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August 30th, 2012

Mackenzie Valley Environmental Impact Review Board
#200 Scotia Centre
5102 – 50 Avenue
Yellowknife, NWT
X1A 2N7
Via email to: chubert@reviewboard.ca

Re: Submission of Additional Information on Constructed Wetlands Treatment Systems (CWTS)

Further to the request of Board Member James Wah-shee during the course of the public hearing Wednesday August 29th, please find attached a list of mines that have used constructed wetlands to treat constituents of concern (COCs).

CWTS have been used for many decades to treat effluents and seepage from mines around the world. Hundreds of human made wetlands have been used to treat mine waste waters for many years (MPERG Report 2010-4; Evaluation of the Effectiveness of Biological Treatment of Mine Waters by Laberge Environmental Services, http://ygsftp.gov.yk.ca/publications/**mperg**/2010/**MPERG2010-4**.pdf). This includes mining operations in North America and in cold climates. Some selected examples, along with references are provided in Table 1 (attached). Examples of scientific review articles and manuscripts discussing constructed wetlands for treatment of mine-related waters are provided below. Studies have also indicated that CWTS operate long-term and show improved function over time (example, Yang et al 2006, http://www.ncbi.nlm.nih.gov/pubmed/16469422).

FML has retained Contango Strategies Ltd and its partners to develop a plan for construction of a CWTS for demonstration and commissioning during operation at the NICO mine to be ready for implementation on closure. This is sufficiently early in the process to give us confidence in the ability to successfully design, test, and commission the system prior to closure. The design process for the greenhouse trials has already commenced.

We would like to stress that the function and design of the CWTS is not related to the activity generating the COC. It is the COC, it's concentration, volume, and the water quality parameters that factor into the design and construction of a CWTS to remove particular COCs. The design of CWTS is not industry-specific, but contaminant and water parameter specific. Therefore, knowledge and experience in treatment of other types of produced waters can be applied to designing CWTS across industries if the contaminant in the water is the same. The contaminants and water parameters predicted for the co-disposal facility's (CDF's) post-closure seepage water quality are within the ranges of waters that have been effectively treated using CWTS. Selected examples of our group's experience in designing and implementing CWTS are provided in Table 2 (attached).

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Sincerely,

Contango Strategies Limited (in partnership with NPS/DUC, and Drs. Rodgers and Castle)

Monique Haakensen, PhD, PBiol
President and Principal Scientist

Additional examples of scientific review articles and manuscripts discussing constructed wetlands for treatment of mine-related waters.

Barton, C.D. and Karathanasis, A.D. 1998 Aerobic and anaerobic metal attenuation processes in a constructed wetland treating acid mine drainage. Environmental Geosciences, 44:43-56.

Sheoran, A.S. and Sheoran, V. 2006 Heavy metal removal mechanism of acid mine drainage in wetlands: A critical review. Minerals Engineering, 19:105-106.

Tarutis, W.J., Stark, L.R., and Williams, F.M. 1999 Sizing and performance estimation of coal mine drainage wetlands. Ecological Engineering 12: 353-372.

Vesper, D.J. and Smilley, M.J. 2010 Attenuation and diel cycling of coal-mine drainage constituents in a passive treatment wetland: A case study from Lambert Run, West Virginia, USA. Applied Geochemistry, 25: 795-808.

Yang, B., Lan, C.Y., Yang, C.S., Liao, W.B., Change, H., and Shu, W.S. 2006 Long-term efficiency and stability of wetlands for treating wastewater of a lead/zinc mine and the concurrent ecosystem development. Environmental Pollution, 143: 499-512.

Vile, M.A. and Wieder, R.K. 1993 Alkalinity generation by Fe(III) reduction versus sulfate reduction in wetlands constructed for acid mine drainage treatment. Water Air & Soil Pollution, 69:425-441.

Wieder, R.K. 1993. Ion input/output budgets for five wetlands constructed for acid coal mine drainage treatment. Water Air & Soil Pollution, 71:231-270.

Table 1: Examples of Constructed Wetlands

Site Name	Location	Treating for	Reference
Almonaster la Real	Monte Romero abandoned mine complex, southwestern Spain	Fe, Al, Cu Pb, As, ZN	Macías, F., Caraballo, M.A., Nieto, J.M., Rötting, T.S., Ayora, C. Natural pretreatment and passive remediation of highly polluted acid mine drainage. Journal of Environmental Management 104 , pp. 93-100
Bell Copper Mine	Newman Pennisula, Babine Lake, BC	Cu	Sobolewski, A. Metal species indicate the potential of constructed wetlands for long-term treatment of metal mine drainage. Ecological Engineering. Vol. 6, pp. 259-271.
Big Five Tunnel	Idaho Springs, Colorado	Fe, Mn, Al, Zn, Pb and Cu	Howard, E. A., Emerick, J. E. and T. R. Wildeman. 1989a. The design, construction and initial operation of a research site for passive mine drainage treatment in Idaho Springs, Colorado, p. 761764. In Constructed Wetlands for Wastewater Treatment, D. A. Hammer, ed. Lewis Publishers, Ann Arbor, MI.
Birchtree Mine	Manitoba, Canada	Ni	Hambley, A.G. 1996. Removal of nickel from mine water by a natural wetland in Northern Manitoba. M.N.R.M. Thesis. Natural Resources Institute, University of Manitoba, Winnipeg, Canada.
Carbonate Mountain	Montana, USA	Al, Fe, Pb	Dollhopf, D. J., J. D. Goering, R. B. Rennick, R. B. Morton, W. K. Gauger, J. B. Guckert, P. M. Jones, K. C. Cooksey, K. E. Bucklin, R. Weed, and M. M. Lehman. 1988. Hydrochemical, vegetational and microbiological effects of a natural and a constructed wetland on the control of acid mine drainage. Report No. RRU 8804, Montana Dept. of State Lands, Abandoned Mine Reclamation Bureau, Helena, MT, U.S.A. 214
Dunka Mine	Minnesota, USA	Cu, Ni	Eger, P. and K. Lapakko. 1988. Nickel and copper removal from mine drainage by a natural wetland. U.S. Bureau of Mines Circular 9183, 301-309.
Electrical Power Station	Springdale, Pennsylvania	Fe, Mn, Co, Ni	Ye, Z.H., Whiting, S.N., Lin, Z.-Q, Lytle, C.M., Qian, J.H., Terry, N., Removal and Distribution of Iron, Manganese, Cobalt, and Nickel within a Pennsylvania Constructed Wetland Treating Coal Combustion By-Product Leachate. Journal of Environmental Quality. Vol. 30, No. 4, p. 1464-1473.
Empire Mine	Near Grass Valley, California	As, Fe, Mn	James Gusek, Lee Josselyn, William Agster, Steve Lofholm, and Daniel Millsap. Process Selection & Design of a Passive Treatment System For The Empire Mine State Historic Park, California. Paper was presented at the 2011 National Meeting of the American Society of Mining and Reclamation, Bismarck, ND Reclamation: Sciences Leading to Success June 11 - 16, 2011. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.
Review of Natural wetlands at 35 coal mines	Pennsylvania, USA	Al, Fe, Mn	Stark, L.R. 1990. A study of natural wetlands associated with acid mine drainage. AML research contract report, U.S. Bureau of Mines. NTIS PB91176370.
Savannah River National Laboratory	Savannah River	Cu, Hg, Zn, Pb	Nelson, E.A., Gladden, J.B. Full-scale treatment wetlands for metal removal from industrial wastewater. Environmental Geosciences, V. 15, No. 1, pp. 39-48.
St. Kevin Gulch	Colorado, USA	Fe	Walton-Day, K. In Press. Iron and zinc budgets in surface water for a natural wetland affected by acidic mine drainage, St. Kevin Gulch, Lake County, Colorado. In: Morganwalp, D.W. and D.A. Aronson (Eds). U.S. Geological Survey Toxic Substances Hydrology Program, proceedings of the technical meeting, Colorado Springs, Colo. September 20-24, 1993. U.S. Geological Survey Water-Resources Investigation Report 94-4015.

Site Name	Location	Treating for	Reference
Tom's Gully Mine	100 km S.E. of Darwin, Australia	As, Cu, Co, Fe, Mn, Ni, Pb, U, Zn	Noller, B.N., P.H. Woods, and B.J. Ross. 1994. Case studies of wetland filtration of mine waste water in constructed and naturally occurring systems in Northern Australia. Water Sci. Tech. 29: 257-266.; Woods, P.H. and B.N. Noller. 1995. Medium-term performance of wetlands improving water quality of near-neutral mine drainage in the Northern Territory. In: National conference on Wetlands for water quality control. James Cook University, Townsville, Australia. 25-29 September, 1995
United Keno Hill Mines	Yukon Territory, Canada	Zn	Laberge Environmental Services. Investigation into Passive Wetlands Treatment of Mine Drainage to Remove Heavy Metals at Various Sites at UKHM. ISBN 1-55018-982-4.
United Keno Hill Mines	Yukon Territory, Canada	Zn	Sobolewski, A. 1995. Development of a wetland treatment system at United Keno Hill Mines, Elsa, Yukon Territory. Proceedings of the Twentieth Annual British Columbia Mine Reclamation Symposium. 17-20 June, Kamloops, British Columbia, Canada. pp. 64-73.
Unnamed coal mine	Pennsylvania, USA	Fe, Mn	Tarutis, W.J., Jr., R.F. Unz, and R.P. Brooks. 1992. Behavior of sedimentary Fe and Mn in a natural wetland receiving acidic mine drainage, Pennsylvania, U.S.A. Applied Geochem. 7: 77-85.
Key Lake	Saskatchewan, Canada	As, Se, other	Personal communication
Unnamed uranium mines	Saskatchewan, Canada	multiple	Personal communication, natural and human assisted wetlands
WISMUT Uranium Mining Site at Pöhla	West of Erzgebirge in Free Staten of Saxony, Germany	As	Mkandawire, M., Kuchler, A., Forster, J., Pieplow, G., Pompe, W. Dynamics of Arsenic in constructed wetland treating water from flooding shaft of an abandoned uranium mine. Abstracts of the International Mine Water Conference Proceedings ISBN Number: 978-0-9802623-5-3
Shell Norco Refinery	St. Charles Parish, Louisiana	Cu, Pb, Zn	W. Bradley Hawkins, John H. Rodgers, Jr., W. B. Gillespie, Jr., A. W. Dunn, P. B. Dorn, and M. L. Cano. Design and Construction of Wetlands for Aqueous Transfers and Transformations of Selected Metals. Ecotoxicology and Environmental Safety. vol. 36, p. 238-248
Agricultural Drainage (removal of Se)	Tulare Lake Drainage District, San Joaquin Valley, California	Se	Gao, S., Tanji, K.K., Lin, Z.Q., Terry, N., and Peters, D.W. Selenium Removal and Mass Balance in a Constructed Flow-Through Wetland System. Journal of Environmental Qaulity. Vol. 32, 1557-1570 (2003)
Unnamed mine site	Shaoguan, Guangdong Province, China	Pb, Zn	Yang, B., Lan, C.Y., Yang, C.Y., Liao, W.B., Chang, H., and Shu, W.S., 2005. Long-term efficiency and stability of wetlands for treating wastewater of a lead/zinc mina dnd the concurrent ecosystem development. Environmental Pollution 143: 499-512

Constructed
Natural

Table 2:Examples of prior experience with design and implementation CWTS (Dr. John Rodgers)

CWTS Owner	Location	Water Treated and Targeted Constituents	Scale (Full – Pilot)
International Paper	Tichonderoga, NY	Pulp Mill Wastewater (BOD, chlorinated organics, COD, etc.)	Pilot and Full
US Air Force	Anchorage, AK	Munitions wastewater	Pilot and Full
DOE/Produced Water Project; Diamond V Project	Clemson, SC	Simulated Produced Water; Energy derived water	Pilot
DOE / Chevron	Near Berry, AL	Coal Bed Methane Produced Water (Se, organics,	Pilot / Demonstration
DOE/ Savannah River Site	New Ellenton, SC	Process Water and Industrial Runoff (Cu, Hg, organics)	Pilot and Full
Duke Energy	Mooresville,NC	Flue gas desulfurization water (metals, organics)	Pilot and Full
Progress Energy	Asheville, NC	Flue gas desulfurization water (metals, organics)	Pilot and Full
Shell	Norco, LA	Refinery wastewater (organics, naphthenic acids, metals)	Pilot and Full
Chevron	Richmond, CA	Refinery wastewater	Pilot
Chevron	KS	Refinery wastewater	Pilot and Full
Chevron, Petronas, Exxon	Kome Field, Chad, Africa	Oil field Produced Water	Pilot
DOE	WV	Natural gas storage produced water	Pilot and Full (Demonstration)
DOE	SC	Fresh Oilfield Produced Water	Pilot
International Paper	Mansfield, LA	Pulp and Paper Mill Wastewater	Pilot and Full
Solutia, Inc.	Columbia, TN	Munitions and Industrial Wastewater	Pilot and Full