TRANSALLOYS (PTY) LTD

FeCr Facility

CLOSURE DESIGN REPORT FOR THE PROPOSED DECOMMISSIONING AND CLOSURE OF THE FECR FACILITY: eMALAHLENI LOCAL MUNICIPALITY, MPUMALANGA PROVINCE

Project: TA007

January 2022

Client:	Transalloys (Pty) Ltd
Project number	TA007
Project reference	Purchase Order Number 032723
Contact Person:	Ephraim Monyemoratho Transalloys (Pty) Ltd P.O. Box 856, eMalahleni, 1035 Tel: 013 693 8078 ephraimm@transalloys.co.za
Contract:	**DESIGN REPORT FOR THE PROPOSED DECOMMISSIONING AND CLOSURE OF THE FeCr FACILITY AT TRANSALLOYS (PTY) LTD**
Service Provider:	redco Rehabilitation Design & Construction Services (Pty) Ltd t/a Redco 3 Fabriek Street Parys, 9585 PO Box 2243 Parys, 9585 Office: +27 56 811 5335 Mobile: +27 82 903 1428 Fax: +27 86 768 3221 Email: dp@redcoservices.co.za VAT no: 4370210595
Project Team & Specialists:	DP van der Merwe Pr.Eng. Antoinette Scheepers Hein Jansen van Vuren Hendrik Arangies
REVISION: ***Date Issued:***	Rev 0: Report to client 3 October 2021

Responsibility	Person	Professional Registration	Date	Signature
Report Drafted	Hein Jansen van Vuren	Candidate Engineer Engineering Council of South Africa (ECSA)		
Reviewed	Hendrik Arangies	Pr. Sci. Nat. (SACNASP) No: 118888/22		
Signed Off	DP van der Merwe	Pr. Eng. (ECSA) No: 990132		

Table of Contents

List of Figures

List of Tables

Definitions and Acronyms

DEFINITIONS

Latent environmental impact: Any environmental impact that may develop from natural events or disasters after a closure certificate has been issued;

Rehabilitation: The process of returning the environment in a given area to some degree of its former state, after some process has resulted in its damage;

Remediation: The process of removing pollutants or contaminants from the environment;

Residual environmental impact: The environmental impact remaining after physical closure and before a closure certificate has been issued;

Sensitive Area: A sensitive area or environment can be described as an area or environment where a unique ecosystem, habitat for plant and animal life, wetlands or conservation activity exists or where there is a high potential for eco-tourism;

Sustainable: Capable of being sustained; using a resource so that the resource is not depleted or permanently damaged (Source: http://www.merriam-webster.com/ dictionary/);

Sustainability: A state in which the demands placed on the environment can be met without compromising the environment and reducing its capacity to allow all people to live well now and in the future;

Sustainable environmental rehabilitation: The process to rehabilitate disturbed areas by the implementation of the necessary rehabilitation designs, plans and practises to an end state and land capability which will ensure the requirements of a sustainable environment is satisfied.

ACRONYMS

Acronym	Description
BoQ	Bill of Quantities
DMRE	Department of Mineral Resources and Energy
FOS	Factor of Safety
FeCr	Ferro Chrome
GCL	Geosynthetic Clay Liner
LaRSAA	Land Rehabilitation Society of South Africa
IWWMP	Integrated Water and Waste Management Plan
NEMA	National Environmental Management Act (No 107 of 1998)
NEM:WA	National Environmental Management Waste Act (Act 59 of 2008)
NGL	Natural Ground Level
NWA	National Water Act (Act no 36 of 1998)
PCD	Pollution Control Dam
RSIP	Rehabilitation Strategic Implementation Programme
RWD	Return Water Dam
SOW	Scope of Work
SWMP	Storm Water Management Plan
TDS	Total Dissolved Solids
WUL	Water Use License
SANAS	South African National Accreditation System
CE	**"conformité européenne" (French for "European conformity**

Professional Team:

Specialist	Contact Details	Professional Registration
DP van der Merwe. Pr. Eng. Redco	OFFICE: +27 56 811 5335 MOBILE: +27 82 903 1428 EMAIL: dp@redcoservices.co.za	Engineering Council of South Africa (ECSA) No: 990132

EXPERIENCE

Mr van der Merwe has over 29 year experience as engineer with over 24 year experience in the field of rehabilitation and closure planning and storm water management for mines and other disturbed areas. This includes the planning, design and implementation of storm water and rehabilitation works. His practical experience underpins his ability to do closure liability assessments. He is a registered professional engineer with the Engineering Council of South Africa and member of the South African Institute of Agricultural Engineers and the South African Institution of Civil Engineering. He has worked on projects in South Africa, Botswana, Angola, Zimbabwe, Zambia, Mozambique and Liberia. He has experience in the asbestos, iron, manganese, diamond, coal, chrome and platinum industries.

Specialist	Contact Details	Professional Registration
Hein Jansen van Vuren. Redco	OFFICE: +27 56 811 5335 MOBILE: +27 76 340 1894 EMAIL: hein@redcoservices.co.za	Candidate Engineer Engineering Council of South Africa (ECSA) Registration No: 985386

EXPERIENCE

Mr. Jansen van Vuren has over 21 years' experience in various disciplines within in the Civil engineering environment. His experience includes precast concrete design for the railway and electrical distribution (5 Years), 3 years as sales engineer for manufacturing and distribution of concrete anchors and 15 years as contract manager for the implementation and design of Geosynthetic solutions for Pollution control dams, tailings storage facilities and various other waste storage facilities, liquid and solid waste. The past 2 years he has worked on rehabilitation and closure and storm water management for mines and other disturbed areas. He has worked on projects in South Africa, Botswana, Namibia, Tanzania, Mozambique, DRC, Zambia, Zimbabwe and Guyana. His experience in the mining includes gold, copper, zinc, chrome, uranium, coal, platinum, diamonds and mineral sands.

CLOSURE SPECIALIST	CONTACT DETAILS	PROFESSIONAL REGISTRATION
Hendrik Arangies. Pr.Sci.Nat Redco	OFFICE: +27 56 811 5335 MOBILE: +27 82 569 9065 EMAIL: hendrik@redcoservices.co.za	Professional Natural Scientist (SACNASP) Registration No: 118888/22 Land Rehabilitation Society of South Africa LaRRSA: 0342

EXPERIENCE

Mr Arangies is an Environmental Management professional with 25 years' experience in the construction and mining industries in both operational and project development capacity. His speciality is mine closure planning and the execution closure & rehabilitation projects but also extend to environmental compliance, project management, waste management, minerals processing, and construction. He is a Registered Professional Natural Scientist with South African Council for Natural Scientific Professions (SACNASP Registration No: 118888/22) and a regular member of the Land Rehabilitation Society of South Africa (LaRRSA Membership ID: 0342).

1 INTRODUCTION

Transalloys (Pty) Ltd (Transalloys), was established in 2007 when the Renova Group of Companies, a Russian diversified investment holdings, acquired the plant. The plant complex is situated approximately 14 km west of eMalahleni and approximately 90 km east of Pretoria (Figure 1). Transalloys is the producer of silico-manganese (Si-Mn) i.e. medium (MCFeMn) and high ferromanganese (HCFeMn) product in South Africa and a recognised supplier of the product globally, with a capacity to produce 165 000 tons of Si-Mn per annum for the world markets.

FeCr facility was established when a separate storage and disposal facility was required for the FeCr facility material which was produced. The FeCr facility has not been operated or used for disposal for more than ten (10) years. The application was lodged with the Authorities in 2017 to decommission and close the facility, since Transalloys has not produced FeCr for the past twenty (20) years and the facility is not required to remain active and continue to be an environmental liability. The application probed a further need for the revision of the civil designs for the FeCr facility. Transalloys is thus reconsidering decommissioning and closure of the facility, which is located to the north east of the main plant complex.

The closure design solution is informed by the following considerations:

- The legislative framework informing the development of an effective closure and rehabilitation solution;
- Design considerations used to develop an appropriate closure and rehabilitation solution; and
- The engineering assumptions, constraints, calculations and designs underpinning the proposed final closure and rehabilitation design.

1.1 Regional Setting and Locality

The Transalloys Plant is located within the eMalaheni Local Municipality within the Nkangala District Municipality of the Mpumalanga Province of South Africa as depicted in Figure 1,.

A summary of the regional and municipal information pertaining to the site is depicted in Table 1:

Table 1: Summary of the Regional and Municipal information

Description	**Details**
Central Coordinate of the Site	25°53'23.41"S; 29° 7'20.70"E
Nearest Town/ City	eMalahleni
Local Municipality	eMalahleni Local Municipality
District Municipality	Nkangala District Municipality
Province	Mpumalanga
Country	Republic of South Africa

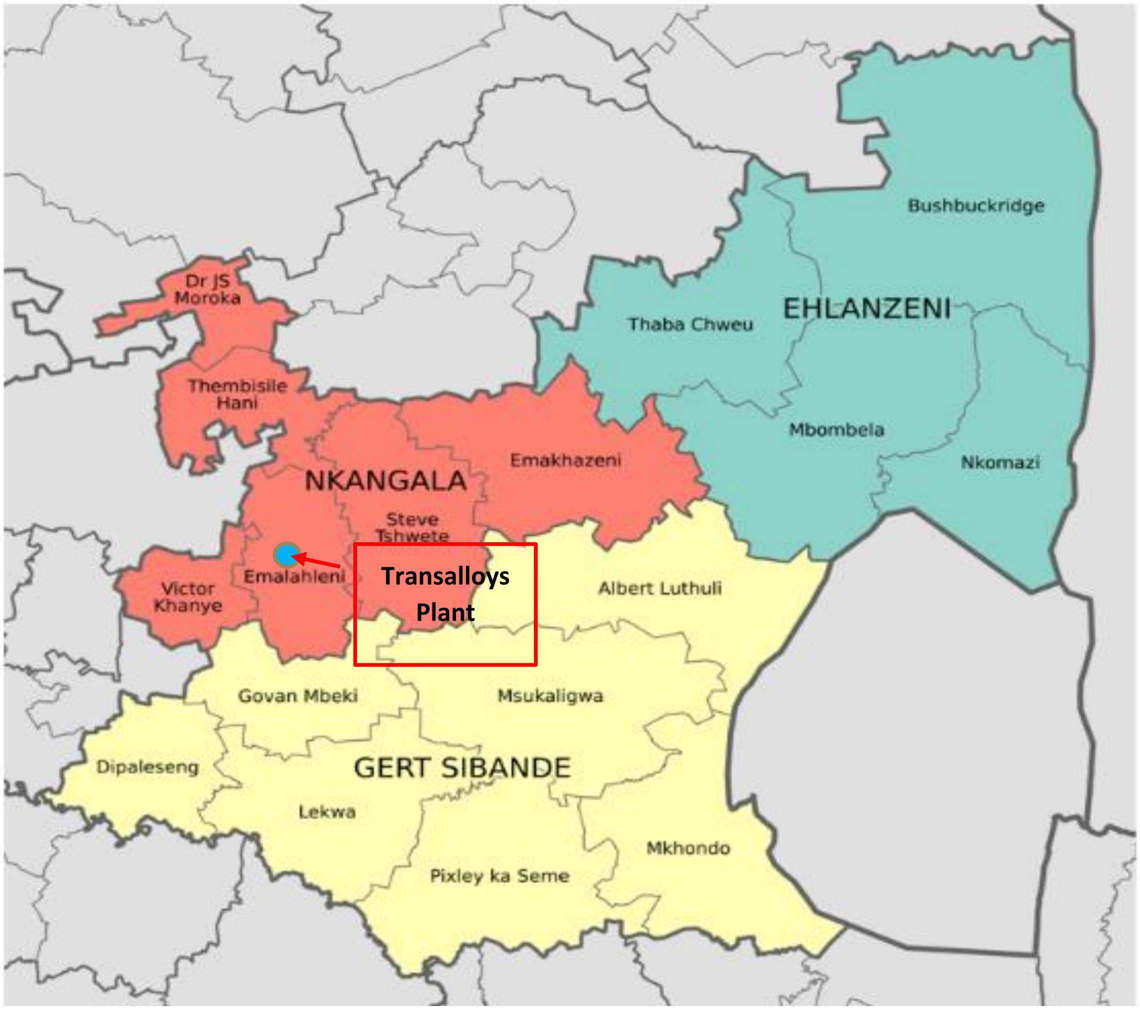


Figure 1: Municipal and District Municipalities

1.2 Legal Requirements

1.2.1 Constitution of the Republic of South Africa, 1998 (Act No. 108 of 1998)

The overarching legal framework governing South Africa is the Constitution of the Republic of South Africa, 1996 (Act No. 108 of 1996). Various rights, including the right to “*an environment that is not harmful to the health or well-being of the population”* – otherwise called the environmental right, are entrenched in the Constitution. In addition, the mining industry is guided by a number of acts and regulations legislating/regulating mining activities as well as aspects pertaining to the natural environment, human health and safety.

The interaction between various Acts of parliament that deals with the environment is varied and complex, as is the range of environmental aspects, activities and processes that requires regulation. In support of this suite of environmental regulations, the Department of Mineral Resources and Energy (DMRE) has published the following principles to regulate/govern mine closure in the South African context. Although Transalloys is not a mine, it is our view that the principles as published by DMRE can also be considered and applied as guidelines pertinent to the proposed closure of the FeCr facility:

- The safety and health of humans and animals are safeguarded from hazards resulting from operations.
- Environmental damage or residual environmental impacts are minimised to such an extent that it is acceptable to all involved parties.
- The land is rehabilitated to, as far as is practicable, its natural state, or to a pre-determined and agreed standard or land use which conforms to the concept of sustainable development.
- The physical and chemical stability of the remaining structures should be such that risk to the environment is not increased by naturally occurring forces to the extent that such increased risk cannot be contended with by the installed measures.
- The optimal exploitation and utilisation of South Africa's mineral resources are not adversely affected.
- Operations are closed efficiently and cost effectively.
- Operations are not abandoned but closed in accordance with this policy.

1.2.2 National Water Act, 1998 (Act No. 36 of 1998)

The closure of the FeCr facility must comply with the specific provisions as set out in the National Water Act, 1998 (Act No 36 of 1998). The purpose of the Act is to ensure the protection of water sources and that the resources are used, developed, managed and be control in ways which take into account amongst other factors:

- Meeting the basic human needs of present and future generations;
- Promoting equitable access to water;
- Promoting the efficient, sustainable and beneficial use of water in the public interest;
- Facilitating social and economic development;
- Providing for growing demand for water use;
- Protecting aquatic and associated ecosystem and their biological diversity;
- Reducing and preventing pollution and degradation of water resources;
- Meeting international obligations;
- Promoting dam safety; and
- Managing floods and droughts.

1.2.3 National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008)

The closure of the facility must comply with provisions of the Environmental Management, 2008 (Act No. 59 of 2008), including but not limited to compliance with Government Notice Regulations (GNR) 634, 635 and 636 published in Government Gazette No. 10008 on 23 August 2013, to regulate the classification and management of waste and prescribed requirements for the disposal of waste to landfills.

1.2.4 The National Environmental Management Act, 1998 (Act No. 107 of 1998)

The Act provides for co-operative and environmental governance by establishing principles for decision-making on matters affecting the environment, institutions that will promote co-operative governance and procedures for co-ordinating environmental functions exercised by organs of state; and to provide for matters connected there with.

In addition, it requires that Environmental Impact Assessments (EIA's) be conducted for activities and processes which will have an impact on the environment makes provision for the implementation of the environmental management plans to-

- Co-ordinate and harmonise the environmental policies, plans, programmes and decisions of the various national departments that exercise functions that may affect the environment or are entrusted with powers and duties aimed at the achievement, promotion, and protection of a sustainable environment, and of provincial and local spheres of government, in order to-
    - minimise the duplication of procedures and functions; and
    - promote consistency in the exercise of functions that may affect the environment;
- Give effect to the principle of co-operative government;
- Secure the protection of the environment across the country as a whole;
- Prevent unreasonable actions by provinces in respect of the environment that are prejudicial to the economic or health interests of other provinces or the country as a whole; and enable the Minister to monitor the achievement, promotion, and protection of a sustainable environment.

The Environmental Management Implementation Plan should include the following:

- A description of policies, plans and programmes that may significantly affect the environment;
- A description of the manner in which the relevant national department or province will ensure that the policies, plans and programmes referred to in paragraph (a) will comply with the principles set out in section 2 as well as any national norms and standards as envisaged under section 146(2)(b)(i) of the Constitution and set out by the Minister, or by any other Minister, which have as their objective the achievement, promotion, and protection of the environment;
- Recommendations for the promotion of the objectives and plans for the implementation of the procedures and regulations.

2 PROJECT BACKGROUND AND SITE CHARACTERISTICS

2.1 Site Background

During the 1960's Transalloys produced FeCr Facility slag over a period of four years; since then, the plant only produced silicomanganese (SiMn) and ferromanganese (FeMn). The historically dumped FeCr Facility slag contains a percentage of metals that is not recovered during the initial steel making process, and so a metal recovery plant was constructed in 1998 by a third-party contractor to remove tramp iron from the historically dumped slag and output from the new plant.

A jigging process was utilised to separate the metal from the slag, with the jigging action stratifying the feed into distinct metal and slag phases, allowing for separation into metal, middlings and clean slag product streams. The metal recovered during this process was conveyed to product stockpiles while the middlings either being delivered to a furnace for recycling or to the middling stockpile. The slag produced from this process has a coarse and fines fraction; these fractions need to be disposed of on a suitable waste facility after all metal that could possibly be removed through further processing is removed (Golder and Associates: 2013).

2.2 FeCr Facility

The FeCr Facility was constructed during June 2007 and the disposal of FeCr Facility slimes ceased during February 2010. The dam is located just to the east of to the historical slag and current arising dump situated north- east of the Transalloys plant. The FeCr Facility Slims Dam is located just west of the Mn Slimes Dam. Refer to Figure 2.

Figure 2: Location of the FeCr Facility Slimes Dam at Transalloys

The FeCr Facility is rectangular in shape and have an approximate footprint area of 1.26 ha and was designed to have two separate waste storage cells i.e. one for storage of fine waste material (particle size <150µm) and the second component designed for the storage of coarse waste material (150µm<particle size<25 mm). The northern compartment of the facility is ± 6m and the southern compartment is ± 7m high.

According to Golder and Associates, 2013 (Prefeasibility Engineering and Costing for the Closure of the Transalloys FeCr Facility Slimes Dam, Report No. 12614856-12207-1, the fine and coarse waste storage cells are constructed on a lined pad consisting of the following layers:

- Base preparation layer (150mm in-situ rip and re-compact);
- Impermeable compacted liner, modified with 7% Ordinary Portland Cement (OPC)(150mm);
- 150mm leakage detection layer consisting of gravel and drainage pipes;
- Geo-synthetic clay liner;
- 1mm HDPE liner (The HDPE liner covers the entire pad and is taken over starter wall);
- 150mm soil protection layer; and
- 300mm leachate collection layer, the drainage pipes is equipped with valves to control discharge during storm events.

According to the Canon Operations Manual_rev_01, 2006, construction of the slimes dam was as follows:

- Fines storage cell:
  - Construction of a 6 m wide x 1 m high starter wall, followed by placement of a HDPE liner over the entire base pad and over the starter wall;
  - Construction of paddocks 6 m wide x 150 mm high on the starter wall; and
  - The crest of the starter wall has been sloped inwards at a slope of 1:12 and the outer slope of the wall is 1: 2.
- Coarse storage cell:
  - Construction of a 2 m high toe wall, followed by placement of a HDPE liner over the base pad and continuing up the inner face of the toe wall;
  - Installation of concrete drains in toe walls with inverts 600 mm below the crest of the toe; and
  - Outer slope is designed to be 1:1.5.

A site inspection and assessment was conducted by REDCO on 10 June 2021, and based on the assessment, it is apparent that the HDPE liner indeed does exist and it is our assumption that the construction of the lining and starter wall was done in accordance with the design as depicted and explained above. The HDPE liner was installed in 2007, 14 years ago. The HDPE 1.0 mm liner generally carries a 10 year warrantee, although in many liners have proven to last much longer than the recommended warranty period.

During the site assessment, minor mechanical damage to the intact HDPE liner was observed. This makes it critical that the current exposed HDPE liner be covered completely to minimise and avoid any further and potential Ultra Violet (UV) degradation of the material. The proposed cover material must also provide an impermeable layer to over the HDPE liner to avoid any water seepage and therefore reduce the risk of leakages through the liner.

The FeCr facility was found to be dry at the time of the site inspection and no visible water was observed flowing through the penstock pipes. Minimal seepage was however observed from other underdrainage pipes and was taken into account and considered for the proposed FeCr Facility closure design.

Figure 3: HDPE Liner installed in Channel and over starter wall - East wall

Figure 4: Penstock - North Dam

Figure 5: Penstock pipe outlets through starter wall

Figure 6: Tailings underdrainage pipes

2.3 Geology and Soil Distribution

According to Jones and Wagner, 2016 (Report No: JW233/16/F87), the geology of the region is the controlling agent for aquifer development. The regional geology in the area is characterised by the sedimentary rocks of the Karoo Supergroup, in particular the Dwyka and Ecca Groups. The Dwyka consists mainly of tillite and diamictite, whereas the Ecca consists of siltstone, shale and sandstone belonging to the Vryheid Formation.

The Dwyka sediments were deposited during late Carboniferous to early Permian times by glacial processes and the underlying rocks, particularly in the north, display well developed striated glacial pavements in places. The group consists mainly of diamictite (tillite), which is generally massive with little jointing, but it may be stratified in places.

The Dwyka diamictite consists of angular to rounded clasts of basement rock embedded in a clay and silt matrix. Individual clasts measure up to 3m in diameter. Subordinate rock types are conglomerate, sandstone, rhythmite and mudstone (both with and without drop stones). In certain parts of the basin the diamictite display distinctive ‘tombstone’ morphology as a result of selective weathering along axial-plane cleavage.

The Ecca Group (Vryheid Formation) overlies the Dwyka Formation gradationally and comprises predominantly clastic sediments deposited in an extensive landlocked basin experiencing only rare marine incursion. Steyn and Beukes (1977) described the lower Vryheid Formation as upwards-coarsening shale and sandstone cycles, which represent prograding deltaic environments. This in turn is overlain by upwards-fining sandstone and shale cycles, which are of a fluvial origin.

The coal beds, which were deposited in the back swamps of meandering river systems, cap the Lower Vryheid lithologies. The depositional environment is believed to be a dendritic channel system that resulted in the deposition of more arenaceous material in the active channels and mud and coal deposited on their floodplains. Channel closure led to the filling of channels by mud, the establishment of swamps and the deposition of coal beds within them. Similar deltaic and fluvial processes characterise the sediments overlying the coal seams, consisting mainly of alternating sequences of shale and sandstone. The more competent sandstone formations can result in localised hilly terrains. The surface and near surface lithologies comprise topsoil, weathered sandstone and some ferricrete. The latter is important as it generally forms an impermeable layer, affecting groundwater flow.

The aquifer development at the site is governed by the local geology. At Transalloys the geology can be divided into two distinct aquifers (see Table 2), namely a shallow weathered aquifer and a deeper fractured aquifer.

Table 2: Site Geology and Aquifer type

Depth	Description	Aquifer Type
0 – 3 m	Topsoil Brown, sandy clay	Weathered Aquifer
3 – 9 m	Sandstone Weathered sandstone	
9 – 16 m	Sandstone Moderate, weathered sandstone	Fractured Aquifer
16 – 30 m	Shale Moderately, weathered to hard rock shale, with interlaced sandstone lenses. Carbonaceous in places and 1 – 3 m thick coal seams	
30 – 60 m	Sandstone Hard rock sandstone	

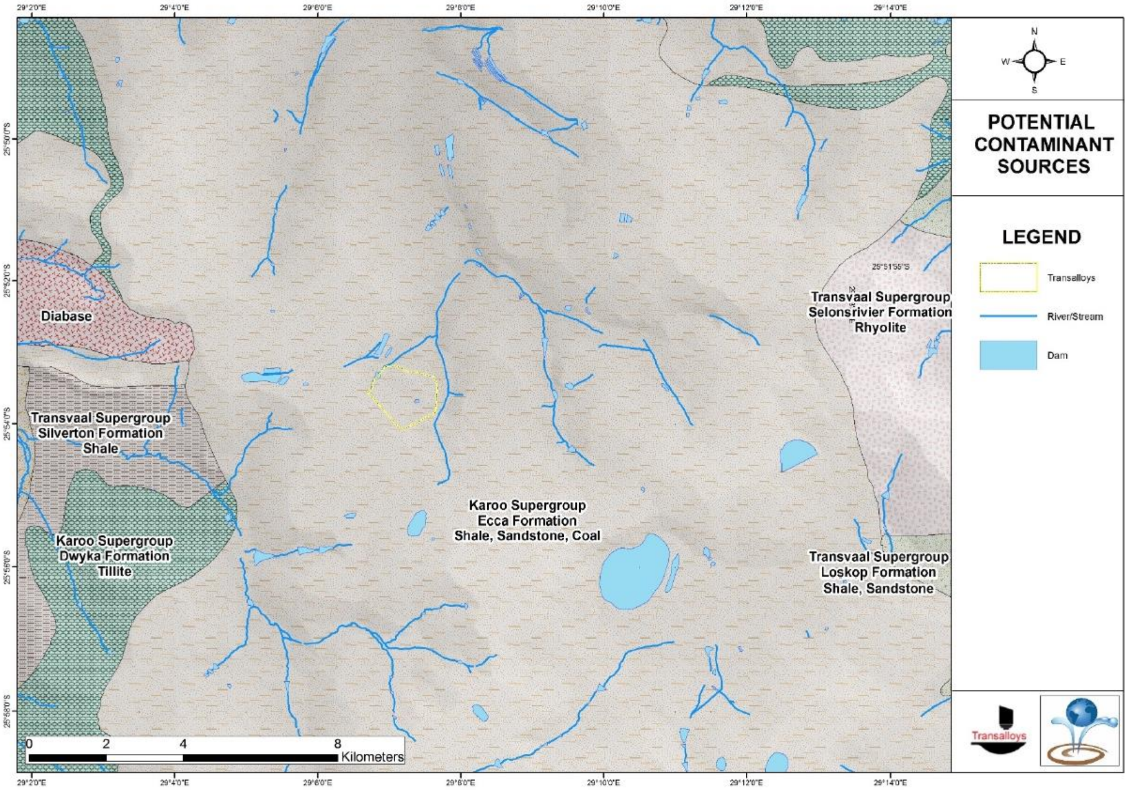


Figure 7: Regional Geology

2.4 Ground Water Quality

The ground water study conducted by MvB Consulting in December 2020 (Report No: MvB065/21/A029). is based on the routine monitoring investigation of the surface water and groundwater quality at Transalloys and deals with the sampling between January 2020 and December 2020.

Based on the assumption that the groundwater mimics the topography, the regional groundwater table can be extrapolated using the Bayesian interpolation. The regional interpolated groundwater gradients are presented in Figure 8.

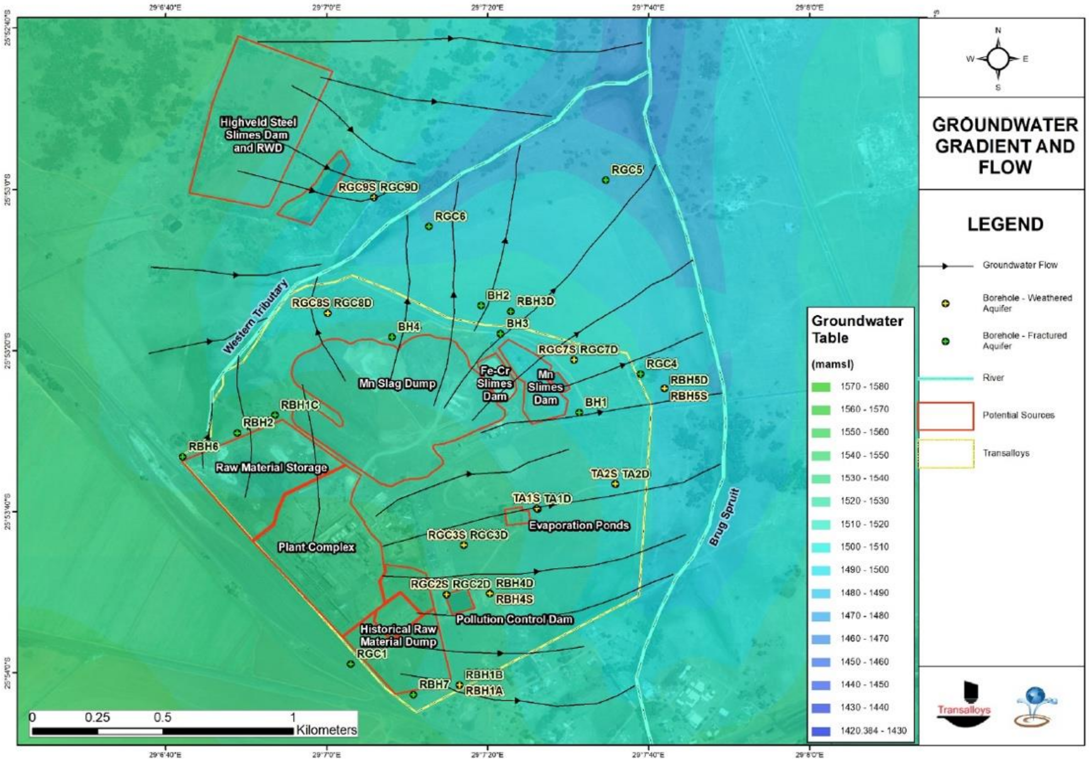


Figure 8: Interpolated groundwater table at Transalloys

The primary contaminant sources at Transalloys, ranked according to potential risk, are listed below:

- The Mn slag dump;
- Raw material stockpile;
- Historical raw material dump; and
- Mn slimes dam.

The manganese slag dump is considered the highest risk in terms of contaminant load to the environment. The contaminant sources at Transalloys with a lower estimated risk include the following:

- Pollution control dam;
- Sewage evaporation ponds;
- Fe-Cr slimes dam; and
- Cr Return water dam.

The following types of boreholes are present on the property:

- Background borehole: A background borehole is located up-gradient from the contaminant source/s and monitors the receiving water quality. Such a borehole is unaffected by contamination and should be used to compare the down-gradient water qualities and assess the impact from a source. Borehole RGC 01.

- Source borehole: A source borehole is located at the down-gradient edge of a contaminant source. The purpose of such a borehole is to assess the contaminant load from the source that enters the aquifer/s. These boreholes are typically contaminated and represents the worst quality. Boreholes RGC 02, RGC 07, TA 1, RBH1A, B, C, RBH 4s / 4d and RBH 5s / 5d.
- Plume borehole: A plume borehole is located some distance from the source and is used to determine the rate of contaminant migration. These boreholes may or may not be impacted on dependent on the groundwater and contaminant flow velocities. Boreholes RGC 03, RGC 04, RGC 08, RGC 09, BH 3, BH 4, and RBH 02.
- Compliance borehole: A compliance borehole is located at the boundary of the mine or at a receptor such as a surface stream. The primary aim is to monitor if down-gradient receptors (groundwater users and surface water bodies) are impacted on. These boreholes must comply with the Water Use Licence conditions. Boreholes RGC 05, RGC 06, TA 2 and RBH 5s / 5d.

The down-gradient receptors at Transalloys are the Brugspruit and the Western Tributary. The risk within these streams is primarily to livestock drinking the water. Due to these risks the surface and groundwater chemistry are compared to the DWAF (1996) Livestock Watering Guidelines (Table 6.2).

The groundwater qualities and impacts from the various sources are summarised as follows:

- The Mn slag dump, Mn slimes dam, Fe-Cr slimes dam and Cr Return water dam. A contaminant plume is moving in a northerly direction towards borehole pair RGC8s/d. A less pronounced plume is also moving in an easterly direction towards borehole RGC4 and borehole pair RBH5s/d. The manganese concentrations in these boreholes are elevated, although they do not exceed the guideline limits.
- Raw material stockpile. A small contaminant plume is moving in a northerly direction towards the Western Tributary. The manganese concentrations are slightly elevated, but still within the guideline limits.
- Plant area. There is no apparent impact from the plant area.
- Historical raw material dump. The concentrations are elevated in the shallower RBH1A borehole, although the guideline limits are not exceeded. The water quality in the deeper fractured aquifer is better than the shallower aquifer.
- Pollution control dam. There is an impact from this dam and both aquifers are affected. This impact is historical and occurred prior to the lining of the dam.
- Sewage evaporation ponds. There is a minor impact immediately down-gradient from the dam, although none of the parameters exceed the guideline limits.

2.5 Surface Water Management

The storm water currently on the FeCr facility is conveyed to the existing HDPE lined sump located to the North of the FeCr facility from where the water is transfer to the operations. Water from the cooling areas and waste lagoons situated to the West of the FeCr facility flows into the peripheral channel around the FeCr facility with no definitive inlet. Water run-off from lagoons to the west of the FeCr facility would need to be redirected in a newly proposed channel. The current peripheral channel for water conveyance around the FeCr facility will be covered during rehabilitation.

A new peripheral earth channel around the FeCr facility will be constructed to convey and separate clean and dirty run-off water to minimise the impact on the environment. Any water to be discharged through the underdrainage pipes will be diverted/conveyed via a half pipe channel to the existing FeCr facility HDPE lined sump, until such time that no water seepage is observed; where after it will be rehabilitated and closed permanently.

3 CLOSURE GUIDELINES

Condition 10 of the Transalloys existing Integrated Water Use Licence (IWUL) requires the site to compile the Integrated Water and Waste Management Plan (IWWMP) and the Rehabilitation Strategy and Implementation Programme (RSIP); and condition 10.3 in particular, states that the licensee must, at least 180 days prior to the intended closure of any facility, or any portion thereof, notify the Regional Head of such intention and submit any final amendments to the IWWMP and RSIP as well as a final closure plan, for approval.

The conditions imply that the RSIP must be developed for each facility, culminating in a final closure plan that must be submitted before commencing with the final closure and rehabilitation. Closure of each individual facility must be planned and conducted in an integrated approach, within the context of the entire operational footprint area. The RSIP must therefore always be read in conjunction with the wider closure plan developed for the operation as a whole. The following factors were considered in the development of the final closure plan for FeCr facility:

- Closure vision;
- Closure objective;
- Preferred End State / Final Land Use; and
- Closure criteria

3.1 Closure Vision

The closure design for the Transalloys FeCr facility conforms to the following closure vision:

Achieve a safe, stable, non-polluting and aesthetically acceptable post-operational landscape, that will minimize the potential impact on the local and regional water resources.

The Regulations Pertaining To The Financial Provision for Prospecting, Exploration, Mining or Production Operations 2015, GN 1147 Appendix 4 (3) stipulates that the final rehabilitation, decommissioning and mine closure plan must be *"measurable and auditable, must take into consideration the proposed post-mining end use of the affected area* ***and must contain information that is necessary for the definition of the closure vision, objectives and design and relinquishment criteria,*** *indicating what infrastructure and activities will ultimately be decommissioned, closed, removed and remediated and the risk drivers determining actions, indicating how the closure actions will be implemented to achieve closure relinquishment criteria and indicating monitoring, auditing and reporting requirements*". In addition, GN 1147 Appendix 4 (3)(d)(iii) also requires that the *"closure vision must* ***reflect the local environmental and socio-economic context*** *and reflect regulatory and corporate requirements and stakeholder expectations"*.

3.2 Closure Objectives

The following closure objectives are proposed for the Transalloys FeCr facility are to:

- Prevent or minimise adverse long-term environmental impacts;
- Create a self-sustaining natural ecosystem or alternate land use;
- Protect the environment, public health and social economic aspects by using safe and responsible closure practices;
- Reduce or eliminate adverse environmental effects once the smelter ceases operations;
- Reduce the need for long-term monitoring and maintenance by establishing effective physical and chemical stability of disturbed areas;
- Provide a basis in order to determine accurate costs for site closure provisioning which include demolition and disposal of fixed plant or infrastructure, and completing of civil rehabilitation and remedial works;
- Satisfy internal and external stakeholder requirements for closure planning and cost provision;
- Identify and document the legal requirements, liabilities, commitments, completion criteria for closure and assumptions made in developing the plan;
- Provide the basis for the ongoing review of closure concepts and closure provisioning;
- Identify opportunities of progressive rehabilitation and cost savings through synergies with existing or planned developments;
- Identify further research, investigations or clarification of closure concepts to ensure closure is achievable and effective and optimum use of available resources and technology are made;
- Ensure through a consultative process that the plan developed is technically achievable, agreed to and followed during the operating life to minimize reworking and life-of-plant costs;
- Provide a tool for the input by interested and affected parties and the development of agreed post operational completion criteria and/or land use objectives; and
- Identify possible sustainable alternative post closure uses for current infrastructure.

3.3 Preferred End State/Final Land Use

The geotechnical properties associated with the waste disposal sites are likely to render the rehabilitated FeCr facility footprint unavailable for alternative post closure development. The rehabilitated footprint should be earmarked as a restricted rehabilitated areas or green zone. The preferred end state will generally be stated in the final closure report of the facility. In the case of this report and the FeCr facility, it is assumed that the end state will be a long-term stable landscape with little to no maintenance. The area can be used for limited grazing under specific management practices when the area has reached stability.

3.4 Closure Criteria

Closure criteria are the agreed tasks/measures involved in mitigating identified closure risks. This involves activities such as removal of infrastructure, erecting fencing, installing drainage structures, reshaping, top soiling, ripping, seeding and planting, maintenance and monitoring.

The FeCr facility should be stable and remain stable for the extended term to prevent erosion, subsidence or collapse. The rehabilitation of this facility must limit the potential for adverse chemical reactions to negate the risk of impact on surface and ground water flows.

The accepted closure methods should allow for a dedicated cover/capping layer placed onto the modified outer slopes of the FeCr facility to fulfil the following primary functions:

- Protecting the integrity/stability of the modified outer slope;
- Limiting the ingress of air and water recharge into residue to reduce the risk of the water seepage arising from the footprint area of the deposits;
- Separation of the deposited material from uncontaminated surface runoff from the outer slopes of the FeCr facility deposits;
- Contribute to the aesthetic appeal of the rehabilitated facility;
- Render the rehabilitated facility maintenance free and meet the engineering criteria for physical stability. The facility may not deteriorate, erode or collapse under wind/water, frost/thaw, human activity, earthquakes etc.; and
- Create a safe water flow to allow contaminated water to be collected and treated using proven techniques where they are available.

4 TECHNICAL FACTORS CONSIDERED IN THE CLOSURE DESIGN

The following factors were considered and evaluated to inform an effective closure design for the FeCr facility:

- Project Standards and Specifications
- Alternative Closure Options Considered
- Waste Classification
- Physical Restrictions and Geometry
- Erosion Control
- Slope Stability
- Geosynthetics
    - Interface shear strength
    - Material Specifications
    - Permeability
    - Service life
- Water Management
- Vegetation

4.1 Project Standards and Specifications

The following SANS standards and references were considered in the proposed rehabilitation designs.

Table 3: SANS Standards referenced

SANS Standard Reference	Title
SANS 1200 AA 1986	General (small works)
SANS 1200 C 1980	Site clearance (amended 1982)
SANS 1200 C	Site clearance
SANS 1200 D 1988	Earthworks
SANS 1200 DK 1984	Gabions and pitching
SANS 1200 G	Concrete (Structural)
SANS 1200 GA	Concrete (Small works)
SANS 1200 LE 1982	Storm water drainage
SANS 1921: 2004:	General Engineering and construction works
SANS 1921 Part 2 2004	Accommodation of traffic on public roads occupied by the contractor
SANS 50197-1:	Common cements
SANS 50413-1	Masonry cements
Reference	
Occupational Health and Safety Act, Act No 85 of 1993 and the Construction Regulations 2014	

4.2 Alternative Closure Options Considered

In a previous study conducted by Golder and Associates, report 12614856-12207-1, July 2013 two options for closure of the FeCr Facility dump was considered.

Option A: Free-draining upper surface and stable landform

The objective was to create a long-term stable landscape with limited, but preferably no maintenance that will facilitate an eventual “walk away from” when required.

The desired landform is to be created as follows:

- Importing available slag from the adjacent slag area to fill the airspace in the upper surface pools and paddocks areas. These voids will be filled to create a convex top, termed a ‘whaleback’. The whale backing will provide a “naturally” free draining surface; and
- Importing benign soil to be placed and shaped on the existing outer slopes to create a uniform 1:5 slope that integrates with the whale backed slag on the upper surface. This will increase the dam footprint area by 7-15m from the current perimeter.
- Installing an impermeable cover onto the created profile that comprise the following:
    - Geotextile Bidim A8;
    - 2mm HDPE liner;
    - Pozi-drain drainage layer;
    - 500mm Topsoil cover; and
    - Vegetation cover.

The cover design prevents contact between surface water and the underlying waste material. Run-off from the rehabilitated facility will be clean for release to the receiving environment.

Option B: Upper surface draining to penstock

This option allows for limited upper surface modification, still allowing runoff to drain towards the existing centre drainage penstocks. The shaped surface will be lined with a single HDPE liner to prevent contact between the surface water and the underlying waste material. Since the water from the discharged from the penstock will be clean it can discharge to the surrounding environment.

The above cover will also prevent the ingress of rainfall into the waste material that could accumulate on the facility bottom liner. As the bottom liner drains will be closed-off at closure, the accumulated water will not be able to drain.

Soil will be imported to be placed and shaped on the outer slopes to achieve a side slope of 1:5 and provide a smooth and stable surface for the impermeable cover consisting of:

- Geotextile Bidim A8 (Over entire dam);
- 2mm HDPE liner (Over entire dam);
- Pozi-drain Drainage layer (Only on slopes);
- 500mm Topsoil cover (Only on slopes); and
- A Vegetation cover (Only on slopes).

The proposed closure design covered in this report is described in detail in Section 5 of this report. In order to compare the proposed design to the designs presented above the comparison are summarized in Table 4.

Table 4: Comparison between three (3) alternative closure designs.

	Option A: Free draining upper surface and stable landform	**Option B: Upper surface draining to Penstock**	**Reshape entire facility and free draining**
Actions	Fill the airspace in the upper surface	The option allows for limited upper surface modification, still allowing runoff to drain towards the existing centre drainage penstocks.	Reshape entire facility to 5 % slope and 11 % slope for the North and South top areas and 1V:5H slope on the East slope to ensure free draining. The reshaping will not extend beyond the HDPE liner peripheral drain boundary.
	Importing available slag from the adjacent slag area to fill the airspace in the upper surface pools and paddocks areas. These voids will be filled to create a convex top, termed a 'whaleback'. The whalebacking will provide a "naturally" free draining surface;	The shaped surface will be lined with a single HDPE liner to prevent contact between the surface water and the underlying waste material.	Install the following layer works: - The reshaped facility will be covered with an imported slag layer to act as capillary layer with a GCL layer and cover layer.
	Importing benign soil to be placed and shaped on the existing outer slopes to create a uniform 1:5 slope that integrates with the whalebacked slag on the upper surface. This will increase the dam footprint area by 7-15m from the current perimeter.	Soil will be imported to be placed and shaped on the outer slopes to achieve a side slope of 1:5 and provide a smooth and stable surface for the impermeable cover.	A final topsoil layer which will be mixed with coarse material will be placed over the cover soil layer. The topsoil layer will be ameliorated and vegetated with grass seeds. No deep-rooted plants will be planted on the slope to avoid penetration though the GCL.
	Installing an impermeable cover onto the created profile that comprise the following - Bidim A8 - 2 mm HDPE - Pozi Drain - 500 Topsoil - Vegetation	The shaped outer slopes will be lined with the following lining system: - Geotextile Bidim A8 (Over entire dam); - 2mm HDPE liner (Over entire dam); - Pozi-drain (Only on slopes); - 500mm Topsoil cover (Only on slopes) - Vegetation cover (Only on slopes)	Install the following layer works - 300 mm slag capillary layer - Geosynthetic clay liner (GCL) over the capillary layer as impermeable layer. - 300 mm Cover soil layer will be placed over the GCL to ensure confined pressure. - Place 300 mm topsoil layer mixed with coarse material. - Ameliorate and Vegetate
	The cover design prevents contact between surface water and the underlying waste material. Run-off from the rehabilitated facility will be clean for release to the receiving environment.	Since the water discharged from the penstock will be clean it can discharge to the surrounding environment.	Construct discharge drain to convey clean run-off from Peripheral drain to the environment
Cost Estimate	Cost in 2013 : R 6130575.00 excl. VAT Net Present Value (NPV) : R 9 184 566.00	Cost in 2013: R 4 050 434.00 excl. VAT Net Present Value (NPV) : R 6 068 227.00	Cost in 2022: R 7 364 843.65 excl. VAT

	Note: NPV is calculated on an inflation rate of 4.5 % per year.		Note: NPV is calculated on an inflation rate of 4.5 % per year.			
	Advantages	Disadvantages	Advantages	Disadvantages	Advantages	Disadvantages
Maintenance	Once the vegetation has established and became self-sustaining on-going care and maintenance can be largely obviated; and is highly likely to obtain "walk away".	Limited	None	The exposed liner on the upper surface of the dam must be maintained and inspected on a regular basis. Damage of the liner could be due to the following: - Weathering; - Animals; and - Humans. - Highly unlikely to obtain walk away.	Once the vegetation has established and become self-sustaining on-going care and maintenance can be largely obviated; and is highly likely to obtain "walk away".	In the short term, regular inspections are required to evaluate the flow from the underdrain discharge pipes until such time that no flow is observed and can then be closed permanently and be rehabilitated
Aesthetic quality	Due to the created land form and the associated vegetation cover, the fully rehabilitated facility will have a highly natural" appearance.	Limited	Side slopes will be covered with vegetation; and the facility will appear natural from a distance.	At close inspection the dam will not appear natural as the upper surface will be uneven, not naturally draining and not vegetated.	Due the created land form and the associated vegetation cover, the fully rehabilitated facility will have a highly "natural" appearance. Can ultimately be used for grazing.	Limited
Drainage and water quality	Surface runoff will drain-off freely to ground level. As this material will drain from the vegetated cover, this water will be clean for release to the surrounding environment.	None	Runoff from the upper surface liner will be clean and drain into the existing penstocks for release to the receiving environment.	Blockages can occur within the penstocks. This will lead to water impounding on the upper surface, with spillage and outer slope damage risks.	Surface run-off will be collected in vegetated drains and will be discharged to the environment at the North East corner of the facility.	None
Costs	On-going care and maintenance should be inconsequential in the long term.	The costs are about R2 mil higher than option B, mainly due the following:	Since the surface area is only increased by the side slopes and minimum cover layers are required,	None	The cost of Geosynthetics is far lower than Option A and B due to lower installation cost of GCL against HDPE lining.	Cost for closing the penstocks permanently is costly.

		- Load and haul of slag and soil material; and - Increased surface area to be covered	the cost for this option is lower.		Exchange rate fluctuations on HDPE and Pozidrain is greater than that of the GCL.	
Stability	With the designed slopes at 1:5 and well vegetated cover, the potential for surface erosion is limited; Overall slope lengths will not exceed about 30m; and experience indicated that this is a typical stable landform.	Limited	The outer slopes are at 1:5 that limits the risk of erosion.	The integrity of the cover is at risk due to exposed edges and surfaces as well as natural wear and tear.	Low risk of failure with slopes of 1V:5H and 5% and 11% on top to the West of the facility. Risk is further reduced due to the non-infiltration capping system.	Limited

4.3 Waste Classification

The National Environmental Management: Waste Amendment Act, 2008 (NEMWAA) was published on 2 June 2014. This Act included residue deposits and stockpiles as waste. New regulations for the planning and management of residue stockpiles and residue deposits were promulgated on 15 July 2015 (GNR 632) in terms of the NEMWAA. As residue deposits and stockpiles are considered waste in terms of the NEMWAA, the following regulations are applicable and were applied as part of this assessment:

Regulation 635 - National norms and standards for assessment of waste prior to the disposal to a landfill site (published under Government Notice Regulation (GNR) 635 in Government Gazette 36784, promulgated on 23 August 2013). These norms and standards recommend the requirements for the assessment of waste prior to the disposal to a landfill site in terms of Regulation 8(1)(a) of the Regulations.

Regulation 636 - National norms and standards for the disposal of waste to a landfill site (published under GNR 636 in Government Gazette 36784, promulgated on 23 August 2013), was used as a secondary reference.

An independent Waste Classification study was conducted by Artesium Consulting Services, (Reference 2021-00048). A total of 19 samples of approximately 1.5kg per sample were collected by Redco on the 10th of June 2021 from the existing Fe-Cr facility, the samples consisted of 9 samples from the top and 10 samples from the toe of the facility in order to obtain a representative sample. (See Figure 9 below).

The samples were submitted to Aquatico Laboratories (Pty) Ltd which is a SANAS accredited laboratory. The 9 samples from the top of the facility and 10 samples from the toe of the facility were composited into a representative sample. Both composite samples were analysed using the following methodologies:

- Closed vessel microwave digestion and ICP-MS analysis of the leachate to determine whole rock (solid Phase or TCT) metal and macro-chemical composition.
- A distilled water leach was done to simulate the leaching potential (aqueous phase or LCT).

Figure 9: Sample locations for Waste Classification of tailings material

4.3.1 Waste Assessment

The GNR 635 and GNR 636 requires that the results of both the leachate (LCT) assessment and the total (TCT) assessment need to be considered. A risk-based approach was followed to determine the waste impact potential on the aqueous environment. The risk-based approach referenced the GNR 635 analysis parameters for the leach test results as well as incorporating current and historical hydrochemical groundwater monitoring data was used to do a first level analysis of the waste material and risk to receptors via the groundwater pathway.

4.3.2 Total Concentration (TCT)

The total concentration values according to GNR 635 requires an analysis of the total (solid) concentration of specific chemical constituents in a sample. The total concentration refers to the mass elemental concentration of the material. For context, the results are compared to the Total Concentration Threshold (TCT) values stipulated in GNR 635. The regulations have three categories (TCT0, TCT1, and TCT2) as specified in GNR 635.

The solid phase is irrelevant for the groundwater pathway as it is immobile and does not impact the groundwater directly, whereas the leachable or fluid phase is more applicable and represents the mobile component of the material with potential to influence the groundwater pathway.

4.3.3 Leachable concentration (LCT)

The leach assessment according to GNR 635 requires a distilled water leach for non-putrescible waste. After the leach test is completed, the leachate, i.e., the fluid phase, is analysed for its chemical composition and the results compared to the Leach Concentration Threshold (LCT) values stipulated in GNR 635. The regulation has four categories (LCT0, LCT1, LCT2, and LCT3) as specified in GNR 635. Although both TCT and LCT results were obtained, from a groundwater perspective LCT results are more applicable as it indicates the leachable/mobile concentration from a given material.

4.3.4 Evaluation and Test Results

4.3.4.1 Total Concentration (TCT) Results

The TCT results for both composite samples indicated that the majority of parameters were below the TCT0 thresholds with the following exceptions (See Hoffman, Artesium: Transalloys Fe-Cr TSF Geochemical Assessment, 2021). A summary of the exceptions are listed in Table 5 below.

Composite sample 1 (Top of TSF):

- Barium (Ba), Chromium 6 (CrVI) and Manganese (Mn), significantly exceeded the respective TCT0 values.
- All results were below the TCT1 values

Composite sample 2 (Toe of TSF):

- Barium (Ba), Chromium 6 (CrVI) and Manganese (Mn), exceeded the respective TCT0 values.
- All results were below the TCT1 values

Table 5: Summary of TCT Exceedance results

Parameter	R635 Total Concentration Threshold Values		Composite Sample 1 (Top of TSF)	Composite Sample 2 (Toe of TSF)
	TCT0	TCT1		
Unit	mg/kg	mg/kg	mg/l	mg/l
Ba	62.5	6250	109	218
Cr(VI)	6.5	500	52.79	43.79
Mn	1000	25000	4940	11700

4.3.4.2 Leachable Concentration (LCT) Results

The LCT results for most parameters were below the LCT0 thresholds with the following exception identified in both composite samples. A summary of the exceptions are listed in Table 6Table 5 below.

Composite sample 1 (Top of TSF):

- Chromium (Cr)
- Hexavalent Chromium 6 (Cr VI)
- No LCT1 threshold exceedances were recorded.

The TDS is 203 mg/L and the pH of the leachate is 10.9.

Composite sample 2 (Toe of TSF):

- Chromium (Cr)
- Hexavalent Chromium 6 (Cr VI)
- No LCT1 threshold exceedances were recorded.
- The TDS is 234 mg/L and the pH of the leachate is 10.5.

Table 6: Summary of LCT exceedance results

Parameter	R635 Leach Concentration Threshold Values		Composite Sample 1 (Top of TSF)	Composite Sample 2 (Toe of TSF)
	LCT0	LCT1		
Unit	mg/l	mg/l	mg/l	mg/l
Ba	0.7	35	<0.7	<0.7
Cr	0.1	5	1.4	2.03
Cr(VI)	0.05	2.5	1.35	1.8
Mn	0.5	25	<0.5	<0.5

The waste classification in terms of GNR 635 requires that the results for both leachate assessment and total (solid) assessment need to be taken into account. Although GNR 635 may not specifically relate to mine residue deposits, it remains the most relevant regulatory guideline for the risk-based approach to selecting the most appropriate liner and capping options for residue disposal facilities.

4.3.4.3 Waste Risk Assessment

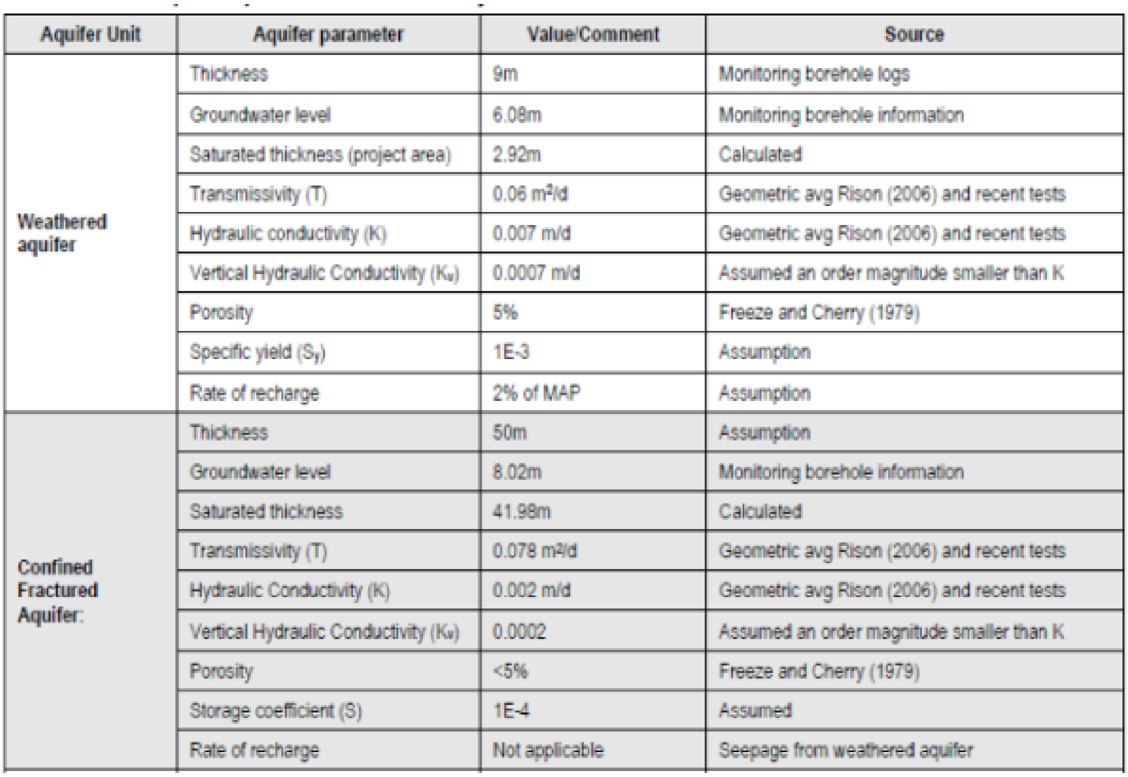
From the geochemical analysis conducted, the exceedances recorded in the TCT and LCT are above the TCT0 and LCT0 thresholds and thus the waste will be classified as a type 3 waste. Although the LCT analysis indicates LCT0 threshold exceedances of chromium (Cr) in both composite samples, the historical groundwater and surface water monitoring results (March 2019 to December 2019) obtained from the client, indicates insignificant Chromium (Cr) and Hexavalent Chromium (Cr VI), however aluminium (Al), Boron (B) and manganese (Mn) exceedances were recorded when compared to SANS 241:2015 drinking water limits.

An initial but conservative 1-Dimensional Analytical solution (Ogata & Banks, 1961) was run for this site over a 100 year period and the Hexavalent Chromium transport was calculated. This analysis assumes free leakage from the system in the future when the synthetic liner has degraded with time. The following assumptions were made when modelling the Hexavalent Chromium Transport:

- The porous media is homogenous and isotropic
- No mass transfer occurs between the solid and liquid phases

- The solute transport across any fixed plane, due to microscopic variations, may be quantitively expressed as the product of a dispersion coefficient and the concentration gradient
- The flow in the medium is assumed to be unidirectional and the average velocity is taken to be constant throughout the length of the flow field

Two analytical models were prepared, one modelling the advective transport and the other the reactive transport.



Aquifer Unit	Aquifer parameter	Value/Comment	Source
Weathered aquifer	Thickness	9m	Monitoring borehole logs
	Groundwater level	6.08m	Monitoring borehole information
	Saturated thickness (project area)	2.92m	Calculated
	Transmissivity (T)	0.06 m^2/d	Geometric avg Rison (2006) and recent tests
	Hydraulic conductivity (K)	0.007 m/d	Geometric avg Rison (2006) and recent tests
	Vertical Hydraulic Conductivity (K_v)	0.0007 m/d	Assumed an order magnitude smaller than K
	Porosity	5%	Freeze and Cherry (1979)
	Specific yield (S_y)	1E-3	Assumption
	Rate of recharge	2% of MAP	Assumption
Confined Fractured Aquifer:	Thickness	50m	Assumption
	Groundwater level	8.02m	Monitoring borehole information
	Saturated thickness	41.98m	Calculated
	Transmissivity (T)	0.078 m^2/d	Geometric avg Rison (2006) and recent tests
	Hydraulic Conductivity (K)	0.002 m/d	Geometric avg Rison (2006) and recent tests
	Vertical Hydraulic Conductivity (K_v)	0.0002	Assumed an order magnitude smaller than K
	Porosity	<5%	Freeze and Cherry (1979)
	Storage coefficient (S)	1E-4	Assumed
	Rate of recharge	Not applicable	Seepage from weathered aquifer

Figure 10: Model Parameters

The results show that advective transport would transport hexavalent chromium under an assumption of constant source leakage over a distance of approximately 34 m over a period of 100 years in the weathered aquifer and transport in the fractured aquifer reach approximately 15 m over a period of 100 years. If no artificial gradient is being caused the Hexavalent Chromium would likely never reach the Brugspruit and its Western Tributary as it is referred to which is the main receptors. See Figure 11.

Figure 11: Groundwater use exclusion buffer zone

4.3.5 Recommended Capping Based on TCT and LCT Results

A Class C capping appropriate for a Type 3 waste, requires only an impermeable capping such as a compacted clay layer or equivalent with a gas / water drainage layer. (See Figure 12)

As part of the proposed capping design a capillary break layer is recommended for the FeCr facility to separate the waste body from the Geosynthetic Clay liner (GCL). A capillary break will reduce the likelihood of elevated salts contained in the tailings migrating into the growth medium covering the capping.

The proposed capping design developed for the FeCr facility (Figure 13) is commensurate with the requirements for capping design according to the Minimum Requirements for Waste Disposal by Landfill depicted below. (2nd Ed., DWAF, 1998).

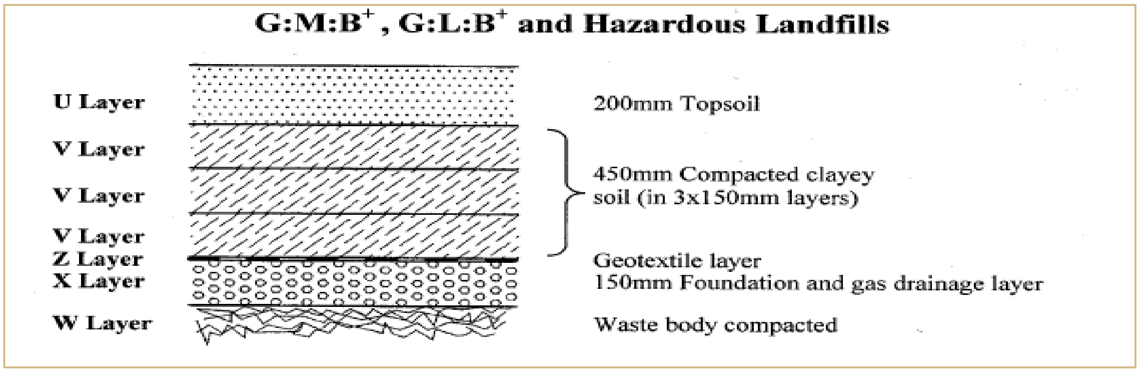


Figure 12: Minimum requirements for capping for waste disposal by landfill

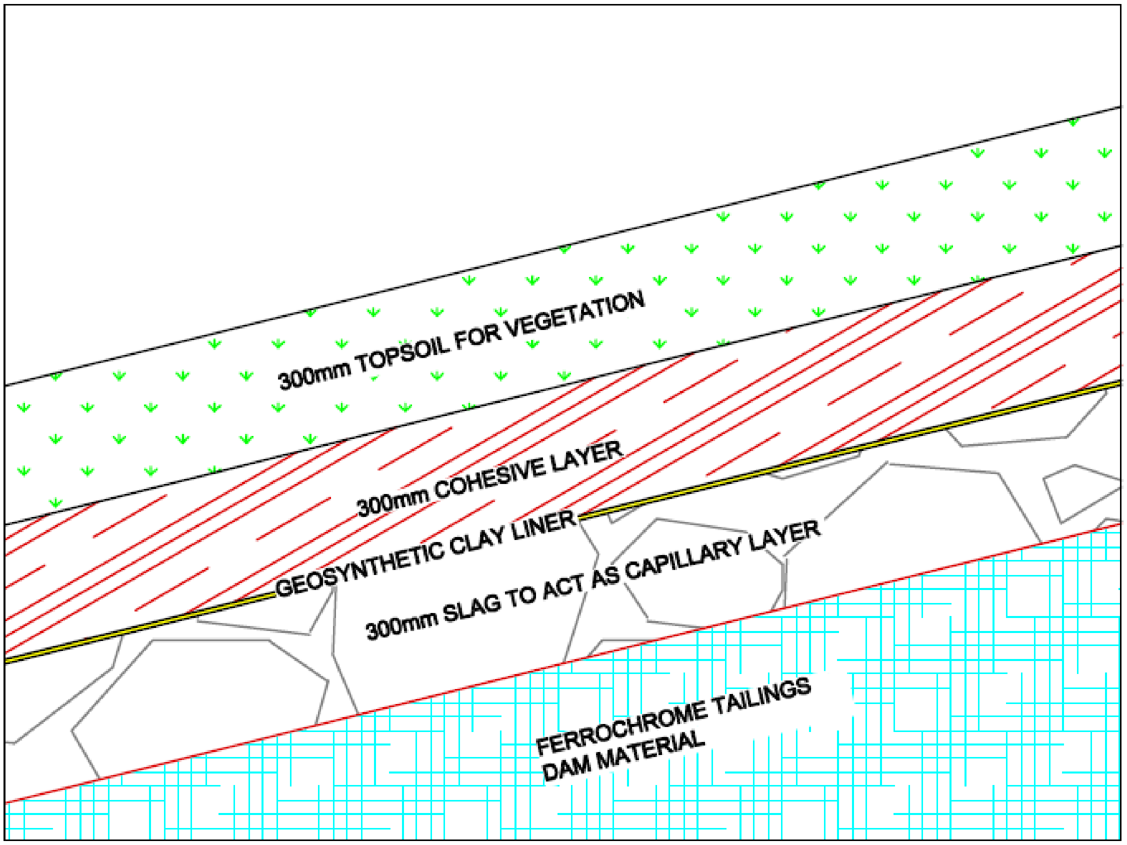


Figure 13: Proposed Capping layer for FeCr Facility Tailings facility

4.4 Physical restrictions

A fence exists to the south and west of the FeCr facility. A road is running along the east side. It was confirmed that these are not hard restrictions and can therefore be removed to allow for the reshaping of the dump.

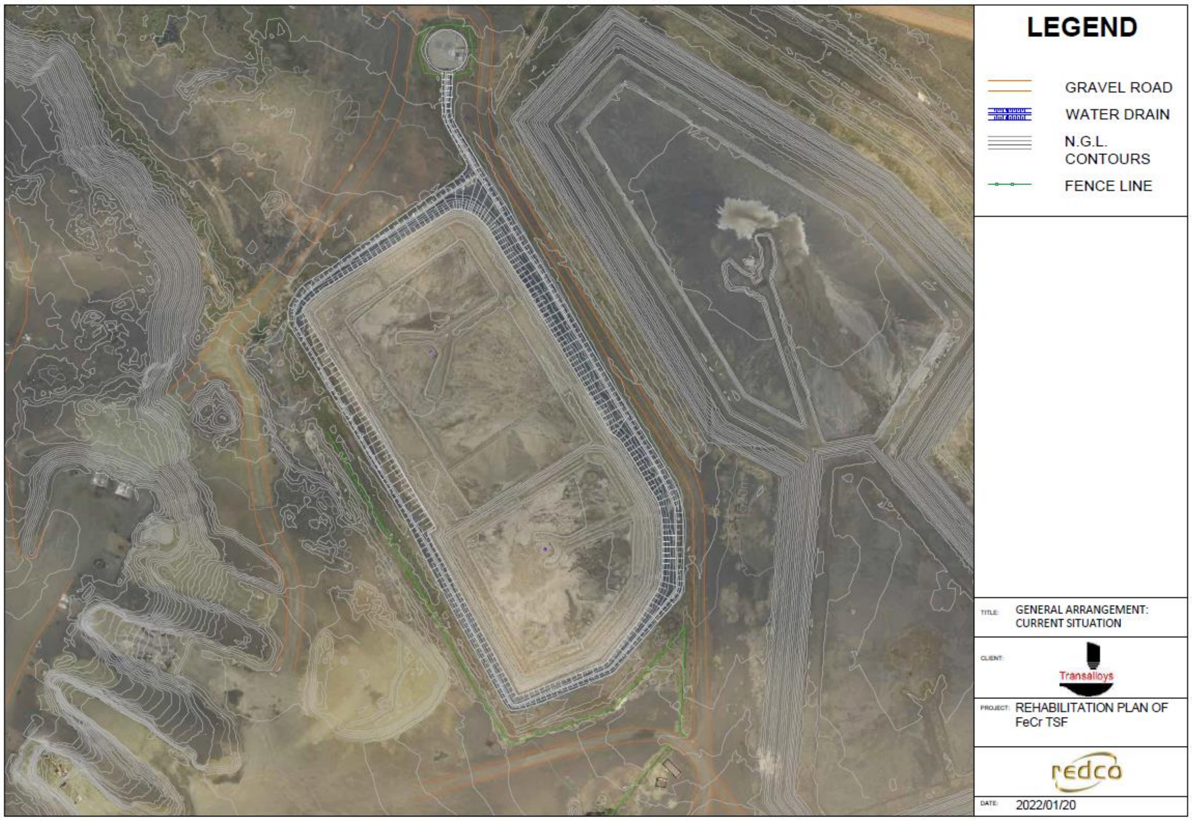


Figure 14:FeCr Facility Tailings Storage Facility – Current Situation

5 CAPPING AND CLOSURE DESIGN

The capping and closure design incorporate the following aspects:

- Final landform
- Slope Stability
- Capping Design
  - Cover layer
  - Geosynthetics
  - Topsoil
  - Erosion Control
- Water and Effluent Management
  - Penstock decommissioning
  - Under drains
  - Surface water management
- Vegetation

5.1 Final Landform

The rehabilitation of the FeCr facility will involve reshaping of the slopes and top area covering the existing lined drain. The top of the FeCr facility will be filled to create a sloped surface towards the west. The top area will slope at a gradient of 5% and 11% for the North and South sections respectively. This will allow free draining of surface water run-off to the new peripheral collector drain. The eastern slope will have gradient of 20 %. The entire reshaped dump including the new toe drain will be covered with topsoil and vegetation to reduce erosion and create a long term free draining landscape. The reshaping of the existing waste will cover the exiting HDPE lined peripheral drain but will remain within the HDPE lined boundaries of the facility. See Figure 15.

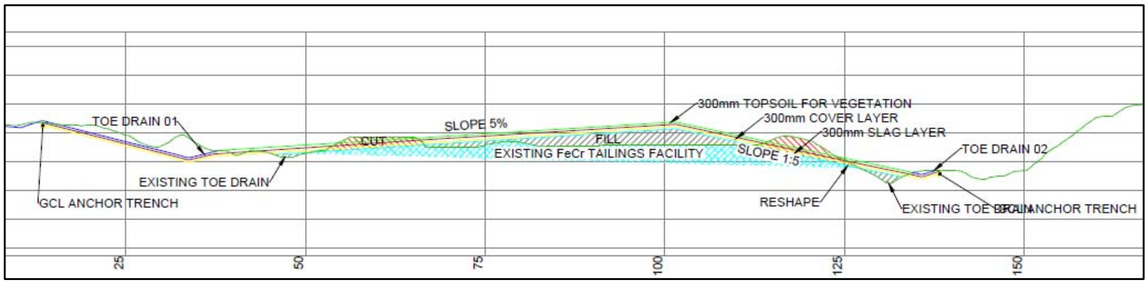


Figure 15: Section of reshaped FeCr facility

5.2 Slope Stability

The result and technical information from a Geotechnical report (Phase 1) compiled by Knight Piesold Consulting, conducted in 2017 for the development of a proposed power station and ash dump facilities were used to determine whether the material in these areas could be suitable for use for the capping layers of the FeCr facility. Although the initial intention for the report was not for the search for borrow pits but for the suitability of the site for the construction of a power station. The investigation included the sourcing of suitable materials for the construction of platforms and embankments.

The information however could be analysed to determine whether a borrow pit for the material required for the closure of the FeCr facility could be identified.

The results of the Geotechnical study were evaluated in relation to the soil required for the capping of the FeCr facility and concluded that the most suitable site would be site 1. The samples at site 1 (one) were taken at various location. (See Figure 16).

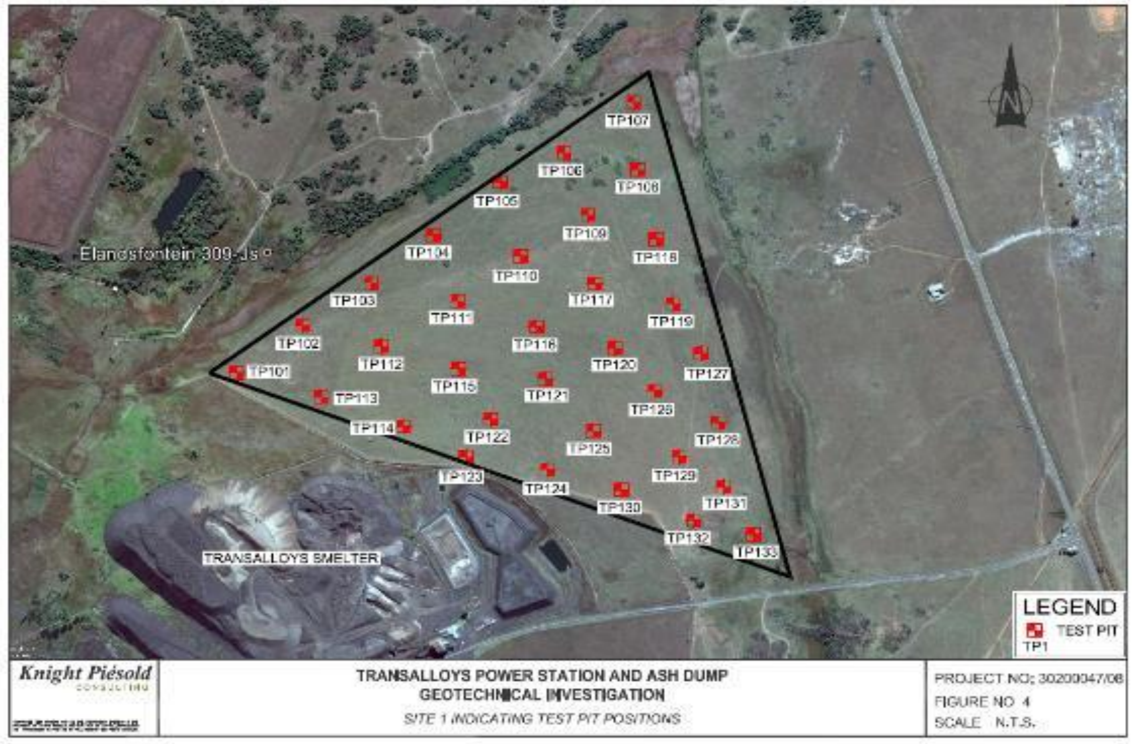


Figure 16: Phase 1: Geotechnical Soil investigation - Sample locations

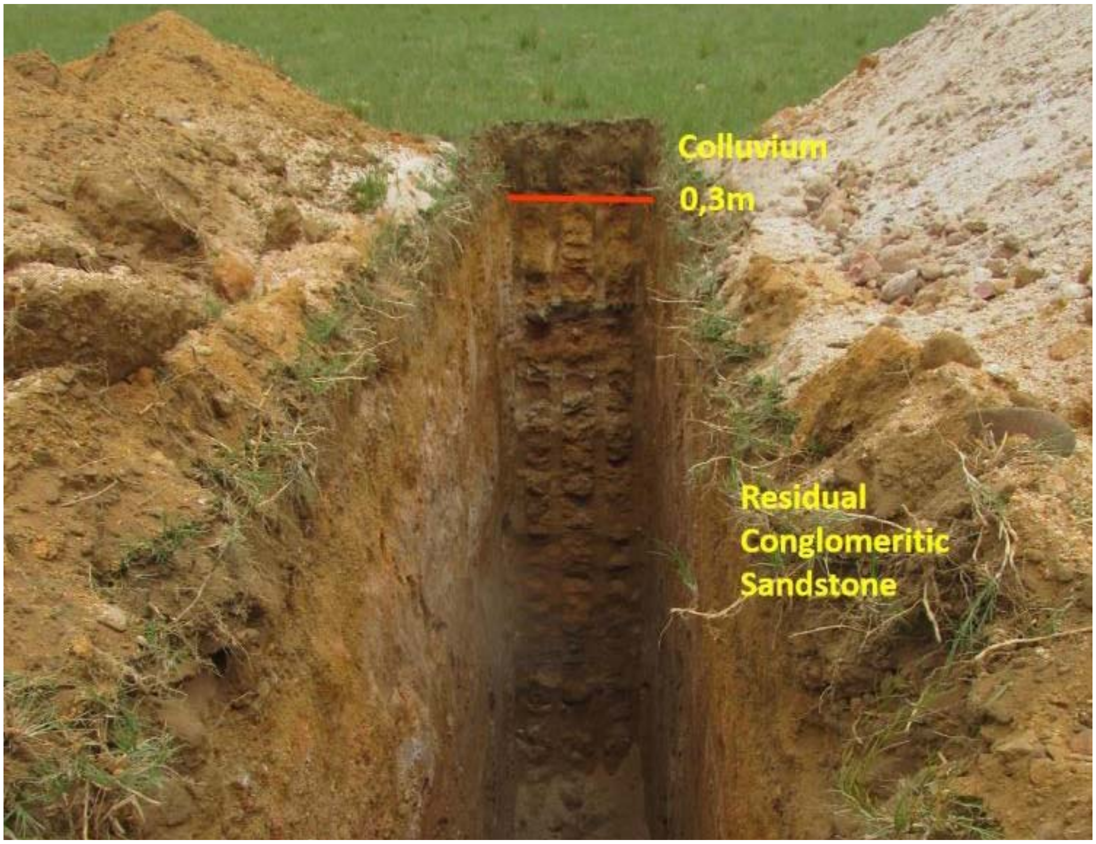


Figure 17: Test Pit profile TP117

Figure 18: Spoil from the residual shale TP107

To determine the most likely foundation properties the geotechnical test results stated in the Phase 1 Geotechnical Investigation Report conducted by Knight Piesold were used for determining the likely foundation material properties below the FeCr facility and are summarized below.

Laboratory results (Standard Proctor, CU Triaxial tests and permeability tests) were commissioned on the FeCr facility material and the results required for the analysis are summarised in Table 7 below. The laboratory results of the triaxial testing provided indicated that the material have no effective cohesion which is highly unlikely. The USBR (Bureau of Reclamation, 1987) provide a value for cohesion for similar classification of SM type of material of 45kPa. A value of 3 kPa is adopted. A more accurate estimation is not necessary as the FoS is already satisfactory.

Table 7: Summary of Geotechnical soil test results

Material	Internal effective friction angle Phi °	Cohesion [kPa]	Material Passing 5 mm %
Tailings Material	43.2 °	3. kPa	97
Foundation Material	36.5 °	5 kPa	52

Table 8: Unit weight of materials

		λw	G	S	e	λw
		Unit weight of water	Specific Gravity	Degree of Saturation	Void Ratio	Soil Unit Weight
Test pit	Test	kN/m^3				kN/m^3
TP114	1	10	2.638	0.505	0.612	18.3
	2	10	2.638	0.495	0.609	18.3
	3	10	2.638	0.470	0.591	18.3
	Average	10	2.640	0.490	0.600	18.3
TP155	1	10	2.567	0.421	0.675	17
	2	10	2.567	0.427	0.678	17
	3	10	2.567	0.410	0.670	17
	Average	10	2.567	0.420	0.670	17
Tailings	1	10	2.175	0.54	0.999	13.6
	2	10	2.175	0.50	0.907	13.8
	3	10	2.175	0.55	0.894	14.1
	Average	10	2.175	0.53	0.93	13.8

The slope stability was calculated for the worst-case scenario which would be the 1V:5H slope located at the South East corner of the rehabilitated FeCr facility.

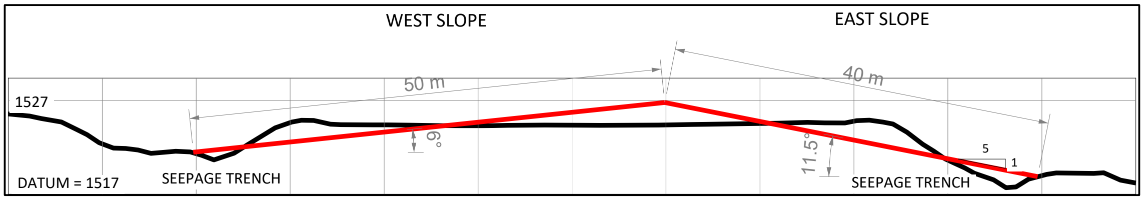


Figure 19: Cross Section of Rehabilitated FeCr Facility

The model was done using software from Geostudio, Slope/W a 2D analysis, 2018 version with the following parameters:

- Morgenstern-Price analysis,
- Half-Sine function,
- Entry and Exit determination by placement method,
- Minimum slip surface depth of 1m,
- 150 slices to evaluate,
- 100 iterations.

The Seismic hazard map as presented by Esterhuyse et al 2014, indicate that the expected ground acceleration with a 10% probability of being exceeded in a 50 year period east of Pretoria is below 0.128. However, for this project 0.128 was used in the stability analysis.

For the current analysis, it was assumed that no pore pressure will be in the FeCr facility as it has been out of operation since 2010. The dryness and hardness of the material was observed during the site inspection and investigation, with very little outflow from the underdrainage pipes observed. (See Figure 20).

Figure 20: Minor seepage observed from Underdrainage pipes

The British Columbia Mine Waste Rock Pile Committee published guidelines for the design of WRD and provided guideline FoS *(Piteau Associates Engineering Ltd, 1991)*. These factors of safety are shown in Table 9 below.

The factor of safety is determined through the forces causing failure and forces opposing failure. A probability can be linked to these factors of safety. It is accepted that if the stability analysis does adhere to the FoS, the probability of occurrence are considered to be acceptably low.

This project provided laboratory results for relevant materials and the Safety Evaluation of the FeCr facility. According to SANS 10286, the facility is a Low Hazard Classification. It is therefore proposed that the FoS for a Case B situation is accepted, although the stability FoS adhere to a Class A as well.

Table 9: Acceptable Factors of Safety

Stability Condition	**Suggested Minimum design values for factors of safety**	
Stability of dump surface	**Case A**	**Case B**
Short term (during construction)	1	1
Long term (reclamation – abandonment)	1.2	1.1
Overall stability (Deep seated stability)	**Case A**	**Case B**
Short term (Static)	1.3 – 1.5	1.1 – 1.3
Long term (Static)	1.5	1.3
Pseudo-static (earthquake)	1.1 – 1.3	1
Case A: - **Low level of confidence in critical analysis parameters** - **Possibly unconservative interpretation of conditions, assumptions** - **Severe consequence of failure** - **Simplified stability analysis method (charts, simplified method of slices** - **Stability analysis method poorly simulates physical conditions** - **Poor understanding of potential failure mechanism(s)**		
Case B: - **High level of confidence in critical analysis parameters** - **Conservative interpretation of conditions, assumptions** - **Minimal consequence of failure** - **Rigorous stability analysis method** - **Stability analysis method simulates physical conditions** - **High level of confidence in critical failure mechanism (s)**		

Table 10: Summary of FoS stability results (Long term Case B)

Section	**Position for FoS**	**FoS Calculated**	**FoS required**	**Seismic FoS Calculated**	**Seismic FoS required**
	Single Slope; Right	5.5	1.3	3.3	1

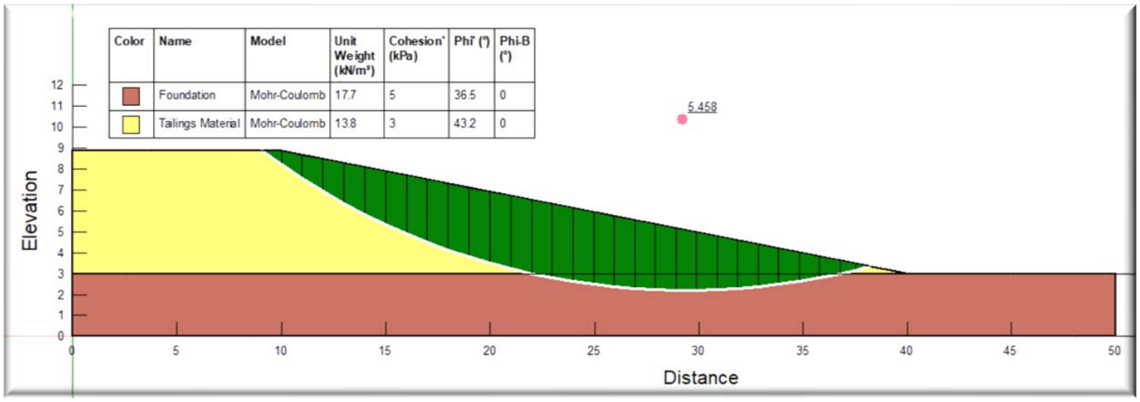


Figure 21: Single Slope, Case B, Long term static

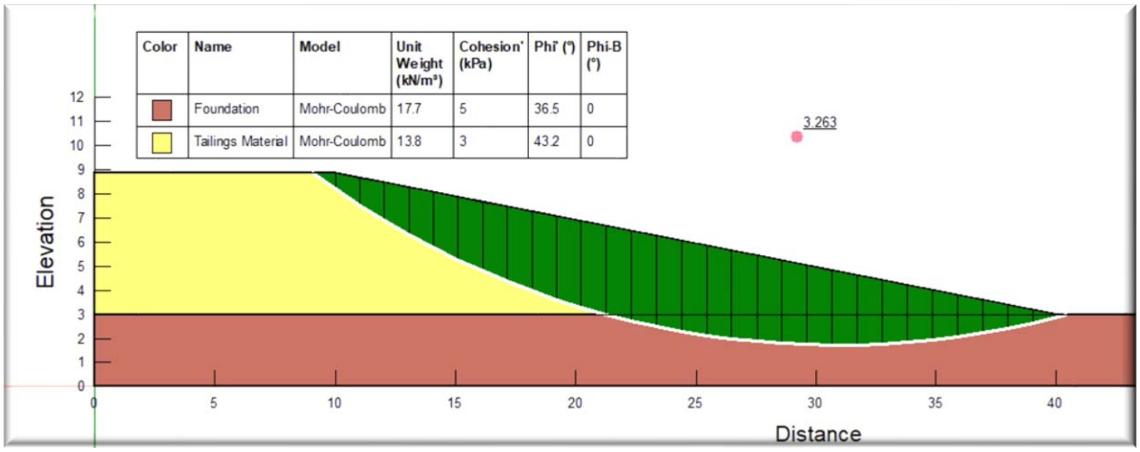


Figure 22: Single Slope, Case B, Pseudo Static

5.2.1 Veneer Slope Stability – Interface Shear Strength

The interface shear strength between the GCL and the soil layers below and above is critical. The interface shear strength is calculated on the maximum roll length of the GCL between anchor trenches which is 30 m. Table 11 indicate the calculated safety factor for the interface shear strength of the GCL, the input values of the GCL and cover material to determine the Factor of Safety.

Table 11: Input and calculated FoS of Interface shear of GCL

Description	Value
Density of cover material	17.00 kN/m^3
Depth of cover material	0.6 m
Maximum length of slope between anchors	40 m
Angle of slope	11°
Friction angle of fill material	36.5°
Internal friction of X800 GCL	25°
Cohesion factor	0
Calculated factor of safety	2.93

The calculated factor of safety exceeds the target FOS of 1.5 and therefore a Geosysnthetic clay liner is acceptable provided it complies with the material specifications as set out in Section 5.3.2, for use as an impermeable layer for the capping of the FeCr facility.

5.3 Capping Design

The proposed capping design developed for the FeCr facility (Figure 23) is commensurate with the requirements for capping design according to the Minimum Requirements for Waste Disposal for Landfill as depicted in Figure 12 (2nd Ed., DWAF, 1998).

Based on the assessment of all the site factors, a proposed closure and capping design for the FeCr facility was developed to include the following basic features:

- Sealing / demolition of existing penstocks
- Reshaping of the current waste will cover the existing HDPE lined drain but will remain within the lined boundary.
- The top of the north and south areas will be reshaped to 5% and 11 % respectively whereas the eastern side will be reshaped to a slope of 1V:5H to create a free draining surface.
- Importing and placing of a 300 mm Mn Slag layer over the reshaped material to act as capillary break layer between the material and the GCL;
- Installation of an Geosynthetic Clay Layer (GCL) to function as an impermeable layer preventing ingress of storm water into the rehabilitated FeCr facility;
- Importing and placing of 300 mm compacted soil layer over the installed GCL. The primary function is to ensure confined pressure on the GCL and not to act as an impermeable layer;
- 300 mm growth medium (topsoil) layer partially mixed with coarser material to reduce erodibility;
- Establish indigenous vegetation (not deep-rooted species, i.e. grasses); and
- Installation of storm water management and drainage infrastructure.

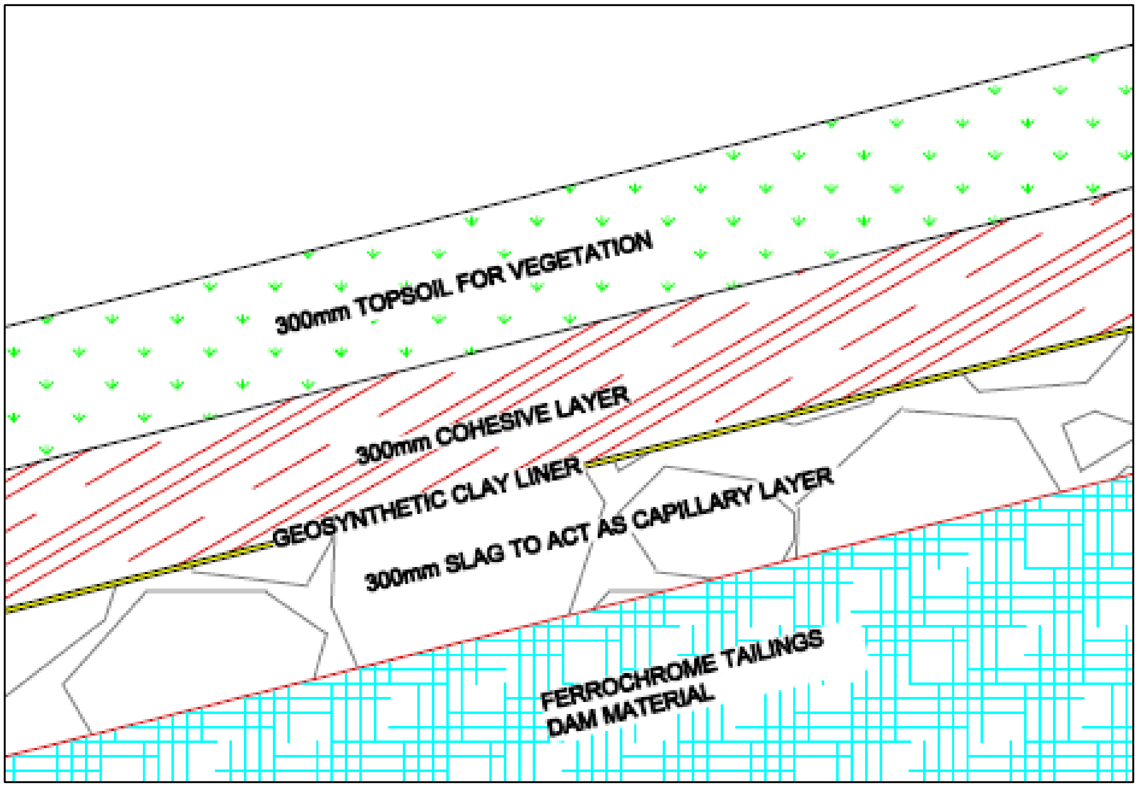


Figure 23: Capping design for FeCr Facility TSF closure

5.3.1 Permeability

The GCL selected for the capping layer has a stated hydraulic conductivity of < 2.56 x 10^{-11} m/s. In addition, the results of the constant head permeability test conducted by Knight Piesold, 2017, in the Geotechnical report on the soil layers between 0.6 and 3.2 m indicated a hydraulic conductivity of

1.17×10^{-09} m/s. This would indicate that the relatively low permeability of the cover material placed over the GCL would greatly reduce the volume of the ingress of run-off / recharge infiltrating/penetrating up to the GCL in the final installed capping, especially along the slopes. The closure design for the FeCr facility requires the dump to be reshaped to eliminate a flat top area where rain water could potentially accumulate with the resulting increased hydraulic head caused by standing water. The top of the facility will be reshaped to a slope of 5 % and 11 % for the Northern and Southern dump respectively, to drain water from the top from the east to the west where the stormwater/clean water will be collected in an earth drain running along the west side and north side of the dump. The slopes on the east side will be reshaped to a slope of 20% (1V:5H) and run-off will be collected in an earth drain running along the east side of the facility.

The leakage through GCL's can be calculated through Darcy's Law.

$Q = kiA$

Q = Flow (m^3/s)

k = Permeability of GCL (m/s)

i = head of water (m)

A = Area (m^2)

The GCL on the capping is not a water retaining structure and therefore the worst case would be 105 mm water depth for a 100 year flood and a concentration time of 41 minutes. The permeability of GCL is 2.56×10^{-11} m/s and the area is 10000 m^2. The leakage rate therefore can be calculated as follows:

$Q = 2.56 \times 10^{-11} \times 0.105 \text{ m} \times 10000$

$Q = 2.688 \times 10^{-8} \text{ m}^3/\text{s}$

$Q = 2.688 \times 10^{-5} \text{ l/s/ha}$

$Q = 2.3224 \text{ l/ha/day}$

The Technical Advisory Practice Note: Capping Closure of Waste Management Facilities and Pollution Point Sources recommends that percolation through the capping system be restricted to less than 15 ℓ/ha/day for non-infiltration caps.

5.3.2 Geosynthetic Clay Liner Material Specifications

This specification covers the work involved in the geosynthetic component for the capping of the facility and must be read in conjunction with the following specifications

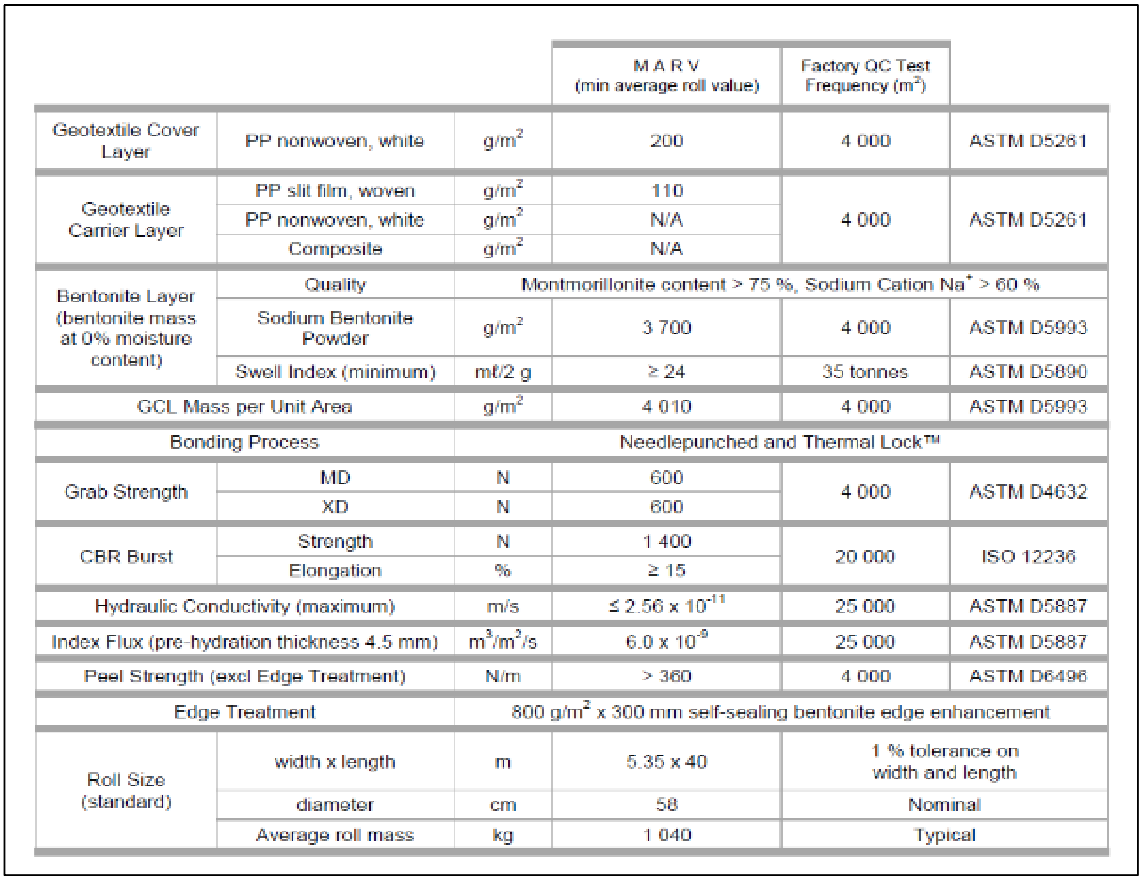
- GRI GCL3 – Standard Specification for "Test Methods, Required Properties, and Testing Frequencies of Geosynthetic Clay Liners (GCLs)"

The GCL shall be a needle-punched Geosynthetic Clay Liner (or GCL) produced in South Africa in accordance with the ISO 9001:2008 Quality Management Systems. In addition, the GCL shall carry the CE marking which serves to ensure that the products are manufactured in compliance with the applicable European directives for specific functions.

The GCL shall consist of natural sodium bentonite powder, which acts as the swelling and sealing component, embedded and sandwiched between two or more geotextiles. The composite is then needle-punched through all layers developing high connection strength.

The GCL must meet or exceed the specifications as set out in Table 12.below.

Table 12: GCL Material Specifications



			M A R V (min average roll value)	Factory QC Test Frequency (m^2)	
Geotextile Cover Layer	PP nonwoven, white	g/m^2	200	4 000	ASTM D5261
Geotextile Carrier Layer	PP slit film, woven	g/m^2	110	4 000	ASTM D5261
	PP nonwoven, white	g/m^2	N/A		
	Composite	g/m^2	N/A		
Bentonite Layer (bentonite mass at 0% moisture content)	Quality	Montmorillonite content > 75 %, Sodium Cation Na^+ > 60 %			
	Sodium Bentonite Powder	g/m^2	3 700	4 000	ASTM D5993
	Swell Index (minimum)	mℓ/2 g	≥ 24	35 tonnes	ASTM D5890
GCL Mass per Unit Area		g/m^2	4 010	4 000	ASTM D5993
Bonding Process		Needlepunched and Thermal Lock™			
Grab Strength	MD	N	600	4 000	ASTM D4632
	XD	N	600		
CBR Burst	Strength	N	1 400	20 000	ISO 12236
	Elongation	%	≥ 15		
Hydraulic Conductivity (maximum)		m/s	$\leq 2.56 \times 10^{-11}$	25 000	ASTM D5887
Index Flux (pre-hydration thickness 4.5 mm)		$m^3/m^2/s$	6.0×10^{-9}	25 000	ASTM D5887
Peel Strength (excl Edge Treatment)		N/m	> 360	4 000	ASTM D6496
Edge Treatment		800 g/m^2 x 300 mm self-sealing bentonite edge enhancement			
Roll Size (standard)	width x length	m	5.35 x 40	1 % tolerance on width and length	
	diameter	cm	58	Nominal	
	Average roll mass	kg	1 040	Typical	

5.3.3 Service Life of GCL

The GCL once covered will not be exposed to UV, therefore the risk of UV breakdown of the Geosynthetic component of the GCL is eliminated. It is however critical to ensure that a minimum of 300 mm soil (6 kN/m2) is placed over the installed GCL to ensure sufficient confined pressure. In order to ensure that long term creep is eliminated, it is advised that a minimum of 450 mm thick layer be placed over the GCL. On the case of the closure for the FeCr facility the following apply:

- 300 mm compacted soil layer to ensure confined pressure.
- 300 mm growth medium.

In a paper presented by Kent P. Von Maubeuge and John Coulson (NAUE) and Falk Hedrich (Engineered Linings) relating to landfill cap design with Geosynthetic Clay Liners, test were conducted and presented on the life-time prediction of GCL's. To determine the life-time prediction of GCL's; it is important to understand the life-time prediction of the reinforcement in GCL's since shear resistance is used for the design on slopes. Two possible failure mechanisms for the reinforcement are:

- Creep rupture
- Oxidation

Research was done by Bundesanstalt für Materialforschung (BAM) and Texas Research Institute (TRI). The experiments were conducted with a 50 kPa superimposed loads at an incline of 1V:2.5 H slopes in 80° C hot water. The test results, based on the widely promulgated Arrhenius extrapolation, has exceeded the minimum functional lifetime of 200 years and was estimated to last for 400 years at 15°C ambient temperature.

The second test conducted by the TRI involved using Arrhenius extrapolation methods to determine the oxidation rate of the fibres in GCL's. The test specimens were exposed in forced-air ovens at temperatures of 100°C, 90°C, 80°C, and 70°C. All tests were done until failure and the maximum load and strain were recorded. The general accepted requirement was that the tested geotextile should maintain over 50 % of its strength when exposed to the tested condition. The test data were used to extrapolate THOMAS (2005) and it was found that when the textiles were continuously exposed to fresh air in a high air-flow environment, the predicted life-time would be 17.8 years at 15°C. This however is not applicable in buried applications. It was concluded that in buried applications with only 8% oxidation the predicted life-time would actually be 373 years.

These results from the two independent studies clearly show the long-term performance of GCL's which will exceed 200 years.

5.4 Storm Water Management

Water management of the run-off from the rehabilitated FeCr facility will be managed through two peripheral drains conveying water around the reshaped dump. The watershed line is located the South-west corner of the rehabilitated facility. Run-off from the top will be collected in an earth drain, Drain 1, running along the west side and north side of the rehabilitated facility. Run-off is considered clean and will be discharged at the North-east corner of the facility.

The East and South run-off will be conveyed via an earth drain, drain 2, along the South and East side of the facility and will intersect drain 1 and discharge at the North- east corner. Run-off will be conveyed via two earth drains (Drain 1 and Drain 2). Runoff from the rehabilitated FeCr facility can be regarded as clean and can therefore be discharged to the receiving environment. (See Figure 24).

In order to continue monitoring, the discharge from the underdrainage system at the discharge pipes currently located through the HDPE lined starter wall will be extended and discharge into a HDPE half pipe which will convey dirty water to the existing FeCr Facility PCD. Once no seepage is visible, the drainage pipe will be closed and no dirty water is expected to be discharged from the facility.

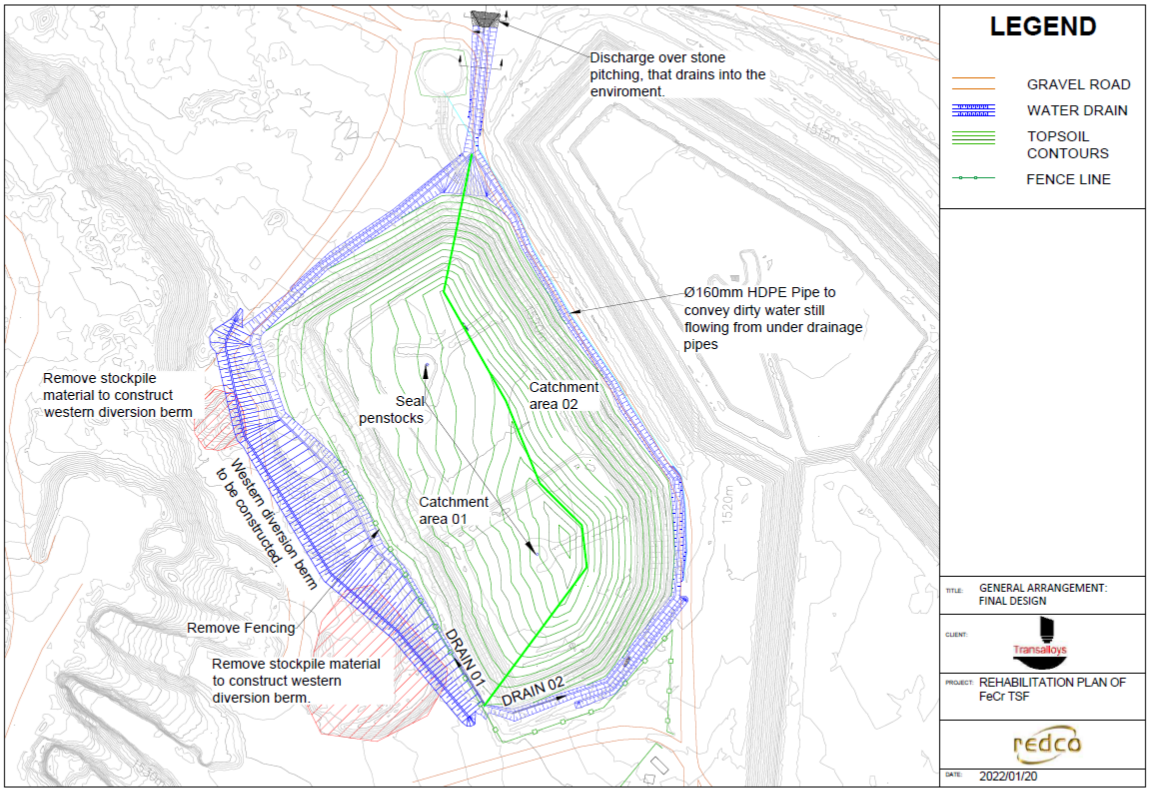


Figure 24: Reshaped dump with toe drain and catchment area for each drain

An earth berm is to be constructed at the top of the slope along the West side of the FeCr facility to direct run-off from the current slag facility, located to the west of the facility, away from the FeCr facility towards the North. The run-off will flow into the natural waterway on the North side of the FeCr facility.

The run-off is calculated based on the rational method using the parameters summarised in Table 13.

Table 13: Run-off Calculation Values

Criteria / parameter	Value
Mean Annual Precipitation (mm)	687
Design Return Period (Years)	100
Rainfall Region	Inland
Dump Slope	Eastern Slope 11°, 5 % and 11% West side
Drain Slope	Average 2.5 %
Hydraulic Soil Class on slope	C
Hydraulic soil Class in Drain	C
Vegetation/ Land use	Grass Veld

Table 14: Summary of Roughness Coefficient of drains

Material type	Coarse gravel (Slag)	n_0	0.028
Degree of unevenness	Average	n_1	0.010
Variation in cross section	Little	n_2	0.005
Influence of obstructions	Little	n_3	0.010
Vegetation	Medium	n_4	0.025
Degree of curvature	Little	n_5	1
Combined Manning roughness coefficient		n	0.070

The typical section of the drain used for the calculation of the velocity and flow depth can be seen in Figure 25.

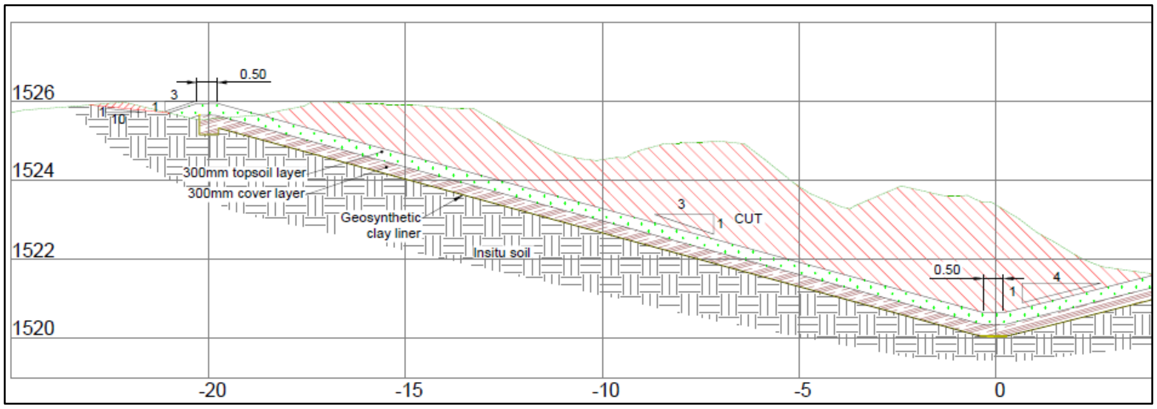


Figure 25: Typical section of Drain 1 taken on Western side of facility

The internal side slope of drain 2 on the east side of the facility is 1V:5H. It is a continuation of the reshaped and capping slope of the facility. The internal slope however of drain 1 on the west side of the facility is 1V:4H. The drain and outer berm are lined with a 300 mm thick topsoil layer. The calculated flow and velocities in the drains are summarised in Table 15 below.

Table 15: Calculated flow rates and velocities

Parameter		Area Q1	Area Q2
Peak flood	**[m³/s]**	0.199	0.118
Manning roughness	**[n]**	0.070	0.070
Flow depth	**[m]**	0.260	0.190
Velocity (Avg Slope2 %)	**[m/s]**	0.5	0.5
Velocity (Max slope of 3.1 %)	**(m/s)**	0.6	0.6
Froude Number		0.40	0.44

The drain will be covered with a vegetated topsoil cover layer to prevent erosion. Based on the permissible velocities as indicated in the Drainage Manual – 5th Edition – Table 5.6 for Mean Annual Rainfall of between 600 and 700 mm, the permissible flow velocities range from 0.6 to 0.8 m/s. The calculated flow velocities in Drain 1 and 2 is lower than the permissible flow velocities for clay content less than 6 % and therefore no erosion in the drains is expected.

5.4.1 Topsoil

As part of the layer works, the long-term stability of the capping layer was evaluated by determining the soil quality and erosion potential of the capping layer. Based on the Geotechnical Report, Site 1 was identified as the most suitable area to obtain cover soil. This can be suitable for erosion protection and vegetation growth. Seven (7) test pits were excavated to an approximate depth of 1.2 meters. Three (3) samples per test pit was taken representing the various layers identified in each location.

The samples taken at the following depths were tested as a representative sample:

- 0-300 mm depth
- 300-600 mm depth
- 600 mm deeper

The test conducted on the samples were:

- Sand, silt and clay
- Ammonia Acetate
- Saturated Water paste extract

Figure 26: Topsoil sample locality plan

Figure 27: Topsoil sample locations

5.4.2 Erosion Control

The erosion modelling was based on the following parameters (Table 16):

-

Table 16:Parameters for Soil erosion modelling

Parameter	Slope West	Slope East
Average Slope Length (m)	60	40
Predominant Slope Gradient (°)	3	12
Hydrological Soil Class	C	C
Vegetation Type	Grassveld	Grassveld
Vegetation Condition	Fair	Fair
Curve Number (CN-II	79	79
Rainfall Distribution Type	3	3

The SCS method was used to determine the runoff and peak flow rates:

The design rainfall depths that were used for the determination of runoff depth (mm) and peak flow rates (m^3/s) were obtained from an earlier flood line study (SRK Consulting (South Africa) (Pty) Ltd, July 2014) and are based on the long term daily rainfall records from the nearest weather station (Clewer weather Station - 0515234_W) (see Table 17).

Table 17: 24 h Rainfall Depth (mm)

Frequency of Occurrence	1:5	1:10	1:50	1:100
24h Rainfall Depth (mm)	75	89	122	138

The properties of the soils that are available for capping the facility and to provide a suitable growth medium was obtained from an earlier geotechnical study for the area just north of the facility (Knight Piesold Consulting, January 2017). The particle size distribution (PSD) is illustrated in Figure 28 and some of the properties summarised in Table 18 together with the values for the soil erodibility factor (K).

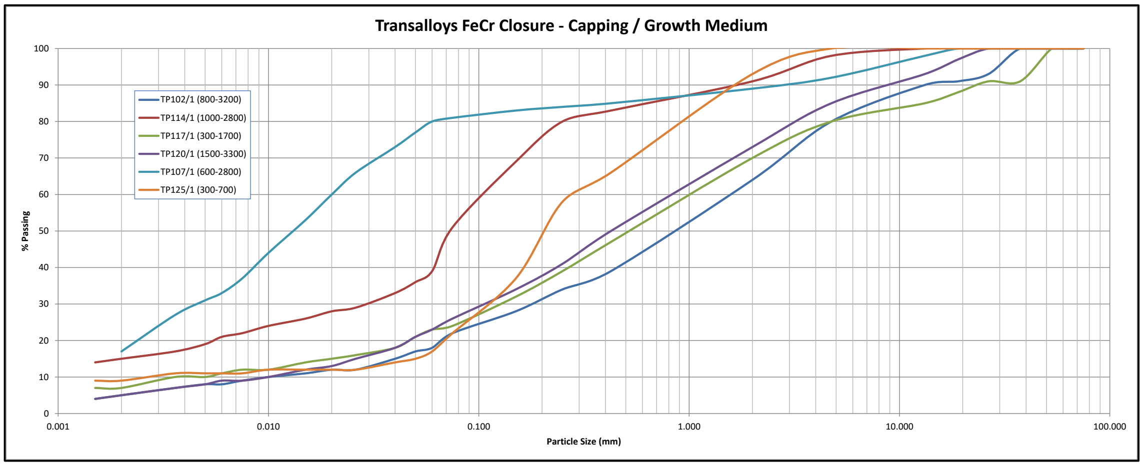


Figure 28: Particle Size Distribution of soil samples

Table 18: Soil Properties and Soil Erodibility Factor (K)

Property	Unit	TP102/1	TP114/1	TP117/1	TP120/1	TP107/1	TP125/1
Depth	mm	800-3200	1000-2800	300-1700	1500-3300	600-2800	300-700
Classification	-	Silty Sand (SC)	Clayey Sand (CL)	Silty Sand (SC)	Silty Sand (SM-SC)	Silty Clay (ML-CL)	Sand (SC)
PRA Classification	-	A-2-4(0)	A-4(3)	A-2-4(0)	A-2-4(0)	A-4(8)	A-2-4(0)
Activity	-	0.6	0.47	0.57	0.8	0.35	0.22
Heave	-	Low	Low	Low	Low	Low	Low
Clay Content	%	5	15	7	5	17	9
PI (whole sample)	-	3	7	4	4	6	2
Geometric average size	mm	0.61	0.06	0.46	0.38	0.02	0.18
K	-	0.082	0.372	0.102	0.120	0.439	0.208

Note:

- Some of the above materials will be used as growth medium together with a portion of the identified topsoil layer from the proposed borrow pit, because some topsoil must remain to rehabilitate the borrow pit;
- The above materials were also analysed for soil fertility and can be used as growth medium with appropriate amelioration as indicated in Section 5.6.3.

The estimated soil loss was based on the Modified Universal Soil Loss Equation (MUSLE) and the results for the two slopes analysed are indicated in Table 19

$$Y = \alpha.(Q.q_p)^{\beta}.K.LS.C.P$$

Where *Y = sediment yield in ton for the specific rainfall event*

α = MUSLE coefficient = 8.934

β = MUSLE coefficient = 0.56

Q = runoff volume for the specific rainfall event (m)

q_p *= peak flow rate for the specific rainfall event (m/s)*

K = erodibility of the material;

LS = slope length and gradient factor

C = cover and management factor

P = support factor

The FeCr facility will be reshaped to be free draining in total with the western slope of the southern compartment having a design gradient of 6° (11% or 1:9.5) and a slope length of up to 50 m as shown in Figure 29. The eastern slope will have a gradient of 11.5° (20% or 1:5) and a slope length of up to 40 m. The slopes of the northern compartment will have lower gradients and slope lengths due to the lower height.

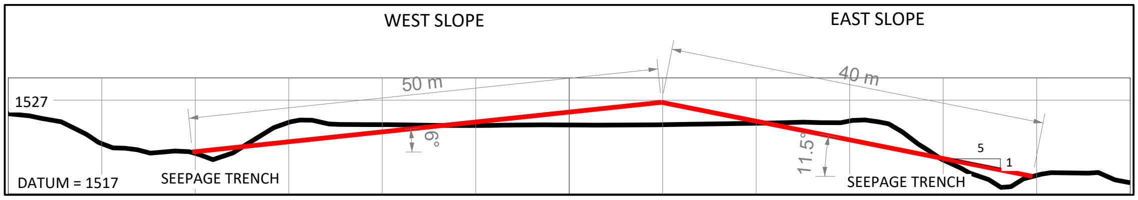


Figure 29: Typical section showing reshaping on southern compartment

Table 19: Sediment Yield (ton/ha/year)

Slope	TP102/1	TP114/1	TP117/1	TP120/1	TP107/1	TP125/1
West (S=12%; L=60m)	2.1	9.7	2.7	3.1	11.4	5.4
East (S=20%; L=40m)	4.0	13.9	4.9	5.7	13.9	10.0

The results indicate that the soil loss on the steeper slope is considerably higher than on the flatter slope. Ideally the soil loss should be limited to < 5 ton/ha/year for long term stability. Material similar to test pit TP107/1 and TP114/1 should be avoided as single surface layer on both slopes, unless it is mixed with some of the other coarser material. Material similar to test pits TP114/1, TP107/1 and TP125/1 should not be used on the steeper slopes. The results indicate that suitable material will be available from the area that will limit erosion to acceptable levels. A pilot mixture must be tested for the correct particle size distribution before construction and then continuously during placement to ensure that an erosion resistant layer is placed.

5.5 Water and Effluent Management

5.5.1 Penstock Decommissioning

The penstocks will be decommissioned and grouted at the inlet and outlet pipes. The grouting should be done prior to the reshaping.

5.5.2 Under drains

The underdrainage pipes currently extending through the starter wall lining will be extended to beyond the stormwater drainage channel located along the east side of the FeCr facility. The extended pipes will be connected to a half pipe drain which any seepage still present will flow along the east side of the facility to the existing FeCr facility sump from where it will be transferred to operation or PCD. The seepage should be continuously monitored and seepage is expected to dry out shortly after the reshaping and cover is installed as no infiltration is expected. When seepage is no longer observed, the pipes will be cut off along the rehabilitated slope and be plugged using a cementitious grout.

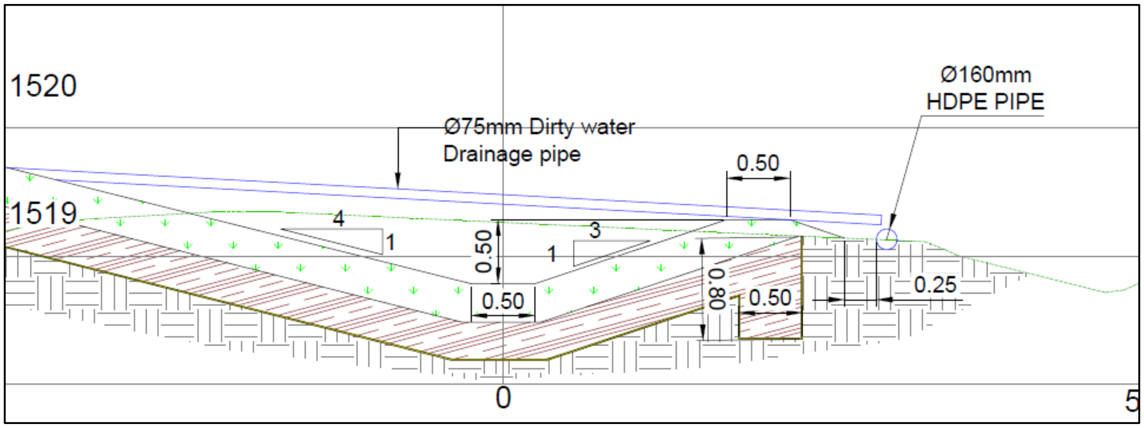


Figure 30:Typical section of East drain- note the half pipe for conveying dirty water from underdrainage pipe

5.5.3 Surface water management

Run-off from the lagoons and cooling area West of the FeCr facility, currently flowing into the lined drain along the northern side, should be channelled in a newly constructed drain to the North of the rehabilitated FeCr facility. The clean water from Drain 1 and Drain 2 will flow into Drain 3 and be discharged over a stone pitch lined discharge outlet. (See Figure 31)

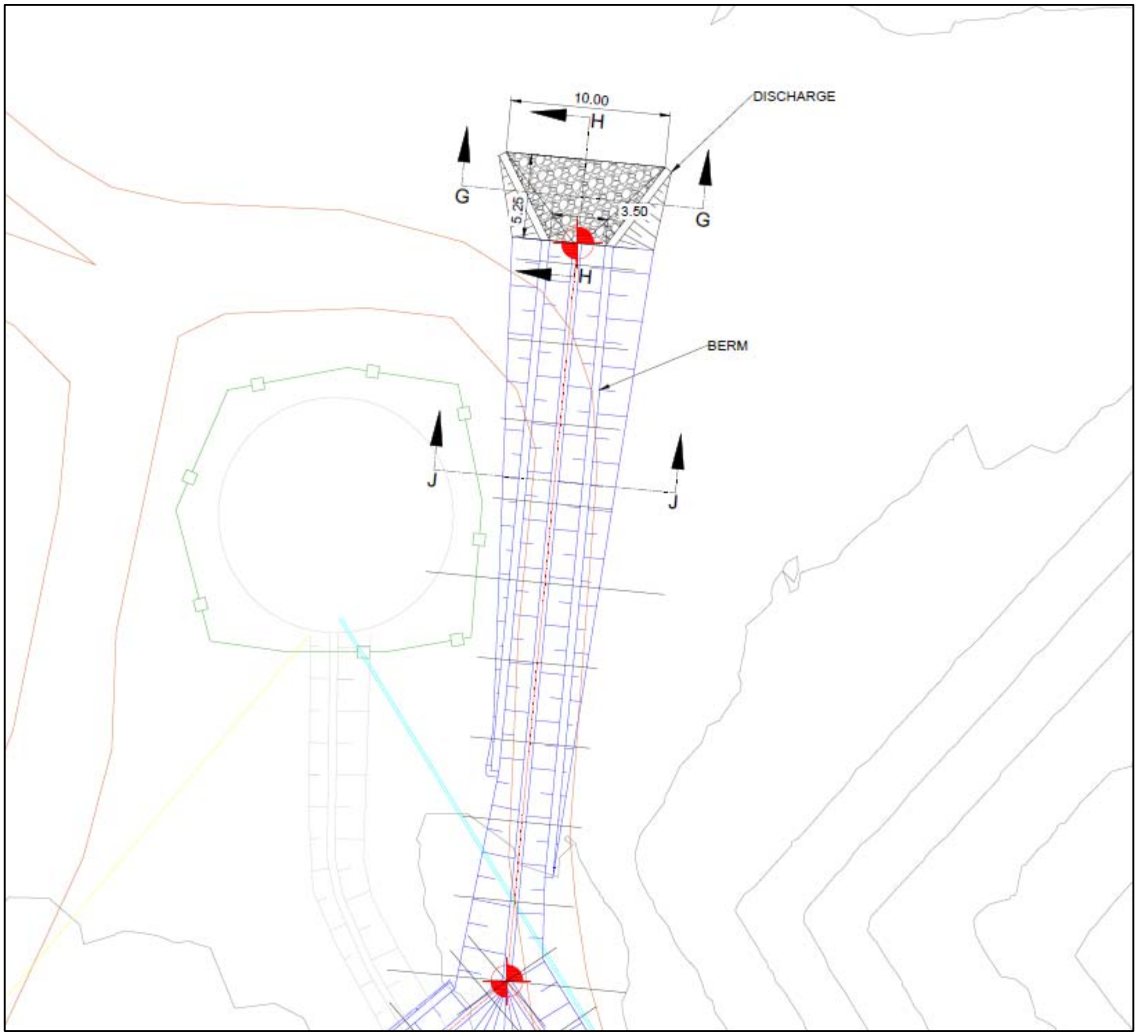


Figure 31: Drain 3 discharge into environment

5.6 Vegetation

5.6.1 Available topsoil and growth medium stockpiles

Due to a few and limited topsoil stockpiles available on site, topsoil samples were obtained from Site 1 (see section 5.4) and were evaluated for use as topsoil and cover material.

5.6.2 Soil Chemical Status and Amelioration

The results of chemical soil analysis and related amelioration recommendation indicate the following:

- Top Soil Sample 1,3 and 4: 0 – 150 mm
  - The soil pH is satisfactory and no lime application is recommended;
  - The soil salinity (EC) is low;
  - Apply 5 ton/ha compost and work into the soil to a depth of 100 mm three weeks before planting;

    - Apply 300 kg/ha 2:3:2(34) and Zn immediately before planting and work in 50 mm; and
    - Apply 200 kg/ha Limestone Ammonium Nitrate (LAN) only six weeks after planting.
- Top Soil Sample 6: 0 – 150 mm
    - The soil Ca and Mg are low. Broadcast 1.5 ton/ha dolomite lime four week before planting and work in 200 mm;
    - The soil salinity (EC) is low;
    - Apply 5 ton/ha compost and work into the soil to a depth of 100 mm three weeks before planting;
    - Apply 400 kg/ha 2:3:2(34) and Zn immediately before planting and work in 50 mm; and
    - Apply 200 kg/ha Limestone Ammonium Nitrate (LAN) only six weeks after planting.
- Soil layer 0 – 150 mm
    - The soil Ca and Mg are low. Broadcast 1.5 ton/ha dolomite lime four week before planting and work in 200 mm;
    - The soil salinity (EC) is low;
    - Apply 10 ton/ha compost and work into the soil to a depth of 100 mm three weeks before planting;
    - Apply 300 kg/ha 2:3:2(34) and Zn immediately before planting and work in 50 mm; and
    - Apply 200 kg/ha Limestone Ammonium Nitrate (LAN) only six weeks after planting.

The compost should be well decomposed and have no foul smells. The EC should be lower than 2,000 mS/m, the carbon content higher than 10 %, the C:N ratio less than 25 and the CEC higher than 15 cmol/kg.

5.6.3 Vegetation

The area must be seeded with indigenous grass species occurring naturally in the area after soil amelioration, as well as selected pioneer species that will ensure rapid establishment and habitat improvement. The seeded area to be covered with a mulch of hay made from pasture grass with brush packing to fix the mulch in place. The following species should be included in the seed mixture and seeded at a rate of 20 kg/ha:

1. Eragrostis tef
2. Melinis repens
3. Enneapogon cenchroides
4. Heteropogon contortus
5. Cynodon dactylon
6. Chloris gayana
7. Digitaria eriantha
8. Eragrostis curvula
9. Hyparrhenia hirta

Vegetation growth should be monitored on an annual basis and can be stimulated based on soil samples and the recommendation of a veld specialist. Senescence must be avoided or dead material removed by mowing based on the recommendation of an ecologist.

6 QUALITY ASSURANCE & QUALITY CONTROL

The design of a facility will yield a predicted performance for the particular suite of design criteria. However, the design alone, does not provide assurance of performance due to construction phase influences during which unforeseen circumstances may arise resulting in changes to design detail of elements of a facility, or substandard materials supplied or substandard construction of components or a combination of the above. These possible construction effects should be considered during the design phase and addressed in a construction quality assurance plan so as to minimise the risk of reduced performance and maintain the design objectives. While it is known that the operational phase may further influence the performance of a barrier system, that aspect is to be addressed in the operation and maintenance plan and confirmed by monitoring over the short and long term. The construction phase impacts are however addressed by a suite of actions planned ahead of construction and implemented so as to assure conformance and independence of the contractors self-implemented quality control.

Quality Assurance is about a plan. It is carried out before the construction project starts. Quality Assurance is a process that manages quality. QA lists the processes, standards and policies that need to be carried out and ensure they are known to the people required to know them.

The key elements of Quality Control are observation and activity. Even with the best plan and system in place (that’s what Quality Assurance does), it is still required to monitor the work as it occurs to make sure the results are what is expect them to be (Quality Control domain). Quality Control verifies the quality of the output.

The following Quality Assurance & Quality Control (QA/QC) should be implemented as a minimum during the execution of the closure and capping of the FeCr facility.

6.1 Earthworks Construction Quality Assurance

The earthworks quality assurance testing program consists of testing of soil and rock materials used during the excavation and the construction of the project’s containment capping system. Quality assurance testing and observation is required during excavation of subgrade, placement of the engineered fill, and construction of the liner system components for the containment barrier system.

All components of the construction shall be observed and tested as required by the Construction Quality Assurance (CQA). Monitor to verify that the construction is in accordance with the Project Specifications. The Design Engineer shall review the work performed by the CQA. Monitor and identify inadequate construction methodologies or materials which may adversely impact the performance of the project’s containment barrier system. Visual observations and verification of the independent survey required for specific layers throughout the construction process shall be made to evaluate whether the materials are placed to the lines and grades as shown on the Project Construction Drawings. The CQA Monitor and Design Engineer will give the Project Manager sufficient notice of anticipated completion of the construction components so that related CQA documentation may be reviewed and accepted without delay to the Contractor.

Specific CQA observation and/or testing are required for the following:

- Engineered Fill and reshaping
- Subgrade Preparation
- Anchor trench excavation and backfill
- Cohesive Soil protection layer
- Drainage Gravel
- Topsoil layer

Final excavations, reshaping and backfilled surfaces shall be constructed within the following tolerances:

- Permissible deviations from design on position (X, Y) will be 100 mm.
- Permissible deviation for Z will be 50 mm.
- Permissible deviations from design for trimming and final reshaping will be 50 mm.

Density control shall be by the sand replacement method and shall be taken at the final thickness of 300 mm to ensure that no damage occur to the GCL liner below. Use of the nuclear density meter will be subjected to the following provisions:

- The tests will not be valid if performed within 1 m of concrete structures or in material containing rocks in excess of 50 mm nominal size.
- For each 50 nuclear density meter tests a minimum of 3 corresponding sand replacement tests shall be performed.
- The accuracy of any nuclear density meter shall be proved by performing at least five comparative nuclear density and sand replacement tests on each type of soil used in the embankment before the results of the nuclear density meter will be accepted as valid.
- Thereafter the correlation between the nuclear density meter and sand replacement tests shall be reviewed on a fortnightly basis and must not vary by more than 5%.
- Proof that no damage can occur to the installed GCL layer.

Each nuclear density meter shall have a certificate provided by the supplier of the machine stating that the machine is in good working order. Each density meter shall be re-calibrated by the supplier at least once a year. Certificates of proof of re-calibration will be required.

Sand replacement created during testing are to be closed with clay material compacted into place.

The acceptance criteria for density test results for both restricted and bulk fill shall be as follows: A minimum of one Maximum Dry Density test, either modified AASHTO or Proctor as the case may be, per two production lots shall be carried out provided the material is obtained from one source and is uniform. The Engineer may instruct that more tests be carried out if material varies in quality.

In addition to the above components, the CQA Monitor and Design Engineer will observe the construction of the aggregate base surfacing (geomembrane protection layer).

6.1.1 Specifications

For Engineered Fill and Anchor Trench Backfill the CQA Monitor shall observe and document the subgrade preparation prior to placement of engineered fill and shall include:

- Monitoring the stripping of vegetated soil, and growth media to be stockpiled, if directed, in the area designated by the Owner.
- Monitoring that appropriate dust control measures are implemented.
- Visually inspecting the excavation for moisture seeps, soft or excessively wet areas, and unstable slopes.
- Monitoring subgrade preparation and confirming that the surface of the subgrade is free of soft, organic, and otherwise deleterious materials, and that the surface is firm and unyielding and in accordance with Project Specifications (e.g., compaction density or CBR).
- Verify that the subgrade is suitable for supporting any overlying geosynthetic layers as required by the Project Specifications.
- Borrow materials for engineered fill and anchor trench backfill will be obtained from the excavation area within the cell or the clay stockpile.
- CQA observation and/or testing is required during construction to verify that the materials and construction are in accordance with the Project Specifications.

Tests shall be performed on an even grid to provide adequate testing coverage.

6.1.2 Test Pad Construction Purpose and Scope

The purpose of the test pad is to establish the placement and compaction procedures to be used to construct the compacted cohesive soil liner component of the containment barrier system and to ensure conformance with the Project Specifications, and regulatory requirements. The test pad program is intended to establish methods, equipment, and procedures for attaining the specified properties, not to pre-qualify materials for the compacted clay liner. Once the methods and procedures have been verified by completing a successful test, the Contractor must use the same method and procedures to construct the compacted cohesive soil layer.

Test Pad Subgrade Preparation

- The test pad shall be in an area of the project site designated by the Project Manager
- The area within the limits of the test pad shall be cleared and grubbed of all trees, debris, stumps, and any other vegetation. After clearing and grubbing, the area shall be stripped of topsoil and/or organic materials
- The surface of the subgrade shall be proof-rolled with a heavy-wheeled vehicle to detect soft zones, irregularities that may require removal and replacement.
- The finished subgrade surface shall be sloped at a grade of 1% to 3%
- Construction of the test pad shall not commence until the condition of the subgrade has been examined and documented by the CQA Monitor

The test pad shall be constructed in a rectangular shape to a minimum plan area of 10 m by 15 m. The test pad should consist of a minimum 300mm thick compacted cohesive soil placed and compacted in accordance with the requirements of the Project Specifications. The compacted clay liner in the test pad shall be constructed in two lifts not exceeding 150 mm loose and 150 mm in compacted thickness. The soil material shall be compacted within the specified moisture-density window. If appropriate, the moisture-density window may be modified by the Design Engineer to improve permeability or constructability based on the results of the test pad.

The Design Engineer shall finalize the moisture-density compaction window in writing prior to full-scale construction of the compacted cohesive soil and inform the CQA Monitor. Only when the CQA Monitor and Design Engineer has determined that each lift meets the target dry density and moisture content requirements, shall the following lift be constructed. The completed compacted cohesive soil layer shall be sealed by rolling with appropriate equipment (e.g., rubber tired or smooth drum roller).

Overbuilding the test pad and trimming back may be necessary to obtain a sufficiently smooth top of cohesive soil surface and to protect the test pad from desiccation and cracking.

The CQA Monitor shall monitor and document the borrow material and construction of each lift of the test pad and shall ensure that construction is performed in accordance with the appropriate sections of the Project Specifications. Monitoring and documentation shall include:

- Weather conditions during construction
- Equipment used in construction
- Manner in which equipment was used
- Soil type and classification
- Moisture content and dry density measurements for each lift
- Approximate thickness of each uncompacted and compacted soil lift

Field and laboratory testing shall be performed by the CQA Monitor, as a minimum, during construction. Upon completion of the test pad, samples shall be collected using 3-inch (76mm) outside diameter thin-walled sampling tubes (Shelby tubes) in accordance with ASTM D1587 or by the block sampling technique in accordance with ASTM D4220, at the discretion of the Design Engineer.

Two samples in each lift shall be collected to represent the compacted clay liner. Samples should be collected outside of the future location of the field scale infiltration test.

The hydraulic conductivity evaluated in the laboratory (ASTM D5084) for the 3-inch (76mm) diameter samples shall be correlated to the hydraulic conductivity evaluated in the field scale testing. Effective confining pressures of 5 psi (35 kPa) shall be applied during the test. The correlation is to provide a means for establishing criteria for laboratory and field testing of the full scale (construction) compacted cohesive soil layer. In addition, in-situ hydraulic conductivity data is to provide information demonstrating the feasibility of constructing a compacted cohesive soil layer meeting the Project Specifications.

The interpretation of the test results shall focus on the feasibility of constructing a full-scale compacted clay liner in conformance with the project and regulatory requirements. A written report summarizing the test results shall be issued by the Design Engineer to the CQA Monitor at the completion of the test pad testing program. This report shall also be included as a part of the final project CQA documentation.

- Compacted Cohesive soil layer construction Monitoring and Testing
- CQA observation and/or testing is required during construction to verify that the compacted cohesive soil layer construction is in accordance with the Project Specifications.
- The tests to be performed, including testing frequency;

Drainage Gravel/ slag layer placement

The slag is used as capillary layer below the GCL and Erosion protection layer above the cohesive soil layer. Both pre-construction and construction testing are required for these materials. Pre-construction testing consists of testing proposed materials from samples obtained at the slag dump on-site. Construction testing consists of testing performed from samples obtained during delivery of materials during the module or layer construction. The tests to be performed, including testing frequency, for each material type are:

- Grading of Slag material
- Thickness of Capillary layer
- Thickness of Erosion protection layer over Cohesive soil layer.

6.1.3 Surveying

Surveying shall be conducted such that all applicable standards are followed. The Surveyor shall furnish "Record Drawings" (also referred to as "as-built" drawings) for review by the Design Engineer. The CQA Monitor shall also review and approve the drawings prior to placement of a new system component over the work. Required Record Drawings shall be as specified in the Project Specifications. All surveying shall be performed under the direction of a registered surveyor. All Record Drawings shall be signed and certified by the registered surveyor who directed the CQA survey work. Record Drawings shall be at a scale not smaller than 1:1000 scale. The accuracy of the surveying shall be sufficient to determine if the measurements are within the tolerances specified in the Project Specifications. The required surveying of the barrier system elevations shall be carried out on a maximum 20 m square grid. Additional survey locations shall be recorded to define the following features in the barrier system: toe of slope, crest of slope, grade breaks, ridges and valleys, anchor trench, drainage system piping, perimeter drainage ditch, and position of liner penetrations and instrumentation. The thickness of the geosynthetic barrier system components on the Project Drawings shall be interpreted as negligible. Refer to the Project Specifications for details of the minimum requirements for surveys, Record Drawings, and grades, lines, and levels.

6.2 Supply and Installation of Geosynthetic Clay liner

6.2.1 Material Specification

The GCL shall conform to the requirements as stated in GRI-GCL3 for GT-Related reinforced GCL. All GCLs shall contain natural sodium bentonite unless otherwise specified on the drawings or in the Project

The contractor shall submit documented certification that the GCL materials supplied, comply with the aforementioned specifications. This documentation for each roll to be delivered shall be submitted to the Employers Agent for approval prior to shipment of any materials to site.

The GCL are to be supplied to site in roll form with width no less than 5 m wide to minimize the number of site welds required. Each roll is to be identified with labels indicating the unique roll number, thickness, length and width and Manufacturer. Labelling should be resistant to fading and moisture degradation such that it is legible at the time of installation.

The material shall be packaged, transported, unloaded and stored in accordance with the Manufacturer's instructions.

The contractor must ensure that the off-loading equipment prior to the delivery of the material is adequate for handling the geomembrane rolls without any risk of damaging them. The storage area for the GCL must be a smooth well-drained surface, free of rocks or any other protrusions, which may damage the material.

After off-loading, the contractor shall conduct a surface observation of all rolls for defects and for damage. This inspection shall be conducted without unrolling rolls unless defects or damages are found or suspected. The contractor shall inform the Employer's Agent and the manufacturer of any defects or damages. Repairs shall be made subject to approval by the Employer's Agent; otherwise, damaged rolls shall be replaced at the contractor's cost.

6.2.2 Qualification of GCL manufacturer

Details of the Manufacturer shall be provided by the GCL Installer. The Manufacturer must demonstrate sufficient production capacity to supply product meeting the specifications within the time frame required.

The ENGINEER may request:

- A reference list of projects where the material under consideration has been used, including area installed, date of installation, and client.
- Manufacturing Quality Control manuals and related documentation

6.2.3 Manufacturing of Geosynthetic clay liner (GCL)

Manufacturing Quality Control documentation from the manufacturer of each type of GCL supplied must be submitted for approval. Submittals must be made before the materials are purchased and delivered to site. Submittals to include:

- Dates of manufacture;
- Batch numbers and roll numbers, length and width;
- Documentation of the manufacturer's specific quality control program, which shall provide test data indicating the actual test values per roll or per batch, as may be applicable as called for in GRI – GCL3.

6.2.4 Packaging, transportation, handling and storage

The products shall be packaged, transported, unloaded and stored in accordance with the manufacturer's instructions, subject to the engineer's approval, and generally in accordance with ASTM Standard D 5888, "Standard Guide for Storage and Handling of Geosynthetic Clay Liners".

All GCL rolls shall be packaged in opaque moisture and ultraviolet resistant plastic sleeves. The roll cores shall be sufficiently strong to resist collapse during transit and handling. The ENGINEER has the right to reject any roll if the core has collapsed or if the roll is damaged in any other way.

Before shipment, the manufacturer shall label each roll, both on the surface of the plastic protective sleeve and on the inside of the core. Labels shall be resistant to fading and moisture degradation to ensure legibility at the time of installation. As a minimum the roll labels shall identify the following:

- Product name, grade and manufacturer;
- Length and width of roll;
- Gross mass of roll;
- Production lot/batch number and individual roll number;
- Manufacturer's quality approval label; and
- Label with handling guidelines.

Any accessory bentonite used for sealing seams, penetrations, or repairs, shall be high-quality powdered or granular sodium bentonite from a recognized producer and must comply with the same specifications as the GCL itself, as contained in GRI-GCL3.

To transport GCL rolls, an appropriate core pipe must be used to support the weight of the roll. During transportation, a roll may not deflect by more than half its diameter.

The method of unloading and handling of GCL rolls shall be as specified below. Any deviation from these procedures shall be pre-approved by the engineer in writing.

GCLs must be supported during handling to ensure worker safety and to prevent damage to the product. Stacking should always allow easy access to at least one end of each roll for handling equipment as well as for roll identification. The construction quality assurance officer shall verify that proper handling equipment exists which does not pose any danger to installation personnel or risk of damage or deformation to the liner material itself.

Under no circumstances may the rolls be dragged, lifted from one end, lifted in the middle of the roll, lifted with only the forks of a forklift, or dropped to the ground from the delivery vehicle.

Spreader Bar Assembly: A spreader bar assembly shall include a core pipe or bar and a spreader bar beam. The core pipe shall be used to uniformly support the roll when inserted through the GCL core while the spreader bar beam will prevent chains or straps from chafing the roll edges. Lifting the rolls should be done with a sufficiently strong pipe/bar that can easily fit in the roll core. This can be accomplished with a 63mm to 75mm outside diameter steel pipe/bar, with a wall thickness capable of providing sufficient beam strength to support the weight of the roll without bending, which, depending on the GCL type, can be up to 1200kg or more.

Carpet Spike (or “stinger”): A carpet spike is a rigid pipe or rod with one end directly connected to a forklift or other handling equipment and the other end rounded off to allow easy insertion into roll material cores. If a carpet spike is used, it must be at least ¾ the width of the roll and inserted to its full length into the roll core to prevent excessive bending of the roll when lifted.

Roller Cradles: Roller cradles consist of two rollers, which both support the GCL roll and allow it to unroll freely without significant deflection.

Each roll shall be visually inspected when unloaded to determine if any packaging or material has been damaged during transit. Possible product conditions and actions are listed below:

Rolls, including the roll cores, exhibiting damage shall be marked and set aside for closer examination during installation. Minor rips or tears in the plastic packaging shall be repaired with moisture resistant tape before being placed in storage to prevent moisture damage.

- The presence of free-flowing water (more than small amount of condensate from bentonite itself) within any roll packaging shall require that the roll be set aside for further examination to ascertain the extent of any damage.
- GCL rolls delivered to the project site shall be those indicated on GCL manufacturing quality control certificates.
- Repairs to damaged GCL rolls shall be performed in accordance with PSC 5.3.6 of this specification, during installation.

The engineer reserves the right to reject any roll at any stage prior to installation should it exhibit any of the above damages or non-conformance.

Storage of the GCL rolls shall be the responsibility of the Installer party. All GCL rolls shall be stockpiled and maintained dry in a well-drained flat area away from high-traffic areas but sufficiently close to the active work area to minimize handling. Rolls should be stacked off the ground using “sleepers” of some kind.

Rolls shall not be stacked on uneven or discontinuous surfaces, in order to prevent bending, deformation, product thinning and damage to the GCL or cause difficulty during handling. GCL roll stacks shall be limited to the height at which installation personnel can safely manoeuvre the handling apparatus. Stacks or tiers of rolls must be situated in a manner that prevents sliding or rolling by chocking the bottom layer of the rolls.

An additional tarpaulin or plastic sheet shall be used over the stacked rolls to provide extra protection for GCL material stored outdoors. Bagged bentonite material shall be stored in a dry location free from the influences of weather conditions. Bags shall be stored on pallets or other suitably dry surfaces that will prevent pre-hydration.

The Contractor shall submit with his tender a detailed methods statement and project quality plan providing detail on how the installation of the geomembrane products will be completed. As a minimum the method statement must cover the following aspects: The CQC Plan shall be submitted to the engineer at least 5 days before construction commences. It shall include:

- A site staff organogram indicating authority and responsibilities
- A Method Statement detailing the CONTRACTOR’s proposed construction procedure of the specific elements of the GCL installation including activities preceding and following the installation (i.e., surface preparation and cover placement). No work related to such elements shall commence before the method statement has been submitted and agreed upon.
- A Delivery note checklist template
- Acceptance and non-conformance templates for subgrade, panel placement, seaming and repairs.
- Placement of the GCL without disturbance or causing damage to the layer being installed or any underlying layers.
- Equipment and procedures used to place the geomembrane.
- Placing of cover material (Cohesive Soil) in accordance with the Designs, on top of the GCL

The Contractor shall furnish the following information to the Employers Agent and Employer prior to installation:

- Installation layout drawings of all materials to be installed.
    - Must show proposed panel layout including seams and details.
    - Must be approved prior to installing the GCL.
- Approved drawings will be for concept only and actual panel placement will be determined by site conditions and the Installer’s Geosynthetic Field Installation Quality Control Plan.

The Contractor will submit the following to the Employers Agent upon completion of installation:

- Certificate confirming the GCL has been installed in accordance with the Contract Specifications.
- Installation warranties.
- As-built drawings showing actual GCL placement and seams including anchor trench detail.
- Material warrantee certificates from the supplier for the materials installed.

The GCL installation shall be carried out in accordance with the manufacturer's installation guidelines and specifications. The following information is highlighted and must be read in conjunction with the specification and requirements.

The GCL shall be installed by a competent CONTRACTOR. If the CONTRACTOR has no prior experience installing GCLs, adequate training should be provided by the GCL supplier to the satisfaction of the ENGINEER.

After acceptance of the CQC Plan, the CONTRACTOR shall notify the ENGINEER in writing prior to any proposed change. Proposed changes are subject to acceptance by the ENGINEER.

The personnel of the ENGINEER include:

- The CQA Officer, who may be the same person as the ENGINEER's representative;
- The ENGINEER's representative who is located at the site; and
- Any other staff or assistant who may be used on the site.

The general duties of a qualified and experienced CQA Officer are set out below.

- The CQA Officer shall review all site-specific documentation, proposed panel layouts, CONTRACTOR's GCL construction programme and methods, and the CONTRACTOR's CQC Plan and he shall attend the Site Meetings where necessary and may be required to produce a final report.

6.2.5 INSTALLATION

6.2.5.1 Subsurface Preparation

Immediately prior to installation of the GCL, the subgrade surface shall be inspected by the Employers Agent or Employers Agent Representative. The Contractor and the Lining Sub-Contractor must provide confirmation that the surface is in a condition to safely accept the GCL. The subgrade must comply with the following requirements prior to installation of the Geomembrane material:

- The area to be lined must be free of all protrusions, stones, roots, vegetation and other materials, which may be detrimental to the performance of the liner. On the surface to be lined, a maximum particle size of 10 mm diameter is permissible.
- The surface must be a smooth rolled finish and compaction must comply with the requirements as stated in the earthworks specifications and drawings.
- Compaction of the subgrade should be in accordance with project specifications, and should be carried out in such a way that wheel ruts, footprints and other abrupt grade changes are removed. As a minimum, the level of compaction should be such that installation equipment or other construction vehicles that traffic the area of deployment do not cause significant rutting.
- The final surface layer shall be left smooth and dense and finished levels shall be correct to within +50 mm as measured under a 3 m long straight edge.

The CONTRACTOR shall certify in writing that the subgrade is acceptable for the installation of the GCL. Surfaces not in compliance with the Specifications shall be rectified and be subjected to another inspection and acceptance before the GCL is deployed. The responsibility for maintenance of the accepted areas is described in the Project Specification.

6.2.5.2 Deployment

The GCL shall be installed on the approved areas as directed by the ENGINEER, using methods and procedures that ensure a minimum of handling. The orientation of the GCL, i.e., which side faces up, shall be instructed by the ENGINEER.

At no time shall GCL rolls be released and allowed to unroll freely under gravity. Damaged, faulty or suspect areas shall be marked for repair. The method used to unroll the GCL shall not damage any underlying geosynthetics or allow stones, mud, or debris to be trapped under the GCL. Care shall be taken to prevent damage to the bottom surface of the GCL when it is finally positioned across the subgrade or underlying geosynthetic.

The GCL shall be placed one panel at a time in a relaxed condition with the required overlap so that it is in intimate contact with the underlying surface at all locations and free of tension or stress upon completion of the installation. All necessary precautions, including installing extra material, shall be taken to avoid bridging of the material. Cutting and trimming of GCL placed over geomembranes shall be undertaken with other geosynthetic materials from damage that could be caused when cutting.

It is important to ensure that the GCL is not left exposed to the elements and therefore the subsequent covering activities must be co-ordinated accordingly with the GCL installation.

The CONTRACTOR shall only deploy as much GCL that can be covered in a reasonably short time in the event of precipitation or as can be covered by the end of the working day with soil cover, geomembrane, or temporary plastic sheeting.

The layout and sequence of panel placement is determined by the direction of water run-off. Panels are laid out according to previously approved panel layout drawings. Generally, the installation is started at the up-wind side and at the highest elevation so that any rainfall runs off the lower part of the impoundment, preventing pooled water from hydrating the GCL.

If unplanned premature hydration occurs the ENGINEER shall be notified. If the extent of the premature hydration is such that, when an average weight person walking over the GCL causes “toothpasting” to occur, the hydrated GCL may need to be replaced at the discretion of the ENGINEER in accordance with the requirements of section PSC 5.3.6.

The extent of the damage of the prematurely hydrated GCL section can be assessed taking the following into account:

- Separation and damage of the geotextiles
- Depth of indentations (and corresponding bentonite thinning) where it has been walked or driven on.
- The integrity of the overlaps and other bentonite enhanced seams.

A sharp utility knife should be used for cutting the GCL if required, e.g. around penetrations. Frequent blade changes are recommended to avoid damage to the geosynthetic components of the GCL during the cutting process. Removed blades should not be discarded on or under the installed GCL. Cutting should be done on an adequately sized, preferably wooden, cutting board.

6.2.5.3 Seaming

GCL seams shall be used where directed by the ENGINEER. The seam shall be created by overlapping adjacent edges and enhancing the seam as recommended by the manufacturer, or as instructed by the ENGINEER.

The overlap zone shall be kept clean and shall not be contaminated with loose soil or other debris. There shall be no folds in the overlap zone and no traffic or walking shall occur on the completed seam. No end overlaps shall be positioned in sumps or inverts.

Overlaps shall be to the ENGINEER’s requirements and shingled in the direction of anticipated water flow.

If the GCL does not incorporate a mechanism to ensure longitudinal overlap sealing overlap areas will require on site overlap bentonite sealing. Edges are pulled back and bentonite of the same source to that used in the product should be poured continuously along all seam edges. The amount of bentonite must be specified by the ENGINEER.

Horizontal seams on steep slopes (greater than 1V:6H) should be avoided. However, these may be required for long slopes, in which case the horizontal seams shall be constructed as directed by the ENGINEER.

When the GCL is cut to fit into small areas, in corners or around structures adjacent panels should be overlapped a minimum 300mm or as directed by the ENGINEER, adding abundant bentonite in overlapped areas, if the overlapped area does not cover a bentonite enhanced longitudinal edge.

6.2.5.4 Repairs

Any portion of the GCL or seam showing a defect shall be repaired. Reasons for requiring repairs to the GCL installation include, but are not limited to:

- A hole, cut, or tear
- Insufficient overlap
- Bridging
- GCL material defects
- A hard object underneath the GCL
- Unconfined and unhydrated GCL material exposure to harmful liquids during installation. This could include hydrocarbon fuels, chemicals, pesticides or non- compatible leachate, as determined by the ENGINEER.

- Premature hydration

Agreement on the appropriate repair method shall be reached between the CONTRACTOR and the ENGINEER. Repairs shall be undertaken using one or a combination of the following methods:

6.2.5.5 Patching

Patching shall be used to repair holes, cuts or tears, insufficient overlap, bridging, GCL material defects, and to remove hard objects underneath the GCL. Patching shall comprise installing a new piece of GCL of the same material type and thickness extending at least 500 mm beyond the affected area in each direction. This 500 mm area must be augmented with bentonite powder/granules or paste per the supplier’s normal jointing requirements for patches and to the ENGINEERs approval. Patch seams shall be created as described in PSC 5.3.3. Patches on slopes steeper than 1V:6H shall be minimized, and in this case the ENGINEER shall approve the location and size of such a patch. In addition to bentonite augmentation around the edge of patches on slopes steeper than 1V:6H the patch shall be temporarily secured such that it is not displaced during cover placement. Patches may be tucked under the damaged area to limit patch movement.

The GCL should always be placed against a moist soil layer to ensure adequate hydration after placement. Pre-hydration of the GCL should be considered very carefully by the ENGINEER and only used in unique project conditions, such as highly saline environments, relatively short-term applications or low-quality cover soils.

6.2.6 Testing

Immediately upon manufacture, Conformance Testing may, at the discretion of the ENGINEER, be carried out by an independent accredited laboratory (MQA laboratory). The testing frequency shall be at the discretion of the ENGINEER but the frequency shown in Table 1 (a) in GRI GCL 3 (Reinforced GCL GT related) can be used as a guideline. The ENGINEER shall approve the laboratory before any testing is done. The ENGINEER has the right to reject any roll or production batch if the samples do not pass conformance testing.

The ENGINEER may request test results produced by a certified laboratory independent of the manufacturer to verify the claimed properties, prior to approval of the product(s) offered. All MQC and CQC testing and reporting thereon are described in the GRI-GCL 3 specification.

An effective construction quality assurance plan depends largely on recognition of all construction activities that must be monitored, and on assigning responsibility for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The ENGINEER will ensure that all quality assurance requirements have been addressed and satisfied.

The Installer/CONTRACTOR is to provide the following to the ENGINEER before installation on site:

- Manufacturer’s conformance certificates.
- A drawing indicating the position and numbers of each individual panel that will be installed (Panel layout).

- A Method Statement describing the method of installation and quality control documentation to be completed.
- A Project Quality Plan with organization chart and detailing inspection procedures.

The Installer/CONTRACTOR is to complete the following:

- Material receipt with roll numbers.
- Subgrade surface acceptance documentation.
- Panel Placement Form showing the location of all panels and joints.
- Project Quality Plan – Signatures.
- Certificate of Acceptance.

The ENGINEERs representative is to complete the following daily reports:

- Field notes, including memoranda of meetings and/or discussions with the CONTRACTOR and GCL Installer.
- Construction problems and solution data sheets.
- Project Quality Plan – Signatures.
- Data on weather conditions.
- Safety Matters.
- Soil cover details.
- Signature of Completion Certificate.

6.2.7 After Installation

The Installer/CONTRACTOR is to provide the following within 14 days to the ENGINEER.

A complete Data Pack containing all completed and signed documentation

The ENGINEER is to provide the following within 30 days of completion of installation to the EMPLOYER.

- The Installer/CONTRACTOR Data Pack.
- An outline of the project.
- A description of the lining system.
- GCL Material Specification.
- Batch and roll numbers of panels used.
- A summary of on-site CQA activities, quantities, samples etc.
- A photographic record of construction.
- Discussion of problems and solutions.
- As built drawings.

7 POST CLOSURE MONITORING AND MAINTENANCE

The success and sustainability of the implementation of the rehabilitation must be monitored and accessed annually. Any pollution and the effect of mitigation measures need to be monitored. This includes but is not limited to the water quality reports during the operational period as well as the post closure period. The current implementation of measures to protect the ground water from further pollution from the plant as well as further measures to improve the water quality will indicate the potential of the natural environment to remediate itself. This could impact on the residual risk assessment future closure cost calculations.

The success of establishing different grass species which will be planted on the disturbed and rehabilitated areas must be monitored and this can only be done at the end of the growing season around February or March each year. Erosion from denuded areas must be monitored and this needs to be done after every huge storm event, alternatively every month. The presence of hexavalent sources needs to be clearly identified and mitigation measures to eliminate this hazard needs to be monitored.

7.1 Parameters to be monitored

Water quality should comply with the water quality standards as provided in the water quality reports, which is in compliance with the water quality standards of the Department of Water and Sanitation and the limits set in the water use licence. See the water quality standards set in the water quality reports.

7.2 Frequency & period

Ground water quality must be monitored quarterly during the operational period and only annually during the post closure period whereas surface water monitoring should be conducted monthly.

All other audits are done annually unless special audits are required. In an effective monitoring system, it is essential that all monitoring localities are optimally selected, formally listed and systematically named. The selection of the localities and the technical specifications for the surface water monitoring/sampling points are critical, as they need to supply data of high integrity, which will support impact and risk assessment, related to the various environmental components being monitored, in support of the Risk Based Environmental Management.

In order to facilitate faultless interpretation and display of data, all data points should be geographically referenced into a Geographical Information System (GIS) and plotted on a map of reasonable scale.

Annual inspections must be carried out to evaluate vegetation growth and erosion and where needed the areas should be ameliorated and re-vegetated to ensure vegetation establishment and established land use as described for final closure of the facility.

Bibliography

Biljon, M. v., 2016. *Jones & Wagener : TRANSALLOYS GEOHYDROLOGY ,* s.l.: s.n.

Biljon, M. v., 2019. *ANNUAL WATER MONITORING REPORT,* s.l.: s.n.

Biljon, M. v., 2020. *ANNUAL WATER MONITORING REPORT,* s.l.: s.n.

Brandt, M., 2011. *Seismic Hazard in South AFrica,* Cape Town: Council for Geoscience.

Bureau of Reclamation, 1987. *Design of small dams.* Washington: Department of the Interior.

Handy, M. G. S. a. R. L., n.d. *Soil Engineering.* Fourth Edition ed. s.l.:s.n.

Hoffman, P., 2021. *Artesium TRANSALLOYS FE-CR TSF GEOCHEMICAL WASTE ASSESSMENT,* s.l.: s.n.

Jacobsz, C. Q. &. S., 2011. *15th African Regional Conference on Soil Mechanics and Geotechnical Engineering.* s.l., s.n.

James, G., n.d. *Geosynthetic Clay liners in South African waste impoundment projects,* s.l.: s.n.

Kent P. von Maubeuge, J. C. a. F. H., n.d. *Landfill Cap design with Geosynthetic Clay Liners.* s.l., s.n.

Knight Piesold Consulting, January 2017. *Transalloys Power Station and Ash Dump; Phase 1 Geotechnical Investigation; Report no KHH2430,* s.l.: s.n.

Koerner, R. M., n.d. *Designing with Geosynthetics.* Fourth Edition ed. s.l.:s.n.

Piteau Associates Engineering Ltd, 1991. *Investigation and Design of Mine Dumps, Interim Guidelines,* Vancouver: British Columbia Mine Dump Committe.

Pretorius, H., 2013. *Prefeasibility Engineering and costing for the Closure of the Transalloys FeCr dam,* s.l.: s.n.

Robert M. Koerner, Y. G. H. a. G. R. K., 2011. *GRI White paper #6 : Geomembrane Lifetime Prediction:,* s.l.: s.n.

Rowe, R., n.d. Short and Long-term leakage through composite liner. The 7th Athur Casagranda lecture.

Shaw, E. M., n.d. *Hydrology in practice.* second edition ed. s.l.:s.n.

SRK Consulting (South Africa) (Pty) Ltd, July 2014. *Transalloys 1:50 and 1:100 Year Floodlines, Report Number 476701/1 Rev 1,* s.l.: s.n.

Synergistics Environmental Services (Pty) Ltd, July 2010. *Environmental Impact Assessment Report and Environmental Management Programme Report,* s.l.: s.n.

Tonder, J. v., 2017. *Knight Piesold - PHASE 1 GEOTECHNICAL INVESTIGATION,* s.l.: s.n.

Annexure A – NATIONAL ENVIRONMENTAL MANAGEMENT WASTE ACT REGULATIONS 2013: CHECKLIST FOR THE LEAD AUTHORITY

1. Check List of Information Available in the Design Report for Confirming Performance of pollution control measures

1.1 The applicant and representative

(a) Name of project:
Transalloys (Pty) Ltd

(b) Name and contact details of the developers' representative e.g. CEO or Municipal Manager:
Mr. Ephraim Monyemoratho
Manager: Environmental Division
Office: +27 13 6938078
Email: ephraimm@transalloys.co.za

(c) Name, contact details and ECSA registration number of the professional registered person (civil) certifying the design report:
DP van der Merwe Pr. Eng.
Engineering Council of South Africa (ECSA) No: 990132
Mobile: +27 82 903 1428
Email: dp@redcoservices.co.za

(d) Title of Design Report, reference number and date:
Closure design report for the proposed decommissioning and closure of the FeCr Facility: eMalahleni, Mpumalanga Province
Project: TA007
Jan 2022

1.2 The waste disposal facility or pollution point source information:

(a) Name and location of facility:
Transalloys – FeCr Tailings Storage Facility
eMalahleni
25°53'23.41"S; 29° 7'20.70"E

(b) Confirmation of waste risk assessment (in accordance with R634 and R635):
Type 3
Refer to Section 4.3 Waste Classification

(c) Description of Waste stream:
Historical tailings / slimes generated from material and product handling at the Transalloys Plant

(d) What is the predicted waste polluting period post closure:
No post closure pollution is expected.
Refer to Section 4.3 Waste Classification

1.3 The base liner system:

(a) What is the waste license reference number and what were the conditions of authorisation pertaining to base liner performance and operational period? :
The facility was constructed during June 2007. The facility is rectangular in shape with an approximate footprint area of 1.26 ha. The facility has a base liner design which comprises of the following:

- Base preparation layer (150mm in-situ rip and re-compact);
- Impermeable compacted liner, modified with 7% Ordinary Portland Cement (OPC)(150mm);
- 150mm leakage detection layer consisting of gravel and drainage pipes;
- Geo-synthetic clay liner;
- 1mm HDPE liner (The HDPE liner covers the entire pad and is taken over starter wall);
- 150mm soil protection layer; and
- 300mm leachate collection layer, the drainage pipes is equipped with valves to control discharge during storm events.

Transalloys submitted an application for a Waste Licence for the Closure of the Ferrochrome (FeCr) slimes dam on 19 March 2018.

This licence were not approved based on the closure designs presented in March 2018.
The following condition of the authorisation is applicable:

> *"Condition 3.1: Note that shaping would not allow increase of the footprint unless the increased area is lined in accordance with the commensurate waste classification."*

The footprint of the reshaped waste facility will cover the existing peripheral HDPE lined drain but will not extend beyond the lined barrier. The capping layers, approximately 900 mm thick, will increase the footprint. The reshaping and capping layers is to allow for a stable and sustainable closure design for the long term. The increased footprint will not be lined with a base liner based on the following considerations:

- All constituents in the slimes samples that were above TCT0 and LCT0 were well below the TCT1 and LCT1 values;
- Although Cr^{6+} was above the LCT0 values for the waste samples, it could not be detected in downstream boreholes during the 2009 to 2020 monitoring period;
- The facility will have no plateau after reshaping that can contain rainfall and increase infiltration;
- The material was dry and compacted during sampling in 2021;
- The proposed capping system is more stringent than what is prescribed in the minimum requirements, because it will prevent infiltration due to the reshaped contours which will prevent ponding on top of the facility and further will contain an impermeable Geosynthetic Clay Liner (GCL) below the cover (See Section 5.3);
- The predicted infiltration of the proposed capping system is very low;
- The facility has been decommissioning since February 2010 and this allowed for possible leaching or attenuation of CoTwo analytical models, one modelling the advective transport and the other reactive transport of Hexavalent Chromium

Transport and it was concluded that if no artificial gradient is being caused the Hexavalent Chromium would likely never reach the Brug Spruit and its Western Tributary as it is referred to which is the main receptors.

(b) Over what period did the waste facility operate? (years):
Commenced in 2007 and operated until Feb 2010.

(c) To what performance standard was the facilities base liner constructed? e.g. Pre-1994; or post 1994 Minimum Requirements attenuation liner; or NEMWA Regulations 2013 containment barrier:
The facility was constructed and commissioned Post-1994 with a formal baseliner. (See section 2.2)

(d) Was the base liner constructed in accordance with the design and CQA? If yes provide evidence thereof:
Yes, base liner was constructed. The design and CQA for the liner installation was not available for verification at the time of this study.

(e) What has the operational period monitoring system confirmed about the design engineers predicted performance of the leachate collection system, leak detection system, and/or containment barrier performance?
Most of the leachate collection drainage pipes showed no seepage through the current FeCr facility at the time of this study.

(f) What is the remaining service life of the contaminant containment basal barrier system? (years):
Based on the thickness of the material the Warrantee period for 1.0 mm HDPE liner is generally 10 years. The lining Warrantee on the liner therefore can be assumed has lapsed in 2017, 10 years from installation in 2007. However, the majority of the HDPE material is covered and therefore UV degradation would be limited. In order to evaluate the useful life of the HDPE testing of the original base HDPE material and the installed HDPE material should be conducted to determine the degradation of the material and therefore determine the useful life of the material. Covered HDPE, in the absence of heat generation leachate, is calculated to last over 100 years at 35°C.

(g) Was an interim cap constructed during the operational phase? If so, describe over which period and its performance (noting the Minimum Requirements 2nd Edition 1998, Volume 2, Chapter 8):
No interim cap was installed during the operational life or after decommissioning.

1.4 Capping design

Layout and layer works:

(a) What are the physical dimensions of the capping facility? e.g. Plan area of the whole cell to be capped, side wall minimum and maximum slopes, plateau area and minimum slope, maximum depth of waste and height above natural ground level:
The dimensions of the final landform will be:

- Current landform footprint size 1.26 ha
- Final landform footprint size – 2.0 ha
- Eastern Slope angle – 11°
- North Western Slope - 2.86°
- South Western Slope - 6.3°
- Average Slope Length – 50m
- Maximum Slope Length - 66m
- Height above NGL of final landform – 9.5m
- Top / plateau area - No plateau area in designed final landform

(b) What is the predicted future surface settlement of the waste body to be capped?
Minimal future settlement is predicted based on the following:

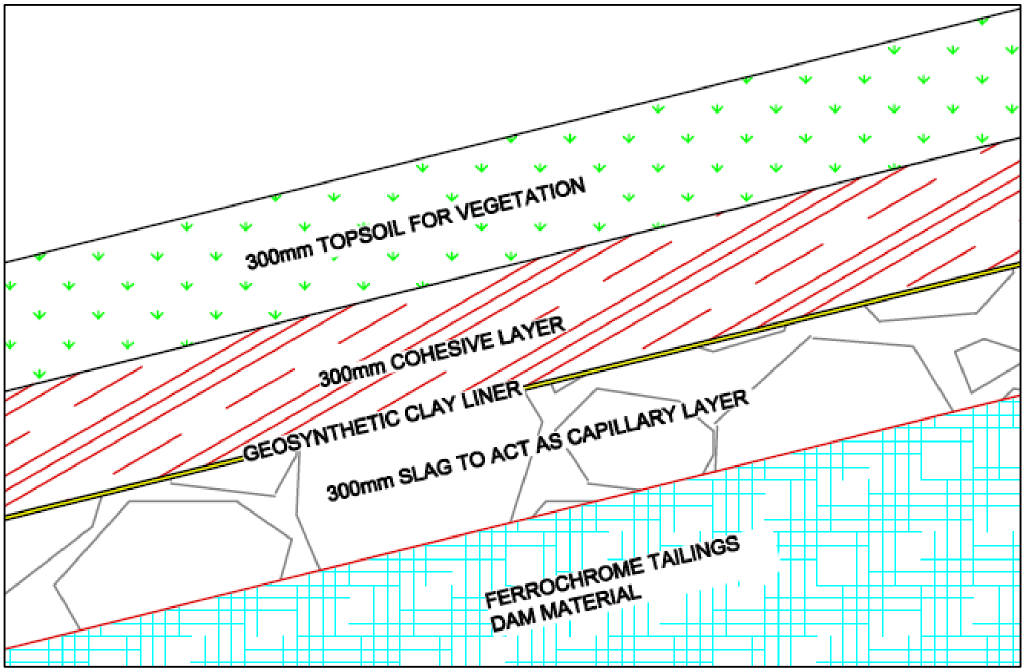
- The facility has been dormant since 2010 allowing the slimes to dewater and consolidate;
- Relatively low levels of moisture was observed in the material during sampling;
- During the sampling for the waste classification, it was observed that the tailings was well compacted material requiring high effort to excavate.

(c) What is the capping layer system for the plateau area? (Slopes less than 1V:4H or similar distinctive slope transition):
No plateau area in designed final landform.

(d) For the plateau cap design specified and CQA plan implementation what is the predicted infiltration rate in l/ha/d?:
No plateau area in designed final landform.

(e) What is the capping layer system for the side slopes area? (Slopes greater than or equal to 1v:4h or similar distinctive slope transition):
Based on the waste classification and assessment of site-specific conditions the following capping system is proposed:

- Sealing/ demolishing of existing penstocks;
- Compaction of reshaped slimes / tailings;
- Importing and placing of a 300 mm Slag layer over the reshaped slimes to act as capillary break layer between the slimes and the GCL;
- Installation of a Geosynthetic Clay Layer (GCL) to function as an impermeable layer preventing ingress of storm water into the rehabilitated slimes dam;
- Importing and placing of 300 mm compacted cover soil layer over the installed GCL;
- 300 mm growth medium (topsoil) layer partially mixed with the coarse material layer;
- Establish indigenous vegetation (not deep-rooted species, i.e. grasses)



Typical section of the proposed capping layer

(f) For the side slopes cap design specified and CQA plan implementation what is the predicted infiltration rate in l/ha/d?:
The predicted infiltration for the proposed capping is calculated at – Q = 2.3224 l/ha/day Also see Section 5.3.1 Permeability

Leachate management:

(g) Describe the leachate management system from collection within the area or cell to be capped, the conveyance to external storage sump or dam and treatment by evaporation, transfer to treatment works or other:
Leachate produced is currently conveyed via an underdrainage pipe system which is extended through the Eastern wall of the facility and discharge any drainage into the currently HDPE lined drain. Very little seepage was observed during the site inspection in 2021. The new design will extend the drainage pipes which will discharge into a lined drain conveying leachate, if still present, to the current sump. See section 5.5.2.

(h) What is the performance of the current leachate collection and management system of the cell or area to be capped?:
Very little seepage was observed.

(i) What is the predicted containment performance of the external leachate storage facility? e.g. leachate sump, pollution control dam or similar:
The leachate collection sump will be decommissioned and rehabilitated upon evidence that no seepage is present in the underdrainage discharge pipe. It can be expected that seepage should stop soon after rehabilitation of the FeCr facility.

Storm Water Management

(j) For what storm event has the surface drainage system been designed? :
The storm water management system was designed for a 1:100 year storm event.

(k) At what spacing are storm water berms and drains placed along contours on slopes and what is the peak conveyance velocity?:
The final closure design does not require the construction of storm water berms due to the relatively low gradient and short slope length of the final landform. The geometry results in a relatively low velocity of surface run-off that will limit the risk of erosion. The topsoil mixed with coarse material will also function as an erosion protection layer.

(l) How is storm water managed at the toe of the facility and to where and how is it discharged?:

Storm water runoff from the rehabilitated slimes dam is discharged into a toe drain lined with 300 mm compacted cover soil and 300 mm Vegetated topsoil. The toe drains discharge will discharge clean water into the environment at the North East corner of the facility. Maximum flow velocity in the toe drain is 0.6 m/s (1:100).
Also See

- Section 5.4 Surface Water Management –

Stability

(m) What is the minimum factor of safety for veneer and for global stability based on material properties assessed via laboratory tests including interface shear strength where applicable?:
The veneer FoS -2.93.
The global FoS -5.5.

  - Section 5.2.1 Interface Shear Safety Factor
  - Section 5.2 Stability Analysis

(n) How has seismic stability and liquefaction of the waste been assessed?
A pseudo-static analysis indicating a FoS of 3.3.

Monitoring

(o) What instrumentation is provided to test, measure and confirm assumed parameters used in design and construction performance assessments? e.g. settlement beacons, flow gauges, vibrating wire piezometers, strain gauges, inclinometers and similar.

The following measures will be implemented:

  - Benchmarks
  - Frequent survey

Cost Effectiveness

(p) What is the engineers estimate for the capping closure design implementation?

Estimated capping closure cost is R 7 484 943.65 Excluding VAT

(q) What is the estimated cost of the cap per cubic metre of waste disposed? (R/m):

The cost per cubic meter of waste disposed is R 210.99 per m^3 of the current waste body of 36 250 m^3

(r) For organs of state and listed companies has the relevant legislation pertaining to competitive procurement been complied with in the design, CQA and specifications?

- Generic materials were specified as far as possible.
- Opportunities will be created for local emerging contractors to tender for certain work components.

Peer review

(s) Has the design been subjected to an internal peer review?
Yes

Note: The authorities thank the applicant and representatives for diligence in completing the checklist with cross-references to the design report and drawings with cross-references to pages and appendices. In undertaking the review the statutory authorities consideration will include a determination of the capping design performance specification's ability to meet or exceed the polluting period of the waste or point source as an integral part of the base liner containment performance.

2. Confirmation of Readiness

For the Applicant _____ / _____ / 20___ For the Engineer _____ / _____ / 20___

_____________________________ _____________________________

Name: DP van der Merwe Pr Eng no. 990132

....

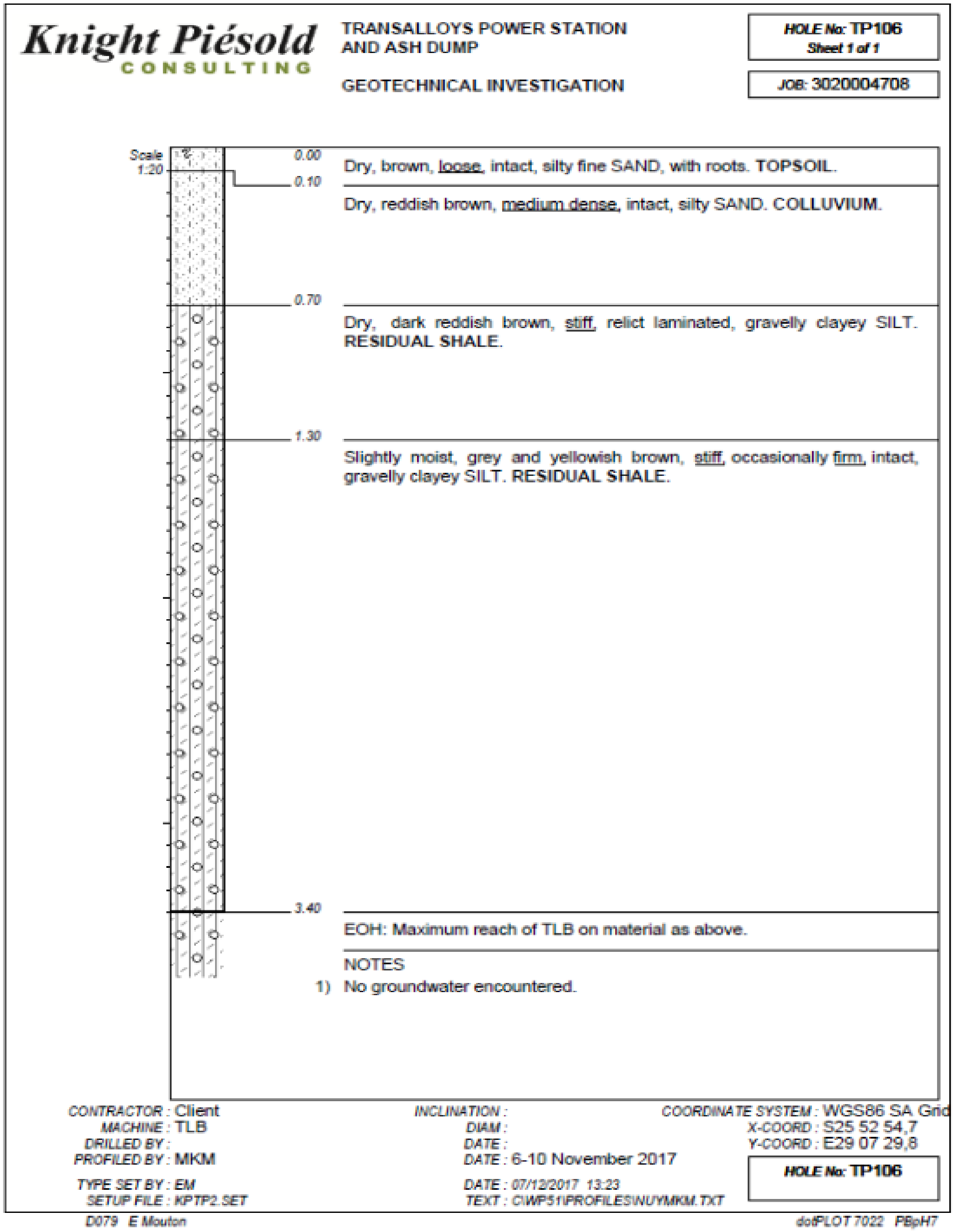
Confirmation of check list completeness by the Lead Authority (Provincial or National Department):

____

Signature, name and rank, contact details (mobile phone and email), date

Submit to the DWS Coordinator upon completion, Director: Resource Protection and Waste for attention Mr M Noe

Annexure B – GEOTECHNICAL SOIL ANALYSIS FOR TAILINGS, COHESIVE SOIL AND SLAG



Knight Piésold
CONSULTING

TRANSALLOYS POWER STATION
AND ASH DUMP

GEOTECHNICAL INVESTIGATION

HOLE No: **TP106**
Sheet 1 of 1

JOB: 3020004708

Scale 1:20

0.00	Dry, brown, loose, intact, silty fine SAND, with roots. **TOPSOIL**.
0.10	Dry, reddish brown, medium dense, intact, silty SAND. **COLLUVIUM**.
0.70	Dry, dark reddish brown, stiff, relict laminated, gravelly clayey SILT. **RESIDUAL SHALE**.
1.30	Slightly moist, grey and yellowish brown, stiff, occasionally firm, intact, gravelly clayey SILT. **RESIDUAL SHALE**.
3.40	EOH: Maximum reach of TLB on material as above.

NOTES

1) No groundwater encountered.

CONTRACTOR : Client
MACHINE : TLB
DRILLED BY :
PROFILED BY : MKM

TYPE SET BY : EM
SETUP FILE : KPTP2.SET

INCLINATION :
DIAM :
DATE :
DATE : 6-10 November 2017

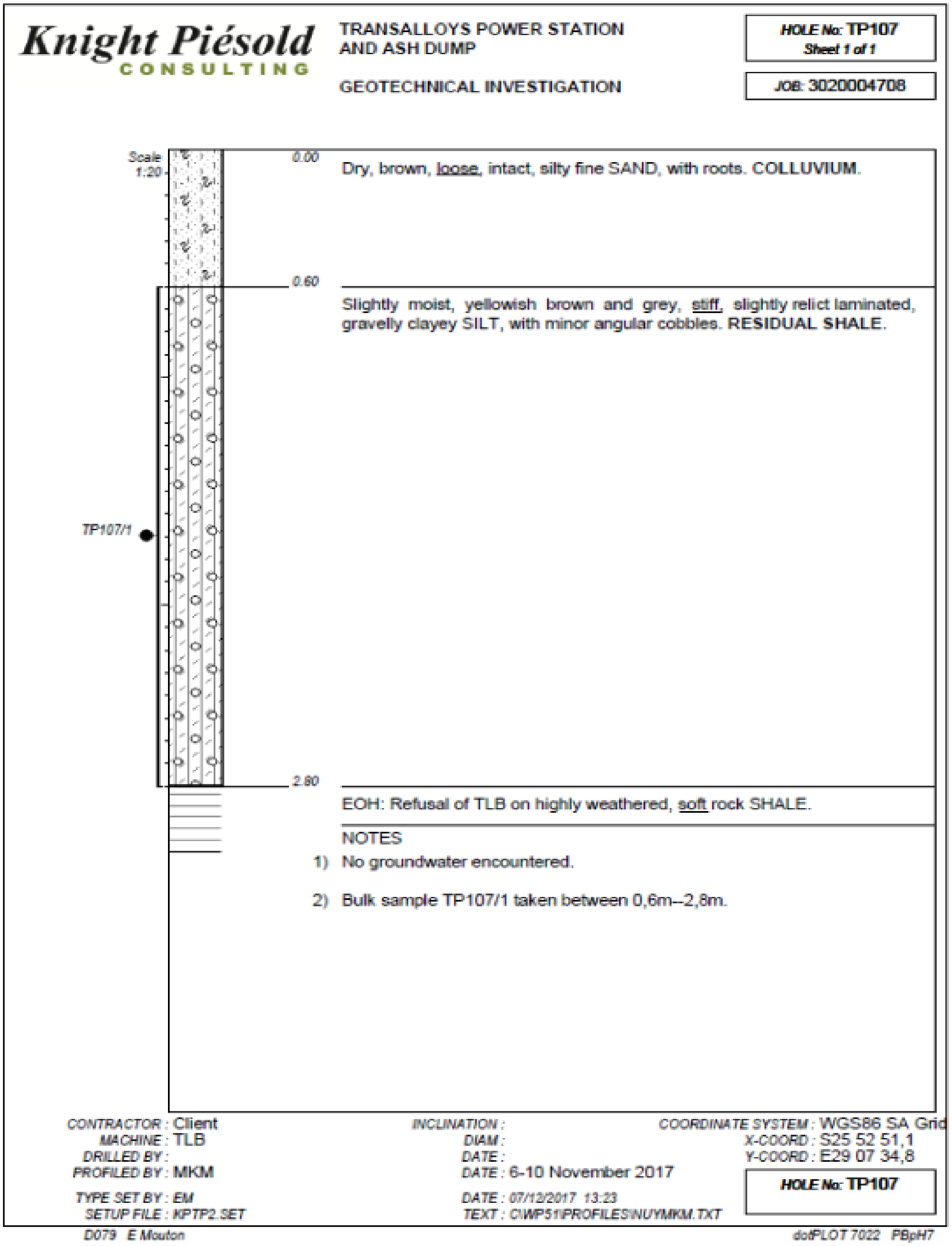
DATE : 07/12/2017 13:23
TEXT : C\WP51\PROFILES\NUYMKM.TXT

COORDINATE SYSTEM : WGS86 SA Grid
X-COORD : S25 52 54,7
Y-COORD : E29 07 29,8

HOLE No: **TP106**

D079 E Mouton

dotPLOT 7022 PBpH7



Knight Piésold
CONSULTING

TRANSALLOYS POWER STATION
AND ASH DUMP

GEOTECHNICAL INVESTIGATION

HOLE No: **TP107**
Sheet 1 of 1

JOB: 3020004708

Scale 1:20

0.00	Dry, brown, loose, intact, silty fine SAND, with roots. COLLUVIUM.
0.60	Slightly moist, yellowish brown and grey, stiff, slightly relict laminated, gravelly clayey SILT, with minor angular cobbles. **RESIDUAL SHALE.**
2.80	EOH: Refusal of TLB on highly weathered, soft rock SHALE.

TP107/1 ●

NOTES

1) No groundwater encountered.

2) Bulk sample TP107/1 taken between 0,6m--2,8m.

CONTRACTOR : Client
MACHINE : TLB
DRILLED BY :
PROFILED BY : MKM

TYPE SET BY : EM
SETUP FILE : KPTP2.SET

INCLINATION :
DIAM :
DATE :
DATE : 6-10 November 2017

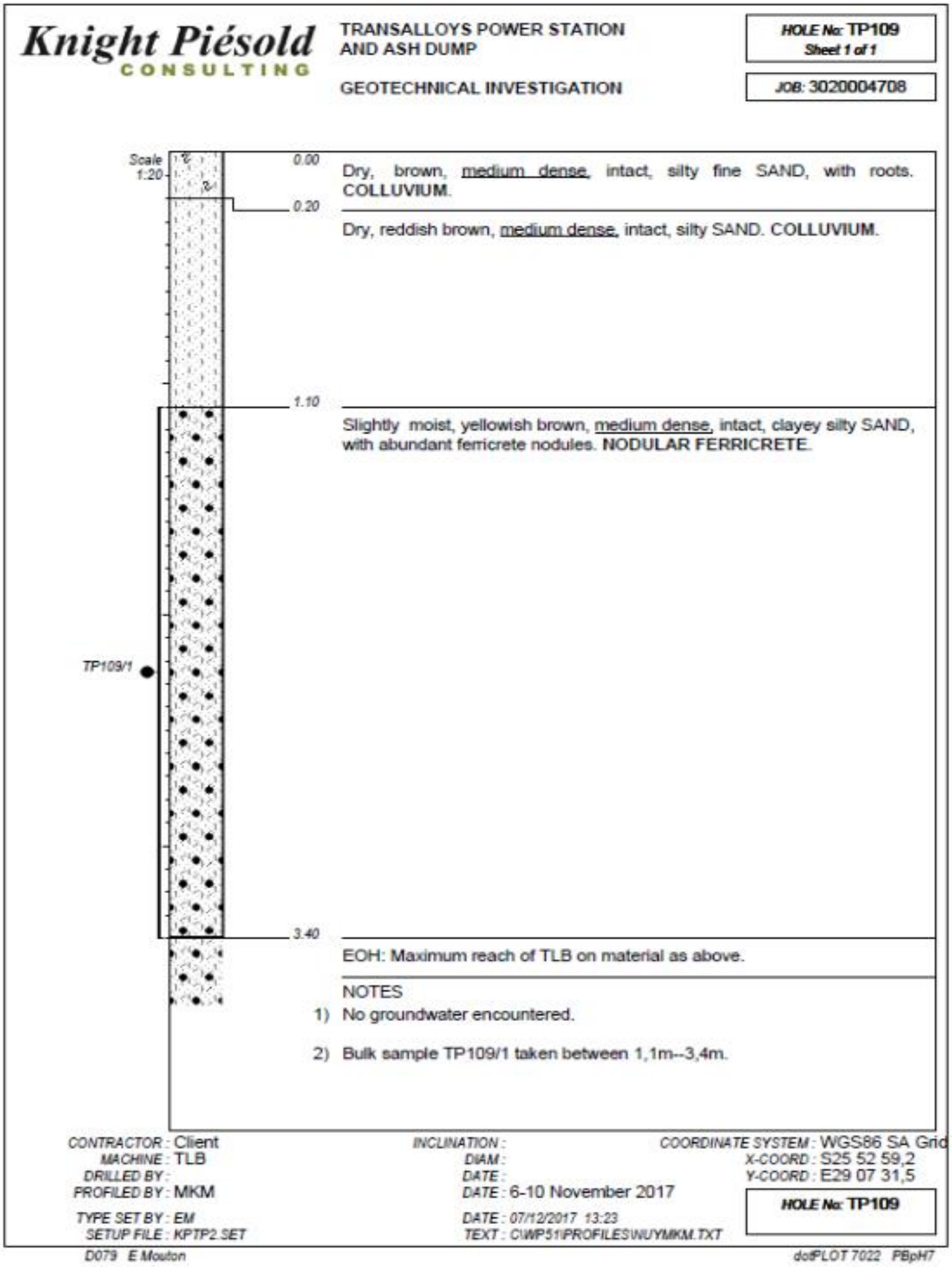
DATE : 07/12/2017 13:23
TEXT : C:\WP51\PROFILES\NUYMKM.TXT

COORDINATE SYSTEM : WGS86 SA Grid
X-COORD : S25 52 51,1
Y-COORD : E29 07 34,8

HOLE No: **TP107**

D079 E Mouton

dotPLOT 7022 PBpH7



Knight Piésold
CONSULTING

TRANSALLOYS POWER STATION
AND ASH DUMP

GEOTECHNICAL INVESTIGATION

HOLE No: TP109
Sheet 1 of 1

JOB: 3020004708

Scale 1:20

Depth	Description
0.00	Dry, brown, medium dense, intact, silty fine SAND, with roots. COLLUVIUM.
0.20	Dry, reddish brown, medium dense, intact, silty SAND. COLLUVIUM.
1.10	Slightly moist, yellowish brown, medium dense, intact, clayey silty SAND, with abundant ferricrete nodules. NODULAR FERRICRETE.
3.40	EOH: Maximum reach of TLB on material as above.

TP109/1 ●

NOTES

1) No groundwater encountered.

2) Bulk sample TP109/1 taken between 1,1m--3,4m.

CONTRACTOR : Client
MACHINE : TLB
DRILLED BY :
PROFILED BY : MKM

TYPE SET BY : EM
SETUP FILE : KPTP2.SET

INCLINATION :
DIAM :
DATE :
DATE : 6-10 November 2017

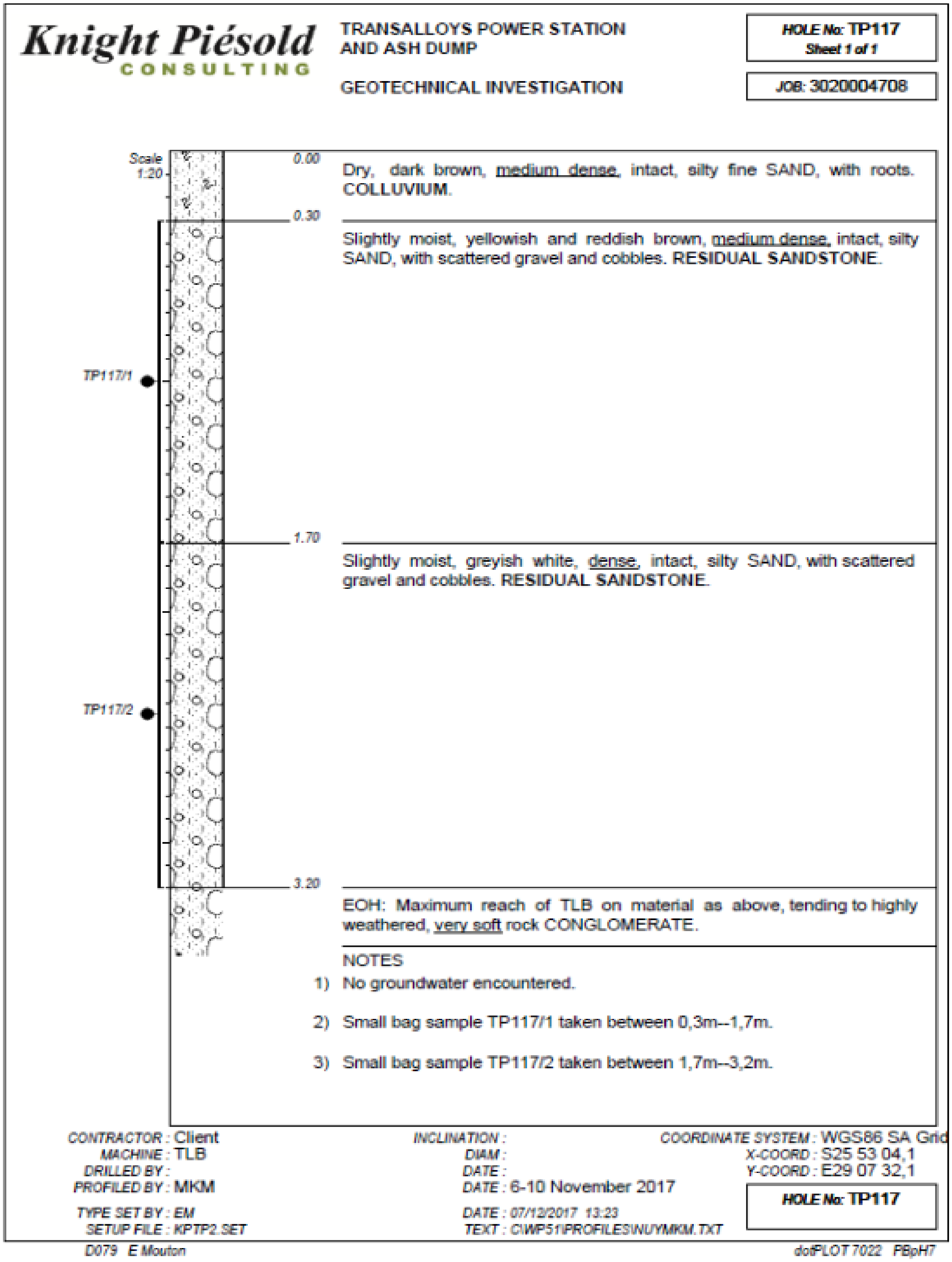
DATE : 07/12/2017 13:23
TEXT : C:\WP51\PROFILES\WUYMKM.TXT

COORDINATE SYSTEM : WGS86 SA Grid
X-COORD : S25 52 59,2
Y-COORD : E29 07 31,5

HOLE No: TP109

D079 E Mouton

dotPLOT 7022 PBpH7



Knight Piésold CONSULTING

TRANSALLOYS POWER STATION
AND ASH DUMP

GEOTECHNICAL INVESTIGATION

HOLE No: TP117
Sheet 1 of 1

JOB: 3020004708

Scale 1:20

0.00	Dry, dark brown, medium dense, intact, silty fine SAND, with roots. **COLLUVIUM**.
0.30	Slightly moist, yellowish and reddish brown, medium dense, intact, silty SAND, with scattered gravel and cobbles. **RESIDUAL SANDSTONE**.
1.70	Slightly moist, greyish white, dense, intact, silty SAND, with scattered gravel and cobbles. **RESIDUAL SANDSTONE**.
3.20	EOH: Maximum reach of TLB on material as above, tending to highly weathered, very soft rock CONGLOMERATE.

NOTES

1) No groundwater encountered.

2) Small bag sample TP117/1 taken between 0,3m--1,7m.

3) Small bag sample TP117/2 taken between 1,7m--3,2m.

CONTRACTOR : Client
MACHINE : TLB
DRILLED BY :
PROFILED BY : MKM

TYPE SET BY : EM
SETUP FILE : KPTP2.SET

INCLINATION :
DIAM :
DATE :
DATE : 6-10 November 2017

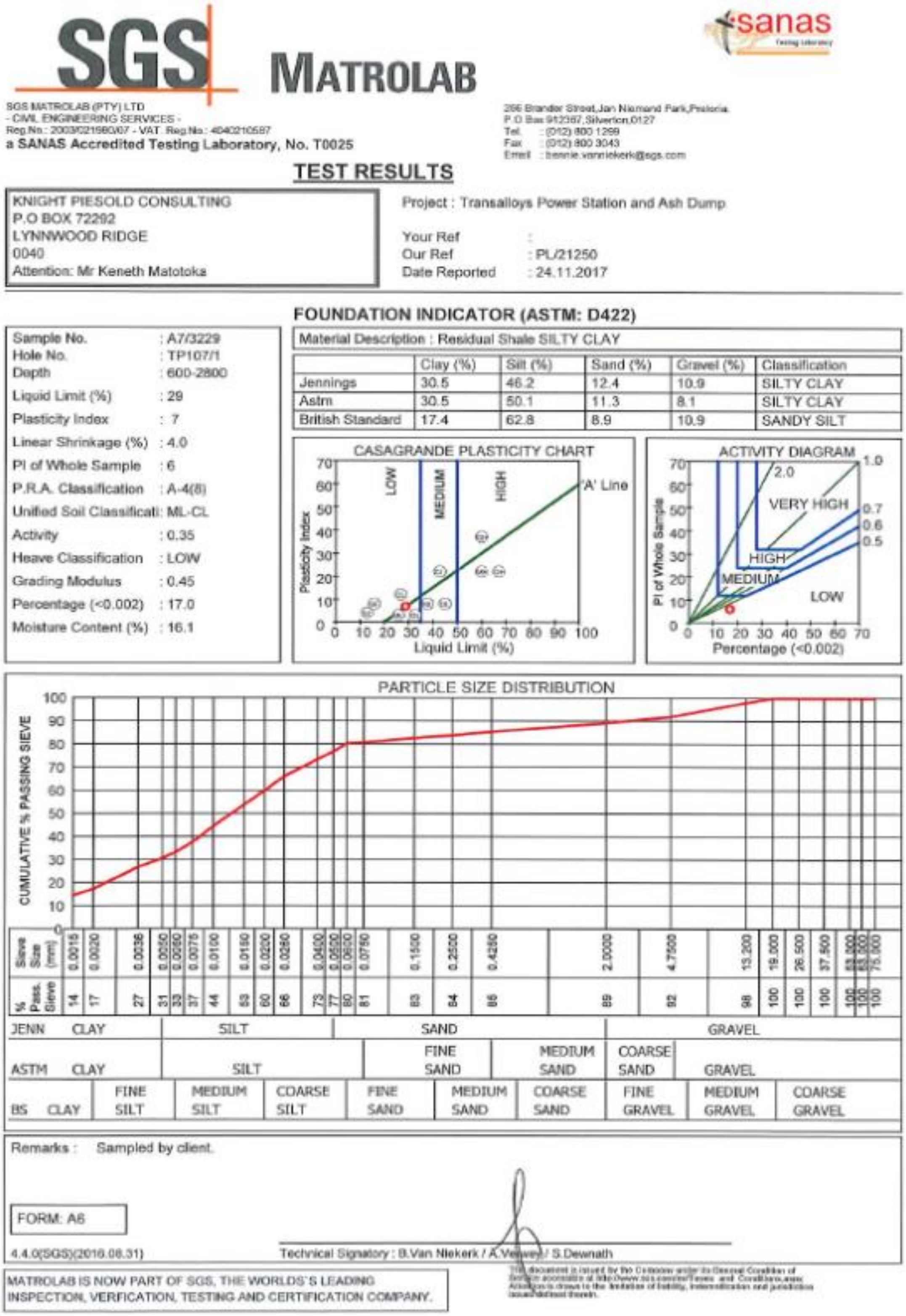
DATE : 07/12/2017 13:23
TEXT : C:\WP51\PROFILES\NUYMKM.TXT

COORDINATE SYSTEM : WGS86 SA Grid
X-COORD : S25 53 04,1
Y-COORD : E29 07 32,1

HOLE No: TP117

D079 E Mouton

dotPLOT 7022 PBpH7



SGS MATROLAB (PTY) LTD
- CIVIL ENGINEERING SERVICES -
Reg.No.: 2003/021980/07 - VAT. Reg.No.: 4040210587
a SANAS Accredited Testing Laboratory, No. T0025

286 Brander Street,Jan Niemand Park,Pretoria
P.O Box 912387,Silverton,0127
Tel. : (012) 800 1299
Fax : (012) 800 3043
Email : bennie.vanniekerk@sgs.com

TEST RESULTS

KNIGHT PIESOLD CONSULTING
P.O BOX 72292
LYNNWOOD RIDGE
0040
Attention: Mr Keneth Matotoka

Project : Transalloys Power Station and Ash Dump

Your Ref :
Our Ref : PL/21250
Date Reported : 24.11.2017

FOUNDATION INDICATOR (ASTM: D422)

Sample No.	: A7/3229
Hole No.	: TP107/1
Depth	: 600-2800
Liquid Limit (%)	: 29
Plasticity Index	: 7
Linear Shrinkage (%)	: 4.0
PI of Whole Sample	: 6
P.R.A. Classification	: A-4(8)
Unified Soil Classificati	: ML-CL
Activity	: 0.35
Heave Classification	: LOW
Grading Modulus	: 0.45
Percentage (<0.002)	: 17.0
Moisture Content (%)	: 16.1

Material Description : Residual Shale SILTY CLAY

	Clay (%)	Silt (%)	Sand (%)	Gravel (%)	Classification
Jennings	30.5	46.2	12.4	10.9	SILTY CLAY
Astm	30.5	50.1	11.3	8.1	SILTY CLAY
British Standard	17.4	62.8	8.9	10.9	SANDY SILT

Sieve Size (mm)	0.0015	0.0020	0.0036	0.0050	0.0060	0.0075	0.0100	0.0150	0.0200	0.0280	0.0400	0.0520	0.0600	0.0750	0.1500	0.2500	0.4250	2.0000	4.7500	13.200	19.000	26.500	37.500	53.000	63.000	75.000
% Pass. Sieve	14	17	27	31	33	37	44	53	60	66	73	77	80	81	83	84	86	89	92	98	100	100	100	100	100	100

JENN CLAY | SILT | SAND | GRAVEL
ASTM CLAY | SILT | FINE SAND | MEDIUM SAND | COARSE SAND | GRAVEL
BS CLAY | FINE SILT | MEDIUM SILT | COARSE SILT | FINE SAND | MEDIUM SAND | COARSE SAND | FINE GRAVEL | MEDIUM GRAVEL | COARSE GRAVEL

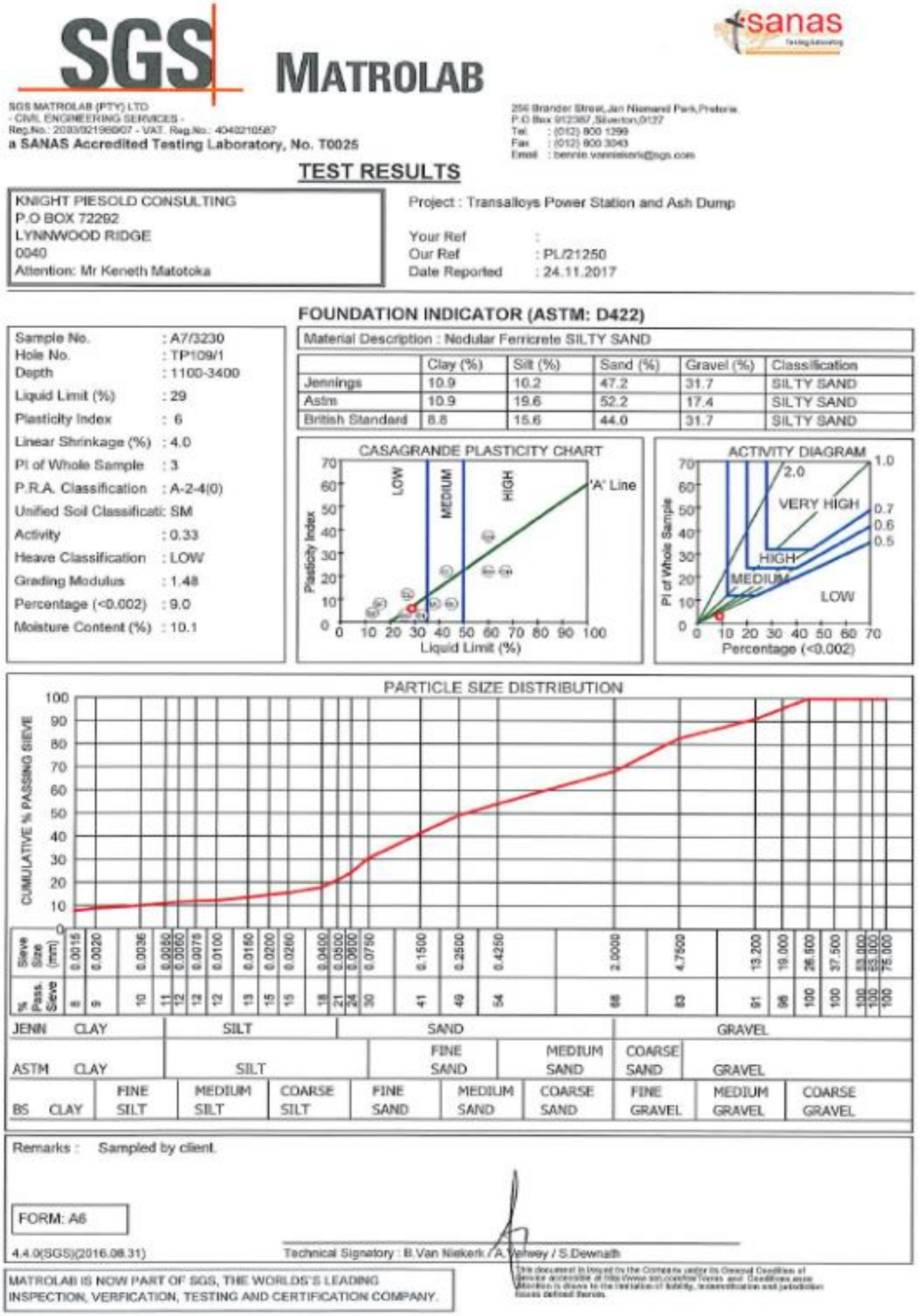
Remarks : Sampled by client.

FORM: A6

4.4.0(SGS)(2016.08.31)

Technical Signatory : B.Van Niekerk / A.Verwey / S.Dewnath

MATROLAB IS NOW PART OF SGS, THE WORLDS'S LEADING INSPECTION, VERFICATION, TESTING AND CERTIFICATION COMPANY.



SGS MATROLAB

SGS MATROLAB (PTY) LTD
- CIVIL ENGINEERING SERVICES -
Reg.No.: 2003/021989/07 - VAT. Reg.No.: 4040210587
a SANAS Accredited Testing Laboratory, No. T0025

256 Brander Street, Jan Niemand Park, Pretoria
P.O Box 912387, Silverton, 0127
Tel : (012) 800 1299
Fax : (012) 800 3043
Email : bennie.vanniekerk@sgs.com

TEST RESULTS

KNIGHT PIESOLD CONSULTING
P.O BOX 72292
LYNNWOOD RIDGE
0040
Attention: Mr Keneth Matotoka

Project : Transalloys Power Station and Ash Dump

Your Ref :
Our Ref : PL/21250
Date Reported : 24.11.2017

FOUNDATION INDICATOR (ASTM: D422)

Sample No. : A7/3230
Hole No. : TP109/1
Depth : 1100-3400
Liquid Limit (%) : 29
Plasticity Index : 6
Linear Shrinkage (%) : 4.0
PI of Whole Sample : 3
P.R.A. Classification : A-2-4(0)
Unified Soil Classificati: SM
Activity : 0.33
Heave Classification : LOW
Grading Modulus : 1.48
Percentage (<0.002) : 9.0
Moisture Content (%) : 10.1

Material Description : Nodular Ferricrete SILTY SAND

	Clay (%)	Silt (%)	Sand (%)	Gravel (%)	Classification
Jennings	10.9	10.2	47.2	31.7	SILTY SAND
Astm	10.9	19.6	52.2	17.4	SILTY SAND
British Standard	8.8	15.6	44.0	31.7	SILTY SAND

Sieve Size (mm)	0.0015	0.0020	0.0036	0.0050	0.0060	0.0075	0.0100	0.0150	0.0200	0.0260	0.0400	0.0500	0.0600	0.0750	0.1500	0.2500	0.4250	2.0000	4.7500	13.200	19.000	26.500	37.500	53.000	63.000	75.000
% Pass. Sieve	8	9	10	11	12	12	12	13	15	15	18	21	24	30	41	49	54	68	83	91	98	100	100	100	100	100

JENN CLAY | SILT | SAND | GRAVEL

ASTM CLAY | SILT | FINE SAND | MEDIUM SAND | COARSE SAND | GRAVEL

BS CLAY | FINE SILT | MEDIUM SILT | COARSE SILT | FINE SAND | MEDIUM SAND | COARSE SAND | FINE GRAVEL | MEDIUM GRAVEL | COARSE GRAVEL

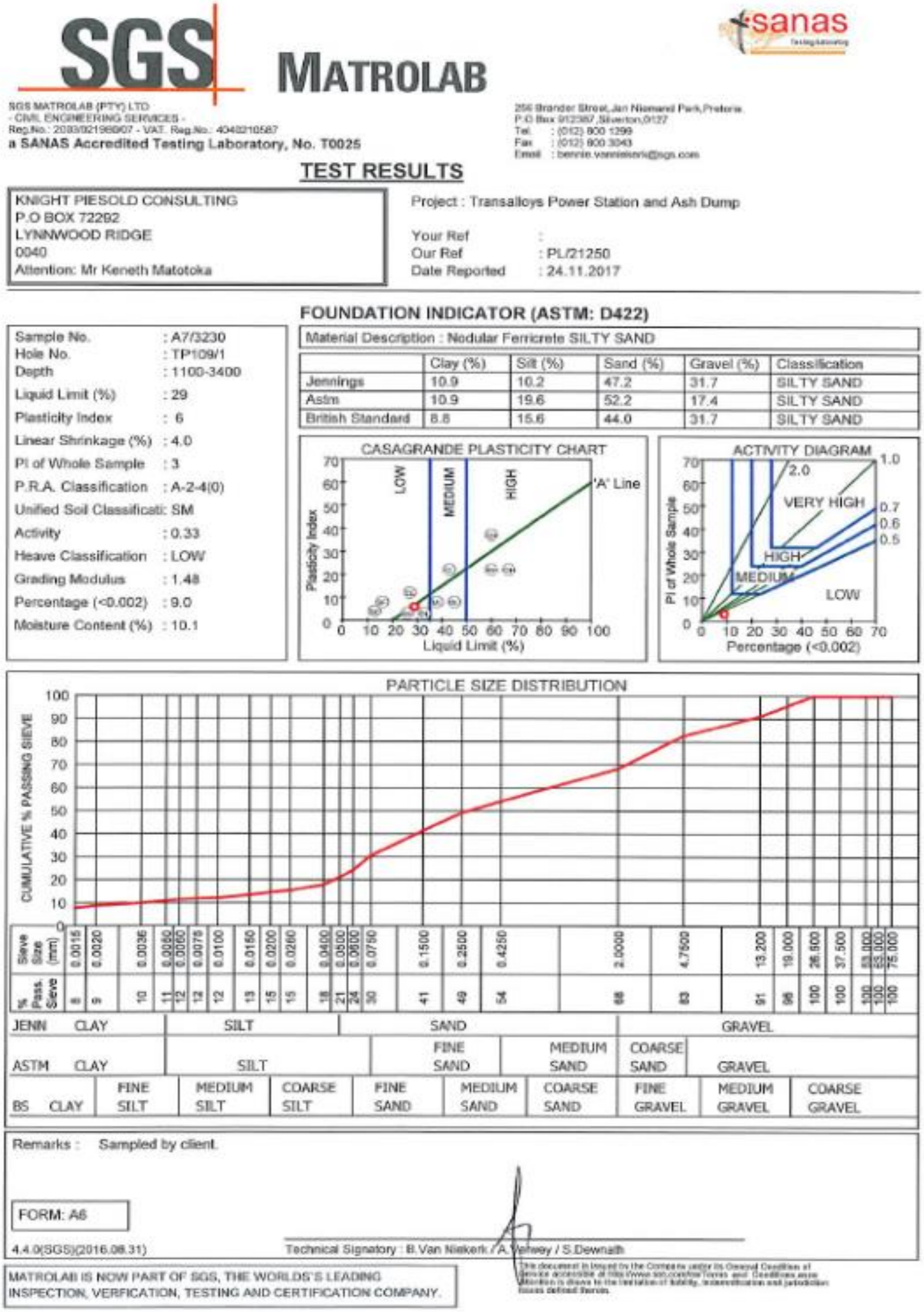
Remarks : Sampled by client.

FORM: A6

4.4.0(SGS)(2016.08.31)

Technical Signatory : B.Van Niekerk / A.Verwey / S.Dewnath

MATROLAB IS NOW PART OF SGS, THE WORLD'S LEADING INSPECTION, VERIFICATION, TESTING AND CERTIFICATION COMPANY.



SGS MATROLAB (PTY) LTD
- CIVIL ENGINEERING SERVICES -
Reg.No.: 2000/021969/07 - VAT. Reg.No.: 4040210587
a SANAS Accredited Testing Laboratory, No. T0025

256 Brander Street, Jan Niemand Park, Pretoria
P.O Box 912387, Silverton, 0127
Tel : (012) 800 1299
Fax : (012) 800 3043
Email : bennie.vanniekerk@sgs.com

TEST RESULTS

KNIGHT PIESOLD CONSULTING
P.O BOX 72292
LYNNWOOD RIDGE
0040
Attention: Mr Keneth Matotoka

Project : Transalloys Power Station and Ash Dump

Your Ref :
Our Ref : PL/21250
Date Reported : 24.11.2017

FOUNDATION INDICATOR (ASTM: D422)

Sample No. : A7/3230
Hole No. : TP109/1
Depth : 1100-3400
Liquid Limit (%) : 29
Plasticity Index : 6
Linear Shrinkage (%) : 4.0
PI of Whole Sample : 3
P.R.A. Classification : A-2-4(0)
Unified Soil Classificati: SM
Activity : 0.33
Heave Classification : LOW
Grading Modulus : 1.48
Percentage (<0.002) : 9.0
Moisture Content (%) : 10.1

Material Description : Nodular Ferricrete SILTY SAND

	Clay (%)	Silt (%)	Sand (%)	Gravel (%)	Classification
Jennings	10.9	10.2	47.2	31.7	SILTY SAND
Astm	10.9	19.6	52.2	17.4	SILTY SAND
British Standard	8.8	15.6	44.0	31.7	SILTY SAND

Sieve Size (mm)	% Pass. Sieve
0.0015	8
0.0020	9
0.0036	10
0.0050	11
0.0060	12
0.0075	12
0.0100	12
0.0150	13
0.0200	15
0.0260	15
0.0400	18
0.0500	21
0.0600	24
0.0750	30
0.1500	41
0.2500	49
0.4250	54
2.0000	68
4.7500	83
13.200	91
19.000	96
26.500	100
37.500	100
53.000	100
63.000	100
75.000	100

JENN: CLAY | SILT | SAND | GRAVEL
ASTM: CLAY | SILT | FINE SAND | MEDIUM SAND | COARSE SAND | GRAVEL
BS: CLAY | FINE SILT | MEDIUM SILT | COARSE SILT | FINE SAND | MEDIUM SAND | COARSE SAND | FINE GRAVEL | MEDIUM GRAVEL | COARSE GRAVEL

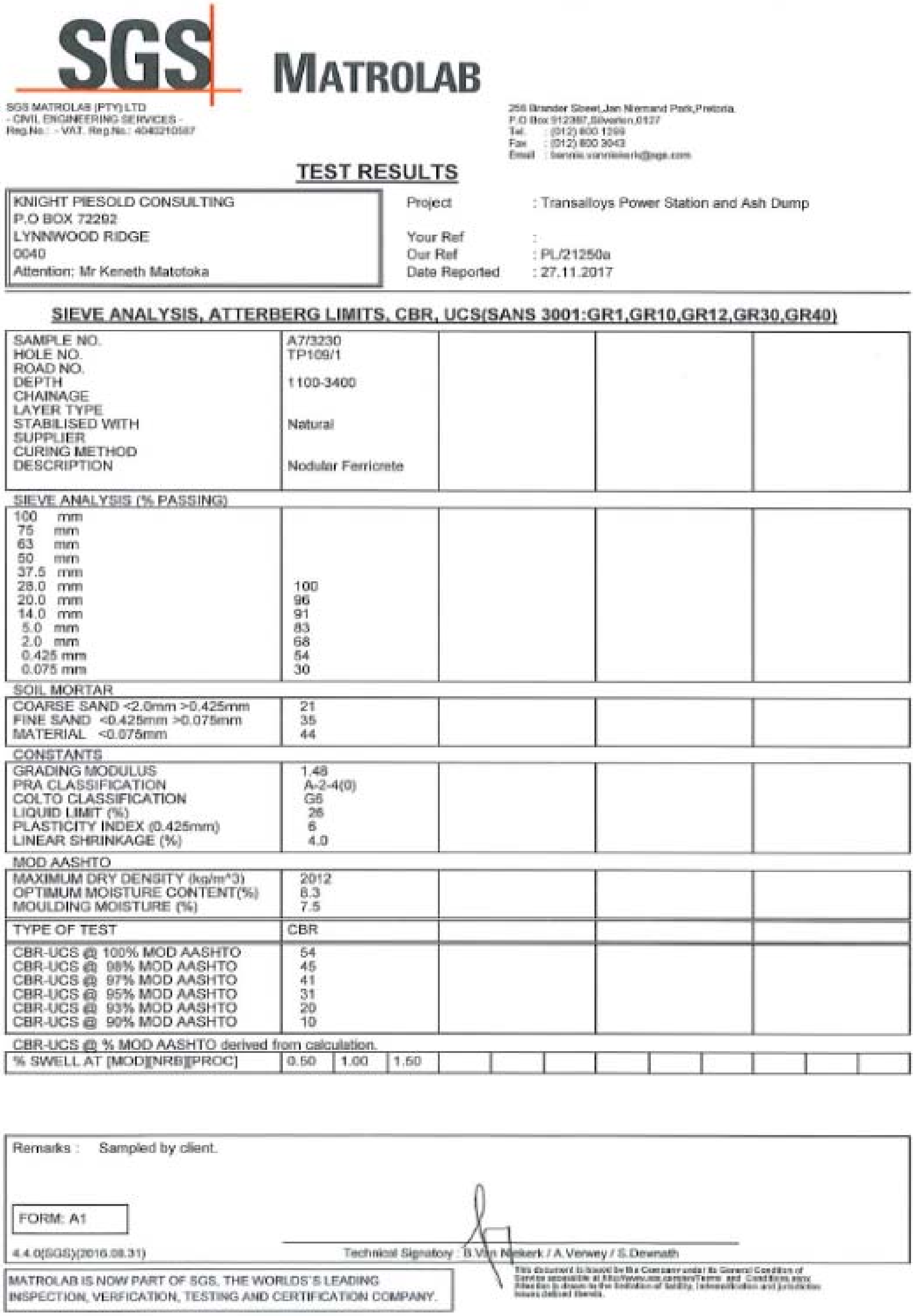
Remarks : Sampled by client.

FORM: A6

4.4.0(SGS)(2016.08.31)

Technical Signatory : B.Van Niekerk / A.Verwey / S.Dewnath

MATROLAB IS NOW PART OF SGS, THE WORLD'S LEADING INSPECTION, VERIFICATION, TESTING AND CERTIFICATION COMPANY.



SGS MATROLAB

SGS MATROLAB (PTY) LTD
- CIVIL ENGINEERING SERVICES -
Reg.No.: - VAT. Reg.No.: 4040210587

256 Brander Street,Jan Niemand Park,Pretoria
P.O Box 912387,Silverton,0127
Tel. : (012) 800 1299
Fax : (012) 800 3043
Email : bennie.vanniekerk@sgs.com

TEST RESULTS

KNIGHT PIESOLD CONSULTING
P.O BOX 72292
LYNNWOOD RIDGE
0040
Attention: Mr Keneth Matotoka

Project : Transalloys Power Station and Ash Dump

Your Ref :

Our Ref : PL/21250a

Date Reported : 27.11.2017

SIEVE ANALYSIS, ATTERBERG LIMITS, CBR, UCS(SANS 3001:GR1,GR10,GR12,GR30,GR40)

SAMPLE NO.	A7/3230			
HOLE NO.	TP109/1			
ROAD NO.				
DEPTH	1100-3400			
CHAINAGE				
LAYER TYPE				
STABILISED WITH	Natural			
SUPPLIER				
CURING METHOD				
DESCRIPTION	Nodular Ferricrete			
SIEVE ANALYSIS (% PASSING)				
100 mm				
75 mm				
63 mm				
50 mm				
37.5 mm				
28.0 mm	100			
20.0 mm	96			
14.0 mm	91			
5.0 mm	83			
2.0 mm	68			
0.425 mm	54			
0.075 mm	30			
SOIL MORTAR				
COARSE SAND <2.0mm >0.425mm	21			
FINE SAND <0.425mm >0.075mm	35			
MATERIAL <0.075mm	44			
CONSTANTS				
GRADING MODULUS	1.48			
PRA CLASSIFICATION	A-2-4(0)			
COLTO CLASSIFICATION	G5			
LIQUID LIMIT (%)	26			
PLASTICITY INDEX (0.425mm)	6			
LINEAR SHRINKAGE (%)	4.0			
MOD AASHTO				
MAXIMUM DRY DENSITY (kg/m^3)	2012			
OPTIMUM MOISTURE CONTENT(%)	8.3			
MOULDING MOISTURE (%)	7.5			
TYPE OF TEST	CBR			
CBR-UCS @ 100% MOD AASHTO	54			
CBR-UCS @ 98% MOD AASHTO	45			
CBR-UCS @ 97% MOD AASHTO	41			
CBR-UCS @ 95% MOD AASHTO	31			
CBR-UCS @ 93% MOD AASHTO	20			
CBR-UCS @ 90% MOD AASHTO	10			

CBR-UCS @ % MOD AASHTO derived from calculation.

% SWELL AT [MOD][NRB][PROC]	0.50	1.00	1.50									

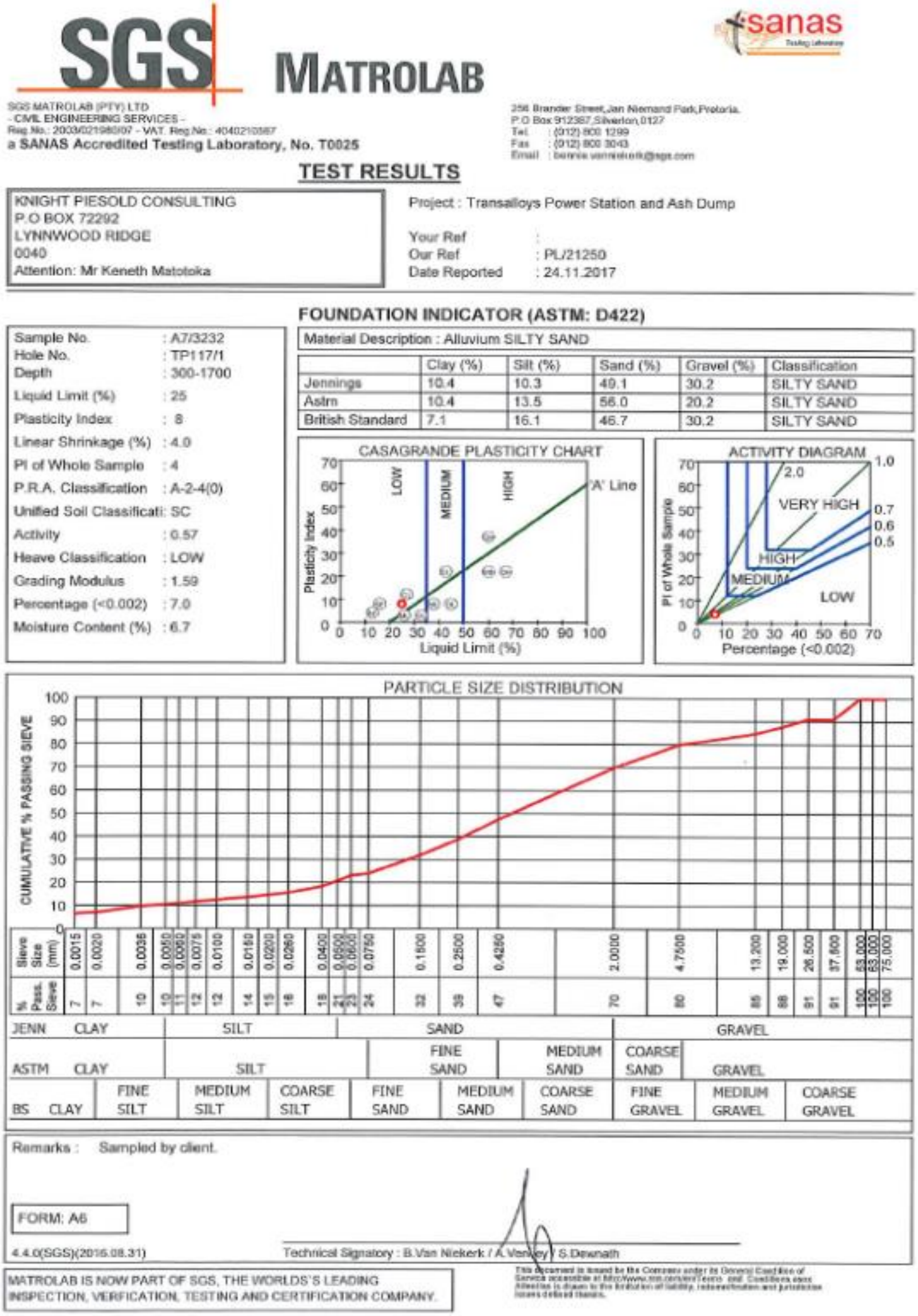
Remarks : Sampled by client.

FORM: A1

4.4.0(SGS)(2016.08.31)

Technical Signatory : B.Van Niekerk / A.Verwey / S.Dewnath

MATROLAB IS NOW PART OF SGS, THE WORLDS'S LEADING INSPECTION, VERFICATION, TESTING AND CERTIFICATION COMPANY.



SGS MATROLAB

SGS MATROLAB (PTY) LTD
- CIVIL ENGINEERING SERVICES -
Reg No.: 2003/021980/07 - VAT. Reg No.: 4040210387
a SANAS Accredited Testing Laboratory, No. T0025

256 Brander Street,Jan Niemand Park,Pretoria.
P.O Box 912387,Silverton,0127
Tel : (012) 800 1299
Fax : (012) 800 3043
Email : bennie.vanniekerk@sgs.com

sanas Testing Laboratory

TEST RESULTS

KNIGHT PIESOLD CONSULTING
P.O BOX 72292
LYNNWOOD RIDGE
0040
Attention: Mr Keneth Matotoka

Project : Transalloys Power Station and Ash Dump

Your Ref :
Our Ref : PL/21250
Date Reported : 24.11.2017

FOUNDATION INDICATOR (ASTM: D422)

Sample No.	: A7/3232
Hole No.	: TP117/1
Depth	: 300-1700
Liquid Limit (%)	: 25
Plasticity Index	: 8
Linear Shrinkage (%)	: 4.0
PI of Whole Sample	: 4
P.R.A. Classification	: A-2-4(0)
Unified Soil Classificati	SC
Activity	: 0.57
Heave Classification	: LOW
Grading Modulus	: 1.59
Percentage (<0.002)	: 7.0
Moisture Content (%)	: 6.7

Material Description : Alluvium SILTY SAND

	Clay (%)	Silt (%)	Sand (%)	Gravel (%)	Classification
Jennings	10.4	10.3	49.1	30.2	SILTY SAND
Astm	10.4	13.5	56.0	20.2	SILTY SAND
British Standard	7.1	16.1	46.7	30.2	SILTY SAND

Sieve Size (mm)	% Pass. Sieve
0.0015	7
0.0020	7
0.0036	10
0.0050	10
0.0060	11
0.0075	12
0.0100	12
0.0150	14
0.0200	15
0.0260	16
0.0400	18
0.0500	21
0.0600	23
0.0750	24
0.1500	32
0.2500	39
0.4250	47
2.0000	70
4.7500	80
13.200	85
19.000	88
26.500	91
37.500	91
53.000	100
63.000	100
75.000	100

JENN	CLAY	SILT	SAND	GRAVEL					
ASTM	CLAY	SILT	FINE SAND	MEDIUM SAND	COARSE SAND	GRAVEL			
BS	CLAY	FINE SILT	MEDIUM SILT	COARSE SILT	FINE SAND	MEDIUM SAND	COARSE SAND	FINE GRAVEL	MEDIUM GRAVEL	COARSE GRAVEL

Remarks : Sampled by client.

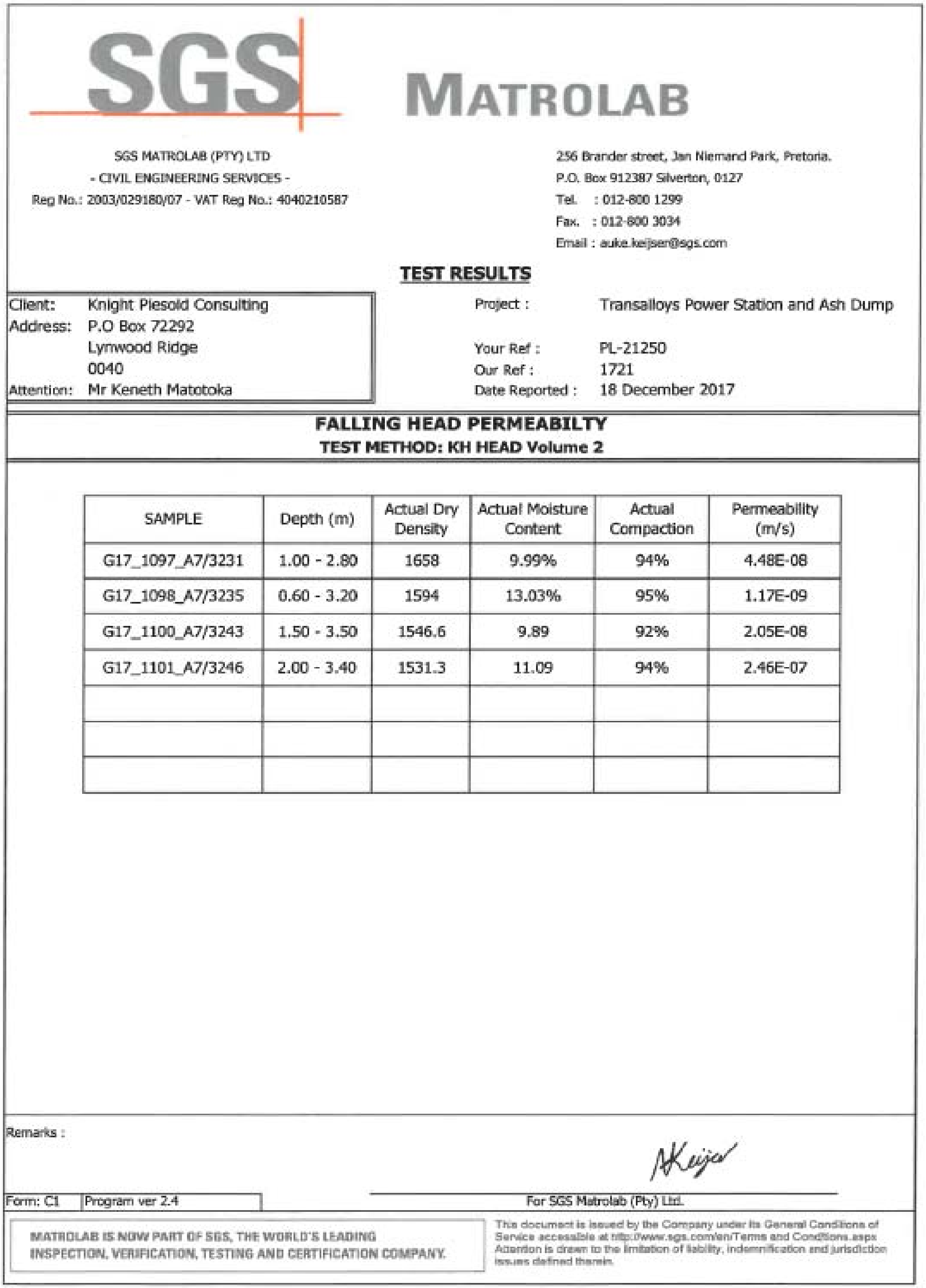
FORM: A6

4.4.0(SGS)(2016.08.31)

Technical Signatory : B.Van Niekerk / A.Vankey / S.Dewnath

This document is issued by the Company under its General Conditions of Service accessible at http://www.sgs.com/en/Terms-and-Conditions.aspx. Attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein.

MATROLAB IS NOW PART OF SGS, THE WORLDS'S LEADING INSPECTION, VERFICATION, TESTING AND CERTIFICATION COMPANY.



SGS MATROLAB

SGS MATROLAB (PTY) LTD
- CIVIL ENGINEERING SERVICES -
Reg No.: 2003/029180/07 - VAT Reg No.: 4040210587

256 Brander street, Jan Niemand Park, Pretoria.
P.O. Box 912387 Silverton, 0127
Tel. : 012-800 1299
Fax. : 012-800 3034
Email : auke.keijser@sgs.com

TEST RESULTS

Client: Knight Piesold Consulting
Address: P.O Box 72292
Lynwood Ridge
0040
Attention: Mr Keneth Matotoka

Project : Transalloys Power Station and Ash Dump

Your Ref : PL-21250
Our Ref : 1721
Date Reported : 18 December 2017

FALLING HEAD PERMEABILTY

TEST METHOD: KH HEAD Volume 2

SAMPLE	Depth (m)	Actual Dry Density	Actual Moisture Content	Actual Compaction	Permeability (m/s)
G17_1097_A7/3231	1.00 - 2.80	1658	9.99%	94%	4.48E-08
G17_1098_A7/3235	0.60 - 3.20	1594	13.03%	95%	1.17E-09
G17_1100_A7/3243	1.50 - 3.50	1546.6	9.89	92%	2.05E-08
G17_1101_A7/3246	2.00 - 3.40	1531.3	11.09	94%	2.46E-07

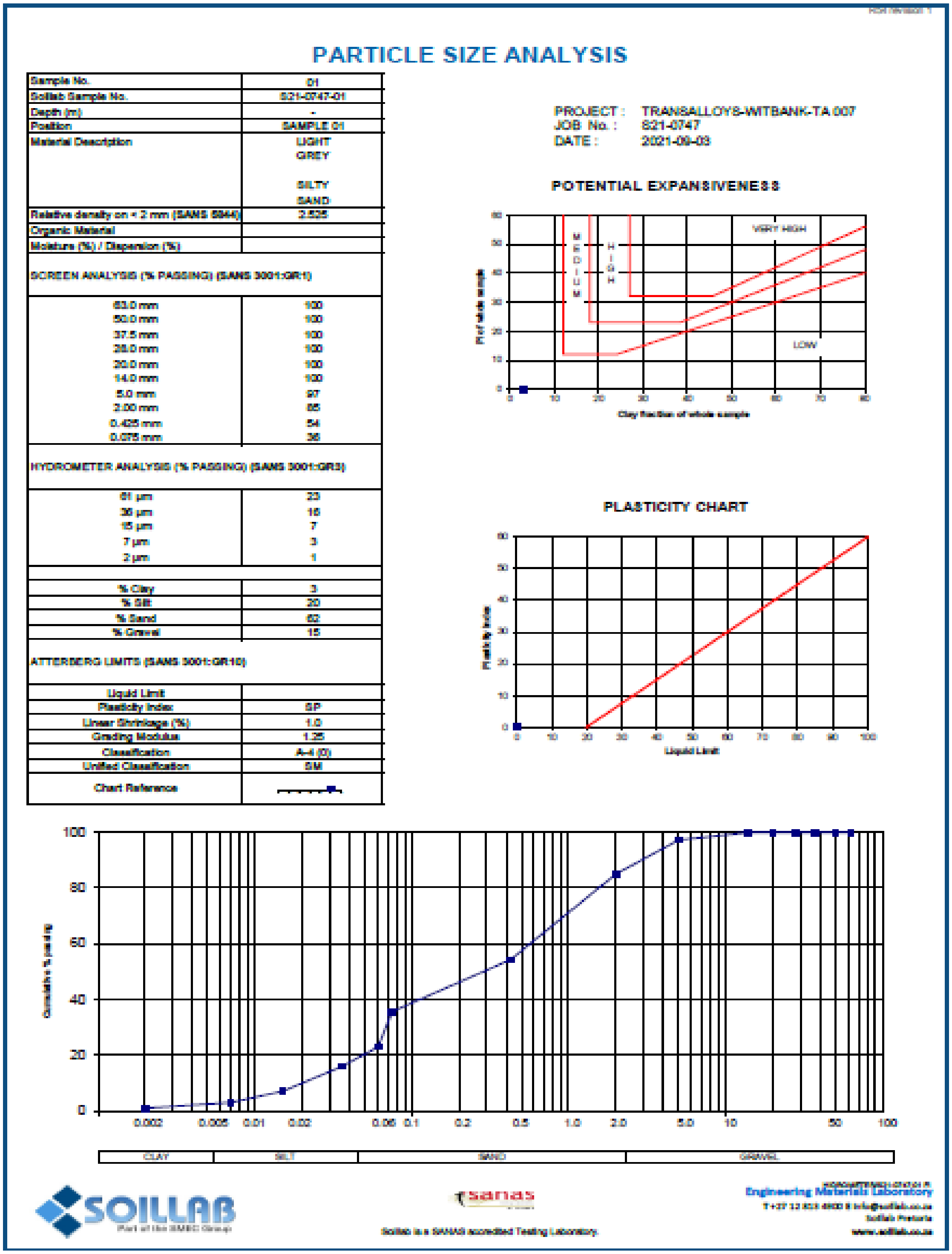
Remarks :

AKeijer

For SGS Matrolab (Pty) Ltd.

Form: C1 Program ver 2.4

MATROLAB IS NOW PART OF SGS, THE WORLD'S LEADING INSPECTION, VERIFICATION, TESTING AND CERTIFICATION COMPANY.



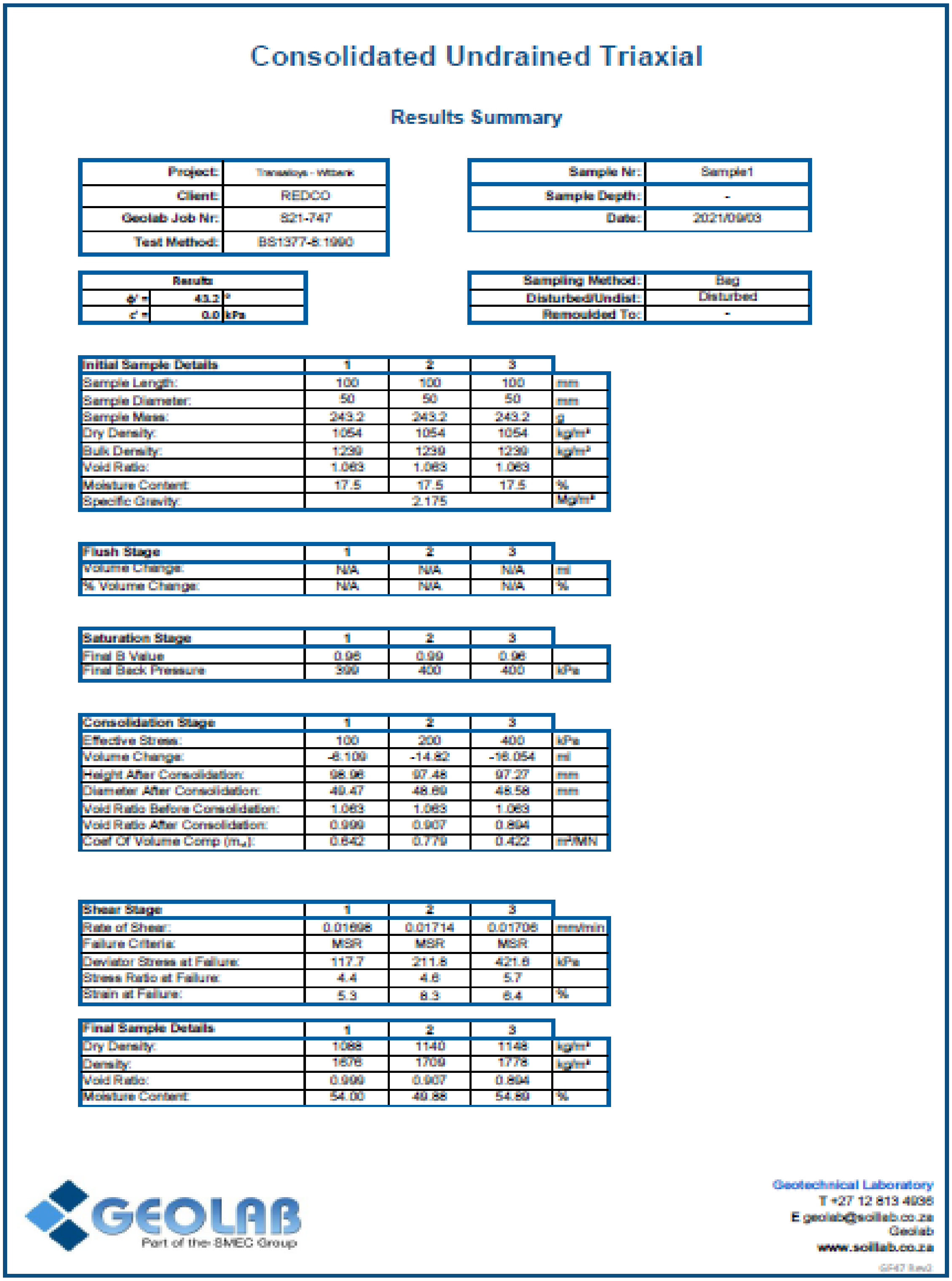
PARTICLE SIZE ANALYSIS

PROJECT : TRANSALLOYS-WITBANK-TA 007
JOB No. : S21-0747
DATE : 2021-09-03

Sample No.	01
Soillab Sample No.	S21-0747-01
Depth (m)	-
Position	SAMPLE 01
Material Description	LIGHT GREY SILTY SAND
Relative density on < 2 mm (SANS 5844)	2.525
Organic Material	
Moisture (%) / Dispersion (%)	
SCREEN ANALYSIS (% PASSING) (SANS 3001:GR1)	
63.0 mm	100
50.0 mm	100
37.5 mm	100
28.0 mm	100
20.0 mm	100
14.0 mm	100
5.0 mm	97
2.00 mm	85
0.425 mm	54
0.075 mm	36
HYDROMETER ANALYSIS (% PASSING) (SANS 3001:GR3)	
61 µm	23
36 µm	16
15 µm	7
7 µm	3
2 µm	1
% Clay	3
% Silt	20
% Sand	62
% Gravel	15
ATTERBERG LIMITS (SANS 3001:GR10)	
Liquid Limit	
Plasticity Index	SP
Linear Shrinkage (%)	1.0
Grading Modulus	1.25
Classification	A-4 (0)
Unified Classification	SM
Chart Reference	■

Soillab is a SANAS accredited Testing Laboratory.

Engineering Materials Laboratory
T +27 12 803 4900 E info@soillab.co.za
Soillab Pretoria
www.soillab.co.za



Consolidated Undrained Triaxial

Results Summary

Project:	Transalloys - Witbank
Client:	REDCO
Geolab Job Nr:	S21-747
Test Method:	BS1377-8:1990

Sample Nr:	Sample1
Sample Depth:	-
Date:	2021/09/03

Results		
ϕ' =	**43.2**	**°**
c' =	**0.0**	**kPa**

Sampling Method:	Bag
Disturbed/Undist:	Disturbed
Remoulded To:	-

Initial Sample Details	**1**	**2**	**3**	
Sample Length:	100	100	100	mm
Sample Diameter:	50	50	50	mm
Sample Mass:	243.2	243.2	243.2	g
Dry Density:	1054	1054	1054	kg/m³
Bulk Density:	1239	1239	1239	kg/m³
Void Ratio:	1.063	1.063	1.063	
Moisture Content:	17.5	17.5	17.5	%
Specific Gravity:		2.175		Mg/m³

Flush Stage	**1**	**2**	**3**	
Volume Change:	N/A	N/A	N/A	ml
% Volume Change:	N/A	N/A	N/A	%

Saturation Stage	**1**	**2**	**3**	
Final B Value	0.98	0.99	0.98	
Final Back Pressure	399	400	400	kPa

Consolidation Stage	**1**	**2**	**3**	
Effective Stress:	100	200	400	kPa
Volume Change:	-6.109	-14.82	-16.054	ml
Height After Consolidation:	98.98	97.48	97.27	mm
Diameter After Consolidation:	49.47	48.69	48.58	mm
Void Ratio Before Consolidation:	1.063	1.063	1.063	
Void Ratio After Consolidation:	0.999	0.907	0.894	
Coef Of Volume Comp (m_v):	0.642	0.779	0.422	m²/MN

Shear Stage	**1**	**2**	**3**	
Rate of Shear:	0.01698	0.01714	0.01706	mm/min
Failure Criteria:	MSR	MSR	MSR	
Deviator Stress at Failure:	117.7	211.8	421.8	kPa
Stress Ratio at Failure:	4.4	4.8	5.7	
Strain at Failure:	5.3	6.3	6.4	%

Final Sample Details	**1**	**2**	**3**	
Dry Density:	1088	1140	1148	kg/m³
Density:	1676	1709	1778	kg/m³
Void Ratio:	0.999	0.907	0.894	
Moisture Content:	54.00	49.88	54.69	%

GEOLAB
Part of the SMEC Group

Geotechnical Laboratory
T +27 12 813 4036
E geolab@soillab.co.za
Geolab
www.soillab.co.za

GF47 Rev0

Consolidated Undrained Triaxial

Consolidation Stage

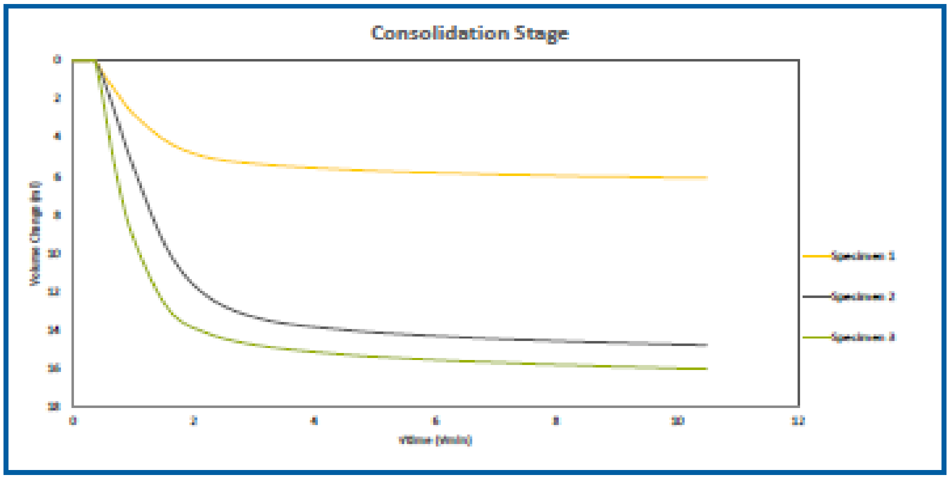
Project:	Transalloys - Witbank
Client:	REDCO
Geolab Job Nr:	S21-747

Sample Nr:	Sample1
Sample Depth:	-
Date:	2021/09/03

Initial Conditions	1	2	3	
Cell Pressure:	499	596	798	kPa
Back Pressure:	399	398	398	kPa
Void Ratio:	1.063	1.063	1.063	
Side Drain Used:	y	y	y	

Final Conditions	1	2	3	
Volume Change:	-6.1	-14.8	-16.1	ml
Volumetric Strain:	-3.11	-7.55	-8.18	%
Corrected Length:	98.98	97.48	97.27	mm
Corrected Diameter:	49.47	48.69	48.58	mm
Void Ratio:	0.999	0.907	0.894	

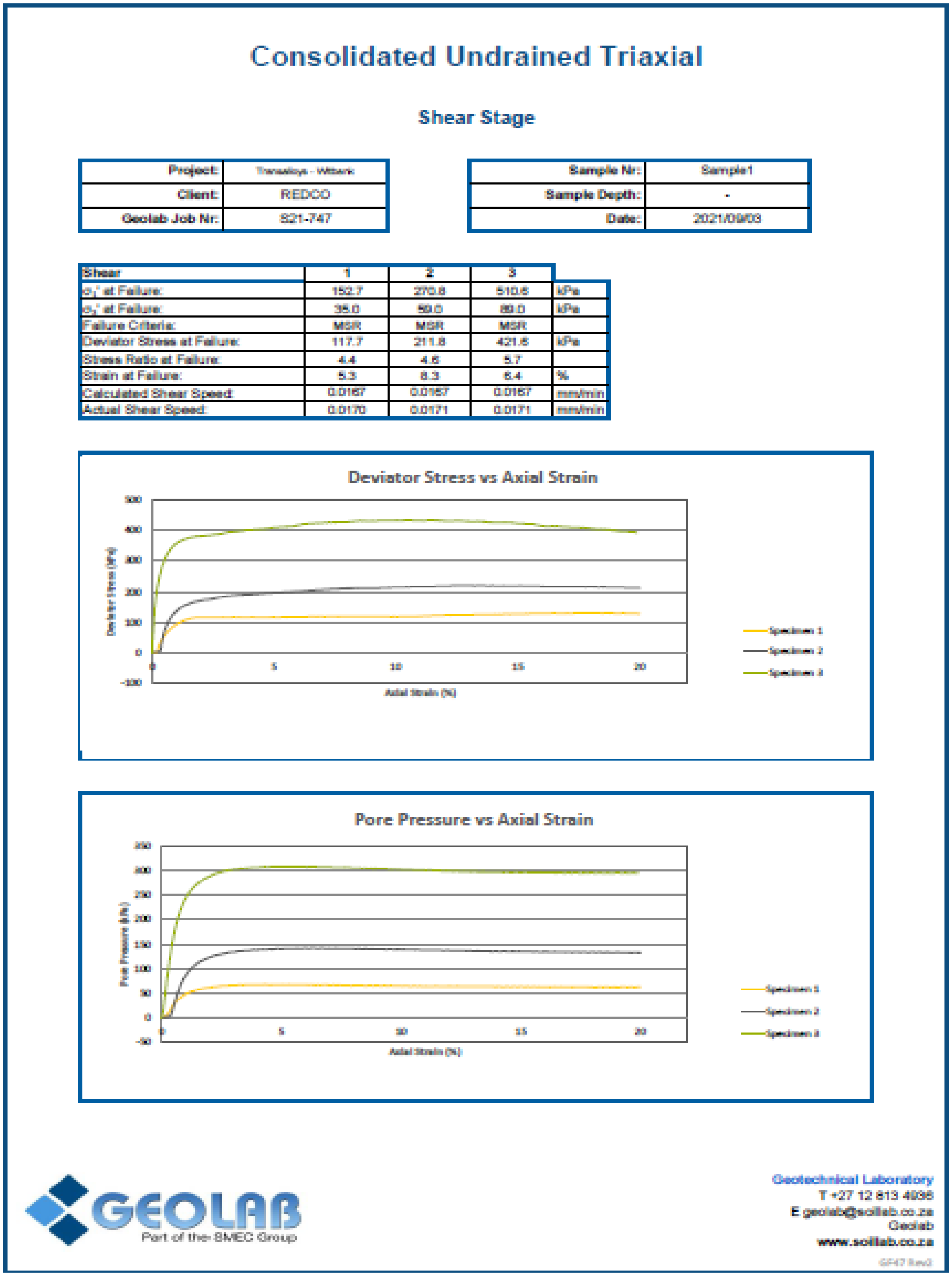
Calculations and Parameters	1	2	3	
Calculated Shear Speed:	0.0167	0.0167	0.0167	mm/min
Coeff of Volume Comp (m_v):	0.642	0.779	0.422	m^2/MN



GEOLAB
Part of the SMEC Group

Geotechnical Laboratory
T +27 12 813 4036
E geolab@soillab.co.za
Geolab
www.soillab.co.za

GF47 Rev3



Consolidated Undrained Triaxial

Shear Stage

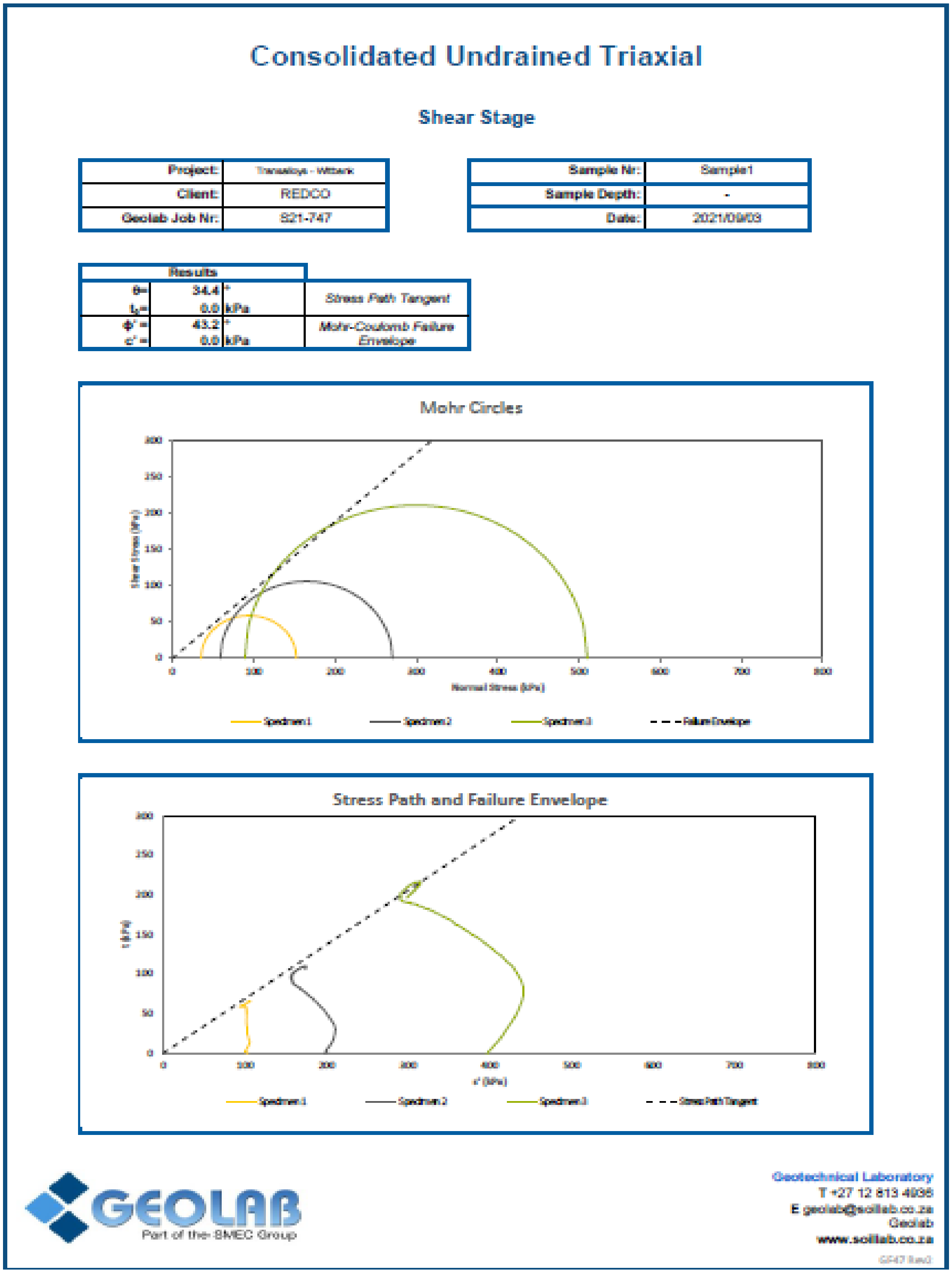
Project:	Transalloys - Witbank
Client:	REDCO
Geolab Job Nr:	S21-747

Sample Nr:	Sample1
Sample Depth:	-
Date:	2021/09/03

Shear	1	2	3	
σ_1' at Failure:	152.7	270.8	510.6	kPa
σ_3' at Failure:	35.0	59.0	89.0	kPa
Failure Criteria:	MSR	MSR	MSR	
Deviator Stress at Failure:	117.7	211.8	421.6	kPa
Stress Ratio at Failure:	4.4	4.6	5.7	
Strain at Failure:	5.3	8.3	6.4	%
Calculated Shear Speed:	0.0167	0.0167	0.0167	mm/min
Actual Shear Speed:	0.0170	0.0171	0.0171	mm/min

Geotechnical Laboratory
T +27 12 813 4036
E geolab@soillab.co.za
Geolab
www.soillab.co.za

GF47 Rev0



Consolidated Undrained Triaxial

Shear Stage

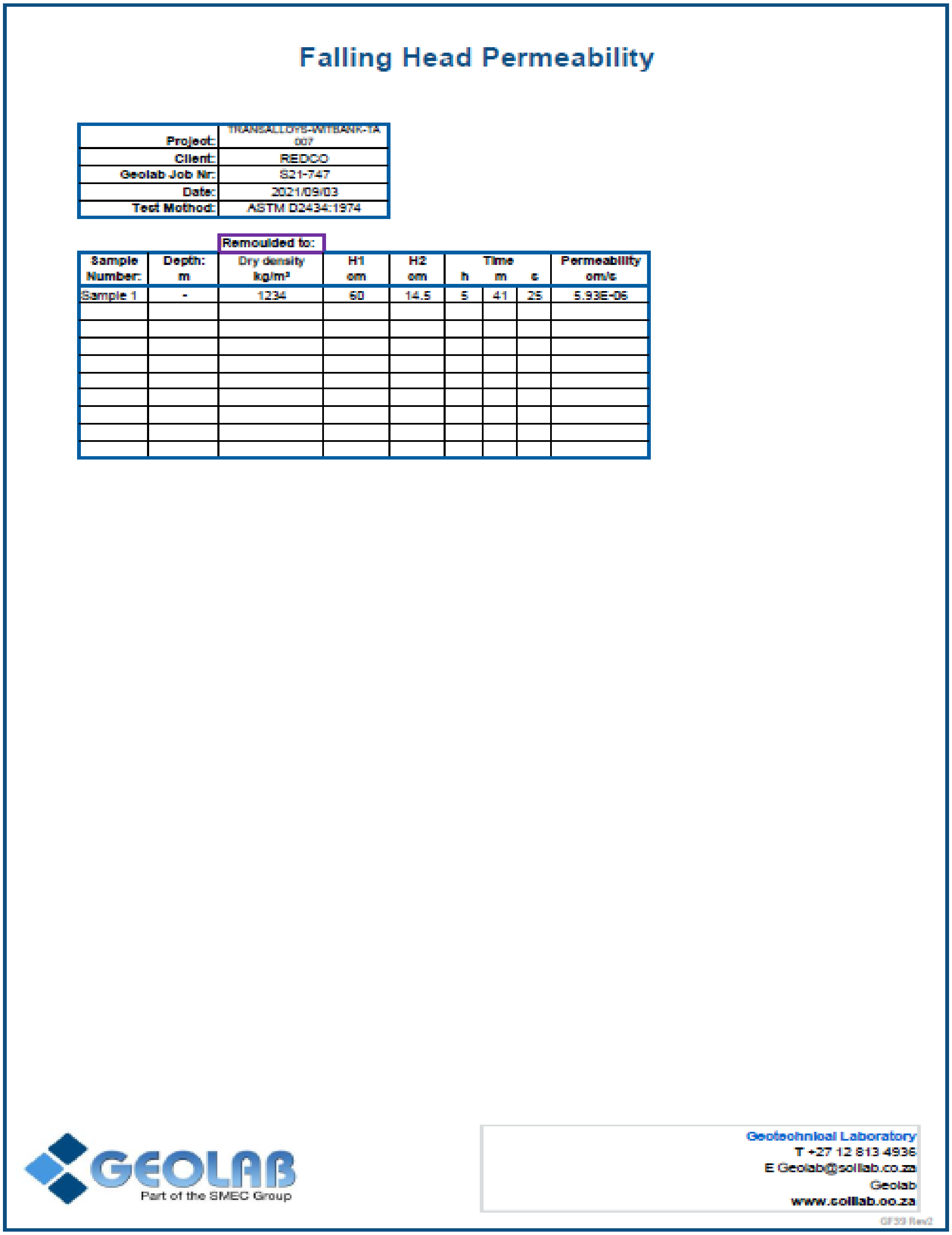
Project:	Transalloys - Witbank
Client:	REDCO
Geolab Job Nr:	S21-747

Sample Nr:	Sample1
Sample Depth:	-
Date:	2021/09/03

Results			
θ= **t_0=**	**34.4** **0.0**	**°** **kPa**	*Stress Path Tangent*
ϕ' = **c' =**	**43.2** **0.0**	**°** **kPa**	*Mohr-Coulomb Failure Envelope*

Geotechnical Laboratory
T +27 12 813 4936
E geolab@soillab.co.za
Geolab
www.soillab.co.za

GF47 Rev0



Falling Head Permeability

Project:	TRANSALLOYS-WITBANK-TA 007
Client:	REDCO
Geolab Job Nr:	S21-747
Date:	2021/09/03
Test Method:	ASTM D2434:1974

Remoulded to:

Sample Number:	Depth: m	Dry density kg/m^3	H1 cm	H2 cm	Time h	m	s	Permeability cm/s
Sample 1	-	1234	60	14.5	5	41	25	5.93E-06

GEOLAB
Part of the SMEC Group

Geotechnical Laboratory
T +27 12 813 4936
E Geolab@soillab.co.za
Geolab
www.soillab.co.za

GF33 Rev2

Annexure C – TOPSOIL ANAYLSIS

To: Redco
DP vd Merwe
Date: 14 September 2019

Grond En Omgewings Laboratorium
Posbus 5546 , Kockspark , 2523
Tel : 0833796540

Sample no	Lab no	pH(KCl)	P(Bray1)	K		Ca		Mg		Na	
			mg kg^{-1}	cmol kg^{-1}	mg kg^{-1}	cmol kg^{-1}	mg kg^{-1}	cmol kg^{-1}	mg kg^{-1}	cmol kg^{-1}	mg kg^{-1}
Top 1 0-150mm	U2851	6.1	3	0.176	68	3.827	765	0.507	61	0.034	8
Top 3 0-150mm	U2852	5.9	6	0.146	57	2.477	495	0.329	40	0.026	6
Top 4 0-150mm	U2853	5.2	1	0.186	72	1.509	302	0.358	43	0.036	8
Top 6 0-150mm	U2854	4.5	2	0.165	64	0.585	117	0.145	18	0.042	10
Top 4 300-600mm	U2855	4.6	4	0.121	47	0.844	169	0.173	21	0.025	6
Top 1,2,3 300-600mm	U2856	6.0	5	0.157	61	2.629	526	0.317	38	0.035	8
Top 6 300-600mm	U2857	4.5	1	0.132	52	0.555	111	0.119	14	0.019	4
Combined > 600mm	U2858	5.3	5	0.095	37	1.224	245	0.159	19	0.036	8

Sample no	Lab no	Ca:Mg	Mg:K	Ca+Mg:K	K%	Ca%	Mg%	Na%	Sand%	Silt%	Clay%	>2mm%
Top 1 0-150mm	U2851	7.5	2.9	24.7	3.9	84.2	11.2	0.7				16
Top 3 0-150mm	U2852	7.5	2.2	19.2	4.9	83.2	11.0	0.9				21
Top 4 0-150mm	U2853	4.2	1.9	10.0	8.9	72.2	17.1	1.7				18
Top 6 0-150mm	U2854	4.0	0.9	4.4	17.6	62.4	15.5	4.5				18
Top 4 300-600mm	U2855	4.9	1.4	8.4	10.4	72.6	14.9	2.2				29
Top 1,2,3 300-600mm	U2856	8.3	2.0	18.8	5.0	83.8	10.1	1.1				19
Top 6 300-600mm	U2857	4.7	0.9	5.1	16.0	67.2	14.4	2.3				43
Combined > 600mm	U2858	7.7	1.7	14.5	6.3	80.8	10.5	2.3				51

			Saturated water paste extract										
Sample no	Lab no	EC	K		Ca		Mg		Na		SAR	Ca:Mg	Ca %
		mS m^{-1}	me l^{-1}	mg l^{-1}	me l^{-1}	mg l^{-1}	me l^{-1}	mg l^{-1}	me l^{-1}	mg l^{-1}			
Top 1 0-150mm	U2851	39	0.560	21.8	3.913	78.3	0.829	10.0	0.197	4.5	0.1	4.7	71.2
Top 3 0-150mm	U2852	20	0.538	21.0	2.419	48.4	0.502	6.0	0.050	1.2	0.0	4.8	68.9
Top 4 0-150mm	U2853	16	0.618	24.1	1.047	20.9	0.397	4.8	0.066	1.5	0.1	2.6	49.2
Top 6 0-150mm	U2854	19	0.481	18.8	0.666	13.3	0.291	3.5	0.086	2.0	0.1	2.3	43.7
Top 4 300-600mm	U2855	24	0.387	15.1	1.916	38.3	0.580	7.0	0.174	4.0	0.2	3.3	62.7
Top 1,2,3 300-600mm	U2856	27	0.580	22.6	3.705	74.1	0.657	7.9	0.176	4.0	0.1	5.6	72.4
Top 6 300-600mm	U2857	18	0.454	17.7	0.743	14.9	0.280	3.4	0.087	2.0	0.1	2.7	47.5
Combined > 600mm	U2858	26	0.249	9.7	2.168	43.4	0.402	4.8	0.271	6.2	0.2	5.4	70.2

Recommendation: Establish grass dry land

Topsoil 1,3,4 0-150mm

Soil pH is satisfactory and no lime application is recommended.

Soil salinity (EC) is low.

Apply 5 ton/ha compost and work in 10cm three weeks before planting.

Apply 300 kg/ha 2:3:2(34)+Zn immediately before planting and work in 5cm.

Topdress 200 kg/ha LAN six weeks after planting.

Topsoil 6 0-150mm

Soil Ca and Mg levels are low. Broadcast 1.5 ton/ha Dolomite lime four weeks before planting and work in 20cm.

Soil salinity (EC) is low.

Apply 5 ton/ha compost and work in 10cm three weeks before planting.

Apply 400 kg/ha 2:3:2(34)+Zn immediately before planting and work in 5cm.

Topdress 200 kg/ha LAN six weeks after planting.

Top 1, 2, 3, 4 300-600mm and Combined > 600mm.

Soil Ca and Mg levels are low. Broadcast 1.5 ton/ha Dolomite lime four weeks before planting and work in 20cm.

Soil salinity (EC) is low.

Apply 10 ton/ha compost and work in 10cm three weeks before planting.

Apply 400 kg/ha 2:3:2(34)+Zn immediately before planting and work in 5cm.

Topdress 200 kg/ha LAN six weeks after planting.

Compost should be well decomposed: No foul smells, EC lower than 2000 mS/m, C% higher than 10, C:N less than 25 and CEC higher than 15 cmol/kg .

Annexure D – DRAWING REGISTER

DRAWING REGISTER

PROJECT NAME:	REHABILITATION PLAN FOR HISTORICAL FERROCHROME DUMP		
CLIENT:	TRANSALLOYS	**PROJECT NO:**	TA007
MINE:	EMALAHLENI	**FROM:**	
TO:		**TRANSMITTAL NO:**	
DISPATCHED BY:	Ruan Jansen van Vuren		
DATE:	25/01/2022		

DRAWING NO	REV	DESCRIPTION	NO OF COPIES	PRINT TYPE
TA007_01	0	GENERAL ARRANGEMENT: CURRENT SITUATION	1	A1
TA007_02A	0	GENERAL ARRANGEMENT: RESHAPE SET OUT POINTS	1	A1
TA007_02B	0	GENERAL ARRANGEMENT: SLAG LAYER SET OUT POINTS	1	A1
TA007_02C	0	GENERAL ARRANGEMENT: COVER SOIL LAYER SET OUT POINTS	1	A1
TA007_02D	0	GENERAL ARRANGEMENT: TOPSOIL LAYER SET OUT POINTS	1	A1
TA007_03	0	GENERAL ARRANGEMENT: DRAIN AND TOPSOIL	1	A1
TA007_04	0	SECTIONS DUMP RESHAPE, CAPPING AND TOPSOIL LAYER	1	A1
TA007_05	0	SECTIONS AND DETAILS, OUTLET STRUCTURE	1	A1
TA007_06	0	SECTIONS AND DETAILS, TOE DRAIN 01 AND 02	1	A1
TA007_07	0	SET OF SECTION: DRAIN 01	1	A1
TA007_06	0	SET OF SECTION: DRAIN 02 AND 03	1	A1