

## Anglo Platinum, Mogalakwena

No. 44  
SRK Consulting's  
International  
Newsletter



The Mogalakwena platinum mine is located approximately 35km to the north west of the town of Mokopane in the Limpopo Province of South Africa and is the only open cast platinum mine within the Anglo American Group.

### **Pilot paste project**

This project involved establishing, commissioning and operating a pilot scale thickener, deposition flumes and evaporation paddocks. The aim of the test work was to characterise the tailings material in terms of rheology and geotechnical properties and to calculate the water consumption of the tailings material at different slurry densities.

The pilot plant was packed into a container and assembled on site along with the evaporation paddocks and deposition flumes. On-site testing included thickener optimisation and rheology testing along with evaporative drying tests. Samples were taken from the evaporation paddocks and tested off site to determine the moisture content with depth over time. Off-site testing included determining the thickener sizing and operating parameters along with geotechnical testing to determine the consolidation and strength characteristics.

# Anglo Platinum, Mogalakwena

(continued)

## Tailings dam project

This project involved the conversion of tailings dam No.2 from a conventional upstream spigot deposition type dam to a waste rock impoundment dam. Dam No.2 originally accommodated the production rate from the South concentrator. The modification was required to accommodate a higher rate of rise on the dam due to an increase in the production rate as a result of

the commissioning of the new North platinum concentrator. The new tailings dam for the new North concentrator was in the process of being constructed after a delay as a result of community and land access issues.

Prior to commencement of the impoundment construction activities, dam No.2 was decommissioned for a period of 6 months. Waste rock material was sourced from the open-pit operations and hauled from the pits to an intermediate stockpile close to dam No.2. In order to overcome access and maneuverability restrictions around tailings dam No.2, a smaller fleet of trucks and other equipment was used to construct the waste rock walls using the downstream wall-building technique. The waste rock walls were constructed in 2 x 6m lifts. A dry compacted tailings interface layer was constructed on the upstream of the waste rock wall to manage and control seepage. Tailings slurry deposition continues to be performed using "spigots".

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## JOHAN BOSHOFF

Johan Boshoff is a Principal Geotechnical Engineer with SRK's Johannesburg Office. His 16 years' experience started at Iscor Mining (now Kumba Iron Ore); he joined SRK in 1997. His expertise includes detailed design, monitoring and project management of tailings dams, mine residue stockpiles and waste disposal facilities. He is involved with paste and thickened tailings storage systems, trade-off studies and value engineering.



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Tailings storage facility rehabilitation project, northern Russia.

**SRK** has a strong track record in assisting clients in Russia and other CIS countries with developing Bankable Feasibility Studies and auditing existing and prospective tailings disposal facilities. A Bankable Feasibility Study refers to the design and costing of a project in accordance with standards accepted by the international financial community that meet both international and Russian engineering requirements.

Tailings storage facilities often represent the most significant environmental liability associated with mining operations. Mine waste materials must be transported and discharged safely into secure impoundments, which will last for an extended period after final mine closure.



Waste rock impoundment

## Challenges of tailings disposal in Russia and CIS countries



International best practice guidelines for tailings and waste management stipulate that storage facilities are designed, operated, closed and rehabilitated to perform in accordance with strict technical and environmental criteria. SRK has developed a framework of management principles and checklists for implementing these activities throughout this entire mine life cycle.

SRK has been responsible for work on numerous gold, platinum, uranium, copper, iron, and coal tailings operations across Russia and other CIS countries. These have involved complex geotechnical, environmental and permitting issues that had to be overcome to meet international standards as well as Russian

requirements. Working closely with the local design institutes SRK has progressed towards synergy in meshing its engineering approach with CIS Best Practice Guidelines. During the course of this work, SRK has developed strong relationships with a number of related organisations and successfully implemented innovative designs on a number of flagship projects.

These have involved complex geotechnical, environmental and permitting issues that had to be overcome to meet both Russian TEO Konditsy and international Feasibility Study standards.

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### KRIS CZAJEWSKI

Kris Czajewski, P.Eng. is a Principal Geotechnical Tailings Engineer at SRK (UK). He worked for 20 years in Canada on a variety of tailings and geotechnical projects before moving to the UK in 2007. At SRK, Kris has been responsible for managing the tasks relating to due diligence and feasibility studies of tailings facilities in Europe, South America, Asia and Africa. In the course of his work, he uses his experience gained in world-class projects, with emphasis on the feasibility and constructability of tailings facilities.



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### JAMIE SPIERS

Jamie Spiers joined the SRK (UK) office in July 2009. Jamie has experience in tailings dam design, geological/geotechnical investigation and environmental engineering, gained from working on large copper, uranium, gold and iron ore mining projects. Jamie currently supplies specialist consulting services in tailings storage facility design, waste rock dump design, foundation engineering and mine site closure/rehabilitation planning. He has worked on projects involving surface water management, hydrology and EIA issues from feasibility level through to closure.



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## Esperanza thickened tailings project



### PEPE MORENO

Juan Jose Moreno has more than 18 years' experience in project management and design associated with geotechnical engineering for mining and civil industries throughout South America, Southern Africa and Australia. His experience includes conceptual and detailed design engineering for tailings and heap leach projects. Pepe is typically involved in site selection, slope stability, infiltration analysis, tailings characterisation, risk assessment and due diligence of tailings projects.



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**SRK** has recently concluded the detail engineering of the Minera Esperanza (ME) tailings storage facility and is currently providing technical supervision for construction. The Esperanza tailings facility is located in northern Chile, in the Atacama Desert and will be the largest thickened tailings facility in the world. Recently, ME was distinguished with the Innovation Award of the Year 2009 in Chile for its efforts in conserving water. The most significant drivers for this award were the usage of sea water for the process and the introduction of thickened tailings to the large-scale mining industry.

The Esperanza tailings will be thickened to 67% solids and the facility has been designed to reach an average 4% beach slope. The facility

was designed to store a maximum of 750 million tonnes of copper tailings.

Paste and thickened tailings are relatively new technologies in Chile, and so gaining permits for the facility was expected to be complicated. Three aspects required special consideration:

- Beach slope prediction
- Infiltration of tailings water to the ground
- Physical stability of the tailings mass – liquefaction

In order to address these issues, SRK carried out various laboratory and onsite testing of the tailings produced from the Esperanza Pilot Plant. These led us to produce a design sufficiently robust to gain permits on time.

## Seepage control at the Colomac tailing containment area

The Colomac gold mine, located at 64° latitude in northern Canada, operated intermittently from 1989 to 1997. The main tailings dam (Dam 1) was built in a narrow, flat-bottomed valley at the original, drainage outlet from a natural lake. The dam foundation consisted of glacial soils overlying bedrock in a discontinuous, warm permafrost setting, with an unfrozen zone (talik) in the valley thalweg. Possibly due to the growth of the unfrozen part of the foundation, seepage from Dam 1 increased from 6 gpm in 1996 to about 300 gpm in mid-1999. For environmental reasons, a seepage pumpback system (SPS) was installed in 1996.

In 1999, after the mine's owner went into receivership, the federal government assumed control of the mine site. SRK subsequently worked with government agencies to develop a site remediation plan, including the development of a new dam (Dam 1B) 80m downstream of Dam 1 with the intention of limiting seepage to acceptable levels and enabling SPS decommissioning.

SRK's Dam 1B design called for the construction of a geomembrane-lined rockfill dam over an area with no unfrozen zones. Thermosyphons, which use passive heat exchange,

would chill the foundation for a period of 20 years after dam construction. Numerical analyses undertaken by another firm (EBA Consultants) indicated the foundation would remain frozen for a period of 150 to 200 years, depending on which global warming scenario was assumed.

During the winter of 06/07, SRK supervised the construction of Dam 1B. In 2008, the SPS was removed. Subsequent inspections have confirmed the thermosyphons are working well and the dam is performing according to its original design objectives.

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Pilot tailings deposition at the Esperanza site. Geotechnical Insitu testing and monitoring of moisture parameters were conducted for 3 months after deposition

State-of-the-art design tools and the latest in thickened tailings research were combined to interpret the relevant test results and develop practical solutions to provide an innovative TSF design, prepare a comprehensive Tailings Management Plan and streamline the approval of the relevant permits, which were granted within six months of application submittal.

The Esperanza TSF was commissioned in late 2010, with SRK acting as technical advisors.

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### CAM SCOTT

Cam Scott, P.Eng., is a Principal Engineer in the GeoEnvironmental Engineering Dept of SRK Canada. He has a Master's degree in geotechnical engineering and



over 30 years of experience, most of which has focused on the geotechnical and hydrogeological aspects of mining, including the site selection, design, permitting, operation and closure of mine waste facilities. In recent years, Cam has worked extensively on mine development and mine closure projects in northern Canada, as well as international projects within the former Soviet Union, Europe and South America.

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Installation of thermosyphons in the foundation of Dam 1B in early 2007

# SRK leads investigation of very coarse granular materials

The challenge faced by some mines in the Andean mountain range is the lack of available space for waste dumps, given the steepness of the typical mountainous topography. Because of this, there is an even more urgent need to design dumps hundreds of meters high, in some cases reaching unprecedented heights. In these cases, detailed knowledge of the geomechanical behavior of the waste material becomes essential.

The Geotechnical Group of SRK Chile, has engaged in the work of characterising coarse waste material, which includes planning for large-scale sampling, scaling and testing of the materials using a large triaxial cell and odometer equipment.

The triaxial equipment used for this work belongs to the University of

Chile in Santiago and allows for testing specimens 2m high and 1m in diameter, under controlled stress conditions, and confining pressures up to 2.5 MPa. The odometer equipment allows testing under applied stresses of up to 15 MPa.

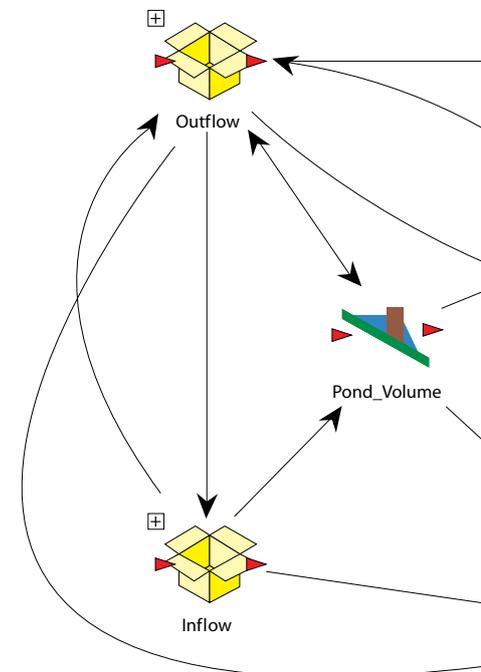
During recent years, the SRK team has been investigating the shear strength, deformation characteristics and particle breakage of different materials under high stresses.

The study has shown the importance of considering the decrease of the angle of internal friction with the increase of normal effective pressure in designing very high dumps of granular materials.

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Large scale sample for triaxial testing

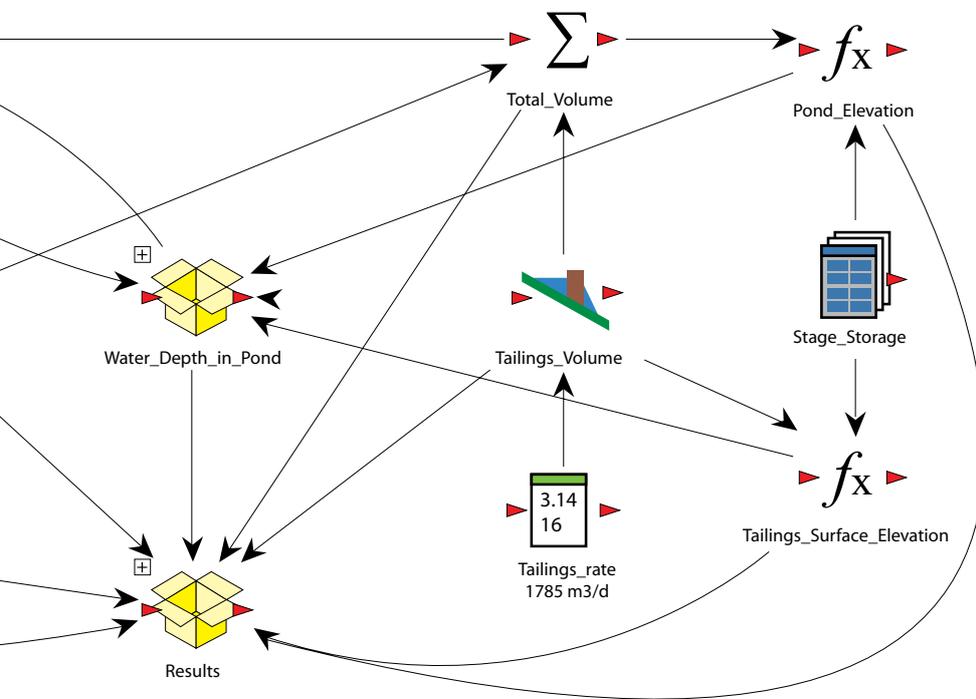


Water balance diagram with elements using GoldSim platform

SRK has recently incorporated the GoldSim™ tool as part of the range of services that the tailings and heap leach group offer to our clients. GoldSim™ is a general program that can be used to simulate almost any process, incorporating the probabilistic simulation of complex systems. While applications for this software in the engineering field are extensive, SRK is currently limiting its use to the construction of water balance models. The aim is to visualise complex inputs, such as the probabilistic simulation of rainfall inputs, to cope with ever stricter Australian water regulations and waste management controls.

When dealing with water balance models for tailings facilities or heap leach systems, many of the controlling parameters, processes and events are uncertain or stochastic; ignoring this uncertainty can lead to poor decision making. Probabilistic

# Constructing water balance models using GoldSim™



simulation is the process of explicitly representing this uncertainty by describing model inputs as probability distributions. If the inputs, such as rainfall or evaporation are uncertain, the prediction of future performance of the tailings facility or heap leach facility is necessarily uncertain.

GoldSim™ uses the probability distribution of such recorded events as climatic inputs while uncertainty is propagated using Monte Carlo simulation. Then, the entire system is simulated multiple times and each individual simulation or possible 'future' contains randomly sampled parameters, selected from their probability distribution.

The water balance models that we currently prepare are focused on tailings operations. The most important parameters that we incorporate for the analysis are: tailings throughput,

climatic data (probabilistic), stage capacity curve of the tailings deposit, capacity curves of the supernatant pond and return water pond, and beach angle, among others.

Using this tool in our models allows us to predict, with a given level of confidence, variables that are among the most useful for the tailings operator, such as freeboard, water reclaim allowable rate, and estimates of the volume of make-up water.

In the future we will be developing other useful applications for the mining and water resources industries, such as closure studies, evaluation of construction budgets, remediation studies, risk assessments and failure analyses.

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## SANDRA LINERO

Sandra Linero is Principal Geotechnical Engineer and Partner at SRK Santiago's Office. She has over 20 years of experience in a wide range of projects in South America, ranging from hydroelectric developments, highways and roads, bridge and building foundations to mine projects. She has been responsible for the planning and supervision of many geotechnical site and materials investigations and has led the design of rock piles for waste, and stock material and leach heaps as well.



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## JUANITA MARTIN

Juanita Martín, P.Eng (Civil), IECA, has more than 15 years' experience in the coordination, design and supervision of civil engineering projects and in water management



for mining infrastructure. Her experience includes the design of hydraulic structures for impacted and un-impacted runoff from tailings and waste rock dumps, retention pond and spillway design, the preparation of pond and tailings water balances, and tailings water management. Juanita has a broad base of experience from her work in climates ranging from arid areas in northern Chile and Western Australia to tropical areas in Venezuela and India.

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## Solutions to reduce infiltration

### ALVARO HUERTA

Alvaro Huerta is a Senior Geotechnical Engineer in SRK's Santiago office. He has 20 years' experience leading civil and mining projects and carrying out technical inspections. In addition, he has experience with projects involving roads, power stations and high-voltage lines, thermal and hydroelectric power stations, dams, and channels. He has carried out hydrogeological studies for drilling, pumping wells, permeability tests, dam designs, drains, earth movement, foundations for high-voltage towers and equipment. He has also prepared technical specifications, managed projects and carried out technical and civil work inspections, and has prepared tender documents for basic studies of major projects.



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Project's tailings impoundment

**SRK** has successfully conducted a feasibility study of medium and long term solutions to infiltration and water management problems for one tailing storage facility (TSF) located in the central valley of Chile.

Monitoring wells in the region identified the problem with this TSF is that sulfate concentration has increased in the aquifer. The problem is exacerbated by an increase in the volume of the supernatant pond; therefore, actions to increase water consumption or removal of the contaminant need to be implemented.

The group of specialists SRK assembled to face this challenge included geotechnical engineers from SRK Chile, and off-shore SRK Australia tailings and geochemistry specialists.

Possible solutions the team analyzed to control infiltration and increase the consumption or reduction of the contaminant in the supernatant pond included: control of pollution sources, control of contaminant migration, and decontamination by means of collection and water treatment. The solutions studied included the use of thickened tailings, forced evaporation, evaporation ponds, and evapo transpiration, increasing the size of the clear water pond, sealing the impoundment, moving the pond, as well as hydraulic barriers, physical barriers, recycling water to the plant, introducing reactive permeable barriers and different types of treatment plants to reduce the concentration of sulfates.

Key activities for this study were verification of the effects of each

## Penstock decant system for large tailings dams



solution, studying the combination of solutions on the expected volume of clear water pond and the expected sulfate concentration in the aquifer. For this purpose, the team developed and calibrated a monthly model for monitoring water balance and also one for contaminants. These tools permitted us to recognize the effectiveness of the solutions proposed.

Finally, the team developed a strategy to implement the solutions to keep contaminant levels under the maximum allowed. As a final solution, we suggested sealing the impoundment using an impervious cover made of a compacted mix of tailings and alluvial material over the natural field that will be in contact with the pond, forced evaporation and installing a treatment plant.

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**SRK Johannesburg** has again become involved in the design of ring dyke tailings dams to accommodate a fairly large deposition rate. The availability of sufficient land is becoming a problem and is increasing the final heights of the tailings dams. The tailings dams therefore have to be designed to use the available space effectively and this is resulting in tailings dams covering an area of approximately 700 to 800ha and with heights of between 80 and 120 meters at the final penstock inlet system.

Designing these decant structures to last for the operating life of the tailings facility, which can vary from 50 to 75 years, needs to be carefully considered; the intake structures need to be constructed in phases as the height of the tailings to be confined by the dam rises. Typically, the project includes three phases that vary from 40 to 50 meters in height. The design of these structures must take into account the down drag forces that will be applied to the structure as the tailings consolidate, the founding conditions on which the structure base rests, seismic activity in the area, wind loading, and possible aviation activities. Another area of concern to be considered during the design of the entire decanting system is the jointing of the penstock outlet pipeline to the intake structure as differential settlements could produce problems in the future.

The design of these structures has resulted in penstock intake towers constructed with reinforced concrete with an external diameter of some 5.5 meters and a wall thickness of 1 meter for the first 50m lift of the tower. Thereafter, the wall thickness reduces to 750mm, and finally 500mm for the last 40 meters. The foundation base for this tower structure is approximately 10 meters by 10 meters in size with a depth of between 5.5 to 6 meters.

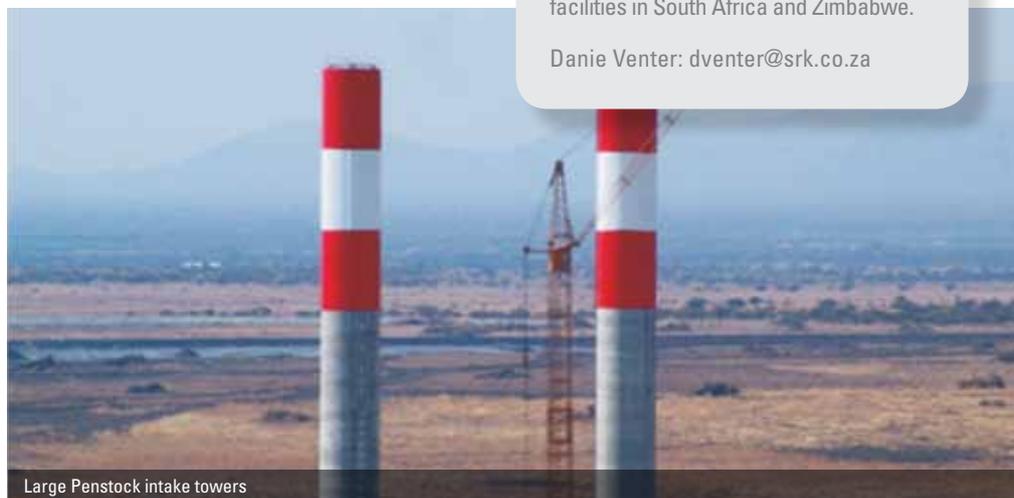
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### DANIE VENTER

Danie Venter is a Principal Technologist with SRK's Johannesburg office. He has 40 years' experience, having started his career in construction and spent 9 years building roads, bridges and concrete structures. Danie joined SRK's Civil department in 1984 and transferred to the Tailings department in 1989 to assist with contract documentation and site administration on various tailings facilities. Over the last 20 years he has been actively involved in the design, contract management and operational management of numerous tailings facilities in South Africa and Zimbabwe.



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Large Penstock intake towers

# Numerical modelling of mineral sands

**SRK** used numerical modelling on a 3D MS Excel platform to solve challenges involving the deposit of a heavy minerals thickened paste on natural valley slopes, to determine maximum coverage and hang-up, and evaluate the potential increase or decrease in design target dry densities of the slimes.

During heavy minerals extraction processes, ultra fine slimes residue is produced as a by-product that presents its own disposal challenges. These challenges are exacerbated along

the south eastern coast of Africa due to steep terrain and high seasonal rainfall, therefore understanding the interdependent relationships between yield/shear stresses, deposition rates, evaporation requirements, placement stability and thickness of deposit layers on steep terrain is imperative to accurately size and design of the storage facility. Steep terrain within the storage facilities basin confines potentially could lower the average target of dry densities, which in turn directly affects the facility's storage requirements and increases the time before rehabilitation or closure begins.

The numerical models provided SRK with graphics and tables summarising the number of deposition cycles per area, and the terrain's effect on the average target dry density and volume of slimes retained on the slopes per deposition cycle. SRK then ascertained the most cost effective method of slimes deposit – by open ending, spigot or spray bar.

This numerical modelling method has also been adapted to size the slimes/sand rehabilitation mixture in co-disposal production plants and determine the developmental phases and capacity curves for both conventional and non-Newtonian thickened slimes/tailings.

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## ROB MCNEILL

Rob McNeill is a Principal Technologist with SRK's Pietermaritzburg office. He has 36 years' engineering experience, having started his career in railways, spending 10 years designing and building railway infrastructure, and the design and acceptance of permanent way materials. Rob joined SRK's Tailings department in 1985 and started his tailings career in platinum, gold and coal tailings storage facilities. Over the last 25 years he has been actively involved in numerous civil engineering developments, tailings dam due diligence studies and the design of numerous tailings storage facilities which extends into the heavy minerals industry that utilises thickened paste technology.



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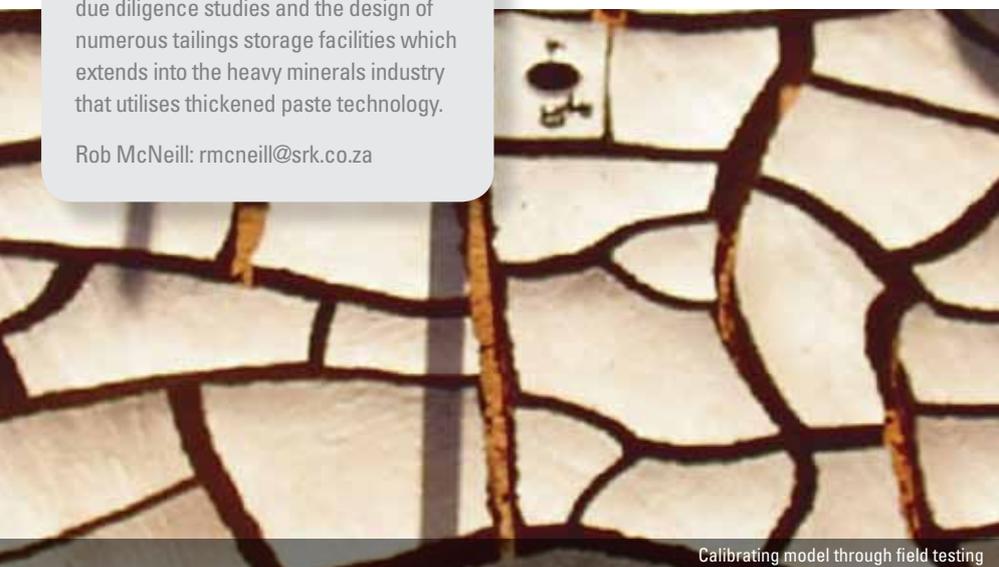


Tailings embankment, cyclone header pipeline and beach

**The Giroux Wash** tailings impoundment at the Robinson Mine in Nevada receives a nominal 42,000 tons per day of milled, processed sulfide flotation tailings. The facility has a compacted earth starter embankment with the majority of embankment raise construction achieved via the centerline construction method using the coarse fraction of cycloned tailings slurry.

SRK consultants were instrumental in formulating and implementing new design initiatives following the commissioning of the facility in 1996. These initiatives were implemented to improve control of slurry deposition and supernatant reclaim due to operational start-up limitations associated with these two design elements. These initiatives included:

- A hydraulically raised cyclone system using a 30-inch diameter steel pipe



Calibrating model through field testing

## Giroux Wash tailings impoundment



### JOHN COOPER

John Cooper, Principal Engineer in our Elko office, has 21 years of combined experience in civil/geotechnical engineering and geology.



A majority of his experience has been spent in the mining industry and includes engineering design, permitting assistance, geotechnical site investigations, quality control and quality assurance during construction and producing record of construction reports. Projects include leach pads, tailings storage facilities, containment structures, waste rock facilities, ponds, road crossings and storm water diversions. His specific tailings facilities experience includes the Round Mountain Facility, Newmont's South Area Mill 5/6 Facility and the Robinson Mine Facility.

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located on the embankment crest with 4-inch hydro-cyclones at 25 foot centers. This system enables the pipeline to be elevated at an adequate height above the crest tailings surface to ensure sufficient height for centerline raising, which typically occurs during the summer and early fall. The cycloned overflow and total tailings are used to maintain a positive beach slope and drainage towards the barge operation channel for recycling of supernatant water.

- The barge operation channel is 150 feet wide, 15 to 20 feet deep, and clay lined. The depth and storage capacity of this facility allows the operator to maintain a water level in the channel to sustain the pump operation and limit the spread of the supernatant pond surface area onto the beached tailings. This

eliminates ponding and results in rapid consolidation and decrease in the hydraulic conductivity of the beach tailings. Construction to extend the channel has also been appropriately phased. As a result, when the facility went into temporary closure in June 1999, the remaining supernatant pond inventory was fully evaporated by the end of August 1999.

Operation of the facility resumed in the fall of 2004 and continues today. Based on inspections and annual dam safety evaluations, the system continues to function as designed and permitted, highlighting the importance of all aspects of tailings impoundment drainage in the design process.

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## ANDREW GARVIE

Andrew Garvie is a Principal in the GeoEnvironmental Group of SRK (Australia). He has a PhD in physics and 17 years' experience in the mining industry.



His expertise lies in quantifying physical processes that contribute to oxidising sulfidic waste dumps, heap leach piles and tailings dams; he characterises mine wastes for their potential to produce acid drainage and metalliferous leachate. Andrew played a major role in the design and development of a measurement program to determine the effectiveness of strategies that control the oxygen supplied to a heap leach pile. He has authored competent persons' reports and conducted environmental reviews.

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## Long term stockpiling of copper ore at Batu Hijau Mine



Measurement of oxygen concentration and temperature in a sulphidic rock dump

## CLAIRE LINKLATER

Claire Linklater, PhD, Principal Consultant, GeoEnvironmental, has 18 years' experience in interpretation of geochemical data, building conceptual models of processes



which control the geochemical behaviour and mobility of contaminants in the environment. Whilst her early career was based in radioactive waste management, her current focus is sulphidic materials management: acid/alkaline rock drainage (ARD) assessment and prediction, water quality and pollutant mobility. She is familiar with application of codes such as PHREEQC and Geochemist's Workbench, and also SRK's numerical model SULFIDOX (developed to estimate rates of sulphide oxidation in waste rock dumps and ore stockpiles).

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**PT Newmont Nusa Tenggara** plans to stockpile approximately 500Mt of copper ore for up to 20 years at the Batu Hijau mine on Sumbawa Island, Indonesia. Cu recovery from unoxidised ore is about 85%.

It was not clear what the impact of oxidation would be on recovery after ore was stockpiled for 20 years. The company decided to undertake a field measurement and modelling program to identify the main controls on oxidation, predict the rate of chalcopryrite oxidation and simulate how alternative stockpile designs could reduce oxidation.

To accomplish this, SRK Australia designed a field program to measure oxygen concentration and temperature distributions within the existing stockpile. The objectives were to determine the oxidising

regions and the rates of oxidation. SRK made predictions of the extent of chalcopryrite oxidation using the numerical model SULFIDOX. Integrating these results with outcomes from flotation studies made it possible to predict future oxidation levels and develop improved stockpile management strategies.

The study concluded that if 500Mt of ore was stockpiled for 15 years, the expected recovery is about 58%. This is equivalent to a loss of about 400,000t of copper, due to stockpiling.

The approaches developed for preserving the value of the stockpiled ore included:

- Increasing the flotation recovery of oxidised ore using Controlled

# Process pond modifications to mitigate groundwater elevation increase



Potential Sulfidisation (CPS). When Newmont conducted testing using CPS, they found that an average 10% increase in copper recovery could be achieved

- Reducing oxidation while the ore is stockpiled by reducing the amount of oxygen that could enter the copper stockpile by selective material placement. The oxidation of higher value ore can be reduced by surrounding it with waste sulfidic material that acts as an oxygen consuming rind. When SRK constructed a model of the stockpile covered in a rind, the results showed that oxidation could be reduced by up to 50%; a saving of 200,000t Cu

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When rising groundwater elevations posed a potential risk to the integrity of existing geomembrane pond liners, Barrick Cortez, Inc. (Barrick) retained SRK for engineering modifications to the process ponds.

SRK performed expedited project planning, geotechnical evaluation, water balance analysis, and engineering design to meet tight compliance deadlines. Key design elements included:

- Increasing pond surface area where possible and using engineered rock fills to raise the pond base elevations above the groundwater elevation and provide permeable, low compressibility foundations with materials available on the mine site
- Modifying pond geometries to enhance evaporation and allow ready conversion to Evapotranspiration Cells for future closure
- Integrating dewatering systems into backfill construction to supply relatively inexpensive groundwater elevation control capabilities
- Synthetic liner systems with leak detection for process fluid containment
- Pumps and piping to provide water transfer capabilities, operational flexibility, freezing mitigation, and operation in case of site power outages

In addition to performing CQA during construction, SRK worked closely with the client and the contractor to optimise the effectiveness and economy of design implementation. For example, SRK evaluated site hydrogeology and construction dewatering approaches ranging from wellpoints to sheet pile walls. Ultimately, the team used a coarse granular fill to backfill to an elevation sufficiently above the water table. The granular and design backfills were constructed in stages, while SRK monitored settlement. The settlement and construction delays were minimal and installing a high-cost construction dewatering system was avoided.

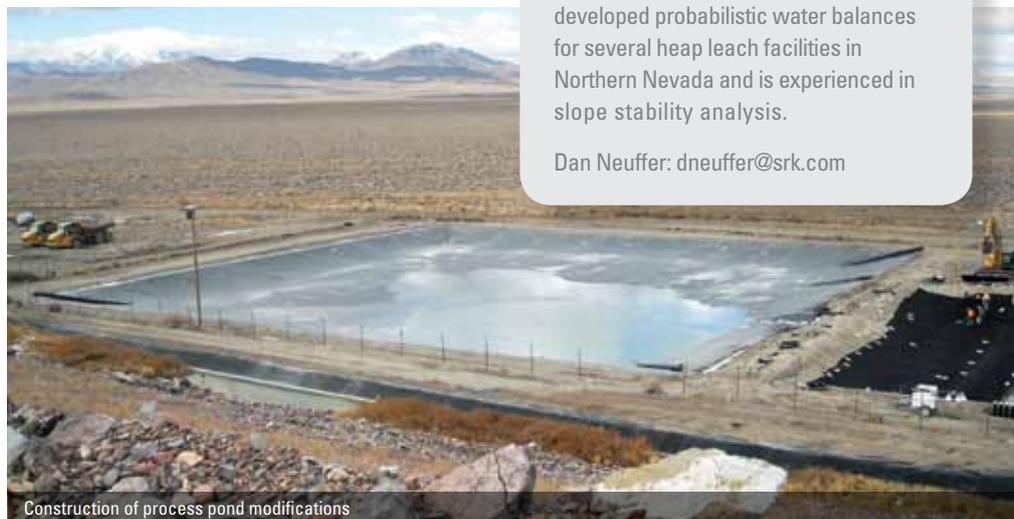
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## DAN NEUFFER

With 7 years' experience in geotechnical and civil engineering, Daniel Neuffer, P.E., works out of SRK's Elko, Nevada office. His experience includes planning, investigation, design, permitting, construction quality assurance, reclamation, and closure for mining and infrastructure projects. Daniel has developed probabilistic water balances for several heap leach facilities in Northern Nevada and is experienced in slope stability analysis.



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Construction of process pond modifications

# Tailings storage facility expansion

**SRK** was commissioned by Focus Minerals Limited to provide professional services associated with their Three Mile Hill in-pit tailings storage facility (TSF) in Western Australia. This facility forms part of the Coolgardie Gold Project and currently receives tailings at a rate of 1.2 Mtpa. Focus requested that SRK undertake an evaluation of the current operations and design the required expansion in support of a mining proposal.

SRK recognised that there were unique challenges associated with this project that included:

- Achieving synergy with the existing tailings disposal operations during the transition
- Integrating the proposed expanded facility with the existing infrastructure on the site
- Accounting for the proximity of the Coolgardie to Kalgoorlie highway
- Working with the limited availability of construction materials

SRK completed an evaluation of the current in-pit TSF and confirmed that the facility had approximately 2 to 3 years worth of storage capacity remaining, after which an expanded facility will be required. As part of this evaluation SRK developed operating strategies for the remaining life of the in-pit TSF to maximise storage, manage the various deposition scenarios, facilitate the decanting process and lay the groundwork for the proposed facility expansion.

SRK evaluated options for an expanded facility for Focus's approval by directing the site investigation, materials assessments, and detailed phases of the project.

As the design and implementation of the expanded facility was not required immediately, the project scope of work was divided into phases to take advantage of the time available. This strategy allowed Focus the time to evaluate the options. SRK is currently completing the detailed design of the expanded above-ground facility.

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## CAROLINE HOLMES

Caroline Holmes is a Principal Engineer in SRK's Perth office with over 14 years' experience with site selection, site investigations, design, construction and project management of waste storage facilities. Her practical expertise includes site selection studies, conceptual and detailed designs, permitting, evaluating methods of disposal, material characterisation, geotechnical investigations, slope stability, composite liner designs, seepage analyses, compiling tender documents, tender adjudication, project management and construction supervision. She has completed numerous due diligence and Competent Person reports for existing and proposed mine waste storage facilities.



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Final cover installation at the Bridgeport Landfill, California

Since the late 1990s, SRK Reno has been providing solid waste landfill design and permitting services for small municipalities in Nevada, Utah, and California. Services have included the design and permitting of landfill and transfer stations, preparing and implementing closure plans, the design and installation of landfill gas and groundwater monitoring systems, quarterly groundwater monitoring, and construction and reclamation and closure bond costs.

Recently, Mono County, California asked SRK to prepare a final closure and postclosure maintenance plan and detailed closure design for the Bridgeport Landfill. The landfill is situated in the eastern Sierra Mountains at an elevation of 6,500 feet, and more than half of its annual precipitation falls in the form of snow.



Three Mile Hill in-pit tailings storage facility

## Solid waste landfills



For final cover, California regulations require a minimum of 18 inches of compacted low-permeability soil with at least 6 inches of growth media or erosion cover on top, or an approved alternative. Lacking an economical source of fine-grained soil, Mono County directed SRK to evaluate alternatives for the final cover. Unsaturated zone modelling indicated that typical store-and-release soil covers would not work for the anticipated high precipitation at the landfill's high elevation, and so SRK explored geocomposite and geomembrane cover alternatives. Compatibility testing with geosynthetic-clay liners and available site growth media indicated the natural salt contents in the native soil were too high and would adversely affect the liner's bentonite component.

SRK and the County decided on a structured geomembrane product from

Agru America called SuperGripNet®, which incorporates an integrated studded drainage medium on the top with a spiked lower surface to increase interface friction angles in contact with the subgrade, overlain by a heat-burnished geotextile to facilitate overliner drainage. Overliner collection drains (gravel and perforated pipe) were installed at specified intervals to facilitate drainage and stabilize the overlying 18-inch growth media layer. Overliner drains were routed away from the final closed landfill surface and into the site's perimeter stormwater control system.

The alternative cover design provided the client with a creative solution for closing the landfill in snow country and a relatively cost-effective alternative, using available soil material.

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### BREESE BURNLEY

Breese Burnley of SRK's Reno office has more than 17 years of experience in engineering consulting. His expertise includes mine and waste disposal site engineering, permitting, stormwater, slope stability, design specifications, cost estimation, bid adjudication, and construction oversight. Breese's work has taken him to numerous industrial, mining, and landfill properties throughout the western United States and South and Central America.



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### DAVE LUPPNOW

David Luppnow has over 18 years of experience in site investigations, site selection, design, construction, reclamation and project management of engineered structures for mine waste disposal, including tailings dams, heap leach pads and mine waste rock dumps. He has managed multi-disciplinary studies for related projects. His specific projects in South Africa, USA, Papua New Guinea, Argentina and Chile involve mine tailings and leach pads for copper, gold and uranium. Recently, David completed the feasibility design of a 90,000 tonnes-per-day copper paste tailings facility in Chile.



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## Experience gained from tailings dam audits



Severe erosion cavity caused by concentrated flow from berm penstock; Broken berm penstock piping causing side wall erosion (right)

### ADRIAAN MEINTJES

Adriaan Meintjes is a Principal Geotechnical Engineer with SRK's Johannesburg Office. He has 27 years' experience, having started work at the Council of Scientific & Industrial Research in the Mechanical Engineering and later in the Building Technology divisions. Adriaan joined SRK in 1992 as part of the Geomechanics group, involved with soil and rock engineering projects; these interests have been maintained. In the last 10 years he has worked in the Tailings department, involved with tailings and slimes related projects for a large variety of commodities and in many countries with wide-ranging climatic and seismic conditions.



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Recently SRK was requested to review 15 old tailings dams in Zambia and evaluate the work required to close them. These tailings dams are all located in the tropics, in an area with high annual rainfall and with summer thunder showers that cause high-intensity rainfall events. While the tailings deposition ceased more than ten years ago, not all the tailings dams were closed after the end of the deposition. All are in a state of disrepair, the degree varying from site to site. The lessons learned can be applied to the design of new tailings dam storage facilities (TSF) under similar climatic conditions.

SRK found the outer slopes of the TSFs are badly eroded in all cases where ongoing vegetation establishment was not implemented as the TSFs were developed. Bench

penstocks (conduits for conveying or diverting water) and related structures were installed on many of the tailings dams. Where these diversions had failed, severe local damage developed with time; the depth of the erosion gullies exceeded 10m at each pipe break. A major conclusion seems to be that all flow control structures (such as berm penstocks) should either be removed, or these structures must be constructed for a design life spanning both operational and closure time frames.

In all cases where tailings deposition occurred from high ground down towards the outer walls, the outer walls have been breached by stormwater erosion causing severe tailings spills. If this deposition practice is to be used, larger allowances have to be made to

## Synthetic liner pipe penetration

**SRK Reno** has designed a “boot” configuration that can be used for pipeline penetrations through a synthetic HDPE geomembrane pond liner; it has been approved via regulatory permitting processes for construction. The boot design, illustrated in the figure below, provides a drainage connection to the low point in a secondary liner to collect and dissipate fluids leaking through the primary liner, thus eliminating the potential for head development and leakage from the secondary liner.

The Leakage Collection and Recovery System (LCRS) system design incorporates a pre-manufactured 6 x 2 inch dual containment elbow. The elbow is factory-welded to a 12 inch diameter blind flange; as is a 4 x 4 foot 80 mil HDPE apron. The apron allows for field overlapping and wedge-welding with the surrounding secondary (lower) liner and minimises field extrusion welds. The elbow is set in a cast-in-place concrete foundation.

The top surface of the concrete is sloped to the center drain at approximately 4H:1V, to form a firm foundation for field welding that minimises stresses on the liner-elbow connection during construction and subsequent loading. It also provides a means for clean-water testing the system for leaks before operational commissioning. The sloped surface also facilitates overlapping of the secondary liner seam in the flow direction to minimise potential hydrostatic head formation over field seams.

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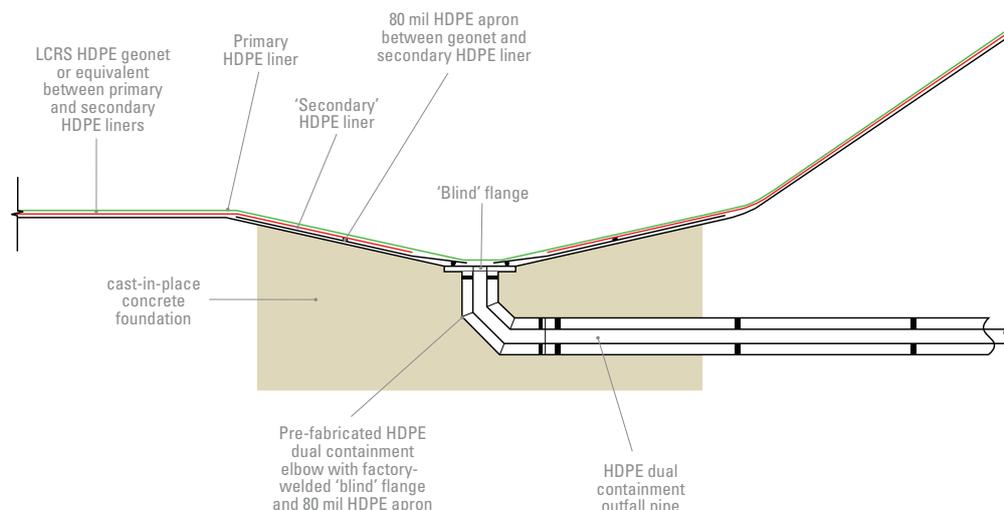
establish sufficient freeboard for more adverse storm events than are catered for during the operating design life of a structure and to ensure that the outer walls retain their geometry. The outer wall geometry can be maintained by a cover of vegetation or suitable soil or, failing that, erosion resistant materials. This design requirement has to be considered in conjunction with providing suitable functional spillways.

In most cases, wind and water erosion of the upper surfaces of the tailings dams led to freeboard losses in critical areas, so that the outer slopes were breached in places. The consequences are that side slope erosion is accelerating with time, as more water is able to flow over the crest edges of the TSFs.

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Illustrated below is a typical liner “boot” detail (not to scale)



# New tailings impoundment feasibility design in Senegal

**SRK** completed the feasibility design of a tailings management facility (TMF) for the Oromin Joint Venture Group at the Sabodala Project in Senegal in 2010. To ensure a consistent water supply to the mine, the TMF facility will be used as a water reservoir during the rainy season to supplement a purpose-built water reservoir of 9.7 million cubic meters about 9 km from the mine site, which SRK also designed.

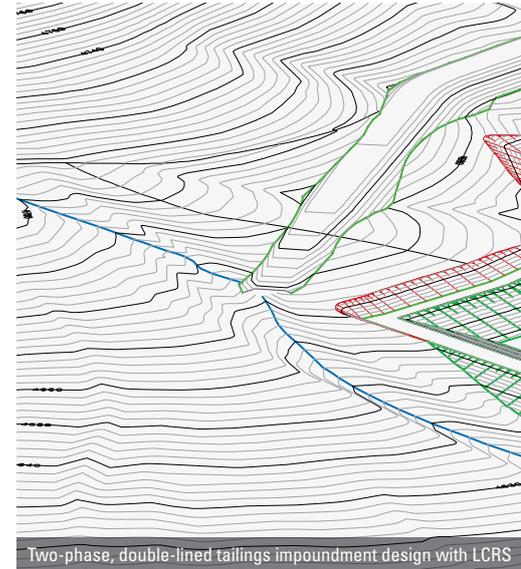
The TMF will contain about 17.6 million tonnes of tailings, with the capacity to expand up to 25.6 million tonnes. Two water-retaining earthen embankments provide containment. The dam will be constructed in phases, using a hybrid downstream-centerline method. The primary and secondary dams will have crest lengths of 550m and 214m, and maximum heights of 28m and 12m, respectively.

Beneath the dams, the foundation consists of a thin veneer of organic topsoil overlying silty clay saprolite that varies in thickness from 5 to 10m. These layers overlie weathered bedrock. The dams are homogenous earth-fill structures,

constructed from compacted saprolite, which is sourced locally. Internal chimney and blanket drains are used to control the phreatic surface in the dams. Upstream and downstream dam slopes are 2H:1V and 2.5H:1V, respectively, and the crest widths are 9m. Upstream slopes will be clad with rip-rap for wave protection, and the downstream slopes will be seeded with erosion resistant vegetation. The dams will have a freeboard of 2m, and a 25m wide spillway, lined with rip-rap, capable of passing the Regional Maximum Flood (RMF), which is equal to a 1:7,000 year flood.

Tailings will be thickened to greater than 60% solids and deposited so that a pond will be maintained against the dam during the early stages of mine development. The pond surface area will be kept as small as possible to minimise evaporation. This pond will be supplemented by natural inflow from the TMF catchment during the rainy season.

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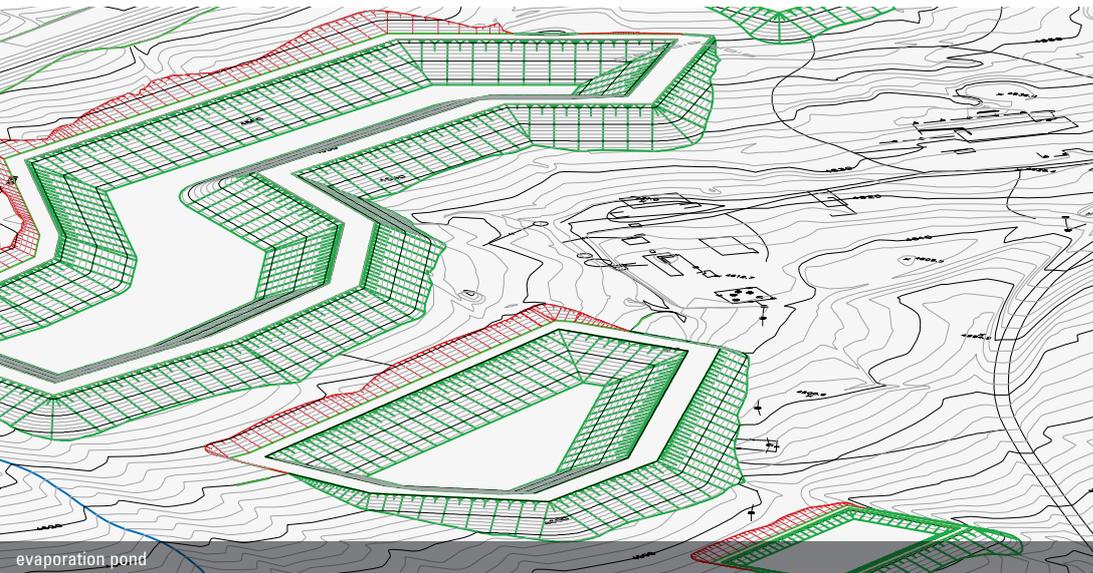
**B**efore a tailings facility can be constructed in Nevada, detailed engineering design must be approved at state level, including plans describing process fluid operating protocols and methods and costs for disposing of process fluids and stabilising process materials. A reclamation plan must be prepared and approved by state and government regulators with a bond posted for these costs (“reclamation bond”), often funded by cash on hand. SRK recently permitted a new disposal system for flotation tailings in Nevada.

The conceptual design envisioned traditional grading, embankment construction, managed deposition into a synthetically-lined impoundment with an above-liner drainage collection system that directs fluids to a recycling system. In addition, the conceptual design incorporated a diversion channel for upstream



View across the valley for the main TMF dam

## Benefits of designing for closure in Nevada



stormwater to control 1-in-100 year, 24-hour peak flows. Initial bond cost estimates for post-closure fluid management were similar in magnitude to the project's capital costs. Therefore, the design was modified to reduce the long-term water management liabilities. The tailings facility was double-lined with a gravity-draining leakage collection and recovery system (LCRS). This LCRS flow is the only water source requiring management under post-closure conditions, and the maximum-flowrate expected is extremely low, less than 150 gallons per day.

In addition, the site grading was designed to limit the rates of rise of the tailings surface to generally less than 10 feet per annum. The drainage system was reconfigured to flow to an internal sump and the water either discharged back onto the tailings surface or recycled to

the plant. If operations suddenly cease, the tailings impoundment would experience a net negative water balance and any surface water remaining at closure would evaporate within the first closure year.

The design was also modified by excavating and stockpiling borrow material upstream of the impoundment to divert peak flows and provide a short-haul borrow for the final closure cover.

While capital costs increased by about 20 percent, reclamation costs decreased by about 70 percent, resulting in a net 25 percent reduction in short-term capital layout for construction and reclamation bond payment for the tailings impoundment.

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### DAVE BENTEL

Dave Bentel has over 30 years of experience providing engineering and environmental permitting services, and financial estimating services for mining facilities. He specialises in cost-benefit evaluations, using risk-based assessments of water and waste management facilities, and planning, design and implementation for closure and reclamation of mine infrastructure, processing plants, tailings impoundments, heap leach facilities, open pits and waste rock facilities.



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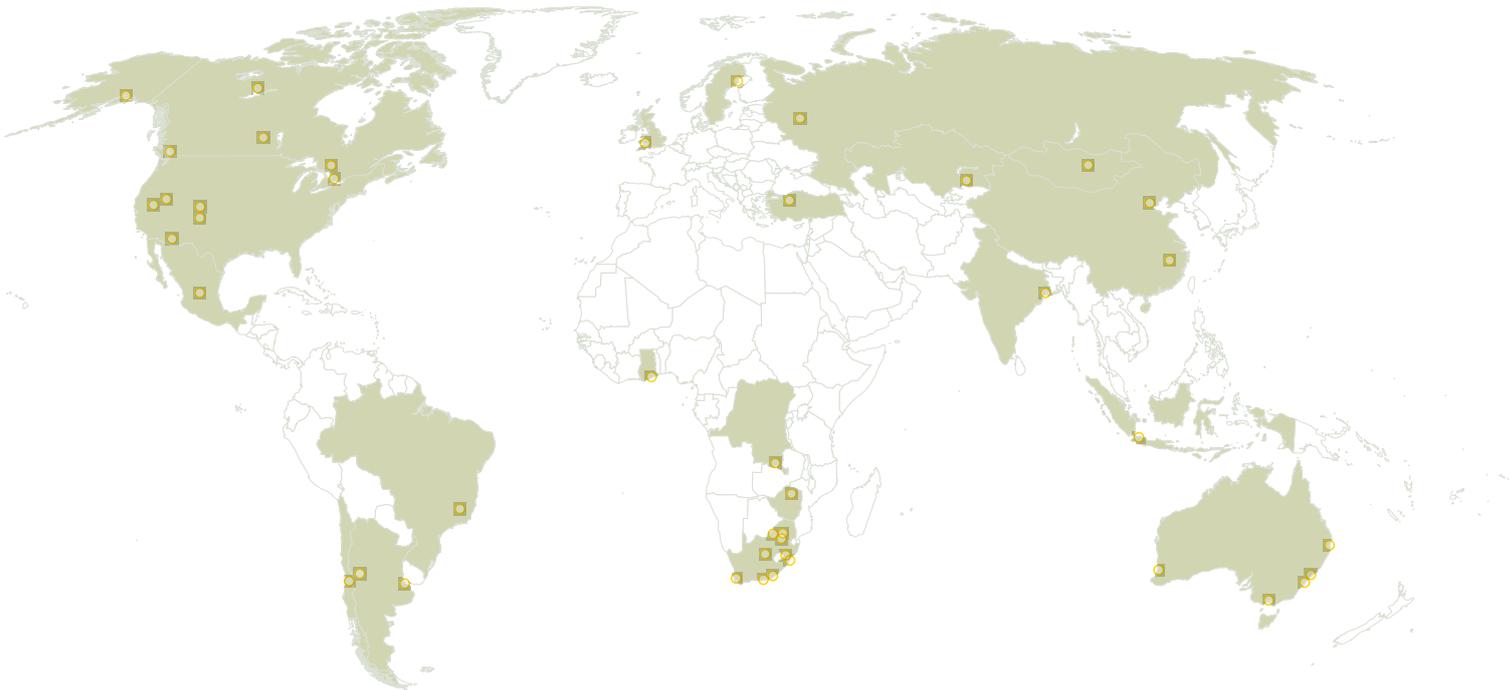
### MARITZ RYKAART

Maritz Rykaart, P.Eng., PhD, is a Principal Geotechnical Engineer in the Vancouver Office. He has 19 years' experience in mine waste management and applied research.



Maritz has been involved in various aspects of the design and construction of river diversions, surface water diversion channels, water dams, pollution control dams and tailings impoundments in Canada, USA, South America, Australia and parts of Africa. He also undertakes routine tailings dam inspections, and contributes towards the tailings components of due diligence reviews and engineering economic studies.

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