An Approach to Closure Planning & Design

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Introduction

This presentation aims to provide guidelines for:

- Conceptual closure planning and design;
- Closure site characterization, analysis and evaluation; and
- Detailed closure design.

Acknowledgements

The guidelines incorporate key requirements of different corporate closure planning guidelines (acknowledging specifically RT and BHP Billiton closure planning guidelines), and SRK experience in developing and auditing closure plans and closure design.

Conceptual Closure Planning and Design

Step 1: Closure Planning Data Base

Develop a site closure data base/library (i.e., existing technically valid data that characterizes site conditions potentially influencing, or potentially influenced by mine closure). Initial planning is performed using available data only (i.e., no additional characterization until it can be justified by the process). The libraries developed to date have been assets for both closure planning and continued operations.

Document Research Matrix identifies potential pertinence of data contained in existing documents a to specific closure elements/characteristics.

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Step 2: Identification and Preliminary Classification of Site Facilities

Identify and document all site facilities and based on available operational data and physical inspection, classify into facility types that may require similar closure actions, e.g., gold heap leach facilities, waste rock dumps consisting of similar waste rock types, tailings disposal facilities, pits with lakes, dry open pits, crushing and milling process plant facilities, buildings, infrastructure, etc. This preliminary classification may change after data review and future characterization.

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Step 3: Documentation of Site Conditions Affecting Closure

Document known and baseline site conditions based on data research and physical inspection for:

- Existing facility status
- Anticipated facility status at closure
- Groundwater resources
- Surface water resources
- Air quality
- Physical and geochemical characteristics of process and waste materials
- Chemical characteristics and flowrates/volumes of site waters requiring management
- Climatologic conditions
- Site soils and erosion potential
- Potential closure borrow sources
- Site vegetation
- Avian and terrestrial wildlife
- Others

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Step 4: Site Regulatory Analysis

To identify regulatory closure criteria. Analysis must cover all pertinent regulatory bodies and regulations.

Note: This is the minimum criteria evaluation required and criteria identified are those required to be met in state and federal closure and reclamation plans. Either of the following four steps (Steps 5, 6, 7 and 8) are optional, depending on corporate policy.

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Step 5: Stakeholder Analysis

Identify all existing and potential stakeholders and perform a site stakeholder analysis to document potential and existing stakeholder issues and develop closure criteria to address these issues.

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Step 6: Corporate and Site Management Criteria

Identify corporate and site management goals (overarching goals) for closure including (for example) financial and cash flow reporting requirements and asset preservation strategies.

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Step 7: Closure Impact Assessment

Use criteria identified in Steps 4 through 6 to identify potential impacts of closure to health, safety, environment and community for conditions potentially resulting from facility closure (i.e., potential impacts if no closure stabilization actions performed (“zero-base”).

Example: Impact Assessment Table including facility information obtained under Steps 1 through 6

Table 1 - Closure Impact Assessment
Facility:
Location:
Relevant Documents:
Legal/Regulatory/Corporate Requirements:
Landowner and Community Expectations:
Post-closure Landuse:
Existing and Future Site Conditions: *Summary of Existing Facilities* *Facilities Anticipated at Closure* *Site Conditions Influencing Closure Planning* **1. Community Activity:** **2. Flora and Fauna:** **3. Cultural Resources:** **4. Groundwater Resources:** **5. Surface Water Resources:** **6. Soil Borrow Resources:** **7. Site Climatology:** **8. Physical Characteristics of Residue:** **9. Environmental Chemical Characteristics of Residue:** **10. Physical Characteristics of Foundation Soils:** **11. Chemical Characteristics of Foundation Soils:**
Impact Assessment:

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Step 8: Risk Assessment

Develop a site closure risk register that:

- Identifies and ranks risk issues resulting from impacts identified under Step 7,
- Identifies risk issues that require risk management to appropriately reduce the zero-base ranking; and
- Develops “risk management criteria”.

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Step 9: Conceptual Closure Design

Develop conceptual engineering options that provide solutions that at a minimum address the established “conceptual design” criteria established under Steps 4, 5, 6 and 8, and address risk management criteria.

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Step 10: Basis of Cost Estimate

Develop a Basis of Cost Estimate that provides details of how quantities are measured and how unit rates are obtained.

Example: Table of Contents

Basis of Closure Cost Estimates

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Step 11: Cost Estimates

Develop cost estimates (that meet corporate financial reporting criteria) to compare capital and operating costs for each conceptual option

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Step 12: Residual Risk Assessment

Use the risk register developed under Step 8 to demonstrate that the closure options selected provide appropriate risk reduction. Evaluate the relative risk reduction benefits for each option.

Qualitative Residual Risk Assessment for Post-Closure Contamination of Groundwater

RESULTS

Issue ID:	
Issue Description:	*Seepage results in contamination of groundwater resources*
Risk Ranking:	*Moderate to Significant*

RISK DETERMINATION

Ranking Methodology: *(1) Determine Likelihood of risk. (2) Determine severity levels using "HSEC Consequence Severity Ranking Table" and summarize in Table-A. (3) Utilizing the maximum severity level and likelihood, determine ranking of risk from Table-B.*

(1) Likelihood Unlikely to Possible

(2) Consequence Severity

Table-A: Consequence Severity Ranking Table Summary[1]

Impact To	*Consequence Severity (Site Level)*				
	Level 1	*Level 2*	*Level 3*	*Level 4*	*Level 5*
Injury and Disease	#				
Environmental Effects			#		
Social/Cultural Heritage		#			
Community, Gov't, Media, Reputation			#		
Legal		#			
Operational Impact	#				
Total Estimated Costs [2]			#		

(3) Risk Ranking Utilizing the maximum severity level and likelihood, determine risk ranking using Table-B.

Table-B: Qualitative Risk Matrix[3]

Likelihood	*Consequence Severity (Site Level)*				
	Level 1	*Level 2*	*Level 3*	*Level 4*	*Level 5*
Almost Certain					
Likely					
Possible			#		
Unlikely			#		
Rare					

HIGH RISK

SIGNIFICANT RISK

MODERATE RISK

LOW RISK

1 Reference Health Safety and Environment (HSE) Consequence Severity Ranking Table

2 Includes safety, health and environment related costs, e.g. potential clean-up, corrective actions, fines, liabilities

3 Reference HSEC Risk Management Manual

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Step 13: Optimization of Conceptual Design

Select and cost the conceptual closure design options that are judged to best meet all established criteria and risk reduction goals.

Closure Characterization, Analysis and Evaluation

Step 1: Identify Characterization Needs

Identify potential cost-reduction opportunities that may meet closure stabilization criteria, but can not be considered feasible at the conceptual design stage as a closure design option based on a lack of data. Also identify key assumptions that need validation and any risk issues that require additional data and evaluation.

Closure Characterization, Analysis and Evaluation

Step 2: Workscope Development

Identify and document additional targeted field characterization, analysis and evaluation required to demonstrate feasibility of potential cost-reduction opportunities, refine risk evaluation or validate key conceptual design assumptions.

Closure Characterization, Analysis and Evaluation

Step 3: Implementation

- Implement site characterization/operational monitoring plans to obtain the targeted data and analytical results, and perform evaluations necessary for demonstration of adequacy of conceptual closure options (including) cost reduction opportunities.

Detailed Closure Design

Step 1: Selection of Detailed Closure Design

Integrate findings of Closure Characterization, Analysis and Evaluation into selected conceptual design (Conceptual Closure Design – Step 13) to define closure actions for which detailed engineering design is required, including incorporation where appropriate of cost-saving opportunities.

Detailed Closure Design

Step 2: Detailed Design Criteria

Revisit criteria assessments and refine to include specific additional engineering criteria required for inclusion in the detailed design, including closure performance criteria.

Detailed Closure Design

Step 3: Closure Design Report

Develop detailed closure engineering designs, including construction drawings, specifications, quantities and construction and post-construction maintenance schedules.

Detailed Closure Design

Step 4: Closure Expenditure Forecast

Revisit the Basis of Cost Estimate, update according to the detailed design scope of work, and use to develop detailed closure expenditure forecasts.

Questions

Criteria vs Objectives vs Goals

- Criterion – a standard on which a judgment may be made
- Goal – aim, purpose (or…a successful attempt to score)
- Objective – aim, goal or end of action

<u>Criteria provide the BASIS for design development</u>

Criteria Matrix

[Criteria Matrix for each facility or facility element requiring closure: Example for Arizona Tailings Impoundment]

Closure Design Elements Include:

- Upstream stormwater diversion facilities
- Tailings embankment
- Tailings beach and basin
- Reclaim water management facilities
- Slurry distribution and deposition facilities
- Downstream stormwater sediment settling and collection facilities
- Monitoring facilities

Upstream Storm Water Diversion Facilities				
APP/BADCT	**MLRP**	**AQ**	**CWA**	**Corporate/Stakeholder**
i. Must be capable of safely routing route peak flows generated by 1 in 100 year, 24-hour duration storm precipitation on upgradient catchment area. .	i. Diversion ditches directed to the tailings impoundments to remain in place. . ii. The intent is for post-closure plant site runoff to be directed to the tailings impoundments for evaporation.	i. Not applicable.	i. Conform to existing SWPPP for construction and post-construction SW management. ii. Diversion discharge to Waters of US must meet Aquatic and Wildlife (Warm Water), Full Body Contact, Fish Consumption and Agricultural Livestock Watering Beneficial Use Limitations.	i. Scenario 1, Section 4. *Catastrophic flood (1 in 1000-year) causes failure of upstream diversion, then a release of tailings into stream.* Low Risk Ranking for current conditions. No risk reduction action required.

APP – Aquifer Protection Program
BADCT - Best Available Demonstrated Control Technology
MLRP – Mining Land Reclamation Program
AQ – Air Quality
CWA - Clean Water Act
SWPPP - Stormwater Pollution Prevention Plan

Design Criteria for Closure of Embankments				
APP/BADCT	**MLRP**	**AQ**	**CWA**	**Corporate/Stakeholder**
i. Mass Stability a.Minimum "Static" FOS = 1.3 (i.e., testing performed). b.Minimum "Pseudostatic" FOS = 1.1 ii. Provide slope protection for erosion control. iii. Provide vegetation for erosion control. iv. Runoff generated on embankment slopes must not degrade aquifer or surface water quality standards (e.g. through seepage or spillage respectively from BMP Ponds).	i. Contour embankment slopes not steeper than 3:1 (H to V). ii. Establish vegetation on embankment slopes using MLRP seed mixtures. iii. Perform post-closure maintenance for drainage control, slope protection, and revegetated surfaces.	i. Prevent fugitive dust from tailings impoundment surfaces. Surface stabilization required.	i. Conform to existing SWPPP for construction and post-construction SW management. ii. Discharge to waters of US must meet Aquatic and Wildlife (Warm Water); Full Body Contact; Fish Consumption; and Agricultural Livestock Watering Beneficial Use Limitations.	*i.Large storm erosion of tailings into stream.* Risk Ranking is low for current conditions. No risk reduction action required. ii. *Blowing dust from tailings...* Risk ranking is high for current conditions. Risk reduction action required. iii. *Long term erosion maintenance…* High risk ranking for current conditions. Risk reduction action is required. Iv .Acid seepage: Moderate risk ranking for current conditions. Risk reduction action may be required.

Design Criteria for Closure of Tailings Beach and Basin				
APP/BADCT	**MLRP**	**AQ**	**CWA**	**Corporate/Stakeholder**
i. Restrict water migration to and from the facility (i.e., surface water run-on and seepage respectively). ii. Grade surfaces to reduce ponding and promote evaporation. iii. Minimize infiltration from precipitation and surface water run-on. iv. Revegetate to control erosion and maximize transpiration potential. v. Store and evaporate runoff from 100-year, 24-hr storm. vi. Provide spillway at 100-year storm storage level to pass peak flows generated by (PMP) larger storms	i. Ensure pools on top surface located wholly on tailings and as far from the embankments as possible. ii. Construct a spillway to drain water from the surface of the impoundments at an elevation that would correspond to a 100-year, 24-hour storm. iii. Establish vegetation on surfaces using MLRP seed mixtures and procedures developed during pilot testing. MLRP seed mixtures.	i. Prevent fugitive dust from tailings impoundment surfaces. Surface stabilization required.	i. Conform to existing SWPP for construction and post-construction SW management. ii. Discharge to waters of US must meet Aquatic and Wildlife (Warm Water); Full Body Contact; Fish Consumption; and Agricultural Livestock Watering Beneficial Use Limitations.	i.Blowing dust from tailings.... i.Long term erosion maintenance… iii. Lack of cover… impairs long term eco-stability. Risk reduction action is required for all three.

Design Criteria for Closure of Tailings Reclaim Facilities				
APP/BADCT	**MLRP**	**AQ**	**CWA**	**Corporate/Stakeholder**
i. Restrict liquid migration from the tailings impoundment facility. ii. Embankment Stability	i. Reclaim and makeup process water distribution piping will be flushed with water and disconnected. Buried lines will be capped and abandoned in place. Surface piping will be recovered for salvage or reuse. ii. The ponds and ditches to be closed will be identified near the time of closure of the facility that they support. They will be closed by re-establishment of drainages, followed by recontouring and reseeding.	i. Not applicable.	i. Conform to existing SWPP for construction and post-construction SW management. i. Discharge to waters of US must meet Aquatic and Wildlife (Warm Water); Full Body Contact; Fish Consumption; and Agricultural Livestock Watering Beneficial Use Limitations.	*i.Attractive nuisance…* i.. *Acid seepage* iii. Leaking of decant pipe causing fines migration and either embankment or basin surface instability (sinkhole) iv. Failure of decant pipes near embankment causing build-up of hydrostatic pressure within embankment soils and embankment instability

Design Criteria for Closure of Tailings Slurry Management Facilities				
APP/BADCT	**MLRP**	**AQ**	**CWA**	**Corporate/Stakeholder**
i. Restrict liquid migration to and from the facility.	i. Flush buried pipelines with clean water and cap and bury ends. ii. Flush surface pipelines with clean water and recover for salvage, or disposed of in approved landfill. iii. Recontour pipeline rights-of-way to approximate the surrounding topography. iv. Perform revegetation of the rights-of-way on a case-by-case basis, depending upon width and routing. v. Salvage tanks, pumps and associated pipelines, or scrap as appropriate. vi. Demolish and bury concrete drop boxes buried along the right-of-way as part of the land restoration or dispose of in approved landfill. vii. Grade, scarify and revegetate rights-of-way.	i. Not applicable.	i. Conform to existing SWPP for construction and post-construction SW management. ii. Discharge to waters of US must meet Aquatic and Wildlife (Warm Water); Full Body Contact; Fish Consumption; and Agricultural Livestock Watering Beneficial Use Limitations.	i. None identified