Sumitomo Metal Mining Pogo LLC

P.O. Box 145
Delta Junction
AK 99737 USA

TEL: +1 907 895 2841
FAX: +1 907 895 2866
URL: www.smm.co.jp

February 19, 2013
COR-13-016
Certified Mail #**7011 1570 0001 1559 1550**

Sharmon Stambaugh, Large Mine Coordinator
State of Alaska Department of Natural Resources
Office of Project Management and Permitting
550 West 7th Avenue Suite 900
Anchorage, Alaska 99501

Re: **Study Plan for Underground Closure Update as Required by Sumitomo Metal Mining Pogo LLC (Pogo) Plan of Operations Approval F20129500 (February 7, 2012) Pogo Reclamation and Closure Plan Stipulation 4 on page 9.**

Dear Ms. Stambaugh:

Sumitomo Metal Mining Pogo LLC (Pogo) is voluntarily providing the enclosed "Study Plan for Pogo Mine Underground Closure Study" prepared by Tetra Tech on February 18, 2013. Pogo is required to update our plans for underground mine closure by Plan of Operations Approval F20129500 under Pogo Reclamation and Closure Plan Stipulation 4 on Page 9. It states: "More detailed procedures and plans for underground mine closure, including final portal plugs, assessment of the need for backfilling and accelerated re-flooding of the underground workings (including costs for these activities), shall be developed and provided to the agencies prior to the end of 2013 or with any amendment to the Plan of Operations that involves significant modifications to the underground development."

The project was kicked off by teleconference on February 13, 2013. The first site visit is tentatively scheduled for the week of March 25, 2013. After Pogo receives the draft final report from Tetra Tech, we would like to hold a meeting with ADNR and ADEC to review the preliminary findings.

Please provide Agency feedback on the Study Plan to us by no later than March 18, 2013. Please let us know if we need to set up a meeting to discuss the project before field work commences.

If you have any questions, please contact me at 907-895-2897 or sally.mcleod@smmpogo.com.

Sincerely,

Sally McLeod, CEM, REM
Environmental Superintendant

Attachments: Study Plan for Pogo Mine Underground Closure Study Tetra Tech Project #114-870024

Cc: Brent Martellaro, ADNR
Tim Pilon, ADEC

STUDY PLAN

Pogo Mine Underground Closure Study

Tetra Tech Project # 114-870024

SUMITOMO METAL MINING Pogo LLC

Prepared for:

Sumitomo Metal Mining Pogo LLC
Post Office Box 145
Delta Junction, Alaska 99737

Contact:

Sally McLeod, Environmental Superintendent
907-895-2879
sally.mcleod@smmpogo.com

TETRA TECH

Submitted by:

Tetra Tech
701 Bidwell Avenue, Suite 303
Fairbanks, Alaska 99701

Contact:

Jack DiMarchi
907-459-5583
jack.dimarchi@tetratech.com

February 18, 2013

complex world CLEAR SOLUTIONS™

TETRA TECH

Table of Contents

Appendices

POGO UNDERGROUND CLOSURE STUDY

PROJECT UNDERSTANDING

Tetra Tech's understanding is that Pogo is required to meet a stipulation in the 2012 Plan of Operations (POO) Approval from the Alaska Department of Natural Resources (ADNR) regarding mine closure.

The stipulation reads: *More detailed procedures and plans for underground mine closure, including final portal plugs, assessment of the need for backfilling and accelerated re-flooding of the underground workings (including costs for these activities), shall be developed and provided to the agencies prior to the end of 2013 or with any amendment to the Plan of Operations that involves significant modifications to the underground development.*

The following is a Study Plan that will be implemented by Tetra Tech in order to generate the data required to develop a better understanding the underground closure characteristics of the Pogo Mine and develop the *procedures and plans* that will meet the 2012 POO permit stipulation.

STUDY PLAN SCOPE OF WORK

The following Tasks reflect Tetra Tech's Study Plan which will meet the closure stipulation in the 2012 POO Approval. Tetra Tech has integrated three major study components into this Study Plan in order to meet the requirements of the POO Approval stipulation including:

1) A geochemical component that will establish a robust pre-closure geochemical baseline for the geochemistry and chemical stability of the wall rock and pastefill in the mine and predict, evaluate, and measure any potential for ARD/ML underground following closure and establish the relative need to accelerate the flooding of the mine at closure,
2) A hydrogeologic component that will model the mine hydrology and evaluate the mine flooding rates, predicts static water levels and static head at closure, and evaluate the potential for mine seepage to the surface at closure, and
3) A geotechnical component that will gather data at each portal and use the geotechnical and hydrological data to develop engineered designs and costs for the portal plugs for the four mine portals. Tetra Tech staff will travel to the mine in order to perform certain portions of these studies.

The Study Plan is divided into 5 Tasks as described below.

Task 1: Kick-Off Teleconference and Assemble Technical Materials

In Task 1, the Tetra Tech team will organize a conference call to kick-off the project. During the call the project scope and tasks will be discussed and procedures for the exchange of technical information will also be discussed as well as potential scheduling for the Tt team to travel to the mine. Following the kick-off call, Tetra Tech will work directly with the Pogo Mine staff to assemble all of the available technical materials from past closure studies, including acid-base accounting (ABA) data, water leach data and kinetic test data, groundwater well monitoring data, and more recent FracMan studies. Some of that work will be done at the mine during the team's mine visit. This Task was completed on February 13, 2013.

Task 2: Wall Rock and Paste Back Fill Chemical Characterization

In Task 2, Tetra Tech will review existing Acid Base Accounting data for wallrock and paste. The Task 2 Lead and a project geochemist will travel to the Pogo mine to review existing paste and wallrock geochemical characterization data, observe the paste-backfill operations and examine geology and pastefill underground. On that basis the Lead will design a sampling and geochemical test program and

work with the mine staff to determine which of those samples will come directly from the mine workings and which will come from archived drill core. The objective of the sampling program is to establish a robust pre-closure baseline for the wall rock and pastefill that will be used to characterize the geochemistry and chemical stability of the wall rock and paste in order to determine the relative need to accelerate the flooding of the mine at closure. If the need for accelerated flooding is established, Tetra Tech will provide a discussion of potential flooding options in the final report. The geochemical test program will likely include: 1) Multi-elemental analysis, 2) Acid Base Accounting (ABA), 3) Single-step static water leach testing (SPLP), and 4) Kinetic testing-column leach tests as described in more detail below. Tetra Tech will work directly with mine staff to determine if any existing data might serve as surrogates for the some of the multi-elemental analysis described below.

The schedule for the Underground Closure Project is most sensitive to the time required to complete humidity cell testwork (up to 40 weeks). The following chemical tests are recommended for any new wall rock and pastefill samples.

Multi-elemental Analysis

Elemental analysis provides the near-total solid phase elemental concentrations that can be compared to crustal variability or background concentrations to identify constituents of potential concern. A subsample of each sample will be pulverized and subjected to elemental analysis using four-acid digestion (hydrofluoric, hydrochloric, nitric, and perchloric acids) with inductively coupled plasma-mass spectroscopy (ICP-MS) analysis. Both representative samples of wall rock and paste backfill would be subjected to elemental analysis. This analysis would be the main screening criteria to ascertain whether the main mine area is similar in geochemical makeup to the L1E Deep area. If statistically dissimilar, then additional samples of the L1E Deep area for kinetic test may be required.

Acid-base Accounting

ABA is a fast and relatively low cost analysis used to estimate the capacity of material to produce and neutralize acid. ABA methods compare the acid generating potential (AGP) with the acid neutralizing potential (ANP) for a given material using either the total sulfur or sulfide sulfur depending upon the sulfur species present and mineralogy.

ABA results will be used to determine the neutralization potential ratio (ANP/AGP) and net neutralization potential (NNP) where NNP is the difference between the ANP and AGP (i.e., NNP = ANP – AGP). These criteria are commonly used to categorize material into potentially acid-producing or non-acid-producing material. Many interpretation schemes have been developed to assess the potential for acid generation using either ANP/AGP or NNP. Industry standard criteria (Price, 2009) categorize samples with ANP/AGP ≥ 2 and NNP ≥ 20 tons of CaCO3 per kiloton of material (tonnes CaCO3/kton) as non-acid-forming (non-PAG). Both wall rock and paste will be subjected to ABA testing.

If the dominant character of the materials in the mine are shown to be non-acid generating, a more relaxed backfill/flooding program can be adopted. If zones are identified that are more acid-prone, then if possible, localized rapid backfilling and/or flooding may be prudent as it will reduce the exposure time the acid-generating material will be exposed to oxygen. It is recommended that up to 36 samples collected from the main mine area and the L1E Deep portions of the mine, regardless of the similarity/dissimilarity between the two areas as determined on bulk chemical parameters.

Water Leaching Tests

Single-step static water leach testing (SPLP) of wall rock will provide an assessment of the potential for release of constituents due to short-term exposure to meteoric precipitation. A number of different water leach testing procedures are available, each with its advantages and disadvantages which in turn result in particular methods being preferred by different environmental specialists and regulatory agencies.

Kinetic Testing-Column Leach Tests (Humidity Cell)

Kinetic tests are mid- to long-term accelerated weathering test methods that create optimal conditions for sulfide-weathering and metal-leaching potential by exposing the sample to abundant water and oxygen. In samples designated as potentially acid generating (PAG), kinetic testing determines the rate of consumption and if the sample will turn acidic. Similarly, samples with higher concentrations of total metals or samples showing static extractable metals near or above the EPA Drinking Water Guidelines are often subjected to kinetic leach testing. Final selection and number of samples will depend upon the initial ABA, metals, and SLPS results. In the case of paste backfill, it may be possible to reduce the number of required samples to those of extreme compositional end-members to "bracket" reactivity and ML/ARD release characteristics.

The results of the analytical data will lead to a characterization of the paste backfill and wall rock relative to their ML/ARD, and support a defensible assessment of the relative need to accelerate flooding of the mine at closure or let it flood naturally over time. The rate of acid generation and sulfide oxidation kinetics will be compared to in-flow rates (discussed below) to identify whether acid formation due to oxidation needs to be mitigated via accelerated flooding.

In Task 2, Tetra Tech will also determine whether the existing groundwater monitoring data are adequate (i.e. Nevada Profile) for characterizing the pre-closure groundwater conditions relative to ML/ARD.

Task3: Hydrogeologic Study

Several steps are combined in this Task which will include: 1) a review of recent hydrogeology studies completed by Golder and SRK at Pogo, including participating in the past meeting with Golder and SRK at the mine in December 2012, 2) a review of the mine geology and identification any geologic structures that might communicate water to the surface at closure, and 3) Perform additional modeling to establish the maximum steady-state water level, water pressure and flood rate underground at closure.

Subtask 3.1 Review Recent Hydrogeology Studies

Tetra Tech understands that Golder and SRK have performed modeling of groundwater in-flows and groundwater geochemistry using FracMan and MODFLOW, respectively, and that Pogo will make those studies available to Tetra Tech. Tetra Tech understands that both models will be available to Tetra Tech for their hydrogeological study work. This will avoid the duplication of hydrogeology studies by Tetra Tech. This was discussed between Golder, SRK, Tetra Tech and mine staff at the hydrology meeting on December 12, 2012 held at the mine.

Subtask 3.2 Identifying Underground Pathways

Many case studies can be cited where the water pressure behind plugs increased rapidly as the mine flooded. Since the presence of a pressure gradient across porous media causes flow, Tetra Tech will assess whether high permeability pathways (i.e. faults) exist that would permit quantities of water to flow uncontrolled to the surface following closure. This Task would involve review of lineaments, the mine geology database, wetlands maps, a review of the world stress map, and a field spring and seep survey. Structural pathways will be assigned an approximate permeability and incorporated in the flow modeling to estimate the amount of flow along these structures. Seep volumes will be predicted for those flow paths that breach the surface. Static water level in the mine may achieve equilibrium at pre-mining in-situ levels after the portal plugs are constructed. At that time seeps may reappear at locations where they existed prior to mining, but had disappeared during mining operations. Water quality may be different in these seeps after closure owing to interactions between mine water and the surrounding wallrock or pastefill.

Subtask 3.3 MODFLOW Modeling-Maximum Steady-State Water Level and Pressure Underground

Tetra Tech will model the mine flood rate, steady state water level and the maximum steady-state water pressure behind the portal plugs at closure. Data inputs for the model will include groundwater monitoring water level data, the spring/seep surveys data, mine water in-flows, mine volumetrics and all relevant data from the recent FracMan and MODFLOW studies being completed by Golder and SRK.

Task 4 Portal Plugs Engineering Design

In this Task, rock mechanics data including unconfined compressive strength, tensile strength, modulus, and others will be identified and qualified for use as inputs to the portal plug design process, including the L1E Deep plug. A benchmark of cement-based plug materials using a variety of additives for strength and resistance to chemical breakdown will be performed to identify the best material for the Pogo portal plugs. Pastefill will be considered as an alternative material for plug construction due to its relative availability and likely lower cost compared to plugs composed of Portland cement.

Plug design will be based primarily on static force criteria. Calculations will be based on criteria input. The design will use the three anchors of calculations: stress modeling, empirical formula, and rock mass rating indices. The seal design will also will include through-plug utilities such as access pipe, corridors for monitoring cable and sensors, and water flow, consistent with the objectives of the plug.

The rock mass ground surrounding the portal plugs will require stabilization for a determined distance on either/both sides of the plugs. The application of stabilizing appliances such as bolts, screens, standing support, and shotcrete will be considered in the Subtask. Tetra Tech proposes one day at each portal site for the rock mechanic lead to perform underground geotechnical mapping and collect a representative rock sample for rock mechanics testing. Tetra Tech will endeavor to work with the University of Alaska Fairbanks School of Mining Engineering or an alternate lab to perform the rock mechanic testwork on these samples.

Tetra Tech staff will travel to the mine to collect geotechnical data at the existing portals.

In addition to developing the portal plug designs, Tetra Tech will develop a cost estimate and construction-level drawings for the portal plugs in this Task.

Task 5: Final Report and Web-Based Presentation

The Project Team will produce a Final Report that describes the methodologies, inputs, conclusions, and recommendations for each of the Tasks described in the Scope of Work. This will include, but not necessarily be limited to:

- Predictions about the long term ML/ARD potential of the paste backfill and underground wall rock
- Model the closure static water level and head and time to achieve these following closure
- Establishing the relative need for accelerate flooding of the mine to minimize ML/ARD
- Providing a cursory list of considerations for accelerated flooding if it appears that it is likely necessary, including sources for flood water, logistical constraints, duration and approximate costs.
- Designs and construction cost estimate for the portal plugs

The draft final report will be provided to Pogo for a review and comment prior to submittal of the Final Report.

The Tetra Tech Team will also organize a web-based meeting with Pogo to present the results of the Underground Closure Study during the draft report review period.

TETRA TECH TEAM

Tetra Tech offers a highly experienced Project Team that will provide the technical and management support for this Study Plan. Mr. DiMarchi, the Project Manager, is an experienced Alaska mine geologist with a background in mine operations and permitting, environmental sciences including water management. Dave Hallman will be the lead Engineer for the rock mechanics, portal plug design, and portal plug cost estimation portions of the Project. Dr. Richers will be the lead geochemist on the Project. Keith Thompson will be the lead hydrogeologist for the Project. Tetra Tech has demonstrated their capabilities and dedication in successfully completing many other similar projects for mines in Alaska and throughout the world. A brief summary of the experience and qualifications of the Team is included below. A resume for each team member is included in **Appendix A**.

Jack DiMarchi, CPG | *Project Manager*

Mr. DiMarchi has more than 30 years of combined experience in geologic investigations, mine geology, mine operations, and mine permitting. He has served as the Qualified Person under National Instrument 43-101 for Environmental Reports, including Reclamation and Closure Plans and coordinated and contributed to the technical review and approval process of mine plans of operation, water management plans, reclamation and closure plans, environmental audits, waste management permits, and mine financial assurances. For the Pogo Underground Closure Study, Mr. DiMarchi will contribute to Tasks 1, 2, 3 and 5 and ensure that adequate expert technical resources are available to perform the studies outlined in the Study Plan in an efficient and timely manner. In addition, Mr. DiMarchi will be the key point of contact between Tetra Tech and Pogo staff and ensure that the client's needs are fulfilled throughout the term of the Project.

Rich Dombrouski, PE, PG | *Engineering Geologist*

Mr. Dombrouski is the geotechnical manager for Tetra Tech's services in the state of Montana and the Missoula office manager. He has over 25 years of diverse geotechnical and construction management experience on a wide variety of geotechnical engineering, construction materials testing (CMT), and environmental projects. Mr. Dombrouski will be the lead for geotechnical mapping in Task 4.

Dave Hallman, PE - Alaska | *Principal Geotechnical Engineer*

Mr. Hallman has 27 years of experience specializing in geotechnical engineering and construction on a variety of mining and civil engineering projects throughout the world. He is a registered civil engineer in Alaska. His technical expertise includes static and dynamic stability of embankments and natural slopes, landslide evaluation, rock slope stability, seismic risk assessments, liquefaction evaluations, dynamic deformation analyses, liner and seepage cutoff system design and evaluation, tailings and water dam design and construction, and design and construction of heap leach and landfill facilities. Mr. Hallman will be the lead Engineer for Task 4.

Mackenzie Fernald | *Geological Engineer*

Ms. Fernald is a 2012 graduate from Colorado School of Mines. She has been a contributing member on a number of studies focused on mine development, mineral economics, resource estimation and research. Ms. Fernald will assist with the underground geotechnical mapping in Task 4.

Dave Richers, PhD | *Senior Geologist/Geochemist*

Dr. Richers has over 35 years of experience as a geologist and geochemist. He has performed extensive geochemical site characterization services. He has worked on mining projects in the United States, Australia, and Canada including both surface and underground operations. Dr. Richers routinely participates in geochemical studies and programs aimed at protecting the environment including quantification of geochemical processes for engineering design and closure planning and impact analysis. His background includes extensive work with ML/ARD and the associated fate and transport. His expertise in geologic computer mapping and 3D GIS brings an added dimension to the Project Team. Dr. Richers will be the Lead for Task 2 in this Study Plan.

Doc Richardson, PhD | *Geochemist*

C. Doc Richardson has several years of professional practice conducting water/soil testing, laboratory analysis, and computer/data interpretation related to a wide range of environmental and mining projects. He has experience in implementing surface and subsurface geochemical studies with an emphasis on computer modeling. He also has a strong background in fate and transport of metals in aqueous systems. Doc will work with Dave Richers in completing Task 2.

Keith Thompson CPG, RG | *Senior Hydrogeologist*

Mr. Thompson has 33 years of project experience with hydrogeology, water resources and environmental assessment and remediation for the mining, energy and chemical industries, government, and private parties. He specializes in mining-related groundwater and surface water studies, and groundwater flow and transport modeling. During Mr. Thompson's 20 years with Tetra Tech, he has held positions of senior scientist, senior project manager, environmental group manager and office manager, including an overseas office coordinating U.S. and local foreign professional and technical staff. He has managed hundreds of projects valued at several million dollars and has supervised professional and technical staff on numerous long-term, multi-disciplinary projects. Mr. Thompson will be the lead for Task 3 in this Study Plan.

PROJECT SCHEDULE

The Pogo Underground Closure Study will take approximately 10 months to complete. The schedule is largely driven by the kinetic testwork that may be required for paste fill and wall rock samples. We assume there will be a need for this work in the schedule proposed here.

Pogo Underground Closure Study Schedule											
Task		Month									
		1	2	3	4	5	6	7	8	9	10
Task 1	Kick-Off and Assemble Materials										
Task 2	Geochemical Tests/Analyses										?
Task 3	Hydrogeologic Study										
Task 4	Portal Plugs Engineering Design										
Task 5	Draft and Final Reports										

Appendix A

Resumes

JACK DIMARCHI, CPG

Project Manager-Senior Scientist: Environmental, Geology and Permitting

TETRA TECH

EDUCATION

BS, Geology, Minor emphasis in Forestry, Colorado State University, 1978

REGISTRATIONS/CERTIFICATIONS

Certified Professional Geologist: American Institute of Professional Geologists (CPG#9217, 1994)
Registered Professional Geologist: Alaska (RPG#403, 1994)

EXPERIENCE SUMMARY

Mr. DiMarchi has more than 25 years of combined experience in geologic investigations, mine geology, mine operations and mine permitting. Mr. DiMarchi spent approximately 15 years managing remote precious and base metal exploration projects throughout Alaska with additional experience in Colorado, Wyoming, Texas, Mexico, Suriname and Peru. He was integral to the team that defined the Pogo gold deposit and then participated in the underground development, permitting, construction and commissioning of the mine, Alaska's largest gold mine. Mr. DiMarchi is an expert in 3-D computer modeling and ore resource estimation. He was also the principal consultant/owner with Core Geosciences and provided senior project management and geologic oversight on several early to mid-stage mining projects in Alaska and Canada. Mr. DiMarchi also has several years of mine permitting experience gained while he was the large mine permitting coordinator for the State of Alaska Department of Natural Resources. During his tenure Mr. DiMarchi managed the environmental permitting process for the Red Dog, Pogo, Fort Knox, Nixon Fork, Rock Creek and Kensington mines as well as the Donlin, Livengood and Niblack advanced exploration projects. He has coordinated and contributed to the technical review and approval process of mine plans of operation, reclamation & closure plans, environmental audits, integrated waste management permits and mine financial assurances His coordination responsibilities also included representing the State of Alaska as a cooperating agency in the NEPA/EIS process with the EPA and Army Corp of Engineers. He is experienced in community outreach and working with Alaska Native tribal and village councils.

PROJECT EXPERIENCE

Environmental

Alaska Department of Natural Resources, Office of Project Management and Permitting. As the *Large* Mine Permitting Coordinator Mr. DiMarchi coordinated state permitting activities for six of the seven large mines Alaska. He facilitated parallel permitting efforts at the Department of Environmental Conservation, Department of Natural Resources and Department of Fish & Game as well as coordinating with Federal agencies including the ACOE and EPA. He directed the public involvement portion of the permitting process by directing public meetings and consulting directly with Alaska Native tribal and Village councils. Mr. DiMarchi coordinated the technical review of permit applications, supporting technical reports and permit modifications. He developed an in-depth working knowledge of mine permitting criteria and BMP's in Alaska as they relate to solid waste management, reclamation and closure, dam safety and geotechnical stability of dams, air quality, water management, tailings management and financial assurances. He coordinated with Federal agencies on NEPA activities as a cooperating agency on the Red Dog SEIS. He coordinated with Canadian provincial and federal agencies and managed State of Alaska's multi-disciplinary teams that reviewed Canadian EA Applications under the Boundary Waters Treaty to ensure that mining operations in Canada (*Kerr-Sulphurets-Mitchell Mine, B.C.)* did not adversely impact transboundary waters that flow into AK. (2008 to 2011)

Subsurface Investigations

Alaska and Canada. For more than 15 years Mr. DiMarchi was a geologist involved in geologic investigations throughout Alaska, and Canada. He was the project manager on regional programs including many diamond drilling and geophysical exploratory programs. He developed an excellent skill set directed at interpreting subsurface geologic conditions by integrating surface and subsurface data into 3-dimensional models. He is experienced in the application/interpretation of most surface electrical and radiometric geophysical methods, as well as down-hole resistivity/gamma radiometric methods. In addition Mr. DiMarchi worked underground for more than 7 years where he developed expert skills in underground geologic mapping, mine geology, ground control, underground drilling, water management and safety. Mr. DiMarchi has logged hundreds of core, RC, and geotechnical (triple tube and modified Shelby tube) drill holes. He has used drill core sampling to investigate hydrothermal alteration, structural deformation, mineralogy, mineralization, permafrost characteristics and geotechnical characteristics in the subsurface. (1980 to 2007)

Mine Operations

Pogo Gold Mine, Alaska. As Chief Geologist, Mr. DiMarchi was responsible for all aspects of the geology at this underground mine. This included developing all geologic SOP's, development and maintenance of 3-D geologic and grade block models, ore reserve estimation, production forecasting, mill/mine production reconciliations, waste rock management, underground mapping and ore control. Mr. DiMarchi developed an innovative waste rock characterization and segregation plan that was the first in Alaska to incorporate mine-site XRF instrumentation for real-time quantitative PAG/NAG determination. This approach is now used at other Alaska mines. Mr. DiMarchi is an expert computer modeler using GEMS 3-D software. He collaborated with Pangeos software developers and the Department of Computational Sciences at the University of Alberta-Edmonton to develop Windows-interfaced software to perform conditional simulation to predict a probabilistic grade block model that was incorporated into mine planning to manage production/cash flow risks related to gold grade uncertainty. The use of conditional simulation in resource estimation and mine planning was another first for an Alaskan mine. Mr. DiMarchi also developed a genetic model for the Pogo gold deposit that was used successfully to explore for additional ore reserves. In addition he was a member of the mine's underground rescue team. (1997 to 2007)

Prefeasibility and Feasibility Studies

Vinasale Mountain and Pogo Gold Projects, Alaska. Contributor to the prefeasibility studies for both the Pogo project and the Vinasale Mountain project, and the feasibility study for the Pogo project. Participation included refining geologic models, ore reserves, mine plans (open pit and u/g), transportation options (river barge/fly-in and road), process options (flotation, cyanidation, bio-oxidation and POX) and remote mine-site communications (Satellite VOIP, Microwave). (1995, 2000 to 2004)

Consulting

Core Geoscience LLC, Alaska and Canada. Owner/Principal of Core Geoscience. Provided senior technical consulting and management of mining and exploration projects in Alaska and Canada. Projects included, Ajax molybdenum (British Columbia/Tenajon Resources), Baird Mountains zinc (Alaska/Nova Gold), Niblack VMS (Alaska/Niblack Mining), Icon uranium (Quebec/Icon Industries), Fairbanks District gold (Alaska/International Tower Hill Mines), Southeast Alaska recon (Hecla Mining), Alaska recon (Alaska/Kiska Minerals), Ogilvie zinc (Yukon/Full Metal Minerals), Alaska Peninsula gold (Alaska Earth Sciences). (2007 to 2008)

PUBLICATIONS

Managing Mine Wastes at Alaska's Large Mines, Proceedings of the 14th International Conference on Tailings and Mine Waste, Vail Colorado 2010, 2011.

Geostatistical Determination of Production Uncertainty: Application to Pogo Gold Deposit, Abstracts, Canadian Institute of Mining Conference, Edmonton, Alberta. 2004.

Structural setting, style and timing of vein-hosted gold mineralization at the Pogo deposit, east central Alaska, Mineralium Deposita, Issue: Vol 38, 2003.

Plutonic Related Gold Deposits of Interior Alaska, Economic Geology Monograph 9: Mineral Deposits of Alaska, Issue: Monograph 9, 1997.

Geology, Alteration, and Mineralization of the Vinasale Mountain Gold Deposit, West-Central Alaska, Professional Report 113, Alaska Department of Geological and Geophysical Surveys, 1993.

RICHARD P. DOMBROUSKI, PE, PG

Engineering Geologist

EDUCATION

MS, Engineering Geology, Purdue University, 1985
BS, Engineering Geology, Purdue University, 1983

REGISTRATIONS/CERTIFICATIONS

Professional Engineer: Idaho (#9356, 1999), Montana (#12859PE, 1998), Utah (#5661156-2202, 2004), Washington (#43059, 2006)
Professional Geologist: Wyoming (#PG-329, 1992)

EXPERIENCE SUMMARY

Mr. Dombrouski is a senior geotechnical engineer and engineering geologist for Tetra Tech with 28 years of practice experience working both internationally and throughout the Rocky Mountain States including Montana. He is the Missoula office manager with diverse geotechnical and construction management experience on a wide variety of geotechnical engineering, construction materials testing (CMT), and environmental projects. Responsibilities include senior project and/or program management, personnel scheduling, supervising drilling operations, planning and supervising geotechnical investigations, analyzing field and laboratory data, monitoring construction, and preparing geotechnical design reports.

SELECT PROJECT EXPERIENCE

Mine Geotechnical Engineering

Formosa Mine Adit #1 Reopening, Douglas County Arizona. Tetra Tech is providing assistance to the USACE to ascertain the methods and estimate costs to reopen the Formosa Mine Adit to assess the underground workings for a closure study. The principle objective is to evaluate the suitability for closure using hydraulic adit plugs and/or pressure grouting of water bearing fault/fracture systems in order to stem outflow of contaminated, metal-bearing, low pH groundwater from the mine adit. As project Geotechnical Engineer, will perform an underground assessment of the rock quality, geomechanics and support characteristics to investigate reopening the adit and the position and suitability of hydraulic plugs to close and plug the adit at the Formosa Mine.

World's Fair Mine Adit Closure, Arizona. As project Geotechnical Engineer, performed an underground assessment of the rock quality, geomechanics and support characteristics to investigate the position and suitability of two hydraulic plugs to close and plug the adit at the World's Fair Mine. The assessment was favorable and Tetra Tech provided design specifications and drawings for the closure, followed by supervision of the closure using two underground, water-tight, hydraulic adit plugs combined with grouting to stem the contaminated water flow to Alum Gulch.

Weber Mine Open Pit Repository Field Investigation and Design Evaluation, Bonner County, Idaho. Project Geotechnical Engineer responsible for a field investigation and engineering design evaluation to determine if the Weber Mine Pit was a suitable repository to dispose of mine wastes within the Gold Creek drainage. The evaluation focused on several key factors including geologic mapping, potential rock slope stability of the existing highway, hydrogeologic characteristics of the groundwater flow regime, potential leachate generation, and source of construction materials. Mapped dimensions and geometries of the bedrock units and bedrock discontinuities in the open pit highway. Statistically contoured the data, identified significant structural systems in the rock mass and observed typical modes of slope development. Performed rock slope stability analysis using stereographic projection and deterministic block limit equilibrium analysis.

Coal Mines and Heavy Industry Facilities Geotechnical Investigations, Montana and Wyoming. As Geotechnical Engineer, analyzed earth pressures on buried structures and overturning or uplift resistance for structures subject to multiple loading conditions. Made recommendations for effective use of soils and aggregates for foundation systems, railroad construction, and roadways. Projects include hard and soft rock ore storage silos, mill facilities, hoist houses, rail load-out facilities and overland conveyor systems, electrical generation plants, petroleum refinery process equipment, coker units, product storage tanks, and grain storage facilities.

Heap Leach Gold Mines Construction Quality Assurance Oversight, Black Hills, South Dakota. As Project Manager, provided quality assurance inspection and testing for heap leach gold mining operations. This included inspection and testing of 4M cubic yards of soil and rock fills, placement and construction of 15 acres of soil liners in process ponds and leach pads, aggregate production quality control, asphaltic concrete paving, and testing of Portland cement concrete. Performed geotechnical investigations and prepared stability analysis design reports for mine waste dumps for Brohm Mining Company, Wharf Resources.

Slope Stability and Additional Geotechnical Engineering

Yellowstone Pipeline Slide MM 306.2, North Side of Interstate 90, 20 miles Southeast of Missoula, Montana. Project Manager responsible for geotechnical investigation, design consultation, 24-hour monitoring of active landslide and pipeline, and construction oversight during slope stabilization of this pipeline slide mitigation project along Interstate 90. Slope stabilization design consisted of the installation of ten 10 foot by 10 foot square reinforced concrete blocks, in two horizontal rows of five blocks each, installed immediately above one-another. Each of the concrete blocks was anchored into competent argillite bedrock using a bundle of nine post-tensioned, cement grouted, high-strength cable strands. The placement and final selection of the anchor block locations optimized ground support adjacent to and beneath the pipeline while mitigating site disturbance and access requirements for the construction equipment. A slope inclinometer was also installed through the stabilized portion of the slide to a depth of 50 feet below the existing surface to detect and monitor for potential future movement of the slide near the pipeline.

Kearl Module Transportation Project, Two Medicine Slide Area, Pondera County, Montana. Project Manager responsible for a geotechnical investigation for the Two Medicine Slide Area along Secondary Highway 358, north of Valier, Montana. The purpose of the investigation was to perform slope stability analyses to evaluate the impact of the anticipated equipment module traffic loads on slope stability. The slope had previously failed three times and temporary stabilization efforts by MDT proved ineffective. Developed a model of the existing slope profile and subsurface geology to identify failure modes, model sensitivity, and evaluate the slope factor of safety with the proposed traffic loads. Included incorporating the proposed slope reconstruction designed by MDT to be completed in the near future. Preparation of geotechnical report including discussion of slope stability analyses, impacts of proposed traffic loads, and proposed slope reconstruction.

Geotechnical Engineering Studies, Keystone XL Pipeline, TransCanada/Trow Engineering, Alberta, Canada, to Port Arthur, Texas. As Project Manager and Senior Geotechnical Engineer, led the Tetra Tech team in providing geotechnical support services on this 30-inch crude oil pipeline. Services included performing subsurface exploration to provide data for the designs of horizontal directional drill (HDD) crossings and pump stations along the pipe line route. Samples collected were tested in Tetra Tech's laboratory to determine physical and engineering characteristics of the on-site soils. Provided reports summarizing the field data and presenting conclusions and general recommendations for soil and rock strength characteristics and engineering properties based upon laboratory analysis and subsurface conditions encountered. Also provided thermal characteristics of the soil, seismic design criteria, and foundation design recommendations for the pump stations.

Highway Development Engineering Services, Montana Department of Transportation. Responsible for managing the indefinite quantities design services contract with Montana Department of Transportation (MDT) Consultant Design and Geotechnical Sections throughout the state of Montana. Responsible for geotechnical and materials testing services offered to respective consultant design teams for comprehensive roadway design and by direct contract with the MDT Geotechnical Section.

Philippines Secondary National Road Development Project, Wright-Taft-Borongan-Guiuan Road, Samar & Eastern Samar, Millennium Challenge Corporation, U.S. Dept of State. The project includes the completion of the Environmental and Social Impact Assessment, Resettlement Action Planning, Engineering Design and bid documents for the rehabilitation of the Wright-Taft-Borongan-Guiuan roadway project. The total length of road is 81.5 km. Mr. Dombrouski is the Senior Geotechnical Engineer, technical discipline lead for all geotechnical engineering design aspects of the roadway and bridge design/rehabilitation.

DAVE S. HALLMAN, PE, PG

Principal Geotechnical Engineer

TETRA TECH

EDUCATION

BS, Geological Engineering, Colorado School of Mines, 1983

REGISTRATIONS/CERTIFICATIONS

Professional Engineer: Alaska (#CE-8086, 1990), Colorado (#26076, 1989), Idaho (#8350, 1996), Missouri (#E-26685, 1994), Texas (#90421, 2002), Wyoming (#PE-9495, 2002)
Professional Geologist: Wyoming (#PG-3536, 2004)

EXPERIENCE SUMMARY

Mr. Hallman has 27 years of experience specializing in geotechnical engineering and construction on a variety of mining and civil engineering projects throughout the world. His technical expertise includes static and dynamic stability of embankments and natural slopes, landslide evaluation, rock slope stability, seismic risk assessments, liquefaction evaluations, dynamic deformation analyses, liner and seepage cutoff system design and evaluation, tailings and water dam design and construction, and design and construction of heap leach and landfill facilities.

SELECT PROJECT EXPERIENCE

Slope Stability

Minas Santa Rosa Rock Slope Stability Evaluation, Central, Panama. As Geotechnical Engineer, conducted an evaluation of rock slope stability for expansion of the open pit mining operations. Evaluated extensively weathered rock and laterite soils in the upper portions of the pit walls and existing slope failures. Evaluated stability of waste rock dumps, which exhibited signs of distress and movement, and the potential impact of heap leach facilities. (1998)

Florida Canyon Mine Rock Slope Stability Evaluation, Winnemucca, Nevada. Staff Engineer responsible for evaluating rock slope stability at this large operating open pit gold mine to determine safe slope angles for continued pit expansion. Analyses included assessment of weak, shattered rock masses. (1990)

Civil Infrastructure

Geotechnical Engineering, Garfield County Regional Airport, Rifle, Colorado. Project manager responsible for geotechnical investigations relating to optimization studies, design and construction of runway upgrades. The runway site is situated atop a 100- to 150-foot-high mesa and expansion necessitated extending the runway aprons beyond the current edges of the mesa. Severe geometric constraints associated with land ownership, county roads, irrigation canal, and a stream channel precluded the use of conventional earthfill for extending the runway. Project included a comprehensive cost-benefit analysis of options for extending the runway and determined that through innovative use of soil-cement to produce steepened fills from local on site borrow materials resulted in considerable cost savings. Optimized soil-cement mix design and provided construction specifications, details, and constructability and cost assessments. (2005 to 2008)

Dams / Reservoirs / Levees

Cottonwood Pit Lining and Post-Closure Land Use Designs, Weld County, Colorado. Project Manager responsible for directing in situ testing program to characterize local site conditions, laboratory testing, and two-dimensional finite element seepage analyses to evaluate effectiveness of seepage cutoff measures, including slurry walls and soil liners. Utilized these evaluations to develop conceptual designs for pit lining and alternatives cost estimates for economic comparison and mine planning for post-closure land use as a water storage reservoir and the ability to meet leakage/containment criteria. Evaluated alternative mine plans and reclamation options to enhance reservoir storage. (2002)

Howe Pit Reservoir A Clay Liner System Design, Henderson, Colorado. Project Manager responsible for designing a clay liner system for conversion of an aggregate quarry pit to water storage reservoir. Prepared design documents and served as the Engineer of Record for liner construction. (2001 to 2006)

Batu Hijau Water Storage Dam Geotechnical Design,, Sumbawa, Indonesia. Senior Geotechnical Engineer responsible for the geotechnical design of a 41-meter high-zoned earth and rock fill water storage dam as part of the overall project water management system. Foundation conditions included thick deposits of residual soils. Prepared design and construction documents and coordinated multidisciplinary engineering analyses produced by professional staff. (2000)

Dillon Dam Toe Drain System Design, Dillon, Colorado. As Staff Engineer, designed toe drain system to alleviate and capture excessive seepage flows from this 231-foot high earthfill embankment dam which is the largest water storage facility in the water supply system for Denver metro area. This dam has a crest length of 5,888 feet (1.7 kilometer), base width of 1,100 feet (335.3 meters), crest width of 32 feet (4.72 meters) and provides storage for 254,036 acre-feet (313,000,000 meters3) of water. (1983)

Geologic Studies / Hazard Investigations

Cañariaco Mine Seismic Hazard Analysis, Central, Peru. Technical specialist responsible for reviewing seismic hazards and developing seismic design parameters for design of the tailings dam at this proposed copper mine. (2008)

Mine Subsidence and Geologic Hazards Investigation, Minturn, Colorado. Principal engineer responsible for project management and coordination of multi-disciplinary technical teams, and geologic and mine subsidence hazards evaluation for the proposed Battle Mountain private ski/golf resort development between Vail and Beaver Creek. The Battle Mountain development area is partially underlain by the historic Eagle Mine operated primarily by the New Jersey Zinc Company from late 1870s until 1984. The area proposed for development includes a large sinkhole located above the old mine workings and possible landslide features associated with the steep rugged terrain. (2008 to Present)

Seismic Hazard Assessment/Mitigation, Eldorado, El Salvador. As Technical Specialist, conducted a detailed assessment of seismic hazards and developed design ground motions for this proposed project. The project is located in an extremely active seismic environment and potentially very high ground motions. (2004)

Sunrise Mine Subsidence Potential/Reclamation Measure Evaluations, Guernsey, Wyoming. Technical Specialist responsible for evaluation of subsidence potential and reclamation measures of large subsidence features associated with block caving practices at this historic iron mine. Assessed landslide-induced wave action associated with potential failure of a large open pit filled with water. Developed automated slope monitoring system to provide warning of impending failure(s) to protect potential downstream inundation zones. (2003 to 2005)

Crystal Cave Geotechnical Evaluation, Jefferson County, Colorado. Senior Geotechnical Engineer responsible for project management and geotechnical evaluation of a natural cave exposed during aggregate quarry development. Provided recommendations to address public safety and liability concerns associated with reclamation and conversion of the quarry land to open space with attendant public access. (2001)

Seismic Hazard Assessment/Mitigation, El Mochito, Honduras. As Senior Geotechnical Engineer, evaluated seismic hazards and developed design ground motions for this copper-zinc mine using current state-of-the-art approaches to update previous studies. (2001 to 2004)

Tumiri Norte Project Seismic Hazard Evaluations, Southern, Peru. Senior Geotechnical Engineer responsible for probabilistic and deterministic seismic hazard evaluations for mine tailings disposal facilities in southwestern Peru. Performed detailed review of historic seismicity and regional seismotectonics. Presented recommendations for seismic design parameters and methodology to be adopted for engineering analyses. (2000)

Cerro Mojon Project Landslide Back Analysis, La Libertad, Nicaragua. As Geotechnical Engineer, performed back analysis of an active landslide in residual laterite soils. Evaluated effectiveness of potential remedial measures to control ground movements and reconfiguration of the project facilities. (1996)

Thunder Mountain Project Geotechnical Engineering Design, Central, Idaho. Project Manager responsible for project management, engineering design, and technical direction for a proposed mining project in central Idaho. Project includes facility development within the limits of a large historic landslide developed in residual soils and weathered tuffaceous bedrock of the Challis Formation. Geotechnical design included detailed back analysis of the landslide and comparison to conditions elsewhere at the site and proposed project development plans. Analyses included assessment of access road and blasting operation vibrations on landslide stability and two-dimensional finite difference consolidation analyses to evaluate development and dissipation of excess pore pressures in the foundation materials during and following construction of the project facilities. (1994 to 1996)

Trans Alaska Gas System Foundation/Rock Slope Stability Evaluation, Valdez, Alaska. Field Manager for geotechnical evaluation of the foundation and rock slope stability for the marine terminal and natural gas liquefaction facilities at Port Valdez and rock slope evaluation for the Keystone Canyon segment of the pipeline route. Involved helicopter-supported, oriented core drilling, instrumentation, and detailed outcrop mapping. Duties included landslide hazard mapping and preparation of site conditions and engineering recommendations reports. (1990)

PUBLICATIONS

Non-linear dynamic analysis of heap leach pad under high phreatic levels., 2006.

Mine tailings deposition practices, liquefaction potential, and stability implications., 1995.

Geosynthetics in heap-leach applications., Geotechnical Fabrics Report, Issue: 9, 8, 1991.

Engineering Geophysics – Mine Subsidence Study, December, 2010.

Garfield County Regional Airport Runway Upgrade Project, Geo-Velopment, The Role of Geological and Geotechnical Engineering in New and Redevelopment Projects, Issue: No. 5, 2008.

Rock Bursts or Earthquakes? A Tale of Two Sources, (author), Dam Safety 2009, Sept 27-Oct 1, 2009.

MACKENZIE B. FERNALD

Geological Engineer

TETRA TECH

EDUCATION

B.Sc., Geological Engineering, Colorado School of Mines, 2012

PROJECT EXPERIENCE

Mine Permitting / Development

Mt. Todd, Vista Gold Corp., Northern Territory, Australia. Evaluated geological drill logs to be used for site-wide geotechnical assessment. Assisted in the compilation of geological data through the use of gINT to assist in the geotechnical study for the mine.

Mineral Economics

Sunshine Mine Mineral Resource, Sunshine Silver Mine, Sunshine Silver Mines Corporation, Idaho. Assisting in a mineral resource estimate through the use of AutoCAD Civil 3D and Micromine computer modeling programs (2012)

Mineral Resource Inventory

Los Gatos Resource Studies. Assisted in the resource study for the Los Gatos project through the use of Micromine. (2012)

Research

Confidential Client, Multiple prospective locations. Assisted senior level staff in the research and development of reviews for future mining prospects. This consisted of research through various mining websites as well as company websites to compile all existing data for each mine from geologic settings to operation methods to yearly revenue

PROFESSIONAL EMPLOYMENT HISTORY

Intern, Tetra Tech, 2011 to 2012

DAVID M. RICHERS, PH.D.

Senior Geologist/Geochemist

TETRA TECH

EDUCATION

Ph.D., Geology/Geochemistry, University of Kentucky, 1980
M.S., Geology/Geochemistry, University of Kentucky, 1977
B.S., Geology, Pennsylvania State University, 1974

EXPERIENCE SUMMARY

Dr. Richers has over 35 years of experience as a geologist and geochemist where he has performed geochemical site characterization services among other duties. He has worked on mining projects in the US, Australia, and Canada including both surface and underground operations. Dr. Richers routinely participates in geochemical studies and programs aimed at protecting the environment including quantification of geochemical processes for engineering design, closure planning and impact analysis. His background includes extensive work with acid rock drainage and metal leaching (ARD/ML) and the associated fate and transport. His added expertise in geologic computer mapping and 3D GIS brings an added dimension to the Project Team.

RECENT PROJECT EXPERIENCE

McArthur River Expansion – Water Rock Facilities Characterization. Cameco Corp., Saskatchewan, Canada. Project manager and geochemist overseeing geochemical characterization of the materials to be placed in the WRF in the McArthur River Underground Expansion Project. (2011 to Present)

Key Lake Project, Sand and Water Quality Geochemical Characterization, Cameco Corp., Saskatchean, Canada. Supporting project geochemist assisting in geochemical evaluation and characterization of sands to be stored in remnant lakes. (2011)

Kintyre Pit Lake Geochemical Characterization, Cameco Corp., Western Australia. Geochemical modeling of probable pit lake at the Kintyre Uranium project in W.A. Characterizing wall rock, ground water interaction in 3D space and temporally to predict water quality in ensuing pit lake. (2011 to Present)

Kintyre Uranium Tailings Project, Cameco Corp., Western Australia. Senior geochemist responsible mapping and characterizing waste rock/ore materials and establishing their affinity for producing ARD/ML. Duties include selecting and evaluating kinetic test samples and mapping geology to the ultimate pit surface (UPS) for possible future predictive geochemical pit lake modeling. This includes performing a feasibility-level waste rock and tailings characterization program to assess ARD/ML potential. (2011 to Present)

Pumpkin Hollow DFS Project, Nevada Copper, Nevada. Senior geochemist providing waste rock characterization for proposed North and South pits Statistical evaluation of metals and NNP to select kinetic test samples for permitting. In addition, generated and derived 3D geologic/Geochemical model as well as calculating relative proportions of various lithologies on UPS surface to assist in predictive pit lake chemical models for various mine phase development. (2011 to Present)

Solomon Iron Mine Geochemical Characterization, Fortesque Corp, Western Australia. Senior geochemist providing waste rock, tailings, and ore characterization for various phases of mine development for the King and Firetail Projects. (2011 to Present)

Cloud Break Iron Mine Geochemical Characterization, Fortesque Corp, Western Australia. Senior geochemist providing waste rock, tailings, and sitewide geochemical characterization. Plan and develop sampling strategy of existing waste rock dumps for closure plane. (2011 to Present)

NEO Iron Mine Geochemical Characterization, Fortesque Corp, Western Australia. Senior geochemist providing overall geochemical characterization for new proposed iron mine for use in closure plan. (2011 to Present)

Greater Gold Quarry Project, Newmont Corp., Nevada. Senior geochemist at Geomega Inc. providing waste rock characterization for proposed expansion of existing pit and predictive pit lake modeling. Plans involved the generation of over a billon tones of additional waste rock, some with extreme PAG potential. Statistical evaluation of metals and NNP to select kinetic test samples for permitting. In addition, generated and derived 3D geologic/Geochemical model as well as calculating relative proportions of various lithologies on UPS surface to assist in predictive pit lake chemical models for various mine phase development. (2010 to 2011)

Lone Tree Project, Newmont Corp., Nevada. Senior geochemist at Geomega, Inc. providing 3D geologic/geochemical depiction of UPS. Duties also included building a web-based PHREEQC interface program integrated into a POSTGRES relational database to evaluate lime control to mitigate ARD issues with the existing pit lake. (2008 to 2011)

Cortez Evapotranspiration Study, Nevada. Senior GIS consultant responsible for creating 20 year plus vegetative stress indices coverage to evaluate possible effects that mining and development had on the regional groundwater budget. This was a highly intensive remote sensing/GIS-centric project requiring the development of customized software to assist in analyzing, manipulating, and reviewing. Automated vegetation identification and stress levels provided a means to track both long term and short term variations in species health and density. (2009 to 2010)

Bald Mountain Project, Barrick, Nevada. Senior geochemist at Geomega, Inc. Merged geologic block model and borehole geochemistry to calculate potential waste rock ARD/ML materials for future pit development in the Giga Pit, as well as subordinate numerous other developmental pits in Nevada. Mapped geology and geochemistry on the UPS in 3D for use in future pit lake models. (2010 to 2011)

Ruth Pit Project, Quadra, Nevada. Senior geochemist at Geomega, Inc. Provided geologic and geochemical oversight for kinetic test sample selection and built the 3D UPS model for future pit lake modeling effort. (2009)

PROFESSIONAL AFFILIATIONS

American Association Petroleum Geologists/ Prof. Geologist Cert. # 2913.
Association Petroleum Geochemical Explorationists, Editor 1990,92,98,99.

PUBLICATIONS

Richers, D.M., Richardson, C.D., Edington, D., Roemer, G., and Bijold, B., Pit lake Modelling – A Total System Approach, 6.p, presented at IMWA, Oct 1, 2012, Bunbury, WA

Richers, D.M., Richardson, C.D., and Moran, P., 2012, Impact of groundwater chemistry on wall rock chemical leaching and pit lake character, 9 p., (Presented at the SME Annual Meeting, Feb 21, 2012, Seattle, WA).

Moran, P., and **Richers, D.M.**, 2011, Mapping wall rock chemistry on the ultimate pit surface of an open pit mine using GIS, presented at Tailings and Waste Water Conference, Vancouver, BC, November 9, 2011.

Jones, V.T., Matthews, M.D., and **Richers, D.M.**, 2000, Light hydrocarbons for petroleum and gas prospecting, Chapter 5, in Handbook of Exploration Geochemistry: Gas Geochemistry, Dr. Martin Hale, Editor, Elsevier Science Publishers, The Netherlands, pp. 133 - 212.

Richers, D. M., 1998, An Old Friend to Oil and Gas Exploration; Imaging Notes, 9/10, 1998, v. 13, #2.

Richers, D.M., and Wyatt, D.E., 1998, Establishment of regional soil gas background values to support waste site screening investigations; in Proceedings of the 1st Inter. Conf. on Site Characterization, Atlanta, GA, Apr., 1998., pp. 713 - 718.

Wyatt, D.E., **Richers, D.M.**, and Cumbest, R.J, 1998, Regional shallow soil gas hydrocarbon results in the southeastern Atlantic Plain; A.A.P.G. - D.E.G. Environmental Geosciences Bull., V 4, #4.

Richers, D.M., and Wyatt, D.E., 1996, Evidence of thermogenic hydrocarbons in central Savannah River area, S. Carolina and Georgia: Presented at AAPG Eastern Section Annual Meeting, Charleston, W. Va.

Cowen, D.J., Cundall., A.J., Heimann, P.W., and **Richers, D.M.**, 1996, Maintaining metadata through a common WEB and GIS interface; Proceedings GIS/LIS 96, pp. 1063-1070, Denver, CO.

Wyatt, D.E., **Richers, D.M.**, and Pirkle, R.J., 1995, Barometric pumping effects on soil gas studies for geologic and environmental characterization; Environmental Geology, Springer-Verlaag, v. 25, pp. 243-250.

Richers, D.M., Maxwell, L.E., and Price, P.E., 1994, A pilot soil gas study of the Zarzis Peninsula, Tunisia; A.P.G.E. Bull., v. 10, #1, pp. 61-75.

Robinson, J.E., **Richers, D.M.**, and Gaylord, M., 1993, A virtual reality approach to GIS visualization; The Canadian Conf. on GIS, Ottawa, March 23-25, 1993,pp. 784-790.

Wyatt, D.E., Price, V, Looney, B.B., **Richers, D.M.**, and Pirkle, R.J, 1993, Soil gas waste site screening at the Savannah River Site; in Proceedings of the Environmental Restoration Conference, U.S. Dept. of Energy, Oct. 24-28, 1993, Augusta, GA., v. 2, pp 853-858.

Robinson, J.E. and **Richers, D.M.**, 1992, Geological Applications of Computerized Virtual Reality; AAPG, V. 76,#13, p. 110.

Richers, D.M., Landrum, J.H., and Li, B., 1992, A soil gas geochemical study of Railroad Valley, Nevada; A.P.G.E. Bull. V. 7, #1, PP.60-87.

Richers, D.M., and Maxwell, L.E., 1991, Application and theory of soil gas geochemistry in petroleum exploration, Chapter 15 in, Source and Migration Processes and Evaluation Techniques, R.K. Merril, Editor, A.A.P.G., Tulsa, OK., pp. 141-158.

Richers, D.M., Jones, V.T., Matthews, M.D., Maciolek, J., Pirkle, R.J., and Sidel, W.C., 1986, A landsat-soil gas geochemical study of the Patrick Draw area, Sweetwater county Wyoming - 1983 survey; A.A.P.G. Bull. V 70,#7, pp. 869-887.

Richers, D.M., 1986, The joint NASA/GEOSAT test case report; Abrams, Conel, and Lang, Editors, A.A.P.G., Tulsa, OK.

Richers, D.M., and Weatherby, C., 1985, A continued study of the Patrick Draw GEOSAT test site, Wyoming; Proceedings of the 4th Thematic Mapper Conf., ERIM, San Francisco, CA., pp. 723-733.

Sidel, W.C., and **Richers, D.M.**, 1985, A geochemical reconnaissance of Cretaceous inliers in north-central Oregon; A.A.P.G. Bull., v. 69, #3, pp. 412-421.

Richers, D.M., Reed, R.J., Horstman, K.C., Baker, R., Lundell, L., and Marrs,R., 1982, A landsat-soil gas geochemical survey of the Patrick Draw oil field, Sweetwater county, Wyoming; A.A.P.G. Bull., v. 66, #7, pp.903-922.

Richers, D.M., 1981, Geochemical survey of the lower Pennsylvanian Corbin Sandstone outcrop belt in eastern Kentucky; A.A.P.G. Bull., v. 9, pp. 1551-1567.

Richers, D.M., 1977, The geochemistry of the Stillwater Igneous Complex, MT; unpublished M.S. Thesis, University of Kentucky, Lexington, KY, 108pp.

DOC RICHARDSON

Geochemist

TETRA TECH

EDUCATION

PhD, Geochemistry, University of Montana-Missoula, 2009
MS, Geochemistry, Aberdeen University, 2003
B.Sc., Geology, University of Colorado, 2001

EXPERIENCE SUMMARY

C. Doc Richardson has several years of professional practice conducting water/soil testing, laboratory analysis, and computer/data interpretation related to a wide range of environmental and mining projects. He has experience in implementing surface and subsurface geochemical studies with an emphasis on computer modeling. He also has a strong background in fate and transport of metals in aqueous systems.

PROJECT EXPERIENCE

Geochemical Evaluation

Cloudbreak Iron Ore Mine, Western Australia. Organized onsite waste rock characterization and site wide geochemical characterization and geochemical predictive modeling. Plan and develop sampling strategy of existing waste rock dumps for closure plan. (2012)

Kurisokova Uranium Project. Project geochemist responsible for characterizing representative water quality conditions of mine, quarry, and tailings that will be a produced during development and operation of this potential mine. This includes static analytical methods to evaluate the potential for acid formation and short-term and long-term release of solutes into the watershed. (2011)

Pumpkin Hollow Copper Project, Nevada, Nevada Copper. Project geochemist developing a predictive pit lake model for the proposed north and south pits. Responsibilities include supporting the development of a 3-dimensional geologic/geochemical model to assist in calculating the relative geological unit proportions on the ultimate pit surface. In addition, duties include providing statistical evaluation of metal and acid generation potential to select kinetic and static test samples in the tailings and cemented paste backfill geochemical characterization program.

Awak Mas Gold Project, Indonesia. Project Geochemist to characterize and predict the affinity of acid generation in waste rock samples and tailings material. Responsible for waste rock management, predictive modeling of potential waste rock dumps and developing long-term source term for chemical constituent release.

Geochemical Modeling

Nyidinghu Iron Ore Project, Western Australia, FMG. Project geochemist responsible for developing a predictive pit lake model for closure planning. This includes kinetic test samples to develop time-dependent release of chemical constituents that affect the aqueous chemical character. Additional responsibilities include developing a waste rock management plan, along with evaluating and reviewing the current geochemical characterization program. (2012)

Goldsworthy Legacy Mine, Western Australia, BHP. Lead geochemist responsible for field oversite, laboratory analysis, and geochemical predictive modeling of AMD generating waste rock dumps. Plan and develop a remediation strategy to mitigate acid generation, along with developing a groundwater monitoring program to attest the potential impact of AMD on aquifers. (2012)

Kintyre Uranium Project, Western Australia. Duties include developing a pit lake predictive model. This includes evaluating kinetic test samples to predict time-dependent release of chemical constituents that affect the pit lake chemical character, along with using GIS-based software to map the geologic units on the ultimate pit surface. Additional responsibilities include assisting in the characterization of waste rock material and determining their affinity for producing ARD/ML. (2012)

Mt. Todd Gold Project. Project geochemist responsible for assisting in constructing a site-wide water quality/water balance for future mine phases and closure planning. Responsibilities include developing a hydrogeochemical predictive model that utilizes both kinetic laboratory test data and current minesite data. These predictive models are extrapolated into a cumulative site-wide water quality/water balance model through the life of mine. (2011)

MacArthur River Uranium Expansion, Canada. Project Geochemist assisting in the characterization of waste rock materials and develop a geochemical model of waste rock seepage.

PROFESSIONAL AFFILIATIONS

American Geophysical Union, Member, 2008
Society for Mining, Metallurgy and Exploration, Member, 2011

PUBLICATIONS

Influence of Groundwater Chemistry on Wall Rock Chemical Leaching and Pit Lake Character, (author), SME Transactions, Issue: in review

Secondary Sulfate Mineralization and Basaltic Chemistry of Craters of the Moon National Monument, Idaho, (author), Planetary and Space Science, 2012.

Biological Activity in the Formation of Secondary Minerals in a Basaltic Environment, (author), International Journal of Astrobiology, Issue: in review

Direct Detection of Aromatic Amino Acids with Thenardite: Implications for the Search for Life on Mars and Europa, (author), International Journal of Astrobiology, Issue: 8, 2009.

The Stellar Stew: Distribution of Extraterrestrial Organics in the Universe." In Astrobiology: From Simple Molecules to Primitive Life, (co-author), American Scientific Publishers, 2009.

Exploring Biosignatures Associated with Thenardite by Geomatrix-Assisted Laser Desorption Ionization Fourier transform Ion Cyclotron Resonance Mass Spectrometry (GALDI-FTICR-MS), (author), Geomicrobiology, Issue: 25, 2008.

KEITH S. THOMPSON, CPG, PG

Senior Hydrogeologist

TETRA TECH

EDUCATION

MS, Hydrogeology, University of Wyoming, 1979
BS, Geology, Youngstown State University, 1975

REGISTRATIONS/CERTIFICATIONS

Certified Professional Geologist: American Institute of Professional Geologists (#6005, 1983)
Professional Geologist: California (#5572, 1993), Idaho (#726, 1991), Nebraska (#PG-0293, 2005), Utah (#5258797-2250, 2003), Wyoming (#PG-2454, 1993)

EXPERIENCE SUMMARY

Mr. Thompson has 33 years of experience with hydrogeologic, water resources and environmental assessment and remediation projects for the mining, oil, gas and chemical industries, governmental entities and private parties. He specializes in resource characterization, impact assessment and remediation, water-supply development, mining-related groundwater and surface water issues, and groundwater flow and transport modeling. During 20 years with Tetra Tech, he has held positions of senior scientist, senior project manager, environmental group manager and office manager, including an overseas office coordinating U.S. and local foreign professional and technical staff. He has managed hundreds of projects ranging from a few thousand to several million dollars and has supervised professional and technical staff on numerous long-term, multi-disciplinary projects.

PROJECT EXPERIENCE

Groundwater Modeling

Kintyre Mine Groundwater Flow and Particle-Tracking Models, Proposed Kintyre Uranium Mine, Cameco, Western Australia, Australia. As Senior Scientist, completed development of groundwater flow and particle-tracking models to assist with design of dewatering systems, predict post-mining water-level recovery and pit-lake development, and evaluate transport of potential seepage from a tailings storage facility at the site of a proposed open-pit uranium mine. (2012)

Dawn Millsite Groundwater Flow and Transport Model, Uranium Mill Site, Dawn Mining Company, Spokane, Washington. As Senior Scientist, refined an existing analytical model and developed a Monte Carlo version of a groundwater transport model to evaluate risk to human health and ecological receptors from contaminant concentrations in a stream receiving groundwater impacted by uranium mill tailings pond seepage. The modeling was in support of a petition for risk-based alternate concentration limits for cleanup of the facility and simulated subsurface transport and mixing of seepage from the tailings ponds and discharge of impacted groundwater to seeps and the stream under closure and failure scenarios. (2011 to 2012)

Rosemont Copper Mine Groundwater Flow and Transport Model, Rosemont Copper Mine, Rosemont Copper Company, Arizona. Developed input for the recharge and evapotranspiration components of a transient, 3-D groundwater flow model to simulate the effects of a proposed open-pit copper mine in southern Arizona. Evaluated and quantified natural recharge prior to mining, evaluated and quantified changes to recharge due to seepage from mine facilities and inhibition of recharge by other mine facilities. Developed particle-tracking model to evaluate post-mining transport of mine-related seepage. (2010)

Groundwater Flow Model for Tailings Pond Closure, Green River Basin, Wyoming. Project Manager/Principal Investigator, developed transient, three-dimensional groundwater flow model to simulate the effects of a soda ash plant tailings pond and groundwater pumpback systems for 30-year historical and 20-year future operating periods an The model incorporated transient changes to hydraulic conductivity and storativity from dissolution of fracture-filling gypsum by pond water seepage. (2008)

Surface Water and Groundwater Loading Model for Upper Blackfoot Mining Complex, Montana. As Senior Hydrogeologist, developed and applied model to quantify transport by surface water and groundwater of metals related to historical mining activities, assessed relative and absolute contributions of various source areas and evaluated potential routes of exposure. (2008)

Groundwater Flow and Transport Model for National Institutes of Health, Montana. As Senior Hydrogeologist, revised and updated finite-difference groundwater flow and chemical transport model for solvent contamination of shallow aquifer system at a landfill site. Assessed operation of remediation system and predicted cleanup times. (2006 to 2007)

Groundwater Flow and Transport Model, San Juan Basin, New Mexico. As Project Hydrogeologist, developed three-dimensional, transient groundwater flow and transport model of a 21,000-square mile geologic basin to simulate effects on and long-term recovery of regional groundwater system from dewatering related to 30 years of underground uranium mining. (2006)

Soda Ash Tailings Pond Embankment Dewatering System, Granger, Wyoming. Project Manager/Principal Investigator responsible for conducting hydrogeologic investigation and developing transient groundwater flow model for a tailings impoundment. Based on model results, developed conceptual and final design, plans and specifications for dewatering system for area downstream of impoundment. Developed design additions as requested by client during construction. (1996)

Conceptual Model for Classification of Groundwater Vulnerability, Wyoming. As Project Manager, developed initial system for state-wide classification of shallow aquifers according to their relative vulnerability to pollution and applied the system to classify the land areas of the state. The project involved developing a conceptual model of groundwater flow and pollution mechanisms based on surficial geology, aquifer lithology, recharge rates and other factors. (1988)

Surface Mine Hydrologic Studies and Modeling, Wyoming and Montana. As Project Hydrogeologist, provided hydrologic modeling and groundwater flow and transport models for surface mining operations. Developed and used two-and three-dimensional, numerical and analytical groundwater flow and transport models to predict water quantity and quality impacts from numerous coal and uranium mines in northeastern, central and southwestern Wyoming and southeastern Montana. (1978 to 1998)

Mine Hydrology

Dolet Hills Lignite Mine Dewatering System Design, Dolet Hills Lignite Mine, North American Coal Corporation, Louisiana. Designed hydrogeologic site investigation and developed a transient, 3-D groundwater flow model to design a dewatering system for expansion of an active lignite mine in northwestern Louisiana. The model simulated existing conditions, installation of a slurry wall system and design and optimization of a dewatering system as part of a design-build slurry wall and dewatering system project. Prepared specifications for construction and installation of dewatering wells and pumps. (2011)

Saddleback Hills Groundwater Flow Model, Saddleback Hills Coal Mine, Arch Coal, Hanna, Wyoming. Prepared groundwater portions of permit applications for a proposed underground coal mine near Hanna, Wyoming, including development of transient, 3-D groundwater flow model to simulate mine inflow and hydrologic effects of mine dewatering. (2010 to 2011)

Surface and Groundwater

Peabody Sage Creek Mine Groundwater Studies, Peabody Sage Creek Mine, Peabody, Hayden, Colorado. Prepared groundwater portions of permit applications and environmental assessment for a proposed underground coal mine, including development of an analytical groundwater flow model to predict mine inflow rates and hydrologic effects to groundwater and surface water. Subsequently revised the model and updated mine inflow and impacts predictions for revision of the mine plan. (2009 to 2012)

Travel Plaza Surface Drainage Projects, Wyoming. As Project Scientist, provided design modification and permitting assistance for stormwater drainage systems at truck stops. (1996 to 1999)

Wyoming State Penitentiary Surface Drainage Project, Rawlins, Wyoming. As Project Scientist, designed stormwater drainage system for state penitentiary. (1994)

PROFESSIONAL AFFILIATIONS
American Institute of Professional Geologists, Member, 1983
Association of Ground Water Scientists and Engineers, Member, 1980

PUBLICATIONS
Volcanoes in the Classroom – An Explosive Learning Experience., (co-author), Science and Children, Issue: 33 (6), 1996.

Groundwater and potential coal mining in the Bull Mountains, south central Montana, Montana Bureau of Mines and Geology Open-File Report MBMG 100, 1982.

Prediction of impacts on ground-water levels and ground-water quality caused by surface coal mining in the Young's Creek-Little Young's Creek-Squirrel Creek area, Big Horn County, Montana, Montana Department of State Lands, 1982.

Estimations of post-mining water quality of the Tongue River, Montana and Wyoming, Montana Bureau of Mines and Geology Hydrogeologic Map 5, 1982.

Hydrology of the lower Squirrel Creek drainage, southeastern Montana, with special reference to surface coal mining, Montana Bureau of Mines and Geology Open-File Report MBMG 84, 1981.

Prediction of water level declines in the Casper aquifer in the vicinity of Laramie, Wyoming, Wyoming Water Resources Research Institute, 1979.