed, and key performance indicators defined to evaluate post-closure performance. This comprehensive approach has allowed site managers to make and effectively communicate proactive decisions that reduce liabilities.

An overview of the NRC's research on acid rock drainage and metal leaching. Dr. Zhong-Sheng (Simon) Liu (National Research Council Canada)

This presentation gives an overview of the NRC's research on acid rock drainage and metal leaching. It covers the main research projects that have been on-going since 2016, for prediction and prevention of acid rock drainage and metal leaching. One of the projects is about how to design smaller scale testing such as humid cell testing and pilot-scale testing, so that the test results can be rigorously and accurately scaled up to the filed; another project is about our observations and explanations of metal leaching from the 30-years of historical monitoring data of the waste rock dump at Equity Silver Mine BC Canada. Since these projects are joint research efforts between the NRC, Canadian consulting companies and mining companies, the presentation will show the importance of collaboration among partners.

A web site for collecting wild seed to support mine reclamation in northern Ontario.

Brittany Rantala-Sykes (Laurentian University) and Daniel Campbell (Birchbark Environmental)

Local communities and government agencies increasingly aim to reclaim mine sites back to native vegetation. The local collection of wild seed ensures good genetic diversity and enhances establishment and compatibility with local plant populations around reclamation sites. But surprisingly, little information is known on best and most simple methods to collect local wild seed in eastern Canada. We compiled literature reviews of best techniques to collect, clean, store and propagate 60 species of upland trees, shrubs and herbs native to boreal and subarctic regions in Ontario, and we field tested them. We produced a user-friendly web site directed at a lay audience at: https://nativewildseed.wixsite.com/nativewildseed. This guide should be useful to help reclaim mine sites or restore other disturbances back to native vegetation in northern Ontario.

Bat friendly progressive rehabilitation of the historic Edison Mine.

Josip Balaban, Paul Palmer (Golder Associates Ltd.) and Jeff Allen (Eaton Corporation)

The historic Edison Mine property is a century-old silver mine located in a remote area of Coleman Township near Latchford, Ontario, and is only accessible by boat or helicopter. Near surface underground mine workings exist on the property and are connected to surface by a shaft, adit and open cut which have been left unprotected for over a century. To eliminate any liabilities associated with the historic mine, Eaton required a permanent remediation solution (i.e. no fencing) be implemented. Golder was retained by Eaton to complete the progressive rehabilitation of the property. The underground mine workings were identified as a potential location for bat hibernacula by the Ministry of Natural Resources and Forestry (MNRF) and were therefore designated as protected habitat for species at risk. Given that conventional rehabilitation measures such as backfilling or engineered concrete caps would inhibit access to the underground workings by bats, an alternative solution for the three surface openings was required. Through a 16 month consultation process involving Golder staff, Eaton, the MNRF and the Ministry of Northern Development and Mines, a bat friendly rehabilitation solution satisfying all those involved was finalized. Two engineered stainless steel bat cupolas and one engineered stainless steel adit bat gate were constructed and installed at the site in 2016 and 2017, outside of bat sensitive periods of swarming. The remote location of the mine property required significant effort in logistical planning, requiring a helicopter and barge to transport 25,000 lbs of equipment and materials to site. The bat friendly structures prevent inadvertent access to the mine, while allowing bats safe entry and exit into the underground workings. The two cupolas and adit gate were one of the first bat friendly structures to be constructed by a private enterprise in Ontario. This presentation will explore Golder's successful efforts in the bat friendly progressive rehabilitation of the historic Edison Mine.

Growth and metal uptake of canola and sunflower along a thickness gradient of organic-rich covers over Ni-Cu mine tailings.

Daniel Campbell (Birchbark Environmental), Kayla Stewart, Graeme Spiers and Peter Beckett (Laurentian University)

A field-scale experiment was completed to determine the thickness thresholds of covers of organic residuals required to grow biofuel crops over low-sulfur metal mine tailings with high metal content. An organic-rich mix made of municipal yard waste composts and wood waste was spread up to ~70 cm thick over low sulfur Ni-Cu tailings. We seeded and fertilized biofuel crops of canola and sunflower across this gradient. We measured biomass production and concentrations of nutrients and trace metals in tailings, organic residuals and plants. Below the threshold organic cover thickness of 15 cm, macronutrient content was reduced and bioavailable Fe, Ni and Cu were 5–50 times higher as compared to thicker organic covers, apparently as a result of tillage. Bioavailable K and Na increased by an order of magnitude and Mo doubled with increasing thickness of organic covers from 5 and 70 cm thick. The plants showed limited uptake of Ni and Cu, with bioconcentration factors of near 1 for sunflower and 0.6 for canola. Biomass production was not affected by the thickness of the organic cover. Plant rooting depth was deeper over thin organic covers, extending up to 15 cm into the tailings. Low stem Fe in plants over thin covers indicated a potential interaction between trace metals and Fe nutrition. These results support the use of covers of organic residuals as thin as 15 cm thick to grow biofuel crops over circumneutral metal mine tailings. Thin covers will make this approach more economical for mine reclamation managers.

Developing pulp & paper mill residuals for land application.

Leyland Johnston, Nathan Basiliko, Graeme Spires, Peter Beckett (Laurentian University)

Pulp and paper mills generate large quantities of both organic and mineral residual products from both energy and chemical recovery processes and the treatment of wastewater. Disposal of these waste products represents a substantial portion of the operational costs for mills, and disposal methods typically involve landfilling or incinerating materials. The objective of this project is to develop pulp mill residuals as soil reclamation amendments across a range of management regimes: agricultural, forestry and mining impacted landscapes. A growth-chamber mesocosm experiment was used to evaluate 5 different soils or mine tailings substrates, mixed with one of 3 pulp and paper biosolids; each from mills with different pulping and wastewater treatment processes at application rates of 20 or 40 t/ha. Pots were seeded with annual ryegrass or white clover and controls of pure soil/tailings and pure sludge were also included. After planting, trays were placed in a plant growth chamber for 5 weeks on a diurnal cycle with temperature and watering matching idealized long-term average July climate conditions in Sudbury Ontario. After 5 weeks; germination rate was monitored and plants in each were harvested with above and below-ground biomass separated, dried, and weighed. There was a significant improvement in both germination rate and biomass with the addition of all pulp and paper biosolids to all soil or tailings types ranging from a productive circumneutral-pH and medium-textured agricultural soil to coarse-textured acidic silvicultural pine forest soils, to heavily S and metal polluted upland soils from downtown Sudbury, to a Ni-Cu mine tailing. New studies are underway to collect additional information on soil mixture and plant tissue concentrations, and mixtures of pulp and paper sludges plus mineral residuals (like wood ash and waste lime mud). However, the preliminary conclusion is that pulp and paper biosolids from a variety of mills can improve soil nutrition across a broad range of soil (and mine tailings) conditions in Northeastern Ontario.

Effects of emission reduction, lime application, and tree planting on carbon accumulation in an acidified and metal-polluted boreal shield watershed.

Robyn Rumney, John Gunn, Nathan Basiliko (Laurentian University)

Ecosystem carbon sequestration is a key component of climate change mitigation. When industries, such as mining, create barren landscapes this represents an opportunity to test carbon sequestration techniques during planned restoration efforts. To assess the effects of mine-site restoration on carbon storage, Studies are proceeding in the Daisy Lake watershed near the abandoned Coniston smelter in Sudbury, Ontario. The Daisy Lake watershed was heavily impacted by smelter emissions that lead to widespread plant mortality and soil erosion. It is also the site of unique remediation research efforts, with parts of the watershed limed and reforested. Restoration treatments in the Daisy Lake watershed will first be compared by directly measuring the carbon stored in soil and plants. Remote sensing will also be used to estimate ecosystem carbon. Research will identify how restoration practices in smelter-polluted watersheds affect carbon storage. In doing so, it will identify restoration protocols that sequester carbon; mitigating climate change and earning carbon credits in Ontario’s cap and trade carbon program.

An evaluation of natural char and wood ash for mine tailings reclamation in a northern boreal forest.

Jillian Bieser, 2017 Tom Peters winner (University of Toronto)

Natural re-vegetation of gold mine tailings, the main waste products of ore processing for gold extraction consisting of crushed rock, is difficult due to their high bioavailability of heavy metals, low nutrient status and limited organic carbon [1-3]. Charcoal produced from the burning of organic matter through controlled pyrolysis, hereafter referred to as 'biochar', has been utilized extensively in agriculture as a climate-friendly option to remediate nutrient-poor and contaminated soils [4,5]. Biochar produced from wood is highly recalcitrant, has a large surface area due to its porous structure and can bind nutrients and water, improving soil fertility [5-7]. Biochar can also bind undesirable compounds within the soil such as heavy metals, limiting their bioavailability to plants. Ash has a liming effect on acidic soils and can contribute large quantities of valuable nutrients to the soil following wildfire disturbance. We hypothesized that tailings amendment with biochar and ash would promote plant growth by inhibiting toxicity effects of heavy metal contamination and improving substrate fertility through increases in soil water and nutrient availability. To test this hypothesis field trials were implemented at the Goldcorp Inc. Musselwhite Gold Mine located in Northern Ontario, Canada. Growth responses of two native grass (*Poa palustris* and *Andropogon gerardii*) and one native tree species (*Pinus banksiana*) grown on a mixed sand and tailings substrate with high-ash biochar amendment were measured. Amendment with two types of biochar were investigated: i) woodash, a 38% biochar waste product from a northern Ontario wood-fired co-generation power plant and ii) natural charcoal harvested from a local wildfire. Statistical analyses indicate a significant increase in plant growth in amended sites compared to controls for both grass species. In addition, during harvest the presence of a highly invasive non-native plant, *Melilotus* (both *M. alba* and *M. officinalis*), was observed to be the dominant taxon colonizing exposed tailings and sand substrates in the area of our trials. A greenhouse study was implemented examining the capacity of the high-ash biochars utilized as treatments in this study to bind the allopathic compounds released by *Melilotus* in order to further understand the mechanisms driving the observed increases in growth of plants in amended plots. Statistical analysis indicated that biochar positively affected seed germination and early seedling growth indicating sorption of the allelopathic compounds. The close proximity of the vast majority of Canadian mine sites to the boreal forest and associated timber mills provides a logistical and economic incentive for the investigation of this potential resource. This study is the first of its kind in a Northern boreal ecosystem and the initial results are extremely promising for future applications of biochar in both mine reclamation and invasive species management.

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Rehabilitation plans for the Goudreau open pits: Part 1 – History and the way forward.

Steven Aiken, Ryan Tibbles, and Andy Phillips (Knight Piesold Ltd.) and Fred Post (Algoma Inc.)

The Goudreau Iron Range Property (Iron Range) is located next to the former town of Goudreau, Ontario approximately 10km southeast of Dubreuilville, and 35 km northeast of Wawa, Ontario. The Iron Range includes five historical deposits including; the A-Pit, Bear Pit, C-Pit, C-Pit Extension and Rand No. 1 deposits. Mining operations occurred in the 1910s up to the early 1960’s with shipments of greater than 1.2 million tonnes of iron ore, as pyrite, over that period. The pits were left exposed, generating acid and affecting water quality for many years. The Rand No. 1 Pit was rehabilitated in the late 1990’s by backfilling the pit with waste rock and by-products from steel manufacturing.

The rehabilitation efforts resulted in significantly improved water quality and the mitigation of safety hazards including steep, exposed pit walls. A comprehensive field investigation was completed in 2015 of the four remaining pits. The investigation included visual inspections of the pits, characterization of waste rock stockpiles, borrow source assessments, hydrology measurements, and water quality sampling of the in pit water and the downstream environment.

Plans have been developed to rehabilitate the four remaining pits, associated waste rock stockpiles and historic concrete mining infrastructure. The plans, based somewhat on the Rand No. 1 pit rehabilitation success, incorporate backfilling the pits with waste rock from the area, local borrow materials and steel making by-products. The design will raise the groundwater level in the backfilled pits to submerge the waste rock and part of the pit walls. One pit is only marginally acidic and will be treated in-situ and not backfilled. Rehabilitation of the other pits will mitigate the pit wall hazards, remove the concrete mine infrastructure, and dramatically improve water quality in the long term.

Rehabilitation plans for the Goudreau open pits: Part 2 – Water quality issues and management.

Derek Amores, Daniel Skruch, Sarah Barabash and R.V. (Ron) Nicholson (EcoMetrix Incorporated) and Fred Post (Algoma Inc.)

The Goudreau Iron Range Property (Iron Range) is located next to the former town of Goudreau, Ontario approximately 10 km southeast of Dubreuilville, and 35 km northeast of Wawa, Ontario. The Iron Range includes five historical deposits including; the A-Pit, Bear Pit, C-Pit, C-Pit Extension and Rand No. 1 deposits. Mining operations occurred in the 1910s up to the early 1960s with shipments of greater than 1.2 million tonnes of iron ore, as pyrite, over that period. Mining in the 1910s occurred dominantly at the C-Pit deposit whereas mining in the late 1950s and early 1960s was focused at the A-Pit, Bear Pit, C-Pit, and C-Pit Extension deposits. A comprehensive field investigation was completed in 2015. The investigation included: visual inspection of the pits and surrounding areas that included associated deposits of waste rock as well as the immediate downstream environment; bathymetry of the water-filled pits; sampling and characterization of the waste rock deposits; stream flow measurements at selected locations; and, water sampling, including the water-filled pits and associated downstream stations. The existing water quality conditions in and downstream of the pits were assessed. The results from the acidic pit waters were used to develop design criteria for in-pit treatment to allow dewatering and backfilling for rehabilitation. The waste rock was characterized to develop design criteria for amendment with lime to neutralize stored acidity prior to relocation of the rock to the pits. The steel making by-products were characterized to develop design criteria for use as supplemental backfill materials in the pits. One pit was only marginally acidic and will be treated and allowed to remain water filled after removing the sources of acidic drainage associated with the local waste rock. Rehabilitation is expected to dramatically Improve downstream water quality in the long term.

Rehabilitation of orphan tailings and soil cover construction at a decommissioned copper mine site.

Michael Gunsinger, Ken Bocking, George Schneider, Andrew Forbes, and Ken De Vos (Golder)

A former copper mine site operated during the ′50's and ′60's generated about 1.35 million tonnes of tailings as part of the ore beneficiation processes. The majority of the tailings were deposited into two main Tailings Management Areas (TMAs), but 'orphan' tailings were also determined to be present in subaerial locations outside of the main TMAs. The upper zone of the orphan tailings were oxidized due to exposure to atmospheric conditions since the end of operations. Geochemical investigations determined that the orphan tailings, in particular the upper-most oxidized tailings, were generating acidity and a source of soluble metals. Water quality analyses indicated that the drainage that flows through the orphan tailings areas was being affected by the presence of soluble metals in the orphan tailings. A rehabilitation plan was developed for the orphan tailings to mitigate further tailings oxidation and improve the quality of drainage. To achieve these objectives, a design-build rehabilitation project was carried out to relocate about 51,000 m3 of the orphan tailings to a 1.9 ha Tailings Relocation

Area (TRA) within one of the main TMAs. This was followed by construction of a multilayer soil cover system over the relocated tailings. The soil cover system was designed to maintain a high degree of saturation in the performance layer in order to: i) act as a barrier to oxygen ingress and therefore mitigate further tailings oxidation, and ii) reduce infiltration into the tailings, promote interflow and lateral drainage during periods of higher precipitation. Post-rehabilitation monitoring included evaluating the performance of the soil cover system and collection of water quality samples. The monitoring indicates that the soil cover is mitigating oxygen influx into the relocated tailings by maintaining an average degree of saturation greater than 85% in the oxygen diffusion barrier layer. Water quality monitoring shows improvement to the chemistry of the surface water flowing through the former orphan tailings areas.

Construction of a capillary barrier cover for reactive mine waste management utilizing municipal biosolids.

Christopher Hey and Paul Simms (Carleton University)

Management of reactive mine tailings and mitigation of acid rock drainage has conventionally utilized water covers or solid soil covers to limit oxygen diffusion and oxidation of tailings materials. Potential for impoundment failures when utilizing water covers, and the high cost of clay and aggregate materials in the construction of soil covers have spurred the development of alternative solutions. Current studies are evaluating the suitability of municipal biosolids for use in capillary barrier covers to effectively manage acid generating tailings.

Three phases of study have been undertaken to determine the potential for municipal biosolids to be used in the construction of a capillary barrier cover as a free alternative to costly clay materials.

The first phase of study involved characterizing the tailings materials and cover components: sand, municipal biosolids, and amendment materials. Low saturated hydraulic conductivities were observed in biosolids during material characterization (k = 4.21×10^{-7} cm/s), and high degrees of saturation have been shown to be maintained at elevated suctions indicating high moisture retention properties.

The second phase determined appropriate cover layer thicknesses using one dimensional numerical modelling with Soil Vision's SV-Flux software. Modelling was also conducted to observe whether the biosolids layer could effectively maintain saturation and mitigate oxygen diffusion. Numerical modelling results indicate a robust saturated layer can be maintained over a 91-day simulation.

The modelling results were used to develop laboratory scale column tests to observe the capillary barrier function when utilizing a 15cm layer biosolids sandwiched between sand layers. The column tests are ongoing, but are expected to demonstrate proof of concept at a laboratory scale. Potential cost savings related to the findings include a reduction in landfill disposal of biosolids, and reduced cost in tailings cover construction.

Heart of a Mountain – Soul of a Town: The Story of Algoma Ore and the Town of Wawa.

Joanna Rowe

From ancient copper mining to 100 years of iron ore extraction, the haunted islands and massive mountains surrounding Wawa echo with the voices of miners from all races and religions searching for their fortunes.

Local historian and author Johanna Rowe will lead you through a History 101 of the rich mining legacy in Wawa including:

- Superior copper
- Wawa's mini-Klondike
- A century of iron ore extraction
- Mining ingenuity and innovation
- Wawa's colourful prospectors
- Diamonds in the rough

Effect of *Typha latifolia*, *Carex lacustris* & *Juncus canadensis* on iron and sulfur dynamics and associated microbial community in a floating treatment wetland.

Varun Gupta, John Gunn, and Nadia Mykytczuk (Vale Living the Lakes Centre, Laurentian University)

The use of natural wetland systems for the passive treatment of mining process waters and waste drainage is an effective means of reducing contaminant transmission into the environment. The long-term sustainability of a treatment wetland is dependent on the polishing and contaminant retention capacity of the physical and biological components of the system. A better understanding of the biological processes that drive metal biogeochemical cycling within the plant and sediment associated microbial communities is an important component of building mitigation strategies in controlling storage and release of acidity and metals. Our research targeted biotic (plants and microbes) and abiotic factors that affect iron and sulfur transformation in a constructed wetland. We development floating wetlands that were capable of reductive processes. The floating wetlands were deployed for a two years period in a large water body directly impacted by mine drainage at two different sites. Porewater samples were collected and analysed for ferrous/ferric iron, sulfide/sulfate, dissolved oxygen and oxidative-reductive potential. Soil samples were collected and analysed for total community analysis (Illumina-MiSeq) and targeted qPCR for sulfate reducers, sulfur oxidizer and iron reducers. Both, *Typha latifolia* and *Carex lacustris* exhibited high hydrogen sulfide and/or ferrous iron concentration in porewater, suggesting reductive environment. While, *Juncus canadensis* had high sulfate porewater concentration, suggesting oxidizing environment. However, preliminary microbial analysis is showing little variation among vegetation types. Here I will present the synthesis of my finding and elucidate on the interaction effect of plants and microbes and how it effects iron and sulfur dynamics.