B04: Mine reclamation: Multidisciplinary studies from across mining sectors

Conveners: Matthew B. J. Lindsay[1] , Lesley A. Warren[2] , and Sean K. Carey[3]

Co-chairs: Matthew B. J. Lindsay[1] , Lesley A. Warren[2] , and Sean K. Carey[3]

[1] Dept. of Geological Sciences, University of Saskatchewan, Saskatoon, SK, S7N 5E2 Phone: 306-966-5693 Fax: 306-966-8593, E-mail: matt.lindsay@usask.ca
[2] Dept. of Civil Engineering, University of Toronto, Toronto, ON, M5S 1A4 Phone: 416-978-5978 Fax: 416-978-6813, E-mail: lesley.warren@utoronto.ca
[3] School of Geography & Earth Sciences, McMaster University, Hamilton, ON, Phone: 905-525-9140 Fax: 905-546-0463, E-mail: careysk@mcmaster.ca

Session Description

Mine reclamation presents considerable challenges for all sectors of the mining industry. Mine wastes stored in reclamation landscapes are in an initial state of chemical, biological and physical disequilibrium, and associated risks to the surrounding environment are often uncertain. Although various reclamation approaches are employed across the mining sector, common short- and long-term challenges include: (1) preventing or minimizing contaminant release; (2) predicting contaminant fate and transport; and (3) achieving measureable environmental improvements. Addressing these and other challenges requires a thorough understanding of interconnected physical, chemical and biological processes. The goal of this session is to bring together hydro(geo)logists, (bio)geochemists, and other reclamation researchers and practitioners to advance our understanding of mine reclamation. Contributions focused on oil sands, metal, and other mining sectors are thus encouraged.

Primary Affiliations: Biogeosciences / Hydrology

NOTE: THIS DOCUMENT CONTAINS INFORMATION FOR ALL SESSION SUB-SECTIONS. PRESENTER ABSTRACTS ARE FOUND AT THE END OF THE DOCUMENT.

SCHEDULE MAY BE SUBJECT TO CHANGE.

ORAL SESSION B04a
Chairs: Matthew B. J. Lindsay, Lesley A. Warren, and Sean K. Carey

Room: AERL 120, Monday, May 29th

TIME	AUTHORS	TITLE
9:00	D. Heisler, C. Wytrykush, T. Penner, & G. Halferdahl	Base Mine Lake: The First End-Pit Lake for the Alberta Oil Sands
9:15	G. Lawrence, E. Tedford, L. Irvine, S. Chang & R. Pieters	Seasonal Variation of Turbidity in Base Mine Lake
9:30	S.K. Carey & G.B. Drewitt	Multi-Year Water Balance and Gas Exchanges from an End Pit Lake, Fort McMurray, Alberta
9:45	E. Tedford, D. Hurley, R. Pieters, & G. Lawrence	Physical Limnology of Base Mine Lake
10:00	D.Hurley*, E. Tedford, R. Pieters, & G. Lawrence	Wind Waves in Base Mine Lake
10:15	J.D. Zettl, S.L. Barbour, M.B.J. Lindsay, & S.K. Carey	Base Mine Lake Chemical Mass Balance 2013-2016

ORAL SESSION B04b
Chairs: Matthew B. J. Lindsay, Lesley A. Warren, and Sean K. Carey

Room: AERL 120, Monday, May 29th

TIME	AUTHORS	TITLE
11:00	G.McKenna	Multidisciplinary Teams for Landform Design and Mine Reclamation
11:30	O. Sutton & J. Price	Simulating the Hydrologic Trajectory of a Constructed Fen Watershed, Athabasca Oil Sands Region, Alberta
11:45	M.C. Lukenbach, C.S. Spencer, C.A. Mendoza, K.J. Devito, S.M. Landhausser, S.K. Carey	Variably Saturated Flow Between Constructed Upland Hummocks and a Wetland in a Reclaimed Watershed Following Oil Sands Mining
12:00	S. DeMars*, A. Ireson, & L. Barbour	Importance of Winter Processes on Salt Redistribution in a Reclamation Cover
12:15	M.G. Clark*, E.R. Humphreys, S.K. Carey	Downscaling Eddy Covariance Measurements of Energy and Carbon Dioxide Fluxes in a Constructed Boreal Wetland

ORAL SESSION B04c
Chairs: Matthew B. J. Lindsay, Lesley A. Warren, and Sean K. Carey

Room: AERL 120, Monday May 29th

TIME	AUTHORS	TITLE
14:00	A.K. Hamilton, B.E. Laval, E.L. Petticrew, S.J. Albers, M. Allchin, S.A. Baldwin, E.C. Carmack, S.J. Déry, T.D. French, B. Granger, K.E. Graves, P.N. Owens, D.T. Selbie, & S. Vagle	Impact of a Catastrophic Mine Tailings Impoundment Spill on the Physical Limnology of Quesnel Lake, British Columbia, Canada: Two Years Post-Spill
14:15	D. Wilson*, R.T. Amos, D.W. Blowes, J.B. Langman, L. Smith, & D.C. Sego	Diavik Waste Rock Project: Development of an Integrated Conceptual Model of Mine Waste Rock Weathering for Scale-Up of Laboratory Experiment Results
14:30	F. Risacher*, P. Morris, D. Arriaga, C. Goad, G.F. Slater, & L.A. Warren	Early Water Cap Oxygen and Geochemical Developmental Trends within the First Oil Sands End Pit Lake, Base Mine Lake
14:45	Goad, C.*, Slater G.F, Arriaga, D., Risacher, F., Morris, P., Lindsay, M., Warren, L.A.	Methane Biogeochemical Cycling Over Seasonal and Annual Scales in an Oil Sands Tailings End Pit Lake
15:00	P. Morris*, F. Risacher, D. Arriaga, C. Goad, G. Slater & L.A. Warren	Depth Dependent Roles of Methane, Hydrogen Sulfide and Ammonia in Water Cap Oxygen Consumption within Base Mine Lake, the first Oil Sands End Pit Lake
15:15	D. Arriaga*, P. Morris, F. Risacher, C. Goad, G.F. Slater, & L.A. Warren	Physical and Geochemical Processes Affecting Water Cap Oxygen Concentrations within Base Mine Lake, the first Oil Sands End Pit Lake

ORAL SESSION B04d
Chairs: Matthew B. J. Lindsay, Lesley A. Warren, and Sean K. Carey

Room: AERL 120, Monday May 29th

TIME	AUTHORS	TITLE
16:00	Q. Liu*, S.B. Rudderham, M.B.J. Lindsay, & S.L. Barbour	Influences of Biogeochemical Processes on Mass Transport Across the Tailings-Water Interface of an Oil Sands End Pit Lake
16:15	G. Slater, D. Bowman, B. McCarry & L. Warren	Characterizing Naphthenic Acid Sources and Potential Processing during Oil Sands Tailing reclamation using Comprehensive Two-Dimensional Gas Chromatography
16:30	E. Asiedu*, A. Ulrich, W. Zubot, J.W. Martin	Predicting the Future of Oil Sands End Pit Lakes by Profiling of Organic Chemicals in

		Aged and Fresh Oil Sands Process-Affected Water Samples
16:45	B. Ma, D. Cologgi, & A. Ulrich	Naphthenic Acids' Degrading Consortia Enriched from Pristine Sediments Beneath an Oil Sands Tailings Pond
16:00	K. Wei, P. Kuznetsov, T. Siddique, & A. Ulrich[1]	Investigating Chemical Flux Across Oil Sands Fluid Fine Tailings-Water Interface in Meso-columns Simulating An End Pit Lake
16:15	M.R. Flynn, S. Balakrishna, O. Mohammed, E. Naikyar, & C. Surma	A Laboratory Experimental Study of Mudline Mixing: Implications for Water Clarity in End-Pit Lakes

POSTER SESSION B04
Chairs: Matthew B. J. Lindsay, Lesley A. Warren, and Sean K. Carey

Room: ESB Atrium, Tuesday May 30th

Poster No.	AUTHORS	TITLE
B04-06	D.L. Pratt & J.J. McDonnell	A Freezable Environmental Test Slope for Cold Regions Reclamation Cover System Studies
B04-08	X. Yu[*] & A. Ulrich	Role of Microbial Mats in Water Capped Tailings: Turbidity Removal and Chemical Flux Mitigation
B04-17	L.A. Swerhone[*], J.A. Nesbitt, VM.B.J. Lindsay	Geochemical Considerations for Including Petroleum Coke in Oil Sands Mine Closure Landscapes
B04-19	C.R.C. Cilia[*] C M.B.J. Lindsay	Assessing Salt Transport within Layered Oil Sands Mine Wastes: Field and Laboratory Experiments
B04-22	S.L. Strilesky[*], S.K. Carey, E.R. Humphreys, R.M. Petrone, G.B. Drewitt, & G. Sutherland	Filling in a Forest Patchwork: A Multi-Site Analysis of Conventional and Constructed Patches of the Canadian Boreal Forest
B04-23	C.J. Vessey[*] & M.B.J. Lindsay	Influence of Ion Exchange Reactions on Salt Migration in Oil Sands Reclamation Soil Cover Materials: Laboratory Column Experiments
B04-24	K. Dompierre, L. Barbour, & J. Zettl	Characterizing Mass Release from Oil Sands Fluid Fine Tailings with Multiple Tracers
B04-29	S. Chang[*], E. Tedford, & G Lawrence	Heat Budget and Fluxes at Base Mine Lake
B04-30	S.E. Irvine[*], M. Strack, & J.S. Price	DOC Transport in a Constructed Watershed in the Athabasca Oil Sands Region, Alberta
B04-31	S. Poon[*], J. Brandon, & A. Ulrich	A Mechanistic Study of CO_2-Induced Turbidity Reduction in Water Capped Tailings

SUBMITTED ABSTRACTS

B04-01: Base Mine Lake: The First End-Pit Lake for the Alberta Oil Sands

Dallas Heisler[1], Carla Wytrykush[2], Tara Penner[2], and Geoff Halferdahl[3]

[1]Reclamation and Closure, Research and Development, Syncrude Canada Ltd., Edmonton, AB, T6N 1H4, Email: Heisler.Dallas@syncrude.com, Phone: 780-970-6910
[2]Reclamation and Closure, Research and Development, Syncrude Canada Ltd., Edmonton, AB, T6N 1H4
[3]Research and Development, Syncrude Canada Ltd., Edmonton, AB, T6N 1H4

Abstract
Alberta's oil sands are among the largest petroleum deposits in the world, containing 166 Bbbl of proven reserves. Extraction of bitumen from surface mined oil sands generates significant quantities of fluid fine tailings (FFT) and oil sands process water (OSPW). Managing the inventory is critical to the sustainability of the surface mineable oil sands industry and has been subject to escalating focus by industry, regulators and stakeholders. One technology for managing both FFT and OSPW involves placing these materials into a mined-out pit, forming an End-Pit Lake (EPL). More than 20 years of research, small-scale piloting in the Syncrude Test Ponds, and input from external experts has been used to design Syncrude's Base Mine Lake (BML). BML is the first full-scale demonstration of water capping tailings technology, containing 186 Mm^3 of FFT and 32 Mm^3 of OSPW in a 50 m deep, 7.7 km^2 mine pit. This presentation will provide an overview of BML and the monitoring program with subsequent presentations covering specific components of the BML Research program.

Presentation Type: Oral

B04-02: The Physical Nature of Fluid Fine Tailings Below Water in Base Mine Lake

Geoff Halferdahl[1], and Dallas Heisler[2]

[1]Research and Development, Syncrude Canada Ltd., Edmonton, AB, T6N 1H4,
E-mail: halferdahl.geoff@syncrude.com, Phone: 780-970-6933
[2]Reclamation and Closure, Research and Development, Syncrude Canada Ltd., Edmonton, AB, T6N 1H4

Abstract
Base Mine Lake (BML) is a demonstration of end-pit lake technology applied to open-pit oil sand mining reclamation practice. It initially sequestered about 186 Mm3 of Fluid Fine Tailings (FFT) below water forming most of the bottom of the lake. For 17 years prior to 2012, BML, a depleted oil sand open pit, was gradually filled with summer placement of FFT. Over time, the FFT will gradually dewater, settle and undergo self-weight geotechnical consolidation, reducing its initial thickness from an average of about 45 m to about 25 m as its void ratio decreases from its initial range of 2 to 6 to less than about 0.9. As FFT settles, the water depth, initially averaging about 8 m, will increase a corresponding amount. In places, the FFT has settled more than 5 m in 4 years with depressions developing in the FFT surface below water. This paper discusses the physical nature of BML FFT and its settlement over the first years of BML.

Presentation type: Oral

B04-03: Multi-year Water Balance and Gas Exchanges from an End Pit Lake, Fort McMurray, Alberta

Sean K. Carey[1] and Gordon B. Drewitt[2]

[1]School of Geography and Earth Sciences, McMaster University, Hamilton, ON, L8S 4K1, Email: careysk@mcmaster.ca, Tel: 905-525-9140 ext. 20134
[2]School of Geography and Earth Sciences, McMaster University, Hamilton, ON, L8S 4K1

Abstract
With over 30 end pit lakes (EPL) being proposed in oil sands closure plans to date, EPLs are critical elements in future post-mining landscapes. The first full-scale EPL demonstration is Base Mine Lake (BML) located at Syncrude Canada Limited's Mildred Lake mine. BML is a 7.7 km^2 water body constructed in a former mining pit with approximately 50 m of fluid fine tailings (FFT) at depth covered with an 8-10 m fresh water cap. The sustainability of EPLs in the closure landscapes, and the exchanges of mass and heat from them is unknown, but a critical scientific question required to address their long-term sustainability. Three water year balances (Nov 2013 – Oct 2016) have been calculated and water-atmosphere exchanges of gasses (H_2O, CO_2, CH_4) measured using the eddy covariance technique. The BML water balance is strongly controlled by management as water from an adjacent reservoir is pumped into BML and water is extracted back to mine operations. In the first three years since commissioning, managed inflows and outflows are the largest fluxes in the BML water balance. Snow and rain were the dominant non-managed inputs to BML as surface and groundwater contributions were small. Evaporation from the lake surface ranged between 350-425 mm, which is less than anticipated. This suppressed evaporation is hypothesized to be related to an intermittent hydrocarbon film on the lake surface. In each water year since November 2013, BML has had a water deficit and lake levels have dropped 335 mm, although management decisions largely control lake levels. The flux of CO_2 and CH_4 were measured during the open water period. An average daily CO_2 efflux of 3 g m^{-2} d^{-1} was observed, with no apparent biological uptake. CH_4 efflux is very large, averaging 700 mg m^{-2} d^{-1}. Over three years, there has been no apparent changes in greenhouse gas production from BML.

Presentation Type: Oral

B04-04: Physical Limnology of Base Mine Lake

Edmund Tedford[1], David Hurley[2], Roger Pieters[2,3], and Greg Lawrence[2]

[1]Department of Civil Engineering, University of British Columbia, Vancouver, BC, V6T 1Z4,
E-mail: ttedford@eos.ubc.ca, Phone: 778-829-9305
[2]Department of Civil Engineering, University of British Columbia, Vancouver, BC, V6T 1Z4
[3]Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, BC, V6T 1Z4

Abstract
We describe the physical limnology processes occurring in Base Mine Lake (7.7 km^2, depth ~10 m) in northern Alberta (57ºN). Temperature, conductivity and turbidity data were collected using moored instruments and by repeated profiling. In addition to the thermal stratification typically observed in natural fresh water lakes, Base Mine Lake exhibited a number of special features. In this presentation we will highlight three of these features:

1. We found strong seasonal variations in turbidity. During the summer the turbidity declines reaching an annual minimum of approximately 10 NTU at the surface. Throughout the fall turbidity rises reaching a maximum of approximately 400 NTU just before ice formation. Once ice forms turbidity rapidly drops to approximately 100 NTU. During spring mixing the turbidity rises to a maximum of approximately 400 NTU.
2. There was strong evidence of upward heat flux from the underlying **F**luid **F**ine **T**ailings (FFT) to the lower part of the water column particularly in the first two weeks immediately following ice-on. During this early under-ice period, near bottom water quickly rose in temperature from approximately 2ºC to the temperature of maximum density (~3.6ºC).
3. Salinity in the water increased throughout the winter at a rate which closely matches the predicted rate due to salt exclusion during ice formation. The prediction of the rate of salt exclusion required the inclusion of the insulating influence of snow.

The dynamical roles of heat transfer between the water cap and the underlying FFT, salinity exclusion from the ice, and suspended solids are discussed.

Presentation type: Oral

B04-05: Wind Waves in Base Mine Lake

David Hurley[1*], Edmund Tedford,[2] Roger Pieters,[2,3] and Greg Lawrence[2]

[1]Department of Civil Engineering, University of British Columbia, Vancouver, BC, V6T 1Z4,
E-mail: dlhurley@ncsu.edu, Phone: 778-323-6143
[2]Department of Civil Engineering, University of British Columbia, Vancouver, BC, V6T 1Z4
[3]Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, BC, V6T 1Z4

Abstract
Base Mine Lake (7.7 km^2), the first demonstration end pit lake in the Canadian oil sands, contains large quantities of fluid fine tailings (FFT), oil sands process affected water (OSPW) and environmental water. One feature of specific interest is the presence of hydrocarbons on the lake surfaces and their subsequent effect on the wind wave field. Since wind waves are the driving force behind many physical processes their modification has direct implications on the function of Base Mine Lake. In this research the wind waves are modelled numerically and examined in the laboratory and on Base Mine Lake. Utilizing the hydrodynamic modelling suite Delft3D coupled with SWAN the wind driven surface waves on Base Mine Lake were modelled. In situ measurements of wind and water level were used as model inputs and results were validated against field measurements of wave heights. A laboratory investigation into the effect of hydrocarbons on wind waves was conducted in a small wind wave flume and results of the laboratory work were compared with field observations of the wind waves in the presence and absence of hydrocarbons on Base Mine Lake. From the results of the numerical, laboratory, and field work it was found that wind waves have little potential to cause resuspension of the FFT in Base Mine Lake. It was also found that because the hydrocarbons modulate the wind wave field there may be a subsequent effect on the fluxes of gas, heat, and momentum.

Presentation type: Oral

B04-06: Base Mine Lake Chemical Mass Balance 2013-2016

Julie D. Zettl[1], S. Lee Barbour[2], Matthew B.J. Lindsay[3], and Sean K. Carey[4]

[1]Department of Civil, Geological and Environmental Engineering, University of Saskatchewan, Saskatoon, SK, S7N 5A9, E-mail: julie.zettl@usask.ca, Phone: 306-381-7448
[2]Department of Civil, Geological and Environmental Engineering, University of Saskatchewan, Saskatoon, SK, S7N 5A9
[3]Department of Geological Sciences, University of Saskatchewan, Saskatoon, SK, S7N 5E2
[3]School of Geography and Earth Sciences, McMaster University, Hamilton, ON, L8S 4K1

Abstract
End pit lakes (EPL) have been proposed for the storage of fluid fine tailings (FFT) as part of closure designs for oil sands mines in Alberta, Canada. A total of 30 EPLs have been proposed as part of the closure designs for various mine sites. The first full-scale EPL demonstration is located at Base Mine Lake (BML) at Syncrude Canada Limited, where approximately 50 m of FFT was covered with an 6m OSPW/ fresh water cap. Annual chemical mass balances have been carried out on BML from 2013-2016. The chemical mass inputs to BML include water pumped from a fresh water reservoir (Beaver Creek), precipitation, surface runoff as well as the mass associated with pore-water expressed from the underlying FFT as a result of settlement. The primary chemical mass output from the lake is water pumped from BML and returned to the extraction plant's recycled water circuit. The contribution of FFT settlement to mass loading of BML was calculated for a conservative tracer (i.e. chloride) for each water year and compared to estimates made directly from measurements of FFT settlement and FFT pore-water concentration. The chloride mass balance was then used to evaluate rates of mass transport from the FFT for non-conservative chemical species (e.g. sodium, calcium, magnesium, sulfate) based on observed FFT concentrations for these species. The concomitant mass balance within BML for these non-conservative species was then used to identify the gains or losses in mass that may be the result of geochemical processes within BML and the upper lake/FFT interface. Results indicated that FFT accounts for a major portion of mass loading to the BML water cover.

Presentation type: Oral

B04-07: Multidisciplinary Teams for Landform Design and Mine Reclamation

Gord McKenna[1]

[1]BGC Engineering Inc, Vancouver, BC, Canada, V6Z 0C8,
E-mail: gmckenna@bgcengineering.ca, Phone: 604-838-6773

Abstract

Traditional mine reclamation projects often rely on one or two reclamation specialists for planning, design, oversight of field implementation, and performance monitoring. But in the past two decades, project scales and reclamation performance expectations have grown. As mine reclamation moves out its artisanal stage and embraces design and construction at the landform / watershed scale, the use of multidisciplinary teams to guide this work is more common. Working in such a team, often over years or decades, is both rewarding and challenging. Most teams include a project manager, mining engineer, geotechnical engineer, surface water hydrologist, groundwater hydrologist, soil scientist, vegetation specialist, and a wildlife biologist. One of these specialists is the lead designer and takes ultimate responsibility for the design. Some teams will have other professionals that may include a climatologist, geomatics specialist, reclamation specialist, geochemist, forester, agrologist, fisheries biologist, limnologist, aquatic biologist, regulatory specialist, stakeholder-engagement specialist, water-treatment specialist, demolition expert, illustrator, landscape architect, and a cost estimator. Some teams actively involve regulators, Indigenous groups, and local communities to provide input, joint decision making, or even active participation in all stages of goal setting, investigation, design, construction, monitoring, and relinquishment. Often, the team will be involved with several different projects / landforms at a given site, each in a different stage. The team must learn to work together, with each person understanding each of the stages with enough cross-training and experience to understand and complement other members of the team. It can take three years for such a diverse and evolving team to become high-performing. An overview of the typical roles of these specialists is provided based on recent interviews with practitioners. Lessons on how a high-performing team works well together are also provided.

Presentation type: Oral (Invited)

B04-08: Simulating the Hydrologic Trajectory of a Constructed Fen Watershed, Athabasca Oil Sands Region, Alberta

Owen Sutton[1*] and Jonathan Price[2]

[1]Department of Geography and Environmental Management, University of Waterloo, Waterloo, ON, N2L 3G1, E-mail: ofsutton@uwaterloo.ca, Phone: 519-888-4567
[2]Department of Geography and Environmental Management, University of Waterloo, Waterloo, ON, N2L 3G1

Abstract
Reclaiming the post-mined landscape in the Athabasca Oil Sands Region (AOSR) to ecosystems of equivalent land capability has become both a matter of public interest and a statutory obligation for the major oil sands companies. In response to the legal obligation to investigate peatland reclamation, a pioneering constructed fen-upland watershed was designed and built on on a post-mined oil sands landscape. This system was designed to supply sufficient water to the fen even under the prolonged drought conditions common in the AOSR. In order to assess the suitability of the design to reclamation on the broader post-mined landscape it is necessary to understand the hydrologic trajectory of the system on a time-scale relevant to closure planning. HYDRUS 1-D was used to simulate soil water dynamics in the upland and determine average and standard deviation recharge to the tailings sand aquifer. Average recharge conditions were used in a Monte Carlo simulation to parameterize a three-dimensional MODFLOW model. Fifty-year transient simulations were conducted assuming a stationary climate. Given the uncertainty associated with predicting recharge under projected climate change, high recharge (+20%) and low recharge (-20%) scenarios were also simulated. Anticipated results include summary statistics on the components of the water budget and groundwater elevations of the system. Furthermore, this approach will allow for the generation of water table exceedance curves in the upland and fen under stable climate and the two recharge scenarios, which will directly provide information on the resilience of the design to climatic stressors.

Presentation type: Oral

B04-09: Variably Saturated Flow Between Constructed Upland Hummocks and a Wetland in a Reclaimed Watershed Following Oil Sands Mining

M.C. Lukenbach[1], C.S. Spencer[2], C.A. Mendoza[2], K.J. Devito[3], S.M. Landhausser[4], and S.K. Carey[5]

[1]Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB, T6G 2E3, E-mail: lukenbac@ualberta.ca, Phone: 587-341-3677
[2]Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB, T6G 2E3
[3]Department of Biological Sciences, University of Alberta, Edmonton, AB, T6G 2E3
[4]Department of Renewable Resources, University of Alberta, Edmonton, AB, T6G 2H1
[5]School of Geography and Earth Sciences, McMaster University, Hamilton, ON, L8S 4L8

Abstract
In reclaimed landscapes following oil sands mining, ensuring that hydrologic connectivity is adequate to provide necessary amounts of freshwater to wetlands is challenging due to the sub-humid climate of the region and salinity of available reclamation materials. In 2012, Syncrude Canada Ltd. constructed Sandhill Fen Watershed on a coarse-textured, soft tailings deposit to investigate reclamation strategies. One objective was to examine the ability of basin-scale upland hummocks to function as sources of water to the fen wetland. To evaluate this designed hydrologic function, hydrologic measurements (*i.e.* water levels, soil moisture, and matric potential) were collected along a series of wetland-upland hummock interfaces from 2013-2015 and coupled with numerical modelling using Hydrus 2D. Field and modelling results indicate that surface runoff is rare and water exchange at wetland-hummock interfaces primarily occurs via shallow groundwater flow. Furthermore, water movement at interfaces is largely dependent on position within the larger-scale groundwater flow system, climatic conditions, vegetation water demand, and soil properties. Upland hummocks located in up-gradient positions of the larger groundwater flow system relative to the wetland exhibit transient groundwater mounds at their bases (toes) immediately following wet periods (*e.g.* spring melt), while groundwater mounds underneath their centers (tops) lag these wet periods due to the asynchronous nature of recharge between the wetland, interface, and upland hummock. In contrast, groundwater mounds consistently form in the wetland when it is located in an up-gradient position of the larger groundwater flow system relative to upland hummocks. Modelling scenarios also indicate that the long-term successional trajectory of vegetation in the wetland and at the wetland-upland hummock interface will play a large role in determining water exchange. Therefore, it is critical to understand the configuration of the larger groundwater flow system and successional trajectories of vegetation when reclaiming landscapes to ensure adequate water availability.

Presentation Type: Oral

B04-10: Importance of Winter Processes on Salt Redistribution in a Reclamation Cover

Shelby DeMars[1*], Andrew M. Ireson[2], and S. Lee Barbour[3]

[1]Global Institute for Water Security, University of Saskatchewan, SK, S7N 3H5,
E-mail: shelby.demars@usask.ca, Phone: 306-361-3625
[2]Global Institute for Water Security, University of Saskatchewan, SK, S7N 3H5
[3]Department of Civil, Geological and Environmental Engineering, University of Saskatchewan, Saskatoon, SK, S7N 5A9

Abstract
Oil sands mining operations involve the removal of large volumes of saline-sodic shale overburden to access the oil sands. The overburden is placed in large above ground dumps and are subject to weathering which releases additional salts. The elevated salinity and sodicity of the overburden dumps create difficult conditions for vegetation growth as well as increasing the risk of salinization of down gradient soils and wetlands. Reclaiming these overburden deposits to re-establish ecosystems similar to those prior to disturbance is a challenge for the industry. Currently, there a lack of understanding of the long-term release of salt from these dumps. Syncrude's South Bison Hill is a reclaimed upland saline-sodic shale overburden dump. The reclamation cover is comprised of a layer of salvaged peat-mineral mix overlying glacial mineral soil. The hydrological performance of the cover has been monitored since cover construction approximately 20 years ago. The current hydrological models for the reclamation cover have focused primarily on water dynamics during unfrozen conditions. Cold regions hydrological processes, including snow accumulation and melt, infiltration into frozen soils, and soil freezing and thaw, strongly influence the movement of water and solutes in the subsurface. Here, we explore the 20-year monitoring dataset to extend the hydrological model to better understand water dynamics during snow melt, with a particular focus on preferential infiltration of snowmelt into frozen soils. A combination of numerical modelling and field observations are used to develop a hydrological conceptual model which can be used to evaluate the long term release of salts from this landscape which incorporates cold region hydrological processes.

Presentation Type: Oral

B04-11: Downscaling Eddy Covariance Measurements of Energy and Carbon Dioxide Fluxes in a Constructed Boreal Wetland

M. Graham Clark[1*], Elyn R. Humphreys[2], Sean K. Carey[3]

[1]Department of Geography and Environmental Studies, Carleton University, Ottawa, ON, K1S 5B6, E-mail: MatthewGClark@cmail.carleton.ca, Phone: 613-520-2600 ext. 4125
[2]Department of Geography and Environmental Studies, Carleton University, Ottawa, ON, K1S 5B6
[3]School of Geography and Earth Sciences, McMaster University, Hamilton, ON, L8S 4K1

Abstract
The Sandhill Fen Watershed project in northern Alberta, Canada, is a reconstructed 60 ha mixed upland and lowland boreal plain ecosystem. The physical construction was completed in 2012, revegetation through both planting and seeding were completed in spring of 2013, and the low-lying areas were flooded in spring of 2013. From 2013 to 2015 the vegetation has developed a substantial surface coverage, but large open pools remain in some of the wettest regions of the lowlands. One construction goal is to promote a fen like system in the lowland region, with water tables near the salvaged peat surface to promote native wetland vegetation communities which are known to be favorable for peat development. Here the energy and mass fluxes are downscaled to determine the effect of revegetating a constructed wetland on the surface-atmosphere exchange. Downscaling was undertaken with the Kljun et al. (2015) Flux Footprint Prediction parameterization of the Kljun et al. (2002) backward Lagrangian model LPDM-B. Using downscaling methods derived in Crawford and Christen 2015 the proportional coverage of each surface was used to build an extrapolated estimate of the diurnal flux from both a 100% open water or vegetated surface. It was found that a closed canopy of emergent wetland species has a 40 % greater peak daily evaporative water loss than pools of open water which will likely lead to future water table drawdown in regions with standing water as the canopy continues to close. This work aims to help us understand the relative contribution of different wetland communities and ecosystem level construction techniques on water use and carbon sequestration, key factors in the eventual establishment of a peat-forming wetland.

Presentation type: Oral

B04-12: Impact of a Catastrophic Mine Tailings Impoundment Spill on the Physical Limnology of Quesnel Lake, British Columbia, Canada: Two Years Post-Spill

Andrew K. Hamilton[1], Bernard E. Laval[1†], Ellen L. Petticrew[2], Sam J. Albers[3], Michael Allchin[3], Susan A. Baldwin[4], Eddy C. Carmack[5], Stephen J. Déry[6], Todd D. French[2,6], Brody Granger[1], Kelly E. Graves[1], Philip N. Owens[6], Daniel T. Selbie[7], and Svein Vagle[5]

[1]Department of Civil Engineering, University of British Columbia, Vancouver, BC, V6T 1Z4, E-mail: blaval@civil.ubc.ca, Phone: 604-822-2204
[2]Geography Program, University of Northern British Columbia, Prince George, BC, V2N 4Z9
[3]Quesnel River Research Centre, University of Northern British Columbia, Likely, BC, V0L 1N0
[4]Department of Chemical and Biological Engineering, University of British Columbia, Vancouver, BC, V6T 1Z4
[5]Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, BC, V8L 5T5
[6]Environmental Science Program, University of Northern British Columbia, Prince George, BC, V2N 4Z9
[7]Cultus Lake Salmon Research Laboratory, Fisheries and Oceans Canada, Cultus Lake, BC, V2R 5B6

Abstract
On 4 August 2014, a breach of the Mount Polley mine tailings impoundment released large quantities of tailings, water, and scoured overburden into the West Basin (i.e., west of Cariboo Island) of Quesnel Lake. We present observations of the physical limnology of Quesnel Lake for 2 years post-spill. From August to November 2014 water column profiles showed the temperature, conductivity, and turbidity of the hypolimnetic waters of the West Basin remained elevated above historical values (6.5-7ºC vs 5ºC; 160 uS/cm vs 110 uS/cm, 10-1000 NTU vs <1 NTU historically), while the epilimnion was less impacted over this period (<120 uS/cm, <10 NTU). However, satellite imagery showed the colour and clarity of surface waters of the entire West Basin changed dramatically from clear blue to cloudy green by 11 November 2014, indicating turbid hypolimnetic water was entrained to the surface during fall turnover. The colour change persisted for several weeks, gradually diminishing over the winter of 2014/15. Following spring turnover in 2015 turbidity in the West Basin had decreased to <1.5 NTU over the full water column and the temperature and conductivity of the hypolimnetic waters had decreased close to historic levels (<5ºC, <120 uS/cm). During the remainder of 2015 and 2016 turbidity in the West Basin remained slightly elevated compared to the Main Basin. However, natural turbidity sources, particularly sediment inputs at Niagara Creek in the East Arm, created strong spatial variability throughout the Main Basin.

Presentation type: Oral

B04-13: Diavik Waste Rock Project: Development of an Integrated Conceptual Model of Mine Waste Rock Weathering for Scale-Up of Laboratory Experiment Results

David Wilson[1*], Richard T. Amos[2], David W. Blowes[3], Jeff B. Langman[4], Leslie Smith[5], and David C. Sego[6]

[1]Department of Earth and Environmental Sciences, University of Waterloo, Waterloo, ON, N2L 3G1, E-mail: dwilson2@uwaterloo.ca, Phone: 519-820-1277
[2]Department of Earth Sciences, Carleton University, Ottawa, ON, K1S 5B6
[3]Department of Earth and Environmental Sciences, University of Waterloo, Waterloo, ON, N2L 3G1
[4]Department of Geological Sciences, University of Idaho, Moscow, ID 83844
[5]Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, BC V6T 1Z4
[6]Department of Geotechnical and Geoenvironmental Engineering, University of Alberta, Edmonton, AB T6G 2R3

Abstract
The laboratory and field-scale experiments comprising the Diavik Waste Rock Project (DWRP) were designed with a primary objective of development of a versatile, mechanistic scale-up strategy to assess the weathering evolution of mine wastes. Weathering rates of sulfide minerals determined in laboratory experiments (i.e., humidity cells) are often used in conjunction with empirical factors to predict the weathering evolution of mine wastes; however, empirical factors commonly fail to adequately capture the complex components of waste rock weathering. As part of the DWRP, a series of long-term humidity cell experiments was conducted to assess the weathering of waste rock produced at Diavik Diamond Mine, NT (Diavik). A conceptual model of sulfide mineral weathering for the humidity cell experiment was implemented using reactive transport code MIN3P. The focus of the reactive transport simulations was to evaluate and refine the conceptual model of long-term weathering of Diavik waste rock and subsequently optimize the simulations for prediction of the weathering evolution of Diavik waste rock under *in situ* conditions. The humidity cell experiments were conducted using varying sulfide content and temperature conditions, which facilitated quantification of the influences of sulfide mineral content and temperature on solute release rates via the reactive transport simulations. The simulations helped to identify the importance of precipitation of secondary minerals including, iron hydroxysulfate and iron hydroxide minerals, and sorption of ions including Ni, Co, Cu, and Zn, which influenced the temporal release of metals. The humidity cell simulations resulted in development of an integrated conceptual model of sulfide mineral weathering that can be used to assess the geochemical evolution of waste rock at the larger DWRP field experiments.

Presentation type: Oral

B04-14: Early Water Cap Oxygen and Geochemical Developmental Trends within the first Oil Sands End Pit Lake, Base Mine Lake

Florent Risacher[1*], Patrick Morris[2], Daniel Arriaga[2], Corey Goad[2], Greg F. Slater[2], and Lesley A. Warren[3,2]

[1]School of Geography and Earth Sciences, McMaster University, Hamilton ON, L8S 4K1, E-mail: risachef@mcmaster.ca, Phone: 905-525-9140 ext. 24815
[2]School of Geography and Earth Sciences, McMaster University, Hamilton ON, L8S 4K1
[3]Department of Civil and Mineral Engineering, University of Toronto, Toronto, ON, M5S 1A4

Abstract:
Syncrude Canada is currently assessing the use of water capped tailings technology as a reclamation strategy for fluid fine tailings (FFT). Base Mine Lake (BML) is the first commissioned demonstration end pit lake (EPL) in the Alberta Oil Sands and thus lessons learned from this system will inform future EPL design. For an EPL to be successful, the overlying water cap must develop sufficient oxygenation to support higher level aquatic biota. FFT contains a variety of redox reactive reduced compounds such as CH_4, NH_4^+, ΣH_2S, and Fe^{2+}, which, if mobilized into the water cap will impact water cap oxygen status. Our objectives were to compare the physico-chemistry and redox biogeochemistry of the BML water cap over two summers (2015 and 2016) and determine the key factors influencing oxygen status within this system. We hypothesized that ongoing dewatering of the underlying FFT layer, which expresses salts and heat into the water cap would limit thermal stratification and that mobilization of reductants from the FFT layer would deplete oxygen within the water cap during this early stage of BML. Physico-chemical survey (°C, O_2, conductivity, pH, ORP) data and samples for geochemical characterization (CH_4, DOC, ΣH_2S, SO_4^{2-}, Fe^{2+}, Fe^{3+}, NH_4^+, NO_2^-, NO_3^-) were collected weekly during summer stratification in both years. Results identify that BML thermally stratifies creating geochemical zonation within the water cap. Oxygen profiles were consistent with the FFT as a source of O_2 consuming compounds: epilimnetic oxygen saturation values (65-75%, 2015 and 80-90%, 2016) rapidly decrease through the metalimnion to low (2-5% saturation), but persistent O_2 at the FFT-water interface (~ 10 m depth). Modeling of the 2015-2016 geochemical results identified a trend of dominantly CH_4 influencing oxygen concentrations in 2015 however NH_3 in addition to CH_4 is important in determing O_2 values in 2016. These results and their implications for oil sands EPL design will be discussed.

Presentation type: Oral

B04-15: Methane Biogeochemical Cycling Over Seasonal and Annual Scales in an Oil Sands Tailings End Pit Lake

Corey Goad[1*], Greg F. Slater[2], Daniel Arriaga[2], Florent Risacher[2], Patrick Morris[2], Matthew B.J. Lindsay[3], and Lesley A. Warren[4,2]

[1]School of Geography and Earth Sciences, McMaster University, Hamilton, ON, L8S 4K1, E-mail: goadca@mcmaster.ca, Phone: 905-510-6250
[2]School of Geography and Earth Sciences, McMaster University, Hamilton, ON, L8S 4K1
[3]Department of Geological Sciences, University of Saskatchewan, Saskatoon, SK, S7N 5E2
[4]Department of Civil and Mineral Engineering, University of Toronto, Toronto, ON, M5S 1A4

Abstract
Bitumen extraction in the Alberta Oil Sand Region (AOSR) produces tailings that are being managed as part of both terrestrial and aquatic reclamation activities. Syncrude Canada Ltd. has undertaken the first full scale test of water-capped tailings reclamation of Fluid Fine Tailings (FFT) via the development of an end pit lake: Base Mine Lake. This study investigated biogeochemical cycling of microbial methane produced within the FFT and released to surface waters during the initial stages of lake development via concentration, isotopic and phospholipid fatty acids (PLFA) analysis. Dissolved methane was observed in the hypolimnion at concentrations that varied temporally from circa 25 to 140 μM. Methane concentrations dropped to below 1 μM in the metalimnion and epilimnion. This trend was opposite to that observed for oxygen which decreased from 75% saturation in the epilimnion to 1-2% in the hypolimnion. Dissolved methane concentrations in the FFT reached saturation within ~0.5m of the FFT-water interface. Stable carbon and hydrogen isotope analyses ($\delta^{13}C$, $\delta^{2}H$) of dissolved methane in the FFT ranged from -60 to -70 ‰ and -298 to -349 ‰ respectively, indicating production via fermentation. Isotopic enrichments in the $\delta^{13}C$ with decreasing concentration were consistent with methane oxidation in the water column. Water column cellular biomass estimates based on PLFA concentrations were generally 3 to 6 $\times 10^5$ cells/mL, with an increase to 2 $\times 10^6$ cells/mL in August/Sept 2015. $\delta^{13}C$ of pooled C16:1 PLFA, which includes the methanotroph biomarker C16:1ω8c were highly depleted (-60 to -40 ‰) in the hypolimnion indicative of utilization of methane derived carbon. The general PLFA C16:0 was likewise depleted in the hypolimnion (-45 to -35 ‰) indicating transfer of methane derived carbon to the rest of the microbial community. Ongoing research is focussed on trends in these parameters as lake development continues in order to assess the potential for continued influence of methane production and release on the system.

Presentation type: Oral

B04-16: Depth Dependent Roles of Methane, Hydrogen Sulfide and Ammonia in Water Cap Oxygen Consumption within Base Mine Lake, the first Oil Sands End Pit Lake

Patrick Morris[1*], Florent Risacher[2], Daniel Arriaga[2], Corey Goad[2], Greg F. Slater[1], and Lesley A. Warren[3,2]

[1]School of Geography and Earth Science, McMaster University, Hamilton, ON, L8S 4K1, E-mail: morrip1@mcmaster.ca, Phone: 905-525-9140 ext. 42815
[2]School of Geography and Earth Science, McMaster University, Hamilton, ON, L8S 4K1
[3]Department of Civil and Mineral Engineering, University of Toronto, Toronto, ON, M5S 1A4

Abstract
Syncrude Canada Limited's Base Mine Lake (BML) is the first commissioned end pit lake (EPL) within the Alberta oil sands (Fort McMurray, AB). BML consists of a ~ 40 m layer of fluid fine tailings (FFT) capped with a ~10 m mixture of fresh and oil sands process waters. For an EPL to be a viable component of the closure landscape, it should be able to support macrofauna; i.e. an oxic zone must develop and persist within the water cap. Early developmental stage water cap physico-chemistry and geochemistry from 2015 and 2016 indicate that while oxygen consuming constituents (OCC) such as methane, ammonia and reduced sulfur and iron containing compounds are mobilized from the FFT, oxygen does persist down to the FFT-water interface within the summer stratified water cap. Here the objectives were to characterize the water cap physico-chemistry and geochemistry at high depth resolution (10 cm intervals over 2 meters) to further investigate the redox biogeochemical processes consuming O_2 specifically within the FFT-water interface and metalimnetic zones. Using a pneumatically controlled piston sampler, water samples were collected in August of 2016 and redox sensitive species (i.e. CH_4, DOC, ΣH_2S, Fe^{2+} and Fe^{3+}) were preserved immediately while the remaining sample was stored at 4°C and analyzed within 48 hours of collection for NH_4^+, NO_2^-, NO_3^- and SO_4^{2-}. Results identify dissolved CH_4, ΣH_2S and NH_4^+ are important to oxygen consumption at the FFT-water interface where oxygen is typically < 10 μM. In contrast, only NH_4^+ persists up into the metalimnion where evident nitrification is occurring associated with oxygen consumption. These results and their implications for BML biogeochemical cycling will be discussed.

Presentation type: Oral

B04-17: Physical and Geochemical Processes Affecting Water Cap Oxygen Concentrations within Base Mine Lake, the First Oil Sands End Pit Lake

Daniel Arriaga[1*], Patrick Morris[2], Florent Risacher[2], Corey Goad[2], Greg F. Slater[2], and Lesley A. Warren[3,2]
[1]School of Geography & Earth Sciences, McMaster University, Hamilton, ON, L8S 4K1, E-mail: arriagd@mcmaster.ca, Phone: 905-525-9140 ext. 2330
[2]School of Geography and Earth Science, McMaster University, Hamilton, ON, L8S 4K1
[3]Department of Civil and Mineral Engineering, University of Toronto, Toronto, ON, M5S 1A4

Abstract
Syncrude Canada's Base Mine Lake (BML), is the first oil sands end pit lake (EPL) and is being used to evaluate the water-capped tailings technology for fluid fine tailings (FFT) management. The key to the viability of EPL as a reclamation strategy, will be the development of the water chemistry such that the water is capable of supporting higher-level aquatic biota. We hypothesized that BML is a bottom-driven system, where the FFT-water interface will exert a significant impact on the oxygen concentration throughout the water cap, associated with mobilization of oxygen consuming constituents (OCC), such as CH_4 and other organics, NH_4^+, $\sum H_2S$, and Fe^{2+}. The objectives of this study were to investigate the oxygen mass balance in the BML summer stratified water cap (July- September 2016) using observed oxygen concentrations measured using a multiparameter probe and oxygen consumption rates (OCR) determined using specially adapted oxygen chambers; and to identify important OCC involved in oxygen consumption. The BML water cap is thermally stratified during the summer with ~84% O_2 saturation in the epilimnion. Oxygen rapidly decreases through the metalimnion to ~ 10% and decreases to ~ 2-3% saturation at the FFT-water interface (~10 m water cap depth). Consistent with our hypothesis, the highest OCR were observed directly at the FFT-water interface while epilimnetic and metalimnetic OCR values were similar and an order of magnitude lower. These results along with geochemical results highlighting the importance of CH_4 and NH_4^+ and water cap oxygen mass balance will be discussed in light of their implications for EPL design.

Presentation type: Oral

B04-18: Influences of Biogeochemical Processes on Mass Transport Across the Tailings-Water Interface of an Oil Sands End Pit Lake

Qingyang Liu[1*], Sarah B. Rudderham[1], Matthew B.J. Lindsay[2], and S. Lee Barbour[3]

[1]Department of Geological Sciences, University of Saskatchewan, Saskatoon, SK
[2]Department of Geological Sciences, University of Saskatchewan, Saskatoon, SK, S7N 5E2,
E-mail: matt.lindsay@usask.ca, Phone: 306-966-5693
[3]Department of Civil, Geological and Environmental Engineering, University of Saskatchewan, Saskatoon, SK, S7N 5A9

Abstract
Oil sands end pit lakes (EPLs) are mine closure landscapes that contain fluid fine tailings (FFT) beneath a water cover within decommissioned open pits. Tailings settlement promotes progressive deepening of the water cover with a concomitant increase in lake capacity. However, settlement is accompanied by chemical mass release with the expressed tailings pore water, which can limit improvements in water cover quality over time. Although biogeochemical processes enhance FFT settlement and dewatering, their potential influence on chemical mass transport across the tailings-water interface is largely unknown. Research conducted in 2015 and 2016 at Base Mine Lake (BML) – the first commercial-scale demonstration EPL in the oil sands region of northern Alberta, Canada – examined relationships between biogeochemical processes and mass transport. Samples were collected at 0.1 m spacing over a 3.0 m depth interval across the tailings-water interface. Pore-water pH sharply decreased with depth from 8.2 to below 7.8 across the interface, and subsequently to less than 7.4 deeper in the FFT. Dissolved Fe exhibited maximum concentrations up to 60 $\mu g\ L^{-1}$ only 0.1 m below the interface, while SO_4 concentrations decreased from $> 150\ mg\ L^{-1}$ to $< 20\ mg\ L^{-1}$ over a 0.2 m depth interval across the interface. This sharp Fe increase and SO_4 decrease corresponded to a peak in dissolved H_2S concentrations of up to $1\ mg\ L^{-1}$. Finally, dissolved CH_4 concentrations generally reached or approached saturation within the upper 1 to 2 m of tailings. Results indicated that carbonate-mineral dissolution, ion exchange, reduction of Fe(III) hydroxides, and secondary Fe(II)-sulfide precipitation influence FFT pore-water chemistry immediately below the FFT-water interface. Overall, this research indicates that anaerobic respiration processes control pore-water pH and have potential to, not only enhance FFT settlement and dewatering, but also promote reactions that influence chemical mass transport across the tailings-water interface.

Presentation Type: Oral

B04-19: Characterizing Naphthenic Acid Sources and Potential Processing during Oil Sands Tailing reclamation using Comprehensive Two-Dimensional Gas Chromatography

Greg F. Slater[1], Dave Bowman[2], Brian McCarry[2] and Lesley A. Warren[3,4]

[1]School of Geography and Earth Sciences, McMaster University, Hamilton, ON, L82 4K1,
E-mail: gslater@mcmaster.ca, Phone: 905-525-9140 ext. 26188
[2]Department of Chemistry, McMaster University, Hamilton, ON, L82 4K1
[3]Department of Civil and Mineral Engineering, University of Toronto, Toronto, ON, M5S 1A4
[4]School of Geography and Earth Sciences, McMaster University, Hamilton, ON, L82 4K1

Abstract
Naphthenic acids (NAs) are persistent, toxic contaminants that are found to accumulate in oil sands process water (OSPW) and fluid fine tailings during bitumen extraction. A number of strategies for the reclamation of oil sands tailings are currently being tested, including the development of the first end pit lake system by Syncrude Canada, Base Mine Lake. An important component of reclamation activities is understanding the source and cycling of naphthenic acids within such reclamation systems. However, naphthenic acids exist as a highly complex mixture of thousands of compounds which makes their analysis an ongoing challenge. Comprehensive two-dimensional gas chromatography coupled to time of flight mass spectrometry has the potential to provide insight into the naphthenic acids present in environmental samples and potentially to enable fingerprinting of NA sources and/or assessment of the occurrence of biodegradation. Our initial work has focused on the identification of abundant, chromatographically resolved NAs. Distributions of isomers of a set of selected elemental compositions were then compared between water samples obtained from the water column and fluid fine tailings porewater in Base Mine Lake, Alberta Canada. Our initial results show that the distributions of the selected isomers are highly consistent in BML surface water, and that initial FFT pore water samples are highly distinct from surface water distributions. Semi-quantitative assessment of total concentrations of the set of NA elemental formulas investigated were either the same or higher in FFT porewater as compared to surface water. Increased concentrations in the FFT porewater were in some cases driven by differences in a small number of isomers. Our ongoing work will focus on assessing whether the differences between surface water and FFT porewater reflect differences in NA sources, or indicate the role of biodegradation of certain isomers.

Presentation type: Oral

B04-20: Predicting the Future of Oil Sands End Pit Lakes by Profiling of Organic Chemicals in Aged and Fresh Oil Sands Process-Affected Water Samples

Evelyn Asiedu[1*], Ania Ulrich[2], Warren Zubot[3], Jonathan W. Martin[4]

[1]Division of Analytical and Environmental Toxicology, Department of Laboratory Medicine and Pathology, University of Alberta, Edmonton, Alberta Canada, T6G 2G3,
E-mail: easiedu@ualberta.ca, Phone: 7804921673.
[2]Department of Civil and Environmental Engineering, University of Alberta, Edmonton, Alberta Canada, T6G 2G3
[3]Syncrude Canada Ltd., Edmonton Research Centre, 9421-17 Avenue, Edmonton, Alberta, Canada T6N 1H4
[4]Division of Analytical and Environmental Toxicology, Department of Laboratory Medicine and Pathology, University of Alberta, Edmonton, Alberta Canada, T6G 2G3

Abstract
For the first time, a thorough review of the organic profiles of oil sands process-affected water (OSPW) from Syncrude Canada Limited has been completed using high pressure liquid chromatography-ultra high resolution Orbitrap mass spectrometry in both positive and negative mode. Three types of OSPW were compared in an attempt to identify the most persistent chemical classes. Three 'aged' samples from experimental ponds (aged at least 25 years) were used as surrogate projections of future OSPW. 'Fresh' OSPW samples (4) were taken from active tailings ponds. Additionally, surface water sampled in 2014 from the first oil sands end pit lake (Base Mine Lake, BML) was also analyzed. Principal components analysis was able to distinguish OSPW types by relative contribution of acidic chemical classes (negative mode). Fewer species were detected in aged OSPW samples, and the oldest samples had the lowest concentrations of organics. Oxygen-containing acids (including naphthenic acids (NAs), O_2^-species) dominated the profile of fresh OSPW whereas in aged OSPW, the mono-oxygenated naphthenic acids (O_3^- species) and NAs had similar relative contributions. Dissolved organic compounds detected in positive mode may have slower rates of degradation than their acidic counterparts, with O_2^+demonstrating the least variation in concentrations across all OSPW types, suggesting this to be a persistent class. Chromatography, however, revealed that many O_2^+ species include two or more distinct isomers groups- some of which are completely absent in aged OSPW. Nitrogen and sulfur-containing organics were nearly absent from the profiles of aged OSPW. Lower concentrations of total organics in aged OSPW may indicate that BML OSPW will become less toxic in the future.

Presentation Type: Oral

B04-21: Naphthenic Acids' Degrading Consortia Enriched from Pristine Sediments Beneath an Oil Sands Tailings Pond

Bin Ma[1], Dena Cologgi[2], Ania Ulrich[2]

[1]Department of Civil and Environmental Engineering, University of Alberta, Edmonton, AB, T6G 2W2
[2]Department of Civil and Environmental Engineering, University of Alberta, Edmonton, AB, T6G 2W2, E-mail: aulrich@ualberta.ca, Phone: 780-492-8293

Abstract
Sediments underlying oil sands tailings ponds can provide a critical barrier for protecting groundwater from the potential risk of tailings water seepage. Previous studies have focused mainly on the biodegradability of naphthenic acids (NAs) in tailings ponds. Little is known about the potential for NAs degrading microbial communities in the native sediments underlying oil sands tailings ponds. This study enriched NAs degrading consortia from clay and sand sediments underlying an oil sands tailings pond under sulfate- and nitrate-reducing conditions. The results show that the nitrate-reducing consortia were significantly different from the sulfate-reducing consortia, but the similarity between the nitrate-reducing consortia in clay and sandy sediments was much higher than that between the sulfate-reducing consortia in clay and sandy sediments. The genera *Bellilinea, Rhizobium*, and *Methanosarcina* dominated in both nitrate- and sulfate-reducing consortia. *Geobacter* dominated in the clay sediment consortia under both nitrate- and sulfate-reducing conditions. *Thauera* dominated in the sandy sediment consortia under nitrate-reducing conditions, while *Desulfomicrobium* dominated in the sandy sediment consortia under sulfate-reducing conditions. NAs degradation was only observed in the nitrate-reducing consortia consisting of clay soils. The relative abundance of the genus *Steroidobacter* in this consortia was significantly higher as compared to other consortia, suggesting that *Steroidobacter* might play a critical role in NAs degradation under nitrate-reducing conditions. This study suggests that the clay sediment layer underlying oil sands tailings ponds could reduce the risk of groundwater contamination by NAs due to indigenous microbes capable of NAs degradation.

Presentation type: Oral

B04-22: Investigating Chemical Flux Across Oil Sands Fluid Fine Tailings-Water Interface in Meso-Columns Simulating an End Pit Lake

Kai Wei[1], Petr Kuznetsov[2], Tariq Siddique[2], and Ania Ulrich[3]

[1]Department of Civil and Environmental Engineering, University of Alberta, Edmonton, AB, T6G 2R3, Phone: 780-492-0248, E-mail: kwei1@ualberta.ca
[2]Department of Renewable Resources, University of Alberta, Edmonton, AB, T6G 2R3
[3]Department of Civil and Environmental Engineering, University of Alberta, Edmonton, AB, T6G 2R3

Abstract
In northeastern Alberta large volumes of fluid fine tailings (FFT) are produced during bitumen extraction from surface-mined oil sands ore. Base Mine Lake (BML) is the first full-scale Athabasca region End Pit Lake that permanently contains FFT under a fresh water cap in an oil sands post-mining pit. The expectation is that BML will develop into a self-sustaining aquatic ecosystem. Potential issues may include movement of constituents of potential concern (COPCs) from the FFT into the overlying cap water driven by microbial methanogenic activity contributing on-going sources of possible toxicity and turbidity. To quantify the COPC flux from underlying FFT into the overlying lake water, twelve laboratory meso-columns were filled with FFT and BML cap water, and incubated under three temperature conditions (10°C, 20°C and 30°C). Under each temperature one set of columns was amended with n-alkanes, aromatics and iso-alkanes to accelerate biogeochemical reactions, whereas the other set was not amended with any organics. TOC, DOC, DIC, BOD, COD, pH, EC, turbidity, naphthenic acids, toxicity and microbial community are monitored at sampling intervals driven by the methane level in each column. To date, microbial methanogenic activities in FFT have been enhanced by organic-amendment, resulting in significant methane production, decreased pH, increased turbidity, increased concentrations of Ca^{2+}, Mg^{2+} and HCO_3^-, and faster FFT settling in organic-amended columns compared to unamended columns. In all columns, TOC has decreased in pore-water from 110 mg/L to 60~80 mg/L, and increased in cap water from 35 mg/L to 40~50 mg/L. DOC, BOD, microtox toxicity, Na^+ and Cl^- have exhibited similar trends. These data confirm the COPC flux from the FFT into the overlying cap water. Upon completion of the experiment, the data set collected will provide important parameters to quantify and model the COPC flux across the mudline in BML.

Presentation type: Oral

B04-23: A Laboratory Experimental Study of Mudline Mixing: Implications for Water Clarity in End-Pit Lakes

Morris R. Flynn[1], Subramaniam Balakrishna[2], Omar Mohammed[2], Esmatullah Naikyar[3], and Christopher Surma[2]

[1]Department of Mechanical Engineering, University of Alberta, Edmonton, AB, T6G 1H9, E-mail: mrflynn@ualberta.ca, Phone: 780-492-5593
[2]Department of Mechanical Engineering, University of Alberta, Edmonton, AB, T6G 1H9
[3]Department of Chemical Engineering, University of Alberta, Edmonton, AB, T6G 1H9

Abstract
Elevated levels of turbidity are a threat to the viability of end-pit lakes as self-sustaining ecological habitats. High turbidity has obvious aesthetic consequences and also inhibits light penetration and photosynthesis, thereby potentially depressing the concentration of dissolved oxygen. Mechanisms by which fine solids from FFT may become suspended in end-pit lake cap water are manifold. With particular reference to Base Mine Lake (BML), the first demonstration scale end-pit lake in the oil sands region, we investigate three mechanisms believed to be potentially important, namely, buoyant convection, ebullition and mixing by ambient currents. In each case, bench-top laboratory experiments were performed and special focus was devoted to an "intermediate turbid layer," which is believed to exist along the mudline-cap water boundary. The resistance to shear of this intermediate layer is shown by rheological measurements to be much less than that of undiluted fluid fine tailings or FFT. From our experiments, the following conclusions are derived: (i) Buoyant convection effects in the vicinity of the mudline do not contribute to significant mixing or to an increase in cap water turbidity. (ii) Ebullition is likely a key factor contributing to elevated levels of turbidity, particularly in winter months when BML is isolated from wind forcing by ice cover. (iii) The impact of wind-driven free surface waves, though not negligible, is likely subordinate to ebullition. As regards (ii) and (iii), laboratory data suggest that the largest solids mass fluxes are associated with an intermediate turbid layer having a wt.% solids of approximately 5 wt.%.

Presentation type: Oral

B04-24: A Freezable Environmental Test Slope for Cold Regions Reclamation Cover System Studies

Dyan L. Pratt[1] and Jeffrey J. McDonnell[2]

[1]Global Institute for Water Security and Department of Civil, Geological and Environmental Engineering, University of Saskatchewan, SK, S7N 3H5, E-mail: dyan.pratt@usask.ca, Phone: 306-966-2335
[2]Global Institute for Water Security and School of Environment and Sustainability, University of Saskatchewan, SK, S7N 3H5

Abstract
Frozen ground is a major factor in mine cover performance. While frozen ground effects on runoff and cover storage and release have been observed in the field and tested in numerical models, few physical models of frozen slopes (at scales from 1-15 m) exist partly because the design of such an experiment requires new engineering design for realistic whole-slope freezing and physical model innovation. Here we present a new freezable tilting hillslope physical model for mine cover testing under a variety of climate conditions with the ability to perform multiple (up to 20 per year) freeze/thaw cycles. The 4 by 2 m hillslope is mobile and tiltable based on a modified tri-axle 16-foot-long dump trailer to facilitate testing multiple cover configurations. The system includes controllable boundary conditions on all surfaces; examples of side and base flow boundary conditions include permeable membranes, impermeable barriers, semi-permeable configurations as well as constant head conditions. To simulate cold regions and to freeze the cover system in a realistic and controlled manner, insulation and a removable freezer system is incorporated onto the top boundary of the hillslope. The freezing system is designed to expedite the freezing process by the addition of a 13,000 BTU refrigeration coil to the top-center of the insulated ceiling. Center placement provides radial freezing of the hillslope in a top-down fashion, similar to what natural systems encounter in the environment. The perimeter walls are insulated with 100 mm of spray-foam insulation, while the base of the hillslope is not insulated to simulate natural heat fluxes beneath the frozen layer of soil. Our preliminary testing shows that covers can be frozen down to -10°C in approximately 7 days, with subsequent thaw on a similar timeframe. We are now using this system to test cover design criteria for single and multi-layer cover systems.

Presentation type: Poster

B04-25: Role of Microbial Mats in Water Capped Tailings: Turbidity Removal and Chemical Flux Mitigation

Xiaoxuan Yu[1*] and Ania Ulrich[2]

[1]Department of Civil and Environmental Engineering, University of Alberta, Edmonton, AB, T6G 1H9
[2]Department of Civil and Environmental Engineering, University of Alberta, Edmonton, AB, T6G 1H9, E-mail: aulrich@ualberta.ca, Phone: 780-492-8293

Abstract
Alberta's oil sands industry has grown exponentially over the past five decades. The use of end pit lakes (EPL) in the closure landscape is one reclamation strategy where tailings are capped with water in a lake. In 2013, Syncrude Canada Ltd. established the first full-scale demonstration EPL, called Base Mine Lake (BML). In this research, microbial mats were investigated for their potential application in EPLs for reducing turbidity in cap water and mitigating chemical flux from tailings. Experiments were conducted in 2 L columns with the addition of nutrients (NH_3-nitrogen and phosphate), microalgae (*Chlorella kessleri*, *Chlorella pyrenoidosa*), and bacterium (*Sporosarcina pasteurii*). Control columns consisted of actual BML cap water. Preliminary results indicate effective turbidity reduction for the nutrient-amended, *C. kessleri*-amended, nutrient and C. *pyrenoidosa*-amended, and *S. pasteurii*-amended treatments. A more stable microbial mat was observed from the settling particles in the *S. pasteurii*-amended treatment, which can potentially resist resuspension of fines during lake turn-over and wind disturbance events. Future research will focus on microbial community analysis by Illumina sequencing (both eukaryotic and prokaryotic cells) and quantify the ability of microbial mats to resist resuspension.

Presentation type: Poster

B04-26: Geochemical Considerations for Including Petroleum Coke in Oil Sands Mine Closure Landscapes

Lawrence A. Swerhone[1*], Jake A. Nesbitt[1], Matthew B.J. Lindsay[2]

[1]Department of Geological Sciences, University of Saskatchewan, Saskatoon, SK, S7N 5E2
[2]Department of Geological Sciences, University of Saskatchewan, Saskatoon, SK, S7N 5E2,
E-mail: matt.lindsay@usask.ca, Phone: 306-966-5693

Abstract
Petroleum coke is a principal byproduct of bitumen upgrading at oil sands operations in the Athabasca Oil Sands Region (AOSR) of northern Alberta, Canada. Although a small proportion of petroleum coke is re-used as fuel at bitumen upgrading facilities, the majority is stockpiled in large on-site deposits. Consequently, the overall coke inventory in the AOSR, which currently exceeds 100 million tonnes, will ultimately be incorporated into oil sands mine closure landscapes. Coke exhibits geotechnical characteristics, (i.e. high permeability), which make it amenable to being integrated into closure landscapes. However, geochemical characteristics and behaviour within mine closure landscapes must be considered during mine closure planning. Coke contains elevated sulfur and iron contents, plus a host of minor and trace elements. Elevated concentrations of nickel, vanadium, and molybdenum in leachates from petroleum coke produced by fluid coking may have negative impacts on water quality. However, recent studies have demonstrated that the release and subsequent mobility of these and other elements is strongly influenced by pH and redox setting. In general, vanadium exhibits greatest mobility under oxic conditions at neutral to alkaline pH (i.e., pH > 7), whereas nickel mobility is greatest under mildly acidic (i.e., pH < 6.5). Consistent with vanadium, molybdenum exhibits enhanced mobility at neutral to alkaline pH, but elevated concentrations persist over a wider range of redox conditions. Sulfate-reducing conditions, which exist in some oil sands mine closure landforms, may be amenable to attenuation of these and other elements. Mine closure landforms may therefore be designed such that coke is stored under geochemical conditions that limit the release and mobility of these and other elements.

Presentation Type: Oral

B04-27: Assessing Salt Transport within Layered Oil Sands Mine Wastes: Field and Laboratory Experiments

Carlo R.C. Cilia[1*] and Matthew B.J. Lindsay[2]

[1]Department of Geological Sciences, University of Saskatchewan, Saskatoon, SK, S7N 5E2
[2]Department of Geological Sciences, University of Saskatchewan, Saskatoon, SK, S7N 5E2,
E-mail: matt.lindsay@usask.ca, Phone: 306-966-5693

Abstract
Oil sands mine closure landscapes are being constructed using various mining wastes and upgrading byproducts. These landscapes often contain multiple layers of different materials with different biogeochemical and hydrogeological characteristics. Understanding mechanisms and rates of salt migration between materials and into overlying reclamation soil cover materials is critical to mine closure planning. Large-scale centrifugation of fluid fine tailings (FFT) technology has been developed to reduce inventories of clay-rich FFT in tailings ponds and to promote progressive reclamation. Coagulants or flocculants added prior to centrifugation enhance FFT dewatering, which occurs very slowly within tailings ponds. The resulting centrifuged fine tailings (CFT) exhibits an initial water content of approximately 45 % and high pore-water salt (i.e., sodium, calcium) concentrations. Following deposition within engineered containment structures, CFT dewatering continues due to self-weight consolidation and freeze-thaw cycling. These processes can promote upward vertical salt migration, which has potential to negatively impact pore-water chemistry within overlying materials. In contrast to CFT, petroleum coke is highly permeable, carbonaceous material produced during bitumen upgrading. Therefore, placing a coke layer above the CFT and below the reclamation soil cover may limit salt migration between these materials. Laboratory column and field lysimeter experiments were conducted to examine salt transport from CFT into overlying layers of fluid petroleum coke and reclamation soil under saturated and unsaturated conditions. Initial results reveal that advective salt transport is important under both saturated and unsaturated conditions, whereas diffusive salt transport is important control in saturated systems. One-dimensional numerical transport models are being developed to further elucidate water and salt transport processes and rates. This research will provide important new insight into the potential for salt migration within layered mine waste systems.

Presentation Type: Poster

B04-28: Filling in a Forest Patchwork: A Multi-Site Analysis of Conventional and Constructed Patches of the Canadian Boreal Forest

Stacey Lynne Strilesky[1*], Sean K. Carey[2], and Elyn R. Humphreys[3], Richard M. Petrone[4], Gordon B. Drewitt[2], and George Sutherland[4]

[1]Department of Geography and Environmental Studies, Carleton University, Ottawa, ON, K1S 5B6, E-mail: stacey.strilesky@carleton.ca, Phone: 613-520-2600 ext. 4125
[2]School of Geography and Earth Sciences, McMaster University, Hamilton, ON, L8S 4K1
[3]Department of Geography and Environmental Studies, Carleton University, Ottawa, ON, K1S 5B6
[4]Department of Geography and Environmental Management, University of Waterloo, Waterloo, ON, N2L 3G1

Abstract
The natural boreal forest cycle of disturbance and regeneration is influenced by human activities such as forestry and fire. Extraction of bitumen reserves from the Athabasca Oil Sands Region (AOSR) is a large-scale disturbance that is being addressed with novel reclamation techniques such as construction of integrated upland and wetland ecosystems. These constructed ecosystems are complementing the patchwork of existing boreal ecosystems that result from harvesting, fire, wind, and pests, for example. This multi-site study involves evaluating water use characteristics of a selection of constructed oil sands reclamation sites and conventional post-disturbance sites of varying ages. Specifically, a mix of long- and short-term eddy covariance data records have been obtained for several sites in the boreal region. The purpose of the research is to assess the functioning of these ecosystems with a focus on resilience mechanisms related to drought recovery and initial growth conditions. Preliminary results indicate that the constructed ecosystems are functioning in a similar manner to conventional counterparts after an initial period of variance attributable to initial growth conditions. It is anticipated that there will be differences in resilience mechanisms attributable to factors such as vegetation type and climate regime but that overall functioning of the ecosystems will be within the range for sites with comparable factors. This research is important to both the understanding of how constructed ecosystems are functioning in relation to their intended target ecosystems and the nature of the current and future boreal forest region.

Presentation type: Poster

B04-29: Influence of Ion Exchange Reactions on Salt Migration in Oil Sands Reclamation Soil Cover Materials: Laboratory Column Experiments

Colton J. Vessey[1*], and Matthew B.J. Lindsay[2]

[1]Department of Geological Sciences, University of Saskatchewan, Saskatoon, SK, S7N 5E2
[2]Department of Geological Sciences, University of Saskatchewan, Saskatoon, SK, S7N 5E2,
E-mail: matt.lindsay@usask.ca, Phone: 306-966-5693

Abstract
Laboratory column experiments were conducted to examine the influence of ion exchange reactions on sodium migration through till, peat and sand used to construct reclamation covers and oil sands mining operations in northern Alberta, Canada. Two simulated oil sands process water (OSPW) solutions were prepared and passed through columns containing each of the individual reclamation cover materials. The first solution contained sodium (1000 mg L^{-1}), bicarbonate (980 mg L^{-1}), chloride (600 mg L^{-1}) and sulfate (900 mg L^{-1}) concentrations characteristic of OSPW from gypsum-amended tailings (e.g., composite tailings). The second input solution contained sodium (1000 mg L^{-1}), bicarbonate (1500 mg L^{-1}), chloride (900 mg L^{-1}) and sulfate (100 mg L^{-1}) concentrations generally consistent with OSPW from fluid fine tailings (FFT). Influent and effluent samples were collected and analyzed at regular time intervals for at least 170 days. Similar results were observed the OSPW solutions passed through a given material. Effluent sodium concentrations decreased by up to 50% over the initial 3 to 4 pore volumes passed through columns containing till and peat. Sodium attenuation by these materials decreased over time, and less than 10% removal was observed after approximately 10 pore volumes. Sodium transport through the sand was conservative, indicating no appreciable ion exchange occurred. Increases in effluent calcium, magnesium and potassium generally corresponded to sodium removal in the columns containing till and peat. Deprotonation of clay and peat surface sites – inferred from slight decreases in effluent relative to influent pH – likely occurred during the experiment. Nevertheless, these experiments indicate that ion exchange at till and peat surfaces can initially limit sodium transport through reclamation soil covers.

Presentation Type: Poster

B04-30: Characterizing Mass Release from Oil Sands Fluid Fine Tailings with Multiple Tracers

Kathryn Dompierre[1], S. Lee Barbour[2], and Julie Zettl[2]

[1]GEO-SLOPE International Ltd., Calgary, AB, T2P 0T8,
E-mail: kathryn.dompierre@geoslope.com, Phone: 403-213-5348
[2]Department of Civil, Geological and Environmental Engineering, University of Saskatchewan, Saskatoon, SK, S7N 5A9

Abstract
Thirty end pit lakes (EPLs) have been proposed for the closure of oil sands mines in the Athabasca oil sands region, Northern Alberta, Canada. The EPLs are to provide long-term storage for fluid fine tailings (FFT) – a by-product of the oil sands bitumen extraction process with high water contents, low shear strengths, and elevated concentrations of dissolved chemical constituents. Containment in depleted mine pits below a water cover allows the FFT to gradually settle and strengthen; however, chemical mass release from the FFT may influence the biogeochemical conditions within the water cover. Chemical constituents of concern may move from the FFT into the overlying water cap via two key processes: (1) advective-diffusive transport with upward pore water flow caused by tailings settlement; and (2) mixing created by wind events or unstable density profiles in the FFT. Multiple tracers – stable isotopes of water, chloride, and heat – were measured through the FFT and water cover to investigate pore water and mass movement at the first oil sands demonstration EPL. Numerical models were developed to simulate the movement of these tracers through the FFT given a range of transport mechanisms. The field measurements and numerical models were compared to determine the main mechanisms contributing to mass transport. Together, the tracer data and numerical models suggested that the dominant mass transport regime was advection-dispersion due to tailings settlement with a disturbance event or mixing mechanism within the upper 1 m of FFT. This investigation provides valuable insight for assessing the water cover biogeochemical regime and the performance of EPLs as an oil sands reclamation strategy.

Presentation type: Poster

B04-31: Heat Budget and Fluxes at Base Mine Lake

Sarah Chang[1*], Edmund Tedford[2], and Greg Lawrence[2]

[1]Department of Civil Engineering, University of British Columbia, Vancouver, BC, V6T 1Z4,
E-mail: sarahchang@alumni.ubc.ca, Phone: 226-929-0240
[2]Department of Civil Engineering, University of British Columbia, Vancouver, BC, V6T 1Z4

Abstract
Natural bodies of water are subject to a variety of heat fluxes, including radiation, conduction, and latent heat fluxes. The 2015 autumn and winter heat fluxes at Base Mine Lake (7.7 km^2, depth ~10 m) in northern Alberta (57° N) were modelled and differ from that of natural lakes due to the presence of FFT below the water column, and potentially due to the presence of hydrocarbons on the lake surface. During autumn, a hydrocarbon sheen at the lake surface appears to reduce the evaporation of water in calm conditions. At the time of ice-on, the water column is initially of uniform temperature, with warmer FFT present beneath the water. The heat from the FFT induces warming in the lower depths of the lake. Falling plumes of saline water excluded from the ice during freezing maintain a mixed layer of uniform temperature beneath the ice.

Presentation type: Poster

B04-32: DOC Transport in a Constructed Watershed in the Athabasca Oil Sands Region, Alberta

S.E. Irvine[1*], M. Strack[2], J.S. Price[2]

[1]Department of Geography and Environmental Management, University of Waterloo, Waterloo, ON, N2L 3G1, E-mail: s2irvine@uwaterloo.ca, Phone: 905-923-3297
[2]Department of Geography and Environmental Management, University of Waterloo, Waterloo, ON, N2L 3G1

Abstract
In the Western Boreal Plain (WBP) fens comprise up to 50% of the landscape, however much of this area has been disturbed due to bitumen extraction in the Athabasca Oil Sands Region. Since there is a legal requirement to return equivalent land capability, an experimental fen watershed was constructed to assess peatland construction success. This watershed comprises a constructed fen, three reclaimed and one natural hillslope and an upland. Dissolved organic carbon (DOC) transport can represent an important component of the carbon cycle and mobilize DOC to downstream ecosystems. This can occur through surface runoff, groundwater, or discharge. Though surface runoff is limited in the WBP due to its sub-humid climate, the constructed fen frequently experiences surface runoff on the reclaimed hillslopes during precipitation events. Therefore, it is important to understand how the hydrology of this constructed watershed mobilizes DOC. We report on hydrologic DOC fluxes and quality within this watershed during 2015 (May-August) and 2016 (July-August). Groundwater and runoff DOC inputs are larger than outputs, being primarily controlled by the groundwater source. DOC concentrations are similar in groundwater, upland, and hillslope runoff sources indicating that the volume of water is more important for DOC transport than source material. However, DOC quality is not comparable, as DOC from the hillslopes appears larger and more aromatic than what is mobilized from the upland, with the groundwater DOC appearing the smallest and least aromatic. This is uncharacteristic of groundwater, which may be due to the presence of poorly characterized DOC sources such as naphthenic acid. Hydrologic losses of DOC are minimal, as outflow from the fen is restricted to surface outflow (10 and 7 mm in 2015 and 2016). DOC at the outflow appears small and non-aromatic, therefore it is unlikely to be sourced from the hillslopes, and minimally from the upland.

Presentation type: Poster

B04-33: A Mechanistic Study of CO_2-induced Turbidity Reduction in Water Capped Tailings

Stanley (Ho Yin) Poon[1]*, Jordan Brandon[2], and Ania Ulrich[2]

[1]Department of Civil and Environmental Engineering, University of Alberta, Edmonton, AB, T6G 2W2, E-mail: hpoon@ualberta.ca, Phone: 780-492-0248
[2]Department of Civil and Environmental Engineering, University of Alberta, Edmonton, AB, T6G 2W2

Abstract:
End pit lakes (EPL) are one of the proposed reclamation and remediation strategies to store oil sands process-affected water (OSPW) and fluid find tailings (FFT), where the goal is to develop the EPL into a self-sustaining aquatic ecosystem. One issue with FFT storage in an EPL scenario is resuspension of fines in the water cap. Turbidity affects sunlight penetration, which in turn delays the development of a healthy aquatic ecosystem. The objective of this study is to provide mechanistic insights for FFT settling in an EPL cap water environment with a focus on how the following interventions impact the process: (1) change of pH and (2) change in divalent cation concentrations through the addition of fresh water. Carbon dioxide (CO_2) was used to reduce the pH of a column study containing a mixture of OSPW and fresh water (from Beaver Creek Reservoir). Turbidity was reduced by 88% due to CO_2 addition, as compared to the control column where 63% reduction was observed. In addition, physical and chemical parameters, including pH, conductivity, alkalinity, total (in)organic carbon, zeta potential, cations and anions, have been measured. These physical and chemical parameters will be used for mathematical (DLVO) and computer (PHREEQC) modelling to gain further mechanistic insights into the effect of CO_2-induced FFT settling. With data generated from this study, a comprehensive understanding of how to best mitigate FFT induced turbidity for EPL systems can be developed.

Presentation Type: Poster

B04-34: Seasonal Variation of Turbidity in Base Mine Lake

Greg Lawrence[1], Edmund Tedford[2], Laura Irvine[2], Sarah Chang[2], and Roger Pieters[2,3]

[1]Department of Civil Engineering, University of British Columbia, Vancouver, BC, V6T 1Z4, E-mail: lawrence@civil.ubc.ca, Phone: 604-822-5371
[2]Department of Civil Engineering, University of British Columbia, Vancouver, BC, V6T 1Z4
[3]Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, BC, V6T 1Z4

Abstract
We discuss the seasonal variation in turbidity in Base Mine Lake (surface area 7.7 km^2, depth ~10 m) in northern Alberta (57^{o}N). Measurements made from April 2013 until August 2016 show turbidity ranging from less than 10 NTU to more than 500 NTU. A distinct seasonal variation in turbidity has been observed: generally turbidity increases from its lowest value at the end of summer to a peak at ice-on; after ice-on it drops rapidly for several weeks before plateauing at an approximately constant level until ice-off; turbidity increases again during spring and then decreases during summer. The reasons for this seasonal variation are discussed and interesting features highlighted, for example: the approximately linear increase in turbidity throughout the fall; the relatively high turbidity plateau during ice-on; and the approximately exponential decay of turbidity in summer. The turbidity generally increases with depth although there are periods, particularly during the fall, when the turbidity is constant throughout the water cap.

Presentation type: Poster