Teck

# Sä Dena Hes
# Quarry Development Plan

**Prepared for**

Teck Resources Limited

**Prepared by**

srk consulting

SRK Consulting (Canada) Inc.
1CT008.042
March 2014

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# Quarry Development Plan

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**Prepared for**

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srk consulting

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# 1 Introduction

## 1.1 Project Description

Teck Resources Limited (Teck) proposes to develop a new rock quarry at the Sä Dena Hes Mine. The mine is owned by a joint venture between Teck and the Pan Pacific Metal Mining Corp., a subsidiary of Korea Zinc Company Ltd. SRK Consulting (Canada) Inc. (SRK) has prepared this Quarry Development Plan under the mine's existing Quartz Mining License for a Type B quartz mine approved in the Dam Decommissioning and Reclamation Plan (DDRP) (SRK 2013).

As shown on the vicinity and project location map displayed in Figures 1 and 2, the proposed quarry would be located approximately 7 km from the mine at the 17 km marker on the mine access road that stems off the Robert Campbell Highway, 50 km north of Watson Lake, Yukon. The proposed rock quarry is located on Eagle 108-111 quartz mineral claims YB16270-YB16273 currently held under the Sä Dena Hes property. This quarry is expected to produce 4,500 $m^3$ of rip-rap that will be used to provide erosion protection for a number of post-closure components. The proposed quarry would be parallel to a 145 m length of the mine access road where surficial till was excavated during construction of the access road. The quarry is expected to operate from May to October 2014.

Figures 3 and 4 present the design plan and sections of proposed quarry location and extents. Rip-rap removal from the proposed quarry will be accomplished by drilling and blasting the exposed bedrock. Blasted rock would be loaded by an excavator and transported to the mine site using dump trucks. The drilling and blasting would be carried out under the supervision of an experienced blaster. Rip-rap production would consist of three average rock diameters ($D_{50}$): 0.3 m, 0.4 m, and 0.5 m.

## 1.2 Regulatory Authorization and Approvals

- The proposed quarry would be permitted under the Yukon mining legislation.
- It is expected that the contracted blaster would follow the Canadian Explosives Act, Yukon WCB, and obtain a valid blasting ticket, proper blasting permits and explosives storage/handling SOPs.

# 2 Project Location and Background

## 2.1 Location

- *Quarry Location:* The proposed quarry is located approximately 7 km from the mine at the 17 km marker on the Sä Dena Hes Mine access road that stems off the Robert Campbell Highway, 50 km north of Watson Lake, Yukon. Approximate UTM coordinates to the site are 9V 504400 m E and 6703900 m N at an elevation of 1010 m.
- *Legal Land Description:* Proposed quarry is located on Eagle 108-111 mineral claims YB16270-YB16273, currently held under the Sä Dena Hes property.
- *Registered Trapline Concession:* Proposed quarry development is located within Registered Trapline Number 358 on the Yukon 105A NTS Map Sheet.
- *Registered Outfitting Concession:* Not in an Outfitting Concession.

## 2.2 Project Background

In February 2013, the owners of the Sä Dena Hes Mine made the decision to initiate the procedures to permanently close the mine. A key aspect to the closure of the mine is the decommissioning of the South Tailings and the Reclaim Dam. In July 2013 the final DDRP was submitted for approval which includes the decommissioning of the South Tailings and Reclaim Dams. To successfully decommission the dams, about 8,100 $m^3$ of rip-rap will be required to provide erosion protection and sediment control in the proposed spillways and diversion channels. Approximately 3600 $m^3$ of rip-rap will be salvaged from the existing structures. The proposed quarry will provide the remaining 4500 $m^3$ rip-rap.

## 2.3 Climate

Climate information at the proposed quarry location is based on the Sä Dena Hes Mine located approximately 7 km to the north. Snowfall is about 230 cm/yr and temperatures vary from an average of -26.3°C in January to an average of 14°C in July. Using Watson Lake Airport (elevation 689 m and mean annual precipitation (MAP) of 490 mm) as a base and applying the observed regional precipitation gradient, the estimated MAP at Sä Dena Hes is about 690 mm. The mean annual runoff for the site was estimated to be in the range from 266 to 330 mm.

## 2.4 Geology and Soils

The mountainous area around Mount Hundere is part of the Hyland Plateau physiographic unit. To the west, the Hyland Plateau gives way to the Liard Plain, a broad southeasterly trending intermontane basin that contains the Liard and Frances rivers. The Yukon Geological Survey has classified the surficial material as Morainal till or Colluvium less than 1 m in depth containing sand, silt, and mud, with mixed rock fragments and potentially boulders.

## 2.5 Water and Water Quality

The proposed quarry site is located 80 m upslope from a tributary in the drainage basin of Tom Creek, a tributary of the Liard River. No distinct creeks or water courses traverse the project area. Proposed site footprint is dry and displays no significant signs of surface erosion. A constructed ditch line parallels the access road and quarry location where surface runoff can be collected and easily managed for sedimentation during construction.

# 3 Quarry Extraction Plan

## 3.1 Quarry Development Rationale

The location and configuration included in the quarry development plan have been developed foremost on safety and environmental protection based on sound engineering practice. Design rationale integrated into the quarry development plan is provided in Table 1.

**Table 1: Quarry Development Rationale**

| Objectives | Design Rationale |
|---|---|
| Favoured quarry location must be within the Sä Dena Hes property mineral licence. | Quarry location parallels mine access road under the mine's mineral licence where the majority of overburden has been stripped exposing bedrock. |
| Quarry rock must be composed of geochemically inert minerals. | Geochemical analysis of bedrock sample returns positive acceptability as quarried rip-rap. |
| Quarry layout must minimize site disturbance for reclamation closure. | Quarry is designed as a strip excavation that parallels 145 m of the mine access road instead of utilizing a centralized pit. |
| Quarry layout must focus on the safe operating procedures for: extraction, loading, and hauling of rock. | 1. Constructing a parallel landing to the access road will allow haul trucks to safely pull off and be loaded away from other traffic.<br>2. The landing is designed as such to only allow one-way haul truck motion, removing blind spots and the need to back up.<br>3. Loaded haul truck will exit the landing with a clear line of site on favourable grades.<br>4. An existing 16 m turn-around location located 600 m below the quarry provides favorable grades and clear lines of site suitable to turn around a loaded haul truck. |
| Design aspects must include environmental considerations such as: erosion, sedimentation, and discharge of impacted water into the environment. | Quarry design plan includes the construction of silt fences, sedimentation catchments, and procedural recommendations for the onsite handling of fuel and explosives. |

## 3.2 Quarry Layout

During the construction of the Sä Dena Hes access road, the majority of surficial soils and vegetation had been stripped exposing bedrock at the proposed quarry location. The proposed quarry will be accessed by the existing Sä Dena Hes Mine access road having 10% adverse centerline grades in the haul direction. Sideslopes to which the quarry will be sited are between 50 to 55% and have a slope length of approximately 40 m. From a field site inspection carried out by SRK, it was estimated that the depth of remaining overburden is less than 0.5 m. See Figures 3 and 4 for details.

## 3.3 Quarry Extraction Methods

The quarry will open during a single construction season from May to October 2014. Within the construction season, the extraction process will consist of minor site stripping prior to extraction. An advantage to using this site is that the majority of surface overburden has been stripped and graded during the construction of the mine access road. Due to the proximity to the Sä Dena Hes Mine there will be no need to provide onsite parking, marshalling, construction trailer, or storage containers at the quarry location. All services will be located at the Sä Dena Hes Mine property.

### 3.3.1 Overburden Stripping:

Minor additional stripping of overburden will be accomplished by using an excavator to pull down excess material to clean off the bedrock surface. Removed material will be used in the construction of the roadside landing used for loading trucks and a 1 m safety berm along the south and east edge of the landing. There is no significant vegetation growing at the proposed quarry site or an organic topsoil layer.

### 3.3.2 Quarry Extraction Summary:

The primary rock extraction method will consist of drilling and blasting the exposed bedrock. Until the entire bedrock surface is exposed, it is unknown if the natural fracturing of the rock will allow excavation without blasting. Quarried riprap will be produced by blasting and screening. All quarried rock will be hauled to the Sä Dena Hes property and stockpiled. Table 2 presents the summary of screened quarry rock riprap sizes and volumes.

**Table 2: Quarry Rock Extraction Summary**

| $D_{50}$ Diameter Size (m) | Volume Required ($m^3$) |
|---|---|
| 0.3 | 2,851 |
| 0.4 | 5,135 |
| 0.5 | 102 |
| Total Volume Required | 8,100 |
| Assumed Salvaged From Reclaim and South Dam | 3,600 |
| **Quarry Extraction Volume** | **4,500** |

### 3.3.3 Transportation:

The recommended hauling equipment used to transport the rip-rap from the quarry to the mine site is the standard dump truck and the articulating rock truck. Loading requirements of both trucks follow the same rationale. An empty haul unit enters the loading landing from the north turn in approach where an excavator loads the unit. The loaded haul unit exits the landing through the south approach and continues south for approximately 600 m to a designated turnaround. Turnaround location will have clear lines of sight for traffic travelling in both directions and transitional grades that will allow appropriate gearing for the 10% adverse haul. Table 3 summarized the transportation needs to load and haul rip-rap from the quarry to the Sä Dena Hes Mine.

**Table 3: Fleet Transportation Summary Table.**

| | | |
|---|---|---|
| **Quarry Loading and Hauling** | | |
| Excavator | CAT 320 | |
| Neat Extracted Quarry Volume | 4500 | $m^3$ |
| Bulked Transported Quarry Volume | 6000 | $m^3$ |
| Roundtrip Haul Distance | 22 | km |
| Average Haul Speed | 35 | km/hr |
| Loading Turnaround Time | 1 | hr |
| Assumed Loads Per Day | 10 | loads |
| **730 Articulating Rock Truck Option** | | |
| Load Capacity | 17 | $m^3$ |
| Daily Haul | 170 | $m^3$/day/unit |
| Fleet Unit Requirement | | |
| 1 | 36 | days |
| 2 | 18 | days |
| 3 | 12 | days |
| **Standard Dump Truck Option** | | |
| Load Capacity | 7 | $m^3$ |
| Daily Haul | 70 | $m^3$/day/unit |
| Fleet Unit Requirement | | |
| 5 | 18 | days |
| 7 | 13 | days |
| 10 | 9 | days |

# 4 Water and Waste Management Plan

## 4.1 Waste Disposal

Currently no washroom facilities for personnel are expected at the quarry site. Future requirement for such facilities will be met by installing self-contained portable toilets. Disposal of the portable toilets will be done offsite at a waste management facility.

Food and garbage wastes will be contained in garbage receptacles located on each piece of heavy equipment. Each receptacle will be removed from site and emptied at the end of each shift to remove the temptation for bears and other curious animals.

## 4.2 Surface Water Management

Surface water flow generated from precipitation will be contained and managed within the quarry development boundaries. It is not anticipated to have significant surface water discharges from offsite impacting the quarry location. Surface waters that collect within the quarry area will be managed as per the following:

- Constructed roadside landing will be graded to shed ponded surface water into the common roadside ditch.
- Constructed landing approach will have a culvert installed to connect ditch conveyance flow through the quarry workings.
- During operation, the quarry excavation will minimize the creation of pits and depressions that lead to standing water.
- Sediment management structures will intercept ditch conveyance flow to remove suspended sediments prior to discharging into receiving waters.

## 4.3 Sediment Management

Any suspended sediments generated from surface runoff will be contained within the quarry development area. To manage sediments, silt fencing will be installed around the base of erodible surfaces within the quarry development. Suspended sediments in ditch water flow will be intercepted by a series of silt fences constructed perpendicular to the ditch flow direction spaced every 20 m. The design and location of the silt fences are displayed on Figure 3. Dust suppression efforts will be managed on-site by the use of vehicle speed restrictions on the access road adjacent to the quarry. A water truck configured with spray bar may be required to dampen trafficable surfaces to supress dust when needed.

## 4.4 Groundwater Effects

Excavation depth will be limited only to the rock available above the groundwater table.

## 4.5 Suitability of Rock for Rip-rap

### 4.5.1 Assessment for Acid Base Accounting

Maxxam Analytics in Burnaby, BC conducted acid-base accounting (ABA) and aqua regia elemental analyses on a bedrock sample (SDH-R4) from the proposed quarry location. The analytical results are included in Appendix A.

Total sulphur content in the sample was below the analytical detection limit (0.02%) and the neutralization potential (NP) and total inorganic carbon (TIC) levels were high, 790 and 840 kg $CaCO_3$/t respectively. Both the NP/AP and TIC/AP ratios were greater than 1,000, indicating that the samples were non-potentially acid generating.

The elemental concentrations in the sample were compared to ten times the average crustal abundance values for sedimentary carbonate rock. The average crustal abundance values were taken from the Draft Guidelines and Recommended Methods for the Prediction of Metal Leaching and Acid Rock Drainage at Minesites in British Columbia prepared by William Price in 1997. The crustal abundance comparison was used as a screening tool to determine potential enrichment (exceeding ten times the average crustal abundance). The sample was enriched in nickel (52 times the average crustal abundance value). Enrichment in the solid phase does not necessarily lead to unacceptable leachate chemistry.

During construction, the active quarry face will be visually inspected for the occurrence of sulphide veining.

### 4.5.2 Abrasion testing

SRK conducted a testing program on a rock sample collected from the proposed quarry location. The testing program was required to identify the location as a suitable location to extract rock rip-rap. The testing program included tests for: intact rock strength, freeze thaw, jar slaking for weak rock, soundness against magnesium sulphide, and an acid test. A full summary of the abrasion testing program is included in Appendix B.

### 4.5.3 Key Conclusions and Recommendations:

The above results from the ABA, Metal Leaching, and Abrasion tests demonstrate that the quarry rock is suitable for rip-rap.

# 5 Hazardous Materials Management Plan

## 5.1 Soil Remediation for Contaminated Soils

A pre-closure inspection of the quarry site will determine if there are any contaminated soils or overburden. The contractor will be responsible for the removal of hydrocarbon contaminated material and transportation to a government approved hazardous waste facility.

## 5.2 Petroleum Handling

The proposed quarry will not require any on-site storage of petroleum products or explosives during operation. Best management practices for fueling quarry equipment will require that fuel is transferred from a pickup truck mounted slip tank. The pickup truck will be outfitted with safety equipment such as a spill kit, fire extinguisher, and a communication device for use during an emergency or to report a spill. If a spill is encountered, the contractor will first report to the supervisor, contain the spill onsite and contaminated soils will be excavated and transported to a government approved hazardous waste facility. The following measures will be taken to prevent and contain a spill:

- All equipment tanks will be visually monitored on a daily basis;
- Wherever practical, fuel level indicators will be provided;
- Refueling will take place in protected areas away from surface drainage channels;
- Training will be provided to all employees and contractors on proper tank filling procedures and emergency response procedures;
- Disposal procedures at the Sä Dena Hes Mine site will be developed by the Health, Safety, Security and Environment Supervisor; and
- Any spills will be reported to the Supervisor.

## 5.3 Explosives Handling

Drilling and blasting equipment will not be required to store explosives at the quarry development site. Explosives handling at the proposed quarry location will be conducted by a valid blasting ticket and permit.

Industry best practices will be adopted to maximize source control and minimize the potential for blasting compound dissolution to downstream waters. The following protective measures will be taken:

- Handling of explosives and blasting equipment will be conducted by qualified and trained personnel.
- When transporting, storing or handling explosives, care will be taken to avoid any spillage. Spilled product will be promptly reported, cleaned up and properly disposed of.

- Prior to loading explosives, blast holes will be inspected for the presence of water. If water is detected, plastic liners will be installed prior to the loading of holes. Water free explosive loads will minimize deterioration and dissolution of the explosives within the blast hole.
- A miss hole event due to an incomplete detonation of explosives will be reported to the site supervisor. Residual un-blasted material represents a potential source of nitrogen compounds having the potential to become soluble and enter fish bearing waters. Miss hole material will be cleaned up and surrounding contact soil will be excavated and disposed of on the Sä Dena Hes Mine site.
- In the event that nitrogen compounds have come in contact with surface waters, the following contingency actions can be taken:
  - Storage of impacted water within the quarry area in constructed sumps;
  - Pumping of water into tanker trucks for disposal; and
  - Other treatment options such as carefully discharging water onto an abundantly vegetated surface (approval may be required) after meeting regulatory requirements for water quality.

# 6 Decommissioning and Reclamation Plan

## 6.1 Closure of Active Quarry Face

The active quarry face will be sloped at 1:17 (H:V) during operation to closely manage closure issues related to drainage. Quarry headwall will be partially backfilled with the available material used to construct the roadside landing and overburden material within the quarry development area.

Figure 3 shows details of the proposed reclamation measures for the quarry including re-grading, backfilling, removal of the landing and approach, all final grades, and the re-establishment of the ditch line.

## 6.2 Approach Road and Landing Reclamation

Approach road and landing will be excavated down to a pre-quarry development state. Excavated material will be used to backfill against the quarry headwall and to cover exposed bed rock. The removed culvert from the landing approach will be recycled or re-used during the Sä Dena Hes decommissioning process. Roadside ditch line through the quarry development area will be re-established and grubbed out to convey surface flow.

## 6.3 Revegetation and Erosion Protection

Presently there is minimal vegetation growth at the proposed quarry development site. The backfilled pit will be scarified and seeded with a suitable native seed mix. If required, fall rye will be applied for erosion control.

# 7 Occupational Health and Safety Plan

## 7.1 Regulations

Quarry development safety is regulated through: the *Yukon Quartz Mining Act*; *Occupational Health and Safety Act* that includes *Surface and Underground Mines or Projects;* and the *Yukon Mine Site Reclamation and Closure Policy.* The Occupational Health and Safety Plan (OHSP) will be implemented throughout the operation and closure of the quarry development. The purpose of the OHSP is to:

- Protect and reclaim land and watercourses affected by quarry activities;
- Manage the extraction of rock rip-rap to maximize extraction and minimize environmental disturbance, taking into account sound engineering practice and economic conditions; and
- Protect employees and other persons from undue health and safety risks arising from quarrying.

## 7.2 Scheduled Hours of Work and Plan Implementation

The OHSP will be an integral part of the quarry development and instated throughout its lifecycle. The quarry development will commence during the 2014 construction season, from May to October 2014. Operations require a 12-hour working shift 7 am to 7 pm, Monday to Friday including some weekends when required. Late starts and early finishes will be scheduled around blasting to minimize stand down time.

To meet the goals of the OHSP, specific programs have been developed in this quarry development plan that address:

- Quarry Extraction;
- Water and Waste Management;
- Hazardous Materials Management; and
- Decommissioning and Reclamation.

## 7.3 Safety and Environmental Management

Safety is the responsibility of each and every person. Actions, or unsafe equipment, that place workers in a hazardous environment must be identified and address immediately. It is everyone's responsibility to immediately report all unsafe conditions to a designated Health, Safety, Security and Environment (HSSE) Supervisor (the Supervisor).

The HSSE Supervisor has the appropriate level of education and previous operational experience to carry out their responsibilities. The Supervisors experience includes inspection, accident and incident investigation and analysis, hazard identification, task analysis and procedures, emergency preparedness, training, record keeping, administration and communications.

## 7.4 Occupational Health Management

The HSSE Supervisor will be responsible for Occupational Health Management (OHM) of the quarry operation. The HSSE Supervisor is responsible for:

- Daily site tailgate meetings that present a safety message addressing Safety Plans and Procedures;
- Maintaining communication systems with each and every person involved with the quarry development;
- Assessing, monitoring, and reporting on all health, safety, and environmental matters;
- Obtaining government approvals, maintaining compliance and reporting in accordance with those approvals;
- Ensuring that environmental protection and mitigation are adequate from the health, safety and environmental perspective;
- Ensuring standards are implemented in the pit, off-site storage, and access roads;
- Ensuring adequate technical, scientific and legal information is available to make informed decisions during quarry operation and closure;
- Conduct routine inspections on equipment and erosion and sediment control structures;
- Develop and implement health and safety policies, procedures and practice. Particular attention will be given to those activities dealing with explosives, petroleum handling and equipment operation. Including maintaining copies of all Material Safety Data Sheets (MSDS) sheets;
- Monitoring employees for acute and chronic exposures within the workplace, including: air born particulate matter, fatigue, noise, and hazardous fumes;
- Monitoring particulate matter in the workplace environment;
- Maintaining that an appropriately equipped first aid kit will be located on the quarry development at all times; and
- Providing all employees with the necessary personal protective equipment such as: hard hats, safety glasses, hearing protection, safety boots, and any additional specialized safety equipment if required.

## 7.5 Training

All workers will be provided general training in safety, health and industrial hygiene; addition specialized training will be provided where necessary. General training includes:

- Workplace Safety;
- Communication using a 2-way radio, and satellite phone;
- Standard operating procedures;
- Proper use and maintenance of protective equipment;
- Housekeeping practices such as: waste disposal and storage of food;
- General first aid;
- Fire suppression;
- Emergency preparedness and procedures;
- Natural hazards;
- Interactions with wildlife;
- Environmental protection; and
- Regulatory requirements.

## 7.6 Wildlife Management

The quarry is located in an area that is frequently visited by black bears and moose. A management plan will be developed for the control of food and garbage wastes to ensure that they are not accessible to curious animals.

Haul traffic speeds will be established by the HSSE Supervisor to reduce the potential of impacting wildlife on the road way. When wildlife is spotted on the haul route or on site the Supervisor will be contacted and an appropriate wildlife management strategy will be employed.

# 8 Environmental Management Plan

## 8.1 Environmental Hazards

Quarry design, operation, and closure will ensure that the quarry development plan is designated and operated in a manner that minimized impacts to the environment.

### 8.1.1 Metal Losses:

Metal loss from equipment operation and drillings are expected to be negligible.

### 8.1.2 Petroleum Lubricants:

All waste oils and lubricants will be collected in a dedicated receptacle and disposed of as per the handling requirements in Section 5.2 of the Hazardous Materials Management Plan.

### 8.1.3 Explosives:

Explosives material handling will be managed as per the requirements in Section 5.3 of the Hazardous Materials Management Plan.

### 8.1.4 Human Presence:

To minimize the effects of human activities the following measures will be implemented:

- Waste management systems for the handling and disposal of refuse and sanitary waste have been developed; and
- Appropriate OHM, training and wildlife management systems have been developed.

### 8.1.5 Refuse and Sewage Disposal:

Refuse and Sewage is expected to be minimal, its handling and storage are addressed in Section 4.1 in the Water and Waste Management Plan.

### 8.1.6 Fuel Storage and Handling:

Fueling of equipment will be accomplished by using a purpose built fueling tank mounted to a pickup truck and no fuel or lubricants will be stored on-site. Section 5.2 in the Hazardous Material Management Plan addresses the handling and storage of Petroleum products on-site.

### 8.1.7 Equipment Wash Water:

All machinery will be removed from the quarry site to be cleaned at the Sä Dena Hes Mine.

### 8.1.8 Potable Water:

Potable water will be brought on-site in bottles or jugs.

### 8.1.9 Noise:

During the development of the quarry and the transportation of rip-rap noise levels will be increased above background levels. The increase in noise is unavoidable but due to the remoteness of the quarry development area the noise receptors are minimal. Noise mitigation measures include:

- Mufflers and noise dampening systems will be installed and maintained on equipment; and
- Sufficient hearing protection will be worn while in proximity and operating loud equipment.

### 8.1.10 Dust:

Dust related to quarry development will be primarily generated during the hauling of rip-rap back to the Sä Dena Hes Mine and during drilling. Speed control measures will be developed for haul traffic to minimize dust exposure and appropriate dust masks will be worn while in proximity to drilling. A water truck with a spray bar will provide dust suppression when necessary.

### 8.1.11 Safety Measures for Public Access:

Access to the quarry development is from the private Sä Dena Hes Mine access road. Proper signage will be erected on the access road warning traffic to reduce their speed. During blasts this road will be barricaded by personnel until deemed safe by the explosives experts.

## 8.2 Materials Handling and Management

A Hazardous Materials Management Plan has been provided in Section 5.0 for all expected materials on-site. Materials on-site that are considered to be hazardous are: diesel fuel, lubricants and explosives. These materials will be transported to site in accordance with the Transportation of Dangerous Goods Act, 1992 and Regulations administered by the Department of Transportation and the Yukon Department of Highways and Public Works.

There will be no storage of fuel or explosives at the quarry development site. All storage will be accommodated at the Sä Dena Hes Mine. Fueling and maintenance of on-site equipment will be conducted by a designated fuel and maintenance truck.

A file containing MSDS will be kept on-site. All personnel will be trained and provided appropriate personal protective equipment to handle all the hazardous materials on-site.

## 8.3 Spill Contingency Plan

Spill prevention and response strategies include:

- Notifying the Health, Safety, Security and Environment (HSSE) Supervisor that will initiate the emergency response plan;
- Initial assessment of the spill to understand its nature and extent;
- Mobilization of resources needed to address the spill;

- Source control activities;
- Initiate spill response activities;
- Reporting to the appropriate level of management; and
- Development of an action plan for reclamation and prevention of future spills.

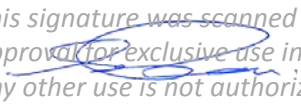
Spill response training will be provided to all personnel. Refresher training will be conducted as per the Occupational Health and Safety Plan. Training will include the instruction on personal protective equipment, safe handling of hazardous materials, good housekeeping measures, and a review of emergency response procedures.

### 8.3.1 Spills on Land:

Regardless the amount of hazardous material that is spilled, every effort should be made to contain and recover spills on land to prevent damage to soil, vegetation, and migration to water bodies. A fully supplied spill kit will be located on each piece of equipment to be used if a spill occurs.

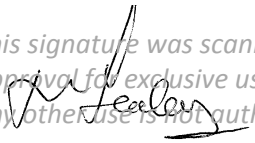
If a spill occurs, the contractor is responsible to remove and transport contaminated material to a government approved hazardous waste facility.

The ***"Sä Dena Hes Quarry Development Plan"***, was prepared by




Staff Consultant

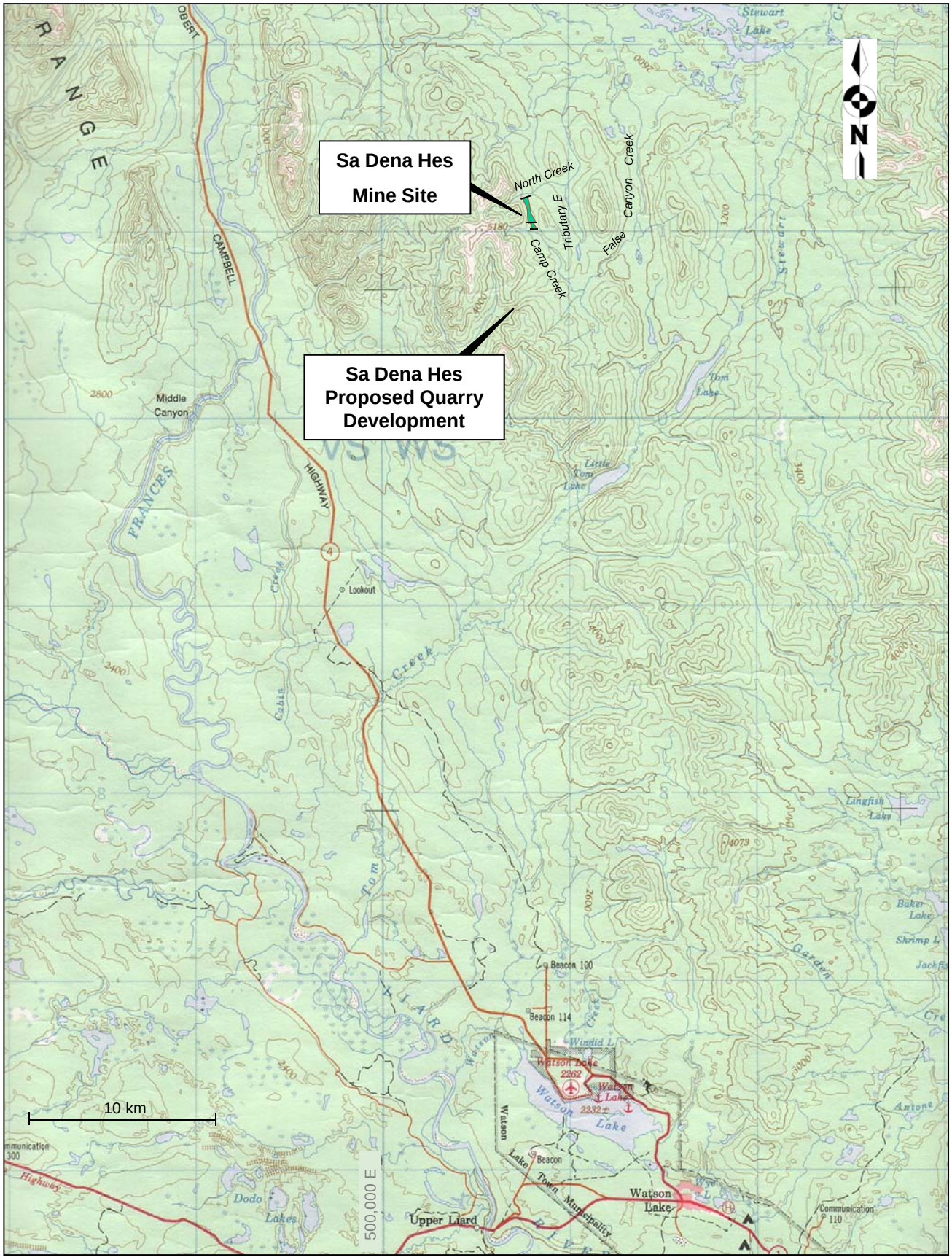
and reviewed by




Peter Healey, PEng
Principal Consultant

All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

Figures




| | | | | |
|---|---|---|---|---|
| srk consulting | Quarry Development plan | | | |
| Teck | **Project location** | | | |
| | PROJECT: 1CT008.035 | DATE: Sept. 2013 | APPROVED: | FIGURE: **1** |

File Ref: Figure1.1_Vicinity Map.ppt

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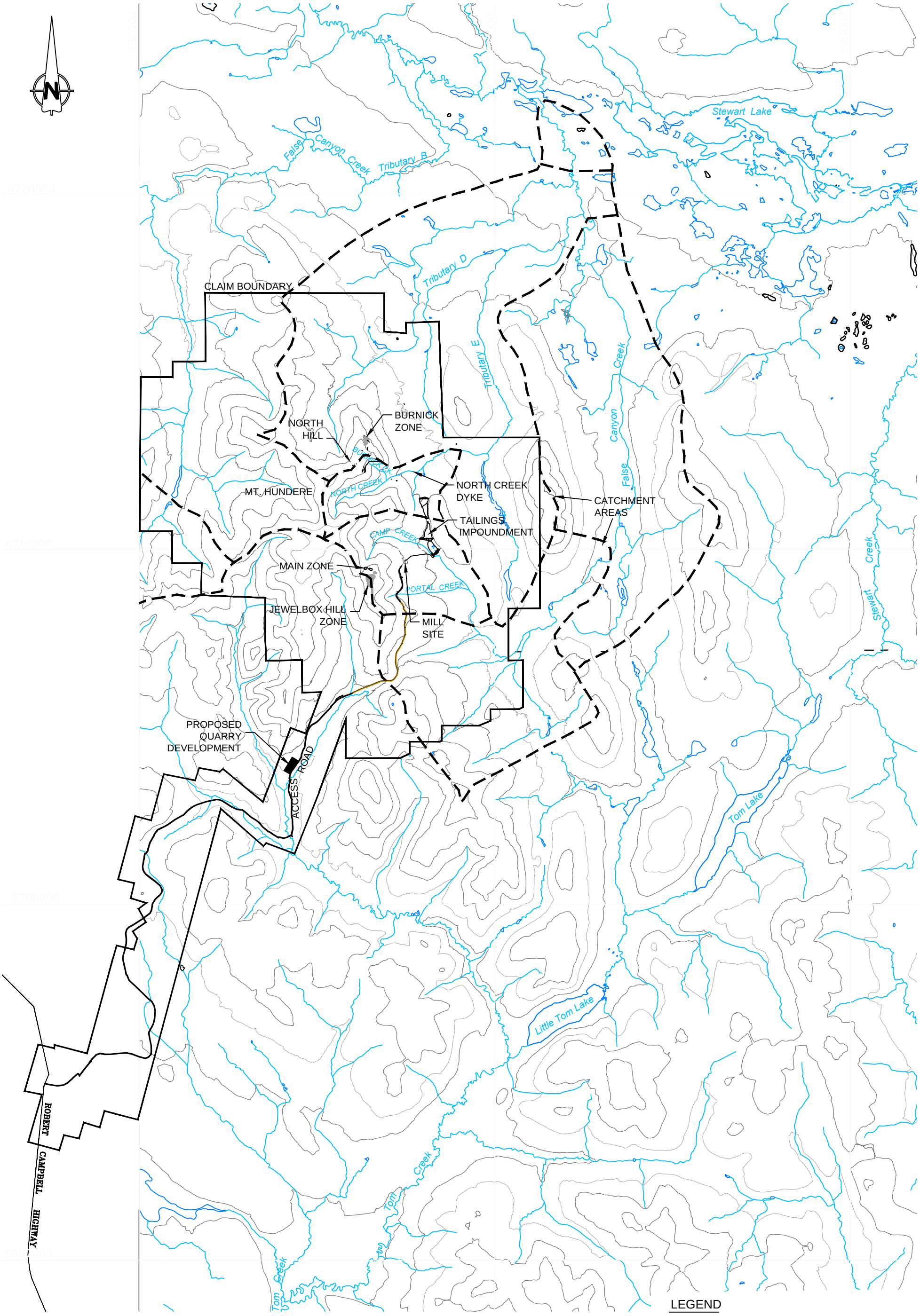



LEGEND

Catchment Area

NOTE

BASE TOPOGRAPHY FROM NORTH AMERICAN DATUM 1983. ALL SURFACE FACILITIES AND BOUNDARIES HAVE BEEN ADJUSTED FROM NAD 1927.

CONTOUR INTERVAL 100m

0 1000 2000 3000 4000 5000

Scale in Metres

srk consulting

Teck

Quarry Development Plan

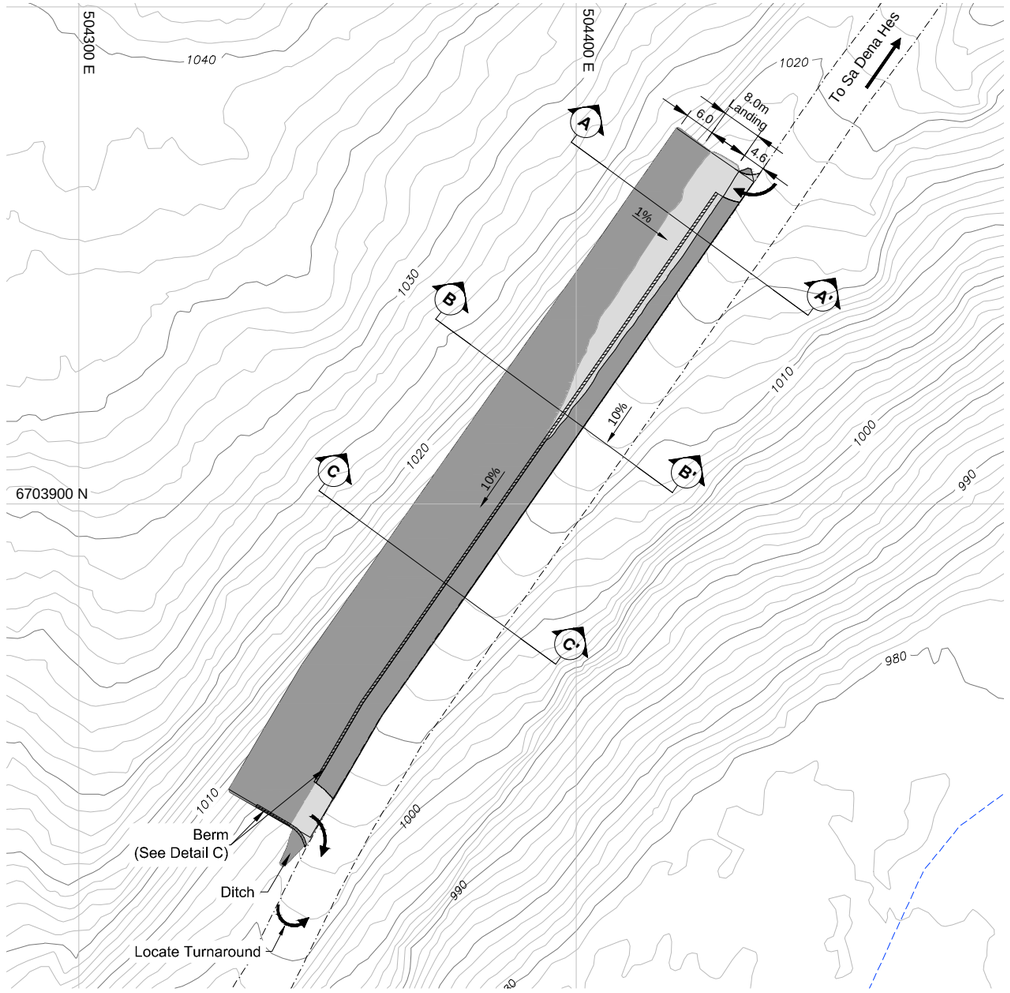
Vicinity Map

SRK JOB NO.: 1CT008-035

FILE NAME: Vicinity Map.dwg

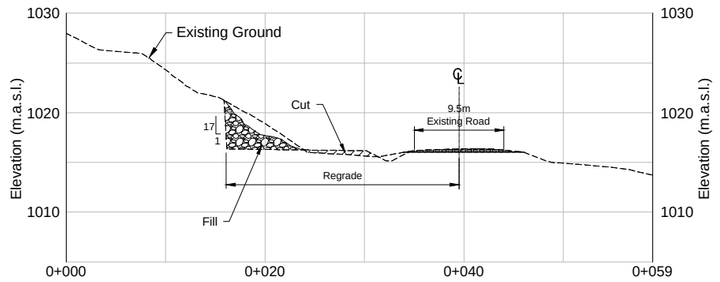
Sa Dena Hes

| DATE: | APPROVED: | FIGURE: |
|---|---|---|
| September 2013 | PMH | 2 |



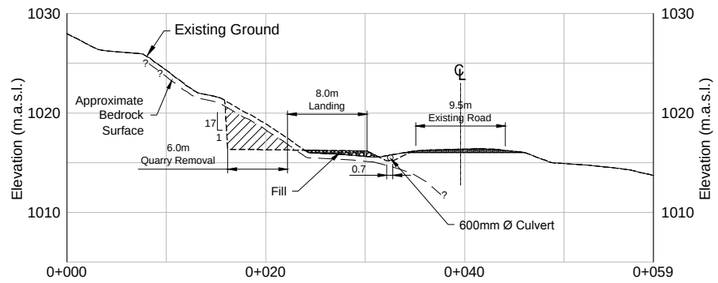

**PLAN VIEW**

0 10 20 30 40 50
Scale in Metres



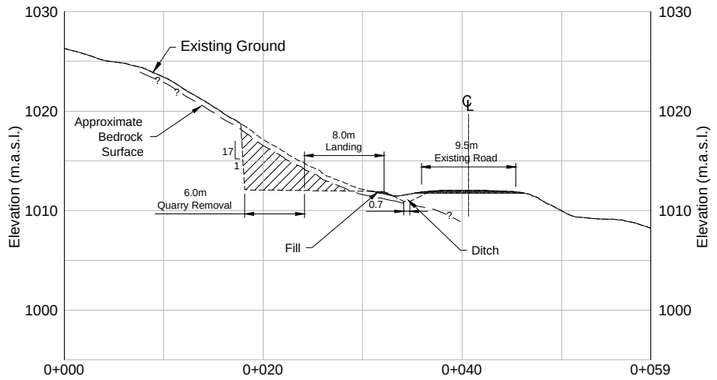

**RECLAMATION DETAIL**

0 2 4 6 8 10
Scale in Metres



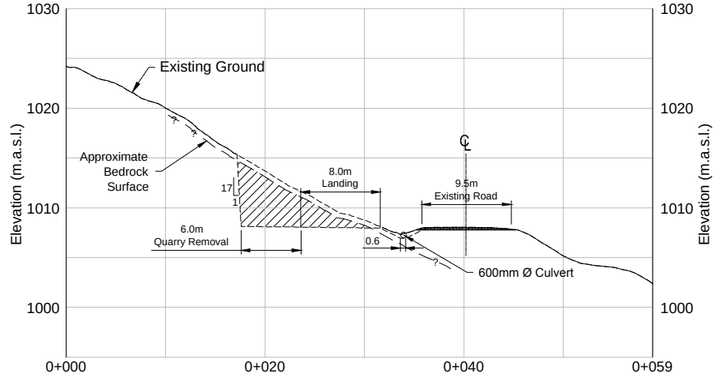

**A** **PROFILE A - A '**

0 2 4 6 8 10
Scale in Metres




**B** **PROFILE B - B '**

0 2 4 6 8 10
Scale in Metres




**C** **PROFILE C - C '**

0 2 4 6 8 10
Scale in Metres

## NOTES:

1. Topographic contour data was obtained from McElhanney and is based on August 15, 2012 LiDAR Survey.
2. Coordinate System is UTM NAD 83 CSRS Zone 9V.
3. Prior to hauling rip-rap a 1m high berm must be constructed at the south end of the landing.
4. Drilling and blasting will be conducted to fracture the bedrock into rip-rap for removal.
5. Quarry cut depth is provided as a distances from the road centerline.
6. Quarry headwall is to be sloped at 1:17 (H:V).
7. Neat quarry extraction volume is 3,500m3.
8. Bulked transported quarry volume is 4,700m3.
9. Reclamation of quarry consists of excavating the berm and landing to loosely backfill material against quarry floor and headwall.

## LEGEND

- Minor Contours
- Tom Creek Tributary
- Existing Road
- Berm
- Proposed Quarry Traffic Pattern
- Cut Area
- Fill Area

**Quarry Rock Extraction Summary:**

| $D_{50}$ Diameter Size (m) | Volume Required ($m^3$) |
|---|---|
| 0.3 | 2851 |
| 0.4 | 5135 |
| 0.5 | 102 |
| **Total Volume Needed** | 8100 |
| **Salvage from reclaim and south dam** | 3600 |
| **Quarry Extraction Volume** | 4500 |

NOT FOR CONSTRUCTION

srk consulting

SRK JOB NO.: 1CT008.035
FILE NAME: SDH-QP001.dwg

Teck

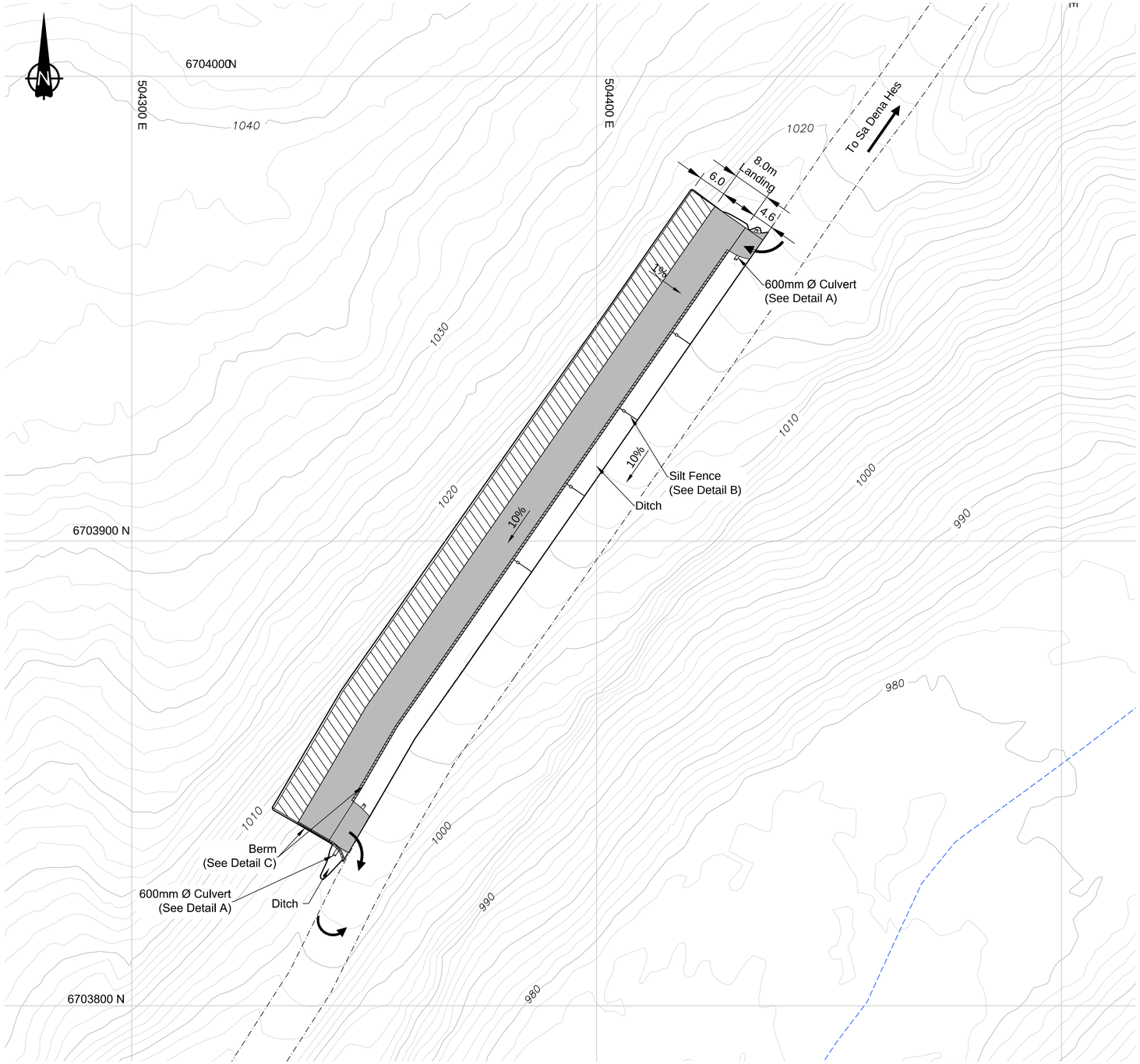
Sä Dena Hes

Quarry Development Plan

Plan and Sections

| DATE: | APPROVED: | FIGURE: |
|---|---|---|
| March 2014 | SM | 3 |

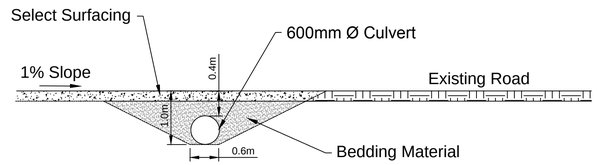
J:\01_SITES\Sa_Dena_Hes_ACAD\Quarry Figures (september 2013)\SDH-QP001-FIGURES_12042013.dwg



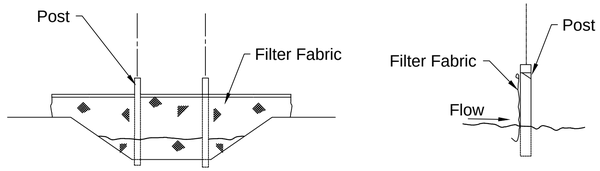

**PLAN VIEW**

0 5 10 15 20 25

Scale in Metres




**A DETAIL - 600mm Ø CULVERT**
**NTS**




**B DETAIL - SILT FENCE**
**NTS**


**C DETAIL - TYPICAL EARTH AND BOULDER BERM**
**NTS**

## LEGEND

- Minor Contours
- Existing Road
- Berm
- Proposed Quarry Traffic Pattern
- Loading Area
- Quarry Excavation

NOT FOR CONSTRUCTION

## NOTES:

1. Topographic contour data was obtained from McElhanney and is based on August 15, 2012 LiDAR Survey.
2. Coordinate System is UTM NAD 83 CSRS Zone 9V
3. Prior to drilling and blasting the overburden on the upslope quarry face will be removed with an excavator to construct the 8m roadside landing.
4. 2m by 1m (Width by Depth) ditch will be established between the mine access road and the landing.
5. 8m wide single direction landing approach roads will be constructed at either end of the landing.
6. Two (2) 600mm diameter culverts, 6m in length, will be installed on approach roads. See detail A.
7. Silt fences will be installed every 20m along the ditch. See Detail B.
8. Haul trucks are required to exit the landing on the south approach and use a safe turnaround at the bottom of the hill.
9. Signage on access road to be provided by contractor in accordance with safety plan.

srk consulting

SRK JOB NO.: 1CT008.035
FILE NAME: SDH-QP001.dwg

Teck

Sä Dena Hes Project

Quarry Development Plan

Plan and Details

| DATE: | APPROVED: | FIGURE: |
|---|---|---|
| March 2014 | SM | 4 |

J:\01_SITES\Sa_Dena_Hes\1_ACAD\Quarry Figures (september 2013)\SDH-QP001-FIGURES_12042013.dwg

# Appendix A: Assessment for Acid Base Accounting

Maxxam Analytics 4606 Canada Way, Burnaby, BC Canada V5G 1K5 Tel: 604 734 7276 Fax: 604 731 2386 www.maxxam.ca

Client: TECK RESOURCES LTD.



**Table 1: ABA Test Results for project SA DENA HES MINE**

| Maxxam Sample No | Sample ID | Paste pH | CO2 | CaCO3 Equiv. | Total S | HCl Extractable Sulphur | Sulphide Sulphur (by diff.) | Acid Generation Potential | Mod. ABA Neutralization Potential | Fizz Rating | Net Neutralization Potential | Neutralization Potential Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Units | pH Units | wt% | Kg CaCO3/T | wt% | wt% | wt% | Kg CaCO3/T | Kg CaCO3/T | N/A | Kg CaCO3/T | N/A |
| HA0013 | SDH-R3 - RECLAIM DAM BUTT | 8.94 | 44.11 | 1003 | <0.02 | <0.01 | <0.02 | <0.6 | 950.0 | STRONG | 950.0 | #N/A |
| HA0014 | SDH-R4 - MAIN ACCESS ROAD | 9.38 | 36.78 | 835.9 | <0.02 | <0.01 | <0.02 | <0.6 | 791.3 | STRONG | 791.3 | #N/A |
| HA0015 | SDH-R3 - RECLAIM DAM BUTT DUP | 8.93 | 43.78 | 995.0 | <0.02 | <0.01 | <0.02 | <0.6 | 948.8 | STRONG | 948.8 | #N/A |
| *Detection Limits* | | *N/A* | *0.02* | *0.5* | *0.02* | *0.01* | *0.02* | *0.6* | *0.1* | *N/A* | *0.1* | *N/A* |
| *Maxxam SOP #* | | *BBY0-00003* | | *Calculation* | *Acme* | *BBY0-00010* | *Calculation* | *Calculation* | *BBY0SOP-00020* | *BBY0SOP-00* | *Calculation* | *Calculation* |

**Notes:**

Lawrence, R.W. 1991. Acid Rock Drainage Prediction Manual

**References:**

Acid Generation Potential = Sulphide Sulphur (by diff.)*31.25

CaCO3 Equivalency = Carbonate Carbon (CO2)*(100/44)*10

Carbonate carbon (CO2; HCl direct method) by Leco done at Acme Labs.

Fizz Rating - Reference method used is based on NP method.

Net Neutralization Potential = (Modified ABA Neutralization Potential)-(Acid Generation Potential (S-S by diff))

Mod. ABA Neutralization Potential - MEND Acid Rock Drainage Prediction Manual, MEND Project 1.16.1b (pages 6.2-11 to 17), March 1991.

Neutralization Potential Ratio = (Neutralization Potential)/(Acid Generation Potential)

Paste pH - Field and Laboratory Methods Applicable to Overburdens and Minesoils, (EPA 600 / 2-78-054, March 1978).

Sulphide Sulphur = (Total Sulphur)-(Sulphate Sulphur)

Total sulphur, total carbon & carbonate carbon (CO2; HCl direct method) by Leco done at Acme Labs.

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Client: RESOURCES LTD.



**Table 2: ABA QAQC Test Results for project SA DENA HES MINE**

| | **Duplicate QC** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Maxxam Sample No** | **Sample ID** | Paste pH Reported | **Paste pH Dup** | | | HCl Extractable Sulphur Reported | **HCl Extractable Sulphur Dup** | Mod. ABA Neutralization Potential Reported | **Mod. ABA Neutralization Potential Dup** | Fizz Rating Reported | **Fizz Rating Dup** |
| | **Units** | pH Units | pH Units | | | wt% | wt% | Kg CaCO3/T | Kg CaCO3/T | N/A | N/A |
| HA0013 Dup | SDH-R3 - RECLAIM DAM BUTT | 8.94 | 8.97 | | | <0.01 | <0.01 | 950.0 | 951.3 | STRONG | STRONG |

| **Reference Material QC** | | | | | | |
|---|---|---|---|---|---|---|
| | Paste pH | | CO2 | Total S | HCl Extractable Sulphur | Mod. ABA Neutralization Potential |
| | | | | | | |
| **Units** | pH Units | | wt% | wt% | wt% | Kg CaCO3/T |
| **Reference Material** | | | | | | |
| ARD Ref Mat C&S (0.16 wt%) | | | | 0.17 | | |
| ARD Spike CO2 (1.55 wt%) | | | 1.37 | | | |
| Reference Material (58.9 Kg CaCO3/T) | | | | | | 56.3 |
| PPHARD 2012-1 (8.34 pH Units) | 8.17 | | | | | |
| ARD Ref Mat C&S (2.35 wt%) | | | | 2.26 | | |
| ARD Spike CO2 (1.55 wt%) | | | 1.46 | | | |
| ARD Ref Mat SO4-S (0.06 wt%) | | | | | 0.07 | |

| **Blank QC** | | | | | | |
|---|---|---|---|---|---|---|
| Method Blank | | | | <0.02 | | |
| Method Blank | | | 0.03 | | | |
| Method Blank | | | | | <0.01 | |

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Client: TECK RESOURCES LTD.



**Table 3: Aqua Regia Metals Test Results for project SA DENA HES MINE**

| Maxxam Sample No | Sample ID | Mo | Cu | Pb | Zn | Ag | Ni | Co | Mn | Fe | As | U | Au | Th | Sr | Cd | Sb | Bi | V | Ca | P | La | Cr | Mg | Ba | Ti | B | Al | Na | K | W | Hg | Sc | Tl | S | Ga | Se | Te |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Units | | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm | % | ppm | ppm | ppb | ppm | ppm | ppm | ppm | ppm | ppm | % | % | ppm | ppm | % | ppm | % | ppm | % | % | % | ppm | ppm | ppm | ppm | % | ppm | ppm | ppm |
| HA0013 | SDH-R3 - RECLAIM DAM BUTT | 0.3 | 1.5 | 10.6 | 15 | <0.1 | 2.7 | 0.3 | 159 | 0.09 | 1.8 | 0.6 | 1.5 | <0.1 | 315 | 1.7 | 0.6 | <0.1 | 2 | 34.8 | 0.014 | <1 | 3 | 0.20 | 29 | <0.001 | <20 | 0.02 | 0.005 | <0.01 | <0.1 | <0.01 | 0.2 | <0.1 | <0.05 | <1 | <0.5 | <0.2 |
| HA0014 | SDH-R4 - MAIN ACCESS ROAD | 2.8 | 3.3 | 1.4 | 11 | <0.1 | 15.6 | 0.4 | 165 | 0.25 | 6.1 | 0.4 | <0.5 | 0.3 | 81 | <0.1 | 1.0 | <0.1 | 89 | 15.2 | 0.017 | 7 | 31 | 9.83 | 417 | <0.001 | <20 | 0.03 | 0.014 | 0.01 | <0.1 | <0.01 | 0.4 | <0.1 | <0.05 | <1 | <0.5 | <0.2 |
| HA0015 | SDH-R3 - RECLAIM DAM BUTT DUP | 0.2 | 1.0 | 8.6 | 18 | <0.1 | 6.4 | 0.4 | 160 | 0.10 | 2.1 | 0.6 | 0.6 | 0.1 | 322 | 2.0 | 0.5 | <0.1 | 2 | 36.0 | 0.015 | <1 | 2 | 0.18 | 28 | <0.001 | <20 | 0.01 | 0.005 | <0.01 | <0.1 | <0.01 | <0.1 | <0.1 | 0.07 | <1 | <0.5 | <0.2 |
| **QAQC** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Duplicates** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| HA0014 Dup | SDH-R4 - MAIN ACCESS ROAD | 2.7 | 3.3 | 1.4 | 10 | <0.1 | 14.5 | 0.4 | 167 | 0.26 | 5.9 | 0.4 | 0.6 | 0.3 | 80 | 0.1 | 1.1 | <0.1 | 90 | 15.2 | 0.018 | 7 | 41 | 9.92 | 416 | <0.001 | <20 | 0.03 | 0.015 | 0.01 | <0.1 | <0.01 | 0.3 | <0.1 | <0.05 | <1 | 0.6 | <0.2 |
| **Blanks** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Method Blank | | | | | | | | | | <0.01 | | | | | | | | | | <0.01 | <0.001 | | | <0.01 | | <0.001 | | <0.01 | <0.001 | <0.01 | | | | | <0.05 | | | |
| Method Blank | | <0.1 | <0.1 | <0.1 | <1 | <0.1 | <0.1 | <0.1 | <1 | | <0.5 | <0.1 | | <0.1 | <1 | <0.1 | <0.1 | <0.1 | <2 | | | <1 | <1 | | <1 | | <20 | | | | <0.1 | <0.01 | <0.1 | <0.1 | | <1 | <0.5 | <0.2 |
| Method Blank | | | | | | | | | | | | | <0.5 | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Reference Material** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REF OREAS45EA (%) | | | | | | | | | | 23.7 | | | | | | | | | | 0.0400 | 0.0300 | | | 0.0900 | | 0.0900 | | 3.14 | 0.0210 | 0.0500 | | | | | <0.05 | | | |
| **True Values REF OREAS45EA** | | | | | | | | | | **22.65** | | | | | | | | | | **0.032** | **0.029** | | | **0.095** | | **0.106** | | **3.32** | **0.027** | **0.053** | | | | | **0.044** | | | |
| Percent Difference | | | | | | | | | | 4.6 | | | | | | | | | | 25.0 | 3.4 | | | -5.3 | | -15.1 | | -5.4 | -22.2 | -5.7 | | | | | | | | |
| **Reference Material** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REF OREAS45EA PPM | | 1.20 | 718 | 14.4 | 30.0 | 0.300 | 403 | 53.2 | 418 | | 8.70 | 1.70 | | 9.90 | 4.00 | <0.1 | 0.200 | 0.400 | 317 | | | 7.00 | 848 | | 138 | | <20 | | | | <0.1 | <0.01 | 77.3 | <0.1 | | 12.0 | <0.5 | <0.2 |
| **True Values REF OREAS45EA PPM** | | **1.78** | **709** | **14.3** | **30.6** | **0.311** | **357** | **52** | **400** | | **11.4** | **1.73** | | **10.7** | **4.05** | **0.03** | **0.64** | **0.26** | **295** | | | **8.19** | **849** | | **148** | | | | | | | **0.34** | **78** | **0.072** | | **11.7** | **2.09** | **0.11** |
| Percent Difference | | -32.6 | 1.3 | 0.7 | -2.0 | -3.5 | 12.9 | 2.3 | 4.5 | | -23.7 | -1.7 | | -7.5 | -1.2 | | -68.8 | 53.8 | 7.5 | | | -14.5 | -0.1 | | -6.8 | | | | | | | -0.9 | | | 2.6 | | |
| **Reference Material** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REF OREAS45EA PPB | | | | | | | | | | | | | 52.7 | | | | | | | | | | | | | | | | | | | | | | | | | |
| **True Values REF OREAS45EA PPB** | | | | | | | | | | | | | **53** | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percent Difference | | | | | | | | | | | | | -0.6 | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Reference Material** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REF DS9% | | | | | | | | | | 2.40 | | | | | | | | | | 0.730 | 0.0860 | | | 0.630 | | 0.107 | | 0.970 | 0.0880 | 0.410 | | | | | 0.170 | | | |
| **True Values REF DS9%** | | | | | | | | | | **2.37** | | | | | | | | | | **0.776** | **0.0844** | | | **0.6437** | | **0.1239** | | **0.9915** | **0.0905** | **0.3874** | | | | | **0.1737** | | | |
| Percent Difference | | | | | | | | | | 1.3 | | | | | | | | | | -5.9 | 1.9 | | | -2.1 | | -13.6 | | -2.2 | -2.8 | 5.8 | | | | | -2.1 | | | |
| **Reference Material** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REF DS9 PPM | | 12.0 | 111 | 140 | 324 | 1.60 | 43.3 | 8.20 | 615 | | 26.6 | 2.70 | | 6.20 | 70.0 | 2.50 | 4.50 | 5.80 | 42.0 | | | 12.0 | 128 | | 320 | | <20 | | | | 2.50 | 0.190 | 2.40 | 5.40 | | 5.00 | 5.70 | 5.20 |
| **True Values REF DS9 PPM** | | **12.74** | **104** | **126** | **322** | **1.69** | **39.5** | **7.6** | **586** | | **27** | **2.9** | | **7.15** | **76.1** | **2.3** | **4.84** | **6.78** | **40** | | | **15.7** | **119** | | **308** | | | | | | **3** | **0.225** | **2.8** | **5.48** | | **4.84** | **5.4** | **5.0** |
| Percent Difference | | -5.8 | 6.8 | 11.2 | 0.6 | -5.3 | 9.6 | 7.9 | 4.9 | | -1.5 | -6.9 | | -13.3 | -8.0 | 8.7 | -7.0 | -14.5 | 5.0 | | | -23.6 | 7.6 | | 3.9 | | | | | | -16.7 | -15.6 | -14.3 | -1.5 | | 3.3 | 5.6 | 4.0 |
| **Reference Material** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REF DS9 PPB | | | | | | | | | | | | | 97.7 | | | | | | | | | | | | | | | | | | | | | | | | | |
| **True Values REF DS9 PPB** | | | | | | | | | | | | | **118** | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percent Difference | | | | | | | | | | | | | -17.2 | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Detection Limits* | | *0.1* | *0.1* | *0.1* | *1* | *0.1* | *0.1* | *0.1* | *1* | *0.01* | *0.5* | *0.1* | *0.5* | *0.1* | *1* | *0.1* | *0.1* | *0.1* | *2* | *0.01* | *0.001* | *1* | *1* | *0.01* | *1* | *0.001* | *20* | *0.01* | *0.001* | *0.01* | *0.1* | *0.01* | *0.1* | *0.1* | *0.05* | *1* | *0.5* | *0.2* |
| *Acme SOP #* | | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* | *1DX* |

Maxxam Analytics 4606 Canada Way, Burnaby, BC Canada V5G 1K5 Tel: 604 734 7276 Fax: 604 731 2386 www.maxxam.ca

**Table 4: Sample List Test Results for project SA DENA HES MINE**

| Maxxam Sample ID | Client Sample ID | Sample Form | Dry Weight Received (kg) |
|---|---|---|---|
| | | | |
| HA0013 | SDH-R3 - RECLAIM DAM BUTT | ROCK | 3.460 |
| HA0014 | SDH-R4 - MAIN ACCESS ROAD | ROCK | 4.060 |

| | |
|---|---|
| Total Weight | 7.52 |
| Total Samples Received | 2 |

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**Table 5: Sample Summary for project SA DENA HES MINE**

TECK RESOURCES LTD., SA DENA HES MINE


| | |
|---|---|
| Date Samples Rec'd by Maxxam: | 3 sample were rec'd on 25-Jul-2013. |
| Sample Prep Conducted by Maxxam: | YES |
| Date of Analysis: | August 2013 |

| | |
|---|---|
| **Client:** | TECK RESOURCES LTD. |
| **Client Project Name:** | SA DENA HES MINE |
| **Client Project No:** | 1CT008.040 SA DENA HES DECOMM. |
| **ARD Project #:** | 8470 |
| **Maxxam Job No:** | B363952 |
| **Contact Person:** | Jay Cherian (SRK) |
| **E-mail Address:** | jcherian@srk.com |

| | |
|---|---|
| **Data Validated by:** | Kevin Bunten |
| **Position:** | ARD - Senior Scientific Specialist |

**Sample Storage**

Sample rejects (and selected test residues where applicable) have been archived
Standard archive protocol is archiving for samples for 3 months after testing is complete.
If archiving is required past 3 months a fee will be required.

# Appendix B: Abrasion Testing

SRK Consulting (Canada) Inc.
Suite 2200 - 1066 West Hastings Street
Vancouver, BC V6E 3X2

**T: +1.604.681.4196**
**F: +1.604.687.5532**

vancouver@srk.com
www.srk.com

# Memo

| | | | |
|---|---|---|---|
| **To:** | Gerry Murdock | **Date:** | Oct 22, 2012 |
| **Company:** | Teck Resources | **From:** | Murray McGregor, Peter Healey |
| **Copy to:** | | **Project #:** | 1CT008.029 |
| **Subject:** | Rip Rap Suitability | | |

## 1 Introduction

SRK Consulting (Canada) Inc. (SRK) has completed a testing program on a sample of rock obtained from a sidehill exposure located at km 17 on the haul road to the Sa Dena Hes mine. The location has been identified as a potential borrow source for riprap material that is required as part of the reclamation and closure of the mine.

## 2 Field Level Indicator Testing

The samples collected are described as fine grained sandstone with trace carbonate veining. Veins are spaced roughly 2cm apart and are typically about 1mm thick. Several simple test procedures were performed to assess the suitability of rock samples as riprap. The procedures are detailed in the following sections.

### 2.1 Intact Rock Strength

The intact rock strength (IRS) provides an indication of material durability. Results from this test are used to assess resistance to particle abrasion and ability to remain intact under passive loading. The test is completed using the standard set by the International Society for Rock Mechanics shown in Figure 1 below and is typically completed as part of geotechnical rock logging of diamond drill holes and assumes a cylindrical shaped sample that is roughly 15cm long. Because the rock being tested is of irregular shapes and size, this test will only provide indicator information.

| | | | |
|---|---|---|---|
| R0 | Extremely Weak | Indented by Thumbnail | 0.25 - 1.0 |
| R1 | Very Weak | Crumbles under firm blow of geologic hammer pick, peeled by pocket knife | 1.0 - 5.0 |
| R2 | Weak | Shallow indentation under firm blow of pick end of geologic hammer | 5.0 - 25 |
| R3 | Medium Strong | Fractured with single firm blow of geologic hammer | 5 - 50 |
| R4 | Strong | Requires more than one blow of hammer to fracture | 50 - 100 |
| R5 | Very Strong | Requires many blows of hammer to fracture | 100 - 250 |
| R6 | Extremely Strong | Can only be chipped with strong blows of hammer | > 250 |

**Figure 1: IRS Guide from the International Society for Rock Mechanics.**

### 2.2 Freeze Thaw

Freeze thaw test is used to assess the susceptibility of particle breakage during seasonal changes in weather. For this test, samples were left to soak in water overnight before freezing and thawing several times in a conventional freezer.

### 2.3 Jar Slaking for Weak Rock

The Jar Slaking test is used to assess type and rapidity of weathering of weak rock. The test is completed by submerging samples in tap water and monitoring them over an hour.

### 2.4 Soundness against Magnesium Sulphate

This test provides information for material susceptibility to weathering. Samples are placed into beakers and filled with a solution of magnesium sulphate. The weights of the samples were recorded before and after to obtain the sample weight reduction due to reaction with the magnesium sulphate solution. In this case the magnesium sulphate solution had a concentration of 140g/L. The loss of material is presented as a percentage of original mass. Three samples were used to double check the results.

### 2.5 Acid Test

A 10% hydrochloric acid solution is dropped on the sample surface and the effect is recorded. This test is performed to check for the presence of carbonate minerals. This is necessary since carbonate minerals can potentially dissolve in acidic water due to acid rock drainage or high dissolved carbon dioxide.

## 3 Results

When testing for IRS, each sample took several blows from a hammer before it broke. Based on the rock strength guide shown in Figure 1, this is strong rock with a uniaxial compressive strength between 50 and 100 MPa. Freeze thaw tests showed no visible signs of frost jacking and subsequent IRS testing continued to indicate strong rock.

Weathering tests—Jar Slaking and Soundness against Magnesium Sulphate—had no visual effect on the sample or the fluid it was submersed in. As well, the sample weights taken before and after both tests confirm that there was no change in mass.

When acid was introduced to the sample, slight to moderate fizzing was noted on veins indicating that carbonate minerals are present within the vein structure. The veins make up a small portion of the overall sample and no fizzing is noted where veins do not exist.

# 4 Discussion and Conclusion

The intact strength of the samples collected indicate that the rock is sufficient to withstand passive pressures and particle abrasion expected of typical riprap use. Vein contacts have comparable strength and are not suspected of presenting significant weakness within the rock structure. Slight breakage can be expected where partially filled joints exist, but this is not flagged as significant concern.

The presence of carbonates can lead to material decay under acidic conditions; however, provided the pH in not excessively low (less than 4 pH) metal oxides can form protective coatings and prevent further weathering. For the conditions expected at Sa Dena Hes, it is unlikely there would be any major deterioration of carbonates. In addition, carbonates make up only a small portion of each rock. Ancillary weathering tests that yield no change in appearance or mass also indicate that there would be minimal weathering for this rock type.

The above results suggests that the material would be a suitable source for use as riprap.

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