Kitikmeot Inuit Association
Kitikmeot Inuit Katuyikatigit
ᖁᑎᖅᑎᑦᑕᓪᓗ ᐃᓄᐃᑦ ᑲᑐᔾᔨᖏᑦᑐᑦ

Technical Review of the Revised Water Licence Application Support Document for the Doris North Project FINAL REPORT

July 2007

Rescan Environmental Services Ltd.
Vancouver, British Columbia

EXECUTIVE SUMMARY

Executive Summary

This report provides technical review comments on the *Revised Doris North Water Licence Application Support Document*. The purpose was to assist the Nunavut Water Board in developing the terms and conditions of the Doris North water licence. Most of the comments concern the proposed water management strategy. The key element of that strategy is a two-component discharge strategy from Tail Lake: (1) end-of-pipe discharge standards in Tail Lake based on the *Metal Mine Effluent Regulations* (MMER); and (2) water quality standards at a compliance point in Doris Creek based on Canadian Council of Ministers of the Environment (CCME) guidelines for protection of freshwater aquatic life. Rescan accepts that this strategy can work but it will require extensive training and rehearsal by staff, accurate and precise results from the on-site analytical laboratory, frequent comparison of predicted and observed water quality, and frequent reporting to the Nunavut Water Board. Rescan recommends that the Board define any exceedance of CCME guidelines in Doris Creek as "significant" and requiring cessation of discharge until the causes can be explained, accompanied by re-calibration of the water quality model. Rescan also recommends a five-year water licence.

ABBREVIATIONS AND ACRONYMS

Abbreviations and Acronyms

ABA	Acid Base Accounting
Bq	Becquerel
CCME	Canadian Council of Ministers of the Environment
DFO	Department of Fisheries and Oceans
Doris North	Doris North Gold Project
EC	Environment Canada
EKATI	EKATI Diamond Mine
FEIS	Final Environmental Impact Statement
KIA	Kitikmeot Inuit Association
MHBL	Miramar Hope Bay Limited
MMER	Metal Mining Effluent Regulations
NIRB	Nunavut Impact Review Board
NP	Neutralization Potential
NTI	Nunavut Tunngavik Inc.
NWB	Nunavut Water Board
Rescan	Rescan Environmental Services Ltd.
SNP	Surveillance Network Program
TSS	Total Suspended Solids
WHO	World Health Organization

TABLE OF CONTENTS

Technical Review of the Revised Water Licence Application Support Document for the Doris North Project

TABLE OF CONTENTS

LIST OF APPENDICES

1. INTRODUCTION

1. Introduction

1.1 Objectives

This report is a technical review of the *Revised Doris North Water Licence Application Support Document* that was submitted by Miramar Hope Bay Limited (or 'MHBL') to the Nunavut Water Board (the 'Board') in April 2007 (MHBL, 2007). The purpose of the review is to assist the Board in developing the terms and conditions of the Doris North water licence.

The review was prepared for the Kitikmeot Inuit Association (KIA) and Nunavut Tunngavik Inc. (NTI) by Rescan Environmental Services Ltd. (Rescan). The report was written by Michael Stewart (Ph.D.), Julius Pretorius (Ph.D.), Susan Ames (Ph.D., P.Ag., CAC), Greg McKillop (B.Sc., P.Geo.) and Michael McGurk (Ph.D., R.P.Bio.). Appendix 1 shows their resumes.

The Doris North Gold Project (or 'Doris North') is located at 68°09'N and 106°40'W, approximately 110 km southwest of Cambridge Bay and 75 km northwest of Omingmaktok. It will be a small (54 ha footprint), underground mine with an average daily throughput of 690 tonnes and an operational life span of 2 years. During that time the mine is expected to process 4458,000 tonnes of ore and yield 306,830 ounces of gold. MHBL is applying for a single Type "A" water licence for the mine.

The review focussed on water management planning, environmental effects monitoring and closure and reclamation planning. The review was based on:

- the *Revised Water Licence Application Support Document*;
- supplementary information on Doris North presented by MHBL at a Technical Meeting held by the Board in Cambridge Bay on June 11 and 12, 2007;
- supplementary information delivered by MHBL to the Board on June 13, 2007, and placed on the Board's website on June 25, 2007;
- the *Fisheries Authorization* for the jetty in Roberts Bay issued by the Department of Fisheries and Oceans (DFO) on June 29, 2007;
- the requirements of a Type "A" water licence for a mine in Nunavut;
- the commitments made by MHBL in their *Final Environmental Impact Statement* (MHBL, 2005) and during the public hearing of the Nunavut Impact Review Board (NIRB); and
- the terms and conditions of NIRB's *Final Hearing Report* on Doris North (NIRB, 2006).

The review did not cover:

- reclamation security;
- compensation to the KIA and NTI for loss of water rights;

- geotechnical and engineering issues (because they were largely addressed by the NIRB process and by responses from MHBL to questioning during the June 11-12 Technical Meeting); and
- issues outside of the mandate of the Board. The jetty in Roberts Bay is included in the Board's mandate.

Rescan concludes that there are no outstanding technical issues that would prevent the issuance of a Type "A" water licence. However, any extension to the life of the mine caused by development of other deposits in the Hope Bay Belt will require additional environmental impact assessments and water licence applications.

Section 1.2 briefly describes the history of the Doris North review process and Section 1.3 summarizes the mandates of the KIA and NTI and their role in the regulatory process. Section 2 describes Rescan's proposed conditions for the water licence and Section 3 summarizes the key points of the review.

1.2 Background

In March 2002, MHBL applied to the Board for a Type "A" water licence for Doris North. The Board referred the water licence application to the NIRB for an environmental screening. In March 2006, after four years of review including two separate rounds of technical meetings and public hearings, the NIRB recommended that Doris North should proceed to the regulatory phase (NIRB, 2006). In August 2006, the Minister for Indian and Northern Affairs Canada approved the recommendation and NIRB issued a Project Certificate.

In October 2006, MHBL submitted to the NWB a *Water Licence Application Support Document* for the Project (MHBL, 2006). On December 27, 2006, the NWB determined that the application was incomplete and would require re-submission (NWB, 2006). In April 2007, MHBL submitted a *Revised Water Licence Application Support Document* (MHBL, 2007). This report is a technical review of that revised document.

From June 11 to 12, 2007, the Board held a Technical Meeting at which KIA, NTI, and federal and territorial government regulatory agencies discussed technical issues related to water licensing of Doris North. MHBL took the opportunity to present changes in mine design that had been developed during the period between NIRB project certification and the review of the revised water licence application. Many of these changes were not directly related to water licensing.

In Rescan's opinion, those changes fall within the scope of the Project Certificate issued by NIRB.

Some of the changes improved the overall environmental quality of Doris North. For example, pumping potable water from Doris Lake using a floating barge rather than pipes laid on the lake bed avoids disturbance to lake benthic habitat. A list of commitments for further information from MHBL was drawn up by the Board and a date for submission of that material to the Board was set. The information was made available to Rescan on June 27, 2007.

1.3 Kitikmeot Inuit Association (KIA) and Nunavut Tunngavik Inc. (NTI)

KIA is the Regional Inuit Association for the Kitikmeot region. KIA is responsible for the implementation of those parts of the Nunavut Land Claims Agreement (NLCA) that are directly assigned to it because of its status as the Regional Inuit Association, and KIA is responsible for other parts of the Agreement that have been assigned to it by the Board of Directors of NTI.

NTI is a corporation established under the NLCA. It is responsible for advancing and protecting Inuit interests and for ensuring that the promises made under the agreement are kept.

The interests of KIA and NTI in the impacts of Doris North are unique and extensive. KIA is responsible for all of the Inuit Owned Lands in the Kitikmeot, which include the Doris North mine site. Hence, KIA is the landowner of this project. KIA is also responsible for the protection and management of water in, on or flowing through Inuit Owned Lands as stated in Article 20 of the NLCA.

KIA also has special interests related to wildlife and fisheries. Kitikmeot Inuit are primary users of the fisheries and wildlife of the Doris North area and they have preferential harvesting rights, as set out in Article 5 of the NLCA. Disruption of Inuit harvesting activities may give rise to compensation under Article 6 of the NLCA.

KIA has negotiated with MHBL in regard to land use permits, compensation for Inuit water rights under Article 20 of the NLCA, an Inuit Impact and Benefits Agreement under Article 26 of the NLCA, and land lease agreements and quarry permits. NTI has negotiated with MHBL exploration leases and a Mineral Production Lease.

KIA and NTI have actively participated in the review of MHBL's water licence application by:

- providing written comments to the Board on the completeness of both the original application and the revised application;
- attending the Technical Meeting of June 11 and 12; and
- submitting interventions to the Board that included, among other things, a technical review of the application (this document).

Rescan acknowledges the reviews that the federal and territorial governments have conducted of MHBL's *Final Environmental Impact Statement* and the *Revised Water Licence Application Support Document*. Their reviews have had a positive influence on the present design of Doris North and on MHBL's environmental management policies. Rescan used those reviews to understand the environmental consequences of Doris North.

2. PROPOSED WATER LICENCE CONDITIONS

2. Proposed Water Licence Conditions

2.1 Scope, Definitions and Enforcement

MHBL has proposed a single water licence for Doris North lasting eight years with periodic reviews at three years intervals. This will cover construction (one year), operation (two years) and closure (five years). After seven years, MHBL expects that water quality of the Tail Lake discharge will have reached a level that will allow unrestricted natural discharge.

Rescan agrees with the idea of a single Type "A" water licence for the project, but proposes that the licence last for no more than 5 years before renewal. This will provide the Board with an opportunity to review the water quality monitoring data and the overall success of water and waste management at Doris North before MHBL is allowed to walk away. During the renewal process MHBL will have to defend their history of environmental management and propose how they plan to successfully complete the post-closure phase.

Rescan has no specific recommendation concerning enforcement penalties, but encourages the Board to adopt strict standards for enforcement of discharge water quality from Tail Lake – the principal waste management issue for Doris North. The critical period for the real-time discharge management system will be during the first year of mine operation and in freshet of each subsequent year. As stated in MHBL's water management plan, should water quality monitored at the Surveillance Network Program (SNP) station in Doris Creek below the waterfall exceed water quality guidelines for the protection of aquatic life established by the Canadian Council of Environment Ministers (CCME), then MHBL must immediately stop discharge. The Board should not allow discharge to resume in that year or in any following year until the Board has received a satisfactory written explanation from MHBL for why the exceedance occurred and how MHBL has solved the problem.

2.2 General Conditions

Rescan has no specific recommendations regarding the scheduling and contents of the Annual Report from MHBL to the NWB, other than that the report should provide a comprehensive summary of mine activities, water and waste management and closure planning.

2.3 Conditions Applying to Security

Rescan has no comment on reclamation security.

2.4 Conditions Applying to Compensation

2.4.1 Fish Habitat Compensation

Rescan has no specific recommendations regarding the Doris North No Net Loss Plan presented in Supporting Document F4 of the *Final Environmental Impact Statement*. If built as designed, the plan will provide adequate compensation for lost fish habitat. As the landowner, KIA must approve any future changes to the No Net Loss Plan.

2.4.2 Compensation for Water Use

Rescan has no comment on compensation to KIA and NTI from MHBL for water use.

2.5 Conditions Applying to Construction

Rescan has no specific recommendations regarding the conditions applying to mine construction.

Rescan supports applying adaptive management strategies to all detailed design plans, but is aware that applying the strict scientific concept of adaptive management (*i.e.*, incorporating controlled experiments to management practices) to a mine with an operating life of only two years will not be possible because there will not be enough time for natural experiments to be conducted and evaluated and for that knowledge to be converted into modified management practices. However, there may be sufficient time to follow a 'troubleshooting' or observation-response paradigm. Regardless of the name that is used, the concept of learning by doing is a key element in construction planning and mine design.

Rescan agrees with the conclusions of Supporting Document S7 *Geochemical Characterization of Quarry Materials* that quarried rock used for construction purposes will not be a source of metal leaching and acid rock drainage.

2.6 Conditions Applying to Water Use

2.6.1 Consumption of Potable Water

The third paragraph of Section 5.1 of the *Revised Doris North Water Licence Application Support Document* anticipates potable water consumption of 40 L per person per day. In comparison, the World Health Organization (WHO) recommends 100 L per person per day (WHO, 2004). This suggests that the actual rate of consumption of potable water during the operations phase of the mine may be more than twice the predicted rate. However, the projected consumption rate of 80.3 m^3/day for the 175-person entire camp (or approximately 30,000 m^3/year) is far greater than the amount that can be predicted from either rate of daily consumption. For example, a daily consumption rate of 100 L per person per day or 0.1 m^3 per person per day for a camp of 175 persons is equal to a camp consumption rate of 17.5 m^3/day or 6,387.5 m^3/year, which is one fifth of the projected rate. We conclude that:

- if the projected rate of approximately 30,000 m^3/year is not in error, then it must be based on more factors than the daily consumption rate per person, in which case section 5.1 of the Application (and Section 3.1 of Supporting Document S10j) is misleading; or
- the projected rate of approximately 30,000 m^3/year is in error by a factor of approximately five times, even if one assumes a personal consumption rate 2.5 times greater than that stated in the Application.

This anomaly was noted after the June 11-12 Technical Meeting, otherwise it would have been raised at that time.

2.6.2 Hydrological Parameter Re-Evaluation

In Supporting Document S5 *Revised Doris North Project Hydroclimatic Parameter Evaluation 2007*, MHBL undertook a revised hydrological assessment of the mine site, following a condition of the NIRB report that stated:

> "MHBL shall collect additional precipitation, evaporation and runoff data and incorporate it into a revised water balance to be submitted to the NWB as part of the water licence application. (NIRB, 2006)."

The results of the revised assessment appear reasonable and are based on best available data. The main constraint on any hydrological estimates in Northern Canada is the limited amount of historical data and the many factors affecting freshet runoff volumes (*e.g.*, snow depth, rate of melting, conditions of soils in the previous summer prior to freeze-up, *etc*.).

2.7 Conditions Applying to Water Management

2.7.1 Water Management Plan

MHBL proposes to discharge mine tailings into Tail Lake, a small lake that lies close to the mine site. The lake will be dammed at both ends, increasing the available storage capacity. Tailings solids will be deposited sub-aqueously within the storage facility and tailings supernatant will be diluted in the lake by natural runoff. Water quality modeling by MHBL predicts that water will be able to be discharged from the facility without treatment. Water will be released with a floating pump (during operations and closure) or over a spillway at the downstream end of the lake (post-closure). During operations and closure the quality of the discharged water will have to comply with MMER at the intake site in Tail Lake and with CCME guidelines for protection of freshwater aquatic life at an SNP sampling station approximately 100 m downstream of the waterfall in Doris Creek.

MHBL discusses a number of different water management options. The preferred option requires the active discharge of water from the storage facility during the summer months when the lake and streams are ice-free. The discharge rate from the facility will be controlled to ensure that the downstream water quality in the receiving environment of Doris Creek does not exceed CCME guidelines. MHBL proposes a novel real-time monitoring system that will comprise:

- real-time monitoring of flows in Doris Creek;
- frequent (bi-daily) water quality analyses of samples from the receiving waters and within the tailings pond. Water quality analyses will be undertaken on-site in a purpose built analytical laboratory;
- real-time calculation of the discharge rate that will ensure that water quality variables in Doris Creek do not exceed CCME guidelines; and
- pumped releases from the tailings facility at 80% of the rate that was calculated to ensure compliance with CCME guidelines.

The benefit of this proposed system is that it is based on meeting CCME guidelines, which because of their conservatism will protect aquatic life in Doris Creek. The plan implicitly assumes the existence of a mixing zone in an approximately 100 m-long reach of Doris Creek between the end of the discharge pipe and the SNP compliance station.

Other water management options include pumped releases based on a pre-defined monthly release schedule; however, this option does not provide the same level of control over discharge volume or downstream water quality. Another option would be to allow the pond to fill without any water being released through the pumps, until the spillway crest level is reached. At that point water would then decant from the pond and flow into the receiving environment. Although, under this management option the maximum dilution of the tailings supernatant would take place in the pond, the operators would have no control on discharges once the crest level is reached. In addition, there would be a marked decrease in stream flow downstream of the tailings facility until the crest level is reached (potentially 7.5 years).

From the information provided in the water licence application, we conclude that with careful management, the preferred water management plan can be made to work. Other mines in Northern Canada (*e.g.*, EKATI) operate their tailings facilities with controlled discharges to the receiving environment during the open water season. The main difference with the proposal for the Doris North is the concept of having real-time control of discharge rates. The water management plan has a number of built-in contingencies, which provide confidence that the system can be operated successfully. These are:

- ***Short mine life.*** The proposed operational life of the mine is only two years. As a result, a limited volume of tailings solids and tailings supernatant can be produced during this time, resulting in relatively low total chemical loading to the storage pond;
- ***Relatively large pond size.*** There is available space in the tailings pond to provide storage for tailings solids and water for 5.5 to 7.5 years. Hence, if there are problems with water quality in the pond during the operational lifetime of the mine, then water can be stored in the pond with no releases until the quality is improved by dilution or until a water treatment plant can be installed;
- ***Predictable local hydrological conditions.*** Although it is very difficult to predict year-to-year changes in stream flow runoff in northern Canada, the annual flow hydrograph for northern watersheds has a predictable shape, with peak flows occurring over a short period at the beginning of summer, and flow decreasing steadily through the year and reaching their lowest flows in August and September. Although flow rates can be affected by rainfall or rapid melting events, for most of the year changes in flow rates are slow and predictable, making real-time adjustment of pumped outflows from the pond a practical water management option; and
- ***Rapid analytical turn-around.*** The presence of an on-site analytical laboratory to allow rapid turn-around of water quality analyses is essential for the successful operation of the water management plan.

Despite these mitigating factors there are a number of concerns and issues with the proposed management plan:

- ***Ensuring the successful operation of the real-time systems.*** Any real-time system requires thorough testing before being put into operation and regular maintenance and it needs to be operated by suitably trained and experienced staff. The critical period for the system will be during the first year of mine operation and in freshet of each subsequent year. In the first year of operations the systems and the operators will be new and care will need to be taken to ensure that excess water is not discharged from the facility. Freshet is a critical period during each year of operations because the highest discharge rates are possible during this time. It is also the period of time when flow rates are changing most rapidly, and peak flow rates may only last a few days once the stream channels become fully open. In addition, it is unlikely that the rating curves at the hydrological monitoring stations will be accurately calibrated for peak flow conditions. MHBL should ensure that systems are well tested and operators are fully trained before the beginning of operations. Training should be repeated before freshet in every subsequent year. During the freshet period, water quality sampling and manual flow measurements should be undertaken more frequently than the proposed bi-daily sampling program. Daily or twice daily measurements may be required;
- ***Uncertainties associated with the water quality model.*** With any water quality modeling that tries to predict future water quality within a tailings storage facility, there will be uncertainties associated with the predictions. MHBL has used conservative assumptions when developing the model, however, the quality of the model predictions can only be fully assessed once tailings are being deposited into the storage facility. Model predictions should be regularly updated using water quality data collected early in the lifetime of the facility;
- ***Potential for background concentrations to be close to CCME guidelines***. According to the water management plan outlined by MHBL, water will only be released from the storage facility when dilution calculations indicate that concentrations in the receiving environment will be less than the CCME guidelines. The volume of water able to be released from the pond will be sensitive to background concentrations in Doris Lake and to natural runoff entering the storage facility. Baseline water quality data indicates that background concentrations of some metals such as copper have on occasion approached CCME guidelines. If background levels are high for a sustained period, then no releases may be possible from the storage facility during these periods, affecting the proposed water management plan and affecting downstream flows;
- ***Winter water quality within the storage pond.*** There will be zero discharge from the pond during winter months. During the winter the water quality in the pond will be expected to deteriorate as tailings are deposited in the pond and there is no natural runoff. In addition, the formation of ice will also concentrate metals and other chemicals within the free water in the storage facility. At the onset of freshet, operators will want to discharge as much water as possible from the facility to take advantage of high flows in the receiving waters. Regular winter water quality monitoring is required to ensure that the evolution of water quality in the pond during winter is well understood. If concentrations in the pond are high, then discharges from the pond may need to be delayed until dilution has occurred. In addition, the pond may stratify during winter, with denser tailings water sitting at the bottom of the pond. At the beginning of freshet full

mixing may not have occurred and surface water quality measurements may not reflect the overall quality of water in the pond. During winter months, water quality samples should be taken at sufficient depth (as well as at the surface of the pond) to exclude stratification as a problem;

- ***Control of TSS.*** The storage facility should act as a sediment settling pond, however, care needs to be taken in the design and construction of the inlet to the pumps to ensure that concentrations of total suspended sediment (TSS) do not exceed the cut-off level of 15 mg/L specified by the MMER The following commitment from the *Final Environmental Impact Statement* is relevant to this issue:

  "To reduce TSS, MHBL must install silt curtains in localized areas of permafrost degradation; and apply geo-textile materials or rip rap to areas where slumping is observed to stabilize the shoreline."

- ***Extension of mining operations.*** MHBL proposes a two year operational mine life. As outlined above, with a mine life of only two years the size of the pond provides contingency against water quality issues. However, if mine life was to be extended and additional tailings deposited into the storage facility, then this would remove storage volume and would increase the concentrations of many variables in the pond (based on the water quality predictions for a two year mine life). It is clear that any extension to the life of the mine caused by development of other deposits in the Hope Bay Belt would require additional environmental impact assessment and the water management plan would have to be re-assessed at that stage.

2.7.2 Adaptive Management

The second paragraph of Section 6.1.4 states:

> "Model calibration would be required only if the model significantly underestimates solute concentrations in Tail Lake AND it is shown to potentially have a significant impact on the water management strategy."

It would be useful for MHBL to quantify the term "significant" with regards to both of its uses in this statement. Our understanding of "significant" in this case would be a potential for exceedance of CCME guidelines in the receiving environment of Doris Creek. However, the preceding sentences in this paragraph suggest that MHBL may define "significant" as a 20% deviation from predicted concentrations. We recommend that the Board define any potential exceedance of CCME guidelines, regardless of magnitude or duration, as "significant" and hence requiring re-calibration of the water quality model.

The third paragraph of Section 6.1.4 states:

> "In the event that the predictions show a significant constraint on achieving the water management strategy, then measures to contain or limit that source will be investigated. Should it not be possible to control the source, then the implications with respect to the discharge strategy/holding time will be assessed. It may then be possible, through adaptive management, to revise the discharge strategy. In

> the event that the discharge strategy cannot be revised to accommodate the changes in water quality, water treatment requirements will be established. Because of the long holding time available, it will be possible to design and implement a suitable water treatment system to continue to meet the project objectives of meeting CCME Guidelines in the receiving environment."

It would be instructive if the Application suggested some example strategies for the relative potential costs of these strategies.

2.7.3 Analytical Laboratory

One of the conditions of the NIRB report was:

> "MHBL will fund and install an on-site laboratory for continuous and real-time monitoring of water quality contained within Tail Lake and Doris Creek after discharge. This will be done prior to the commencement of operations. The laboratory shall be certified to Canadian standard of certification for Mineral Analysis Laboratories by the Standards Council of Canada, or a demonstrably equivalent certification standard, with standards to include the calibration of water quality monitoring instruments. MHBL shall file proof of application to become accredited, upon the request of the NWB [Nunavut Water Board] or NIRB's Monitoring Officer. (NIRB, 2006)"

The on-site analytical laboratory is a critical element of the water management plan and its accreditation is essential. The Board should require as a condition of the Water Licence that MHBL provide proof of laboratory accreditation prior to discharge of water from Tail Lake into Doris Creek.

Another NIRB condition was that:

> "upon the commencement of operations, MHBL shall ensure that the monitoring of Tail Lake and Doris Creek water quality, above and below the waterfall, be verified and reported to NIRB three times during discharge by an independent, third party laboratory. The sampling must be carried out independently or supervised in which case MHBL must provide the sampling and delivery of samples to the independent, third party laboratory, with copies of the results directly to the NWB and NIRB's Monitoring Officer."

Rescan supports third-party verification of the accuracy and precision of MHBL's analytical laboratory.

2.7.4 Water Quality Model

MHBL developed a water quality prediction model for the tailings storage facility. The model is a spreadsheet-based dilution model, which assumes that the pond is fully mixed at all times. This is reasonable approach considering that the main uncertainties in the study are associated

with the hydrological inflows and water quality loadings to the pond, rather than the mixing processes in the pond.

The model input parameters appear to be reasonably conservative. The main loading is from the tailings supernatant. Water quality data for the tailings supernatant are based on pilot plant test work, which should provide reasonable estimates of supernatant quality. However, as with any tailings pond modeling study there is a high degree of uncertainty associated with the input chemistry. The uncertainty in model predictions will only be overcome through monitoring of the tailings supernatant quality and pond water quality during operations. The proponent should also monitor waste rock seepage water as a priority to confirm the predicted seepage quality values used in the model.

The water quality model should be regularly updated during the operational lifetime of the mine using field data. Updated long-term model predictions and a comparison of predicted and observed concentrations should be provided in annual monitoring reports.

2.7.5 Proposed Tail Lake Discharge Strategy

Rescan supports the concept proposed by MHBL of a two-component discharge strategy from Tail Lake. The first component is the application of MMER standards for end-of-pipe discharge that will have to be met at the pumping station in Tail Lake (Table 2.7-1). These standards are obligatory for metal mines in Canada. They were based on acute toxicity tests for aquatic organisms.

Table 2.7-1
MMER Discharge Standards from Tail Lake

Variable	Units	Average	Maximum
TSS	mg/L	15	30
Total Cyanide	mg/L	1	2
Total Arsenic	mg/L	0.5	1.0
Total Copper	mg/L	0.3	0.6
Total Lead	mg/L	0.2	0.4
Total Nickel	mg/L	0.5	1.0
Total Zinc	mg/L	0.5	1.0
Radium 226	Bq/L	0.37	1.11

TSS = Total Suspended Solids.
Average = maximum average allowable concentration in Tail Lake at pipe intake measured over one reporting month.
Maximum = maximum allowable concentration in Tail Lake at pipe intake measured in a single sample.
Bq/L = Becquerel/Liter.

The second component is MHBL's proposal to use CCME guidelines for protection of aquatic life as standards that must be met in Doris Creek at an SNP station approximately 100 m downstream of the waterfall (assuming that water quality in Doris Creek above the discharge site for Tail Lake water meets CCME guidelines) (Table 2.7-2). These guidelines were based on chronic toxicity tests for aquatic organisms to which safety factors were then applied. The proposed water quality standards shown in Table 2.7-2 are only applicable when water is being discharged from Tail Lake into Doris Creek.

Table 2.7-2
Proposed Water Quality Standards in Doris Creek

Variable	Units	MMER Standards	CCME Guidelines	Proposed Standards[b]	
				Average	Maximum
pH	pH units	-	6 to 9	6 to 9	-
TSS	mg/L	15	-	15	-
Free Cyanide	mg/L	-	0.005	0.005	-
Total Cyanide	mg/L	1	-	0.01	-
Total Ammonia	mg/L	-	1.54[a]	1.54[a]	-
Nitrate-N	mg/L	-	2.94	2.94	2.94
Nitrite-N	mg/L	-	0.06	0.06	0.06
Total Aluminum	mg/L	-	0.1	0.1	0.1
Total Arsenic	mg/L	0.5	0.005	0.005	0.005
Total Cadmium	mg/L	-	0.000017	0.000017	0.000017
Total Chromium	mg/L	-	0.001	0.001	0.001
Total Copper	mg/L	0.3	0.002 to 0.004	0.002[c]	0.002[c]
Total Iron	mg/L	-	0.3	0.3	0.3
Total Lead	mg/L	0.2	0.001	0.001	0.001
Total Mercury	mg/L	-	0.000000026	0.000000026	0.000000026
Total Molybdenum	mg/L	-	0.073	0.073	0.073
Total Nickel	mg/L	0.5	0.025	0.025	0.025
Total Selenium	mg/L	-	0.001	0.001	0.001
Total Silver	mg/L	-	0.0001	0.0001	0.0001
Total Thallium	mg/L	-	0.008	0.008	0.008
Total Zinc	mg/L	0.5	0.03	0.03	0.03

Dashes indicate no data were available.
TSS = Total Suspended Solids.
[a]based on a pH of 7.5 and a temperature of 20°C. Value follows CCME pH- and temperature-dependent chart.
[b]standards apply whenever water is discharged from Tail Lake.
[c]the low end of the copper range is necessary because of the very low hardness of Doris Creek.

If conducted as planned, this discharge strategy will protect the aquatic life of Doris Creek and downstream waterbodies (*e.g.*, Little Roberts Lake). Protection will be due mainly because of the conservative nature of CCME guidelines.

The key to effective protection is ensuring that the discharge strategy actually works as planned – something that has to be demonstrated to be believed. The Board should scrutinize the discharge operation through the requirement of frequent reporting and MHBL should be required to immediately stop discharge should the discharge plan go awry. In that case, the Board should require a satisfactory explanation for failure from MHBL, and a proposal for a methodology that will prevent failure in the future, before allowing discharge to resume.

2.7.6 Proposed Sedimentation Pond Discharge Standards

According to Table 6.7 of the *Revised Doris North Water Licence Application Support Document*, MHBL's proposed discharge standards for the camp and mill pad sedimentation pond are equal to or lower than those for small volume releases from the Sable, Pigeon and Beartooth Pits of the EKATI diamond mine, the Diavik diamond mine, and the Boston exploration camp.

However, they are higher than those for the Snap Lake diamond mine. MHBL justifies these standards by implying that the water will be 'cleaned' by being discharged onto the tundra 500 m upstream of Doris Lake. This assumption is often made in the mining industry because most metals in soils are inert and will not be picked up by water passing over or through them, and because the electrical charge on soil particles can attract and hold metals and other contaminants. (However, it is not clear that this purported cleaning ability has any empirical basis.)

However, the tundra soils of the Doris North area are shallow and are often wet or frozen. Therefore, prolonged discharge of water from sedimentation ponds onto tundra may overwhelm the cleaning capacity of the soils. Rescan accepts MHBL proposal that discharges from the sedimentation pond will occur mainly during freshet and therefore that continuous discharge is not expected. However, the Board should consider requiring MHBL to monitor the frequency, volume and duration of discharges from the sedimentation pond to ensure that the assumptions of the proposed protocol actually apply. If MHBL cannot satisfy their assumptions, then Rescan recommends that MHBL investigate diverting the water from the sedimentation ponds to the tailings water stream, as they propose to do for the water that collects around the base of the waste rock pile.

2.7.7 Monitoring Plan

The proposed monitoring plan outlines continuous hydrological flow monitoring at seven sites and water quality sampling at ten sites.

Regular (bi-daily) water quality samples and flow measurements will be made in order to determine releases from the tailings storage facility. Rescan suggests that additional samples should be taken during early freshet in each year and possibly for most of freshet in year one until confidence is achieved in the real-time water management system that will control releases from the pond. During freshet manual flow measurements may be required in Doris Creek to ensure the accuracy of the flow data. Once the rating curve for the flow monitoring station is calibrated for peak freshet flows, then manual flow monitoring may not be required during the freshet period. Water quality sampling within Tail Lake should continue during the winter months (monthly samples), and it is suggested that samples should be taken at more than one depth in the pond to ensure the results are not biased by stratification of the water column.

In terms of reporting, MHBL proposes that water quality results will be presented in an annual report. Rescan suggests that short monthly reports be prepared during the first year of operations, to provide confidence that the water management plan is being applied successfully. These reports should include all water quality data, flow measurements in Doris Creek, discharges from the pond and pond water levels. All data used in calculating the discharge rate from the pond should be provided.

One of the conditions of the NIRB report was:

> "monitoring information collected under this approval shall contain the following information:
>
> - the person(s) who performed the sampling or took measurements;

- date, time, and place of sampling or measurement;
- date of analysis;
- name of the person who performed the analysis;
- analytical methods or techniques used; and
- results of any analysis.
- the results and records of any monitoring, data, or analysis shall be kept for a minimum of the life of the project including closure and post closure monitoring. This time period shall be extended if requested by NIRB, DFO [Department of Fisheries and Oceans], EC [Environment Canada] or the NWB [Nunavut Water Board]."

Rescan supports this condition.

2.8 Conditions Applying to Waste Management

Rescan accepts the conclusions of Supporting Document S8 *Geochemical Characterization of Portal Development Rock* that portal development rock will not be a source of acid rock drainage and metal leaching when temporarily stockpiled on the surface.

2.9 Conditions Applying to Aquatic Effects Monitoring

2.9.1 MMER Monitoring Cycles

According to section 8.0 of Supporting Document S10m *Monitoring and Follow-up Plan*, MHBL will submit a study design for MMER sampling within 12 months after mine operations begin. The first interpretive report will not be submitted until 36 months after mine operations begin – one year after the mine is planned to enter closure. The second interpretive report will be submitted within 24 to 72 months of submission of the first interpretive report, depending on the findings of the first report. Hence, the MMER program envisioned for the Doris North is necessarily more of a closure monitoring program than an operational monitoring plan.

Rescan understands that Doris North must follow the MMER schedule. Nor does Rescan argue that the Doris North should follow an accelerated reporting schedule – it would be unfair to ask MHBL to follow a schedule that is not demanded of other mines. Rescan understands that mine effects, if they occur, will take years to become detectable and that the collection and analysis of biological samples, and the evaluation and reporting of that data, takes time. However, there is clearly a logical problem with applying the conventional time scales of MMER to a Project with a two year life span.

If MHBL eventually develops the Madrid and Boston deposits of the Hope Bay Belt, as it briefly discusses in the introduction to the revised water licence application, then the lessons learned at Doris North may be useful in modifying management practices.

2.9.2 Locations of Sampling Sites

Rescan has no specific recommendations regarding MHBL's proposed environmental effects monitoring sites (as described in Supporting Documents S10m and S11). They are located in the

logical places and will provide adequate coverage of the potentially affected areas. There are both stream and lake reference sites.

2.9.3 Water Quality Variables

Rescan has no specific recommendations regarding MHBL's proposed list of water quality variables to be monitored. The list is comprehensive and covers the relevant variables.

2.9.4 Duration of Monitoring

MHBL should measure the quality of the water discharged from Tail Lake until that water has met CCME guidelines in Doris Creek consistently for several years. A cap of 9 years may not be appropriate despite water quality modeling.

2.10 Conditions Applying to Other Monitoring

Table 7.1 (Monitoring Program Summary) states that vegetation and soils will be monitored for metal concentrations once during construction, once each year during operations and once during closure. It would seem appropriate to measure metal concentrations in vegetation and soils after closure as well as during closure. Slow growing arctic vegetation may not show metal uptake immediately. Therefore, we recommend that the Board place a condition on monitoring of metal concentrations in vegetation and soils such that if the results of closure sampling show a statistically significant increase compared to baseline concentrations, then at least one more monitoring event should occur within the next five years to determine whether average metal concentrations remain elevated or have returned to baseline levels.

2.11 Conditions Applying to Closure and Reclamation

2.11.1 Jetty

A fuel spill management plan should be in place when dismantling the upper layer of the jetty as this will require heavy equipment which will be at least partially used below the water surface. The concern is that fuel and grease from equipment may enter the water during dismantling. Further, a sediment management plan should be in place in the vicinity of the jetty. The goal should be to minimize disturbance along the bank. Rescan understands that MHBL will check for the presence of contaminated soils on the jetty prior to de-commissioning as part of its site-wide commitment to identifying and mitigating contaminated soils.

2.11.2 Fuel Tanks

The containment berms around the fuel tanks will be breached and recontoured to encourage natural drainage once the tanks have been removed. The berm material and any standing water behind the berms should be sampled for hydrocarbon analysis prior to breaching the berms. The concern is that hydrocarbon-rich sediment may be lodged within the berm material, perhaps in low-lying areas, or that hydrocarbon-rich standing water will enter natural drainages. This should be mitigated before breaching the barriers.

The hydrocarbon sludge from the fuel tanks may be burned on site. The area where incineration is to take place should be lined to prevent the incinerated material from entering water when natural drainage is restored. Ash should be disposed of prior to breaching the berm.

2.11.3 Doris Lake Dock Removal

The removal of the dock at Doris Lake will require heavy equipment. This may result in the generation of sediment due to the disturbance of the lake edge. A sediment control plan should be developed to minimize sediment entering Doris Lake.

2.11.4 Rock Quarry Closure

At closure, the quarry floors will be channelled to allow precipitation runoff to drain onto the surrounding tundra which could potentially enter a local stream in the vicinity. It is assumed that the material exposed by quarrying will not be acid generating (or stored materials will not be deleterious). If there is a potential for such an issue with this material, then this should be assessed prior to carrying out channelling.

2.11.5 Tail Lake

Breaching of the northern dam after closure may cause turbulence in Tail Lake and stir up buried tailings, potentially resulting in changing the chemistry of the water. MHBL should take this into consideration when planning for closure. Once the dam is breached, mitigation will likely be very difficult.

3. SUMMARY

3. Summary

- The changes in project design introduced by MHBL at the Technical Meeting held on June 11 and 12, 2007, fall within the scope of the Project Certificate issued by NIRB.
- Rescan recommends that the water licence be renewed within five years of issuance.
- During the freshet period, water quality sampling and manual flow measurements should be undertaken more frequently than MHBL's proposed bi-daily sampling program. Daily or twice daily measurements may be required until confidence is achieved in the real-time water management system that will control releases from Tail Lake.
- The predictions of the water quality model should be regularly updated during the operational lifetime of the mine by comparing them with field-collected water quality data. Updated long-term model predictions and a comparison of predicted and observed concentrations should be provided in annual monitoring reports.
- We recommend that the Board define any exceedance of CCME guidelines predicted by the water quality model, regardless of magnitude or duration, as "significant" and requiring re-calibration of the water quality model.
- We recommend that the Board define any measured exceedances of CCME guidelines in Doris Creek during discharge from Tail Lake as grounds for immediate cessation of discharge.
- During winter and spring months, water quality samples should be taken from Tail Lake at sufficient depth to exclude stratification as a problem.
- Care needs to be taken in the design and construction of the inlet to the pumps in Tail Lake to ensure that concentrations of total suspended sediment (TSS) do not exceed the cut-off level of 15 mg/L specified by the MMER.
- Rescan supports the concept proposed by MHBL of a two-component discharge strategy from Tail Lake: (1) end-of-pipe MMER discharge guidelines in Tail Lake and (2) CCME guidelines for protection of aquatic life in Doris Creek.
- If discharge of water from sedimentation ponds onto tundra is frequent enough to overwhelm the cleaning capacity of tundra soils, then MHBL should divert water from the sedimentation ponds to the tailings water stream.
- During freshet, manual flow measurements may be required in Doris Creek to ensure the accuracy of the flow data.
- Rescan suggests that short monthly reports be prepared during the first year of operations, to provide confidence that the water management plan is being applied successfully. These reports should include all water quality data, flow measurements in Doris Creek, discharges from the pond and pond water levels. All data used in calculating the discharge rate from the pond should be provided.
- The Board should place a condition on monitoring of metal concentrations in vegetation and soils that if the results of closure sampling show a statistically significant increase

compared to baseline concentrations, then at least one more monitoring event should occur within the next five years to determine whether average metal concentrations remain elevated or have returned to baseline levels.

- A fuel spill management plan and a sediment management plan should be in place when dismantling the upper layer of the jetty because this will require heavy equipment which will be at least partially used below the water surface.
- At closure, the material of the containment berms around the fuel tanks and any standing water behind the berms should be sampled for hydrocarbon analysis prior to breaching the berms.
- At closure, the hydrocarbon sludge from the fuel tanks may be burned on site. In that event, the area where incineration is to take place should be lined to prevent the incinerated material from entering water when natural drainage is restored. Ash should be disposed of prior to breaching the berm.
- At closure, the removal of the dock at Doris Lake will require heavy equipment. This may result in the generation of sediment due to the disturbance of the lake edge. A sediment control plan should be developed to minimize sediment entering Doris Lake.
- At closure, the quarry floors will be channelled to allow precipitation runoff to drain onto the surrounding tundra which could potentially enter a local stream in the vicinity. It is assumed that the material exposed by quarrying will not be acid generating (or stored materials will not be deleterious). If there is a potential for such an issue with this material, then this should be assessed prior to carrying out channelling.
- After closure, once the northern dam of Tail Lake is breached, turbulence in Tail Lake may stir up tailings, potentially changing water chemistry. MHBL should take this into consideration in closure planning because mitigation will likely be very difficult once the dam is breached.

REFERENCES

References

Environment Canada. 2005. *The New Metal Mining Effluent Regulations*. Accessed at: http:/www.//www.sc.gc.ca./nopp/docs/regs/mmer/en/index.cfm.

MHBL. 2005. *Final Environmental Impact Statement, Doris North Project, Nunavut, Canada*. Submitted to the Nunavut Impact Review Board by Miramar Hope Bay Limited. October 2005.

MHBL. 2007. *Revised Water Licence Support Document, Doris North Project, Nunavut, Canada*. Submitted to the Nunavut Water Board by Miramar Hope Bay Limited. April 2007.

NIRB. 2006. *Final Hearing Report for the Doris North Gold Project*. Nunavut Impact Review Board File No. 05MN047. March 2006.

NWB. 2006. *Additional Guidelines for the Doris North Water Licence Application*. Letter to Larry Connell, Miramar Mining Corporation, by Joe Murdock, Nunavut Water Board. December 27, 2006.

WHO. 2004. *Guidelines for Drinking-Water Quality*. Third Edition. World Health Organization, Geneva.

APPENDIX 1
RESUMES OF RESCAN SCIENTISTS

Susan Ames, Ph.D., M.Sc., P.Ag., CAC

Rescan™ Environmental Services Ltd.
Head Office: Sixth Floor - 1111 West Hastings Street, Vancouver, B.C., Canada • Tel: (604) 689-9460 • Fax: (604) 687-4277
Email: rescan@rescan.com • Website: www.rescan.com

Offering a full range of environmental and engineering solutions to clients around the world

Education

Ph.D. Resources Management and Environmental Studies
University of British Columbia, Vancouver, B.C.

M.Sc. Soil Science
University of British Columbia, Vancouver, B.C.

B.Sc. Biology
Dalhousie University, Halifax, Nova Scotia

Professional Affiliations

- BC Institute of Agrologists (BCIA)
- Pacific Regional Society of Soil Science (PRSSS)
- Canadian Soil Science Society (CSSS)
- Canadian Consulting Agrologists Association (CCAA)
- Organic Growers of Canada

Experience

Dr. Ames is the Senior Soil Scientist at Rescan and coordinates all projects related to soils, land reclamation, and mine closure. As an Environmental Scientist, she has over 20 years of experience for a wide range of projects including land reclamation, rehabilitation and closure planning, designing of store and release covers for mine waste, impact assessments, soil surveys, agricultural capability evaluations, land use mapping, climate change effects assessments, scientific and technical writing, and teaching at the university and college levels. She has a Ph.D. in Resource Management and Environmental Studies, a M.Sc. in Soils, and a B.Sc. in Biology. Dr. Ames has presented at numerous conferences, workshops and before local government agencies and the public. She has held numerous positions in various organizations including three terms as President of the Vancouver Branch, BCIA, three years as BC Director for CCAA, and three years as Treasurer of PRSSS. She is currently President Elect of BCIA. She is a team player with a focus on innovative and sustainable approaches to environmental issues.

Offering a full range of environmental and engineering solutions to clients around the world

Selected Project Experience

Baseline Report for Ferguson Lake Mine, and Closure Plan for Mining Camp, Nunavut

- Carried out detailed field survey and sampling program as part of Terrestrial Ecosystem Mapping (TEM)
- Analyzed chemical data
- Prepared baseline report
- Developed closure plan for original camp

Baseline and Environmental Assessment for Pueblo Viejo Transmission Line and Power Plant, Dominican Republic

- Prepared baseline (as part of TEM) and environmental effects assessment, mitigation and management plans for power plant site, transmission line, borrow pit, and dustfall area
- Prepared closure plan for burrow pit

Baseline and Environmental Assessment for Aqua Rica Mine Project, Argentina

- Prepared baseline (as part of TEM) and environmental effects assessment, mitigation and management plans for mine site, transmission line, pipeline, processing plant site, and port area .
- Developed closure plans for waste dump and tailings stack
- Assessed irrigation options for filter plant water

Baseline, Environmental Assessment, Reclamation and Closure Planning for New Afton Project

- Carried out baseline and effects assessment of mine site
- Carried out agricultural capability assessment
- Developed reclamation and closure plans for stockpiled soils, tailings storage facility, dam slopes, plant facility, and other disturbed areas to meet end land use objectives
- Oversaw preparation of costing estimate for reclamation and closure
- Designed visual berm

Baseline, Environmental Assessment, Reclamation and Closure Planning for Davidson Project, BC

- Prepared baseline report and carried out overview of effects assessment of mine site and assess road
- Prepared closure plan for mine site and site road

- Oversaw development of closure and reclamation plans for haul road, plant site, pipeline and power line corridor

Environmental Assessment, Kutcho Project, BC

- Planned and carried out baseline studies as part of TEM for mine site
- Oversaw baseline program for access road

Modeling of the Impacts of Land Use and Management on Carbon Storage and Sequestration Rates

- Designed various management and land use scenarios
- Developed data sets
- Carried out sensitivity analyses of the CENTURY model
- Assessed the impacts of time and management on carbon storage, NPP and NEP

Assessment of Climate Change on the Galore Creek Project

- Modeled climate change effects on precipitation and temperature
- Assessment of climate change on glacier melting as it affects river hydrology over time

Effects of Climate Change on Glacier Melting for Reclamation Planning of the Kumtor Mining Project, Kazakhstan

- Researched global climate change evidence/predictions
- Reviewed IPCC reports and background research
- Assessed the potential for glacier melting on the waste dumps
- Developed reclamation plans for tailings and plant site areas and assessed the potential for glacier melting on the waste dumps

Reclamation Planning of the Cogburn Mining Project, BC – Part of EA

- Assessed the potential for air particulate enhancement in the Vancouver/Fraser Valley area based on GVRD data
- Designed and carried out field program
- Assessed soils for suitability for reclamation purposes
- Developed a staged soil extraction, storage, and volume estimate
- Evaluated the effects of precipitation/snowmelt on potential runoff/erosion
- Made recommendations for final rehabilitation

Reclamation Planning for the Wolverine Coal Mine Project, BC – Part of EA

- Designed and carried out field program

- Assessed soils for suitability for reclamation purposes
- Developed a suitability mapping system
- Interpreted soil susceptibility for erosion

Reclamation Planning of the Maqui Maqui Project, Peru

- Assessed the vegetation species mix for reclamation
- Evaluated the efficiency of constructed covers
- Modeled covers for heap leach pad using the VADOSE/W hydrology model

Reclamation of the Sullivan Mine Acid Generating Mine Tailings, Kimberly, BC

- Carried out a detailed review of reclamation practices/approaches for acid generating mine waste materials
- Designed a method to reclaim tailings (use of cover with and without a rock barrier)
- Collected and prepared oxidized mine tailings and soils from the mine site for study to test design
- Carried out laboratory chemical and statistical analyses and interpretation
- Method used to reclaim the tailings at the mine site and is now commonly used to reclaim acid generating wastes

Gravel Pit Planning - Several Properties in the Fraser Valley, BC

- Designed and carried out field programs
- Surveyed and assessed soils for conservation for final reclamation
- Reviewed zoning regulations and worked with Municipal and Agricultural Land Commission staff to formulate the preparation of staged extraction and reclamation programs
- Developed site plans, long term storage and rehabilitation plans
- Wrote reports
- Monitored the extraction and rehabilitation operations

Mapping and Classification of Soils for Susceptibility to Acid Deposition at a Proposed Gas Plant Expansion in Northern, BC

- Mapped and tested soils for acidic effects
- Evaluated the susceptibility of the soils to acidification
- Developed a susceptibility to acidification system

Reclamation Planning of the Carbon Creek Coal Mine for Utah Mines Ltd., BC

- Evaluated topsoil suitability by mapping unit and depth
- Made recommendations for stripping, stockpiling, seeding and fertilizing
- Made recommendations for final reclamation of site

Assessment of the Extent of Salt Affected Soils

- Reviewed field program, site history, and chemical analyses of various properties in Alberta
- Mapped the areal extent of salinization
- Assessed impact on crops
- Designed amelioration procedures

Additional Skills

- Working Effectively with First Nations
- Bio-Resource Engineering
- Being an Expert Witness
- Resource Management Negotiations
- Media Wise Relations
- Data Archiving
- Agroforestry
- Facilitation Skills
- Leading Discussion Groups
- Presentation Skills
- Instructional Skills Workshop

Other

- Chair of the ALR Protection and Enhancement Committee
- Organized numerous workshops including the 2004 Agricultural Land Reserve Workshop, the 2004 Land Summit Conference, numerous professional development workshops for the Pacific Regional Society of Soil Science and the BCIA
- Fund raising for the BC Land Summit and the ALR Protection and Enhancement Committee
- Moderated at the 2004 BC Land Summit
- Developed and taught Soil Chemistry and Soils 200 (distance learning) (UBC); developed and taught course on BC and Canadian EA Process (BCIT); developed and taught course on Soils for Growing Grapes for the Wine Industry (Okanagan College)
- President–Elect of BCIA

Michael D. McGurk, Ph.D., R.P.Bio.

Rescan™ Environmental Services Ltd.

Head Office: Sixth Floor - 1111 West Hastings Street, Vancouver, B.C., Canada • Tel: (604) 689-9460 • Fax: (604) 687-4277
Email: rescan@rescan.com • Website: www.rescan.com

Offering a full range of environmental and engineering solutions to clients around the world

Education

Ph.D. (Zoology)
University of British Columbia, 1986

M.Sc. (Biology)
Memorial University, 1979

B.Sc. (Biology)
McGill University, 1975

Professional Affiliations

- Registered Professional Biologist, Association of Professional Biologists of British Columbia (APBBC: number 419)

Experience

Michael McGurk has over 20 years experience as a fisheries scientist, project manager, risk assessor and technical writer. During the mid- to late-1980s, he conducted ichthyoplankton surveys for the US government in south-eastern Alaska, Prince William Sound, and the Bering Sea to assess the potential impact of offshore oil and gas exploration on Alaskan fisheries resources. He subsequently worked on freshwater and marine systems of British Columbia (*e.g.*, hydroelectric facilities and Pacific salmon populations of the Nechako River basin, copper-gold mines and rainbow trout of the Cariboo-Chilcotin region, water use planning in the Allouette, Seton and Bridge Rivers, and log dumping on the Central Coast). Since joining Rescan in 2001 he has worked on a wide range of mine-related projects in western and northern Canada (e.g., monitoring of Island Copper Mine reclamation, environmental issues surrounding the Cheviot Coal Project, environmental monitoring of the Eskay Creek Mine, Kemess North Project, EKATI Diamond Mine, Colomac Gold Mine, Diavik Diamond Mine, Jericho Diamond Mine, the Bathurst Inlet Port and Road Project and the Doris North Project). His international work includes projects in Central and South America (e.g., the Rosebel Gold Project of Suriname, the Pueblo Viejo Gold Mine of the Dominican Republic and the CELCO pulp mill of Chile), Africa (e.g., the Buzwagi Gold Project and Tulawaka Gold Mine of Tanzania) and the Pacific rim (e.g., the Goro Nickel Project, New Caledonia). He has published 26 scientific papers, mainly in the aquatic sciences press.

Offering a full range of environmental and engineering solutions to clients around the world

2001 to present
SENIOR ENVIRONMENTAL SCIENTIST
Rescan™ Environmental Services Ltd.
Vancouver, British Columbia

- team leader – hypothesis formulation for loss of macrophyte community and swan nesting in the Rio Cruces basin of south-central Chile (Celulosa Arauco y Constitución S.A.)
- fish habitat compensation planning for the Galore Creek Project (NovaGold Canada Inc.)
- environmental monitoring, ecological risk assessments and fish habitat compensation planning for the EKATI Diamond Mine (BHP Billiton Diamonds Inc.) and the Island Copper Mine (BHP Base Metals)
- environmental surveys of aquatic resources of the Colomac Mine, Northwest Territories (Public Works Canada)
- environmental effects monitoring of the Eskay Creek Mine (Barrick Gold Corporation)
- baseline surveys of fish and fish habitat at stream crossings and near a potential marine port and writing of Environmental Impact Statement (Bathurst Inlet Port and Road Project, Nunavut)
- review of the Aquatic Effects Monitoring Program of the Diavik Diamond Mine (Mackenzie Valley Land and Water Board)
- review of the Mine Waste Management Program of the Kemess North Project (Northgate Minerals Corp.)
- review of the Final Environmental Impact Statement and Water License Application for the Jericho Diamond Project and the Doris North Project (Kitikmeot Inuit Association and Nunavut Tunngavik Inc.)
- review of environmental issues of the Cheviot Creek Pit/Cardinal River Coal Expansion (Teck Cominco Ltd.)
- environmental impact assessment of the Pueblo Viejo Gold Project of the Dominican Republic (Barrick Gold Corporation)
- environmental impact assessment of the Buzwagi Gold Project of Tanzania (Barrick Gold Corporation)
- environmental impact assessment of the Rosebel Gold Project of Suriname (Cambior Inc.)
- environmental impact assessment of the Goro Nickel Mine of New Caledonia (Hatch Associates Ltd. and Inco Ltd.)
- baseline environmental surveys of Ferguson Lake Project, Nunavut (Starfield Resources Inc.)

1989 to 2000
FISHERIES SCIENTIST/PROJECT MANAGER
Triton Environmental Consultants Ltd.
Richmond, British Columbia

- mark-recapture estimate of rainbow trout population number in Fish Lake and baseline surveys of fish and fish habitat of the Chilcotin region, BC, for the Prosperity Copper-Gold Project (Taseko Mines Ltd.)
- laboratory incubation of herring eggs from Prince William Sound, Alaska, to assess the impact of the *Exxon Valdez* oil spill on viable hatch (Alaska Department of Fish and Game, Cordova)
- survey of juvenile white sturgeon abundance and distribution in the upper Nechako River (Alcan Smelters and Chemicals Ltd.)
- population dynamics of mountain whitefish in the Columbia River below Hugh Keenleyside Damn, BC (B.C. Hydro)
- environmental issues surrounding the installation of a fifth turbine at the Revelstoke Dam and at the Mica Dam (BC Hydro)
- effects of environmental factors on Pacific herring larvae and sand lance larvae in the southeastern Bering Sea in relation to oil and gas development on the continental shelf (US Minerals Management Service)
- ecological risk assessment of oceanographic factors responsible for the decline in abundance of the Cherry Point herring stock, Bellingham WA (EVS Environmental Consultants)
- consequences of the *Exxon Valdez* oil spill to future herring harvests in Prince William Sound, Alaska (Wilmer, Cutler and Pickering, Washington, D.C.)
- fish and fish habitat of Cuisson Creek, BC (Gibraltar Mines Ltd.)
- population biology of sockeye salmon and chinook salmon in the Fraser River basin (Alcan Smelters and Chemicals Ltd.)
- management of the sablefish fishery off Canada's west coast (Pacific Coast Blackcod Fisherman's Association)
- emergence and outmigration of chinook salmon fry, Nechako River, BC (Nechako Fisheries Conservation Program)
- public hearings into the Kemano Completion Project by the B.C. Utilities Commission (Alcan Smelters and Chemicals Ltd.)
- methods for determining minimum instream flows of the Allouette, Bridge and Seton Rivers (B.C. Hydro)
- water quality and fish resources of Revelstoke and Arrow Lakes (B.C. Hydro)

1986 to 1989
FISHERIES SCIENTIST/PROJECT MANAGER
Envirocon Pacific Limited
Burnaby, British Columbia

- survey of Port Moller, Alaska, as a site for a large-scale study of the population dynamics of Alaskan herring larvae. (US National Oceanic and Atmospheric Administration, Alaska)
- survey of Pacific herring larvae distribution and size in Prince William Sound, Alaska, after the *Exxon Valdez* oil spill (US National Oceanic and Atmospheric Administration, Alaska)
- survey of Pacific herring eggs and larvae in Auke Bay, Alaska. (US National Oceanic and Atmospheric Administration, Anchorage, Alaska)
- environmental impact statement on the effects of surface elevation changes of BC hydroelectric dams on recreational and fishery resources of British Columbia (Bonneville Power Authority, Oregon)
- commercial sampling of the 1989 B.C. roe herring fishery. (Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo)

1984 to 1985
LIBRARIAN
University of British Columbia, Zoology Department
Vancouver, British Columbia

- Maintained the Bioscience Department's collection of scientific literature on fisheries and wildlife ecology, and assisted faculty and students in locating research literature.

1979 to 1981 and 1982 to 1984
TEACHING ASSISTANT
University of British Columbia, Zoology Department
Vancouver, British Columbia

- Assisted in instruction of courses on introductory biology, invertebrate biology, vertebrate biology, and statistical techniques of ecological research.

1979
BIOTECHNICIAN
Westwater Research Center
Vancouver, British Columbia

- Assisted biologists in a study of the fish community of the Fraser River estuary.

1977 to 1978
RESEARCH ASSISTANT
Memorial University, Biology Department
St. John's, Newfoundland

- Assisted in animal geneticist in the maintenance and selective breeding of a colony of laboratory rats with inherited diabetes.

1978
BIOCHEMISTRY TECHNICIAN
Victoria Hospital
Montreal, Quebec

- Measured concentrations of metabolites in body fluids of patients.

Publications

Harding, L., J. Pretorius, and M. McGurk. 2007. Recent changes in the Rio Cruces: comment on Mulsow and Grandjean (2006). *Ethics in Science and Environmental Politics* 2007: 1-3.

McGurk, M.D., F. Landry, A. Tang, and C.C. Hanks. 2006. Acute and chronic toxicity of nitrate to early life stages of lake trout and lake whitefish. *Environmental Toxicology and Chemistry* 25: 2187-2196.

McGurk, M.D. 2000. Comparison of fecundity-length-latitude relationships between the non-anadromous (kokanee) an anadromous sockeye salmon (*Oncorhynchus nerka*). *Canadian Journal of Zoology* 78: 1791-1805.

McGurk, M.D. 1999. Size-dependence of natural mortality rate of sockeye salmon and kokanee in freshwater. *North American Journal of Fisheries Management* 19: 376-396.

Marty, G.D., J.E. Hose, M.D. McGurk, E.D. Brown, and E.D. Hinton. 1997. Histopathology and cytogenetic evaluation of Pacific herring larvae exposed to petroleum hydrocarbons in the laboratory and in Prince William Sound, Alaska, after the *Exxon Valdez* oil spill. *Canadian Journal of Fisheries and Aquatic Science*s 54: 1946-1857.

McGurk, M.D., and E.D. Brown. 1996. Egg-larval mortality of Pacific herring in Prince William Sound, Alaska, after the *Exxon Valdez* oil spill. *Canadian Journal of Fisheries and Aquatic Sciences* 53: 2343–2354.

Hose, J.E., M.D. McGurk, G.D. Marty, D.E. Hinton, E.D. Brown, and T.T. Baker. 1996. Sublethal effects of the *Exxon Valdez* oil spill on herring

embryos and larvae: morphologic, cytogenetic, and histopathological assessments, 1989-1991. *Canadian Journal of Fisheries and Aquatic Sciences* 53: 2355-2365.

Brown, E.D., T.T. Baker, J.E. Hose, R.M. Kocan, G.D. Marty, M.D. McGurk, M.D., B.L. Norcross, and J. Short. 1996. Injury to the early life stages of Pacific herring in Prince William Sound after the *Exxon Valdez* oil spill, p. 448-462. *In* S.D. Rice, R.B. Spies, D.A. Wolfe, and B.A. Wright (eds.). *Proceedings of the Exxon Valdez Oil Spill Symposium. American Fisheries Society Symposium* 18.

McGurk, M.D. 1996. Allometry of marine mortality of Pacific salmon. U.S. National Marine Fisheries Service, *Fishery Bulletin* 94: 77-88.

Edinger, J.E., E.M. Buchak, and M.D. McGurk. 1993. Analyzing larval distributions using hydrodynamic and transport modeling, p. 536-550. In *Proceedings of the American Society of Civil Engineer (ASCA) Specialty Conference on Estuarine and Coastal Modeling III*, September 8-10, 1993, Oak Brook, Illinois.

McGurk, M.D. 1993. Allometry of herring mortality. *Transactions of the American Fisheries Society* 122: 1035-1042

McGurk, M.D., A.J. Paul, K.O. Coyle, D.A. Ziemann, and L.J. Haldorson. 1993. Relationships between prey concentration and condition, growth and mortality of herring larvae in an Alaskan embayment. *Canadian Journal of Fisheries and Aquatic Sciences* 50: 163-180.

McGurk, M.D., and H.D. Warburton. 1992. Pacific sand lance larvae in Port Moller, southeastern Bering Sea: an estuarine-dependent early life history. *Fisheries Oceanography* I: 306-320.

McGurk, M.D., H.D. Warburton, M. Galbraith, and W.C. Kusser. 1992. RNA-DNA ratios of individual Pacific herring, *Clupea pallasi,* larvae. *Canadian Journal of Fisheries and Aquatic Sciences* 49: 967-974.

McGurk, M.D. and W.C. Kusser. 1992. Comparison of three methods of measuring RNA-DNA ratios of individual Pacific herring, *Clupea pallasi*, *larvae. Canadian Journal of Fisheries and Aquatic Sciences* 49; 967-974.

McGurk, M.D. and W.C. Kusser. 1992. Avoidance of towed plankton nets by herring larvae: a model of nightday catch ratios based on larval length, net speed, and mesh width. *Journal of Plankton Research* 14: 173-182.

McGurk, M.D. 1989. Advection, diffusion and mortality of Pacific herring *(Clupea harengus pallasi*) larvae in Bamfield Inlet, British Columbia. *Marine Ecology Progress Series* 51: 1-18.

McGurk, M.D. 1987. Spatial patchiness of Pacific herring larvae. *Environmental Biology of Fish* 20: 81-89.

McGurk, M.D. 1987. Age and growth of Pacific herring larvae based on length frequency analysis and otolith ring number. *Environmental Biology of Fish* 20: 33-47.

McGurk, M.D. 1987. Natural mortality and spatial patchiness: reply to Gulland. *Marine Ecology Progress Series* 39: 201–206.

McGurk, M.D. 1986. Natural mortality of marine pelagic fish eggs and larvae: role of spatial patchiness. *Marine Ecology Progress Series* 34: 227-242.

McGurk, M.D. 1986. Some remarks on "Model of monthly marine growth and natural mortality for Babine Lake sockeye salmon (*Oncorhynchus nerka*)" by Furnell and Brett. *Canadian Journal of Fisheries and Aquatic Sciences* 43: 2535-2536.

McGurk, M.D. 1985. Effects of net capture on the postpreservation morphometry, dry weight and condition factor of Pacific herring larvae. *Transactions of the American Fisheries Society* 114: 348-355.

McGurk, M.D. 1985. Multivariate analysis of morphometry and dry weight of Pacific herring larvae. *Marine Biology* 86: 1-11.

McGurk, M.D. 1984. Effects of delayed feeding and temperature on the age of irreversible starvation and on the rates of growth and mortality of Pacific herring larvae. *Marine Biology* 84: 13-26.

McGurk, M.D. 1984. Ring deposition in the otoliths of larval Pacific herring Clupea harengus pallasi. U.S. National Marine Fisheries Service, *Fishery Bulletin* 82: 113-120.

McGurk, M.D., J.M. Green, W.D. McKone, and K. Spencer. 1980. Condition indices, energy density, and water and lipid content of Atlantic herring (*Clupea harengus harengus*) of southeastern Newfoundland. *Canadian Technical Report of Fisheries and Aquatic Sciences* No. 958.

In preparation

Powell, L., L. Harding, and M. McGurk. In preparation. Satellite imagery analysis of the Carlos Anwandter nature Sanctuary, Rio Cruces, Chile.

Greg McKillop, B.Sc., P. Geo.

Rescan™ Environmental Services Ltd.
Head Office: Sixth Floor - 1111 West Hastings Street, Vancouver, B.C., Canada • Tel: (604) 689-9460 • Fax: (604) 687-4277
Email: rescan@rescan.com • Website: www.rescan.com

Offering a full range of environmental and engineering solutions to clients around the world

Education

B.Sc. (Geology)
University of British Columbia, 1973

Experience

Mr. McKillop has over 30 years of experience in mineral exploration and government mineral policy and permitting functions. His experience has provided him a broad knowledge of government and industry processes. Throughout his career, he has held a number of supervisory and managerial roles. Prior to joining Rescan, Mr. McKillop worked for the British Columbia Ministry of Energy and Mines where he advised on policy, legislation, permitting and land and resource management issues.

2005 to Present
MANAGER – POLICY ASSESSMENT AND PERMITING
Rescan Environmental Services Ltd
Vancouver, British Columbia

- Upon joining Rescan Environmental Services Ltd. in 2005 Mr. McKillop participated in the environmental assessment of the Pueblo Viejo project in the Dominican Republic and the Agua Rica project in Argentina. He has also managed an environmental assessment process for Western Keltic Mines Inc.'s Kutcho project and permitting activities for several exploration and pre-development projects in British Columbia and Nunavut. More recently Mr. McKillop has managed the coordination of federal and provincial environmental assessment processes and concurrent permits for the Galore Creek Project. He is currently co-managing the environmental assessment of the Sabina Silver Corporation Hackett River project in Nunavut.

2002 to 2005
DIRECTOR – MINERAL POLICY & INITIATIVES BRANCH
Ministry of Energy and Mines, Mining and Mineral Resources Division
Victoria, British Columbia

- Extensive involvement in land and resource management processes, review of socio-economic assessments, strategic advice for the development of B.C.'s long-term mining plan, policy support for development of B.C.'s Internet-based mineral tenure management system, economic assessment of the proposed Omineca to Stewart resource road, management of mineral statistics collection and analysis, mining sustainability initiative.

1996 to 2002
MANAGER – PROGRAM DEVELOPMENT
MINERAL POLICY & INITIATIVES BRANCH
Ministry of Energy and Mines, Mining and Mineral Resources Division
Victoria, British Columbia

- Gravel pit and quarry policy (Secretariat to Aggregate Advisory Panel), supervised development of Aggregate Operators Best Management Practices Handbook, managed mineral rights compensation project, revision of placer mining regulations.

1998
EXECUTIVE DIRECTOR – OIL & GAS INITIATIVE PROJECT IMPLEMENTATION
Ministry of Employment and Investment, Energy & Minerals Division
Victoria, British Columbia

DIRECTOR & DEPUTY COMMISSIONER
Oil & Gas Commission
Victoria, British Columbia

- Developed organizational model, budget, operating procedures, fee structure and transition strategies to implement a one-stop shop for permitting of oil and gas activities.

1993 to 1996
ASSISTANT DIRECTOR – REGIONAL OPERATIONS
Land Management and Policy Branch,
Ministry of Energy, Mines and Petroleum Resources
Victoria, British Columbia

- Managed regional mine permitting, inspections, geological and land use planning functions.

1991 to 1993
ASSISTANT DIRECTOR – ENVIRONMENTAL IMPACT MANAGEMENT
Ministry of Energy, Mines & Petroleum Resources, Resource Management Branch
Victoria, British Columbia

- Managed regional mine permitting and inspection functions and reclamation and geotechnical engineering sections.

1990 to 1991
MANAGER – PROGRAM DEVELOPMENT
Ministry of Energy, Mines & Petroleum Resources, Mineral Policy Branch
Victoria, British Columbia

- Represented ministry in planning, design and approval of the $13 million Iskut mine road.

Offering a full range of environmental and engineering solutions to clients around the world

1985 to 1990
MANAGER
Canada/British Columbia Mineral Development Agreement

- Developed and managed contracts for delivery of a 5 year, $10 million program of geoscience, technology development and communications to stimulate the mining sector

1973 to 1985
DISTRICT GEOLOGIST
Duval International Corporation (Mining subsidiary of Pennzoil Company)
Vancouver, British Columbia

- Managed exploration programs in British Columbia and Washington State.

P. Julius Pretorius, Ph.D.

Rescan™ Environmental Services Ltd.
Head Office: Sixth Floor – 1111 West Hastings Street, Vancouver, B.C., Canada • Tel: (604) 689-9460 • Fax: (604) 687-4277
Email: rescan@rescan.com • Website: www.rescan.com

Offering a full range of environmental and engineering solutions to clients around the world

Education

Ph.D. (Chemistry)
University of Cape Town, 1998

M.Sc. (Chemistry)
University of Cape Town, 1991 (with distinction)

Professional Affiliations

- Member, Society of Environmental Toxicology and Chemistry
- Member, International Association of Geochemistry
- Editorial Board, Journal of Soils and Sediments (2001-2005)

Experience

Dr Pretorius has more than 15 years of experience in the field of aqueous solution chemistry. After obtaining an MSc degree in Chemistry from the University of Cape Town, South Africa, he joined the South African Council for Scientific and Industrial Research as an Environmental Chemist. There, he applied solution chemistry principles to a number of fundamental and applied research projects. These included projects in the ambit water-, soil- and sediment quality, industrial chemistry, waste beneficiation and ecotoxicology. In this time he completed a PhD in Chemistry at the University of Cape Town. His PhD research focused on measuring thermodynamic data required to model, predictively, the adsorption of nickel, copper, zinc, lead and cadmium by δ-MnO_2. In a joint study with the Dutch Institute of Public Health and the Environment, these results were incorporated into a predictive model of metal partitioning over the soil solid – soil water interface. Before joining Rescan, Dr Pretorius was employed as a Principal Scientist at Sasol Technology Research and Development, the technology arm of Sasol, a South African petrochemical company. There, he applied solution chemistry principles to, amongst others, the preparation iron and cobalt based catalysts.

2006
SENIOR AQUATIC CHEMIST
Rescan Environmental Services, Inc.
Vancouver, BC

- Test work to investigate the removal of copper from mine process waters

- Chemical speciation calculations to predict upper-limit metal concentrations to be expected in process waters
- Chemical speciation calculations to evaluate the importance of precipitate formation as a mode of metal removal receiving waters
- Chemical speciation calculations to predict the potential secondary mineral phases that may form from waste rock seepage

2001 to 2006
PRINCIPAL SCIENTIST (HETEROGENOUS CATALYSIS RESEARCH)
Sasol Technology R&D
South Africa

- Investigation into the relationship between the aqueous chemistry of a precipitation reactor and the catalytic properties of iron hydroxides used as catalysts
- Development of an environmentally-friendly process for the manufacturing of iron hydroxides
- Development and testing of catalytic systems for synthesis of linear alcohols from synthesis gas
- Liaison with management and international research and development partners

2000 to 2001
SENIOR SCIENTIST (ENVIRONMENTAL CHEMISTRY)
SRK Consulting
South Africa

- Assessment of soil contamination at a copper mine, South Africa
- Auditing of chemical monitoring practices as part of a due diligence study
- Water quality of a severely impacted urban stream
- Project management and client liaison

1991 to 2000
ENVIRONMENTAL CHEMIST
Council for Scientific and Industrial Research (CSIR)
South Africa

- Metal fate in marine sediments
- Predictive modeling of metal partitioning in soils
- Fundamental investigation into the adsorption of metals by manganese and iron (hydr)oxides

- Synthesis of zeolitic material from coal fly-ash for use as permeable membrane materials
- Implications of water chemistry on bioavailability and toxicity of metals
- Predictive modeling of phosphate fate in riverine systems
- Waste Load Allocation studies
- Aqueous chemistry of hydrometallurgical systems
- Project management and client liaison

Scholarships and Awards

- Star of the Year Award, Sasol Technology, 2002
- DM Kisch Silver Medal, South African Academy for Science and Art, 1990
- Post-graduate studentship, Foundation of Research Development, South Africa, 1989 - 1990
- Post-graduate bursary, Foundation of Research Development, South Africa, 1988

Publications

THESES

Pretorius, P.J. 1998. *The adsorption of Ni, Cu, Zn, Pb and Cd by δ–MnO_2 and its inclusion in an equilibrium model of metal partitioning in soils*. PhD thesis, University of Cape Town, South Africa.

Pretorius, P.J. 1991. *A computer simulation of the protonation and metal complexation properties of fulvic acids*. M.Sc. thesis, University of Cape Town, South Africa.

JOURNAL ARTICLES

Pretorius, P.J. and P.W. Linder 2003. *Letter to the editor: Comment on "Acid-base titrations of hydrous ferric acids: Lützenkirchen (2000)"*. Chemical Speciation and Bioavailability, 15, 127–128.

Pretorius, P.J., and C.D. Woolard. 2003. *The surface chemical properties of high surface area solids synthesised from coal fly-ash.* South African Journal of Chemistry, 56, 34-39.

Pretorius, P.J. and P.W. Linder. 2001. *The adsorption characteristics of δ–MnO_2: Diffuse Double Layer constants for the adsorption of H^+, Cu^{2+}, Zn^{2+}, Cd^{2+} and Pb^{2+}.* Applied Geochemistry, 16, 1067–1082.

Linder, P.W., **P.J. Pretorius**, J.L. Slabbert, and P.W. Wade. 2001. *The relationship between the chemical behaviour of heavy metals and their*

bioavailability/toxicity to organisms: Implications for environmental quality criteria. South African Journal of Science, 97, 431-434.

Pretorius, P.J. and P.W. Linder. 1998. *Determination of Diffuse Double Layer protonation constants for Hydrous Ferric Oxide (HFO): Supporting evidence for the Dzombak and Morel compilation.* Chemical Speciation and Bioavailability, 10, 115–119.

CONFERENCES

van de Loosdrecht, J., V.K. Bothma, P.S. Nkwanyana, **P.J. Pretorius**, M.A.S. Rawat, P.J. van Berge and J.L. Visagie. 2003. *Cobalt-based Fischer-Tropsch synthesis catalyst prepared on carbon-coated alumina.* EuropaCat VI, Austria.

Monteiro, P.M.S., S. Luger, **P.J. Pretorius** and R. van Ballegooyen. 1999. *Simulation of eutrophication and particle dynamics in a bay system in order to predict the transport and fate of trace metals using the Delft3D–FLOW and –WAQ models.* Pollution 99 Conference, Greece.

Pretorius, P.J., P.W. Linder, J.L. Slabbert and P.W. Wade. 1998. *The relationship between the chemical behaviour of heavy metals and their bioavailability/toxicity to ecosystems: Implications for environmental quality criteria.* The Science of Minerals Conference, Muldersdrift, South Africa.

Wade, P.W., **P.J. Pretorius** and J.L. Slabbert 1997. *The intrinsic toxicity of chemical species of zinc to* Daphnia pulex*: A toxicological statistical and chemical speciation study.* SETAC 18th Annual meeting, 16–20 November 1997, San Francisco, USA.

Pretorius, P.J. and P.W. Linder 1997. *A surface complexation model for metal and proton adsorption by δ–MnO_2.* The 4th International Symposium on Applied Bioinorganic Chemistry, Cape Town, South Africa.

Pretorius, P.J. and P.W. Linder 1996. *Proton and metal sorption properties of δ–MnO_2.* The 14th European Chemistry at Interfaces Conference, Antwerp, Belgium.

Janssen, R.P.T., **P.J. Pretorius**, W.J.G.M. Peijnenburg and M.A.G.T. van den Hoop. 1995. *Relation between soil characteristics and field based partition coefficients for heavy metals.* The 10th International Conference on Heavy Metals in the Environment, Hamburg, Germany.

Pretorius, P.J., R.P.T. Janssen, W.J.G.M. Peijnenburg and M.A.G.T. van den Hoop 1995. *Chemical equilibrium modelling of metal partitioning in*

soils. The 10th International Conference on Heavy Metals in the Environment, Hamburg, Germany.

Wade, P.W., **P.J. Pretorius**, A. Schoemann A and J.L. Slabbert. 1995. *Methodology of determining intrinsic toxicity of heavy metals.* The 10th International Conference on Heavy Metals in the Environment, Hamburg, Germany.

Pretorius, P.J. and P.W. Wade. 1993. *Heavy metal speciation, bioavailability and toxicity.* International Symposium on Metals in Solution, Malelane Lodge, South Africa.

Pretorius, P.J. and P.W. Linder 1991. *A computer simulation of the protonation and metal complexation properties of Fulvic Acids.* South African Chemical Institute 31st Convention, Rhodes University, Grahamstown, South Africa.

CONTRACT AND RESEARCH REPORTS

Pretorius, P.J. 2005. *Evaluation and further development of Süd-Chemie's GreenCat™ technology for the preparation of a working SBR catalyst.* Sasol Technology.

Pretorius, P.J. 2005. *A fundamental investigation into the preparation and resulting characteristics of Sasol's Slurry Bed Reactor iron Fischer-Tropsch catalysts.* Sasol Technology.

Pretorius, P.J. 2004. *The synthesis of higher alcohols from syngas using a co-precipitated Cu/Co/Zn/Al/X catalyst, where X = Na, K, Li and Mn.* Sasol Technology.

Pretorius, P.J. 2003. *A potentiometric investigation into the surface characteristics of catalyst supports.* Sasol Technology.

Pretorius, P.J. 2003. *A Monte-Carlo simulation of the error propagation in methane selectivity calculations.* Sasol Technology.

Pretorius, P.J. 2002. *An investigation into the accuracy of the gas chromatographic analysis of alcohol mixtures.* Sasol Technology.

SRK Consulting, 2001. *Risk-based approach to the management of soil contamination in the Phalaborwa region: Phase 1.*

SRK Consulting, 2000. *Encrustation potential of borehole water at the Carbochem site, Newcastle.*

Sipos, P., A. Stanley, **P.J. Pretorius**, S. Kratsis, F. Samani, G. Hefter, and P.M. May. 1999. *Prediction and measurement of the physicochemical*

properties of Bayer liquors. Report P507A submitted to the Australian Mineral Industries Research Association.

Pretorius, P.J. 1999. *The surface chemical properties of high surface area solids synthesised from coal fly ash.* CSIR Report ENV-S-I9910, CSIR, Pretoria, South Africa.

Pretorius, P.J., P.M.S. Monteiro and A. Pascall. 1999. *Trace metal partitioning in Saldanha Bay sediments.* CSIR Report ENV-S-I9911, CSIR, Pretoria, South Africa.

Wade, P.W., **P.J. Pretorius** and T. Mali. 1998. *Environmental Chemistry in the CSIR: a discussion document.* CSIR Report ENV-S-I98082, CSIR, Pretoria, South Africa.

Pretorius, P.J. 1998. *Protonation constants for humic substances derived from literature data.* CSIR Report ENV-S-I98016, CSIR, Pretoria, South Africa.

Slabbert, J.L., J. Oosthuizen, E.A. Venter, E. Hill, M. du Preez and **P.J. Pretorius**. 1998. *Development of guidelines for toxicity bioassaying of drinking and environmental waters in South Africa.* WRC Report Nº 358/1/98. Report to the Water Research Commission by the Division of Water, Environment and Forestry Technology, CSIR.

Slabbert, J.L., J. Oosthuizen, E.A. Venter, E. Hill, M. du Preez and **P.J. Pretorius**. 1998. *Development of procedures to assess whole effluent toxicity.* WRC Report Nº 453/1/98. Report to the Water Research Commission by the Division of Water, Environment and Forestry Technology, CSIR.

Bailey, G., G.S. Mackintosh and **P.J. Pretorius**. 1997. *Stellenbosch drinking water quality management program: 1997 Month July.* Confidential report to Stellenbosch Municipality, South Africa.

Pretorius, P.J., R.P.T. Janssen, W.J.G.M. Peijnenburg and M.A.G.T. van den Hoop. 1996. *Chemical eauilibrium modelling of metal partitioning in soils.* National Institute for Public Health and the Environment Report Nº 71910124, Bilthoven, The Netherlands.

Janssen RPT, **P.J. Pretorius**, W.J.G.M. Peijnenburg and M.A.G.T. van den Hoop. 1996. *Determination of field based partition coefficients for heavy metals in Dutch soils and the relationships of these coefficients with soil characteristics.* National Institute for Public Health and the Environment Report Nº 71910123, Bilthoven, The Netherlands.

Pretorius, P.J. 1994. *The relationship between zinc speciation and toxicity to* Daphnia pulex*.* Internal report, Water Quality Information Systems, Division of Water Technology, CSIR, Pretoria, South Africa.

Pretorius, P.J. 1994. *The chemical speciation of bioassay growth media and growth media–effluent mixtures.* Health Program, Division of Water Technology, CSIR, Pretoria, South Africa.

Murray, K., **P.J. Pretorius** and M.M. Jooste. 1993. *Manganese Metal Company process optimization: Phase 1.* Confidential report for Manganese Metal Company, Nelspruit, South Africa.

Pretorius, P.J. (1993. *The speciation of PO_4^{3-} in the Middle Vaal River. Ad Hoc* report, Water Quality Information Systems, Division of Water Technology, CSIR, Pretoria, South Africa.

CSIR, 1993. *Lower Selati and Olifants Rivers waste load allocation and investigation of water use and waste water options.* Confidential report for the Phalaborwa Mining and Industrial Complex, Phalaborwa, South Africa.

Ashton PJ, **P.J. Pretorius**, K. Murray and P.H. McMillan. 1992. *A Water Quality Study of the Middle Reaches of the Crocodile River Eastern Transvaal.* Confidential report for Manganese Metal Company, Nelspruit, South Africa.

Pretorius, P.J., J. Harris and C.V. Dunjwa. 1992. *A Preliminary Impact Assessment of the Enstra Mill's Effluent on the Water quality in the Blesbokspruit and Cowles Dam.* Confidential report to SAPPI Enstra, Springs, South Africa.

Michael D. Stewart, Ph.D.

Rescan™ Environmental Services Ltd.
Head Office: Sixth Floor - 1111 West Hastings Street, Vancouver, B.C., Canada • Tel: (604) 689-9460 • Fax: (604) 687-4277
Email: rescan@rescan.com • Website: www.rescan.com

Offering a full range of environmental and engineering solutions to clients around the world

Education

Ph.D. (Geography)
University of Leeds, United Kingdom, 1995

B.A. (Geology, Upper Second Class Honours)
Oxford University, United Kingdom, 1991

Experience

Dr. Stewart is a hydrologist and hydrological modeler with over 12 years experience of numerical modeling, flood studies, hydraulic and hydrological assessments. Michael has experience of the development and application of numerical models for a wide range of environmental applications, including; river and coastal hydraulic modeling, water quality modeling, sediment transport modeling, wave modeling, and hydrological modeling. He also has extensive field experience in terms of the planning, setting up and management of a river and floodplain hydrological monitoring programs as well as geological and geomorphological mapping. Dr Stewart has also been involved in the development and implementation of two major flood forecasting and flood warning systems for the Firth of Clyde, UK and in Andhra Pradesh, India. Since, joining Rescan Dr Stewart has been involved in a number of hydrological and water quality studies for mine sites in Northern Canada. This work has involved the installation of stream gauging stations, the review of available hydrological data, the development of hydrological models and the modeling of dilution and water quality in lakes and sedimentation ponds.

2004 to Present
ENVIRONMENTAL SCIENTIST
Rescan™ Environmental Services Ltd.
Vancouver, British Columbia, Canada

Recent projects have included;

- Installation of stream flow gauging network near Repulse Bay, Nunavut for baseline environmental assessment. Flow measurement and development of rating equations for gauging stations.
- Installation and mobilization of 12 stream flow gauging stations at Ekati Diamond Mine, Northwest Territories. Also training of Ekati site staff on flow measurement, rating equation development and data management.

- Hydrological review for Taltson River Basin, Northwest Territories, including development of proposals for future hydrological monitoring and modeling.
- Hydrological assessment and water mass balance model for Grizzly Lake, Grizzly Stream and Panda Diversion Channel, Ekati mine site, Northwest Territories.
- Assessment of dilution effect of chain of lakes downstream of waste rock storage pond, Ekati mine site, Northwest Territories. Work included hydrological assessment, development of annual flow hydrographs and chemical mass balance models of six lakes.
- Development of hydrological and chemical mass balance models for sedimentation pond at Ekati mine site, Northwest Territories
- Development of fish habitat compensation plan for stream at Ekati mine site, Northwest Territories.
- Assessment of performance of river flow gauges at mine site, British Columbia
- Review of ditch inspection report for mine site, British Columbia

2003
PRINCIPAL ENGINEER/SCIENTIST
Babtie Group Limited
Glasgow**,** United Kingdom

- Manager of modeling team within rivers and coastal business unit.
- Managed numerous hydrological and river modeling studies with preliminary engineering design: River Lugg, River Hexham, Candren Burn, Broadsfoot Brook, and River Nar.
- Reviewed river modeling work (MIKE11, ISIS and HEC-RAS) undertaken by other consultants.
- Performed strategic risk analysis of potential coastal and river flood damage for Anglian Water.
- Involved with politically sensitive flood risk assessment for a large development site in south-east England; work included modeling, flood mapping, and hydrological review.

1999 – 2003
LEAD MODELER
Babtie International
Hyderabad, India

Managed a team of eight engineers; developing a real-time flood forecasting system for the state of Andhra Pradesh. This included:

- Development of MIKE11 models and UP2 hydrological model of 24 river basins;
- Assisting in the planning and supervision of installation of hydrometric gauging network that included 102 field gauging stations (river water level and rain gauges with satellite communications)
- Preparation of flood maps for all coastal districts of Andhra Pradesh;
- Development of disaster management strategies and setting up of and training of staff in state government disaster management unit;
- Development of GIS user-interface and GIS based tools for flood management and post-event disaster management; and
- Development for models for use in water resources component of study

During the study Dr Stewart provided key technical input to all aspects of model and real-time systems development from the planning stages through to implementation. He also effectively fulfilled the role of deputy team leader in an office of 25 staff. In this role he helped plan resources, acted as key contact for client representatives, coordinated UK based sub-contractors, and delivered presentations to the client, World Bank officials, and senior Indian technical experts. When operational it is likely that the flood forecasting system will be one of the largest in the world.

1999 – 2002
SENIOR ENGINEER/ENGINEER
Babtie Group Ltd.
Glasgow**,** UK

Key projects:

- Project manager and lead author of Flood Warning Feasibility Study report for the Northern Ireland Rivers Agency. This strategic report considered the potential for the development of a national flood warning system for Northern Ireland.
- Project manager for Burry Port coastal and wave modeling. Assessment of port development options using MIKE21 2-D hydraulic and wave modeling software.
- Development of an automated Flood Warning System for the Firth of Clyde region in south-west Scotland. Linkage of 2-D coastal model to a 1-D river model in order to simulate the effect of storm surges on tidal water levels throughout the Firth of Clyde. Also planning of field monitoring program for wave data and wave data analysis.
- Firth of Forth sediment transport modeling. Assessment of the impact of bridge construction on sediment transport patterns in Forth estuary.

Required development and application of in-house 2-D hydraulic and sediment transport modeling software. Model also used to assess sedimentation and flood attenuation effects of proposed managed retreat at an environmentally sensitive site within the Firth of Forth.

- Water quality modeling study of the River Carron, Scotland. Application of CE-QUAL-W2 2-D laterally averaged model to assess water quality impacts of two construction options within the tidal reach of the River Carron.
- Irvine Bay water quality modeling. 3-D modeling of sewage outfall dispersal to ensure compliance with European Environmental legislation. Project considered the effects of diffuse pollution and watershed management practices on water quality. Project also included planning of dye release and drogue tracking field studies.
- Numerous river flood risk assessments, involving hydrological studies, 1-D river modeling, flood mapping, and development of preliminary flood alleviation options.

1999 – 2000
RESEARCH FELLOW
Department of Geography, University of Glasgow
Glasgow**,** UK

- Developed research projects concerning flood modeling, hydrology, sediment transport, and landscape evolution.

1995 – 1998
POSTDOCTORAL RESEARCH ASSISTANT
University of Bristol
Bristol**,** UK

Three year UK NERC funded research project. Key research topics included:

- development and application of TELEMAC2-D river modeling software;
- construction and management of a river and floodplain field monitoring station looking at interaction of floodplain and hill slope hydrology;
- modeling of interaction of hill slope runoff and flood waters and the effect on nitrate buffering in floodplains using a linked 2-D river and 3-D groundwater model; and
- application of 2-D modeling in planning sediment sampling strategies and predicting infiltration of pollutants into floodplain soils.
- spent two months as visiting scientist at Electricité de France's National Hydraulics Laboratory in Paris.
- researching gravel bed transport on the River Po, Italy, including field assessments

1991 – 1995
PHD STUDENT
University of Leeds
Leeds, UK

PhD research considered effects of tectonic uplift on river and hillslope erosion in Basin and Range Province, Nevada, USA. Work included numerical modeling of erosion processes (including dating of active fault scarps), geomorphological mapping, land surveying, soil analysis, geological mapping. In total 4 months spent undertaking field work in Nevada, USA. Also periods of field work in California, Italy, northern India and western Nepal.

Publications

Kaya, Y., Stewart, M.D. and Becker, M (2005). Flood Forecasting and Flood Warning in the Firth of Clyde, UK. *Natural Hazards Journal, v. 36, 257 - 271*.

Burt, T.P., M.G. Anderson, P.D. Bates, D.A. Price, and M.D. Stewart. 2002. Hydrological interactions within the floodplain of a lowland river. *Journal of Hydrology*. 262: 1–20.

Stewart, M.D., D.J. Buzzacott, D.S. Rao, and J.L. Wilson. 2001. River modeling for flood forecasting in Andhra Pradesh. In *Proceedings of Institute of Engineers (India) Water Resources Day 2001 Conference on the Management of Floods and Drought.* Hyderabad, India.

Stewart, M.D., D.J. Buzzacott, C.G. Kilsby, K.J. Riddell, and T.M. van Kalken. 2001. Flood forecasting in Andhra Pradesh. In: *River Basin Management.* (R.A. Falconer and W.R. Blain eds.), WIT Press, Southampton, U.K., p.119–128.

Bates, P.D., M.G. Anderson, M.G., A. Desitter, J.P. Renaud, and M.D Stewart. 2000. Numerical simulation of floodplain hydrology. *Water Resources Research*. 36: 2517–2530.

Bates, P.D., J.M. Hervouet, M.D. Stewart, and C.A.M.E Wilson. 1999. Two dimensional finite element modeling of floodplain flow. *La Houille Blanche*. 354: 82–88.

Stewart, M.D., M.G. Anderson, P.D. Bates, and T.P. Burt. 1999. Modeling floods in hydrologically complex lowland river reaches. *Journal of Hydrology*. 223: 85–106.

Stewart, M.D., M.G. Anderson, P.D. Bates, T.P. Burt, and D.A. Price. 1998. Modeling the spatial variability in floodplain soil contamination during flood events to improve chemical mass balance estimates. *Hydrological Processes*. 12: 1233–1255.

Stewart, M.D., P.D. Bates, and T.P. Burt. 1998. Modeling the effects of non-point source pollution on the dissolved loads of lowland rivers. IN: *Hydrology in a Changing Environment.* (H.S. Wheater and C. Kirby, eds.), John Wiley and Sons, London. 3: 261–273.

Bates, P.D., J.M. Hervouet, R.H.J. Sellin, G.B. Siggers, and M.D. Stewart. 1998. Internal and external validation of a two-dimensional finite element model of river and floodplain flow*. Proceedings of the Institute of Civil Engineers, Water, Maritime and Energy*. 130: 127–141.

Bates, P.D., J.M. Hervouet, M.D. Stewart, and C.A.M.E Wilson. 1998. Calibration et validation de un modél bi-dimensional aux éléments finis pour les prévisions d'inondations en plaine / Calibration and validation of two-dimensional finite element models of floodplain flow. *Congres de la Société Hydrotechnique de France*, 25émes Journées de l'Hydraulique. 2: 417–426.

Bates, P.D., G.B. Siggers, and M.D. Stewart. 1998. Physical model and validation of two-dimensional finite element models for flood flow prediction. In: *Hydrology in a Changing Environment.* (H.S. Wheater and C. Kirby, eds.), John Wiley and Sons, London. 3: 67–78.

Desitter, A., P.D. Bates, and M.D. Stewart. 1998. Comparison of finite element and analytical solutions of the Richards' unsaturated flow equation. In: *Hydrology in a Changing Environment.* (H.S. Wheater and C. Kirby eds.), John Wiley and Sons, London. 3: 79–88.

Talling, P.J., S. Gupta, C.P. Stark, and M.D. Stewart. 1998. Regular spacing of drainage outlets from linear fault blocks. *Basin Research.* 9: 275–302.

Leeder, M.R. and M.D. Stewart. 1996. Fluvial incision and sequence stratigraphy: alluvial responses to relative sea-level fall and their detection in the geological record. In: *Sequence stratigraphy in British geology.* (S.P Hesselbo and D.N. Parkinson eds.), Special Publication of the Geological Society of London. 103: 25–39.