Series A: Activity Guidelines

A2

BEST PRACTICE GUIDELINE

Water Management for Mine Residue Deposits

Best Practice Guidelines for Water Resource Protection in the South African Mining Industry

DIRECTORATE: RESOURCE PROTECTION & WASTE

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DOCUMENT INDEX

This document is the second in a series of the following Activity Best Practice Guideline documents:

BPG A1: Small-Scale Mining

BPG A2: Water Management For Mine Residue Deposits

BPG A3: Water Management in Hydrometallurgical Plants

BPG A4: Pollution Control Dams

BPG A5: Water Management for Opencast Mines

BPG A6: Water Management for Underground Mines

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Since 1999 a number of steering committee meetings and stakeholder workshops were held at various stages of the development and drafting of this series of Best Practice Guidelines for Water Resource Protection in the South African Mining Industry.

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APPROVALS

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PREFACE

Water is typically the prime environmental medium (besides air) that is affected by mining activities. Mining adversely affects water quality and poses a significant risk to South Africa's water resources. Mining operations can further substantially alter the hydrological and topographical characteristics of the mining areas and subsequently affect the surface runoff, soil moisture, evapo-transpiration and groundwater behaviour. Failure to manage impacts on water resources (surface and groundwater) in an acceptable manner throughout the life-of-mine and post-closure, on both a local and regional scale, will result in the mining industry finding it increasingly difficult to obtain community and government support for existing and future projects. Consequently, sound management practices to prevent or minimise water pollution are fundamental for mining operations to be sustainable.

Pro-active management of environmental impacts is required from the outset of mining activities. Internationally, principles of sustainable environmental management have developed rapidly in the past few years. Locally the Department of Water Affairs and Forestry (DWAF) and the mining industry have made major strides together in developing principles and approaches for the effective management of water within the industry. This has largely been achieved through the establishment of joint structures where problems have been discussed and addressed through co-operation.

The Bill of Rights in the Constitution of the Republic of South Africa, 1996 (Act 108 of 1996) enshrines the concept of sustainability; specifying rights regarding the environment, water, access to information and just administrative action. These rights and other requirements are further legislated through the National Water Act (NWA), 1998 (Act 36 of 1998). The latter is the primary statute providing the legal basis for water management in South Africa and has to ensure ecological integrity, economic growth and social equity when managing and using water. Use of water for mining and related activities is also regulated through regulations that were updated after the promulgation of the NWA (Government Notice No. GN704 dated 4 June 1999).

The NWA introduced the concept of Integrated Water Resource Management (IWRM), comprising all aspects of the water resource, including water quality, water quantity and the aquatic ecosystem quality (quality of the aquatic biota and in-stream and riparian habitat). The IWRM approach provides for both resource directed and source directed measures. Resource directed measures aim to protect and manage the receiving environment. Examples of resource directed actions are the formulation of resource quality objectives and the development of associated strategies to ensure ongoing attainment of these objectives; catchment management strategies and the establishment of catchment management agencies (CMAs) to implement these strategies.

On the other hand, source directed measures aim to control the impacts at source through the identification and implementation of pollution prevention, water reuse and water treatment mechanisms.

The integration of resource and source directed measures forms the basis of the ***hierarchy of decision-taking*** aimed at protecting the resource from waste impacts. This hierarchy is based on a *precautionary approach* and the following order of priority for mine and waste water management decisions and/or actions is applicable:

RESOURCE PROTECTION AND WASTE MANAGEMENT HIERARCHY

Step 1: Pollution Prevention

↓

Step 2: Minimisation of Impacts
Water reuse & reclamation
Water treatment

↓

Step 3: Discharge or disposal of waste and/or waste water
Site specific risk based approach
Polluter pays principle

The documentation describing **Water Resource Protection and Waste Management** in South Africa is being developed at a number of different levels, as described and illustrated in the schematic diagram below.

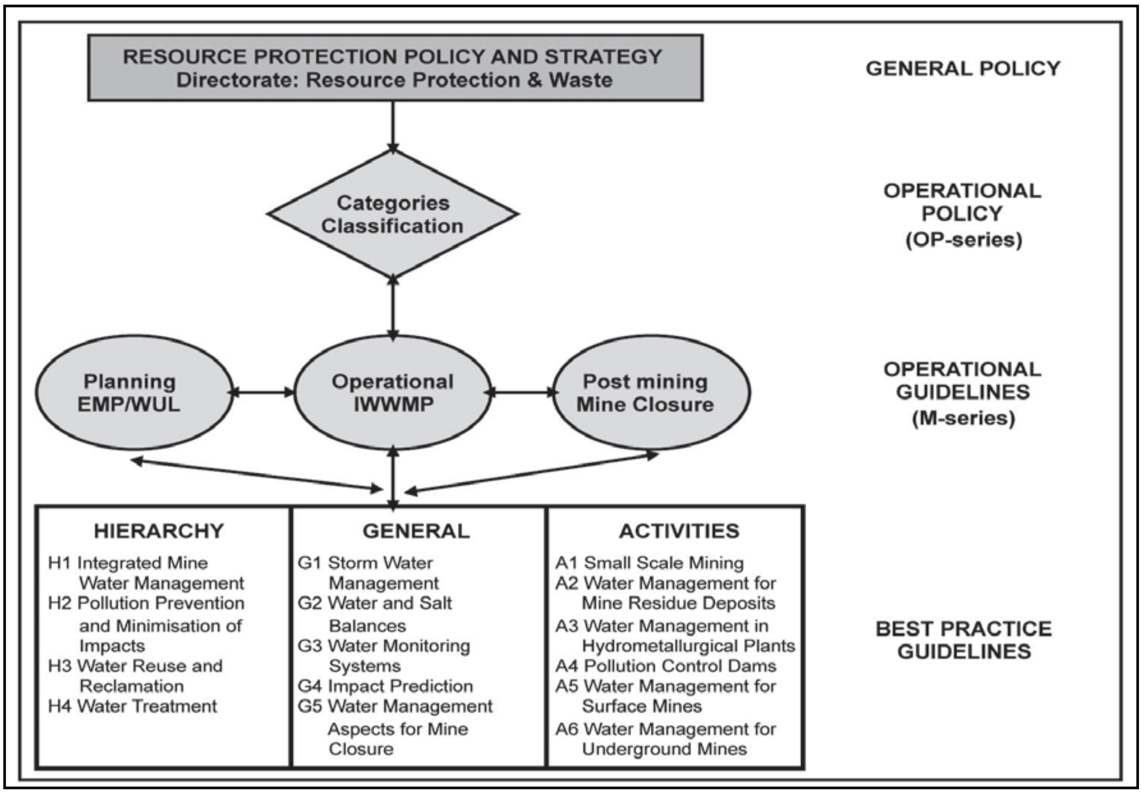
The overall Resource Protection and Waste Management Policy sets out the interpretation of policy and legal principles as well as functional and organisational arrangements for resource protection and waste management in South Africa.

Operational policies describe the rules applicable to different categories and aspects relating to waste discharge and disposal activities. Such activities from the mining sector are categorised and classified based on their potential risks to the water environment.

Operational Guidelines contain the requirements for specific documents e.g. water use authorisation application reports.

Best Practice Guidelines (BPG's) define and document best practices for water and waste management.

Schematic Diagram of the Mining Sector Resource Protection and Waste Management Strategy



The DWAF has developed a series of **Best Practice Guidelines** (BPGs) for mines in line with International Principles and Approaches towards sustainability. The series of BPGs have been grouped as outlined below:

BEST PRACTICE GUIDELINES dealing with aspects of DWAF's water management **HIERARCY** are prefaced with the letter **H**. The topics that are covered in these guidelines include:

- H1. Integrated Mine Water Management
- H2. Pollution Prevention and Minimisation of Impacts
- H3. Water Reuse and Reclamation
- H4. Water Treatment

BEST PRACTICE GUIDELINES dealing with **GENERAL** water management strategies, techniques and tools, which could be applied cross-sectoral and always prefaced by the letter **G**. The topics that are covered in these guidelines include:

- G1. Storm Water Management
- G2. Water and Salt Balances
- G3. Water Monitoring Systems
- G4. Impact prediction
- G5: Water Management Aspects for Mine Closure

BEST PRACTICE GUIDELINES dealing with specific mining **ACTIVITIES** or **ASPECTS** and always prefaced by the letter **A**. These guidelines address the prevention and management of impacts from:

- A1. Small-Scale Mining
- A2. Water Management for Mine Residue Deposits
- A3. Water Management in Hydrometallurgical Plants
- A4. Pollution Control Dams
- A5. Water Management for Opencast Mines
- A6. Water Management for Underground Mines

The development of the guidelines is an inclusive consultative process that incorporates the input from a wide range of experts, including specialists within and outside the mining industry and government. The process of identifying which BPGs to prepare, who should participate in the preparation and consultative processes, and the approval of the BPGs was managed by a Project Steering Committee (PSC) with representation by key role-players.

The BPGs will perform the following functions within the hierarchy of decision making:

- Utilisation by the mining sector as input for compiling water use authorisation applications (and other legally required documents such as EMPs, EIAs, closure plans, etc.) and for drafting authorisation conditions.
- Serve as a uniform basis for negotiations through the licensing process prescribed by the NWA.
- Used specifically by DWAF personnel as a basis for negotiation with the mining industry, and likewise by the mining industry as a guideline as to what the DWAF considers as best practice in resource protection and waste management.
- Inform Interested and Affected Parties on good practice at mines.

The information contained in the BPGs will be transferred through a structured knowledge transfer process, which includes the following steps:

- Workshops in key mining regions open to all interested parties, including representatives from the mining industry, government and the public.
- Provision of material to mining industry training groups for inclusion into standard employee training programmes.
- Provision of material to tertiary education institutions for inclusion into existing training programmes.
- Provision of electronic BPGs on the DWAF Internet web page.

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1 INTRODUCTION AND BACKGROUND

The management of the disposal of mine residue is of critical importance to the success of any mining project. Methodologies and locations for mine residue deposition and disposal may vary between mines and for different mineral types. The mine residue disposal aspects are often the main focus of regulatory scrutiny during the permitting process for a mine development, and during mine operations and closure, due to the inherent risk in the operations of these facilities and the long-term nature of the impacts. Successful management of mine residue disposal requires a good understanding of the methodologies and the complete life cycle of Mine Residue Deposits (MRDs).

The following documentation exists within South Africa to assist in the understanding of the design, operations and closure of MRDs:

- Chamber of Mines of South Africa: Guidelines for Environmental Protection. The Engineering Design, Operation and Closure of Metalliferous, Diamond and Coal Residue Deposits, and
- SABS 0286: 1998. Code of Practice for Mine Residue.

Water management for MRDs is a critical aspect of the design, operational management and closure of these facilities. It is thus also important that practitioners within this field have a good understanding of the management of water, both surface and groundwater, when designing and/or operating a MRD facility. To this end, the Department: Water Affairs and Forestry (DWAF) have commissioned an activity-related Best Practice Guideline (BPG) to focus on the water management aspects within and around MRDs.

The BPG provides details on the recommended processes to follow for best practice water management for various types of MRDs. In practice, the actual process followed may vary, depending on the site-specific conditions of the MRD. In these instances, a motivation should be provided to DWAF detailing the need to deviate from the recommended processes.

The recommended processes should however be followed in instances where the MRD is used to contain sulphide or other reactive materials.

Figure 1.1: Areas of applicability and interaction between various BPGs

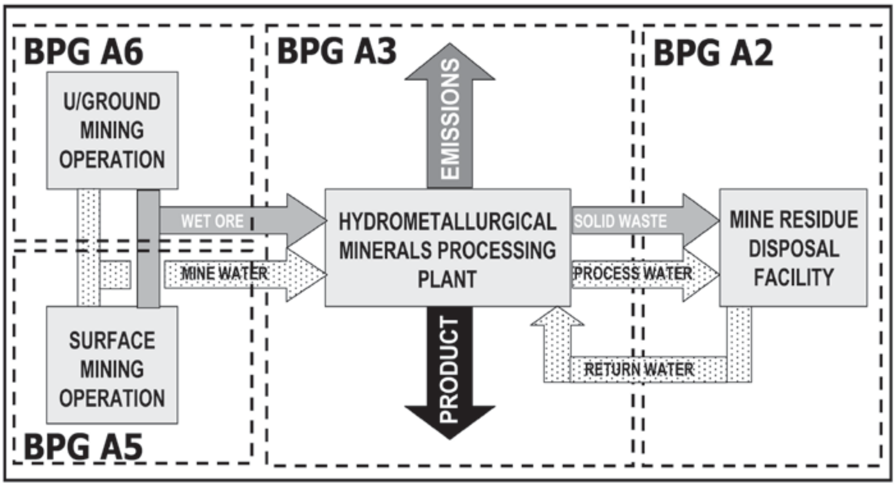


Figure 1.1 illustrates the areas of applicability and interaction between the various BPGs, including:

- BPG A2: Water Management For Mine Residue Deposits
- BPG A3: Water Management in Hydrometallurgical Plants
- BPG A5: Water Management for Opencast Mines
- BPG A6: Water Management for Underground Mines

2 GENERAL PRINCIPLES FOR WATER MANAGEMENT ON MINE RESIDUE DEPOSITS

Best Practice water management for MRDs is based on the following general principles:

- All MRDs must comply with the legal and regulatory conditions within South Africa
- The design, operation and closure of MRDs should take into account the optimisation of water use for a mine and, in particular, on and around the MRD as well as the minimisation of the potential impact of the MRD on water quantity and quality
- The design, operation and closure of MRDs should consider the water management through the full life cycle of the MRD
- The precautionary approach is applicable. Thus, worst-case conservative assumptions must be made in instances where there is lack of information or level of knowledge
- Technical studies and the design of MRDs should be undertaken by suitably qualified personnel
- Water management on MRDs must take into account the internalisation of overall actual (operating) costs of the MRD as well as the potential costs of the MRD, e.g. the polluter pay principle
- The MRD design should adopt a holistic approach, including:
  - Sustainability
  - Full life cycle of the MRD
  - Water quantity and quality, and
  - Surface water and groundwater
- Water management principles should play a key and decisive role when evaluating and deciding on rehabilitation and closure strategies.

3

OBJECTIVES AND KEY CONSIDERATIONS

3.1 Objectives of this guideline

This guideline seeks to provide the necessary guidance for the management of water-related aspects for MRDs by attainment of the following objectives:

- To provide practical guidance and steps on water management best practice over the full life cycle of the MRD or the mines MRD requirements
- To provide clarity on legal requirements and compliance and to provide guidance on the legal requirements for water management, in terms of the prevailing South African legislation
- To minimise potential impacts on safety and the environment over the life of the MRD or mines MRD requirements through the use of best practice guidelines for water management
- To cover water management aspects for various types of MRDs
- To provide guidance on appropriate tools to be used for water management on MRDs, to complement those that are covered in other BPGs
- To provide examples of some of the water management aspects for MRDs.

3.2 Key considerations

Table 3.1 provides detail on the general aspects that should be considered in the design, operation and closure of MRDs. In addition, the BPG has been developed, and should be used, taking into account the following considerations:

- The BPG is aimed at personnel with a basic understanding of water management aspects for MRDs
- The BPG draws on established international best practice
- The BPG augments (and does duplicate) existing literature on MRDs, such as those prepared by the Chamber of Mine, SABS and others
- The BPG refers to, summarises and expands (where necessary) on relevant water management areas not fully covered in the existing literature
- The BPG references other BPGs prepared and issued by DWAF (see preface)
- The focus of the BPG is on greenfields sites and thus covers water management through the full life cycle of these sites; the BPG is however also applicable to brown fields or existing operations
- The BPG is developed taking into account the differentiation between MRDs. The BPG thus considers the water management and water use license requirements for all MRDs.

Table 3.1: General considerations in the design, operation and closure of MRDs

No.	Consideration	Description	Aspects to consider
1	Pollution prevention	Deterioration of water quality must be prevented wherever possible and minimised where complete prevention is not possible	• Identify and apply opportunities for the prevention of water pollution on and around MRDs. • Implement the necessary management measures to minimise impacts in the case where pollution prevention is not possible, e.g. in the design and operation of return water dams. • Ensure that the water use practices on and around the MRD do not result in unnecessary water quality deterioration, e.g. use of the return water dam for storage of poorer quality water. • Minimise contact between water and major pollution sources where possible. • Undertake geochemical assessments to evaluate long-term pollution effects of alternatives and apply those options that optimise pollution prevention.
2	Conservation	Losses of water and consumptive use of water must be minimised	• Design and operate the MRDs to minimise the evaporative losses, e.g. by limiting the size of the supernatant pool on the MRD surface. • Ensure that seepage/overflow losses from storage facilities are minimised, e.g. facilities that can possibly impact on the water resource through seepage may need to be lined, and storage facilities should be designed with sufficient capacity and operated at a level to allow it to accommodate storm events without overflowing or spilling (capacity requirements as stipulated by GN No 704). • Use raw water only for processes requiring such good water quality and additional water requirements that cannot be supplied within the water network of the mine. • Assess the technology being used for the design, operations and closure of MRDs including whether alternative technologies could be applied (particularly important for new mines) or whether the technology could be modified or improved.
3	Sustainability	Water management practices and designs should be sustainable over the life cycle of the MRD	• Develop water and salt balance projections based on geochemical investigations (see ***BPG G2: Water and Salt Balances and BPG4: Impact Prediction***) for future mining scenarios, including mine closure and post-closure. • Long-term planning and sustainability should be considered and therefore predictions on water quality and quantity into the future should also be incorporated (predictive modelling) to ensure that reuse and reclamation plans are not affected by future processes. • The design, operation and closure of MRDs should incorporate consideration of the risk of changes in the mining and plant operations, and hence the mine water balance, through the life cycle of the mine.

4

STRUCTURE AND FOCUS OF THE BEST PRACTICE GUIDELINE

4.1 Residue types and characteristics

In mining and mineral processing, materials are separated according to their particle size and mineralogy. The residues produced fall into the following categories:

- Fine-grained (residue, slimes and coal slurry)
- Coarse-grained (waste rock and coarse rejects, e.g. coal discard)

These residues are conventionally disposed of separately. Co-disposal involves the combining of these residue streams.

Table 4.1 presents the naming convention for different types of fine and coarse-grained MRDs typically associated with different types of minerals mined in South Africa. While the table does not cover every type of mineral mined, it is sufficiently diverse to indicate the types of MRDs associated with different minerals.

Table 4.1: Naming convention for coarse and fine-grained residues

Mineral	Fine-grained Residue	Coarse-grained Residue	Co-disposal commonly applied
Andalusite	Slimes; Tailings storage facility	None	
Coal	Slurry	Discard/Reject Overburden Spoil Stockpiles	Yes
Chrome	Slimes; TSF	Waste rock	Yes
Diamonds	Slimes; grits; Fine residue deposits	Tailings Coarse residue deposits	Yes
Gold	Slimes; TSF	Waste rock Heap leach pad Overburden	
Iron Ore	Slimes; TSF	Waste rock Overburden	
Heavy minerals	Slimes; FRD	Sands	
Platinum	Slimes; TSF	Waste rock Overburden	
Manganese	Slimes; TSF	Waste rock	
Nickel	Slimes; TSF	Waste rock Overburden	
Zinc-Lead	Slimes; TSF	Waste rock Overburden	
Copper	Slimes; TSF	Waste rock Overburden	
Uranium	Slimes; TSF Calcine	Waste rock Overburden	
“Gypsum” Phos rock	Slimes; TSF Gypsum	Waste rock Overburden	

Table 4.2: Residue types and characteristics

Description		Pumping and Transportation	Discharge	Disposal Facility	Supernatant water Management	Storm Water Management
Fine-grained MRDs	Conventional residue	Centrifugal pumping and piping	Open ending, spigotting, cycloning	Impoundment, Day wall, cycloned raising	Penstock, floating barge	Storage in return water dam, evaporation, reuse in plant
	Thickened residue	Centrifugal pumping and piping	Open ending, spigotting, cycloning	Impoundment, Day wall, cycloned raising	Penstock, floating barge	Storage in return water dam, evaporation, reuse in plant
	Paste Residue	Positive Displacement pumping and piping	Top-down and bottom-up methods	Paste stacking	N/A	Storage in return water dam, evaporation, reuse in plant
	Filter Cake/Dry Residue	Non-pumpable	Conveyor/ Earth moving Plant	Dry stacking	N/A	Drainage control measures
Coarse-grained MRDs		Non-pumpable	Conveyor/ Earth moving Plant	Waste rock facility	N/A	Drainage control measures
Fine/coarse co-disposal MRDs		Pumping and piping possible	Open ending	Void backfilling, disposal in or covering of conventional residue storages. Elevated waste heaps	N/A	Required for elevated waste heaps

Table 4.2 provides a summary of the various residue types and their characteristics, including:

- **Fine-grained MRDs**
  - Conventional (Low Density residues): Unthickened residue that are produced by most conventional milling processes. Conventional residues comprise a slurry of solids and solution with a solids content (by mass) ranging from 30 to 50% depending on the process and the material. The residue segregates after deposition and produce supernatant water
  - Thickened (Medium density residues): Residue thickened to the "gel" point i.e. the consistency at which a yield stress is first developed, or to a negligible yield stress for a central thickened discharge system. The thickened residue slurries will generally not segregate, but a limited amount of supernatant water will separate from the deposited residue and flow down slope
  - Paste (High to very High-Density residues): Residue thickened to a consistency involving a yield stress up to the paste boundary. There is little to no segregation or supernatant water flow but the paste residue will still flow down a slope as a mudflow. This is used for "dry" stacking and multiple discharge point operations.
  - Filter Cake: The term filter cake is used to describe a waste that has been dewatered with a filter press etc and is suitable for transporting by truck or conveyor.
- **Coarse-grained MRDs:**
  - Waste rock can be defined as the rock separated in the mining process and not treated. It can have a particle size generally greater than 1 mm
  - Coarse rejects from the beneficiation process

- **Fine and coarse co-disposal MRDs, which can include the following:**
  - The coarse and fine-grained products are transported and placed separately but will be in contact and may mix within the disposal site after deposition
  - The coarse and fine-grained products are transported separately and mixed together just prior to or on placement in the disposal site
  - The coarse and fine waste products are mixed together before they are transported to the disposal site.

4.2 Disposal options

4.2.1 Above ground

Above-ground disposal system refers to those MRDs that are elevated above the natural topography. These are the most common form of MRD in South Africa. Waste rock dumps, discard dumps, residue dams, etc. are all above ground.

4.2.2 In-pit

In-pit disposal requires an exemption from Regulation 4 of GN704 (see Section 5 and Appendix A) through the use of Regulation 3.

There are generally short term economic advantages of storing mine residues in mined-out open pits but these may be offset by very considerable monitoring, remediation and rehabilitation costs. The types of open pit disposal that could be considered are:

- Wholly above the groundwater table
- In contact with a static or fluctuating groundwater table, or
- Wholly below the groundwater table.

4.2.3 Underground

Underground disposal requires an exemption from Regulation 4 of GN704 (see Section 5 and Appendix A).

Mine backfill operations can be undertaken in two forms, depending on the consistency of the residues, as follows:

- The residue is in the form of a “thickened tailings” and has a consistency as high as can be pumped or pushed down a pipe back into the mine
- The residue is reconditioned by mixing with water to achieve the consistency necessary to achieve the required slump when mixed with aggregates (e.g. sand) and a binder (e.g. cement). In this case the residue is generally required to have a yield stress in excess of 200 Pa.

In addition to the above, coarse residue from the mining operation may be separated and disposed underground.

4.3 Life cycle phases of a MRD

The different phases in the life cycle of a greenfields MRD will include most, if not all, of the following:

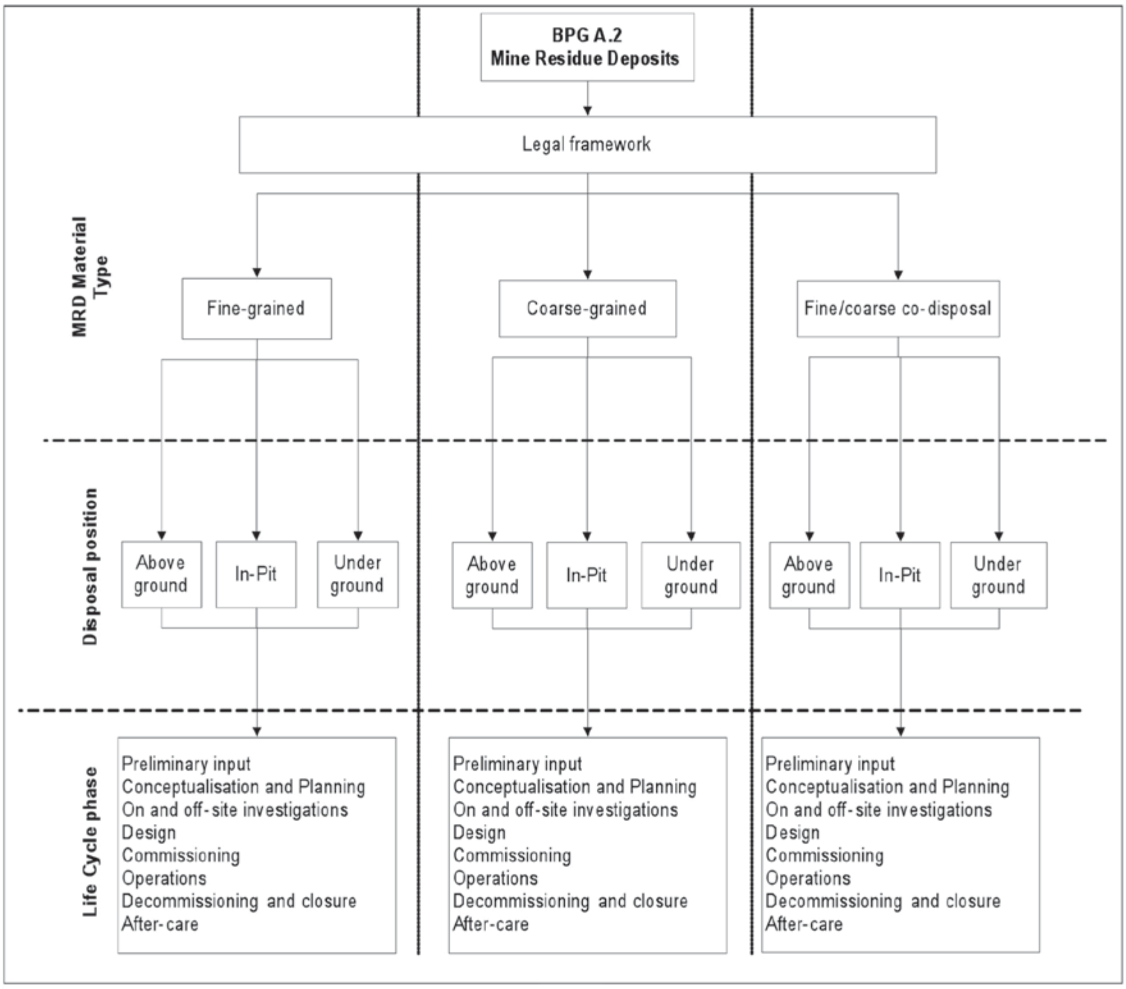
- Preliminary input
- Conceptualisation and planning phase, which can include the following:
  - Identification of all regulatory requirements and laws governing the design, operation and closure of a residue facility
  - Definition of the quantity and physical and chemical characteristics of the residue to be stored
  - Siting study
  - Environmental baseline studies
  - Scoping level design for prefeasibility
  - Preliminary design for feasibility
  - Environmental impact assessment and permitting
- On and off-site investigations
- Design phase:
  - Detailed design, construction drawings and specifications
  - Regulatory review and approval
  - Preparation of operating manuals
  - Construction of the initial stage(s) of the MRD
- Commissioning and operations phase
  - Startup and commissioning
  - Monitoring of operations
  - Ongoing staged construction
  - Safety reviews and risk management
  - Performance assessments and EMP updates
- Decommissioning, closure and after-care
  - Final design, assessment and approval of rehabilitation and closure measures
  - Implementation of closure measures
  - Reclamation
  - Post closure monitoring

NOTE: ***In many cases, the BPG will be applied to existing operations where the conceptualisation, planning and design phases have been completed. For these facilities, some of the life-cycle phases may need to be reviewed and revisited to be aligned with current legislation and practice and enable decommissioning and closure.***

4.4 Structure and focus of the BPG

Figure 4.1 summarises the details provided in the sections above relating to mine residue types, disposal options and the life cycle phases. With reference to these details, **Section 6** of this document sets out a robust assessment process that addresses the potential water management issues associated with a MRD over its complete life cycle. The process described in Chapter 6 is presented in the context of a fine-grained MRD, with disposal above-ground. The process is however also valid for all different types of MRDs. The main difference between the various types of MRDs and the disposal position is the particular impact pathways that apply. In this regard, the specific issues to consider for the different MRDs (coarse-grained and co-disposal MRDs) are covered in Section 7.

Figure 4.1: Types of MRDs

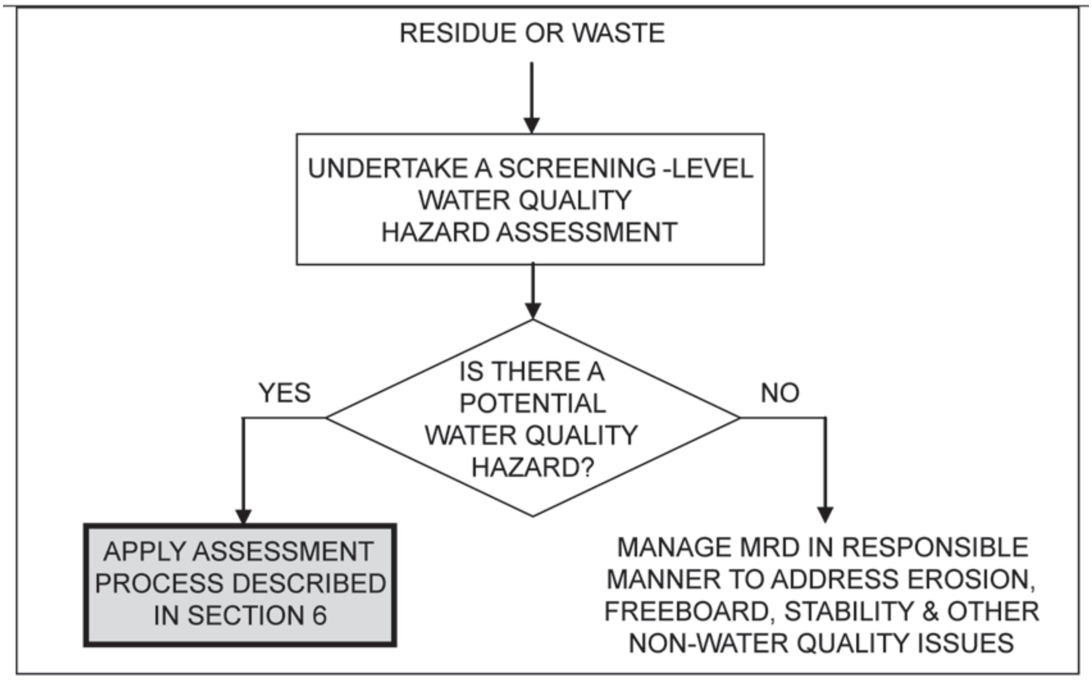


The process advocated in this BPG does not assume a hazard or absence of hazard simply based on the type of mineral being mined and does not characterise mines as category A, B or C. Instead, each waste or residue that is generated, needs to be subjected to a screening level hazard assessment as shown in Figure 4.2 below. This assessment is undertaken using a conservative approach to determine whether there is a potential water quality hazard associated with a particular residue.

If the assessment concludes that there is no potential water quality hazard associated with the residue being assessed, then the disposal and management of that residue can be undertaken in accordance with the guidelines provided in SABS 0286: 1998, with the knowledge that no particular measures are required to deal with water quality issues, other than erosion of sediments. On the other hand, if a potential water quality hazard is assessed, then the residue or waste in question will need to follow the detailed assessment process described in Chapter 6 to determine whether the potential hazard does in fact exist and then design, operate and close the disposal facility for that residue in accordance with best practice described in this document.

As the screening-level assessment shown in Figure 4.2 is conservative, it is possible that the more detailed assessment process described in Chapter 6, where conservative assumptions are replaced with more realistic ones or real data, may assess the waste in question to not pose a water quality hazard. In which case, the residue disposal will also need to comply with the SABS 0286: 1998 with no additional water-specific considerations being relevant.

Figure 4.2: Screening-level assessment process for all MRDs



5 LEGAL FRAMEWORK

Appendix A provides details of the legal requirements for water management at a MRD, within the prevailing mining, water and environmental legislation in South Africa. This review focuses on the requirements of the National Water Act, 1998 (Act 36 of 1998) and the Mineral and Petroleum Resources Development Act, 2002 (Act 28 of 2002). The provisions included in other legislation are also considered.

The following provides a summary of the principle legal framework for MRDs:

- National Water Act, 1998 (Act No.36 of 1998) stipulates that a water use authorisation must be obtained before construction of a MRD and/or return water dam may commence. Some guidance on a water use authorisation application is given below.
- Government Notice No. 704, National Water Act, 1998 (Act No. 36 of 1998) dealing with regulations on use of water for mining and related activities aimed at the protection of water resources. Specific attention is drawn to the following pertinent regulations under this notice:
  - Regulation 2: Information and notification
  - Regulation 4: Restrictions on locality
  - Regulation 5: Restrictions on use of material
  - Regulation 6: Capacity requirements of clean and dirty water systems
  - Regulation 7: Protection of water resources
  - Regulation 8: Security and additional measures
  - Regulation 9: Temporary or permanent cessation of a mine.
- The Dam Safety Regulations (published in Government Notice R. 1560 of 25 July 1986) requires that every dam with a safety risk shall be classified in accordance with regulation 2.4 on the basis of its size and hazard potential. An authorisation is required from the dam safety office before construction of a dam commences.
- National Environmental Management Act, 1998 (Act No.107 of 1998) requires that an environmental impact assessment (EIA) must be carried out before the construction of a new MRD.
- Mineral and Petroleum Resources Development Act, 2002 and its regulations requires that an environmental impact assessment be undertaken for a mine, which will include MRDs. The EIA will include a scoping report and an environmental impact assessment report.

Table 5.1 summarises the authorisation requirements for MRDs and provides guidance on the application procedures for these authorisations. It is important that the mine owner liaises with the appropriate government departments, including DWAF, DEAT and DME, to ensure that it complies with all legal requirements for licensing of a MRD.

Table 5.1: Summary of authorisation requirements for MRDs

Applicable Act	Section	Legal requirements	Guiding notes
National Water Act, 1998 (Act No.36 of 1998)	21	21 (c) impeding or diverting the flow of water in a watercourse 21(f) discharging waste or water containing waste into a water resource through a pipe, canal, sewer, sea outfall or other conduit 21(g) disposing of waste in a manner which may detrimentally impact on a water resource 21(i) altering the bed, banks, course or characteristics of a watercourse.	A section 21 (g) water use authorisation is the **primary** authorisation that is required for all MRDs and return water dams. This includes compliance with Regulation No. 704. A section 21(f) water use authorisation is required if discharge is envisaged from the return water dam. Section 21 (c) and (i) authorisations are required if local or regional Storm Water diversion schemes are envisaged. The water use authorisations, and the application therefore, are combined into an Integrated Water Use Authorisation for the mine.
The Dam Safety Regulations (published in Government Notice R. 1560 of 25 July 1986)	9C of the NWA	Classification of the dam Approval to construct a MRD	Use form DW 692E For Category I dams, use form DW 694E and submit construction drawings For Category II and III dams, the APP must apply for a authorisation to impound (this involves the submission of an operation and maintenance manual and emergency preparedness plan together with an application form DW 696E)
Environment Conservation Act (ECA), 1989 (Act 73 of 1989)	Gov Notice R. 1182 and R. 1183	Environmental impact assessment (EIA)	The EMP and EIA processes for licensing of a MRD on a mine site should be integrated
Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002)	39, 48, 49, 50	Environmental management programme or plan (EMP) and environmental impact assessment (EIA)	

6

GUIDELINES FOR WATER MANAGEMENT FOR FINE GRAINED RESIDUE DISPOSAL ABOVE GROUND

6.1 Introduction

The management of the disposal of fine-grained residue, and the management of water in and around these deposits, is of critical importance to the success of any mining project. The residue disposal aspects are often the main focus of regulatory scrutiny during the authorisation process for a mine development, due to the inherent risk in the operations of these deposits. Successful management of residue disposal and the associated water management aspects requires a good understanding of the inputs and details required during the complete life cycle of the deposit.

The various water management steps included in the design of a deposit are shown in Figure 6.1. This diagram illustrates the integration of tasks that are required during the conceptualisation, planning and design phases between:

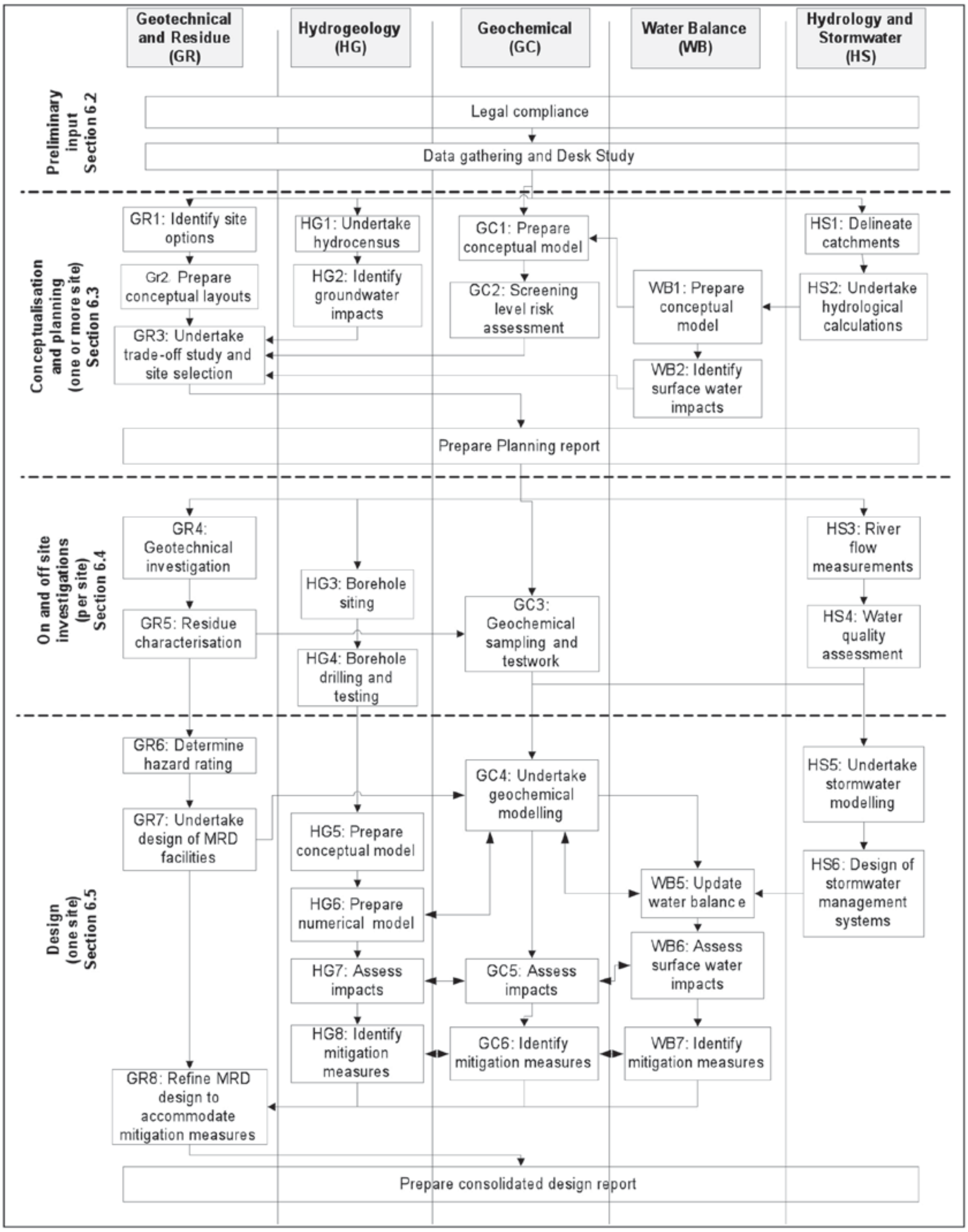
- Geotechnical and Residue (GR) assessments
- Hydrogeological (HG) assessments
- Geochemical (GC) assessments
- The MRD water balance (WB) , and
- Hydrological assessments and Storm Water management (HS).

The various steps identified in Figure 6.1 are described in the sections of the BPG below, as follows:

- Section 6.2: Preliminary input
- Section 6.3: Conceptualisation and planning
- Section 6.4: On-site investigations
- Section 6.5: Design.

The relevant portion of Figure 6.1 relating to each of the design phases for MRDs is repeated, for clarity, at the beginning of section 6.3, 6.4 and 6.5.

Figure 6 .1: Integration of tasks in the conceptualisation, investigation and design phases



6.2 Preliminary input

The preliminary input covers an assessment of the requirements for legal compliance and the necessary data gathering to prepare a desk study report.

6.2.1 Legal compliance

All necessary authorisations, as covered in Section 5 above and in Appendix A, must be obtained **before** construction of a MRD can commence.

An overall description of the legal requirements for dams is provided in ***BPG No. A4: Pollution Control Dams***. Currently, owners of mines are exempt from the provisions of the dam safety regulations for MRDs, with the exception of the obligation to register such residue dams with the Department.

6.2.2 Data gathering and desk study

All available water related information will be required at an early stage in the design process. Table 6.1 below identifies the likely information requirements for the various design areas. The output of this phase will be a desk study report which will:

- Summarise the available hydrogeological, geo-chemical and hydrological information
- Identify gaps in the information, and
- Provide input and guidance into the conceptualisation and site investigation phase.

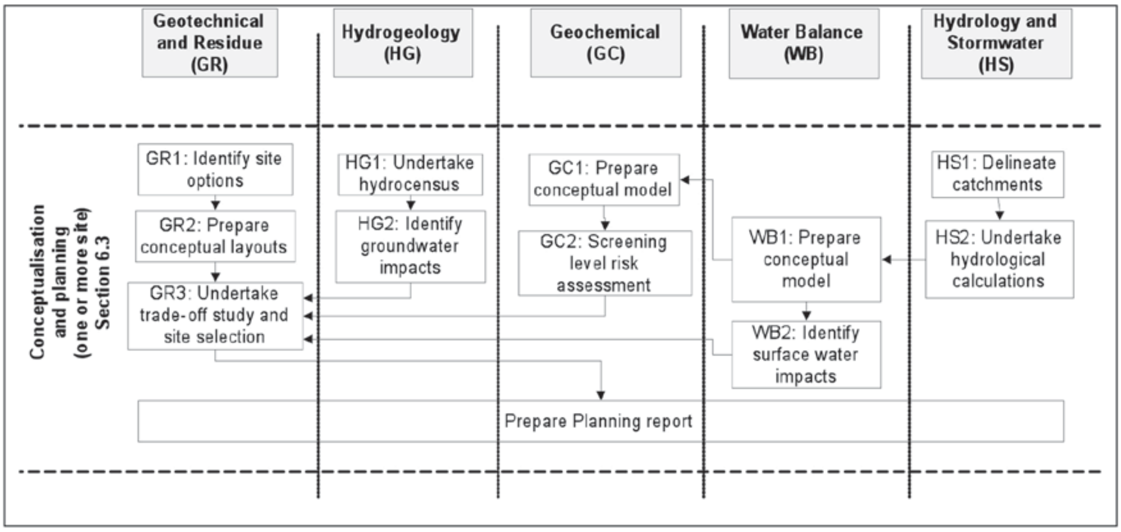
Table 6.1: Information requirements for planning

Design area	Information Requirements
Mine residue	• Annual anticipated tonnage and overall total tonnage • Life of mine • Results of any testwork on the mine residue • Residue characteristics, such as particle size distribution, dry density, etc
Hydrology and Storm Water	• Climate data: Patterns of temperature, rainfall, evaporation and atmospheric moisture for the area • Reports, documents and maps on the hydrology of the area • All available river flow data • Surface water quality information • Downstream water users and their quality criteria • Resource quality objectives for the affected catchment(s).
Water balance	• Reports and document on the mine water balance • Water flow and water quality measurements or predictions • Possible flows to and from the MRD • Ambient water qualities
Geotechnical	• Reports and documents on the geology and geotechnical conditions for the area • Geotechnical reports and information for the MRD site(s)
Hydrogeology	• Published and unpublished geological and hydrogeological reports, maps and documents • Borehole positions and logs • Details of groundwater abstractions and groundwater users in the area • Conceptual and/or detailed groundwater models • Recharge estimations • Groundwater quality information • Any available monitoring data
Geochemical	• Reports and document on the geochemical properties of the residue, e.g. particle size distribution, porosity, moisture content including soil moisture retention tests, mineralogy, acid base accounting, kinetic data, etc • Geotechnical conditions for the area • Ambient water quality • MRD details, e.g. footprint area, rate-of-rise
General	• Archaeological sites within the mine area • Wetlands and ecologically sensitive areas

6.3 Conceptualisation and Planning Phase

Figure 6.2 indicates the various tasks that are likely to be undertaken during the conceptualisation and planning phase.

Figure 6 .2: Tasks in the conceptualisation and planning phases



The conceptualisation and planning phase is the first step in the life cycle of a MRD and includes the site selection process. This process provides an opportunity to consider a wide range of options before a commitment is made to follow a particular option. Alternatives to consider at this early stage may include:

- Different methods of residue preparation
- Different residue disposal methods, and
- Different disposal sites.

6.3.1 Geotechnical and Residue (GR)

Step GR1: Identify site options

The objective of the site selection process is to identify the most appropriate site for the development of a MRD. The site selection process should adhere to the general principles and key considerations given in Sections 2 and 3 above. Site selection for MRDs should be made on the basis of:

- Technical viability
- Economics (development, operational and closure costs)
- Environmental impact
- Hazard and risk, and
- Resource utilisation.

The investigations and studies undertaken for the MRD site(s) during the site selection process are likely to be cursory. These should nevertheless be carried out by suitably qualified persons. The appropriate level will be dictated by the safety classification rating of the MRD as defined in SABS 0286. Sites that contain potentially fatal flaws such as dykes/faults, wetlands or major water courses within the MRD footprint area are not recommended without suitable mitigation measures.

The design team will initially identify one or more suitable site locations for the MRD. Conceptual layouts for these MRD options will be prepared. Once identified, the water related aspects covered in the sections below will be undertaken.

Step GR2: Prepare conceptual layouts

The overall footprint of the MRD should be estimated at this stage, based on the total residue tonnage and the residue characteristics. Conceptual layouts of the

MRD at the various site location options should then be prepared. These conceptual layouts should include:

- The overall layout of the MRD on the available topographical information
- Conceptual level details of the water management aspects, such as decant facilities, size and position of the return water dam, paddocks and the requirements for clean Storm Water diversion systems
- A typical cross-section through the MRD showing initial and final wall height and the likely construction method of the MRD during operations
- Other infrastructure, such as access roads, pipelines, perimeter fences, etc.

Step GR3: Undertake trade-off study and site selection

The preliminary studies on hydrogeological (HG), geochemical (GC), water balance (WB) and hydrology and Storm Water (HS) will provide input into the trade-off study. This trade-off study is likely to be on a semi-quantitative basis and should assess the following:

- The cost for each MRD location, at a conceptual level of detail
- The technical issues associated with each location
- The potential environmental and social impacts associated with each location, including potential impacts on archaeological sites, any wetland areas and/or other ecologically sensitive areas
- Potential land use issues, and
- Any regulatory issues associated with each MRD site.

The trade-off study will identify which location (or locations) for the MRD to take forward to the on and off-site investigation phase.

6.3.2 Hydrogeology (HG)

Step HG1: Undertake hydrocensus

The hydrogeology team will undertake a hydrocensus of all existing boreholes, dug wells and springs within the project area. The following information should be collected during the hydrocensus:

- GPS co-ordinates
- Owner
- Existing borehole equipment
- Current water use
- Reported yields (historical and current)
- Reported or measured depth
- The static water level, and
- Field groundwater quality testing.

Step HG2: Identify groundwater impacts

The design team will use the results of the desk study and the hydrocensus to identify the potential groundwater impacts for each MRD location. Such impacts may be, amongst others:

- The impact on downstream water users
- Impacts on sensitive or protected areas
- Impacts on any open-cast or underground workings, shafts or occupied premises; the stability of the underground/excavated workings can be affected by possible seepage and the mass of the MRD,
- Effects of seepage on dam stability, and/or
- Groundwater quality impacts.

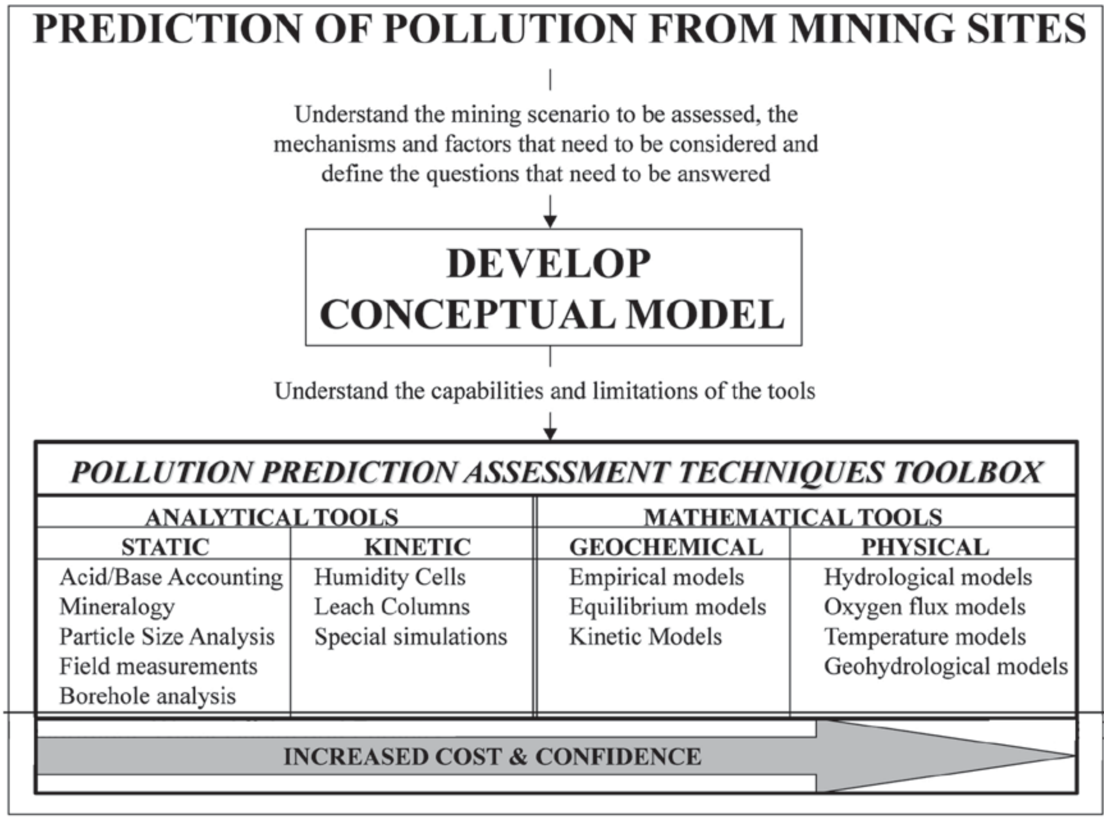
NOTE: ***In particular, potential fatal flaws in terms of groundwater impacts for each site location should be identified at this stage. Additionally, where the seepage water quality is not known for certain, conservative assumptions should be used in making the assessment***.

The groundwater impacts identified as part of this step will be used in the trade-off study and site selection (Step GR3).

6.3.3 Geochemistry (GC)

The generic process shown in Figure 6.3 should be followed so as to be able to make a prediction of future pollution from a MRD.

Figure 6.3: Pollution prediction process and assessment techniques



The geochemical assessment tools as presented in Figure 6.3 above will be represented in any assessment of the pollution potential of MRDs. It is necessary to analyse site specific data, and to conduct preliminary sampling before a conceptual model can be finalised.

Acid Base Accounting (ABA) is often used as one of several tools in any geochemical assessment investigation in order to determine the pollution potential of the dump. ABA in itself should not be used as a predictive tool as it has very limited predictive powers, but rather it can be used as a screening tool to assess the uniformity of the residue with respect to minerals which contribute to Acid Potential (AP) and Neutralising Potential (NP) and also as supporting information in the determination of long term pollution risks of the material in question. Geochemical modelling should ultimately be used for long term prediction of water quality, which will not only focus on the potential for acidic drainage but also the potential total salt and metal load of the drainage (see BPG G4: Impact Prediction).

An implicit assumption in the formulation of this methodology, and one which is well supported by various literature sources, is that the 'reactive' zone of the MRDs is an outer layer approximately 5-10 meters thick. This simplifies and restricts the sampling program to this outer layer for the residue. This assumption does however not apply to waste rock dumps.

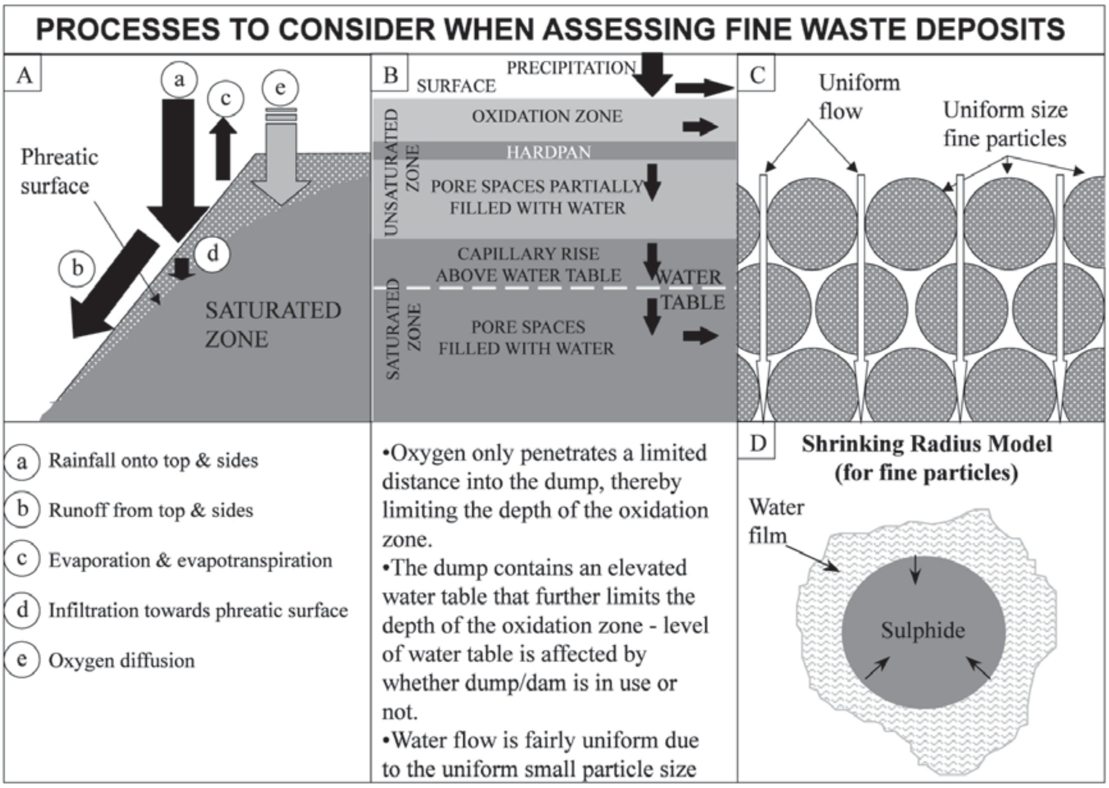
Step GC1: Prepare conceptual model

A conceptual model for the MRD must be developed. This should first be conducted on a preliminary basis (See Figure 6.3) so that a geochemical sampling program (Step GC3) can be developed. This conceptual model should also incorporate data obtained from site investigations and a simple preliminary sampling and analytical campaign. The conceptual model is used in subsequent steps to develop a comprehensive sampling program. Only after this has been done should the first meeting with regulatory authorities be held since no fixed and firm sampling and analytical program can be developed before this point.

The MRD water balance (Step WB1) will form a key input into the geochemical assessment of the MRD. The developed conceptual model should be shown diagrammatically and must link the MRD water balance with the geochemical assessment.

Fine-grained residue is distinctly different from coarse-grained waste rock in terms of particle size uniformity, dam water table level, and the location of seepage points. Relatively large differences in size, shape, and origin further distinguish the difference between these types of residue. Basic geochemical models of these residues therefore differ markedly, as can be illustrated in a detailed assessment of the processes which occur in each of these types of residues. The typical processes for fine-grained residue are shown in Figure 6.4 below. The variations for coarse-grained MRDs are covered in Section 7.

Figure 6.4: Processes to consider when assessing fine-grained MRDs



Once the conceptual models have been finalised and detailed sampling programs have been confirmed, meetings should be held between the mine and the regulatory authorities to ensure that the proposed approach to the pollution potential assessment is agreed.

Step GC2: Screening level risk assessment

MRDs have the potential to impact on the water resource in a number of ways. A source term characterisation project should start with a qualitative screening risk assessment of the MRD in question, focusing on water-related issues. In this context the MRD, topography, and location with respect to potentially sensitive receptors (such as ground and surface water bodies) and drinking water sources (such as dams and boreholes) should be evaluated. This screening level risk assessment should be conducted under the premise that the MRD will eventually give rise to poor quality drainage. As a part of this assessment all documentation relevant to the MRD in question should be studied.

6.3.4 Hydrology and Storm Water (HS)

Step HS1: Delineate catchments

The design team will use suitably scaled topographical maps to delineate the relevant catchments that will have an impact on the MRD or that are impacted on by the MRD and will thus require Storm Water management. The determination of the catchments that need to be investigated, and the collection and routing of run-off requires a base map, that should include the following information:

- 1 in 10 000 or 1 in 20 000 topographical map with a suitable contour interval. An aerial photograph as a background to the topographical map should also be considered
- The location of the rivers and streams
- The 100 year flood lines marked on the map, if available
- The mine lease area and mineral right boundaries
- The locations of the current or proposed mining infrastructure. The infrastructure will include the office complex, plant, workshops, waste deposits, product loading areas, mine shafts and mine workings
- Archaeological sites, and
- Any wetland areas or ecologically sensitive areas that may need to be considered in the development of the mine water plan.

The base map will be used to identify catchment areas whose runoff is considered to be “clean” and “dirty”. The areas that are typically considered to be “dirty” are the surface area and side slopes of the MRD, while “clean” areas are:

- Office and administration areas
- Residential and social facilities, including mine villages, sports fields, golf courses, etc, and
- Areas surrounding the MRD that are not impacted by mining.

Care should be taken in assessing the clean areas in and around the offices, as these areas can often be impacted by mining operations, e.g. impacts of wind-blown contaminants.

Additional guidance on this process can be obtained in ***BPG G1: Storm Water Management***.

The runoff from the “dirty” areas must be captured, retained and managed on or around the MRD, through the use of catchment paddocks or other suitable systems.

Every effort should be made to maximise the clean area and minimise the dirty area when locating the MRD and the diversion berms and channels. In the case of a new mine, the maximisation of the clean areas should influence the location of the mine infrastructure.

Step HS2: Undertake hydrological calculations

The ***BPG G1: Storm Water Management*** and ***BPG A4: Pollution Control Dams*** provide details and guidance on the necessary hydrological calculations for Storm Water management on a mine site.

6.3.5 Water Balance (WB)

Step WB1: Prepare preliminary model

The ***BPG G2: Water and Salt Balances*** provides details and guidance on the setting up and use of a water balance for a MRD. A water balance for a MRD requires the identification of all the hydrological sub-catchments which make up the MRD. These are typically:

- The area whose runoff reports to the pool in the MRD
- Runoff from the side slopes of the MRD captured in paddock dams (for unrehabilitated side-slopes) or discharged to clean water catchments (for rehabilitated side-slopes where the runoff is of acceptable quality), and
- Any upstream catchment which is not yet covered with mine residue whose runoff reports to the MRD.

The typical water inputs to a MRD are:

- Water contained in the feed from the residue delivery line (process water)
- Runoff from the subcatchments
- Rainfall on the surface of the pool, return water dam and the paddocks
- Extraneous water pumped onto the surface of the MRD
- Potential artesian flows from elevated groundwater conditions.

The water outputs typically consist of:

- The discharge from the penstock to the return water dam
- The seepage into the underdrainage system (if any) which surrounds the MRD and which is fed back to the return water dam

- Seepage losses into the foundation of the MRD and from the return water dam that are irrecoverable and report to the groundwater
- Moisture retained in the residue
- Evaporation from the surface area of the dam and the return water dam or dams, and
- Abstraction from the return water dam for reuse.

The water balance will enable the calculation of the storage capacity and freeboard of the surface of the MRD, as well as the size of the penstock off- take which must be matched to the storage volume.

A continuous water balance model operating at an appropriate time step should be set up for the MRD. The model must account for the pathways covered above and illustrated in the schematic given in Appendix B. The MRD water balance should be included in the overall mine water balance if the abstraction from the return water dam is linked to other parts of the mine water balance.

Step WB2: Identify surface water impacts

The design team will use the results of the above work to identify the potential surface water impacts for each MRD location. Such impacts may be, amongst others:

- The impact on downstream water users
- Impacts on sensitive or protected areas
- The requirements for Storm Water management for each of the delineated catchments, and/or
- Surface water quality impacts.

In particular, potential fatal flaws in terms of surface water impacts for each site location should be identified at this stage.

The surface water impacts identified as part of this step will be used in the trade-off study and site selection (Step GR3).

6.3.6 Planning Report

The output from the conceptualisation and planning phase will be a conceptual plan for the operational life, closure, decommissioning and after-care of the proposed MRD. The plan should include all the assumptions, parameters and alternatives considered and the justifications and reasons for the final selections. This document should be retained by the owner throughout the life of the facility and should be referred to in the event that the scope or objectives of the facility changes.

The planning report should contain the following information:

- Background information
- Design criteria and assumptions i.e. source of residue, life of mine, rate of production, total tonnage and relation to volume, etc.
- Baseline Information i.e. geology, topography, geotechnical, climate, hydrological and surface water, groundwater, air quality, noise, fauna and flora, buildings count, sites of archaeological and cultural interest, etc.
- Consideration of alternatives i.e. alternative sites, slurry water content and water balance, deposition techniques, footprint size, phased construction, lining systems, etc.
- Preliminary considerations of water balance, hydrogeological and geochemical impacts
- Comparison of candidate schemes and fatal flaw assessment
- Conceptual design of preferred scheme including preliminary safety and environmental classification as per SABS 0286:1998, closure provisions and intended final land use aims
- Recommendations for investigations.

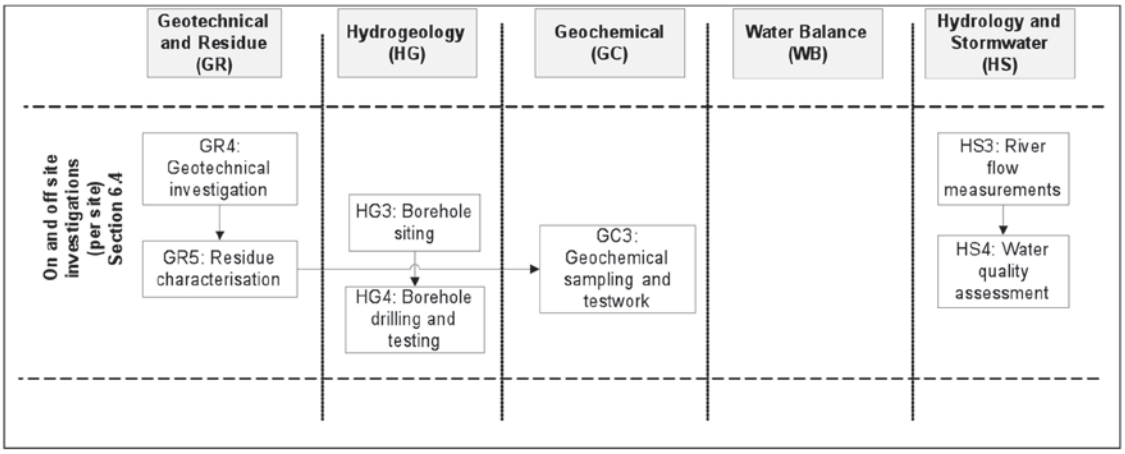
An example of a Table of Contents for a Planning Report for all aspects of a MRD is included in Appendix C.

6.4 On and off site investigations

6.4.1 Introduction

The on and off site investigations for MRDs is generally an iterative process and requires significant integration between the various disciplines (geotechnical/residue, hydrogeology, geochemical and hydrology and Storm Water). Figure 6.5 indicates the various tasks that are likely to be undertaken during the on and off site investigations phase.

Figure 6.5: Tasks in the investigation phase



The investigational requirements will be influenced by the MRD site location (from the site selection process) and specific design requirements. Preliminary investigations of a number of sites might be required in order to arrive at the optimal solution in respect of the final selection of the site and the design of the facility.

Typically the on-site investigations will require the following:

- Geotechnical investigation
- Geochemical characterisation
- Groundwater investigations
- Storm Water quantity and quality investigations, and
- Environmental guidelines.

Off-site investigations include residue characterisation.

The aims of these investigations are to provide:

- Sufficient and reliable information on the circumstances and conditions in which the MRD is to be constructed
- Sufficient and reliable information on the predevelopment environment so that an assessment of environmental impacts can be made
- Background environmental data against which to monitor the performance of the MRD
- The basis for comparison of alternatives in terms of potential environmental impacts
- A basis for the assessment of the performance of alternative impact management measures.

Note that all technical investigations should be integrated across disciplines and take cognisance of the scope and results of all other investigations, as shown in Figure 6.5. The planning of the investigations should be based on well-developed design concepts, to ensure cost and technical efficiency.

6.4.2 Geotechnical and Residue (GR)

Step GR4: Geotechnical investigation

Geotechnical information is required for each of the potential MRD sites, to provide information for the design stage. The scope and extent of the geotechnical information should be planned based on the level of available information and the geotechnical complexity of the site.

Step GR5: Residue characterisation

The objectives of the residue characterisation study are the determination of the following geotechnical properties:

- Shear strength for stability analysis
- Densities for airspace use calculations
- Rate of rise limits for pore pressure management and cycle times for access to residue surface
- Permeability for computation of seepage rates and design of over-drainage system
- Relationship between solids concentration and segregation potential

The test results are interpreted to provide recommendations on the following:

- Dry density as a function of drying time, confining stress and deposition environment

- Shear strength as a function of dry density
- Permeability as a function of confining stress
- Grading envelope for filter materials
- Allowable rate of rise for upstream construction
- Moisture retention and relationship between moisture content and permeability
- K_0 loading on horizontal and vertical pipes and towers.

In terms of water management, the geotechnical study and residue characterisation will provide input for the water balance, seepage analysis, drain design, etc.

6.4.3 Hydrogeology (HG)

Design of a MRD facility requires a thorough understanding of the groundwater regime in and around the preferred site. The extent of the groundwater investigation on the site of a planned new MRD should be determined by the significance of the potential impact of the MRD on the groundwater environment. In the case of an MRD that has the potential to impact significantly on groundwater, the investigation should include the steps set out below and follows the preliminary assessment made from the hydrocensus and desk study.

Step HG3: Borehole siting

Boreholes may be required in strategic locations in the vicinity of the MRD, to obtain information on the groundwater regime. Borehole siting should be undertaken based on the following suggested steps:

- Stereo pair air photography interpretations to identify geological structures in and around the site which could act as preferential groundwater flow paths
- Site walk-over, and
- A geophysical survey around the proposed MRD site(s) to delineate any features identified from the air photo interpretation as determined by a suitably qualified person. This survey may comprise frequency domain and magnetic techniques, supported by electrical resistivity, gravity or other applicable technique as warranted.

Step HG4: Borehole drilling and testing

Technical specifications for the drilling and testing of the exploratory/monitoring required for the groundwater study should be prepared and incorporated into a tender document. The documentation should take account of the site-specific logistics of the MRD site.

Only contractors known to possess suitable experience and equipment should be invited to submit tenders for the work required.

A site inspection for tenderers should be arranged to ensure the logistics and access of the site are understood.

Adjudication of tenders received should be undertaken on the basis of a bill of quantities and rates, experience and equipment offered.

The drilling of exploratory/test/monitoring boreholes may be required, unless sufficient information is currently available. The depth of the boreholes will be controlled by the depth of the water table and prevailing hydrogeological conditions. Additional details on borehole drilling and testing can be found in ***BPG G3: Water Monitoring Systems***.

Boreholes must be positioned to ensure sufficient data are gathered to gain a thorough understanding of the hydrogeological situation, including correct definition of the groundwater flow mechanism in and around the site. The drilling of a sufficient number of boreholes to gain this understanding is therefore essential.

The boreholes should be completed for incorporation into the groundwater monitoring network, as appropriate.

Short term testing of the boreholes to gain an understanding of the aquifer hydraulics should be undertaken. The hydraulic parameters determined from the test data provide essential inputs to the numerical flow and solute transport model.

Samples should be collected from the newly drilled boreholes and submitted together with any samples collected during the hydrocensus to an accredited laboratory for analysis. The water samples should be analysed for the key water quality parameters relevant to the site-specific conditions, the mine EMP and the water use authorisation conditions.

The data should be included with any available existing chemical data and used to prepare the baseline groundwater quality assessment against which potential future impacts can be measured

The output of these hydrogeological investigations will be a characterisation of the prevailing hydrogeological situation around the preferred site, including:

- Determining the occurrence and depth of aquifers under and surrounding the site

- The depth to the static water level
- The groundwater flow network
- Identification of geological structure that could act as preferential flow paths for the movement of groundwater away from the site
- Assess where seepage will flow, and
- Determination of the baseline groundwater quality.

6.4.4 Geochemical (GC)

Step GC3: Geochemical sampling and testwork

The hydrogeological and geochemical investigations are often carried out in tandem as the geochemical investigation determines the source term used in the groundwater modelling. The focus of the geochemical investigations is to characterise the geochemistry of the residue, including:

- Forecasting the quality of seepage from the residue as a function of the residue geochemical characteristics and geochemical controls
- Evaluating the likely seepage volumes emanating from the residue as a function of residue properties, time and climatic variation
- Assessing the impact of seepage volumes and quality groundwater and understand cause and effect relationships for off site groundwater impacts.

The success of any geochemical source term characterisation and prediction assessment hinges on the quality of the sample selection and preparation. This consideration must be balanced against the cost of the sampling exercise which can range through several orders of magnitude. A sampling program should be defined in detail and agreed upon with the regulatory authorities in terms of objectives and principles. It is most certainly also necessary to agree on acceptable levels of confidence that the sampling program must comply with in order that the results of the sampling program can be evaluated against the agreed confidence limits to determine whether additional sampling is required or not. See ***BPG G4: Impact Prediction*** for more detail on geochemical sampling programs.

The geochemical characterisation of both the solid and solution portions of the residue should be considered. The acid generating potential and metal leaching characteristics of the solids and the chemistry of the liquid effluent will influence the design of the MRD.

A phased approach to residue characterisation is recommended. The following static tests on the MRD solids should be undertaken:

- Trace element content determination
- Acid Base accounting (ABA) to determine the relative balance of potentially acid generating and potentially acid consuming minerals
- Leach extraction testing to determine the soluble components of the sample
- Mineralogy using XRD, XRF and determination orf sulphide surface area.

Kinetic testing is used to confirm the acid generating or neutralizing characteristics while determining the rates of reaction for acid generation and neutralization. Kinetic tests should include:

- Humidity cell tests
- Humidity column test
- Column leach tests
- Soxhlet extraction test
- Field plot tests.

It is equally important to characterise the residue solution. A sample of the residue solution from the pilot test work (if available) should be analysed for the following:

- Total and dissolved metals (ICP-MS)
- Nutrients
- Reagents and reagent by-products in the process
- Speciation of any metals of concern
- Turbidity and suspended solids.

The results of the data collection exercise should be documented and the data should be assessed to determine risks of long-term water quality problems in accordance with procedures set out in ***BPG G4: Impact Prediction***. The collected data will be used for geochemical modelling studies.

The sampling and testwork results can be utilised as follows:

- The effluent concentrations, coupled with site hydrology can also be used to perform water quality modelling exercises if discharge to a nearby water way is considered
- The characterisation of residues is relevant in terms of defining the source term to model/estimate the effect on the groundwater resources.

Note that the engineering characteristics of the residue are influenced by the method of deposition and the method of residue preparation. This must also be taken into account when defining the source term.

6.4.5 Hydrology and Storm Water (HS)

Step HS3: River flow measurements

It is often useful for the design phase to augment existing river flow data with actual flow measurements from site. These data also provide useful information on the predevelopment river flows. The ***BPG G3: Water Monitoring Systems*** provides details and guidance on obtaining river flow measurements.

Step HS4: Water quality assessment

Sampling and testing of the river water quality is also recommended, as this provides useful predevelopment information. Water samples collected should be analysed for some or all of the following constituents:

- pH, TDS, Electrical Conductivity, Suspended Solids
- Biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon, turbidity, suspended solids, Ca, Na, Mg, K, Total Alkalinity, total hardness as $CaCO_3$, SO_4, Cl, F, NO_3, NO_2, PO_4, Organic and Total Phosphorous, Fe (dissolved), Mn (dissolved), faecal and total coliforms, (including E. Coli), faecal streptococcus, oils and grease, cyanide, and radionuclides
- An ICP scan of an initial set of samples can be undertaken to select appropriate trace metals for analysis in future rounds of sampling. The ICP scan should be for Ag, Al, As, B, Ba, Be, Bi, Cd, Co, Cr, Ga, Ge, In, Ni, Mo, P, Pb, Sb, Se, Si, Sn, Sr, Te, Th, Ti, Tl, U, V and Zr, and
- Other constituents dictated by site-specific requirements.

The information collected from the water sampling and testing campaigns should be captured into a suitable database and will constitute the baseline data for the design and operations phase of the MRD.

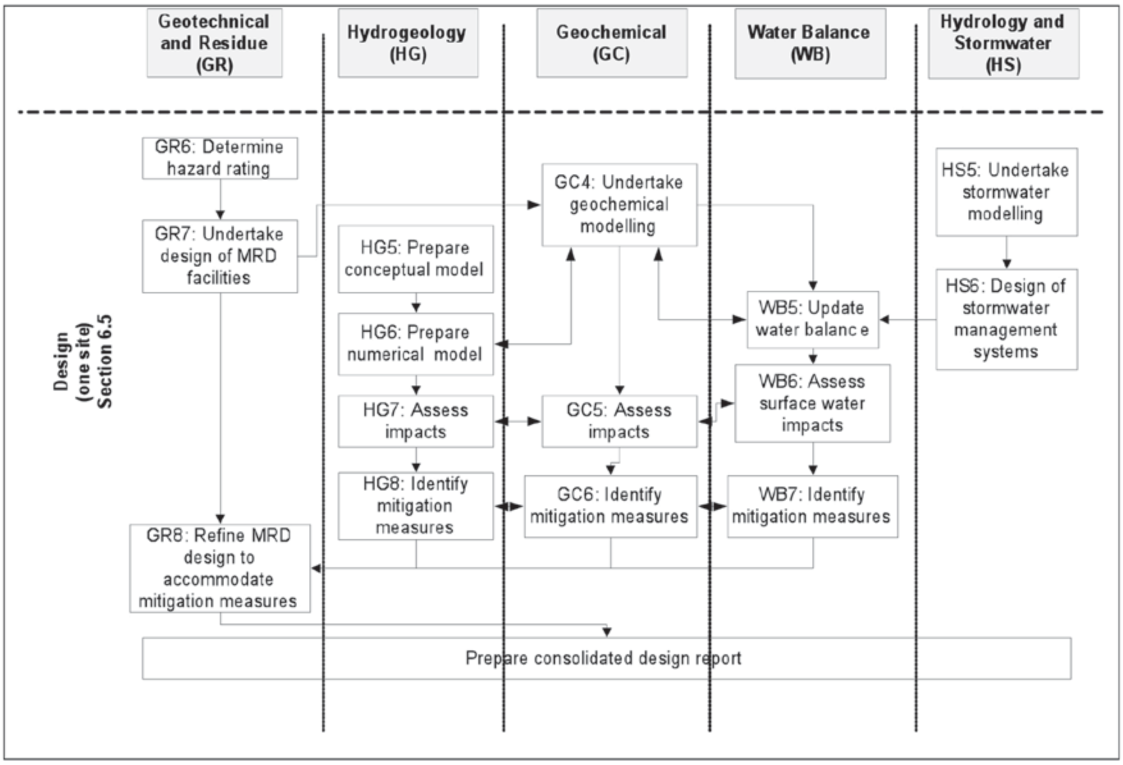
6.5 Design Phase

6.5.1 Introduction

The design phase for MRDs is an iterative process and will require integration between the various disciplines (geotechnical/residue, hydrogeology, geochemical and hydrology and Storm Water). Thus, for example, the geochemical modelling should interface with the groundwater models developed, and together with the hydrological and Storm Water design work, provide input on both water quantity and quality to the MRD water balance.

Figure 6.6 indicates the various tasks that are likely to be undertaken during the design phase for MRDs.

Figure 6.6: Tasks in the design phase



6.5.2 Geotechnical and Residue (GR)

Step GR6: Determine hazard rating

The safety hazard rating of the MRD as per SABS 0286:1998 will be required at the start of the design phase. This will determine whether the residue deposit is classified as a:

- Low hazard MRD
- Medium hazard MRD
- High hazard MRD.

The hazard rating determines the design requirements and the level of skill of the designer for a MRD.

A low hazard MRD requires a rudimentary design.

The design requirements for a medium hazard MRD should be determined by a professional engineer who will be required to consult with appropriately qualified personnel who have the skills and experience in environmental impact assessment. The design requirements may be satisfied on the basis of professional judgment.

The design requirements for a high hazard MRD should be determined and verified by the responsible professional engineer. Designs should in all instances be verified by one or more of the following methods:

- Independent calculations
- Prescriptive measures
- Experimental models and tests, and/or
- Observational methods.

Step GR7: Undertake design of MRD facilities

The BPG covers the water-related aspects of design, including under-drainage and liner systems.

Design of under-drainage

The purpose of an under-drainage system is to:

- Improve the stability of a MRD by lowering the phreatic surface. Unsaturated residue is more stable and less mobile (in the event of failure) than saturated residue
- Reduce the long term seepage and hence facilitate a reduction in ground and surface water impacts

- Reduce the post closure differential settlement, and
- Increase the return water to the plant.

In some circumstances, drains are placed on top of a lined floor. The purpose of these "over drains" is to reduce the hydraulic head on the liner and thereby reducing the quantity of seepage or leakage through the liner.

Under-drainage is required for a MRD for the following conditions:

- All hydraulically placed residues
- Certain non-hydraulically placed MRDs that require slope stabilisation.

The principle inherent in the design of an under-drainage system is to prevent the stability of the slope from being threatened by the presence of the seepage or raised phreatic surface. This is achieved by the under drain terminating the lateral migration of the seepage before it reaches the slope face. This principal applies throughout the life of the MRD.

The information requirements for design are as follows:

- The permeability of the residue and the foundation of an outer wall
- Grading curve of the residue
- The proposed final profile of the MRD, and
- For the use of geosynthetic filter fabrics such as geotextiles the susceptibility to blinding by mechanical or chemical means must be determined.

A worked example for the design of an under-drainage system is included in Appendix D.

Additional information on the design of an under drainage system is provided in Appendix VI of the Chamber of Mines Guidelines.

Design of lining systems

The purpose of a lining system is to prevent the pollution of groundwater resources during the operational and post closure phases of the MRD. The need for the liner system over the full MRD footprint should be assessed based on the hydrological, geochemical and geotechnical investigations and modelling and, hence the potential impact of the MRD on the groundwater and surface water regimes. It is however, generally best practice to provide a liner system for the return water dam of the MRD, as this receives water off the MRD surface and retains this water prior to return to the mine water system.

The principle inherent in the design is to minimise the rate of seepage into the foundation layers of the MRD by providing a layer with low permeability. A lining system is required for a MRD for the following conditions:

- Leachate or seepage from the residue has a high pollution potential, and
- The MRD is underlain by a groundwater resource of a strategic nature.

For design purposes, determining the pollution potential of the residue requires information regarding the geochemical properties, the hazard rating and the potential for possible contaminants to be mobilised.

The recommended design approach is as follows:

- Determine the required residue properties and the source term
- Undertake a risk based approach to evaluate the effects of possible contaminants on the receiving environment. This method should be used to determine the effectiveness of different lining systems and over and under drainage requirements with the use of appropriate leakage rates and permeabilities.

Four main types of liners are usually selected, namely:

- Geological liners
- Clay liners
- Synthetic liners such as geomembranes, gunite, asphaltic concrete, or sprays, or
- Compacted soil or soil cement.

Natural geological liners occur when the hydraulic conductivity of the formation soils or rocks are sufficiently low that the rate of seepage is reduced to an acceptable value. Mass permeability values of less than $1x10^{-8}$ m/s can typically be achieved. Fractures in and heterogeneity of the foundation soils are the main concerns.

Clay or low permeability soil liners may be used to form a core in the embankment, to line the impoundment basin or cover the residue deposit. Admixtures of bentonite or other low hydraulic conductivity, natural soils additives may also be considered. Hydraulic conductivity values of less than $1x10^{-8}$ m/s can typically be achieved for an appropriate layer thickness. Such liners must be checked to ensure that they are not degraded by the residue.

Flexible membrane liners may be divided into two common types, namely:

- Geomembranes, and
- Spray applied asphaltic liners

Both these membrane types can be used to line impoundments of complex geometric shape. The most commonly used geomembranes are High Density Polyethylene (HDPE) and Liner Low Density Polyethylene (LLDPE). These geomembranes have been used extensively in the waste management field and have excellent chemical resistant properties. A minimum thickness of 1.5 mm is recommended for geomembranes. The operative permeability of these liners are compromised by liner defects and typically expected values are $1x10^{-10}$ m/s and $1x10^{-12}$ m/s for asphaltic and geomembranes respectively.

The selection and design of a liner will depend on the site-specific conditions and the management of risk at the MRD, and should be decided upon by a suitably qualified person.

A worked example for the design of a lining system is included in Appendix E.

Step GR8: Refine MRD design to accommodate mitigation measures

The design team will refine the MRD design based on the impacts and mitigation measures identified during the hydrogeology, geochemical and water balance design steps.

6.5.3 Hydrogeology (HG)

Step HG5: Prepare conceptual groundwater model

The data collected during this site investigation phase should be interpreted and used to prepare a conceptual model of the dynamics of the groundwater system, including aquifer distribution and groundwater flow directions. The conceptual model provides the basic input to the groundwater modelling.

Step HG6: Numerical Groundwater Flow and Contaminant Transport Modelling

The potential impact of the MRD on the groundwater system should be assessed through numerical groundwater and/or contaminant (mass) transport modelling. A 3-D finite element or finite difference modelling package (such as MODFLOW or FEFLOW) should be used, depending on the complexity of the hydrogeological situation. The models can be used to describe the spatial and temporal distribution of groundwater contaminants, to estimate the duration and travel times of pollutants in aquifers, to plan and design remediation strategies and interception techniques, and to assist in designing alternatives and effective monitoring schemes.

The modelling inputs should include:

- The conceptual model
- Water levels, hydraulic gradients and flow directions
- Quantified aquifer hydraulic parameters
- Groundwater quality
- Site layout
- Surface topography (x,y,z co-ordinates)
- Source term derived from the geochemical modelling.

The modelling process is summarised in the sections below.

The first step in the modelling study is the development of a conceptual flow model. This is an idealisation of the real world that summarises the current understanding of site conditions and how the groundwater flow system works. It should include all of the important features of the flow system, while incorporating simplifying assumptions. The conceptual model will rely heavily on the information gathered during the field investigation phase.

Model set–up and calibration often constitute 50% to 70% of the total modelling effort. This entails selecting the model domain, discretizing the model domain, discretizing data in space and time, defining boundary and initial conditions, and assembling and preparing model input data.

Model calibration is the process of varying uncertain model input data over likely ranges of values until a satisfactory match between simulated and observed data is obtained. The measured values may include water levels, rainfall and hydraulic conductivity of the different aquifers which should be used to calibrate the model for steady–state (pre-mining) water levels.

A sensitivity analysis of the input parameters in the model is often required as there is always uncertainty in the input parameters used in a modelling exercise, mainly because of heterogeneity and the fact that parameters are measured at specific locations which may or may not be representative of the aquifers in general. The results of a sensitivity analysis can be used to:

- Identify sensitive parameters for the purpose of guiding additional field data collection and, perhaps, focussing calibration efforts,

- Define parameters to be used in uncertainty (risk) analysis.

Step HG7: Assess groundwater impacts

The calibrated groundwater flow and contaminant (mass) transport models should be used to address the objectives of the hydrogeological investigation, including an assessment of the potential groundwater impacts from the MRD. All activities and potential contamination facilities must be taken into account in an integrated manner, and where known, future facilities and activities should be included. The calibrated model should also be used to simulate various scenarios to determine the impact of the MRD on the groundwater system and the need for mitigation measures.

Step HG8: Identify mitigation measures

Various management alternatives, including various mitigation options, can be generated and simulated using the calibrated groundwater flow and contaminant (mass) transport models. These mitigation measures will be used to refine the MRD design (step GR8).

A hydrogeological report should include all borehole logs, test data, modelling results, water quality impact assessment, etc. The report should discuss the groundwater regime, including the distribution of aquifers and groundwater quality. Impacts on the groundwater regime by the MRD should be identified and the need for mitigation be addressed as relevant.

The hydroegological report should include the following:

- A description of the hydrogeological regime
- The identification of aquifers, aquitards and aquicludes,
- The piezometric map and groundwater flow directions
- The baseline groundwater quality profile
- The classification of aquifers present in terms of importance
- An assessment of groundwater impacts
- The proposed mitigation measures to limit any groundwater pollution
- A proposed groundwater monitoring programme.

All maps supplied should be geo-referenced and in GIS format.

The information contained in this report should be documented in the mine's environmental management programme.

6.5.4 Geochemical (GC)

Step GC4: Undertake geochemical modelling

Kinetic geochemical tests such as humidity cells, together with geochemical modelling,are often used to assess the long term water quality which may be expected to seep from certain MRDs and residues. See **BPG G4: Impact Predicction**. There is significant merit in the use of this method. However, the following limitations of geochemical modelling should be borne in mind:

- The ability to simulate actual field conditions in the geochemical model, both for the short-term and long-term conditions. This relates to both the geochemical processes present in a MRD and the unsaturated or saturated flow processes
- The input data obtained from the preliminary data gathering and investigation phases will define the level and accuracy of the model predictions
- Geochemical modelling is not an exact science and thus requires extensive verification over time, including monitoring, field test plots and model refinement and calibration
- Due to the inherent limitations in predictive geochemical modelling, use should be made of probabilistic analysis techniques to represent the uncertainty or limitations of the water quality predictions,
- Geochemical test results should be used together with information from a variety of other sources since there is often no single piece of evidence or conclusive test, and
- The outputs from geochemical models should be interpreted by suitably qualified personnel.

Geochemical modelling is required where long-term predictions and characterisation of the source term is needed. An advantage of this approach is that the modelling can be updated, verified and refined periodically so that at the time of closure application, the model results can be proved to be of high confidence. Other methods, although less costly in the short-term, are ultimately more expensive since geochemical models need future refinement and not redevelopment. An additional key motivation for making use of models is that it enables quantitative comparative assessment of a range or remediation options – something that cannot be simulated in humidity cells or other kinetic lab tests.

MRDs are generally modelled using a basic kinetic model to estimate water quality over a 100 year period. The model can be calibrated using current seepage water quality and can be updated and refined on a regular basis in future. It should be noted that while models should not be used for the estimation of absolute water quality parameters they are very useful in identifying trends and broad water quality issues. The model must incorporate the conceptual model developed through an on-site preliminary sampling programme and also incorporate a simplified water balance.

Step GC5: Assess impacts

The design team will use the geochemical model to assess impacts that the MRD will have on the water resource.

Step GC6: Identify mitigation measures

At the project design phase this step will concentrate on identifying methods which can be used to minimise/ mitigate long-term pollution problems. The general objective would be to evaluate methods to manipulate the water and/or oxygen balance of a MRD, thereby modifying the sulphide mineral oxidation reactions. Kinetic models should be used to assess the suitability of a range of management/mitigatory measures.

All geochemical assessment programs will require subsequent verification. To this end, a detailed environmental monitoring program must be developed for incorporation into the mine's monitoring program.

6.5.5 Hydrology and Storm Water (HS)

Step HS5: Undertake Storm Water modelling

Guidance on Storm Water modelling can be obtained in ***BPG G1: Storm Water Management*** and ***BPG A4: Pollution Control Dams***.

Step HS6: Design of Storm Water management systems

The hydrological requirements which must be met by the design of any MRD are set out by regulations 4, 5, 6 and 7 of Government Notice No. 704 (GN704). The important clauses are summarized in the sections below.

Diversion of external surface water

A system of storm water drains must be designed and constructed to ensure that all water that falls outside the area of the MRD is diverted clear of the deposit. Provision must be made for the maximum precipitation to be expected over a period of 24 hours with a probability of once in one hundred years. A freeboard of at least 0.5 m must be provided throughout the system above the predicted maximum water level. This requirement applies to all MRDs, both fine and coarse-grained MRDs.

Containment of Storm Water

All water that falls within the catchment area of the MRD must be retained within that area. For most MRDs the catchment can be divided into component catchments, as follows:

- The top area of the MRD together with any return water storage dams which have been connected to the top area of the MRD by means of an outfall penstock, and
- The faces of the MRD together with the catchment paddocks provided to receive run-off from the faces and any additional catchment dams associated with the faces and catchment paddocks.

Water that has been in contact with residue, and must therefore be considered polluted, must be kept within the confines of the MRD until evaporated, treated to rendered acceptable for release, or re-used in some other way.

The storage capacities for each component catchment must be sufficient to ensure a freeboard of at least 0.8m above the maximum predicted water level. It should be based on the average monthly rainfall for the area concerned less the gross mean evaporation in the area plus the maximum precipitation to be expected over a 24 hour period with a frequency of once in 50 years. The storage capacity of the top surface of a MRD should be calculated from accurately surveyed contours where possible.

Water removal from the MRD

Water can be removed by various means, including a barge, penstock or siphon. The design of a penstock system is set out in the Chamber of Mines (1996) guidelines. Penstocks should be designed to remove process water and to clear the design storm off the surface of the MRD within a suggested period of 48 to 72 hours. Other discharge periods should be adequately motivated.

Similar design principles will apply to the other water removal systems.

6.5.6 Water Balance (WB)

Step WB5: Update water balance

The results of the Storm Water modelling and design of the Storm Water management systems will be used to update the water balance.

Step WB6: Assess surface water impacts

The Storm Water modelling will be used to address the potential Storm Water impacts from the MRD. The modelling should also be used to simulate various scenarios to determine the impact of the MRD on the water resource and the need for mitigation measures.

Step WB7: Identify mitigation measures

Various mitigation measures should be identified to address the Storm Water impacts. These mitigation measures will be used to refine the MRD design (step GR8).

6.5.7 Closure and after use determination

The closure and after use of a MRD should be determined at the conceptualisation and planning phase. During the design phase the overall profile of the MRD will be established and consideration should be given to surface water and groundwater management at closure.

6.5.8 Design report

All studies should also be integrated into a consolidated design report for the MRD.

6.6 Commissioning phase

There are two components:

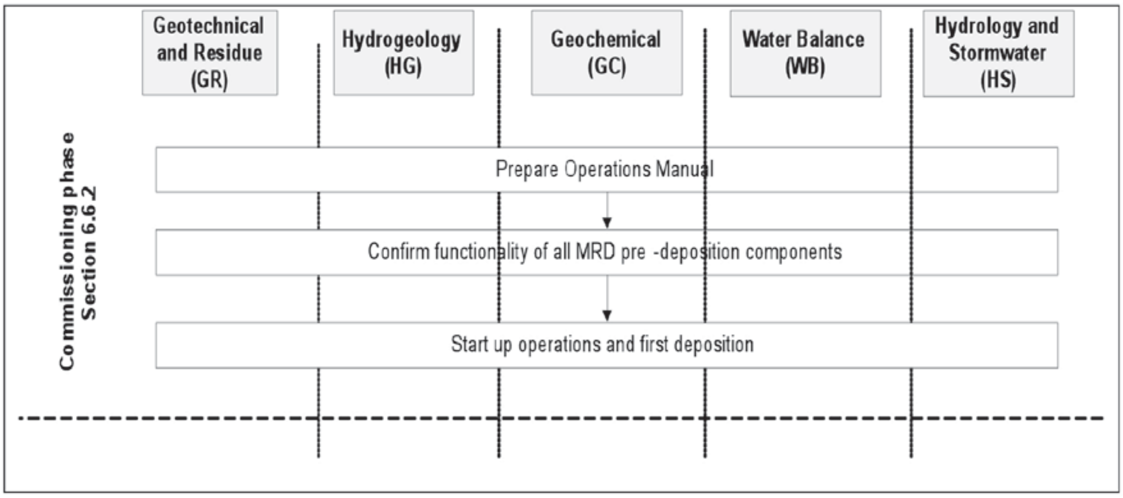
- Mechanical equipment
- First deposition and initial operation

6.6.1 Introduction

The commissioning phase for MRDs follows the construction work. It is important that this phase of the MRD life-cycle confirms the functionality of the various components of the MRD prior to operations and that the design details, standards and specifications have been adhered to.

Figure 6.7 indicates the tasks that are likely to be undertaken during the commissioning phase of MRDs.

Figure 6.7: Tasks in the commissioning phase



6.6.2 Summary of tasks to be undertaken

Prepare Operations Manual

The design and operations personnel should compile the MRD Operations Manual before completion of construction. An Operations Manual for a MRD has two primary purposes, namely:

- To provide a documented procedure for the safe and efficient storage of residue in accordance with the assumptions and principles adopted by the designer, and
- To provide a documented process that complies with all legislation and with public expectations, and can be used as a reference during any auditing of the facility.

The following water management aspects should be included in the Operations Manual:

- Legal requirements of the authorisations, eg. water use authorisation
- Confirmation of Safety Classification and Environmental Classification in terms of SABS 0286:1998
- Deposition Methodology
- Pond control and surface water management
- Seepage control measures
- Delivery pipeline management
- Water balance for commissioning phase as well as operations phase
- Groundwater and surface water monitoring requirements
- Incident reporting procedures for any uncontrolled release of residue or polluted water and seepage.

These aspects are covered in more detail in the sections under the operational phase of the MRD.

A typical Table of Contents for an Operations Manual is included in **Appendix F.**

Confirm functionality of all MRD pre-deposition components

The construction management team should undertake the following tasks during the commissioning phase:

- Ensure that all components of the pre-deposition works are functioning in accordance with the prescribed design details and specifications
- Test and sign-off that the MRD is in a functional state for ongoing operations, and
- Make safe and protect components of the pre-deposition works that might be vulnerable to damage during the normal operational phase.

Start up operation and first deposition

The starting specifications are generally prescribed in the Operations Manual. The specific aims of the commissioning phase relating to water management aspects are:

- Covering and protecting the under drains from the effects of erosion by Storm Water, wind and residue that can be discharged across or onto the drains
- Protecting the under drains from blinding by windblown fines and residue fines
- Protection of the under drains from damage by equipment used during operations and by termites, burrowing animals and vegetation
- Handling of the initial residue flow, to prevent damage to other components of the pre-deposition works.
- Ensuring that the residue reports to the correct locations and performance is as anticipated e.g. to prevent collection of fines in thick layers behind the starter wall where it is not able to consolidate
- To develop a pool of clear water as soon as possible in the correct position, and
- To examine and evaluate the residue properties and, if they are not as anticipated, to alter the operations to suit.

6.7 Operations phase

6.7.1 Introduction

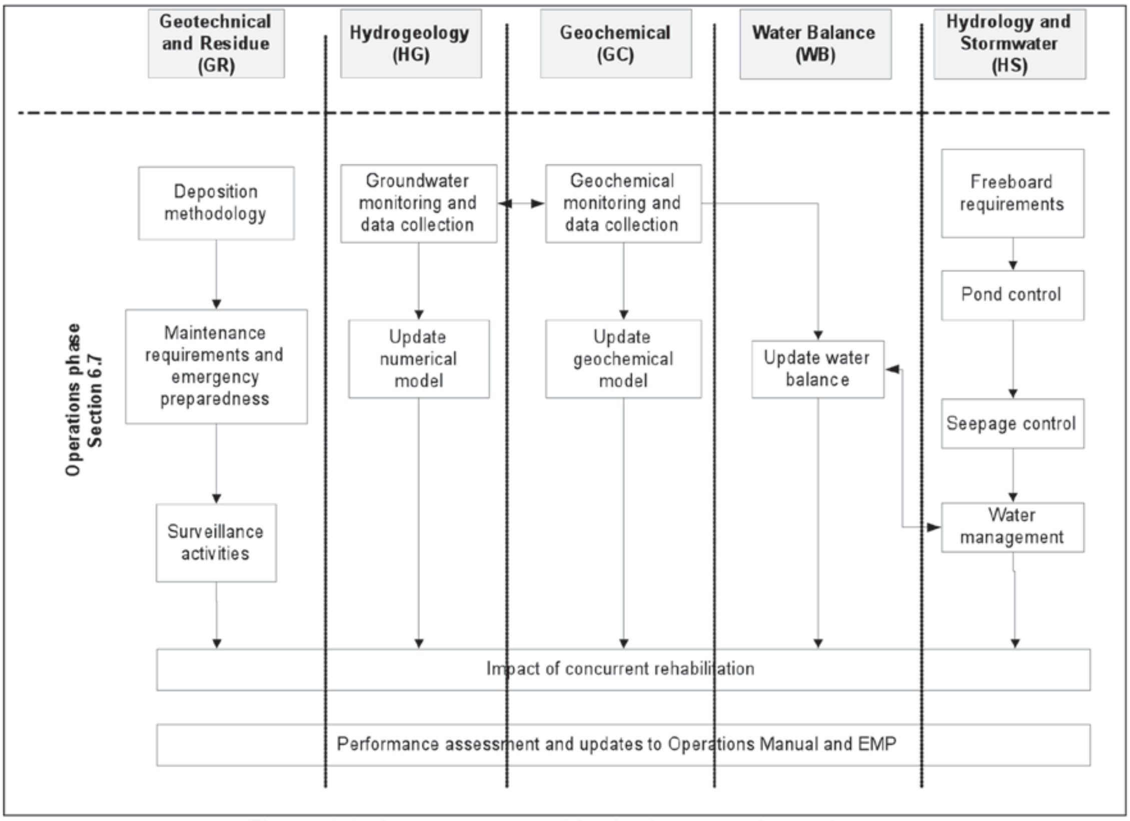
The operations phase for MRDs involves the following broad areas:

- Monitoring and management of the residue deposition methodology
- Data collection and the use of this information to update and refine the various models developed during the design phase
- Ongoing review of the maintenance requirements and the emergency preparedness.

Figure 6.8 indicates the aspects to consider during the operations phase of MRDs. These aspects are generally covered in the regular surveillance reports, the Operations Manual and the EMP for the mine.

Each of the aspects in Figure 6.8 is covered in the sections below.

Figure 6.8: Aspects to consider in the operations phase



6.7.2 Geotechnical and Residue (GR)

The aspects below should be fully detailed in the Operations Manual for the MRD (see **Appendix F**). Key pointers are thus only covered in the sections below.

Deposition methodology

The surveillance team should regularly review the actual residue deposition methodology against the guidelines and predictions set in the Operations Manual. It is also recommended that regular updates are made to the MRD airspace model, using the information on actual residue deposition, to confirm the layout and size of the MRD in the longer-term.

Maintenance requirements and emergency preparedness

The surveillance team should regularly review the maintenance requirements on the MRD. This will include the maintenance required for the safety and stability of the dam and that required for water management.

The surveillance team should also regularly check and test the emergency preparedness around the MRD, including:

- The emergency processes and procedures relating to the different emergency levels
- The roles and responsibilities.

Surveillance activities

The surveillance team should regularly inspect the MRD and provide regular reports on the safety and stability of the MRD, including aspects such as:

- The current and predicted geometry of the MRD
- The residue production and relative density delivered to the MRD
- Particle size distribution of the delivered residue
- Available freeboard
- Rainfall, evaporation and other meteorological information
- Data from the instrumentation on and around the MRD, and
- Instrumentation tests.

6.7.3 Hydrogeology (HG)

Groundwater monitoring and data collection

The Operations Manual should include a groundwater monitoring plan. This plan should include the following aspects:

- A plan showing the location and co-ordinates of the monitoring boreholes
- The expected groundwater levels in the monitoring boreholes
- The monitoring frequency (usually quarterly) and the monitoring procedure
- The groundwater sampling procedure
- The list of tests to be undertaken on the groundwater samples to monitor the groundwater quality

The surveillance team will use the groundwater monitoring plan to collect and test groundwater samples. This information will be used to prepare or update the monitoring report. Graphical representation (for example trend graphs) of key monitoring components and constituents of concern, as determined for each site, is recommended, together with comparison of the groundwater analyses with agreed Resource Quality Objectives (RQOs) or published water quality standards (such as SABS 241 2001 or DWAF water quality guidelines)

Update numerical model

The groundwater monitoring information should be used to update the numerical groundwater model developed during the design stage. The groundwater model should be used on an ongoing basis to assess the impacts of the MRD on the groundwater regime. Mitigation measures and actions plans should be designed and implemented should an impact become evident.

6.7.4 Geochemical (GC)

Geochemical monitoring and data collection

It is recommended that the surveillance team collect and store the following data and information which will be critical for the geochemical assessments that will need to be undertaken as a prelude to closure:

- Monthly samples of fresh residue analysed for particle size distribution, acid-base accounting (ABA), detailed mineralogy (XRD, XRF, water and aqua-regia extraction), pyrite morphology and surface area
- Monthly samples of seepage from the toe or underdrains, analysed for full chemistry (macro, micro and radionuclide)
- Documentation, with photographic record where appropriate, of any changes in residue characteristics, (physical, chemical and mineralogical), placement methodology, residue reclamation, etc, with dates on when the changes occurred
- Phreatic surface data for the full operational life and beyond to track the movement thereof, and
- All MRD water balance data to be collated and filed and kept for the full lifecycle of the facility.

Update geochemical model

The geochemical, hydrogeological and hydrological monitoring information should be used to update the geochemical model on an ongoing basis. This will provide regular calibration or verification of the geochemical model, for use in the management of the MRD and for closure planning.

6.7.5 Hydrology and Storm Water (HS)

Freeboard requirements

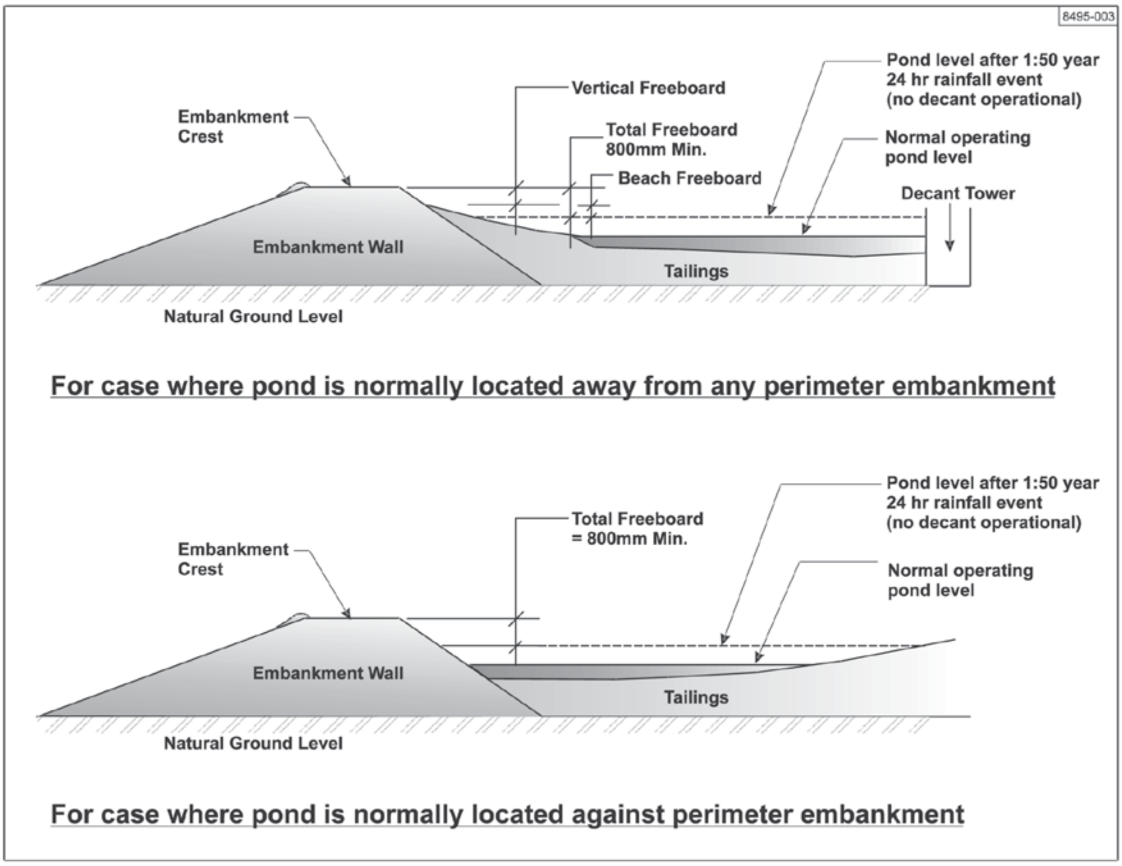
The maintenance of an adequate freeboard on a MRD is of paramount importance, particularly when the deposited residue and/or water level approaches the embankment crest level. The purpose of freeboard is to provide a safety margin over and above all the estimated inflows of liquids from extreme natural events and operational situations, so that the risk of overtopping leading to embankment erosion and ultimate failure of a MRD above ground is minimised. The freeboard should be sufficient to contain unforeseen increases in the level and movement of liquid within the storage caused by the one or more of the following:

- Residue spills or overflow from spigot malfunctioning
- Back flow and overtopping as a result of mounding of residue at discharge points
- Outlet or recovery system failures
- Uncertainties in the hydrological design estimates
- Uncertainties in the catchment and run-off design estimates
- Extreme wind effects such as wave run-up and wind setup, and
- Any other effects such as seismicity, land slips, etc. that may generate waves.

The Operations Manual should contain the definitions of freeboard applicable for the MRD and highlight the minimum freeboard required to satisfy the above mentioned conditions.

The freeboard requirements for a MRD are illustrated in Figure 6.9 below.

Figure 6.9: Illustration of freeboard requirements for MRDs



The various terminology related to freeboard are as follows:

- Total Freeboard: Total freeboard is defined as the vertical height between the lowest point of the crest of the perimeter embankment of the MRD and the normal operating pond level plus an allowance for an inflow corresponding to the 1:50 year 24-hour duration rainfall event falling in the catchment of the pond, assuming that no uncontrolled discharge takes place for the duration of the rainfall event. The total freeboard also corresponds to the sum of the "vertical freeboard" and "beach freeboard" as defined below.
- Vertical Freeboard: Vertical freeboard also referred to as operational freeboard is defined as the vertical height between the lowest elevation of the perimeter embankment and the residue beach immediately inside the embankment. The operational freeboard varies over the course of a deposition cycle as the storage is raised and fills with residue. The operational freeboard becomes critically important at the end of the deposition cycle, particularly to minimize the potential for back flow and overtopping as a result of mounding of residue at discharge points.

In some instances the vertical freeboard will be set as zero and the total freeboard equals the beach freeboard. These instances would include the following situations:

- The wall is narrow and will not withstand seepage forces or wave action
- The wall has been raised by hand or machine without compaction to support delivery pipes
- Where the outer wall is constructed of coarse residue e.g. cycloned underflow and excessive seepage will scour if it is wetted
- Beach Freeboard: Beach freeboard is defined as the vertical height between the normal operating pond level plus an allowance for an inflow corresponding to the 1:50 year 24 hour duration rainfall event falling in the catchment of the pond, assuming that no uncontrolled discharge takes place for the duration of the rainfall event, and the point on the beach where the wall freeboard is measured. The beach freeboard can vary significantly during the life of the storage and depends on the beach length, slurry characteristics, deposition methodology etc. Beach freeboard is not applicable where the pond is normally located against the perimeter embankment.

Note that the legal requirements for freeboard on an MRD are provided in GN704 (regulation 6) and shown in Figure 6.9 i.e. 0.8m plus 1:50 year 24 hour storm assuming no decanting. Note that this supercedes the requirements set out in SABS 0286 (1998) and Chamber of Mines (1996) as these references were based on R287 of the National Water Act which has been replaced by GN704.

NOTE: ***The above requirements apply to South African operations. International practice or client requirements may be different and dictate other more stringent freeboard requirements.***

It should be noted that the design team must also investigate the most unfavourable likely storm – which may not coincide with the 1:50 year storm of 24 hour duration. For example, in certain areas the 1:20 year storm of 0.5 hour duration taken in conjunction with the outflow capacity of the penstock may be more critical.

Pond control

In a MRD with a centrally located decant, operational factors can give rise to a pond which is pushed away from the decant, or elongated towards the perimeter of the storage. In the case of an elongated or displaced pond the effective beach freeboard may be decreased. This may increase the risks associated with overtopping of the perimeter wall. Pond control is thus a prerequisite requirement for all MRDs. The Operations Manual should provide details on the envisaged methods to control the pond and suggest methods to correct any adverse pond location or geometry, such as:

- Forming a steeper beach across the longer flanks of the facility by adjustment of the deposition methodology
- Controlled and managed spigotting from selected positions around the perimeter
- Construction of pond control walls around the decant position, and
- Subdividing the MRD into more geometrically symmetrical configurations.

The pond should be as small as possible to ensure maximum reuse of water in the system, to reduce evaporative losses and water make-up requirements.

The Operations Manual should describe the lateral limits that the pond is expected to vary between and specify actions that are to be taken in the event that the pond position, it's normal operating level or the beach lengths do not fall within the recommended guidelines.

Water management

Operational difficulties and faults such as decant blockages, pump breakdown, return water sump problems and poor water clarity during or after storms may necessitate large volumes of water being retained on the surface of the MRD for a period of time. This practice is not advisable as:

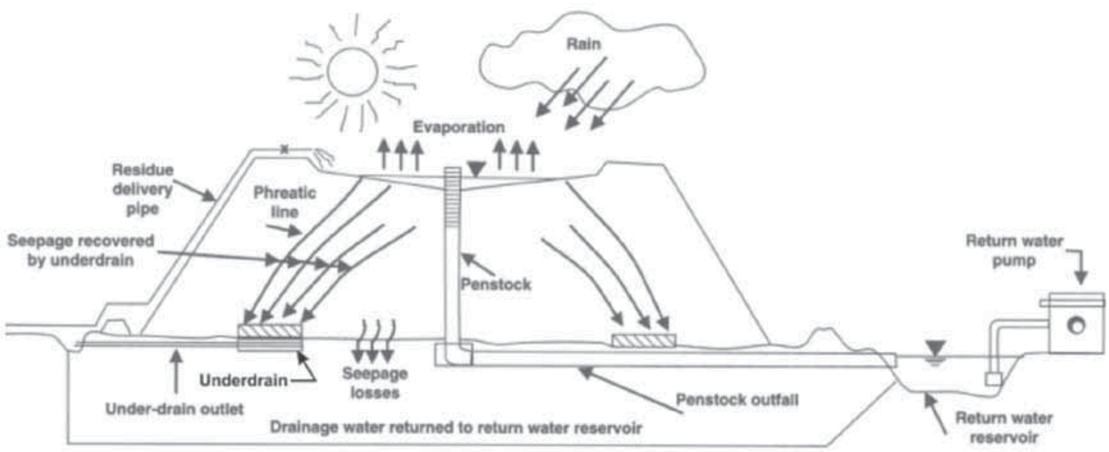
- A large pond on the upper surface of a MRD will raise the level of the phreatic surface which may have a detrimental influence on the outer slope stability
- A large pond will encourage more residue to settle subaqueously and have a negative impact on the available storage volume due to lower settled dry density. This will have a negative impact on the long term consolidation and hence ease of rehabilitation
- A larger pond will increase the amount of seepage which may not be controlled through underdrains; there may thus be an adverse effect on the surface and ground water quality. The management of seepage water may also become more difficult
- Retention of water on the MRD is not a safe practice and may mean that the plant will need to obtain water from an alternative source, which may be costly or not sustainable

The Operations Manual should therefore address the management of water to and from the facility and include a conceptual water balance that illustrates all inflows and outflows associated with a MRD facility. These are shown graphically in Figure 6.10 below.

The water balance developed during the design stage should be regularly updated during the operational phase to take account of the ongoing MRD construction.

Note that sediment collection areas upstream of the return water dam should be large enough for maximum settling and easy cleaning.

Figure 6.10: Illustrative MRD water balance



Seepage Control

Seepage flow through residue contained in a MRD is very likely. The control of seepage water during the operational and post-operational phases of a MRD is thus important to ensure the stability of the structure is not compromised and to ensure compliance with environmental standards relating to ground and surface water qualities. Seepage flow is best controlled through the installation of adequate underdrains. The Operations Manual should contain details of any underdrainage that is installed in the MRD facility, including:

- Drawings showing details of filter drains, and
- A plan showing the location and reference numbers of underdrain outfall pipes.

The Operations Manual should also contain the expected flows or rest water levels associated with the drainage systems. The Operations Manual should include a seepage monitoring plan, including the frequency of record-taking (generally monthly) and a procedure for action in the event of flows or levels falling outside the expected values is to be included. Such action may include:

- Installation of piezometers to monitor the phreatic surface (or increasing the monitoring frequency of pre-existing piezometers)
- Installation of other monitoring devices, e.g. inclinometers to monitor slope movement
- Installation of elevated drains
- Installation of external surface drains and slope buttresses
- Reduction in production or water deposited on the MRD facility.

The Operations Manual should also stipulate actions that are required in the event that the saturated zone rises above the expected level on the outer face of the perimeter wall.

6.7.6 Water Balance (WB)

Update water balance

The surveillance team should regularly update the MRD water balance. The updated water balance should include the following:

- Current information from the hydrogeological, geochemical and hydrological data collection
- Input from the updated groundwater, geochemical and Storm Water models, and
- Any amendments to the inflows to and outflows from the MRD.

6.7.7 Impacts of concurrent rehabilitation

The practice of concurrent rehabilitation of a MRD during operation is strongly advised. The impacts of concurrent rehabilitation on water management are as follows:

- Storm Water runoff from rehabilitated areas can be discharged to the natural watercourses, once it has been established that this discharge is of suitable quality for discharge. This will reduce the requirements for dirty water management around the MRD
- The water management requirements for closure, and hence the closure costs, will be reduced.

6.7.8 Performance assessment and updates to Operations Manual and EMP

The operational information collected during the above surveillance and studies should be used to periodically review the performance of the MRD and to update the Operations Manual and the EMP.

The information should also be used to regularly update the closure plan.

6.8 Decommissioning and Closure

6.8.1 Introduction

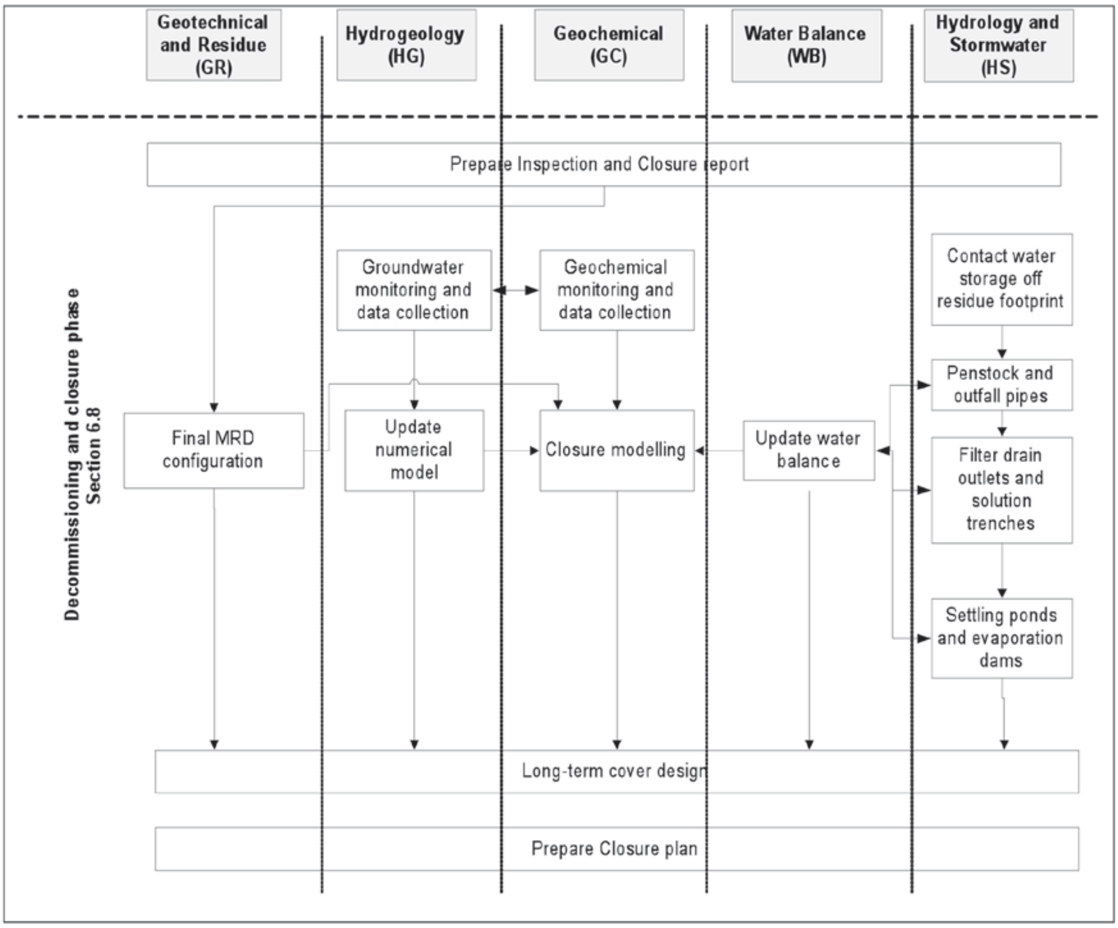
The objectives for decommissioning and closure of the MRD facility are as follows:

- Minimisation of long-term post-closure water quality impacts
- Long-term stabilisation of the MRD
- Minimising the environmental impacts of the MRD
- Creating an acceptable aesthetics closure scenario, and
- Determining the post-closure maintenance requirements.

Figure 6.11 indicates the aspects to consider during the decommissioning and closure phase MRDs. These aspects should be summarised in the updated closure plan for the MRD.

Each of the aspects in Figure 6.11 is covered in the sections below.

Figure 6.11: Aspects to consider in the decommissioning and closure phases



6.8.2 Prepare Inspection and Closure Report

Regulations 56 to 60 in the MPRDA deal with the requirements for mine closure including the principles for mine closure, closure objectives and the contents (framework) of the environmental risk assessment report and closure plan.

Prior to the closure of a MRD, an inspection is required by a professional engineer or technologist who should prepare a report on the existing state of the MRD and list all actions that are required to ensure that the MRD complies with the provisions of the Chamber of Mine's Guidelines.

The report should contain a plan as required by Government Notice 704.

The particular water related aspects to be checked during the closure inspections are as follows:

- The condition of the seepage exit points and the penstock outlets, including:
  - Water seepage along the outside surfaces of the pipes
  - Sediment in the seepage water
  - Sloughing or accentuated surface erosion at these points
- The penstock and diversion structures, including:
  - The state of repair of these structures
  - The capability of these structures performing as required by the design
- The extent of erosion on the embankment and abutment slopes and in the channels of stream

diversions, Storm Water diversions, solution trenches, starter walls, etc.

The closure report should note areas where attention is required.

6.8.3 Geotechnical and Residue (GR)

Final MRD configuration

The design team will model and confirm the final MRD configuration for closure, including overall MRD height, outer wall slopes, crest slopes and water drainage paths. These details will be used in the closure modelling and closure planning and form part of the closure plan.

6.8.4 Hydrogeology (HG)

Groundwater monitoring and data collection

The monitoring programme undertaken during the operational phase will need to be continued after decommissioning and during the closure phase. The procedures detailed in the Operations Manual should continue to be followed, although it may be possible to review the frequency of the monitoring readings and sample collection.

An estimate of the time period that monitoring will be required will be available from the numerical groundwater model that was continuously updated during the operational phase. Monitoring will, however, continue until the groundwater quality trends are within the previously agreed RQOs and that sufficient information is available to calibrate and confirm the accuracy of the groundwater model.

Where RQOs are not met, the implementation of (additional) mitigation measures, or changes in the cover design, will need to be considered.

Update numerical model

The groundwater monitoring information should be used to update the numerical groundwater model used during the operations phase. The updated groundwater model will be used in the closure modelling and closure planning.

6.8.5 Geochemical (GC)

Geochemical monitoring and data collection

The geochemical monitoring and data collection protocol developed for the operations phase should continue for the closure phase.

Closure modelling

On closure of a MRD, the primary focus will be on long term impacts and the mine will be required to demonstrate that it has understood the long-term impacts and that these have been quantified using appropriate assessment techniques operated by suitably qualified persons. With regard to long-term water impacts from MRDs, this implies that modelling will need to be undertaken to cover issues such as hydrology, water balances, geochemistry, geohydrology, etc., and that appropriate monitoring programmes will need to be developed and implemented to demonstrate to DWAFs satisfaction that the long-term impacts have been correctly understood (see ***BPG G4: Impact Prediction***). A typical sequence of actions for the rehabilitation of a MRD is as follows:

- Modelling of final dump shape to minimize movement of material and to ensure sustainability of placed cover in terms of erosion. If slopes are steeper than 18º, then a suitably qualified person may be required to undertake erosion modelling to confirm the sustainability of the selected slope cover
- Undertaking of a soil survey to identify and quantify appropriate soil reserves for use as dump cover material. Such a survey would include sampling and analysis of soils to determine parameters such as fertility and soil-water characterisation curves that are important in determining soil suitability as a cover material
- Detailed characterisation of the dump in order to enable the development of a conceptual dump model in terms of physical, hydrological and geochemical distinguishing features
- Detailed hydrological and infiltration modelling to develop detailed water balances for the dump
- Development and execution of an appropriate geochemical sampling program to obtain the necessary data to input into a geochemical modelling exercise
- Development of a kinetic geochemical prediction model that is capable of predicting long-term water pollution from the dump for its unrehabilitated state

and for various cover options. This is an iterative exercise that is coupled with a process of modelling various specified cover options in terms of their ability to modify the water and oxygen balance within the dump and with a geohydrological model that models the final impact on the receiving groundwater resource

- Specification of an appropriate cover design based on the outcome of the geochemical and geohydrological modelling and the availability of appropriate soil (obtained from the above soil survey), coupled with a cost-benefit assessment of the various options and their ability to meet closure water quality objectives
- Development of an appropriate monitoring program that will collect the data required to validate the models and to satisfy the authorities that the prediction exercise has been appropriate and that closure can be granted.

6.8.6 Hydrology and Storm Water (HS)

All MRDs should be left, at closure, in such a state where these facilities are able to withstand the effects resulting from the maximum probable precipitation appropriate to the location of the MRD, with a minimum of detrimental consequences.

In all other respects, the hydrological requirements are set out by regulations 4, 5, 6 and 7 of Government Notice No. 704 (GN704). These requirements are:

- Diversion of off-site storm water
- Provision of adequate freeboard on the surface of the facility
- Containment of water that falls within the catchment area of the MRD within the catchment, and
- Preparation of a water balance for closure.

A decision must be made as to whether to retain all water on the top of the MRD following decommissioning, or whether to transfer it to the ground level for evaporation, treatment or alternative use. This decision should be based on the outcome of a suitable geochemical assessment, as defined in ***BPG G4: Impact Prediction***, and summarized in the sections above.

Contact water storage off residue footprint

It is usually preferable to remove any storm water that accumulates on top of a MRD. At ground level it can be stored, evaporated or discharged into a stream depending on its quality. If it is decided to transfer water that has precipitated onto the top of a deposit, and store it at the base, adequate provision must be made to ensure that the existing penstocks are suitably sized and durable.

Adequate provision should be made to evaporate or treat all the water that collects. The top surface should be modified so that a balance can be maintained between evaporation and precipitation. If the water is not stored in a lined pond, then the surface of the MRD should be subdivided by paddock walls so that the water is stored in a series of shallow ponds with a high ratio of area to maximum depth. Water should not be held near the outer slopes of the MRD and should not be allowed to accumulate in deep pools that will seep.

Evaporation paddocks may be constructed from in-situ residue or other suitable soil. The interconnection between the paddocks, where required, should be by means of concrete pipes or spillways of adequate size, durability and strength which pass through the base of the paddock separation walls.

Catchment paddocks should be provided around the entire perimeter of the facility. The sizes of the existing storm water drains should be checked to ensure that they are adequate to cope with the maximum probable precipitation.

Penstock and outfall pipes

Penstocks and outfall pipes should be in a state at closure where these structures do not constitute a potential failure risk and hence unacceptable impact to persons or the environment. All penstocks and outfall pipes should be in such a condition (or be modified) so that these do not constitute a route whereby residue or uncontrolled water may discharge from the MRD.

Typical potential problems with penstocks and outfall pipes are as follows:

- Fracture of outfall pipe
- Flow of residue through open joints or cracks
- Collapse of pipe due to loss of support caused by piping
- Structural failure at change in cross section.

The potential remediation measures for penstock or outfall pipe failure include the following:

- The penstock inlet may be raised to allow water flow only from a storm of defined duration and recurrence interval. A storm of 24 hour duration and 50 year recurrence interval is recommended for the design

- The penstock may be blocked or closed. This can be done by plugging the inlet either at the top or at the junction with the outfall pipe
- If plugging of the penstock is not possible, a reverse filter and buttress may be constructed around and over the outlet.
- Any continued flow of water from a penstock or outfall pipe should be stored in settling and evaporation dams.

Filter drain outlets and solution trenches

Filter drain outlets and solution trenches should be in a state where these structures are able to function effectively on a long term basis and without deterioration. Solution trenches should be designed to discharge any seepage into suitable evaporation dams or sumps.

The following aspects should be considered when determining whether drain outlets and solution trenches are likely to function effectively on a long-term basis:

- Drainage outlet pipes should not be of a material likely to corrode, deteriorate or otherwise disintegrate with time. Provision should be made for repair or replacement as necessary
- The point of discharge from the outlet pipe to the solution trench should be protected from erosion, free of vegetation and above the invert of the solution trench to prevent blockage due to siltation build-up in the main trench.
- The solution trench should have side slopes that are flat enough to prevent possible sloughing and allow easy access for persons or animals
- The grading of the solution trench should be such as to be self cleansing and prevent erosion from storm flows
- Vegetation in the solution trench should not impede the proper functioning of the trench but can be used to assist with erosion prevention.

Settling ponds, sumps and evaporation dams

Settling ponds, sumps and evaporation dams should be constructed (or suitably modified) at closure of a MRD to:

- Provide effective control of the discharge of water from the MRD, and
- Prevent the discharge of silt or suspended solids from the MRD.

Settling ponds may be used in lieu of catchment paddocks to retain run-off and residue eroded from the sides of the MRD. This may be in areas of steep topography where eroded residue is easily transported.

The embankment of any settling pond or dam should have an adequate factor of safety against failure and the outer slopes should preferably be vegetated. Ponds and dams must be provided with a suitable combination of emergency spillways or other discharge measures to handle water from the design storm.

Guidance on the design of settling ponds and dams is provided in ***BPG A4: Pollution Control Dams***.

6.8.7 Water Balance (WB)

The water balance model used during the operational phase should be updated for the closure condition of the MRD. This will include the outputs from the updated groundwater, geochemical and Storm Water models.

6.8.8 Long-term cover design

The capping of MRDs should address a number of issues and various options and techniques are available (Lacey and Barnes, 2006). These issues, options and techniques are summarised in Table 6.2.

Table 6.2: Issues, options and techniques for long-term cover design

Issues and Consequences	Options and Techniques
Erosion and structural instability • Overtopping from floodwaters • High phreatic (water table) surfaces • Piping of materials during seepage • Sedimentation • Surface flooding and erosion of batters • Erosion of the side-slopes	• Geotechnical review/risk assessment on closure • Integrity from construction phase • High quality operational management • Rock armouring • Buttressing • Drainage control • Erosion resistant cover • Integration of cover into surrounding environment
Acid Rock Drainage • Internal and external instability • Water Impacts • Acid Soil • Toxic to biotic systems • Gas and thermal emissions • Cover deterioration and failure	• Geochemical characterisation and selective discharge • Cover and capping research studies and design to reduce water and oxygen reactions • Identification of cover material source and availability • Monitoring of cover performance and integrity • Capture store – release systems • Use as waste backfill in open pits or underground • Neutralisation (e.g. lime) and treatment (stimulation of sulphate reducing bacteria) • Segregation/isolation/encapsulation • Passive leachate management and treatment
Dust • Visual impact • Offsite pollution effects • Flora and fauna	• Surface capping to prevent wind erosion (e.g. rough cover, rock mulching • Revegetation • Wind breaks • Hydromulch • Wet cover/wetlands
Groundwater • Aquifer contamination • Limitation of beneficial use • Recharge impact • Localised mounding	• Reduce hydraulic head by water shedding • Integrate capture store-release systems • Utilise evapotranspiration • Cap and cover with capillary break • Drainage diversions • Neutralisation and detoxification of tails seepage • Wetland filtration
Aesthetics • High visual impact • Industry reputation • Negative public reaction	• Revegetated • Effective landform and cover design • Stakeholder engagement to inform development of action plans to address public concerns
Public and Fauna Safety • Injury or death	• Effective landform and cover design • Restrict access
Long term viability of rehabilitation	• Stock and feral animal control • Monitoring • Weed control as required

The most important issues from a water management perspective are erosion, acid rock drainage and groundwater impacts.

Four basic types of cover systems are generally distinguished, as follows:

- A water cover
- A conventional low hydraulic conductivity cover
- A store-release cover, and
- A capillary barrier cover.

The materials utilised to construct these basic cover system designs are generally site-specific. These cover options are discussed in more detail in the sections below.

Water cover

In a water cover the waste is submerged under water, typically by flooding the MRD impoundment or relocating the MRD/waste rock to an alternative storage basin (such as an open pit). The water cover significantly reduces the potential for air to move into the deposit, hence providing protection against future oxidation of the residue. A water cover is sometimes the preferred cover in humid environments and in particular for MRDs. There may however be problems with the physical stability of the storage facility (many MRDs were not designed to be flooded), as well as seepage, water quality and land use issues.

Water covers are generally not applicable or frequently used in South Africa, due to the dry climatological conditions prevalent in most parts of the country.

Low hydraulic conductivity cover

A conventional infiltration-limiting cover system typically consist of a low hydraulic conductivity layer (clay, geomembrane or geosynthetic clay liner GCL), in combination with a number of other layers. For a clay or GCL cover a protective soil layer is required to minimize deterioration of the low hydraulic conductivity layer due to desiccation, frost action, erosion, animal burrowing and/or plant rooting. Typically, a complex cover system of several layers and considerable depth results. If the low hydraulic conductivity layer must also serve as an oxygen barrier, then additional constraints apply, e.g. the clay layers must remain tension-saturated.

Store-release cover

The simplest form of a store-release cover is a ‘monocover’ which consists of a single layer of silty or fine sandy soil that may contain a small to negligible amount of clay. A fundamental requirement is that the soil has a low (preferably zero) linear shrinkage, since the primary problem that a monocover system seeks to overcome is that of desiccation cracking. With suitable pre-treatment, the monocover soil can also be used for the growing layer. A monocover is still expected to have a relatively low saturated hydraulic conductivity (no greater than about 10^{-6} m/s). The primary function of a monocover is not as a hydraulic barrier, but rather as a moisture storage facility during particularly wet periods of extremely high rainfall events, whereafter this moisture will be released via evaporation or evapotranspiration during subsequent dry periods.

Capillary barrier cover

A more complex form of store-release cover is a capillary barrier cover. This barrier consists of two discreet layers, the upper (storage) layer constructed of relatively fine, cohesionless soil (much the same as a monocover) overlying a coarse layer of clean soil, such as gravel. Water is retained in the upper layer by capillarity but not transferred to the lower layer because the larger voids in this layer are unable to maintain the capillary action (hence the name of capillary barrier or capillary break).

A limitation of a capillary barrier cover is the selection of appropriate soils. There must be a distinct difference in the particle size distributions of the soils used for the two discrete layers. If this is not achieved, or some ‘contamination’ of the coarser soil with the finer soil occurs, wicking may occur, whereby a continuity (rather than a break) of capillary action develops and moisture is able to flow into the coarse layer and thus into the MRD. In South Africa a potential problem is to obtain sufficient coarse rounded gravel (the ideal capillary break layer) e.g. river gravel. The use of angular gravel, such as from a crushing plant, suffers from wicking if the fines are not first washed out.

In South Africa covers have generally been vegetative or rock armouring. These covers are however unlikely to address the water quality, geochemical or groundwater related aspects. More recent covers comprising a combination of rock, soil and vegetation may meet the criteria more adequately. In recent years the store-release or sponge covers have been designed for several mine sites in arid or semi-arid climates e.g. Twin Creeks Mine, Nevada USA and Mt. Whaleback. The store-release monocover has the following advantages over low permeability and capillary break covers (Wels et. al. 2002):

- A monocover is the simplest to install, will require the least long-term maintenance and has the lowest potential for long term degradation (and potential failure)
- The effectiveness of a monocover will increase in time as the vegetative growth matures (this is however applicable to all three cover types, if vegetation is established), and
- A monocover is financially the most economical to implement.

The design of final cover will require the following steps (Wels and O'Kane, 2003):

- A conceptual cover design selected on site-specific considerations such as type of waste, size and geometry of the storage facility, climate, etc.
- A detailed cover design analysis which explores different cover design options and relates cover design parameters e.g. cover thickness to cover performance (net percolation to the underlying waste and generation of poor quality seepage)
- An impact assessment, which aims at quantifying the relationship of cover design parameters (such as cover thickness) to environmental impacts (e.g. groundwater quality)
- An evaluation of impacts against regulatory standards. This step may include a comparison of predicted impacts (e.g. metal concentration in groundwater) against numerical standards, or may involve a complex risk assessment. If the predicted impacts comply with all standards, or pose no unacceptable risk then the design can proceed. If, however, the impacts (or estimated risks) are unacceptable, then the preliminary design will require modification. A "fatal flaw" in the design is triggered if simple modifications to the cover design are not adequate and as a result a different conceptual design is required.
- Modification and finalisation of the cover design, based on the output of the risk assessment.

For a case study see Wels and O'Kane (2003).

6.8.9 Prepare Closure plan

Before the final cover and rehabilitation design can be decided upon and implemented, the mine must submit a closure plan for the MRD in compliance with the provisions of the MPRDA and its Regulations. This closure plan will be incorporated into the closure EMP and will incorporate a risk assessment report that includes the geochemical assessment discussed in the above sections, as well as a clear record of the stakeholder consultation process that was followed in arriving at the agreed closure plan. The performance objectives against which the performance of the proposed closure and rehabilitation measures are to be evaluated must be clearly defined and motivated from a water management perspective. Refer to **BPG G5: Water Management Aspects for Mine Closure.**

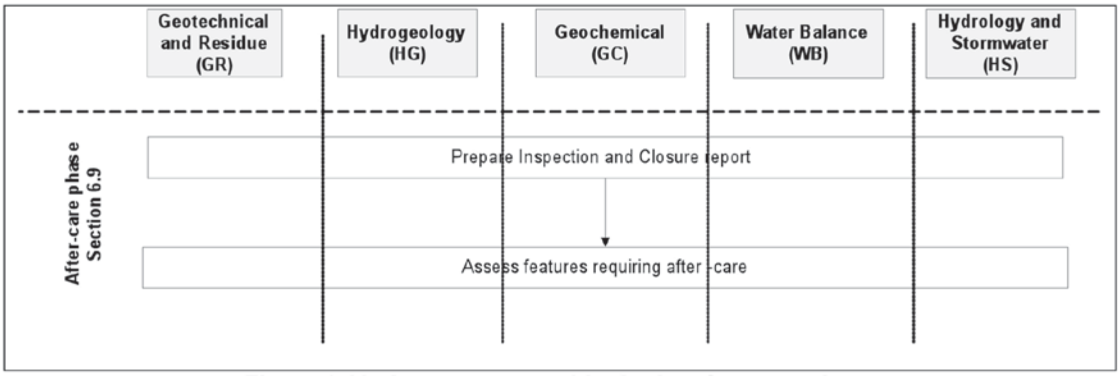
6.9 After care of decommissioned MRDs

6.9.1 Introduction

The aftercare of decommissioned MRDs should be such as to ensure that the facilities are maintained in a state where they continue to comply with the closure requirements. Once a closure certificate has been issued, the responsibility for aftercare is assumed by the State.

Figure 6.12 indicates the aspects to consider during the after-care phase MRDs. Certain aspects of a decommissioned MRD are likely to require special attention, as covered in the sections below.

Figure 6.12: Aspects to consider in the after-care phase



6.9.2 Aftercare Report

All decommissioned MRDs should have regular inspections (as defined in the closure plan) by a suitably qualified person who should report on any alteration or deterioration of conditions at the MRD to the responsible authority.

If deemed necessary, the responsible authority should arrange for an inspection of the MRD by a Professional Engineer or Professional Technologist and must act on his report. Alternatively the responsible authority should take such other action as it considers appropriate to ensure that the MRD continues to be safe and does not pose a threat to persons or the environment.

6.9.3 Features requiring aftercare

Particular points to be checked during an aftercare inspection and which may require maintenance are:

- All items covered in the closure report
- The adequate functioning of the water management and treatment (if any) structures on and around the facility
- The presence or extension of any slope failures.
- The extent to which material eroded from the slopes of the MRD has filled, blocked or silted catchment paddocks, settling ponds, catchment berms or other impoundments. Depending on the extent of erosion it may be necessary to:
  - Raise the walls or other barriers to increase storage capacity
  - Clear the accumulated eroded material from the paddocks or other barriers
  - Raise the level of penstocks or other outfall systems.
- The extent of vegetative growth in the solution trenches
- Erosion damage to paddock walls, crest walls, the sides of drainage ditches, the embankments of settling ponds, etc. should be noted and if necessary repaired.

7

VARIATIONS TO GUIDELINES FOR WATER MANAGEMENT FOR RESIDUE AND SITE SPECIFIC CONDITIONS

7.1 Introduction

Chapter 6 of the BPG sets out a robust assessment process that addresses the potential water management issues associated with a MRD over its complete life cycle. The process described in Chapter 6, while presented in the context of a fine-grained MRD, is also valid for all different types of MRDs.

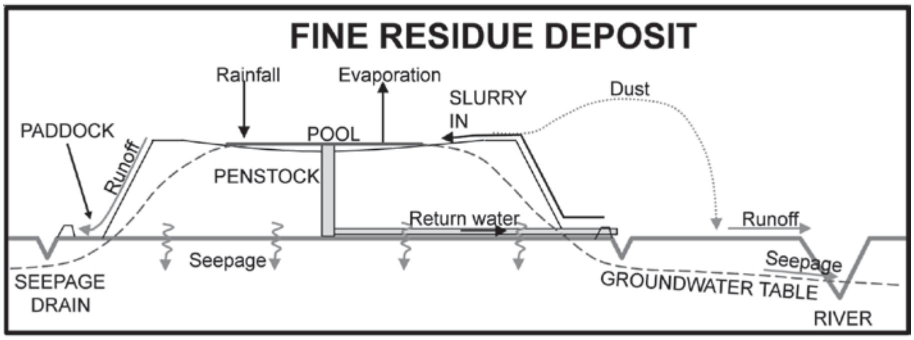
This chapter provides information on the variations from a water management perspective for different types of MRDs (coarse-grained MRDs and fine and coarse-grained co-disposal MRDs) as well as different disposal methods (in-pit and underground). The main difference is the particular impact pathways that apply.

7.2 Impact pathways

7.2.1 Fine-grained MRDs

Fine-grained MRDs are generally slurried and hydraulically conveyed to the disposal site. Potential impact pathways associated with fine residue MRDs are shown in Figure 7.1 below.

Figure 7.1: Features of a Fine-grained MRDs



Key potential issues and impact pathways that need to be considered for all fine-grained MRDs are the following:

- The geochemical nature of residues and the presence of reactive minerals or minerals and salts that can be mobilized by dissolution results in water quality deterioration as water migrates through the MRD, with potential impacts on ground and surface water
- The liberation of fugitive dust from the surface of the MRD can give rise to a secondary source of water pollution by dispersing reactive material outside of the facility footprint
- The rate of rise of a fine-grained MRD has a significant impact on dust generation – the higher the rate of rise, the wetter the facility surface and the less dust will be generated. High rates of rise however also have stability implications that need to be considered
- The consequence of the segregation of hydraulically-placed fine-grained residues must be understood. Where the fine-grained residues are placed using cyclones or spigots, the waste segregates into a coarser outer edge with higher permeability and a finer centre with reduced permeability. This has implications for the water balance and water quality that need to be considered. This feature is not associated with the paddock technique for placing fine-grained residues

- The permeability of the residues as deposited must be well understood as this characteristic has a very important impact on the water balance and the water quality. Some fine-grained residues, such as those that arise from diamond mining, have extremely low permeabilities, giving rise to a reduced seepage volume generation
- Water balance: the pool size on a fine-grained or co-disposal MRDs has a major impact on water conservation and seepage volume. A large pool size gives rise to elevated evaporative losses and should be avoided in the interest of water conservation. In particular, care should be taken to ensure that a large pool does not become the route to dispose of excess water that should rather be treated and discharged or reused. The large pool also increases the driving head for seepage from the base of the MRD into the underlying aquifer. The pool size is primarily affected by the relative density at which the fine-grained residue is placed and the option selected for water removal. Paste technology will result in optimum water conservation while a penstock system will generally allow a smaller pool than a barge system. The size of the return water dam and its ability to hold and equalize hydrologically-induced flow imbalances also plays a big role in determining pool size
- The phreatic surface is typically elevated in an operating fine-grained MRD and is in contact with the underlying aquifer. The phreatic surface rapidly drops after decommissioning, exposing the fine-grained residues to oxidizing (geochemically reactive) conditions
- The runoff from side slopes should be captured in toe paddocks to prevent sediment load to surface water systems, although runoff may be contaminated and storage in unlined paddocks can give rise to seepage pathways to underlying aquifers
- The underlying aquifers may be hydraulically connected to adjacent surface water systems and contaminated seepage may reach surface water systems through this route
- Vertical hydraulic conductivity is typically very low and fine-grained MRDs are normally anisotropic, i.e. horizontal hydraulic conductivity is many times higher than vertical hydraulic conductivity.

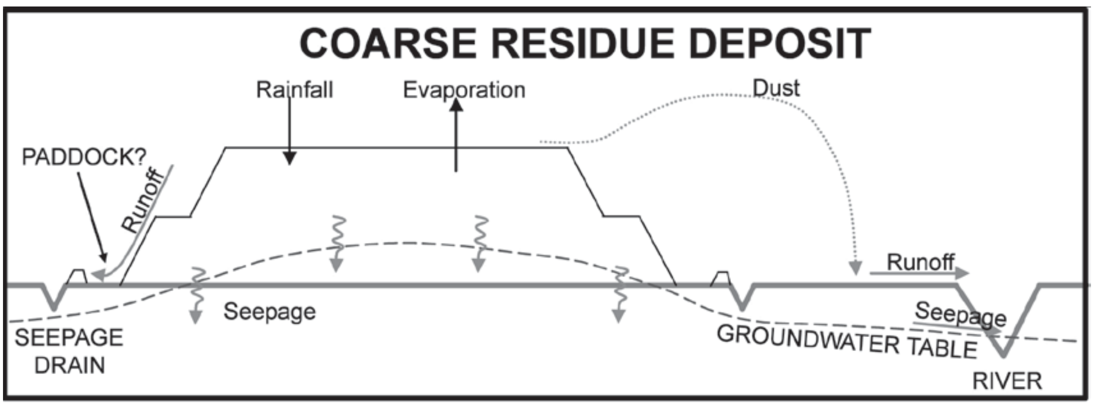
Particular considerations that may apply to different types of fine-grained MRDs are highlighted as follows:

- Gold, uranium and gypsum fine-grained MRDs may be authorised by the National Nuclear Regulator and will need to take account of particular radioactivity-related issues and pathways
- Gypsum MRDs, while not geochemically reactive, do contain contaminants that can be mobilized through dissolution
- Coal slurry is normally disposed of within earth impoundment walls (or co-disposed with coarse residue) and is often recovered and sold as a product. Coal slurry also has a potential spontaneous combustion potential above the phreatic surface that needs to be assessed
- Calcine MRDs are associated with uranium recovery operations and may have unique water quality and radioactivity issues that need to be considered.

7.2.2 Coarse-grained MRDs

Coarse-grained MRDs are normally conveyed to the disposal site by conveyor or truck. Potential impact pathways associated with coarse-grained MRDs are shown in Figure 7.2 below.

Figure 7.2: Features of a Coarse-grained MRD

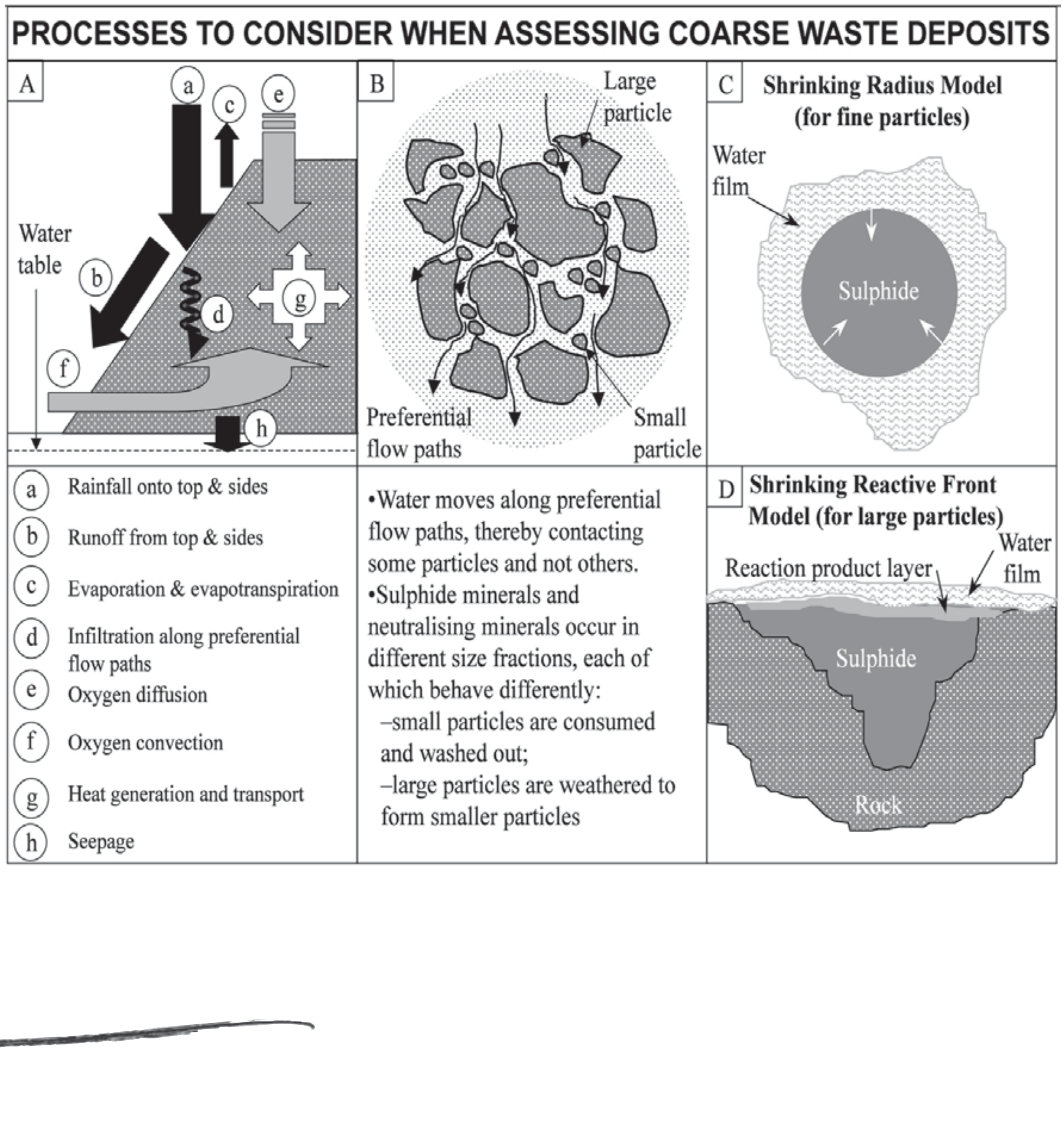


Key potential issues and impact pathways that need to be considered for all coarse-grained MRDs are the following:

- Water balance: coarse-grained MRDs are typically porous with high hydraulic conductivity and a significant portion of rainfall reports to seepage
- While coarse-grained MRDs do sometimes include toe paddocks, older facilities often do not, giving rise to direct pathways of contaminated runoff and sediment load to surface water systems
- The geochemical nature of residues and presence of reactive minerals or minerals and salts that can be mobilized by dissolution results in water quality deterioration as water migrates through the deposit, with potential impacts on ground and surface water. While coarse-grained MRDs do have lower reactive surface area per unit mass due to higher particle size, these facilities (unless they only contain washed waste) do contain a wide range of particle sizes ranging from very fine to very coarse and should be considered as geochemically very reactive facilities
- Fugitive dust from MRD surfaces can deposit geochemical reactive dust particles outside of the direct management area of the facility, giving rise to potential contaminated runoff to surface water systems
- The phreatic surface is typically depressed in a coarse-grained MRD but may still be in contact with the underlying aquifer. Due to the low phreatic surface, practically the complete coarse-grained MRD is exposed to oxidizing (geochemically reactive) conditions
- The underlying aquifer may be hydraulically connected to adjacent surface water systems and contaminated seepage may reach surface water systems through that route

The processes to consider for the geochemical modelling of coarse-grained MRDs are shown in Figure 7.3 below.

Figure 7.3: Processes to Consider when Assessing Coarse-grained MRDs



Particular considerations that may apply to different types of coarse-grained MRDs are highlighted as follows:

- Coal coarse-grained residue need to be compacted in terms of GN 704 in order to reduce its hydraulic conductivity and to reduce its spontaneous combustion potential
- Coal coarse-grained residue is typically geochemically very reactive and requires the placement of an engineered cover that is specifically designed to minimize long-term water pollution potential in accordance with appropriate detailed geochemical assessment techniques (see ***BPG G4: Impact Prediction***)
- Salinity build-up in covers due to capillary uptake of salts from underlying residues must be considered in cover design for coarse-grained MRDs
- Coarse-grained residue from diamond mines is generally dispersive and hence highly erodable. Shaping for water management is therefore critical
- The water quality impact of the coarse-grained MRD is likely to be significantly reduced in instances where the waste rock is washed to recover fine-grained residues (e.g. some gold mines)
- The use of conveyor tip sprays to control dust generation and keep conveyor ends clean has the potential to result in washout of fine-grained residues from the toe of the MRD and to enhance the seepage load from the MRD. The washout of fine-grained residues may cause stability problems and also poses secondary water quality risks by mobilizing the fine-grained residue away from the MRD towards surface water systems. Such a practice must be subject to careful impact assessment and the incorporation of appropriate water management systems to mitigate the potential impacts
- Gold, uranium and gypsum coarse-grained MRDs must be authorised by the National Nuclear Regulator and will need to take account of particular radioactive issues and pathways
- Waste rock generated by platinum and gold mining operations is often reused as aggregate and the environmental impact of this practice must be understood
- Waste rock from iron ore mining operations is typically not reactive (needs to be confirmed for each site) but special consideration is required to ensure that sediment loads from such facilities are managed
- Coarse-grained residues from base metal operations have a potential for the leaching out of metals into seepage from the MRDs
- Coarse-grained residues or waste from opencast mines may be shown, through appropriate studies and under certain conditions where very rigorous selective removal of non-reactive overburden has occurred, to have a low potential impact and can then be disposed of and managed accordingly.
- Where dragline operations are applied, selective handling of different layers is often practically impossible and a mixed waste with an inverted profile may be generated and will then need to be considered as residue with a water quality hazard potential.

7.2.3 Co-disposal MRDs

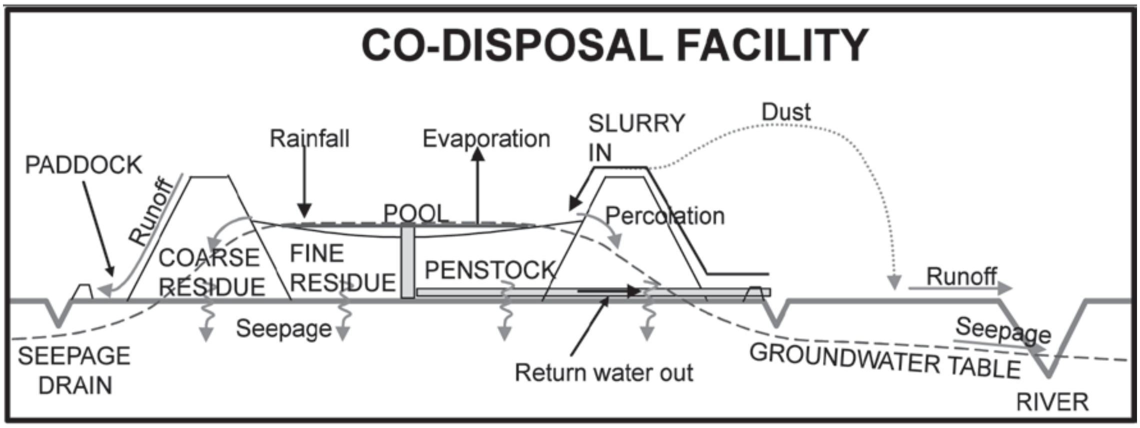
Co-disposal MRDs make provision for the co-disposal of fine and coarse-grained residues within the MRD facility. The coarse-grained residue is normally conveyed to the disposal site by conveyor or truck and the fine-grained residue is normally hydraulically conveyed. The most common type of co-disposal MRDs found in South Africa and the associated potential impact pathways are shown schematically in Figure 7.4 below.

The co-disposal method of developing a MRD does often introduce additional risks, in particular the following:

- Safety and stability, including the management of freeboard using coarse discard to build the outer wall, and
- Water quality, particularly in instances where the supernatant pool intersects the coarse-grained residue.

These risks are however generally manageable in the co-disposal process.

Figure 7.4: Features of a Co-disposal MRD



Key potential issues and impact pathways that need to be considered for all co-disposal MRDs are the following:

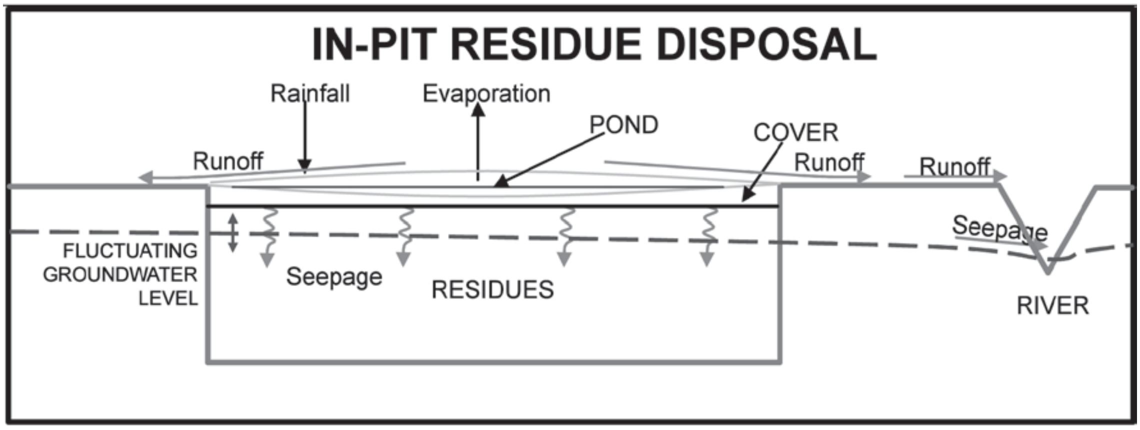
- Water balance: co-disposal MRDs feature water balance considerations that are similar to fine and coarse-grained MRDs, as covered above
- Co-disposal MRDs generally pose a high water quality risk should the supernatant pool intersect the coarse-grained residue that typically makes up the outer wall within which the fine-grained residue is deposited. When this happens, water migrates or percolates through the coarse-grained residue giving rise to extremely elevated leaching conditions and generation of high volumes of contaminated seepage. This risk must be explicitly considered in the impact assessment, the design, operation, decommissioning and closure of the co-disposal facility.
- Even for well-designed and operated co-disposal facilities that do not have a liner between the coarse and fine-grained residues, enhanced seepage volumes and poorer seepage quality can be expected due to the need to deposit the fine-grained residue up against the coarse-grained residue. The enhanced seepage conditions will continue until such time as a sufficiently thick layer of fine-grained residue has formed against the coarse-grained residue.
- Co-disposal MRDs must incorporate underdrainage systems to intercept and manage the enhanced seepage volumes
- The geochemical nature of residues and the presence of reactive minerals or minerals and salts that can be mobilized by dissolution results in water quality deterioration as water migrates through the MRD, with potential impacts on ground and surface water
- Fugitive dust from the surfaces of co-disposal MRDs can deposit geochemically reactive dust particles outside of the direct management area of the MRD, giving rise to potential contaminated runoff to surface water systems
- The phreatic surface is typically elevated under the fine-grained residue portion of a co-disposal MRD but may still be in contact with the underlying aquifer. This elevated water table also extends into the reactive and hydraulically conductive coarse-grained residues that are adjacent to the fine-grained material, giving rise to enhanced oxidizing (geochemically reactive) conditions
- The underlying aquifer(s) may be hydraulically connected to adjacent surface water systems and contaminated seepage may reach surface water systems through this route
- Shaping of the coarse-grained outer walls around the fine-grained residues must be in accordance with final rehabilitated profiles in order to minimize the risk of cutting through the fine-grained residues if final shaping only occurs during final rehabilitation.

Co-disposal is most typically applied to the management of coal mining residues and the issues previously highlighted for coal fine and coarse-grained MRDs need to be considered for such a co-disposal facility.

7.2.4 In-pit residue disposal

The disposal of coarse and/or fine-grained mine residues into mine voids or opencast pits requires an exemption in terms of GN 704 as there are particular water quality related impacts and risks that need to be considered before such a disposal practice can be approved. As in-pit (or underground) disposal of mine residues places the residues in a location where the impacts are less visible to the naked eye and where the ability to apply retrospective management actions to deal with unforeseen impacts is normally not possible, particular attention and rigour needs to be applied to the assessment process. Potential impact pathways associated with in-pit residue disposal are shown schematically in Figure 7.5 below.

Figure 7.5: Features of In-pit Residue Disposal



Key potential issues and impact pathways that need to be considered for all in-pit residue disposal operations are the following:

- Water balance: in-pit disposal systems are subjected to a number of unique water balance considerations. The water table is normally located somewhere within the residues and may, in fact, fluctuate in response to seasonal hydrological considerations. Such a fluctuating water table, if it does happen within the reactive residues, may give rise to elevated leaching of contaminants from the residues
- Enhanced seepage through the residues may occur if ponding on the surface occurs due to inappropriate shaping of the surface. This is dependent on the methodology and effectiveness of the cover and shaping of the pit. Such enhanced seepage should generally be avoided and the surface should be shaped to enhance runoff of clean water to the surface water systems and minimize infiltration and seepage to the underlying aquifer
- The placement of the reactive residues in relation to the water table must be decided on the basis of a suitably detailed geochemical assessment which considers both the reactive oxidation of minerals and the dissolution of leachable contaminants out of the residues. While the oxidation process may be retarded by placing residues below the water table, this may give rise to enhanced potential for dissolution pathways and these factors must be carefully considered.
- Groundwater actively flows through the pit, especially after closure, and could also present a pathway for contaminants to reach surface water systems in contact with the aquifer.

8

REFERENCES AND FURTHER READING

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9 GLOSSARY

Activity	Any mining related process on the mine including the operation of washing plants, mineral processing facilities, mineral refineries and extraction plants, and the operation and the use of mineral loading and off-loading zones, transport facilities and mineral storage yards, whether situated at the mine or not, in which any substance is stockpiled, stored, accumulated or transported for use in such process or out of which process any residue is derived, stored, stockpiled, accumulated, dumped, disposed of or transported.
Approved professional person (APP)	A professional engineer approved by the Minister of Water Affairs and Forestry after consultation with the Engineering Council of South Africa (ECSA), for the purposes of executing certain "tasks" relating to dams.
Clean water system	Any dam, other form of impoundment, canal, works, pipeline and any other structure or facility constructed for the retention or conveyance of unpolluted water.
Dam	Any settling dam, slurry dam, evaporation dam, catchment or barrier dam and any other form of impoundment used for the storage of unpolluted water or water containing waste.
Dam with a safety risk	A dam with a storage capacity in excess of 50 000 cubic metres and a vertical height in excess of 5 metres. The design of new dams, alterations to existing dams, quality control during construction, dam safety inspections and dam safety studies are described as "tasks" relating to dams. MRDs are currently exempt but can be classified under certain circumstances.
Dirty area	Any area at a mine or activity which causes, has caused or is likely to cause pollution of a water resource.
Dirty water system	Any dam, other form of impoundment, canal, works, pipeline, residue deposit and any other structure or facility constructed for the retention or conveyance of water containing waste.
Environmental management programme	An environmental management programme submitted in terms of section 39 of the Mineral and Petroleum Resources Development Act, 2002 (MPRDA).
Facility	In relation to an activity, includes any installation and appurtenant works for the storage, stockpiling, disposal, handling or processing of any substance.
Height of dam	In the case of a dam situated across a water course, the maximum wall height is measured from the natural level of the bed of the water course on the downstream face of the dam to the top of the dam, which is the level of the roadway or walkway. In the case of any other dam the height is measured from the lowest elevation of the outside limit of the dam to the top of the dam which is the level of the roadway or walkway. In the case of a dam consisting of a spillway across the full dam width, the height is measured to the crest level of the spillway.

Mine Manager	The meanings assigned to them in the Mine Health and Safety Act, 1996 (Act No. 29 of 1996)
Person in control of a mine, activity or holder	In relation to a particular mine or activity, includes the owner of such mine or activity, the lessee and any other lawful occupier of the mine, activity or any part thereof; a attributer for the working of the mine, activity or any part thereof; the holder of a mining authorisation or prospecting permit and if such authorisation or permit does not exist, the last person who worked the mine or his or her successors-in-title or the owner of such mine or activity; and if such person is not resident in or not a citizen of the Republic of South Africa, an agent or representative other than the manager of such a mine or activity must be appointed to be responsible on behalf of the person in control of such a mine or activity.
Residue	Includes any debris, discard, tailings, slimes, screenings, slurry, waste rock, foundry sand, beneficiation plant waste, ash and any other waste product derived from or incidental to the operation of a mine or activity and which is stockpiled, stored or accumulated for potential re-use or recycling or which is disposed of.
Residue deposit	Includes any dump, tailings dam, slimes dam, ash dump, waste rock dump, in-pit deposit and any other heap, pile or accumulation of residue.
Solids content	The volumetric concentration (Cv) is defined as the ratio of the volume of solids to the total volume of the mixture or slurry. The mass concentration (Cw or Cm) is defined as the ratio of the mass of dry solids to the total mass of the mixture or slurry
Stockpile	Includes any heap, pile, slurry pond and accumulation of any substance where such substance is stored as a product or stored for use at any mine or activity
Suitably qualified person	A person with suitable professional expertise for the task who can be accountable for the output of the task.
Water system	Any dam, any other form of impoundment, canal, works, pipeline and any other structure or facility constructed for the retention or conveyance of water.

10 LIST OF ACRONYMS AND ABBREVIATIONS

ABA	Acid Base Accounting
APP	Approved Professional Person
BPEO	Best Practical Environmental Option
BPG	Best Practice Guideline
CMA	Catchment Management Agency
DEAT	Department: Environmental Affairs and Tourism
DME	Department: Minerals and Energy
DWAF	Department: Water Affairs and Forestry
ECA	Environment Conservation Act, 1989 (Act 73 of 1989)
EIA	Environmental Impact Assessment
ELU	Existing Laful Water Use
EMP	Environmental Management Plan/Programme
FRD	Fine Residue Deposit
GA	General Authorisation in Terms of Section 39 of the National Water Act, 1998 (Act 36 of 1998)
GCL	Geosynthetic Clay Liner
GN704	Government Notice No. 704, National Water Act, 1998 (Act No. 36 of 1998)
HDPE	High Density Polyethylene
ICP	Inductively Coupled Plasma
LLDPE	Liner Low Density Polyethylene
MHSA	Mine Health and Safety Act, 1996 (Act 29 of 1996)
MPRDA	Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002)
MRD	Mine Residue Deposit
NEMA	National Environmental Management Act, 1998 (Act No.107 of 1998)
NNR	Natural Nuclear Regulator
NWA	National Water Act, 1998 (Act No. 36 of 1998)
RQOs	Resource Quality Objectives
SABS	South African Bureau of Standards
SABS 0286: 1998	SABS 0286: 1998. Code of Practice for Mine Residue
TSF	Tailings storage facility
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence Spectrometry

APPENDIX A
LEGAL FRAMEWORK

A1 Introduction

The legal review provides an outline of the requirements for water management within the prevailing mining, water and environmental legislation in South Africa. The focus of the legal review is on the water management requirements of the National Water Act, 1998 (Act 36 of 1998) and the Mineral and Petroleum Resources Development Act, 2002 (Act 28 of 2002). The provisions included in other legislation are also considered.

Note that the regulatory environment is continuously being amended within South Africa. The legal framework and review covered in this BPG thus covers the current legislative status.

A.2 WATER NATIONAL ACT, 1988 (ACT 36 OF 1998)

A.2.1 Water use

The disposing of waste in a manner which may detrimentally impact on a water resource is defined as a water use in section 21(g) of the National Water Act, 1998 (Act 36 of 1998) (NWA). Waste includes *any solid material or material that is suspended, dissolved or transported in water (including sediment) and which is spilled or deposited on land or into a water resource in such volume, composition or manner as to cause, or to be reasonably likely to cause, the water resource to be polluted*.

In terms of section 4 of the NWA, water may only be used if it is a Schedule 1 use, a continuance of an existing lawful use (ELU), or authorised in terms of a general authorisation (GA) or licence. A water use may therefore not be implemented unless it is properly authorised through one of these types of authorisations. The circumstances that will determine the type of authorisation to be issued for a specific water use that is not a Schedule 1 use, and the different possibilities for regulating particular water uses are briefly discussed below.

General Authorisations (GAs: Section 39*) - the aim of GAs is to set a cut-off point below which strict regulatory control is not necessary. If a water use is not described under Schedule 1, but authorised under a GA as published in the* Government Gazette*, such water use does not require a licence, unless the GA is repealed or lapses, in which case licensing will be necessary. Government Notice No. 399 (GN399) of 26 March 2004 provides for GAs with respect to water use in terms of section 21(g) and provides that a person may dispose of mine residue into mine residue deposits, provided that:*

- the mine is not a Category A mine, where a Category A mine means any gold or coal mine, any mine with an extractive metallurgical process, including heap leaching, or any mine where the mineral deposit contains sulphide or where acid-forming minerals occur in the mineral deposit;
- the disposal is in accordance with the requirements of GN704;
- the disposal is in accordance with SABS Code 0286; and
- the residue deposit is not located in any subterranean government water control areas, as set out in Table 4.1 of GN399.

A.2.2 Existing Lawful Water Uses (Sections 32 to 35)

Section 32 identifies water uses that were authorised under legislation, which was in force immediately before the date of commencement of the NWA (such as the 1956 Water Act), as ELUs. This is subject to the requirement that such water use took place at any time during the two years prior to the date of commencement of the NWA. Should a person have had such authorisation to use water but have not exercised this authorisation in the two years prior to this date, that person may apply to have the water use declared as an ELU in terms of section 33 of the Act. The section on ELU is designed to enable existing economic activities based on the use of water to continue until such time as compulsory licensing is called for in a particular catchment management area.

A.2.3 Licences (Sections 40 to 52)

A person who wishes to use, or who uses water in a manner that is not a Schedule 1 use, not covered under a GA, or in a manner that is not regarded or declared as an ELU, may only use that water under the authority of a license (section 4). The NWA makes provision for two types of applications for water use Licences, namely individual applications and compulsory applications. The provisions applicable to an individual application for a water use license are described in sections 40 to 42 of the NWA. These sections also provide that a responsible authority may require an assessment by the applicant of the likely effect of the proposed water use on the resource quality, and that such assessment be subject to the Environmental Impact Assessment (EIA) regulations promulgated under section 26 of the Environment Conservation Act, 1989 (Act 73 of 1989) (ECA). In terms of sections 43 to 48 of the NWA, compulsory applications for Licences will be required under certain circumstances (e.g. in catchment management areas which are under water stress) from all water users using a particular water resource or in a specific geographical area, irrespective of whether or not their water use has been authorised by a GA or an ELU. Compulsory applications for the authorisation of these water uses are subject to the development of a Water Allocation Plan, which needs to be prepared by the responsible authority.

In the event that the purpose of the NWA will be met by the granting of a license, permit or other authorisation under any other law, the licensing authority may either dispense with the requirement for a license in terms of section 22(3), or may combine the various license requirements of other organs of state into a single license (section 22(4)). These provisions are of particular importance with regard to certain multiple water uses (section 22(4)), such as a concern which has both a section 21(f) and 21(g) water use, or the disposal of certain types of waste on land (section 22(3)), since the provisions for permitting a waste disposal facility in terms of section 20 of the ECA are still in force.

Section 27 of the NWA specifies some factors that must be taken into consideration when considering a water use authorization, including:

- existing lawful water uses;
- the need to redress the results of past racial and gender discrimination;
- the efficient and beneficial use of water in the public interest;
- the socio-economic impact of the water use or uses if authorised of the failure to authorise the water use or uses;
- any catchment management strategy applicable to the relevant water resource;
- the likely effect of the water use to be authorised on the water resource and on other water users;
- the class and the resource quality objectives of the water resource;
- investments already made and to be made by the water user in respect of the water use in question;
- the strategic importance of the water use to be authorised;
- the quality of water in the water resource which may be required for the Reserve and for meeting alignment with the catchment management strategy;
- international obligations; and
- the probable duration of any undertaking for which a water use is to be authorized.

These decision-making considerations are important when contemplating the prioritisation of a particular application, and when establishing preferences when evaluating competing applications for specific water uses.

Section 148(1)(f) of the NWA makes provision for an appeal to the Water Tribunal against a decision on a license application under section 41 by the applicant or any other person who has lodged a written objection against the application. If applicable, appeals against decisions on license applications may also be taken to the High Court.

A.2.4 Water use regulations

Government Notice No. 704 (GN704), regulations on use of water for mining and related activities aimed at the protection of water resources, was promulgated in terms of section 26 of the NWA on 4 June 1999. The following regulations have direct relation to residue deposits:

- Regulation 2 deals with information and notification and stipulates that the DWAF be notified:
  - not less than 14 days before the commencement of a new mine or activity (including mine residue deposits);
  - in writing 14 days before the temporary or permanent cessation, or resumption, of a mining or related activity; and
  - by the fastest possible means of any emergency or potential emergency incident involving a water resource.
- Regulation 3 deals with exemption from requirements of regulations:
  - The Minister may in writing authorise an exemption from the requirements of regulations 4, 5, 6, 7, 8, 10 or 11 on his or her own initiative or on application, subject to such conditions as the Minister may determine.
- Regulation 4 deals with restrictions on locality and stipulates that:
  - Residue deposits, dams and reservoirs with associated structures (excluding monitoring boreholes) may not be located within the 1:100 year flood-line or within a horizontal distance of 100m from a watercourse/ estuary, borehole or well or waterlogged ground;
  - Residue or other substances, which may cause pollution, may not be disposed within workings of any underground or opencast mine excavation, prospecting diggings, pits or any other excavation;
- Regulation 5 restricts the use of residue or substance, which may cause pollution of a water resource, for the construction of any dam, roads, railways or other purpose;
- Regulation 6 deals with the separation of clean and dirty water systems and stipulates that every person in control of a mine shall comply with the following requirements relating to the separation of clean and dirty water systems, which includes:
  - confinement of unpolluted water to a clean water system;
  - collect water arising from any dirty area, including water seeping from mining operations, outcrops or any other activity into a dirty water system;
  - design, construct, maintain and operate any dirty water system at the mine or activity so that it is not likely to spill into any clean water system more than once in 50 years, and *visa versa*;
  - any dam or residue dam that forms part of the dirty water system shall have a minimum freeboard of 0.8m above full supply level; and
  - all water conveyance systems must be designed, constructed and maintained to service all flows, including the maximum flood of once in 50 years.
  - *Note: The capacity requirements of these systems are all based on the design, construction and maintenance thereof.*
- Regulation 7 deals with the protection of water resources and places an obligation on the person in control of a mine to take reasonable measures to protect any water resources. The reasonable measures must be able to protect such resources in the following manner:
  - Prevent water containing waste or any substances which causes or is likely to cause pollution from entering water resources, either by natural flow or seepage and must retain and collect such substance or water containing waste for use, re-use, evaporation or for purification or disposal in terms of the alteration of flow characteristics;
  - All water systems, including residue deposits must be capable of preventing pollution of any water resource and restrict the possibility of damage to the riparian or in-stream habitat through erosion or sedimentation, or disturbance of vegetation or the alteration of flow characteristics;
  - Any dam, residue deposit or stockpile for residue, slimes, ash, etc., must be designed, constructed and maintained such that the waste or water contained therein will not result in the failure thereof or impair the stability thereof;
  - Prevent the erosion or leaking of materials from residue deposit or stockpile, which could pollute any water resource (barrier dams or evaporation dams, etc.);
  - Recycle water as far as practicable and prevent the spillage, seepage or release of water containing waste; and

  - Any water system must be kept free of obstructions to ensure continued efficiency thereof.
- Regulation 8 deals with security and additional measures and places an obligation on a person in control of a mine to take certain security and additional measures, which include:
  - Fencing off of impoundments or dams containing poisonous, toxic or injurious substances and the erection of warning notice boards to warn person of hazardous contents;
  - Ensure access control in stockpile areas or disposal areas for residue/substances which has or may cause pollution of a water resource so as to protect the measures taken; and
  - Protection of existing pollution control measures or replacement of damaged or destroyed measures and establishment of additional measures.
- Regulation 9 deals with the temporary or permanent cessation of a mine or activity, and stipulates that:
  - All pollution control measures must be designed, modified, constructed and maintained so as to comply with the requirements of GN704 at the time of cessation of operations;
  - The in-stream and riparian habitat of any water resource, which may have been affected by the mine or activity, is remedied so as to comply with the requirements of GN704;
- Regulation 11 requires that all coal residue deposits are compacted and rehabilitated concurrent with the mining operations;
- Regulation 12 allows the DWAF to request any additional information or direct a person in control of a mining or related activity to conduct a detailed study, should this information not be available in any other reports or documents and be necessary to evaluate and manage certain aspects related to the specific mine or activity;
- Regulation 13 states that the person in control of a mine or activity must provide the manager with the means and afford him or her every facility required to enable the manager to comply with the provisions of GN704, and includes making available the necessary financial and human resources, training and education, management structures, contact with expertise for necessary investigations, etc.

A.2.5 Dam safety requirements

Chapter 12 of the NWA contains measures aimed at improving the safety of new and existing dams with a safety risk so as to reduce the potential for harm to the public, damage to property or to resource quality. A dam with a safety risk means any dam which can contain more than 50 000 m^3 of water (irrespective whether such water contains substances or not) and which has a wall of a vertical height of more than 5 metres, or which has been declared as a dam with a safety risk under section 118(3)(a). Dam Safety Regulations published in Government Notice R.1560 of 25 July 1986, which are still in force under the NWA, require that dams with a safety risk must be classified into categories, and that licenses must be issued before any task relating to a specific category of dam may commence. These regulations also prescribe the conditions, requirements and procedures to classify, register, obtain a license to construct a new dam, impound a dam, or alter an existing dam. It further stipulates the requirements and responsibilities in respect of dam safety inspections, emergency procedures, recording and reporting.

A.2.6 Other important requirements in the NWA

Section 19 of the NWA further stipulates the general duty of care on persons who own, control, use or occupy land on which any activity or process is or was performed or undertaken, or any other situation exists which causes, has caused or is likely to cause pollution of a water resource, to take all reasonable measures to prevent any such pollution from occurring, continuing or recurring.

Section 20 deals with the reporting, containment and remedying of any incident or accident in which a substance pollutes or has potential to pollute a water resource or have a detrimental effect on a water resource. It further states that the CMA may take the necessary measures, if the remedial measures fail or inadequately comply, at the expense of the responsible person(s). Section 30 of the National Environmental Management Act, 1998 (Act 107 of 1998) (NEMA) stipulates similar requirements.

Sections 56-60 deals with water use charges and allows the Minister to establish a pricing strategy with charges for any water use to fund the direct and related costs of water resource management, development and use, and for achieving equitable and efficient allocation of water. These charges may be used to ensure compliance with prescribed standards and water management practices according to the *user pays* and *polluter pays* principles.

Provision is made for incentives for effective and efficient water use and could therefore be used as a means of encouraging reduction in waste and water wastage.

The Department of Mineral and Energy Affairs (DME) administrates the Mineral and Petroleum Resources Development Act, 2002 (MPRDA), but due to the major impact that mining can have on the environment, especially the water environment, DME is obliged to consult with DWAF with regard to certain decisions made in terms of this Act.

A.3 Mineral and Petroleum Resources Development Act, 2002 (Act 28 of 2002)

A.3.1 Mining Authorisation

Section 5(4)(a) of the MPRDA stipulates that no person may prospect for or remove, mine, conduct technical or reconnaissance operations, explore for and produce any mineral or petroleum or commence with any work incidental thereto (including the construction of any residue deposits) on any area without *inter alia* an approved environmental management programme or approved environmental management plan, as the case may be. This requirement is further supported in the MPRDA.

A.3.2 Prospecting rights

If the application for a prospecting right is accepted by the Regional Manager, the Regional Manager must within 14 days from the date of acceptance notify the applicant in writing to *inter alia* submit an environmental management plan (section 16(4)(a)). The granting of a prospecting right only becomes effective on the date on which the environmental management plan is approved in terms of section 39 of the MPRDA (section 17(5)). The application for renewal of a prospecting right must *inter alia* be accompanied by a report reflecting the extent of compliance with the requirements of the environmental management plan, the rehabilitation completed and the estimated cost thereof (section 18(2)(c)) and the Minister must grant the renewal of a prospecting right if the application complies with sections 18(1) and 18(2) and the holder of the prospecting right has *inter alia* complied with the requirements of the approved environmental management plan (section 18(3)(c)). The holder of a prospecting right must comply with the requirements of the approved environmental management plan in terms of section 19(2)(c). In the case of a retention permit, the environmental management plan approved in respect of the prospecting right remains in force as if the prospecting right had not lapsed in terms of section 32(2) (section 32(3)) and the holder of the retention permit must give effect to the approved environmental management plan (section 35(2)(a)).

A.3.3 Mining rights

If the application for a mining right is accepted, the Regional Manager must within 14 days from the date of acceptance notify the applicant in writing to *inter alia* conduct an environmental impact assessment and submit an environmental management programme for approval in terms of section 39 (section 22(4)). A mining right granted in terms of section 23(1) comes into effect on the date on which the environmental management programme is approved in terms of section 39(4) (section 23(5)). An application for renewal of a mining right must *inter alia* be accompanied by a report reflecting the extent of compliance with the requirements of the approved environmental management programme, the rehabilitation to be completed and the estimated cost thereof (section 24(2)(b)) and the Minister must grant the renewal of a mining right if the application complies with sections 24(1) and 24(2) and the holder of the mining right has *inter alia* complied with the requirements of the approved environmental management programme (section 24(3)(c)). The holder of a mining right must comply with the requirements of the approved environmental management programme in terms of section 25(2)(e).

A.3.4 Mining Permits

If the Regional Manager accepts the application for a mining permit, the Regional Manager must, within 14 days from the date of acceptance, notify the applicant in writing to *inter alia* submit an environmental management plan (section 27(5)(a)). The Minister must issue a mining permit if *inter alia* the applicant has submitted the environmental management plan (section 27(6)(b)).

A.3.5 Environmental management

Section 37 requires that the principles set out in section 2 of NEMA must apply to all prospecting and mining operations, and that the generally accepted principles of sustainable development must be applied by integrating social, economic and environmental factors during the planning and implementation phases of mining projects.

Section 38(1) requires that the holder of a reconnaissance permission, prospecting right, mining right, mining permit or retention permit:

- Must at all times give effect to the general objectives of integrated environmental management laid down in Chapter 5 of NEMA;
- Must consider, investigate, assess and communicate the impact of his or her prospecting or mining on the environment as contemplated in section 24(7) of NEMA;
- Must manage all environmental impacts in accordance with his or her environmental management plan or approved environmental management programme, as the case may be; and as an integral part of the reconnaissance, prospecting or mining operation, unless the Minister directs otherwise;
- Must as far as it is reasonably practicable, rehabilitate the environment affected by the prospecting or mining operations to its natural or predetermined state or to a land use which conforms to the generally accepted principle of sustainable development; and
- Is responsible for any environmental damage, pollution or ecological degradation as a result of his or her reconnaissance prospecting or mining operations and which may occur inside and outside the boundaries of the area to which such right, permit or permission relates.

Section 39 of the MPRDA deals with the requirements of an environmental management programme or plan, whichever is applicable. Section 40 allows for the consultation with other State departments that administers any law relating to matters affecting the environment.

Section 41 deals with the financial provision for remediation of environmental damage, and the requirement to maintain and retain the financial provision in force until the Minister issues a certificate in terms of section 43, which states that the holder of a prospecting right, mining right, retention permit or mining permit remains responsible for any environmental liability, pollution or ecological degradation, and the management thereof, until the Minister has issued a closure certificate to the holder concerned. In terms of section 43(5) no closure certificate may be issued unless the Chief Inspector (MHSA) and the DWAF (NWA) have confirmed in writing that the provisions pertaining to health, safety and management of potential pollution to water resources have been addressed.

Section 42 deals specifically with the management of residue stockpiles and residue deposits, and stipulates that these must be managed in the prescribed manner on any site demarcated for that purpose in the environmental management programme or plan in question only. Regulation 73 provides comprehensive supporting information for this section of the act.

In line with section 20 of the NWA and section 30 of NEMA, section 45 of the MPRDA allows the Minister to direct the implementation of urgent remedial measures in the case of ecological degradation, pollution or environmental damage which may be harmful to the health or well-being of anyone. If the holder of the relevant right, permit or permission fails to comply with this directive, the Minister may take the necessary steps to implement the required remedial measures and recover the cost for implementation from the holder concerned.

A.3.6 Mineral and Petroleum Resources Development regulations

Government Notice No. R.527 (R527), dealing with the mineral and petroleum resources development regulations was published in the Government Gazette of 23 April 2004 (GG No. 26275, Volume 466). In particular, Part III of R527 deals with environmental regulations for mineral development, petroleum exploration and production.

In terms of regulation 48, an environmental impact assessment contemplated in section 39(1) of the MPRDA is a process which results in the compilation of a:

- Scoping report, the contents of which is described in regulation 49; and
- An environmental impact assessment report, the contents of which are described in regulation 50.
- The contents (framework) of an environmental management programme or plan, whichever is applicable, is described in regulations 51 and 52, respectively, while the requirements for monitoring and performance assessments of these programmes/ plans are described in detail in regulation 55. The methods and quantum of financial provision for the rehabilitation, management and remediation of negative environmental impacts (including those associated with mine residue deposits) are given in regulations 53 and 54.

Regulations 56 to 2 deal with the requirements for mine closure, including the principles for mine closure, closure objectives and the contents (framework) of the environmental risk assessment report and closure plan.

Part IV of R527 deals with pollution control and waste management regulation and stipulates a number of requirements specific to the management of mine residue stockpiles and deposits (regulation 73). Regulation 73(1) stipulates that the assessment of impacts relating to the management of residue stockpiles/deposits must form part of the environmental impact assessment report (regulation 50) and environmental management programme or plan, as the case may be. Other requirements with respect to the design, operation and maintenance, and decommissioning and closure of a mine residue deposit include:

- Characterisation of mine residue, by a competent person, to identify any significant health or safety hazard and environmental impact that may be associated with the residue when stockpiled or deposited at the site(s) under consideration (regulation 73(2));
- Classification of residue stockpiles/deposits, by a competent person, in terms of the safety and environmental hazard/impact thereof. The classification will determine the level of investigation and assessment required, the requirements for design, construction, operation, decommissioning, closure and post-closure maintenance, and the qualifications and expertise required of person undertaking the necessary investigations and/or assessment (regulation 73(3));
- Selection and investigation of a site, following the prescribed process, with specific requirements for geotechnical and groundwater investigations (regulation 73(4));
- Incorporations of prescribed considerations during the design of residue stockpile/deposits (regulation 73(5));
- Implementation of a monitoring system for residue stockpiles/deposits with respect to potentially significant impacts (regulation 73(7)); and
- Management requirements for residue deposits during the decommissioning, closure and post-closure phases (regulation 73(8)).

A holder of any right or permit must further ensure that (regulation 73(6)):

- The residue deposits, including surrounding catchment paddocks, are constructed and operated in terms of the approved environmental management programme/plan;
- The residue deposit is constructed strictly in accordance with the design, and if not, that the necessary approvals are obtained and the environmental management programme/plan amended accordingly;
- All residue transported to and the surplus water removed from the site are recorded as part of the monitoring system;
- Appropriate security measures are in place to limit unauthorised access to the site;
- Specific action is taken in respect of any sign of pollution;
- Adequate measure are implemented to control dust pollution and erosion of the slopes; and
- Details of the rehabilitation of the residue deposit are provided in the environmental management programme/plan.

Other requirements which could apply to MRDs are stipulated, namely:

- Regulation 64: Air quality management and control;
- Regulation 65: Fire prevention;
- Regulation 66: Noise management and control;
- Regulation 68: Water management and pollution control;
- Regulation 69: Disposal of waste material, including mining waste; and
- Regulation 70: Soil pollution and erosion control.

A.4 Provisions of other Legislation

Certain other legislation of general application are relevant to mine residue deposits. These are included in the sections below.

A.4.1 Constitution of the Republic of South Africa Act, 1996 (Act 108 of 1996)

Section 24 of the Constitution provides that *everyone has the right … to an environment that is not harmful to their health or well-being; and … to have the environment protected for the benefit of present and future generations through reasonable legislative and other measures that - (i) prevent pollution and ecological degradation; (ii) promote conservation; and (iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development*. Section 33 of the Constitution entitles everyone to administrative action that is lawful, reasonable and procedurally fair and, if one's rights have been adversely affected by administrative action, to be given written reasons for the decision. Section 38 provides locus standi or the right to get involved to any member of public. This means that a member of public has the right to take appropriate action to prevent environmental damage. This may include taking action against the responsible authority for failing to perform its duties in preventing environmental damage or against an individual or authority who are in the process of undertaking a water use identified in the NWA without the necessary authorisation to undertake such water use.

A.4.2 National Environmental Management Act, 1998 (Act 107 of 1998)

The National Environmental Management Act, 1998 (NEMA) contains certain principles in section 2. These principles apply throughout the country to the actions of all organs of state (as defined in the Constitution) that may significantly affect the environment and:

- Shall apply alongside all other appropriate and relevant considerations, including the State's responsibility to respect, protect, promote and fulfil the social and economic rights in Chapter 2 of the Constitution and in particular the basic needs of categories of persons disadvantaged by unfair discrimination;
- Serve as the general framework within which environmental management and implementation plans (referred to in section 11 of NEMA) must be formulated;
- Serve as guidelines by reference to which any organ of state must exercise any function when taking any decision in terms of NEMA or any statutory provision concerning the protection of the environment;
- Serve as principles by reference to which a conciliator appointed under NEMA must make recommendations; and
- Guide the interpretation, administration and implementation of NEMA, and any other law concerned with the protection or management of the environment.

NEMA reiterates the provisions of section 24 of the Constitution, and contains the internationally accepted principles of sustainability. It therefore becomes a legal requirement that these principles must be taken into consideration in all decisions that may affect the environment. Furthermore, the need for intergovernmental co-ordination and harmonisation of policies, legislation, and actions relating to the environment, is emphasised. NEMA also emphasises the need for a mechanism that promotes sustainable use, and states that a risk-averse and cautious approach, which takes into account the limits of current knowledge about the consequences of decisions and actions, must be used in decision-making. It is also important to note that the Best Practical Environmental Option (BPEO) is defined in NEMA as *the option that provides the most benefit or causes the least damage to the environment as a whole, at a cost acceptable to society, in the long term as well as the short term*.

In the context of mining, these principles are given further effect through section 37 of the MPRDA, which stipulates that the principles set out in section 2 of NEMA:

- Apply to all prospecting and mining operations, as the case may be, and any matter relating to such operation; and
- Serve as guidelines for the interpretation, administration and implementation of the environmental requirements of the MPRDA.

Section 28 of NEMA further establishes a general duty of care on every person who causes, has caused or may cause significant pollution or degradation of the environment to take reasonable measures to prevent such pollution or degradation from occurring, continuing or recurring, or, in so far as such harm to the environment is authorised by law or cannot reasonably be avoided or stopped, to minimise and rectify such pollution or degradation of the environment.

A.4.3 Mine Health and Safety Act (MHSA), 1996 (Act 29 of 1996)

Section 2(1) stipulates that the owner of a mine that is being worked must ensure, as far as reasonably practicable, that the mine is designed, constructed and equipped to provide conditions safe for operations and a healthy working environment and that the mine is commissioned, operated, maintained and decommissioned in such a way that employees can perform their work without endangering the health and safety of themselves or of any other person. Section 2(2) further stipulates that the owner of a mine that is not being worked, but in respect of which a closure certificate has not been issued, must take reasonable steps to prevent injuries, ill-health, loss of life or damage of any kind from occurring at or because of the mine. The Chief Inspector of Mines has the power to monitor and control those environmental aspects at mines that affect, or may affect, the health or safety of employees or other persons and is required to consult with the Director: Mineral Development concerning the exercise of those powers.

The above is reiterated in Section 5 which states that every manager must, to the extent that it is reasonable practicable:

- Provide and maintain a working environment that is safe and without risk to the health of employees;
- Identify the relevant hazards and assess the related risks to which persons who are not employees may be exposed; and
- Ensure that persons who are not employees, but who may be directly affected by the activities of the mine, are not exposed to any hazards to their health and safety.

Regulation 2.10.15, promulgated in terms of the MHSA, stipulates that the appointed manager must ensure that in the construction of any dump or any slimes dam in the neighbourhood of any building, thoroughfare or other public road, railway or public place, no danger to life or limb or damage to property can result there from.

In terms of Section 9, a manager must prepare and implement a code of practice on any matter affecting the health or safety of employees and other persons who may be directly affected by activities at the mine if the Chief Inspector requires it. These codes of practices must comply with guidelines issued by the Chief Inspector. One such mandatory code of practice is a **Code of Practice for Mine Residue Deposits**, which must be drawn up in accordance with Guideline DME Reference Number DME 16/3/2/2/2-A1 issued by the Chief Inspector of Mines (also refer to the requirements of SABS Code 0286).

According to section 11(1) every manager must:

- Identify the health and safety hazards to which employees may be exposed while at work;
- Assess the health and safety risks to which employees may be exposed while at work; and
- Record the significant hazards identified and risks assessed and make these records available for inspection by employees.

Sections 11(2) and 11(3) states that the manager must determine and implement all measures necessary to:

- Eliminate the risk;
- Control the risk at source;
- Minimise the risk;
- Provide protective equipment; and
- Institute a programme to monitor the risk.

A.5 Air Quality Act, 1965 (Act 45 of 1965)

Part II of the Atmospheric Pollution Prevention Act, 1965 (APPA) describes the control of noxious and offensive gases, as described in sections 9 to13 and summarised below:

- Schedule 2 of APPA contains a list of scheduled processes;
- Any operator of a scheduled process shall apply for a registration certificate from the Chief Air Pollution Control Officer (CAPCO) before operation to register the premises on which the scheduled process will be carried on;
- Maximum allowable ambient level control measures and apparatus will be included as the conditions of the registration certificate;
- The CAPCO will firstly issue a provisional certificate, valid for a certain period;
- If the measures, apparatus and controls implemented are effective, the CAPCO will issue a final registration certificate which will be valid until changes to the process, plant or building takes place or until it is withdrawn by the CAPCO;
- The holder of the certificates shall at all times comply with provisions of all certificates (provisional and final certificates).

Part IV of APPA deals with dust control and states that the owner or occupier shall take steps (prescribed) or if not prescribed, adopt the best practicable means to prevent the dust dispersion from causing a nuisance (Section 28). Further, if the CAPCO is of the opinion that any other dust generation, apart from that described in Section 28 (1) is causing a nuisance, an abatement notice may be served on the owner/occupier to take prescribed steps or to adopt best practicable means to abate such nuisance (Section 29).

Finally, according to Section 32, if a mine has received a notification of the Chief Inspector of Mines that the mine is likely to cease operations within 5 years, the owner of the mine may not dispose of any assets without a certificate issued by the CAPCO to the effect that that all necessary dust control measures has been taken, or without the consent of the Minister of Health in consultation with the

DME. Any such disposal in contravention with above constitutes an offence.

A.6 Environment Conservation Act, 1989 (Act 73 of 1989)

Waste is defined in section 1 of the Environment Conservation Act, 1989 (ECA) as *any matter, (whether gaseous, liquid or solid, or any combination there-of) which from time to time may be proclaimed by the Minister (of Environmental Affairs and Tourism) by notice in the Government Gazette as an undesirable or superfluous by-product, emission, discharge, excretion, or residue of any process or treatment.*

Government Notice No. 1986 in Government Gazette 12703 of 24 August 1990 describes what is meant by waste in this context. This definition specifically excludes (and is therefore not applicable to mine residue deposits):

- Water used for industrial purposes as governed under the 1956 Water Act;
- Any matter discharged into a septic tank or french drain sewerage system;
- Building rubble used for filling or levelling purposes;
- Any radio-active substances;
- Any minerals, residue, waste rock or slimes produced at a mine; or
- Ash produced by or resulting from the generation of electricity.

A.7 National Heritage Resources Act, 1999 (Act 25 of 1999)

Section 34 stipulates that a permit is required from the relevant provincial heritage resources authority to alter or demolish any structure or part of a structure which is older than 60 years. Various other forms of protection may also apply.

A.8 National Nuclear Regulator Act, 1999

The National Nuclear Regulator Act, 1999 (NNR) is applicable to "facilities specifically designed to handle, treat, condition, temporarily store or permanently dispose of any radioactive material which is intended to be disposed of as a waste material". The following sections of the NNR are relevant to MRDs:

- Chapter 3 provides details on authorisations of facilities and the responsibilities of holders of nuclear authorisations. A licensing guide (LG-1032) has been published by the Council for Nuclear Safety (CNS). This guide provides details on the methodology for the assessment of nuclear hazards and guidance on submissions to the CNS
- Chapter 4 details the financial securities and liabilities that are applicable to holders of nuclear authorisations, and
- Chapter 5 provides information on safety and emergency measures.

A.9 Other Acts

The Conservation of Agricultural Resources Act, 1983 (Act 43 of 1983) and the Biodiversity Act, 2004 (Act 10 of 2004) are relevant in the design, operations and closure of MRDs.

APPENDIX B MRD WATER BALANCE

A water balance for a MRD requires the identification of all the hydrological sub-catchments which make up the MRD. These are typically:

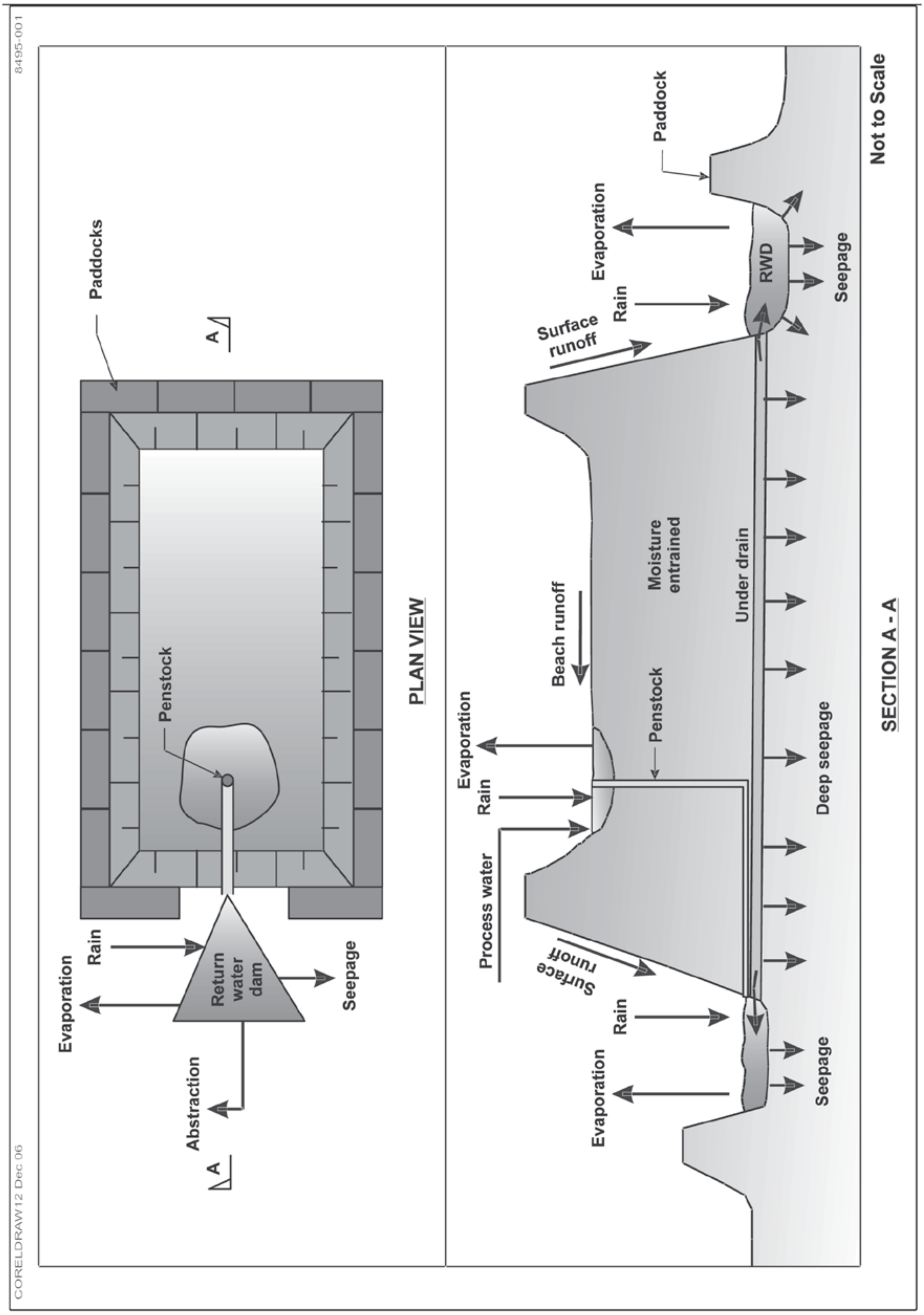
- The area whose runoff reports to the pool in the MRD
- Runoff from the side slopes of the MRD captured in paddock dams (for unrehabilitated side-slopes) or discharged to clean water catchments (for rehabilitated side-slopes where the runoff is of acceptable quality), and
- Any upstream catchment which is not yet covered with mine residue whose runoff reports to the MRD.

The typical water inputs to a MRD (see schematic overleaf) include:

- Water contained in the feed from the residue delivery line (process water)
- Runoff from the subcatchments
- Rainfall on the surface of the pool, return water dam and the paddocks
- Extraneous water pumped onto the surface of the MRD
- Potential artesian flows from elevated groundwater conditions.

The water outputs from a MRD (see schematic overleaf) typically consist of:

- The discharge from the penstock to the return water dam
- The seepage into the underdrainage system (if any) which surrounds the MRD and which is fed back to the return water dam
- Seepage losses into the foundation of the MRD and from the return water dam that are irrecoverable and report to the groundwater.
- Moisture retained in the residue,
- Evaporation from the surface area of the dam and the return water dam or dams, and
- Abstraction from the return water dam for reuse.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Not to Scale
Beach runoff
Moisture entrained
Under drain
Evaporation
Rain
Process water
Penstock
Deep seepage
Surface runoff
Rain
Evaporation
Seepage
SECTION A - A

APPENDIX C TABLE OF CONTENTS FOR PLANNING REPORT

The planning report will be the output from the conceptualisation and planning phase. The planning report should include all the assumptions, parameters and alternatives considered and the justifications and reasons for the final selections. A typical table of contents is included overleaf. Based on this, the planning report should contain the following information:

- Background information (section 1)
- Study objectives, design criteria and assumptions i.e. source of residue, life of mine, rate of production, total tonnage and relation to volume, etc. (section 2)
- Sources of information (section 3)
- Baseline Information i.e. geology, topography, geotechnical, climate, hydrological and surface water, groundwater, air quality, noise, fauna and flora, buildings count, sites of archaeological and cultural interest, etc. (section 4)
- Consideration of alternatives i.e. alternative sites, slurry water content and water balance, deposition techniques, footprint size, phased construction, lining systems, etc. (sections 5 and 6)
- Preliminary considerations of water balance, hydrogeological and geochemical impacts (section 6)
- Comparison of candidate schemes and fatal flaw assessment (section 6)
- Conceptual design of preferred scheme including preliminary safety and environmental classification as per SABS 0286:1998, closure provisions and intended final land use aims (sections 7 and 8)
- Recommendations for investigations (sections 9, 10 and 11).

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APPENDIX D DRAIN DESIGN

The purpose of an under-drainage system is to:

- Improve the stability of a MRD by lowering the phreatic surface. Unsaturated material is more stable and less mobile (in the event of failure) than saturated material
- Reduce the long term seepage and hence facilitate a reduction in ground and surface water impacts
- Reduce the post closure differential settlement, and
- Increase the return water to the plant.

This appendix provides details on the calculation for a typical blanket drain as part of the design of a MRD.

- Blanket Drains

The selection of seepage boundary conditions for the estimation of q and the position of the phreatic surface is usually very difficult. Even the best estimates of the coefficients of permeability from field and/or laboratory measurements are usually only within one order of magnitude. It has however been shown that a number of different calculation methods (van Zyl and Robertson, 1980) give a similar flow rate for a residue impoundment for:

$L/h \geq 3$, where L = the horizontal distance from the drain to the edge of the pool and h = the vertical distance from the pool to the base of the residue facility and drain

The following equation can be used

$q = kh^2/2L$, where k = the coefficient of permeability.

It was shown by van Zyl and Harr (1977) that the effective length of a drain L_{dr} can be taken as about 0.1 h for $L/h \geq 2$. The width of the drain is furthermore controlled by the coefficient of permeability of the finest layer in the drain. Consider figure …, the value of L_{dr} must be such that the flow rate q1 through the residue is equal to the available flow rate q_2 into the drain. The magnitude of q_2 can be calculated by the extension of Darcy's law:

$q_2 = k_2\, i_2 A_2$ (2)

where k_2 = coefficient of permeability of the finest layer in the drain;

$i_2 = 1$

$A_2 = L_{dr}$ x unit length of the drain.

Therefore $q_1 – k_2.L_{dr}$ (3)

It is recommended that the width of drain used be at least 50% more than the value of L_{dr} obtained from equation (3) to account for possible blinding of the drain, etc. It is further recommended that the drain width be a minimum of 2m.

The drain must transport all the water flowing into it. The spacing of outlets is therefore dependent on the capacity of the drain, i.e. the capacity of the drain pipes.

The capacity of the drain pipes can be estimated using Manning's equation:

Q = 1.486/n.R2/3S1/2A

Where n = Manning's roughness coefficient
R = Hydraulic radius of the pipe
R = A/P
A = Area of pipe in square feet
P = wetted perimeter of pipe in feet
S = hydraulic slope of the pipe

APPENDIX E
LINER DESIGN

The purpose of a lining system is to prevent the pollution of groundwater resources during the operational and post closure phases of the MRD. The design of a lining system requires the evaluation of performance of alternative lining systems.

The following information is required:

- Geotechnical properties of underlying layers i.e. permeability, thickness and location of water table
- Geotechnical properties of residue i.e. permeability
- Expected concentration of pollutant in residue pore water
- Availability of material for natural low permeability layer, and
- Leakage rates for synthetic lining systems.

For the following example two natural lining materials were available:

- Saprolite (weathered residual volcanics), and
- Mbuga clays (alluvial black cotton soils).

The saprolite was considered marginally suitable as a liner since its permeability was expected to be between 1×10^{-6} m/s and 1×10^{-7} m/s, which was only on the order of one order of magnitude less than the residue. Compacted saprolite had the advantage however of being workable and volumetrically stable.

The Mbuga clays were considered to be best from the point of view of permeability (less than 1×10^{-11} m/s when remoulded and compacted), but were volumetrically unstable and difficult to remould and compact. It was thus decided that if the Mbuga-type soils were used in the lining then it would be advisable to sandwich one or more layer of Mbuga between layers of saprolite. This would reduce the exposure of the Mbuga to the elements although continuous watering of the material would still be required until the residue are placed over the lining.

The following lining options were thus evaluated:

- Four compacted layers of 150 mm saprolite ($k = 1x10^{-7}$ m/s)
- One layer of 150 mm Mbuga clay ($k = 1x10^{-11}$ m/s) between two 150 mm saprolite layers ($k = 1x10^{-7}$ m/s)
- 1.5 mm High Density Polyethylene (HDPE) geomembrane.

For a geomembrane lining system the recommended minimum thickness is 1.5 mm.

A two dimensional modelling program (LandSim) was used to model potential aquifer contamination at a hypothetical off site compliance point 250 m from the toe of the proposed residue facility. The contaminant considered was free Cyanide. The World Bank Limits for free Cyanide in groundwater is <0.1 ppm. The concentration of free Cyanide in the residue pore water was assumed to be either 2 ppm or 5 ppm. The evaluation of the geomembrane liner is based on an assumed defect rate which determines the leakage rate. The size and number of defects was based on Giroud and Bonaparte (1989). Typically for liner performance evaluation, one defect per 4 000 m^2 is considered with a defect area of 0.1 cm^2 (equivalent to defect diameter of 3.5 mm). The results are shown in Table E.1.

Table E.1: Comparison of different lining systems on possible groundwater pollution

Liner Description	Cyanide Concen-tration in residue (ppm)	Cyanide Concentration at compliance point (ppm)			
		Percentile: 50% less than		Percentile: 90% less than	
		10 Years	30 Years	10 Years	30 Years
4 – 150 mm Saprolite	2	0.89	0.94	2.00	2.00
1 – 150 mm Mbuga between 2 – 150 mm Saprolite	2	0.00	0.00	0.00	0.00
1 - 1.5 mm HDPE geomembrane	2	0.11	0.16	0.50	0.62
4 - 150mm Saprolite	5	3.06	3.13	5.00	5.00
1 – 150 mm Mbuga between 2 – 150 mm Saprolite	5	0.00	0.00	0.00	0.00
1 - 1.5 mm HDPE geomembrane	5	0.48	0.65	1.5	1.75

The model was conservative as it assumed that there is no sorption along the route and that the only reduction in concentration is due to dilution within the aquifer. It indicated that a saprolite liner with four layers of 150 mm and a hydraulic conductivity of $1x10^{-7}$m/s would only be suitable if the cyanide concentration in the residue is reduced to well below 1ppm. The mbuga/saprolite sandwich was likely to outperform a geomembrane and to reduce the cyanide concentration to an acceptable level. The cost of a geomembrane was approximately 2.5 times greater than that of the saprolite lining, and the cyanide concentration in the residue pore water will have to be reduced to less than 1 ppm to manage the environmental risk in the desired range.

A saprolite/mbuga liner was thus adopted as the preferred option for the study. The over-drainage and lining system must ultimately be designed to ensure that the risk to the groundwater system is reduced to an acceptable level. The performance assessment will depend on a thorough understanding of the hydrogeology, of the characteristics of the material that will be used for lining (saprolite), and of the residue.

References

J.P. Giroud and R. Bonaparte, “Leakage Through Liners Constructed with Geomembranes, Part I: Geomembrane Liners”, Geotextiles and Geomembranes, 8, 1: 27-67, 1989.

APPENDIX F OPERATIONS MANUAL TABLE OF CONTENTS

The Operations Manual should cover all aspects of the operations of an MRD. A typical Table of Contents for an Operations Manual is included below. The main headings for the Operations Manual are shown as:

- The roles and responsibilities for all personnel involved in the operations and management of the MRD
- A description of the MRD facility
- Details of the operations of the MRD facility
- Details on maintenance and emergency preparedness, and
- Details on the regular surveillance to be undertaken for the MRD.

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