

## Technical Memorandum

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<b>To:</b>	Dale Ortman, P.E.	<b>Date:</b>	May 11, 2010
<b>cc:</b>	Tom Furgason, SWCA File, SRK	<b>From:</b>	Vladimir Ugorets, PhD, SRK Michael Sieber, P.E., SRK Stephen J. Day, P.Geo., SRK
<b>Subject:</b>	Technical Review of <i>Davidson Canyon Hydrogeologic Conceptual Model and Assessment of Spring Impacts, Rosemont Copper Project</i> (Tetra Tech, 2010a) and <i>Comparison of Natural Fluctuation in Groundwater Level to Provisional Drawdown Projections, Rosemont Mine</i> (Montgomery & Associates, 2010)	<b>Project #:</b>	183101/1700

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A technical review was undertaken and this Technical Memorandum was prepared at the request of SWCA and the Coronado National Forest, in accordance with a statement of work from Mr. D. Ortman dated March 15, 2010. Provided here are comments related to the review of the following two reports:

- (a) *Davidson Canyon Hydrogeologic Conceptual Model and Assessment of Spring Impacts, Rosemont Copper Project* (Tetra Tech, 2010a), and
- (b) *Comparison of Natural Fluctuation in Groundwater Level to Provisional Drawdown Projections, Rosemont Mine* (Montgomery & Associates, 2010)

These comments were prepared by Vladimir Ugorets, Michael Sieber, and Stephen Day of SRK Consulting, Inc. (SRK). Review was performed by Larry Cope, also of SRK.

This memorandum is organized into two sections, per the two reviewed documents listed above.

### 1 Davidson Canyon Hydrogeological Conceptual Model and Assessment of Spring Impacts

The report is relatively comprehensive, well presented, and well written. The report describes the most likely hydrologic dynamics and key physical processes that are governing groundwater-surface water interactions in Davidson Canyon. It includes a discussion of creeks and springs and their interface with the groundwater system (Tetra Tech, 2010a).

This document is a good compilation of available groundwater, surface water, local geology, and water chemistry data indicating that:

- (a) The Rosemont Project will have some effect on Davidson Canyon due to the changes in the surface and groundwater flow patterns at the Project site.
- (b) The estimated area affected by the Rosemont Project comprises about 16 percent of the Davidson Canyon watershed.
- (c) In average annual conditions, Tetra Tech (2010a) estimated that most of the stormwater entering the flow-through drains will result in infiltration and likely will reduce flows to downstream receptors.

- (d) The areas with the most for potential groundwater-surface water interactions are in topographically lower areas of Davidson Canyon (Reach 4), which are the furthest from the proposed Rosemont Project.
- (e) Changes to baseline conditions in Davidson Canyon and Cienega Creek as a result of open pit dewatering operations will not occur unless the cone of depression extends to an aquifer that is hydraulically connected to surface water.
- (f) Three springs (Questa, Rosemont, and Davidson) are potentially hydraulically connected with the regional bedrock groundwater system and might be impacted by in-pit dewatering, if drawdown propagates to their location. Other local (or perched-water) springs would be less likely to be affected by mine activities, unless they are proximate to the pit where the pit may alter the local flow system that is yielding water to the springs.
- (g) The long term impacts to the water resources in Davidson Canyon and the larger Cienega Creek basin will not exceed the predicted rate of pit inflow (300 to 400 gallons per minute (gpm) during mining, and will continuously decrease to 120 gpm after 100 years of pit lake infilling (M&A, 2009). This model is currently being revised and the impact on Davidson Canyon should be re-examined when the revisions are complete.

### **Mine Impacts**

The mining operations that could potentially impact the Davidson Canyon and Cienega Creek watersheds are the open pit dewatering (M&A, 2009 and Tetra Tech, 2010b) and seepage from the Dry Stack Tailings Storage Facility (TSF) (AMEC, 2009, Tetra Tech, 2010b), the Waste Rock storage area (waste rock), and Heap Leach facility (heap) (Tetra Tech, 2010b). The M&A numerical groundwater flow model is currently being revised and the impacts to Davidson Canyon from pit dewatering should be re-evaluated once the revisions are complete. Should the Infiltration and Seepage Model (Tetra Tech, 2010b) that was reviewed by SRK (2010) be revised, the impacts of seepage from the TSF, waste rock, and the heap also should be re-evaluated.

SRK found Tetra Tech's conceptual model of Davidson Canyon and their conclusions regarding possible impacts from the mining operations to be reasonable. The isotopic interpretations they presented seem reasonable based on the information provided in the report. However, we feel that it should be considered preliminary due to limited available data and uncertainties in the groundwater modeling predictions (discussed in SRK (2010)). Our specific comments are:

- (a) Figure 9: Local spring isolated from regional groundwater—groundwater flow lines are shown above the water table.
- (b) Figure 15: Schematic cross section of Reach 2 spring development—what data are used for the unsaturated zone as shown between the alluvial and bedrock groundwater systems?
- (c) The water quality data described in Section 7.6 need to be added in the spring comparison table, shown in Figure 8.
- (d) There is reference to Stiff diagrams prepared by others. It would be helpful to include these in this report.
- (e) A number of descriptors used in the report are relative but not quantified. Waters are described as “different,” “very similar,” and “dissimilar,” Inclusion of charts showing the data or more statistics would illustrate these differences.
- (f) There are references to MC1 and MC2 differences being explained by the degree of rock alteration. Trace element characteristics could be included here as indicators. This would be a useful overall aspect to be added that could provide more in the geological context. A conclusions section should be included in the report.

Potential impacts to Davidson Canyon should be re-evaluated on the basis of the predictive simulations and sensitivity analyses of the 3-D numerical groundwater model currently being revised by M&A.

## **2 Comparison of Natural Fluctuation in Groundwater Level to Provisional Drawdown Projections, Rosemont Mine**

This section presents the results of our review of the report on short-term and long-term groundwater fluctuations as compared to projected drawdown 100 years after closure of the proposed Rosemont mine (M&A, 2009). The document provides a thorough compilation of available groundwater level data that indicate that:

- (a) Calculated short-term (2 to 3 years) groundwater level fluctuations measured in 52 wells range from 0.7 to 33 feet, with an averaged value of 7 feet.
- (b) Calculated long-term (37 to 55 years) groundwater level fluctuations measured in 14 wells range from 0.7 to 69 feet, with an averaged value of about 20 feet.
- (c) The projected drawdown at existing non-Rosemont wells east of the mine area, 100 years after closure of the proposed Rosemont mine, is generally of similar magnitude to the natural short-term fluctuation in groundwater levels observed during a 2- to 3-year period and is generally less than the long-term natural fluctuation in groundwater levels observed during the long-term 37- to 55-year period.
- (d) The projected drawdown at existing non-Rosemont wells west of the Santa Rita ridge and at livestock wells in the immediate mine area, 100 years after closure of the proposed Rosemont mine, appears to exceed the natural short-term groundwater fluctuation (2-year period). No data are available concerning long-term groundwater fluctuation west of the Santa Rita ridge.

SRK has the following specific comments:

- (1) It is not clear why the simulated drawdown of 100 years after closure was chosen for comparison with measured natural groundwater fluctuations. In SRK's opinion, the comparison should be made with the time of maximum drawdown (during the early or intermediate stage of pit-lake infilling) and at steady state, post-mining conditions, which will be significant after 100 years of pit lake infilling. The existing groundwater model (M&A, 2009) did not simulate full pit lake recovery and did not clearly indicate when maximum drawdown occurs at particular locations.
- (2) Surface water bodies (such as creeks and springs) that show the propagation of drawdown need to be added to Figures 1 and 2.
- (3) This comparison analysis should be repeated after existing numerical groundwater model is revised based on the transient calibration (recommendation by SRK (2010)) and to incorporate the revised model simulations.

### 3 REFERENCES

- AMEC, 2009, Rosemont Copper Company, Dry stack tailings storage facility, Final design report: unpublished report prepared for Rosemont Copper Company, AMEC Project 842-1191, 54 p, 7 appendices.
- Montgomery & Associates, 2009, *Groundwater-flow modeling conducted for simulation of proposed Rosemont pit dewatering and post-closure*: unpublished report prepared for Rosemont Copper by Errol L. Montgomery & Associates, Inc., October 28, 2009, 73 p.
- \_\_\_\_\_, 2010, *Comparison of natural fluctuation in groundwater level to provisional drawdown projections, Rosemont Mine*: Technical Memorandum prepared for Rosemont Copper by Errol L. Montgomery & Associates, Inc., March 1, 2010.
- SRK, 2010, *Technical review of M & A (2009) groundwater flow model report prepared Rosemont Copper*: Technical Memorandum prepared for SWCA, February 9, 2010, 6 p.
- Tetra Tech, 2010a, *Davidson Canyon Hydrogeologic Conceptual Model and assessment of Spring Impacts*: unpublished report prepared for Rosemont Copper, Tetra Tech Project No. 114-320869, April 2010, 72 p, 1 appendix.
- \_\_\_\_\_, 2010b, *Infiltration, Seepage, Fate and Transport Modeling Report*: unpublished report prepared for Rosemont Copper, Tetra Tech Project No. 114-320794, February 2010, 68 p., 6 appendices.

### 4 QUALIFICATIONS OF KEY TECHNICAL REVIEWER

The Senior Reviewer for Hydrogeology, Vladimir Ugorets, Ph.D., is a Principal Hydrogeologist with SRK Consulting in Denver, Colorado (résumé attached). Dr. Ugorets has more than 31 years of professional experience in hydrogeology, developing and implementing groundwater flow and solute-transport models related to mine dewatering, groundwater contamination, and water resource development. Dr. Ugorets's areas of expertise are in design and optimization of extraction-injection well fields, development of conceptual and numerical groundwater flow and solute-transport models, and dewatering optimization for open-pit, underground and in-situ recovery mines.

**ATTACHMENT A**  
**Resumes of Key Technical Personnel**

# Vladimir I. Ugorets

## Principal Hydrogeologist



**Profession** Principal Hydrogeologist

**Education** M.S. (Mining Engineering/Hydrogeology) Geology-Prospecting Institute, Moscow Russia  
Ph.D. (Hydrogeology) Geology-Prospecting Institute, Moscow Russia

**Registrations/Affiliations** Senior Scientist in Hydrogeology, USSR/Russia  
National Ground Water Association  
MSHA

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**Specialization** Mining Hydrogeology, Groundwater Modeling, and Wellfield Optimization.

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**Expertise** Dr. Ugorets has more than 31 years of professional experience in hydrogeology, developing and implementing groundwater flow and solute-transport models related to mine dewatering, groundwater contamination, and water resource development. Dr. Ugorets' areas of expertise are in design and optimization of extraction-injection wellfields, development of conceptual and numerical groundwater flow and solute-transport models, and dewatering optimization for open-pit, underground and ISR mines.

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### Employment Record

**2007 – Present** **SRK Consulting (U.S.), Inc.**, Principal Hydrogeologist  
Denver, CO

**1996 – 2007** **Hydrologic Consultants Inc. (HCI)**, Senior Hydrogeologist  
Lakewood, CO

**1991 – 1995** **Hydrogeoecological Research and Design Co (HYDEC)**, Lead Hydrogeologist  
Moscow, Russia

**1978 – 1990** **Geology-Prospecting Institute (MGRI)**, Senior Scientist in Hydrogeology  
Moscow, Russia

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**Languages** Russian, English

# Vladimir I. Ugorets

## Principal Hydrogeologist

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### Publications

#### English

- Ugorets V.I. and Howell, R.L. 2008 “3-D Characterization of Groundwater Flow in Hard-Rock Uranium Deposits”, presented at 2<sup>nd</sup> International Symposium – Uranium: Resources and Production, VIMS, Moscow, p. 120-121.
- Ugorets, V.I., Howell, R.L., and Mahoney, J.J. 2006 “Challenges to Hydrogeologic Investigations in the Canadian North”, presented at 59th Canadian Geotechnical Conference and 7th Joint CGS/IAH-CNC Groundwater Specialty Conference (seatoskygeo.ca), October 2006, Vancouver. Sea to Sky Geotechnique, p. 1608-1612
- Ugorets, V.I., and MacDonald, A. K. 2003 “Design and Optimization of Mine Dewatering Based on Ground-Water Flow Modeling,” in Computer Applications in the Minerals Industries (Proceedings of Forth International Conference, CAMI, Calgary, Alberta, Canada).
- Ugorets, V.I., Rusdinar, Y., Parseryo, G. and Liu, H. 2002 “Identification of Dewatering Targets for Graberg Pit Using Hydrogeochemical Fingerprint Approach,” presented at 2002 Denver Annual Meeting of The Geological Society of America.
- Ugorets, V.I., Hanna, T. M., Howell, R. L., Ternes, T. and McCarter, J. 1999 “Use of Frozen Earth Wall to Reduce Effects of Dewatering on Alluvial Aquifer in Vicinity of the Proposed Aquarius Open Pit Mine,” in Sudbury — Mining and the Environment II (Sudbury, Ontario, Canada). D. Goldsack et al., Eds. Sudbury: Laurentian University, Centre in Mining and Mineral Exploration Research.
- Ugorets, V. I., Azrag, E. A. and Atkinson, L. C. 1999 “Use of a Finite Element Code to Model Complex Mine Water Problems,” Annual Meeting of American Institute of Hydrology and Fourth USA/CIS Joint Conference on Environmental Hydrology and Hydrogeology (San Francisco), pp. 163-164. San Francisco: American Institute of Hydrology.
- Ugorets, V.I., Azrag, E. A., and Atkinson, L. C. 1998 “Use of a Finite Element Code to Model Complex Mine Water Problems,” in Mine Water and Environmental Impacts (Proceedings of the International Mine Water Association Symposia, Johannesburg, South Africa), Vol. 1, pp. 31-41. Johannesburg: International Mine Water Association.
- Ugorets, V.I., Borevsky, B.V., and Borevsky, L. V. 1994 “Regulation of the Movement of Different-Density Fluids During Injection of Waste: An Optimization Model with Special Reference to the Injection System in the Krasnodar Region,” in Scientific and Engineering Aspects of Deep Injection Disposal of Hazardous and Industrial Wastes (Proceedings of the International Conference, Berkeley, California), pp.21. Berkeley, California: Lawrence Berkeley Laboratory.
- Ugorets, V.I., and Tserkovsky, Y. A. 1992 “Optimization of Extraction-Injection Wells Sitting in Groundwater Management Problems / Flow Through Porous Media: Fundamentals and Reservoir Engineering Applications, (Proceedings of the International Conference, Moscow, September, 1992), pp. 52-55.

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### Principal Hydrogeologist

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*Russian*

- Ugorets, V.I., and Tserkovsky, Y. A. 1991 "Optimization Models for Ground-Water Withdrawal and Protection from Contamination Problems" (review). Moscow: Geoinformark.
- Ugorets, V. I. and Tserkovsky, Y. A., 1991 "Optimization Model of 2<sup>nd</sup> Donetsk Ground-Water Intake Site as Applied to the Problem of Ground-Water Safe Yield Re-Evaluation with Ecological Restrictions," in Proceedings of 6th Conference of Young Scientists of Moscow Geological Survey Institute, manuscript deposited in VINITI, No. 2520-B91.
- Ugorets, V. I., and Tserkovsky, Y. A., 1990 "Optimization of Water Abstraction from Multi-Layered System with Simultaneous Pumping and Injection of Industrial Ground Water," in Proceedings of 5th Conference of Young Scientists of Moscow Geological Survey Institute, manuscript deposited in VINITI, No. 3011-B90.
- Ugorets, V. I., and Tserkovsky, Y. A. 1989 "Evaluation of Safe Yield of Malkinskoe Ground-Water Basin by Using of Optimization Model," in Proceedings of 4th Conference of Young Scientists of Moscow Geological Survey Institute, manuscript deposited in VINITI, No. 4919-B89.
- Ugorets, V. I., and Gavich, I. K. 1988 "Hydrodynamic Calculations of Ground-Water Intakes," in Hydrogeodynamics, pp. 271-279. Moscow: Nedra.
- Ugorets, V. I., Greisukh, L. V., and Filippova et al, G. A. 1988 "Ground-Water Flow Model of Ala-Archinskoe Ground-Water Basin," in Chu Depression and Optimization Model of its Development. *Izv. Vys. Ucheb. Zav., Geologiya I Razvedka*, No. 9.
- Ugorets, V. I. 1988 "3D Ground-Water Flow Model of Multi-Layered System Using Economic Finite-Difference Schemes," in Proceedings of 3rd Conference of Young Scientists of Moscow Geological Survey Institute, manuscript deposited in VINITI, No. 7857-B88.
- Ugorets, V. I., and Tserkovsky, Y. A. 1987 "Axisymmetric Ground-Water Flow Model in Multi-Layered System," in Proceedings of 2nd Conference of Young Scientists of Moscow Geological Survey Institute, manuscript deposited in VINITI, No. 3036-B87.
- Ugorets, V. I., Gavich, I. K. and Mikhailova, A. V. 1985 "Optimization of Ground-Water Development by Using Automated System of Management: Water Abstraction Under Complex Hydrogeologic Conditions," in *Methods of Ground-Water Protection Against Contamination and Depletion*. Moscow: Nedra.
- Ugorets, V. I. and Lenchenko, N. N. 1985. "Hydrodynamic Calculation of Ground-Water Intakes with Variable Pumping Rates," *Izv. Vys. Ucheb. Zav., Geologiya I Razvedka*, No. 11.
- Ugorets, V. I., Gavich I. K., and Mikhailova, A. V. 1984. "Optimization Models in Hydrogeology," in *Mathematical Modeling of Hydrogeological Processes*. Novosibirsk: Institute of Hydrology.



# Vladimir I. Ugorets

## Principal Hydrogeologist

### Key Experience: Mining Hydrogeology

- **Grasberg Copper/Gold Mine, West Papua (Indonesia):** Conducted site characterization, design of hydrogeologic testing, and review of Grasberg open pit and EESS underground mine dewatering on semi-annual and annual basis. Developed a series of conceptual hydrogeologic models and groundwater flow models of the Ertzberg Mining District. Modeling has included development of regional and "window" models, the latter for detailed analysis of pore pressures related to slope stability in open pit and dewatering of underground block caves. Predicted inflow and pore pressures in Grasberg open pit as input to slope stability analysis. Predicted inflow to underground mines (the existing IOZ and DOZ block cave mines and the proposed Kucing Liar, and Grasberg Deep block caves, and Big Gossan mine) from karstic limestones under very high (but variable) precipitation. Estimated the persistence of mill water supply during periods of El Niño-induced drought. Evaluated major groundwater sources in vicinity of Grasberg pit and EESS underground mine based on water chemistry fingerprints. Conducted ARD study and predicted quantity and quality of groundwater captured by existing developments and proposed ARD capture drifts and missed water in Wanagon basin. Conducted regional hydrogeology study and developed regional groundwater flow model of Ertzberg mining district to predict potential migration of ARD during post-mining conditions as part of Integrated Control and Capture Plan (ICCP). Conducted training in hydrogeologic data analysis and groundwater flow modeling for PTFI personnel. Developed a special numerical algorithm to simulate non-Darcian flow into underground openings from highly transmissive geologic structures.
- **Snap Lake Diamond Project, Northwest Territories (Canada):** Developed a conceptual hydrogeological, numerical groundwater flow, and hydrogeochemical mixing modes. Work has included a) planning and evaluating the results of hydrogeologic drilling, testing, and groundwater sampling from existing underground workings, b) developing a conceptual hydrogeologic model of the kimberlite dyke partially beneath a lake within open talik and partially below a permafrost, c) predicting inflow to the proposed underground mine, d) simulating hydrologic effect of paste backfilling on mine water discharge, and e) predicting the water quality of the mine discharge under lake and lake draining scenarios by using mixing simulations based on TDS vs. depth profile. Participated in numerous Technical Group meetings to provide hydrogeological input in design and instrumentation of mine test panels for geotechnical analysis. All work was completed for pre-production studies of existing mine and business case improvement studies for expanded mine.
- **Gahcho Kué Diamond Project, Northwest Territories (Canada):** Conducted hydrogeological investigation for desktop and pre-feasibility studies including: a) planning and analyzing results from hydrogeologic testing program (packer and airlift recovery tests and from Westbay monitoring wells, b) developing a comprehensive conceptual hydrogeologic model including kimberlite pipes, permafrost, and open/closed taliks, c) developing a series of numerical groundwater flow and solute transport models, d) predicting inflow to multiple open pits, e) estimating impacts to surface-water bodies in the vicinity of the pits, f) predicting the water quality of the mine water discharge, g) estimating leakage around/under man-made dykes for lake drainage scenario, and f) simulating pit lake infilling and post-mining hydrogeologic conditions taking into consideration a density effect. Represented client at numerous meetings with permitting agencies.
- **Fort à la Corne and Star Diamond Projects, Saskatchewan (Canada):** Conducted hydrogeologic investigations for three diamond projects, including: a) planning and analyzing results of hydrogeologic drilling and testing (including 4 pumping tests), b) developing a comprehensive conceptual hydrogeologic model, c) developing numerical axisymmetric and 3D groundwater flow models, d) predicting inflow to the open pits and designing dewatering systems, e) predicting pore pressures in pit walls as input for the slope-stability analysis, and f) estimating potential environmental impacts to water

# Vladimir I. Ugorets

## Principal Hydrogeologist

levels and streamflows during mining/dewatering and pit lake infilling. Represented client at meeting with permitting agencies.

- **Victor Diamond Project in Ontario (Canada):** Developed a series of conceptual hydrogeologic and numerical groundwater flow models for desktop, pre-feasibility, feasibility, and pre-production studies. Work has included a) planning and analyzing results of hydrogeologic investigations (drilling and testing, including 3 long-term pumping tests), b) developing a comprehensive conceptual hydrogeologic model of a karstified limestone groundwater system recharged by surface water through overburden, c) predicting inflow to the proposed open pit, d) designing a dewatering system with an optimal pumping rates and schedule of installation, and e) estimating potential environmental impacts to streamflows, ponds, and muskeg during mining/dewatering and pit- lake infilling. Represented client at numerous meetings with regulators and at public hearings, and prepared detailed discussions of potential environmental impacts.
- **Aquarius Gold Project, Ontario (Canada):** Developed conceptual hydrogeologic model of area of the proposed Aquarius open pit mine. Conducted groundwater flow modeling of inflow to proposed open pit and designed an optimal dewatering system by using traditional pumping wells. Predicted potential effects of dewatering on trout-bearing streams and lake levels within a nearby provincial park and designed potential groundwater mitigation measures. Completed groundwater flow modeling of freeze wall system around the proposed pit and developed hydrogeological input for freeze wall design.
- **Skyline Coal Mine, Utah:** Conducted groundwater flow modeling to evaluate various alternative sources and pathways of groundwater inflow to the underground mine and estimated the effect of mine inflow and pumping on surface-water resources. Predicted long-term dewatering requirements for mine expansion, and assessed Probable Hydrologic Consequences to surface resources using numerical groundwater flow model. Represented client at numerous meetings with permitting agencies, water boards, and plaintiff groups.
- **Premier Diamond Project, South Africa:** Developed axisymmetric groundwater model to predict passive inflow to the open pit and pore pressures in pit walls during future mining development.
- **Confidential Mine Dewatering Project, Russia:** Analysis of all available hydrogeological data and developing recommendations regarding dewatering requirements for different alternative mining methods. Developed groundwater flow model to predict a) inflows to open pit and underground mine (under different mining methods) and b) associated environmental impacts to the surface-water bodies and shallow groundwater system.
- **Confidential Coal Project, Virginia:** Developed groundwater flow model to a) predict inflow to underground coal mine and b) evaluate possible hydrogeologic effect of underground mining on water levels within shallow groundwater systems.
- **Confidential Mine Dewatering of Silver and Gold Deposits in Mexico (states of Durango and Nayarit):** Conducted a technical audit of existing hydrogeological data and developed plan for an effective dewatering system of underground mine workings for the first deposit. Conducted hydrogeological investigations to evaluate possible groundwater inflows to proposed underground mine at the Scoping Study level for the second deposit.
- **Uranium Deposits in the Athabasca Basin (Central Canada) – two confidential projects:** Developed a program of field hydrogeological work and performed an analysis for the collected hydrogeological data to make assessment of groundwater inflow to proposed underground mine for the first project. Comprehensive data analysis and predictions of possible inflows were made based on developed

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numerical groundwater model. Peer review of the dewatering requirements for an underground mine was completed for the second project at the Feasibility Study level, based on additional groundwater flow modeling conducted.

- **Uranium ISR Projects in Russia and Kazakhstan – three confidential projects:** Completed a technical audit of possible uranium recovery by ISR mining. Conducted a comprehensive ISR numerical modeling of one of the projects, including simulation of streamlines and reactive mass transport along them, to evaluate maximum uranium recovery from four paleochannels.
- **Hard Rock Uranium Deposits in Russia – five confidential projects:** Implemented a technical audit and hydrogeological study of groundwater inflow to proposed underground mines, quality of mine water discharge, possible impact to the surface-water bodies. Two 3-D numerical groundwater flow models were developed for two projects at the Pre-Feasibility Study level.
- **Uranium deposit in Niger – a confidential project:** Completed an analysis of available hydrogeological data and made an expert opinion on the possibilities of using ISR method to mine the uranium deposit.
- **Coal deposit in Russia – a confidential project:** Completed hydrogeological study of possible water inflow into underground longwall mine workings and impact to a river flow. Predictions and sensitivity analysis were conducted based on developed 3-D numerical groundwater flow model, calibrated to all available hydrogeological data collected for both pre-mining steady state and trial dewatering transient conditions. Recommendations were developed to reduce uncertainties in hydrogeological characterization, to bring project to the required Feasibility Study level.
- **Confidential Mine Dewatering Project in Columbia:** Technical audit of available hydrogeological data, development and implementation of field hydrogeological program, and assessment by groundwater modeling of possible groundwater inflow to expanded open pit operation mined in vicinity of the river.
- **Polimetallic Ore Deposit in Russia (Kola Peninsula):** Analysis of the available hydrogeological data and the previously performed studies to substantiate the possible impact of proposed in-pit dewatering to a shallow groundwater system and surface water bodies as part of the ESIA.
- **Gold Deposit Project in Pakistan:** Analysis of the available hydrogeological data and the previously performed studies to substantiate the possible impact of proposed in-pit dewatering and mine water supply wellfield to a shallow groundwater system as part of the ESIA.

### Key Experience: Russia and Former USSR (1978-1995)

Hydrogeological investigation and numerical modeling of groundwater development for potable, thermal, and industrial water supplies and mine dewatering in complex hydrogeologic settings. Developed and implemented numerical algorithms for optimizing groundwater management under hydrogeologic, environmental, and economic constraints.

Specific project experience includes:

- Groundwater flow modeling to estimate inflow and design dewatering system for Vorontsovskoy open pit gold mine in Ural region of Russia.

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## Principal Hydrogeologist

- Wellfield optimizing based on the groundwater flow models to quantify safe yield at the Priokskii (Moscow region), Lesnoe (Tataria), Pozhneyal-Sediuskii (Komi), Avatchinskii (Kamchatka), and Minsk (Belarus) water-supply projects.
- Optimizing pumping from the extraction wells at low salinity groundwater system in Mangyshlak Basin (West Kazakhstan) based on numerical 3-D groundwater flow model. Developing an analytical solution of a complex aquifer-well-pump-pipeline system and selecting appropriate pumping equipment to provide optimal withdrawal. Applying basic principles and methods of automated groundwater monitoring systems for water resource management.
- Developing conceptual, analytical, and numerical methods of wellfield optimization to design cost-effective water supply systems in complex hydrogeologic settings for Sredne-Kliazminsky site in Moscow region.
- Determining safe yield and optimal pumping rates of water-supply wells in multi-aquifer systems, within Malkin groundwater basin in North Caucasus area, and plan protection against contamination and depletion.
- Developing integrated numerical modeling system including groundwater flow, mass transport, and heat transport for Slaviansko-Troitsky iodine-bearing groundwater basin in Kuban to maximize safe yield, optimize wellfield of extraction and injection wells, and develop most rational method of water management.
- Using groundwater flow models to optimize locations and pumping rates of wells to minimize operational and environmental costs at Donetsk (Ukraine) and Ala-Artchinsky (Kirgizstan) water-supply projects.
- Designing and conducting laboratory column tests, experimenting with physical models, and evaluating field infiltration ponds to assess feasibility of purifying waste water through sandy deposits for the uranium mine in Western Kazakhstan.
- Developing numerical code (*OPTLIB*) for simulation of groundwater flow and wellfield optimization under multi-disciplinary constraints. This code was used during hydrogeological studies for all projects in Russia and Former USSR listed above.

# Mike Sieber, P.E.

## Hydrogeologist



**Profession** Hydrogeologist

**Education** M.S. in Agricultural Engineering (Groundwater), Colorado State University, 1993  
B.S. in Geological Engineering, Colorado School of Mines, 1983

**Registrations/  
Affiliations** P.E.: Arizona # 44868 , Colorado # 35703  
Member, National Groundwater Association

**Certifications** 8-Hour MSHA Surface Metal

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**Specialization** Groundwater hydrology, field investigations, and data analyses.

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**Expertise** Mr. Sieber is a professional engineer in Arizona and Colorado. He has broad experience in environmental hydrogeology. His emphasis has been groundwater and surface water characterization where he has been involved in planning and conducting fieldwork, data analysis, and report preparation for clients and for regulatory review and approval. He has extensive field experience including hydraulic characterization, installation of wells, instrument installation, and surface water characterization. He has designed pumping tests and has analyzed aquifer test data. He also has international work experience in South America and Canada.

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### Employment Record

**1995– Present** **SRK Consulting**, Fort Collins and Denver, CO; Tucson, AZ Hydrogeologist

**1994 - 1995** **Advanced Sciences, Inc.**, Hydrogeologist/Engineer

**1993 - 1994** **Martin Marietta Energy Systems**, Hazardous Waste Remedial Actions Program, Intern

**June – Nov. 1992** **Water, Waste & Land, Inc.**, Engineering Technician (part-time)

**May – Nov. 1990** **Goldstake Exploration**, Geologist

**June – Dec. 1989** **ACZ Laboratories, Inc.**, Lab Technician

**April – Nov. 1986** **Summitville Consolidated Mining Company, Inc.**, Lead Pit Technician

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**Languages** English

# Mike Sieber, P.E.

## Hydrogeologist

### Key Experience: Field Projects

- Installation of monitoring and recharge wells at Jerritt Canyon Mine in Nevada
- Conducted packer and airlift tests, and vibrating pressure transducers in core hole at Mt. Hope in Nevada
- Conducted packer and airlift test, and installed and grouted vibrating transducers into a core hole for Vale Inco near Thompson Manitoba, Canada
- Conducted airlift test and performed geotech core logging
- Prefeasibility hydrogeologic study in a permafrost region, including packer tests and installation of thermistors into core holes at Newmont's Hope Bay project in Nunavut, Canada
- Supervised surface water sampling required for operational permit at Alaska Gold Corporation
- Site investigation and construction QA/QC for wick installation for dewatering uranium mill tailings for Moab Reclamation Trust in Moab, Utah
- Site investigation of historic radium and uranium tailings for DIAND at Port Radium, Northwest Territories, Canada

### Key Experience: Groundwater Hydrology Characterization

#### Asarco, Leadville, Colorado Groundwater Flow Characterization

- Conducted an investigation of the operation of two drainage tunnels of historic underground mine workings and the interaction of ground and surface water flow in the Leadville area.
- Prepared report describing the operation of the drainage tunnels and the affect on the historical and recent trends of groundwater levels and surface water flow.
- Designed remedial actions for residential soils and prepared closure reports for completed properties. Provided QA/QC for the remediation construction.

#### Goldfields Gold Mine, Bolivar State, Venezuela

- The site drill core was reviewed to identify zones for packer tests in core holes.
- Developed a MODFLOW model of the proposed mine site to design the mine pit dewatering system.
- Prepared the hydrology section of the pre-feasibility report for the mine.
- Prepared standard procedures for single well and long-term pumping test.

#### DeBeers Victor Project, Ontario, Canada

- Contributed to the hydrogeological pre-feasibility and feasibility study for a diamond mine.
- Completed drilling and installation of a large diameter well and piezometers for long-term pumping tests.
- Completed airlift tests while drilling and conducted two long-term pumping tests.

# Mike Sieber, P.E.

## Hydrogeologist

### Key Experience: Groundwater Remediation Projects

#### Hewlett Packard Industrial Facility, Loveland, Colorado

- Routine monitoring of pump and treat system, including system inspection and surface and groundwater sampling.
- Prepared monthly, quarterly, and annual reports.

### Key Experience: Mining Hydrology

#### BHP San Manuel Plant Site, San Manuel, Arizona BHP Copper, Inc.

- Developed infiltration models to estimate infiltration through the tailings storage facility to evaluate the reclamation covers.
- Developed 2-D saturated unsaturated flow model with SEEP/W software to estimate the long-term drainage time and rates from the tailing impoundments.
- Lead hydrogeologist on the routine monitoring, sampling, and reporting required by the Arizona Aquifer Permit (APP).

#### BHP San Manuel Mine Site, San Manuel, Arizona BHP Copper, Inc.

- Assisted with developing a numerical groundwater flow model to predict formation of open pit lake loss of containment pit lake and underground workings
- Lead hydrogeologist on the routine monitoring, sampling, and reporting required by the Arizona Aquifer Permit (APP).
- Lead hydrologist for APP for closed landfill, completed infiltration modeling of the cover, and installed three methane monitoring wells.
- Re-calibrated the numerical groundwater flow model using an additional five years groundwater recovery data of the underground workings.

#### Tailings Impoundment Seepage Study, Argentina

Simulated seepage through the tailings impoundment dam with SEEP/W, a two-dimensional finite element code. The seepage through the bottom of the tailings impoundment was simulated with FEFLOW, a three-dimensional finite element code.

#### Aggregate Industries Gravel Pits, Longmont, Colorado: Permit and Reclamation

- Developed a numerical groundwater flow model using FEFLOW to simulate two existing gravel pits.
- The model was calibrated to existing conditions and then used to predict the impact of the proposed gravel pits to the groundwater system.
- The model was also used to estimate groundwater inflows to the reclaimed gravel pits.

#### Rio Grand Resources Uranium Tailings Seepage Study, Hobson, Texas

- A numerical groundwater flow and mass transport model was developed with MODFLOW and MT3D<sup>96</sup> code to simulate the preferred remediation plan.
- An Alternate Concentration Limit (ACL) petition was prepared for the facility using the long-term results of the numerical simulations.

## **Mike Sieber, P.E.**

### **Hydrogeologist**

#### **Conoco Conquista Uranium Mine and Mill Site, Falls City, Texas**

- Designed installation of compliance monitoring wells, developed a statement of work, and obtained bids for drilling and analytical work.
- Maintained database and prepared data transmittal report.

#### **Key Experience: Environmental**

##### **Loring Air Force Base, Caribou, Maine RI/FS investigation**

- Conducted over-sight of field activities that included various types of drilling and sampling.
- Work also included data analysis, report preparation, and document review.
- Prepared and assisted with quarterly water level measurements of approximately 300 monitoring wells.

##### **Robins Air Force Base, Warner Robins, Georgia: Site Investigation of landfill,**

- Assisted with preparation of work plan and standard operating procedures for the site investigation of an old landfill.
- Utilized Geoprobe™ push technology for collecting soil and groundwater samples.
- Sample analysis was completed with an on-site portable gas chromatograph-mass spectrophotometer.

##### **Massachusetts Military Reservation Cape Cod, Massachusetts**

- Managed fieldwork work on two sites to characterize soils and groundwater, data review and analysis, and document preparation for regulatory agencies.
- The site investigation consisted of Geoprobe™ borings and screened auger borings to collect groundwater field screening samples, installing monitoring wells, and collecting groundwater samples.
- Collected soil samples with split spoons using hollow stem augers and Geoprobe™ equipment.
- Served as the construction over-sight engineer during the installation an air sparging/soil vapor extraction system consisting of 21 air sparge wells and 20 soil vapor extraction wells.



## Stephen J. Day

### Principal Geochemist



**Profession** Professional Geoscientist

**Education** M.Sc, Geochemistry, University of British Columbia 1988.  
B.Sc., Geology, University of British Columbia 1985.

**Registrations/  
Affiliations** Professional Geoscientist (BC) No. 18,467.  
Professional Geologist (Northwest Territories and Nunavut) No L1283.  
Association of Professional Engineers and Geoscientists of B.C.  
Fellow of the Geological Association of Canada.  
Fellow, The Association of Applied Geochemists.

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### Specialisation

Stephen Day is Principal Geochemist at SRK's Vancouver office. He is an experienced specialist in the development of waste management plans to address acid rock drainage and leaching of mine wastes in general. He has particular expertise in the development of prediction methods for mine planning and modeling of leachate chemistry. His project experience includes development of innovative approaches to management of potentially acid generating wastes at new mines, assessment of existing waste disposal facilities at operating and abandoned mines to determine options for reduction or elimination of contaminated drainage, and environmental audits of mines.

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### Certification

Occupational Safety and Health Administration (OSHA).  
Hazardous Wastes Operations and Emergency Response (OSHA 29 CFR 1910)  
40-hour course.

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### Employment Record

**1998 – Present** SRK Consulting (Canada) Inc., Principal Geochemist

**1992 – 1998** Dames & Moore, Senior Geochemist/Manager, Geosciences

**1989 – 1992** Norecol Environmental Consultants Ltd., Geochemist

**1987 – 1989** British Columbia Geological Survey, Geochemist

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### Publications

Fifteen technical papers on metal leaching and acid rock drainage studies, stream sediment sampling, formation of placer deposits, mineral exploration in glacial terrains.

## **Stephen J. Day**

### **Principal Geochemist**

#### **Key Experience: New Mine Approvals and Permitting**

##### **PolyMet Mining Corp., Northmet Project, Minnesota (1999-2001, 2004-current)**

- Development and implementation of geochemical test program, and water quality predictions for proposed open pit PGM, nickel and copper mine at the facilities of an existing iron mine.

##### **Taseko Mines, Prosperity Project (2006-current)**

- Geochemical assessment of waste rock and tailings for proposed open pit copper-gold mine.

##### **Niblack Mining, Niblack Project (2006)**

- Review of geochemical aspects for permitting of underground exploration development.

##### **Teck Cominco, Morelos Project (2006-2008)**

- Geochemical assessment of waste rock and tailings for proposed open pit gold mine.

##### **Miramar, Doris North Project (2006-current).**

- Geochemical characterization of quarry rock

##### **AES Wapiti Coal Project, Hillsborough Resources (2006)**

- Geochemical characterization of waste rock and coal for proposed drag line coal mine.

##### **Horizon Project, Hillsborough Resources (2006)**

- Geochemical characterization of waste rock and coal processing products for proposed underground and open pit coal project.

##### **Barrick Gold, Donlin Creek Project (2006-current)**

- Geochemical characterization of waste rock and tailings for proposed open pit gold mine.

##### **Westhawk Development Corp., Coal Creek Project (2006).**

- Geochemical characterization of waste rock and proposed small coal mine.

##### **Crowflight Minerals, Bucko Mine (2005)**

- Geochemical characterization of rock and tailings for proposed underground nickel mine.

##### **Doublestar Resources, Catface Project**

- Geochemical characterization of rock and tailings for proposed open pit copper mine.

##### **Novagold Corporation, Galore Creek Project (2004-current)**

- Geochemical characterization
- Prediction of water quality impacts and recommendations for waste handling at a proposed open pit copper-gold mine

##### **Pebble Partnership, Pebble Project (2004-Current)**

- Geochemical characterization.
- Prediction of water quality impacts and recommendations for waste handling at a proposed open pit copper-gold-molybdenum mine

## **Stephen J. Day**

### **Principal Geochemist**

#### **bcMetals Corporation, Red Chris Project (2003-Current)**

- Geochemical characterization
- Prediction of water quality impacts and recommendations for waste handling at a proposed open pit copper-gold mine

#### **Brule Project, Western Canadian Coal (2004-2006)**

- Geochemical characterization, water chemistry predictions and input to waste management planning for a coal mine

#### **Dillon Mine, Western Canadian Coal (2004)**

- Geochemical characterization, water chemistry predictions and input to waste management planning for small coal mine

#### **Doublestar Resources Limited, Sustut Copper Project (2001-2003)**

- Assessment of geochemical issues for proposed copper mine
- General permitting assistance under the BC Environmental Assessment Process

#### **Barrick Gold Corp, Pascua Project, Chile/Argentina (1999-2001)**

- Assessment of waste rock and tailings geochemistry and prediction of drainage quality

#### **Alaska Department of Natural Resources, True North Project (2000-2002)**

- Review of expansion proposals for the Fort Knox Mine

#### **BHP Billiton Diamonds, Ekati Diamond Mine<sup>TM</sup>, Northwest Territories (2001-Current)**

- Characterization of waste rock and prediction of water quality for the Sable, Pigeon and Beartooth Pipes
- Compilation of Waste Rock Management Plans

#### **Crystal Graphite Corporation, Black Crystal Graphite Project, British Columbia (2001-2002)**

- Geochemical characterization of waste rock and tailings for a proposed graphite mine

#### **Teck Corp, Pogo Project, Alaska (1996-2004)**

- Geochemical characterization
- Prediction of water quality impacts and recommendations for waste handling at a proposed underground gold mine

#### **Indian and Northern Affairs Canada, Northwest Territories (1999-2001)**

- Review of geochemical aspects of Diavik Diamond Mines

#### **Coeur d'Alene Mines, San Bartolome Project, Bolivia (2001-2002)**

- Geochemical characterization of waste rock and tailings for a proposed silver mine

#### **Manalta Coal, Telkwa Coal Project, B.C. (1991-2000)**

- Development of waste management plan to address acid drainage potential

#### **Sutton Resources, Bulyanhulu Project, Tanzania (1997-1998)**

- Waste management planning and prediction of impacts for proposed underground gold mine

#### **Teck Corp, Marte Lobo Project, Chile (1997)**

- Assessment of potential impacts to groundwater due to waste rock leaching at proposed open pit gold mine

## **Stephen J. Day**

### **Principal Geochemist**

#### **Pine Valley Coal, Willow Creek Coal Project, B.C. (1996-1997)**

- Baseline evaluation of acid generation potential and water quality for proposed coal mine

#### **Teck Corp, Petaquilla Project, Panama (1996-1997)**

- Prediction of potential impacts due to leaching of waste rock at proposed open pit copper mine

#### **Cominco, Kudz-Ze-Kaya project, YT (1996)**

- Retained to address acid generation issues in waste management plan for proposed zinc-copper-lead mine

#### **Termopacifico, Colombia (1994)**

- Assessment of existing waste management for small coal mines as part of proposed thermal power plant

#### **Manhattan Minerals, Moris Mine, Mexico (1993)**

- Developed closure plan for proposed heap leach gold mine. Also addressed acid generation issues

#### **TVI, Canatuan Project, Philippines (1993)**

- Development of waste management plan for proposed gold mine

#### **El Condor, Kemess South Project, B.C. (1992)**

- Evaluated natural weathering of rock and soil in support of waste management plan for proposed copper mine

#### **Brewery Creek (1991)**

- Soil and vegetation geochemistry study

#### **Galore Creek Project (1991)**

- Conducted initial assessment of acid generation at proposed large porphyry copper mine

#### **Snip Mine (1991)**

- Developed cyanide degradation model for tailings pond

#### **Berg Project (1990)**

- Investigated acid generation in waste rock and proposed waste handling approach for porphyry copper mine

#### **Taiwan Limestone Project (1990)**

- Conducted environmental assessment of proposed limestone quarry

#### **Geddes Resources, Windy Craggy Project, B.C. (1989-1991)**

- Investigated acid generation in waste rock, tailings, and underground workings and developed waste management plan for proposed massive sulphide copper mine

#### **Cinola Project (1989-1990)**

- Development of waste rock and tailings management plan for proposed epithermal gold mine

#### **Cheni Gold Mines (1989)**

- Developed waste rock handling plan for potentially acid generating rock at gold vein mine

#### **Silver Butte Mine (1989)**

- Interpreted acid generation data for waste rock and underground development for proposed massive sulphide base metal mine

# Stephen J. Day

## Principal Geochemist

### **Confidential Client**

- Due diligence audit for a proposed porphyry copper mine
- Prediction of impacts due to rock and tailings leaching and recommendation of waste management strategies

### **Key Experience: Operating Mines**

#### **Alaska Department of Environmental Conservation and Hecla Greens Creek Mining Company, Greens Creek Mine**

- Team leader for environmental audit of an underground silver mine.

#### **Elk Valley Coal Corporation (2007-current)**

- Development of a geochemical model for leaching of selenium to the Elk River and Cardinal River from six large open pit coal mines.

#### **Imperial Metals, Mount Polley Mine (2004-Current)**

- Geochemical characterization and water quality predictions for mine expansion.
- Water quality predictions for closure of copper heap leach.

#### **Inmet, Troilus Mine (2005)**

- Development of an approach for waste rock segregation at open pit copper gold mine.

#### **BHP Billiton, Mina Tintaya (2005-2006)**

- Evaluation of selenium sources in waste rock and downstream attenuation and transport.
- Geochemical characterization for closure planning.

#### **TeckCominco, Elkview Coal Mine (2003)**

- Detailed assessment of occurrence and release of selenium from mine facilities, and recommendations for management approaches

#### **Teck Cominco Alaska, Red Dog Mine, Alaska (1997-Current)**

- Development of innovative methods for characterization of the geochemical behaviour of waste rock
- Ongoing geochemical advice and interpretation

#### **Thompson Creek Mining, Endako Mine (1999-2000)**

- Assessment of waste rock geochemistry

#### **Huckleberry Mines Limited (1996-current)**

- Ongoing advice to operating open pit copper and molybdenum on waste management and prediction of long term water quality impacts

#### **TeckCominco, Luscar Ltd., Fording Coal, Elk Valley Coal Mines, British Columbia (1999-2002)**

- Technical review of university research on the occurrence and release of selenium from waste rock

#### **Hudson Bay Mining and Smelting (1998)**

- Environmental audit of more than ten massive sulphide copper and zinc mines, mills and associated smelter

#### **Confidential, Colombia (1997)**

- Assessment of existing environmental liabilities and scoping of environmental impact assessment for an operating coal mine as part of due diligence review

## **Stephen J. Day**

### **Principal Geochemist**

#### **Cominco Trail Operations, B.C. (1993)**

- Developed slag pile leachate model for proposed slag disposal site

#### **Gold Mine Yellowknife, NWT (1993)**

- Environmental assessment of operating gold mine as part of due diligence

#### **Macrae Mining, New Zealand (1993)**

- Presented arguments on acid generation thresholds in tailings. Evaluated reports on arsenic leaching from waste rock and tailings

#### **Equity Silver Mines (1991)**

- Developed water quality model for an acid generating open pit to address disposal of water treatment sludge in pit

#### **Tanco Mining company (1991)**

- Environmental audit of tantalum mine and mill

#### **Endako Mines (1990)**

- Evaluated acid generation potential of waste rock and tailings at molybdenum mine

### **Key Experience: Mine Closure Planning**

#### **Barrick Gold, Nickel Plate Mine (2005)**

- Geochemical characterization for closure planning of waste rock, mine workings and tailings from open pit gold mine.

#### **Teck Cominco, Pine Point Mine (2006)**

- Evaluation of monitoring requirements for tailings discharge.

#### **Teck Cominco Alaska, Red Dog Mine (2003-Current)**

- Water quality predictions for mine closure planning

#### **Deloitte & Touche, Faro Mine (2002-Current)**

- Design and implementation of geochemical studies for closure planning

#### **BHP Billiton, Island Copper Mine (2001-2005)**

- Geochemical studies for closure planning
- Chemical load modelling

#### **Hudson Bay Mining and Smelting, Flin Flon Operations (2005)**

- Input to estimation of closure costs.

#### **Teck Cominco, HB Mine (2005)**

- Review of geochemical issues for tailings.

#### **Viceroy Resources, Brewery Creek Mine (2002-2004)**

- Evaluation of water quality aspects related to closure.
- Assessment of selenium leaching.

#### **Inmet, Samatosum Mine (2003)**

- Environmental audit of former open pit copper-silver mine.

## **Stephen J. Day**

### **Principal Geochemist**

#### **BHP Billiton, Confidential Internal Reviews (2002)**

- Reviewed geochemical aspects of closure plans for two mines

#### **BHP Billiton, Robinson Mine, Nevada (2001-2002)**

- Geological and geochemical characterization of waste rock as part of closure planning for a large open pit copper mine
- Operation of a field laboratory for determination of leachable metal concentrations

#### **British Columbia Ministry of Water Land and Air Protection, Britannia Mine, British Columbia (2001-Current)**

- Evaluation of the effects of the use of mine workings for storage of contaminated mine water prior to treatment

#### **Highland Valley Copper, Highmont Mine, BC (2000-2001)**

- Geochemical assessment of tailings for closure planning

#### **Dupont Canada, Baker Mine, B.C. (1999-Current)**

- Evaluation of long term drainage quality for an inactive underground gold and silver mine
- Closure Planning

#### **TeckCominco Ltd., Sa Dena Hes Mine, Yukon Territory (1999-Current)**

- Assessment of geochemical characteristics of underground lead-zinc mines, waste rock and tailings, and downstream loading and impact assessment

#### **Environment Canada, Mount Washington Mine, B.C. (1999-2000)**

- Assessment of geochemistry as part of closure planning for a inactive open-pit copper mine

#### **Holden Mine, Washington State (1998-Current)**

- Support for Feasibility Study for closure of underground mine, waste rock and tailings
- Development of a site geochemical model to support selection of closure measures for a disused underground copper and zinc mine

#### **Westmin Resources, Premier Gold Mine, B.C. (1998-2002)**

- Prediction of long term geochemical behaviour of waste rock and tailings at an open pit gold mine

#### **Homestake, Snip Mine, B.C. (1998)**

- Prediction of post-closure impacts due to leaching of mine wastes at underground gold mine

#### **Confidential Client (1996)**

- Evaluated leaching of mercury from a former mercury mine as part of decommissioning

#### **COMIBOL, Bolivia (1996-1997)**

- Assessment of environmental issues for operating and closed mines as part of due diligence review

#### **Weldwood Canada, Various Properties, B.C. (1996)**

- Environmental evaluation of large area of former coal mining to assess remediation measures and potential costs

#### **Stronsay, B.C. and Sa Dena Hes, Y.T. projects (1993)**

- Initial assessment of potential environment liabilities

## **Stephen J. Day**

### **Principal Geochemist**

#### **Kinross Gold, QR Gold Mine, B.C (1993, 1998-2000)**

- Predictions of post-closure impacts due to long term leaching of waste rock and pit walls at open pit gold mine

#### **Cominco, Sullivan Mine, B.C. (1992-1998)**

- Evaluation of metal leaching from oxidized waste rock and tailings as part of closure planning. Geochemical interpretation of regional groundwater chemistry downgradient of tailings facility. Modelling of dry cover materials for acid generating tailings

#### **Cominco, Pinchi Lake Mine (1994-1995)**

- Evaluation of mercury distribution and leaching from mine wastes as part of closure planning

#### **Survey of Abandoned Mines (1991)**

- Compiled data relating to acid generation potential at more than 1000 abandoned mines in British Columbia. Assessed five coal and metal mine sites

### **Key Experience: Government Projects**

#### **Association of Professional Engineers and Geoscientists of British Columbia (2006-2007)**

- Delivered a short course acid rock drainage assessment (five venues)

#### **MEND Program (2005-2006)**

- Lead author for a report on the effect of low temperatures on geochemical processes.

#### **U.S. Trade and Development Agency, Dominican Republic (2002)**

- Delivered part of a short course to federal government personnel on acid rock drainage assessment and remediation

#### **State of Alaska (2001)**

- Workshop on mine site geochemical assessment

#### **Canadian International Development Agency, Peru (2000-2001)**

- Preparation of guidelines for inspection of mines

#### **MEND Program (2000-2001)**

- Managed and co-authored preparation of report titled Acidic Rock Drainage and Technology Gap Analysis

#### **MEND Program (1996-2000)**

- Co-author of technology manual on acid rock drainage prediction, control and treatment

#### **MEND Program (1998)**

- Reviewed and assisted with selection section of Procedures for Assessing the Subaqueous Stability of Oxidized Waste Rock

#### **MEND Program (1997)**

- Co-authored Blending and Layering Waste Rock to Delay, Mitigate or Prevent Acid Generation

#### **MEND Program (1996)**

- Co-authored Guide for predicting water geochemistry from waste rock piles



## **Stephen J. Day**

### **Principal Geochemist**

#### **Japan International Cooperation Agency, Brazil (1995-1996)**

- Part of a multi-disciplinary team led by Mitsubishi that evaluated remediation of coal mines in the State of Santa Catarina

#### **Indian and Northern Affairs (1994)**

- Prepared a long range research plan for acid rock drainage

#### **Mine Environment Neutral Drainage Program, Cinola Project, B.C. (1994)**

- Assessed long term potential for acid generation in waste rock and evaluated limestone addition to prevent acid release from waste rock

#### **QA/QC for Acid Generation Studies (1990)**

- Prepared manual for BC Acid Mine Drainage Task Force

#### **Review of Acid Generation Determination Methods (1990)**

- Assessed methods and recommended new approaches to testing for Energy, Mines and Resources Canada

#### **Acid Rock Drainage Technical Guide (1989)**

- Co-authored state-of-the-art manual covering prediction and monitoring of acid mine drainage

### **Key Experience: Contaminated Sites and Other Projects**

#### **Ministry of Health**

- Directed sampling of 240 wells to assess potential pesticide contamination

#### **Fullerton Lumber**

- Assessed soil contamination and potential approaches to on-site processing and soil remediation

#### **Fisheries and Oceans Canada**

- Assessed soil, sediment and water contamination at a marine repair station. Developed and costed remediation options

#### **Fisheries and Oceans Canada**

- Assessed contaminated woodfill on Crown lands. Developed and costed remediation options

#### **Western Steel**

- Interpretation of arsenic sludge chemistry.

#### **Grand Metropolitan**

- Assessment and management of several hydrocarbon underground storage tanks

#### **Transport Canada**

- Senior review of project to assess liabilities associated with underground fuel storage tanks at 28 remote beacon sites

# Lawrence E. Cope

## Senior Hydrogeologist



<b>Profession</b>	Senior Hydrogeologist
<b>Education</b>	M.S. Hydrogeology, Colorado State University, 1989 B.A. Earth Sciences, University of Colorado, 1978
<b>Certifications</b>	OSHA Hazardous Waste Site Investigation Health and Safety Training Course  MSHA Certification – Open Pit and Underground

### Specialization

Mr. Cope is a senior hydrogeologist with 25 years experience consulting to the mining industry in the areas of mine water management, hydrogeologic characterization, contaminant evaluation, baseline studies, groundwater and soils restoration, and environmental data management. Mr. Cope's technical experience has involved:

- Groundwater resource impacts analysis, open pit and underground mine inflow and water management evaluations, investigations of groundwater/surface water interactions, and basin hydrologic budgets.
- Design, installation, and performance testing of high capacity water supply wells.
- Aquifer hydraulic testing and analysis: variable and constant head, constant discharge, specific discharge tracer, and various packer techniques.
- Groundwater monitoring systems design, monitoring systems performance assessment, and evaluation of hydrogeologic data. Innovative groundwater sampling methods using specific discharge and micropurging techniques.
- Database development and management, data capture, validation, and quality control analyses.
- Statistical data analysis, probabilistic analysis (Monte Carlo simulation, distribution fitting), RCRA statistical evaluations.
- Numerical and analytical modeling of groundwater flow and contaminant fate and transport.
- Preparation of CERCLA, RCRA, and NEPA deliverables.

### Employment Record

<b>1998 – Present</b>	<b>SRK Consulting Inc.</b> , Senior Hydrogeologist
<b>1997 – 1998</b>	<b>CGRS Inc.</b> , Senior Hydrogeologist
<b>1988 – 1997</b>	<b>Golder Associates Inc.</b> , Project Hydrogeologist to Hydrogeology Group Leader
<b>1986 – 1988</b>	<b>Colorado State University</b> , Graduate Research Assistant
<b>1984 – 1985</b>	Dames & Moore, Staff through Project Hydrogeologist
<b>1983 – 1984</b>	<b>U.S.G.S., Water Resource Division</b> , Assistant Hydrologist
<b>1980 – 1983</b>	<b>Wahler Associates</b> , Staff Hydrogeologist

### Languages

Fluent Spanish / Working French

# Lawrence E. Cope

## Senior Hydrogeologist

### Key Experience:

#### Mine Water Management and Characterization

- **Molycorp Questa Mine, New Mexico:** Project Manager and Technical Lead for the Characterization of underground mine inflows and significant surface water flow related to block cave subsidence. The work differentiated surface recharge through the subsidence zone from other groundwater sources. A water control monitoring system was designed and installed, and is currently operational. Continuous flow measurements combined with quarterly water quality sampling provide data for source identification and water and chemical mass balance analyses. Current efforts are focused on the evaluation and optimization of the mine water management system with the objective of maximizing temporary storage of inflow through the active block from large precipitation events. The work includes modifications to underground storage and conveyance facilities and a tracer study to quantify travel time and pathways of infiltration to the mine from the overlying open pit.
- **Stillwater Mining Co, Montana:** Manager and lead hydrogeologist for a pressure injection testing to program to locate structure-controlled zones of high groundwater pressure above the underground Stillwater Mine in Montana. Designed the test program to enable monitoring formation pressures and transient drainage conditions at the drill collar without using complex down hole straddle packer equipment.
- **Echo Bay Lamefoot Projects, Washington:** Evaluation of groundwater inflow quantity and quality in underground workings. Developed a conceptual hydrogeologic model based on the characteristics related to rock structure and lithology. A significant component of the model was a detailed understanding of the interaction between the alluvial and deep bedrock groundwater flow systems. Applied a water balance approach to estimate inflow and acid generating potential during future mine development.
- **Eagle Mine, Colorado:** Hydrogeology team leader to evaluate impacts from a mine and mill facility and on the local groundwater system and the adjacent Eagle River. Supervised drilling and installation of multiple nested piezometers, and conducted long-term pumping tests. Installed digital data acquisition system to remotely monitor water level in the rapidly flooding closed mine.
- **Cuajone Mine, Southern Peru Copper, Peru:** Team leader and technical lead for a hydrogeologic evaluation for suitability of a proposed large valley-fill leach operation. The work entailed hydrogeologic and surface water characterizations, impacts assessments, and design of mitigation measures in a fractured volcanic rock setting. The work focused on defining zones of fracture-enhanced groundwater flow, the relationship of a regionally significant river to the groundwater flow system, and the ability to contain and recover leach solutions from the fractured system. A phased approach was used to first conduct a fatal flaw evaluation, the results of which served to focus a detailed characterization. The characterization field program involved 10,000 feet of well installation, oriented angled core drilling, packer testing, long-term aquifer testing, seismic geophysical survey, spring and seep evaluation, and river flow gauging. The results were applied to a basin-scale three dimensional multi-layer groundwater flow and transport model. The defensibility of the model is critical to the client obtaining permit approval for the operation.
- **San Manuel Mine Site, Pinal County, Arizona:** Hydrogeology team lead and principal investigator for the assessment of the impacts of an existing open pit on the surrounding groundwater flow system. Directed deep monitoring well installation (600 to 1500 feet) and performed in-situ hydraulic testing (e.g., packer testing, aquifer test). Specified, procured and successfully installed a 1,500 foot deep

## Lawrence E. Cope

### Senior Hydrogeologist

grouted transducer column including 12 vibrating wire transducers and data logging equipment. The aquifer test program included low flow (less than 2 gpm) drawdown tests in undisturbed bedrock formations over extended periods of time. Performed data interpretation and analysis in support of the predictive groundwater flow model and Aquifer Protection Permit Application.

- **Franklin/Zeus Joint Venture, Colorado:** Project manager and technical lead for the permitting of proposed gold mining and milling operations at the Franklin and Mogul mines in Clear Creek and Boulder counties. Conducted an underground evaluation to predict future mine water discharge volume and quality. Co-authored Environmental Protection Plan, Plan of Operation, and Stormwater Management Plan as part of mining permit application.
- **Pueblo Viejo Mine, Dominican Republic:** Evaluation of the groundwater flow system in a complex terrain of a tight silicified volcanics structurally juxtaposed to highly karstic limestone. Formulated a regional conceptual model that addressed impacts from the open pit mine and extensive tailings facilities that overly this complex system.
- **Phelps Dodge Ambatovy-Analamay Project, Madagascar:** Baseline environmental assessments of surface and groundwater hydrology in remote tropical terrain for a large proposed nickel-cobalt mine and mill. Scope included baseline data collection, assessment of environmental risks within the framework of World Bank Environmental Standards, analysis of potential groundwater and surface water impacts, and mitigation of the impacts. Also collected data to support site selection and feasibility studies for tailings facility. Though the work was severely challenged by complicated logistics and rugged jungle conditions, the project produced rigorous high quality data that met permitting and design needs.
- **Hecla Grouse Creek Operations, Idaho:** Developed a water balance that incorporated tailings and waste rock facilities, mill makeup water requirements, water expressed during consolidation of newly deposited tails, and runoff contributions from disturbed and undisturbed small watersheds surrounding the site. Site climate data were calculated using statistical adjustments from a number of stations in central Idaho and west-central Montana. Statistical distributions for precipitation, evaporation, runoff, spring melt-out duration and timing, mill tonnage, and makeup water volumes were incorporated into the analysis to simulate natural and operational variability. The calibrated spreadsheet was subsequently used by mill operators as a solution management tool.
- **San Juan Ridge Mine, California:** Developed multi-layer finite element groundwater models to predict mine water inflow to a proposed underground gold mine. Models simulated both local mine inflow and regional impacts to private water supply wells. Subsequent operation of the mine showed that the inflow predicted by the model was within 10 percent of actual inflow.
- **Various Mines, Idaho, Montana, New Mexico, Arizona:** Conducted water balance analyses for mining heap leach projects located in arid and humid environments. Performed both deterministic and probabilistic water balance analyses that included components of the natural hydrologic cycle and various operational solution application, storage, and extraction processes. The water balance models were calibrated on a monthly basis to actual measured climatic precipitation and process flow data and were used by clients as an ongoing operational decision tool.

### Mine Contamination, Reclamation

- **General Atomics, Rio Grande Resources, Panna Maria, Texas:** Project manager to review and amend an Alternate Concentration Limit Application submitted as part of the groundwater compliance

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### Senior Hydrogeologist

strategy at the site. Work included development of a multilayer three-dimensional, variably saturated flow and transport model to support an update to the site human health risk assessment. Also developed the environmental monitoring data management system currently being used at the site.

- **Confidential Client, Copper Operation, USA:** Project manager for a remedial investigation under an AOC to characterize impacts from historic smelter and tailings operations on the soils and surface water surrounding the site.
- **Conoco, Conquista Uranium Mill, Texas:** Lead hydrogeologist to characterize the groundwater flow system in the vicinity of a closed uranium mill tailings facility. Investigations were conducted to quantify site impacts and to establish background water chemistry potentially influenced by an adjacent upgradient uranium mine and mill operation.
- **Tailings Characterization, PricewaterhouseCoopers, Atlas Minerals Uranium Mill Site, Utah:** Technical groundwater lead for investigation to support the dewatering program at the Atlas Mill uranium tailings impoundment. The project consisted of hydrogeologic, geotechnical and geochemical characterization of the tailings to enable the selection of a dewater method, and assess the changes that might occur in the tailings porewaters as a result of dewatering.
- **Leadville Superfund Site, Colorado:** Principal investigator for supplemental Feasibility Study groundwater investigations to refine impacts analyses for the Apache Tailings Impoundment. Responsible for performance assessment of groundwater and surface water monitoring network, refinement of the conceptual groundwater/surface water model, installation of nested monitoring wells, aquifer hydraulic testing and groundwater sampling.
- **Eagle Mine, Colorado:** Hydrogeology team lead for an environmental assessment and evaluation of extent of heavy metals contamination associated with a low pH tailings facility and mine workings.
- **Wishbone Hill Open Pit Mine, Alaska:** Groundwater baseline and impact studies for proposed Idemitsu Wishbone Hill open pit coal mine in Alaska. Responsible for the collection and analysis of field test data for characterization of the site hydrogeology. The characterization culminated in predictive pit inflow analyses using various numerical and analytical solutions.
- **Gallegos Dimensional Stone Quarry, Colorado:** Environmental Impacts Assessment of acid rock drainage from quarry operation near Telluride. Assessed conditions through soil and surface water sampling. Proposed cost-effective modifications of operational practices to minimize impacts to environmentally sensitive surface waters in area. Also recommended permitting strategies for incorporation into storm water permit and technical revisions to an existing mining permit.
- **Blackhawk Mill Site, Colorado:** Performed environmental site assessment of a historic mining property adjacent to a CERCLA superfund site. Defined areas of hazardous and non-hazardous mine and mill wastes as a pre-remedial design activity. Evaluated remedial alternatives, recommended the preferred alternative, and developed cost estimate to complete the cleanup.
- **Cotter Corporation, Wyoming:** Detailed investigation to determine feasibility of in-situ leaching of a uranium property near Pumpkin Buttes. Responsible for installation of wells and long-term pumping tests.

## Lawrence E. Cope

### Senior Hydrogeologist

#### Groundwater Resource Evaluation and Development

- **Montana Explorada, Guatemala:** Developed water supply for a new gold mine/mill operation through an assessment of the resource potential, identification of candidate well locations, and the installation, and testing of a successful large bore 1,000 foot deep production well.
- **Nevada Power Company, Nevada:** Design, installation and performance testing of a 1,000-foot deep, 1,500 gpm water supply well.
- **Pinnacle West Capital, Nevada:** Groundwater resource evaluation and the design, installation, and production testing of 2,000-foot deep high-capacity water supply well.
- **Colorado Springs Landfill, Colorado:** Evaluation of an alluvial groundwater resource with respect to potential impacts from a proposed expansion of a solid waste landfill. Development of basin and sub-basin water budgets, verification of the water budgets using numerical methods, and semi-analytical computer modeling of potential contaminant release scenarios. Also conducted a study of the hydrogeologic suitability of existing and proposed solid waste landfill sites across El Paso County, Colorado. Developed a ranking procedure to compare the sites across diverse hydrogeologic regimes.

#### Mine Permitting

- **Wishbone Hill Open Pit Mine, Alaska:** Groundwater baseline and impact studies for proposed Idemitsu Wishbone Hill open pit coal mine in Alaska. Responsible for the collection and analysis of field test data for characterization of the site hydrogeology. The characterization culminated in predictive pit inflow analyses using various numerical and analytical solutions.
- **Confidential Client, Central America:** Baseline line measurement of flow and sampling for water quality at a precious metal mining prospect.
- **Echo Bay K2 and Key Projects, Washington:** Assessment of potential impacts to groundwater and surface water from Key Project open pit gold mine. Designed groundwater monitoring well network. Also planned and directed field investigations at the proposed K2 Project to evaluate baseline potentiometric and water quality conditions.

#### Solid and Hazardous Waste

- **Rocky Flats Environmental Technology Site, Colorado:** Program Manager and technical lead for multidisciplinary projects at the DOE facility related to groundwater sampling, aquifer testing and analysis, and evaluation of innovative technologies and field methods. Multiple simultaneous investigations involved up to twenty professional technical staff.

The evaluations focused on determining the feasibility and applicability of the Rocky Flats site to alternative groundwater sampling methods, state-of-the-art field water quality measurement instrumentation, aseptic methods for drilling and well installation, and improving well design. Principal author and lead investigator for *1994 Site Wide Well Evaluation Report*, *Summary of Historic Water Quality Field Parameter Data*, and *Evaluation of Geochemical Analytical Suites*.

## Lawrence E. Cope

### Senior Hydrogeologist

Evaluation of water quality data and database management of more than 250,000 environmental records for the *1997 Rocky Flats Cleanup Agreement (RFCA) Annual Groundwater Monitoring Report*. Responsibilities included extraction and conditioning of the data for analysis, quality control analyses based on P.A.R.C.C. parameters, analyses to document exceedences of site-specific action levels, trend analysis, and preparation of data analysis sections of the report. Developed data management procedures to automate the input, analysis, and reporting of the data.

#### Unsaturated Zone Studies

- **Nevada Nuclear Waste, Isolation Program (USGS), Yucca Mountain, Nevada:** Responsible for construction, calibration, and emplacement of down-hole instrumentation to measure moisture content of tuffaceous rocks at the proposed high level nuclear waste repository at Yucca Mountain, Nevada. Supervised the set-up and operation of a vadose zone instrument calibration laboratory for the Nevada Nuclear Waste Isolation Program. Developed moisture-characteristic curves, unsaturated hydraulic conductivity, and matric potentials in tuffaceous rocks.