Iron Ore (WA)

Spontaneous Combustion and ARD (SCARD) Management Plan

for Operations

(Formerly known as the Black Shale Management Plan)

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1 Purpose

The Spontaneous Combustion and Acid Rock Drainage (SCARD) Management Plan for operations outline the activities and groups accountable for the management of the environmental, safety, health, reputational and business risks associated with:

- Black shale
- Sulfidic material within detritals
- Sulfidic material within Banded Iron Formation (BIF)
- Elevated-sulfur material within shale, waste and ore.

Due to differing risks, the management of sulfides within black shale has been delineated from that associated with sulfides within detritals and BIF, and material containing sulfates.

This plan enables the development and implementation of appropriate risk reduction measures to lower risk. It sets and implements the appropriate monitoring plans that quantify the actual impacts and compares them with that predicted, to determine if risk reduction methods have been effective.

2 Definitions

2.1 Abbreviations

ABA	Acid Base Accounting
AMD	Acid and Metalliferous Drainage
ANC	Acid Neutralising Potential
ARD	Acid Rock Drainage
BIF	Banded Iron Formation
BS	Black Shale
DG	Dales Gorge Member
EP	Expansion Projects
FWZ	Footwall Zone
MCS	Mount McRae Shale
NAF	Non-Acid Forming
PAF	Potentially Acid Forming (including black shale and sulfides in BIF and detritals)
RRMs	Risk Reduction Measures
SWP	Safe Work Practice
WS	Whaleback Shale Member

2.2 Hazards Definitions

The risks associated with black shale, BIF and detritals are triggered by the presence of sulfides, in particular pyrite (FeS_2) within these material types. Pyrite will remain stable if constantly water-saturated with no exposure to oxygen or ferric iron. Alunite ($KAl_3(SO_4)_2(OH)_6$) and jarosite ($KFe_3(SO_4)_2(OH)_6$) have been identified in AWT waste and ore. When excavated during mining, pyrite can oxidise and sulfate minerals dissolve and generate the following risks to the operation:

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ARD (also known as Acid and Metalliferous Drainage (AMD))

The process of pyrite oxidation results in the release of dissolved acidity, sulfate, iron and other metal ions into drainage waters. The acidic conditions can often induce weathering of clay minerals in the host material and also release dissolved metals such as aluminium, manganese, zinc and/or copper into the drainage. The Acid Neutralising Capacity (ANC) of many of the other waste materials in the Hamersley Group is low and insufficient to neutralise the acidity released from most pyritic waste rocks.

Alunite weathers to an aluminium oxyhydroxide phase (e.g. gibbsite or boehmite, etc.) via dissolution; it can produce acid and buffer the pH in the region of 4.0 to 4.5. The rate of acid release is low and the acidity can be neutralised by any minerals that have the capacity to consume acid.

Risk Areas: Contamination of surface and/or ground water and soil, and potential disturbance to surrounding ecosystems from ARD generated within waste rock dumps and pits or voids. Potential health risks from direct handling or accidental consumption of ARD products.

Premature Blast Detonation

Spontaneous combustion is a major safety concern to RTIO (WA) due to the risk of reaction with explosives in loaded blast holes potentially leading to premature detonation. Ammonium nitrate (NH_4NO_3) based explosives, commonly known as ANFO, are typically used however due to the risk of spontaneous combustion, explosives based on inhibited emulsion blended with ANFO are used if spontaneous combustion may occur.

Risk areas: Potential safety risk from the premature and unexpected detonation of explosives.

Spontaneous Combustion within Dumps

In waste dumps where self-heating occurs, heat may be transferred from hot to cold regions of the dump through the evaporation of moisture (water vapour) in hot areas and subsequent condensation in colder areas. This heat transfer is in addition to the transport of heat by natural convection (Takos and Lucas 2004). Water vapour transport is an important heat transfer mechanism within waste dumps and therefore it is not recommended that water is added to a hot spot. The added water may shift the heat from one region to another. This may be the reason that self-heating is observed in black shale after increases in humidity and rain (Takos and Lucas 2004). If the rate of energy generated by oxidation is greater than the rate at which energy can be dissipated to the environment via conduction, convection and evaporation then the dump will self-heat (Davies 2002).

Risk areas: Gas venting from waste dumps, geotechnical instability and increased rates of ARD generation due to the elevated temperatures and oxygen exposures.

Gas Exposures

The major gases produced from the spontaneous combustion of the black shale (and possibly lignite in detritals) are likely to be sulfur dioxide (SO_2), carbon dioxide (CO_2), hydrogen sulfide (H_2S), carbon monoxide (CO) and methane (CH_4). In the open air, the rate of reaction is slow and the heat of reaction is quickly dissipated to the environment (Takos and Flint 2001). Within waste dumps, the heat cannot dissipate as readily and there can be localised hot spots that promote SO_2 generation. The SO_2 generated can then vent from the waste, potentially causing problems with the establishment of vegetation.

Risk areas: Human exposure to toxic gases and safety risks.

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Dust Exposure

Black shale can be fine and powdery with elevated concentrations of alumina and silica.

Risk areas: Human exposure to dust and safety risks.

2.3 Waste Definition

Waste containing sulfur can have the potential to generate ARD and some materials can also spontaneous combust. The potential for wastes to generate ARD or spontaneously combust is defined at Rio Tinto Iron Ore (WA) operations as:

ARD/AMD potential: The propensity for a material to generate ARD/AMD is determined using a series of tests referred to as Acid Base Accounting (ABA) (Green 2006). Without site-specific ABA data, a total sulfur concentration of 0.1% is used as the approximate boundary between non-acid forming and potentially acid forming material (Green 2006). Marra Mamba Iron Formation BIF and detritals are the only material that can use a 0.3% sulfur cut-off value and this is due to the presence of some acid neutralising materials (see Brown 2008 and site specific AMD Risk Assessments). Specific test work undertaken on sulfidic BIF at Hope Downs 1 has identified that a 0.6% sulfur cut-off for PAF/NAF be used at that site.

Spontaneous Combustion potential: The spontaneous combustion mechanisms of pyritic black shale are poorly understood. However, it is likely to be associated with the following properties of the shale: high surface area, high porosity, small particle size distribution, moisture content, carbon content and sulfur content (Davies 2002; Zhang 2003). All black shale and lignite material is deemed by RTIO (WA) to pose a spontaneous combustion risk (although significant tonnages of lignite are yet to be mined so spontaneously combust has not been observed).

Depending on the potential for ARD generation and/or spontaneous combustion (risk), waste should be classified into one of three categories and it should be dumped in accordance with the specifications for that category (Appendix 4).

Inert waste: Material is currently classified as inert by RTIO (WA) if it does not contain sulfur or carbonaceous material (i.e., S < 0.3% for BIF and detritals located below the water table (BWT); S < 0.1% for elevated-sulfur material located above the water table (AWT); and not including any black shale or lignites). Black shale within the Whaleback Shale Member may be classified as inert waste when it represents a small fraction of a mine block and the average sulfur content of the block is < 0.1%.

Cold black shale/sulfidic BIF/sulfidic siderite: This material is not likely to spontaneously combust within the dump and is managed only to control the ARD risk. Typical material within this category includes:

- Cold black shale (MCS): Represents black shale with low sulfur concentrations. Due to possible variability within the unit, this material requires special management. Whilst the sulfur content is low (i.e., < 0.1%), there is still the potential for metalliferous drainage as a result of oxidation of the organic carbon material within the black shale.
- Dales Gorge Member (DG) black shale: Represents black shale with sulfur concentrations up to 2% and containing some acid neutralising capacity (e.g.,15 kgH_2SO_4/t). Samples are mostly non-acid forming but may be potentially acid forming with low capacity.
- Sulfides within BIF and detritals (siderite): The sulfur concentration in these materials is generally in the range of 0.1% to 0.3% but can reach 15%. The risk of spontaneous combustion in the dump is considered low due to the lack of organic carbon associated with this material.

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- Whaleback Shale Member (WS) black shale: If the average sulfur content is > 0.1% or black shale accounts for the majority of the block material, then this material should be placed in a cold black shale dump as there is very low potential for acid generation[1]

Hot black shale/Lignite: This material may spontaneously combust in the dump and is managed to control combustion within the dump. Typical material within this category is:

- Hot black shale (MCS): Black shale which generally has significantly higher sulfur concentrations and high organic carbon concentrations typically > 2%.
- Sulfides in lignite: The risk of spontaneous combustion of sulfidic lignite material is currently unknown. Until proven otherwise, sulfidic lignites should be managed to minimise the risk of spontaneous combustion.

Elevated sulfur: The sulfate minerals alunite and jarosite can be found AWT, predominantly in the Dales Gorge Member, Whaleback Shale Member and oxidised MCS. These are found particularly in close proximity to those units containing sulfide minerals (RTTI 2012), and/or a source of potassium such as dolerite dykes (Danaher 2012). When alunite or jarosite occur in significant quantities (termed elevated-sulfur material) it will need to be specially managed due to its propensity to release acid and associated metals (RTTI 2012). Without site specific test work for sulfates, a total sulfur concentration of 0.1% is used as the approximate boundary between non-acid and potentially acid forming material due to the low solubility of these minerals and presence of some acid neutralising materials.

3 Assessing if a Site needs to implement this Management Plan

The RTIO (WA) Mineral Waste Management Plan describes the ARD, spontaneous combustion and mineral waste characterisation work that must be undertaken during Resource Evaluation, Studies and Mine Operations. A detailed ARD Risk Assessment should be undertaken for any new deposits or significant expansions of current operations to identify whether excavated sulfides will represent a risk to health, safety and environment (including the impacts on-site, off-site and to the receiving environment). If risks are deemed to be minimal then a management plan will not be required. If a risk assessment has already been undertaken at a site then for any additional significant resource drilling or expansions of the operation the risk assessment should be updated. For any mine site that exposes or could potentially expose sulfidic or elevated-sulfur material, then this SCARD Management Plan will need to be implemented.

The following mine sites currently need to comply with Sections 4 to 6 and the relevant Appendices of this Plan:

- Section 4: Tom Price, Channar, Brockman (2 and 4), Hope Downs 4, Paraburdoo (4EE) (see Figure 6 to Figure 14).
- Section 5: Hope Downs 1, Nammuldi.
- Section 6: Brockman 2.

The accountability for the identification and subsequent management of spontaneous combustion and ARD risks associated with black shale and sulfidic BIF and detritals are listed in Section 4 and Section 5. It provides an overview of management at RTIO (WA) operations from initial characterisation and modelling, through project development, mine planning, production

[1] Regular acid base accounting should occur on WS black shale samples at Tom Price to ensure this material remains inert as the mine deepens. The WS at other operations should be properly characterised to determine if it can also be treated as inert material. Black shale within WS in proximity to fault zones is known to be potentially acid forming, where the release of sulfate and metal ions (such as Mg) may require management.

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and closure. The RTIO (WA) SCARD management strategy is broadly based upon the following principles:

1) Identification of PAF material distribution and character;
2) Minimising the exposure and mining of PAF material to the extent possible;
3) Identification and special handling of PAF material that must be mined;
4) Encapsulation of PAF material inside inert waste rock dumps to limit water contact and allow the dumps to be revegetated, or placement of PAF material below the water table in backfilled open pits to limit oxygen contact; and
5) Monitoring impacts and taking corrective actions (when necessary).

4 Requirements, Accountabilities and References for Black Shale

Black shale management during mining operations is conducted in accordance with Figure 1 and Figure 2. The mining protocols are designed to:

1) Minimise the risk of unplanned detonations in charged blast holes;
2) Ensure that hot and cold black shale truck loads are transported and placed in designated black shale dumps according to design requirements;
3) Ensure that the location and geometry of all black shale repositories is recorded;
4) Minimise environmental impacts of AMD products; and
5) Refine geological block models and block-out procedures.

Requirements	Accountabilities	Reference Documents
4.1 Mine Planning and Closure		
4.1.1 Mine plans must include estimates for hot and cold BS production and compare to inert waste production to ensure that sufficient material will be available for dump construction. 4.1.2 Ensure that BS dumps are sited to minimise long term environmental impacts and financial liabilities. Obtain signoff from Environment, Hydrogeology and Hydrology. 4.1.3 Ensure that final pit and dump designs are consistent with Appendix 4, Appendix 6, Appendix 7 and the RTIO Landform Design Guidelines. Waste dump designs must be coupled with a rehabilitation design showing how the dump is proposed to be rehabilitated upon closure. The rehabilitation design should be provided to the Rehabilitation team for review. Obtain signoff from Environment, Hydrogeology and Hydrology. 4.1.4 During the mine planning process identify areas that are available for rehabilitation and inform the rehabilitation and closure team. 4.1.5 WTS and Koodaideri specific action: New pit shell designs should continue to avoid black shale exposures.	Manager Mine Engineering	Rio Tinto Iron Ore (WA) Landform Design Guidelines Progressive Rehabilitation – Process and Responsibilities Appendix 4 Appendix 6 Appendix 7

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Requirements	Accountabilities	Reference Documents
4.2 Mine Technical Services - Planning		
4.2.1 Ensure that Medium Term plans predict hot and cold BS production from each pit and delivery to each dump. Ensure that sufficient inert waste will be produced for encapsulation in accordance with the specifications in Appendix 4 and that sequencing will allow dump construction to occur as required. 4.2.2 Major changes to waste dump designs must be reflected in changes to the associated rehabilitation design. Receive sign-off from Environment, Rehabilitation Team, Hydrogeology and Hydrology before major modifications to BS dump designs are implemented. 4.2.3 Plan and design works for final waste rock dump surfaces and inactive open pits in a manner consistent with Appendix 4, Appendix 7 and the RTIO Landform Design Guidelines. Waste dump designs must be coupled with a rehabilitation design showing how the dump is proposed to be rehabilitated for closure. The design should be provided to the Rehabilitation Team for review. Obtain sign-off from Environment, Hydrogeology and Hydrology. 4.2.4 During the mine planning process identify areas that are available for rehabilitation and inform the rehabilitation and closure team. 4.2.5 When planning open pits that will intersect BS, the possibility of dewatering discharge/groundwater becoming acidic must be considered so that appropriate mitigation infrastructure can be installed. 4.2.6 Black shale exposed on the waste rock dumps must be minimised during the wet season (November to April). 4.2.7 WTS and Koodaideri specific action: New pit shell designs should continue to avoid black shale exposures.	Superintendent Mine Technical Services	Appendix 4 Appendix 7 Rio Tinto Iron Ore (WA) Landform Design Guidelines Progressive Rehabilitation – Process and Responsibilities
4.3 Mine Geology		
Blasting 4.3.1 Identify BS in blast hole cones and demarcate using agreed methods. 4.3.2 Alert key personnel in Mine Technical Services Planning and Pit Operations of the location of BS blast holes via e-mail. Dumping 4.3.3 Based on visual inspection, total S values and stratigraphy, designate holes as cold BS, hot BS or inert waste. Create Block-outs that show contacts between waste types within blast patterns. 4.3.4 Perform periodic reconciliations between the Block-outs and the geological block model.	Superintendent Mine Technical Services	AEISG Code of Practice - Elevated Temperature and Reactive Ground - Edition 4 March 2017 SWP-10 Identification & Sampling of Black Shale

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Requirements	Accountabilities	Reference Documents
4.3.5 Collect (at least every five years) representative samples of hot and cold black shale for full ABA and NAG analysis. 4.3.6 Regularly review the boundary between cold BS and hot BS to ensure it is still valid and has not changed as mining progresses deeper. Advise the relevant teams of the results and undertake change management if necessary.		Appendix 3
4.4 Survey		
4.4.1 Maintain as-built dump designs that include a 3D plan showing approximate locations and volumes of BS. 4.4.2 Ensure that monthly face pick-up surveys are conducted on all active BS waste dumps.	Superintendent Mine Technical Services	Surveying of Black Shale Areas Process, Data Collection and Recording Process
4.5 Operational Planning		
4.5.1 Create a "Waste Dump Progression Plan" at least every three months to implement the detailed dump designs in the field. 4.5.2 Create "PLOD" sheets to aid dig operators in waste assignment and check that CAES is working. 4.5.3 Monitor and adjust to reconcile rehabilitation plans with original designs as appropriate. 4.5.4 Perform field inspections to ensure that BS is transported to the proper dump locations and placed as required. Register non-conformances in SAP. 4.5.5 Ensure reports contain hot and cold BS volumes delivered to every dump. 4.5.6 In consultation with Mine Geology perform regular reconciliations between Block-outs, survey and ORDW data for hot and cold BS volumes. 4.5.7 Black shale exposures on the waste rock dumps must be minimised during the wet season.	Superintendent Mine Technical Services	
4.6 Drill, Blast and Development		
4.6.1 Ensure all safety procedures related to BS management are followed during the charging and firing of blast holes i.e., temperature logging, timing. 4.6.2 Maintain site specific Drill and Blast SWPs and ensure it is consistent with this management plan and other SWPs and guidance notes. 4.6.3 Submit samples for isothermal reactivity testing for compatibility with ANFO explosives.	Superintendent Mine Technical Services	Guidance Notes on the Health Effects of Pyritic Black Shale AEISG Code of Practice - Elevated Temperature and Reactive Ground - Edition 4 March 2017
4.7 Load and Haul		
4.7.1 Ensure that BS is properly identified and placed in the correct dump location consistent with PLOD sheets, CAES mining assignments and the Waste Dump Progression Plan from Operations Planning.	Superintendent Load and Haul	Guidance Notes on the Health Effects of Pyritic Black Shale

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Requirements	**Accountabilities**	**Reference Documents**
4.7.2 Perform field inspections to ensure that BS is transported to the proper dump locations and placed as required. Register non-conformances in SAP.		
4.7.3 Ensure that "Exclusions" in CAES are reviewed and corrected in the field as required.		
4.7.4 The time between blasting and hauling of BS should be minimised and generally should occur within three weeks or less during the wet season (November to April) and within 12 weeks during the dry season (May to October). This will limit the amount of time the material has to oxidise in an uncontrolled manner.		
4.7.5 Whenever possible the outer inert waste rock "skin" of a BS lift should be constructed first. This will ensure that BS lifts are not extended beyond the design footprint of the BS dump, will limit convective oxygen transport through the uncompacted sides of the dump lift, and will help contain contaminated contact water on the dump.		
4.7.6 Hot BS lifts should be covered as rapidly as possible with the overlying inert waste rock layer, particularly during the wet season. Ideally, hot BS should be covered within two weeks of placement in the waste rock dump. If rapid covering is not possible the paddock-dumped hot BS piles should at least be dozed into a planar surface as soon as possible. This will help minimise infiltration and oxygen transport into the material.		
4.7.7 The locations, volumes and sulfur concentrations (if available) of all BS repositories should be recorded so that a three dimensional plan of BS distribution within each dump is maintained by the survey group.		RTIO PAF Inventory
4.8 Hydrogeology/Technical Services		
4.8.1 Maintain and implement a site specific "Acid Water Management Plan" and SWPs to deal with poor quality water that has contacted BS exposures or waste dumps. This should include information regarding bunding requirements, water quality monitoring (including the action response and relevant corrective actions including treatment) and disposal or use.	Superintendent Water Resource Evaluation	BS2 Acid Water Management Plan BS4 Acid Water Management Plan Tom Price Pit Acid Water Procedure
4.8.2 Ensure that water management and storage practices do not cause offsite surface water impacts or groundwater quality degradation in down gradient aquifers.		
4.8.3 Provide technical overview and support during planning for above-ground and in-pit BS waste disposal.		
4.8.4 Ensure that routine sampling, visual inspection, and analysis is performed for in-pit locations, including: • groundwater monitoring wells (surrounding BS dumps and pits;	Superintendent Mine Technical Services	

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Requirements	Accountabilities	Reference Documents
• dewatering water; and • surface water bodies (including temporary or permanent pit lakes within inactive open pits that contain BS exposures). This should be consistent with the master monitoring schedule for the site.		
4.9 WRE Mineral Waste Management Team		
4.9.1 Provide site support for the management of mineral waste, as necessary. Facilitate the transfer of knowledge between RTIO sites and studies. 4.9.2 Undertake or update AMD Risk Assessments for significant changes to the pit shell or geochemical risks. Advise the site leadership and environment group for significant changes to risk. 4.9.3 Ensure the SCARD management plan is updated at least every 2 years. More frequent updates may be required for significant changes to risk or the knowledge base. 4.9.4 For pits that intersect the water table, ensure the following information is available which would contribute to a conceptual understanding: • Catchment size; • Depth to pre-mining water table; • Current and ultimate pit depth; • Available water storage within the entire ultimate pit and above the pre-mining water table in the pit; • Predicted runoff volume for a 100 year storm event; • Distance to closest down-gradient permanent surface water body; and • Down-gradient water use. Determine the geochemical risk of the pit. Update this report for any significant changes. 4.9.5 Geochemical, hydrogeology and hydrology modelling to determine contaminant release from the pit should be undertaken if the report (in Item 4.9.4) finds a significant geochemical risk (i.e., a significant amount of PAF material exposed on the pit wall, a significant amount of dewatering occurring over many years, a likely saline and flow through water body, etc.). 4.9.6 For PAF material waste dumps, compile a ‘Conceptual Model’ report for each site. This report should contain the following information for each waste dump on the site: • Footprint; • Up-gradient catchment area; • Likely material types in the waste dump i.e., oxidised MCS, DG1 BIF; • Quantify the PAF tonnes and the total tonnes of material within each waste dump; • Dumping methodology; • Underlying and down-gradient geology; • Distance to the closest regionally significant	Superintendent Mineral Waste Management	

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Requirements	Accountabilities	Reference Documents
aquifer; • Distance to closest down-gradient permanent surface water body; • Down-gradient water use; and • Closure/rehabilitation plans for the dump (or reference to the appropriate document). 4.9.7 Geochemical modelling to determine long-term contaminant release from the waste dump should be undertaken if the 'Conceptual Model' finds a significant geochemical risk (i.e., a significant amount of PAF material within the waste dump or significant receptors nearby).		
4.10 Environment		
4.10.1 Perform field inspections to ensure BS management, dump construction, rehabilitation and store and release cover performance is consistent with the requirements of the SCARD Management Plan.	Site Environmental Officer	HSEQ Water Monitoring Procedure - Acid Rock Drainage HSEQ Water Monitoring Procedure - Groundwater Water Monitoring Procedure - Surface Water
4.10.2 Undertake relevant ecological assessment (appropriate for the scale of the SCARD generation and predicted level of pollution/ecological impacts), develop and implementation appropriate risk reduction measures and monitoring programmes.	Principal Environmental Scientist	
4.10.3 Ensure that routine sampling, visual inspection, and analysis is performed for out of pit locations that could potentially be impacted by AMD. This may include • groundwater monitoring wells surrounding BS dumps and pits (if they can be accessed outside the pit) • surface water bodies (including abandoned pit lakes, permanent or seasonal natural water bodies, dewatering discharge to creeks). This should be consistent with the master monitoring schedule for the site.	Site Environmental Officer	
4.10.4 Record the environment risks related to BS in a site risk register and annually review/verify/validate these risks; verify that the ministerial conditions, legal and other requirements and obligations are met.	Superintendent Environment	
4.11 Rehabilitation and Closure		
4.11.1 In consultation with relevant stakeholders identify monitoring requirements (e.g. lysimeters) for BS waste dumps following rehabilitation.	Rehabilitation and Closure Specialist	
4.11.2 Coordinate the review and approval of the BS waste dump design by relevant stakeholders, including the Mineral Waste Management Team to ensure compliance with this document.		Rehabilitation – Design and Approval Process Appendix 4 Appendix 7
4.11.3 Assess the risks that need to be managed as part of the rehabilitation process for BS dump designs, focussing on the SCARD risks and ensure that all key stakeholders are consulted.		

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Requirements	Accountabilities	Reference Documents
4.12 Health and Safety		
4.12.1 Monitor the occupational gas and dust exposures surrounding BS. Ensure data is captured in a user friendly database. Ensure problems are brought to the attention of the site Mineral Waste Management Team. 4.12.2 Train occupational exposure groups on the correct use of respiratory equipment and monitors. Competency should be assessed and recorded in SAP. 4.12.3 Ensure the site specific guidance notes on acceptable gas levels, monitoring and demarcation are periodically refined and updated so it is consistent with current best practice. 4.12.4 Record health and safety risks associated with BS in a site risk register and annually review these risks.	Health and Safety Superintendent	Guidance Notes on the Health Effects of Pyritic Black Shale
4.13 Site Mineral Waste Management Team		
4.13.1 A site based Mineral Waste Management Team should be formed and meet on a regular basis (e.g., monthly). It should include representatives of every department that has accountabilities related to SCARD management. 4.13.2 The primary function of the Site Mineral Waste Management Team is to ensure on-going improvement and implementation of the SCARD Management Plan. 4.13.3 Agenda items and meeting minutes should be produced for every meeting. 4.13.4 An overview of issues relating to BS must be included in any introductory training provided to new employees and contractors. The level of training should be commensurate to the level of risk BS poses to the site. 4.13.5 Develop emergency and contingency plans related to spontaneous combustion, ARD and BS management on an as need basis. 4.13.6 Coordinate a technical review of BS management by an external expert every four years. Track progress against outstanding actions at each meeting. 4.13.7 Coordinate all research related to BS characterisation, BS management, spontaneous combustion and ARD. 4.13.8 Ensure that SCARD related SWPs and guidance notes represent current practise and are up to date. 4.13.9 Changes to the SCARD management plan need to be provided to the Water Resource Evaluation Mineral Waste team to be included in future updates.	Site Mineral Waste Management Team – E13 champion	Example: Minutes from Tom Price meetings Minutes from Brockman 2 meetings Minutes from the HD4 meetings Appendix 7 HD4 PAF Strategy

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Requirements	Accountabilities	Reference Documents
4.14 Management		
4.14.1 Ensure progress is made against outstanding spontaneous combustion and AMD audit actions.	Registered Site Manager	

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Figure 1: Black shale (BS) management overview.

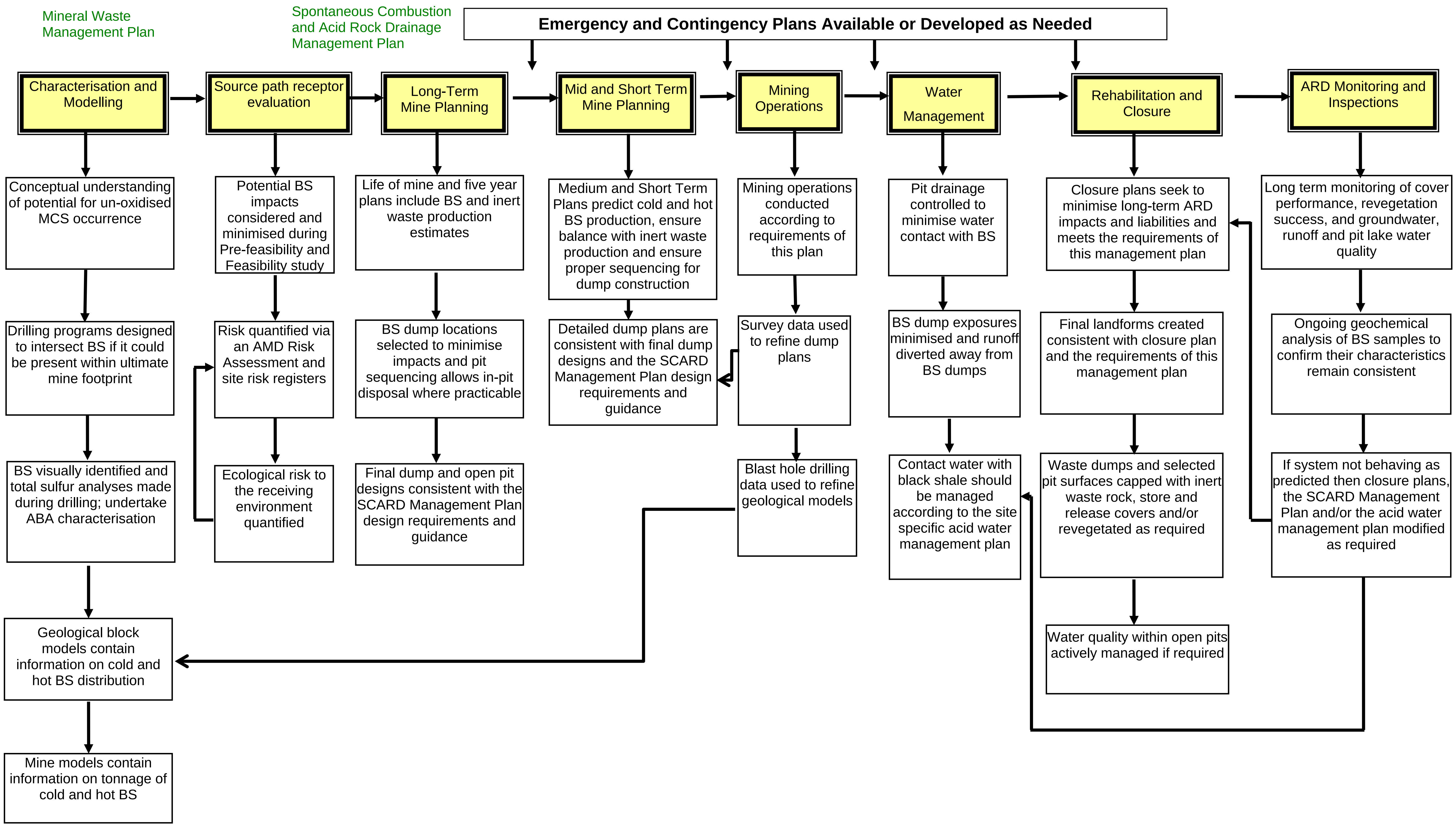

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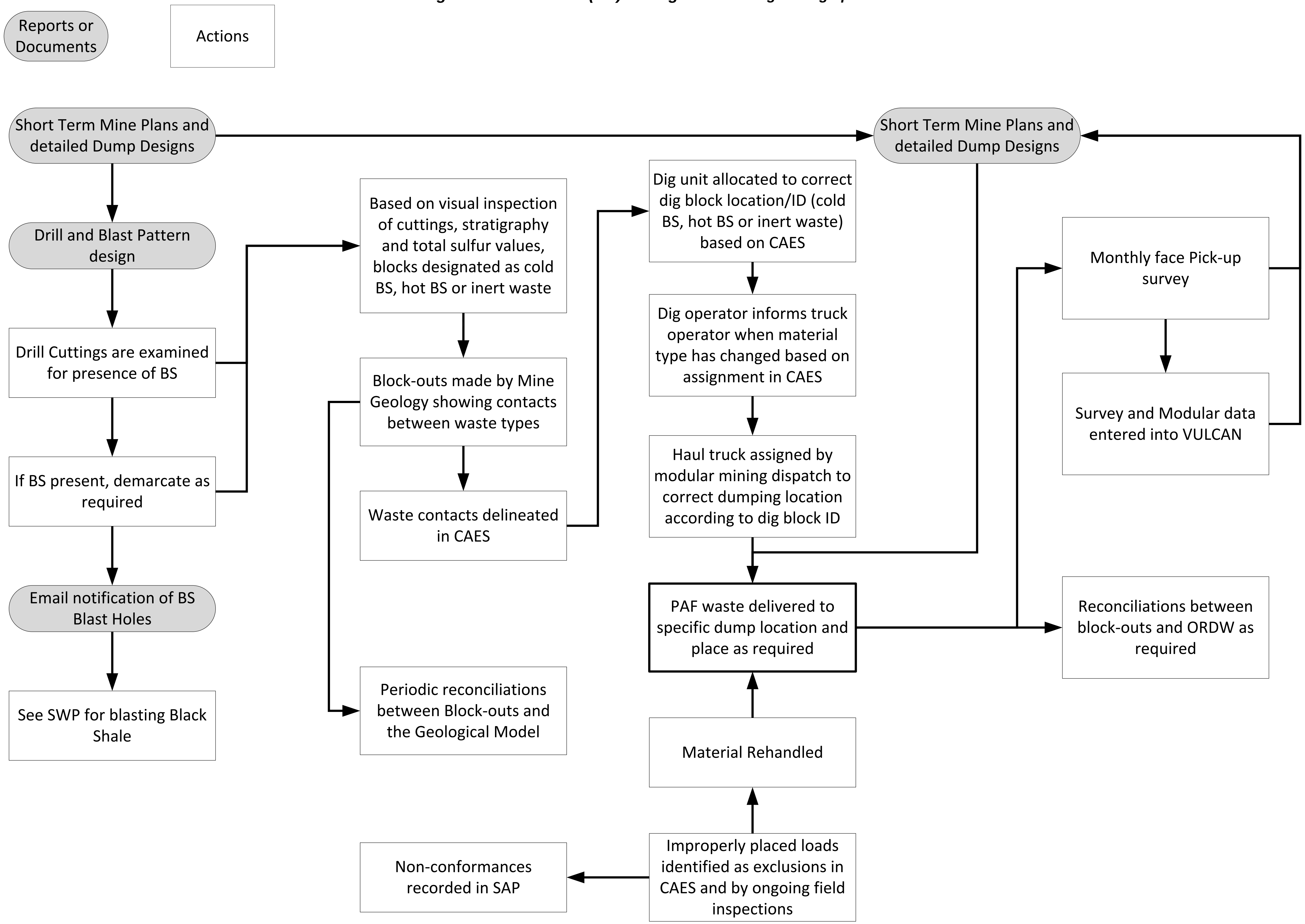
Figure 2: Black shale (BS) management during mining operations.



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5 Requirements, Accountabilities and References for Sulfides within BIF and Detritals

Management of sulfidic BIF and detritals during mining operations is conducted in accordance with Figure 3 and Figure 4. The mining protocols are designed to:

1) Minimise the risk of unplanned detonations in charged blast holes;
2) Ensure that sulfidic BIF and detrital truck loads are transported and placed in PAF dumps according to design requirements;
3) Ensure that the location and geometry of all PAF repositories is recorded;
4) Minimise environmental impacts of ARD products; and
5) Refine geological block models and block-out procedures.

Requirements	Accountabilities	Reference Documents
5.1 Mine Planning and Closure		
5.1.1 Mine Plans must include estimates for production of PAF, neutralising and inert waste material. 5.1.2 Ensure that PAF dumps are sited to minimise long-term environmental impacts and financial liabilities. Obtain signoff from Environment, Hydrogeology and Hydrology. 5.1.3 Ensure that final pit and dump designs are consistent with Appendix 4, Appendix 5, Appendix 6, Appendix 7 and the RTIO Landform Design Guidelines. Waste dump designs must be coupled with a rehabilitation design showing how the dump is proposed to be rehabilitated upon closure. The rehabilitation design should be provided to the Rehabilitation Team for review. Obtain signoff from Environment and Hydrogeology and Hydrology. 5.1.4 During the mine planning process identify areas that are available for rehabilitation and inform the rehabilitation specialist.	Manager Mine Engineering	Appendix 4 Appendix 5 Appendix 6 Appendix 7 Pilbara Iron Landform Guidelines
5.2 Mine Technical Services - Planning		
5.2.1 Ensure that Medium term plans predict PAF material and net neutralising material production from each pit and delivery to each dump. Ensure that sufficient inert and net neutralising waste will be produced for encapsulation in accordance to the specifications in Appendix 4 and that sequencing will allow dump construction to occur as required. The tonnes of material with neutralising potential should be quantified and used with PAF dump designs in accordance with Appendix 5. 5.2.2 Major changes to waste dump designs must be reflected in changes to the associated rehabilitation design. Receive sign-off from Environment, Rehabilitation Team, Hydrogeology and Hydrology before major modifications to BS dump designs are implemented. 5.2.3 When planning open pits that will intersect sulfidic	Superintendent Mine Technical Services	Appendix 4 Appendix 5 Appendix 6 Appendix 7

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Requirements	Accountabilities	Reference Documents
material, the possibility of dewatering discharge/groundwater becoming acidic must be considered so that appropriate mitigation infrastructure can be installed. 5.2.4 Lignite exposed on the waste rock dumps must be minimised during the wet season (November to April).		
5.3 Geology		
5.3.1 Identify lignite in blast hole cones and demarcate using agreed method. 5.3.2 Alert key personnel in Mine Technical Services and Pit Operations of the location of lignite blast holes via e-mail. 5.3.3 If the geological block model indicates that sulfur grades may be > 0.3%, then samples from drill hole cuttings should be collected for total sulfur concentration analysis. 5.3.4 Review total S results and demarcate holes that contain > 0.3% S (for drill and blast identification). 5.3.5 Based on visual inspections, total S values and stratigraphy, designate holes as PAF, net neutralising or inert waste. Create Block-outs that show contacts between waste, net neutralising material and the PAF material within blast pattern. Material blocked out for the PAF dump include: • BIF: S > 0.6% • Detrital Siderite: S > 0.3% • Detrital Lignite: All (to manage neutral mine drainage risks in additional to PAF risks) 5.3.6 Perform periodic reconciliations between the Block-outs and the geological block model. 5.3.7 Collect (at least every five years) representative samples of sulfidic material associated with BIF and detritals for full ABA and NAG analysis. Ensure results are communicated to the relevant teams.	Superintendent Mine Technical Services	AEISG Code of Practice - Elevated Temperature and Reactive Ground - Edition 4 March 2017
5.4 Survey		
5.4.1 Maintain as-built dump designs in Vulcan that include a 3D plan showing approximate locations and volumes of sulfidic material. 5.4.2 Ensure that monthly face pick-up surveys are conducted on all active sulfidic material waste dumps.	Superintendent Mine Technical Services	
5.5 Operational Planning		
5.5.1 Create a "Waste Dump Progression Plan" at least every three months to implement the detailed dump designs in the field. 5.5.2 Create "PLOD" sheets to aid dig operators in waste assignment and check modular mining system is working. 5.5.3 Monitor and adjust to reconcile rehabilitation plans with	Superintendent Mine Technical Services	

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Requirements	Accountabilities	Reference Documents
original designs as appropriate.		
5.5.4 Ensure that reports from ORDW contain sulfidic material volumes delivered to every dump. Confirm that sulfidic material has been transported to the correct dump and register non-conformances in SAP.		
5.5.5 In consultation with Mine Geology perform six-monthly reconciliations between Block-outs, survey and ORDW data for sulfidic material volumes.		
5.5.6 Sulfidic material exposures on the waste rock dumps must be minimised during the wet season. Lignites should be covered rapidly during the wet season to reduce the spontaneous combustion risk (i.e. 1 month)		Appendix 5
5.5.7 The location, volume and sulfur concentration (if available) of all PAF (sulfidic material) repositories should be recorded so that a three dimensional plan of the distribution within each dump is maintained.		RTIO PAF Inventory
5.6 Drill and Blast		
5.6.1 Ensure all safety procedures related to pyritic material and in particular lignite are followed during the charging and firing of blast holes.	Superintendent Mine Technical Services	AEISG Code of Practice - Elevated Temperature and Reactive Ground - Edition 4 March 2017
5.6.2 Annually submit samples for isothermal reactivity testing for compatibility with ANFO explosives.		
5.7 Load and Haul		
5.7.1 Ensure that sulfidic material is properly identified and placed in the correct dump location consistent with PLOD sheets, CAES mining assignments and the Waste Dump Progression Plan from Operations Planning.	Superintendent Load and Haul	
5.7.2 Ensure that “Exclusions” in CAES Mining are reviewed and corrected in the field as required.		
5.7.3 The outer inert waste rock “skin” of a sulfidic material lift should be constructed first. This will ensure that sulfidic material lifts are not extended beyond the design footprint of the sulfidic material dump, will limit convective oxygen transport through the uncompacted sides of the dump lift, and will help contain contaminated contact water on the dump.		
5.7.4 Lignite material should be covered rapidly (i.e. 1 month) with net neutralising material during the wet season to reduce the risk of spontaneous combustion.		
5.8 Hydrogeology/Technical Services		
5.8.1 Maintain and implement the site specific “Acid Water Management Plan” and SWPs to deal with poor quality water that has contacted sulfidic material exposures or waste dumps. This should include information regarding bunding requirements, water quality monitoring (including the action response and relevant corrective actions including treatment) and disposal or use.	Superintendent Water Resource Evaluation	

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Requirements	Accountabilities	Reference Documents
5.8.2 Ensure that water management and storage practices do not cause offsite surface water impacts or groundwater quality degradation in down gradient aquifers. 5.8.3 Provide technical overview and support during planning for above-ground and in-pit sulfidic material waste disposal. 5.8.4 Ensure that routine sampling, visual inspection, and analysis is performed for in-pit locations, including: • groundwater monitoring wells (surrounding BS dumps and pits; • dewatering water; and • surface water bodies (including temporary or permanent pit lakes within inactive open pits that contain BS exposures). This should be consistent with the master monitoring schedule for the site.	Superintendent Mine Technical Services	
5.9 WRE Mineral Waste Management Team		
5.9.1 Provide site support for the management of mineral waste, as necessary. Facilitate the transfer of knowledge between RTIO sites and studies. 5.9.2 Undertake or update AMD Risk Assessments for significant changes to the pit shell or geochemical risks. Advice the site leadership and environment group for significant changes to risk. 5.9.3 Ensure the SCARD management plan is updated at least every 2 years. More frequent updates may be required for significant changes to risk or the knowledge base. 5.9.4 For pits that intersect the water table, ensure the following information is available which would contribute to a conceptual understanding: • Catchment size; • Depth to pre-mining water table; • Current and ultimate pit depth; • Available water storage within the entire ultimate pit and above the pre-mining water table in the pit; • Predicted runoff volume for a 100 year storm event; • Distance to closest down-gradient permanent surface water body; and • Down-gradient water use. Determine the geochemical risk of the pit. Update this report for any significant changes. 5.9.5 Geochemical, hydrogeology and hydrology modelling to determine contaminant release from the pit should be undertaken if the report (in Item 5.9.4) finds a significant geochemical risk (i.e. a significant amount of PAF material exposed on the pit wall, a significant amount of dewatering occurring over many years, a likely saline and flow through water body etc). 5.9.6 For PAF material waste dumps, compile a 'Conceptual Model' report for each site. This report should contain the	Superintendent Mineral Waste Management	

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Requirements		Accountabilities	Reference Documents
	following information for each waste dump on the site: • Footprint; • Up-gradient catchment area; • Likely material types in the waste dump i.e., LIG, SID, CAL. • Quantify the PAF tonnes and the total tonnes of material within each waste dump; • Dumping methodology; • Underlying and down-gradient geology; • Distance to the closest regionally significant aquifer; • Distance to closest down-gradient permanent surface water body; • Down-gradient water use; and • Closure/rehabilitation plans for the dump (or reference to the appropriate document).		
5.9.7	Geochemical modelling to determine long term contaminant release from the waste dump should be undertaken if the 'Conceptual Model' finds a significant geochemical risk (i.e. a significant amount of PAF material within the waste dump or significant receptors nearby).		
5.10	**Environment**		
5.10.1	Perform field inspections to ensure sulfidic material management, dump construction, rehabilitation and store and release cover performance is consistent with the requirements of the SCARD Management Plan.	Site Environmental Officer	HSEQ Water Monitoring Procedure - Acid Rock Drainage HSEQ Water Monitoring Procedure - Groundwater Water Monitoring Procedure - Surface Water
5.10.2	Undertake relevant ecological assessment (appropriate for the scale of the SCARD generation and predicted level of pollution/ecological impacts), develop and implementation appropriate risk reduction measures and monitoring programmes.	Principal Environmental Scientist	
5.10.3	Ensure that routine sampling, visual inspection, and analysis is performed for out of pit locations that could potentially be impacted by AMD. This may include • groundwater monitoring wells surrounding BS dumps and pits (if they can be accessed outside the pit) • surface water bodies (including abandoned pit lakes, permanent or seasonal natural water bodies, dewatering discharge to creeks). This should be consistent with the master monitoring schedule for the site.	Site Environmental Officer	
5.10.4	Record sulfidic material environment risks in a site risk register and annually review/verify/validate these risks; verify that the ministerial conditions, legal and other requirements and obligations are met.	Superintendent Environment	
5.11	**Rehabilitation and Closure**		
5.11.1	Ensure that the rehabilitation process is completed as outlined within the Progressive rehabilitation – process and responsibilities and Rehabilitation design and	Rehabilitation and Closure Specialist	Progressive Rehabilitation – Process and Responsibilities

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Requirements	Accountabilities	Reference Documents
approval process documents. 5.11.2 In consultation with relevant stakeholders identify monitoring requirements (e.g. lysimeters) for waste dumps following rehabilitation. 5.11.3 Coordinate the review and approval of the design by relevant stakeholders including the mineral waste team to ensure compliance with this document. 5.11.4 Assess the risks that need to be managed as part of the rehabilitation process for BS dump designs, focussing on the SCARD risks and ensure that all key stakeholders are consulted.		Rehabilitation – Design and Approval Process Appendix 4 Appendix 6 Appendix 7
5.12 Health and Safety		
5.12.1 Monitor the occupational gas and dust exposures surrounding sulfidic material (and gas generation if appropriate for lignite material). Ensure problems are brought to the attention of the site Mineral Waste Management Team. 5.12.2 If spontaneous combustion is likely to occur, train occupational exposure groups on the correct use of respiratory equipment and monitors. Competency should be assessed and recorded in SAP. 5.12.3 Ensure health and safety guidance notes relating to spontaneous combustion gas generation and dust are developed, periodically refined and updated so it is consistent with the current best practice. 5.12.4 Record sulfidic material health and safety risks in a site risk register and annually review these risks.	Superintendent Health Safety and Training	
5.13 Site Mineral Waste Management Team		
5.13.1 A site based Mineral Waste Management Team should be formed and meet on a regular basis. It must include representatives of every Department that has responsibilities related to ARD management. 5.13.2 The primary function of the Mineral Waste Management Team is to ensure on-going improvement and implementation of the SCARD Management Plan. 5.13.3 Agenda items and meeting minutes should be produced for every meeting. 5.13.4 An overview of PAF issues must be included in any introductory training provided to new employees and contractors. Further training of those groups involved in the mining of PAF should be commensurate to the level of risk PAF material poses to the operation. 5.13.5 Develop site specific emergency and contingency plans related to spontaneous combustion, ARD and sulfidic material management on an as needs basis. 5.13.6 Coordinate a technical review of ARD management by an external expert every four years. Track progress against	Site Mineral Waste Management Team – E13 Champion	Appendix 7 Example: Minutes from Tom Price meetings

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Requirements	Accountabilities	Reference Documents
outstanding actions at each meeting. 5.13.7 Coordinate all research related to sulfidic material characterisation, management, spontaneous combustion and ARD. 5.13.8 Ensure that related SWPs and guidance notes represent current practise and are up to date. 5.13.9 Changes to the SCARD management plan need to be provided to the Water Resource Evaluation Mineral Waste Team to be included in future updates.		
5.14 Management		
5.14.1 Ensure progress is made against outstanding spontaneous combustion and AMD audit actions.	Registered Site Manager	

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Figure 3: Sulfidic material in BIF and detritals management during mining operations

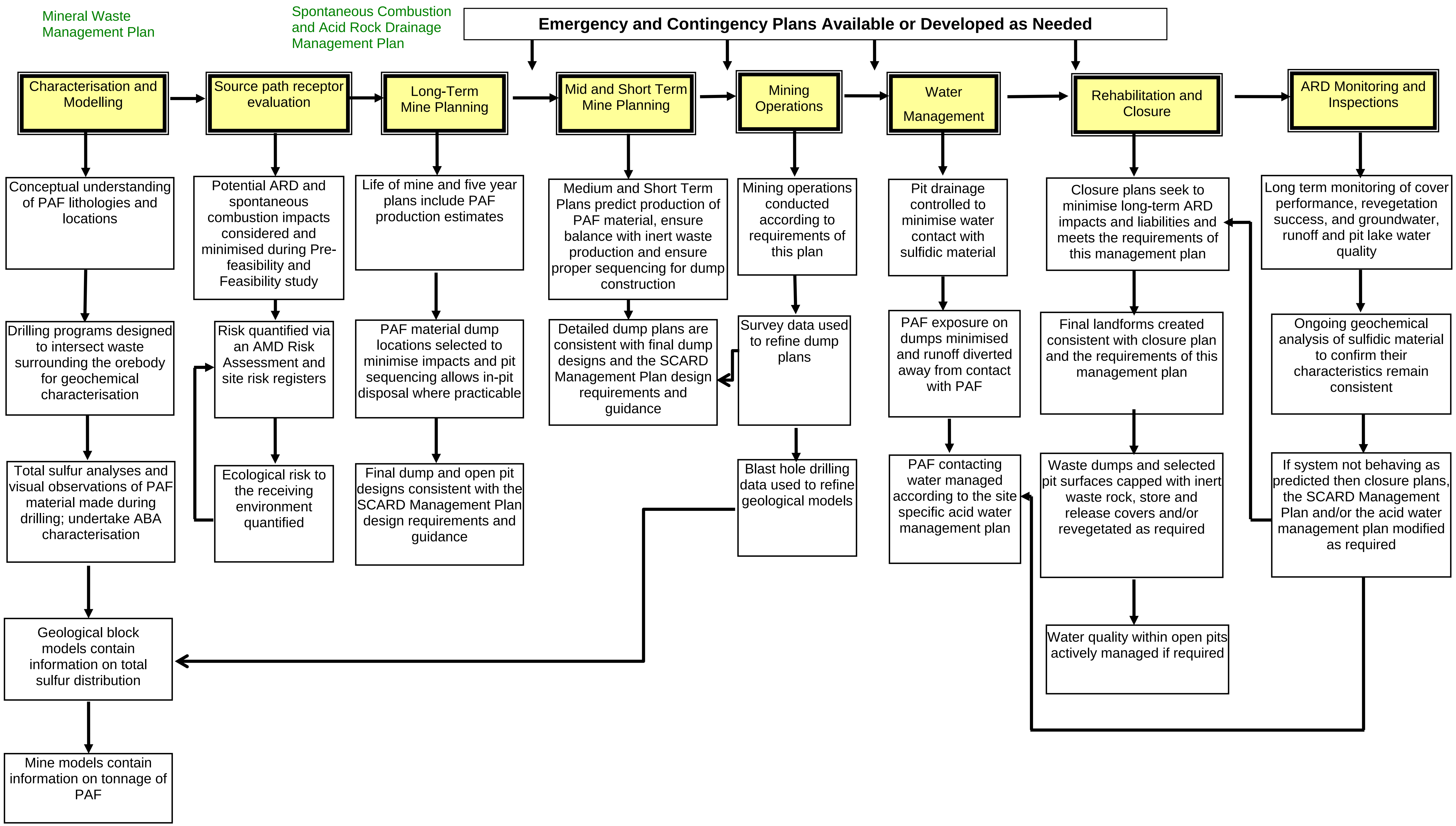

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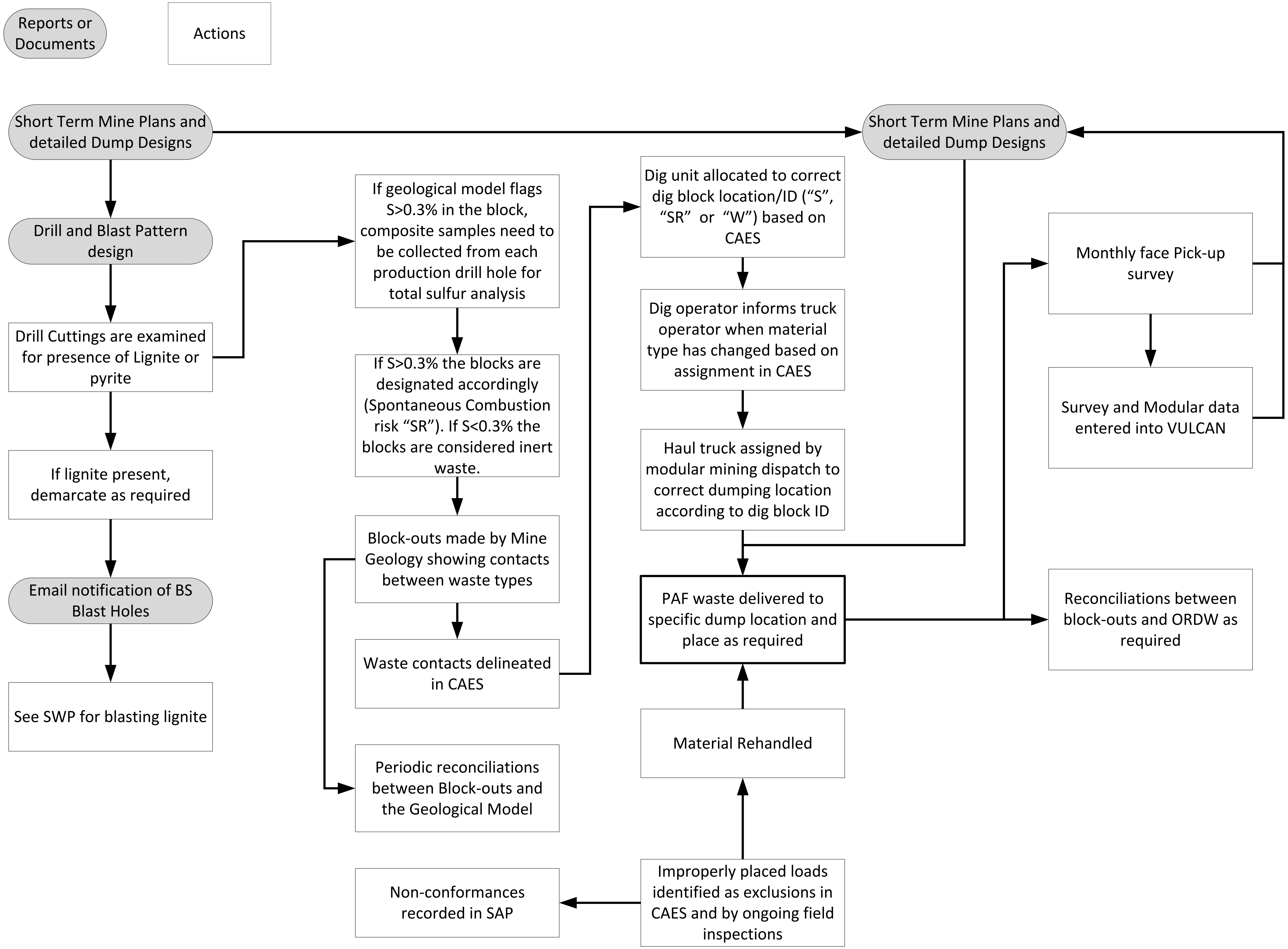
Figure 4: Sulfidic material in BIF and detritals management during mining operations



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6 Requirements, Accountabilities and References for Elevated Sulfur Material (including alunite)

It is expected that elevated sulfur presents an ARD risk but not a spontaneous combustion risk. This is based on the fact that the sulfur bearing mineral is sulfates rather than sulfides (AEISG, 2017).

The following is based on the current requirements for the management of elevated sulfur material at Brockman 2.

Requirements	Accountabilities	Reference Documents
6.1 Mine Geology		
6.1.1 Identify from the geological model waste and low grade blocks estimated to contain elevated sulfur. Use these to create block-outs to show the contacts between elevated sulfur material and waste and low grade types within the blast patterns. 6.1.2 Collect (at least every five years) representative samples of elevated sulfur material for full ABA and NAG analysis. Ensure results are communicated to the relevant teams.	Superintendent Mine Technical Services	
6.2 Mine Technical Services - Planning		
6.2.1 Design elevated sulfur waste dump and low grade stockpiles such that the elevated sulfur material is not located within one metre of the outer surface at closure.	Superintendent Technical Services	
6.3 Survey		
6.3.1 Monitor the construction of the dump such that elevated sulfur will not be located on the outer surface.	Superintendent Mine Technical Services	
6.4 Operational Planning		
6.4.1 Ensure material flagged as elevated sulfur is scheduled in CAES such that material is sent to the correct dump/stockpile.	Superintendent Mine Technical Services	
6.5 Load and Haul		
6.5.1 Ensure that elevated sulfur material is delivered to the correct location as assigned by mine geology. 6.5.2 Ensure that elevated sulfur material is dumped (where possible) from a tip head to ensure blending with inert material. If this is not achievable then paddock dumping will be satisfactory.	Superintendent Load and Haul	
6.6 Hydrogeology		
6.6.1 Ensure background water quality is established from water bores surrounding dumps and stockpiles where elevated sulfur material is stored. Undertake analysis of monitoring bores as required during dump construction and at closure.	Superintendent Water Resource Evaluation and Services	

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7 References

AEISG Code of Practice - Elevated Temperature and Reactive Ground - Edition 4 March 2017

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RTTI (2012), Mineral Waste Management in the Pilbara: A Position Statement (RTIO-PDE-0097780)

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Appendices

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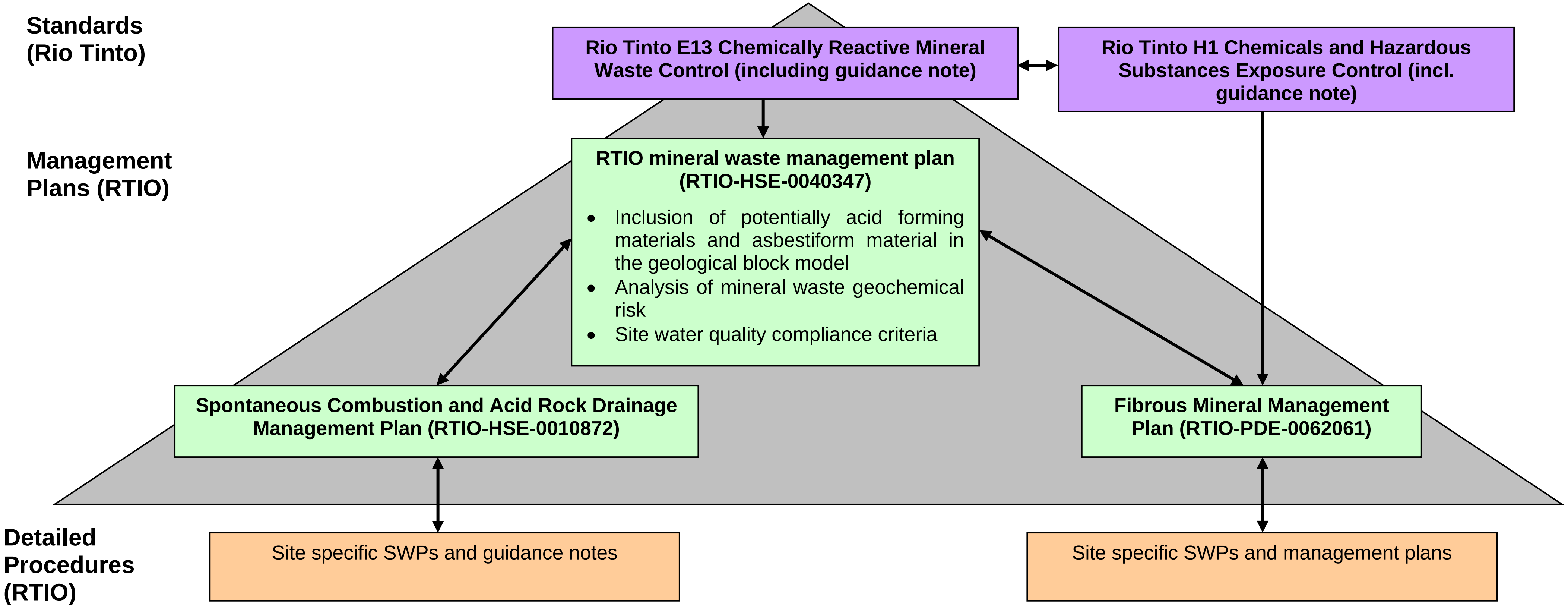
Appendix 1 RTIO Mineral Waste Procedures Map



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Appendix 2 Rio Tinto Iron Ore Mineral Waste Bibliography

The link below contains hyperlinks to all RTIO and general reference mineral waste documents. This link is continually updated as new documents are produced.

Link to Mineral Waste Bibliography

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Appendix 3 Geological Setting and Framework

A3.1 Overview of Hamersley Group Geology

Banded Iron Formation (BIF) iron deposits occur where BIF has been locally enriched *in situ*. BIF-derived iron deposits may be hosted in the Marra Mamba Iron Formation, or in the Joffre and Dales Gorge Members of the Brockman Iron Formation (Figure 5). Of the BIF-derived iron ore deposits, only those associated with the Dales Gorge Member of the Brockman Iron Formation are likely to occur in close proximity to the potentially carbonaceous and sulfide-bearing Mount McRae Shale (MCS) (Figure 5). Black shale may also be found in the Jeerinah Formation, Wittenoom Formation, Footwall Zone, Dales Gorge Member, Whaleback Shale Member, Ashburton Formation and Nanutarra Formation.

Marra Mamba ore is most commonly found in the Mount Newman Member and whilst carbonaceous black shale is not typically associated with these units, pyrite may be present in all three members of the Marra Mamba Iron Formation.

Detrital Iron Deposits (DIDs) and Channel Iron Deposits (CIDs) occur where enriched BIF has been exposed at the ground surface and material has been eroded and/or transported and redeposited. Detrital iron ore units, including unconsolidated screen, hematite conglomerate and CIDs of pisolite also occur in alluvial valleys. Sulfidic material may be associated with carbonaceous lignites and siderite.

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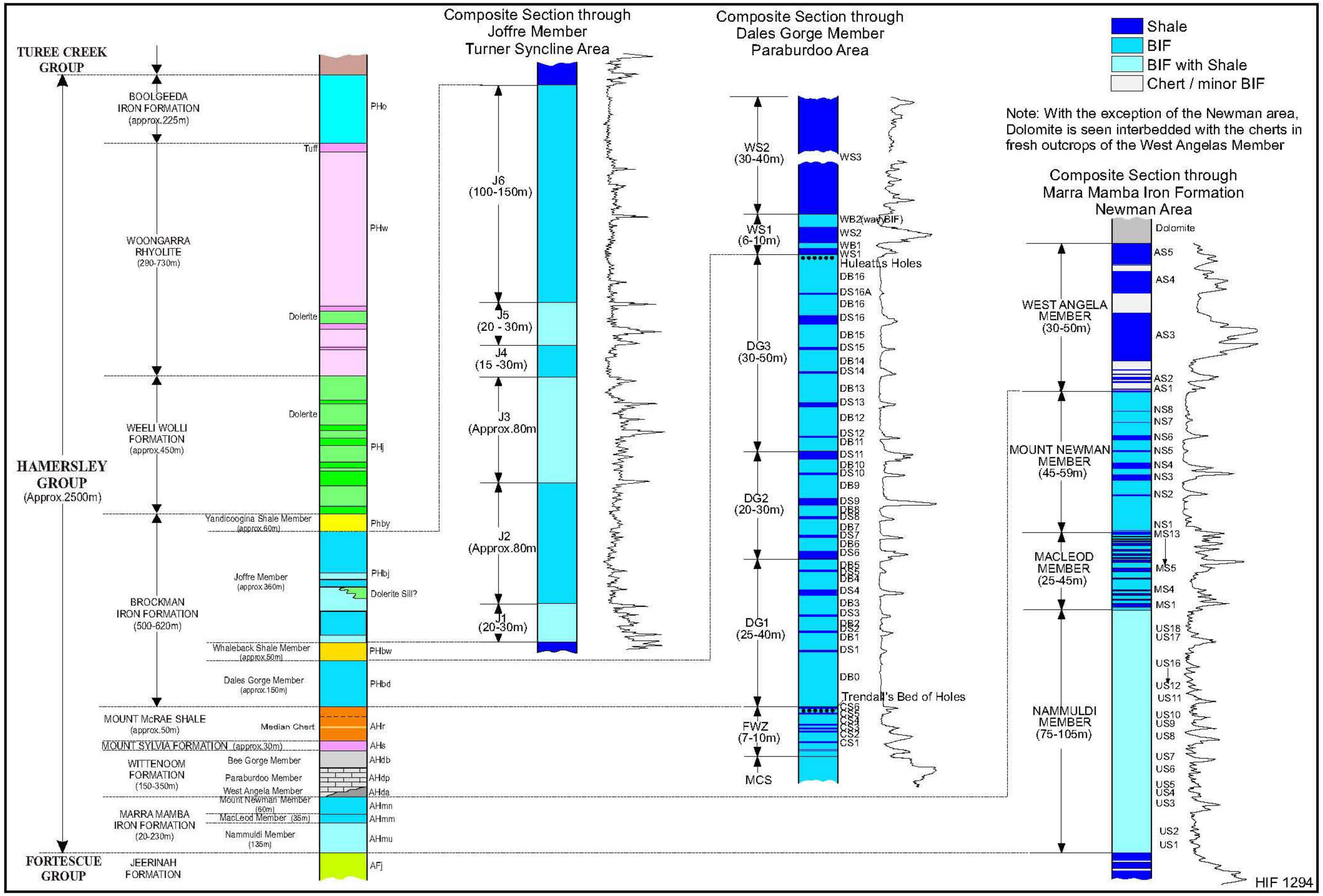

Figure 5: Stratigraphic column of the Hamersley Group.

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A3.1.1 Brockman Iron Formation

The thickness of the Brockman Iron Formation varies considerably regionally, from 500 m near Paraburdoo and Newman, up to 620 m at Mount Tom Price (Szulc 2003). The sequence may lose up to 50% of the total thickness when enriched from BIF (~30% Fe) to ore (>60% Fe).

The Brockman Iron Formation consists of an alternating sequence of BIF, shale and chert. It is subdivided into four members (Szulc 2003):

- The Dales Gorge Member (~150 m) is an alternating assemblage of 17 BIF and 16 shale macrobands. The member is informally divided into three units DG1 through to DG3. The subdivision is based on the location of shale bands and is designed to maximise head grade due to the abundance of shale (the major contaminant) in DG2.
- The Whaleback Shale Member (~50 m) has two zones, a lower zone of alternating thick bands of BIF and shale, which may be mineralised, and an upper zone of thin interbedded chert and shale.
- The Joffre Member (~360 m) is dominated by BIF with only minor shale interbands that are thinner and not as laterally persistent as those of the Dales Gorge Member.
- The Yandicoogina Shale Member (~60 m) is a sequence of interbedded chert and shale, intruded variably by dolerite.

A3.1.2 Mount McRae Shale (MCS)

The MCS can be divided into four units consisting of the Footwall Zone, upper MCS, middle MCS and lower MCS.

The uppermost 12 m of MCS, known as the Colonial Chert Member, or more commonly as the Footwall Zone (FWZ), consists of thin BIF units with interbedded shale. This is mineralised in the Mount Tom Price orebody. It is generally oxidised and has low sulfide concentrations, but some thin green to black shale beds may contain more than 10% total sulfur. If fresh FWZ material with elevated sulfide concentrations is processed as ore, the tailings may require selective management. Footwall Zone material that is potentially acid forming should to be dumped as cold black shale. However, if the total sulfur concentrations in FWZ are elevated and also associated with carbonaceous material, then it should be dumped as hot black shale.

When located above the groundwater table (AWT) the MCS is generally oxidised; however unoxidised black shale may also be found AWT (i.e., in the 4 East and 4 West pits at Paraburdoo). Oxidised MCS contains few intact sulfides, generally has less than 0.1% sulfur, is characterised by red, yellow, orange and white colours, and poses little ARD or self-heating risk. Below the water table (BWT), and locally immediately above the water table, the MCS is a black, carbonaceous and sulfide-bearing shale that poses an ARD and potential self-heating risk.

Pyrite within the black MCS can occur as: thin (2 to 20 mm) bands along bedding; as veinlets and stringers sub-parallel to bedding; as thicker (up to ~10 cm) and discontinuous bands (boudins and nodules); or as scattered pellets (‘peppercorn’ texture) along distinct layers (Bitencourt 2003).

The Upper MCS, Middle MCS and Lower MCS is classified as either cold or hot at each of the different mine sites according to Figure 6 to Figure 15. Hot and cold black shale are transported to different dumps and managed differently in accordance with Appendix 4.

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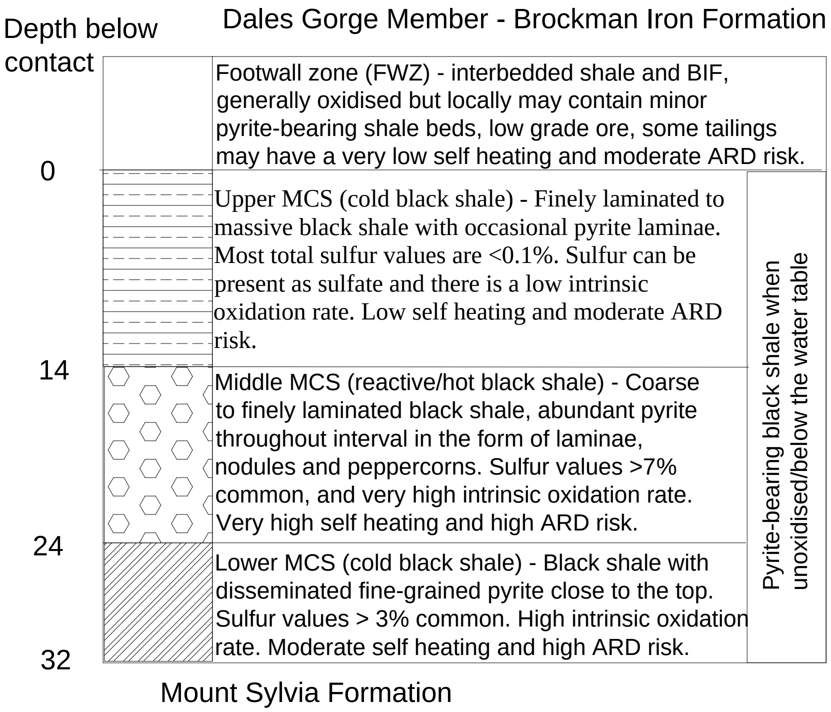

Figure 6: Stratigraphy of MCS at Tom Price (Bitencourt 2003).

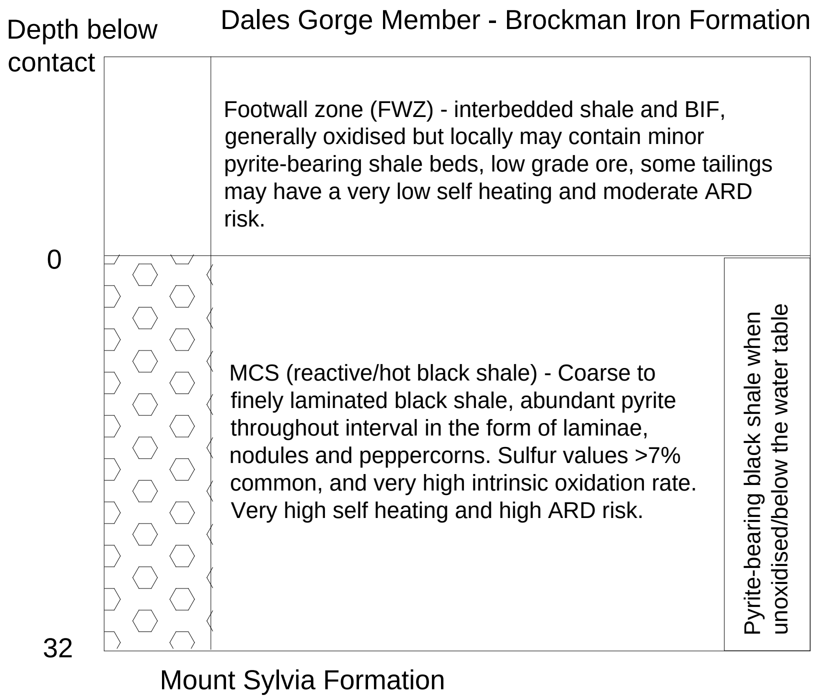

Figure 7: Stratigraphy of MCS at Channar (Paine 2007).

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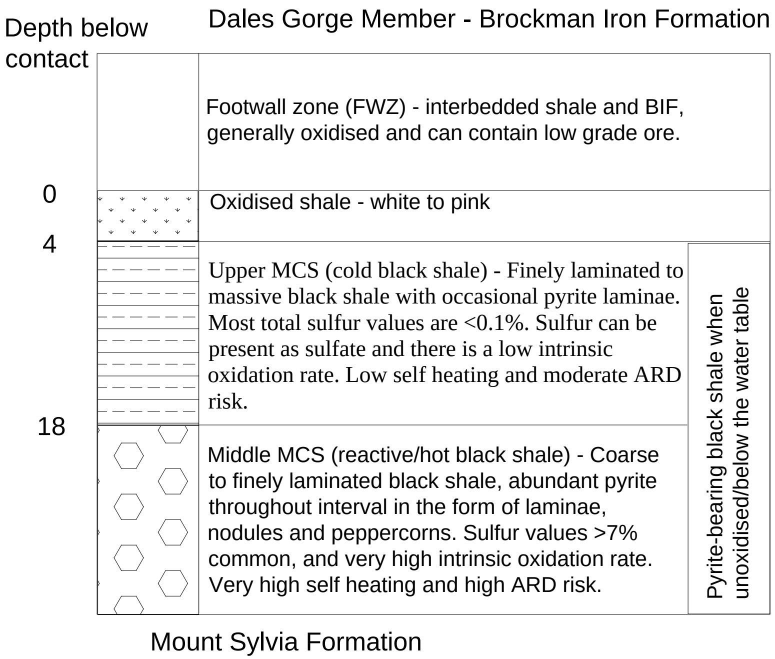

Figure 8: Stratigraphy of MCS at Brockman 2 (Boyle 2007).

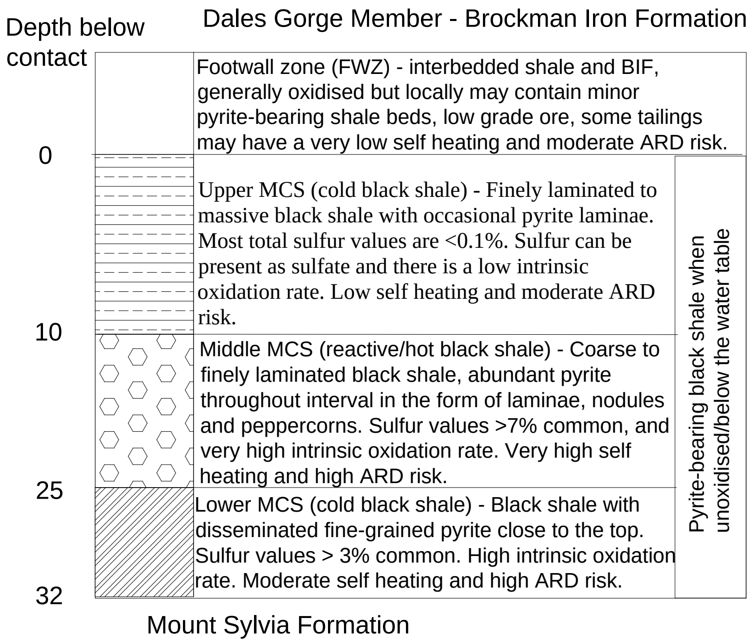

Figure 9: Stratigraphy of MCS at Brockman 4. [2] [3]

[2] Pit 11 had sulfidic material in the FWZ and further investigation is required to classify this material as either non or potentially acid forming material.

[3] Based on a limited number of drilling samples. These boundaries should be confirmed with further investigation during mining.

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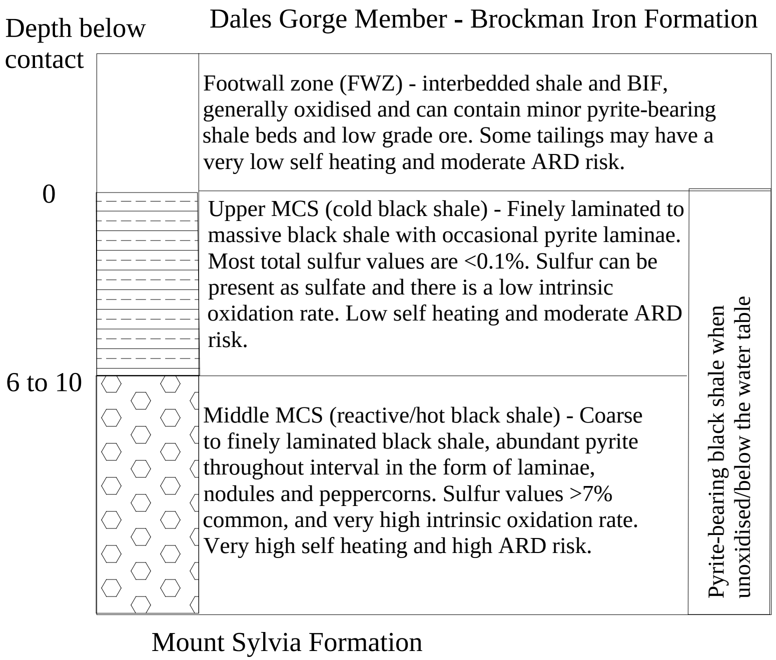

Figure 10: Stratigraphy of MCS at Western Turner Syncline (Section 17).4

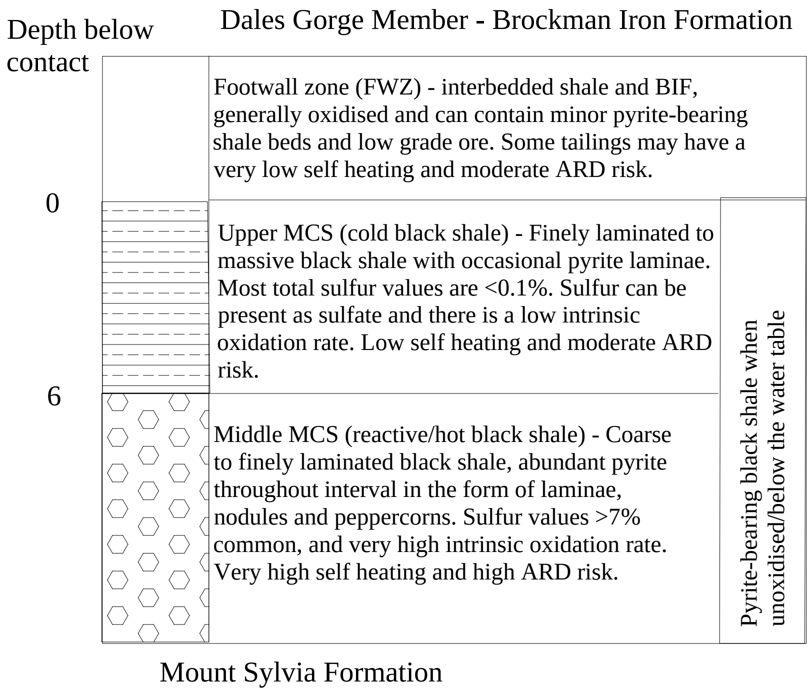

Figure 11: Stratigraphy of MCS at Western Turner Syncline (B1) (Jewbali and Geddes 2007). 5

[4] Some MCS in the geological model have been modelled as entirely hot black shale due to elevated sulfur concentrations in drill hole data at the FWZ and MCS boundary.

[5] Based on a limited number of Evaluation Geology drilling samples. These boundaries should be confirmed with further investigation during mining.

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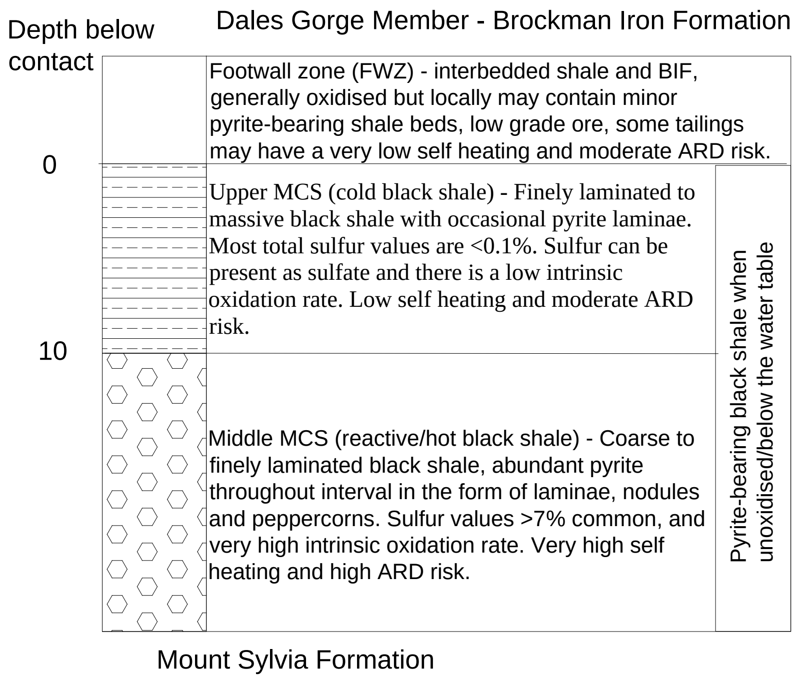

Figure 12: Stratigraphy of MCS at Western Turner Syncline (SE10). 6

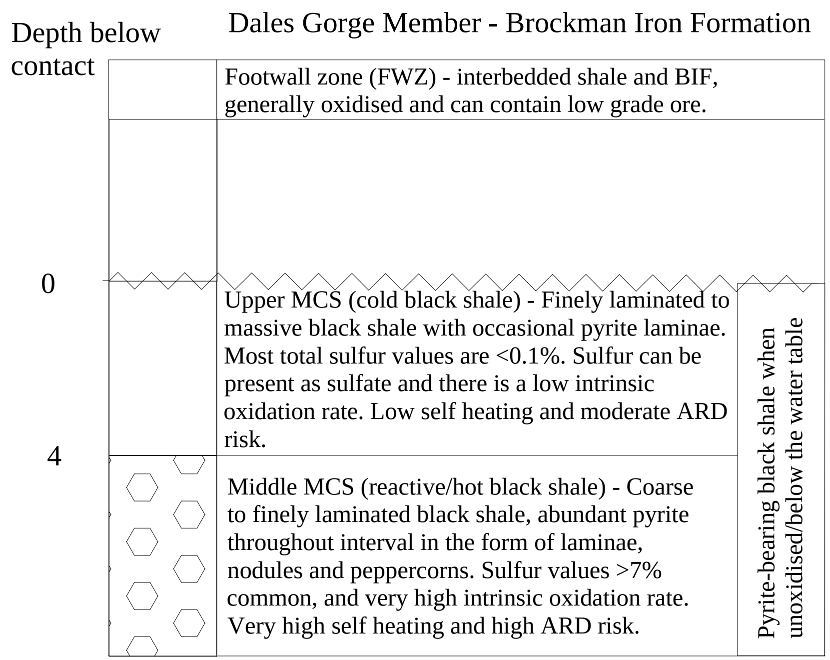

Figure 13: Stratigraphy of MCS at Hope Downs 4. 6

[6] Based on a limited number of Evaluation Geology drilling samples. The HD4 Mine Geology team use a sulfur assay of 0.5 % to differentiate cold and hot black shale (instead of this figure).

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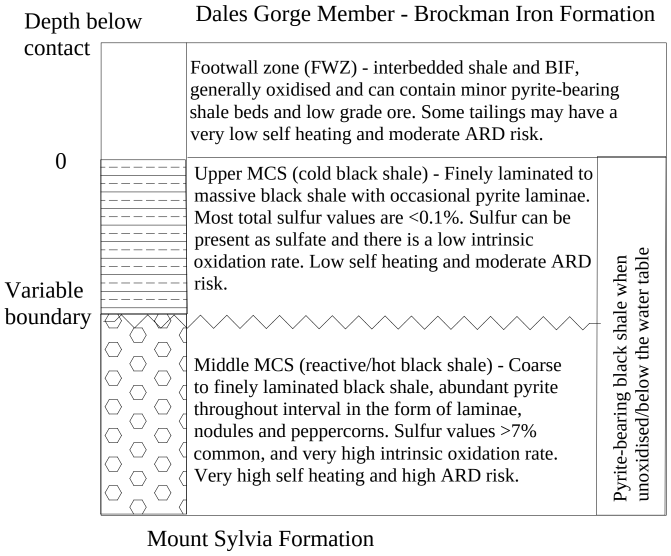

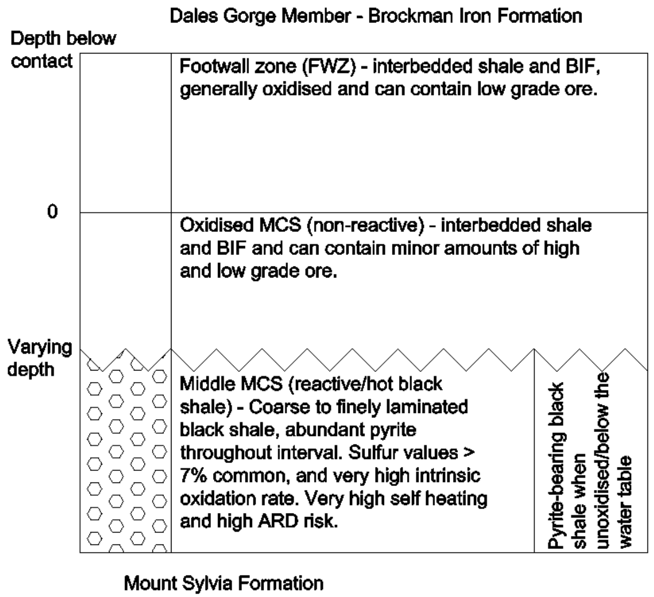

Figure 14: Stratigraphy of MCS at Paraburdoo – 4 East Extension. 7 8

Figure 15: Stratigraphy of MCS at Koodaideri.

[7] Based on a limited number of Evaluation Geology drilling samples. These boundaries should be confirmed with further investigation during mining.

[8] A consistent boundary between cold and hot black shale could not be determined due to large variability in the deposit. A variable line has been modelled based on acid base accounting and available sulfur concentrations in drill hole data. Further investigation is required to determine if a consistent line can be drawn on a pit by pit basis – otherwise black shale will need to be assayed during mining to verify which dump the material should be allocated.

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A3.1.3 Marra Mamba Iron Formation BIF and Detritals

Elevated sulfide concentrations have been found within the Marra Mamba Iron Formation BIF in the Hope Downs 1, West Angelas, Tom Price and Nammuldi areas. In addition, elevated sulfide concentrations have also been found in detritals at Hope Downs 1 and Nammuldi.

The Archaean Marra Mamba Iron Formation (the oldest Formation of the Hamersley Group) hosts bedded iron ore deposits. Mineralisation also occurs within the overlying West Angela Member of the Wittenoom Formation.

The Marra Mamba Iron Formation has been divided into three members: Nammuldi Member, MacLeod Member and Mount Newman Member. The Nammuldi Member conformably overlies the Jeerinah Formation and consists of massive yellow chert bands and cherty banded iron formation (BIF) with, occasional intercalated, fissile shale partings. The MacLeod Member is a sequence of BIF, banded chert and chert interbedded with a number of thick shale bands. The Mount Newman Member is composed of alternating mesobands of iron oxide and white to yellow chert bands. This member contains eight major shale bands of which four shales are used to mark distinct zones.

Hope Downs 1

The HD1N deposit is within the southern margin of the Hamersley Basin, located at the eastern end of the northern limb of the Weeli Wolli Anticline. Mineralisation ranges from shallow to deep, mainly located in the Mount Newman Member of the Marra Mamba Iron Formation (Hamersley Iron 2009), over a strike length of 7 km (Selliani *et al.* 2005). Lesser amounts of bedded mineralisation occur in the MacLeod Member and the West Angela Member of the Wittenoom Formation (Selliani *et al.* 2005).

In addition to the bedded mineralisation, deposits of secondary surficial canga, pisolite and limonite, as well as red ochre detritals, occur overlying, and adjacent to, the bedded mineralisation (Selliani *et al.* 2005). These deposits occur in plains between the two main iron formations, formed by the erosion of mainly Wittenoom Formation stratigraphy (Selliani *et al.* 2005).

Dalstra (2007) examined several diamond drilled holes at HD1 within the detritals and made the following observations:

- The siderite at Hope Downs occurs as “spotted” massive masses of amorphous yellow grey/brown siderite and goethite, usually with no recognisable crystal structures, but sometimes as concretions.
- The limonite has a pisolitic texture and contains occasional wood fragments (hence resembles classic CID), and overlies thick siderite, lignite and other organic-rich deposits and conglomerates.
- Importantly the siderite is closely associated with lignite and organic rich siltstone bands.
- Holes that intersect this sequence have a general upward succession of 1: weathered basement, 2: conglomerates, sometimes interbedded with red-ochre detritals, 3: siderite and lignite/organic siltstone interbedded with clay and conglomerate (conglomerate decreases upwards), 4: low grade CID, 5: calcrete and overburden (see Figure 16).

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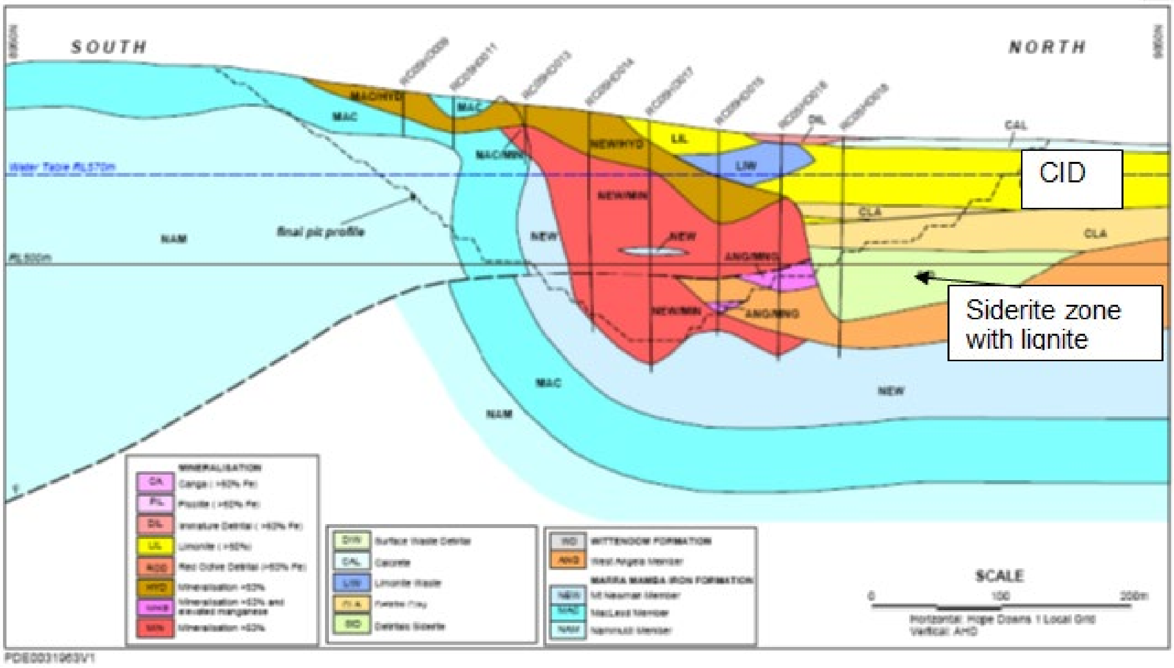

Figure 16: Hope Downs 1 North, Cross section 12850E (looking west) (Dalstra 2007).

During the 2006 Rio Tinto Iron Ore Resource Evaluation drilling program at HD1N, pyrite was observed in detrital clays (particularly lignites), disseminated dolomites in the Wittenoom Formation and in fresh Marra Mamba Iron Formation BIF (Figure 17). Elevated total sulfur concentrations were measured in many of the lithologies but the greatest amounts were found in the Wittenoom Formation, Nammuldi Member BIF and detrital siderites/clays (lignite).

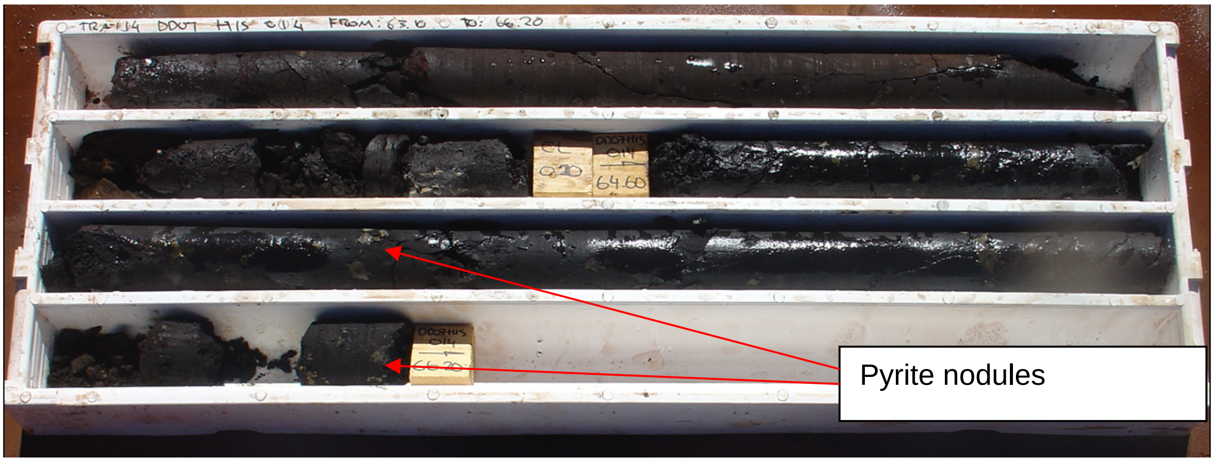

Figure 17: Pyrite within lignite in a diamond core from HD1S (DD07H1S014 63.1 to 66.2 m).

A3.1.4 Elevated Sulfur

Alunite has been observed to occur in a number of stratigraphic units of the Hamersley Group, particularly in close proximity to those units that contain sulfide minerals. It can be found in the presence or absence of elevated levels of sulfide sulfur and, in some occurrences, the alunite content can be relatively high (> 10%). Jarosite has also been observed in some samples of the Hamersley Group stratigraphic sequence, and both alunite and jarosite can occur together as shown in Figure 18. When alunite (or jarosite) weathers (dissolves), the rate of weathering is restricted by the low solubility of the mineral. However, acid can be produced if the weathering product is an aluminium (or iron) oxyhydroxide mineral phase, such as gibbsite ($Al(OH)_3$) or

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boehmite (AlO(OH)), and for alunite the acidity released may produce solutions with a pH as low as 4. In some samples, acid release may be controlled to a lower pH (down to 2) by another aluminium hydroxysulfate mineral, jurbanite ($AlSO_4(OH).5H_2O$). The occurrence of this latter phase, however, may be subjective and in situations where high acidity is released, the associated release of aluminium and iron, as well as the acidity, may all be associated with the dissolution of jarosite containing some aluminium (e.g. as in Figure 18; RTTI 2012).

For alunite to form, a source of potassium is required. One potential source are dolerite dykes that contain muscovite. High sulfate content fluids, where the sulfate originated from the oxidation of pyrite either in the dolerite dyke or in MCS, flow upwards along the dyke. These fluids are also likely to contain high aluminium. Subsequently, they are retarded by an impermeable layer where alunite forms. Two other minerals are also found in close association with the alunite; gibbsite and kaolinite. Gibbsite can form from the continued weathering of alunite, and kaolinite may result as the weathering product of the muscovite that provided the potassium source for the alunite. Kaolinite, a clay, is a typical weathering product of aluminosilicate minerals (RTTI 2012). Elevated sulfur material has been found at a number of sites, however it has only been found to be acid forming (in a low capacity) at BS2 (i.e., within the AWT DG and WS rock types).

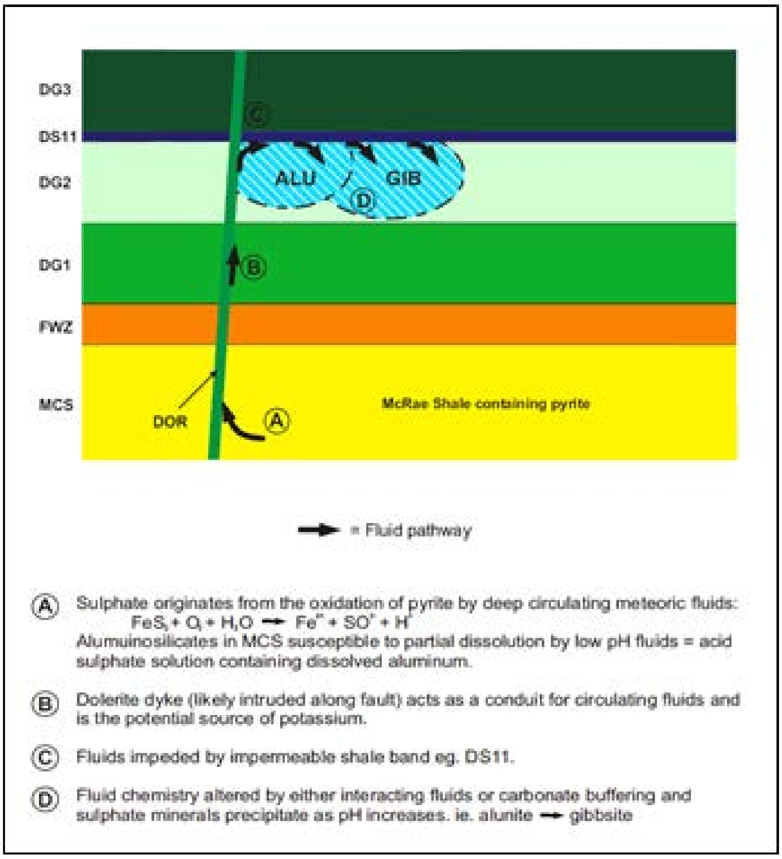

Figure 18: Possible scenario for alunite genesis (Danaher 2012)

A3.1.5 Neutralising Materials

A number of mine sites will expose material with readily available neutralising potential. The enriched and not enriched BIF mined in the Pilbara typically has a low acid neutralising potential. Shales also typically have low neutralising potential. However, calcretes mined in detrital deposits can have readily available neutralising potential (Acid Neutralising Capacity or ANC of 265-660 kg H_2SO_4/t). In addition dolomite within the Wittenoom Formation (ANC of 301-885 kg H_2SO_4/t), carbonaceous BIF (ANC of 134-333 kg H_2SO_4/t) and dolerites (ANC of 63-92 kg H_2SO_4/t) can offer some readily available neutralising potential.

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Table 1 provides an indication on the necessary ANC required to neutralise various sulfur contents. This table can be used as a first pass assessment, however it is recommended further work is undertaken to assess the availability of the ANC. Sometimes the ANC value can be overestimated if siderite is present or if slow reacting alumina-silicates contribute to the measured ANC. Calcite and dolomite are the most effective ANC contributing minerals. Further test work or kinetic leach test work would be required to verify that the ANC is effective in neutralising the acidity. It is critical that sufficient ANC is achieved through all size fractions and that the ANC/MPA of the finer fraction is not less than 1.5.

Table 1: Necessary ANC (kg H_2SO_4/t) to neutralise various sulfur contents. Factors of safety of 2 (good) and 3 (high) are allowed for.

Sulfur	MPA	ANC/MPA	
		2	3
%	kg H_2SO_4/t	Good	High
0.5	15	31	46
1	31	61	92
2	61	122	184
5	153	306	459

A3.1.1 *Acid Base Accounting Summary*

Detailed acid base accounting for each RTIO mine site and analysis of drill hole sulfur concentration with ARD Risk Assessments can be found in the Mineral Waste Bibliography.

A3.1.2 *References*

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Appendix 4 Dump Specifications for Black Shale and Elevated Sulfur Material

Management of sulfates or sulfides within black shale, BIF or detritals needs to be considered during all phases of waste rock dump design, from initial selection of dump locations during the long-term planning process (five year and longer time horizon) to the detailed dump designs generated during short term planning (time horizon less than a year). The Waste Dump Design Checklist is to be filled in for all new waste dump designs to help ensure environmental issues are adequately considered.

The following guidelines are not relevant for Hope Downs 1 and instead Appendix 5 should be followed.

A4.1 Selection of Dump Locations

When designing new PAF material dumps, the dump location and footprint should be selected to minimise potential long term environmental impacts and financial liabilities. Selection and design criteria that must be considered include:

- Under no circumstances should PAF material be used for works such as windrows, construction fill, ramps, fantails, roads or any other use that would disperse the material over a broad area in an uncontrolled manner.
- The PAF dump location should not receive runoff from surrounding areas. In particular waste dumps must not be sited in established drainages with significant upstream catchments.
- In pit disposal should be considered a priority instead of the construction of above ground waste rock dumps. However, hydrogeology investigations are required to evaluate water recovery levels and timeframes, and connection of the void to receptors.
- Placement of PAF material within pits that already contain PAF wall exposures is preferable to placement in pits that do not have these exposed on the pit walls.
- PAF dumps should not be placed over or adjacent to significant regional aquifers such as saturated valley fill alluvial deposits or fractured bedrock aquifers such as the Wittenoom Formation.
- PAF dumps should not be placed over ore grade or near ore grade CID or BIF-derived deposits. These not only have potential economic value, but may act as significant local aquifers.
- PAF dumps should not be placed over, adjacent to, or where there is a connection to significant seeps or springs.
- Avoid siting new PAF dumps in catchment basins that do not already contain PAF material.
- The number of sites containing PAF material and the footprint of these dumps should be kept to a minimum.
- PAF dumps should be located near sources of clean waste rock for encapsulation.
- Background groundwater quality surrounding the dump location must be measured before any material is dumped. This will require the installation of groundwater monitoring bores. These bores will be used to provide a temporal record of groundwater quality in the vicinity of the dump.

A4.2 In-Pit Disposal Requirements

In pit disposal of PAF material is generally more secure than disposal in above ground waste rock dumps. Where practicable, in pit disposal should be considered the preferred disposal alternative because it:

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- Reduces the risk of erosion exposing PAF material in the long term;
- Inhibits convective oxygen transport because the waste is surrounded by relatively impermeable rock walls;
- Reduces the footprint of the waste disposal facilities;
- Reduces the volume of inert or net neutralising waste needed to encapsulate the PAF material; and
- May help to prevent the formation of acidic or hyper-saline pit lakes if the pit can be filled to above the post-mining water table.

Note that in some pits it may be possible to place PAF material both above and below the water table with a minimum 10 metre thick inert waste layer placed against the predicted mean post-mining water table. If PAF material is placed BWT, hydrogeology investigations are required to determine the water recovery level, rate of recovery and if there are any connections to receptors.

The following sections of BWT PAF disposal are not applicable for Hope Downs 4. PAF material may only be placed AWT and not under final rehabilitation slopes at Hope Downs 4 due to regulatory commitments. Further approval is required for placement of PAF material BWT.

A4.2.1 In Pit Disposal Below the Water Table

If PAF material is placed below the post-mining water table, it will become permanently flooded which will control subsequent oxidation and acid release. In the long term, placement below the water table is the most secure and low risk disposal option. It is particularly beneficial for hot black shale because it removes the long-term risk of spontaneous combustion. If a pit can be backfilled so that the fill elevation is above the pre-mining water table level, it is possible that the water table will eventually rebound to or near the pre-mining elevation. If the pit is only partially backfilled to below the pre-mining water table, it is likely that a shallow intermittent, seasonal or permanent pit lake will form on top of the fill material.

Elevated sulfur material (i.e., containing sulfate minerals such as alunite or jarosite) should not be placed below the post-mining water table as the release of acid is controlled by the dissolution of the minerals and is not a kinetic controlled reaction as is the case for sulfidic PAF materials.

For sulfidic PAF material placed below the post-mining water table the following minimum design criteria apply:

- For pits backfilled above the predicted post-mining water table, the top of the PAF material backfill must be at least 5 metres below the mean predicted post-mining water table (Figure 19).

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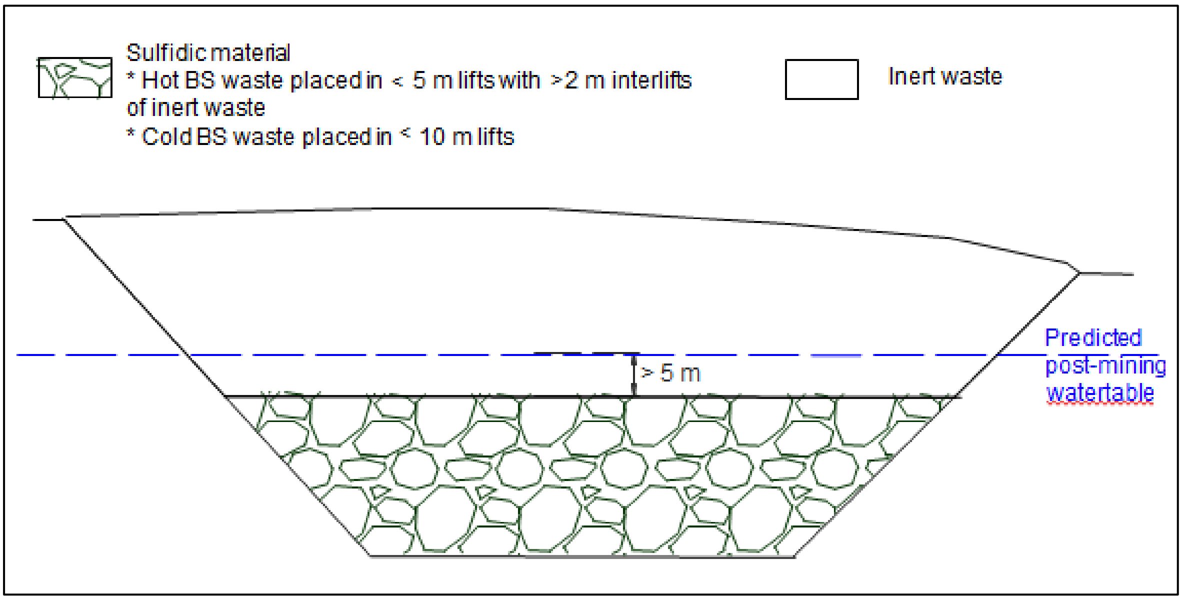

Figure 19: Example of PAF material placed BWT and with the pit completely backfilled.

- For pits that are only partially backfilled to below the pre-mining water table, the top of the PAF material backfill must be at least 5 metres below the estimated mean pre-mining water table and at least 5 metres below the predicted post-backfilling water table (Figure 20). In this situation it can generally be assumed that the mean post-mining water table will be at the top of the backfill. Thus, the PAF waste will be covered by at least 5 metres of inert waste.

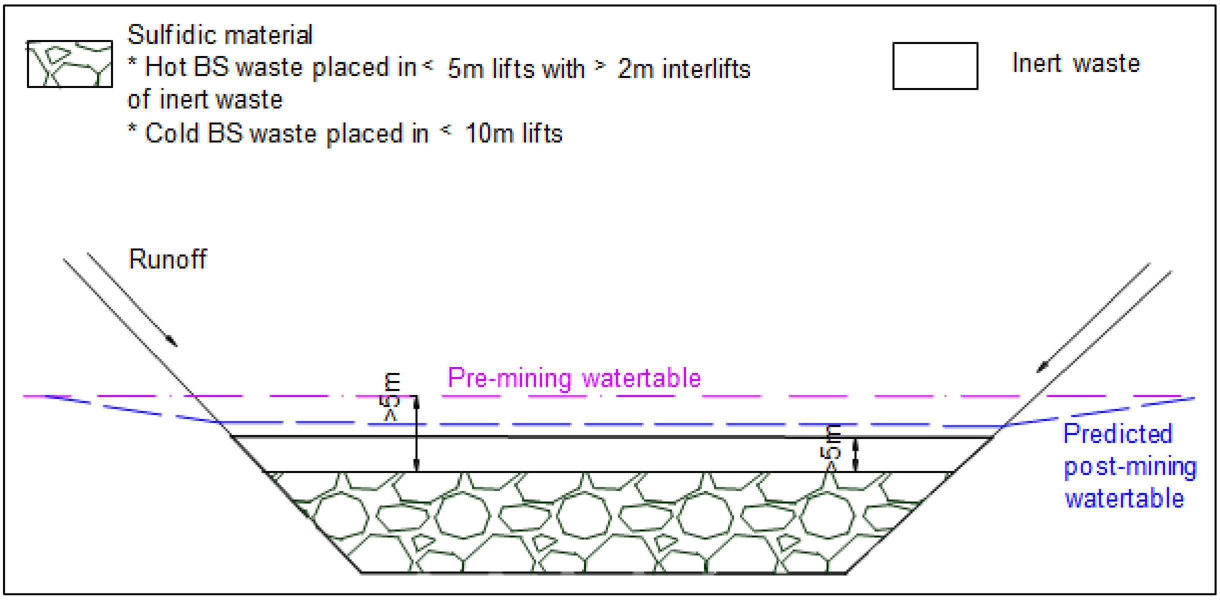

Figure 20: Example of PAF material placed below the water table and with the pit partially backfilled.

- The thickness of each hot black shale material lift must not exceed 5 metres followed by a minimum 2 metre lift of inert or net neutralising waste rock between each hot black shale layer.
- The thickness of each cold black shale material lift must not exceed 10 metres. No inert or net neutralising waste rock layer is needed between cold black shale lifts.
- The uppermost lift of both cold and hot black shale material must be covered with a minimum 5 metre layer of inert or net neutralising waste rock.
- Each lift must be placed so that it ties into the pit walls on all sides to minimise the risk of convective oxygen transport until the waste is flooded.

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- If backfilled to above the post-mining water table, the upper inert waste rock surface must be revegetated.
- A store and release cover is not needed if all PAF material in a pit is placed below the water table.

In addition to the minimum design requirements listed above, the optimum design for in-pit disposal below the water table also includes:

- Enough inert or net neutralising backfill should be placed on top of the PAF waste to raise the fill level to at least above the post-mining water table (preventing the formation of a pit lake) and preferably above the pit walls so that runoff is not directed into the pit fill (see Figure 19).
- If required, flooding of the backfilled pit should be enhanced by diverting surface water flows into the pit or directing dewatering water from active open pits into the backfilled pit. The more rapidly the waste can be inundated, the less pyrite will ultimately oxidise. Rapid flooding will minimise the build-up of soluble sulfide oxidation products in the material. As long as geotechnical safety requirements are met, construction of waste lifts into standing water on the pit floor is acceptable. Figure 21 demonstrates that less than 50% of the sulfidic material oxidises if the water table is recovered within 100 years and less than 15% oxidises if the water table is recovered in 30 years. This may differ from site to site, however this example clearly demonstrates the advantage of BWT PAF storage and rapid water recovery.

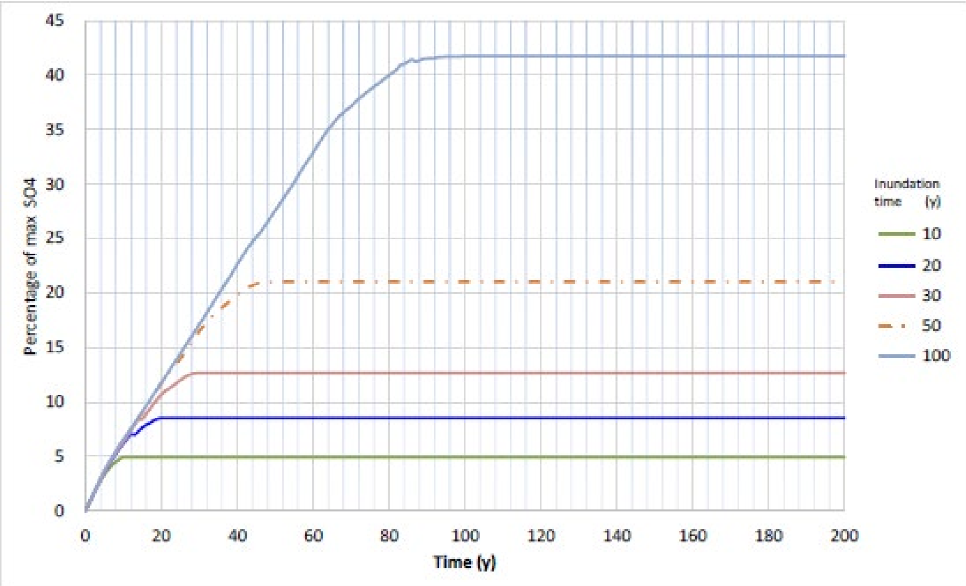

Figure 21: An example from HD1 on the effects of different inundation time on sulfate generation.

A4.2.2 In Pit Disposal Above the Water Table

If PAF material is placed above the post-mining water table it must be ensured that long-term variations in the water table elevation do not allow water to rise into the overlying PAF material. Intermittent contact with infiltrating water from above must also be minimised. For PAF material placed above the post-mining water table the following minimum design criteria apply:

- The base of the PAF material backfill must be at least 5 metres above the predicted mean post-mining water table.
- At least 5 metres of inert or net neutralising waste rock must be placed at the base of the open pit before PAF backfill is placed. The most likely location for a perched water table to form is at the base of the backfilled pit because of the permeability contrast between the bedrock and the backfill.

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- The thickness of each hot black shale material lift must not exceed 5 metres followed by a minimum 2 metre lift of inert or net neutralising waste rock between each hot black shale layer.
- The thickness of each cold black shale material lift must not exceed 10 metres. No inert or net neutralising waste rock layer is needed between cold black shale material lifts.
- The uppermost lift of both cold and hot black shale material must be covered with a minimum 2 metre layer of inert or net neutralising waste rock. This will prevent runoff water from contacting the underlying PAF material until the minimum 4 metre-thick store and release cover can be constructed.
- If the pit can be completely backfilled so that no high walls are exposed above the inert waste rock fill, then each inert, cold and hot black shale material layer should tie into the pit walls on all sides to minimise the risk of convective oxygen transport (see Figure 22 and Figure 23 for examples).

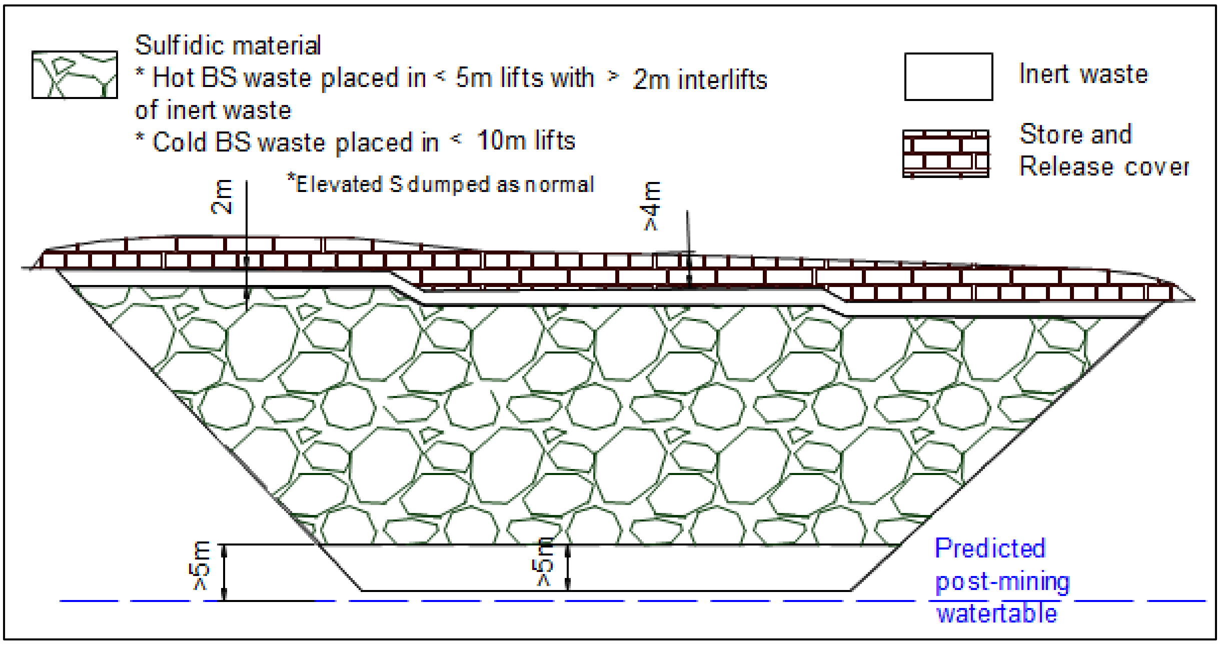

Figure 22: Example of PAF material placed in a dry pit that is completely backfilled.

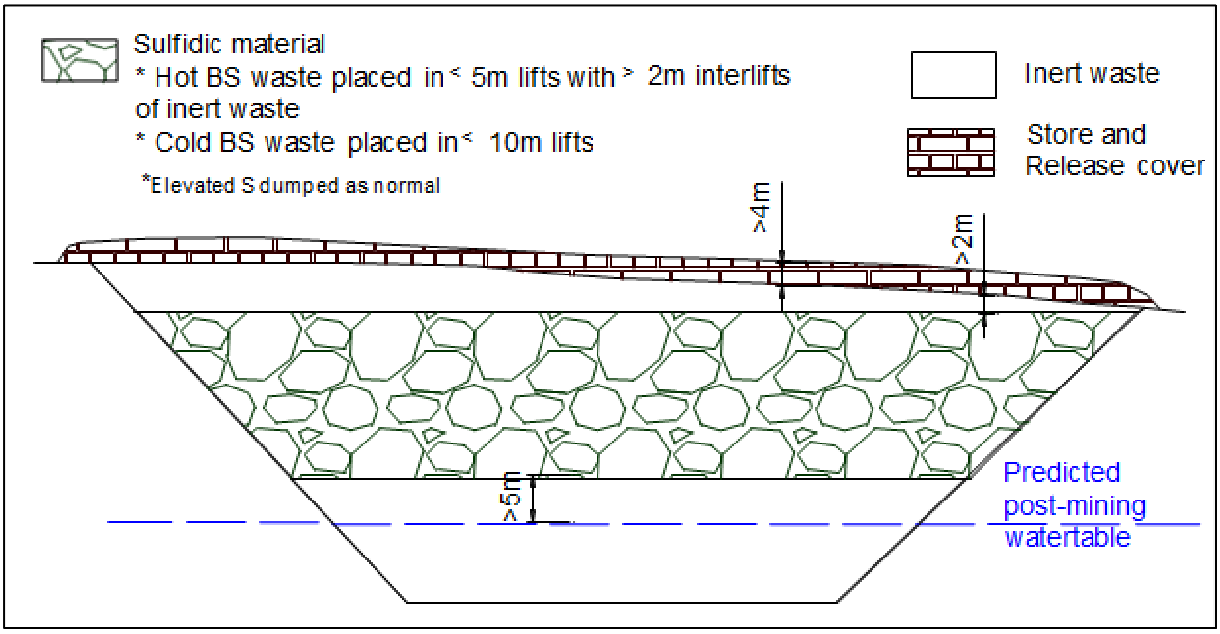

Figure 23: Example of PAF material placed above the water table and with the pit completely backfilled.

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- If the pit will only be partially backfilled so that highwalls are exposed above the final backfill surface and that the runoff from the remaining highwalls will flow towards the backfill, a minimum five metre (measured both horizontally and vertically) buffer of inert waste rock must be placed between the pit walls and each PAF material lift where possible (see Figure 23 for an example). A 2 metre high by 5 metre wide abandonment bund will also need to be placed adjacent to the exposed high walls to prevent run on water from infiltrating into the cover over the PAF material.

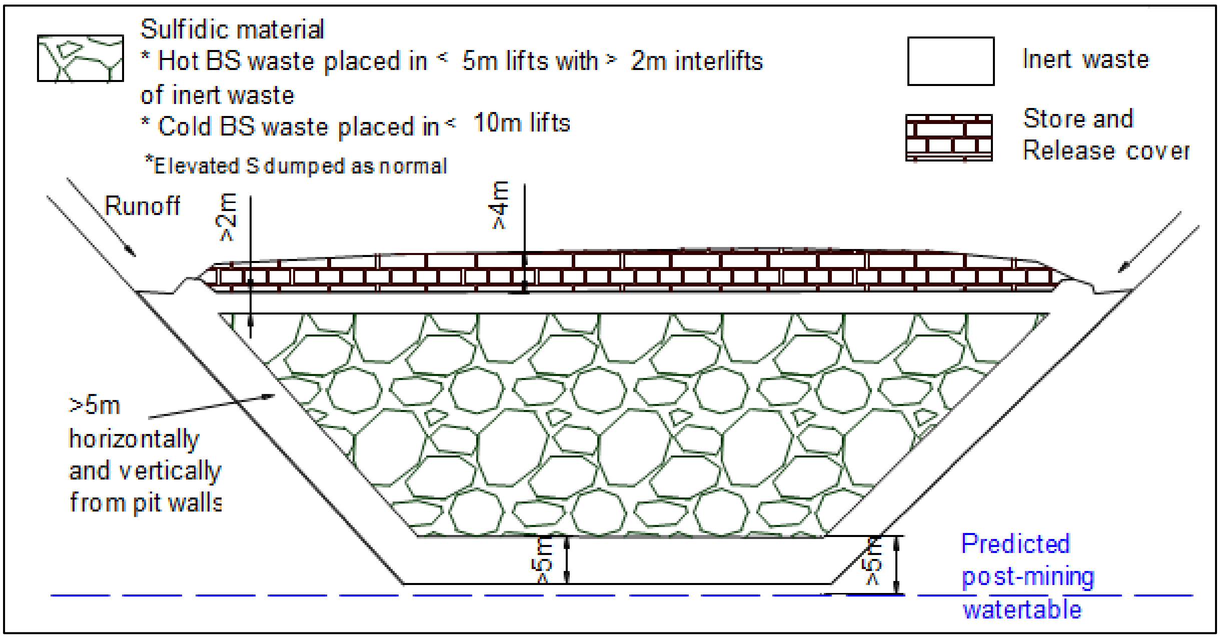

Figure 24: Example of PAF material placed above the water table and with the pit partially backfilled.

In addition to the minimum design requirements listed above, the optimum design for in-pit disposal above the water table also includes:

- If possible, the pit should be backfilled above the lowest point on the pits walls so that the final backfill surface can be sloped to allow runoff water to flow out of the pit footprint.
- The optimum design would be to backfill the pit so that there are no highwalls exposed that could direct runoff onto the store and release cover and underlying PAF material (see Figure 22and Figure 23).

A4.3 Above Ground Disposal Requirements

If PAF material waste rock dumps are to be constructed on top of the original ground surface, more stringent design criteria is required than for in-pit disposal because of the risk of erosion exposing encapsulated PAF material and because of the likelihood of the convective transport of oxygen through the side slopes of the dump. Design criteria for hot black shale dumps are also more stringent than for cold black shale dumps and elevated-sulfur dumps.

A4.3.1 *Design of Outer Waste Rock Dump Slopes*

To the extent possible, cold and hot black shale material should be excluded from beneath final waste rock dump slopes. There are several issues associated with the placement of cold and hot black shale beneath waste rock dump slopes:

- There is an increased risk of slope erosion damaging vegetation and covers in the short term, or in the long term exposing the underlying material.

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- The probability of convective oxygen transport to the sulfidic material is higher than for cold and hot black shale material only placed in the dump interior.
- Store and release covers cannot be built on slopes because they are constructed with more erodible fine-grained materials. It is likely that infiltration rates into the underlying cold and hot black shale material will be higher on slopes than on flat surfaces with a store and release cover, which could result in increased AMD.
- Uncertainties with the requirements for final dump slopes may require the importation of additional inert material to achieve the final landform design to ensure the preservation of the minimum 5 metres of inert cover over the sulfidic material.
- The berm and batter design of final slopes would direct water through the slopes and into the underlying PAF material.

The minimum design criteria in the following section reduce but do not completely mitigate these risks. **For this reason, hot black shale should not be placed under final slopes, and the volume of cold black shale should be minimised wherever possible[9].** The greatest benefit can be derived from excluding hot black shale material from beneath the slopes because it not only has the potential to spontaneously combust, but also has anywhere from 2 to 70 times more acid producing potential on average than the cold black shale material.

A4.3.2 *Hot Black Shale*

Figure 25 shows the optimum design for the waste rock dumps in which hot black shale is completely excluded from beneath the footprint of the final recontoured slope.

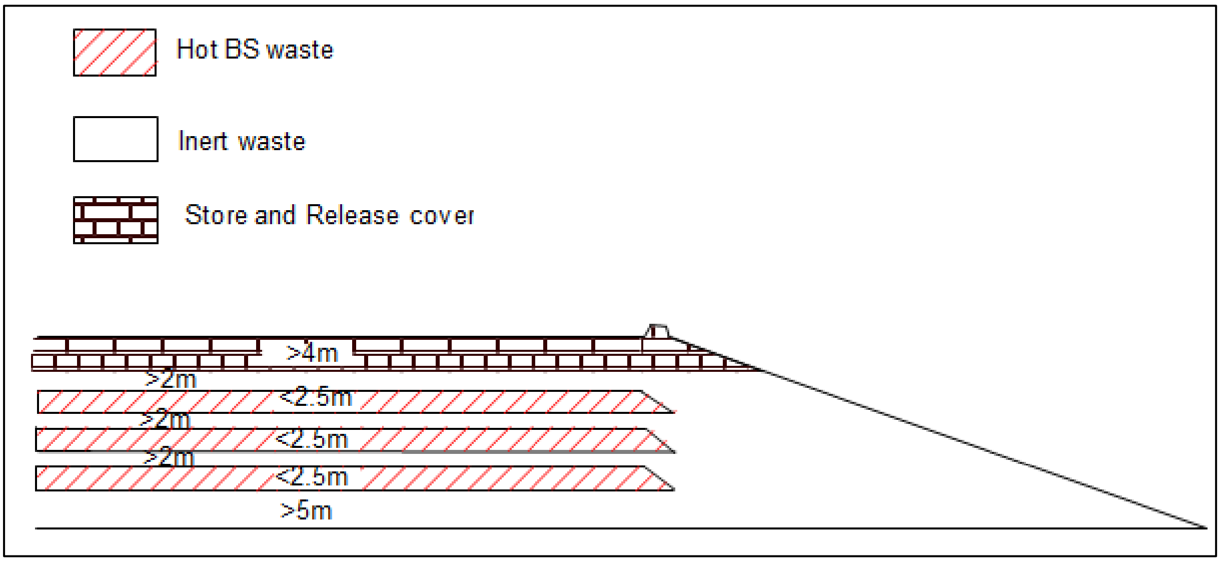

Figure 25: Example of the design for hot black shale dumps.

The minimum design criteria for hot black shale dumps are:

- A minimum of 5 metres of inert or net neutralising waste rock must be placed on the original land surface at the base of the dump.
- Enough inert waste rock must be placed against hillsides so that PAF material is not located within 5 metres of the hillside as measured both vertically and horizontally.
- The thickness of each hot black shale material lift must not exceed 2.5 metres followed by a minimum 2 metre lift of inert or net neutralising waste rock. Lifts are to be constructed by paddock dumping (or reverse paddock dumping and pushing out) so that the hot black shale can cool and so that incident vehicle traffic helps create a compacted layer every 2 to 2.5 metres to inhibit water movement and convective oxygen transport.

[9] Effective from the 2016 SCARD update. Earlier designs and dumps can still contain hot black shale under slopes.

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- Enough inert or net neutralising waste rock must be placed on the outer skin of the hot black shale waste rock dump so that no hot black shale material is located under the final slopes.[10]
- Hot black shale may be mixed with Elevated S material in dumps, however elevated sulfur material should not be used on the outer slopes.
- The final lift on a hot black shale waste rock dump must be composed of a minimum 2 metre-thick inert or net neutralising layer. This will prevent runoff water from contacting the underlying PAF material until the minimum 4 metre-thick store and release cover can be constructed.
- During construction and at closure, the upper dump surface of the hot black shale waste dump should be designed so that it only receives incident rainfall with no run-on from adjacent areas.

A4.3.3 *Cold Black Shale*

An example of a cold black shale waste rock dump constructed according to the minimum dump design criteria is shown in Figure 26. The minimum design criteria for cold black shale dumps are:

- A minimum of 5 metres of inert or net neutralising waste rock must be placed on the original land surface at the base of the dump.
- Enough inert waste rock must be placed against hillsides so that cold black shale is not located within 5 metres of the hillside as measured both vertically or horizontally.
- The thickness of each lift of cold black shale must not exceed 10 metres. This will create a vehicle compacted layer every 10 metres in the dump to inhibit water movement and convective oxygen transport[11].
- No inert or net neutralising waste rock layer is needed between cold black shale lifts.
- Enough inert or net neutralising waste rock must be placed on the outer skin of the cold black shale waste rock dump so that no material is located within 5 metres of the final dump surface after the slope has been re-contoured at closure. [12]
- The final lift on a cold black shale waste rock dump must be composed of a minimum 2 metre-thick inert or net neutralising layer. This will prevent runoff water from contacting the underlying material until the minimum 4 metre-thick store and release cover can be constructed.
- During construction and at closure, the upper dump surface of the cold black shale dump should be designed so that it only receives incident rainfall with no run-on from adjacent areas.

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[10] Effective from the 2016 SCARD update. Dumps designed and built prior to 2016 can continue to dump hot black shale under slopes, however it must be located > 5 metres (measured across the shortest distance) from the final dump slope. HD4 dumps cannot be constructed with PAF under final slopes due to regulatory commitments.

[11] Note that this has been changed from 5 m lifts as the gas movement through waste dumps has been shown during ANSTO testing to be diffusive and it is likely that the difference in ARD generation between 10 and 5 m lifts will be negligible. Refer to Feb 2006 Tom Price ARD meeting minutes.

[12] Due to regulatory conditions, HD4 cannot place cold or hot black shale under final slopes.

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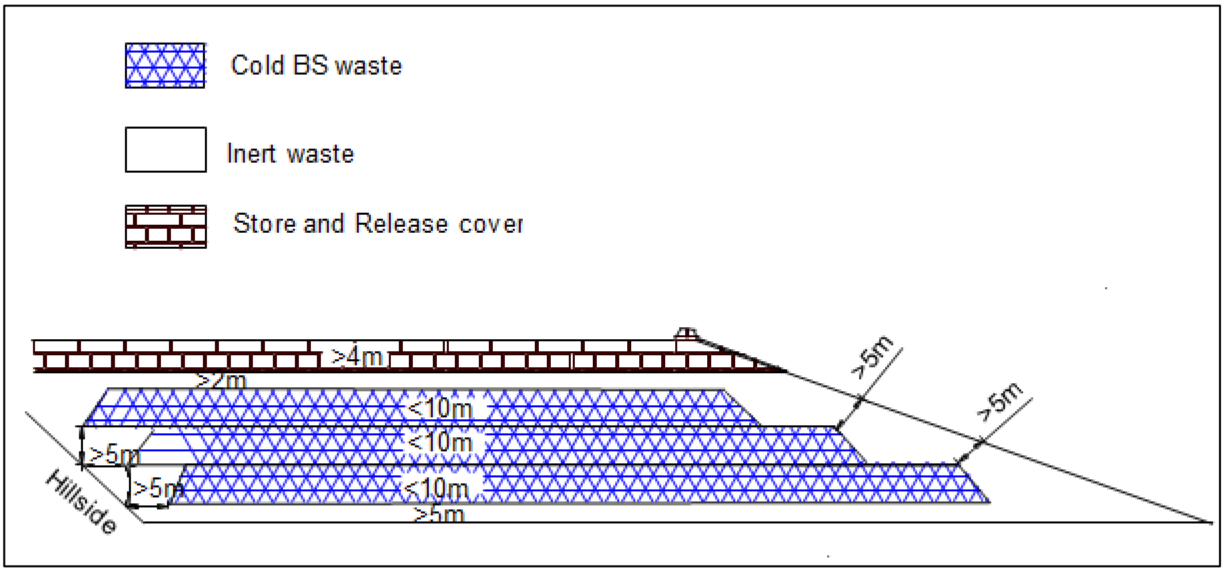

Figure 26: Example of the minimum design criteria for cold black shale dumps. [12]

A4.3.4 *Elevated S*

An example of an Elevated S waste rock dump constructed according to the minimum dump design criteria is shown in Figure 27. The minimum design criteria for elevated-sulfur dumps are:

- Inert or net neutralising waste rock must be placed on the original land surface at the base of the dump.
- At least one (1) metre of inert material is located on the outer surface of the waste dump at closure.
- Elevated-sulfur material can be mixed with inert material and dumped accordingly.
- Co-disposal of elevated-sulfur waste with materials containing excess available neutralising capacity is recommended.
- During construction and at closure, the upper dump surface of the elevated-sulfur dump should be designed so that it only receives incident rainfall with no run-on from adjacent areas.

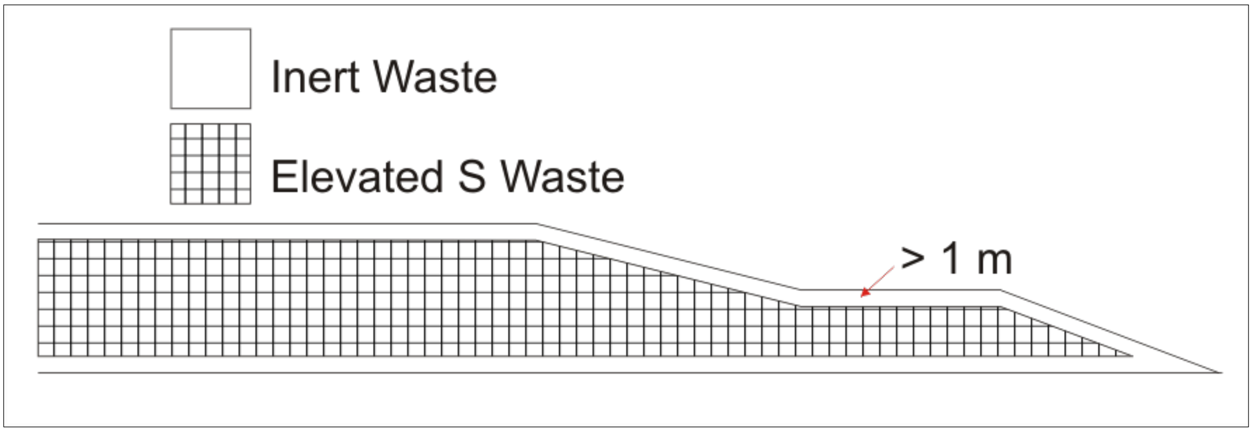

Figure 27: Example of the minimum design criteria for Elevated S dumps. No store and release cover is required and only 1 metre inert material cover at surface required.

A4.3.5 *Composite Designs*

Figure 28 shows an example of a composite hot and cold black shale dump in which hot black shale is excluded from the beneath the slope and cold black shale is placed below the slope. Composite dumps of this kind may significantly reduce the residual risk associated with the dump slopes without significantly reducing the total storage capacity for sulfidic material within

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the dump. There must be at least a one metre buffer (measured horizontally or vertically) between the hot and cold black shale material where they are in close contact on the outer slopes of the hot black shale repository.

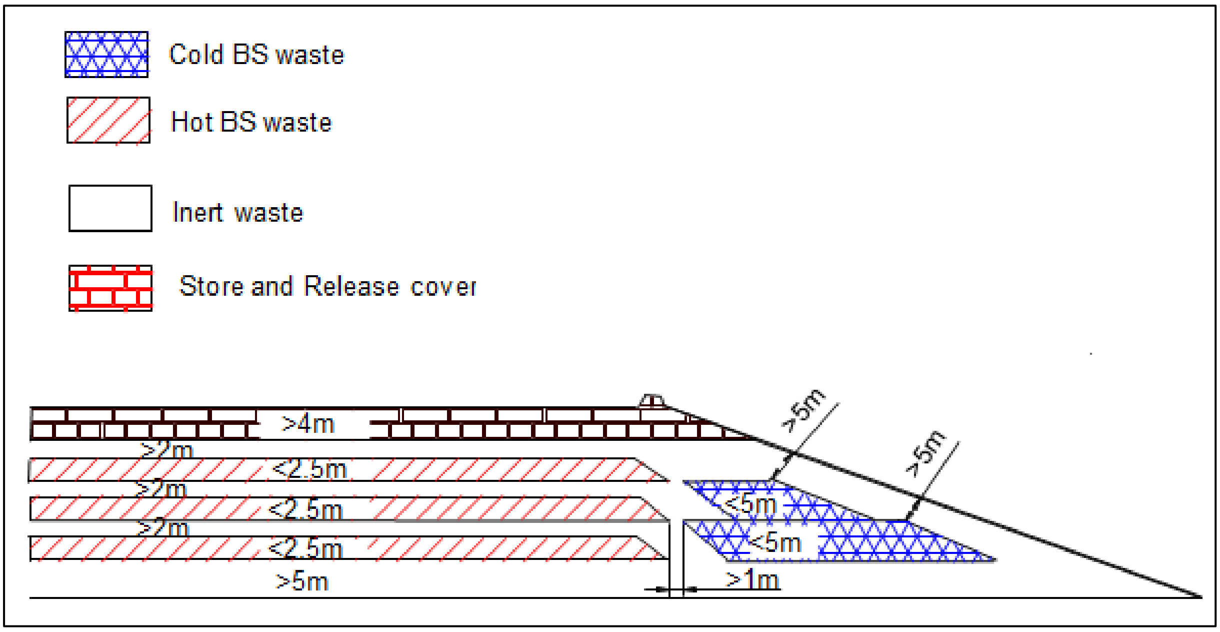

Figure 28: Example of optimum composite designs for cold and hot black shale dumps.

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Appendix 5 Dump Designs for Material with Neutralising Potential

A5.3 Hope Downs 1 Dumping Scenarios

The following dump designs were developed specifically for Hope Downs 1, due to the potential risk to receptors and the availability of neutralising material. Calcrete is the preferred net neutralising material, however if calcrete is not available then dolomite from the Wittenoom Formation can be used as net neutralising waste. Please note that only the dolomite within the Wittenoom Formation has sufficient neutralising material and it is not mapped separately within geological models and could be difficult to source.

A5.3.1 *Above Ground Disposal Requirements*

An example of a HD1 waste rock dump constructed according to the minimum dump design criteria is shown in Figure 29.

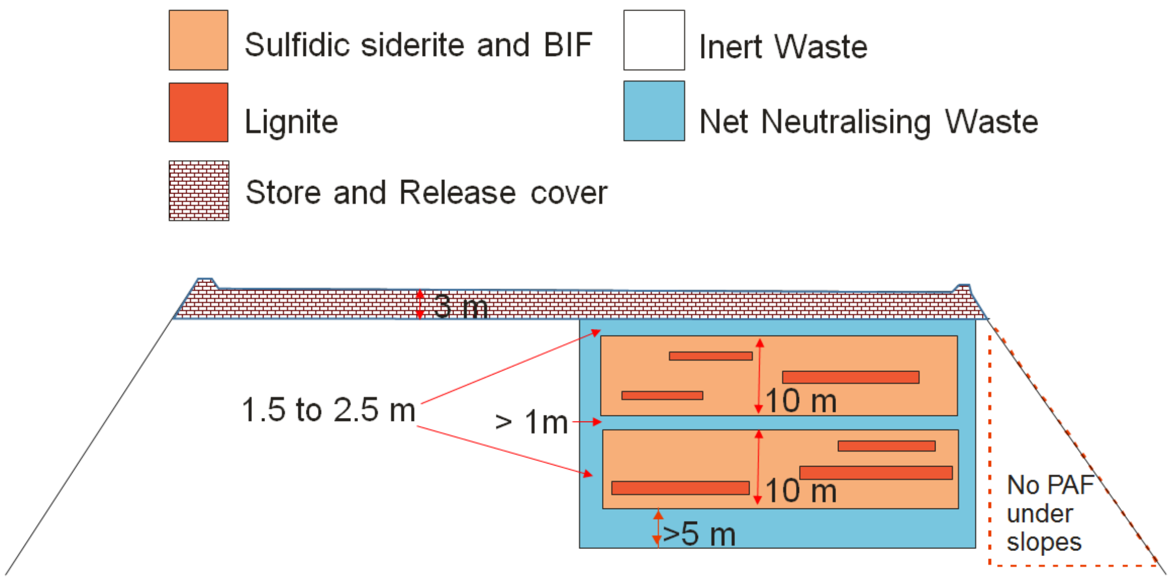

Figure 29: Example of minimum design for a combined sulfidic BIF and siderite with lignite dump at HD1 – Permanent storage

The minimum design criteria for HD1 AWT PAF dumps are:

- No PAF material is to be placed under the final rehabilitation slopes of the waste dump.
- Minimum of 5 metre of net neutralising waste rock must be placed as a basal layer prior to PAF placement within the dump. This material can be end tipped. This basal layer can be reduced in thickness to 2.5m, if the PAF cell is located higher in the waste dump. The mineral waste team should assess this.
- A 1.5 – 2.5 metre layer of net neutralising waste should be placed at the top, sides and base of each PAF lift i.e. a net neutralising waste bund should be created prior to PAF placement. This will reduce the lateral flow of incident rainfall.
- If spontaneous combustion is a risk, the thickness of each lignite material lift must not exceed 2.5 metre followed by a 1.5 to 2.5 metre lift of net neutralising waste rock. Lifts are to be constructed by paddock dumping so that lignite material can cool and so that incident vehicle traffic helps create a compacted layer every 1.5 to 2.5 metres to inhibit water movement and convective oxygen transport.

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- The thickness of each lift of sulfidic BIF and siderite material must not exceed 10 metre. A 1.5 – 2.5 metre paddock dumped layer of net neutralising waste should then be placed on top of the PAF lift.
- The 10 metre PAF layer should be paddock dumped in a number of small lifts to limit the risk of material segregation and tightly compact the waste dump to prevent oxygen ingress i.e. 4 x 2.5 metre thick PAF layers.
- The dumping of PAF material during the wet season should be avoided, where possible.
- Only incident rainfall and no run-on from adjacent areas should pass through the dump.
- The final lift on the PAF waste rock dump must be composed of a minimum 1.5-2.5 metre thick inert or net neutralising layer. This will prevent runoff water from contacting the underlying sulfidic material until the minimum 3 metre thick store and release cover can be constructed.
- If there is insufficient PAF to create the 10 metre lift, the >1 metre net neutralising waste layer can be constructed at <10 metre.
- If spontaneous combustion is a risk, lignite material should be covered with net neutralising material within 1 month during the wet season (due to the spontaneous combustion risk). Where possible, the sulfidic BIF and sulfidic siderite material should be covered with net neutralising waste during the wet season.
- If PAF is temporary stored within a waste dump, the previous criteria still applies, however PAF can be stored underneath the final slopes, as long as there is a 10 metre offset (consisting of calcrete closest to the PAF and inert waste) (Figure 30). If PAF is placed on 30m of inert material, it would need to be rehandled within 20 years. If there is a delay in rehandling then the placement of a temporary cover on the dump should be considered.

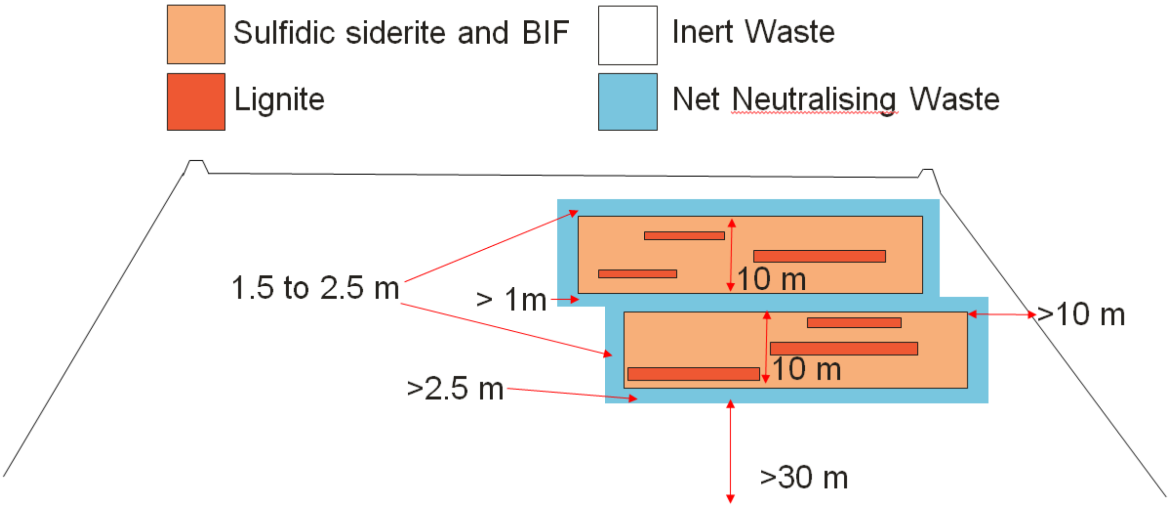

Figure 30: Example of minimum design for a combined sulfidic BIF and siderite with lignite dump at HD1 – Temporary storage

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Appendix 6 Rehabilitation and Closure

A6.1 Final Landforms

To reduce the risk of erosion and to minimise infiltration, final landforms should be designed in accordance with the following criteria:

- Final landform design should be designed in accordance with the Rio Tinto Iron Ore (WA) Landform Design Guidelines.
- Final landforms must be designed so that runoff is not directed onto surfaces that are underlain by sulfidic material.
- A back-sloping crest bund must be placed around the top of each dump slope and berm. This will prevent runoff water flowing from the dump surface over the slopes and causing erosion.
- If PAF material is exposed during the re-contouring of waste rock dumps that were created before waste rock segregation was practiced, it must be covered with at least 2 metres of inert waste rock. This will help ensure that the entire final dump surface is able to support vegetation.
- Wrapping the PAF dump is preferred rather than dozing down the slope.

A6.2 Store and Release Covers

A6.2.1 *Design*

Store and release covers must be constructed on all flat surfaces over PAF waste dump repositories and over some sulfide/black shale exposures within open pits. Store and release covers are designed to limit infiltration into the underlying waste rock by maximising the evapo-transpiration of incident rain water. The cover is designed to store water near the surface during the wet season so that it can be removed from the cover material and returned to the atmosphere during the dry season by evaporation and plant transpiration.

Waste rock that is used to construct store and release covers must contain sufficient fine-grained material to have both a high moisture retention capacity and a relatively low permeability (i.e. large boulders should not be placed on the cover). Waste rock composed of well-graded clayey, silty, sandy gravel or clayey silty gravely sand makes the best store and release cover material. As a rough guide, waste rock containing more than 1/3 coarse sand size and finer particles (< 5 mm) will make a suitable cover material. **Blocky BIF composed of gravel with very little silt, sand or clay is not ideal** for use in cover construction and should be avoided if another more suitable waste type is available (Figure 31).

When possible, 4 metres of oxidised shale should be used in preference to 4 metres of BIF on flat top covers. If detrital material is available then a cover constructed out of 4 metres of detrital material overlying 2 metres of oxidised shale has been shown to reduce net percolation and salt uptake (O'Kane 2014). Topsoil should be preferentially placed on covers as the vegetation can significantly reduce the amount of net percolation through the cover. If the cover will be less than 6 metres thick then advice should be sought from the mineral waste management team. The cover for Hope Downs 1, can be 3 metres thick, preferable consisting of shale or limonitic detritals. For guidance on the covers on slopes please see the Rio Tinto Iron Ore (WA) Landform Design Guidelines.

A6.2.2 *Construction*

During construction there should be regular quality control checks to ensure large boulders have not been placed into the cover.

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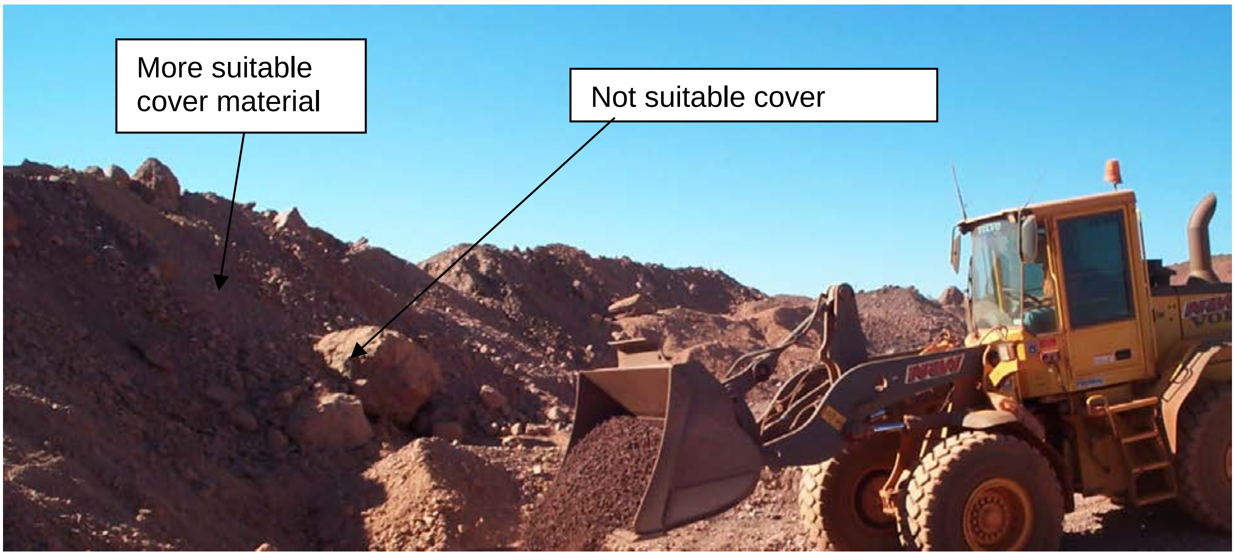

Figure 31: An example of suitable and not suitable material to be used in the construction of a store and release cover.

Waste rock that is used to construct store and release covers must also be able to support vegetation, so materials with high salinity, and acidic or very basic pH should be avoided. The waste rock should be placed in a manner that minimises segregation of the material into coarse and fine particles. For this reason covers should be paddock dumped, they should never be constructed by dumping in four metre lifts.

Store and release covers should be constructed as follows (Figure 32):

- Paddock-dump store and release cover material on top of a vehicle compacted surface so that the average depth of the cover material is greater than 2 metres.
- A dozer should then be used to knock down the crest of each paddock dump pile and to fill in the depressions between piles to create a trafficable surface.
- Paddock-dump a second layer of store and release cover material on top of the first lift so that the average depth of the second lift is greater than 2 metres. Vehicle traffic during this dumping will create a compacted layer on top of the first store and release cover layer.
- A dozer should again knock down the crest of each paddock dump pile in the second layer and fill in the depressions between piles to create a surface that is nearly planar.
- Topsoil should be placed on top of the second store and release cover layer. The surface should then be ripped and seeded. Ripping needs to be deep enough (> 0.3 metres) to mix in the topsoil and to ensure that there are not compacted zones that could inhibit plant growth and rooting on top of the upper layer.

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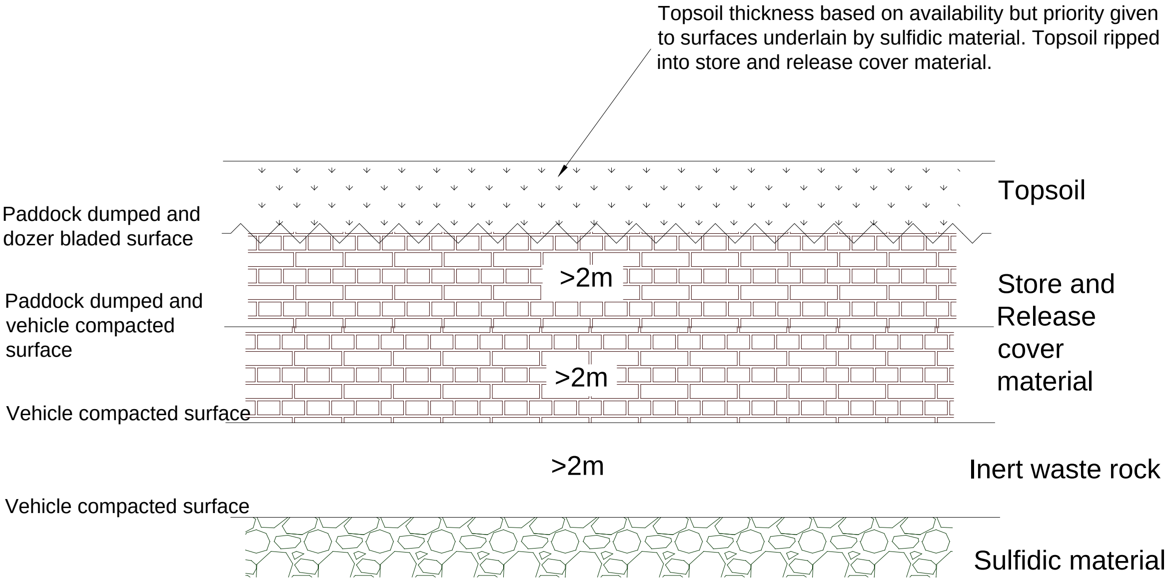

Figure 32: Detail of store and release cover design.

A6.3 Topsoil Management

Topsoil placement can greatly accelerate the establishment of native vegetation on waste rock surfaces. This in turn will help to maximise evapo-transpiration, minimise infiltration into the underlying waste rock and inhibit erosion on dump slopes. If topsoil resources are limited, the most benefit for ARD management can be gained by preferentially utilising topsoil for the revegetation of waste rock dumps that contain sulfidic material. In decreasing order of importance, topsoil should be placed on:

1. Dump slopes underlain by hot black shale/lignites material;
2. Dump slopes underlain by cold black shale/sulfidic BIF/sulfidic siderite material;
3. Flat store and release cover dump surfaces underlain by hot black shale/lignites material;
4. Flat store and release cover dump surfaces underlain by cold black shale/sulfidic BIF/sulfidic siderite material;
5. Store and release covers within open pits;
6. Waste rock dumps that were created before waste rock segregation was practiced and which may contain dispersed black shale or material containing sulfides;
7. Assessable inert waste rock surfaces within pits that contain black shale or sulfidic material exposures; and
8. Waste rock dumps that do not contain any black shale or sulfidic material.

For further information on topsoil management refer to the RTIO Soil Resource Management Work Practice (RTIO-HSE-0011596).

A6.4 Open Pit Closure

The geology and hydrogeology of an open pit will largely control the potential closure issues associated with the final void. Open pits that are located above the water table and which do not contain any black shale or sulfidic material exposures should not pose any geochemical risks at closure. Open pits that intersect the water table but do not contain any black shale or sulfidic material exposures may ultimately contain saline water bodies with neutral pH that could

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impact down gradient groundwater. Open pits that contain black shale or sulfidic material exposures will likely contain ephemeral or permanent acidic and potentially saline water bodies that could impact down gradient groundwater and could represent a direct exposure risk to wildlife or humans.

Hypersaline pit lakes may be considered acceptable on relinquishment as long as down-gradient beneficial use is not impacted. Further consultation with stakeholders would be required for specific locations. Mitigation measures will likely be required if net acid generating materials such as pyritic black shale are exposed on the final pit walls. In pits with extensive exposures of pyritic black shale that will not be backfilled to above the water table, long term mitigation measures will likely be required to attain the proposed water quality criteria (Borden 2006).

The hydrogeological and geochemical behaviour of each pit should be predicted so that it can be managed appropriately at closure to minimise significant groundwater impacts and surface water exposures to wildlife and humans. As discussed previously, the most protective pit closure strategy is to completely backfill the pit or to backfill the pit to above the estimated pre-mining water table where practicable. Backfilling to above the pre-mining water table should lead to a near complete recovery of the water table elevation and should cut off oxygen to the majority of black shale or sulfidic material exposed on the pit walls.

In order of decreasing benefit, pit backfilling should be prioritised as follows: 1) pits with black shale or sulfidic material exposures that intersect the water table and will discharge to groundwater at closure, 2) pits with black shale or sulfidic material exposures that intersect the water table but that will not discharge to groundwater at closure, 3) pits with black shale or sulfidic material exposures that are above the water table, 4) pits without black shale or sulfidic material exposures that intersect the water table and that will discharge water to groundwater at closure, 5) pits without black shale or sulfidic material exposures that intersect the water table but that will not discharge to groundwater at closure, and 6) pits that do not contain any black shale or sulfidic material exposures and that are above the water table. The proximity to nearby regionally significant aquifers or ecologically significant seeps and springs should also be considered when evaluating potential pit closure issues.

Extensive backfilling is not practicable for many open pits because of the size of the final void and because of pit sequencing issues. Where backfilling is not practicable the following actions should be taken:

- Haul roads and accessible benches that are underlain by inert waste rock should be ripped and seeded to minimise runoff, to promote vegetation establishment and to maximise evapo-transpiration.
- A minimum 4 metre store and release cover system should be constructed on top of accessible black shale or sulfidic material exposures for those portions of the pit that will be located above the water table and that will not be periodically flooded by cyclone events.
- A minimum 5 metre lift of inert or net neutralising rock should be placed on top of accessible black shale or sulfidic material exposures for those portions of the pit that will be located below the water table or that will be periodically flooded by cyclone events.
- Consideration should be given to covering black shale or sulfidic material exposed on pit highwalls with inert or net neutralising material pushed or dumped from the sides.

An example of these pit closure strategies is illustrated in Figure 33.

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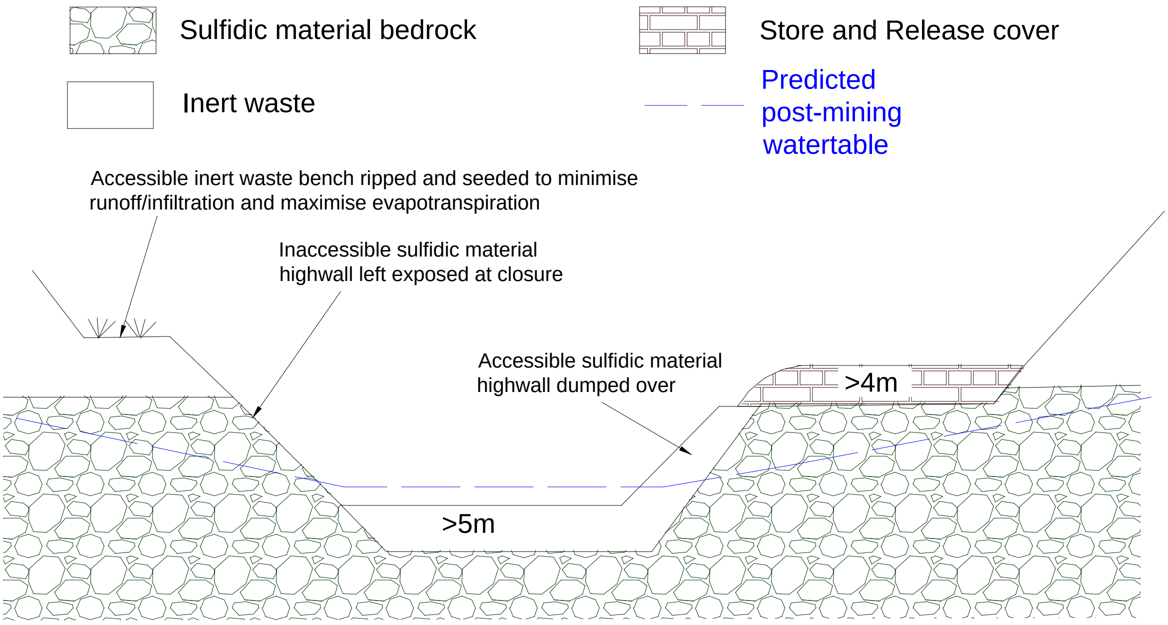

Figure 33: Examples of closure strategies for a pit with sulfidic material that will not be backfilled.

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Appendix 7 Contingency Planning

Contingency plans for most upset conditions and unexpected impacts related to sulfidic material management will need to be developed on a case by case basis. Contingency plans will generally be developed by the site Mineral Waste Management team or at a minimum they must be approved by the Team. Contingency plans for spontaneous combustion and inert materials shortages are outlined in the following sections.

A7.1 Spontaneous Combustion

Site specific pit safety procedures should be followed.

All occurrences of burning black shale or lignites must be reported to Mine 2 and the pit safety team as soon as possible. If possible, fires should be extinguished by rapid burial of the burning material under at least five metres of inert waste rock (see relevant SWPs). For locations where this may be difficult such as beneath pit ramps, the black shale or lignite should be covered with as much inert material as practicable. The inert material should be placed so that the upper surface is well compacted and so that side slopes are adequately covered to prevent lateral convective transport of oxygen to the burning rock mass. If rapid coverage is not an option, the material can be excavated and transported to the toe of an advancing inert dump lift where it can be rapidly buried. Water should not be used to extinguish the fire because this could actually enhance the spontaneous combustion risk of black shale or lignite that is not already burning and because the volumes of water that would be required are generally prohibitively high.

A7.2 Inert Materials Shortages

Medium and short term mine plans should be designed so that inert waste rock is produced in adequate volumes and at appropriate times to allow timely encapsulation of PAF material. Hot black shale and lignite material requires the highest volumes of inert material (approximately 1:1) because of the requirement for an inert interlayer every 2.5 metres. If there were temporary shortages of inert material, hot black shale or lignite dumps could be designed with cold black shale or sulfidic BIF and siderite material if it contains a low sulfide concentration, some neutralising potential and low organic carbon (i.e. no black shale or lignite) material. The appropriate material to use in the heat dissipating interlayer should be confirmed as appropriate by Mine Geology. But under no circumstances should black shales or lignites with both elevated sulfide and organic carbon concentrations be used. If acid base accounting tests prove the material to be non-acid forming, coarse tails could be used as inert waste in dumps (i.e. EGi 2007). If there is a shortage of inert material then inert waste in other waste dumps may need to be rehandled and transported to the black shale waste dump.

A7.3 Surface Water Management

Every endeavour should be made to divert surface water runoff from contacting black shale or sulfides exposed on pit walls. Site specific acid water and flood management plans should be developed that plan for the appropriate disposal of potentially acidic water in pits with PAF exposures. Some strategies to manage surface water runoff include:

- Slope pit floor away from pit PAF exposure
- A sump should be constructed below the PAF exposure to collect acidic water.
- Surface water runoff from inert exposures should be segregated from coming in contact with acidic water.

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- Bund upper catchment to run over competent material such as BIF rather than PAF exposures.

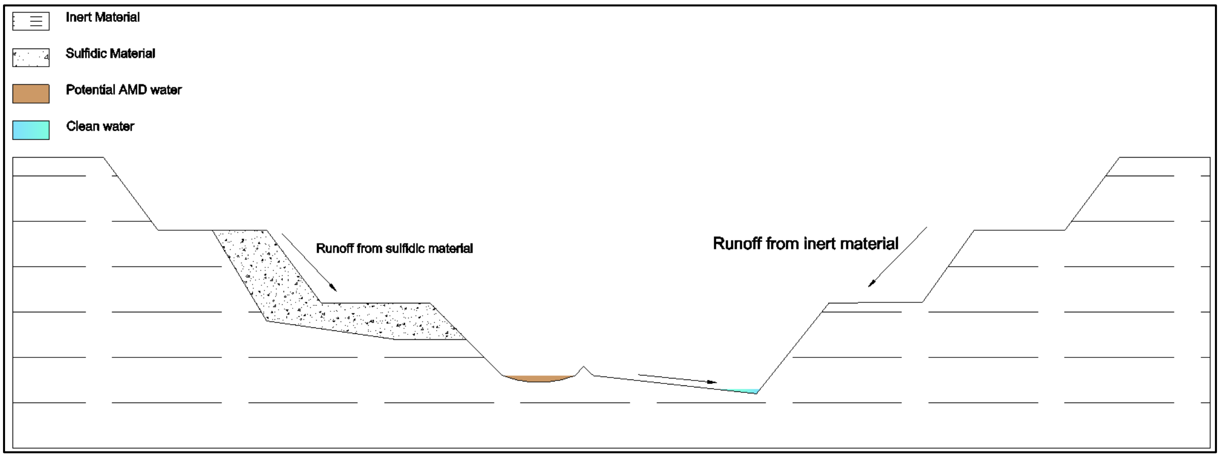

Figure 34: Suggested surface water management for sulfide exposures.

Where possible, PAF exposures in waste dumps should be covered with inert material during the wet season, particularly hot black shale and lignites. A bund at the top of the waste dump surface will reduce any surface water from travelling over the sulfidic material and transporting contaminated drainage into the surrounding environment.

Pipelines transporting acidic water should be shut down and repaired if there is a leak. Acid water pipelines should be labelled with purple stripes and non-acidic pipelines can be labelled with green stripes (as per Australian Standards).

A7.4 Geotechnical Stability

A6.4.1 Pit Walls

Pit walls excavated in MCS are designed with the same concept as for other stratigraphic units. That is, generally the design is for a Factor of Safety of at least 1.20 and a Probability of Failure of around 10% on the inter-ramp scale and up to 30% for the batter scale. The management of slopes excavated in MCS is therefore no different from that of any other stratigraphic unit, whereby a process called Geotechnical Design Management is utilised. This involves identifying hazards and hence risks associated with the geotechnical design and undertaking a risk management strategy to minimise these risks. Actions include design review, geotechnical investigation, mapping, conformance to design and monitoring. Contingency plans are established through Slope Management Plans in consultation with mine management.

The occurrence of MCS is of little consequence to the geotechnical management process.

A6.4.2 Dump failures

Whilst no specific stability analyses have been undertaken on black shale waste dumps, they can generally be considered stable due to the process of encapsulation of the material well within a dump. Also, the process of undertaking earthworks to prepare the encapsulation is considered to add a significant contribution to the stability of the dump location. It is anticipated that future stability analyses may be documented in a Waste Dump Management Plan.

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